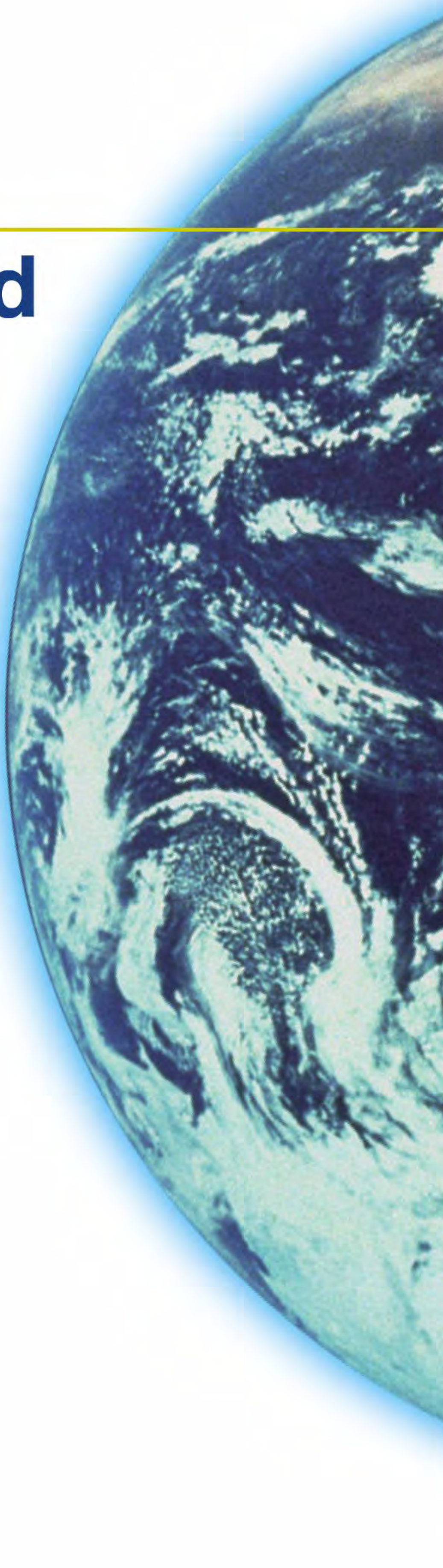
Asia-Pacific
Economic Cooperation

APEC

Energy Demand and Supply Outlook 5th Edition

February 2013



APERC

Asia Pacific Energy Research Centre

APEC ENERGY DEMAND AND SUPPLY OUTLOOK

5TH EDITION

ASIA PACIFIC ENERGY RESEARCH CENTRE

This report, along with detailed tables of the model results,
is published at http://aperc.ieej.or.jp/

FEBRUARY 2013

Published by:

Asia Pacific Energy Research Centre
Institute of Energy Economics, Japan
Inui Building Kachidoki 11F, 1-13-1 Kachidoki
Chuo-ku, Tokyo 104-0054 Japan
Tel: (813) 5144-8551
Fax: (813) 5144-8555
Email: master@aperc.ieej.or.jp (administration)
Website: http://aperc.ieej.or.jp/

Produced for:

APEC Secretariat
35 Heng Mui Keng Terrace, Singapore 119616
Tel: (65) 68 919 600
Fax: (65) 68 919 690
E-mail: info@apec.org
Website: www.apec.org

February 2013

APEC#213-RE-01.5 ISBN 978-4-931482-45-6

TABLE OF CONTENTS

List of Tables ii
List of Figures iii
Foreword viii
Acknowledgements ix
List of Abbreviations xiv
Tables of Approximate Conversion Factors xvii
1 Summary of Key Trends 1
Sidebar – "Have We Dealt With a Challenge Like Climate Change Before?" 13
2 APEC Energy Demand and Supply Overview 15
Sidebar – "APEC's Energy Intensity Goal: The Lessons Learned" 22
3 Overview of APERC's Energy Demand and Supply Model 25
4 Final Energy Demand 31
5 Transport Sector Energy Demand 41
Sidebar – "APERC's Transport Sector Energy Demand Model and How It Works" 61
6 Industrial Sector Energy Demand 65
Sidebar – "APERC's Industrial Sector Energy Demand Model and How It Works" 71
Sidebar – "Industrial Energy Intensity, China and the United States" 72
7 Non-Energy Sector Demand 75
8 Residential, Commercial, and Agricultural Sector Energy Demand 79
Sidebar – "APERC's 'Other' Sector Energy Demand Model and How It Works" 87
Sidebar – "Improving Energy Efficiency with Residential Fuel Cells" 89
9 Electricity Demand and Supply 91
Sidebar – "APERC's Electricity Supply Model and How It Works" 103
10 Primary Energy Demand and Supply 107
Sidebar – "APEC's Goal to Rationalize and Phase Out Fossil Fuel Subsidies" 110
Sidebar – "Modelling Fossil Fuel Production" 111
11 Oil Supply 113
Sidebar – "The Increasing Importance of Frontier and Unconventional Oil" 114
12 Natural Gas Supply 123
13 Coal Supply 131
Sidebar – "Improving the Efficiency of Coal-fired Electricity Generation" 134
14 Nuclear Supply 137
15 Renewable Energy Supply 141
16 Carbon Dioxide Emissions 151
Sidebar – "Modelling CO_2 Emissions" 158
Sidebar – "Did the Kyoto Protocol Get It Backwards?" 159

LIST OF TABLES

Table 1.1: Assumed APEC GDP and Population Growth Rates ... 2
Table 1.2: Climate Change Stabilization Scenarios ... 4
Table 3.1: Assumed APEC GDP and Population Growth Rates ... 28
Table 3.2: Assumed Projections of Total GDP and GDP per Capita by Economy ... 29
Table 5.1: Vehicles per 1000 Population in APEC Economies: History and Projection including Compound Annual Growth Rates (2000–2035) ... 44
Table 5.2: Urban Population Growth Projection in the APEC Region among OECD and Non-OECD Economies ... 51
Table 5.3: Key Indicators for Hydrogen Production Alternatives ... 56
Table 5.4: Comparison of Long-term BAU Vehicle Saturation Levels of Available APEC Economies ... 61
Table 6.1: Energy Intensity in China and the United States ... 72
Table 8.1: Estimated Potential Percentage Energy Savings from Appliance Energy Efficiency Standards by Economy ... 85
Table 8.2: Estimated Potential Percentage Energy Savings from Building Energy Codes by Economy ... 86
Table 9.1: APEC's Electricity Demand by Economy, in TWh ... 91
Table 9.2: APEC's Electricity Demand as a Percentage of Total Final Energy Demand (TFED) ... 91
Table 9.3: APEC Economies' Access to Electricity ... 100
Table 9.4: Energy Efficient Technologies for T&D Networks ... 102
Table 10.1: Estimated Consumer-oriented Fossil Fuel Subsidies in 2010 ... 110
Table 12.1: APEC's Technically Recoverable Conventional and Unconventional Gas Resource Base, in Mtoe ... 126
Table 12.2: APEC's Technically Recoverable Shale Gas Resource Base, in Mtoe ... 126

LIST OF FIGURES

Figure 1.1: Assumed APEC GDP and Population ... 2
Figure 1.2: Assumed Oil Prices ... 2
Figure 1.3: APEC Total Oil Production and Net Oil Imports ... 3
Figure 1.4: Change in APEC Primary Energy, GDP, and Energy Intensity ... 3
Figure 1.5: CO_2 Emissions for a Range of Stabilization Levels ... 5
Figure 1.6: APEC CO_2 Emissions from Fuel Combustion ... 6
Figure 1.7: APEC Nuclear Output ... 6
Figure 1.8: APEC Projected Gas Production ... 7
Figure 1.9: High Gas Scenario – Reduction in CO_2 Emissions from Electricity Generation ... 7
Figure 1.10: APEC Projected Electricity Production from New Renewable Energy (NRE) ... 8
Figure 1.11: Per Capita Transport Energy Demand vs. Urban Density ... 9
Figure 1.12: APEC Light Vehicle Oil Demand Per Capita under Alternative Urban Development Scenarios ... 10
Figure 1.13: Impact of Alternative Vehicles on APEC Light Vehicle Oil Product Consumption ... 11
Figure 1.14: Impact of Alternative Vehicles on APEC Light Vehicle CO_2 Emissions from Fuel Combustion ... 12
Figure 2.1: APEC Average GDP per Capita ... 15
Figure 2.2: APEC Final Energy Demand by Energy Type ... 16
Figure 2.3: APEC Final Energy Demand by Sector ... 16
Figure 2.4: APEC Electricity Generation by Primary Energy Source ... 17
Figure 2.5: APEC Primary Energy Supply by Energy Source ... 18
Figure 2.6: APEC Net Imports from Outside the APEC Region ... 19
Figure 2.7: APEC Final Energy Intensity Improvement ... 20
Figure 2.8: APEC Primary Energy Intensity Improvement ... 20
Figure 2.9: APEC Final Energy Intensity by Economy ... 21
Figure 2.10: APEC Primary Energy Intensity by Economy ... 21
Figure 3.1: Structure of APERC's Model ... 25
Figure 3.2: International Crude Oil Prices, 1861–2011 ... 27
Figure 3.3: APERC's Crude Oil Price Assumptions, 2010–2035 ... 28
Figure 3.4: Assumed APEC GDP and Population ... 28
Figure 4.1: Annual Percentage Growth Rates in Final Energy Demand by Economy ... 31
Figure 4.2: APEC Final Energy Demand by Energy Source ... 32
Figure 4.3: Final Energy Demand by Energy Source, Higher Final Demand Economies ... 33
Figure 4.4: Final Energy Demand by Energy Source, Lower Final Demand Economies ... 33
Figure 4.5: Final Energy Demand by Energy Source Per Capita, Higher Final Demand per Capita Economies ... 34

Figure 4.6: Final Energy Demand by Energy Source Per Capita, Lower Final Demand per Capita Economies ... 34
Figure 4.7: APEC Final Energy Demand by Sector ... 35
Figure 4.8: Final Energy Demand by Sector, Higher Final Demand Economies ... 36
Figure 4.9: Final Energy Demand by Sector, Lower Final Demand Economies ... 36
Figure 4.10: Final Energy Demand by Sector Per Capita, Higher Final Demand per Capita Economies ... 37
Figure 4.11: Final Energy Demand by Sector Per Capita, Lower Final Demand per Capita Economies ... 37
Figure 5.1: Transport Sector Energy Demand by Energy Source, Larger Economies ... 42
Figure 5.2: Transport Sector Energy Demand by Energy Source, Smaller Economies ... 43
Figure 5.3: Transport Final Energy Demand Average Growth Rate ... 43
Figure 5.4: Light Vehicle Fleet Share by Vehicle Technology ... 45
Figure 5.5: Present Value of Lifecycle Fuel Savings relative to US Conventional Vehicle (6% Discount Rate, in USD) ... 46
Figure 5.6: Additional Upfront Cost of Alternative Vehicles above that of Conventional Vehicles by 2035 (Assuming Mass Production) ... 47
Figure 5.7: Passenger Vehicle Energy Use per Capita versus the Urban City Density in People per Hectare (Data Year = 1995) ... 49
Figure 5.8: Trend in Urban Density for APEC Cities Relative to the Size of Population and Growth in GDP per Capita between 1984 and 2002 ... 50
Figure 5.9: APEC Motor Vehicle Saturation under Urban Planning Alternative Scenarios in 2035 ... 52
Figure 5.10: APEC Light Vehicle Oil Demand per Capita under Urban Planning Alternative Scenarios ... 52
Figure 5.11: APEC Vehicle Ownership under the Urban Planning Scenarios ... 53
Figure 5.12: Oil Use in the APEC Light Vehicle Fleet under the Urban Planning Scenarios ... 53
Figure 5.13: CO_2 Emissions in the APEC Light Vehicle Fleet under the Urban Planning Scenarios ... 54
Figure 5.14: Primary Fuel to Meet Added Demand for Electricity in the Electric Vehicle Transition and Hydrogen Vehicle Transition Scenarios ... 57
Figure 5.15: APEC Oil Consumption in the Light Vehicle Fleet across the Virtual Clean Car Race Scenarios ... 57
Figure 5.16: APEC Light Vehicle Oil Consumption per Capita in 2035 for each Virtual Clean Car Race Scenario ... 58
Figure 5.17: APEC CO_2 Emissions in the Light Vehicle Fleet across the Alternative Scenarios ... 59
Figure 5.18: APEC Light Vehicle CO_2 Emissions per Capita in 2035 for the Virtual Clean Car Race Scenarios ... 59
Figure 6.1: Final Industrial Energy Demand by Energy Source, Larger Economies ... 66
Figure 6.2: Final Industrial Energy Demand by Energy Source, Smaller Economies ... 66
Figure 6.3: Per Capita Industrial Sector Energy Demand by Energy Source, Highest Demand Per Capita Economies ... 67
Figure 6.4: Per Capita Industrial Sector Energy Demand by Energy Source, Lowest Demand Per Capita Economies ... 67
Figure 6.5: Annual Percentage Growth Rates in Industrial Sector Energy Demand by Economy ... 68

Figure 6.6: Annual Percentage Growth Rates in Industrial Demand by Energy Source, 2010–2015 68
Figure 6.7: APEC's Final Industrial Energy Demand by Industry Type 69
Figure 6.8: APEC's Final Industry Energy Demand, Percentage Share by Fuel Source 70
Figure 7.1: Non-Energy Demand, Larger Non-Energy Consuming Economies 76
Figure 7.2: Non-Energy Demand, Smaller Non-Energy Consuming Economies 76
Figure 7.3: Per Capita Non-Energy Demand by Energy Source, Larger Non-Energy Per Capita Consuming Economies 77
Figure 7.4: Per Capita Non-Energy Demand by Energy Source, Smaller Non-Energy Per Capita Consuming Economies 77
Figure 8.1: Other Sector Energy Demand by Energy Source, Higher Other Sector Demand Economies 80
Figure 8.2: Other Sector Energy Demand by Energy Source, Lower Other Sector Demand Economies 80
Figure 8.3: Per Capita Other Sector Energy Demand by Energy Source, Higher Other Sector Demand per Capita Economies 81
Figure 8.4: Per Capita Other Sector Energy Demand by Energy Source, Lower Other Sector Demand per Capita Economies 81
Figure 8.5: Annual Percentage Growth Rates in Other Sector Energy Demand by Economy 82
Figure 8.6: APEC Total Other Sector Energy Demand by Energy Source 83
Figure 8.7: General Approaches to Modelling 'Other' Sector Energy Demand 87
Figure 8.8: Relationship Between Income Elasticity of Residential Energy Demand and GDP/Person by Economy 88
Figure 8.9: Residential Energy Demand Projection Example: Japan and Viet Nam 88
Figure 9.1: Projected APEC Electricity Final Demand by Sector, Higher Final Demand Economies 92
Figure 9.2: Projected APEC Electricity Final Demand by Sector, Lower Final Demand Economies 92
Figure 9.3: APEC's Electricity Generation Mix (1990–2035) 93
Figure 9.4: APEC's Projected Electricity Generation Capacity by Energy Source 94
Figure 9.5: Projected Generating Capacity by Economy and Energy Source, Economies with Larger Capacities 96
Figure 9.6: Projected Generating Capacity by Economy and Energy Source, Economies with Smaller Capacities 96
Figure 9.7: Annual Growth Rates of APEC Economies' Generation Capacities between 2010–2020 and 2020–2035 97
Figure 9.8: Electricity Generation Supply by Economy and Energy Source, Larger Generating Economies 98
Figure 9.9: Electricity Generation Supply by Economy and Energy Source, Smaller Generating Economies 98
Figure 9.10: Annual Growth Rates of APEC Economies' Electricity Generation Supply between 2010–2020 and 2020–2035 99
Figure 9.11: APEC Economies T&D Losses in 2009 101
Figure 9.12: APERC's Electricity Supply Model 103

Figure 10.1: Total Primary Energy Supply, in Mtoe and Percent, 2010 and 2035 107
Figure 10.2: Primary Energy Supply by Energy Source, Higher Primary Energy Supply Economies 108
Figure 10.3: Primary Energy Supply by Energy Source, Lower Primary Energy Supply Economies 108
Figure 10.4: Primary Energy Supply Average Annual Growth Rate by Economy, 2010–2020 and 2020–2035 109
Figure 11.1: APEC Total Oil Production and Net Oil Imports, 1990–2035 113
Figure 11.2: APEC's Projected Oil Production in 2010, 2020 and 2035, Higher Oil Production Economies 119
Figure 11.3: APEC's Projected Oil Production in 2010, 2020 and 2035, Lower Oil Production Economies 119
Figure 11.4: Net Oil Imports for Net Oil Importing Economies 120
Figure 11.5: Net Oil Imports for Net Oil Exporting Economies 120
Figure 12.1: Projected Gas Production, Larger Gas-Producing Economies 123
Figure 12.2: Projected Gas Production, Smaller Gas-Producing Economies 123
Figure 12.3: Projected Net Import of Gas in APEC Economies 125
Figure 12.4: Projected Net Export of Gas in APEC Economies 125
Figure 12.5: High Gas Scenario – Increase in Gas Production 128
Figure 12.6: High Gas Scenario – Sources of Additional Gas Production 129
Figure 12.7: High Gas Scenario – Reduction in CO_2 Emissions from Electricity Generation 130
Figure 13.1: Projected Coal Production in Mtoe, Major Coal Producing Economies 131
Figure 13.2: Projected Coal Production in Mtoe, Other Economies 131
Figure 13.3: Projected Net Export (-) of Coal, APEC Coal Exporting Economies, in Mtoe 132
Figure 13.4: Projected Net Import of Coal, APEC Coal Importing Economies, in Mtoe 132
Figure 13.5: Projected Production and Net Imports of Coal, all APEC Economies, in Mtoe 133
Figure 13.6: Efficiency of Electricity Generation Technologies 134
Figure 13.7: Improving Coal Thermal Plant Efficiencies 135
Figure 14.1: Projected Electricity Generation from Nuclear Energy 138
Figure 14.2: Projected Nuclear Power Generation Capacity 138
Figure 15.1: Projected Renewable Energy Supply, Larger Supplying Economies 141
Figure 15.2: Projected Renewable Energy Supply, Smaller Supplying Economies 142
Figure 15.3: APEC Region Electricity Generation Mix (1990–2035) 142
Figure 15.4: NRE Capacity Additions in APEC by Energy Source (Total for 2010–2035) 144
Figure 15.5: NRE Electricity Generation in APEC by Energy Source (1990–2035) 144
Figure 15.6: Wind-based Generation Growth, Top Two and Other APEC Economies (2005–2035) 144
Figure 15.7: Biomass-based Generation Growth, Top Three and Other APEC Economies (2005–2035) 145
Figure 15.8: Geothermal-based Generation Growth, Top Three and Other APEC Economies (2005–2035) 145
Figure 15.9: Solar-based Generation Growth, Top Three and Other APEC Economies (2005–2035) 145

Figure 15.10: Median Lifecycle Emissions Estimates, by Electricity Generation Technology 146
Figure 15.11: APEC Region Total Primary Energy Supply Mix (1990–2035)...147
Figure 15.12: Biofuel Use in Transport Sector in APEC Economies 148
Figure 15.13: Direct Use of NRE by Sector, Larger Supplying Economies 149
Figure 15.14: Direct Use of NRE by Sector, Smaller Supplying Economies...149
Figure 16.1: APEC Projected Business-as-usual CO_2 Emissions from Fuel Combustion.........................151
Figure 16.2: APEC Projected Shares of CO_2 Emissions from Fuel Combustion by Sector in 2035 152
Figure 16.3: CO_2 Emissions from Fuel Combustion by Sector, Higher Emitting Economies 153
Figure 16.4: CO_2 Emissions from Fuel Combustion by Sector, Lower Emitting Economies 153
Figure 16.5: CO_2 Emissions per Capita from Fuel Combustion by Sector, Higher Per Capita Emission Economies 154
Figure 16.6: CO_2 Emissions per Capita from Fuel Combustion by Sector, Lower Per Capita Emission Economies 154
Figure 16.7: APEC Projected BAU CO_2 Emissions from Fuel Combustion, by Fuel 155
Figure 16.8: APEC Projected Shares of CO_2 Emissions from Fuel Combustion by Fuel in 2035...........155
Figure 16.9: CO_2 Emissions from Fuel Combustion by Fuel, Higher Emitting Economies.....................156
Figure 16.10: CO_2 Emissions from Fuel Combustion by Fuel, Lower Emitting Economies......................156

FOREWORD

We are pleased to present the *APEC Energy Demand and Supply Outlook – 5th Edition*. This Outlook is designed to provide a basic point of reference for anyone wishing to become more informed about the energy choices facing the APEC region.

Concerns about energy security, the impacts of energy on the economy, and environmental sustainability are becoming increasingly important drivers of policy in every APEC economy. The business-as-usual projections presented here illustrate the risks of the development path the APEC region is currently on. A new feature of this Outlook is the alternative scenarios, which examine options for increasing natural gas use and reducing energy demand in transportation.

Readers who desire a quick overview of our most important findings should read Chapter 1, "Summary of Key Trends". Readers who desire a quick overview of our business-as-usual projections should read Chapter 2, "APEC Energy Demand and Supply Overview". Because of the summaries provided in these two chapters, an Executive Summary would be redundant and is not included. Detailed tables of the model results are available on the APERC website http://aperc.ieej.or.jp/.

This report is the work of the Asia Pacific Energy Research Centre (the 'we' used throughout this report). It is an independent study, and does not necessarily reflect the views or policies of the APEC Energy Working Group or individual member economies. But we hope that it will serve as a useful basis for discussion and analysis of energy issues both within and among APEC member economies.

I would like to express a special thanks to the many people outside APERC who have assisted us in preparing this report, as well as to the entire team here at APERC. We at APERC are, of course, responsible for any errors that remain.

I would especially like to acknowledge the contributions of my predecessor as APERC President, Kenji Kobayashi. Under Mr. Kobayashi's leadership, the *Outlook – 5th Edition* project was already well organized and underway when I joined APERC in July 2012.

Takato Ojimi
President
Asia Pacific Energy Research Centre (APERC)

ACKNOWLEDGEMENTS

The development of the *APEC Energy Demand and Supply Outlook – 5th Edition* could not have been accomplished without the contributions of many individuals and organizations. We would like to thank all those whose efforts made this Outlook possible, in particular those named below.

We are very grateful to our sponsors. The Ministry of Economy, Trade and Industry, Japan, provided the primary funding for this project. The Petroleum Institute of Thailand funded the participation of Charothon Ung-Jinda and Nontaphorn Udomwadhanaphorn. The United States Department of Energy funded the participation of Monterey R. Gardiner.

We wish to express our appreciation to the APERC Annual Conference and Workshop participants who met with us and provided invaluable insights into the issues raised in the draft report.

We also would like to thank members of the APEC Energy Working Group (EWG), the APEC Expert Group on Energy Data and Analysis (EGEDA), and the APERC Advisory Board, along with numerous government officials, for their helpful information and comments.

PROJECT MANAGER

Ralph D. Samuelson

MAIN CONTRIBUTORS TO THIS VOLUME

Chapter 1 – Summary of Key Trends: Ralph D. Samuelson
Sidebar – "Have We Dealt With a Challenge Like Climate Change Before?": Ralph D. Samuelson

Chapter 2 – APEC Energy Demand and Supply Overview: Ralph D. Samuelson
Sidebar – "APEC's Energy Intensity Goal: The Lessons Learned": Ralph D. Samuelson

Chapter 3 – Overview of APERC's Energy Demand and Supply Model: Ralph D. Samuelson and Juan Roberto Lozano Maya

Chapter 4 – Final Energy Demand: Bing-Chwen Yang and Ralph D. Samuelson

Chapter 5 – Transport Sector Energy Demand: Luke Leaver
Sidebar – "APERC's Transport Sector Energy Demand Model and How It Works": Luke Leaver

Chapter 6 – Industrial Sector Energy Demand: Kensuke Kanekiyo, Elvira Torres Gelindon, Gayathiri Bragatheswaran and Nontaphorn Udomwadhanaphorn
Sidebar – "APERC's Industrial Sector Energy Demand Model and How It Works": Kensuke Kanekiyo
Sidebar – "Industrial Energy Intensity, China and the United States": Ralph D. Samuelson and Gayathiri Bragatheswaran

Chapter 7 – Non-Energy Sector Demand: Kensuke Kanekiyo, Elvira Torres Gelindon and Gayathiri Bragatheswaran

Chapter 8 – Residential, Commercial, and Agricultural Sector Energy Demand: Lei Chen and Ralph D. Samuelson
Sidebar – "APERC's 'Other' Sector Energy Demand Model and How It Works": Ralph D. Samuelson
Sidebar – "Improving Energy Efficiency with Residential Fuel Cells": Monterey R. Gardiner

Chapter 9 – Electricity Demand and Supply: Bing-Chwen Yang, Tran Thanh Lien and Aishah Mohd. Isa
Sidebar – "APERC's Electricity Supply Model and How It Works": Ralph D. Samuelson

Chapter 10 – Primary Energy Demand and Supply: Juan Roberto Lozano Maya
Sidebar – "Modelling Fossil Fuel Production": Juan Roberto Lozano Maya and Ralph D. Samuelson
Sidebar – "APEC's Goal to Rationalize and Phase Out Fossil Fuel Subsidies": Ralph D. Samuelson

Chapter 11 – Oil Supply: Juan Roberto Lozano Maya
Sidebar – "The Increasing Importance of Frontier and Unconventional Oil": Juan Roberto Lozano Maya

Chapter 12 – Natural Gas Supply: Dmitry Aleksandrovich Sokolov and Ralph D. Samuelson

Chapter 13 – Coal Supply: Dmitry Aleksandrovich Sokolov
Sidebar – "Improving the Efficiency of Coal-Fired Electricity Generation": Kensuke Kanekiyo

Chapter 14 – Nuclear Supply: Tran Thanh Lien and Kazutomo Irie

Chapter 15 – Renewable Energy Supply: Bing-Chwen Yang, Aishah Mohd. Isa and Luke Leaver

Chapter 16 – Carbon Dioxide Emissions: Ralph D. Samuelson
Sidebar – "Modelling CO_2 Emissions": Ralph D. Samuelson
Sidebar – "Did the Kyoto Protocol Get It Backwards?": Ralph D. Samuelson

PUBLICATION

Aishah Mohd. Isa and Gayathiri Bragatheswaran

ENERGY DEMAND AND SUPPLY MODEL MANAGEMENT

Elvira Torres Gelindon

EDITORS

Naomi O'Connor and Lyn Fletcher

GRAPHICS

Charothon Ung-Jinda and Aishah Mohd Isa

ADMINISTRATIVE SUPPORT

Masatsugu Kamakura, Kaori Najima and Tomoyo Kawamura

COMPUTER SUPPORT

Ping Zhang

ACKNOWLEDGEMENT OF APERC ADVISORY BOARD MEMBERS

Institute of Energy Economics, Japan: Kenichi Matsui

Bureau of Resources and Energy Economics, Department of Resources, Energy and Tourism, Australia: Rupert Quentin Grafton

Canadian Energy Research Institute, Canada: Marwan Masri

Energy Research Institute of National Development and Reform Commission, China: Fengqi Zhou

Tsinghua University, China: Zongxin Wu

ASEAN Center for Energy, Indonesia: Hardiv Harris Situmeang

Institute of Energy Economics, Japan: Masakazu Toyoda

Korea Energy Economics Institute, Korea: Jin-woo Kim

Energy Systems Institute, Siberian Branch Russian Academy of Sciences, Russia: Nikolay I. Vorapay

Center for Energy-Environment Resources Development, Foundation for International Human Resource Development, Thailand: Thierry Lefevre

Lawrence Berkeley National Laboratory, USA: Mark Levine

ACKNOWLEDGEMENT OF EXPERTS OUTSIDE APERC

MODELLING CONSULTANTS

The Institute of Energy Economics, Japan Energy Data and Modelling Center, Japan: Kokichi Itoh, Shigeru Suehiro, Shen Zhungyuen, Naoko Doi, Yuji Matsuo, and Satoshi Nakanishi

Stockholm Environment Institute: Victoria Clark and Charlie Heaps

AUSTRALIA

Department of Resources, Energy and Tourism, Australia: Micheal Gurner and Andrew Scally

BRUNEI DARUSSALAM

Energy Department, Prime Minister's Office, Brunei Darussalam: Noor Dina Zharina Binti Hj Yahya, Hj Amirul Ariffin Hj Mohd Salleh, Siti Hafsah Haji Abd Hamis and Ahmad bin Haji Mohamad

Brunei National Energy Research Institute: Weerawat Chantanakome

CANADA

Natural Resources Canada: Kristi Varangu and Susan Moir

Foreign Affairs and International Trade Canada: Michelle Campbell

CHILE

International Department, Ministry of Energy, Chile: Carlos Piña, Pia Suarez and Corissa Petro

CHINA

Department of International Cooperation, National Energy Administration, China: Sun Yang

Center for International Energy Strategy Studies, Renmin University of China: Xu Qinhua

Energy Research Institute, National Development and Reform Commission of P.R. China: Angie An

HONG KONG, CHINA

Electrical and Mechanical Services Department, Government of the Hong Kong Special Administrative Region: Li Kwok-keung, Eddie W.K. Wu, Mak Ka Chun, Ming Sang Kam and Cho-Yee Ip

INDONESIA

National Energy Council of Indonesia: Farida Zed

Directorate General of New Renewable Energy and Energy Conservation: Maritje Hutapea, Dadan Kusdiana, and Edi Sartono

JAPAN

Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, Japan: Ryo Minami, Shinji Kakuno and Terumi Munetake

Institute of Energy Economics, Japan: Tomoko Murakami, Naoki Nishida, Naoko Doi, Yuji Matsuo and Yoshiaki Shibata

KOREA

Korea Energy Economics Institute, Korea: Gue Jae Jeong and Woonam Seok

Korea National Oil Corporation: Joonbeom Lee

Ministry of Foreign Affairs and Trade, Korea: Eunji Han

MALAYSIA

Ministry of Energy, Green Technology and Water, Malaysia: Loo Took Gee, Anbalagan Kannan, Satish Ranggayah and Mohd Azlan bin Othman

Energy Section, Economic Planning Unit: Nik Adnan Nik Abdullah

Institute of Energy Policy Research, Universiti Tenaga Nasional, Malaysia: Leong Yow Peng

Corporate Strategic Planning Division, Petronas: Ridzuan Zulkifli

MEXICO

Ministry of Energy, Mexico: Leydi Barcelo Córdova

NEW ZEALAND

Ministry of Business, Innovation and Employment: Mark Hashimoto and Bryan Field

PAPUA NEW GUINEA

Department of Petroleum and Energy, Papua New Guinea: Vore Veve and Idau Kopi

PERU

Ministry of Energy and Mines, Peru: Luis Alberto Espinoza, Raul Bastidas, Maria del Rosario Castillo and Roxana Pareja

PHILIPPINES

Department of Energy, Philippines: Jesus T. Tamang and Victoria B. Capito

RUSSIA

Ministry of Energy, Russian Federation: Talyat Aliev and Svetlana Beznasyuk

SINGAPORE

Energy Planning and Development Division, Energy Market Authority, Singapore: Jonathan Goh, Faith Gan, Latha Ganesh, Pang Yan Wei, Agnes Koh, Haresh Mohanan and Dennis Tay

CHINESE TAIPEI

Bureau of Energy, Ministry of Economic Affairs, Chinese Taipei: Jerry J. R. Ou, Jyuung-Shiauu Chern, Yunn-Ming Wang, and Su-fang Chen

Taiwan Institute of Economic Research: Lynn Wang, Feng-Shuo Yang and Grace Chung

THAILAND

International Energy Cooperation Office, Ministry of Energy of the Kingdom of Thailand: Chawalit Pantaros

Department of Alternative Energy Development and Efficiency, Ministry of Energy of the Kingdom of Thailand: Twarath Sutabutr, Prasert Sinsukpraset and Vinuchada Talangsri

Energy Policy and Planning Office, Ministry of Energy of the Kingdom of Thailand: Reukrit Kenharaj and Sittichod Wantawin

UNITED STATES

Office of Policy & International Affairs, U.S. Department of Energy: Phyllis Yoshida, Karen Alozie, Jeffrey Skeer and Antonio Ruiz

Pacific Northwest National Laboratory, United States: Cary N. Bloyd

VIET NAM

General Directorate of Energy, Ministry of Industry and Trade, Viet Nam: Cao Quoc Hung and Pham Thanh Tung

INTERNATIONAL ORGANIZATIONS

International Energy Agency: Fatih Birol, Amos G. Bromhead, Sharon Burghgraeve, Jean-Yves Garnier, Nigel Alan Jollands, Lisa Ryan, Peter Taylor and Akira Yanagisawa

HAPUA Secretariat, Association of South-East Asian Nations: Syaiful Bakhri Ibrahim

List of Abbreviations

APEC ECONOMIES

AUS	Australia
BD	Brunei Darussalam
CDA	Canada
CHL	Chile
CT	Chinese Taipei
HKC	Hong Kong, China
INA	Indonesia
JPN	Japan
MAS	Malaysia
MEX	Mexico
NZ	New Zealand
PE	Peru
PNG	Papua New Guinea
PRC	People's Republic of China
ROK	Republic of Korea
RP	the Republic of the Philippines
RUS	the Russian Federation
SIN	Singapore
THA	Thailand
US or USA	United States of America
VN	Viet Nam

ORGANIZATIONS AND INSTITUTIONS

ADB	Asian Development Bank
APEC	Asia Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of South-East Asian Nations
CIA	Central Intelligence Agency (USA)
EDMC	Energy Data and Modelling Center (of IEEJ)
EIA	Energy Information Administration (USA)
EWG	Energy Working Group (of APEC)
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of the Petroleum Exporting Countries
WTO	World Trade Organisation
UN	United Nations

TECHNICAL TERMS

BAU	business-as-usual
bcf	billion cubic feet
bcm	billion cubic metres
bpd	barrels per day
BRT	bus rapid transit
BTU	British thermal unit
CBM	coal bed methane
CCGT	combined cycle gas turbine
CCS	carbon capture and sequestration
CDM	Clean Development Mechanism
CNG	compressed natural gas
CO_2	carbon dioxide
CSP	concentrated solar power
DSM	demand-side management
EOR	enhanced oil recovery
EV	electric vehicles
FCV	fuel cell vehicles
FED	final energy demand
FDI	foreign direct investment
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gases
g/kWh	grams per kilowatt-hour (used to measure the emissions caused by the generation of one unit of electricity)
GNP	gross national product
GTL	gas-to-liquids
GW	gigawatt
GWh	gigawatt-hour
IGCC	integrated coal gasification combined cycle
IGFC	integrated coal gasification fuel cell
IOC	international oil companies
IPP	independent power producers
kgoe	kilogram of oil equivalent
km	kilometre
ktoe	thousand tonnes of oil equivalent
kW	kilowatt
kWh	kilowatt-hour
LEAP	Long-range Energy Alternatives Planning System
LHV	lower heating value
LNG	liquefied natural gas
LPG	liquefied petroleum gas
mbd	million barrels per day
mcm	million cubic metres
MEPS	minimum energy performance standards

Mmbls	million barrels
mmscf	million standard cubic feet
MBTU	million British thermal units
MOU	memorandum of understanding
MPa	megapascals
MRT	mass rapid transit
MSW	municipal solid waste
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWp	megawatts peak
NAFTA	North American Free Trade Agreement
NGV	natural gas vehicle
NRE	new renewable energy
NYMEX	New York Mercantile Exchange
NO_x	nitrogen oxides
PHV	plug-in hybrid vehicles
PJ	petajoules
PPP	purchasing power parity
PSC	production sharing contract
PV	(solar) photo-voltaic
R&D	research and development
R/P	reserves-to-production ratio
SO_x	sulphur oxides
SUVs	Sports Utility Vehicles
T&D	transmission and distribution
tcf	trillion cubic feet
tcm	trillion cubic metre
toe	tonnes of oil equivalent
TPES	total primary energy supply
TWh	terawatt-hours
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical (coal power generation technology)
USD	US Dollar

TABLES OF APPROXIMATE CONVERSION FACTORS

Crude Oil*

From	To: tonnes (metric)	kilolitres	barrels	US gallons	tonnes per year
	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US gallons	0.00325	0.0038	0.0238	1	–
Barrels per day	–	–	–	–	49.8

* Based on worldwide average gravity

Products

	To convert: barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
Liquefied natural gas (LPG)	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.240
Gas oil/diesel	0.133	7.5	0.839	1.192
Fuel oil	0.149	6.7	0.939	1.065

Natural Gas (NG) and Liquefied Natural Gas (LNG)

	To: billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.74	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	0.021	1.01	0.19
1 million tonnes oil equivalent	1.11	39.2	1	0.82	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	1	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	0.021	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	0.11	5.41	1

Units

1 metric tonne	= 2204.62 lb = 1.1023 short tons
1 kilolitre	= 6.2898 barrels = 1 cubic metre
1 kilocalorie (kcal)	= 4.187 kJ = 3.968 Btu
1 kilojoule (kJ)	= 0.239 kcal = 0.948 Btu
1 British thermal	= 0.252 kcal unit (Btu) = 1.055 kJ
1 kilowatt-hour (kWh)	= 860 kcal = 3 600 kJ = 3 412 Btu

Calorific Equivalents

One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million British thermal units
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	See Natural Gas (NG) and Liquefied Natural Gas (LNG) table
Electricity	12 megawatt-hours

One million tonnes of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt-hours) of electricity in a modern power station.

1 barrel of ethanol = 0.57 barrel of oil
1 barrel of biodiesel = 0.88 barrel of oil

Reproduced from the BP *Statistical Review of World Energy June 2012* with the kind permission of BP p.l.c.

1 SUMMARY OF KEY TRENDS

The *APEC Energy Demand and Supply Outlook – 5th Edition* is designed to present policymakers with an understanding of the energy trends and issues facing the APEC region to the year 2035. With this goal in mind, this first chapter presents an overview of the most important trends that deserve the attention of policymakers. This chapter appears in place of the Executive Summary that would normally appear at the beginning of a report of this size.

KEY ASSUMPTIONS

The trends discussed in this chapter and throughout this report are shaped by some specific assumptions about the future. This section explains those assumptions and why we make them.

Business-As-Usual

As this report is being written, the energy policies of APEC governments continue to change rapidly. These changes are driven by at least six factors.

1. *Volatility in the oil market.* The first decade of this century saw a dramatic rise in world oil prices, followed by a precipitous drop in late 2008, followed by another rapid rise (see Chapter 3, Figure 3.2). Oil's price volatility has been damaging to businesses and consumers throughout the APEC region. Perhaps even more worrying, however, is that much of the price volatility has reflected tensions in the Middle East, which, if not resolved peacefully, could pose serious threats to oil supply security. Governments are, therefore, increasingly seeking policies that will reduce dependence on oil in general and imported oil in particular.
2. *Climate change.* Governments are seeking policies that will reduce greenhouse gas emissions in order to limit the damage from climate change. Since the production and use of energy accounted for more than two-thirds of greenhouse gas emissions on a world scale in 2010 (IEA, 2011a, p. III.47), these policies are likely to have a profound effect on the energy sector.
3. *Rapid growth of developing economies.* Developing economies, especially in the APEC region, have been remarkably successful in their pursuit of economic growth. While this growth has lifted hundreds of millions of people out of poverty and improved the lives of additional hundreds of millions in other ways, it has had the downside of turning these economies into major world-scale energy consumers and, in some cases, energy importers. Their governments are increasingly recognizing that their own policies will have a significant impact on world energy markets and world greenhouse gas emissions, which could have damaging impacts on their own economies along with others.
4. *The continuing economic crisis.* Despite the continuing growth in the developing economies, most of the developed economies of the APEC region continue to suffer from slow growth and high unemployment. When the last *APEC Energy Demand and Supply Outlook* was published in 2009, governments were attempting to address the problem partly through stimulus programs involving increasing government spending. However, because of increasing concern over the sustainability of the deficit spending involved, governments have been shifting their policies for combating the economic crisis. In addition to monetary policies, the new focus has been on finding ways to do more with less. In the energy sector, this has meant promotion of innovation, economic liberalization and reform, and reduction of taxpayer subsidies for both fossil fuels and renewables. Developing economies have also been attempting to secure their economic future by promoting many of these same policies.
5. *The Fukushima Nuclear Accident.* The tragic events at Japan's Fukushima Daiichi Nuclear Power Plant have provoked a review of policies on nuclear power throughout the APEC region.
6. *Advances in technology.* As detailed in various chapters of this report, energy technology continues to advance in nearly every area, including fossil fuel supplies, renewable supplies, 'smart grids', and more efficient vehicles and other energy-consuming devices. Each innovation requires appropriate policy responses if its full benefits are to be realized.

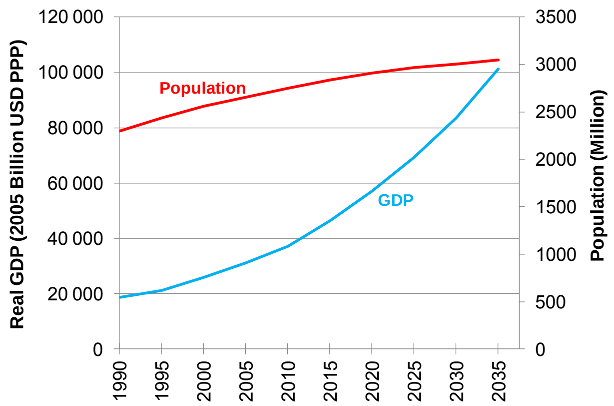
Clearly the policies of the future will not be business-as-usual. Yet what will they be? Given the uncertainties, the safe course would appear to be to assume 'business-as-usual' in our projections. Any other approach has a very real risk of 'counting our chickens before they are hatched'—that is, assuming policymakers do the right thing—resulting in an overly optimistic view of the current situation. Also, policymakers need an independent standard of comparison. Any projection that has built into it assumptions about what policymakers themselves are going to do in the future fails to provide this standard, and is likely to cause confusion.

So, except for the alternative scenarios that are considered, we assume business-as-usual throughout this report. The definition of business-as-usual includes existing policies. It also includes policies that are already being implemented; that is, any necessary legislation has already been passed and there is little uncertainty that the policy is really going to happen. On the other hand, the definition does not include 'targets', 'goals', or policy proposals that governments may have announced, but whose implementation is not yet certain or well defined.

GDP and Population

We assume that the APEC region will continue to enjoy economic growth and progress over the long term, especially in the developing economies. In developing economies, this will include increasing use of commercial fuels, increasing access to electricity, and increasing use of motorized vehicles for transportation. Figure 1.1 shows our specific assumptions about GDP and population for the APEC region as a whole.

Figure 1.1: Assumed APEC GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Table 1.1 shows the assumed APEC GDP and population growth rates. Reflecting the growing GDP share of fast-growing developing economies, and recent demographic trends, it can be seen that GDP growth rates over the 25-year outlook period are assumed to be slightly higher than recent history, while the population growth rate is a bit lower.

Table 1.1: Assumed APEC GDP and Population Growth Rates

Growth	GDP (%)	Population (%)
1990—2005	3.4	1.0
2005—2010	3.6	0.7
2005—2030	4.0	0.5
2005—2035	4.0	0.5
2010—2035	4.1	0.4

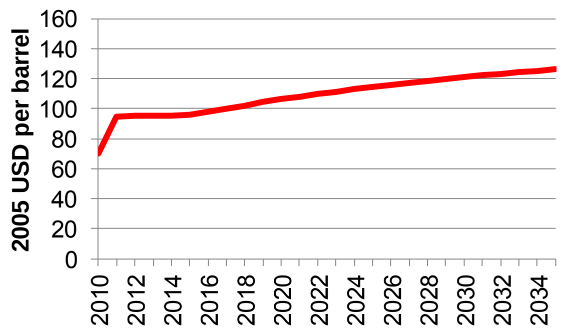
Sources: Global Insight (2012) and APERC Analysis (2012)

Oil Prices

Oil prices have been highly volatile since the oil shocks of the 1970s, and there is no reason to think that the future will be any different. There are many diverse opinions about the future of oil prices offered by well-informed people. Probably the most thorough, publicly available analysis of the long-term future of the oil market is that of the International Energy Agency (IEA) in their *World Energy Outlook 2011*. Their 'Current Policies Scenario' is based on assumptions similar to our business-as-usual assumptions. In this scenario, they assumed that the average IEA member crude oil import price would rise to USD 126/barrel in 2005 USD by 2035 (IEA, 2011b).

As discussed in Chapter 3, we have adopted the IEA's oil price projection in this report. Figure 1.2 shows our oil price assumptions.

Figure 1.2: Assumed Oil Prices



Note: Actual data for 2010 and 2011.
Historical Data: *Energy Prices and Taxes* © OECD/IEA 2012b

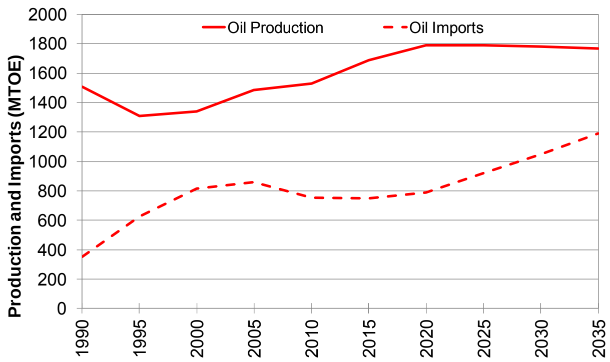
Having explained our key assumptions, the remainder of this chapter examines some expected key trends in the energy sector between now and 2035 that should be of concern to policymakers.

KEY TREND #1

Oil security remains a major threat to the economy of the APEC region

Since 1990, oil production in the APEC region has increased only slightly, while oil demand has risen significantly. As a result, oil imports into the APEC region have grown faster than production. Our business-as-usual projections, as shown in Figure 1.3, indicate that these trends will continue to 2035. Despite some significant increases in APEC's own oil production, the APEC region will become more dependent upon oil imported from outside the region.

Figure 1.3: APEC Total Oil Production and Net Oil Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

This increasing dependency on oil imported from outside the region means that APEC economies may face at least four kinds of risks to their economies:

1. The availability of oil supplies could be threatened by political events in other regions, such as the Middle East and Africa.
2. The availability of oil supplies will depend upon the ability of national oil companies and multi-national oil companies in these other regions to make adequate investments.
3. As oil production becomes more concentrated in a few countries, oil prices will be increasingly influenced by the market power of the producing countries.
4. Increasing amounts of oil will need to be shipped over long distances, typically from the Middle East or Africa, which poses additional security risks.

The likely outcomes of APEC's import dependency are that:

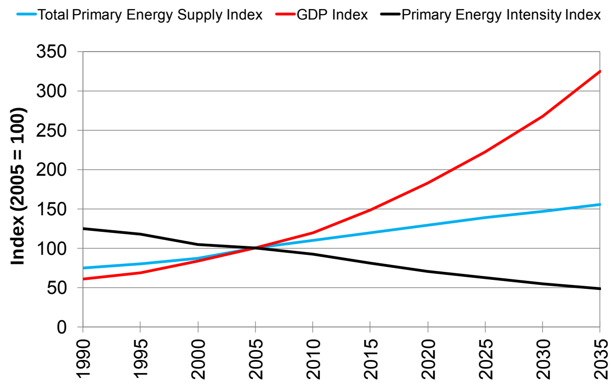
- Continued oil price volatility will be a near certainty.
- There will be significant risks of supply disruptions.
- Both of the above threaten the economic stability of APEC economies and the world.

KEY TREND #2

APEC's energy intensity goals will probably be met under business-as-usual

At their meeting in Sydney in September 2007, APEC leaders called for APEC economies to work toward achieving an APEC-wide regional aspirational goal of a reduction in energy intensity of at least 25% by 2030 (with 2005 as the base year) (APEC, 2007). The goal was revised upward in 2011 at the APEC Leaders' meeting in Honolulu, Hawaii to an improvement of 45% by 2035 (APEC, 2011) since it was becoming apparent that the APEC economies would easily surpass the original goal.

Figure 1.4: Change in APEC Primary Energy, GDP, and Energy Intensity



Source: APERC Analysis (2012)

By 2035, we would expect the APEC region primary energy supply to increase by about 53% compared to 2005, while GDP will increase by about 225%. As shown in Figure 1.4, the net impact will be a decrease in primary energy intensity of about 53%.

This improvement in energy intensity is significantly higher than past trends. Between 1990 and 2009, energy intensity declined at a rate of about 1.4% per year. Under our business-as-usual assumptions, between 2005 and 2035 it will decline at a rate of about 2.5% per year. This decline primarily reflects improvements in technology driven by market forces (including rising energy prices) and the impacts of existing government policies promoting energy efficiency.

KEY TREND #3

Business-as-usual is still environmentally unsustainable

The expected improvement in energy intensity is, unfortunately, not sufficient to put the APEC region on a path toward environmental sustainability. In fact, the best science suggests that the path we are on has a great probability of disastrous climate change consequences.

To understand why this is, we must first understand what science says needs to happen to greenhouse gas emissions to mitigate the risks of climate change. In fact, managing greenhouse gas emissions is a problem very different from managing other types of air pollution. With most air pollution, if the emissions can be stabilized, the impacts can be stabilized, and if the emissions can be reduced, the impacts will be reduced. This is not true of greenhouse gas emissions, since they build up cumulatively in the atmosphere and break down only over extremely long time periods (typically decades or centuries). Hence, only very large reductions in greenhouse gas emissions can stabilize the impacts.

Table 1.2 summarizes the challenges posed by climate change. It is taken from the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* (the Fifth Assessment Report is due for release in 2014). The IPCC is the scientific body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP) to provide objective information about climate change (IPCC, 2012).

Table 1.2: Climate Change Stabilization Scenarios

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005=375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes (from IPCC):

a) The emission reductions to meet a particular stabilization level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b) Atmospheric CO_2 concentrations were 379 ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455 ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375 ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure 2.1).

d) The best estimate of climate sensitivity is 3°C.

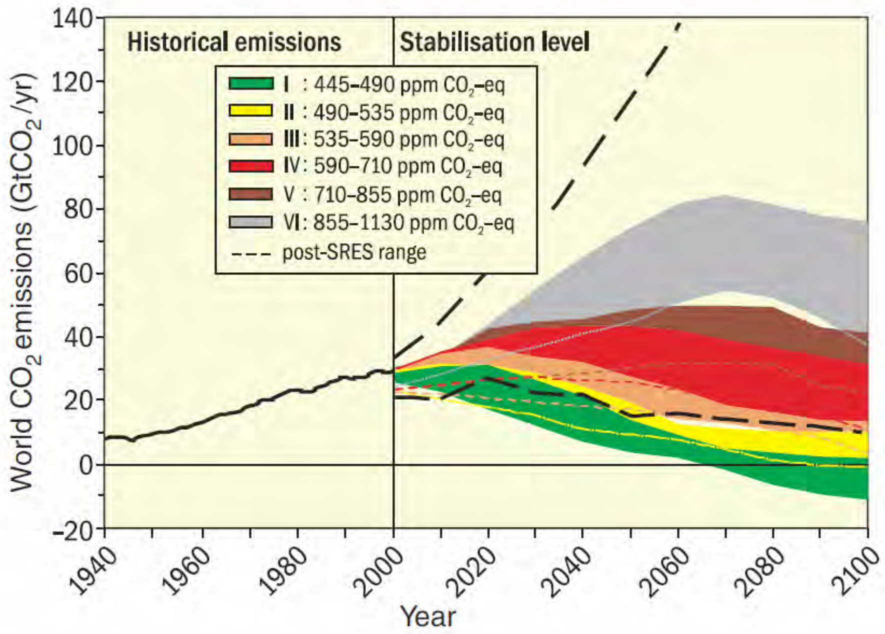
e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilization of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilization of GHG concentrations occurs between 2100 and 2150 (see also Footnote 30).

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6 m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

Source: IPCC (2007), Table 5.1, p. 67

The table shows five possible scenarios for greenhouse gas emissions. Category I, which limits the average global temperature increase to 2.0–2.4 degrees Celsius, requires concentrations of greenhouse gases in the atmosphere to stabilize at a level of 445–490 ppm of CO_2-equivalent. To achieve stabilization at this level would require global CO_2 emissions in the year 2050 to be reduced by 50–85% compared to the year 2000, with global CO_2 emissions peaking between the years 2000 and 2015. The green range in Figure 1.5 illustrates the path of emissions under such a scenario.

Figure 1.5: CO_2 Emissions for a Range of Stabilization Levels



Source: IPCC (2007), Figure 5.1, p. 66

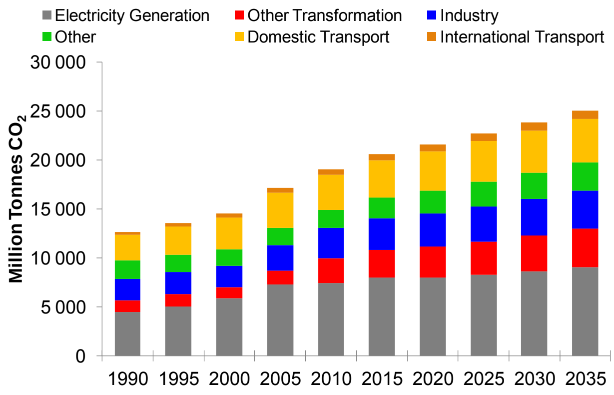
The impacts of climate change are wide-ranging, complex, and vary by location. A fair summary of the IPCC's assessment of the impacts of climate change is that there is a mixture of beneficial and damaging impacts in the 2.0–2.4 degrees Celsius range of warming. Beyond this, most impacts turn out to be damaging, some significantly so. These include:

- rising sea levels—by the 2080s many millions more people are likely to experience coastal flooding each year, especially in the low-lying mega deltas of Asia (IPCC, 2007, p. 48)
- declines in global food production potential (IPCC, 2007, p. 48)
- future tropical cyclones (typhoons and hurricanes) becoming more intense (IPCC, 2007, p. 46 and Table 3.2, p. 53)
- widespread loss of glaciers and snow cover, reducing water availability, hydro potential, and changing the seasonality of water flows in regions supplied by melt water from major mountain ranges (Hindu–Kush, Himalaya, Andes), where one-sixth of the world population currently lives (IPCC, 2007, p. 49)
- adverse health impacts, including increased diarrhoeal, cardio-respiratory, and infectious diseases (IPCC, 2007, p. 51)
- increases in rainfall in some wet, tropical areas, including East and South–East Asia, accompanied by decreases in rainfall in many semi-arid areas including the western United States; drought-affected areas are expected to increase in extent (IPCC, 2007, p. 49)
- widespread damage to coral reefs and their dependent species, including Australia's Great Barrier Reef, due to ocean acidification (IPCC, 2007, pp. 50–51)
- greater frequency of extreme weather events, including heat waves and heavy precipitation (IPCC, 2007, Table 3.2, p. 54).
- widespread extinctions of wildlife: 20–30% of species assessed so far are at risk of extinction if global average warming exceeds 1.5 to 2.5 degrees Celsius relative to 1980–1999 levels; as global average warming exceeds 3.5 degrees Celsius, this rises to 40–70% of species assessed (IPCC, 2007, p. 54).

Cooperative efforts to reduce emissions at the global level remain a work in progress. There does, however, appear to be a consensus that climate warming should be limited to 2 degrees Celsius. This consensus was reflected in the Cancun Agreements adopted at the United Nations Framework Convention for Climate Change (UNFCCC) Conference of Parties in Cancun, Mexico in December 2010, which called for holding "the increase in global temperature below 2 degrees Celsius" (UNFCCC, 2010, p. 3). The UNFCCC enjoys near universal membership, with 194 member countries plus the European Union (UNFCCC, 2012).

This need to dramatically reduce emissions may be contrasted with the business-as-usual projection of APEC region CO_2 emissions from fuel combustion, shown in Figure 1.6. CO_2 emissions from fuel combustion accounted for about 89% of greenhouse gas emissions from energy and for over 60% of greenhouse gas emissions from all sources worldwide on a CO_2-equivalent basis in 2010 (IEA, 2012a, p. III.47).

Figure 1.6: APEC CO_2 Emissions from Fuel Combustion



Source: APERC Analysis (2012)

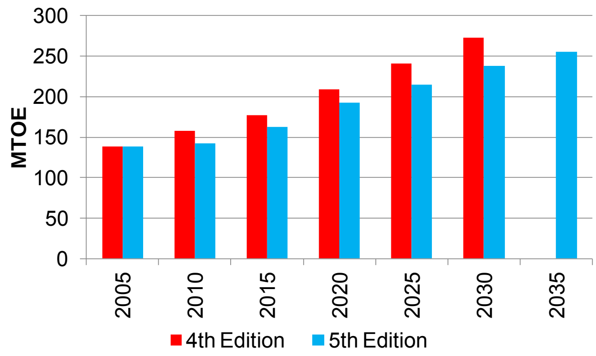
The figure shows that APEC region CO_2 emissions from fuel combustion are expected to rise by about 32% between 2010 and 2035. The threat these emissions pose to humanity, to the environment, and to the economies of the APEC region and the world certainly make it one of the greatest challenges facing the region.

KEY TREND #4

Nuclear development slows down, but not by much

As noted above, the Fukushima Nuclear Accident in Japan has caused the APEC economies that use nuclear power, or are considering using nuclear power, to reassess their policies. Nuclear safety regulation is being reviewed and upgraded in all APEC economies with nuclear power. These safety reviews will necessarily cause some delays and slow-downs in nuclear power development. However, except in Japan itself and Chinese Taipei, all the evidence suggests that the outcome over the long term will not be a lot different from what would have happened if the accident had not happened. Figure 1.7 shows a comparison of APERC's projection of nuclear electricity output in our previous *APEC Energy Demand and Supply Outlook – 4th edition* and this *Outlook– 5th Edition*. It can be seen that the differences are not large.

Figure 1.7: APEC Nuclear Output



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

Why is this the case? Based on the information available to APERC, all APEC economies with existing nuclear power plants plan to continue to operate them as originally planned, with the possible exceptions of Japan and Chinese Taipei. All APEC economies that were planning new nuclear plants, again with the possible exception of Japan and Chinese Taipei, also appear to be proceeding with their plans, subject only to the safety reviews mentioned above.

In Chinese Taipei and especially in Japan, there is a great deal of uncertainty regarding the future of nuclear power. At the time of writing this report, most nuclear power plants in Japan have been shut down pending a comprehensive nuclear safety review. When and whether they will resume operation is not clear. It will be up to the Japanese government that was newly elected in December 2012, to sort out Japan's nuclear policy going forward. In this report, we have assumed that the existing nuclear plants will resume operation, but there will be no new nuclear plants in Japan and no life extensions for existing plants beyond their 40-year life. So nuclear will effectively be slowly phased out in Japan over the outlook period.

In Chinese Taipei, the existing nuclear plants continue to operate, and work continues on two units currently under construction. However, the government has announced a policy of not granting life extensions for the existing units and of shutting down the oldest two units once the two units currently under construction are completed. As a result, we assume that nuclear output in Chinese Taipei will drop to about half of its 2009 level by 2035.

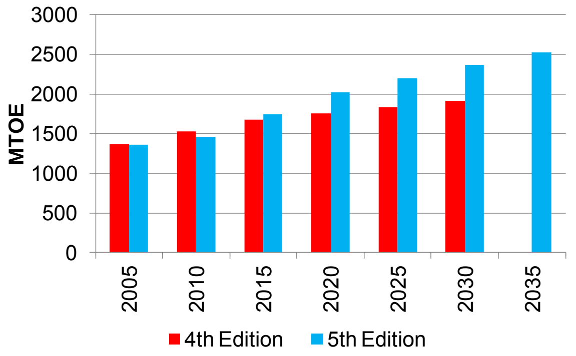
KEY TREND #5

Gas production growth speeds up, and could challenge coal

As discussed in Chapter 12, the growing production of unconventional gas, especially in the US and Canada, has far exceeded expectations of only a few years ago. This is primarily the result of new technology for producing shale gas, including horizontal drilling and hydraulic fracturing. Although this development was anticipated and discussed in the 2009 *APEC Demand and Supply Outlook – 4th Edition*, the technology has continued to prove itself in the real world over the interim.

Figure 1.8 shows the projected APEC gas production in our previous *APEC Energy Demand and Supply Outlook – 4th Edition* and this *Outlook – 5th Edition*. It can be seen that our projected gas production is now significantly higher after 2015.

Figure 1.8: APEC Projected Gas Production



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

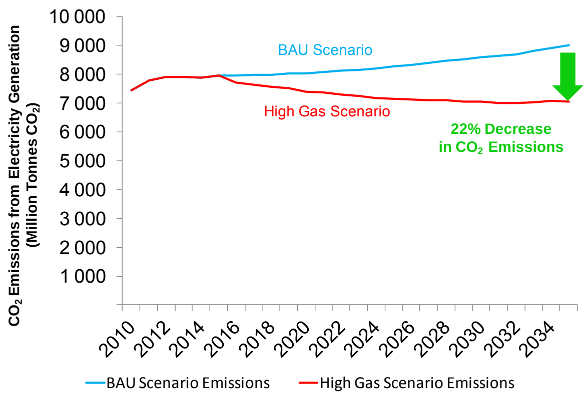
The business-as-usual scenario shown in Figure 1.8 does not include significant shale gas development outside North America and includes fairly conservative estimates of production from both conventional and non-shale-gas unconventional resources outside of North America. However, as discussed in Chapter 12, the conventional and unconventional gas resources of the Asia–Pacific region are immense. And with LNG prices in Asia several times as high as those in North America the economics of gas development outside of North America, as well as further gas development in North America for export, should be compelling.

With appropriate policies and regional cooperation, the APEC economies could use their gas resources to move toward a cleaner energy system, while promoting energy security and mutual prosperity. To illustrate some of the benefits that might accrue from removing the barriers to gas production and trade, APERC developed an alternative 'High Gas Scenario'. In the High Gas Scenario, APERC estimated the gas production that might be available without raising prices if existing constraints on gas production and trade were reduced. In this still-conservative scenario, gas production on an APEC-wide basis was about 30% higher compared to business-as-usual by 2035.

There are many ways the additional gas could be used in the APEC region, almost all of them positive in terms of economics, energy security, and/or the environment. Using gas to replace coal in electricity generation is an especially good option from a CO_2 emissions perspective, since gas-fired generation typically has less than half the CO_2 emissions of coal-fired generation per unit of electricity produced.

APERC therefore assumed the additional gas in the High Gas Scenario would be used to replace coal in electricity generation. As shown in Figure 1.9, the additional gas in the High Gas Scenario could reduce CO_2 emissions from electricity generation in 2035 by about 22% compared to business-as-usual. This implies an overall reduction in energy CO_2 emissions of about 8% compared to business-as-usual.

Figure 1.9: High Gas Scenario – Reduction in CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

It is important to recognize that, in some APEC economies, there is growing public concern over the environmental risks of unconventional gas development. These concerns will need to be addressed through better regulation if gas development is to win the public confidence it will need to deliver benefits like those illustrated in this scenario.

KEY TREND #6

New renewable energy (NRE) goes mainstream

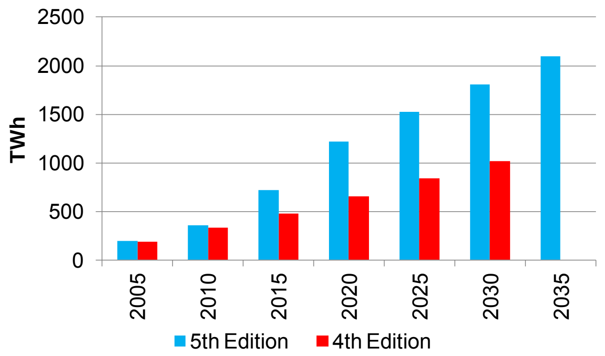
Two forces are driving new renewable energy (NRE) into the mainstream, especially in electricity production. The first is that many APEC economies are responding to the climate change challenges with policies to promote NRE development. These may include:

- feed-in tariffs under which electric utilities are required to buy electricity generated from renewables at a guaranteed price
- renewable portfolio standards, which require electric utilities to obtain a minimum fraction of their electricity from renewable sources
- carbon pricing, such as a tax on CO_2 emissions, which discourages the use of fossil fuels
- regulations limiting greenhouse gas emissions.

Some APEC economies are also promoting the use of biofuels in transportation through requirements that gasoline and diesel fuels have a minimum biofuel content.

The second force driving NRE into the mainstream is technological improvement that continues to reduce the cost and improve the performance of renewable energy. A number of APEC economies have been making substantial investments in research and development to improve renewable energy technology. Businesses and entrepreneurs also perceive a growing market for this technology and are responding with investments of their own. Reductions in the cost of solar photovoltaics (PV) have been especially impressive, with the cost of solar PV electricity now approaching the retail price of electricity in some cities.

Figure 1.10: APEC Projected Electricity Production from New Renewable Energy (NRE)



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011a

Figure 1.10 compares projected electricity production from new renewable energy (NRE) sources in this *Outlook – 5th Edition* with that of the previous *Outlook – 4th Edition*. Reflecting the two forces discussed above, the figure shows a significant upward revision to projected APEC NRE supplies.

The growth in NRE projected in this *Outlook – 5th Edition* is impressive in percentage terms. This is especially true in electricity generation where NRE output will grow at an average of 7.4% per year over the outlook period, which is the fastest growth of any form of electricity generation. However, the overall role of NRE in energy supply remains modest under business-as-usual assumptions, even in 2035. Further expansion of renewable energy will be needed to meet the challenge of climate change.

An earlier APERC study (APERC, 2010, p. 82) concluded that the APEC region should have a non-fossil primary energy share of about 30% by 2030 if the APEC region is to contribute to stabilizing concentrations of greenhouse gases in the atmosphere at 450 ppm of CO_2-equivalent. This compares to a share of 18% by 2030 in our business-as-usual scenario. The same study also concluded that to meet this goal, APEC's low-carbon electricity generation share (which could include both nuclear and carbon capture and storage) should reach 60% by 2030. This compares to a share of 36% by 2030 in our business-as-usual scenario.

KEY TREND #7

Big opportunities to improve efficiency, especially in transportation

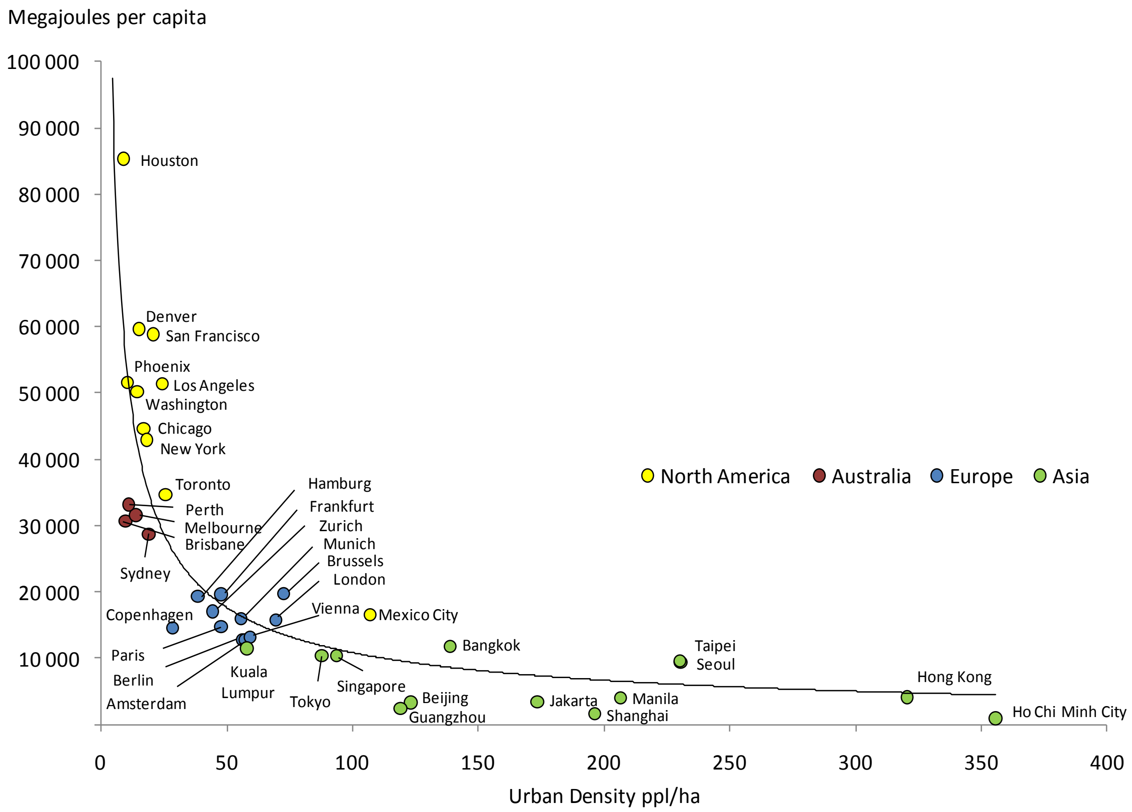
Improving energy efficiency remains the largest and cheapest opportunity to help create a more sustainable energy future. Although there are a set of market failures (discussed in Chapter 4) that tend to inhibit energy efficiency improvements, addressing these market failures offers a unique opportunity to protect the environment, help the economy, and save money for energy users all at the same time. This *Outlook – 5th Edition* closely examines two alternative approaches for improving energy efficiency in the transport sector: alternative urban development and alternative vehicle designs.

Alternative Urban Development Scenarios

The 'Alternative Urban Development' scenarios start from the observation that cities vary dramatically in their per capita energy consumption. It can be seen in Figure 1.11, for example, that per capita transport energy demand in Tokyo or Singapore is about one-seventh what it is in Houston. What if we could design future cities to be more like Tokyo or Singapore and less like Houston?

Of course, redesigning cities is a long-term undertaking. However, the APEC region will be doing a huge amount of city building over the next few decades. The United Nations (2009) estimates that the urban population of the APEC region will grow by 576 million people, or 38%, by 2035 compared to 2010. By 2050, the growth will be 782 million or 51%. And, of course, much of the existing building stock will also be replaced over this time. Clearly, the rapid growth of APEC's cities presents a unique opportunity to build them in an energy-efficient manner.

Figure 1.11: Per Capita Transport Energy Demand vs. Urban Density



Source: Adapted from IUPT/ISTP (1995)

Our model of the energy-saving potential for alternative urban development builds on the observed correlation between per capita urban transport energy use and urban population density that is clear from Figure 1.11. This is, however, a correlation, not necessarily causation. Urban planning can introduce transport-energy-saving design characteristics in a number of ways, including:

- diversity (better mix of land uses, improved jobs–housing balance)
- design (more street connectedness, greater pedestrian/bicycle friendliness)
- transport infrastructure (increased focus on transit over road and parking investments).

More compact cities (those with a higher population density) tend to have lower energy use than less dense 'sprawling' cities for at least three reasons:

1. *Direct effect.* Compact cities have shorter travel distances.
2. *Indirect effect.* Compact cities *tend* to have more of the energy-saving design characteristics discussed above.
3. *Reverse effect.* Cities with the energy-saving design characteristics discussed above *tend* to develop in a more compact way.

In short, building energy-efficient cities will require a full range of better planning decisions, not just higher population densities.

In our modelling, however, we take population density as an indicator of a city's energy efficiency. We ask, what if APEC cities could grow to be like today's higher density cities rather than like today's sprawling cities—like them in all ways, not just population density.

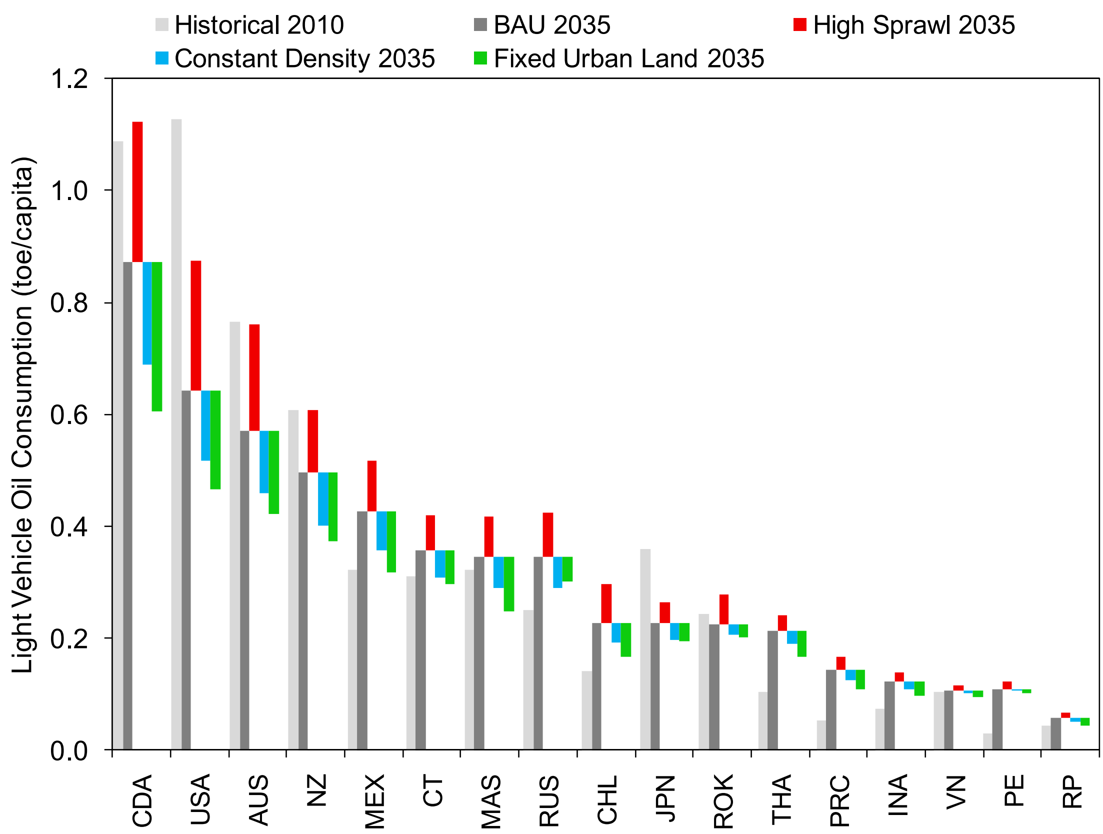
Specifically, we looked at four possible alternative futures:

1. *Business-As-Usual (BAU).* In this scenario urban population density declines at a rate of 1.8% per year, consistent with current worldwide trends.
2. *High Sprawl.* In this scenario urban population density declines at 3.6% per year, or twice the current worldwide trend, consistent with the observed rate in some APEC cities.
3. *Constant Density.* In this scenario the urban population density remains constant, so cities expand in land area in proportion to their population growth.
4. *Fixed Urban Land.* In this scenario the land area of the city remains constant, with population expansion accommodated through growing 'up' rather than 'out'.

The impacts of these scenarios on urban transport energy use by 2035 could be quite dramatic, as shown in Figure 1.12. Note that the alternative urban development scenarios were not run for Brunei and Papua New Guinea due to lack of data, and were not run for Singapore or Hong Kong, China due to their natural geographical limitations.

Overall, the Constant Density scenario would reduce APEC urban transport oil product demand by about 16% by 2035 compared to business-as-usual; the Fixed Urban Land scenario would reduce it by 24%. On the other hand, the High Sprawl scenario would increase oil product demand by about 25% compared to business-as-usual.

Figure 1.12: APEC Light Vehicle Oil Demand Per Capita under Alternative Urban Development Scenarios



Source: APERC Analysis (2012)

Virtual Clean Car Race

Another way to improve transportation energy efficiency is by introducing alternative vehicle designs. The 'Virtual Clean Car Race' alternative scenarios looked at the impacts of introducing four alternatives to conventional internal combustion light vehicles:

1. *Hyper Cars*. These are conventionally powered vehicles with light carbon-fibre bodies and other energy-efficient features.
2. *Electric Vehicles*. These are 100% electric-battery-powered vehicles of otherwise conventional design.
3. *Natural Gas Vehicles*. These are compressed natural gas internal combustion vehicles of otherwise conventional design.
4. *Hydrogen Vehicles*. These are powered by fuel cells running on hydrogen; they are of otherwise conventional design.

We made the assumption in each of four sub-scenarios that each vehicle was introduced uniformly in each economy starting in 2013, with a new vehicle market share rising to 50% by 2020. While not intended to be realistic, these assumptions allow a straightforward comparison of the energy-saving potential of each vehicle type.

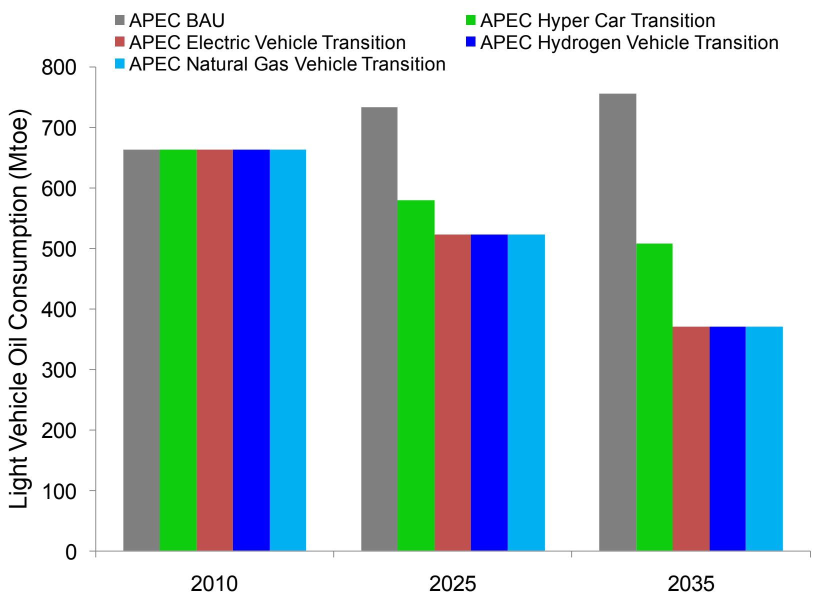
For the Electric Vehicle Transition scenario, we assumed the electricity came from the grid, with additional electricity produced from fossil fuels, either coal or gas, as projected by our electricity supply model. Hydrogen for the hydrogen vehicles was always assumed to be produced by reforming natural gas. We chose not to assume renewable sources were used to produce the additional electricity and hydrogen, since this would be counting the benefits of additional renewable energy supply as a benefit of electric or hydrogen vehicles, which it is not. There is considerable room in every APEC economy to add renewable energy supply without using hydrogen or electric vehicles at all.

The alternative vehicles could potentially provide two types of benefits:

- lower oil demand, thereby increasing energy security
- lower greenhouse gas emissions.

Figure 1.13 shows the impact of the alternative vehicles on oil products demand. It can be seen that by 2035, oil demand when using electric, natural gas, or hydrogen vehicles is about half what it would be compared to using conventional vehicles. This is not surprising, since these vehicles use no oil product for fuel and, by assumption, will constitute about half the vehicle fleet by 2035. Hyper cars also use significantly less oil product than conventional vehicles, reflecting their high fuel efficiency—more than twice that of a conventional vehicle.

Figure 1.13: Impact of Alternative Vehicles on APEC Light Vehicle Oil Product Consumption



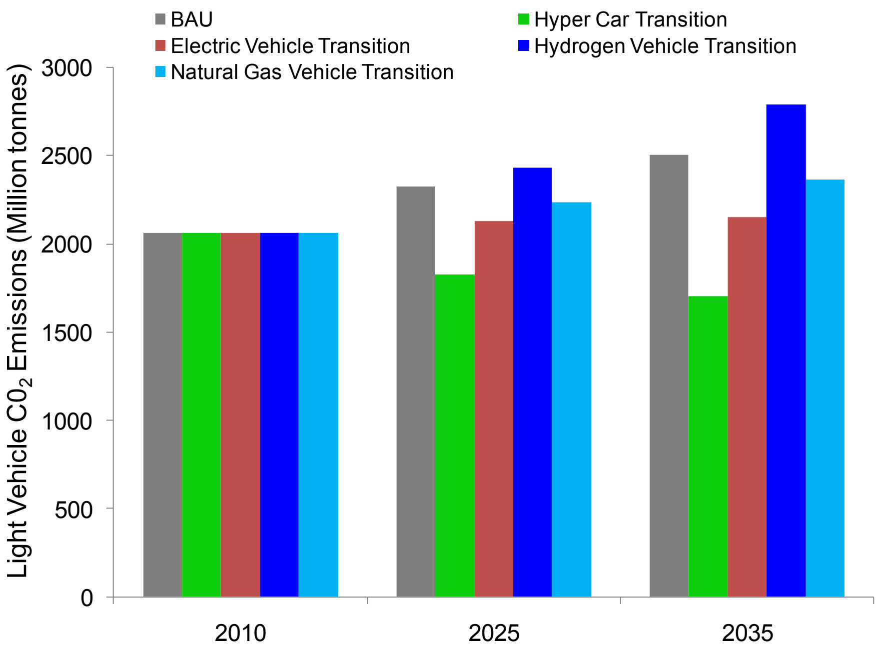
Source: APERC Analysis (2012)

Figure 1.14 shows the impact of the alternative vehicles on CO_2 emissions from fuel combustion. The figures shown include the additional emissions required to produce electricity for the electric vehicles and hydrogen for the hydrogen vehicles.

Here, the hyper cars are the clear winner, reflecting their efficiency, which is more than double that of a conventional vehicle. Since they make up about half the fleet in 2035, CO_2 emissions are about 32% lower than in the business-as-usual scenario. Natural gas vehicles offer a modest reduction in CO_2, reflecting the lower emission factor of natural gas compared to oil products. Electric vehicles also offer only a modest reduction in CO_2 emissions, reflecting our assumption that the electricity is produced from fossil fuels. The impacts of electric vehicles on CO_2 varied considerably between economies, with electric vehicles offering a larger reduction in emissions for those economies where natural gas, rather than coal, was the marginal source of electricity. Hydrogen vehicles turned out to be worse than conventional vehicles from a CO_2 emissions perspective, reflecting the inefficiencies of producing hydrogen from natural gas and then converting the hydrogen to electricity in the vehicle fuel cell.

Of course, the ideal vehicle would have the light weight and high efficiency of the hyper cars, combined with the reduced dependence on oil of any of the other three alternative vehicle types. Both technology paths should be pursued.

Figure 1.14: Impact of Alternative Vehicles on APEC Light Vehicle CO_2 Emissions from Fuel Combustion



Source: APERC Analysis (2012)

HAVE WE DEALT WITH A CHALLENGE LIKE CLIMATE CHANGE BEFORE?

The challenges posed by climate change can sometimes seem overwhelming to those of us who are attempting to do something about them. Avoiding a tragic outcome will require major, and potentially expensive, changes in government policies and technology in a number of sectors. The broad public will need education, both because public support will be required to make these changes happen politically, and because individual behaviour will need to change, too. And all of this needs to happen on a worldwide scale. Has anything like this been done before? The answer is a qualified 'yes'. There are many similarities between the challenges posed by climate change and the challenges posed by infectious diseases in the late nineteenth century.

It is easy to forget the threats that infectious diseases once posed, since no one today, at least in the developed economies, can remember the time when infectious diseases like tuberculosis, pneumonia, typhoid, cholera, scarlet fever, whooping cough, and diphtheria were both common and deadly. But in the United States, for example, in the 1870s and 1880s, one-fifth of all infants died in their first year of life, and even those who survived until adulthood faced a one-in-four chance of dying between the ages of 20 and 30 (Tomes, 1998, p. 25). Moreover, the disease rates were rising alarmingly in fast-growing cities.

Fortunately, at just this time, a new wave of scientific discovery was suggesting that a variety of micro-organisms, colloquially referred to as 'germs', were capable of causing diseases. Today, the germ theory of disease is one of the most widely known and widely accepted findings of science, but in the late nineteenth century, this was not yet the case. Indeed, to many at the time, it seemed rather radical to suggest that diseases were being caused by living organisms. As of 1880, the majority of the medical community found this whole concept hard to accept (Tomes, 1998, p. 27). From 1865 to 1895, Western medicine underwent a virtual civil war over the germ theory of disease. In Europe and the United States, the profession divided into hostile camps that debated in medical journals and textbooks. But by the 1890s, it had become scientific orthodoxy (Tomes, 1998, p. 28).

Inspired by the known value of smallpox vaccinations, many early converts to the germ theory of disease dreamed of developing vaccines or 'internal antiseptics' that could prevent or cure diseases. But, aside from a few exceptions like the rabies vaccine and the diphtheria antitoxin, such hopes for a silver bullet were repeatedly dashed (Tomes, 1998, p. 45). It was not until the 1930s and 1940s that sulfa compounds, penicillin, and other antimicrobial drugs were discovered. As with climate change today, the focus had to be on prevention.

And, as with climate change, prevention was a daunting and expensive task. It required a radical expansion of collective public health practices, including municipal sewerage systems, water purification, garbage collection, building codes, and food inspection. Indeed, our modern conceptions of government responsibility for public health date from the period from 1890 to 1930 (Tomes, 1998, p. 6).

Prevention also required private responses. Entrepreneurs, for one, saw opportunities in the germ theory of disease to promote modern plumbing, soaps, disinfectants, sanitary packaging, water filters, and so forth. Their advertisements, while sometimes exaggerated or inaccurate, still served an important educational role (Tomes, 1998, Chapter 3).

But this era also saw huge educational campaigns to change individual behaviour. In the United States, for example, this role was assumed by a wide variety of organizations, including municipal and state health departments, life insurance companies, women's clubs, settlement houses (organizations that provided charitable services to the poor), Boy Scouts and Girl Scouts, youth service organizations like YMCAs and YWCAs, and labour unions. The era happened to coincide with expanded educational opportunities for women, especially in social work, home economics, and nursing. Many women of this pioneer generation dedicated themselves to bringing the insights of "household bacteriology" to every homemaker (Tomes, 1998, pp. 9–10).

Today, we take all these changes for granted. As Tomes (1998, p. 2) puts it "The rituals of germ avoidance are so many and so axiomatic that we scarcely can remember when or where we first learned them". Yet for the people of the late nineteenth century, these must have seemed like huge and wrenching changes with high costs and uncertain benefits. But still they made it happen, and it can happen again.

REFERENCES

APEC (Asia-Pacific Economic Cooperation) (2007), 'Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development' website page, www.apec.org/Meeting-Papers/Leaders-Declarations/2007/2007_aelm/aelm_climatechange.aspx

— (2011), '2011 Leaders' Declaration: The Honolulu Declaration – Toward a Seamless Regional Economy' website page, www.apec.org/Meeting-Papers/Leaders-Declarations/2011/2011_aelm.aspx).

APERC (Asia Pacific Energy Research Centre) (2010), *Pathways to Energy Sustainability: Measuring APEC Progress in Promoting Economic Growth, Energy Security, and Environmental Protection,* www.ieej.or.jp/aperc/

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011a), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

— (2011b), *World Energy Outlook 2011.*

— (2012a), *CO_2 Emissions from Fuel Combustion*, 2012 edition.

— (2012b), *Energy Prices and Taxes,* 1st Quarter 2012.

IPCC (Intergovernmental Panel on Climate Change) (2007), *Climate Change 2007: Synthesis Report*, www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

— (2012), 'Organization' website page, www.ipcc.ch/organization/organization.shtml

IUPT/ISTP (International Union of Public Transport, Brussels, and Institute for Sustainability and Technology Policy) (1995), Millennium Cities Database.

Tomes, Nancy (1998), *The Gospel of Germs: Men, Women and the Microbe in American Life,* Harvard University Press, Cambridge, Mass., USA.

UNFCCC (United Nations Framework Convention on Climate Change) (2010), "Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010; Addendum Part Two: Action taken by the Conference of the Parties", http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf

— (2012), 'Fast facts & figures' website page, http://unfccc.int/essential_background/basic_facts_figures/items/6246.php

United Nations (2009), *World Urbanization Prospects: The 2009 Revision*, Department of Economic and Social Affairs, Population Division, http://esa.un.org/unpd/wup/Documents/WUP2009_Highlights_Final.pdf

2 APEC ENERGY DEMAND AND SUPPLY OVERVIEW

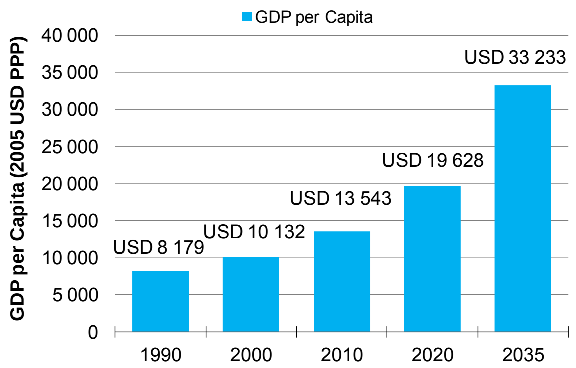
This chapter presents an overview of the business-as-usual (BAU) energy demand and supply results for the APEC region as a whole. We also discuss a key driver behind these results—GDP per capita—and, where appropriate, some policy implications.

GDP PER CAPITA

Chapter 1 discussed our assumptions about APEC-wide economic growth and population growth. Before examining our BAU demand and supply projections, it is worth examining the implications of economic growth and population growth for average GDP per capita in the APEC region and in the individual APEC economies. This is what will shape the kind of energy services consumers are able to afford.

Figure 2.1 shows that average GDP per capita in the APEC region will rise from USD 13 543 (2005 USD PPP) in 2010 to USD 33 233 by 2035. To put these figures in perspective, the average APEC GDP per capita in 2010 is comparable to the 2010 GDP per capita of Chile (USD 13 644), Malaysia (USD 13 244), Mexico (USD 12 427), or Russia (USD 14 348). By 2035, APEC GDP per capita will be comparable to the 2010 GDP per capita of Australia (USD 35 460), Canada (USD 35 383) or Chinese Taipei (USD 32 249).

Figure 2.1: APEC Average GDP per Capita



Source: APERC Analysis (2012)

As a result of the projected large increases in GDP per capita in the APEC region, by 2035 we can expect to see energy used throughout the APEC region in ways typical of the wealthier APEC economies today. This will include a much wider use of energy in motor vehicles, in intercity travel, in more spacious and more climate-controlled housing, in more home appliances, in commercial services (such as restaurants, hotels, healthcare facilities, retail stores, entertainment and recreational facilities, and educational institutions), as well as in industry. Hundreds of millions more people in the APEC region will be rising out of poverty. This is a good economic future if it can be achieved.

FINAL ENERGY

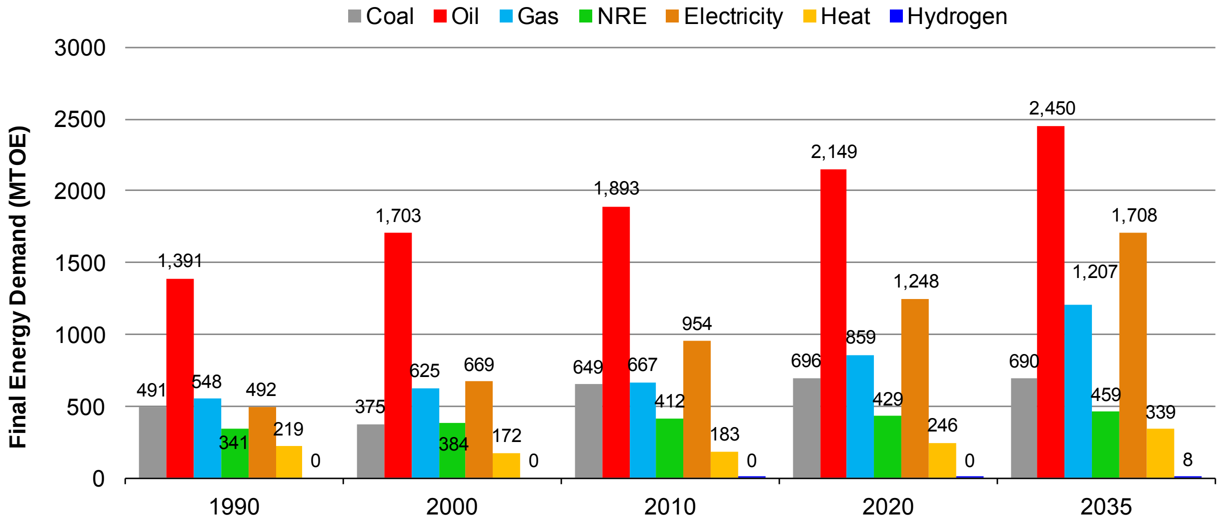
The consequence of this increase in wealth, at least under our BAU assumptions, will be a corresponding increase in the final demand for energy. Final energy is energy in the form it is finally consumed; this means final energy statistics count electricity consumption rather than the primary energy used to make the electricity.

As shown in Figure 2.2, demand for every form of final energy will rise. The largest absolute increase between 2010 and 2035 will be in the demand for electricity (up 754 million tonnes of oil equivalent (Mtoe)), reflecting the growth in demand in the residential and commercial ('other') sectors and in industry.

However, growth in electricity demand will be followed closely by the growth in demand for oil products (up 557 Mtoe), reflecting the increase in motor vehicle use. This will be offset somewhat by increasing vehicle fuel efficiency. Natural gas demand will also rise significantly (up 540 Mtoe).

In percentage terms, the final demand for purchased heat (mainly from district heating systems) will grow the fastest in the 2010–2035 period (up 85%), followed closely by natural gas (up 81%) and electricity (up 79%). Final demand for other fuels will grow more slowly. New renewable energy (NRE) final demand will grow by only about 11% because the demand for this fuel in 2010 was dominated by traditional residential biomass. Residential biomass demand is not expected to grow significantly, since consumers will be increasingly able to afford commercial fuels.

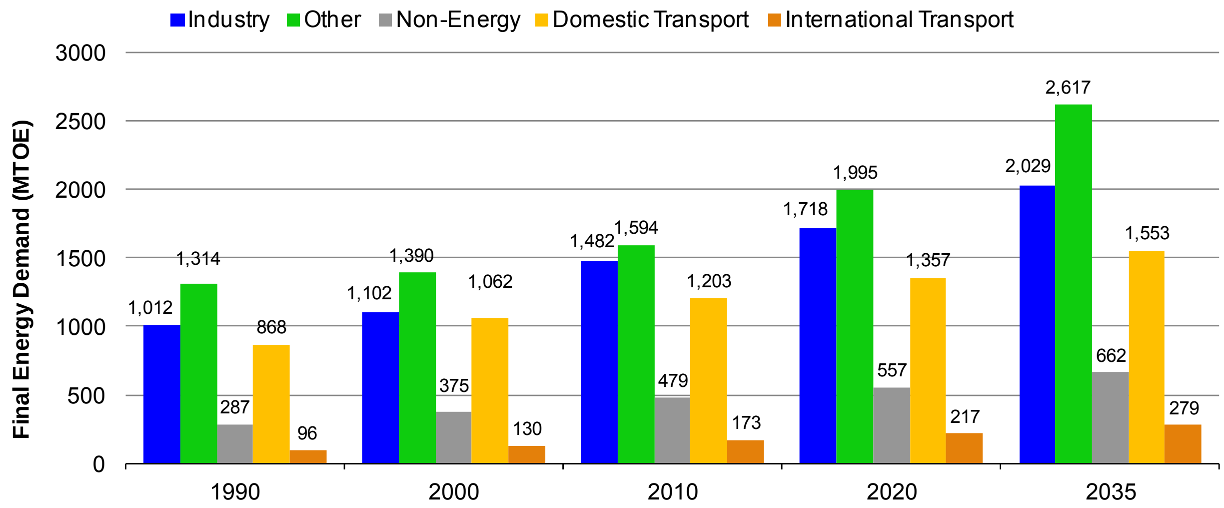
Figure 2.2: APEC Final Energy Demand by Energy Type



Source: APERC Analysis (2012)

Figure 2.3 shows that, between 2010 and 2035, final demand will grow in all the five sectors we model. The 'other' sector (residential and commercial) will grow the fastest in both absolute (up 1023 Mtoe) and percentage (up 64%) terms. However, international transport will grow almost as quickly (up 61%), reflecting an increasingly globalized economy. Domestic transport demand, on the other hand, will be the slowest growing sector, with energy demand growing by 'only' 29%. In this sector, increasing auto ownership will be offset somewhat by increasingly efficient vehicles.

Figure 2.3: APEC Final Energy Demand by Sector



Source: APERC Analysis (2012)

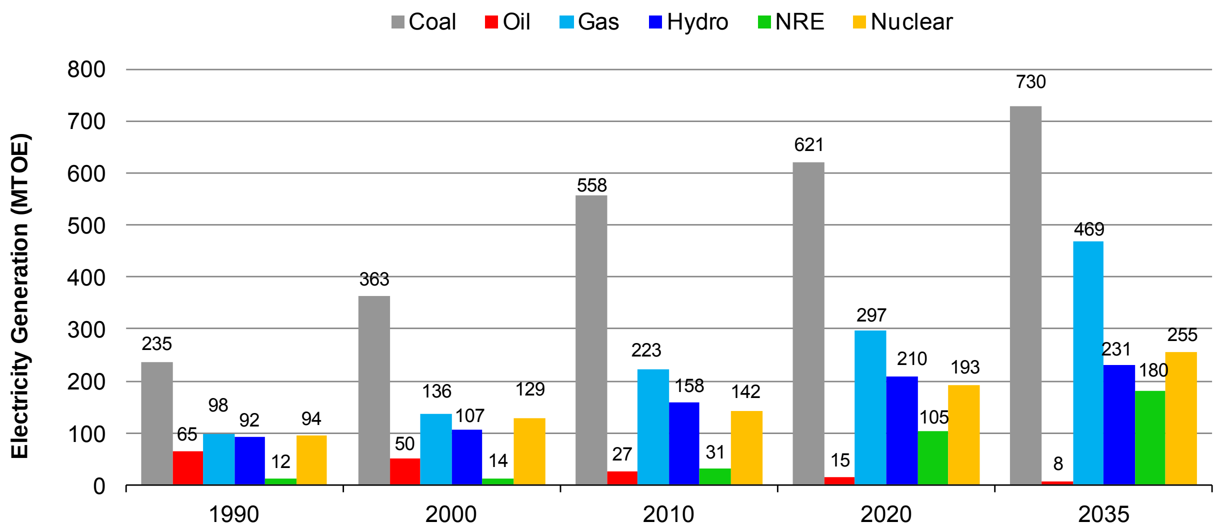
ELECTRICITY SUPPLY

As shown in Figure 2.4, coal was by far the dominant source of primary energy for electricity generation in the APEC region in 2010. Under our BAU assumptions, it will continue to be so in 2035. Coal has the advantages of being widely available and relatively inexpensive in many APEC economies. Therefore, it will experience significant growth: 172 Mtoe or 2002 terawatt-hours (TWh). Growth in China's output of electricity from coal accounts for most of this growth (161 Mtoe or 1872 TWh), while coal generation in the United States is projected to decline by 37 Mtoe or 426 TWh.

The absolute demand for natural gas generation will grow much more rapidly than coal (246 Mtoe or 2867 TWh). Gas has the advantages of also being widely available in many APEC economies and environmentally preferable to coal, since its greenhouse gas emissions are generally lower. New renewable energy (NRE) (which does not include hydro) will show the third-largest absolute growth of 150 Mtoe or 1740 TWh, spurred by declining costs and supportive government policies in many economies. Despite the re-examination of policies on nuclear energy in many APEC economies, nuclear generation is also projected to show a significant growth of 113 Mtoe or 1315 TWh. About two-thirds of this growth will be in China.

In percentage terms, the picture is different. NRE will have by far the largest percentage growth of 490%, followed by gas (111%), and nuclear (89%). As discussed in Chapter 15 (see Figure 15.5), the growth of NRE in electricity generation is dominated by wind energy. Coal generation will grow by about 31%.

Figure 2.4: APEC Electricity Generation by Primary Energy Source



Source: APERC Analysis (2012)

PRIMARY ENERGY SUPPLY

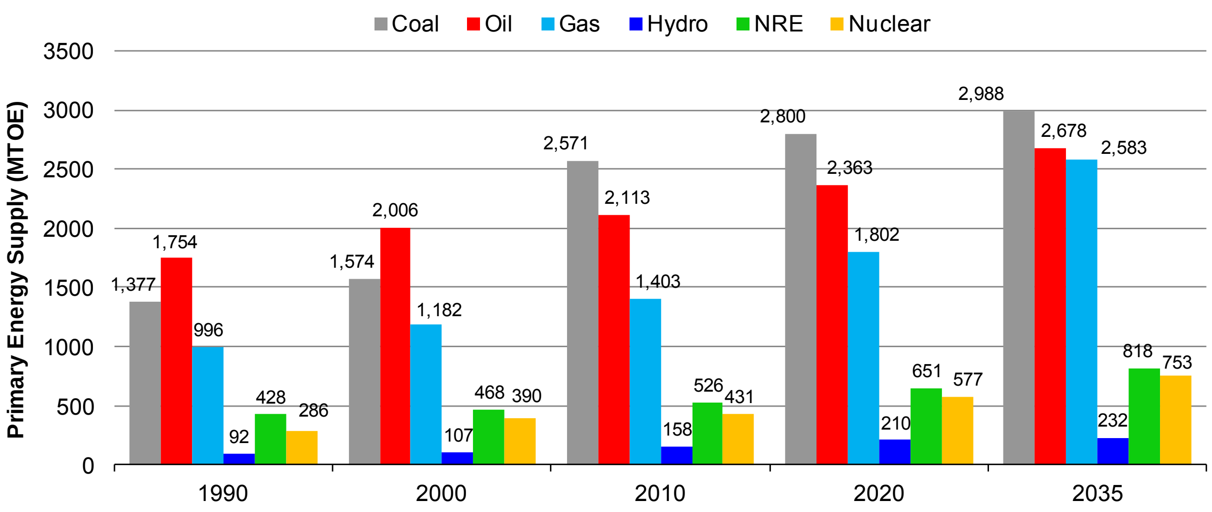
As shown in Figure 2.5, under BAU assumptions coal, oil and natural gas run a close competition to be APEC's leading primary energy source by 2035, with coal still having a slight lead in 2035.

In absolute terms, gas will have the fastest growth in demand between 2010 and 2035 (up 11879 Mtoe). As discussed in Chapter 12, gas supply is benefiting from new technology that allows the economic development of unconventional gas resources. However, our BAU projection may be conservative in that it does not assume large-scale development of shale gas outside of North America. The demand for oil will also grow significantly in absolute terms—565 Mtoe.

Gas also has the largest growth in percentage terms—up 84%. Perhaps surprisingly, nuclear energy is projected to show the second fastest growth in percentage terms, about 75%. As noted above, about two-thirds of this growth will be in China.

NRE will take third place with 55% growth. As discussed above, the use of NRE will grow quickly in electricity generation (up 490%). It will also grow quickly in the domestic transport sector in the form of biofuels (about 130%). In both sectors, this growth will be spurred by favourable existing government policies toward NRE in many APEC economies, as well as technological improvements. However, the use of NRE in the residential and commercial ('other') sector, which accounted for about 60% of the NRE demand in 2010, is not expected to show significant growth. As explained above, many residential and commercial consumers in developing economies are expected to switch their cooking and heating from traditional biomass to commercial fuels as they become able to afford it

Figure 2.5: APEC Primary Energy Supply by Energy Source

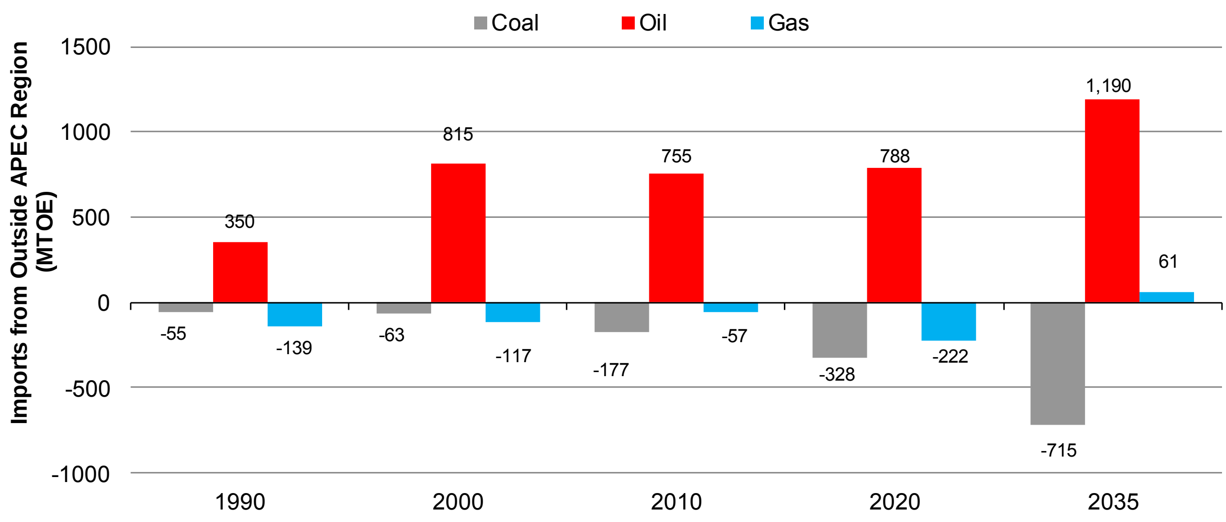


Source: APERC Analysis (2012)

ENERGY IMPORTS FROM OUTSIDE THE APEC REGION

As shown in Figure 2.6, under BAU assumptions, over the 2010–2035 period the APEC region will be a growing exporter of coal to the rest of the world, roughly self-sufficient in gas, and a large and growing importer of oil. In 2010, the APEC region imported about 36% of its primary supply of oil. By 2035, this will rise to about 44% of a significantly larger primary supply of oil. As discussed in Chapter 1, this rising dependence on imported oil poses a serious threat to the economic stability and energy security of the APEC region.

Figure 2.6: APEC Net Imports from Outside the APEC Region



Source: APERC Analysis (2012)

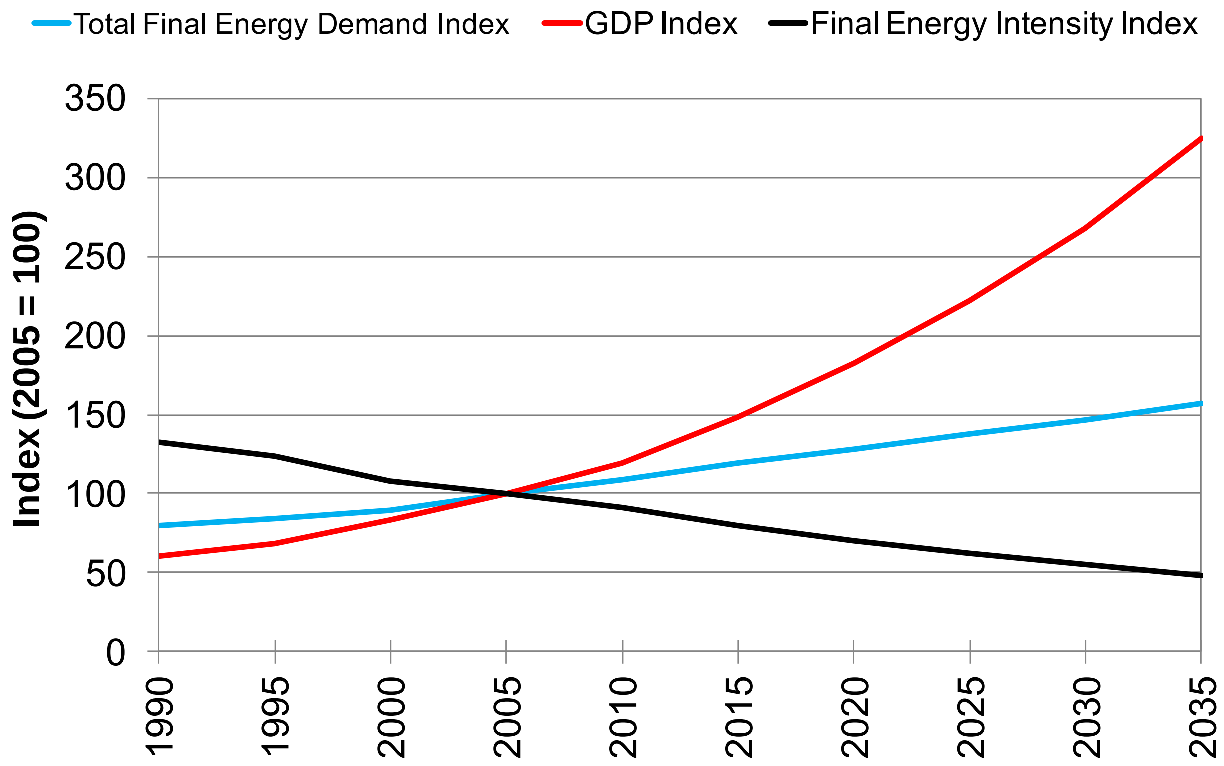
ENERGY INTENSITY

The APEC leaders have agreed to "aspire to reduce APEC's aggregate energy intensity by 45% by 2035" (APEC, 2011), using 2005 as the base year. Energy intensity is defined as energy use divided by gross domestic product (GDP). The APEC energy intensity goal is intended to encourage the APEC economies to work together to improve their energy efficiency to gain economic benefits (cost savings, less exposure to energy price increases), improved energy security, and improved environmental sustainability.

The model results presented here suggest the APEC region will meet the APEC leaders' energy intensity goal under BAU. The APEC leaders did not specify whether energy intensity is to be calculated based on final energy demand or primary energy supply. Figure 2.7 shows the intensity results based on final energy demand, while Figure 2.8 shows the intensity projection based on primary energy supply.

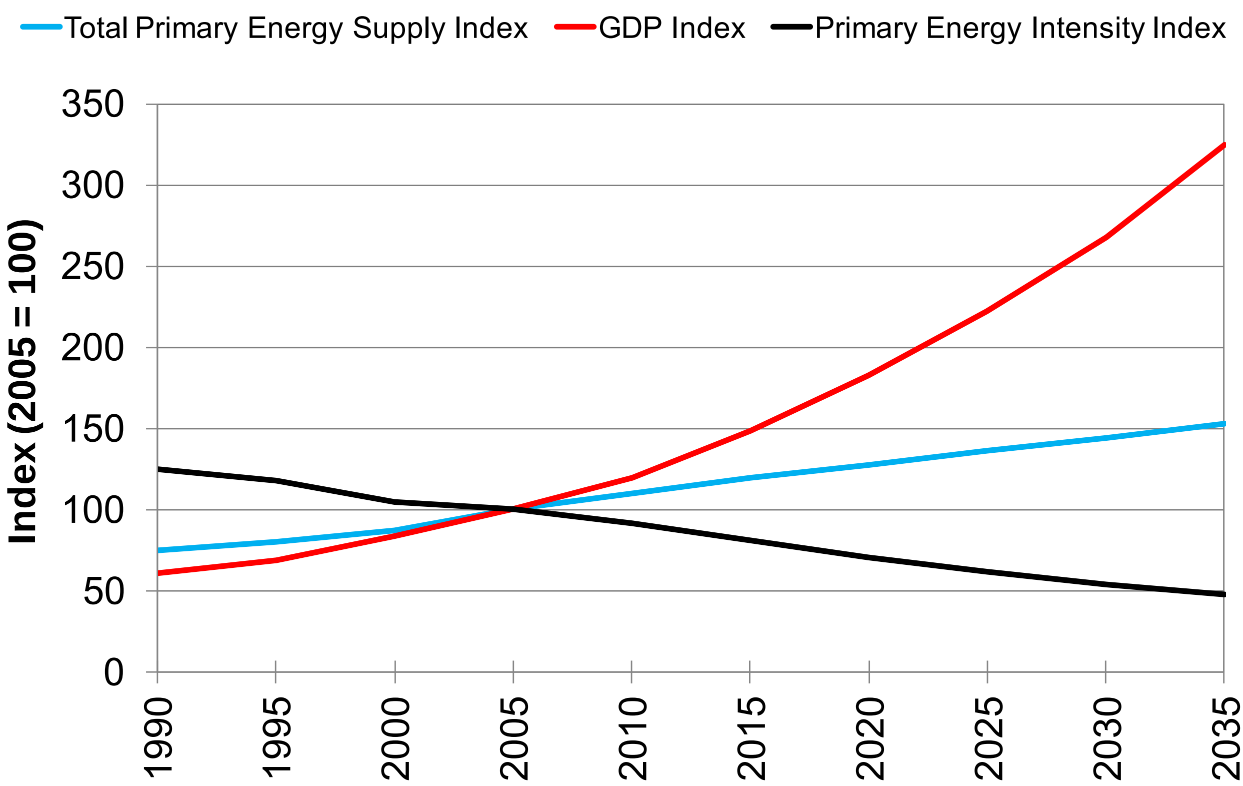
The results in the two cases are virtually identical. Final energy demand increases by about 57% while primary energy supply increases by about 53%. GDP increases by about 225%. The net result in is a decline in final energy intensity of about 48% and a decline in primary energy intensity of about 47%, both exceeding the 45% goal.

Figure 2.7: APEC Final Energy Intensity Improvement



Source: APERC Analysis (2012)

Figure 2.8: APEC Primary Energy Intensity Improvement



Source: APERC Analysis (2012)

Changes in energy intensity can result from changes in energy efficiency as well as from changes in economic structure (where economic sectors with different energy intensities grow or contract at different rates). Changes in economic structure, such as a transition from manufacturing to service industries, can significantly change the energy intensity of an economy.

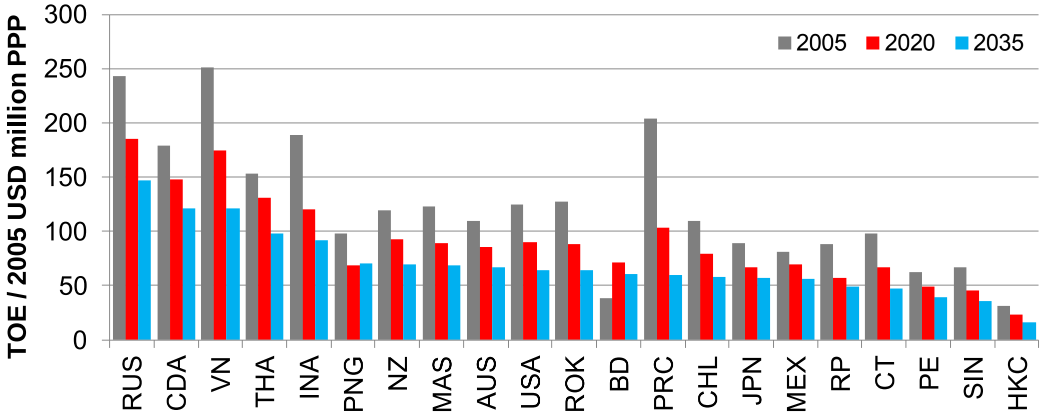
Figure 2.9 shows the expected changes in final energy intensity by economy, while Figure 2.10 shows the expected changes in primary energy intensity by economy.

Every APEC economy, with the exception of Brunei Darussalam for final energy intensity only, is expected to show a significant improvement in energy intensity between 2005 and 2035. (Brunei Darussalam is an outlier only because in 2010 they opened a large export-oriented methanol plant, which significantly increased their industrial energy demand.) There will be a tendency for the economies with the highest energy intensity to show the highest levels of intensity improvement. This will happen as global competitive pressures, government policies, and international cooperation lead all APEC economies to move toward international best practice.

The fact it is likely APEC will meet the APEC leaders' goal for energy intensity improvement under BAU should not be a cause for complacency. As noted in the previous section, despite the improvement in energy intensity, oil imports into the APEC region will grow significantly, posing serious economic and energy security risks. Greenhouse gas emissions from fuel combustion will also rise significantly, the opposite of what the best science says is needed to deal with the challenges of climate change.

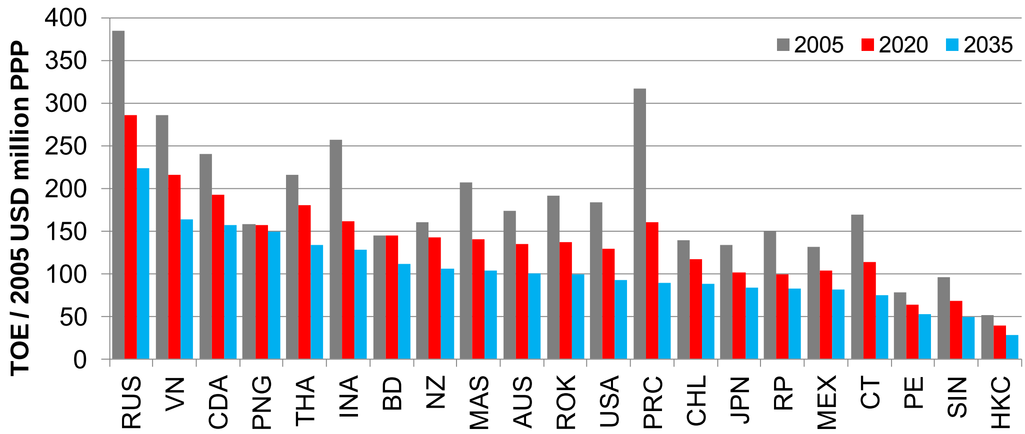
There are a number of factors that can explain the variations in energy intensity among APEC economies. The ratio can be affected by many non-energy-related factors such as climate, geography, travel distances, home sizes and industrial structures (IEA, 2008). As such, it would be misleading to judge an economy's energy-efficiency performance based on its energy intensity alone.

Figure 2.9: APEC Final Energy Intensity by Economy



Source: APERC Analysis (2012)

Figure 2.10: APEC Primary Energy Intensity by Economy



Source: APERC Analysis (2012)

APEC'S ENERGY INTENSITY GOAL: THE LESSONS LEARNED

When the APEC leaders first agreed on an energy intensity improvement goal in 2007, the goal was an improvement of at least 25% by 2030 with 2005 as the base year (APEC, 2007). The goal was revised upward in 2011 to an improvement of 45% by 2035 with 2005 as the base year (APEC, 2011) since it was becoming apparent that APEC economies would easily surpass the original goal. APERC's research work to support the APEC Energy Working Group (EWG) in establishing a revised goal suggests three key lessons that any organization wishing to set an energy intensity improvement goal may wish to keep in mind:

1) *Energy intensity improvement is happening surprisingly quickly, but not quickly enough to meet the world's energy challenges.* Large reductions in energy intensity, in the order of 35–40%, can be expected between 2005 and 2035. However, because of expected rapid economic growth, especially in developing economies, these improvements in energy intensity will not stop the growth of energy demand, with its associated threats to the environment and the stability of the world economy.

2) *It is difficult to find a definition of energy intensity that can make it suitable for use as an indicator of regional energy efficiency.* There are at least three alternative approaches to measuring energy demand, the numerator in the calculation of energy intensity (energy demand/GDP). First, energy intensity can be calculated based on the 'physical energy content' method used by the International Energy Agency (IEA), the OECD, and Eurostat (IEA et al., 2004). However, under this approach, energy intensity will increase (get worse) if an economy uses more nuclear or geothermal electricity generation. The reason is that, under this approach, both nuclear and geothermal have large 'losses' between their primary energy input (nuclear-produced steam and geothermal steam, respectively) and their final energy output (electricity), and are thus counted as inefficient forms of generation. This anomalous outcome runs counter to a presumed objective of the energy intensity improvement goal, which is to encourage low-carbon energy sources, including nuclear and geothermal.

   A second alternative is to calculate energy intensity based on final energy demand (energy after conversion to electricity) rather than primary energy supply. This approach would give a clearer measure of end-user energy efficiency improvement, which is the focus of energy efficiency improvement efforts in many economies. However, it would not reflect the improvements an economy makes in the efficiency of its electricity generation, which in many economies represents a major opportunity to improve energy efficiency.

   A third alternative is to use primary energy calculated using the 'direct equivalent method', as used in the United Nations Statistics Division and various IPCC (Intergovernmental Panel on Climate Change) reports (Moomaw et al., 2011, Appendix II.4). This approach simply counts one unit of electricity generated from nuclear or renewables other than biomass as one unit of primary energy, effectively assuming generation from these low-carbon sources to be 100% efficient. This method would avoid the anomalous outcome of the 'physical energy content method', while still reflecting improvements in fossil fuel generating efficiency. However, it is less well-known among policy-makers and therefore potentially confusing to them.

   The EWG took no position as to whether primary energy or final energy should be used to calculate energy intensity, but it did reject the direct equivalent method for the calculation of primary energy (APEC EWG, 2011). Therefore, primary energy in this publication is calculated using the 'physical energy content' method.

3) *Whether the GDPs of individual economies are converted to a common currency using market exchange rates or purchasing power parity (PPP) can dramatically change the energy intensity improvement calculations.* To calculate energy intensity for a group of economies, one must first calculate their aggregate GDP, the denominator in the calculation of energy intensity (energy demand/GDP). The literature suggests that PPP is the more correct aggregation approach because it is the actual purchasing power of each economy that will drive its energy use (Samuelson, 2012). Energy intensity improvement will typically be downward biased if aggregate GDP is calculated using market exchange rates rather than purchasing power parities. The reason is the economies with the highest market exchange rates relative to purchasing power tend to be the developed economies, which also tend to have lower growth rates than developing economies. Hence, aggregate GDP growth will be slower if calculated using market exchange rates than it would be using PPP, causing energy intensity to decline more slowly. In this publication, all GDP values are consistently expressed in terms of 2005 PPPs.

This sidebar is a summary of Samuelson (2012), a draft paper intended for future publication in a professional journal.

REFERENCES

APEC (Asia-Pacific Economic Cooperation) (2007), 'Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development' website page, www.apec.org/Meeting-Papers/Leaders-Declarations/2007/2007_aelm/aelm_climatechange.aspx

— (2011), '2011 Leaders' Declaration – Toward a Seamless Regional Economy' website page, www.apec.org/Meeting-Papers/Leaders-Declarations/2011/2011_aelm.aspx

APEC EWG (Asia-Pacific Economic Cooperation Energy Working Group) (2011), 'Statement Regarding the APEC-wide Energy Intensity Reduction Goal – EWG Recommendation to Senior Officials' website page, http://aimp.apec.org/Documents/2011/SOM/CSOM/11_csom_003.pdf

IEA (International Energy Agency) (2008), *Worldwide Trends in Energy Use and Efficiency*, www.iea.org/publications/freepublications/publication/Indicators_2008-1.pdf

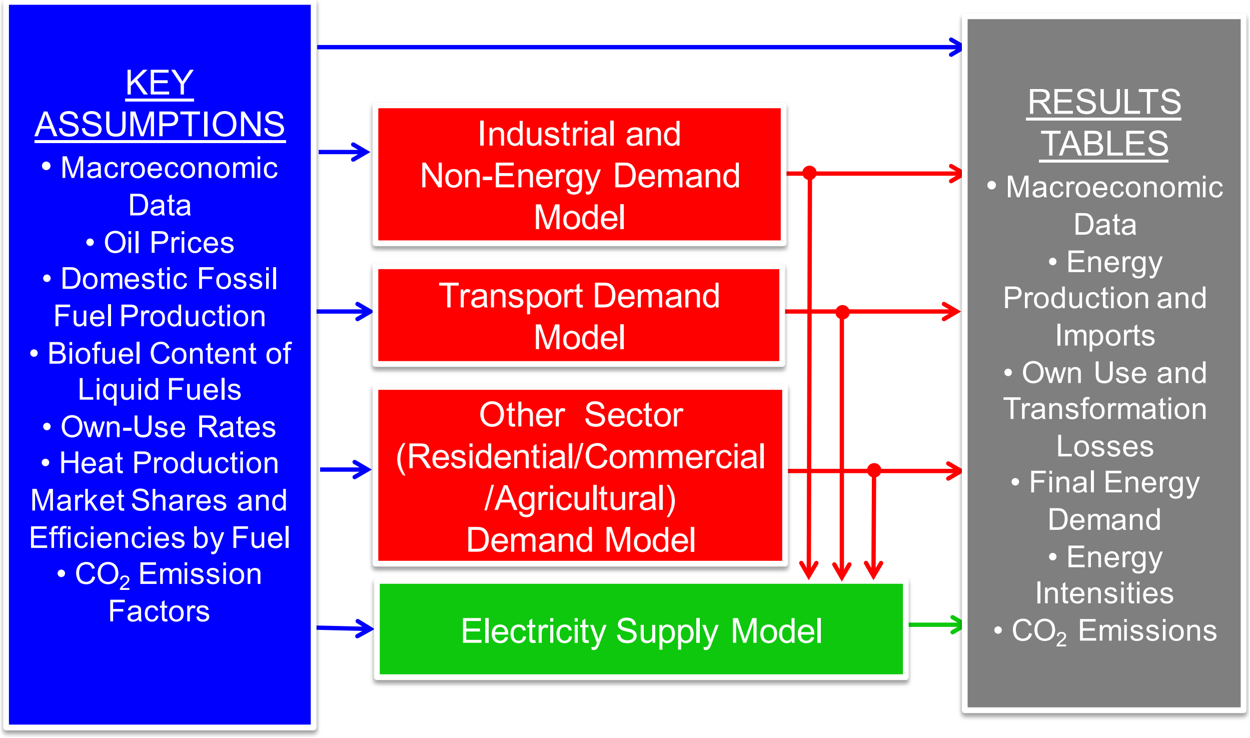
IEA et al. (International Energy Agency, Organisation for Economic Co-operation and Development, and Eurostat) (2004), *International Energy Statistics Manual*, http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/NRG-2004/EN/NRG-2004-EN.PDF

Moomaw, W., Burgherr, P., Heath, G., Lenzen, M., Nyboer, J., and Verbruggen, A. (2011), "Annex II: Methodology", in *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlömer, S., and von Stechow, C. (Eds), Cambridge University Press, Cambridge and New York, http://srren.ipcc-wg3.de/report/IPCC_SRREN_Annex_II.pdf

Samuelson, Ralph D. (2012), "The Unexpected Challenges of Using Energy Intensity as a Policy Objective: Examining the Debate over the APEC Energy Intensity Goal", Asia-Pacific Energy Research Centre, draft paper available upon request from the author, samuelson@aperc.ieej.or.jp

3 OVERVIEW OF APERC'S ENERGY DEMAND AND SUPPLY MODEL

Figure 3.1: Structure of APERC's Model



This chapter presents an overview of the model APERC has used to project energy demand and supply by economy and for APEC as a whole. It also discusses the key assumptions that were made in developing these projections.

MODEL OVERVIEW

Figure 3.1 shows the overall structure of the model for each economy; the model is always the same for each of the 21 APEC economies. APERC's regional and APEC-wide results are simply sums of results for the relevant economies.

The modelling process begins by assembling a database of key assumptions for each economy. These key assumptions are either required by more than one of the sub-models or are used in the summary sheets to estimate results not modelled in one of the sub-models. These key assumptions include:

- historical and projected macroeconomic data (including population, GDP, employment, and agricultural value-added projections)
- historical and projected crude oil prices
- historical and projected domestic fossil fuel production (including coal, oil, and gas)
- historical and projected percentage content of biofuel in road gasoline, road diesel, and rail diesel
- historical and projected average energy sector own-use rates (for coal, oil, and gas)
- historical and projected fuel shares and efficiency rates for heat production (coal, oil, gas, new renewable energy (NRE), and nuclear)
- CO_2 emissions factors for coal, oil, and gas.

The development of these key assumptions estimates is discussed in subsequent sections of this chapter.

There are three sub-models that estimate energy demand in key sectors. These are:

- *The Transport Demand Model*. This sub-model projects demand in the transport sector, for both domestic and international transport. It is discussed in more detail in Chapter 5 on Transport Sector Energy Demand.
- *The Industrial Demand Model*. This sub-model projects demand in the industrial sector, for both energy consumed in industry and 'non-energy'. Non-energy refers to coal, oil, and gas used as feedstocks in the production of petrochemicals and other non-fuel products. This sub-model is discussed in more detail in Chapter 6 on Industrial Sector Energy Demand.
- *The Other Sector Demand Model*. This sub-model projects demand in the residential, commercial, and agricultural sectors. It is discussed in more detail in Chapter 8 on Residential, Commercial, and Agricultural Sector Energy Demand.

These three sub-models also require a number of additional assumptions. These are examined in the chapters that discuss each sub-model.

The fourth sub-model is:

- *The Electricity Supply Model*. This takes as inputs the demand for electricity projected by the three sub-models (above) and simulates the production of this electricity from primary fuels. It also simulates the capacity expansion for each type of electricity generating capacity.

Finally, the Results Tables pull together the results of all four sub-models and present them in an organized fashion. They include a complete energy supply and demand balance sheet for each economy, known as the Summary Table.

The Results Tables are, however, not just passive reports; they contain 'models' for some outputs not modelled in the four sub-models, although the models are fairly simple. These outputs include:

- *Energy sector own-use*. This is the energy consumed in the energy sector itself, including in energy production and in refineries. These projections are based on the loss rates in the Key Assumptions database (see above). However, energy losses in the production, transmission, and distribution of electricity are modelled in the Electricity Supply Model. The demand for fuel used to operate gas and oil pipelines is modelled in the Transport Demand Model.
- *CO_2 emissions from energy combustion*. These are modelled by multiplying the assumed emissions factors for each fuel by the quantities of each fuel demanded. This modelling is discussed in more detail in Chapter 16 on Carbon Dioxide Emissions.
- *Liquid biofuel demand*. The Transport Demand Model estimates the final demand for gasoline and diesel fuel in the road sector and diesel fuel in the rail sector. The Results Tables break each of these demands into the demand for oil product and the demand for biofuel, based on the percentage content of biofuel shown in the Key Assumptions database (see above).
- *Heat production*. The Other Sector Demand Model and the Industrial Demand Model estimate the demand for heat (usually in the form of steam) in these sectors. The Results Tables use the fuel shares and efficiency rates shown in the Key Assumptions database (see above) to estimate the demand for the primary fuels needed to produce heat. Note, 'heat production' refers only to heat produced for sale; it does not include self-produced heat.

The Results Tables also calculate projected energy intensities for each economy (see Chapter 2) and produce a set of graphs for each economy, some of which are reproduced in Volume 2.

Because of their size, the Results Tables for each economy are not reproduced in this report. Rather, they are available on-line on the APERC website http://aperc.ieej.or.jp. There is an on-line document that explains how to read the Results Tables and defines the terms used.

The APERC website includes business-as-usual (BAU) Results Tables for each APEC economy, along with a Results Table for the APEC region as a whole. It also includes a similar set of Results Tables for the High Gas Scenario discussed in Chapter 12 on Natural Gas Supply.

HISTORICAL DATA SOURCES AND KEY ASSUMPTIONS

This section discusses the historical data sources and key assumption projections for key assumptions other than macroeconomic data, oil prices, and domestic fossil fuel production. Macroeconomic data and oil prices are discussed in later sections of this chapter. Domestic fossil fuel production is discussed in Chapter 10 on Primary Energy Demand and Supply.

Historical Data on Energy Demand and Supply

Many of the graphs and tables in this outlook report, as well as the Results Tables, show historical data for 2009 and prior years for comparison with APERC's future outlook. For all economies except Papua New Guinea, this data is from International Energy Agency (IEA) statistics (IEA, 2011c). It is reproduced here with the kind permission of the IEA and is ©2011 IEA/OECD. For Papua New Guinea, the historical data is from the APEC Energy Database (APEC, 2011).

Biofuel Content of Gasoline and Diesel

Historical data on the percentage content of biofuel in road gasoline, road diesel, and rail diesel was obtained from the IEA (IEA, 2011c). Future projections for the BAU scenario were estimated by APERC researchers based on the requirements of the existing laws and regulations in each economy. For economies with no legal biofuel requirements, researchers estimated the amount of biofuel that might be economic in a competitive market, which was generally a very small or zero amount.

Energy Sector Own-Use Rates

Historical data on the percentage energy sector own-use of each fuel was obtained from the International Energy Agency (IEA, 2011c). In most cases, the 2009 percentage rates were assumed to continue into the future. However, in some cases APERC researchers made adjustments based on projected changes to the economy's energy infrastructure or production methods.

Fuel Shares and Efficiency Rates for Heat Production

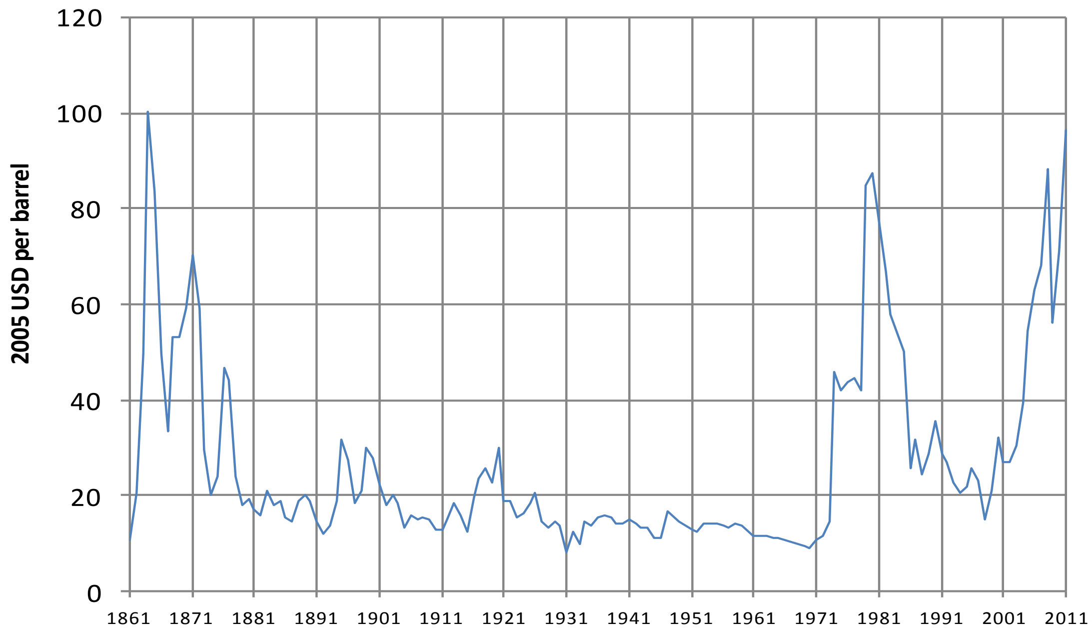
Historical data on fuel shares and efficiency rates for heat production for each fuel was obtained from the IEA (IEA, 2011c). In most cases, the 2009 fuel shares and efficiency rates were assumed to continue into the future. However, in some cases APERC researchers made adjustments based on projected changes to the economy's energy infrastructure or primary energy production. Note, only a few APEC economies have significant commercial heat production.

OIL PRICE AND AVAILABILITY ASSUMPTIONS

Crude Oil Prices and Resources Availability

As depicted in Figure 3.2, crude oil prices have been historically volatile. Particularly since the 1970s, oil prices have been susceptible to geopolitical events that have affected global supply. The major price upswings were caused by the Arab Oil Embargo and the Iranian Revolution in the 1970s, and more recently by the Iraq War and the social movements known as the 'Arab Spring' in North Africa and the Middle East. This volatility has made crude oil prices rather complex to analyse and project.

Figure 3.2: International Crude Oil Prices, 1861–2011



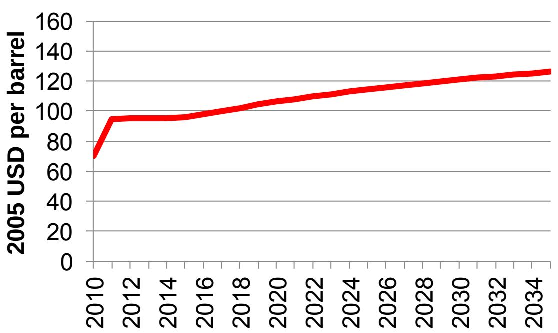
Source: BP (2012)

APERC bases its crude oil price assumptions on the modelling work of the IEA for their *World Energy Outlook 2011* (IEA, 2011b). In particular, APERC follows the crude oil price assumptions of the IEA's Current Policies scenario which, like APERC's BAU scenario, assumes the continuance of existing policies. The IEA bases its crude oil price projections on a sophisticated field-by-field model of the worldwide crude oil supply (IEA, 2011a).

There are many different crude oil prices in the world. The crude oil price projected by IEA is an average price for crude oil imports into IEA member economies. However, over the long term, this price tends to closely mirror the price of key marker crudes, such as Brent and West Texas Intermediate (WTI).

Figure 3.3 shows APERC's assumed crude oil prices for this edition of the *APEC Energy Demand and Supply Outlook*. The oil price assumed by 2035 amounts to USD 126 per barrel, and represents a 79.2% jump from the IEA's 2010 average crude oil import price. Despite the smooth trend suggested by the projection, unpredictable events are nearly certain to cause prices to continue to fluctuate dramatically, as they have in the past.

Figure 3.3: APERC's Crude Oil Price Assumptions, 2010–2035



Note: Actual data from 2010 and 2011
Source: IEA (2011b)

Aside from the uncertainties due to unpredictable short-term events, there are also uncertainties about the long-term evolution of oil supply. In particular, the perspectives of analysts differ on the long-term sufficiency of oil resources. However, there appears to be a reasonable alignment between the views of the Organization of the Petroleum Exporting Countries (OPEC), which represents the major oil exporting economies, and those of the IEA, which represents the major oil importing economies.

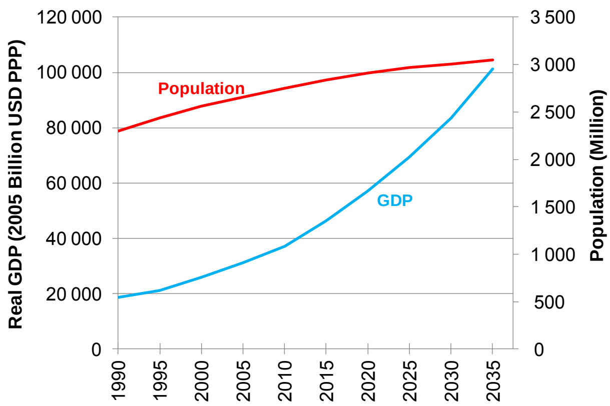
OPEC's opinion is "the world has enough oil resources to meet demand and satisfy consumer needs for decades to come" (OPEC, 2011, p. 2). The IEA's position accepts the "end of cheap oil" and stresses the risks of underinvestment by Middle Eastern and African oil producing countries, but does not appear to question the basic adequacy of oil resources for the foreseeable future (IEA, 2011b, p. 41).

There is a general consensus that unconventional resources will be increasingly important to the world's oil supply, and that these resources will be difficult and costly to develop. Consequently, it is likely higher prices will prevail in the years to come.

MACROECONOMIC DATA ASSUMPTIONS

Figure 3.4 shows the assumed APEC-wide GDP and population up to 2035; Table 3.1 shows the assumed APEC-wide growth rates for GDP and population for the same period. Reflecting the growing GDP share of fast-growing developing economies and the recent demographic trends, the GDP growth rate over the 25-year outlook period is assumed to be slightly higher than that of the previous 20 years, while the population growth rate is a bit lower.

Figure 3.4: Assumed APEC GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Table 3.1: Assumed APEC GDP and Population Growth Rates

Growth	GDP (%)	Population (%)
1990—2005	3.4	1.0
2005—2010	3.6	0.7
2005—2030	4.0	0.5
2005—2035	4.0	0.5
2010—2035	4.1	0.4

Sources: Global Insight (2012) and APERC Analysis (2012)

GDP, Employment, and Agricultural Value-Added

Historical figures and future projections of GDP, employment, and agricultural value-added for all economies except Brunei Darussalam and Papua New Guinea were obtained from IHS Global Insight (Global Insight, 2012), a well-known macroeconomic forecasting service, as of May 2012. In a few cases, the data was modified by APERC researchers based on data from the United States Department of Agriculture (USDA, 2011) as of December 2011, or from other sources. Projections for 2032–2035 are trend extrapolations by APERC.

For Brunei Darussalam and Papua New Guinea (economies not covered by IHS Global Insight), historical and projected GDP data was obtained from the United States Department of Agriculture (USDA, 2011) as of December 2011. Employment in these economies was assumed to grow in proportion to the population, while agricultural value-added was assumed to grow in proportion to GDP. Projections for 2031–2035 are trend extrapolations by APERC.

For all economies, the original source data on real GDP in local currency was converted to 2005 purchasing power parity (PPP) values using conversion rates from the World Bank (The World Bank, 2008, Summary Table).

Table 3.2 shows the assumed projections of total GDP and GDP per capita, by economy. The economies that have the lowest income per capita in 2010 will tend to have the largest percentage increases in GDP. There will thus be a tendency in the APEC region toward less income disparity between economies by 2035.

Population Assumptions

Historical and projected population figures for each economy are based on data and projections by Global Insight (2012). They are generally based on United Nations projections (United Nations, 2011).

Table 3.2: Assumed Projections of Total GDP and GDP per Capita by Economy

Economy	Total GDP (Billion USD PPP)			GDP Growth Rate (%)	GDP per Capita (USD PPP)		
	2010	2020	2035	2010–2035	2010	2020	2035
Australia	790	1 038	1 533	2.7%	35 460	41 103	52 755
Brunei Darussalam	18	22	28	1.7%	45 763	46 731	50 564
Canada	1 206	1 539	2 170	2.4%	35 383	40 543	49 320
Chile	233	375	724	4.6%	13 644	20 299	36 259
China	9 120	19 564	45 117	6.6%	6 802	14 099	32 415
Hong Kong, China	295	447	729	3.7%	41 818	59 667	86 727
Indonesia	931	1 603	3 341	5.2%	3 880	6 106	11 605
Japan	3 946	4 430	4 672	0.7%	30 807	35 539	40 044
Korea	1 321	1 885	2 727	2.9%	27 415	37 845	54 025
Malaysia	376	576	1 000	4.0%	13 244	17 450	25 325
Mexico	1 410	2 056	3 433	3.6%	12 427	16 326	24 515
New Zealand	110	142	203	2.5%	25 258	29 500	37 570
Papua New Guinea	15	27	45	4.4%	2 217	3 311	4 044
Peru	248	407	788	4.7%	8 417	11 945	20 956
Philippines	332	526	1 006	4.5%	3 561	4 792	7 443
Russian Federation	2 014	2 868	4 505	3.3%	14 348	20 336	33 617
Singapore	264	398	632	3.6%	51 801	71 057	102 588
Chinese Taipei	743	1 078	1 687	3.3%	32 249	47 598	70 611
Thailand	530	783	1 505	4.3%	7 674	10 864	20 392
United States	13 088	16 843	24 362	2.5%	42 157	49 305	62 389
Viet Nam	250	462	1 148	6.3%	2 845	4 803	11 055

Source: APERC Analysis (2012), based on data from Global Insight (2012) and USDA (2012)

REFERENCES

APEC (Asia-Pacific Economic Cooperation) (2011), APEC Energy Database, www.ieej.or.jp/egeda/database/database-top.html

BP (2012), *BP Statistical Review of World Energy 2012*, www.bp.com/statisticalreview

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011a), *World Energy Model—Methodology and Assumptions*, www.iea.org/media/weowebsite/energymodel/WEM_Methodology_WEO2011.pdf

— (2011b), *World Energy Outlook 2011*.

— (2011c), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

OPEC (Organization of the Petroleum Exporting Countries) (2011), *World Oil Outlook 2011*, www.opec.org/opec_web/static_files_project/media/downloads/publications/WOO_2011.pdf

United Nations (2011), *World Population Prospects: The 2011 Revision*, Department of Economic and Social Affairs, Population Division, http://esa.un.org/wpp/Excel-Data/population.htm

USDA (United States Department of Agriculture) (2011), International Macroeconomic Data Set, Economic Research Service, www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx

The World Bank (2008), *Global Purchasing Power Parities and Real Expenditures: 2005 International Comparison Program*, http://siteresources.worldbank.org/ICPINT/Resources/icp-final.pdf

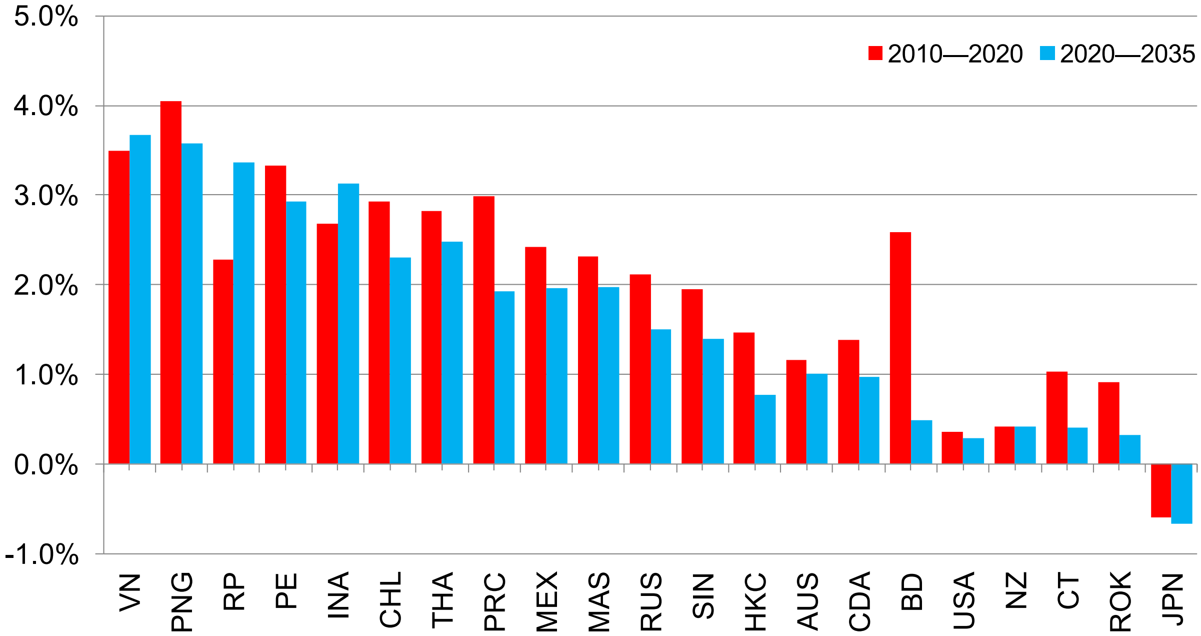
4 FINAL ENERGY DEMAND

TOTAL FINAL ENERGY DEMAND

The projected APEC final energy demand will increase over the outlook period from 4758 Mtoe in 2010 to 6861 Mtoe in 2035. This represents an increase of 44%, and an average annual growth rate of 1.5% between 2010 and 2035.

Figure 4.1 shows the growth rates by economy for the periods 2010–2020 and 2020–2035. As one would expect, the developing economies tend to have the faster growth rates, while final energy demand in the developed economies grows more slowly or, in the case of Japan, actually declines.

Figure 4.1: Annual Percentage Growth Rates in Final Energy Demand by Economy



Source: APERC Analysis (2012)

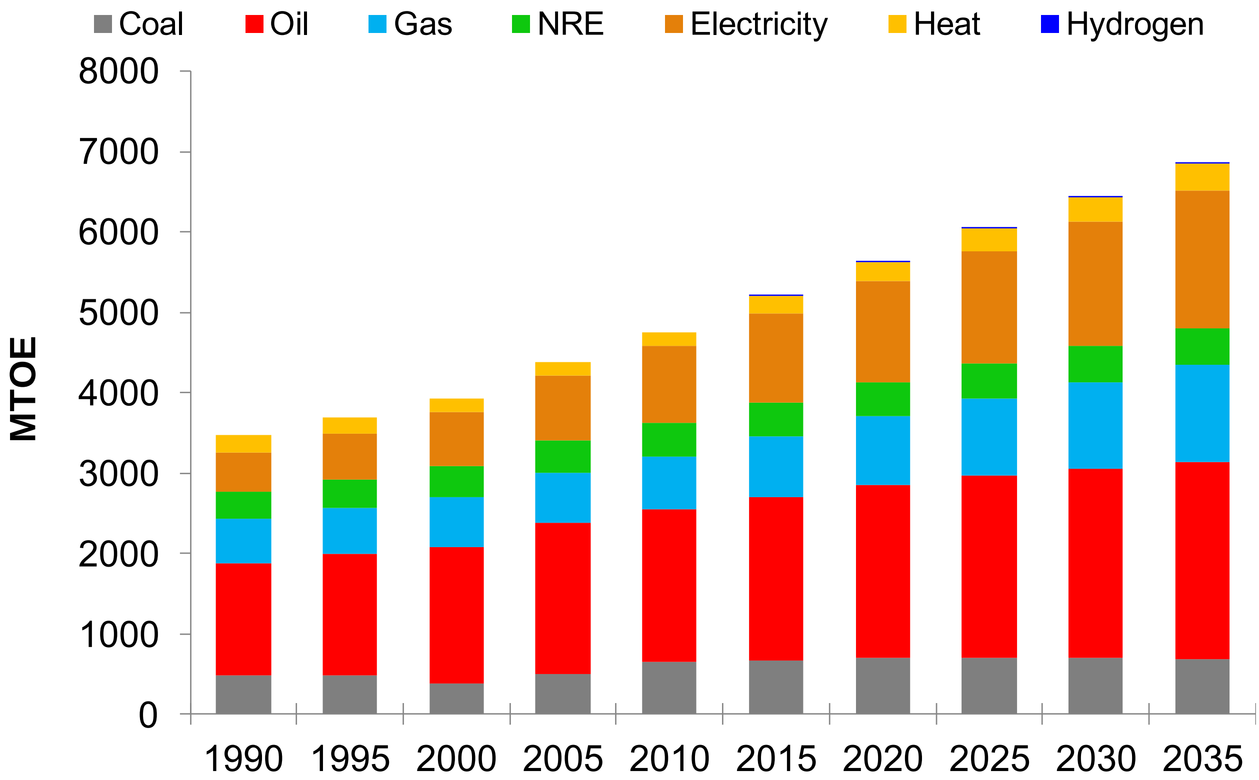
Final Energy Demand by Energy Source

Figure 4.2 shows the total APEC final energy demand by energy source. Figures 4.3 and 4.4 show these results broken out by economy. Note the difference in the vertical axis scales for the latter two figures.

Figures 4.3 and 4.4 show that China and the US will dominate the final energy demand in the APEC region: together they will account for more than 60% of the APEC final energy demand in 2035. China's final energy demand had already overtaken that of the US in 2010, and it is projected to grow at a rate of 2.3% over the 2010–2035 period, compared to 0.3% for the US.

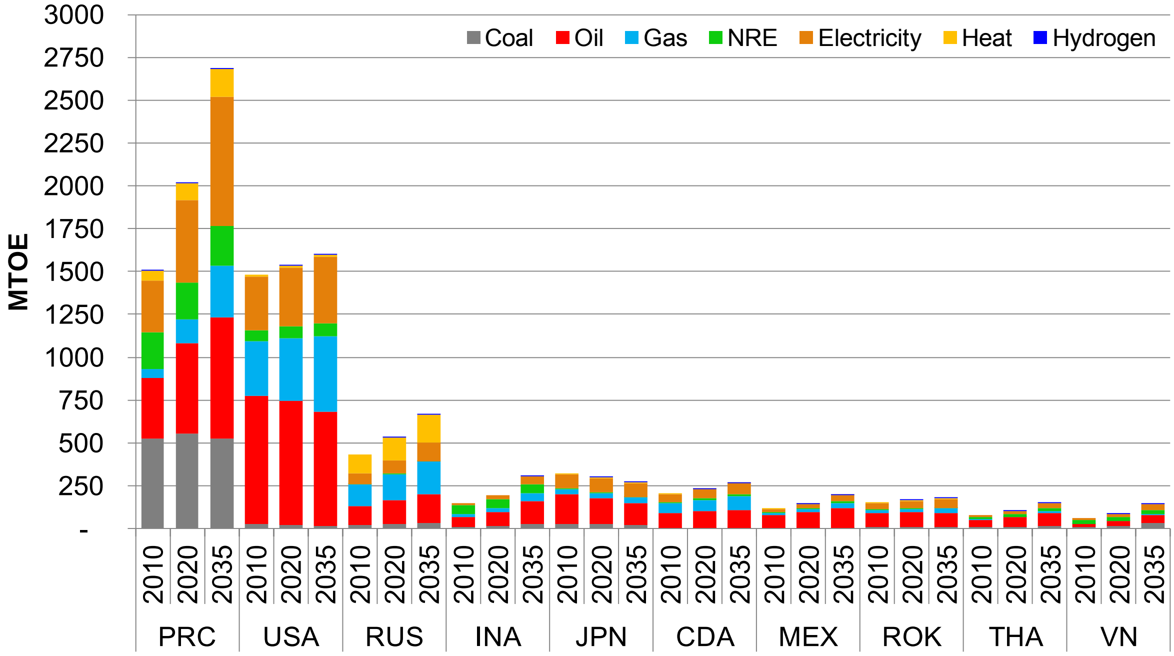
China will also clearly dominate the final demand for coal in the APEC region, accounting for about 76% of the APEC region's final coal demand in 2035. (Note that final demand for coal excludes the demand for coal in power plants, which will be much more widely distributed across the APEC economies.) The US has historically dominated demand for oil in the APEC region, accounting for about 40% of the region's final oil demand in 2010, but by 2035, China's demand for oil will slightly exceed that of the US; at that time, China's share of APEC oil demand will be 28% while the US share will be 27%.

Figure 4.2: APEC Final Energy Demand by Energy Source



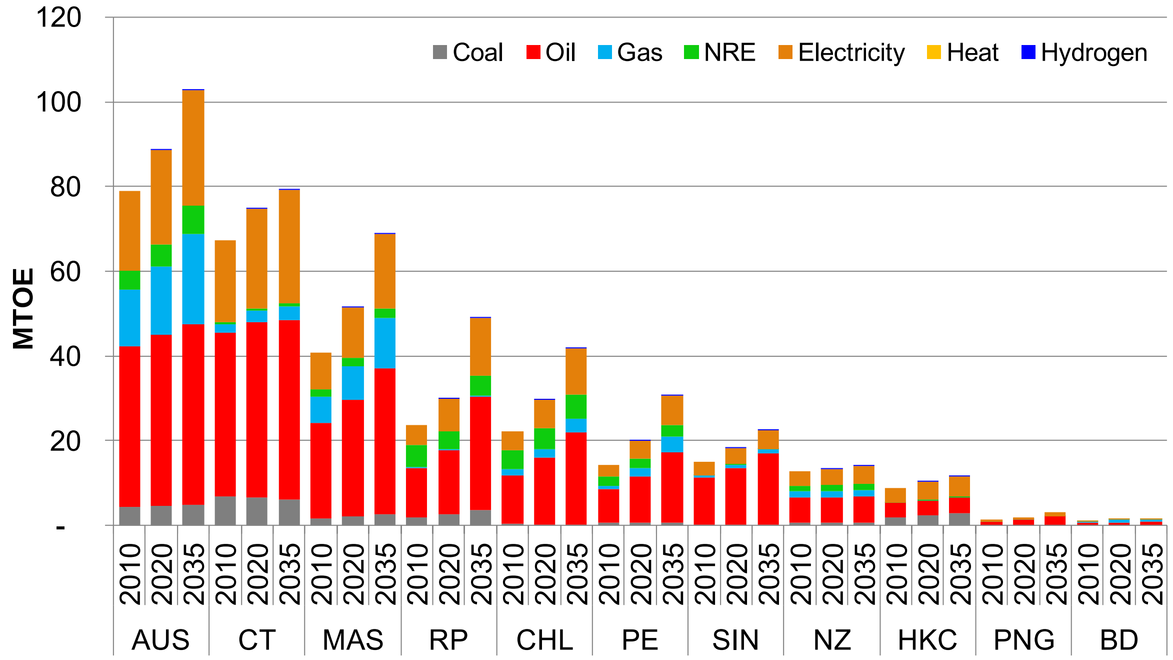
Source: APERC Analysis (2012)

Figure 4.3: Final Energy Demand by Energy Source, Higher Final Demand Economies



Source: APERC Analysis (2012)

Figure 4.4: Final Energy Demand by Energy Source, Lower Final Demand Economies

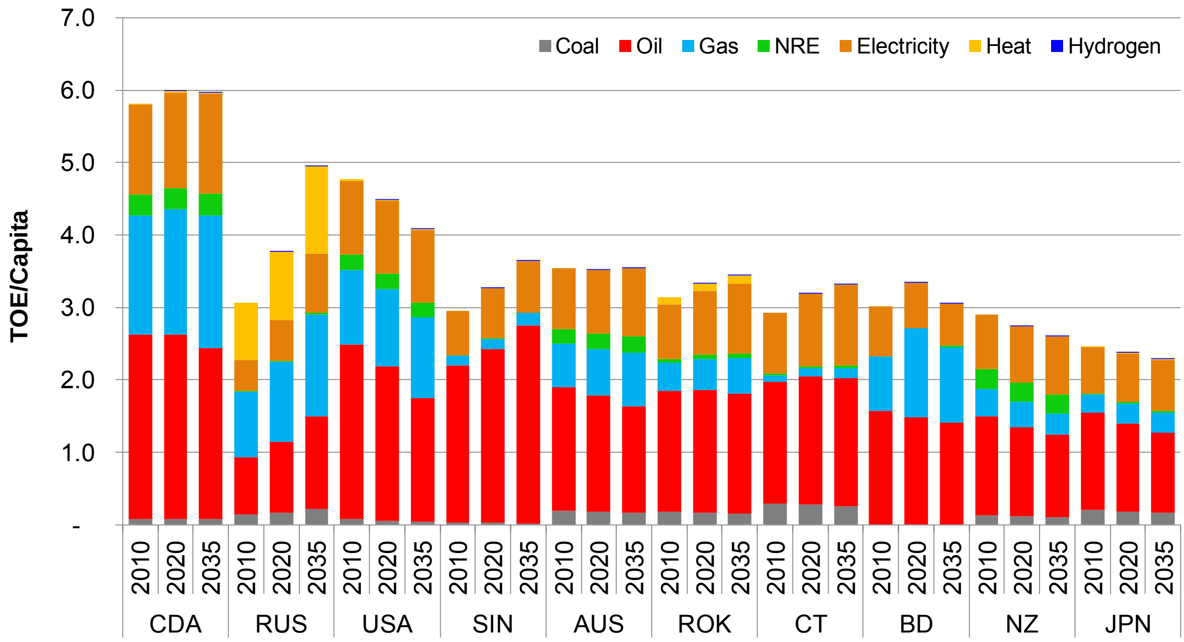


Source: APERC Analysis (2012)

Figures 4.5 and 4.6 show the final energy demands by energy source on a per capita basis. Again, note the differences in the vertical axis scale between the two figures. There are stark differences in final energy demand per capita between the economies with the highest per capita demand and the economies with the lowest per capita demand. Naturally, per capita consumption tends to be highest in the developed economies and lowest in the developing economies. Some developing economies are projected to show large increases in per capita final energy demand.

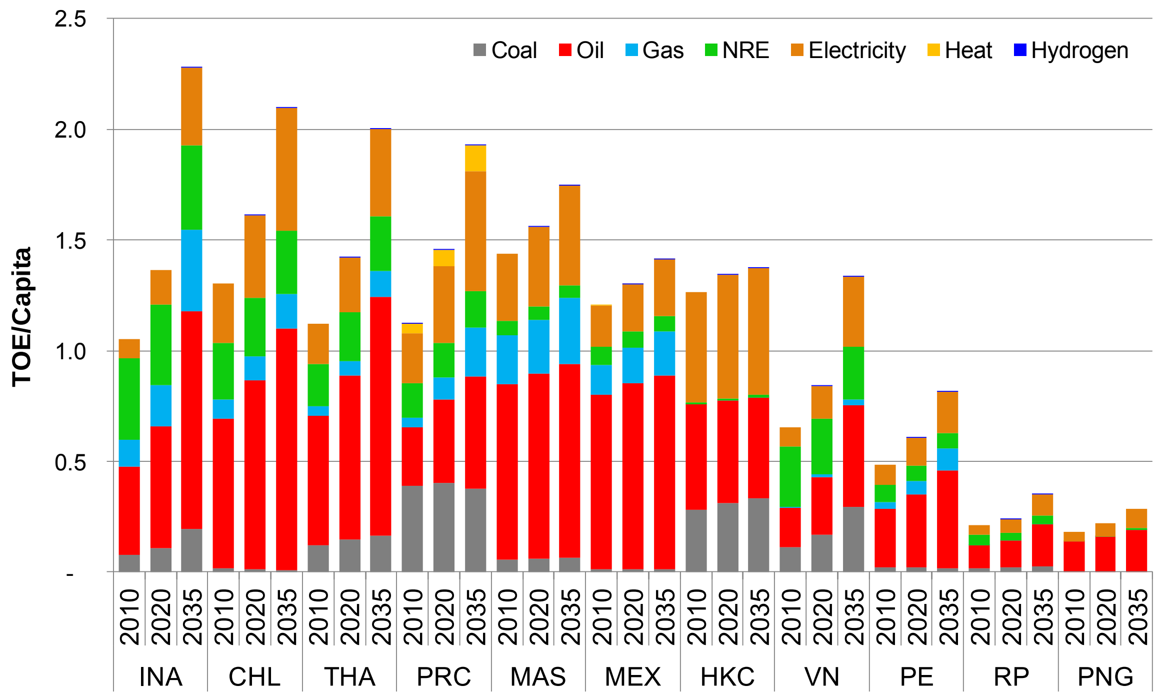
There is little that can be said in general regarding the differences in per capita use of various energy sources between economies, except that the developed economies tend to use more of just about every energy source. The notable exception is new renewable energy (NRE), which tends to be more heavily used in developing economies, in the form of biomass used in the residential sector.

Figure 4.5: Final Energy Demand by Energy Source Per Capita, Higher Final Demand per Capita Economies



Source: APERC Analysis (2012)

Figure 4.6: Final Energy Demand by Energy Source Per Capita, Lower Final Demand per Capita Economies



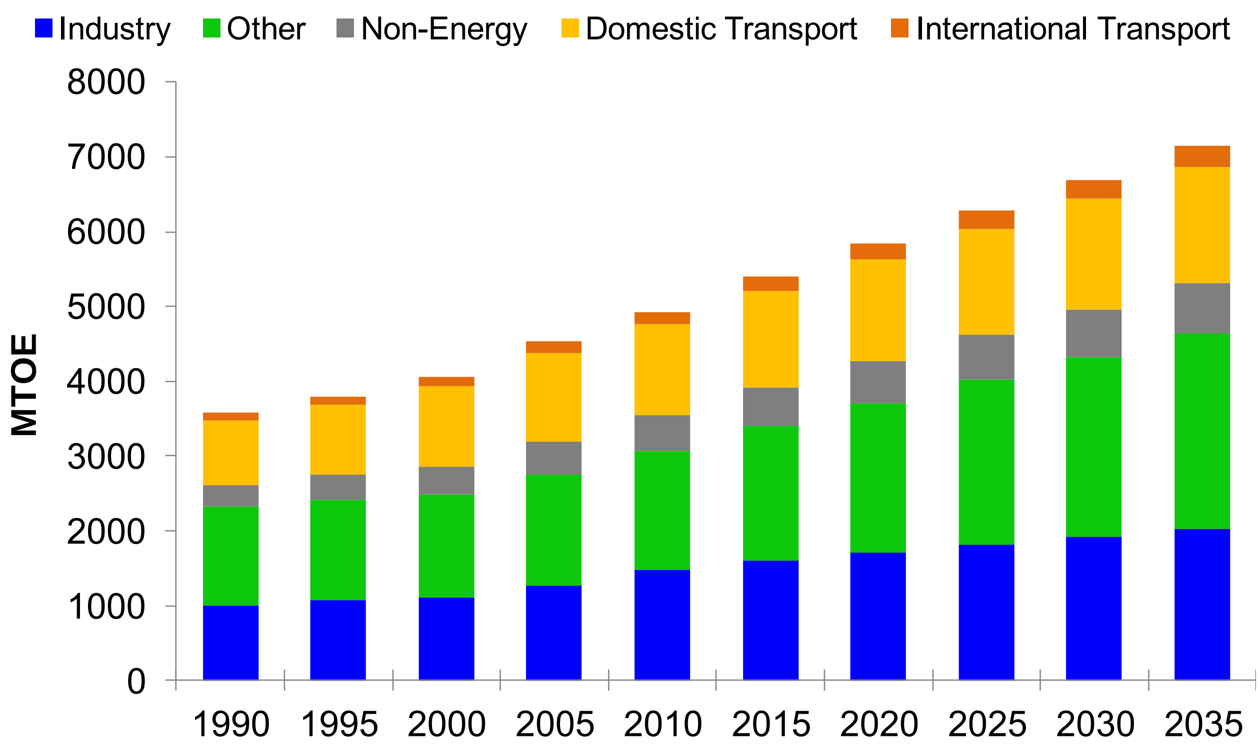
Source: APERC Analysis (2012)

Final Energy Demand by Sector

Figure 4.7 shows the total APEC final energy demand by sector. Figures 4.8 and 4.9 show these results broken out by economy. Figures 4.10 and 4.11 show the same results on a per capita basis. These sector figures include the international transport sector, which was not included in the final energy demand by energy source figures above. Under International Energy Agency (IEA) statistical conventions, international transport is not considered part of an economy's final demand, presumably because it is not necessarily consumed within the economy's borders. Singapore and Hong Kong, China have disproportionately large demands for international transport energy, due to their roles as major international shipping and air transport hubs. Without this international transport demand, they would otherwise rank in the mid range of the APEC economies in per capita energy demand.

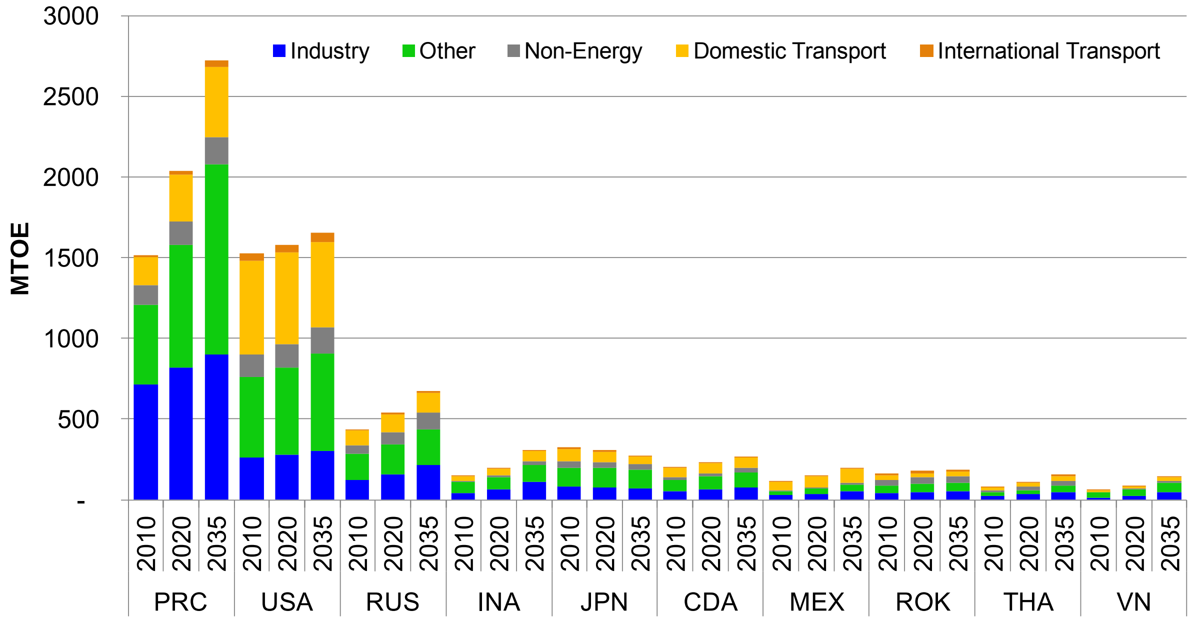
In general, developed economies tend to use more energy in every sector. Transport demand tends to be especially large in the developed economies and, not surprisingly, non-energy use tends to be largest in economies that have large refinery industries.

Figure 4.7: APEC Final Energy Demand by Sector



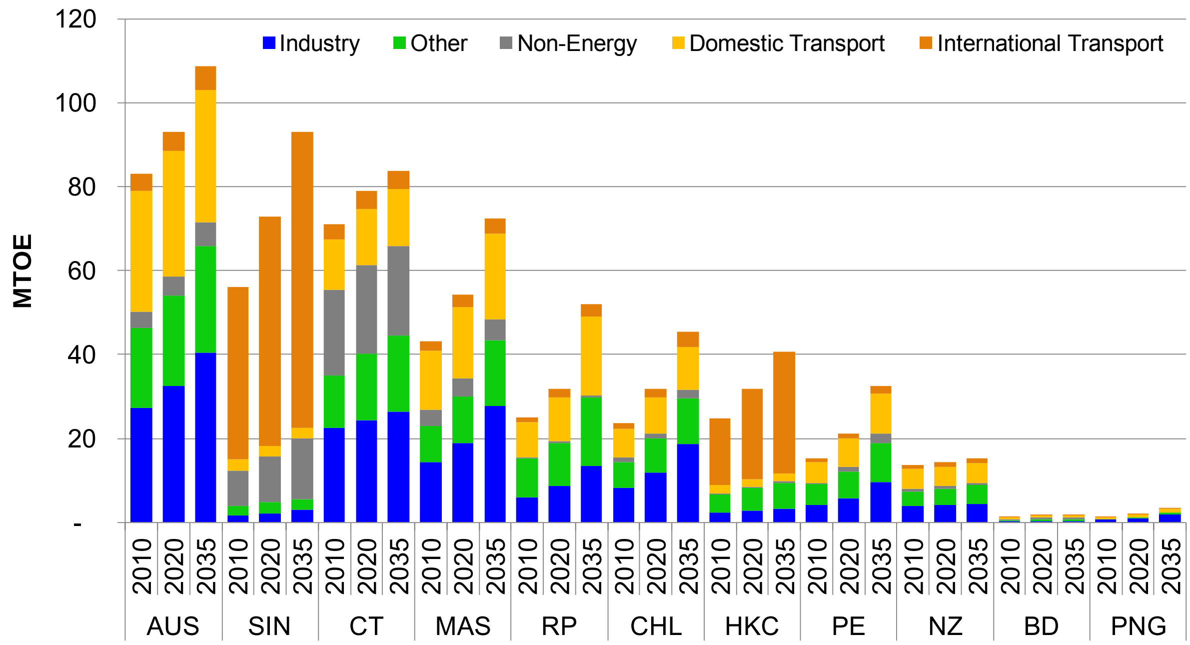
Source: APERC Analysis (2012)

Figure 4.8: Final Energy Demand by Sector, Higher Final Demand Economies



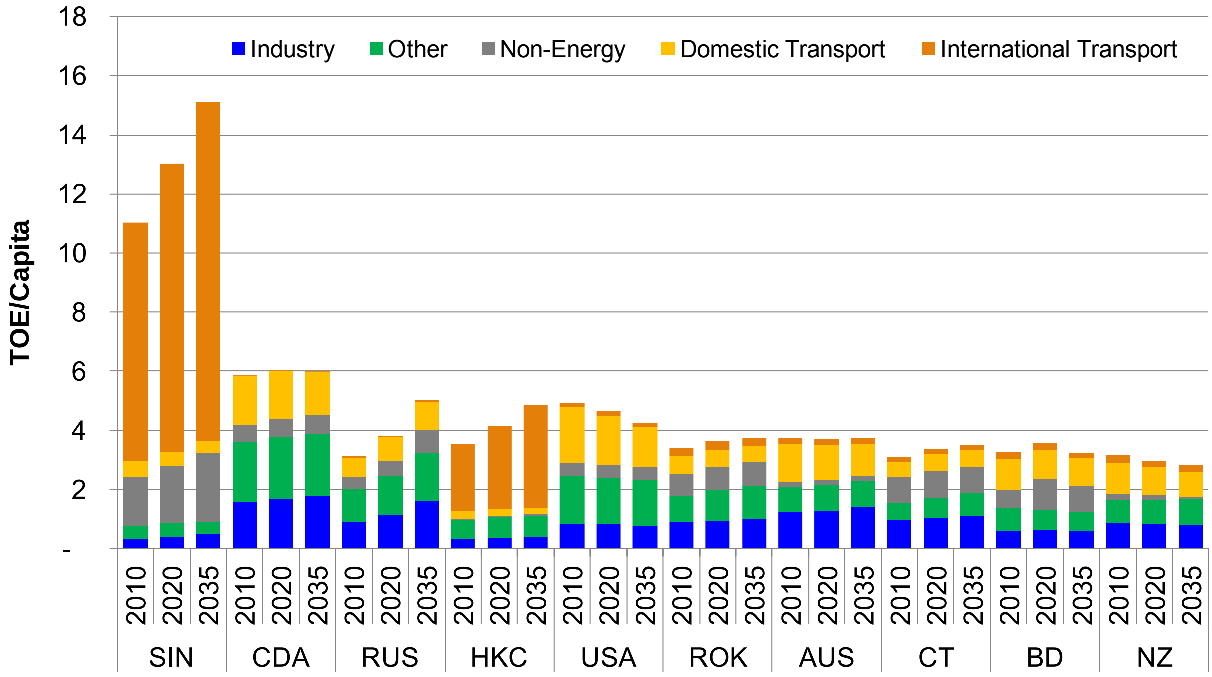
Source: APERC Analysis (2012)

Figure 4.9: Final Energy Demand by Sector, Lower Final Demand Economies



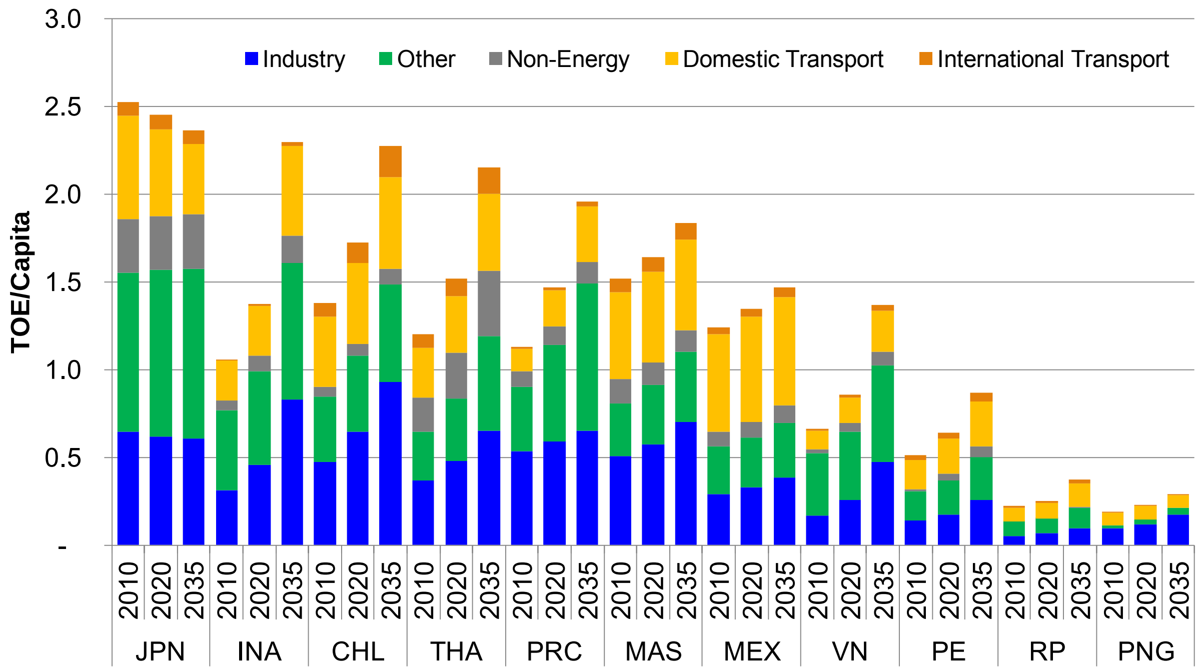
Source: APERC Analysis (2012)

Figure 4.10: Final Energy Demand by Sector Per Capita, Higher Final Demand per Capita Economies



Source: APERC Analysis (2012)

Figure 4.11: Final Energy Demand by Sector Per Capita, Lower Final Demand per Capita Economies



Source: APERC Analysis (2012)

MARKET FAILURES AND ENERGY EFFICIENCY

Chapters 5–8 discuss the energy challenges and opportunities in specific energy-using sectors. Before examining specific sectors, however, it is appropriate to examine the challenges and opportunities presented by energy demand in general. The key message of the remainder of this chapter, is that there are many opportunities to improve the efficiency with which energy is used. These opportunities should be viewed as equal in significance to measures on the supply side for achieving a more sustainable energy future.

At first glance, saying that there are many opportunities to improve energy efficiency does not sound like a particularly useful insight. After all, by 'working smarter' (such as better planning, better engineering, or improved technology) the efficiency of virtually every economic activity could be, and probably will be, improved. But the key point of this section is that the opportunities to improve energy efficiency are particularly large and often obvious because *energy demand is different* from other economic activities.

In the case of energy demand, there are strong economic barriers that tend to deter people from 'working smarter'. The result is that there are many actions that energy users could take to improve energy efficiency that do not get taken, even though they would be economic from the perspective of society as whole. These actions do not get taken because they are not economic, or perhaps not even possible, from the perspective of the energy user. Before we can improve energy efficiency, we need to address the *market failures* that cause the behaviour of energy users and the interests of society as a whole to diverge.

The Market Failures

There are at least four kinds of market failures that lead to energy inefficiency.

1. *Lack of information.* Energy users generally want to compare the energy efficiency of the options they face, but may be unable to do so due to lack of information. This may occur in several ways:

   Lack of data. Energy users shopping for a place to live, a vehicle or an appliance, may want to compare the energy efficiency of the various alternatives, but are unable to do so due to a lack of reliable data.

   Lack of skills. Most consumers are not engineers, and may find the calculations involved in comparing options with different upfront and ongoing costs to be difficult or beyond their capabilities. Even large organizations may not have engineers with knowledge of the latest technologies for improving energy efficiency.

   Lack of time. Even those energy users who have the skills to compare alternatives may not have the time to actually perform the analysis.

2. *Split incentives.* The lack of information described above can frequently be compounded by the fact that the person who makes a decision that affects energy use is not the person who pays the resulting energy costs. Consequently, the decision that gets made is not the correct one from the perspective of society. Some examples:

   Landlord/tenants. The landlord generally pays the cost of energy-efficiency improvements in apartments and offices. The tenant, however, typically pays the energy bills, and thus receives the benefits of these investments.

   Building developers/buyers. The developer pays the cost of features to enhance energy efficiency in buildings, but the ultimate buyer receives the benefits.

   Internal organization. In many governments and companies, the administrative unit that manages the capital budget is not the administrative unit that manages the operating budget. Each may seek to minimize their own costs without regard to the impact on the overall organization.

   Free energy. In some situations, customers are not expected to pay separately for the energy they use. Hotel guests, for example, have no incentive to limit their use of air conditioners, heaters, hot water, and lights.

3. *Underpricing of energy.* In most parts of the world, energy is underpriced relative to its real costs to society. Consequently, energy users have less incentive to improve the efficiency of their activities than would be socially optimal. Some examples:

   Externalities. In most economies, the energy price typically includes the costs of producing the energy, but not the costs of its adverse impacts on the environment, including greenhouse gas emissions and local pollution.

   Subsidies. In some economies, energy is explicitly subsidized, so its price does not even cover the full costs of production.

4. *Financing constraints.* Energy users may wish to make an investment that would improve their energy efficiency, but lack the capital or the access to financing that is required. This is a particular problem not only for low-income consumers, but also in the public and non-profit sectors (such as schools, hospitals, and municipal governments), where capital budgets are often tightly constrained.

The Policy Remedies

Improving energy efficiency is generally a very attractive approach, both politically and economically, for creating a more sustainable energy future. Because of the market failures outlined above, energy efficiency improvements offer a unique opportunity to protect the environment, help the economy, and save money for energy users all at the same time.

The policy prescriptions for improving energy efficiency generally, will directly address the market failures outlined above.

1. *Provide better information.* This may take the form of requiring labels or ratings on appliances, vehicles, and residential/commercial buildings. Ideally, the labels or ratings should be easily understood by people with limited technical training and/or limited time (APERC, 2010 and APERC, 2011). Websites can also be useful in promoting public education and making information available on energy-saving products and technologies.

2. *Set minimum energy efficiency standards for appliances, vehicles, buildings, and commercial/industrial equipment.* As long as the standards are set at a level that energy users would choose for themselves if they had the option to choose, then both energy users and society will be better off. These standards should include active devices to help energy users monitor and reduce waste, such as devices to shut off the heat and air conditioning in unoccupied hotel rooms. See the further discussion of energy efficiency standards and labeling, as well as building energy efficiency codes and labeling, in Chapter 8.

3. *Raise the price of energy to reflect its full costs to society.* This should include putting a price on carbon in some fashion (such as a carbon tax or emissions trading) as well as additional charges to cover the costs of local pollution and other environmental damage, related to energy production and use. In those economies that subsidize energy, the subsidies should be rationalized and phased out as quickly as possible, while protecting those energy consumers who are truly in need (see the sidebar in Chapter 10 'APEC's Goal to Rationalize and Phase Out Fossil Fuel Subsidies').

4. *Ensure that financing is available for cost-justified energy efficiency investments.* These investments will provide benefits that exceed their costs. Therefore, given proper legal and regulatory frameworks, there should be little risk to the lender and little cost to the taxpayer.

5. *Promote energy service companies.* Energy service companies (ESCOs) can provide a total solution for large energy users wishing to improve their energy efficiency. Such a company has engineers trained to identify opportunities for energy saving and to propose appropriate energy-saving investments. Once appropriate investments are identified, the ESCO can provide the necessary financing, manage the implementation, and provide subsequent maintenance. The ESCO can often do all this in return for a share of the energy cost savings to the customer, so the customer is guaranteed to profit from the arrangement.

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2010), APEC CEEDS Phase 1 Final Report: Appliance Energy Efficiency Standards and Labeling, www.ieej.or.jp/aperc/CEEDS/Final_Report_CEEDS_Phase_1.pdf

— (2011), APEC CEEDS Phase 2 Final Report: Building Energy Codes and Labeling, www.ieej.or.jp/aperc/CEEDS/Final_Report_CEEDS_Phase_2.pdf

5 TRANSPORT SECTOR ENERGY DEMAND

The continued dependence on oil-derived fuels for transport poses two major concerns for all APEC economies, especially the oil importing economies. First, there is the oil security concerns discussed in Chapter 11. These oil security concerns mean continued oil price volatility will be a near certainty, and there will be significant risks of supply disruptions. Second, oil is a fossil fuel and its use in the transport sector is a major source of greenhouse gas emissions in all APEC economies. For these reasons, there is a strong need to reduce dependence on oil in the transport sector.

Motorization correlates closely with economic growth. However the relationship between the two varies greatly depending on the circumstances. For developing economies, growing income is usually accompanied by rapid growth in vehicle ownership per capita. As economies become wealthier, the growth in vehicle ownership slows down. Eventually economies approach vehicle saturation, or a maximum vehicle ownership level per capita. At this point, growth in per capita vehicle ownership slows to almost zero. However, the level of vehicle ownership per capita at which saturation is reached is strongly tied to the way cities are planned. This suggests better urban planning is a key policy for reducing oil dependence in transport.

More broadly, transport energy demand is a combination of three variables. These variables are: the demand for mobility, the transport mode used for mobility and the energy efficiency of the mode. Policies for reducing energy use in transport correspond to these variables: 'Avoid' (the demand for mobility), 'Shift' (to alternative modes) and 'Improve' (energy efficiency). Better urban planning is the main tool to accomplish 'Avoid' and 'Shift'. On the other hand, better vehicle design is the main tool to accomplish 'Improve'.

All three variables also respond to the price of energy. In the transport sector, this primarily means the price of oil. In recent years oil prices have increased rapidly. Under business-as-usual (BAU), real oil prices are assumed to remain high by historical standards, and to rise to above USD 120 per barrel by 2035. This is a key reason why the growth in oil demand in APEC economies is expected to be moderate over the outlook period.

This chapter first examines the BAU model results for the APEC region. It then discusses two sets of alternative scenarios exploring options for better urban planning and better vehicle design.

BUSINESS-AS-USUAL TRANSPORT DEMAND RESULTS

Energy Demand

Figures 5.1 and 5.2 show the projected domestic transport energy demand by economy and by fuel under a business-as-usual (BAU) scenario. Note the differences between the scales of the vertical axes in the two figures. Over the outlook period domestic transport energy demand in the APEC region is projected to increase from 1203 million tonnes of oil equivalent (Mtoe) in 2010 to 1555 Mtoe in 2035, or a compound annual growth rate of 1.1%. The OECD APEC member economies, which tend to be economically more mature, are projected to show a net decline in domestic transport energy demand from 790 Mtoe in 2010 to 720 Mtoe in 2035 (-0.4% compound annual growth rate). In contrast, non-OECD APEC economies, which tend to be developing economies, show an increase from 415 Mtoe to 880 Mtoe (a 3.2% compound annual growth rate) over the same period.

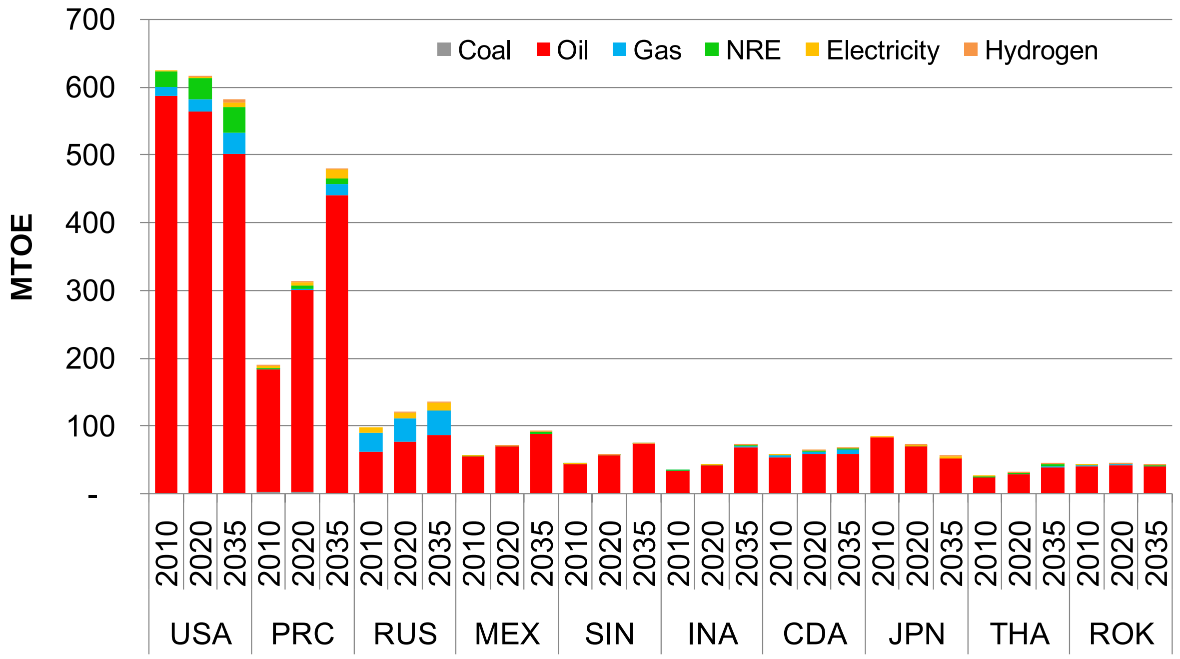
Oil remains the primary fuel used in the transport sector, supplying 87% of domestic transport demand in 2035, a small reduction from 92% in 2010. Growth in alternative fuels is supported by the growing use of biofuels, natural gas and electricity.

The United States (US) and Japan are two notable exceptions to the trend of increasing energy demand in the domestic transport sector. In the economies of the US and Japan, transport energy demand is projected to decline 8% and 38% respectively between 2010 and 2035. The US transport energy demand is projected to decline due to more stringent Corporate Average Fuel Economy (CAFE) energy efficiency standards for vehicles, combined with an already nearly saturated vehicle ownership and a greater use of alternative vehicles. These factors will outweigh the growth in the vehicle fleet due to population growth. Japan's transport energy demand decline is more pronounced, with the compounded effect of a declining population leading to a shrinking vehicle fleet in combination with the aforementioned factors (see the United States and Japan economy reviews detailed in Volume 2).

Perhaps the most notable transport energy demand development in the APEC region is the transport energy demand growth in China. By 2035, transport energy demand in this huge economy is expected to be about 2.5 times that of 2010. This growth in transport energy demand will be driven by two key factors. Firstly, economic growth will continue rapidly with real per capita income expected to rise to a purchasing power parity (PPP) equivalent of about USD 32 400 in 2035 (a level that will put China among the wealthy economies, as detailed further in Table 3.2 of Chapter 3). The high economic growth will result in the rapid growth in per capita vehicle ownership, which will be particularly apparent during the 2010 to 2020 period. By 2035, vehicle ownership is projected to reach 343 vehicles per 1000 people, up from 58 per 1000 people in 2010 (as detailed ahead in Table 5.1). Secondly, the urban population will continue to increase rapidly, not only in China but across all APEC economies.

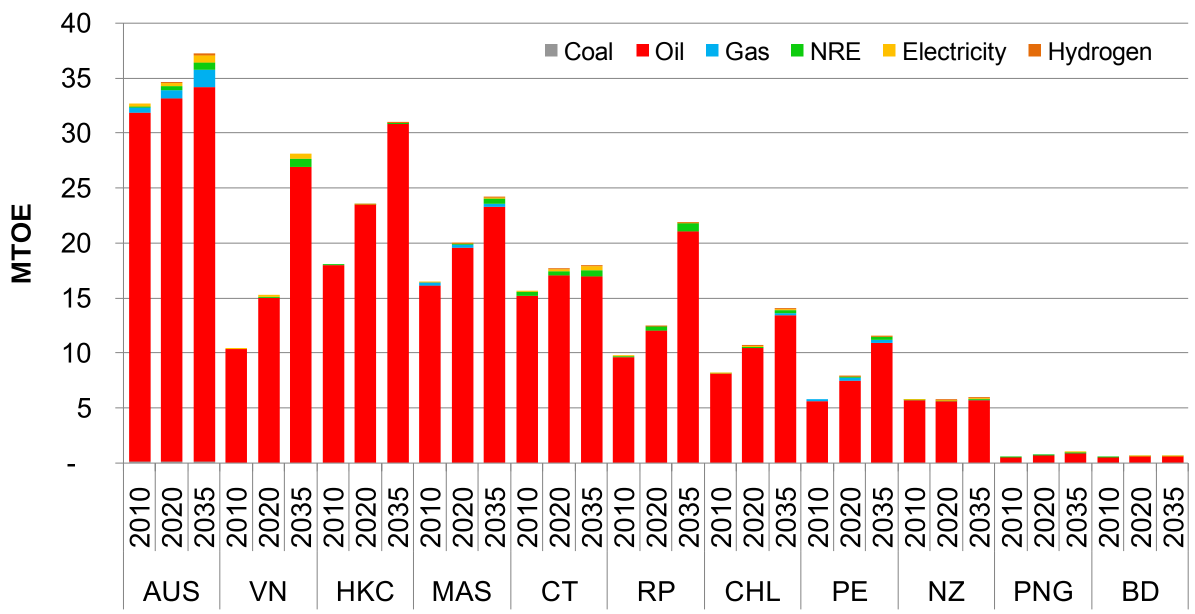
The corresponding growth rates in transport energy demand between 2010–2020 and 2020–2035 are shown in Figure 5.3. China's growth in transport energy demand is especially rapid in the current decade with an annual growth rate between 2010 and 2020 of 5.1%. This growth rate will ease between 2020 and 2035 to 2.9%, due to the increasing adoption of alternative vehicles, the slower growth in vehicle ownership and the continued improvement in the fuel efficiency of conventional vehicles. Growth in transport energy demand is also rapid in other developing APEC member economies. Economies with annual transport energy demand growth rates exceeding 3% in the period 2020–2035 include Viet Nam, the Philippines and Indonesia.

Figure 5.1: Transport Sector Energy Demand by Energy Source, Larger Economies



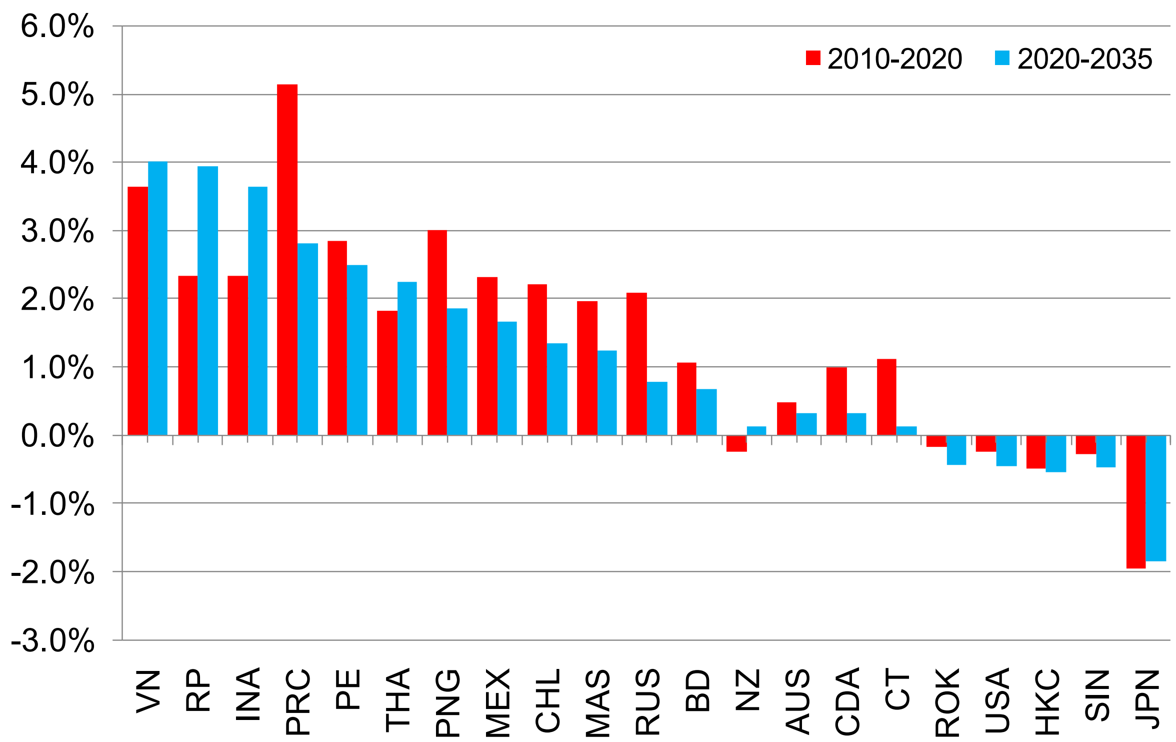
Source: APERC Analysis (2012)

Figure 5.2: Transport Sector Energy Demand by Energy Source, Smaller Economies



Source: APERC Analysis (2012)

Figure 5.3: Transport Final Energy Demand Average Growth Rate



Source: APERC Analysis (2012)

Vehicle Ownership

Table 5.1 shows the change in vehicle ownership across the APEC economies. As a whole, per capita vehicle ownership (in vehicles per 1000 people) in the APEC region is projected to grow at an average annual growth rate of 2.8% over the outlook period.

Future Vehicle Technology Mix

Figure 5.4 shows the change in vehicle technology within the light vehicle fleet in the APEC member economies in 2010, 2020 and 2035. The vehicles types assessed are defined as follows:

- Conventional (Gasoline or Diesel Fueled) Vehicles
- Natural Gas Vehicles
- Hydrogen Fuel Cell Vehicles
- Hybrid Electric Vehicles (Gasoline or Diesel Fueled)
- Plug-in Hybrid Vehicles
- LPG (Liquefied Petroleum Gas) Vehicles
- Battery Electric Vehicles.

Biofuels are not considered here. The reason is that biofuels are usually mixed with oil products and used in vehicles that differ only slightly, if at all, from conventional vehicles. Therefore, APERC models biofuels as a change in liquid fuel supply, rather than as a change in vehicle technology. Refer to the Biofuels discussion in Chapter 15 on Renewable Energy Supply.

APERC models the share of new vehicle sales for each of the vehicle types each year by simulating consumer choices. The consumer choice model takes into account differences in initial purchase price, fuel cost, driving range and refuelling availability. Overall, the adoption of alternative vehicles in APEC economies over the outlook period is modest in the BAU case.

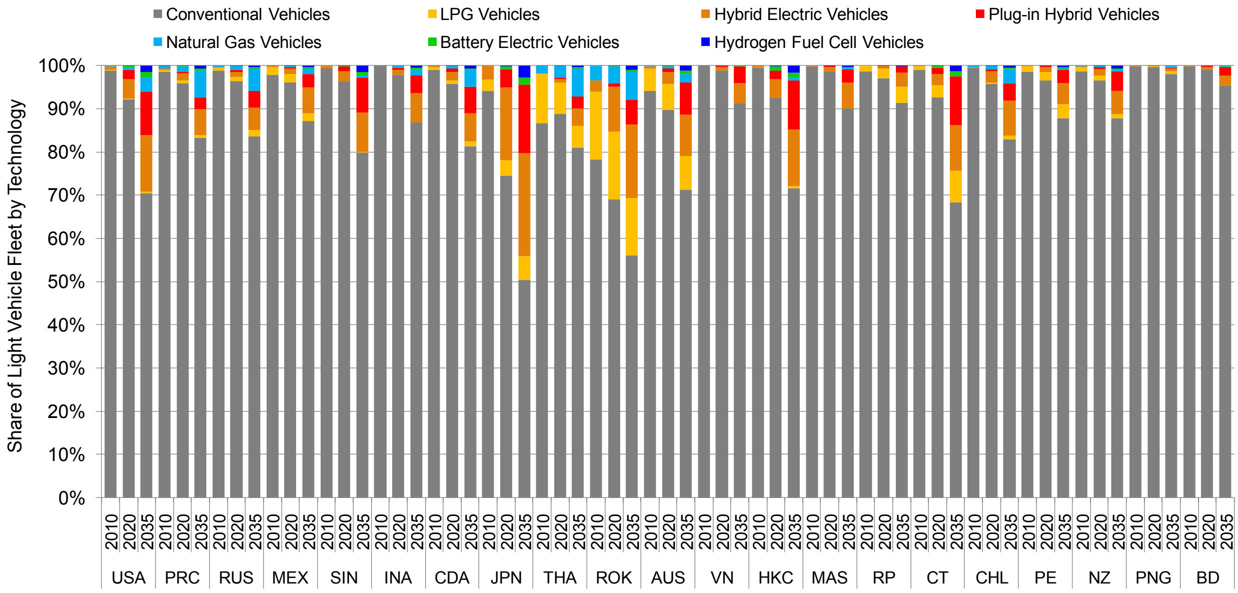
However, the developed APEC economies are world leaders in both the technological development and adoption of alternative vehicles. Several economies including the US, Japan and China currently have temporary rebate subsidies to encourage the adoption of alternative vehicles. Although these subsidies are not assumed to remain in place over the long term, in Japan the share of alternative vehicles in the light vehicle fleet, even excluding LPG and hybrid vehicles, reaches 20% by 2035.

Table 5.1: Vehicles per 1000 Population in APEC Economies: History and Projection including Compound Annual Growth Rates (2000–2035)

Vehicle Ownership (per 1000ppl)	2000	2005	2010	2015	2020	2025	2030	2035	2010-2020	2020-2035
Australia	627	662	691	705	725	746	769	792	0.5%	0.6%
Brunei Darussalam	408	452	544	603	640	662	676	684	1.6%	0.5%
Canada	543	570	591	621	645	663	677	689	0.9%	0.4%
Chile	132	150	178	212	260	311	359	399	3.8%	2.9%
China	13	24	58	114	167	223	280	343	11.1%	4.9%
Hong Kong, China	81	70	74	76	78	79	79	79	0.5%	0.2%
Indonesia	25	42	77	85	109	148	205	272	3.4%	6.3%
Japan	574	594	581	580	581	583	585	587	0.0%	0.1%
Korea	260	324	357	375	389	398	405	410	0.9%	0.3%
Malaysia	225	292	358	420	475	520	556	582	2.9%	1.4%
Mexico	186	204	265	295	337	383	427	466	2.4%	2.2%
New Zealand	649	725	711	700	700	707	715	725	-0.2%	0.2%
Papua New Guinea			10	13	17	22	26	31	5.7%	4.0%
Peru	45	50	62	92	131	180	234	291	7.7%	5.4%
The Philippines	32	34	32	32	36	44	58	75	1.1%	5.1%
Russia	174	215	271	322	384	448	506	553	3.6%	2.5%
Singapore	127	144	156	157	157	158	158	158	0.1%	0.0%
Chinese Taipei	251	292	297	336	371	398	419	435	2.2%	1.1%
Thailand	122	146	171	218	286	368	456	535	5.3%	4.3%
United States	755	803	797	799	801	805	808	811	0.1%	0.1%
Viet Nam	7	11	16	24	39	66	114	186	9.1%	11.0%
APEC	164	185	212	248	286	328	373	420	3.1%	2.6%

Source: APERC Analysis (2012)

Figure 5.4: Light Vehicle Fleet Share by Vehicle Technology



Note: There are other feasible, but less widely-studied, alternative vehicle technologies which are not assessed here. These include hydrogen internal combustion vehicles, compressed air vehicles, solar vehicles, ammonia fuelled vehicles, methanol fuelled vehicles, liquid nitrogen fuelled vehicles, and biogas fuelled vehicles.

Source: APERC Analysis (2012)

Potential for Improvements in Conventional Vehicle Technology

Although the adoption of alternative vehicles is modest in the BAU case, conventional vehicles are likely to improve rapidly in energy efficiency in response to high oil prices and existing government regulations. In particular, hybrid vehicle technology will become more widely adopted in conventional vehicles.

However, there remains much additional potential for improvement in the fuel efficiency of conventional vehicles beyond what is assumed in the BAU case. Weight reduction is the largest single component of fuel savings potential. Reducing vehicle weight principally reduces the energy needed for acceleration (Cheah and Heywood, 2011). Emerging lightweight composites, in particular carbon fibre, are becoming increasingly attractive substitutes for traditional steel components in vehicle manufacturing. Composite substitution has the added benefit of secondary weight reductions from the downsizing of various vehicle subsystems including the engine, suspension and braking systems (Cheah and Heywood, 2011). Cheah and Heywood (2011), suggest the greater use of lighter-weight material substitution combined with secondary weight reduction benefits have the potential to reduce the average US new vehicle curb weight by up to 38% or 600 kilograms (kg) by 2030. In addition, it is estimated that for every 100 kg of weight reduction in conventional passenger vehicles, there is a 0.4 litres per 100 km reduction in fuel consumption without changes in the vehicle's performance (Cheah and Heywood, 2011). So far, the integration of composites has been slow due to the vehicle industry's large capital investment in metal fabrication. Could this slow pace be accelerated?

One approach would be to move to a fundamentally different vehicle design. This would be an ultra light-weight vehicle type with a fully carbon composite body, known as the 'hyper car'. To fully capture the weight reduction benefits, the hyper car could employ a hybridized power train as well as low drag and rolling resistance design features. Approximately two-thirds of the fuel efficiency improvement of hyper cars would be attributed to the weight reduction from both composite substitution and component downsizing, with the remaining benefits from power train hybridization and a low drag design. Overall, hyper cars would be approximately 50–60% lighter than the average curb weight of conventional vehicles (Lovins et al., 2005). This is comparable, although slightly more optimistic than the vehicle weight reduction potential stated by Cheah and Heywood (2011).

Ultimately, hyper cars have the potential to reduce fuel consumption per kilometre (km) by 50–66% compared to conventional vehicles sold today (Lovins et al., 2005). Lovins et al. (2005) estimates the fuel efficiency of a hyper car would be around 38 km per litre (90 miles per gallon). Safety should not be a problem since carbon fibre composite components are stronger than traditional steel components.

The additional cost of the hyper car is uncertain since there is, as yet, no large-scale manufacturing. Early estimates range from about USD 5000–7000 in added costs above conventional vehicle costs once mass production is established (Bandivadekar et al., 2008; Cheah and Heywood, 2011; Lovins et al., 2005). This estimate includes the additional costs involved in composite substitution as well as hybrid technology.

The Challenging Economics of Alternative Vehicles

Alternative vehicles can drastically improve energy efficiency and shift reliance away from oil derived fuels. They have the added benefit of reducing local air pollution and some technologies offer near-zero vehicle emissions. So why is their adoption so low under BAU?

While the potential benefits of alternative vehicles are apparent, their upfront capital costs relative to conventional vehicles are higher. Therefore an important obstacle to the adoption of alternative vehicles is consumer acceptance of higher upfront costs in return for later fuel-cost savings.

To illustrate this trade-off, APERC calculated average fuel costs over the life of each vehicle. These fuel costs were calculated as present values—that is, how much the consumer would need to put into an interest-paying bank account on the day the vehicle was purchased to cover the cost of fuel for the vehicle over its entire life. In principle, a rational consumer should not be willing to spend more in extra vehicle purchase costs for an alternative vehicle than the present value of the future savings in fuel costs.

So how much extra should the consumer be willing to spend for an alternative vehicle? Assume the consumer is from the US, and consider first the most extreme case—a hypothetical 'zero energy' vehicle that has no fuel cost at all. Since the average present value of fuel costs for a conventional vehicle in the US is about USD 10 000, assuming a modest 6% interest rate, a typical US consumer should not be willing to pay more than USD 10 000 extra to purchase the 'zero energy' vehicle rather than a conventional vehicle.

The 'zero energy' vehicle is, of course, an ideal case. All real-world vehicles incur some fuel costs, so the consumer should not be willing to spend as much for them as they would be willing to spend for a 'zero energy' vehicle. Figure 5.5 shows the average lifecycle fuel savings for a US consumer for several types of alternative vehicles under three sets of assumptions about energy costs and improvements in conventional vehicle technology. These values will differ in other economies, depending on fuel prices and lifecycle distances driven.

Figure 5.5: Present Value of Lifecycle Fuel Savings relative to US Conventional Vehicle (6% Discount Rate, in USD)

Year	Assumptions	Hybrid Electric	Plug-in Hybrid (16km)	Plug-in Hybrid (48km)	Plug-in Hybrid (96km)	Battery Electric (320 km)	Hyper Car	Zero Energy
Current Technology	Oil $100/bbl Electricity 11c/kWh	$3000	$4400	$5600	$6000	$6900	$6700	$10 300
↓	*Higher oil prices **favor the economics** of alternative vehicle technologies*							
Current Technology	Oil $126/bbl Electricity 15c/kWh	$4200	$6000	$7600	$8100	$8500	$9000	$14 000
↓	*Low cost efficiency improvements in conventional vehicles will **limit the economic** potential of alternative vehicles—even with higher oil prices*							
2035 (BAU)	Oil $126/bbl Electricity 15c/kWh	$3700	$4500	$5100	$5400	$5900	$5000	$8600

Assumptions: Vehicle travel is around 15 000 miles (24 100 km) per year per vehicle and vehicle life is 150 000 miles (241 000 km) (RITA|BTS, 2011). Under BAU, the fuel economy of US conventional non-hybrid vehicles improves from around 30 miles per gallon (12.8 km per litre) in 2010 to 45 miles per gallon (19.1 km per litre) in 2035. In all cases a probabilistic trip length distribution is applied to plug-in hybrid electric vehicles in the calculation of the oil and electricity fuel use.

Source: APERC Analysis (2012)

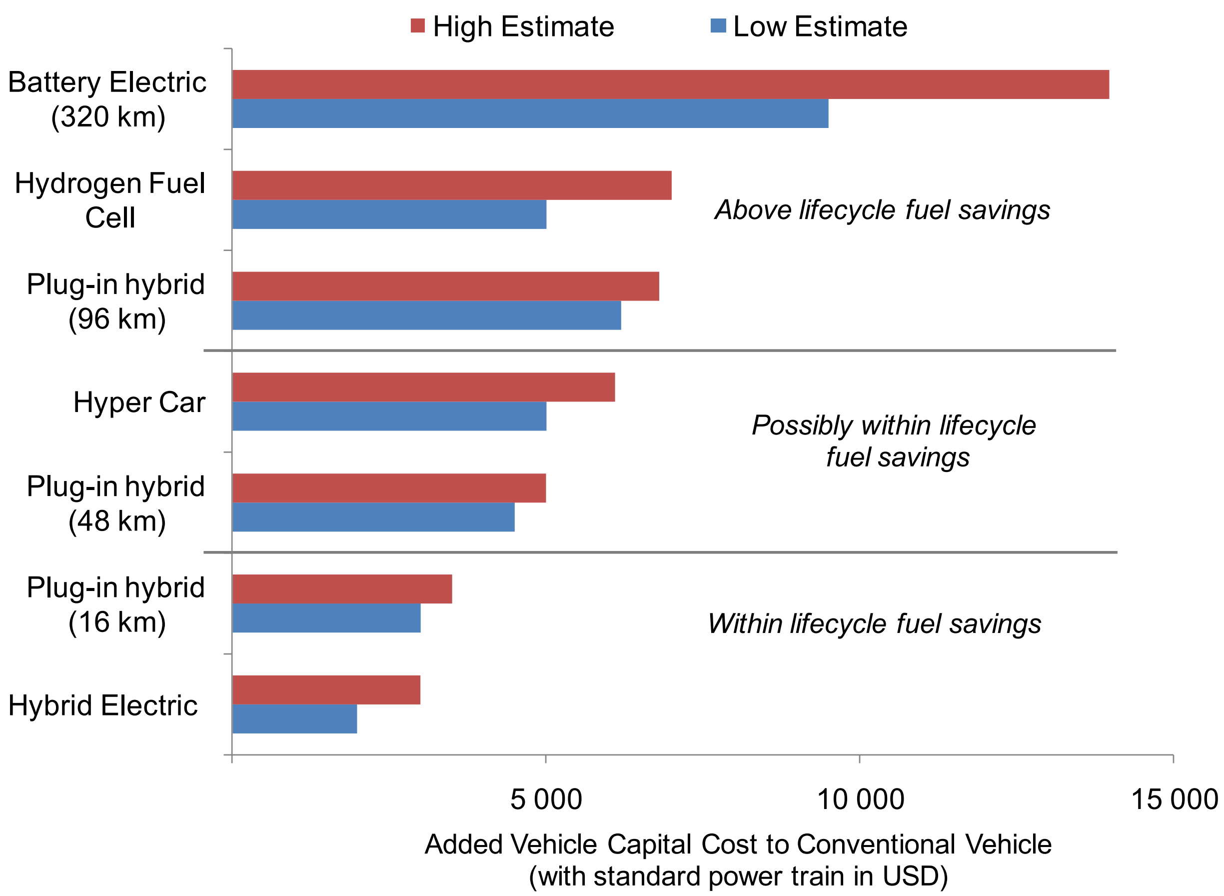
In the top part of Figure 5.5, the present value of lifecycle fuel savings assumes real energy prices over the vehicle's life are constant—at an oil price of USD 100 per barrel and an electricity price of USD 0.11c per kilowatt-hour (kWh). Under this scenario the present value of fuel savings for a Battery Electric Vehicle with a 320 km (200 mile) range is approximately USD 6900. The fuel savings for Plug-in Hybrid Vehicles are variable depending on the electric propulsion range. For a 96 km (60 mile) range Plug-in Hybrid Vehicle, the present value of fuel savings is around USD 6000. As we reduce the electric propulsion range our potential present value of fuel savings decreases accordingly.

In the middle part of Figure 5.5, real oil prices are assumed to increase to USD 126 per barrel in 2035. This aligns with APERC's BAU oil price assumption. Similarly, real electricity prices increase to USD 0.15c per kWh. Under higher energy prices the present value of fuel savings are more substantial, with potential savings reaching USD 8500 for a Battery Electric Vehicle with a 320 km range. For the 'zero energy' vehicle, the present value of lifecycle fuel savings increases to USD 14 000.

In the bottom part of Figure 5.5, the benefit of rising energy costs is counteracted by the potential for low cost energy efficiency improvements in conventional vehicles, as assumed in the BAU case.

The key point here is the extra amount the rational consumer should be willing to pay for an alternative vehicle is not large. For alternative vehicles to penetrate the market, they will have to be priced at levels not a lot higher than a conventional vehicle. Yet, for the most part, this condition was not met under the BAU case. Figure 5.6 shows the expected range of additional capital costs for an alternative vehicle compared to a conventional vehicle in 2035. Only with the 16 km (10 mile) Plug-in Hybrid Vehicle and the Hybrid Electric Vehicle would the additional purchase costs be less than the present value of fuel savings for the average US consumer under BAU.

Figure 5.6: Additional Upfront Cost of Alternative Vehicles above that of Conventional Vehicles by 2035 (Assuming Mass Production)



Sources: APERC Analysis (2012), Kromer and Heywood (2007), Lovins et al. (2005), Cheah and Heywood (2011)

This analysis is probably conservative. Additional barriers for some alternative vehicles include battery degradation (requiring replacement), higher depreciation rates (caused by uncertainty over reliability), the disutility of shorter driving ranges (requiring more frequent refuelling or even limits on the distance the vehicle can be driven in a day), and inadequate refuelling infrastructure. Furthermore, research also shows consumers weigh the upfront vehicle capital cost more heavily than the potential lifecycle fuel savings in their decision-making (Hidrue et al., 2011). This finding implies higher discount rates in relation to consumer choice may be more appropriate, which raises further barriers to the adoption of alternative vehicles. This finding is supported by Train (1986) and other studies that show consumer discount rates for automobile ownership could be as high as 13%.

In short, the economics of alternative vehicles are challenging. The outlook for these vehicles would, of course, be improved by higher energy prices and/or carbon pricing. But, for alternative vehicles to penetrate the market in a big way, an intensive effort will be needed to lower the initial cost of these vehicles to a level competitive with the cost of conventional vehicles.

ALTERNATIVE SCENARIOS

Despite significant improvements in vehicle fuel efficiency, driven in part by high oil prices, the rapid growth of the APEC region's vehicle fleet is expected to continue to push up total oil demand in the transport sector. Under our business-as-usual (BAU) assumptions, we do not project any shift away from conventionally fuelled vehicles during the outlook period, although the penetration of hybrid vehicles, including plug-in hybrids, is expected to rise modestly.

Two alternative scenarios were developed to investigate potential energy-saving opportunities. These scenarios are discussed below.

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

Urban areas are major drivers of economic growth. For developing economies the emergence of wealth starts first in major cities, creating inequality in wealth between cities and rural communities. Once economies mature the distribution of wealth is dispersed more equally between urban and rural areas. Urban areas also tend to be the main drivers of motorization in developing economies. However, the way urban areas are planned and managed is a key driver of future demand for vehicle ownership. This section discusses scenarios modelling the impact better urban planning and management could have on light vehicle energy demand, with particular focus on the connection to vehicle saturation.

Better urban planning and management goes by several names. These include 'smart development', 'compact development', and 'transit-oriented development'. Each of them emphasizes the use of public transit, walking and cycling while reducing motor vehicle dependence through infrastructure investment and policies promoting these alternative transport modes. The goal is not only to save energy, but also to promote cities that are healthy, safe, and pleasant places to live.

Smart cities have a lot of transport energy-saving design features and policies. Prominent examples of design features and policies of smart cities include:

- Mixed-use development with reduced distances between housing, jobs, shopping, and community services.
- Inter-connected streets to provide for easier access to destinations.
- Better facilities and environment for walking and bicycling.

- Higher quality transit services and more accessibility of destinations to transit.
- A de-emphasis of urban motorway and parking development, which tend to promote automobile use.
- In some cases, policies or taxes designed to limit vehicle ownership and use such as road and fuel pricing policies.

The Relationship of Population Density to Transport Energy Use

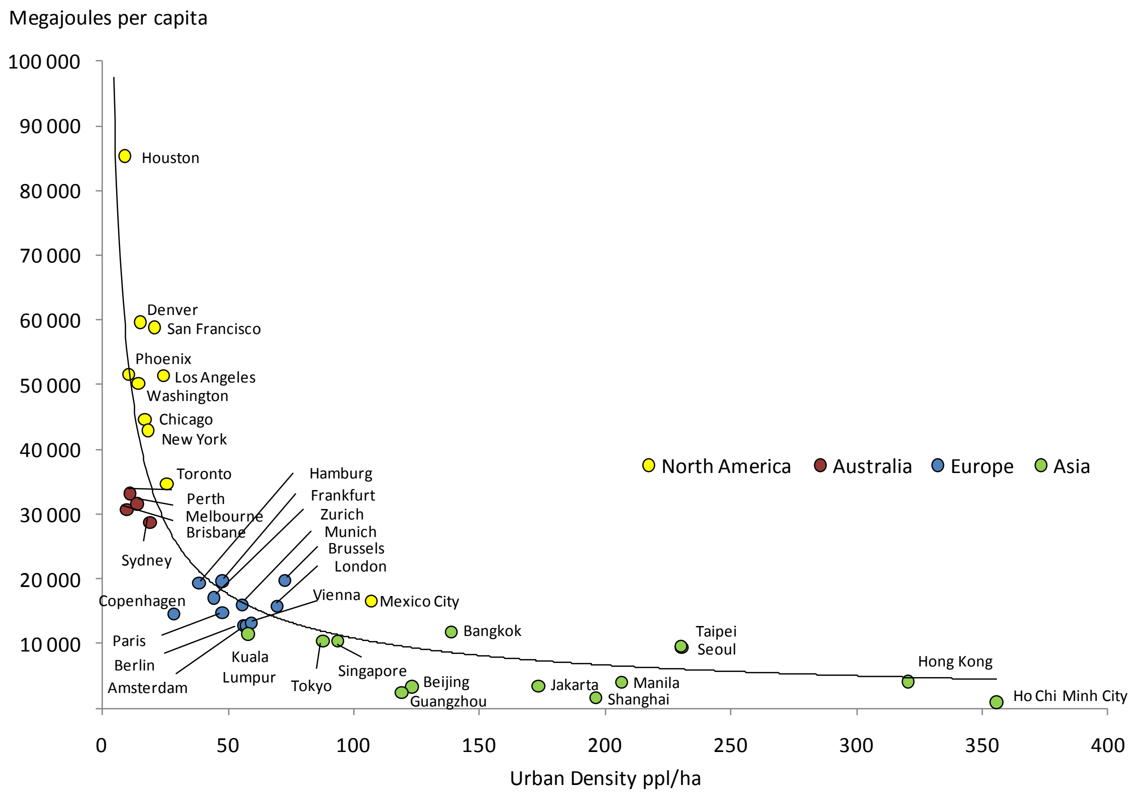
There is strong evidence to suggest cities with a higher population density are cities with a much lower energy use (see Figure 5.7 and Ewing et al., 2008). This is not necessarily a cause and effect relationship, but the two go together for at least three reasons. First, the shorter travel distances in more compact cities contribute directly to lowering transport energy demand. Second, design features and policies that reduce transport energy demand, such as those listed above, tend to have more favourable economics in denser cities, and are therefore more likely to be adopted. And third, the causation can also run the other way: cities that have design features and policies to reduce transport energy demand, such as those listed above, tend to develop in a more dense fashion.

In any case, the correlation between energy use and population density is so strong we can model a city's transport energy use based on its population density. This can be seen in Figure 5.7, which shows the light vehicle energy demand per capita and population densities of various cities.

Note also that the differences in light vehicle energy demand per capita between cities is huge. A comparison of two wealthy cities, Houston and Singapore, is informative. Houston is a sprawling city with a population density of about 15 people per hectare, while Singapore is a more compact city with a population density of about 95 people per hectare. While the income per capita of these two cities is similar, the light vehicle energy use per capita is eight times greater in Houston than it is in Singapore.

What is also apparent from Figure 5.7 is the critical urban density where transport energy demand begins to accelerate rapidly. The critical point is around 50 people per hectare. Urban density above this broad threshold has only a moderate impact on light vehicle energy consumption. However, below this level, light vehicle energy demand rises rapidly.

Figure 5.7: Passenger Vehicle Energy Use per Capita versus the Urban City Density in People per Hectare (Data Year = 1995)



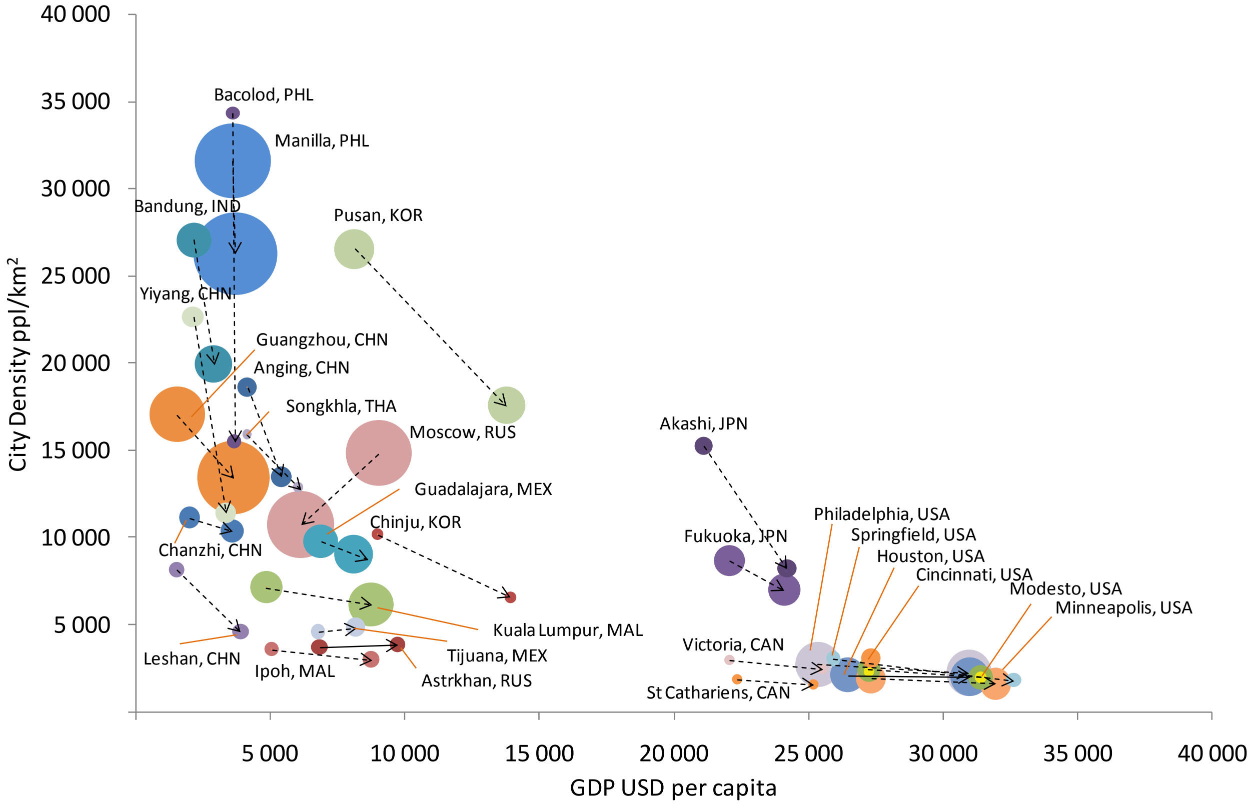
Note: The urban city statistical indicators shown here were collected on a common base year of 1995.

Source: Adapted from UITP/ISTP (1995)

The Declining Trend in Urban Density

Urban density has a long history of decline in both developing and developed cities. A World Bank study in the early 2000s assessed the trend in urban density for over 120 global cities. The study concluded that urban density had declined at an average rate of 1.7% between 1984 and 2002, with the density decline in developing cities up to three times higher than that in developed cities (Angel et al., 2005, p. 205). Figure 5.8 shows the change in urban density relative to the urban population (bubble size) and to the average real gross domestic product (GDP) per capita for the APEC cities assessed. The majority of cities in Figure 5.8 show urban density declining with growing per capita GDP. The decline in urban density is particularly rapid for cities in developing economies, where small changes in per capita GDP result in rapid changes in urban density.

Figure 5.8: Trend in Urban Density for APEC Cities Relative to the Size of Population and Growth in GDP per Capita between 1984 and 2002



Source: Data adapted from Angel et al. (2005)

The Window of Opportunity for Better Urban Planning

As shown in Table 5.2, cities in the APEC region are undergoing rapid urbanization. The United Nations (UN) predicts that by 2050 the urban population in the APEC region will grow by around 700 million people. Approximately 70% of APEC's urban population will be in the non-OECD (developing) APEC economies (UN, 2011).

The developing APEC economies will thus have a one-time opportunity for energy saving urban design which many cities in developed economies have already forfeited. This window of opportunity is closing quickly since once cities mature and infrastructure is built, energy saving urban design becomes increasingly expensive, difficult, and slow to implement.

Table 5.2: Urban Population Growth Projection in the APEC Region among OECD and Non-OECD Economies

(million people)	2010	2035	2050
Total APEC Urban Population	1601	2200	2,327
% Change from 2010		+37%	+45%
Total APEC Non-OECD Urban Population	1037	1518	1606
% Change from 2010		+46%	+55%
Total APEC Non-OCED + Mexico and Chile Urban Population	1140	1653	1749
% Change from 2010		+45%	+53%

Source: Adapted from UN (2011)

Urban Development Scenarios Considered

Given the high correlation between urban population density and energy use, we take population density as an (admittedly imperfect) indicator of better urban planning and management. We ask, what would be the impact on light vehicle energy demand if we could make the cities in the APEC region grow to be more like the denser cities of today's developed economies, rather than the 'sprawling' ones.

Three alternative scenarios are modeled in addition to the BAU case. These scenarios are defined as follows:

- BAU—Urban density continues to decline at the historical world average of 1.7% per year.
- High Sprawl—Urban density declines at 3.4% per year (or twice the historical average), leading to rapid urban land area expansion.
- Constant Density—Urban density is maintained at a constant level (2009) where urban land area expansion is proportional to population growth.
- Fixed Urban Land—Urban land area is fixed and population growth is contained inside existing urban boundaries.

The projected light vehicle energy use is estimated in each scenario by modelling the change in light vehicle ownership as well as the change in unit vehicle travel by each of these vehicles as a function of changes in urban density and income. The urban planning scenarios are conservative in scope as they do not consider the further potential energy savings in the heavy vehicle fleet. The heavy vehicle fleet in some APEC economies accounts for over 50% of road transport energy use.

Vehicle Saturation and Urban Development

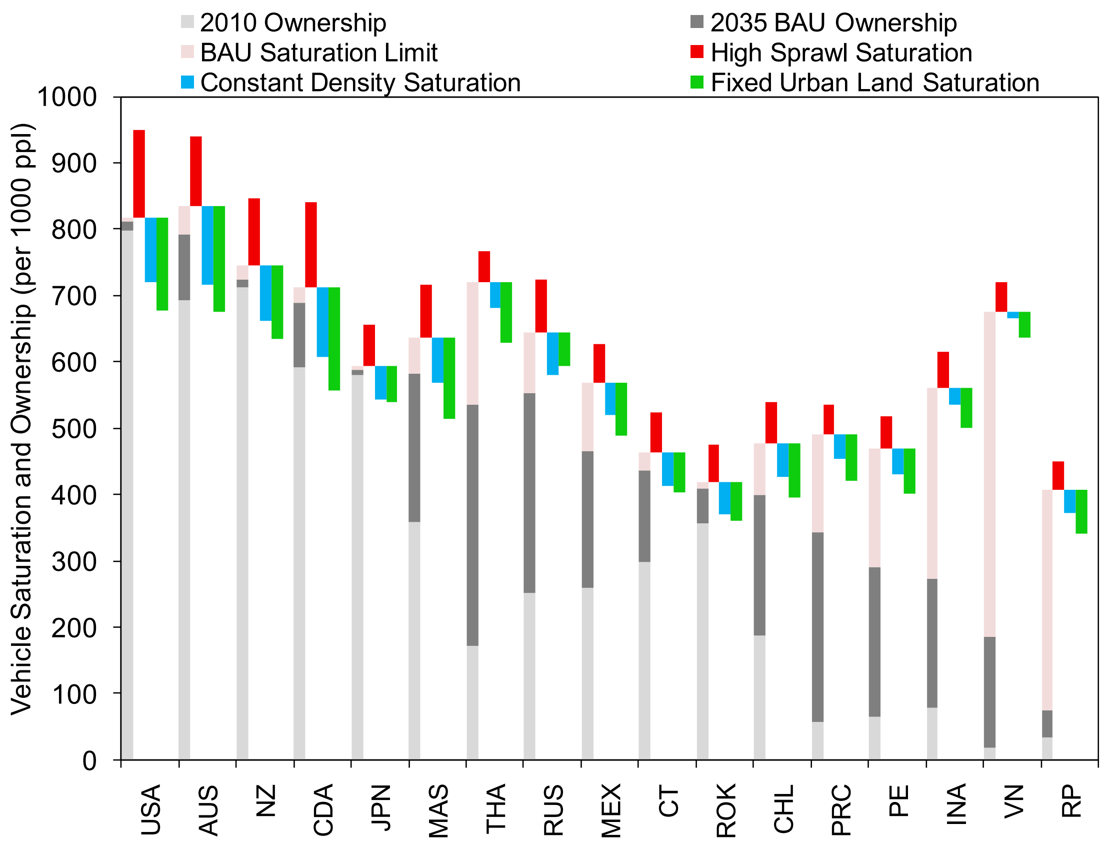
Urban density is highly correlated with the saturation levels of vehicle ownership seen in developed economies. Lower population densities correlate with higher saturation levels of vehicle ownership. In the future, as the developing economies become wealthier, we would expect the vehicle ownership in their urban areas to approach the saturation levels seen today in developed economy urban areas with similar population densities.

There is a similar relationship between urban density and unit vehicle travel that we also model, but it is a bit more complicated. In developing economies, unit vehicle travel is closely related to vehicle ownership. For example, as income grows the number of households shifting from one vehicle to two vehicles increases in response to higher living standards. However, the distance each vehicle now travels is less on a per vehicle basis than in households with a single vehicle.

Urban Development Scenario Results

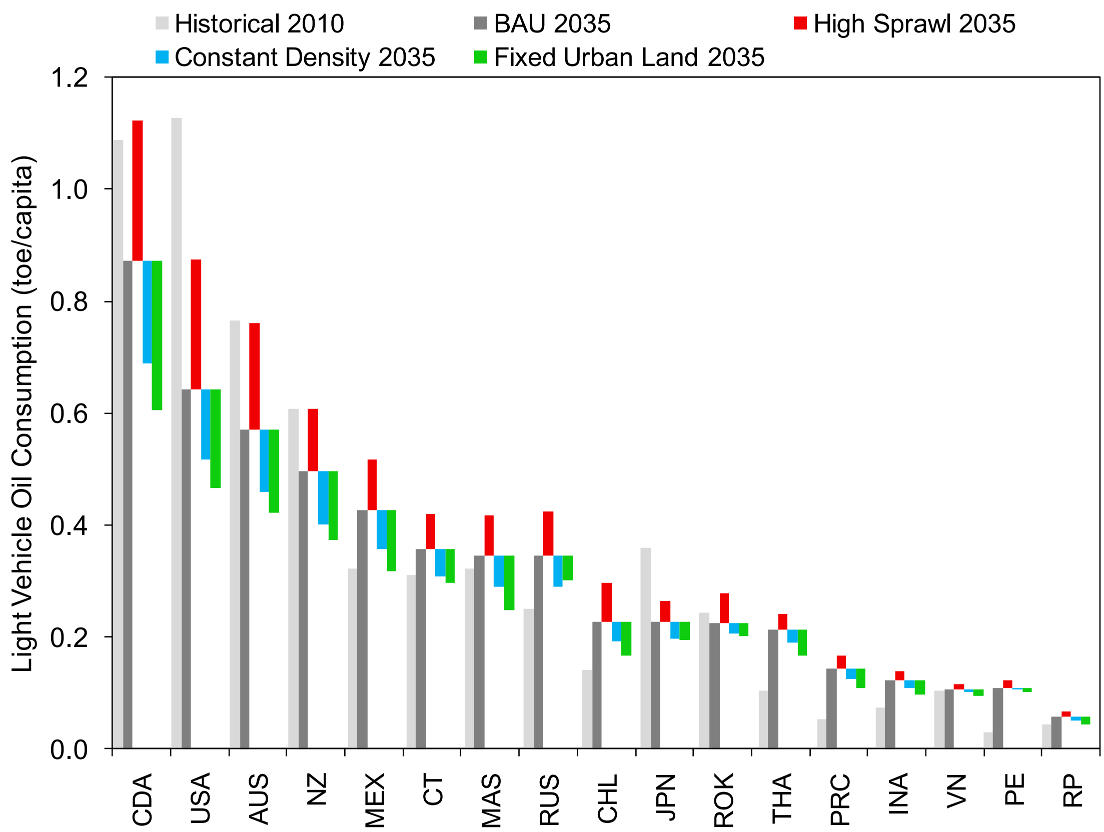
Figure 5.9 shows the change in vehicle saturation under each urban development scenario. Figure 5.10 shows the comparison of per capita oil demand in the light vehicle fleet. The economy rankings are based on the BAU projections for 2035. Singapore and Hong Kong, China are not considered due to their natural land area constraints. Papua New Guinea and Brunei Darussalem are also not considered due to insufficient urban area statistical data.

Figure 5.9: APEC Motor Vehicle Saturation under Urban Planning Alternative Scenarios in 2035



Source: APERC Analysis (2012)

Figure 5.10: APEC Light Vehicle Oil Demand per Capita under Urban Planning Alternative Scenarios

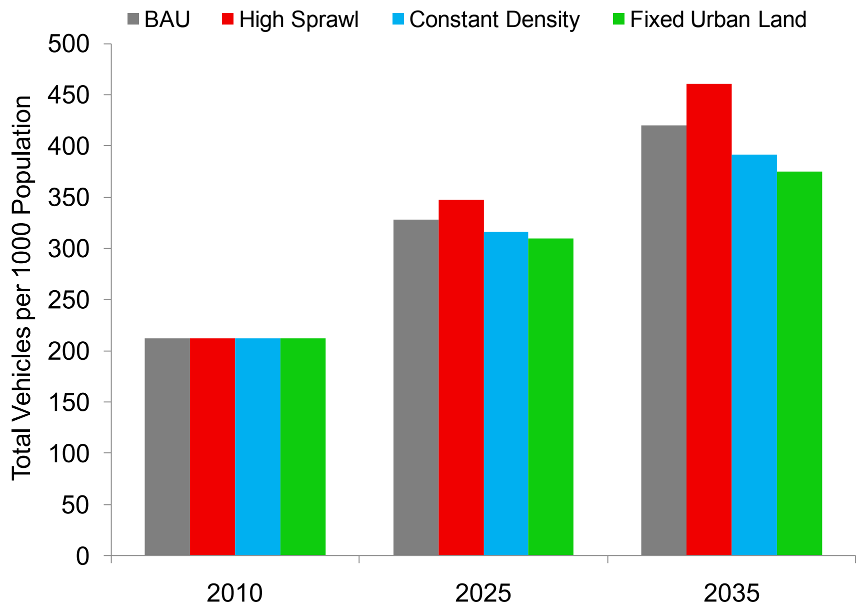


Source: APERC Analysis (2012)

Figures 5.11, 5.12 and 5.13 show the APEC economies' light vehicle ownership per capita, oil consumption and CO_2 emissions for the alternative urban planning scenarios. The APEC region's vehicle ownership per capita accelerates under all alternative urban planning cases. Vehicle growth is driven by rapid economic growth in the developing APEC economies. However, by 2035, the APEC region's vehicle ownership is 10% higher in the High Sprawl scenario compared to BAU.

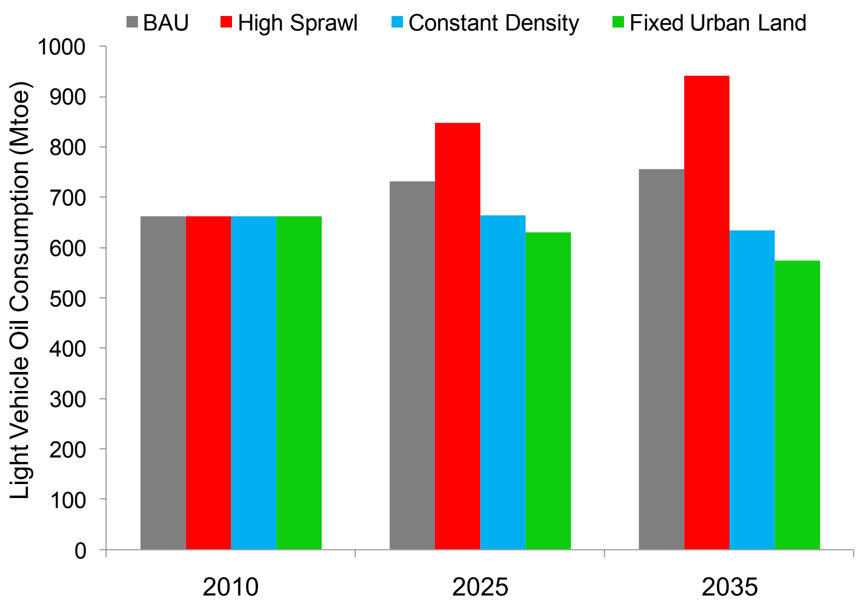
In 2035, the APEC economies' oil use and CO_2 emissions in the light vehicle fleet are 25% higher than BAU under the High Sprawl scenario; but 16% and 24% lower than BAU under the Constant Density and Fixed Urban Land scenarios respectively. Under the Fixed Urban Land scenario, both oil use and CO_2 emissions in the APEC economies' light vehicle fleet decline. The impact on oil use and CO_2 emissions is more pronounced than for vehicle ownership.

Figure 5.11: APEC Vehicle Ownership under the Urban Planning Scenarios



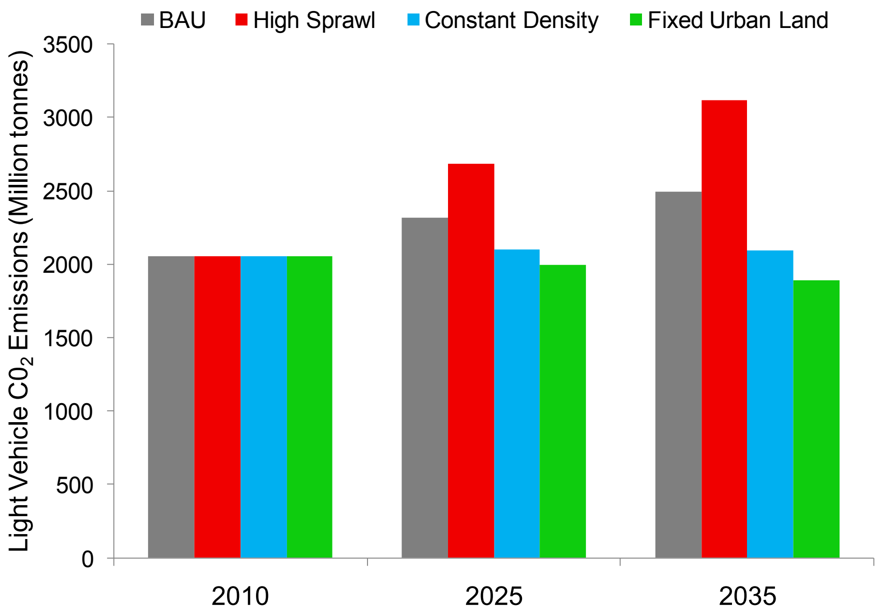
Source: APERC Analysis (2012)

Figure 5.12: Oil Use in the APEC Light Vehicle Fleet under the Urban Planning Scenarios



Source: APERC Analysis (2012)

Figure 5.13: CO_2 Emissions in the APEC Light Vehicle Fleet under the Urban Planning Scenarios



Source: APERC Analysis (2012)

Oil use and CO_2 emissions depend not only on the change in vehicle ownership but also on the change in unit vehicle travel. For compact cities, the unit vehicle travel is lower than for sprawling cities.

Urban Development Scenarios Summary

Urban planning and management has a substantial long-term impact on domestic transport energy use. 'Smart growth' policies could reduce the APEC region's oil use and CO_2 emissions in the light vehicle fleet by 24% compared to BAU by 2035.

There are two additional thoughts regarding these scenarios that should be considered:

- Owing to the anticipated scale of urban growth in developing APEC economies over the next several decades, there is a one-time opportunity to implement energy-saving smart urban design. Once the cities are built, the urban land use patterns and infrastructure become difficult and expensive to alter.
- The oil savings and CO_2 emissions reduction benefits from smart urban design are significant, but these benefits are realized over a long timeframe. The benefits shown in this analysis may be understated due to the limited time horizon of this outlook projection. We would expect the oil savings and emissions reduction benefits of smart urban design to continue to grow in magnitude beyond the end of the outlook period. This is especially true for developing economies, where vehicle saturation may not be reached until well after 2035.

THE VIRTUAL CLEAN CAR RACE SCENARIOS

APEC economies are promoting alternative vehicle technologies and alternative fuels as a means of reducing oil consumption, improving energy efficiency and promoting low-carbon transport (APEC, 2011). The potential for oil savings from the adoption of alternative vehicles is apparent. The impact on CO_2 emissions is less obvious since the emissions from fuel production for specific alternative fuels, such as hydrogen and electricity, must be considered. Therefore, the difference in emissions intensity between vehicle technologies depends on both the efficiency of the vehicle itself (the energy use per km) and the carbon intensity of its fuel (carbon content per energy unit).

Four scenarios are modelled in this analysis to assess the relative merits of four types of alternative vehicles in reducing oil use and CO_2 emissions in each APEC economy. Since these four scenarios simulate a competition between these four vehicle types, we denote these scenarios as the 'Virtual Clean Car Race'.

In each of the four scenarios, we assume sales of new alternative vehicles increase incrementally from BAU, starting in 2013, and rise to a market share 50 percentage points above BAU by 2020 and thereafter. For example, if the market share of natural gas vehicles is 5% of new vehicle sales in 2020 in the BAU scenario, the share of natural gas vehicles would be 55% of new vehicle sales in 2020 in the Natural Gas Vehicle Transition scenario.

The market share of new conventional vehicles in each scenario would be correspondingly reduced. To continue the example, if the market share of conventional vehicles is 90% of new vehicle sales in 2020 in the BAU case, it would be 40% of new vehicle sales in 2020 in the Natural Gas Vehicle Transition scenario. At the same time, the share of alternative vehicles other than natural gas vehicles remains the same in the Natural Gas Vehicle Transition scenario as it was in the BAU scenario. Note that, while the market share of the alternative vehicles in new vehicle sales levels-off at its maximum value by 2020, the actual number of alternative vehicles in the fleet does not level-off until some years later, reflecting the time required for all vehicles in the fleet in 2020 to be replaced.

These assumptions are not intended to be realistic depictions of how alternative vehicle technology might enter the marketplace. Given that it will take many years to implement new vehicle designs and fuelling infrastructures, the assumptions are probably quite unrealistic. However, the assumptions do have two advantages in an exercise designed to compare the merits of the vehicle technologies. First, the number of additional alternative vehicles in each year is always the same in all four cases, allowing an apples-to-apples comparison. Second, the planned transition to at least 50% alternative vehicles in the vehicle fleet can be almost entirely completed by 2035, the final year of this outlook period.

The scenarios to be examined are defined as follows:

- Hyper Car Transition scenario
- Electric Vehicle Transition scenario—this case assumes pure battery electric vehicles
- Hydrogen Vehicle Transition scenario
- Natural Gas Vehicle Transition scenario.

For each of the alternative vehicle types, we have modelled energy consumption and emissions based on published studies. As mentioned earlier, Lovins et al. (2005) report an energy savings potential for the hyper car of between 50–66%. Kromer and Heywood (2007) report that pure electric and hydrogen vehicles have a relative energy use compared to conventional vehicles of about 20% and 30% respectively, that is they consume 80% and 70% less energy. Finally, Semin (2008) reports that natural gas vehicles typically offer energy savings of 10% compared to conventional vehicles.

For the calculation of CO_2 emissions we must also consider the assumptions regarding how the hydrogen and electricity are produced. These are discussed below.

Hydrogen Production Pathways

Hydrogen, like electricity, is an energy carrier not a primary energy source. Therefore hydrogen must be produced from a primary energy resource, either fossil fuel, renewable, or nuclear. There are many possible production paths for hydrogen. Three of these processes are generally regarded as being scalable. These technologies are steam methane reforming or SMR (using natural gas), gasification (using coal or biomass) and electrolysis of water (using electricity).

A major potential advantage of hydrogen (and electric) vehicles is the potential for using a low-carbon primary energy source (renewable, nuclear, or fossil fuel with carbon capture and storage) to produce the hydrogen or electricity. We could have assumed the use of a low-carbon primary energy source for our Hydrogen Vehicle Transition and Electric Vehicle Transition scenarios, in which case these vehicles would have looked very good in terms of CO_2 emissions. However, this assumption would have required us to assume that enough new low-carbon hydrogen or electricity generation capacity is built to meet the energy needs of the hydrogen and electric vehicles. In this case, we would be counting the benefits of this additional low-carbon generation as a benefit of hydrogen or electric vehicles. This did not seem appropriate, especially since you could get the same emission reductions by simply building more low-carbon electricity generation capacity without using any hydrogen or electric vehicles at all.

Therefore, to provide a fair comparison we assumed the use of conventional energy sources in all the Virtual Clean Car Race scenarios. Table 5.3 compares the characteristics of the three processes considered for producing hydrogen. Note that, as shown in the table, coal gasification and SMR require inputs of electricity as well as of fossil fuels.

Table 5.3: Key Indicators for Hydrogen Production Alternatives

Indicator	Coal Gasification	SMR	Electrolysis
Assumed Primary Fuel	Coal	Natural Gas	Electricity from Fossil Fuels
MJ of Energy Input (including Electricity) per Kilogram Hydrogen	231	206	195
Efficiency (MJ Hydrogen per MJ of Energy Input, including Electricity) based on Thermal High Heating Value	61%	69%	72%
Electricity Input (kWh/kg H2)	15.5	11.2	54.2

Note: Electricity as an input is required in both the large scale hydrogen production process of coal gasification and SMR. This is to liquefy the hydrogen gas produced for tanker distribution to forecourt stations. Pipeline distribution of gaseous hydrogen was assumed to be too costly to implement on a wide scale, while distribution using the adsorption properties of a metal hydride is still unproven for large scale distribution applications.

Source: Adapted from Leaver, J et al. (2009)

SMR is the most well established process for hydrogen production. Coal gasification is not as efficient as SMR—but it uses coal, rather than gas, which is cheaper and more readily available domestically in many APEC economies. Although electrolysis appears to be the most efficient of the three production processes in Table 5.3, this does not include the conversion losses involved in making the electricity, which are usually at least 50%. Therefore electrolysis is likely to be the least economic of the three pathways for large-scale hydrogen production (Simbeck and Chang, 2002). For this analysis, we assume all hydrogen production in the APEC region is entirely from large-scale SMR. Its high efficiency and use of gas as a primary fuel should make it the most favorable of the three processes from a greenhouse gas emissions perspective.

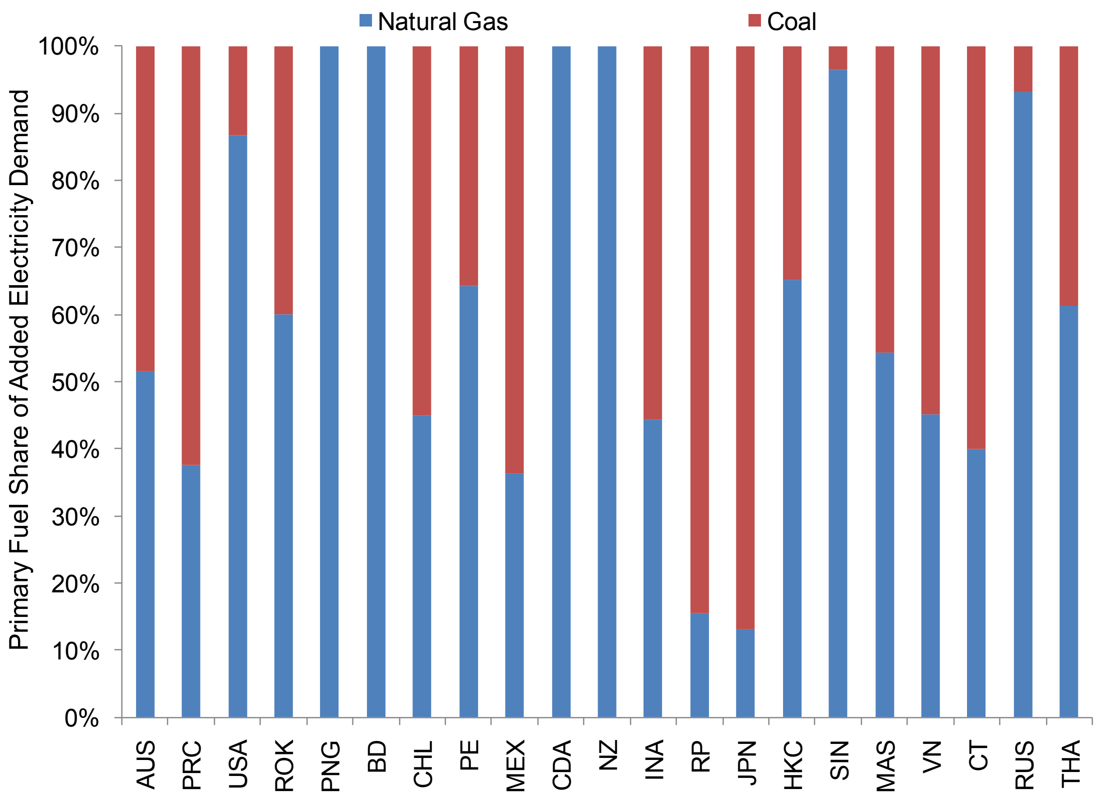
Electricity Production

The additional demand for electricity above BAU in both the Electric Vehicle Transition scenario and the Hydrogen Vehicle Transition scenario is produced from coal or gas. The specific mix of coal or gas used by each economy varies depending on which fuel our electricity supply model (see Chapter 9) determined to be the marginal source of electricity generation in that economy. The ratio of coal to natural gas to meet the additional electricity demand is shown in Figure 5.14.

Virtual Clean Car Race Scenario Results

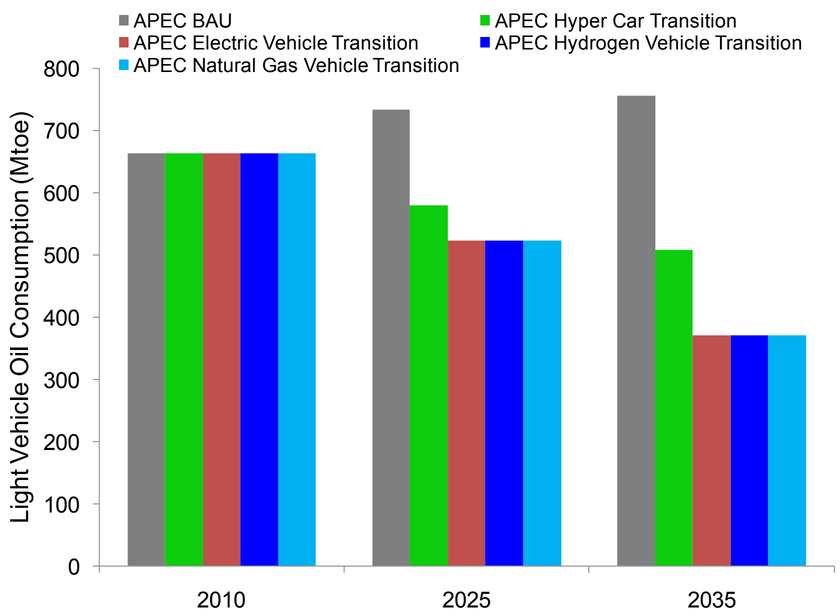
Figure 5.15 shows the APEC region's total light vehicle fleet oil demand in each Virtual Clean Car Race scenario in 2010, 2025 and 2035. In the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios, oil demand has dropped by 51% by 2035 compared to BAU. We would expect the drop to be around 50% as these vehicles constitute about 50% of the vehicle fleet in 2035 in these scenarios and they consume no oil. In the Hyper Car Transition scenario, oil demand has dropped by 32%. We would expect the drop to be around 30% as these vehicles constitute about 50% of the vehicle fleet in 2035 in this scenario, and they are (at this year) roughly 60% more energy efficient than conventional vehicles.

Figure 5.14: Primary Fuel to Meet Added Demand for Electricity in the Electric Vehicle Transition and Hydrogen Vehicle Transition Scenarios



Source: APERC Analysis (2012)

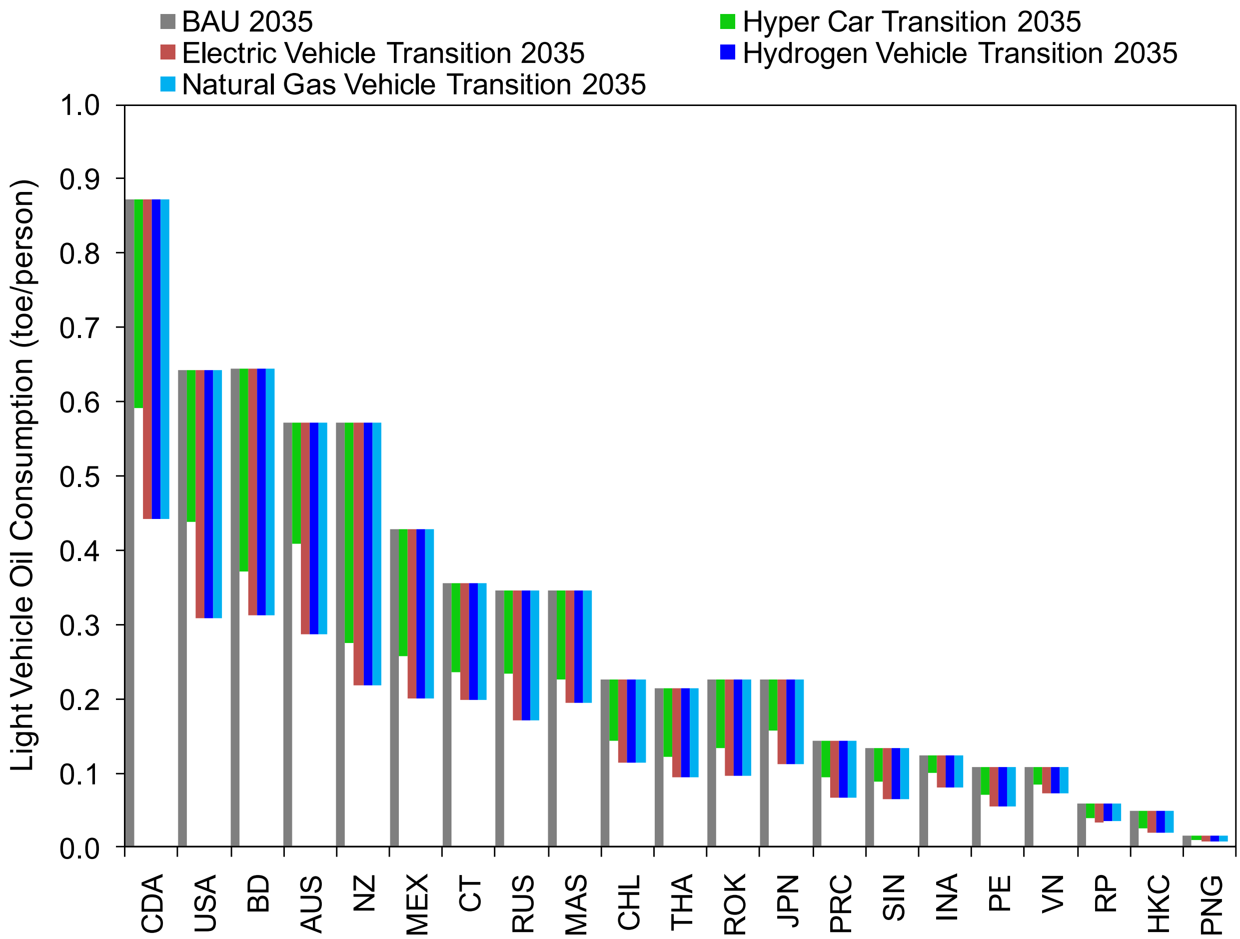
Figure 5.15: APEC Oil Consumption in the Light Vehicle Fleet across the Virtual Clean Car Race Scenarios



Source: APERC Analysis (2012)

Figure 5.16 shows the reduction in oil demand by economy in 2035, compared to BAU. The reduction in oil demand in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios may be a bit less than 50% in those economies with large fleets of motorcycles. Motorcycle oil demand is included in light vehicle energy demand, but the motorcycle fleet was assumed to be unchanged in these scenarios. On the other hand, the reduction may be a bit more than 50% in those economies where alternative vehicles would constitute a significant share of the vehicle fleet in 2035, even under BAU. In this case, the additional 50% of the vehicle fleet that are alternative vehicles can replace more than 50% of the remaining conventional vehicles. The reduction in the Hyper Car Transition scenario similarly varies a bit depending on the size of the motorcycle fleet and the penetration of alternative vehicles in the BAU case.

Figure 5.16: APEC Light Vehicle Oil Consumption per Capita in 2035 for each Virtual Clean Car Race Scenario

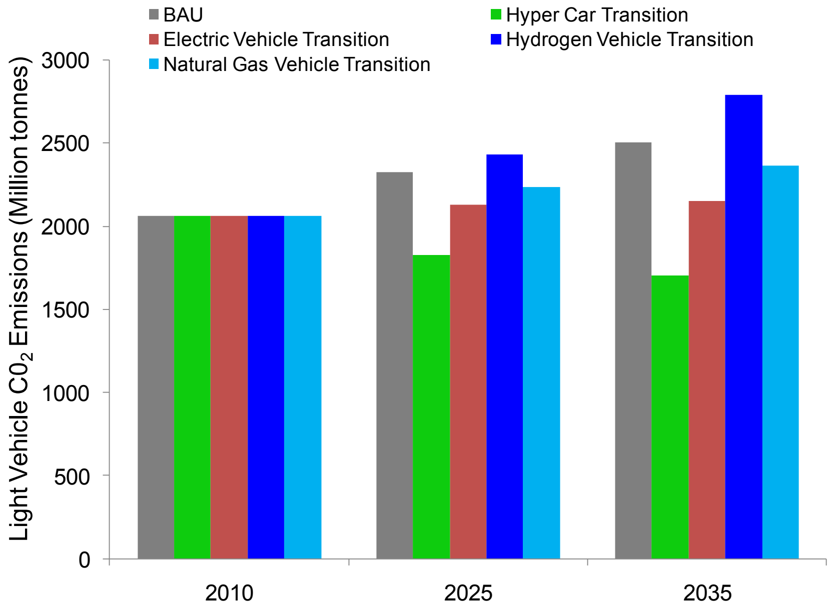


Source: APERC Analysis (2012)

Figure 5.17 shows the APEC region's total light vehicle fleet CO_2 emissions in each Virtual Clean Car Race scenario in 2010, 2025 and 2035. Reflecting its high fuel efficiency, the Hyper Car Transition has the highest potential for CO_2 emissions reductions in APEC economies. The reduction would be about 32% compared to BAU. Again, we would expect the drop to be around 30% as these vehicles are assumed to constitute an additional 50% of the vehicle fleet in 2035 in this scenario, and they are roughly 60% more energy efficient than conventional vehicles.

Emissions reductions for the Electric Vehicle Transition were more modest but still a significant 7%. This more modest reduction reflects the conversion losses in producing electricity from fossil fuels and, in some economies, the use of carbon-intensive coal as a primary energy source. The Natural Gas Vehicle Transition offered a smaller CO_2 reduction of 6%, reflecting the slightly lower carbon intensity of natural gas compared to oil, although efficiency improvement prospects compared to conventional vehicles are lower. The Hydrogen Vehicle Transition actually increased CO_2 emissions, reflecting the losses in the two conversions involved (gas to hydrogen in the hydrogen plant, then hydrogen to electricity in the vehicle).

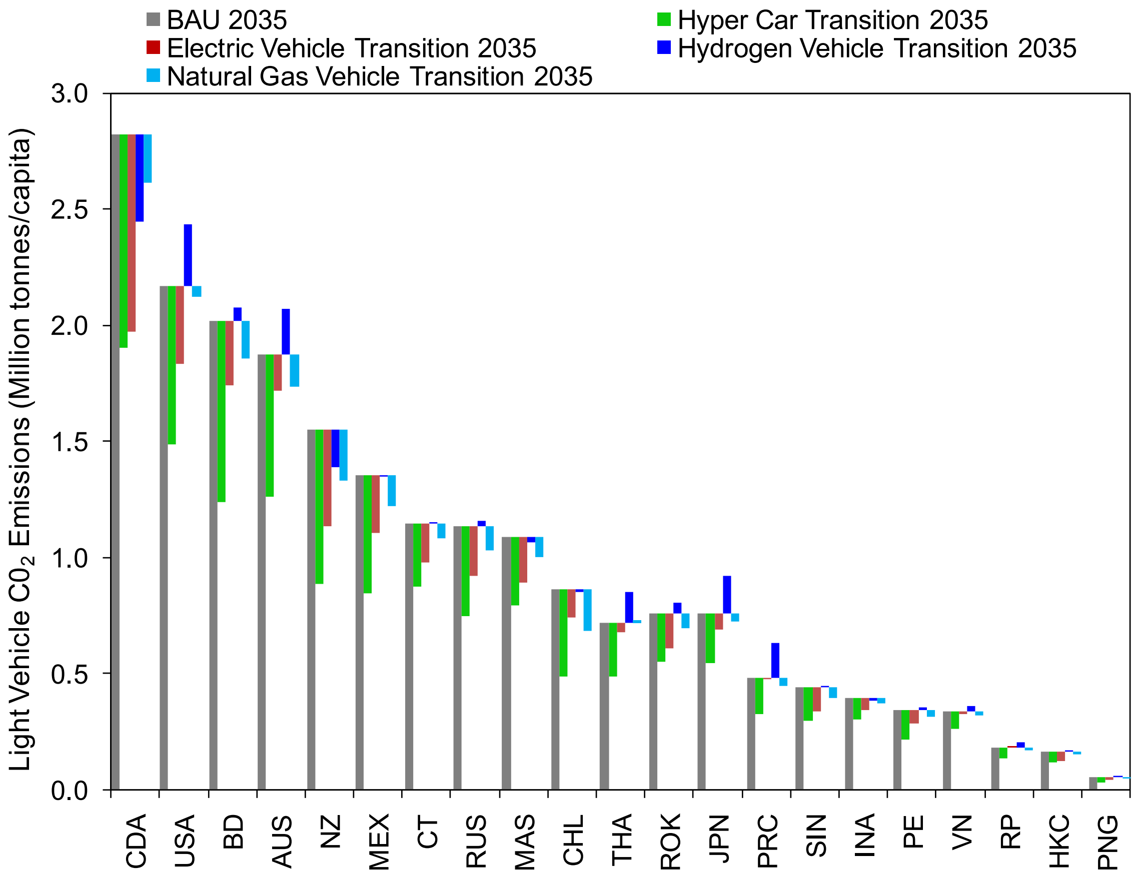
Figure 5.17: APEC CO_2 Emissions in the Light Vehicle Fleet across the Alternative Scenarios



Source: APERC Analysis (2012)

Figure 5.18 shows the CO_2 emissions results by economy. It can be seen that the emissions reductions for the Electric Vehicle Transition scenario vary considerably between economies. This reflects the differences in the gas to coal mix of the marginal generation in each economy, as well as the differences in generation efficiencies. Reductions for the Hyper Car Transition, the Natural Gas Vehicle Transition, and the Hydrogen Vehicle Transition scenarios were more consistent among economies, reflecting the similarities of these technologies across economies.

Figure 5.18: APEC Light Vehicle CO_2 Emissions per Capita in 2035 for the Virtual Clean Car Race Scenarios



Source: APERC Analysis (2012)

Virtual Clean Car Race Scenarios Summary

This analysis shows the way to energy security and low-carbon emissions is not easily achieved through the pursuit of alternative vehicles. All pathways require some compromises between the twin goals of reducing oil dependence and reducing greenhouse gas emissions.

Hydrogen vehicles offer the obvious benefit of energy diversification away from oil. However, the production of hydrogen from gas using SMR would result in a Hydrogen Vehicle Transition scenario that increases the CO_2 emissions in the light vehicle fleet by an average of 15% in the APEC economies. The CO_2 emissions would be significantly higher if coal gasification were used for the production of hydrogen.

Electric vehicles also offer energy diversification away from oil. They are, on average, less carbon intensive than conventional vehicles, but not by a large amount. An Electric Vehicle Transition scenario could reduce the carbon emissions of the light vehicle fleet by an average of 7% in the APEC economies. However, the CO_2 intensity of electric vehicles varies widely by economy and may exceed that of conventional vehicles for economies strongly dependent on coal for electricity generation. Although battery technology is improving, electric vehicles are still at a disadvantage to conventional vehicles, and even hydrogen vehicles, in terms of their driving range, refuelling times, and initial cost (refer to Figure 5.6).

Another alternative to oil-fuelled conventional vehicles is natural gas. Natural gas vehicles traditionally offer greater energy efficiency than conventional vehicles as a result of the high octane content of the fuel enabling more efficient combustion (Semin, 2008). Owing to their higher combustion efficiency, natural gas vehicles offer about a 10% improvement in energy efficiency compared to a conventional gasoline vehicle (Semin, 2008). However, it is expected the energy efficiency of conventional vehicles in the future will match or exceed that of natural gas vehicles with the diffusion of hybrid electric drive, clean diesel, and lighter weight body technologies. Still, we find a Natural Gas Vehicle Transition scenario could offer a small reduction in the APEC region's light vehicle fleet CO_2 emissions of around 6% by 2035.

The best all-around option for reducing both oil dependence and CO_2 emissions would appear to be hyper cars. On an APEC-wide basis, a Hyper Car Transition scenario could reduce light vehicle fleet oil use and corresponding CO_2 emissions by 32% compared to BAU in 2035. A Hyper Car Transition scenario would be relatively easy to achieve compared to the other alternative vehicles. It would require no change in fuelling infrastructure and the vehicles would have a driving range and performance characteristics similar to conventional vehicles.

The results of the Virtual Clean Car Race scenarios indicate that dealing with the twin challenges of energy security and climate change may require looking beyond the options examined here. Three suggestions worth considering are as follows:

1) The hyper car concept could be combined with alternative energy sources. For example, an electric hyper car would use no oil and require considerably less electricity than a conventional electric car. Because of the lower electricity requirements, it would have lower CO_2 emissions than a conventional electric car. Since the electric hyper car would need smaller batteries for any given driving range than a conventional car, it could probably be produced more cheaply.
2) A major potential advantage of electric and hydrogen vehicles is that they could ultimately be powered by primary energy from low-carbon sources. This would allow both a move away from oil and significant reductions in CO_2 emissions. But this conversion should probably be done in the context of a conversion of all electricity generation to low-carbon sources, since it would make no sense for the vehicle fleet to have its own dedicated source of low-carbon electricity while the rest of the economy continued to run on conventionally-generated electricity.
3) Meeting the twin challenges of energy security and climate change in the transport sector is a problem that will require multiple solutions. Vehicle technology changes alone will probably not be sufficient. As discussed at the beginning of this chapter, solutions include 'Avoid', 'Shift', and 'Improve'. The APEC economies would be best served by pursuing all three of these options.

Suggestion #1 implies that electric or hydrogen propulsion, in combination with the hyper car concept, offers a further medium-term opportunity to dramatically reduce oil demand in transportation. Suggestion #2 implies that electric and hydrogen propulsion offers a long-term path to truly low-carbon vehicles. For these reasons, research on electric and hydrogen vehicle technologies continues to merit the support of policymakers.

APERC'S TRANSPORT SECTOR ENERGY DEMAND MODEL AND HOW IT WORKS

The transport sector is modelled as five separate sub-sectors in each APEC economy:

1. Road vehicle fleet—further divided into the light and heavy vehicle fleets
2. Aviation—domestic and international
3. Shipping—domestic and international
4. Rail
5. Pipeline.

The road sub-sector has been the major focus of APERC's transport modelling effort, as in most APEC economies it constitutes the largest source of transport energy demand by far.

Energy use in the road sub-sector is modelled as:

Number of Vehicles x Number of Kilometres per Vehicle
x Energy Consumption per Kilometre.

This calculation is performed separately for the light vehicle fleet and the heavy vehicle fleet. Within the light vehicle fleet, it is also performed separately for each of seven vehicle technologies (both conventional and alternative vehicles).

APERC's road vehicle model represents the turnover of the vehicle fleet (purchases and retirements) each year for each vehicle type for each APEC economy. It thus allows the calculation of the number of vehicles of each technology on the road in each economy in each year. The market share for each vehicle technology among newly purchased vehicles each year depends on the merit of that vehicle technology to consumers. Using research detailed in Leaver and Leaver (2011), the calculation of use to the consumer takes into account:

- Upfront capital expenditure
- Annual fuel cost
- Vehicle range limitation
- Refuelling infrastructure availability.

The total number of light vehicles in each economy approaches a saturation level as the GDP per capita rises. But for economies whose GDP per capita is still relatively low, vehicle ownership will be well below the saturation level. APERC's estimate of the saturation level in each economy is a function of the urban population density of major cities (higher population densities imply lower saturation vehicle ownership) as well as the urban population numbers.

Because of the consideration given to urban density in estimating vehicle ownership saturation levels, APERC's estimates of vehicle saturation levels differ from those given in the literature. Table 5.4 shows a comparison of APERC's projected vehicle saturation levels to vehicle saturation levels of available APEC member economies from Dargay et al. (2007).

Table 5.4: Comparison of Long-term BAU Vehicle Saturation Levels of Available APEC Economies

Vehicle Saturation (per 1000ppl)	*APERC 2035*	*Dargay et al*
Australia	825	785
Canada	710	845
Chile	480	810
China	490	807
Indonesia	595	808
Japan	615	732
Korea	440	646
Malaysia	650	827
Mexico	610	840
New Zealand	750	812
Chinese Taipei	485	508
Thailand	770	812
United States	820	852

Sources: APERC Analysis (2012), Dargay et al. (2007)

The number of kilometres travelled per vehicle in each economy is a function of vehicle ownership, energy efficiency, income growth, and oil price. For example, when households shift from one vehicle to two vehicles the distance each vehicle is now driven does not double. Thus in non-OCED economies with strong vehicle ownership growth, unit vehicle travel decreases. In OECD economies with near saturation in vehicle ownership, oil price, income growth and vehicle efficiency have a higher effect on unit vehicle travel. Energy consumption per kilometre depends on the vehicle type and the year of manufacture. Estimates of energy consumption per kilometre by vehicle type, along with projected energy efficiency improvement trends, are drawn from the literature.

The non-road transport sectors employ a much simpler top-down approach, strongly tied to the changes in either GDP or GDP per capita. However, for the aviation and shipping models the demand response is also a function of the oil price. In addition, further consideration is given to possible modal shifts between road, rail, aviation and shipping based on expected infrastructure investment. APERC makes this assessment on a case by case basis for each APEC economy.

This section is a short summary of the APERC transport model. Further details of the mathematical derivation including case studies are given in Leaver, L et al. (2012).

REFERENCES

Angel, S., Sheppard, S.C. and Civco, D. (2005), *The Dynamics of Global Urban Expansion*, The World Bank Transportation and Urban Development Department, Washington DC, USA.

APEC (Asia–Pacific Economic Cooperation) (2011), 7th APEC Transportation Ministerial Meeting – Joint Statement, www.apec.org/Meeting-Papers/Ministerial-Statements/Transportation/2011_transport.aspx

Bandivadekar, A., Bodek, K., Cheah, L., Evans, C., Groode, T., Heywood, J., Kasseris, E., Kromer, M. and Weiss, M. (2008), *On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions*, Report No. LFEE 2008-05 RP, MIT Laboratory for Energy and the Environment, Cambridge, Massachusetts.

Cheah, L. and Heywood, J. (2011), "Meeting U.S. passenger vehicle fuel economy standards in 2016 and beyond", *Energy Policy*, Volume 39 Issue 1, January 2011, pp. 454–466.

Dargay, J., Gately, D. and Sommer, M. (2007), "Vehicle Ownership and Income Growth, Worldwide: 1960–2030", *The Energy Journal*, 28(4), pp 143–170.

Ewing, R., Bartholomew, K., Winkelman, S., Walters, J. and Chen, D. (2008), *Growing Cooler: The Evidence on Urban Development and Climate Change*, The Urban Land Institute, Washington DC, USA.

Hidrue, M., Parsons, G., Kempton, W. and Gardner, M. (2011), "Willingness to pay for electric vehicles and their attributes", *Resource and Energy Economics*, Volume 33 Issue 3, September 2011, pp 686–705.

Kromer, M. and Heywood, J. (2007), *Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet*, Publication No. LFEE 2007-03 RP, MIT Laboratory for Energy and the Environment, Cambridge, Massachusetts.

Leaver, J., Gillingham, K. and Leaver, L. (2009), "Assessment of primary impacts of a hydrogen economy in New Zealand using UniSyD", *International Journal of Hydrogen Energy*, Volume 34 Issue 7, April 2009, pp 2855–2865.

Leaver, J. and Leaver, L. (2011), *Potential impact of consumer behaviour and carbon price on national energy policy in New Zealand*, Energy, Utility and Environment Conference Journal (Online), www.euec.com/euecjournal.aspx

Leaver, L., Samuelson, R. and Leaver, J. (2012), *Potential for low transport energy use in developing Asian cities through compact urban development*, paper presented at the 3rd Asian International Association for Energy Economics Conference, Kyoto, http://eneken.ieej.or.jp/3rd_IAEE_Asia/pdf/paper/036p.pdf

Lovins, A., Datta, E. K., Bustnes, O-E., Koomey, J. and Glasgow, N. (2005), *Winning the oil endgame: innovation for profits, jobs and security*, Rocky Mountain Institute.

RITA|BTS (Research and Innovative Technology Administration|Bureau of Transportation Statistics) (2011), *National Transportation Statistics, Table 4-9: Motor Vehicle Fuel Consumption and Travel and Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles*, www.bts.gov/publications/national_transportation_statistics/

Semin, R. (2008), "A Technical Review of Compressed Natural Gas as an Alternative Fuel for Internal Combustion Engines", *American Journal of Engineering and Applied Sciences*, 1(4), pp 302–311.

Simbeck, R. and Chang, E. (2002), *Hydrogen Supply: Cost Estimate for Hydrogen Pathways – Scoping Analysis*, Mountain View, CA: SFA Pacific, Inc.

Train, K. (1986), *Qualitative Choice Analysis: Theory, Econometrics, and an Application to Automobile Demand*, The MIT Press, Cambridge, MA, USA.

UITP/ISTP (International Association of Public Transport, Brussels, and Institute for Sustainability and Technology Policy) (1995), Millennium Cities Database.

UN (United Nations) (2011), *World Urbanization Prospects: The 2011 Revision*, Department of Economic and Social Affairs, Population Division, http://esa.un.org/unpd/wup/CD-ROM/Urban-Rural-Population.htm

6 INDUSTRIAL SECTOR ENERGY DEMAND

BUSINESS-AS-USUAL INDUSTRIAL DEMAND

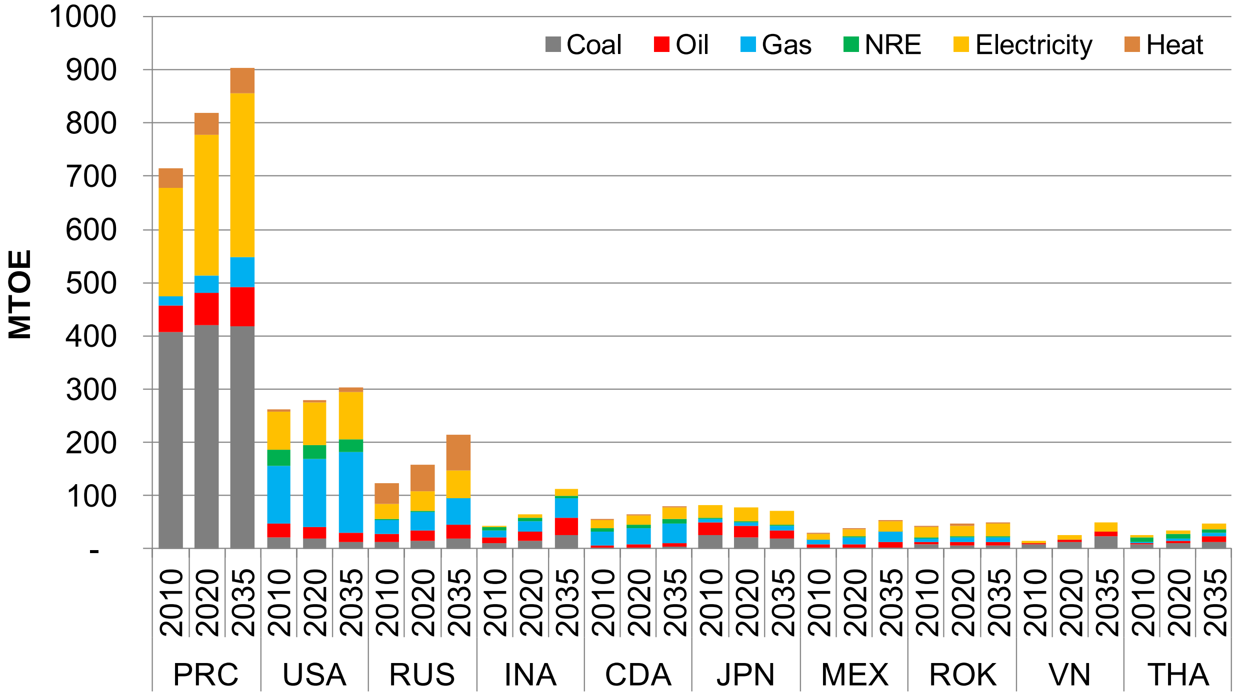
The APEC region's total industrial energy demand in a business-as-usual (BAU) scenario is projected to grow at an annual rate of 1.3% during the outlook period 2010–2035. This is roughly in line with the APEC region's projected total final energy demand annual growth rate of 1.5% over the same period. It translates to an industrial energy demand level of 2 029 million tonnes of oil equivalent (Mtoe) in 2035, up from 1 481.7 Mtoe in 2010.

Industrial Sector Demand by Economy

Figures 6.1 and 6.2 show the projected industrial demand by energy source for each APEC economy during the outlook period 2010–2035. Clearly, the mix of energy sources used varies significantly across the region. The large difference between the vertical axis scales in the two graphs demonstrates the vast difference in energy consumption in the industrial sector between the large and small economies.

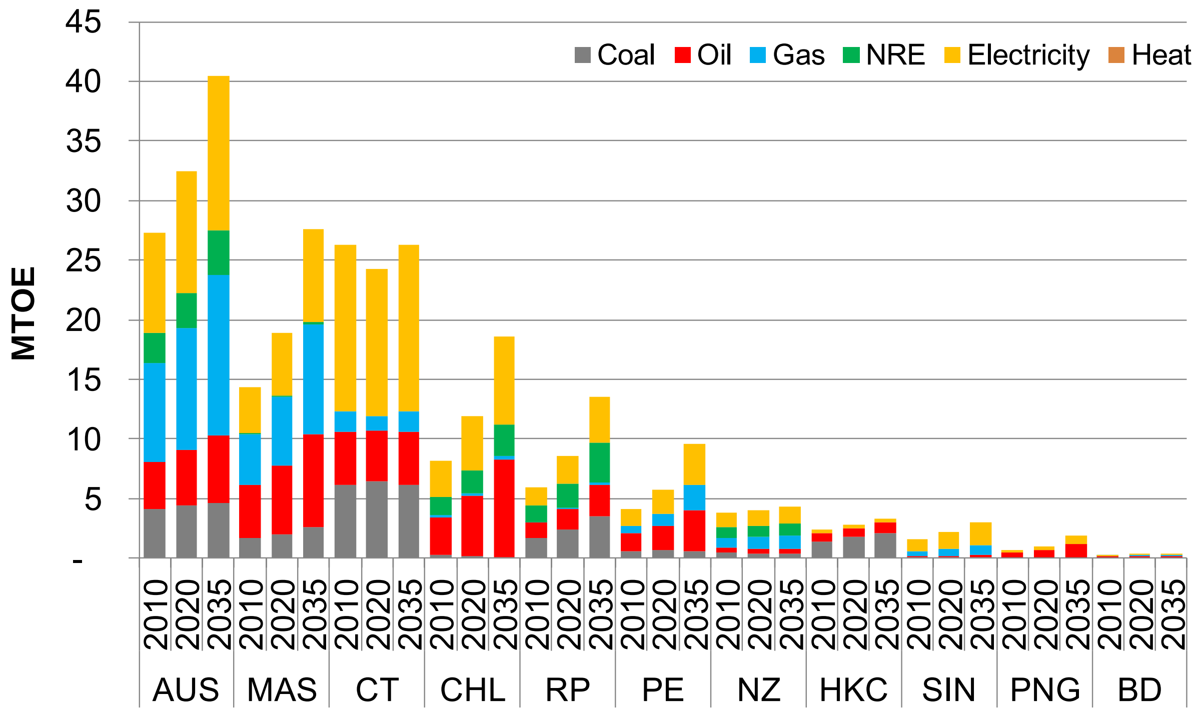
The three economies expected to have the highest industrial energy demand during the outlook period are China, the United States (US) and Russia, in that order. The combined industrial energy demand of these economies is projected to represent more than 70% of the APEC region's total industrial demand between 2010 and 2035. China will have the highest industrial demand in the region—902.8 Mtoe in 2035—which alone represents 44% of the APEC region's total industrial demand. US industrial demand level on the other hand is expected to have about 16% of the APEC region's total industrial demand throughout the period.

Figure 6.1: Final Industrial Energy Demand by Energy Source, Larger Economies



Source: APERC Analysis (2012)

Figure 6.2: Final Industrial Energy Demand by Energy Source, Smaller Economies

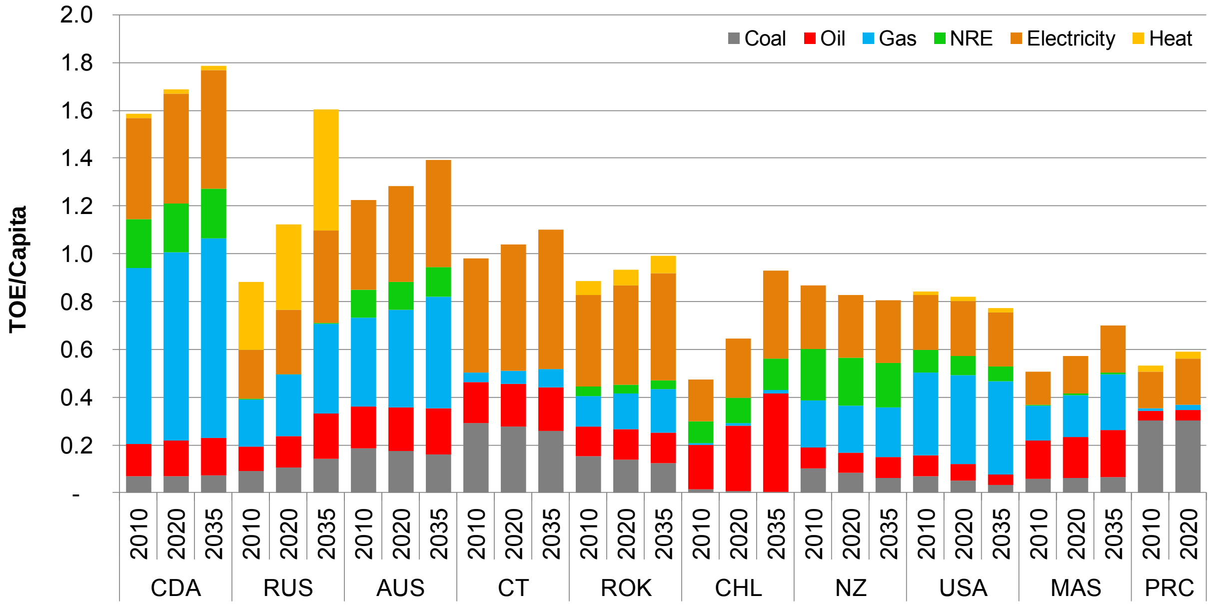


Source: APERC Analysis (2012)

Per Capita Industrial Sector Energy Demand by Economy

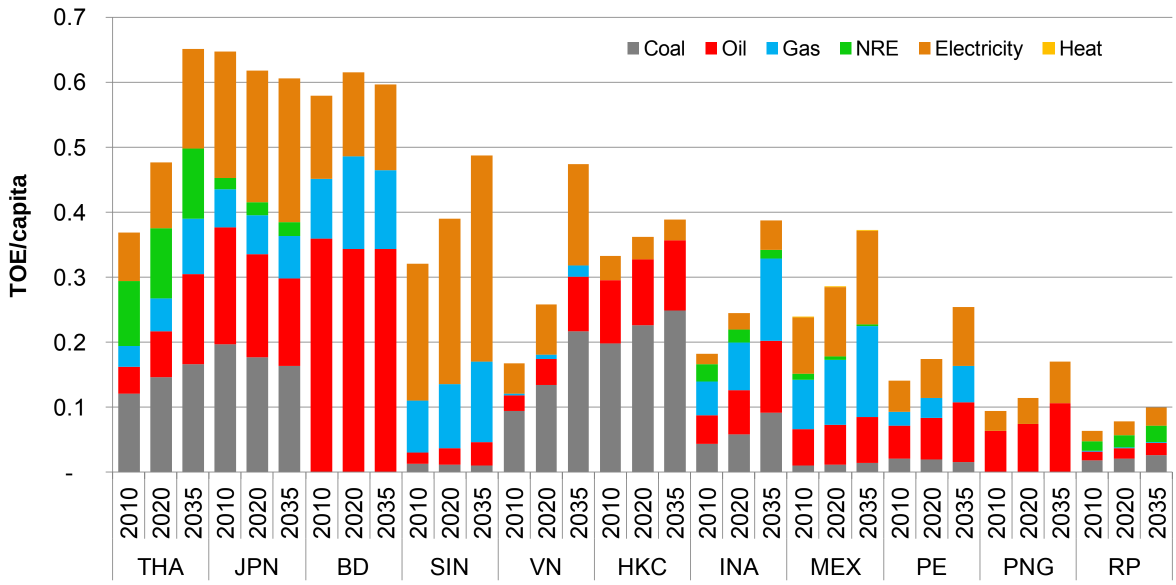
As seen in Figures 6.3 and 6.4, in 2035 Canada, Russia and Australia will have the highest per capita industrial sector energy demand, in that order. With their abundant resources and low population densities, it is likely energy-intensive industries will dominate the industrial structure of these economies over the next 25 years. Chinese Taipei and Korea will also continue to have energy-intensive industries as a core of their economies, albeit fully dependent on imported resources. While oil will continue to be used in moveable industrial applications, growth in industrial demand will be increasingly dominated by a demand for gas, electricity, and (in Russia) district heating ('heat') as the required delivery infrastructures are developed.

Figure 6.3: Per Capita Industrial Sector Energy Demand by Energy Source, Highest Demand Per Capita Economies



Source: APERC Analysis (2012)

Figure 6.4: Per Capita Industrial Sector Energy Demand by Energy Source, Lowest Demand Per Capita Economies



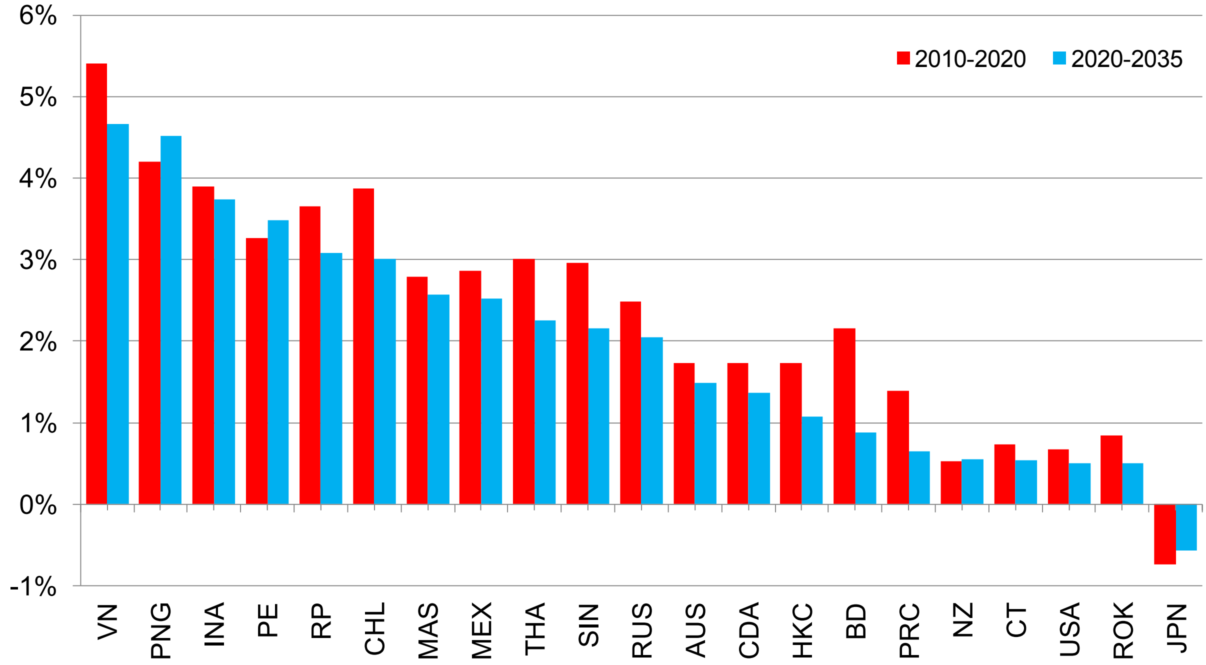
Source: APERC Analysis (2012)

Industrial Sector Growth in Energy Demand by Economy

As shown in Figure 6.5, industrial energy demand is expected to grow most rapidly in APEC's developing economies, other than China. These high levels of growth can be attributed to the rapid industrial development of these economies. Although China's economy is expected to grow rapidly, it is already heavily industrialized and it is likely to have a growth rate more akin to a mature economy.

In the mature economies, industrial demand growth will be slower, as overall economic growth will be slower. These economies will exhibit a structural shift away from energy-intensive industries toward higher value-added industries and services. In particular, Japan's industrial demand is projected to decline by 0.6% over the outlook period, from the 2010 level of 82.9 Mtoe down to 70.7 Mtoe by 2035. This will be the result of Japan's relatively slow economic growth accompanied by an explicit policy of structural change (METI, 2010).

Figure 6.5: Annual Percentage Growth Rates in Industrial Sector Energy Demand by Economy



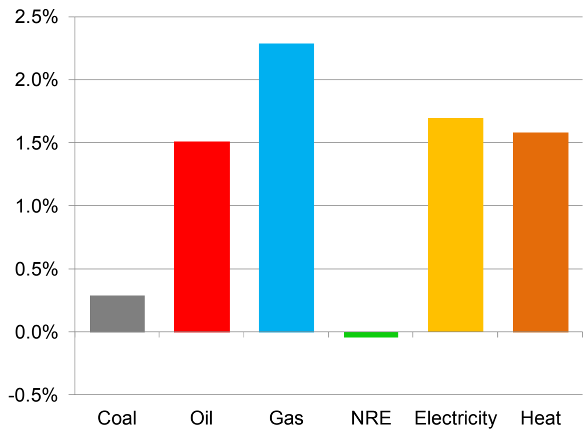
Source: APERC Analysis (2012)

Industrial Sector Growth in Energy Demand by Energy Source

As shown in Figure 6.6, gas is projected to grow the fastest among the energy sources at about 2.3% from 2010 to 2035. This translates to energy demand levels of 231.1 Mtoe in 2010 and 406.8 Mtoe in 2035. Gas is clean, easy to use and energy efficient for many industrial applications. As discussed in Chapter 12, gas will be available in abundant quantities in many APEC economies.

Electricity comes in second with 1.7% growth. It is the only energy source that can generally be used to power electronic and many types of mechanical equipment. Oil comes in third at 1.5%; although oil is expensive, it is the only energy source that can be used with many types of moveable equipment.

Figure 6.6: Annual Percentage Growth Rates in Industrial Demand by Energy Source, 2010–2015



Source: APERC Analysis (2012)

APERC's model projects negative growth for new renewable energy (NRE) in the industrial sector. NRE in the industrial sector consists mainly of biomass used in the pulp and paper and, to a lesser extent, food processing industries, where biomass is a production by-product. Although it is possible new applications for the direct use of NRE in industry may be developed, these are not reflected in APERC's models as there is little encouraging information to go on as yet. Industry can, of course, more easily use NRE indirectly in the form of electricity.

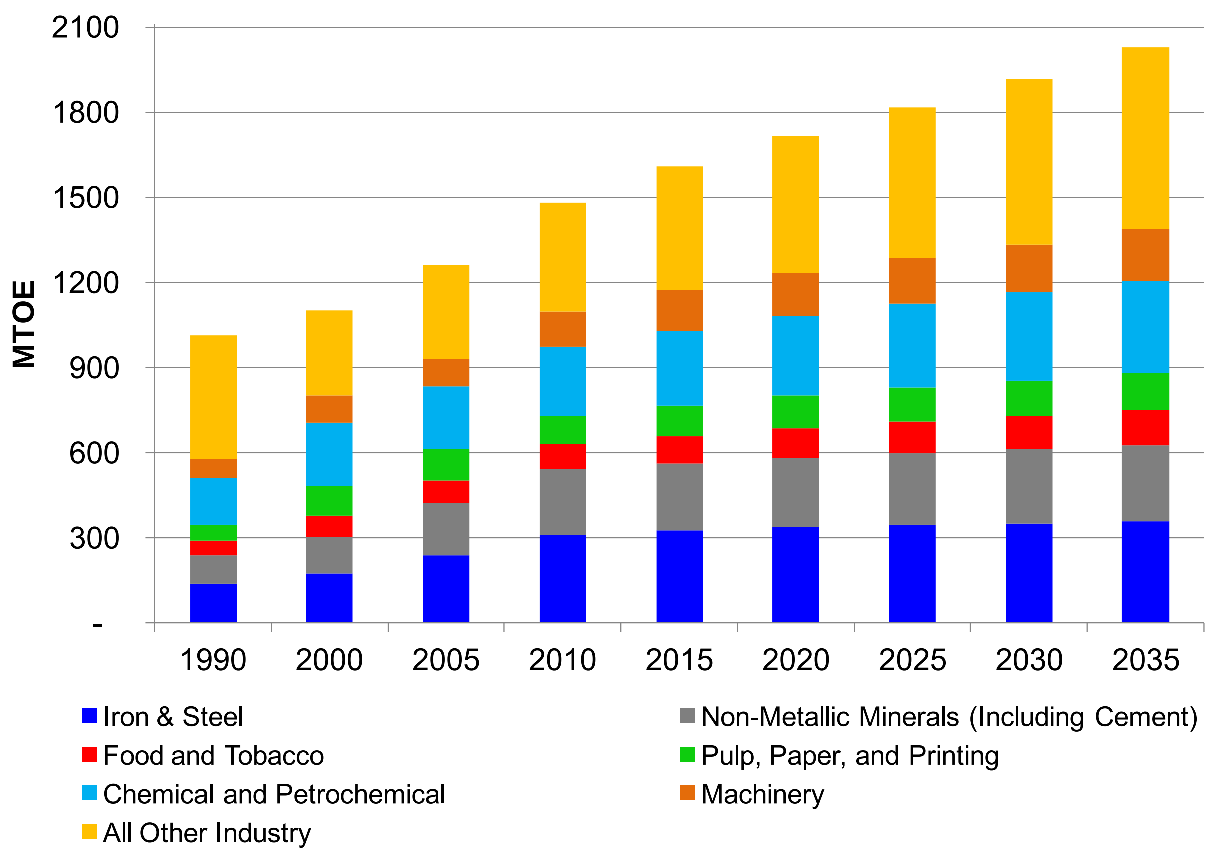
Coal consumption in industry is also projected to grow slowly. It will be used mainly in heavy industrial facilities that either technically need coal or can afford the personnel and equipment needed to manage its use. As discussed above, these industries are likely to grow slowly in many APEC economies. In addition, it is worth noting that 78% of the industrial coal demand in the APEC region in 2010, and 74% in 2035, is in China. China is an economy with an intensive focus on improving industrial energy efficiency (see the sidebar 'Industrial Energy Intensity, China and the United States' at the end of this chapter).

APEC's Energy Demand by Industry Type

Figure 6.7 shows APEC's projected industrial energy demand by industry. Over the outlook period, APEC's developing economies will reach a more mature stage of development. Industries supplying the materials necessary for basic infrastructure, such as steel and cement, will make way for high-tech industries. Thus, the region's industry structure will become less energy intensive. The growth rate of industrial energy consumption will gradually slow, while most of the increase in industrial energy demand will occur in the less energy-intensive industries.

Some economies do not collect data on energy demand by specific industries. This means the 'All Other Industry' category includes not only energy demand by industries other than the six specifically listed in Figure 6.7, but also energy demand in economies where industrial energy demand is not broken out by specific industry.

Figure 6.7: APEC's Final Industrial Energy Demand by Industry Type

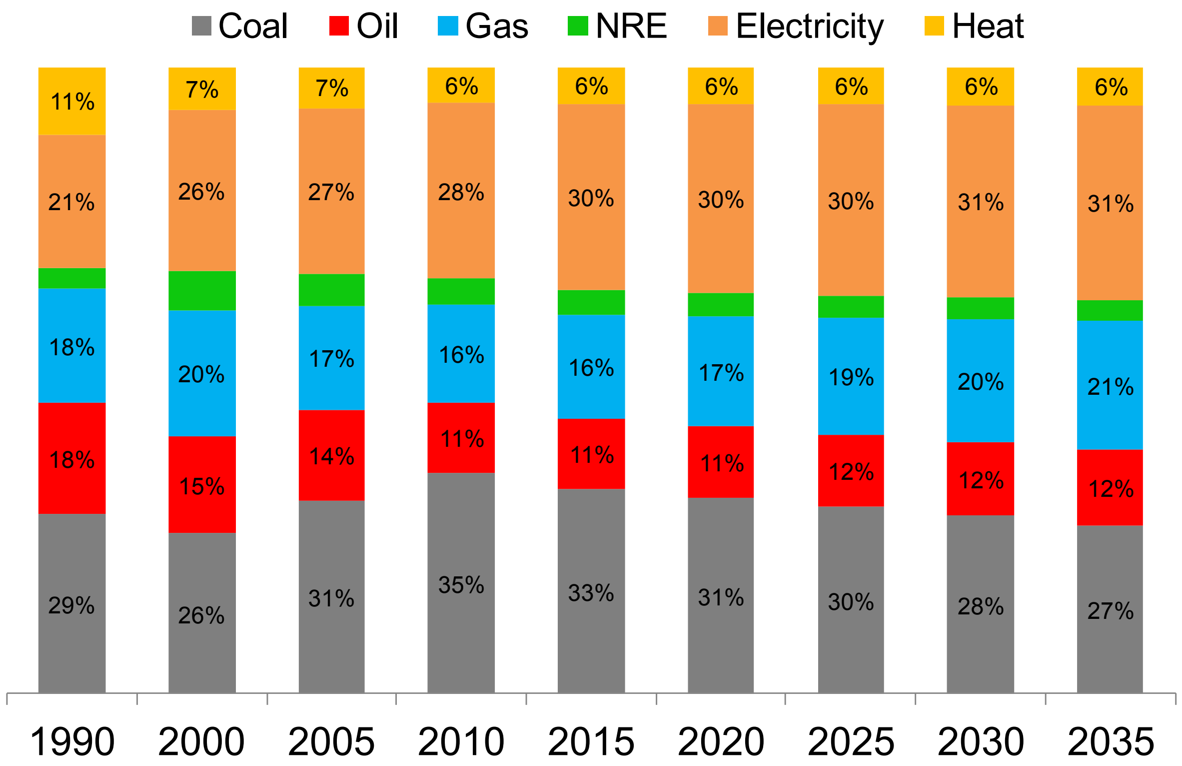


Source: APERC Analysis (2012)

Industrial Sector Market Shares by Energy Type

Figure 6.8 shows the projected market shares for each energy type in the industrial sector. Coal will lose some of its share in the energy mix to natural gas and electricity as the heavy industries intensively using coal, such as iron and steel and cement, reach saturation. Gas and electricity will replace coal as high quality energy sources for high-tech industries. Oil products including liquefied petroleum gas (LPG) will gradually be replaced by gas and electricity pending the development of their delivery networks. NRE will decline modestly unless technologies are developed for its extensive direct use in industry.

Figure 6.8: APEC's Final Industry Energy Demand, Percentage Share by Fuel Source



Source: APERC Analysis (2012)

APERC'S INDUSTRIAL SECTOR ENERGY DEMAND MODEL AND HOW IT WORKS

APERC's industrial demand models are based on an econometric approach. That is, equations are specified relating energy demand to other 'dependent' variables such as industry output and energy prices. The coefficients of the equations are then estimated statistically, based on historical data. Given the projections of the dependent variables, one could then use the estimated equations to make projections of future energy demand.

APERC was fortunate to have access to a database of potential dependent variables and their projected future values over the outlook period compiled by IHS Global Insight (Global Insight, 2012). IHS Global Insight is one of the world's leading economic data and forecasting services. Global Insight's database covered 19 of the 21 APEC economies (all but Brunei Darussalam and Papua New Guinea). For the remaining two economies, basic data on historical and projected GDP was available from the US Department of Agriculture, Economic Research Service (USDA ERS, 2012).

Ideally, one would build an industrial energy demand model that is consistent across industries and economies. However, due to data limitations, this was not feasible. Since the data limitations in many ways shaped the model, they deserve noting.

Data on total industry energy demand by type of energy is available from the IEA's World Energy Statistics (IEA, 2011) for all APEC economies except Papua New Guinea. The level of detail varies greatly. For some economies, data on specific industries may be available only for certain industries or for certain types of energy (such as electricity). The data also varies greatly in quality, and in some cases there were values that appeared questionable.

Global Insight provided an extensive database of historical and projected sales by specific industries in each economy. In some cases, APERC researchers modified the projected values to reflect their knowledge of policies and resource constraints that Global Insight may not have considered. Global Insight also provided historical and projected macroeconomic data on each economy, including GDP, employment, and various price indexes.

Data on historical energy prices is available from the IEA publication Energy Prices and Taxes (IEA, 2012a) and other sources. However, the level of coverage varies greatly by economy. Even where coverage is good, it does not necessarily give a clear picture of what is happening to the energy prices faced by individual industrial customers. These energy prices may depend on where the customer is located within the economy, the precise energy product used, and what type of tariffs, regulations, taxes, or contractual conditions apply.

Because of these data limitations, each economy had to be modelled individually. Ideally, at least seven specific industries would be modelled in each economy: iron and steel; chemicals and petrochemicals; non-metallic minerals (including cement); machinery; food and tobacco; pulp, paper and printing; and all other. But, for some economies, it was necessary to further aggregate industries. Also, the models had to be customized to the quality of the data available. What worked for one economy did not necessarily give satisfactory results for another.

In general, APERC focused on modelling energy intensities (that is E/Y, where E = energy consumption and Y = industry sales) for each economy, specific industry, and energy type. Energy intensity was generally modelled as changing over time, with changes in energy prices, and with the growth of the industry or the economy. If one can formulate a projection of energy intensity, it is simply a matter of multiplying it by projected industry sales to obtain a projection of energy demand. The merit of this approach is that it can be used to analyze future changes in industrial structure and energy intensity separately.

A risk of using any econometric model is that coefficients obtained through econometric analyses only show the historical trend, while innovative technology may bring a drastic change in the future. Thus, the energy intensity model is built combining results of econometric analyses and supplementary studies on sub-sector energy trends in each economy. Shifts in the choice of energy types among those available also had to be considered separately.

INDUSTRIAL ENERGY INTENSITY, CHINA AND THE UNITED STATES

As part of the process of developing the industrial energy demand models described above, APERC did some comparisons between industrial energy intensities in APEC's two largest economies, China and the United States (US). The results raise some interesting questions about the competitiveness of the two economies. A summary of the results is shown in Table 6.1.

Table 6.1: Energy Intensity in China and the United States

	Energy Intensity (kilogram oil equivalent/USD)		
	1990	2009	2010
Iron and steel			
China - Based on 2005 Real USD	0.897	0.381	0.368
United States - Based on 2005 Real USD	0.184	0.239	0.200
China - Based on 2005 PPP USD	0.377	0.160	0.155
Chemical and petrochemical			
China - Based on 2005 Real USD	0.696	0.186	0.168
United States - Based on 2005 Real USD	0.157	0.133	0.136
China - Based on 2005 PPP USD	0.293	0.078	0.071
Non-metallic minerals			
China - Based on 2005 Real USD	3.446	0.693	0.580
United States - Based on 2005 Real USD	0.130	0.309	0.334
China - Based on 2005 PPP USD	1.451	0.292	0.244
Machinery			
China - Based on 2005 Real USD	0.371	0.030	0.029
United States - Based on 2005 Real USD	0.020	0.025	0.024
China - Based on 2005 PPP USD	0.156	0.013	0.012
Food and tobacco			
China - Based on 2005 Real USD	0.457	0.055	0.049
United States - Based on 2005 Real USD	0.017	0.044	0.047
China - Based on 2005 PPP USD	0.193	0.023	0.021
Paper, pulp and printing			
China - Based on 2005 Real USD	0.777	0.113	0.102
United States - Based on 2005 Real USD	0.044	0.081	0.089
China - Based on 2005 PPP USD	0.327	0.048	0.043
Others			
China - Based on 2005 Real USD	0.379	0.059	0.052
United States - Based on 2005 Real USD	0.071	0.022	0.023
China - Based on 2005 PPP USD	0.160	0.025	0.022
Total			
China - Based on 2005 Real USD	0.638	0.118	0.106
United States - Based on 2005 Real USD	0.069	0.054	0.056
China - Based on 2005 PPP USD	0.268	0.050	0.045

Sources: *World Energy Statistics* 2011 © OECD/IEA 2011, Global Insight (2012) and The World Bank (2008)

For each specific industry, the first row labeled "China – Based on 2005 Real USD" shows energy intensity in China, measured as kilograms of oil equivalent per 2005 real US dollars (USD) of sales. To get the sales figures, sales in real 2005 Chinese Yuan (CNY) were converted to 2005 real USD at the 2005 CNY to USD exchange rate. The second row labeled "US – Based on 2005 Real USD" shows the comparable figures for the US.

It can be seen that, in 1990, every Chinese industry was far more energy intensive than its US counterpart. However, between 1990 and 2009, China's industrial energy intensities decreased dramatically in every industry. This improvement probably reflects both the huge scale of industrial development and modernization that took place in China over this period, as well as China's comprehensive and assertive policies for promoting industrial energy efficiency. For a description of these policies, see the APEC study Understanding Energy in China: Geographies of Energy Efficiency (APERC, 2009).

What happened to energy intensity for US industry during this period depended on the specific industry—for some industries it went down, but for others it went up. Overall, the gap between China's industrial energy intensities and those of the US narrowed considerably. Because 2009 was a year of deep recession in the US, especially for energy-intensive industries, figures are also shown for the year 2010, based on the International Energy Agency's (IEA's) statistics that became available shortly before the release of this outlook (IEA, 2012b). Compared to 2009, the 2010 results show a continued decline in energy intensity in China and a mixed impact on energy intensity in the US.

There is another way to do the comparison between China and the US. The third row labeled "China – Based on 2005 PPP USD" shows energy intensity in China measured as kilograms of oil equivalent per 2005 purchasing power parity (PPP) USD of sales. To get these sales figures, sales in real 2005 CNY were converted to 2005 USD at the 2005 PPP rate. The PPP rate tells how many CNY it would take in China to buy the same amount of goods and services as one USD would buy in the US. The World Bank has compiled data on 2005 PPP rates for most economies (The World Bank, 2008).

When comparing energy intensities across economies, PPP is arguably superior to using exchange rates. Ideally, any comparison of energy intensities between two economies would compare the energy required to produce identical goods and services in both economies. However, the goods produced by the same industry in two economies will never be identical, so a perfect comparison is impossible. Since PPP dollars are calculated to buy the same amount of goods in every economy, using them to calculate energy intensities should provide a better approximation to the energy required to produce identical goods.

In 2005, CNY 1 was worth 2.375 times more when converted to USD at PPP rates compared to when converted at market exchange rates. That is, one CNY would buy 2.375 times more in China than it would buy if it was converted to USD at the market exchange rate and the dollars spent in the US. Therefore, to convert the Chinese energy intensities from a real 2005 USD basis to a PPP 2005 USD basis, one can simply divide by 2.375. Of course, no adjustment is needed to the energy intensities for the US, since by definition one USD in the US always has a purchasing power parity of one USD.

Comparing the US energy intensities in the second row to the Chinese energy intensities based on PPP values in the third row, we see that China's industrial energy intensities in 2009 are actually lower than those for the US in every industry except 'Others'. In 2010, China's energy intensity is lower in every industry. It would thus appear that China has already surpassed the US in the efficiency by which its industry uses energy, at least when energy intensity based on PPP is used as the measure.

Many factors can distort comparisons of energy intensities between economies. We have already mentioned the impact of the different mix of goods produced in the two economies. There are also issues related to the types of energy used (electricity, for example, can be used more efficiently than coal) and the quality of the data. Nevertheless, this data suggests that by using energy more efficiently, China's industry may be gaining a competitive advantage over US industry. This development should be of concern to both policymakers and industrial managers in the US.

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2009), *Understanding Energy in China: Geographies of Energy Efficiency*, www.ieej.or.jp/aperc/

Global Insight (2012), 'Country & Industry Forecasting: IHS Global Insight' website page, www.ihs.com/products/global-insight/index.aspx

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

— (2012a), *Energy Prices and Taxes*, On-Line Service, www.iea.org/w/bookshop/add.aspx?id=606

— (2012b), *World Energy Statistics 2012*, retrieved from OECD/IEA CD-ROM Service.

METI (Ministry of Economy, Trade and Industry, Japan) (2010), *The Industrial Structure Vision 2010*, www.meti.go.jp/english/policy/economy/pdf/Vision_Outline.pdf

The World Bank (2008), *Global Purchasing Power Parities and Real Expenditures: 2005 International Comparison Program*, http://siteresources.worldbank.org/ICPINT/Resources/icp-final.pdf

USDA ERS (United States Department of Agriculture, Economic Research Service) (2012), International Macroeconomic Dataset, www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx

7 NON-ENERGY SECTOR DEMAND

APEC NON-ENERGY DEMAND

'Non-energy demand' refers to demand for fuels that are used as raw materials and not consumed as a source of energy or transformed into another fuel. This would include the manufacture of products such as bitumen (used in road asphalt and various building materials), lubricants, solvents, paraffin waxes, and ammonia (used for making fertilizers). It would also include feedstocks for the production of various petrochemicals (IEA et al, 2005, pp. 29 and 67). Petrochemicals are the building blocks for a wide variety of products including plastic, paints, adhesives, artificial fibres, and detergents (AFPM, 2012).

Of the four final demand sectors, non-energy demand accounts for the smallest share of the APEC final energy demand, about 10% in 2010. However, it is projected to grow under business-as-usual (BAU) assumptions at a similar rate to total industry energy demand, about 1.3% per year. Specifically, consumption is projected to grow from 479 Mtoe in 2010 to 662 Mtoe in 2035.

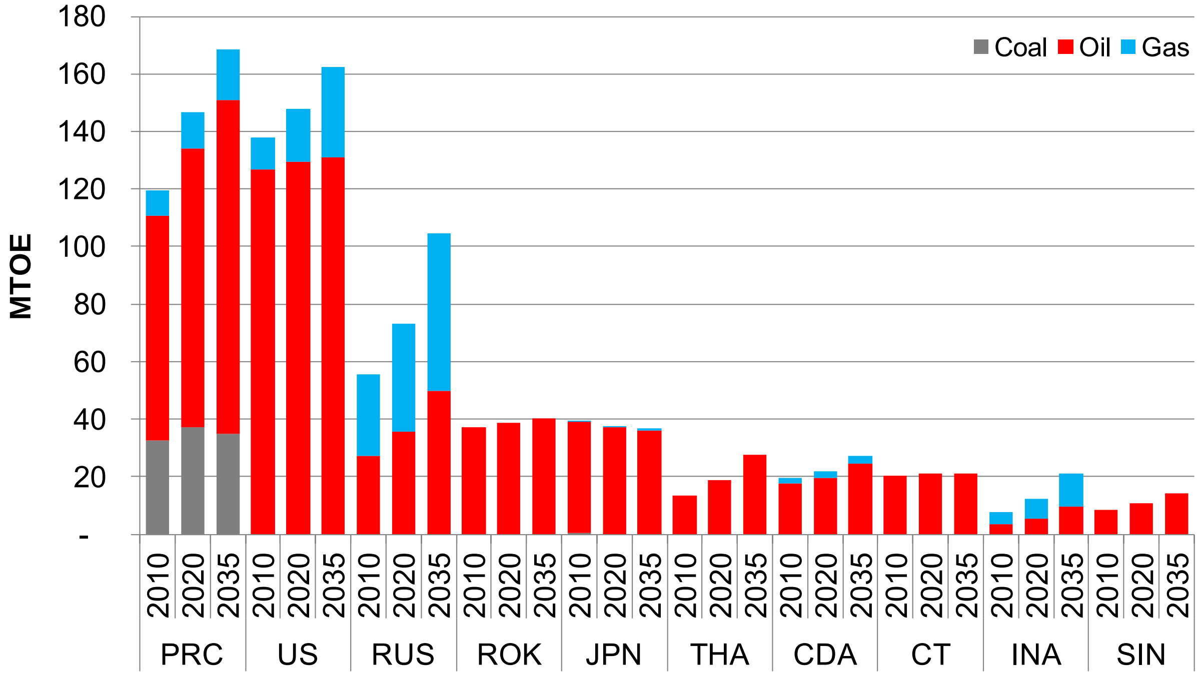
Non-Energy Demand by Economy

Figures 7.1 and 7.2 show the projected non-energy demand by energy type for each APEC economy during the outlook period, from 2010 to 2035. The large difference in vertical axis scales between the two graphs demonstrates the considerable difference in non-energy demand between larger and smaller non-energy consuming economies.

The economies that will likely post the highest non-energy use by 2035 are China, the United States and Russia. The combined non-energy use of these three economies represents over 60% of the total non-energy consumption of the APEC region.

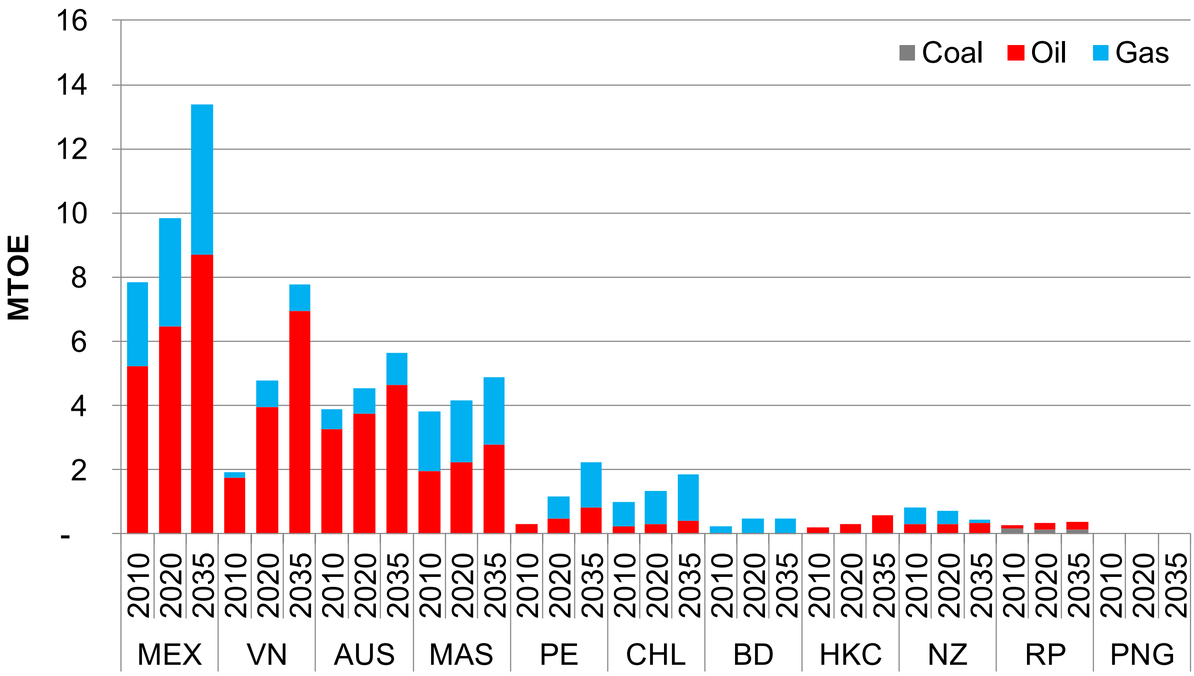
Oil meets the largest share of non-energy demand in most APEC economies. However, the gas share is larger than the oil share in Russia, Indonesia, Peru, Chile, and Brunei Darussalam.

Figure 7.1: Non-Energy Demand, Larger Non-Energy Consuming Economies



Source: APERC Analysis (2012)

Figure 7.2: Non-Energy Demand, Smaller Non-Energy Consuming Economies

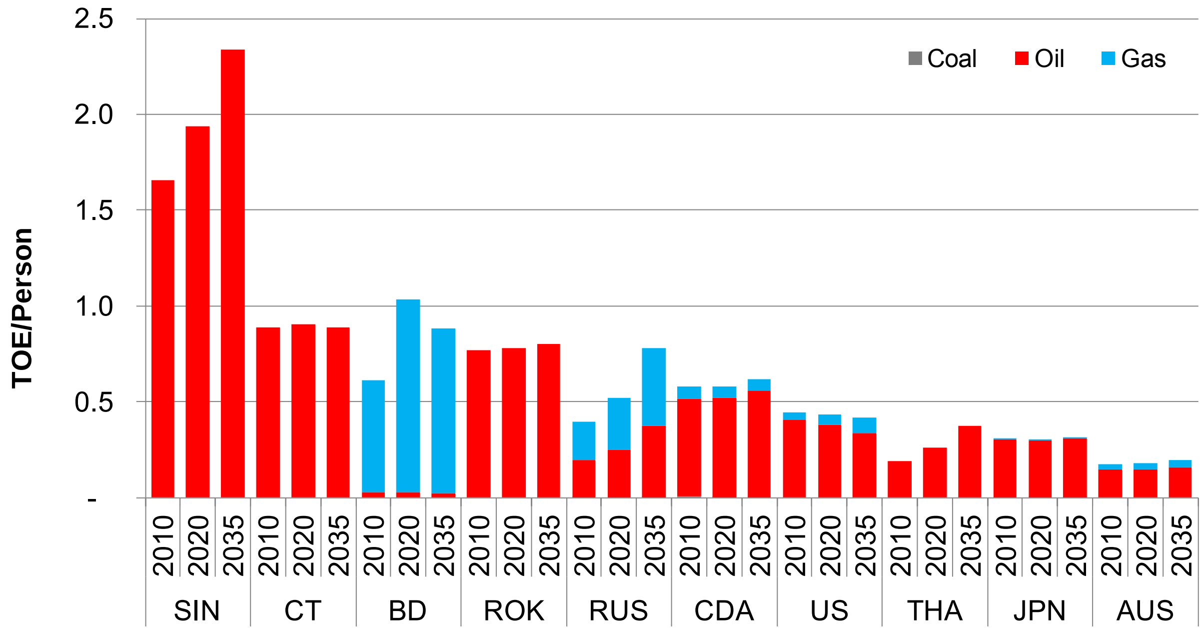


Source: APERC Analysis (2012)

Per Capita Non-Energy Demand by Economy

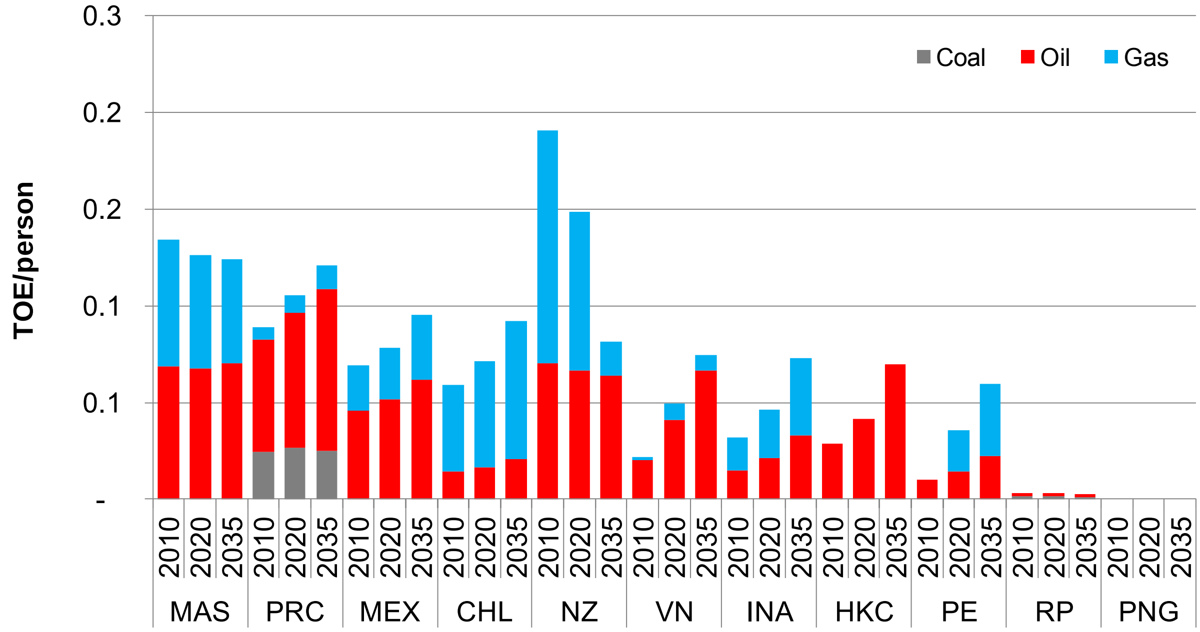
Figures 7.3 and 7.4 show the projected per capita non-energy demand by energy type for each APEC economy during the outlook period, from 2010 to 2035. The economies with the largest per capita demand are those with relatively large petrochemical industries: Singapore, Chinese Taipei, Brunei Darussalam, and Korea.

Figure 7.3: Per Capita Non-Energy Demand by Energy Source, Larger Non-Energy Per Capita Consuming Economies



Source: APERC Analysis (2012)

Figure 7.4: Per Capita Non-Energy Demand by Energy Source, Smaller Non-Energy Per Capita Consuming Economies



Source: APERC Analysis (2012)

REFERENCES

AFPM (American Fuel & Petrochemical Manufacturers) (2012), *Chart of Products Made from Petrochemicals*, www.afpm.org/petrochemicals/

IEA et al (International Energy Agency, Organisation for Economic Co-operation and Development, and Eurostat) (2005), *Energy Statistics Manual,* www.iea.org/stats/docs/statistics_manual.pdf

8 RESIDENTIAL, COMMERCIAL, AND AGRICULTURAL SECTOR ENERGY DEMAND

This chapter examines the energy challenges and opportunities in the 'other' sector, which encompasses residential, commercial, agriculture, forestry, fishing and all other services.

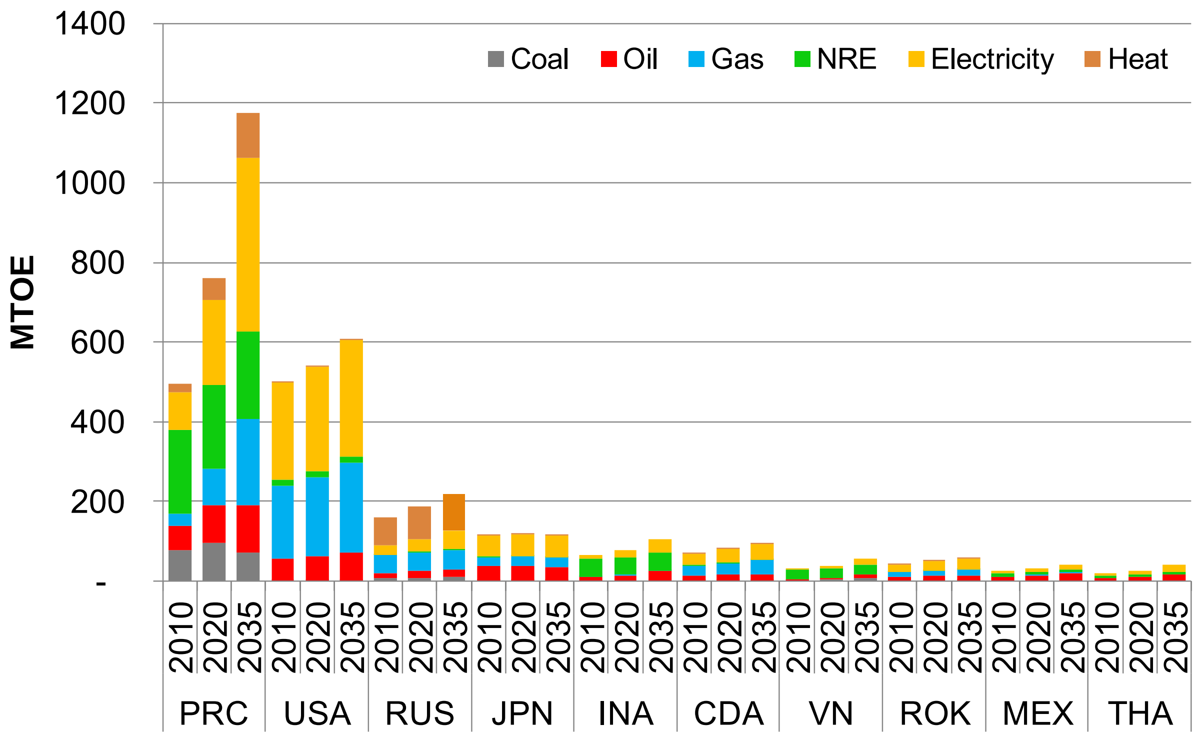
BUSINESS-AS-USUAL 'OTHER' SECTOR ENERGY DEMAND

In 2010, energy use in the 'other' sector accounted for about 33% of the total APEC final energy consumption. The energy sources and the amount of energy used in the 'other' sector vary greatly from economy to economy. Not surprisingly, developed economies had a much higher per capita energy use than did developing economies. Also, electricity and gas were the dominant energy sources in the 'other' sector in developed economies, while some developing economies still relied heavily on biomass and coal. For example, in the United States, where GDP per capita was about USD 42 000, energy consumption per capita in the 'other' sector was 1.61 tonnes of oil equivalent (toe)/capita, with electricity and gas as the main energy sources. In China, on the other hand, where GDP per capita was about USD 6800, energy consumption per capita in the 'other' sector was 0.37 tonnes of oil equivalent/capita, and new renewable energy (NRE), primarily biomass, was by far the largest 'other' sector energy source, with coal ranking number three after electricity.

'Other' Sector Total Energy Demand by Economy and Energy Source

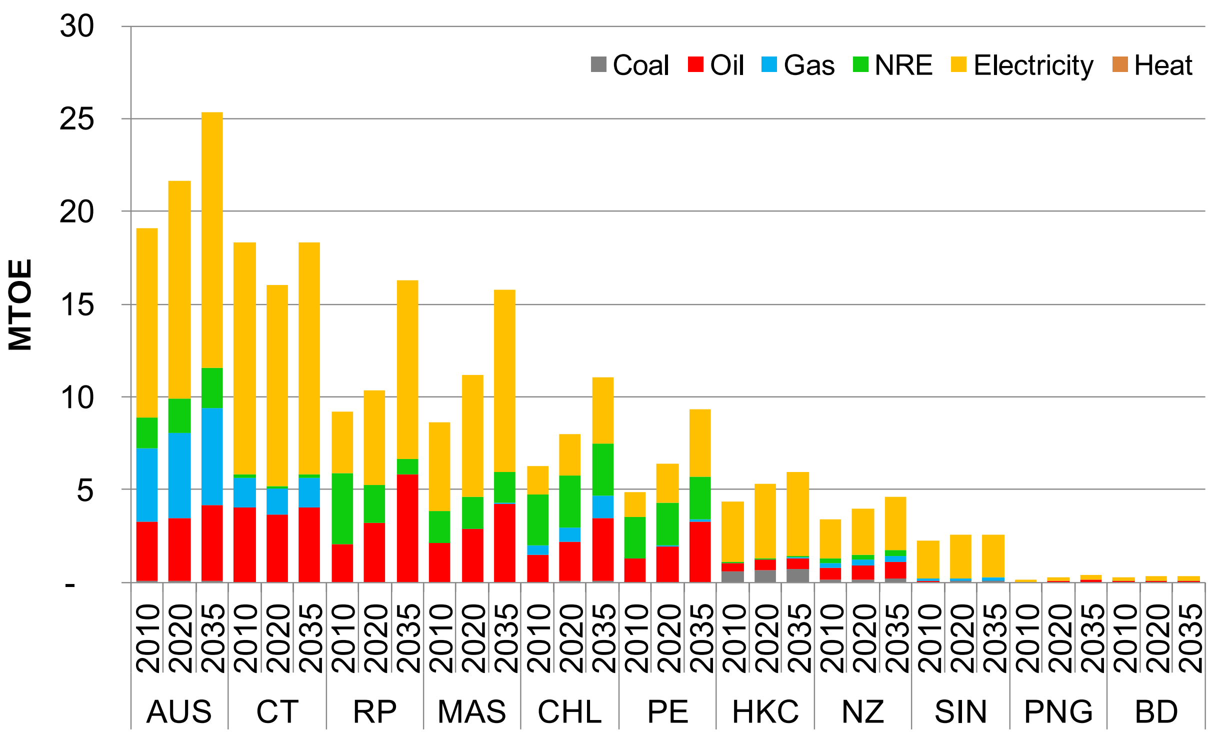
Figures 8.1 and 8.2 show the projected 'other' sector demand in each APEC economy, under business-as-usual. Note, the vertical axes of the two graphs have different scales. Over the period 2010–2035, the total 'other' sector demand is projected to increase from 1593 million tonnes of oil equivalent (Mtoe) in 2010 to 2617 Mtoe in 2035, an average annual increase of 2.0%. By 2035, the 'other' sector will account for about 38% of the total APEC final energy demand. By 2035, China will become the economy consuming the largest amount of energy in the 'other' sector (1177 Mtoe). This will account for about 45% of the total APEC 'other' sector energy demand. The US will be second, with 607 Mtoe (about 23%).

Figure 8.1: Other Sector Energy Demand by Energy Source, Higher Other Sector Demand Economies



Source: APERC Analysis (2012)

Figure 8.2: Other Sector Energy Demand by Energy Source, Lower Other Sector Demand Economies

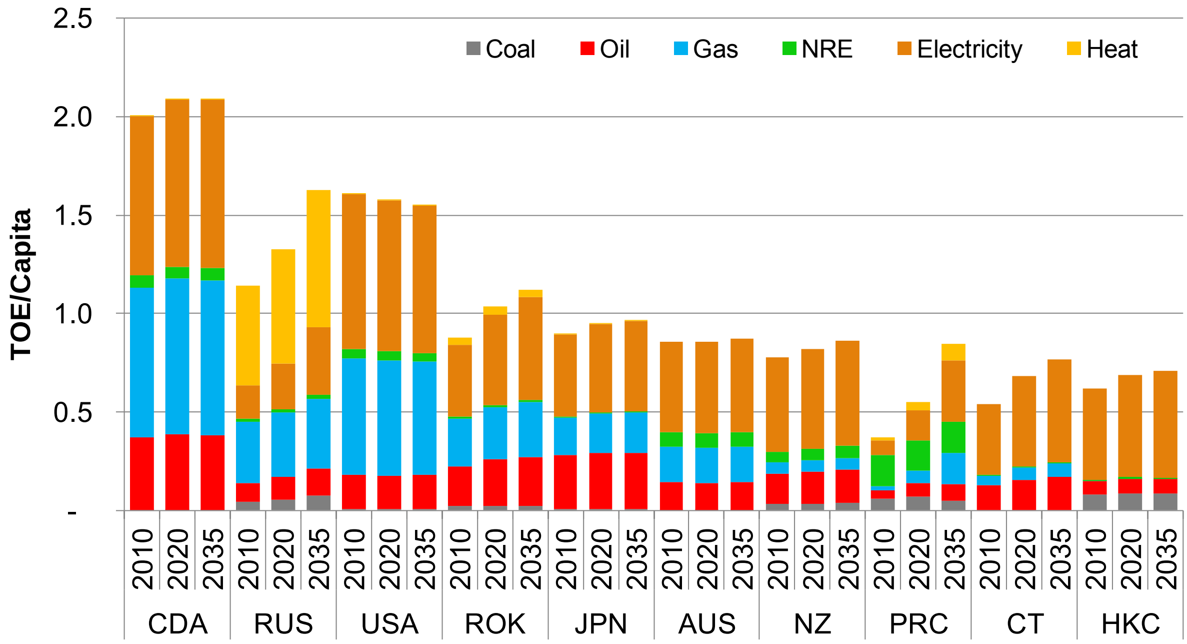


Source: APERC Analysis (2012)

'Other' Sector Per Capita Energy Demand by Economy and Energy Source

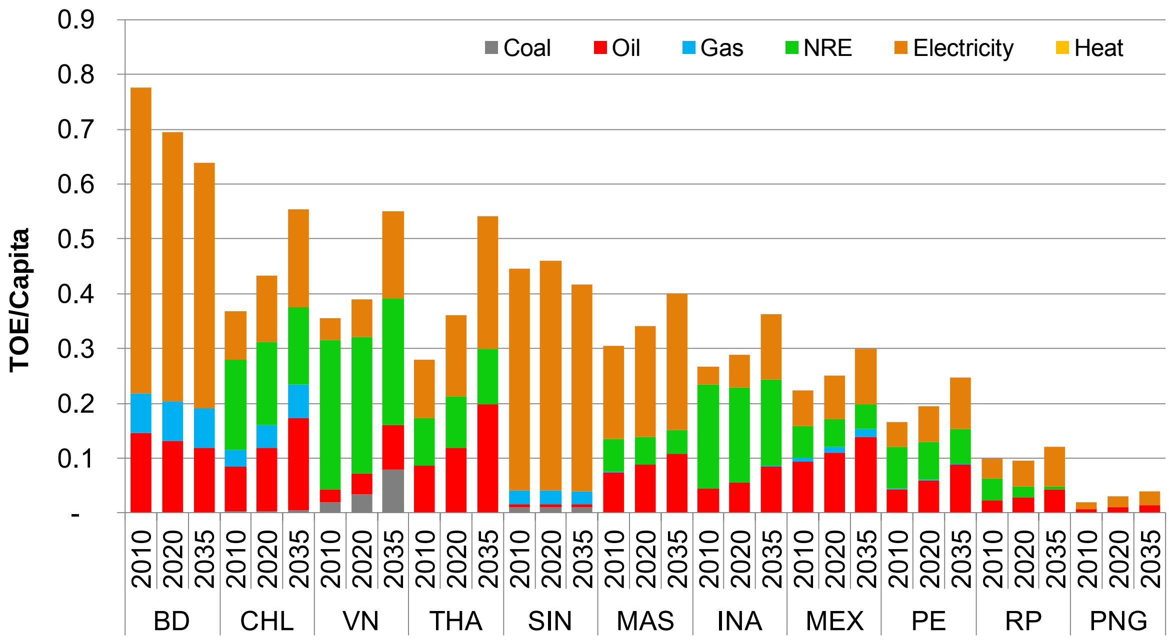
Figures 8.3 and 8.4 show 'other' sector energy demand on a per capita basis. It can be seen that, in 2035, the US will still be using far more energy per capita in the 'other' sector (at 1.55 toe/capita) than China (0.85 toe/capita).

Figure 8.3: Per Capita Other Sector Energy Demand by Energy Source, Higher Other Sector Demand per Capita Economies



Source: APERC Analysis (2012)

Figure 8.4: Per Capita Other Sector Energy Demand by Energy Source, Lower Other Sector Demand per Capita Economies

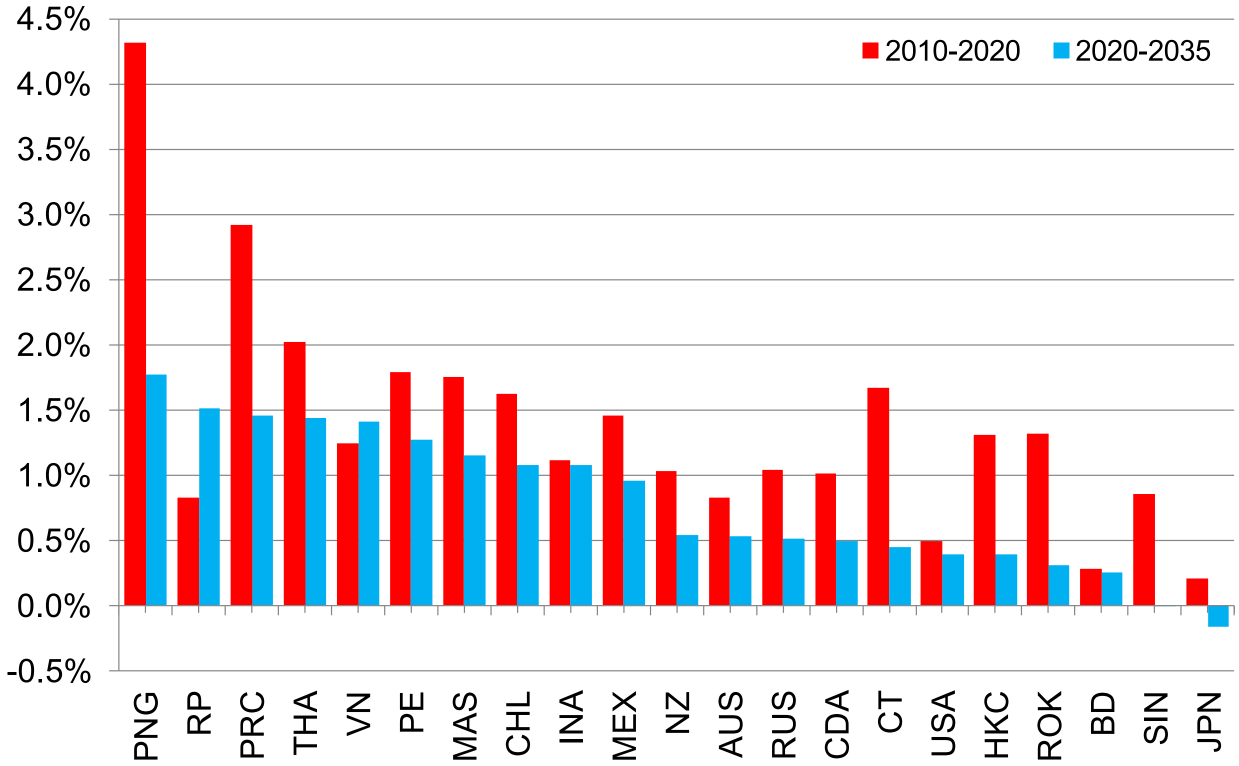


Source: APERC Analysis (2012)

'Other' Sector Percentage Growth in Energy Demand by Economy

Figure 8.5 shows the projected growth rates in the 'other' sector energy demand. The higher growth rates tend to be in the developing economies.

Figure 8.5: Annual Percentage Growth Rates in Other Sector Energy Demand by Economy



Source: APERC Analysis (2012)

APEC 'Other' Sector Total Energy Demand by Energy Source

Figure 8.6 shows the total APEC 'other' sector energy demand by energy source. Among these sources, electricity is projected to be consistently the largest between 2010 and 2035. Electricity demand will grow at an average annual rate of 2.8% over the outlook period, driven by increasing income levels and growing activity in the commercial sector. These factors will result in an increasing requirement for air conditioning, space and water heating, lighting, and home appliances. The expansion of rural electrification and the wider use of air conditioning and refrigerators in China and South-East Asia is a significant factor contributing to an increased demand for electricity in the residential sector. By 2035, China will account for 42% of the total APEC 'other' sector electricity demand, while the US will account for 28%.

Natural gas is projected to be the second-largest 'other' sector energy source between 2010 and 2035. Gas demand will grow at an average annual rate of 2.3%. Rapid growth in natural gas demand is expected as income levels expand and the extensive development of gas infrastructure continues. This will allow gas to replace non-commercial biomass for heating and cooking. 'Other' sector natural gas demand in China, in particular, is expected to grow at about 8.5% a year.

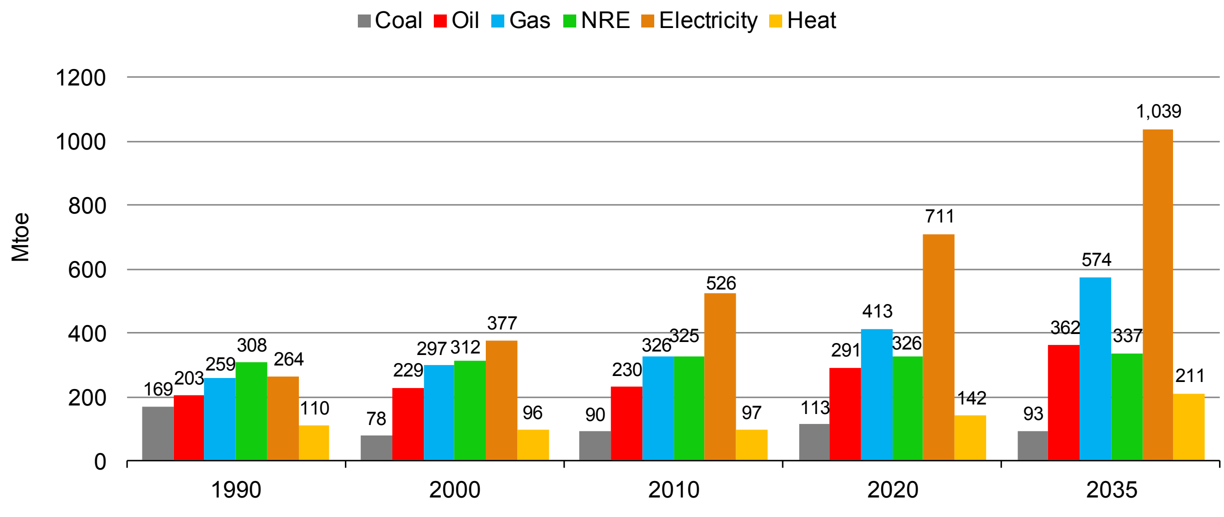
The demand for oil products, which is dominated in the 'other' sector by LPG (liquefied petroleum gas), will be at a more modest rate of 1.8% a year. The growth in demand for oil products will be held back by their relatively high prices and by the loss of some markets to natural gas, due to the expanded coverage of gas distribution networks.

The demand for heat (mainly district heating systems) is projected to be the fastest growing of any form of 'other' sector energy, at 3.2% a year. District heating is potentially a very efficient energy source, since relatively low-temperature heat from power plants and industrial facilities that would otherwise be wasted can be used for space and water heating in nearby buildings. China and Russia, which already have extensive district heating systems, are projected to represent about 98% of the total APEC 'other' sector heat demand in 2035.

Coal demand is expected to have the lowest growth among the commercial fuels in the 'other' sector, at 0.1% annually. Coal will be increasingly replaced by electricity, natural gas and LPG. In 2035, China will remain the largest 'other' sector coal consumer in the APEC region, consuming about 75% of the total 'other' sector coal demand.

Commercial fuels will increasingly replace biomass in the 'other' sector. However, while the biomass share of 'other' sector energy demand will decline overall, its use is expected to persist in rural areas, especially in China and South-East Asia, as a fuel for cooking and water heating. In regard to other NRE sources, there will also be some growth in the demand for solar water heating in the 'other' sector; however, it is not expected to be large compared to biomass. The net result will be a more or less stable demand for NRE in the 'other' sector over the outlook period.

Figure 8.6: APEC Total Other Sector Energy Demand by Energy Source



Source: APERC Analysis (2009)

'OTHER' SECTOR CHALLENGES AND SOLUTIONS

Growth of about 64% in the 'other' sector energy demand between 2010 and 2035 will have a number of favourable consequences. In many economies it will bring healthier living conditions, bring greatly improved standards of living, give children more time to pursue education, and give women more time to pursue both education and income earning opportunities.

It does, however, pose some challenges. These challenges include those related to greenhouse gas emissions, security of energy supply, and price risks for fossil fuels. There are also significant issues in the residential sector related to poverty and affordability. Although people will increasingly have access to electricity and commercial fuels, even in rural areas, many people may still not be able to afford to use very much of them.

All APEC economies recognize these issues, and are working to address them. Approaches to consider include:

- greater use of low-carbon energy sources, such as solar water heaters and the cleaner, more efficient use of biomass
- improved energy efficiency, such as higher energy-efficiency standards for buildings and appliances (see below), and a phase-out of incandescent light bulbs
- targeted assistance for those who would otherwise be facing energy poverty.

Most energy in the 'other' sector is either consumed by building systems (heating, cooling, hot water, lighting) or by appliances and other equipment in the buildings. APERC has been working with APEC developing economies to improve 'other' sector energy efficiency in both these areas through two phases of the APEC-sponsored Cooperative Energy Efficiency Design for Sustainability (CEEDS) project.

Phase 1 of CEEDS (2009–2010) addressed Appliance Energy Efficiency Standards and Labeling (APERC, 2010). Phase 2 of CEEDS (2010–2011) addressed Building Energy Codes and Labeling (APERC, 2011). In each phase, economy delegates worked with internationally recognized experts and APERC researchers to quantify potential energy savings, and to identify characteristics of an effective program. The next two sections discuss the potential energy savings identified in each phase.

Appliance Energy Efficiency Standards and Labeling

As discussed in Chapter 4, consumers often lack the information needed to make an informed trade-off between the initial purchase price of an appliance and the long-term operating costs, which are often primarily energy costs. This may be because comparative information on actual energy usage by different appliances is difficult to obtain, because the consumer lacks the skills to analyze this information, or because the consumer lacks the time to do the analysis of what is, for individual consumers, a relatively small cost difference. As a result, consumers tend to focus on the initial purchase price, and appliance manufacturers tend to focus on lowering the initial purchase price of their products.

For both consumers and society, these 'cheap' appliances may actually be quite expensive in the long run (ECS, 2009). Consumers themselves are burdened over the long term with excessively high energy costs, while society as a whole is burdened by excessively high investments in energy supply infrastructure, threats to energy security, and environmental damage.

Energy efficiency standards and labels break this cycle. Energy efficiency standards prescribe a minimum energy performance for specific types of appliances. Energy efficiency labels summarize key information consumers should know about the energy performance of an appliance. Standards keep the most inefficient and obsolete appliances off the market; labels encourage consumers to go beyond the standard and purchase even more efficient products.

Six developing economies participated in CEEDS Phase 1 on appliance energy efficiency standards and labeling: Chile, China, Malaysia, the Philippines, Thailand, and Viet Nam.

To understand the energy saving potential of appliance energy efficiency standards within these six economies, APERC undertook an analysis of energy saving potential in collaboration with the Collaborative Labeling and Appliance Standards Program (CLASP) and Lawrence Berkeley National Laboratory (LBNL). The model assumed cost-effective standards, achievable with existing technology, were adopted immediately in each economy for six types of appliances, as well as for fluorescent lamps, incandescent lamps, and standby power (power use while switched off) for electronic equipment.

The deployment of the new equipment was then modelled in each economy each year. The savings grow larger each year as the old inefficient appliances are replaced with models that meet the standards. By 2030, most appliances in service meet the standards. Table 8.1 shows the percentage energy savings by economy by type of equipment compared to business-as-usual.

These are obviously significant savings. The full analysis (APERC, 2010) also included a discussion of the total energy savings by economy by type of equipment, which is not reproduced here. Advances in technology over this period, which would allow a further tightening of the standards, as well as the additional benefits from labeling programs could add to these savings.

Table 8.1: Estimated Potential Percentage Energy Savings from Appliance Energy Efficiency Standards by Economy

	Fan	Fluorescent Lamps	Incandescent Lamps	Laundry	Refrigeration	Air Conditioner	Standby	Television	Rice Cooker
Chile	32.2%	NA	39.4%	33.7%	41.7%	26.2%	78.6%	35.4%	NA
China	36.4%	21.7%	41.6%	46.9%	43.3%	37.7%	79.9%	26.9%	29.7%
Malaysia	32.4%	17.1%	39.4%	42.5%	49.5%	20.1%	78.7%	35.4%	29.7%
Philippines	40.3%	9.6%	39.4%	3.7%	49.8%	17.1%	78.4%	35.4%	29.7%
Thailand	31.9%	9.6%	39.4%	41.9%	49.3%	19.0%	78.8%	35.4%	29.7%
Vietnam	40.0%	17.0%	39.4%	17.3%	50.8%	25.0%	78.4%	35.4%	29.7%

Source: APERC Analysis (2012)

Building Energy Codes And Labeling

Consumers and businesses seeking to buy or rent building space face the same informational challenges as appliance consumers discussed above. Building developers, therefore, face the same pressures as appliance manufacturers to keep the initial cost of buildings down, even when the result is higher total costs over the life of the building. The result is a similar under-investment in energy efficiency.

Although it is possible to improve the energy efficiency of buildings through retrofits after they are built, there are at least three additional factors that work strongly against such retrofits:

- First, and perhaps most importantly, it is usually far easier and cheaper to make buildings energy efficient at the time they are designed and built, rather than through later retrofits.
- Second, in the case of rental buildings, the landlord generally must make the investments to improve energy efficiency, but the tenant generally pays for the energy and will reap the benefits of the landlord's investment.
- Third, even in the case of owner-occupied buildings, the owner may not be confident of owning the building long enough to recover the investment through energy savings and, because of the informational challenges mentioned above, may not be confident of recovering the investment when the building is sold.

These three factors make energy efficiency building retrofits hard to justify.

So buildings need to be initially designed and built in an energy-efficient manner. If they are underinvested in energy efficiency at the time they are built, they are likely to stay that way. Because the life of a building is quite long—typically several decades or more—an energy inefficient building will lock-in wasteful energy use for decades to come (Laustsen, 2008).

Building energy codes and labeling can break this cycle. It is especially critical to do so in developing economies, where urbanization and building construction is proceeding at a rapid pace. In addition to energy and environmental benefits, energy efficient residential buildings can help to alleviate energy poverty without the need for on-going subsidies.

Six developing economies participated in CEEDS Phase 2 on building energy codes and labeling: China, Indonesia, Malaysia, Mexico, Thailand, and Viet Nam.

To understand the energy saving potential of building energy codes within these six economies, APERC undertook an analysis of energy saving potential using eQUEST building simulation software developed under the auspices of the California Public Utilities Commission (EDR, 2012).

Using the eQUEST software, APERC analyzed the energy saving potential of implementing the International Energy Conservation Code 2009 as tailored to the climate in each economy, to four building types common in each economy. Typical efficiency provisions included wall insulation, air-tightness, window insulation, window solar properties, lighting power density, ventilation system efficiency, pump and fan controls (VSD), high-efficiency chillers and boilers, and efficient motors for fans and pumps.

The International Energy Conservation Code 2009 is a model building code developed by the International Code Council (ICC). The ICC is a membership association which develops codes for the construction of residential and commercial buildings. It is dedicated to building safety, fire prevention and energy efficiency. Most US cities, counties and states choose to adopt the International Codes developed by the ICC. The International Codes also serve as the basis for the construction of US federal properties around the world, and as a reference for many economies outside the US (ICC, 2012).

The US Department of Energy Building Technologies Program has analyzed the International Energy Conservation Code 2009 for single family and multi-family homes and determined it would "yield positive benefits for US homeowners and significant energy savings for the nation" (USDOE, 2012).

Table 8.2 shows the resulting energy savings compared to business-as-usual for each building type in each of the six economies. Again, the energy savings are significant. The full analysis (APERC, 2011) also included a discussion of the total energy savings by economy by type of equipment, which is not reproduced here.

Because the turnover of buildings is relatively slow, even in developing economies, it would take a number of years for building energy codes to have a big impact. Therefore, it is important to implement building energy codes as soon as possible. As with appliance energy efficiency standards, future advances in technology, which would allow a further tightening of the standards, as well as the additional benefits from labeling programs could add to the savings.

Table 8.2: Estimated Potential Percentage Energy Savings from Building Energy Codes by Economy

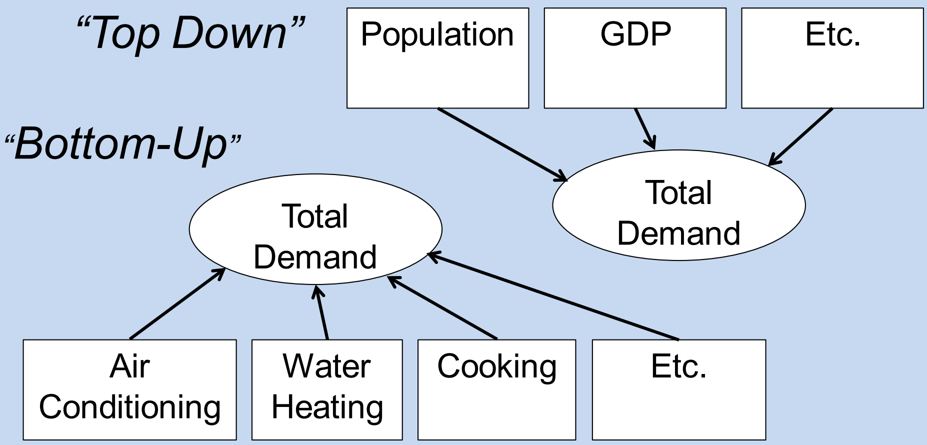
Economy	Building Type	Energy Savings
China	Apartment	16%
China	Office	35%
China	Retail	36%
China	Small Apartment	16%
Indonesia	Apartment	13%
Indonesia	Office	44%
Indonesia	Retail	19%
Indonesia	Single Family House	13%
Malaysia	Apartment	17%
Malaysia	Office	43%
Malaysia	Retail	45%
Malaysia	Terrace Housing	10%
Mexico	Apartment	6%
Mexico	Office	38%
Mexico	Retail	14%
Mexico	Single Family House	15%
Thailand	Apartment	12%
Thailand	Office	29%
Thailand	Retail	28%
Thailand	Single Family House	15%
Viet Nam	Apartment	13%
Viet Nam	Office	38%
Viet Nam	Retail	34%
Viet Nam	Single Family House	19%

Source: APERC (2011, p. 13)

APERC'S 'OTHER' SECTOR ENERGY DEMAND MODEL AND HOW IT WORKS

Two general approaches are possible for modelling residential, commercial, or agricultural energy demand, as shown in Figure 8.7. In the 'bottom-up' approach, separate sub-models are developed for each energy application and these are aggregated into the total residential demand. In the 'top-down' approach, energy demand is modelled based on aggregated statistics for the economy. The bottom-up approach is preferable, as it tells a more detailed story of what is happening to energy demand, and more easily allows the modelling of alternative policies that may affect specific energy applications, such as improving the efficiency of certain appliances. However, it requires detailed data on each energy application, which may not be available in many economies.

Figure 8.7: General Approaches to Modelling 'Other' Sector Energy Demand



APERC developed both kinds of models. However, because of data limitations, the bottom-up approach was used only for the residential sector and only for those economies with adequate data: Australia, Canada, Chinese Taipei, Japan, Korea, New Zealand, Russia, and Singapore. This section, therefore, focuses on the 'top-down' approach that was used elsewhere, and specifically focuses on residential demand modelling.

To model demand in the residential sector, APERC sought an approach that could:

- be consistent across economies
- work with the limited data available for many APEC economies
- use knowledge of what is happening in all APEC economies to project the demand in specific APEC economies.

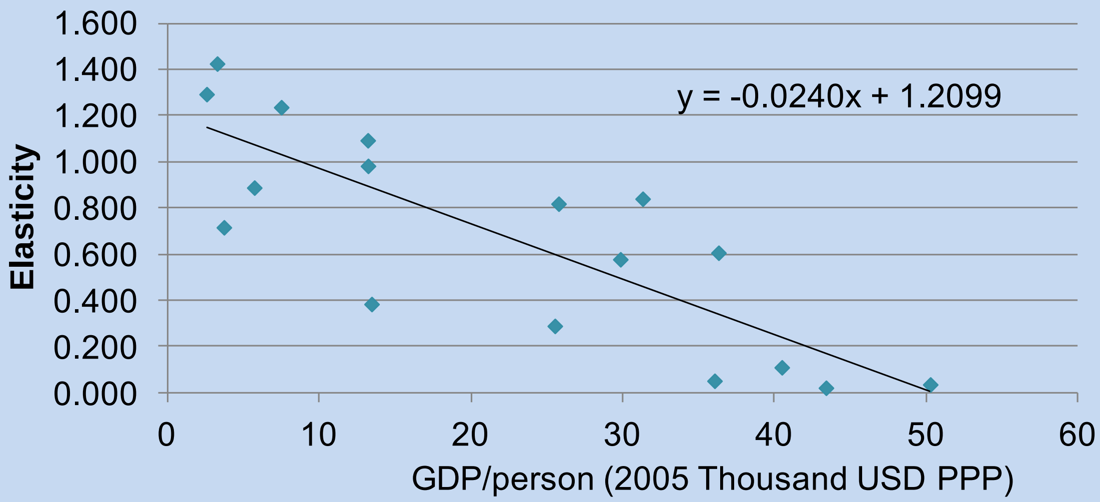
Economic literature (Judson et al., 1999) suggests that:

1. Per capita GDP is the major driver of residential energy demand.
2. The rate at which residential energy demand per capita increases as GDP per capita increases (the income elasticity) declines as GDP per capita increases.

The second conclusion is intuitively quite reasonable, especially for the residential sector. When a poor economy first starts to grow wealthier, among the first things its residents seek to buy are basic home appliances, such as commercial fuel cooking equipment, hot water heaters, refrigerators, washing machines, air conditioners, and televisions. As a result, the residential energy demand of an economy in the early stages of industrialization rises rapidly. A common flaw in residential demand modelling for developing economies is to assume this rapid rate of demand growth will continue indefinitely into the future. It does not. Once people get wealthy enough that they already have basic home appliances, further increases in income tend to be spent in other, less energy-intensive ways.

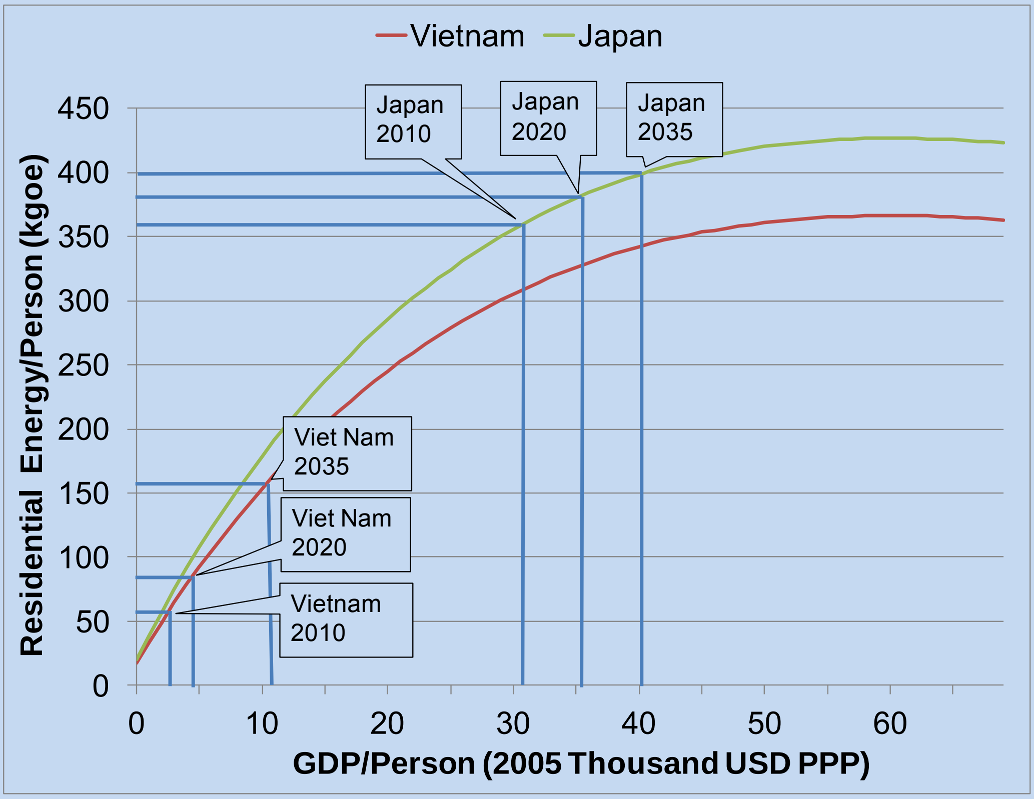
APERC modelled this relationship between the income elasticity of residential energy demand/person and GDP/person based on historical data, as shown in Figure 8.8. The results indicated the income elasticity of residential energy demand is greater than one for poorer economies (that is, a 1% increase in income results in a more than 1% increase in residential energy demand), but drops off rapidly as income rises.

Figure 8.8: Relationship Between Income Elasticity of Residential Energy Demand and GDP/Person by Economy



Using a bit of calculus, the elasticity relationship shown in Figure 8.9 can be used to construct a general relationship between per capita income and residential energy demand/person. Such a curve can be fitted to an individual economy by forcing it to pass through the economy's 2010 residential energy demand per capita and GDP per capita. If one has an estimate of future GDP per capita for the economy, the future residential energy demand per capita can then be simply read off the curve. Figure 8.9 shows an example for Japan and Viet Nam (which does not reflect the actual numbers used in APERC's final residential demand projection for these economies). Note, Viet Nam's residential energy demand/person, although much lower than Japan's, is increasing much more rapidly with GDP/person.

Figure 8.9: Residential Energy Demand Projection Example: Japan and Viet Nam



Note: kgoe = kilograms of oil equivalent

This section is a short summary of Chen and Samuelson (2012), which should be consulted for more detailed information on APERC's 'other' sector demand modelling.

IMPROVING ENERGY EFFICIENCY WITH RESIDENTIAL FUEL CELLS

Fuel cells use an electrochemical process—not moving parts—to generate electricity and heat from gaseous or liquid fuels. Fuel cells can be built in almost any size, and therefore have many potential applications in the energy sector. Perhaps the best known of these is as a source of electricity to power hydrogen vehicles, as discussed in Chapter 5. Another application is as a small scale source of electricity and domestic hot water that could be installed in individual residences. The fuel source for residential fuel cells would most likely be natural gas, but could also be hydrogen, biogas, propane, or liquid fuels.

The main advantage of fuel cells in a residential application would be their high level of efficiency. A modern residential fuel cell could produce electricity from gas with an efficiency of about 40%—comparable to many of today's utility generation plants—but, in addition, could produce hot water from the waste heat with an efficiency of up to 50% (Tokyo Gas and Panasonic, 2011). This would allow an overall efficiency far higher than even today's most efficient utility combined cycle gas turbine generating units, which are in the 55–60% range before transmission losses (Sano, 2010, Figure 3).

Additional advantages of residential fuel cells stem from the fact they are a form of distributed electricity generation, which could eliminate electricity transmission losses and enhance the security and robustness of the energy grid. Small power plants like these can be easily turned on or off remotely, making them amenable to integration into a future smart grid. They are almost noiseless and, when running on natural gas, produce emissions of CO_2 only.

In the future, residential fuels cells could also potentially integrate well with residential solar and wind installations. These renewable electricity sources could be used to electrolyze hydrogen from water during the hours when electricity demand is low; the hydrogen could then be used to generate electricity in a fuel cell during peak electricity demand hours. Such an arrangement could overcome the intermittency limitations of solar and wind power, while providing true zero-emission electricity and hot water.

The greatest barrier to the widespread commercialization of residential fuel cells is their high initial cost. For example, in Japan a 750 W Panasonic Ene-Farm fuel cell is currently sold for about USD 35 000 (JPY 2 761 500) (Tokyo Gas and Panasonic, 2011). This stationary fuel cell will provide about 50% of the electricity needed by a typical Japanese household, and save the household about USD 600 to USD 750 a year on electricity and gas costs compared to buying the electricity from the grid and buying gas for hot water only. The estimated life of the fuel cell unit is only about 10 years, so the initial purchase price cannot be recovered. However, there is substantial room for cost reductions. Various Japanese research and demonstration programs are aiming to reduce the initial cost to around JPY 500 000 by later in this decade (JX Nippon Oil & Energy Corporation, 2011; Daily Yomiuri, 2012), which could offer a payback period of as little as eight years.

While this target cost may still seem high, there may be additional benefits. The hot water could be circulated in the floor of the building to also provide comfortable and economical space heating, allowing the system to be more fully utilized. As these systems are upgraded to allow off-grid operations in the event of blackouts, they could provide even more value and peace of mind to homeowners.

One potential early application for residential fuel cells might be on small islands and in other off-grid communities, which exist in nearly every APEC economy. Here the fuel cells might run on propane or liquid fuels, but could offer substantial efficiency gains over the expensive and inefficient diesel generators commonly used in such locations today.

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2010), *APEC Cooperative Energy Efficiency Design for Sustainability (CEEDS) Final Report For CEEDS Phase 1: Appliance Energy Efficiency Standards and Labeling*, www.ieej.or.jp/aperc/CEEDS/Final_Report_CEEDS_Phase_1.pdf

— (2011), *APEC Cooperative Energy Efficiency Design for Sustainability (CEEDS) Final Report for CEEDS Phase 2: Building Energy Codes and Labeling*, www.ieej.or.jp/aperc/CEEDS/Final_Report_CEEDS_Phase_2.pdf

Chen, Lei and Ralph D. Samuelson (2012), *Residential Energy Demand Modeling Based on Multi-Economy Data*, presentation to the 3rd International Association for Energy Economics Conference, Kyoto, Japan, http://eneken.ieej.or.jp/3rd_IAEE_Asia/pdf/paper/057p.pdf

Daily Yomiuri (2012), "Gas firms pushing fuel cells/Eco-friendly household power units efficient but costly, bulky", 24 April 2012, www.yomiuri.co.jp/dy/business/T120423004042.htm

ECS (Energy Charter Secretariat) (2009), *Policies that Work: Introducing Energy Efficiency Standards and Labels for Appliances and Equipment*, Brussels, www.encharter.org/index.php?id=468

EDR (Energy Design Resources) (2012), 'eQUEST' website page, www.energydesignresources.com/resources/software-tools/equest.aspx

ICC (International Codes Council) (2012), 'About ICC' website page, www.iccsafe.org/AboutICC/Pages/default.aspx

Judson, Ruth A., Richard Schmalensee and Thomas M. Stoker) (1999), "Economic Development and the Structure of Demand for Commercial Energy", *Energy Journal*, Vol 20 No 2, 1999.

JX Nippon Oil & Energy Corporation (2011), *Development of fuel cell at JX*, presentation to the Hydrogen and Fuel Cell Technical Advisory Committee, Washington DC, www.hydrogen.energy.gov/pdfs/htac_02_2011_jx_eneos_takami.pdf

Laustsen, Jens (2008), *Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings*, IEA information paper in Support of the G8 Plan of Action, International Energy Agency, Paris, www.iea.org/efficiency/CD-EnergyEfficiencyPolicy2009/2-Buildings/2-Building%20Codes%20for%20COP%202009.pdf

Sano, Toshihiro (2010), *Development of the Ultra High Efficiency Thermal Power Generation Facility*, World Energy Congress, Montreal, www.worldenergy.org/documents/congresspapers/312.pdf

Tokyo Gas and Panasonic (Tokyo Gas Company Ltd. and Panasonic Corporation) (2011), "Tokyo Gas and Panasonic to Launch New Improved 'Ene-Farm' Home Fuel Cell with World-Highest Generation Efficiency at More Affordable Price", media release, 9 February 2011, www.tokyo-gas.co.jp/Press_e/20110209-01e.pdf

USDOE (United States Department of Energy) (2012), *National Energy and Cost Savings for New Single– and Multifamily Homes: A Comparison of the 2006, 2009, and 2012 Editions of the IECC*, Building Technologies Program, www.energycodes.gov/sites/default/files/documents/NationalResidentialCostEffectiveness.pdf

9 ELECTRICITY DEMAND AND SUPPLY

HISTORICAL TREND

Electricity demand in the APEC region grew robustly between 1990 and 2009 at an average annual rate of 3.3% per year, from 5720 terawatt-hours (TWh) in 1990 to 10 528 TWh in 2009. Rapid growth was observed particularly in developing Asian economies. Viet Nam experienced the highest average annual growth rate from 1990 to 2009 (14.2%), followed by China (10.2%), Malaysia and Indonesia (both 8.6%), as shown in Table 9.1.

In 1990, developed OECD-member economies including Australia, Canada, Japan and the United States (US) accounted for 69% of the APEC region's total electricity consumption, with the US alone consuming 46%. However, by 2009, the total share consumed by these economies had decreased to 50%; this was due mainly to increasing electricity demand in China and other developing South-East Asia economies. China's share of the APEC region's total electricity demand has increased from 8% in 1990 to 29% in 2009, as calculated from Table 9.1.

Table 9.1: APEC's Electricity Demand by Economy, in TWh

Economy	Final Electricity Demand (TWh)			Average Annual Percentage Change	
	1990	2009	2035	1990-2009	2009-2035
Australia	129	214	318	2.7%	1.5%
Brunei Darussalam	1	3	4	6.3%	0.5%
Canada	418	477	701	0.7%	1.5%
Chile	15	54	128	6.8%	3.4%
China	482	3065	8765	10.2%	4.1%
Hong Kong, China	24	42	56	3.0%	1.2%
Indonesia	28	135	546	8.6%	5.5%
Japan	750	934	957	1.2%	0.1%
Korea	94	406	573	8.0%	1.3%
Malaysia	20	96	206	8.6%	3.0%
Mexico	100	201	402	3.7%	2.7%
New Zealand	28	38	50	1.6%	1.1%
Papua New Guinea	2	3	11	3.5%	5.0%
Peru	12	30	82	5.0%	4.0%
Philippines	21	51	157	4.7%	4.4%
Russia	827	686	1278	-1.0%	2.4%
Singapore	13	36	51	5.5%	1.3%
Chinese Taipei	77	202	312	5.2%	1.7%
Thailand	38	135	339	6.9%	3.6%
United States	2634	3643	4544	1.7%	0.9%
Viet Nam	6	77	385	14.2%	6.4%
APEC Total	5720	10528	19864	3.3%	2.5%

Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

BUSINESS-AS-USUAL ELECTRICITY OUTLOOK RESULTS

ELECTRICITY DEMAND

Electricity demand is expected to continue to grow between 2009 and 2035, at a rate of 2.5% per year. By region, North America, especially the US, is projected to contribute significantly to demand for electricity. Electricity demand in the US is projected to reach 4544 TWh in 2035 or about 22.9% of APEC's total electricity demand in 2035. However, China's expected high economic growth rate will mean its electricity demand will surpass all other APEC economies by the end of the outlook period—it is expected to reach 8765 TWh or 44% of APEC's total electricity demand in 2035, as shown in Table 9.1.

Table 9.2 shows electricity demand as a share of projected total final energy demand (TFED) for each APEC member economy. Electricity's share of TFED is expected to increase for all economies during the outlook period, with the exception of Brunei Darussalam and Singapore. For these two economies, a growing demand for other fuels (especially natural gas feedstock in Brunei Darussalam and oil feedstock in Singapore) will cause electricity's share to decline.

Table 9.2: APEC's Electricity Demand as a Percentage of Total Final Energy Demand (TFED)

(Percentage)

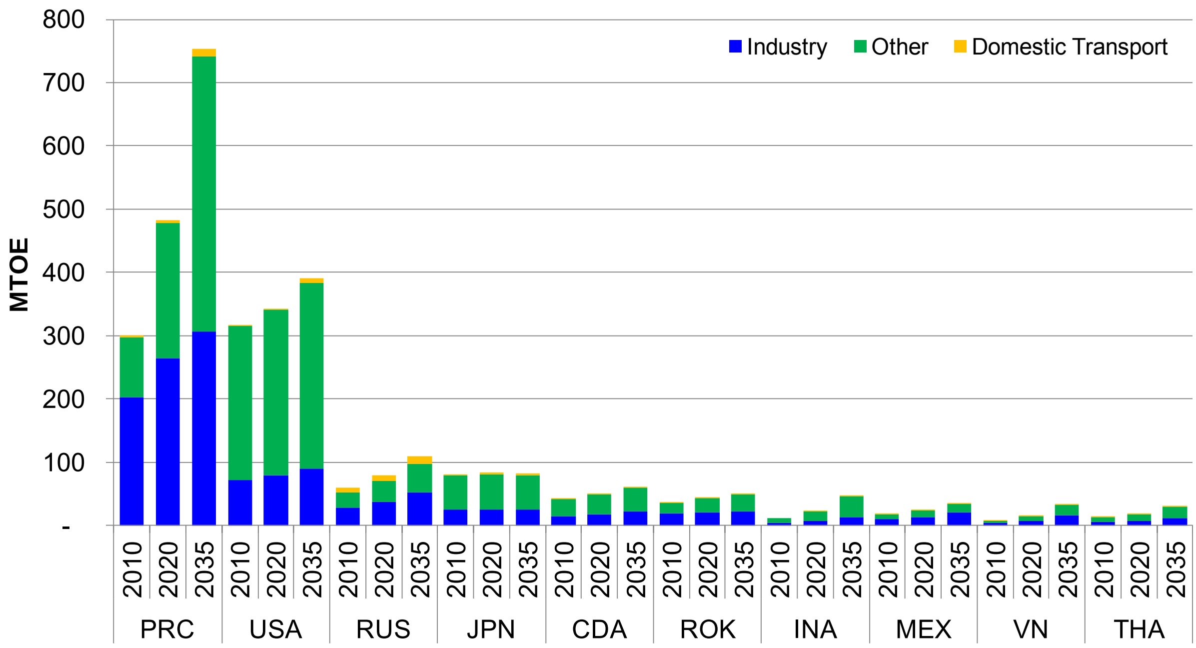
Economy	1990	2009	2035
Australia	20	24	27
Brunei Darussalam	25	31	19
Canada	23	21	32
Chile	12	21	26
China	6	18	28
Hong Kong, China	39	40	42
Indonesia	3	8	15
Japan	21	26	31
Korea	13	24	28
Malaysia	12	21	26
Mexico	10	16	18
New Zealand	24	26	31
Papua New Guinea	26	24	31
Peru	12	18	23
Philippines	9	19	28
Russia	11	14	17
Singapore	22	22	19
Chinese Taipei	22	28	34
Thailand	11	15	20
United States	18	21	24
Viet Nam	2	12	24
APEC	14	20	25

Source: APERC Analysis (2012)

Final Electricity Demand by Sector

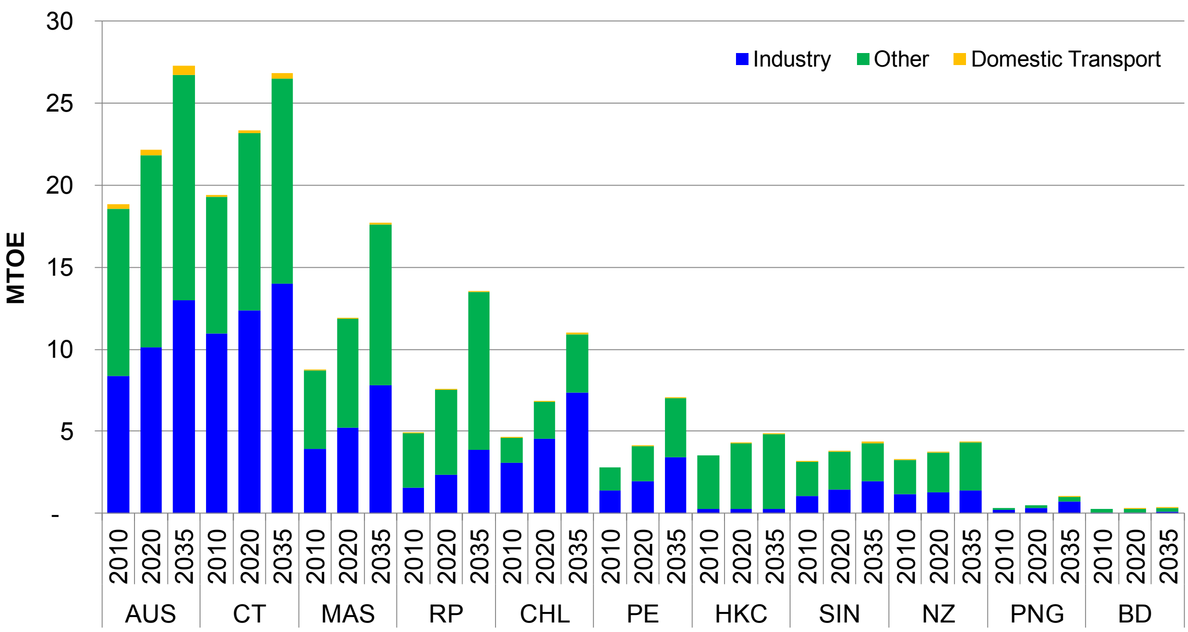
Projections for final electricity demand by sector for each APEC economy are shown in Figures 9.1 and 9.2. Note the difference in the scales of the vertical axes in the two figures. Total electricity demand is projected to increase in all APEC economies from 2010 to 2035.

Figure 9.1: Projected APEC Electricity Final Demand by Sector, Higher Final Demand Economies



Source: APERC Analysis (2012)

Figure 9.2: Projected APEC Electricity Final Demand by Sector, Lower Final Demand Economies



Source: APERC Analysis (2012)

For most APEC economies, by 2035, more than half of the electricity demand will be from the 'other' sector—this includes the residential, commercial and agricultural sub-sectors. The exceptions are Russia, Mexico, Chinese Taipei, Chile and Papua New Guinea. In these economies, more than half the electricity final demand will be from the industry sector.

The rise in electricity demand in the 'other' and industry sectors will be underpinned by increasing trends in both population and economic growth rates. Another important factor will be the continuing shift to electricity from primary energy sources. For instance, in the 'other' sector, primary fuels like traditional biomass, coal and kerosene are still used for cooking, lighting and space heating in some of the less developed areas of the APEC region. With better access to electricity, it is expected these primary fuels will be supplemented or displaced by electricity. At the same time, rising incomes and improving standards of living will drive the demand for electrical devices, which in turn will spur electricity demand in the 'other' sector, particularly in developing Asian economies like China and Indonesia.

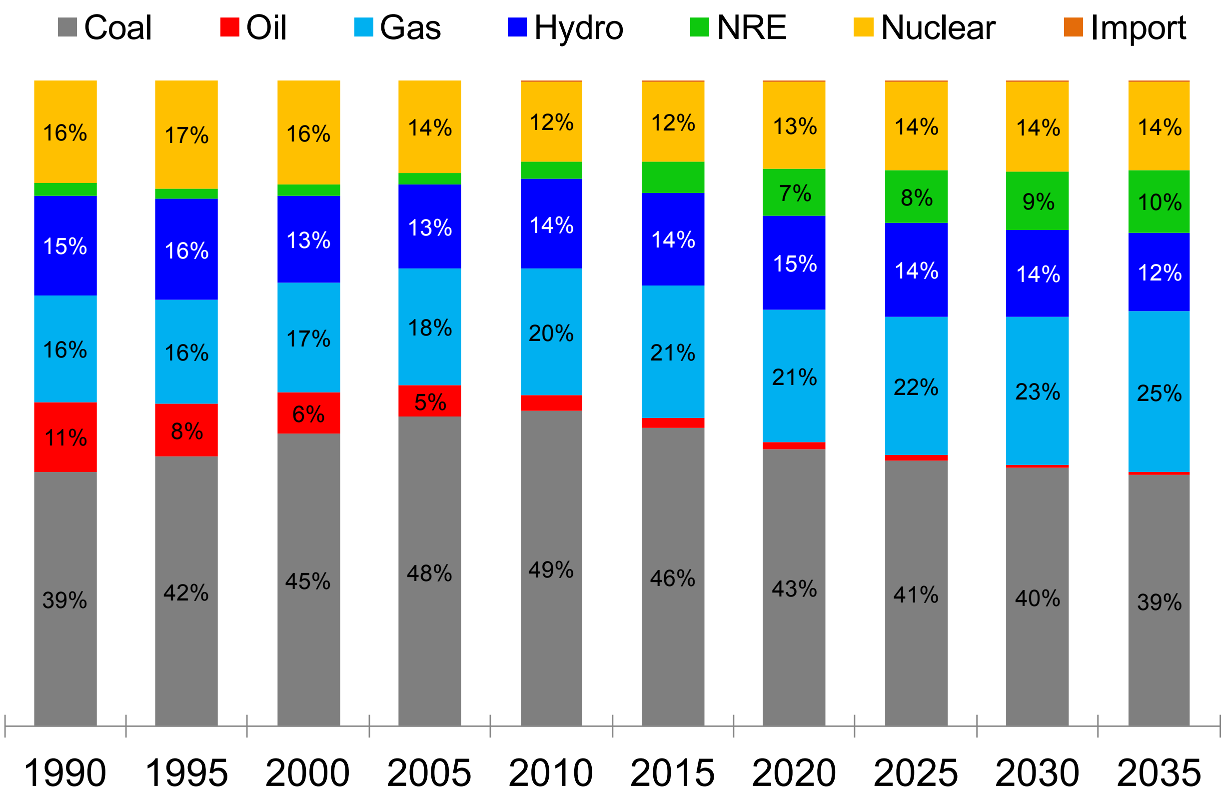
For the domestic transport sector, although the share for each economy is small (less than 5% for all economies with the exception of Russia) the total electricity demand will increase from 2010 to 2035 for all economies. This increase can reflect either one of two major developments, or a combination of both. The first is a transportation modal shift from private vehicles to electrically-powered public transport. The second is the penetration of more vehicles that use electricity instead of oil as their energy source.

ELECTRICITY SUPPLY

Electricity supply across the APEC region is expected to grow at an average annual rate of 2% between 2010 and 2035. Figure 9.3 shows APEC's historical and future electricity generation mix in percentage terms.

Nuclear shares will remain fairly consistent throughout the outlook period. New renewable energy (NRE)—that is renewable energy other than hydro—and gas will show increasing trends, while coal and oil will show significant decreases. Please refer to Chapter 2 for a detailed discussion of projected electricity supply by energy source in absolute quantities.

Figure 9.3: APEC's Electricity Generation Mix (1990–2035)



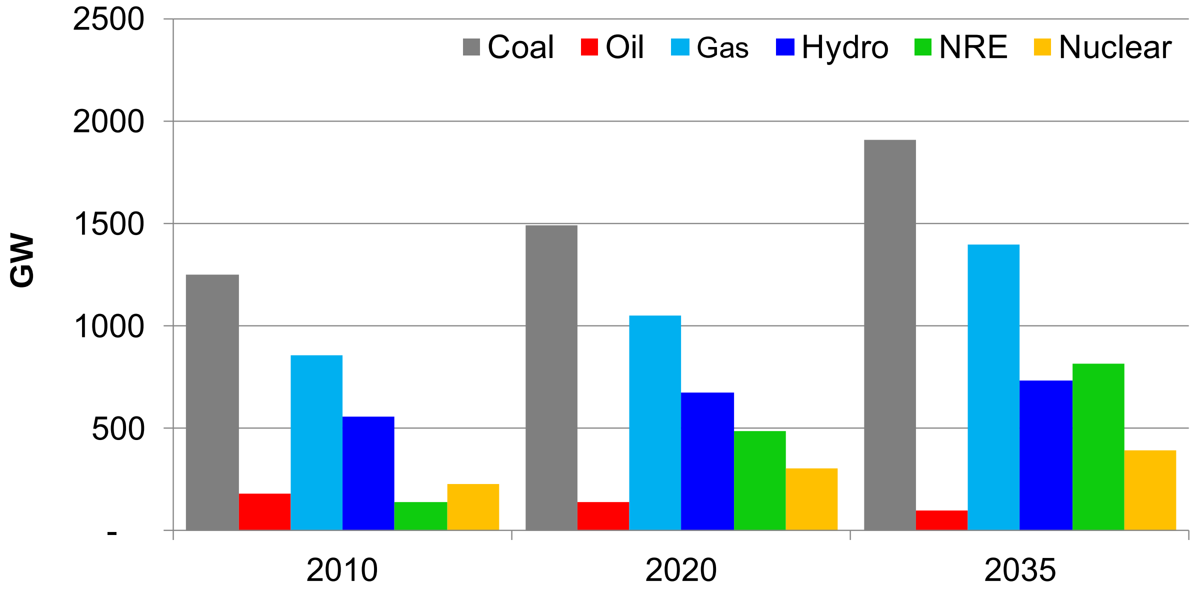
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Electricity Generating Capacity by Energy Source

Figure 9.4 shows the projected electricity generating capacity by energy source. To meet the projected increase in total electricity demand, total generating capacity in the APEC region is projected to almost double over the outlook period, from 3212 gigawatts (GW) in 2010 to 5340 GW in 2035. As new generating capacity is added, the supply mix is expected to change, driven by a number of factors. Some of the more vital drivers are as listed below:

- available energy resources — which includes both indigenous resources and available imports, and can be either fossil fuels, renewable energy resources or nuclear
- fuel costs and capital investment costs, and the ability to secure funds for both
- available technologies and infrastructure, and the feasibility of implementing new technologies
- government policies — especially policies related to energy security, environmental regulations and emissions targets
- public acceptance of certain resources that may be perceived as either "risky" (nuclear) or "dirty" (coal).

Figure 9.4: APEC's Projected Electricity Generation Capacity by Energy Source



Source: APERC Analysis (2012)

Over the outlook period, oil prices are expected to continue to increase while coal prices are expected to remain stable and relatively low, as coal is an energy resource with abundant deposits worldwide. On the other hand, with more unconventional gas resources like shale gas and coal bed methane being produced, gas prices will probably begin to decrease—especially in Asia. Gas prices in North America are already low although they are expected to trend upward in the coming years but it is unlikely they will reach the same level as oil prices. For these reasons, coal and gas capacities will continue to be the dominant electricity resources in the APEC region.

Coal, however, generates more greenhouse gases (GHG) than any other fossil fuel and causes more severe local air pollution. Even under business-as-usual (BAU) assumptions, concerns about climate change may limit the growth of coal-fired generating capacity.

Coal-fired generating capacity is expected to grow at an average annual rate of 1.7%, while the share of generating capacity that is coal fired will decrease, from 39% in 2010 to 36% in 2035. The decrease in share is mainly due to growing concerns about the detrimental effects of emissions from coal-fired generation, and a general shift from coal-fired generation capacity togas, NRE and nuclear generation capacities.

Oil-fired electricity generation is expected to continue its historical decline during the outlook period. It will be maintained only in areas where no other fuels are readily available, such as on small islands and other remote off-grid communities. This is due primarily to high fuel costs, security of supply risks and environmental considerations. Oil-fired generating capacity APEC-wide is projected to decrease at an average annual rate of 2.5%. The share of generating capacity that is oil fired will also decrease significantly from 6% in 2010 to 2% in 2035.

Natural-gas-fired combined-cycle gas turbines (CCGT) are very efficient at converting gas to electricity, have little impact on the local environment, can be built quickly, have a fairly low initial capital cost, and have fewer GHG emissions than coal. Additionally, older steam turbines (which may use coal, oil or natural gas as fuel) will be replaced by the more efficient CCGTs, thus increasing CCGT capacity in the APEC region. Nonetheless, the combined share for all natural-gas-fired generating capacity (which includes CCGTs, open-cycle gas turbines and steam turbines burning gas as fuel) will likely experience a slight decrease in share of capacity from 27% in 2010 to 26% in 2035.

Hydro is an attractive option as it has no fuel costs and low GHG emissions (see Chapter 15), but its further development will be hindered in many APEC economies by a lack of suitable sites. Hydro generating capacity is expected to grow at an average annual rate of 1.1%, but the hydro share of generating capacity will slowly decrease from 17% in 2010 to 14% in 2035.

A number of initiatives are being undertaken by APEC member economies to promote the rapid development of NRE under our BAU assumptions. Therefore, the installed capacity of NRE is expected to increase at the fastest rate of any generation energy source, 7.3% per year from 2010 to 2035. The NRE share of generating capacity will increase significantly from 4% in 2010 to 15% in 2035.

The Fukushima Nuclear Accident of March 2011 has somewhat changed the nuclear outlook in the APEC region. Higher safety standards, increasing costs and construction times, as well as eroding public acceptance of nuclear energy power plants mean the APEC economies will become more cautious in expanding their nuclear generation capacity. Our nuclear generating capacity projection has been revised to reflect this situation, especially in Japan and Chinese Taipei. In this new climate, nuclear energy is projected to grow at a slower rate of 2.2% annually, and the nuclear share of generating capacity will remain constant at about 7% throughout the outlook period.

To reduce GHG emissions and to control costs, APEC economies are expected to focus on energy efficiency and conservation measures that include reducing transmission and distribution losses, as well as increasing the efficiency of electricity generation from fossil fuels.

Our BAU projections indicate that average coal generation efficiency will increase from 36% in 2010 to 42% in 2035, and average gas generation efficiency will increase from 44% to 50%. Similarly, we expect that overall electricity losses will be reduced by about 29% from 2008 to 2035. For this outlook, electricity losses are defined as the difference between the amount of electrical energy entering the system (electricity generated and imported) and the demand. These losses may include power dissipated from transmission and distribution lines, transformers and measurement systems (also known as transmission and distribution losses) as well as internal losses and auxiliary consumption in the power generation stations. Further discussions on improvements in generation, transmission and distribution efficiencies are included in a later section of this chapter.

Electricity Generation Capacity by Economy

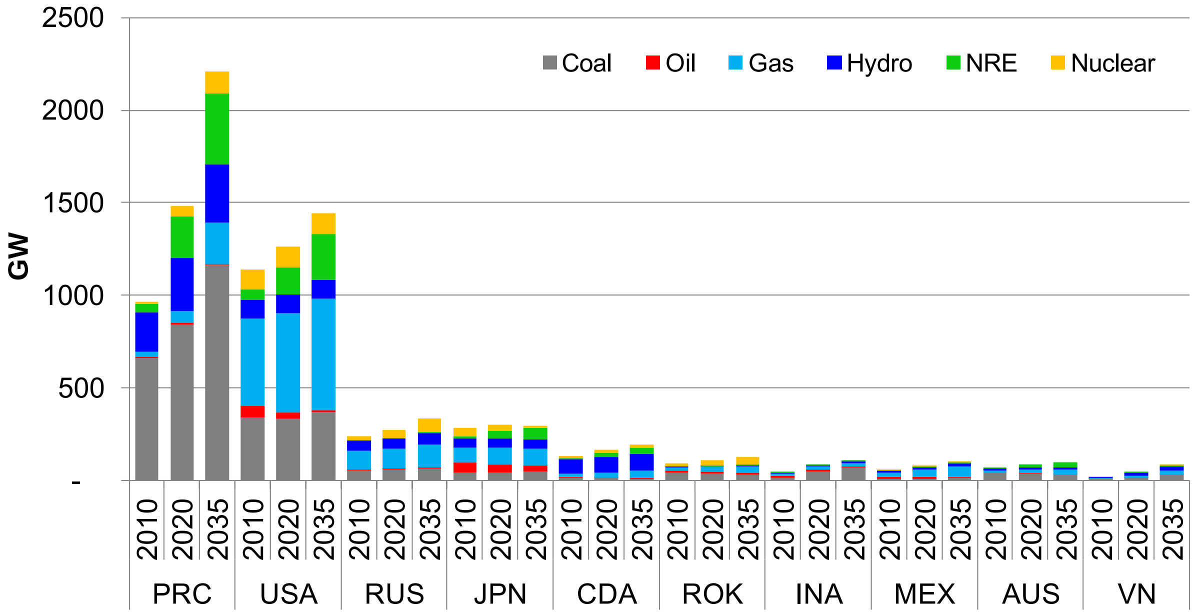
In 2010, the largest installed generation capacity was in the US. Its total capacity, of over 1130 GW, was dominated by gas (42%) and coal (30%). China's 2010 installed capacity was the second highest, at 966 GW, of which coal was 68% and hydro was 22%. However, by 2035, China's installed capacity is expected to exceed that of the US, reaching 2211 GW compared to the US's 1444 GW. After these two economies, Japan and Russia will have the next largest installed capacities, in both 2010 and 2035.

By 2035, thermal generating capacities are still dominant in most APEC economies. The exceptions are Canada, New Zealand and Papua New Guinea where hydro generating capacities are more prominent. Several of APEC's Asian economies are expected to introduce nuclear generating capacity by 2035; these include Thailand and Viet Nam, while Chinese Taipei and Japan are expected to reduce their nuclear generating capacity over the outlook period.

As technologies for harnessing NRE improve, economies with suitable resources are projected to further develop their NRE capacities to improve energy security and to mitigate environmental emissions problems. As a result, several economies will experience a substantial increase in NRE penetration. In Australia, for example, NRE's share of generating capacity will increase from 4.6% in 2010 to 31% in 2035—this will consist mostly of wind generation capacities. Please refer to Chapter 15 on Renewable Energy Supply for a more complete discussion of renewable energy power installations in the APEC region.

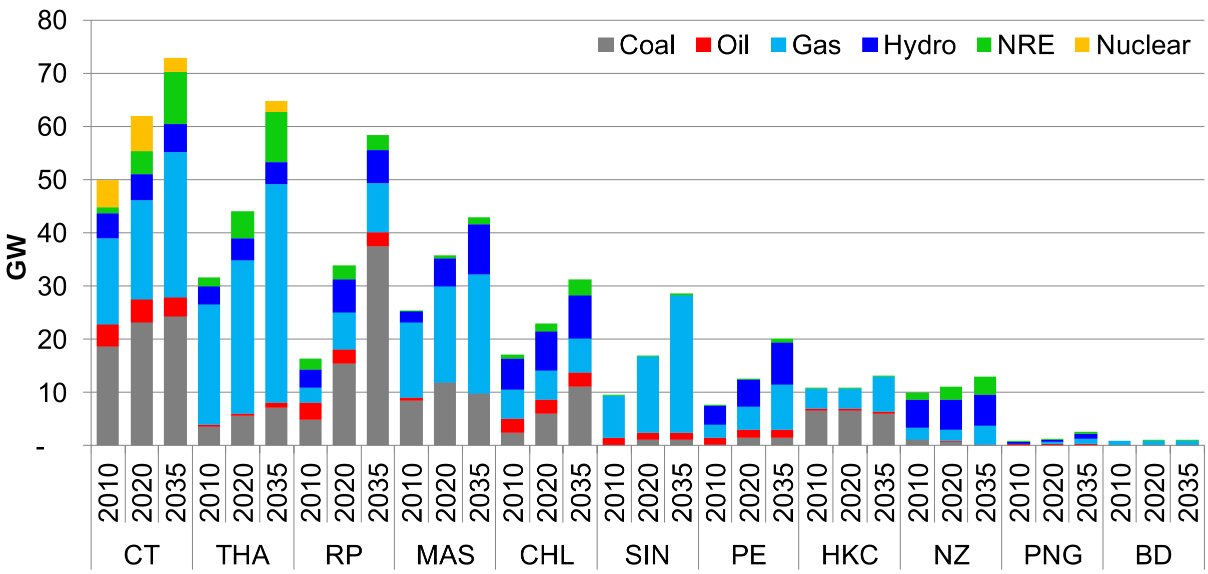
Figures 9.5 and 9.6 show the installed generation capacities by energy source and economy. Note the two graphs have different scales on the vertical axes.

Figure 9.5: Projected Generating Capacity by Economy and Energy Source, Economies with Larger Capacities



Source: APERC Analysis (2012)

Figure 9.6: Projected Generating Capacity by Economy and Energy Source, Economies with Smaller Capacities

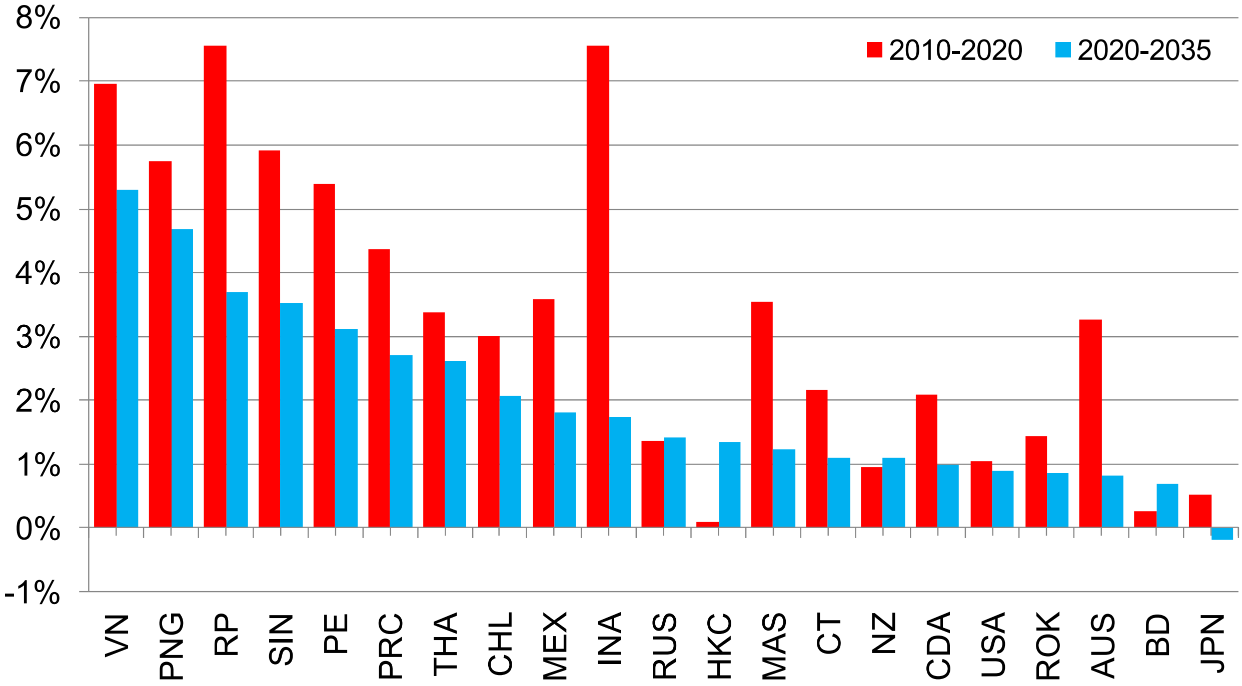


Source: APERC Analysis (2012)

Figure 9.7 shows the annual growth rates for generating capacity across all APEC economies during the first 10 years compared to the final 15 years of the outlook period.

With the exception of four economies (Hong Kong, China; Russia; New Zealand; and Brunei Darussalam), it is projected that capacity build-up will be more aggressive during the earlier years of the outlook period. Electricity growth rates are generally higher overall for developing Asian economies like Viet Nam, the Philippines and Indonesia, where there is much room for growth and massive generation capacity will be necessary to meet the rapidly growing demand. For developed, high-income economies like Japan and Brunei Darussalam where demand growth is slower, there will be more focus on maintaining and improving existing infrastructure.

Figure 9.7: Annual Growth Rates of APEC Economies' Generation Capacities between 2010–2020 and 2020–2035



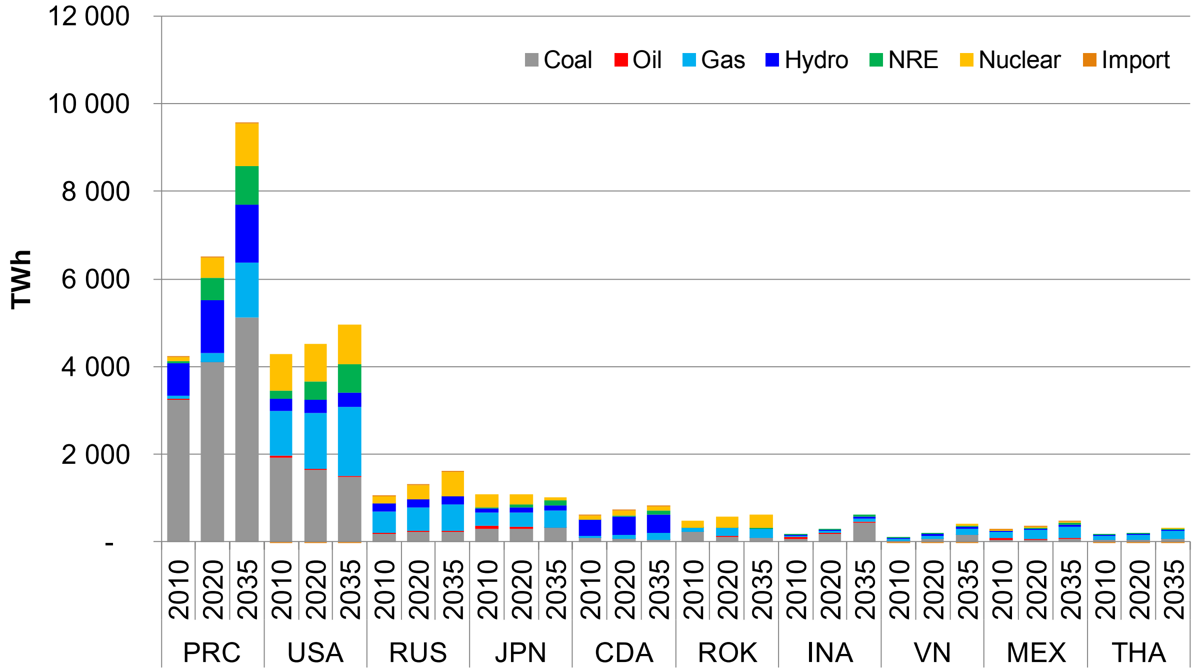
Source: APERC Analysis (2012)

Electricity Generation Supply by Economy

Figures 9.8 and 9.9 show the electricity supply for each APEC economy by energy source for the years 2010, 2020 and 2035. Again, note the vertical axes of the two graphs have different scales. The results are very much in line with the graphs of generating capacity by economy presented in Figures 9.5 and 9.6 above.

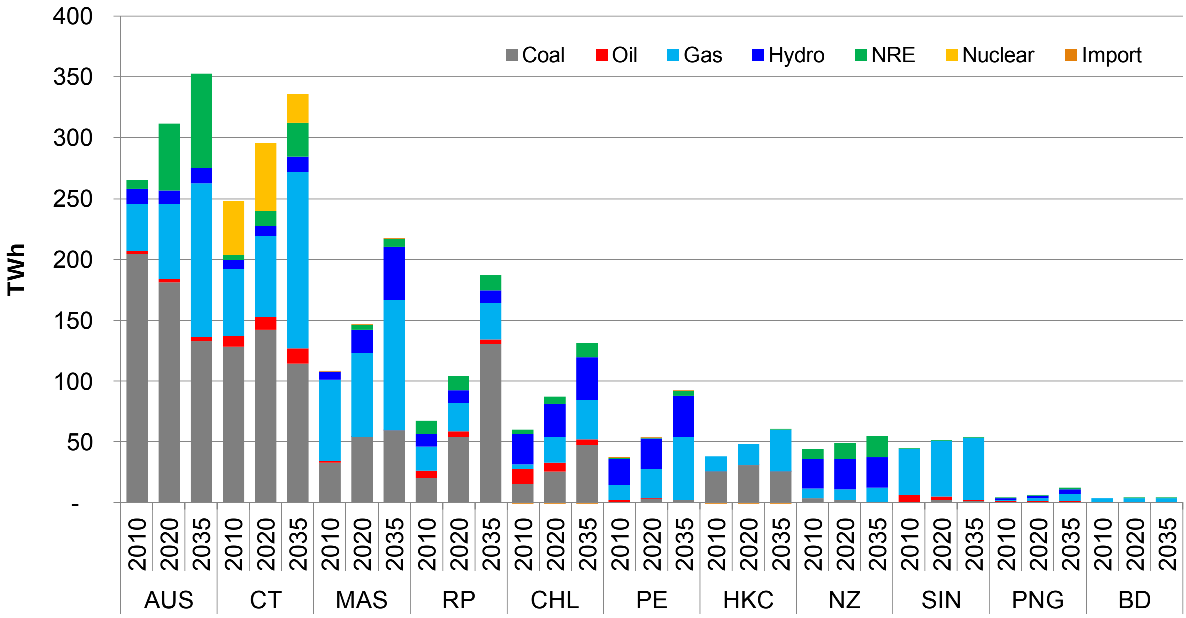
China and the US once again dominate the APEC region: the two economies will account for over 60% of total electricity generation supply over the outlook period. At the other end of the spectrum are the smaller-sized economies: Singapore, Papua New Guinea and Brunei Darussalam.

Figure 9.8: Electricity Generation Supply by Economy and Energy Source, Larger Generating Economies



Source: APERC Analysis (2012)

Figure 9.9: Electricity Generation Supply by Economy and Energy Source, Smaller Generating Economies

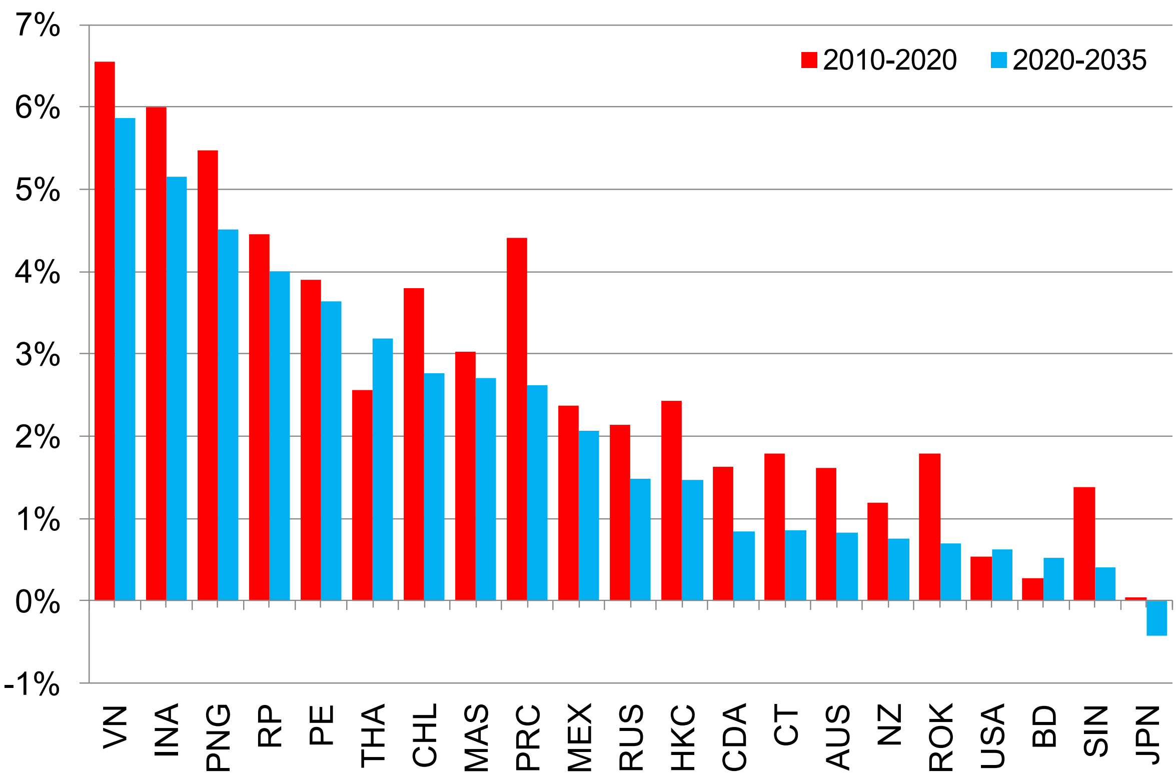


Source: APERC Analysis (2012)

Figure 9.10 shows the electricity supply growth rates for the APEC economies. There is a marked trend of higher generation growth in the earlier 10 years of the outlook period compared to the later 15 years. The exceptions to this trend are China, the US and Brunei Darussalam.

The slower electricity generation growth rate in the APEC region for the later years can probably be attributed to the increasing maturity of most APEC economies, as developing economies tend to have faster GDP growth rates and therefore faster electricity demand growth rates. This increasing maturity is also accompanied by a shift from energy-intensive industry to a less energy-intensive high-value added industry and services.

Figure 9.10: Annual Growth Rates of APEC Economies' Electricity Generation Supply between 2010–2020 and 2020–2035



Source: APERC Analysis (2012)

ACCESS TO ELECTRICITY

Rural electrification is quite properly a key development objective for those economies that have not yet achieved nearly universal access to electricity. Rural electrification not only significantly enhances the quality of life of people living in rural areas, but it can also bring significant economic benefits. Studies show that providing communities with access to electricity has significant positive impacts on household income, expenditure, and the educational achievement of children. It can also lead to significant reductions in poverty (Khandker et al., 2012; World Bank, 2009).

Table 9.3 shows that most APEC economies have already achieved this critical development milestone. The successes of China and Viet Nam in the last decade in providing 99% and 98%, respectively, of their populations with access to electricity in 2009, are especially impressive.

Table 9.3: APEC Economies' Access to Electricity

Economy	Percentage of Population	Percentage of Household
Australia[a]	100	100
Brunei Darussalam[b]	99.7	n/a
Canada[a]	100	100
Chile[c]	98.5	n/a
China[c]	99.4	n/a
Hong Kong, China[a]	100	100
Indonesia[d]	n/a	67.2
Japan[a]	100	100
Korea[a]	100	100
Malaysia[c]	99.4	n/a
Mexico[e]	97.3	n/a
New Zealand[a]	100	100
Papua New Guinea[f]	n/a	12.9
Peru[c]	85.7	n/a
Philippines[g]	n/a	73.7
Russia[h]	100	100
Singapore[c]	100	100
Chinese Taipei[a]	100	100
Thailand[i]	n/a	86.8
United States[a]	100	100
Viet Nam[j]	97.6	98.5

n/a= not available

Sources: [a] APERC Analysis (2012), [b] BDEPD (2010), [c] World Bank (2012), [d] IDGEEU (2011), [e] MSener (2010), [f] PNG (2010), [g] PNGCP (2011), [h] RME (2012), [i] TDEDE (2010) and [j] VGSO (2009)

Only five APEC economies still had access-to-electricity rates less than 95% in the most recent year for which data is available (generally 2009): Indonesia at 67.2% of households, Papua New Guinea at 12.9% of households (PNG, 2010, p. 77), Peru at 85.7% of the population, Philippines at 73.7% of households, and Thailand at 86.8% of households. These economies are moving aggressively to provide increased access, and we expect nearly universal access by 2035, although Papua New Guinea's goal is 70% access by 2030 (PNG, 2010, p. 77).

POTENTIAL FOR ENERGY EFFICIENCY IMPROVEMENTS IN THE ELECTRICITY SUPPLY SYSTEM

Energy efficiency improvements can greatly enhance energy security, reduce costs, and help protect the environment. In an electricity supply system, improving energy efficiency refers to minimizing the primary energy used in producing each unit of electricity consumed. This utilisation can be broadly divided into two categories. The first is the power generation category which encompasses converting primary energy into electricity. The second is the transmission and distribution of electricity category which consists of energy that is used in transporting electricity between sources of supply and the ultimate end-users.

Energy Efficiency in Electricity Generation

About one-third of the APEC total primary energy supply is used to generate electricity, and from this amount, more than 70% are from fossil fuels (In 2009, about 2006 million tonnes of oil equivalent (Mtoe) of fossil fuels were used for electricity generation, out of 2662 Mtoe of total energy supplied for electricity generation and 7005 Mtoe of total primary energy supply). Of the primary fossil fuels used for electricity generation, less than 40% of their energy content is actually converted to electricity (767 Mtoe of electricity produced from 2006 Mtoe of fossil fuels in 2009). The remainder is lost in the transformation process. Therefore, there is a great potential for energy savings in the APEC region by improving the thermal efficiency of fossil-fuel electricity generation. For APEC economies, this can be achieved through either retro-fitting or refurbishing existing capacity to improve efficiency, or by installing new generation capacity with higher efficiencies (APERC, 2008, p. 32).

Thermal generation plant efficiency deteriorates with time but it is possible to offset this aging process with timely investment in refurbishment and retrofitting measures (IEA, 2010, p. 22). There is a broad range of technical possibilities since entire parts of a plant are subjected to replacement or reconditioning. Measures that can lead to energy savings include improvements in a plant's heat recovery system (economisers) and heat transfer (including condensers); better energy management supported by the variable control of energy consuming devices (such as pumps and fans), better combustion control, and the use of more efficient turbine blades (when blade replacement is necessary).

It is also possible to completely refurbish a plant. One example of a complete refurbishment measure is generation plant repowering, in which a coal-fired generation plant is converted into a gas-fired generation plant. Another example is converting a simple open-cycle gas turbine into a combined-cycle gas turbine. Both examples will improve the overall efficiency of the plant, since the latest combined-cycle gas turbine technology, the H-Class, is capable of achieving efficiency of over 60% compared to the 39–47% efficiency of a typical coal steam turbine or the 35–40% efficiency of a typical open-cycle gas turbine (Siemens, 2012; Eurelectric, 2003).

The refurbishment and retrofitting measures described, in conjunction with the implementation of best practices in generation plant operation and maintenance, would likely improve a generation plant's performance and efficiency, as well as extend its lifetime.

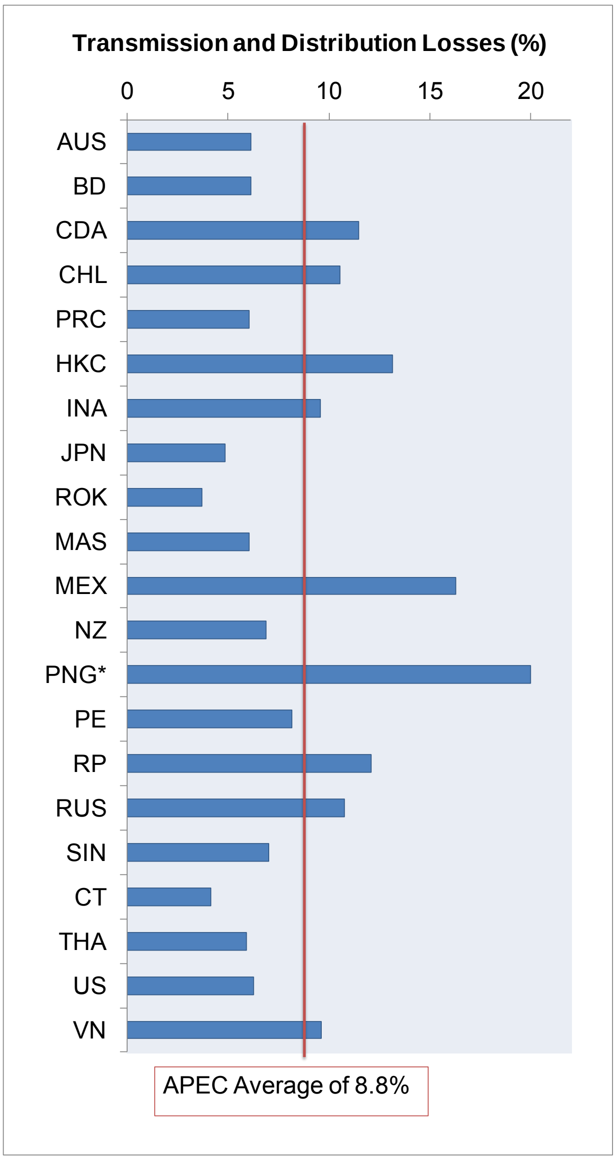
Of course, new generation capacity will also be needed either to replace obsolete existing capacity or to meet the needs for additional electricity in those economies where electricity demand is growing despite efforts to improve end-user energy efficiency. Choosing the generation technology to be used is a major investment decision. It requires a complex decision-making process, taking into account various technical, economic and environmental factors that will best suit the economy's needs.

The variety of options available for new capacity additions is especially broad for coal-fired generation. There are currently several new technological options that are being developed or are commercially available that offer high-efficiency and low-emissions relative to conventional coal-fired technology. These are discussed in the sidebar 'Improving the Efficiency of Coal-Fired Electricity Generation' in Chapter 13. Given the climate change challenges facing the APEC region, as discussed in Chapter 16, all new generation capacity should ideally be low-carbon: renewable, nuclear, or fossil-fuel with carbon capture and storage (CCS). However, if an economy must build non-CCS coal-fired capacity, these advanced technologies for coal-fired generation can significantly reduce emissions, as well as fuel costs, and deserve careful consideration.

Energy Efficiency in Transmission and Distribution

Transmission and distribution (T&D) losses are defined as the share of electricity losses between sources of supply (generating stations), and the ultimate end-users. In 2009, the T&D losses among APEC economies ranged from 3.7% (Korea) to about 20% (Papua New Guinea), with an average of about 8.4% for all APEC economies.

Figure 9.11: APEC Economies T&D Losses in 2009



Sources: *World Energy Statistics 2011* © OECD/IEA 2011 and *PNG (2011)

T&D losses can be attributed to both technical and non-technical losses, where technical losses are related to the dissipation of energy in conductors and equipment while non-technical losses are caused by pilferage and meter-related issues (Bhalla, 2000). Technical losses can be reduced by installing more energy efficient equipment in the T&D network.

Several technological improvements that would improve efficiency in T&D networks are tabulated in Table 9.4. The better management of grid electricity flow will also boost efficiency. This can be achieved through load forecasting, optimal load flow planning, loss minimization and reactive power management (Pezzini et al., 2011).

Table 9.4: Energy Efficient Technologies for T&D Networks

Equipment	Energy Efficiency Technology
Cables	Superconductors, HVDC lines, Underground Distribution Lines
Power flow control	Flexible AC Transmission System (FACTS) devices, Phase Shifting Transformers (PTS)
Transformers	High energy efficiency classes, Amorphous Metal Distribution Transformer (AMDT)
Substations	Gas-Insulated Substations (GIS)

Sources: Pezzini et al. (2011) and ABB (2007)

Smart Grids

The APEC region's grids are constantly evolving. Energy resources are becoming increasingly heterogeneous with the introduction of distributed technologies like intermittent renewable energy generation, plug-in electrical vehicles, combined heat and power (CHP) and energy storage facilities. Modern electrical and electronic devices are much more complex, being more sensitive to voltage or frequency fluctuations in electricity supply.

To meet these new challenges, several APEC economies are planning to update their grids with sophisticated 'smart grid' technologies. The smart grid concept is set to restructure the traditional T&D network from one that is centralized and producer-controlled to one where control is more distributed, automated, and consumer-interactive. Digital technologies and communications are used to coordinate the actions of intelligent devices and systems throughout the electricity power network.

Smart grid monitoring applications, automation and control functions will provide more flexibility to integrate distributed energy resources with their varied characteristics into the T&D system. The same smart grid applications can also enhance overall T&D system efficiency with real-time system performance optimization and increased asset utilization.

The importance of smart grid technology in the APEC region is emphasized in The Fukui Declaration from the Ninth Energy Ministers Meeting in June 2010 (APEC, 2010) which states that "smart grid technologies, including advanced battery technologies for highly-efficient and cost-effective energy storage, can help to integrate intermittent renewable power sources and building control systems that let businesses and consumers use energy more efficiently, and they can also help to enhance the reliability of electricity supply, extend the useful life of power system components, and reduce system operating costs".

This declaration was reinforced with instructions to the Energy Working Group (EWG) "to start an APEC Smart Grid Initiative (ASGI) to evaluate the potential of smart grids to support the integration of intermittent renewable energies and energy management approaches in buildings and industry" (APEC, 2011). ASGI comprises four main elements:

1. Survey of Smart Grid Status and Potential.
2. Smart Grid Road Maps.
3. Smart Grid Test Beds.
4. Smart Grid Interoperability Standards.

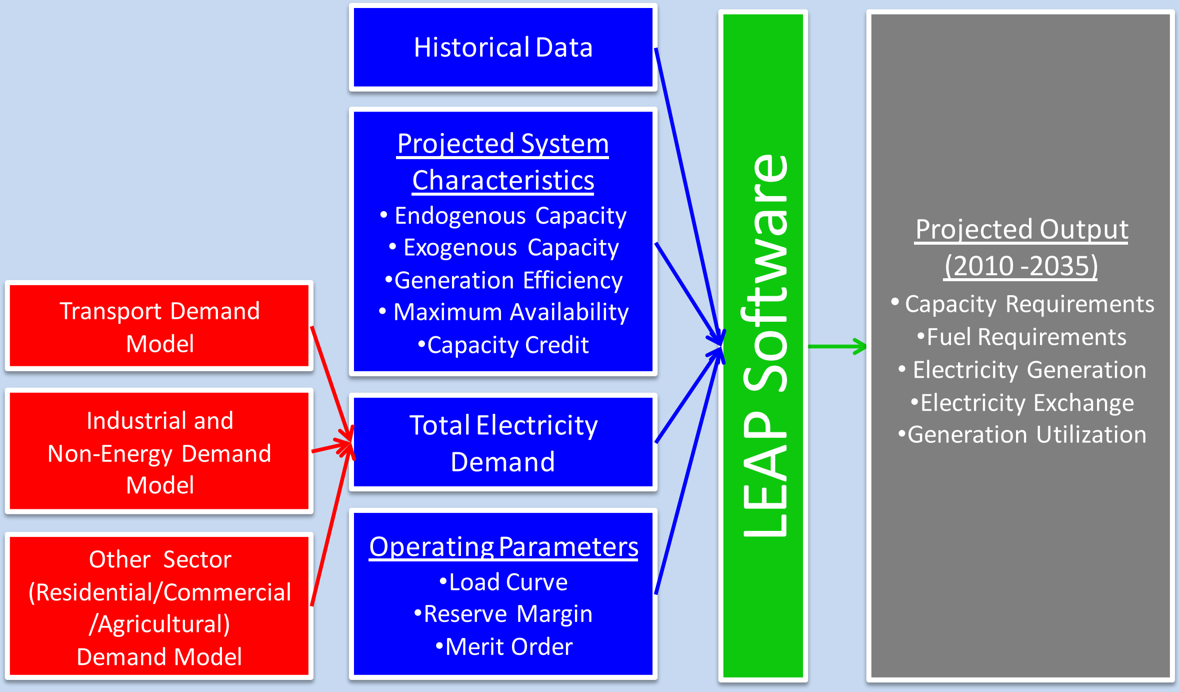
As of 2011, APEC member economies are in various states of smart grid development, including conducting demonstrations and engaging in joint projects with other economies (APEC, 2011). The Knowledge Sharing Platform (KSP), established in the EWG-41 Meeting in May 2011, is a tool for collecting and sharing best practices for creating energy smart communities. The KSP website is the best resource for the latest information on smart grid initiatives and projects in APEC economies (APEC, 2012).

APERC'S ELECTRICITY SUPPLY MODEL AND HOW IT WORKS

Because of the complexities involved in modelling electricity supply, APERC uses an off-the-shelf model known as the LEAP (Long-Range Energy Alternatives Planning) system developed by the Stockholm Environment Institute (SEI, 2012). LEAP is a flexible planning tool used in many organizations worldwide. Although LEAP is a complete energy supply and demand modelling system, APERC has elected to use LEAP only for modelling electricity supply. Other parts of the APEC Energy Demand and Supply model were developed by APERC and are described in other chapters of this volume.

LEAP simulates decision-making in the electricity supply sector based on the inputs shown in Figure 9.12 below. The outputs extracted from LEAP simulations are listed in the same figure.

Figure 9.12: APERC's Electricity Supply Model



Two types of generation capacities are defined in LEAP. 'Exogenous capacity' is generation capacity that either already exists or which the modeller believes is sure to be built. 'Endogenous capacity' is additional generation capacity that LEAP can choose to build if required by the system. Both types of generation capacities are defined in terms of key variables, including fuel type and generation efficiency, maximum availability, and percentage capacity credit. For exogenous generation, the year in which the capacity will be retired is also defined.

Total demand for electricity in each year is a model input that comes from summing the electricity demand results from each demand sector model. For this outlook, the demand sector models are the Industrial and Non-Energy Demand Model, the Transport Demand Model and the Other Sector Demand Model. These demand models are described elsewhere in this volume.

LEAP requires the modeller to specify a load curve for the economy, which defines how this demand fluctuates throughout the day and throughout the year. LEAP is thus able to effectively estimate a demand for electricity during each hour of the year. The modeller also supplies a merit order, which defines the order in which various types of generation capacities are to be used. In general, renewable generation is used first since it has no fuel cost, next the efficient base-load generation (usually coal or combined-cycle gas turbine) is used, and, when these types are not sufficient, a less efficient peaking unit such as an open-cycle gas turbine is used. Based on this information, LEAP decides how to dispatch the generation in each hour of the year.

Over the longer term, LEAP must also decide what new generation should be added. The user supplies a required level of reserve capacity for the economy. In years when this reserve requirement cannot be met during the hour of peak demand, LEAP adds capacity from the modeller-specified endogenous capacity. The modeller specifies an addition order for each increment of endogenous capacity, allowing LEAP to add endogenous capacity according to this pre-specified order until it can meet the reserve requirement in that year.

In this way, LEAP simulates electricity supply for an economy in each year of the outlook period. It then sums up and reports the results in each year, including fuel requirements for each fuel, the amount of electricity generated by each fuel type, the required capacity additions, and the use of each type of generation.

In setting up the model inputs for each economy, APERC researchers considered the energy resources available in the economy and the economy's policies and plans for generation capacity additions.

REFERENCES

ABB (2007), *Energy Efficiency in the Power Grid*, http://www04.abb.com/global/seitp/seitp202.nsf/c71c66c1f02e6575c125711f004660e6/64cee3203250d1b7c12572c8003b2b48/$FILE/Energy+efficiency+in+the+power+grid.pdf

APEC (Asia-Pacific Economic Cooperation) (2010), *Fukui Declaration – Low Carbon Paths to Energy Security: Cooperative Energy Solutions for a Sustainable APEC*, www.apec.org/Meeting-Papers/Ministerial-Statements/Energy/2010_energy.aspx

— (2011), *Using Smart Grids to Enhance Use of Energy-Efficiency and Renewable-Energy Technologies*, APEC Energy Working Group, http://publications.apec.org/publication-detail.php?pub_id=1152

— (2012), *Smart Grids, APEC Energy Smart Communities Initiatives – Knowledge Sharing Platform*, http://esci-ksp.org/?task=smart-grids

APERC (Asia Pacific Energy Research Centre) (2008), *Energy Efficiency in the APEC Region*, www.ieej.or.jp/aperc/2008pdf/2008_Reports/Energy%20Efficiency%20in%20the%20APEC%20Region%201%20APERC%202008.pdf

BDEPD (Brunei Darussalam Department of Economic Planning and Development) (2010), *Brunei Darussalam Statistical Yearbook 2010*, www.depd.gov.bn/SI/BDSYB2010/BDSYB%202010.pdf

Bhalla, M. S. (2000), "Transmission and Distribution Losses (Power)", National Conference on Regulation in Infrastructure Services: Progress and Way Forward, 14–15 November 2000, www.teriin.org/index.php?option=com_publication&task=details&sid=355

Eurelectric (Union of the Electricity Industry) (2003), *Efficiency in Electricity Generation*, www.eurelectric.org/Download/Download.aspx?DocumentID=13549

IDGEEU (Indonesia Directorate General of Electricity and Energy Utilization) (2011), *Statistics Book of Electricity and Energy Number 24-2011*, www.djlpe.esdm.go.id/modules/_website/files/1049/File/Statistik%202010%20DITJEN%20LISTRIK.pdf

IEA (International Energy Agency) (2010), *Power Generation from Coal: Measuring and Reporting Efficiency Performance and CO_2 Emissions*, www.iea.org/ciab/papers/power_generation_from_coal.pdf

— (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

Khandker, Shahidur R., Douglas F. Barnes and Hussain A. Samad (2012), "The Welfare Impact of Rural Electrification in Bangladesh", *The Energy Journal*, Vol 33 No 3, 2012, pp. 187–206.

MSener (Mexico Secretaría de Energía) (2010), *Cuarto Informe de Labores 2010*, www.sener.gob.mx/res/0/CuartoInformeLaboresSENER2010.pdf

Pezzini, Paola, Oriol Gomis-Bellmunt and Antoni Sudrià-Andreu (2011), "Optimization techniques to improve energy efficiency in power systems", *Renewable and Sustainable Energy Reviews*, No 15, pp 2028–2041.

PNG (Papua New Guinea Department of National Planning and Monitoring) (2010), *Papua New Guinea Development Strategic Plan 2010–2030*, www.treasury.gov.pg/html/publications/files/pub_files/2011/png-development-strategic-plan.2010-2030.pdf

— (2011), *Papua New Guinea presents Power Energy and Sources,* http://nrec.mn/data/uploads/Nom%20setguul%20xicheel/Water/badrakh%20china/Papua%20new%20guinea%20presents.pdf

PNGCP (Philippines National Grid Corporation) (2011), *Transmission Development Plan 2011*, www.ngcp.ph/tdp.asp

RME (Russian Federation Ministry of Energy) (2012), *The Russian Federation Energy Data 2011*, in Russian, www.minenergo.gov.ru/activity/

SEI (Stockholm Environment Institute) (2012), 'Introduction to LEAP' website page, www.energycommunity.org/default.asp?action=47

Siemens (2012), "Siemens receives German Industry's Innovation Award – Award for world's most efficient gas turbine power plant", 12 February 2012, www.siemens.com/press/en/pressrelease/?press=/en/pressrelease/2012/energy/fossil-power-generation/efp201202028.htm

TDEDE (Thailand Department of Alternative Energy and Efficiency) (2010), "Electric Power in Thailand" in *Annual Report 2010*, www.dede.go.th/dede/images/stories/060554_circular/report_electric__2553_3.pdf

VGSO (Vietnam General Statistics Office) (2009), *Statistical Yearbook of Vietnam*, www.gso.gov.vn

World Bank (2009), *Welfare Impact of Rural Electrification, Evidence from Vietnam*, http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2009/09/17/000158349_20090917100619/Rendered/PDF/WPS5057.pdf

— (2012), 'Access to Electricity' website page, http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS/countries?display=default

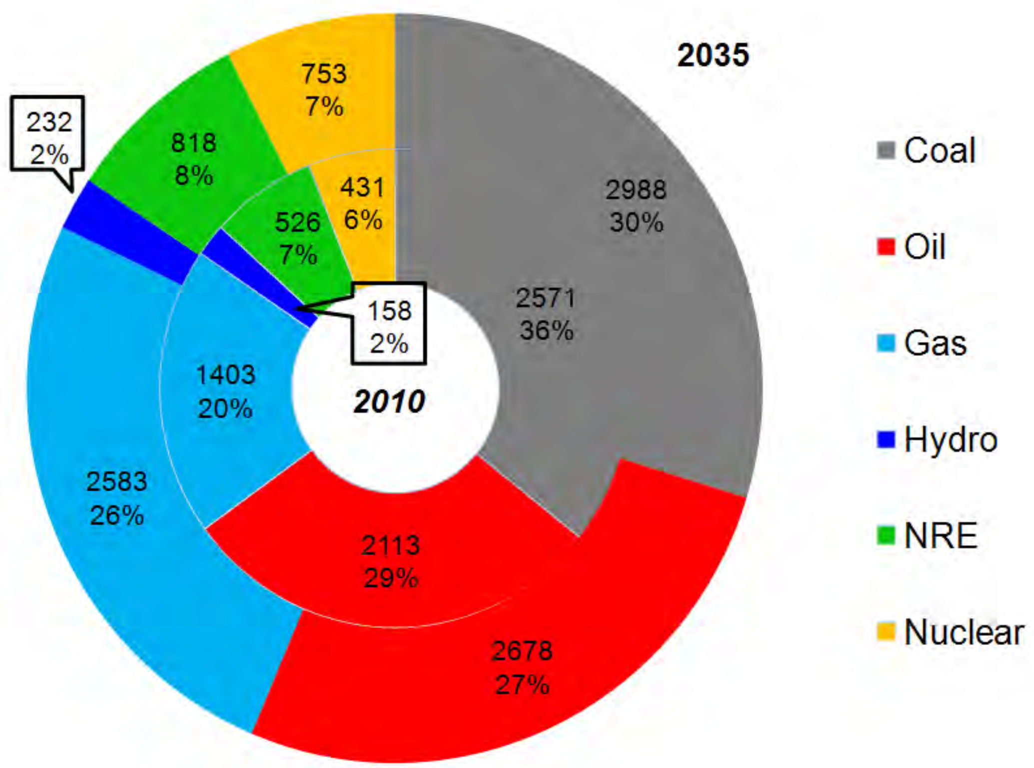
10 PRIMARY ENERGY DEMAND AND SUPPLY

APEC contains some of the world's largest energy producers, but also some of the world's largest energy importers. Most coal, gas and nuclear fuels used in the APEC region are sourced within the region, while a considerable share of oil is sourced from outside APEC. Overall, APEC's 2010 oil production was equivalent to nearly three-quarters of its primary oil demand.

This chapter discusses the outlook for the primary energy supply in the APEC region. 'Primary energy' refers to energy in its original form, before the conversion of primary fuels to electricity and before the conversion of crude oil into petroleum products.

Given that demand must equal supply, the term 'primary energy demand' can be used almost interchangeably with 'primary energy supply'. However, customary usage appears to favour 'primary energy supply', so that term is used in this chapter. Primary energy supply includes energy from both domestic and imported sources.

Figure 10.1: Total Primary Energy Supply, in Mtoe and Percent, 2010 and 2035



Source: APERC Analysis (2012)

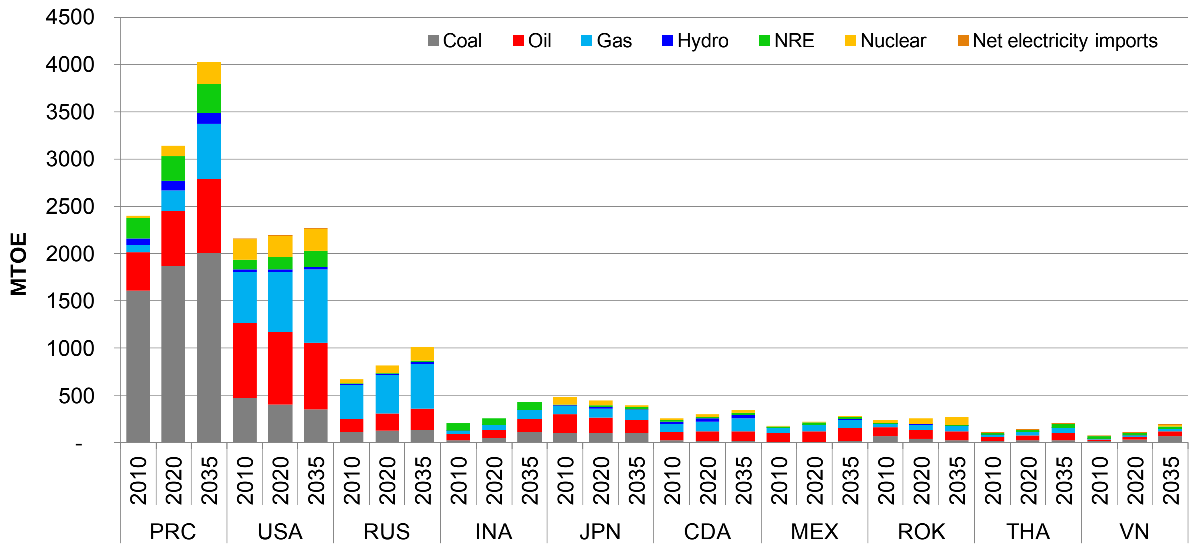
TOTAL PRIMARY ENERGY SUPPLY

APEC's total primary energy supply amounted to about 7204 Mtoe in 2010. Under business-as-usual (BAU) assumptions it is projected to grow 40% to reach 10 057 Mtoe by 2035. This amounts to an average annual growth rate of 1.3%.

Of all the energy sources that compose primary energy supply, gas will be the fastest growing in both absolute and percentage terms in the outlook period. Gas will grow 84%, while nuclear will grow 75%, new renewable energy (NRE) will grow 55%, hydro will grow 46%, and oil will grow 27%. The slowest growing primary energy supply source will be coal, which is expected to grow about 16%. As discussed in Chapter 14, despite concerns about nuclear energy's safety in light of the accident at Japan's Fukushima Daiichi Nuclear Power Plant in 2011, APERC's analysis of member economy's policies suggest that nuclear development in the APEC region will continue under BAU scenario. Only in Japan and Chinese Taipei is nuclear power production projected to decline.

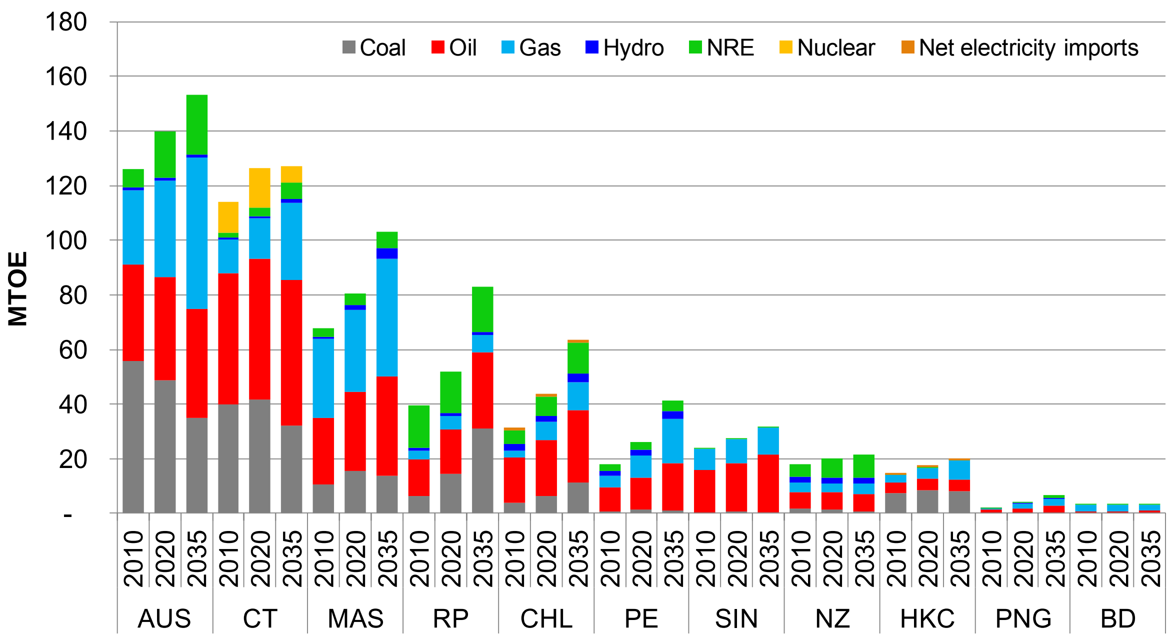
As shown in Figure 10.1, projections indicate that by 2035 the total APEC primary energy supply will be made up of coal (30%), oil (27%), gas (26%), NRE (8%), nuclear (7%) and hydro (2%). The most significant changes from 2010 will be within the fossil fuels—coal will decrease its share considerably while gas will expand its contribution. Nuclear and NRE are also likely to increase their role in the primary energy supply by 2035. Many APEC economies are striving to lower their CO_2 emissions by shifting away from coal and oil in favour of gas, NRE and nuclear.

Figure 10.2: Primary Energy Supply by Energy Source, Higher Primary Energy Supply Economies



Source: APERC Analysis (2012)

Figure 10.3: Primary Energy Supply by Energy Source, Lower Primary Energy Supply Economies



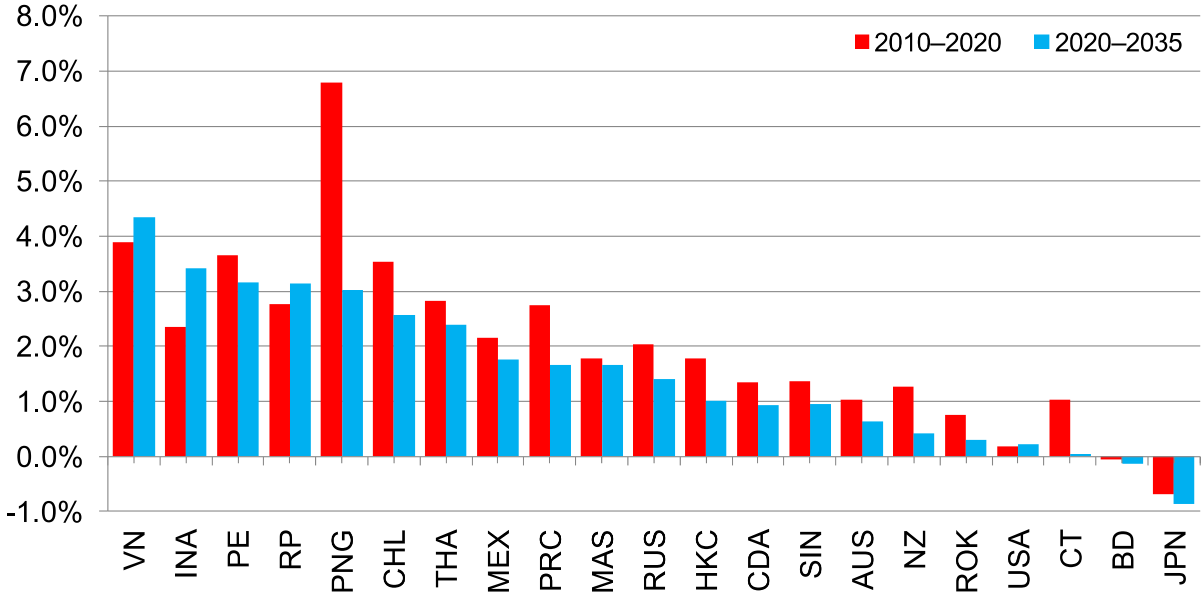
Source: APERC Analysis (2012)

On an economy basis, China, the US and Russia will represent more than two-thirds of APEC's primary energy supply by 2035. Figures 10.2 and 10.3 show the projected primary energy supply by economy—note the different scale used in the two figures.

Figure 10.4 presents the estimated primary energy supply growth rates for all APEC economies. The largest increases are expected in developing economies, particularly in Viet Nam, Indonesia, Peru, the Philippines, and Papua New Guinea.

Estimates of primary energy supply growth in China and other developing economies are lower. Growth is generally moderate in the developed economies. In Brunei Darussalam and Japan, the primary energy supply will decrease over the outlook period—in Brunei by 2.5% and in Japan by 18%. In the case of Brunei, the replacement of its electricity generation infrastructure with more efficient combined-cycle plants will improve the efficiency of gas utilization, while in the case of Japan, population shrinkage and energy efficiency improvements are the main drivers.

Figure 10.4: Primary Energy Supply Average Annual Growth Rate by Economy, 2010–2020 and 2020–2035



Source: APERC Analysis (2012)

APEC'S GOAL TO RATIONALIZE AND PHASE OUT FOSSIL FUEL SUBSIDIES

Subsidies for fossil fuels have many adverse impacts. For the economies concerned:

- (where subsidies are government funded) they drain government budgets
- (where subsidies take the form of price controls on energy producers) they discourage investment and reduce domestic production
- they encourage wasteful consumption
- consequently, they threaten energy security by reducing fossil fuel exports and/or increasing fossil fuel imports
- they increase CO_2 emissions and local pollution.

They also:

- encourage fuel smuggling
- discourage low-carbon energy investment.

While often justified as assistance for the poor, in practice fossil fuel subsidies disproportionately benefit the middle-class and the rich, who can afford the appliances and vehicles that consume fossil fuels. The IEA estimates that of the USD 409 billion spent on fossil fuel subsidies worldwide in 2010, only USD 35 billion, or 8%, reached the poorest 20% of the population (IEA, 2011, p. 519).

Despite their adverse impacts, fossil fuel subsidies are widespread around the world and in the APEC region. Politically, they are difficult to remove, as the benefits to individual consumers are easy for them to see, while the adverse impacts on society as a whole are less obvious. Intensified educational efforts and greater transparency about the costs of subsidies may be helpful.

There are many ways to measure the cost of fossil fuel subsidies. The IEA has used a 'price gap' approach to measure consumer-oriented energy subsidies. This approach measures the difference between the prices paid by consumers and the full cost of supply. Based on this approach, the IEA has identified fossil fuel subsidies in 11 APEC economies. These are shown in Table 10.1. This approach measures only subsidies that result in prices below those that would prevail in a competitive market. There are numerous other subsidies targeted at encouraging production that are not reflected here, and these exist in additional APEC economies not listed in the table, including Australia, Canada, and the United States (IEA, 2011, p. 511).

Because of their adverse impacts, APEC leaders, beginning with their Singapore Declaration of 2009, have committed the APEC economies to "rationalise and phase out over the medium term fossil fuel subsidies that encourage wasteful consumption, while recognising the importance of providing those in need with essential energy services" (APEC, 2009). The Leaders 2011 Honolulu Declaration added the call for a voluntary reporting mechanism on progress, which they will review annually (APEC, 2011). This mechanism is currently under development by the APEC Energy Working Group.

Table 10.1: Estimated Consumer-oriented Fossil Fuel Subsidies in 2010

Economy	Subsidy as Percent of Full Cost of Supply	Subsidy in USD/person	Subsidy as Percent Share of GDP	Subsidy by Fuel (Billion USD/Year)			
				Oil	Gas	Coal	Electricity
Brunei Darussalam	31.9	840	2.6	0.19	0	0	0.15
China	3.8	16	0.4	7.77	0	2.01	11.54
Indonesia	23.2	66	2.3	10.15	0	0	5.79
Korea	0.4	4	0	0	0	0.18	0
Malaysia	20.0	200	2.5	3.89	0.97	0	0.81
Mexico	12.5	84	0.9	9.34	0	0	0.16
Philippines	7.3	12	0.6	1.10	0	0	0
Russian Federation	22.6	274	2.7	0	16.95	0	22.26
Chinese Taipei	1.8	25	0.1	0.24	0	0	0.34
Thailand	20.7	123	2.7	2.11	0.48	0.44	5.44
Viet Nam	14.4	33	2.8	0	0.23	0.01	2.69

Source: IEA (2012)

MODELLING FOSSIL FUEL PRODUCTION

In our projections of the future supply of fossil fuels in the APEC region, APERC has relied primarily on official government or government-sponsored projections from each economy. For economies where these are not available, APERC sought to find reliable independent sources. However, very few economy governments or independent sources make projections 25 years ahead, so a good deal of judgement on the part of APERC was required for the later years of the projection. Typically, we based projections for the later years on trends in the earlier years and on available estimates of the extent of the economy's resources. These long-term projections are, therefore, subject to a high degree of uncertainty.

Most APEC economies have not been well explored for oil and gas, so the full extent of their resources is not known. Furthermore, oil and gas exploration and production technology continues to improve (see the discussion of unconventional oil in Chapter 11 and unconventional gas in Chapter 12), and by 2035 this progress could allow production of resources not currently considered economic. APERC's oil and gas production estimates should, therefore, be viewed as conservative.

REFERENCES

APEC (Asia-Pacific Economic Cooperation) (2009), '2009 Leaders' Declaration: Singapore Declaration – Sustaining Growth, Connecting the Region' website page, www.apec.org/Meeting-Papers/Leaders-Declarations/2009/2009_aelm.aspx

— (2011), '2011 Leaders' Declaration: The Honolulu Declaration – Toward a Seamless Regional Economy' website page, www.apec.org/Meeting-Papers/Leaders-Declarations/2011/2011_aelm.aspx

IEA (International Energy Agency) (2011), *World Energy Outlook 2011*, Paris.

— (2012), 'World Energy Outlook, Fossil Fuel Subsidies Database' website page, www.iea.org/subsidy/index.html

11 OIL SUPPLY

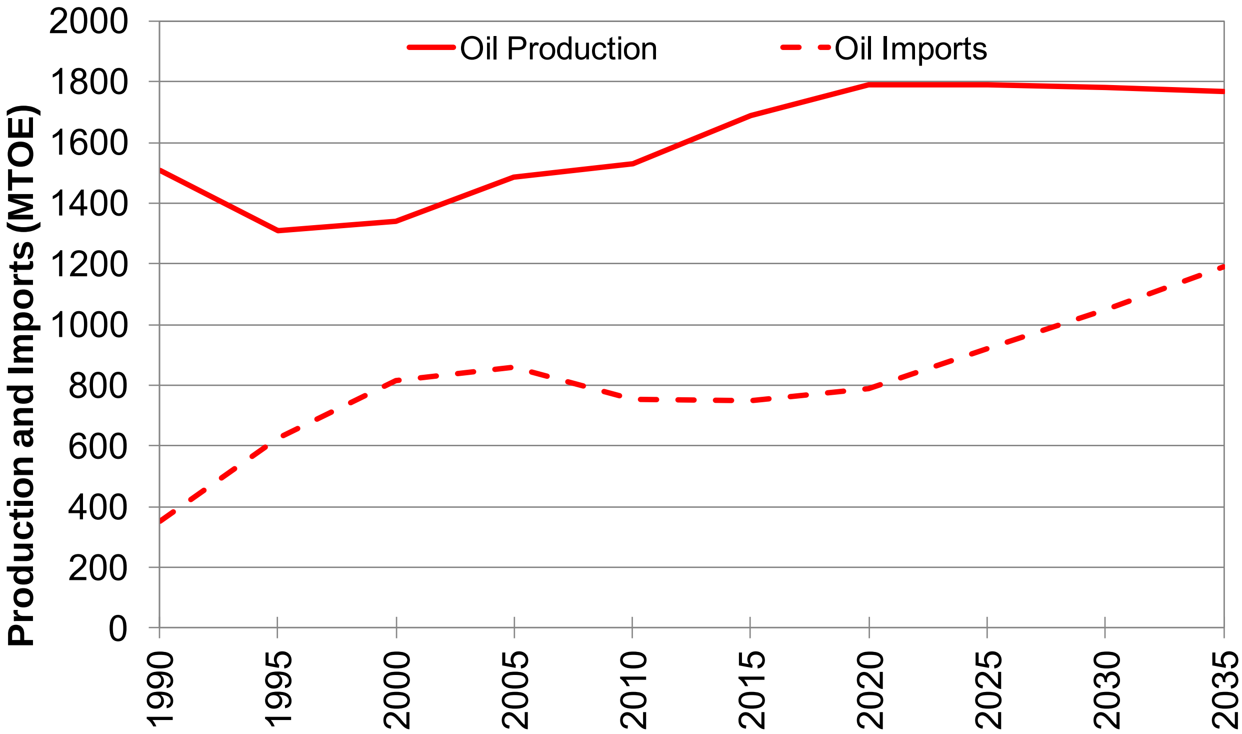
APEC OIL PRODUCTION AND IMPORTS

Since 1990, oil production in the APEC region has increased only slightly, while oil demand has risen significantly. As a result, oil imports into the APEC region have grown faster than oil production. APEC's oil production, including natural gas liquids (NGLs) reached 1498 million tonnes of oil equivalent (Mtoe) in 2009, which accounted for roughly 37% of worldwide production.

As shown in Figure 11.1, oil production in the APEC region is projected to grow to about 1790 Mtoe in the early 2020s and then to roughly level off. On the other hand, APEC's oil demand is likely to continue to grow faster than its oil supply.

As discussed in Chapter 5, rapid oil demand growth is being driven primarily by growing vehicle ownership in the developing economies of the APEC region. As a result, APEC's oil imports are likely to grow 55% between 2009 and 2035. There are, of course, many uncertainties in these projections, especially in the later years when the increased production of unconventional oil could push production upward.

Figure 11.1: APEC Total Oil Production and Net Oil Imports, 1990–2035



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011

Today, technologies for oil exploration and production are evolving quite rapidly. As the existing oil reserves deplete and traditional supplies become scarcer, producers are shifting their targets towards resources that are more costly and technically complex. High oil prices have made this shift possible, stimulating advances in technology that have made many unconventional and frontier resources economic. Resources long considered sub-commercial are now being integrated into the world oil supply; see the sidebar 'The Increasing Importance of Frontier and Unconventional Oil' in this chapter.

Unlike conventional oil, which is predominantly located in a few regions in a few economies, unconventional resources are more widely distributed, which is another incentive for developing them. Since the late 2000s, efforts to develop unconventional oil resources have been especially intensive in the APEC economies in North America. As with unconventional gas, discussed in Chapter 12, the ability to develop these resources in other APEC economies may depend as much on the institutions that make their development possible as it does on the resources themselves. In addition to extensive technology transfer, providing a reasonably stable and transparent system of regulations, taxes, and fiscal terms for oil producers is of critical importance.

THE CHALLENGE OF OIL SECURITY

This increasing dependency on oil imported from outside the region in the business-as-usual (BAU) case means the APEC economies may face at least four kinds of risks to their economies:

1. The availability of oil supplies could be threatened by political events in other regions, such as the Middle East and Africa.
2. The availability of oil supplies will depend on the ability of national and international oil companies in these other oil producing regions to make adequate investments.
3. As oil production becomes more concentrated in a few countries, oil prices will be increasingly influenced by the market power of the producing countries.
4. Increasing amounts of oil will need to be moved longer distances, typically from the Middle East or Africa, which poses additional security risks.

The likely outcomes of the APEC region's import dependency are:

- Continued oil price volatility will be a near certainty.
- There will be significant risks of supply disruptions.
- Both of the above threaten the economic stability of APEC economies and the world.

These conclusions hold even for the APEC economies that are not oil importers, or that are likely to become less dependent on oil imports over the outlook period (such as the United States). In today's globally-integrated economy, a crisis in the oil market affecting oil imports anywhere, will be felt everywhere.

THE INCREASING IMPORTANCE OF FRONTIER AND UNCONVENTIONAL OIL

Frontier and unconventional oil development requires complex technologies, facilities, and processes which differ from those traditionally used by the oil industry. Compared to conventional oil, their cost is higher and their environmental impacts are potentially larger. Nevertheless, their emergence has substantially expanded the scope of hydrocarbons available for mankind. This section provides a brief overview of the opportunities and challenges posed by each type of frontier and unconventional oil.

Deepwater Oil

Generally, the greater the water depth, the greater the efforts required to extract hydrocarbons and hence the larger the investment required. Oil extraction activities at water depths of less than 300 metres (1000 feet) are regarded as shallow water wells and are similar to onshore wells since the continental shelf is still present. On the other hand, wells drilled in water depths from 300 metres (1000 feet) to approximately 1500 metres (5000 feet) are considered deepwater wells. Although this range may differ among producers and economies, these are the boundaries adopted by the industry in the Gulf of Mexico, the most intensive deepwater oil producing area in the world (USEIA, 2009a; USBSEE, 2012). Production beyond the upper limit is regarded as ultra-deepwater, entailing the highest risks and most intricate technical requirements.

Despite this complexity, technological progress is constantly allowing the drilling of oil wells in water of greater depths. While many wells in the Gulf of Mexico and Brazil are producing oil at water depths of 2 kilometres (km), in April 2011 a well was drilled in India at a water depth of over 3.1 km (10 194 feet) (Transocean, 2012). Especially since the early 1990s (USBSEE, 2012), deepwater oil has increased its strategic role in the total oil supply. This is particularly true in the US, where deepwater operations started in the 1970s. The contribution of the deepwater output in the Gulf of Mexico accounted for almost a quarter of US domestic oil production in 2010 (USEIA, 2012b).

In addition to the US, deepwater operations are concentrated in Brazil and West Africa. Deepwater output is estimated to account for as much as 7% of the world's total oil output in 2012, and is expected to rise to nearly 10% by 2020 (BP, 2012). The general consensus is that this contribution is likely to grow over the next few years. In Brazil, for instance, the ultra-deepwater reservoirs at Lula in the Santos Basin hold resources estimated to be 5–8 billion barrels (Petrobrás, 2009); while nearly all of Angola's current production and proved reserves of 9.5 billion barrels lie offshore, mostly in deepwater (USEIA, 2011).

Deepwater oil projects require special technology and infrastructure. Since their costs are greater than those for conventional oil production, they call for significant capital expenditure and expansion of current technical frontiers. As a reference, in the US from 2007 to 2009, the average total costs of offshore oil production were 64% higher than the costs of onshore oil production (USEIA, 2012c). Adding to this complexity, tighter environmental and safety requirements after the 2010 Deepwater Horizon oil spill in the Gulf of Mexico could entail additional costs.

Arctic Oil

The Arctic is one of the world's least explored and exploited oil frontiers. In spite of being regarded as conventional in terms of its geological characteristics, the technical challenges of developing it are huge. This is primarily due to the Arctic's extreme weather and ice, its lack of infrastructure, its logistical limitations and its isolated conditions. Even though the first large field discovered was Russia's Tazovskoye in 1962, the Alaskan North Slope is by far the best known project (USEIA, 2009b). According to a US Geological Survey's assessment of 25 Arctic basins (USGS, 2008), the potential technically-recoverable conventional oil resources are estimated to be nearly 90 billion barrels, which amounts to about three years of global oil demand in 2010. A third of those resources are concentrated in the Arctic Alaska Basin.

The rapid development of the Arctic oil in the US started in the 1970s when significant oil resources were discovered at Prudhoe Bay in Alaska's North Slope. In spite of its high costs and environmental challenges, the energy shocks in the 1970s helped push the project to completion. By 1988 production had reached its peak at 2.2 million barrels per day, accounting for 24% of the US oil production in that year. Although natural decline and the lack of significant further discoveries have resulted in a production drop at an average annual pace of 5.3% from 1988 to 2010, the North Slope still represents nearly all of Alaska's oil output. The state accounted for 11% of the US production in 2010 and it is the second-largest oil producing state after Texas. According to the US Department of Energy (USDOE, 2009a), Alaska's untapped oil resource in its already developed fields has an estimated potential of 6.1 billion barrels. That could expand to roughly 35 billion barrels if restrictions are lifted on exploration and production in the 1.5 million-acre coastal plain designated as the 1002 Area of the Arctic National Wildlife Refuge, the National Petroleum Reserve and the Outer Continental Shelf.

During the second quarter of 2012, Russia's oil company Rosneft reached agreements with several international oil companies to advance its Arctic exploration and production activities, including in its four blocks in the Kara and Barents Seas (Rosneft, 2012b). These blocks have an oil potential amounting to 46 billion barrels. According to current schedules, seismic studies will be done shortly, with the first wildcat well to be drilled by 2015 and full-scale production expected from 2016 or 2017 (Rosneft, 2012a).

Tight Oil

'Tight oil' is a term used primarily to describe oil produced from low permeability shales, the same shales that produce 'shale gas', as described in Chapter 12. Tight oil is sometimes referred to as 'shale oil'. Although it might seem more natural to refer to tight oil as 'shale oil', that term is easily confused with 'oil shale', a term which describes a completely different type of resource (see below). APERC uses the term 'tight oil'. The word 'tight' denotes the characteristic low permeability of the rock in the reservoirs. It is this characteristic which calls for different production methods to extract the oil.

Due to this low permeability, tight oil has historically been unattractive for development, with producers in the US bypassing it to focus on other resources less difficult to develop (USDOE, 2009b, p. 14). It was only in the late 2000s that tight oil was able to be commercially produced by means of a combination of hydraulic fracturing and horizontal drilling.

Technological advances in the last few years, as well as high oil prices, mean conditions are favourable for the expansion of tight oil supply in the US. Since the technology and methods involved in producing tight oil and shale gas are basically the same, at least in the US, tight oil supply is affected by the relative prices of oil and gas. Specifically, gas producers have moved to reservoirs richer in oil as the price of gas has fallen relative to oil. According to recent US Government projections (USEIA, 2012a), tight oil production in the US could grow at an average rate of 8.1% per year under the most optimistic scenario, rising from 0.4 million barrels per day in 2010 to 2.8 million barrels per day (about 140 Mtoe per year) by 2035. This is roughly equivalent to 37% of the total oil output of 7.5 million barrels per day produced in the US in 2010.

As with other unconventional resources, tight oil development presents some challenges. It requires cutting-edge technology and expertise, intensive drilling, the availability of considerable volumes of water to be injected into the wells, and extensive infrastructure and auxiliary services. All these mean tight oil production requires larger capital expenditures in comparison to conventional oil production (IHS, 2011). Rising environmental concerns, mainly to do with the risk of polluting groundwater aquifers and with land disturbance due to drilling activities, might hinder accelerated tight oil development on a global basis (USDOE, 2009b).

In response to these concerns, governments are considering or implementing stricter environmental standards, which could slow the development of tight oil. There are also uncertainties about the ability of other economies to replicate the successful experience of the US. The US has some advantages including a vast resource base, flexible land leasing arrangements, extensive oil development infrastructure and supporting services, and decades of practice and knowledge not present in most other economies. Additional characteristics of the US stimulating the development of tight oil supply are an abundance of small-sized independent oil producers who are willing to take risks, combined with a financial sector eager to fund new ventures (Maugeri, 2012).

Extra-Heavy Oil

Extra-heavy oil is viscous and does not flow easily under normal conditions. Apart from being far more challenging to produce, it yields less high-value products in comparison to lighter crude oil types. Extra-heavy oil reservoirs are located mainly in Venezuela and Russia as well as in the oil sands of Canada.

Oil sands are a solid, extra-heavy type of crude oil composed of a mixture of natural bitumen, sand, water and clay. The largest known deposits are located in the Athabasca oil fields of the Canadian province of Alberta. Sometimes referred to as 'tar sands', this term is considered less appropriate in the industry as oil is the ultimate product obtained from these resources. Since its beginning in 1967, Canada's oil sands production has grown continuously—by 2010 it amounted to 1.6 million barrels per day, accounting for as much as 57% of Canada's total oil production. According to domestic industry projections, oil sands supply is likely to grow 2.3 times by 2030 to reach 5.3 million barrels per day (about 265 Mtoe per year) and represent 85% of Canada's total oil production (CAPP, 2012a).

For oil sands to be economically produced, two methods are employed. For deposits that are deeply buried, a process intensive in energy and water known as in-situ recovery is used. In this process, steam is injected into the ground to soften the bitumen and allow it to flow to the wellbore. Later, it can be converted to synthetic crude (syncrude) at special processing units (upgraders). For resources that lie close to the surface, the oil sands can be mined and processed aboveground. Although both methods are used in Canada, in-situ production accounts for about 80% of the total production (CAPP, 2012b).

Extra-heavy oil and oil sands are expected to become more significant in global oil production. While the extra-heavy oil deposit in the Orinoco Belt of Venezuela is believed to be one of the largest oil reservoirs in the world and constitutes 86% of Venezuela's total oil reserves (PDVSA, n.d.), the share of oil sands in Canada's oil reserves, at 97%, is even higher (CAPP, 2012b). The abundance of these unconventional resources gives both these economies the largest oil reserves in the world along with Saudi Arabia (OGJ, 2011).

Since late 2011, the available pipeline network that transports Canadian oil to the consuming and refining centres in eastern Canada and across the US has reached capacity. This poses a major challenge to the further development of the oil sands. Apart from the large investments required to develop the potential of these unconventional resources, the role of technology in increasing their sustainability will be critical in determining their future contribution. As a reference, technology has enabled a 26% reduction in carbon emissions per barrel of oil produced in 2012 compared to 1990 levels (IPIECA, 2012) and the improving trend is expected to continue.

Oil Shale

Oil shales are sedimentary rocks (mudstones and shales) containing organic matter known as kerogen. Since these rocks have not been buried deep enough and long enough for heat and pressure to transform the kerogen into oil, it is common to find them at shallow depths. This calls for production methods different to those used for conventional oil. Since the main component present in the rock is kerogen, oil shale is sometimes known as 'kerogen oil' (IEA, 2011, p. 120).

The most common method of yielding oil from rock is to retort the rock to very high temperatures (approximately to 450°C) either in place or by having the rock mined first and processed later. Since the in-situ heating and injection of fluids, or the mining, retorting and upgrading of the rock, involves huge amounts of capital and energy, oil prices need to be high for oil shale to cover the investment required and to be considered viable. Studies done for the US Department of Energy (Bartis et al., 2005) found that for a project of this kind to be feasible oil prices would need to be at least USD 70–95 in 2005 terms. For this reason, some economies just burn the mined rock in a similar manner to coal. This is the case in Estonia, where this method provides more than 90% of its electricity generation (EMOE, 2008).

Estimates suggest the global oil shale resources are very large, amounting to at least 4.8 trillion barrels (WEC, 2010, p. 93). One of the richest oil shale deposits is in the Green River area of the US, in the states of Colorado, Utah and Wyoming. Other significant oil shale resources are located in Australia, Brazil, China, Estonia, Jordan and Morocco. However, commercial exploitation was carried out in only a few of those economies in 2010, and mainly on a small scale. In the APEC region, apart from the US there are projects underway in Australia, Canada, China, Russia and Thailand (WEC, 2010).

As well as needing sustained high oil prices to cover its costs, oil shale production is energy intensive. It entails larger emissions of CO_2 than conventional oil production and it may have other significant environmental impacts. Therefore, to promote oil shale production and to increase its integration into the global oil supply, intensive research aimed at lowering its costs and minimising its environmental impacts is needed.

Other Sources of Oil

Apart from the unconventional resources discussed above, other technologies have not been widely commercialized yet, due to their prohibitive costs and adverse environmental impacts. One of these technologies is gas-to-liquids (GTL). This involves the use of natural gas as an input which is then processed to produce heavier hydrocarbons, similar to those obtained from oil refining. In 2011, the application of GTL was limited, with some plants installed in Malaysia, South Africa and Qatar. However, more GTL facilities could be built, especially on the US Gulf Coast and in Russia (IEA, 2011; Shell, n.d).

In the case of coal-to-liquids (CTL), coal is used as a feedstock to produce oil products. The use of CTL is also limited and its employment is favoured in those economies with abundant coal resources. In South Africa, a little less than one-third of its gasoline and diesel demand is supplied from coal (World Coal Organization, n.d.).

The development of these technologies may appear tempting—gas and especially coal reserves are larger and better distributed, and their prices are usually lower on an energy basis compared to conventional oil. Nonetheless, the technology involved in these processes is costly; and the processes themselves are energy intensive due to the loss of heat value in processing, and they require huge amounts of water.

Technology could play a critical role, not only in adding volumes of unconventional oil to the global oil supply, but also in designing solutions to reduce the environmental impacts. To illustrate, one of the processes of enhanced oil recovery aimed at improving the productivity of oil wells, CO_2 injection, could both increase oil production and avoid the release of CO_2 into the atmosphere. But for this practice to be feasible, costs need to be reduced. Although there has been limited use of CO_2 injection in the US and Saudi Arabia (IEA, 2011, p. 132; Hyne, 2001, p. 443), the speed and magnitude of technology developments during the outlook period will influence its further implementation.

OIL PRODUCTION BY ECONOMY

APEC's oil production is expected to grow 15% from 1530 Mtoe in 2010 to 1767 Mtoe in 2035. Nearly all of this growth is expected to come from North America, with the contributions from Canada, the US and Mexico projected to expand by 114%, 42% and 29% respectively during the outlook period. This growth will be driven mainly by the development of their unconventional resources.

The increase in oil production in Canada is expected to be supported by its oil sands, and in the US by its tight oil supply going hand-in-hand with its rapidly-growing shale gas production. In Mexico, the beginning of its deepwater production, the development of new fields, and the use of enhanced recovery methods in mature fields will provide the incremental production.

Outside North America, other economies are also likely to increase their production by 2035. These economies include China, Peru and Australia, although their joint contribution to APEC's growth during the outlook period is expected to be less significant.

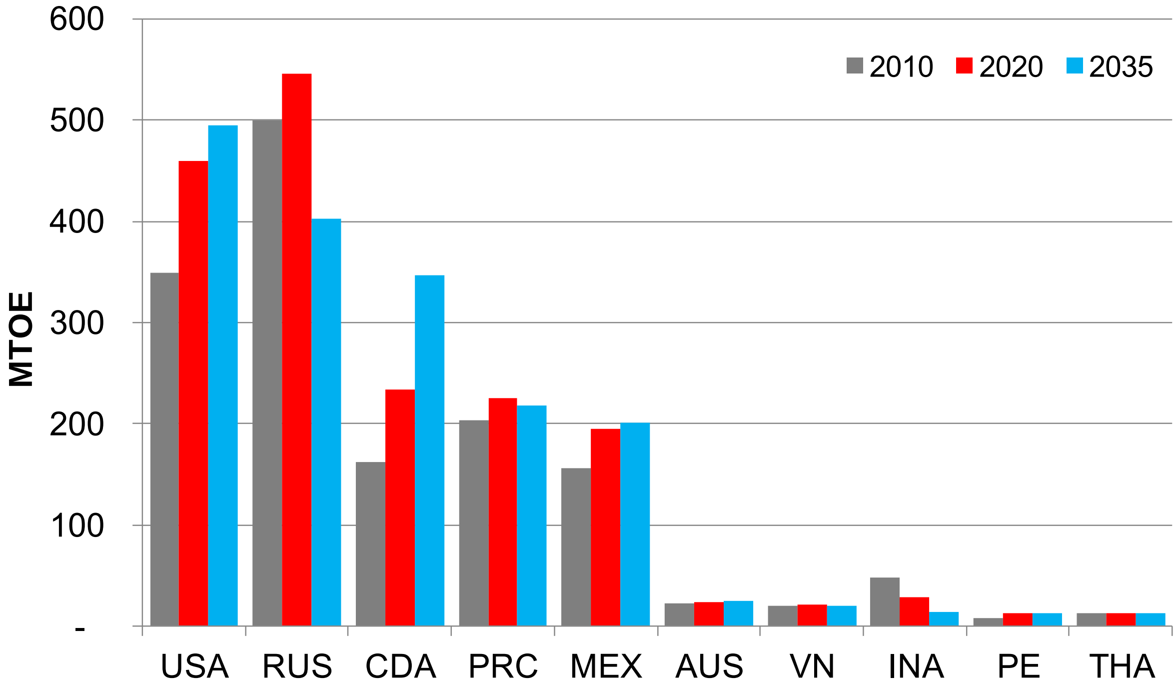
In contrast, oil production is projected to decline in Russia, Indonesia, Malaysia, Brunei Darussalam and the Philippines over the same period. As noted earlier, though, there are large uncertainties in these projections. In the remaining APEC economies, a lack of resources prevents them from developing significant domestic oil production.

In 2010, Russia was APEC's largest oil producer followed by the US, China, Canada and Mexico. By 2035, it is projected the US will lead APEC's oil production, followed by Russia, Canada, China and Mexico, with their joint output representing 94% of the APEC region's production.

Apart from exploration and production activities, the APEC region has a significant role in refining. The largest crude oil refining economies in the APEC region are the US, China, Russia, Japan and Korea, which together represented nearly 80% of the region's distillation capacity and about one-third of the worldwide distillation capacity in 2010.

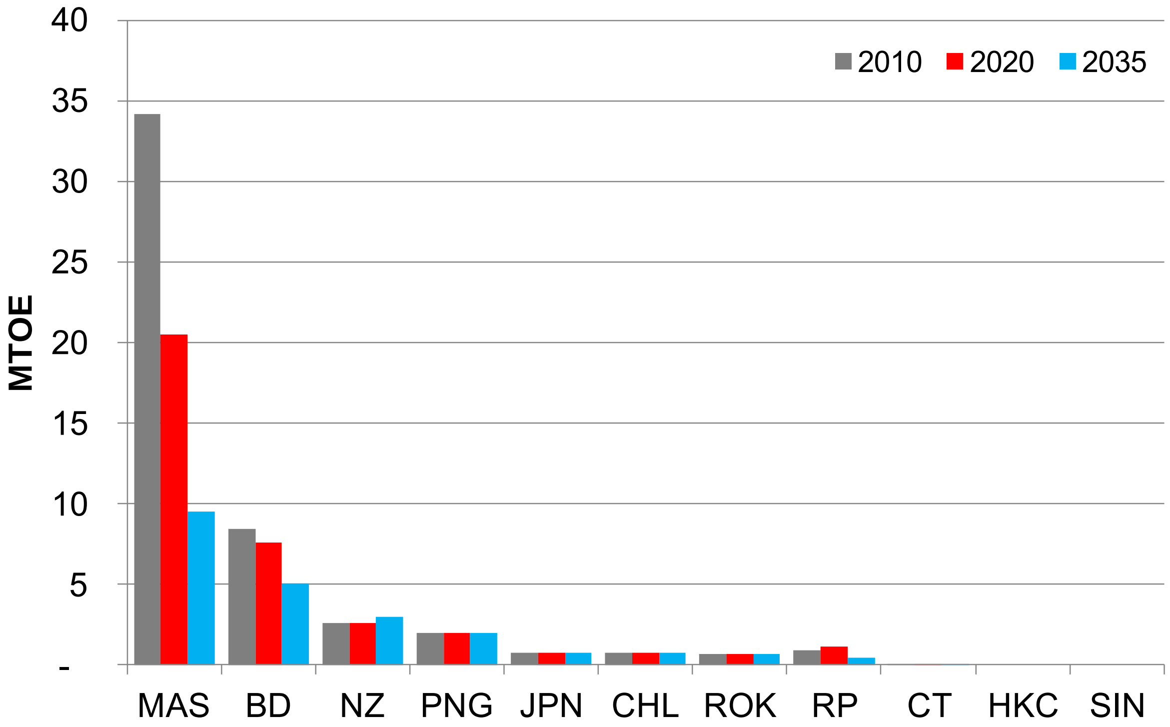
Beyond distillation, the APEC region also has a leading role in other refinery processes. Many refineries are adding capacity to process increasingly heavier crude oil feedstock and to yield more high-value oil products such as gasoline and distillates. In 2010, APEC's refineries accounted for 65% of the global catalytic cracking capacity, 61% of the global hydroconversion capacity (including hydrocracking and catalytic hydrotreating) and 70% of the global coking capacity (OGJ, 2010).

Figure 11.2: APEC's Projected Oil Production in 2010, 2020 and 2035, Higher Oil Production Economies



Source: APERC (2012)

Figure 11.3: APEC's Projected Oil Production in 2010, 2020 and 2035, Lower Oil Production Economies



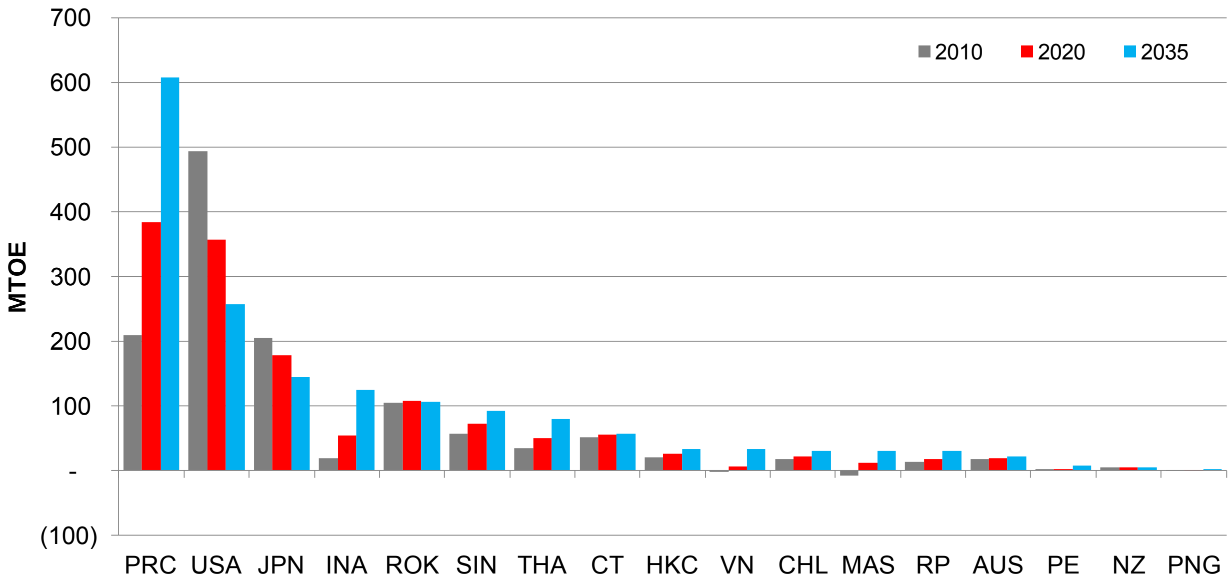
Source: APERC (2012)

INTERNATIONAL OIL TRADE BY ECONOMY

In the BAU case, the APEC region will be a growing oil importer, with its net imports expanding 58% between 2010 and 2035. Much of this growth in imports will be driven by China's rising primary oil demand, which is expected to almost double between 2010 and 2035. Despite the fact China's domestic production is expected to increase during the outlook period, it will be insufficient to meet the growth in demand. It is projected the net oil imports to China will grow 191%, from 209 Mtoe in 2010 to 608 Mtoe in 2035. This will account for almost half of the APEC region's net imports.

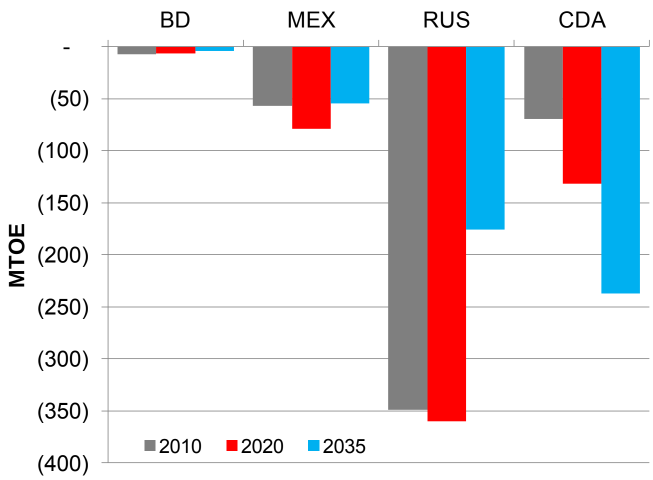
After China, the largest net importers in the APEC region in 2035 are expected to be the US, Japan, Indonesia and Korea, though the US is expected to reduce its oil imports significantly over the outlook period. Viet Nam, Malaysia, and Papua New Guinea will go from net oil exporters in 2010 to net oil importers by 2035. Projections indicate that by 2035 Canada, Russia, Mexico and Brunei Darussalam will continue to be net oil exporters.

Figure 11.4: Net Oil Imports for Net Oil Importing Economies



Note: (Negative) indicates net exports
Source: APERC (2012)

Figure 11.5: Net Oil Imports for Net Oil Exporting Economies



Note: (Negative) indicates net exports
Source: APERC (2012)

REFERENCES

Bartis, J., LaTourrette, T., Dixon, L., Peterson, D. and Cecchine, G. (2005), *Oil Shale Development in the United States: Prospects and Policy Issues*, The RAND Corporation, 2005, www.rand.org/pubs/monographs/2005/RAND_MG414.pdf

BP (2012), 'Deepwater Drilling Oil and Gas' website page, www.bp.com/sectiongenericarticle800.do?categoryId=9040474&contentId=7067100

CAPP (Canadian Association of Petroleum Producers) (2012a), Canadian Crude Oil Forecast and Market Outlook, www.capp.ca/forecast/Pages/default.aspx

— (2012b), Upstream Dialogue: *The Facts on Oil Sands*, www.capp.ca/UpstreamDialogue/OilSands/Pages/default.aspx

EMOE (Republic of Estonia, Ministry of the Environment) (2008), National Development Plan for the Utilization of Oil Shale 2008–2015, www.envir.ee/orb.aw/class=file/action=preview/id=1155858/P%F5levkivi_arengukava_+EN.pdf

Hyne, Norman J. (2001), *Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production*, 2nd edition, Pennwell Books, United States.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

IHS (IHS Global Insight) (2011), *The Economic and Employment Contributions of Shale Gas in the United States*, www.ihs.com/info/ecc/a/shale-gas-jobs-report.aspx

IPIECA (International Petroleum Industry Environmental Conservation Association) (2012), Oil Sands Fact Sheet, 'Oil Sands: Managing Impacts While Providing Energy Security', http://rio20.ipieca.org/sites/default/files/fact-sheets/pdfs/ipiecaogpfactsheetoilsands.pdf

Maugeri, L. (2012), *Oil: The Next Revolution. The Unpredecented Upsurge of Oil Production Capacity and What it Means for the World*, Harvard Kennedy School, belfercenter.ksg.harvard.edu/files/Oil-%20The%20Next%20Revolution.pdf

OGJ (Oil & Gas Journal) (2010), "Worldwide Refineries–Capacities as of January 1, 2011", Vol 108 Issue 46, 6 December 2010.

— (2011), "Worldwide Look at Reserves and Production (Estimated Proved Oil Reserves at 1 January 2013)", Vol 109 Issue 49, 5 December 2011.

PDVSA (Petróleos de Venezuela, S.A.) (n.d.), Reservas [in Spanish], www.pdvsa.com/index.php?tpl=interface.sp/design/readmenu.tpl.html&newsid_obj_id=527&newsid_temas=16

Petrobrás (2009), 'Operations in the Pre-salt: A New Frontier' website page, www.petrobras.com.br/minisite/presal/en/a-new-frontier/

Rosneft (2012a), "Rosneft and ExxonMobil Announce Progress in Strategic Cooperation Agreement", press release, 16 April 2012, www.rosneft.com/news/pressrelease/30082011.html

— (2012b), 'Russia's Arctic Seas' website page, www.rosneft.com/Upstream/Exploration/arctic_seas/

Shell (n.d.), 'Gas-to-Liquids' website page, www.shell.com/home/content/future_energy/meeting_demand/natural_gas/gtl/

Transocean (2012), 'Firsts & records' website page, www.deepwater.com/fw/main/Firsts-and-Records-4.html

USBSEE (United States Bureau of Safety and Environmental Enforcement) (2012), 'Deepwater Production Summary by Year' website page, www.data.bsee.gov/homepg/data_center/production/production/summary.asp.

USDOE (United States Department of Energy) (2009a), *Alaska North Slope Oil and Gas: A Promising Future or an Area in Decline? – Addendum Report*, www.netl.doe.gov/technologies/oil-gas/publications/AEO/ANS_Potential.pdf

— (2009b), *Modern Shale Gas Development in the United States: A Primer*, www.netl.doe.gov/technologies/oil-gas/publications/epreports/shale_gas_primer_2009.pdf

USEIA (United States Energy Information Administration) (2009a), *Gulf of Mexico Proved Reserves and Production by Water Depth*, www.eia.gov/pub/oil_gas/natural_gas/data_publications/crude_oil_natural_gas_reserves/current/pdf/gomwaterdepth.pdf

— (2009b), Arctic Oil and Natural Gas Potential, www.eia.gov/oiaf/analysispaper/arctic/index.html

— (2011), Country Analysis Briefs: Angola, www.eia.gov/EMEU/cabs/Angola/pdf.pdf

— (2012a), *Annual Energy Outlook 2012*, www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf

— (2012b), Gulf of Mexico Fact Sheet, www.eia.gov/special/gulf_of_mexico/index.cfm

— (2012c), How much does it cost to produce crude oil and natural gas?, www.eia.gov/tools/faqs/faq.cfm?id=367&t=6

USGS (United States Geological Survey) (2008), Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle, Fact Sheet, pubs.usgs.gov/fs/2008/3049/fs2008-3049.pdf

WEC (World Energy Council) (2010), *2010 Survey of Energy Resources*, www.worldenergy.org/documents/ser_2010_report_1.pdf

World Coal Organization (n.d.), 'Coal to Liquids' website page, www.worldcoal.org/coal/uses-of-coal/coal-to-liquids/

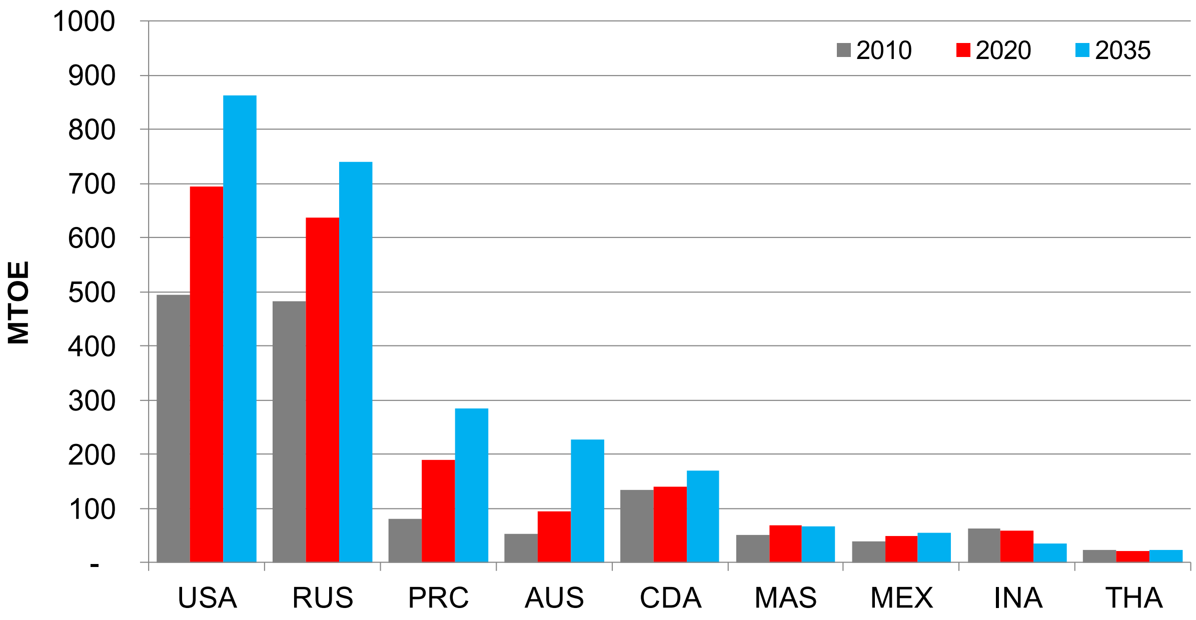
12 NATURAL GAS SUPPLY

GAS PRODUCTION

Production of gas in the APEC region under a business-as-usual (BAU) scenario is projected to grow by 80%, from 1405 Mtoe in 2009 to 2522 Mtoe in 2035. Figures 12.1 and 12.2 show projected gas production by economy. Note the difference in the scales of the vertical axis in the two figures.

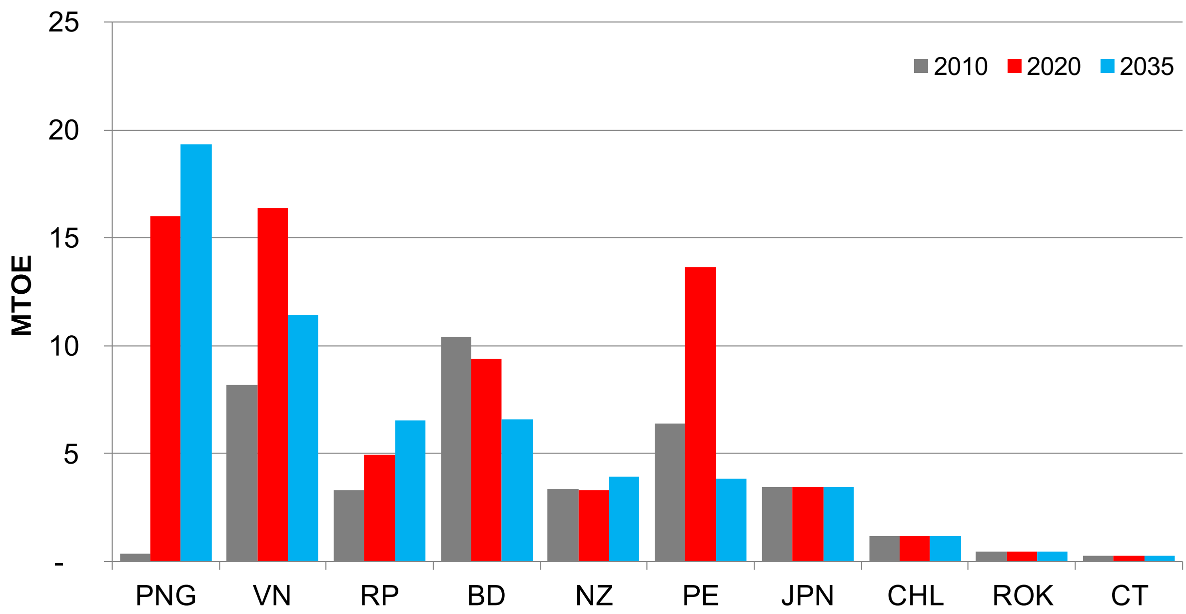
It can be seen that most of the growth in production will occur in four economies: the United States, Russia, China, and Australia. The drivers of growth in each of these economies are somewhat different, but all are contributing to meeting the growing demand for gas worldwide, as gas becomes increasingly recognized as a relatively clean, economical, and easy-to-use fuel.

Figure 12.1: Projected Gas Production, Larger Gas-Producing Economies



Source: APERC Analysis (2012)

Figure 12.2: Projected Gas Production, Smaller Gas-Producing Economies



Source: APERC Analysis (2012)

In Russia, immense resources of conventional gas are available (see Table 12.1) to satisfy both growing domestic demand and export demand. However, much of this gas is in remote locations, so production is expected to move away from mature, existing fields to new and more-difficult-to-develop regions that will require significant investment in infrastructure.

The United States (US) is expected to continue experiencing a boom in the production of unconventional gas, especially shale gas. The growth in unconventional gas in the US is driven by advances in technology, especially horizontal drilling and hydraulic fracturing, which have made it profitable to develop resources that were previously considered to be uneconomic. As discussed in the United States Economy Review in Volume 2, the growth in unconventional gas production in the US is projected to shift the US from a net gas importer to a net gas exporter.

China is seeking to develop its significant conventional and unconventional gas resources, as that economy's rapid economic growth drives rapid growth in domestic demand for energy. Increased gas production will diversify China's energy supply away from coal, while helping to reduce the need for imported energy.

Australia also has significant conventional and unconventional gas resources, some of which are located in areas of that economy that are remote from the domestic pipeline network. Australia is therefore in the process of developing several major LNG projects, which will export gas to growing Asian markets.

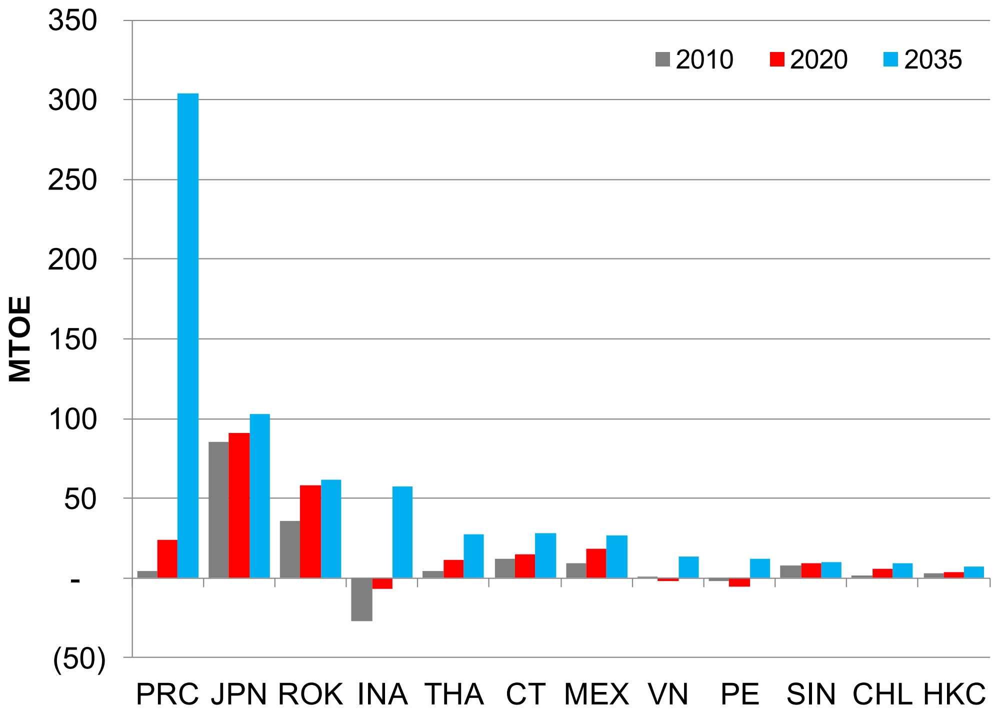
GAS IMPORTS AND EXPORTS

APEC's net gas exports are projected to increase from 48 Mtoe in 2009 to 222 Mtoe in 2020. But after 2020, the trend toward growing exports will reverse and by 2035 APEC could have net imports of 61 Mtoe. These imports and exports are quite small numbers relative to APEC's total gas demand and supply, and are subject to many uncertainties. In general, we can say that APEC will be more-or-less self sufficient in gas during the outlook period.

As shown in Figure 12.3, imports of gas are projected to increase in all importing economies over the outlook period with the exception of the US. The APEC region currently includes some of the largest importers of LNG in the world including Japan, Korea, and Chinese Taipei. China is likely to become an increasingly large importer of gas, utilizing both pipeline transportation from neighbouring economies and LNG. Indonesia is likely to switch from being a net gas exporter to a net gas importer (BP, 2012, p. 28).

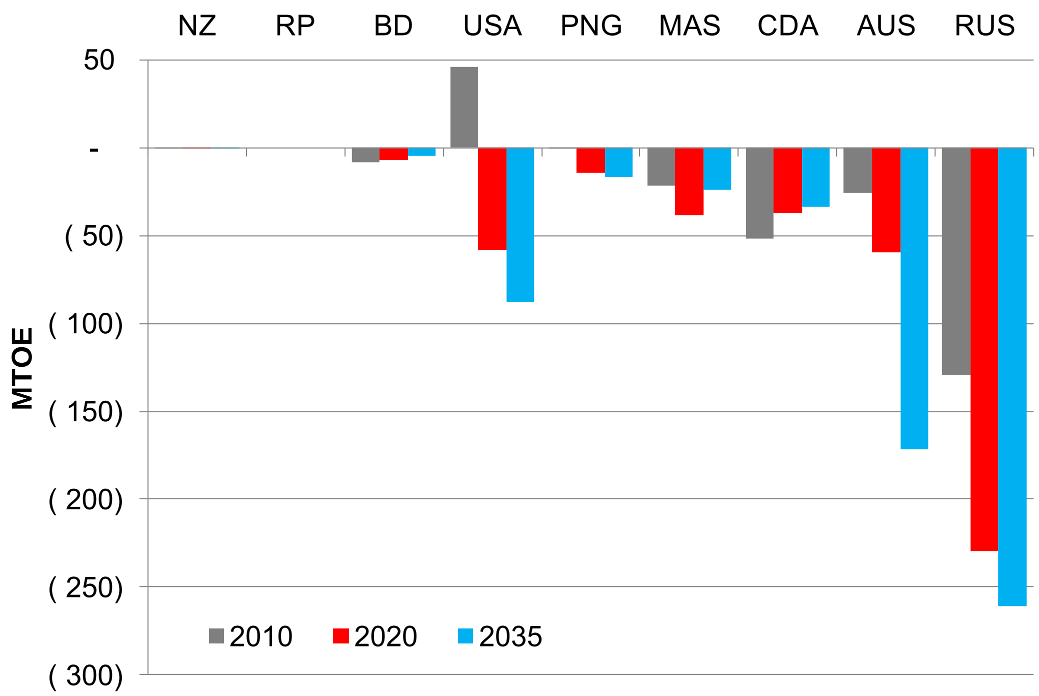
As shown in Figure 12.4, Russia will remain the largest gas exporter in APEC, while Australia will dramatically increase its exports during the outlook period. Canada has historically exported gas by pipeline to the US, but given the booming production in the US, will increasingly turn to overseas exports of LNG. The Philippines and New Zealand are projected not to import or export natural gas.

Figure 12.3: Projected Net Import of Gas in APEC Economies



Source: APERC Analysis (2012)

Figure 12.4: Projected Net Export of Gas in APEC Economies



Source: APERC Analysis (2012)

THE POTENTIAL FOR UNCONVENTIONAL GAS

We have already mentioned the boom in unconventional gas in the US, which includes coal bed methane, tight gas, and especially shale gas. In 2009, 10% of US gas production came from coal bed methane, 31% from tight gas, and 14% from shale gas, implying that more than half of the US gas supply is already coming from unconventional sources. The United States Energy Information Administration projects that in 2035, 6% of US production will come from coal bed methane, 22% from tight gas, and 49% from shale gas (USEIA, 2012, Table A14), implying that more than three-quarters of US gas production will be unconventional by 2035.

A number of other APEC economies are already utilizing unconventional gas resources, especially coal bed methane. In 2011, unconventional gas provided about half of Canada's natural gas supply (70 billion cubic metres (bcm) or about 63 Mtoe). China produced 36 bcm (roughly 32 Mtoe) of tight gas, while Mexico produced about 2 bcm (roughly 2 Mtoe) in 2011. Australia produced 6 bcm (roughly 5 Mtoe) of coal bed methane in 2011 (Moodhe, 2012).

The APEC region is believed to have immense resources of conventional and unconventional gas. Table 12.1 shows estimated technically recoverable resources of conventional gas, shale gas, coal bed methane, and tight gas for those APEC economies whose resources were assessed in the APEC Unconventional Natural Gas Census, as well as Russia. For comparison purposes, 2009 production is also shown and the implied number of years of production at the 2009 production rates. It can be seen that in each case, more than 100 years of production should be available, often considerably more.

Table 12.1: APEC's Technically Recoverable Conventional and Unconventional Gas Resource Base, in Mtoe

Economy	Conventional Gas	Unconventional Gas				Conventional & Unconventional Gas	2009 Production	Years of Production
		Shale Gas	Coal Bed Methane	Tight Gas	Total			
China	5 225	22 150	9 625	na	31 775	37 000	76.7	482
US	30 750	14 475	3 500	13 000	30 975	61 725	532.7	116
Australia	5 700	9 950	10 975	500	21 425	27 125	38.1	712
Canada	8 650	2 250	1 125	4 250	7 625	16 275	147.6	110
Mexico	2 375	7 425	100	na	7 525	9 900	49.1	202
Russia	86 125	1 825	50	na	1 875	88 000	474.9	185

na = not assessed

Sources: Conventional gas: Ejaz (2011, Table 1)—all conventional figures shown are remaining recoverable resources which exclude gas already produced; figure for Australia includes Oceania. Unconventional gas: Moodhe, (2012, slides 9 and 15). 2009 production: BP (2012, p. 24). Original data in trillion cubic feet (Tcf) converted to Mtoe using a conversion factor of 25 Mtoe/Tcf as per BP (2012, p. 44).

Unconventional resource estimates are subject to considerable uncertainty given the limited amount of exploration that has been done in most APEC economies. Table 12.2 shows another set of technically recoverable shale gas resource estimates from a separate analysis by the United States Energy Information Administration. In addition to the economies shown in these tables, Indonesia is known to have significant resources of coal bed methane and shale gas. More modest unconventional gas resources are also known to exist in other South-East Asian economies, Peru, and New Zealand. However, the extent to which these resources are technically recoverable has not been assessed.

Table 12.2: APEC's Technically Recoverable Shale Gas Resource Base, in Mtoe

Economy	Technically Recoverable Shale Gas
China	31 875
US	21 550
Australia	9 900
Canada	9 700
Mexico	17 025
Russia	na
Chile	1 600

Source: USEIA (2011, Table 1). Original data in trillion cubic feet (Tcf) converted to Mtoe using a conversion factor of 25 Mtoe/Tcf as per BP (2012, p. 44).

While the US is experiencing a shale gas boom, and several other APEC economies are developing unconventional gas, the extent to which unconventional gas can be developed throughout the APEC region remains a huge uncertainty. In particular, shale gas has so far been developed on a large scale only in the US.

The shale gas boom in the US has benefitted from unique circumstances that could be difficult to replicate elsewhere. There are questions whether the geology elsewhere is really as attractive as it would appear, and what kind of technology will be required to develop it, which require further investigation.

But perhaps more importantly, the US provides a reasonably stable and transparent system of regulation, taxes, and fiscal terms for gas producers. This includes, on the one hand, an unusual system of privately owned mineral rights, which allows any gas producer to gain land access simply by contracting with the landowner. On the other hand, it also includes another unusual system of privately owned and freely tradable pipeline capacity rights, which allows anyone to access pipeline transportation (or even have it built) simply by contracting for it in the market (see Makholm, 2012). The result is an environment uniquely suited to the entrepreneurial firms who have pioneered shale gas technology. APEC would do well to promote understanding not only of unconventional gas geology and technology, but also of the institutions that could make its development possible.

HIGH GAS SCENARIO

The BAU scenario discussed above does not include significant shale gas development outside North America and includes fairly conservative estimates of production from both conventional and non-shale-gas unconventional resources outside of North America. As discussed above, the conventional and unconventional gas resources of the Asia–Pacific region are immense. And with LNG prices in Asia several times as high as those in North America the economics of gas development outside of North America, as well further gas development in North America for export, should be compelling. For example, in 2011 the average Japanese LNG import price was USD 14.73 per million British thermal units (Btu) compared to an average US Henry Hub price of USD 4.01 per million Btu (BP, 2012, p. 27).

How could development of these resources be better promoted? A first step might be to address some significant barriers to gas development that exist in a number of APEC economies. These include:

- Policies requiring a domestic price of gas below market levels (a form of subsidy), thereby limiting the profitability of gas development and making investment in gas development less attractive.
- Limited technology in some economies for gas development, especially unconventional and deepwater gas development.
- Protective policies restricting the export of gas.
- Policies granting a monopoly on gas development or pipeline access to certain domestic firms, or limiting the participation of foreign-owned firms, or otherwise limiting competition in gas development.
- Slow and cumbersome regulatory approvals and land access processes for gas producers.

APEC could help its member economies to overcome potential constraints on gas production and trade constraints by:

1. Continuing to encourage member economies to rationalize and phase out fossil fuel subsidies in accordance with the APEC Leaders' Declarations; these subsidies can discourage gas development especially when they take the form of price controls on gas producers.
2. Including goods and services for gas industry development in the definition of 'environmental goods and services', and continuing to encourage member economies to reduce existing barriers and refrain from introducing new barriers to trade and investment in environmental goods and services.
3. Encouraging member economies to reform policies that discourage the export of gas or restrict the involvement of foreign firms in gas development.
4. Cooperating to promote best practices in gas industry regulation (safety, environmental protection, economics).

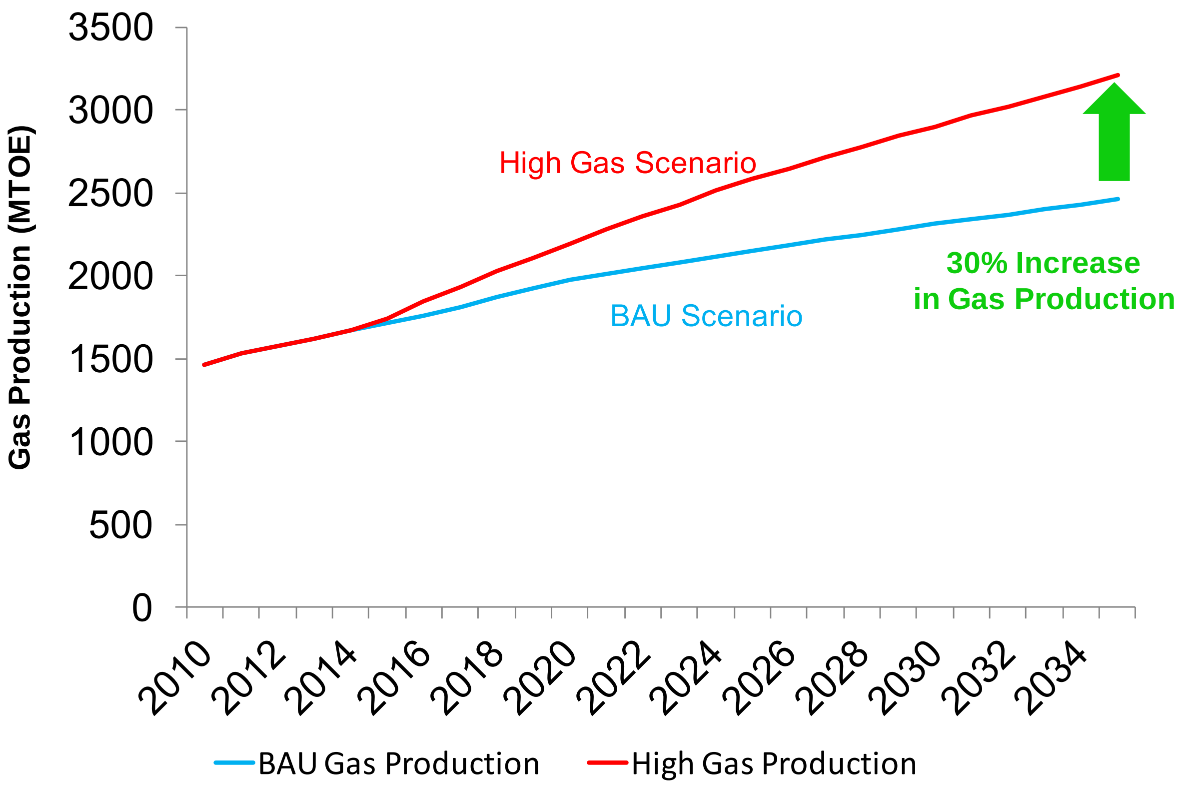
Items 1 and 2 are existing APEC initiatives where the implications for gas development might receive greater emphasis. Items 3 and 4 would be likewise consistent with APEC's mission of championing free and open trade and investment, promoting and accelerating regional economic integration, encouraging economic and technical cooperation, and facilitating a favourable and sustainable business environment (APEC, 2012).

With appropriate policies and regional cooperation, the APEC economies could use their gas resources to move toward a cleaner energy system, while promoting energy security and mutual prosperity. To illustrate some of the benefits that might accrue from removing the barriers to gas production and trade, APERC has developed an alternative 'High Gas Scenario'.

In the High Gas Scenario, APERC estimated the gas production that might be available without raising prices if existing constraints on gas production and trade were reduced. In most cases, the estimates are based on 'high gas' scenarios developed by economy governments. The results are conservative, since estimated shale gas production in some cases was low or not included. The assumptions and results for each APEC economy are discussed in the Economy Reviews in Volume 2.

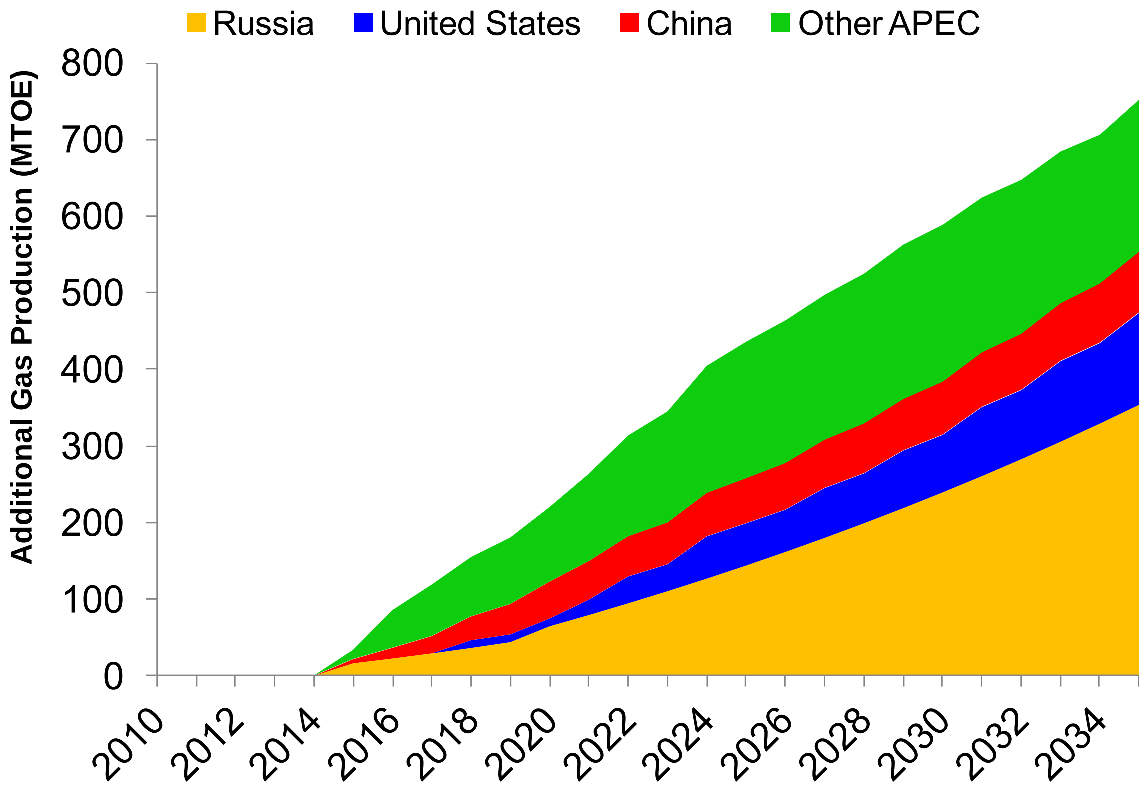
As shown in Figure 12.5, on an APEC-wide basis, gas production by 2035 was about 30% higher in the High Gas Scenario compared to BAU. As shown in Figure 12.6, Russia is the largest source of the additional gas, with the US and China also making large contributions. This should come as no surprise, given the immense estimated gas resources of those three economies.

Figure 12.5: High Gas Scenario – Increase in Gas Production



Source: APERC Analysis (2012)

Figure 12.6: High Gas Scenario – Sources of Additional Gas Production



Source: APERC Analysis (2012)

There are many ways the additional gas could be used in the APEC region, almost all of them positive in terms of economics, energy security, and/or the environment. Using gas to replace coal in electricity generation is an especially good option from a CO_2 emissions perspective due to the combined effect of two factors. First, because of its lower-carbon chemical composition, gas produces considerably less CO_2 emissions per unit of heat than coal—typically around 40% less, depending upon the type of coal (Ecofys, 2010, p. 21). Second, gas-fired generation is generally significantly more efficient than coal-fired generation in converting heat to electricity (see the sidebar 'Improving the Efficiency of Coal-Fired Electricity Generation' in Chapter 13). The combined effect of these two factors means that gas-fired generation typically has less than half the CO_2 emissions of coal-fired generation per unit of electricity produced.

Using gas in electricity generation would have other environmental benefits. When efficiently used:

- gas produces much less local air pollution than coal
- gas production is typically less damaging to land and water resources than coal production
- gas electricity generation can typically be more easily cycled on or off than coal, which allows it to better complement wind and solar generation.

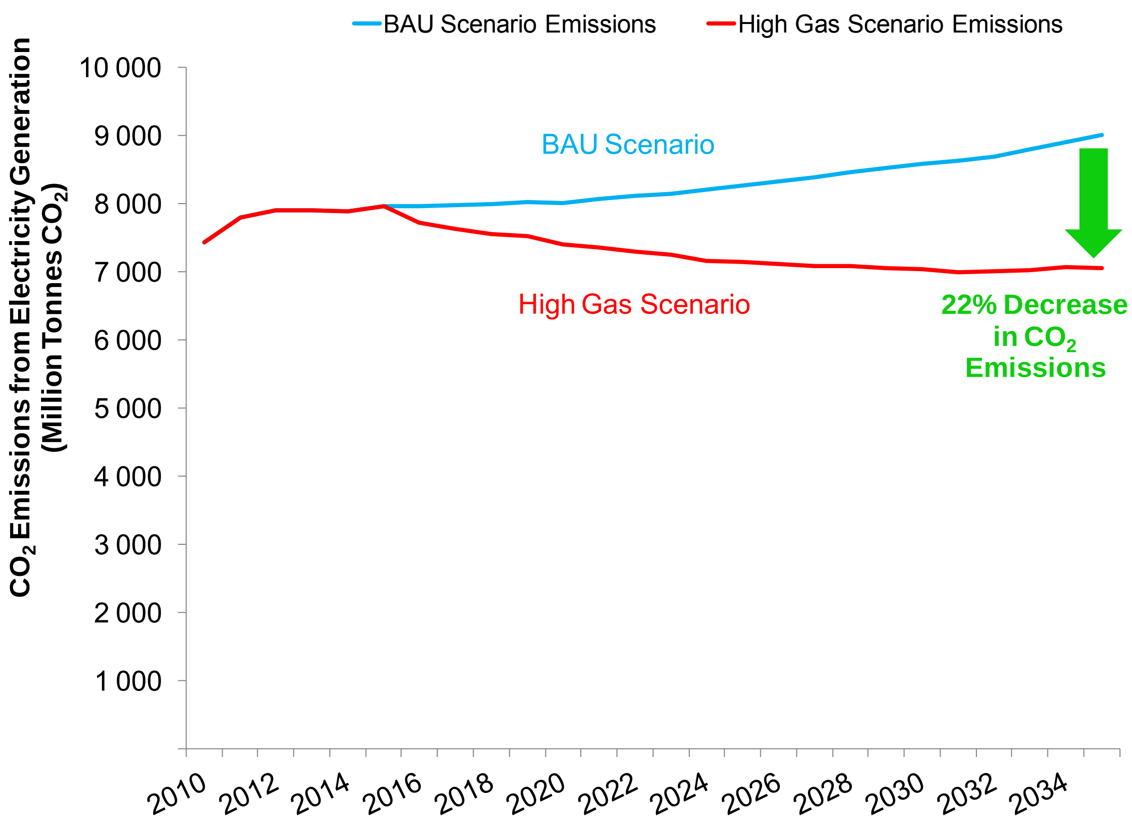
APERC therefore assumed that the additional gas in the High Gas Scenario would be used to replace coal in electricity generation.

As shown in Figure 12.7, the additional gas in the High Gas Scenario could reduce CO_2 emissions from electricity generation in 2035 by about 22% compared to BAU. This implies an overall reduction in energy CO_2 emissions of about 8% compared to BAU.

Alternatively, some of this added gas could be used to replace oil. In this case, there would be additional benefits from reduced oil imports in the form of greater energy security and economic stability. And regardless of how the gas is used, there would be large economic benefits to both producer and consumer economies.

It is worth re-emphasizing that given the immense gas resources of the APEC region, this High Gas Scenario is a conservative example of what could be accomplished if the potential constraints on gas production and trade could be reduced. It is also important to recognize that, in some APEC economies, there is growing public concern over the environmental risks of unconventional gas development. These will need to be addressed through better regulation if gas development is to win the public confidence it will need to deliver benefits like those illustrated in this scenario.

Figure 12.7: High Gas Scenario – Reduction in CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

REFERENCES

APEC (Asia–Pacific Economic Cooperation) (2012), 'Mission Statement' website page, www.apec.org/About-Us/About-APEC/Mission-Statement.aspx

BP (2012), *Statistical Review of World Energy 2012*, www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481

Ecofys (2010), International Comparison of Fossil Power Efficiency and CO_2 Intensity, www.ecofys.com/en/publication/international-comparison-of-fossil-power-efficiency-and-co2-intensit/

Ejaz, Qudsia (2011), "Supplementary Paper SP2.2, Background Material on Natural Gas Resource Assessments, with Major Resource Country Reviews" in Ernest J. Moniz (Chair), *The Future of Natural Gas: An MIT Interdisciplinary Study*, http://mitei.mit.edu/publications/reports-studies/future-natural-gas

Makholm, Jeff D. (2012), "Marginal Costs with Wings a Ball and Chain: Pipelines and Institutional Foundations for the US Gas Market", *Economics of Energy & Environmental Policy*, Vol. 1, No. 3, September 2012.

Moodhe, Keith (2012), "APEC Unconventional Natural Gas Census: Evaluating the Potential for Unconventional Gas Resources to Increase Gas Production and Contribute to Reduced CO_2 Emissions", PowerPoint presentation prepared for the APEC Workshop on Unconventional Natural Gas, Advanced Resources International, Arlington, Virginia, USA, 6 November 2012. Note: This presentation is a summary of a full report due for release in the near future.

USEIA (United States Energy Information Administration) (2011), *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States.*

— (2012), *Annual Energy Outlook 2012*, www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf

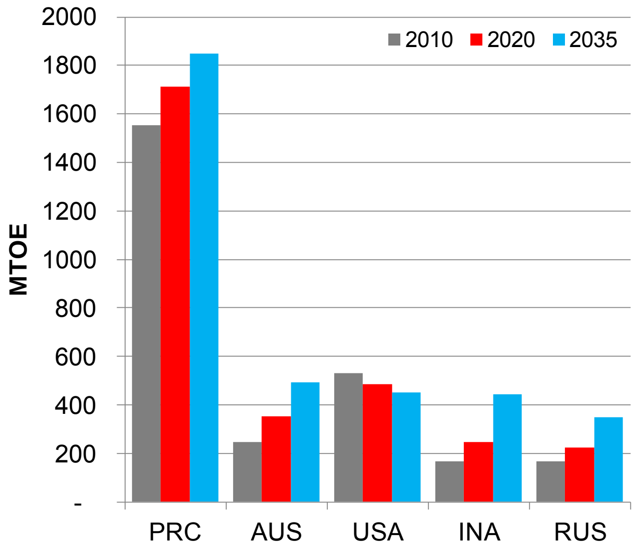
13 COAL SUPPLY

COAL PRODUCTION

Under business-as-usual (BAU) assumptions, coal production in the APEC region will continue to grow by 0.9% per year during the outlook period. It will amount to 3703 million tonnes of oil equivalent (Mtoe) in 2035 or about 37% more than in 2009. All 15 existing coal producing economies will continue to produce coal, while Papua New Guinea may start some minor production.

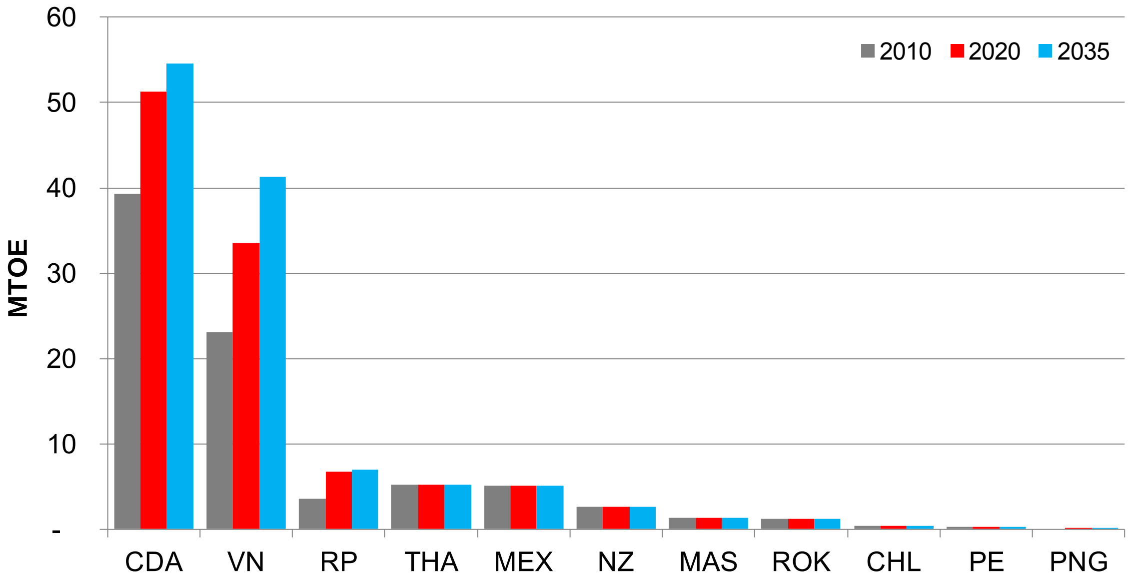
The five major coal producing economies (China, Australia, United States, Indonesia and Russia) are projected to maintain their 97% share of APEC's coal production throughout the forecast period. China will continue to be the major coal producing economy not just among the APEC economies, but worldwide. Production in China will be 1849 Mtoe in 2035, or about 50% of the APEC region's production; it was 57% in 2009.

Figure 13.1: Projected Coal Production in Mtoe, Major Coal Producing Economies



Source: APERC Analysis (2012)

Figure 13.2: Projected Coal Production in Mtoe, Other Economies



Source: APERC Analysis (2012)

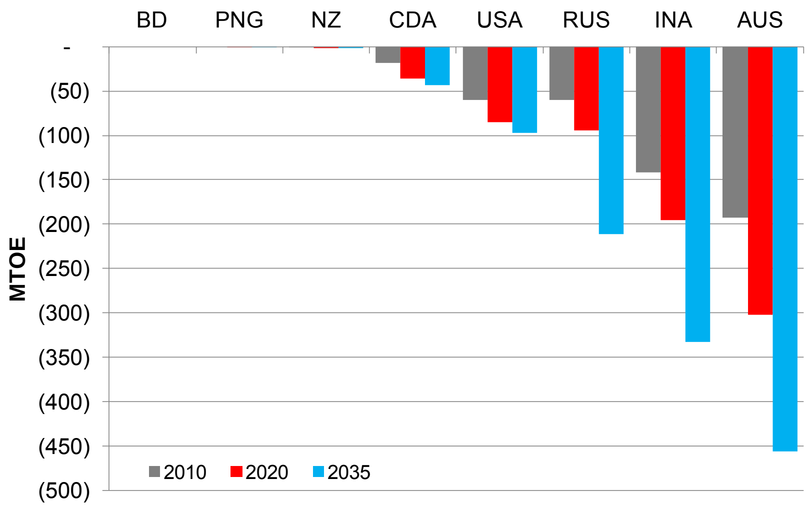
COAL IMPORTS AND EXPORTS

The APEC region is likely to be a net coal exporting region. Australia, Indonesia, Russia, United States and Canada will be able to supply 1046 Mtoe of coal to the international market in 2035. Papua New Guinea and New Zealand may start some minor export.

Figures 13.3 and 13.4 show that by 2035 there will be seven net coal exporting economies in APEC, and 13 more APEC economies that are net importers of coal. Brunei Darussalam is projected to have no production, consumption, imports, or exports of coal during the outlook period.

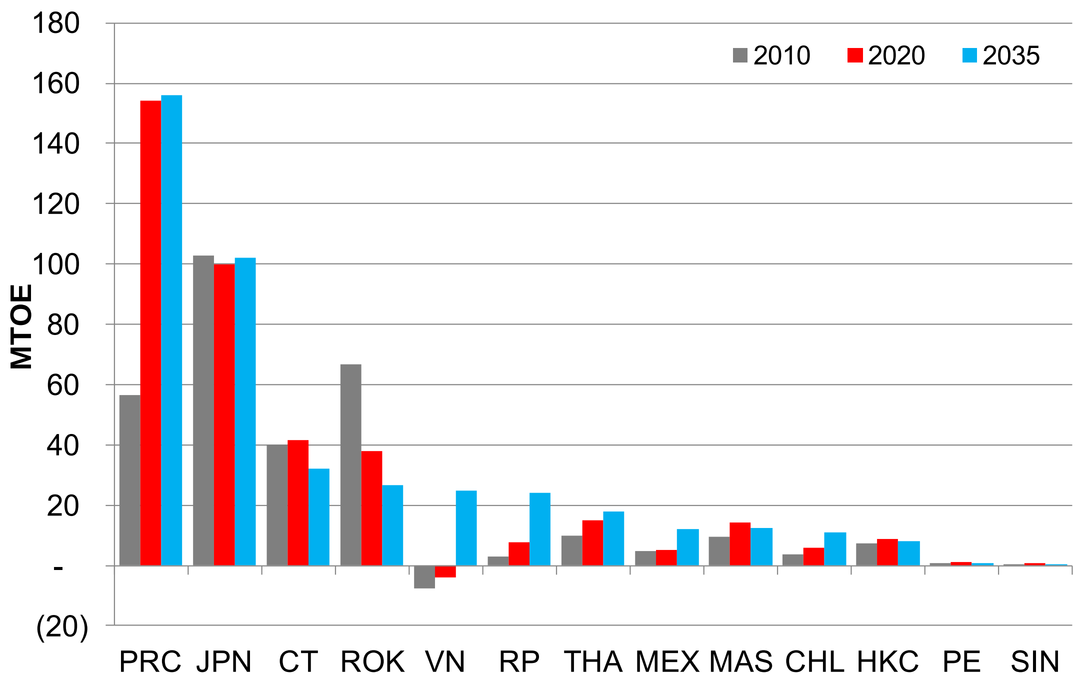
The largest coal importing economies are China, Japan, Chinese Taipei and Korea. Coal imports by Japan are projected to decline in the 2020–2035 period. China will be a large and growing net importer of coal, but imports will supply only about 5% of its demand in 2035. Viet Nam will become a net coal importer after 2020.

Figure 13.3: Projected Net Export (-) of Coal, APEC Coal Exporting Economies, in Mtoe



Source: APERC Analysis (2012)

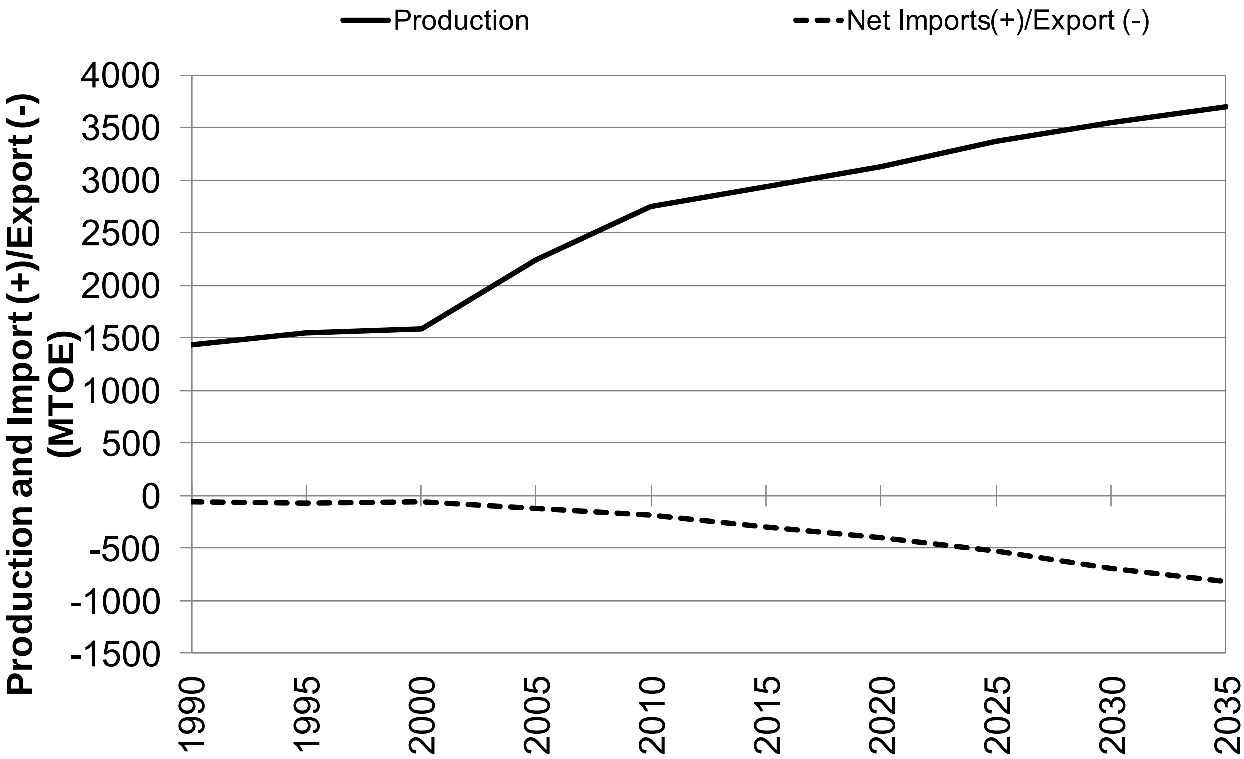
Figure 13.4: Projected Net Import of Coal, APEC Coal Importing Economies, in Mtoe



Source: APERC Analysis (2012)

As shown in Figure 13.5, net coal exports of the APEC economies are projected to increase from 122 Mtoe in 2009 to 715 Mtoe in 2035 under BAU assumptions. Note that negative net imports are exports.

Figure 13.5: Projected Production and Net Imports of Coal, all APEC Economies, in Mtoe

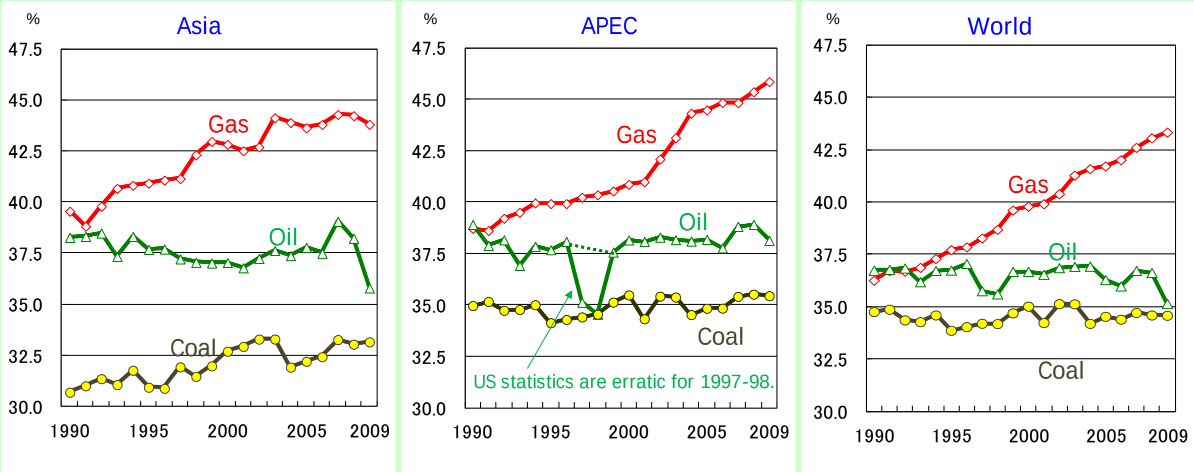


Source: APERC Analysis (2012)

IMPROVING THE EFFICIENCY OF COAL-FIRED ELECTRICITY GENERATION

In 2009, fossil fuels for electricity generation amounted to 38% of the world's total primary energy supply (TPES)—coal was dominant among them with a share of 47%. Thus, the efficiency of coal generation is a key for reducing greenhouse gas emissions. However, world coal generation efficiency has been hovering at around 35% for decades, while natural gas generation efficiency has improved remarkably as a result of combined cycle gas turbine (CCGT) technology. Due to the high cost of oil, oil generating plants are generally being phased out, with little new construction or replacement of plants being done.

Figure 13.6: Efficiency of Electricity Generation Technologies



Source: *World Energy Statistics* 2011 © OECD/IEA 2011

The lower efficiency of coal generation is because the energy density of coal is lower than that of oil and gas and, as coal is a solid, its combustion control is complicated. It is more so when low quality coals with high ash contents or high moisture contents are used.

At traditional coal generating plants, efficiencies may be assessed in three areas: coal combustion at the boiler, driving the steam turbines, and running supplementary systems (such as moving and pulverizing coal before burning, exhaust gas treatment to remove particulates, SOx and NOx, and ash disposal). Needless to say, coal preparation is an important process before combustion. Ramping rates and the optimum operation of the power plant are also important factors.

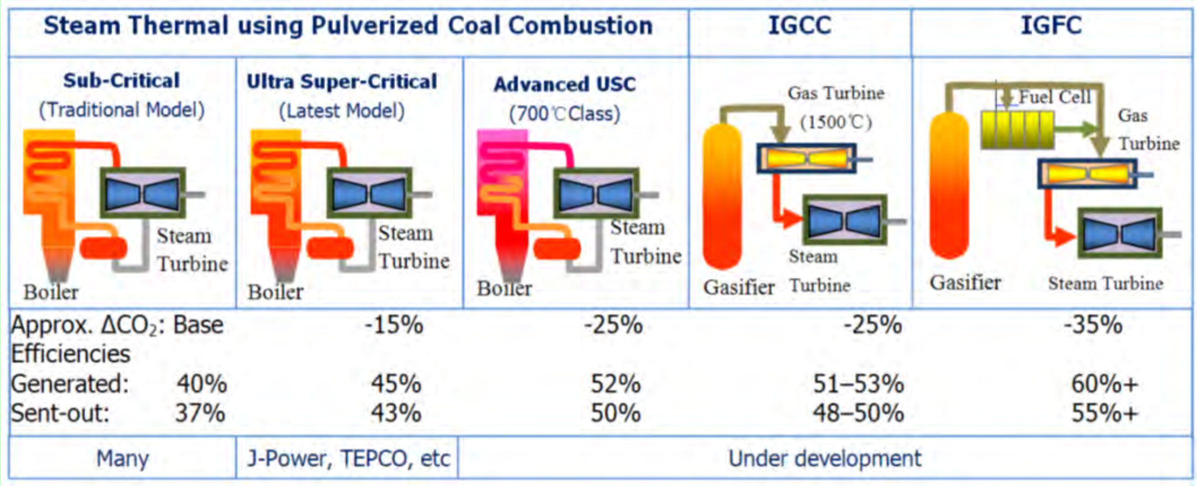
Regarding coal combustion, various technologies were tested in the 1960s and 1970s, and pulverized coal burning has become the standard technology. Recent efficiency improvements are mainly achieved through improvements in driving the steam turbines. In general, higher temperature and higher pressure steam drives turbines more efficiently. Turbine driving technology has evolved from the 'sub-critical' system to the 'super-critical' (SC) system. The latter uses steam above the critical temperature and pressure where distinct liquid and vapour phases cease to exist. The SC technology was adopted in Japan around 1980. It was further upgraded to the 'ultra-super critical' (USC) system in the late 1990s, with steam temperatures around 600 degrees C. The typical design efficiency (based on sent-out electricity and lower heating values of the coal) is:

- below 38–40% for sub-critical plants (250 MW class, typically at 16.6 megapascals (MPa), 566(main steam)/538(recovery steam) degrees C)
- 40–42% for super-critical plants (500-1000 MW class, typically at 24.1 MPa, 538/538 degrees C)
- 41–43% for ultra-super critical plants (600–1000 MW class, typically at 25 MPa, 600/610 degrees C).

The best USC plants in Japan have achieved 45% efficiency (25 MPa, 600/620 degrees C). Currently, a 700 degrees C, 35 MPa turbine system is under development as an 'advanced USC' (A-USC) aiming at a generating efficiency of 52% or a sent-out efficiency of 50% (J-Power, 2011).

Water becomes highly corrosive under super-critical conditions. The manufacture of USC systems requires high quality materials to cope with the high temperatures, pressures and corrosiveness. Sub-critical plants are still used in many economies as they are less expensive. Some may not even have exhaust gas treatment systems to remove particulates, SOx and NOx, resulting in heavily polluted air. Such situations need to be improved as soon as possible.

Figure 13.7: Improving Coal Thermal Plant Efficiencies



Sources: J-Power (2011), Energia (2010), METI (2009) and IEEJ (2012)

In addition to research and development on A-USCs, higher efficiency technologies are being developed to burn a synthetic gas produced from coal (coal gasification). This technology would bring the efficiency of natural gas CCGT generation to coal generation. Known as IGCC (integrated coal gasification combined cycle), such a hybrid system would burn the gas in a gas turbine then use recovered heat to produce steam to drive a steam turbine. An IGCC plant with a 1500 degree C gas turbine is expected to achieve 51–53% net energy efficiency. Although this is lower than the efficiency of natural gas CCGT generation (CCGT has already achieved 60% efficiency with 1600 degree C gas turbines at the #4 system of Tokyo Electric's Futtsu Power Station), IGCC will improve coal generation efficiency by almost 20% to 51–53%, from 43–45% for the best existing USCs. A further technological development would be an IGFC (integrated coal gasification fuel cell) system, using fuel cells on top of IGCC. IGFC aims at further efficiency improvements to above 60%. These technologies are now being intensely researched. They are expected to reduce greenhouse gas emissions substantially, especially when used in combination with carbon capture and storage.

In Japan, a verification test of IGCC with 1200 degree C gas turbines is being conducted on a commercial scale plant at the Nakoso Power Station by the Clean Coal Power R&D Co., Ltd. (a joint venture of Japanese power companies). At present, many developing economies are introducing SC and USC technology; the latter will dominate as the main technology for the near future. With the existing best USC systems, global coal thermal efficiency can be improved from 35% to 45%.

Although USC is an effective technology, its benefits would be limited where low-quality coal is the main fuel source, as the high moisture and ash contents prohibit efficient burning. Coal gasification can overcome this limitation by extracting pure gaseous fuel from the coal before burning. According to a recent study by the Institute of Energy Economics, Japan (IEEJ) on a renovation plan for a power plant in an Asian economy burning lignite, generation efficiency by the existing sub-critical system (16.1 MPa, 538/538) is 36.2% and that for a USC system (24.5 MPa, 600/600) will be 38.4%. Compared with this, an IGCC system (10 MPa, 550/550) is expected to achieve a 43.4% net generation efficiency (IEEJ, 2012). Thus, IGCC will bring significantly improving efficiencies to generating plants burning low quality coal, which are common all over the world.

REFERENCES

Energia (Chugoku Electric Power Co., Inc.) (2010), *Outlook of Coal Thermal Power Technology*, in Japanese, www.brain-c-jcoal.info/news_images/20100301ccs_sakotani.pdf

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

IEEJ (Institute of Energy Economics, Japan) (2012), "Feasibility of Introducing IGCC at the Mae Moh Electric Power Station, Thailand", draft report, July 2012, in Japanese.

J-Power (Electric Power Development Co., Ltd) (2011), *Overseas Deployment of High Efficiency Coal Thermal Power*, in Japanese, www.nedo.go.jp/content/100119409.pdf

METI (Ministry of Economy, Trade and Industry, Japan) (2009), *High Efficiency Coal Thermal Power Generation and Multiple Use of Coal: Technology System and Future Direction of R&D*, Study Group for Clean Coal Technology Development, in Japanese, www.meti.go.jp/committee/materials2/downloadfiles/g90617a29j.pdf

14 NUCLEAR SUPPLY

OUTLOOK FOR NUCLEAR ENERGY IN THE APEC REGION

Even after the serious accident at the Fukushima Daiichi Nuclear Power Plant in Japan in March 2011, considerable growth of nuclear energy utilization in the APEC region is projected over the outlook period. This growth reflects not only the economic and environmental advantages of nuclear energy, but also the focus on ensuring nuclear safety that has intensified since the accident. The economic advantages of nuclear energy include its low fuel cost and lower risk of fuel price fluctuations compared to fossil fuels. The environmental advantages include the technology's relatively low greenhouse gas emissions throughout its supply chain.

The main impediment to nuclear expansion is low public acceptance due to safety issues. The Fukushima accident has, of course, lead to increased concerns about safety. Since the accident was triggered by a huge natural disaster, the resilience of nuclear facilities in the face of natural disasters has gathered much attention. At the same time, there are concerns that similar serious accidents could be caused by malicious human attacks.

Therefore, an enormous effort will need to be made worldwide by the scientific, business and governmental communities to address these concerns and recover public confidence in the safety of nuclear power. In this regard, initiatives to develop advanced nuclear technologies, upgrade nuclear safety standards for construction and operation, and tighten nuclear security are being undertaken in many economies, and should be continued in the future.

The growth of nuclear energy utilization in the APEC region is expected to be predominantly centred in China, Russia, and Korea, whose policies promote large-scale development of nuclear power. Viet Nam also plans to add nuclear to its energy mix sometime after 2020. Other South–East Asian economies, like Thailand, continue preliminary studies and planning for construction of nuclear plants, but without a firm commitment to proceed as yet. On the other hand, the future of nuclear energy in Japan and Chinese Taipei, which have historically been major nuclear power users in the APEC region, is very uncertain at the time of writing.

On the other side of the Pacific Ocean, the United States currently has the largest nuclear capacity in the APEC region. However, the US nuclear fleet is aging. Before 2012, no construction of new reactors had been approved since 1978. Two new reactors in Georgia were given approval for construction in February 2012 and two more in South Carolina were approved in March 2012 (Wall Street Journal, 2012).

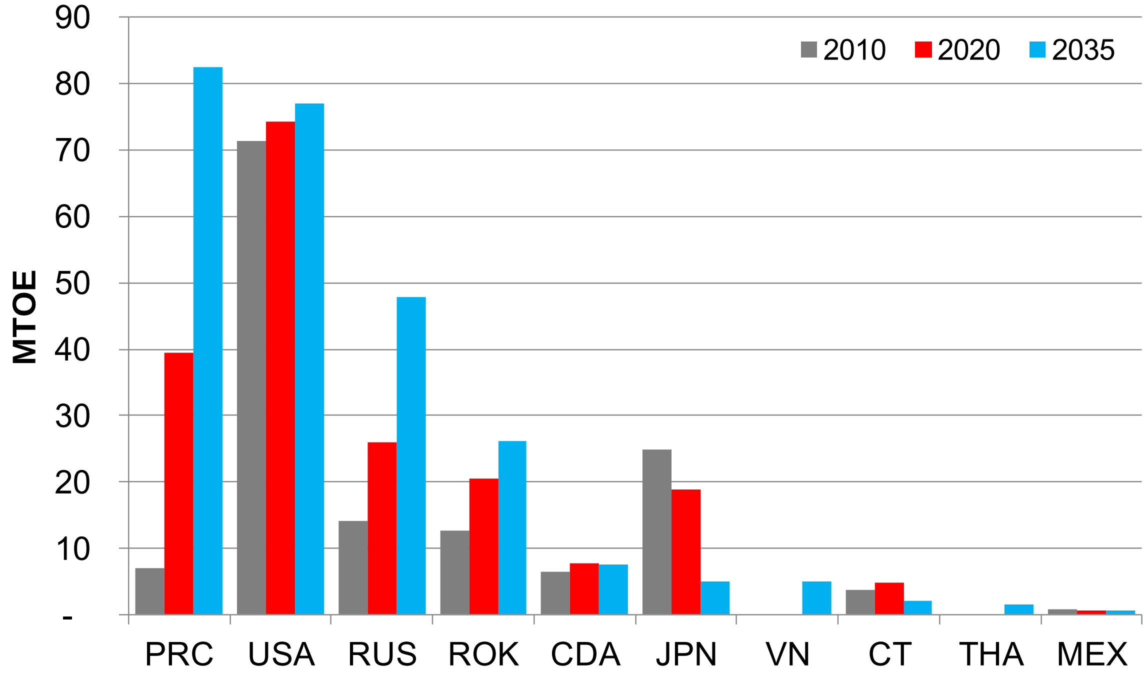
However, beyond these four reactors, plus one in Tennessee approved in the 1970s but only now being completed, further construction of new reactors in the US is likely to come slowly if at all (USEIA, 2012, pp. 50–51; Scientific American, 2012). Even before the Fukushima accident, high initial construction costs, regulatory uncertainties, safety concerns, the unresolved issue of waste disposal, and competition from low-cost natural gas were major obstacles to new US reactor construction. Nuclear energy in Canada and Mexico (which has only one commercial nuclear plant) faces similar obstacles.

Figure 14.1 shows projected electricity generation from nuclear energy by economy in Mtoe. By 2035, the amount of electricity generation by nuclear is expected to reach 292 Mtoe, compared to 141 Mtoe in 2009.

Overall, nuclear energy supply is projected to grow at a rate of 2.2% from 426 Mtoe in 2009 to 753 Mtoe in 2035. The share of nuclear energy in total primary energy is also projected to increase from 6% in 2009 to 7% in 2035.

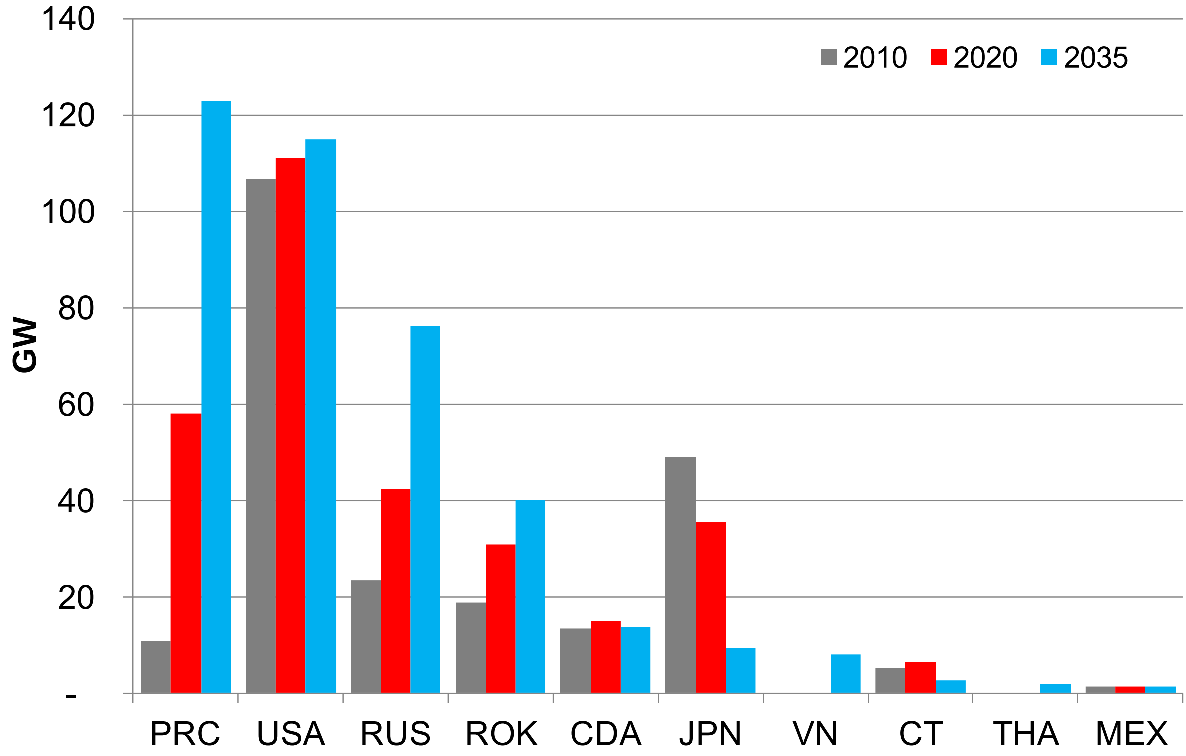
Figure 14.2 shows projected nuclear capacity by economy. In the APEC region, China is expected to be the clear leader in growth in nuclear power capacity, adding about 114 GW of capacity by 2035 to their 2009 capacity of about 9 GW. Russia will add 53 GW of new capacity, while Korea is expected to add about 21 GW of new capacity by 2035.

Figure 14.1: Projected Electricity Generation from Nuclear Energy



Source: APERC Analysis (2012)

Figure 14.2: Projected Nuclear Power Generation Capacity



Source: APERC Analysis (2012)

THE IMPACT OF THE FUKUSHIMA NUCLEAR ACCIDENT

When Japan revised its Strategic Energy Plan in 2010, aiming at doubling the rate of energy self-sufficiency (18% in 2010) and that of the zero-emission power sources (38% in 2010) by 2030, the key resource for achieving these targets was nuclear power. The share of nuclear generation in Japan's electricity generation mix was expected to be about 50% in 2030. That would require 14 or more nuclear power reactors.

However, the accident at the Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company (TEPCO), triggered by the Great East Japan Earthquake on 11 March 2011, has substantially changed not only the Strategic Energy Plan of Japan but also the outlook for nuclear development around the world.

The most dramatic impact was seen in Europe. In May 2011, Germany reconfirmed its earlier policy of phasing out nuclear energy by the early 2020s, beginning with the immediate shutdown of eight older plants, reversing a more recent policy of granting life extensions (BBC, 2011a). Switzerland dropped plans for new nuclear plants and decided to phase out its existing plants, although not until 2034 (New York Times, 2011). In Italy, which had abandoned nuclear energy in the 1980s, voter response to a referendum in June 2011 was 94% in favour of cancelling their government's plans for new reactors (BBC, 2011b).

Compared with Europe, the impact of the Fukushima accident in the APEC region has been more limited. Though all economies have reviewed their plans, and especially their safety regulations, no economy has so far decided to abandon nuclear energy. Except for two economies, the outlook for nuclear appears to be little changed.

The two exceptions are Japan and Chinese Taipei. In Japan, nuclear energy has become highly controversial, and there exists a great deal of uncertainty regarding its future. At the time of writing, only two of Japan's 50 remaining nuclear power units are in operation (four others at Fukushima Daiichi were decommissioned). The current nuclear situation in Japan is discussed in the Japan Economy Review in Volume 2. It will be up to the new Japanese government as elected in December 2012 to sort out Japan's nuclear policy going forward. In this Outlook, APERC has assumed nuclear generation will resume in Japan, but no new nuclear units will be built during the outlook period and existing units will be phased out at the end of their 40-year life.

In Chinese Taipei, the government has announced a policy of reducing dependence on nuclear generation, but has stopped short of a nuclear phase-out. Specifically, no life extension will be granted for the existing three nuclear power plants (six units), implying that the first unit will be decommissioned in 2018 and that all six existing units will be decommissioned by 2025. The one new plant currently under construction (two units) will, however, be completed and put into operation. See the Chinese Taipei Economy Review in Volume 2 for more discussion of the nuclear situation in that economy.

Recommendations of the Fukushima Nuclear Accident Independent Investigation Commission

As a basis for future nuclear policy, the National Diet of Japan established the Fukushima Nuclear Accident Independent Investigation Commission (NAIIC). The outcome of the NAIIC's investigation was seven recommendations. Although these recommendations were addressed to Japan, they provide important lessons for other economies involved in nuclear power development. In summary, the recommendations were (NAIIC, 2012):

1. **The National Diet should establish a permanent committee to supervise nuclear industry regulators** in order to secure the safety of the public.
2. **The crisis management system must be reformed**, including a consolidated chain of command and the power to deal with emergency situations. The boundaries dividing the responsibilities of national and local governments and operators must be made clear.
3. **The government must take responsibility for the public health and welfare consequences of the accident.** This includes continued monitoring of hotspots and spread of contamination, a detailed program of decontamination and relocation, and medical diagnosis and treatment of victims at state expense. Full information disclosure should be a priority.
4. **TEPCO should undergo a 'dramatic corporate reform',** including addressing issues of governance, risk management, and information disclosure with safety as the sole priority. The government should set rules and disclose information regarding its relationship with operators. Operators should set up a system of mutual peer review to maintain safety standards at the highest global level.

5. **A new regulatory body should be established which is independent, transparent, professional, consolidated, and proactive.**
6. **Laws related to nuclear energy should be reformed to meet global standards for safety, public health, and welfare.**
7. **Japan should establish a system of independent investigation commissions to deal with unresolved issues** including the reactor decommissioning process, spent fuel disposal, and post-accident decontamination.

REFERENCES

BBC (2011a), "Germany: Nuclear power plants to close by 2022", 30 May 2011, www.bbc.co.uk/news/world-europe-13592208

— (2011b), "Italy nuclear: Berlusconi accepts referendum blow", 14 June 2011, www.bbc.co.uk/news/world-europe-13741105

NAIIC (National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission) (2012), *The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission: Executive Summary (English Translation),* http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/wp-content/uploads/2012/09/NAIIC_report_lo_res10.pdf

New York Times (2011), "Switzerland Decides on Nuclear Phase-Out", 25 May 2011, www.nytimes.com/2011/05/26/business/global/26nuclear.html?_r=2&

Scientific American (2012), "Nuclear Reactor Approved in US for First Time Since 1978", 9 February 2012, www.scientificamerican.com/article.cfm?id=first-new-nuclear-reactor-in-us-since-1978-approved

USEIA (United States Energy Information Administration) (2012), *Annual Energy Outlook 2012 with Projections to 2035,* www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf

Wall Street Journal (2012), "U.S. Approves Nuclear Plants in South Carolina", 30 March 2012, http://online.wsj.com/article/SB10001424052702303816504577313873449843052.html

15 RENEWABLE ENERGY SUPPLY

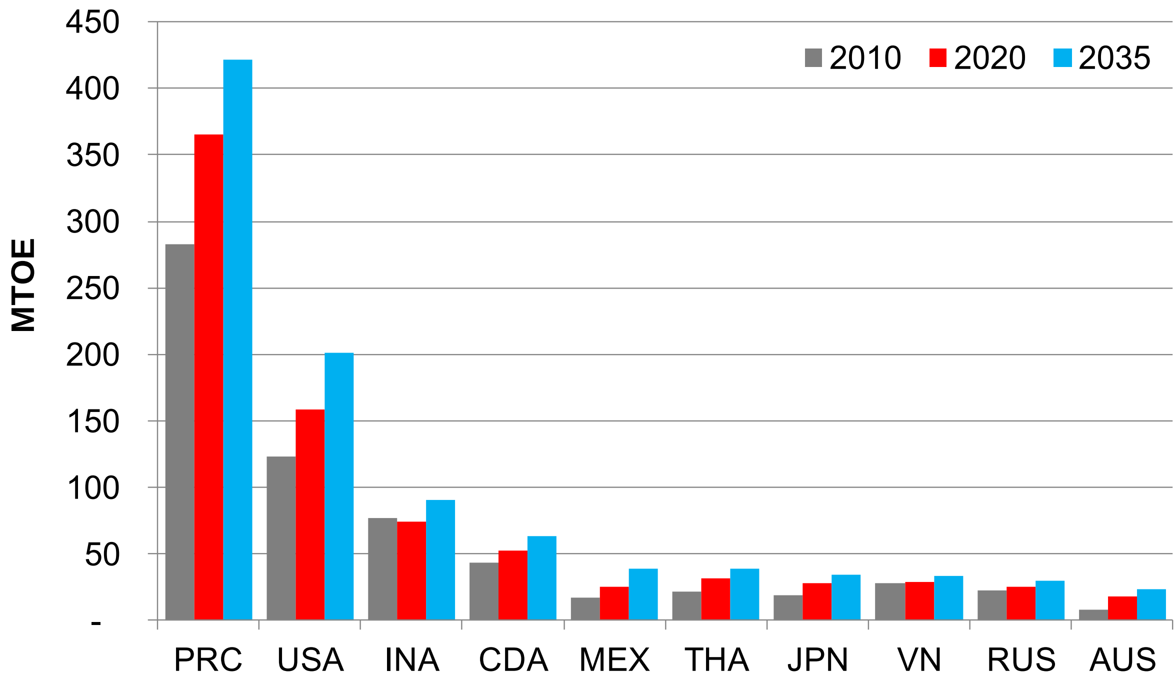
Renewable energy resources offer significant benefits for APEC economies. They are potentially secure, sustainable, and low in greenhouse gas (GHG) emissions. The quantity of resource potentially available is enormous.

Technological advancements have made it possible for APEC economies to harness more renewable energy resources, especially in the power generation sector. Spurred by these technological advances, coupled with existing supportive government policies, the contribution of renewable energy to the APEC region's energy supply is projected to grow over the outlook period under business-as-usual (BAU) assumptions—at an average annual rate of 1.8%, increasing from 684 Mtoe in 2010 to 1050 Mtoe by 2035.

China and the United States are expected to be the major contributors, making up over 50% of the total APEC primary renewable energy supply by 2035. At the same time, all APEC economies are expected to have some form of renewable energy contribution by 2035.

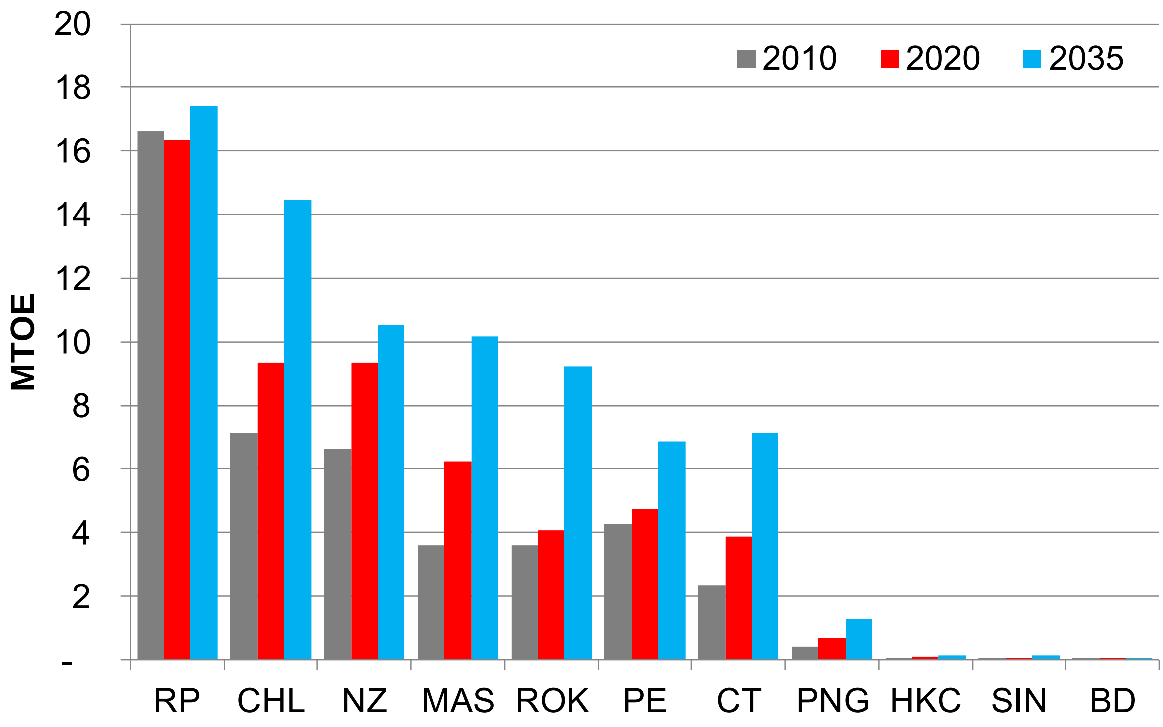
Figures 15.1 and 15.2 show the projected renewable energy supply for each APEC economy in the years 2010, 2020 and 2035. Note the difference in the scales of the vertical axis in the two figures.

Figure 15.1: Projected Renewable Energy Supply, Larger Supplying Economies



Source: APERC Analysis (2012)

Figure 15.2: Projected Renewable Energy Supply, Smaller Supplying Economies

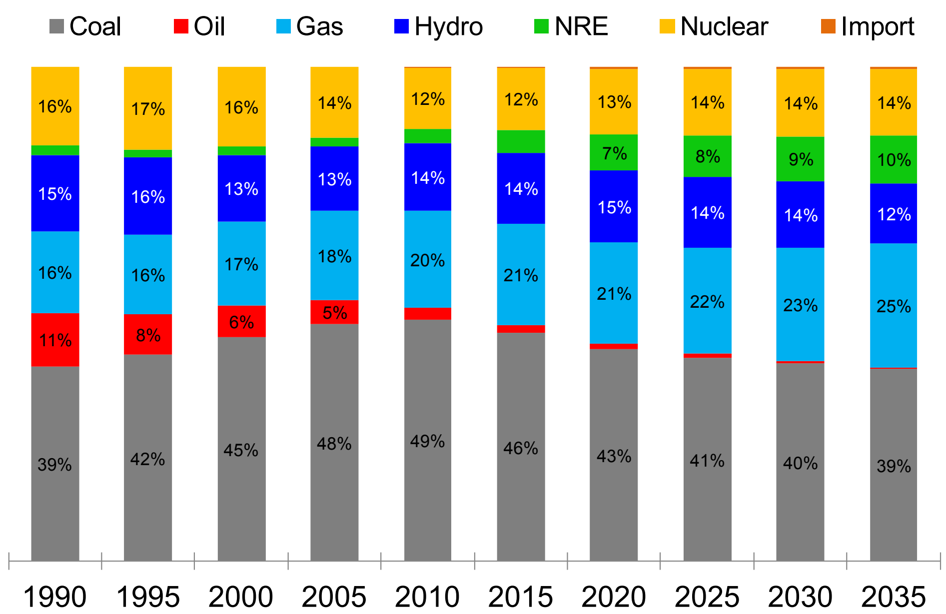


Source: APERC Analysis (2012)

RENEWABLE ENERGY IN THE ELECTRICITY GENERATION SECTOR

As APEC economies strive to minimize greenhouse gas emissions and air pollution, more renewable energy power generation capacity is being developed to counter the harmful effects of fossil fuel combustion. Figure 15.3 shows the renewable energy share (including hydro and new renewable energy) in the power generation mix will increase over the outlook period from 17% in 2010 to 22% by 2035. In APERC's terminology, new renewable energy (NRE) is understood to mean all renewable energy other than hydro.

Figure 15.3: APEC Region Electricity Generation Mix (1990–2035)



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The Role of Hydro in Electricity Generation

Use of renewable energy resources is not new in the APEC region. New Zealand, Canada and Peru used hydropower—mostly large-scale hydro—to generate more than half of their total electricity needs in 2010. Large-scale hydropower is a mature technology with generally favourable economic viability.

Further development options for large-scale hydro are limited in many APEC economies, as the best sites have already been developed. In addition, large-scale hydro has substantial social and environmental effects, such as dislocation of large numbers of people, loss of considerable amounts of productive land, and downstream impacts including diversion of water and trapping of silt. Hydro reservoirs may also emit methane, a potent greenhouse gas. However, the Intergovernmental Panel on Climate Change (IPCC) notes that for most hydro projects, lifecycle assessments have shown low overall net greenhouse gas emissions (IPCC, 2007, p. 274).

Total hydropower capacity in the APEC region is projected to increase from 532 GW in 2010 to 732 GW in 2035 under BAU assumptions. Accordingly, hydropower generation will increase at an annual average rate of 1.5% from 1840 TWh in 2010 to 2690 TWh in 2035. As shown in Figure 15.3, the share of hydro in the electricity generation mix will fluctuate between 12-15% over the outlook period. Since electricity production is growing faster than the primary energy supply growth, the share of the total primary energy supply coming from hydropower generation will increase from 2.1% in 2010 to 2.3% in 2035.

The Role of Non-Hydro Renewable Energy in Electricity Generation

NRE generation capacity is projected to grow rapidly in the APEC region over the outlook period, at an average annual rate of 7.3%. The growth in NRE capacity will be driven by existing supportive policies, as well as by rapidly declining costs. Wind energy is expected to be the technology with the greatest increase in capacity.

The long-term future of NRE, however, is likely to be based on solar energy. Solar is a rapidly advancing technology, which is easily scalable and distributable. Solar manufacturing costs, particularly for solar photovoltaic (PV) systems that directly convert sunlight into electricity, have declined rapidly as a result of advances in technology and from manufacturing economies of scale. Like computer chips, solar PV is a semiconductor technology that is amenable to the application of advanced science and engineering. It is expected that solar PV costs will continue to decline more quickly than those for mechanical and thermal technologies. Historically, solar PV has competed with concentrated solar power (CSP), which concentrates sunlight to produce heat. However, owing to its versatility in both small and large-scale applications, as well as its more rapidly declining costs, solar PV can be expected to lead the long-term growth in solar generation installations in the APEC region.

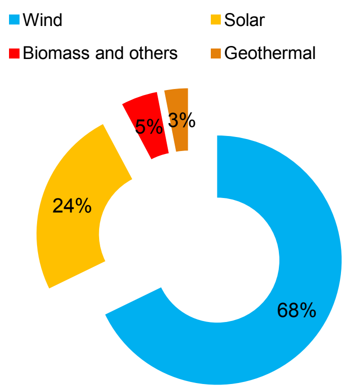
Module production costs for solar PV have declined sharply in recent years (IHS Consulting, 2012). Silicon module costs have declined from USD 4.50 per watt in the year 2000 to below USD 1.00 per watt in late 2011 (LBNL, 2011; IHS Consulting, 2012). Early estimates for module costs at the end of 2012 suggest they may be as low as USD 0.50 per watt. These cost estimates are for low-efficiency modules, but they serve as a good indication of the rapidly improving economics of PV solar. In the future, an increasing focus will be on reducing costs for the balance of the PV system other than the modules themselves, such as costs associated with installation and grid connection. Because of the decline in module costs, the balance of the PV system now typically accounts for two-thirds of total PV installation costs (LBNL, 2011).

Unsubsidized solar PV costs are expected to become competitive with the retail price of electricity in many regions as early as 2020—this is known as 'grid parity' (IEA, 2010). The economics of solar PV is especially attractive in places where electricity demand peaks on hot days when sunshine is likely to be most intense, which describes many APEC economies. Once the economics of solar are firmly established and cost competitive with conventional generation technology, growth in NRE should accelerate.

The NRE growth projections in this Outlook are founded on the plans of the individual APEC economies. It is likely that these projections do not consider the rapidly declining costs of NRE, particularly for solar PV. Therefore the NRE growth projections across APEC are conservative in nature.

From 2010 to 2035, it is projected that a total of 677 GW of NRE generation capacity will be installed in the APEC region under BAU assumptions. The likely breakdown (by energy source) of NRE generation capacity added from 2010 to 2035 is shown in Figure 15.4. It is expected that wind will dominate, followed by solar, biomass and others, and geothermal. In APERC terminology, 'biomass and others' means combustible renewable sources, which comprise solid biomass, liquid biomass, biogas, industrial waste and municipal waste.

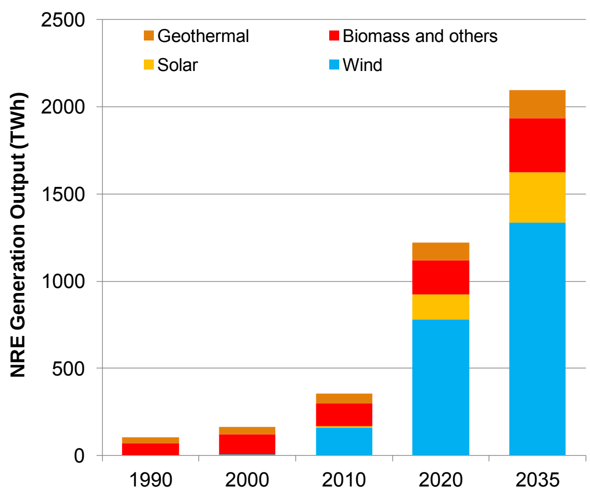
Figure 15.4: NRE Capacity Additions in APEC by Energy Source (Total for 2010–2035)



Source: APERC Analysis (2012)

Electricity generation output from NRE sources will increase dramatically from 355 TWh in 2010 to 2095 TWh in 2035. Figure 15.5 shows the growth in NRE electricity generation output by energy source. As with capacity additions, wind dominates, contributing 64% of the NRE generation mix. 'Biomass and others' is the second largest contributor at 15%, followed by solar (14%) and geothermal (8%).

Figure 15.5: NRE Electricity Generation in APEC by Energy Source (1990–2035)

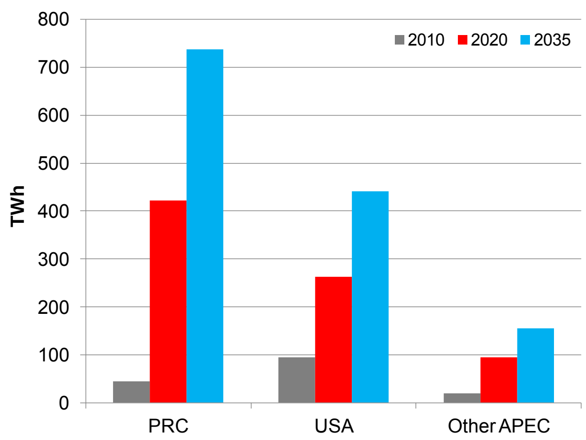


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Wind Power Generation

Figure 15.6 shows the breakdown of wind generation by economy. By 2035, China leads in the output of electricity generated from wind energy, reaching around 738 TWh. This is followed by the US on about 440 TWh. Together China and the US account for around 88% of wind-based generation output across the APEC region.

Figure 15.6: Wind-based Generation Growth, Top Two and Other APEC Economies (2005–2035)



Source: APERC Analysis (2012)

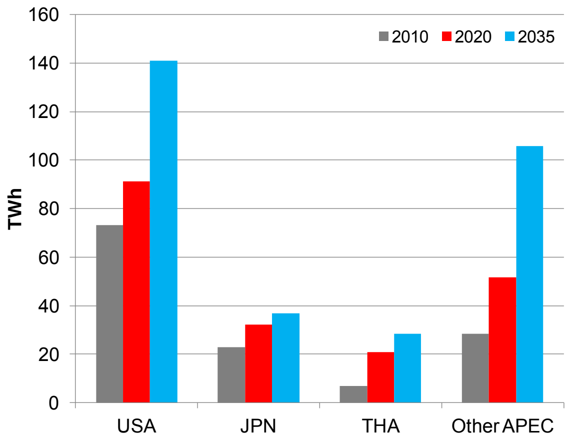
Biomass Power Generation

Biomass feedstock fuels used for electricity generation include forest wood and residuals, industrial waste, municipal waste and landfill gases. The most scalable biomass fuel source is from forests, where much of the projected growth in biomass generation in the APEC region will be sourced. Biomass has an increasing role as a feedstock for direct use in electricity production but also as a feedstock that is blended with coal to reduce GHG emissions.

Biomass is also expected to play an increasing role in improving energy security, as well as reducing emissions throughout APEC economies. The APEC-wide average annual growth rate in biomass generation is 3.5% over the outlook period.

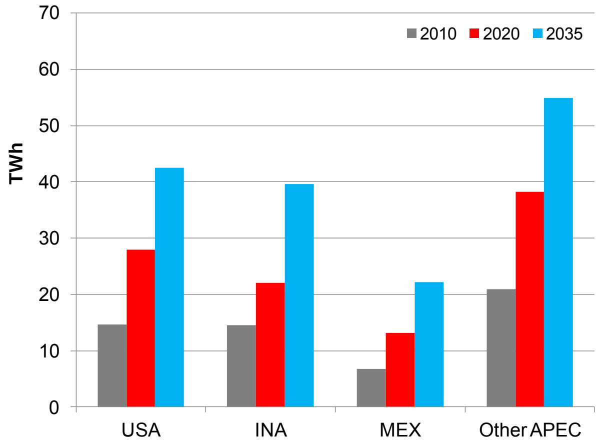
For the US, biomass use is vital to meeting many of the State Renewable Portfolio Standards for emission reductions (US EPA, 2012). Over the outlook period, the US will see rapid growth in biomass-based generation, with an average annual growth of 2.7%.

Figure 15.7: Biomass-based Generation Growth, Top Three and Other APEC Economies (2005–2035)



Source: APERC Analysis (2012)

Figure 15.8: Geothermal-based Generation Growth, Top Three and Other APEC Economies (2005–2035)



Source: APERC Analysis (2012)

Geothermal Power Generation

In some APEC economies, geothermal is one of the most economically attractive NRE sources. A major advantage of geothermal energy is that it can provide dependable base-load power generation. However, the potential for geothermal development in APEC is limited by its resource potential. Only around half of all APEC economies will have a geothermal capacity exceeding 300 MW by 2035 under BAU assumptions.

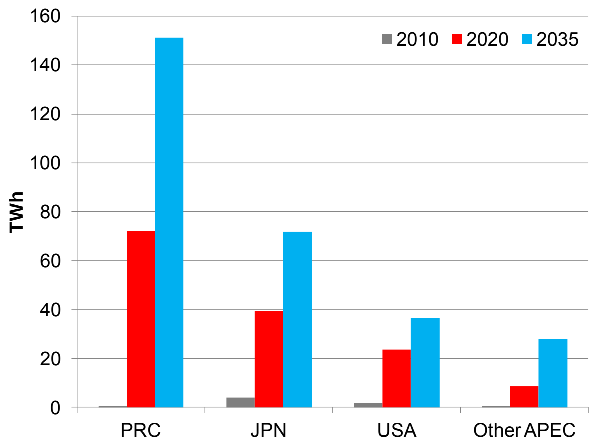
In the APEC region geothermal power generation is expected to grow at around 4.2% per year over the outlook period. The United States will lead the growth in geothermal-based generation, reaching 43 TWh in 2035, followed by Indonesia and Mexico. Australia, Chile and Japan are also likely to see modest growth in geothermal power generation.

Owing to its small electricity demand and attractive geothermal resources, the share of geothermal generation in New Zealand will reach 19% of its total generation in 2035—the highest in the APEC region.

Solar Power Generation

As discussed earlier, solar technology is advancing rapidly. From a base of near zero in 2010, solar-based electricity output (lead by China, Japan and the US) will reach over 288 TWh in 2035. This is an average annual growth rate of 16%.

Figure 15.9: Solar-based Generation Growth, Top Three and Other APEC Economies (2005–2035)

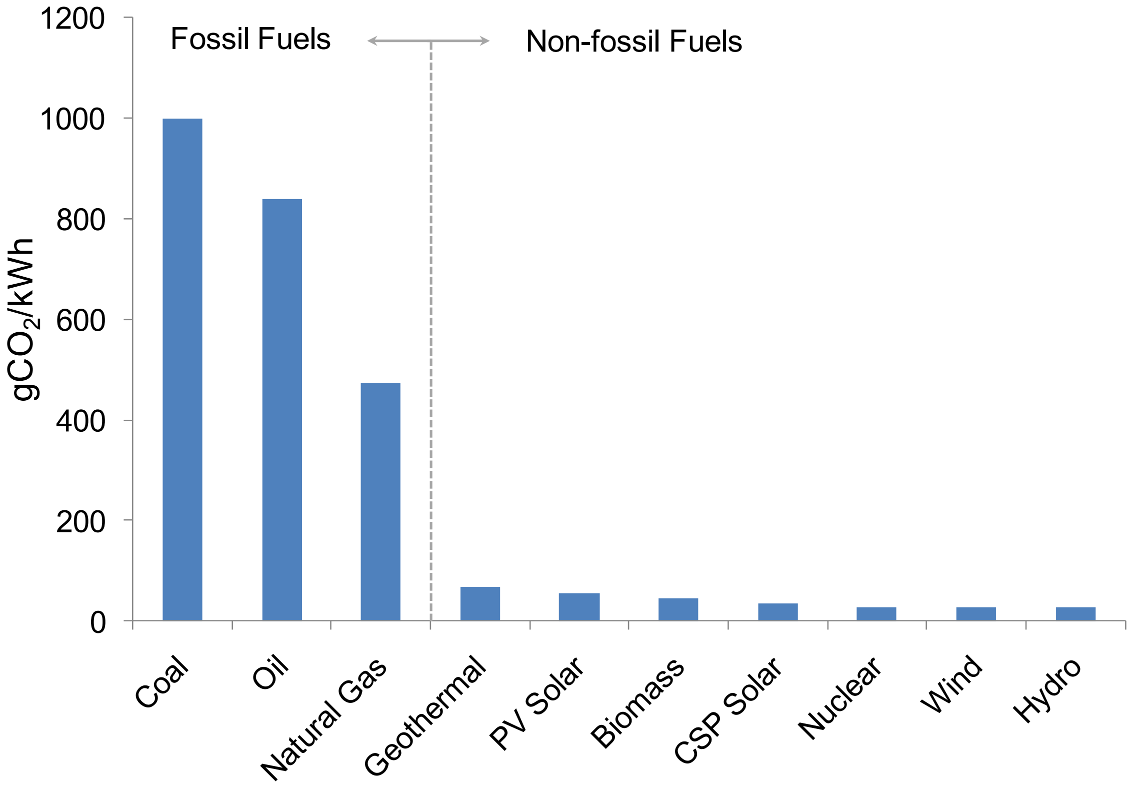


Source: APERC Analysis (2012)

Lifecycle Emissions of Renewable and Non-Fossil Electricity Generation

While the energy security benefits of electricity generation from renewable and non-fossil energy sources are readily apparent, there are often misunderstandings as to whether it offers significant reductions in greenhouse gas emissions on a lifecycle basis. Obviously, renewable and non-fossil generation, as the names suggest, use non-fossil energy sources. However, since the technology to extract this energy often involves an extensive upfront investment in manufacturing and construction, net emissions benefits must consider all stages of development and all production inputs. The World Nuclear Association (WNA) and Intergovernmental Panel on Climate Change (IPCC) have each summarized the findings from a comprehensive number of different research analyses. Based on these two sources, the median lifecycle emissions for each generation technology were estimated and are shown in Figure 15.10.

Figure 15.10: Median Lifecycle Emissions Estimates, by Electricity Generation Technology



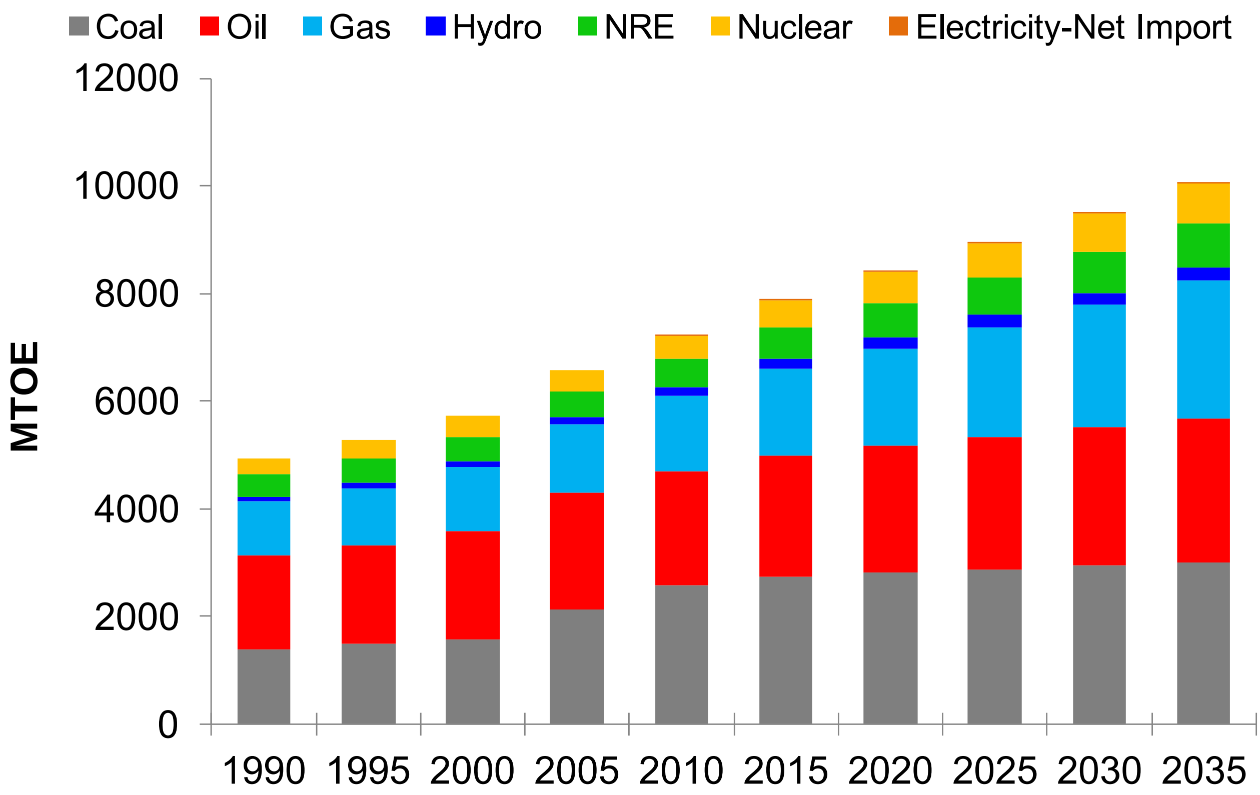
Sources: Adapted from WNA (2011) and IPCC (2011, p. 732)

Figure 15.10 illustrates the clear divide in lifecycle CO_2 emissions between fossil and non-fossil generation. Among fossil fuels, natural gas generation has the lowest lifecycle emissions, while geothermal and PV solar have the highest lifecycle emissions of the non-fossil fuels. (In earlier years, PV lifecycle emissions were noticeably higher than shown in Figure 15.10. However, advances in manufacturing and technology have now reduced PV solar lifecycle emissions estimates to levels comparable with other renewable energy technologies.) Overall, CO_2 emissions on a lifecycle basis for both geothermal and PV solar are less than natural gas by more than a factor of 6.

DIRECT USE OF NRE

The NRE share of the total APEC primary energy supply was 7.3% (530 Mtoe) in 2010. Of this, about 80% was used directly, rather than converted to electricity. In 2035, the NRE share is projected to have increased to 8.1% (818 Mtoe), of which about 41% is expected to be used directly. NRE resources are currently dominated by biomass, and this is expected to remain the case in 2035.

Figure 15.11: APEC Region Total Primary Energy Supply Mix (1990–2035)



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

NRE Use in the Residential Sector

NRE utilization in the APEC region varies depending on the resources and technology available. Biomass resources such as wood, animal dung and agricultural residues have been used for many centuries for residential cooking, space heating and lighting. These fuels are still widely used by the poor in some less developed areas of the APEC region, where commercial fuels are too expensive or unavailable. The use of residential biomass may have negative impacts, especially in terms of severe indoor air pollution, which causes diseases and respiratory problems. Gathering of biomass may reduce the fertility of the land. In addition, residential biomass use may also lock people, especially women and children, into poverty, since time spent gathering fuel means reduced time for education and income-generating activities (APERC, 2009, p. 45).

In the APEC region, rising incomes, improved availability of commercial fuels and urbanization will likely work against the use of residential biomass. However, there are many uncertainties about residential biomass, starting with a lack of basic data: since most residential biomass is never traded commercially, it is not possible to survey producers or marketers.

It is likely that residential biomass will continue to be popular in the APEC region throughout the outlook period, given its affordability and availability, and the cultural preferences for wood fires and wood cooking. This need not be a cause for concern, as modern technology allows biomass to be produced in an environmentally sustainable fashion and to be burned cleanly and efficiently. It is important that government policies ensure that this modern technology gets applied, and that those who use residential biomass do so by choice, and not by poverty-driven necessity.

NRE Use in the Commercial and Industrial Sectors

More sophisticated methods are also being developed to extract energy cleanly and more efficiently from solar and geothermal resources, as well as from biomass, for non-power applications in the commercial and industrial sectors. These include:

- *Biomass energy.* The pulp and paper, forest products, food, and chemical industries are examples of industries that utilize biomass energy directly in their industrial processes by burning their own waste products. Biomass feedstock can now be transformed into more convenient solid, liquid or gaseous forms to generate heat for industrial processes and combined heat and power (CHP) systems (IPCC, 2011, p. 217).
- *Solar energy.* New buildings are being designed to effectively manipulate solar energy for heating, cooling and natural lighting. This method is called 'passive solar technology', whereas 'active solar technology' uses collectors with chemical, mechanical or electrical elements to collect, circulate and store heat from solar energy more effectively. A popular use for solar energy in Asian countries is the domestic solar water heater, which is a cost-effective system to generate hot water for bathing and washing.
- *Geothermal energy.* Direct applications of geothermal energy include space heating, bathing and balneology (therapeutic use of baths), horticulture (greenhouses and soil heating), industrial process heat and agricultural drying, aquaculture (fish farming) and snow melting (IPCC, 2011, p. 416).

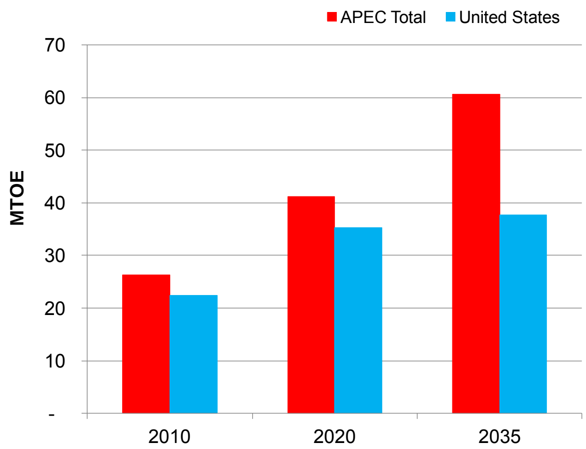
NRE Use in the Transport Sector

Biomass feedstock can be converted into liquid biofuels such as ethanol and biodiesel for use in road transportation. Ethanol today is made primarily from corn and sugar cane, while biodiesel can be produced from virgin plant oils, waste vegetable oil, animal fats, fish oil and algae (REN21, 2011, p. 31). These are categorized as first-generation biofuels.

While first-generation biofuels provide net energy benefits, when all associated emissions are accounted for, biofuels may produce more greenhouse gas emissions than they avoid. There are also added negative externalities in the form of rising food costs and damage to local ecosystems (APERC, 2009, p. 78).

Second-generation technology is expected to solve some of the problems of today's commercial biofuels. 'Cellulosic' biofuel can be made from almost any plant, as well as from forestry and agricultural residues and from city waste. It has even been reported that this advanced biofuel could help cut transport emissions by 80% (Renewable Energy World, 2011). However, due to the significant production and technological challenges, as of 2012 there is still no large-scale commercial production of second-generation biofuels. Many organizations are working, some with government support, to commercialize various pathways for producing cellulosic biofuels. Until these second-generation technologies are deployed, the increased energy security offered by biofuels comes at a high cost.

Figure 15.12: Biofuel Use in Transport Sector in APEC Economies



Source: APERC Analysis (2012)

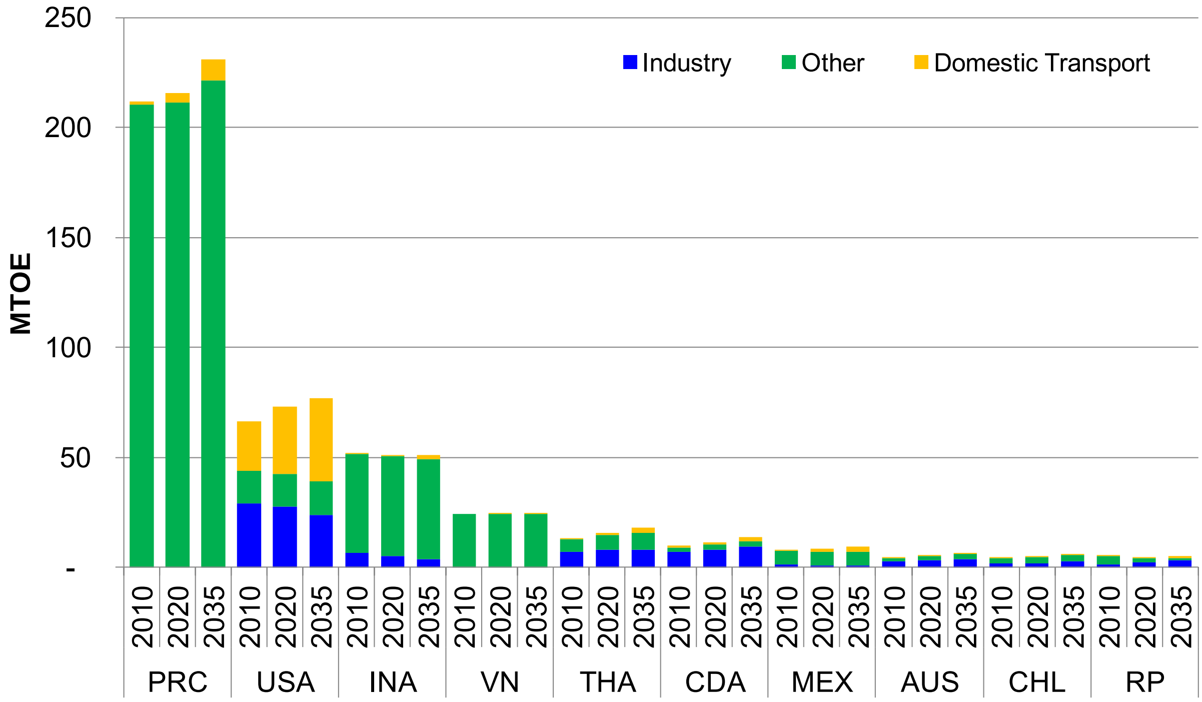
From Figure 15.12, it can be seen that the United States is the leading biofuel consumer in the APEC region, consuming up to 85% of the total 26 Mtoe biofuel demand in 2010. As other economies begin to adopt the technology, the United States share is expected to decline, reaching about 62% by 2035, with China taking up 15.5%, Thailand 4.5%, and Mexico 3.8%.

Projections for Direct Use of NRE in the APEC Region by Economy

Projections of direct use of NRE in APEC economies by sector are shown in Figures 15.13 and 15.14. As noted earlier, data on direct use of renewable energy is limited, so available data may not represent a complete picture of NRE utilization.

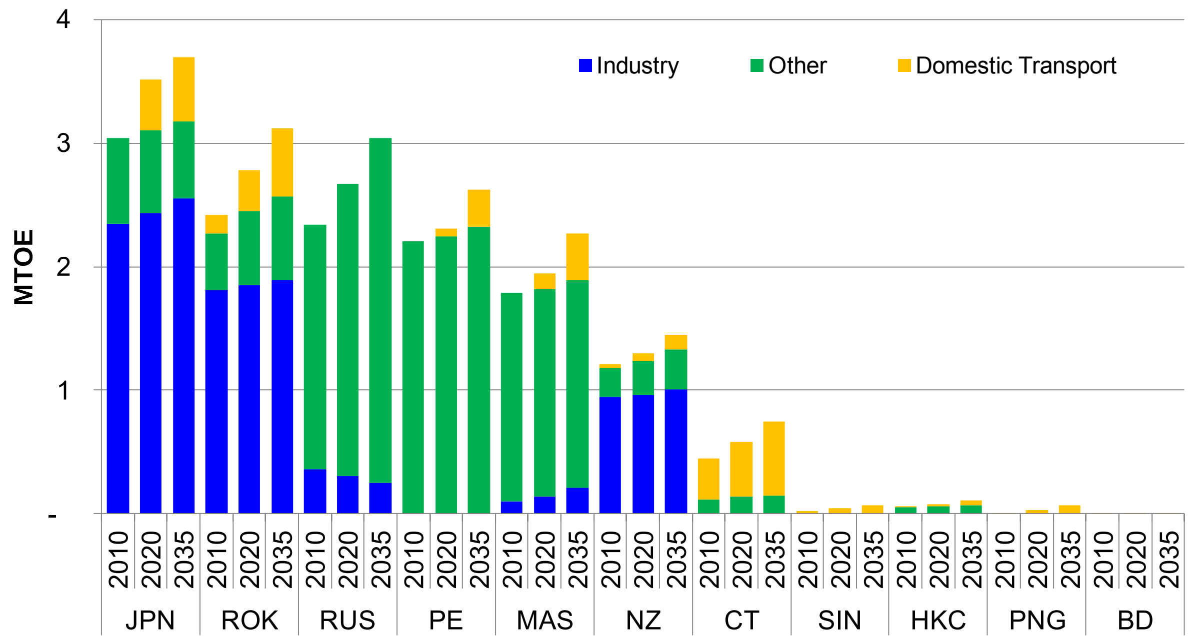
Overall, direct use of NRE will show an increase across all economies. Developing economies like China and Indonesia tend to use more NRE sources in the 'other' sector, while developed economies like United States, Japan and Korea use more NRE in industry. NRE use in the 'other' sector in developing economies would mostly be for residential biomass—with better access to commercial energy, biomass use in the residential sector would decline. However, this reducing trend in residential biomass use would likely be offset by the growth of modern NRE direct use technologies in the industry and transport sectors. By 2035, China will account for about half of NRE direct use in the APEC region, followed by South-East Asian economies (24%) and North American economies (19%).

Figure 15.13: Direct Use of NRE by Sector, Larger Supplying Economies



Source: APERC Analysis (2012)

Figure 15.14: Direct Use of NRE by Sector, Smaller Supplying Economies



Source: APERC Analysis (2012)

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2009), *APEC Energy Demand and Supply Outlook 4th Edition, Volume 1*, www.ieej.or.jp/aperc/

IEA (International Energy Agency) (2010), *Technology Roadmap: Solar Photovoltaic Energy,* www.iea.org/publications/freepublications/publication/pv_roadmap-1.pdf

— (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

IHS Consulting (2012), *Mapping Key Trends in Leading Global Renewable Power Markets*, presentation at the IHS Focus Forum on Emerging Energy Research, Japan, 30 August 2012.

IPCC (Intergovernmental Panel on Climate Change) (2007), *Fourth Assessment Report 2007: Mitigation of Climate Change,* www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf

— (2011), *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change,* http://srren.ipcc-wg3.de/report

LBNL (Lawrence Berkeley Laboratory) (2011), *Tracking the Sun IV: A Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998–2010,* http://eetd.lbl.gov/ea/emp/reports/lbnl-5047e.pdf

REN21 (Renewable Energy Policy Network for the 21st Century) (2011), *Renewables 2011: Global Status Report*, www.ren21.net

Renewable Energy World (2011), 'Second-Generation Biofuels Gain Traction but Growth Challenges Remain', 6 May, www.renewableenergyworld.com/rea/news/article/2011/05/second-generation-biofuels-gain-traction-but-growth-challenges-remain

US EPA (United States Environmental Protection Agency) (2012), *Carbon Pollution Standard for New Power Plants,* http://epa.gov/carbonpollutionstandard/index.html

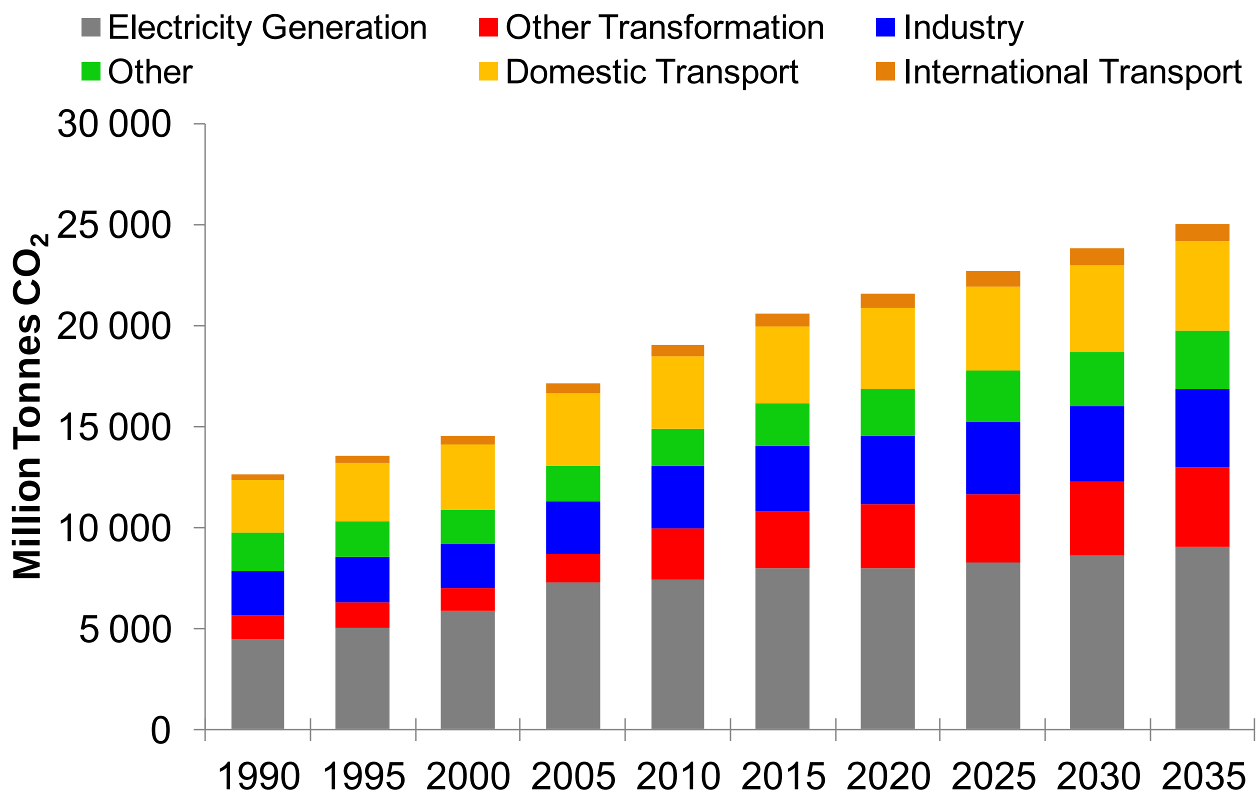
WNA (World Nuclear Association) (2011), *Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources,* www.world-nuclear.org/uploadedFiles/org/reference/pdf/comparison_of_lifecycle.pdf

16 CARBON DIOXIDE EMISSIONS

The APEC region's CO_2 emissions from fuel combustion are projected to rise by about 32% between 2010 and 2035 (see Figure 16.1). These emissions pose a threat to humanity, to the environment, and to the economies of the APEC region and the world. This chapter discusses the details of these emission projections and their implications for policymakers.

APERC has modelled only the emissions of carbon dioxide (CO_2) from fuel combustion. As noted in Chapter 1, in 2009 CO_2 emissions from fuel combustion accounted for 89% of energy-related greenhouse gas emissions worldwide on a CO_2-equivalent basis, and these energy-related emissions in turn accounted for about two-thirds of total greenhouse gas emissions on a CO_2-equivalent basis (IEA, 2011, p. III.45). Non-CO_2 energy emissions are difficult to model because they depend not just on the quantity of fuel burned, but also on details of the conditions under which the fuel was burned or escaped into the environment (IPCC, 2006).

Figure 16.1: APEC Projected Business-as-usual CO_2 Emissions from Fuel Combustion

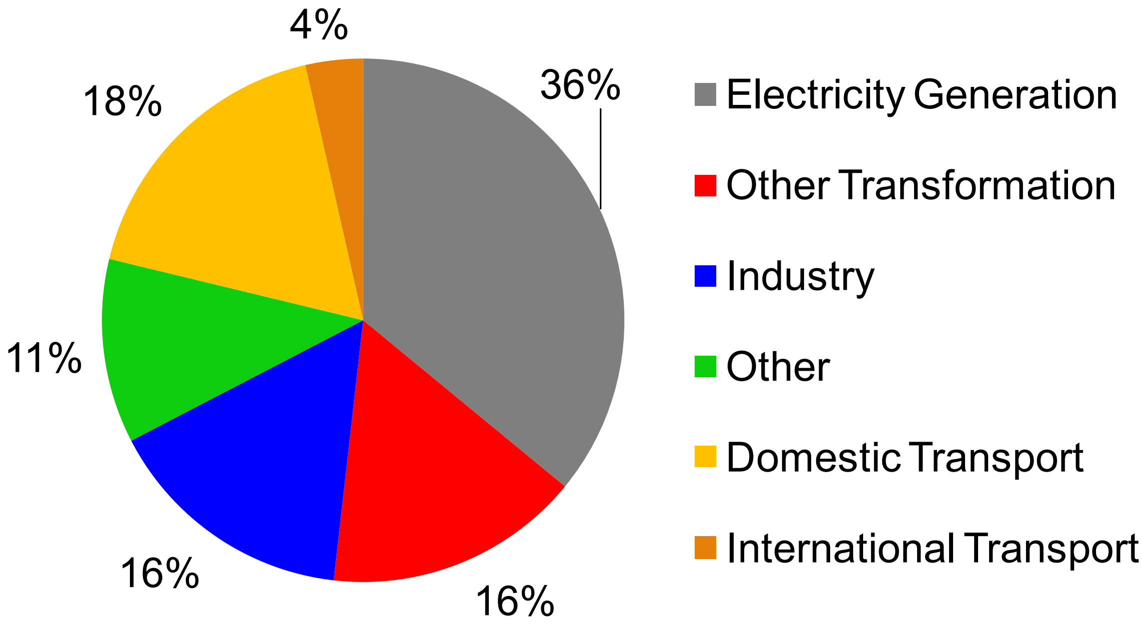


Source: APERC Analysis (2012)

CO_2 EMISSION RESULTS

CO_2 emissions from APEC economies are projected to increase under our business-as-usual (BAU) assumptions from 19.0 billion tonnes in 2010 to 25.1 billion tonnes in 2035. Electricity generation alone (Figure 16.2) will account for 9.0 billion tonnes, or about 36% of these emissions in 2035. Domestic transport at 4.4 billion tonnes or about 18% is in second place. 'Other Transformation' (which includes refineries and other energy sector own use, heat generation, and hydrogen generation) at just under 4.0 billion tonnes or 16% is almost tied for third place with Industry at a bit more than 3.9 billion tonnes (16%).

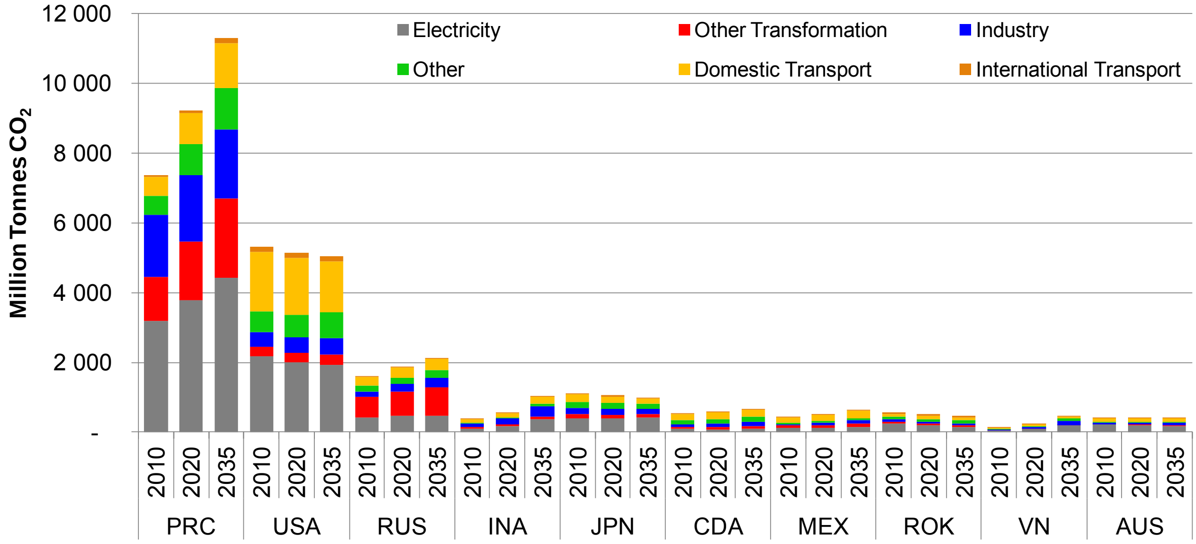
Figure 16.2: APEC Projected Shares of CO_2 Emissions from Fuel Combustion by Sector in 2035



Source: APERC Analysis (2012)

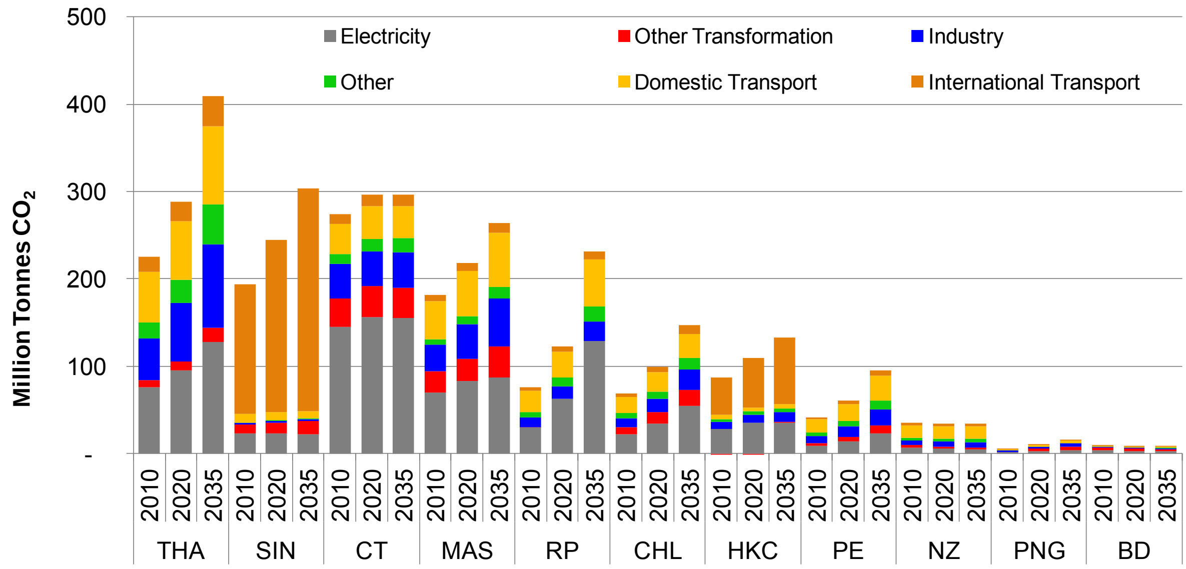
As shown in Figure 16.3 and Figure 16.4 (note the difference in scales between the figures), the importance of each sector in contributing to emissions varies considerably by economy. However, in 13 of the 21 APEC economies, electricity will be the leading source of CO_2 emissions in 2035.

Figure 16.3: CO_2 Emissions from Fuel Combustion by Sector, Higher Emitting Economies



Source: APERC Analysis (2012)

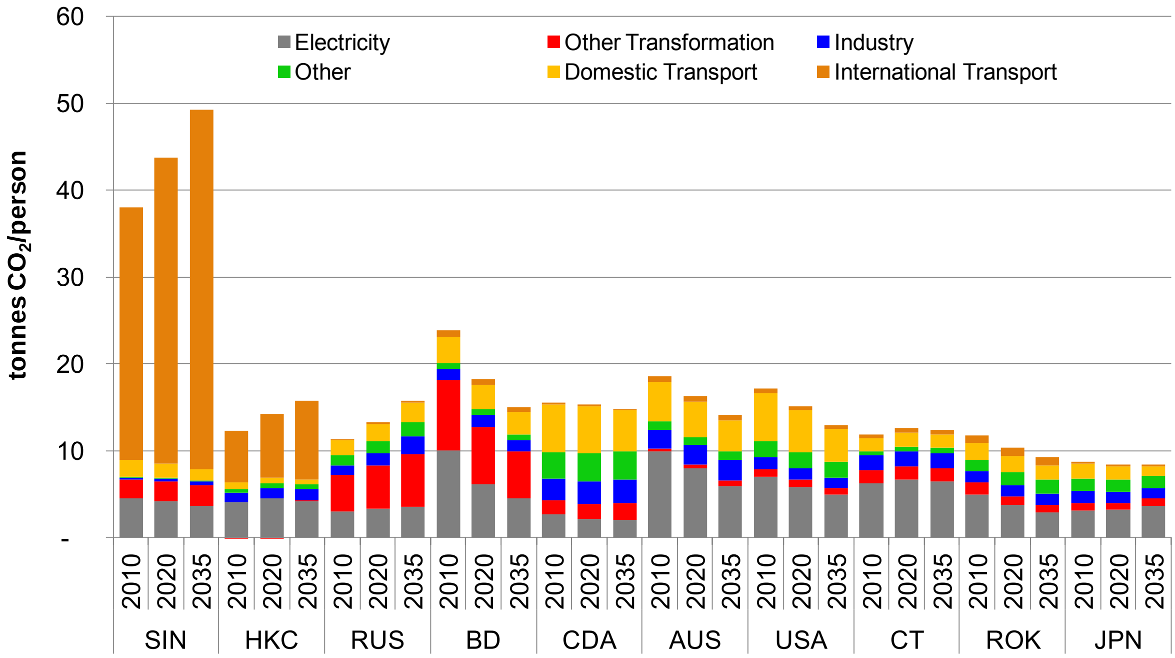
Figure 16.4: CO_2 Emissions from Fuel Combustion by Sector, Lower Emitting Economies



Source: APERC Analysis (2012)

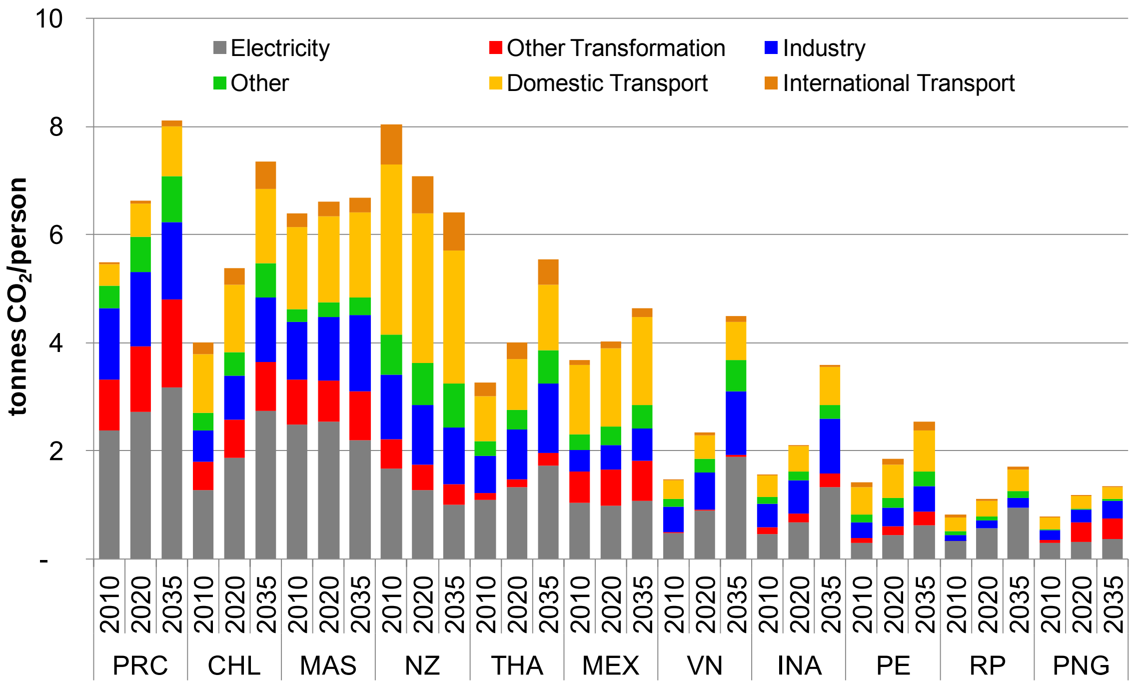
Considering emissions on a per capita basis paints a somewhat different picture of who is responsible for these emissions. As shown in Figure 16.5 and Figure 16.6, it is the APEC's more developed economies that have the highest per capita emissions, although emissions per capita in the developing economies are also rising rapidly. Singapore and Hong Kong have high emissions from international transport due to their role as major shipping and air transport hubs.

Figure 16.5: CO_2 Emissions per Capita from Fuel Combustion by Sector, Higher Per Capita Emission Economies



Source: APERC Analysis (2012)

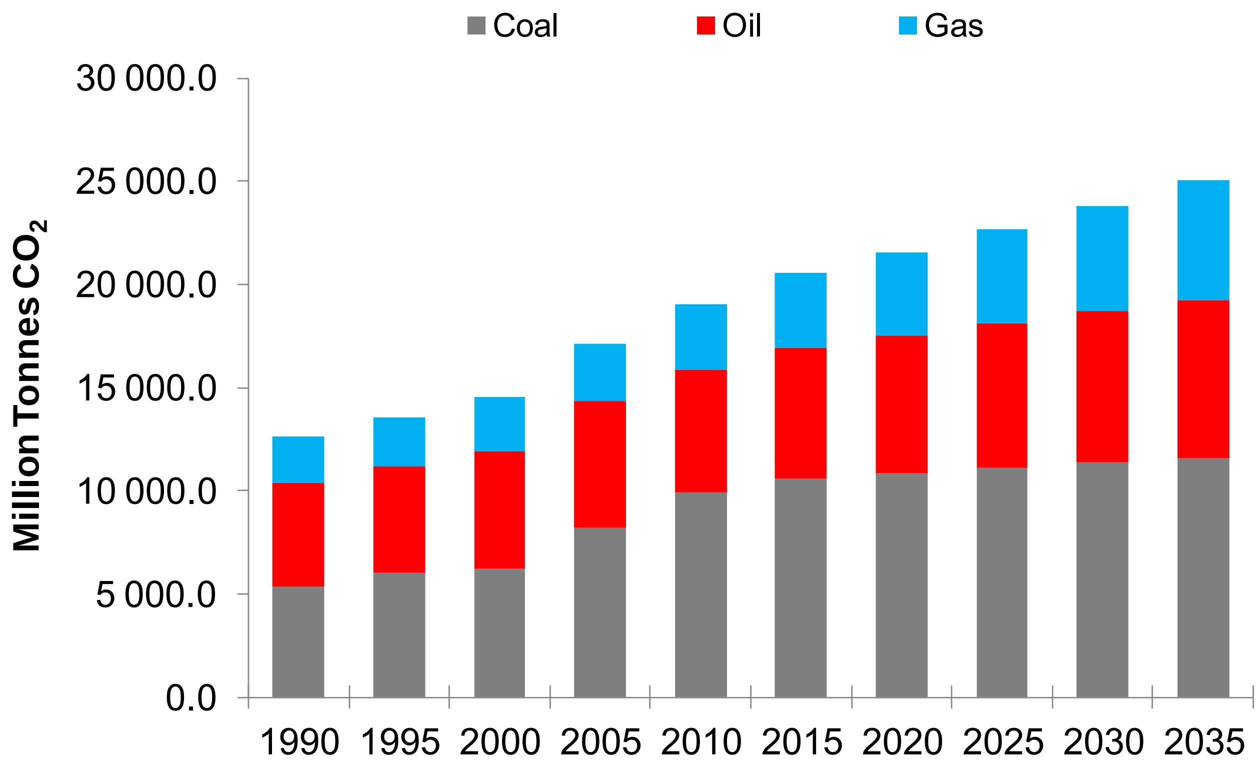
Figure 16.6: CO_2 Emissions per Capita from Fuel Combustion by Sector, Lower Per Capita Emission Economies



Source: APERC Analysis (2012)

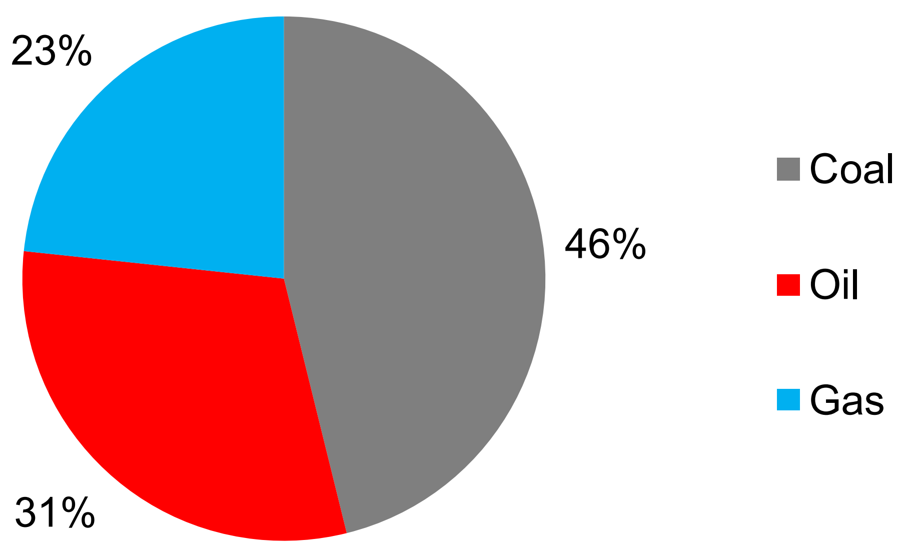
Among the fossil fuels, coal is projected to provide the largest contribution to APEC's primary energy supply by 2035. As it is also the most carbon intensive of the fossil fuels, coal not surprisingly contributes the most to CO_2 emissions. Coal contributes 46% of greenhouse gas emissions in 2035, whereas oil and gas contribute 31% and 23%, respectively (Figures 16.7 and 16.8).

Figure 16.7: APEC Projected BAU CO_2 Emissions from Fuel Combustion, by Fuel



Source: APERC Analysis (2012)

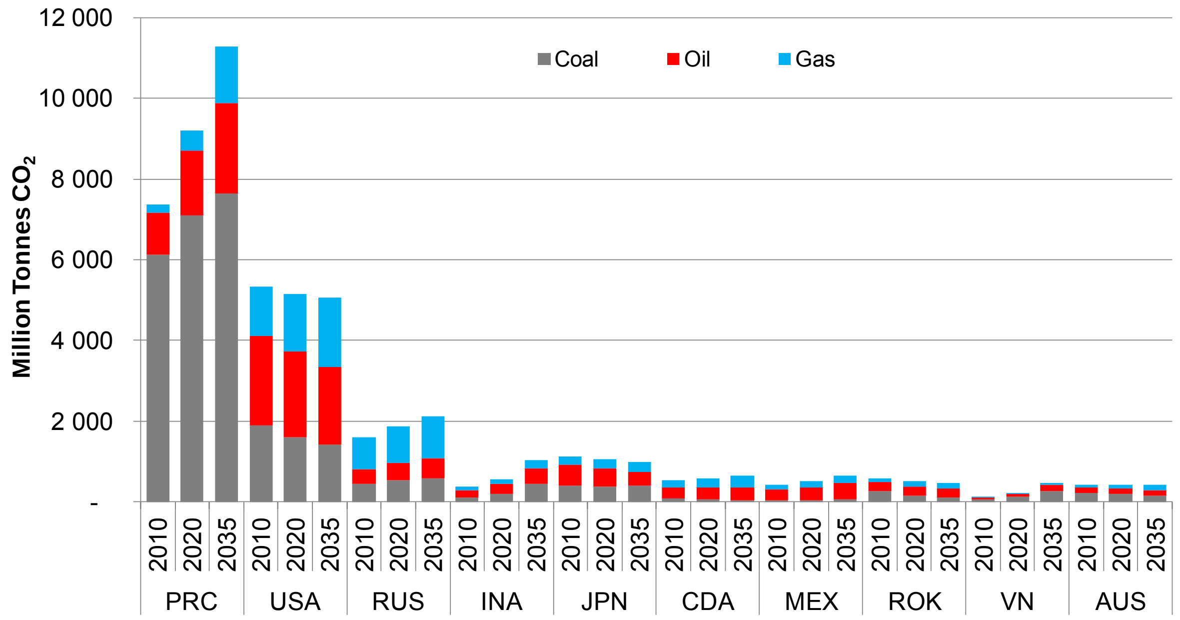
Figure 16.8: APEC Projected Shares of CO_2 Emissions from Fuel Combustion by Fuel in 2035



Source: APERC Analysis (2012)

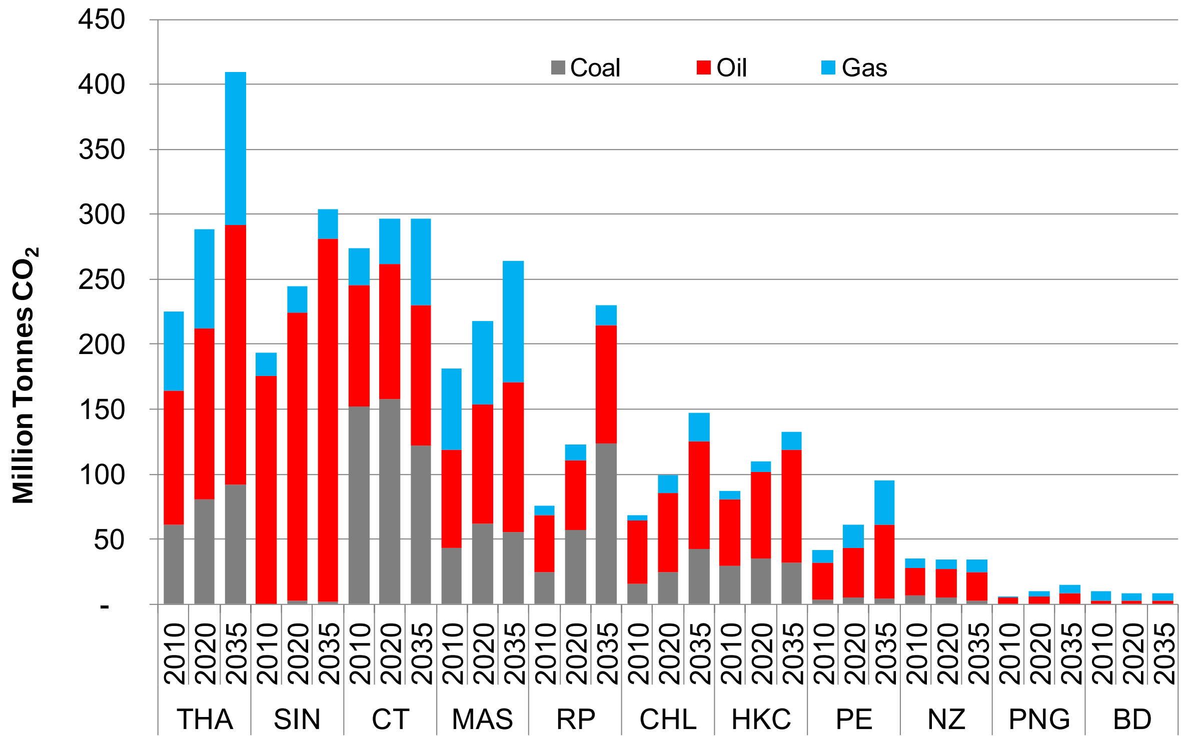
However, as shown in Figure 16.9 and Figure 16.10, the share of the three fuels in CO_2 emissions varies dramatically among the economies.

Figure 16.9: CO_2 Emissions from Fuel Combustion by Fuel, Higher Emitting Economies



Source: APERC Analysis (2012)

Figure 16.10: CO_2 Emissions from Fuel Combustion by Fuel, Lower Emitting Economies



Source: APERC Analysis (2012)

In 2009, the APEC economies accounted for about 60% of world CO_2 emissions from the combustion of fossil fuels (calculated from IEA, 2011, pp. III.45–49). It is, therefore, no exaggeration to say what happens in APEC will largely determine what happens in the world. As discussed in Chapter 1, the best science is saying that the world needs to make dramatic reductions in greenhouse gas emissions to avoid potentially disastrous climate change consequences. This need for reductions stands in stark contrast with the 32% increase in CO_2 emissions from fossil fuel consumption between 2010 and 2035 under our BAU scenario. Clearly, the BAU projection is incompatible with APEC's commitment to "…prevent dangerous human interference with the climate system" (APEC, 2007).

THE WAY FORWARD

Finding ways to make large reductions in greenhouse gas emissions in fast-growing economies, such as those of the APEC region, is a challenge that ranks among the greatest of our times. CO_2 is an inherent product of fossil fuel consumption; unlike toxic air pollutants, it cannot be eliminated with improved combustion technology. There are fundamentally only three ways to reduce CO_2 emissions: use less energy, switch to less-emission-intensive energy sources, or find a way to capture and permanently store the CO_2. Given that under our BAU projections the APEC region will depend upon fossil fuels for over 80% of its primary energy supply in 2035, each of these alternatives will involve huge changes.

While this study has not attempted a detailed analysis of alternatives, there are some general recommendations that emerge from the analysis presented here.

1. *Educate*. Dealing with a challenge the size of the climate change problem will require a serious commitment from a lot of people. Policymakers will need support and cooperation from their stakeholders and constituents if effective policies are to be agreed upon and adopted. This kind of support and cooperation will only come if those stakeholders and constituents understand the magnitude of the challenge and the consequences of an inadequate response. Since climate change is a challenge that will have to be dealt with over a time span of decades, it makes sense to insure that young people are appropriately educated on climate change science, technology, and institutions in schools of all levels. And no opportunity should be lost to educate their elders as well.
2. *Promote energy efficiency*. As discussed in Chapter 4, there are a variety of market barriers preventing the most efficient use of energy resources. Removing these barriers, or adopting policies to offset them, can often simultaneously reduce emissions, reduce costs, and promote energy security. Improved energy efficiency is likely to be the quickest and least-cost first line of attack on the climate change problem.
3. *Promote energy research*. As discussed in Chapter 15 and others, there are a variety of promising low-emission energy supply technologies, including various types of renewable energy, carbon capture and storage, and advanced nuclear. Technology can also improve energy efficiency using advanced vehicles, smart grids, better communication as an alternative to transportation, and in many other ways. The cheaper and more convenient that emissions-reducing technology can be made, the easier it will be to deal with the challenges of climate change. Technology will be especially important over the longer term, since once the economic emission reductions from the technology available today have been achieved, further reductions will require new technology.
4. *Put a price on emissions*. As noted in Chapter 4, a major market failure results from the fact those who emit greenhouse gases pay no cost for the damage they are doing. Some kind of scheme for putting a price on emissions, such as an emissions cap and trade program, or a carbon tax, would address this market failure. Some low-emission technologies, such as carbon capture and storage, can probably never be cheaper than conventional technology, while others may take a long time to get there. A price on emissions will pave the way for low-emissions technology to move from research to commercialization.

   An economy could avoid a loss of competitiveness to their industry by levying the emissions price on the emissions embedded in what is consumed, rather than on the emissions from production. Such an approach might make a price on emissions more politically acceptable (see the sidebar 'Did the Kyoto Protocol Get It Backwards?' in this chapter).

5. *Cooperate*. Climate change is a global challenge. No one economy can deal with it alone. Trade is a key example of where cooperation will be required, but there are a number of others, including infrastructure development, financial mechanisms, regulatory frameworks, research and development, information sharing, and education and capacity building (APERC, 2008). APEC could play an important role in many of these areas.

MODELLING CO_2 EMISSIONS

Projecting CO_2 emissions from combustion is, in principle, simple if we know the amount of each fuel to be combusted: just multiply the quantity of each fuel combusted by the emission factor (CO_2/unit of fuel) for that fuel. The emission factor for each fuel is a fixed chemical property of the fuel.

In practice, data limitations make these calculations more uncertain. There are many types of coal, many types of oil and oil products, and even natural gas may vary slightly in chemical composition. However, because of limitations on data and model complexity, APERC projects the demand for only three generic fossil fuels: coal, oil, and gas. So what to do?

One approach would be to use the worldwide average emission factor for each of these three generic fossil fuels. These may be calculated by dividing worldwide CO_2 emissions from that generic fuel by worldwide demand. Such a calculation (using data from IEA, 2011, pp. II.7–16) yields the following generic emission factors for the year 2009:

- Coal—3.8293 million tonnes CO_2/Mtoe
- Oil—3.0179 million tonnes CO_2/Mtoe
- Gas—2.3972 million tonnes CO_2/Mtoe.

These emission factors are broadly consistent with the default emission factors for combustion given in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006, Table 1.4). (The IPCC's figures are given in TJ/Mtoe; given there are 41 868 TJ/Mtoe (IEA, 2012), the emission factors above would imply average CO_2 emissions of about 91 500 kg/TJ for coal, 72 081 kg/TJ for oil, and 57 300 kg/TJ for gas.)

These emission factors could be multiplied by the projected demand for each of the three generic fuels to project CO_2 emissions. This approach, however, fails to capture the differences in the mix of specific fuels used in each economy.

APERC, therefore, goes one step further, calculating a specific emission factor for each generic fuel for each APEC economy for the base year 2009. This is accomplished by dividing the economy's CO_2 emissions from each generic fuel (again from IEA, 2011, pp. II.7–II.16) by demand for that generic fuel. These emission factors thus take into account the specific mix of fuels in each economy. For the year 2009, modelled emissions are guaranteed to match actual emissions, since the emission factors were calculated from actual emissions. For future years, the mix of fuels in the economy could change somewhat over time, but this method should be a good approximation and probably about the best possible given the limitations of the demand models.

DID THE KYOTO PROTOCOL GET IT BACKWARDS?

Under the Kyoto Protocol, 37 developed economies and the European Union agreed to limit their greenhouse gas emissions over the five-year period 2008–2012 (UNFCCC, 2012). However, a post-2012 successor agreement with binding limits has attracted only meagre participation thus far (Washington Post, 2012). In many economies, there has been strong opposition to such binding emissions limits, and especially to the carbon pricing (carbon taxes or emission trading) that will probably be needed to enforce them.

The basic dilemma here is that any disparity in the regulation of emissions between economies, and especially in the price of carbon, will put the economy with the stricter regulations at a competitive disadvantage. And unless every economy in the world agrees to a common carbon pricing scheme—an unlikely outcome given the 'free-rider' advantages accruing to any economy that stays out of the agreement—there will always be disparities.

Energy-intensive industries, and their workers, tend to be politically powerful, and will demand that carbon pricing be abandoned, or at least that export-competitive industry be exempted or compensated, which significantly weakens the emission reduction impact. Governments are effectively forced to make a trade-off: climate protection vs. economic growth and jobs. When the policy question is posed in these terms, it is inevitable that climate protection will lose. No-one likes new taxes, but when they look like a tariff on your economy's own products that is not faced by foreign competitors, the difficulties can become overwhelming for even the most environmentally committed political leaders. Indeed, a 'race to the bottom' for weaker emission regulation would seem to be the natural outcome, and it largely has been.

What is happening here can be viewed as a classic market failure. Economic principles tell us markets work when consumers pay the full cost (including environmental costs) of the products they consume, and any departure from this principle produces 'market failures' that give people an incentive to behave in ways that are not in society's best interests. Yet under the Kyoto Protocol, with its limits on the emissions produced by each economy, the consumer can avoid paying the full environmental costs they are imposing on society by purchasing products from economies with weak emission regulation. The result is a classic market failure, which explains much of the difficulty in reaching and in implementing an agreement.

The alternative that avoids market failure is for each participating economy to pledge to limit the emissions embedded in what they *consume*, not what they *produce*. As with the Kyoto Protocol, the limits could be enforced in each participating economy through measures of their own choosing. Some kind of carbon pricing scheme, such as a carbon tax or emissions trading, but applicable only to domestic consumption, would be the obvious choice. The carbon price would, however, need to cover *all* domestic consumption, whether the product was produced domestically or imported. So it would need to be charged on imported products, and refunded on exported products.

With consumption-based emission limits, there would be no competitive benefit to the industries in an economy that does not participate in the agreement. The products of non-participating economies would have to bear the same carbon price when they are sold to participating economies as domestic products in those economies. This means, even if an economy chooses not to participate in the agreement, their industries would still face strong economic incentives to minimize the carbon embedded in their products if they wish to remain competitive in participating economies. Thus, the incentives facing each economy and their industries would be completely different from those under Kyoto-style production-based limits.

Such a proposal raises two obvious questions. The first is whether such a scheme would be legal under international trade agreements. The basic requirement of international trade agreements is non-discrimination. The border adjustments proposed here would meet this requirement, since imported products in each economy would be charged for carbon emissions in the same manner as domestically produced products (Horn and Mavroidis, 2011 and Khrebtukova, 2010). Today's value-added taxes, which are charged on imports and refunded on exports by many countries, have set a precedent for this (Lockwood and Whalley, 2008). Of course, the most logical way to avoid the risk of trade disputes over border adjustments for carbon pricing would be to explicitly incorporate the rules for them into international trade agreements (Barrett, 2011; Whalley, 2011).

The second question is whether the carbon accounting required by border adjustments could be implemented in the real world fairly and at reasonable cost. Clearly, there are accounting challenges in implementing such consumption-based emission limits, specifically in determining what the carbon content of a particular product is. These accounting challenges should be manageable, although full implementation would take time. Efforts already underway in this area include the Greenhouse Gas Protocol of the World Resources Institute and World Business Council for Sustainable Development (WRI/WBCSD, 2012) and ISO Standard 14067 (PCF World Forum, 2012).

This section is a short summary of Samuelson (2012), which should be consulted for a more detailed discussion of consumption-based emission limits.

REFERENCES

APEC (Asia-Pacific Economic Cooperation) (2007), 'Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development' website page, www.apec.org/Meeting-Papers/Leaders-Declarations/2007/2007_aelm/aelm_climatechange.aspx

APERC (Asia Pacific Energy Research Centre) (2008), *Understanding International Energy Initiatives in the APEC Region,* Tokyo, Japan, www.ieej.or.jp/aperc/2008pdf/2008_Reports/APERC_2008_UIEI2.pdf

Barrett, Scott (2011), "Rethinking Climate Change Governance and Its Relationship to the World Trading System", *Working Paper P20, Fondation pour les Etudes et Recherches sur le Developpement International*, www.ferdi.fr/uploads/sfCmsContent/html/112/P20.pdf

Horn, Henrik and Petros C. Mavroidis (2011), "To B(TA) or Not to B(TA)? On the Legality and Desirability of Border Tax Adjustments from a Trade Perspective", *The World Economy*, Vol. 34, Issue 11, pp. 1911–1937, http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9701.2011.01423.x/full

IEA (International Energy Agency) (2011), *CO_2 Emissions from Fossil Fuel Combustion 2011*, Paris, France.

— (2012), *Unit Converter,* www.iea.org/stats/unit.asp

IPCC (Intergovernmental Panel on Climate Change) (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 2: Energy, Chapter 1: Introduction, www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

Khrebtukova, Alexandra (2010), "Using National Border Climate Adjustment Schemes to Facilitate Global Greenhouse Gas Management in Industrial Production", *Washington & Lee Journal of Energy, Climate, & Environment*, Vol. 1, No. 93, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1631468

Lockwood, Ben and John Whalley (2008), "Carbon Motivated Border Tax Adjustments: Old Wine in Green Bottles?", National Bureau of Economic Research, Working Paper 14025, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1138192

PCF World Forum (2012), "ISO 14067" website page, www.pcf-world-forum.org/initiatives/international-standards/iso-14067/

Samuelson, Ralph D. (2012), "Reconciling the Needs of Developing and Developed Countries in Climate Change Agreements: A Consumption-Based Approach", USAEE Working Paper No. 2054058, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2054058

UNFCCC (United Nations Framework Convention on Climate Change) (2012), "Kyoto Protocol" website page, http://unfccc.int/kyoto_protocol/items/2830.php/

Washington Post (2012), "Kyoto Protocol extended in contentious U.N. climate talks", 9 December 2012, www.washingtonpost.com/national/health-science/kyoto-protocol-extended-in-contentious-un-climate-talks/2012/12/08/f64a51c0-4178-11e2-ae43-cf491b837f7b_story.html

Whalley, John (2011), "What Role for Trade in a Post 2012 Global Climate Policy Regime?", *Working Paper P21, Fondation pour les Etudes et Recherches sur le Developpement International,* www.ferdi.fr/uploads/sfCmsContent/html/112/P22.pdf

WRI/WBCSD (World Resources Institute and World Business Council for Sustainable Development) (2012), Greenhouse Gas Protocol website page: "About the GHG Protocol", www.ghgprotocol.org/about-ghgp

Published by
Asia Pacific Energy Research Centre (APERC)
Institute of Energy Economics, Japan
Tokyo, JAPAN
E-mail: master@aperc.ieej.or.jp
Website: http://aperc.ieej.or.jp

Produced for
APEC Secretariat
35 Heng Mui Keng Terrace, Singapore 119616
Telephone: (65) 68 919 600
Fax: (65) 68 919 690
E-mail: info@apec.org
Website: www.apec.org

APEC# 213-RE-01.5   ISBN 978-4-931482-45-6

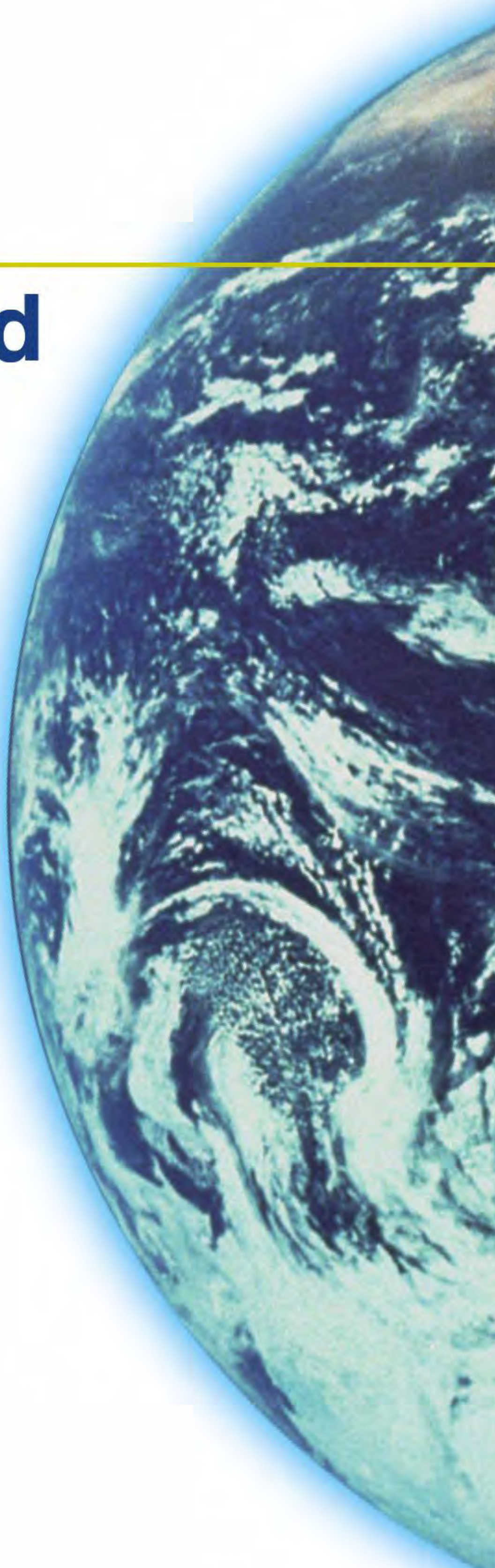
Asia-Pacific
Economic Cooperation

APEC

Energy Demand and Supply Outlook 5th Edition

Economy Reviews

February 2013



APERC

Asia Pacific Energy Research Centre

APEC ENERGY DEMAND AND SUPPLY OUTLOOK

5TH EDITION

ECONOMY REVIEWS

ASIA PACIFIC ENERGY RESEARCH CENTRE

This report, along with detailed tables of the model results,
is published at http://aperc.ieej.or.jp/

FEBRUARY 2013

Published by:

Asia Pacific Energy Research Centre
Institute of Energy Economics, Japan
Inui Building Kachidoki 11F, 1-13-1 Kachidoki
Chuo-ku, Tokyo 104-0054 Japan
Tel: (813) 5144-8551
Fax: (813) 5144-8555
Email: master@aperc.ieej.or.jp (administration)
Website: http://aperc.ieej.or.jp/

Produced for:

APEC Secretariat
35 Heng Mui Keng Terrace, Singapore 119616
Tel: (65) 68 919 600
Fax: (65) 68 919 690
E-mail: info@apec.org
Website: www.apec.org

February 2013

APEC#213-RE-01.5 ISBN 978-4-931482-45-6

TABLE OF CONTENTS

Foreword ii
Acknowledgements iii
List of Abbreviations viii
Tables of Approximate Conversion Factors xi
Australia 1
Brunei Darussalam 11
Canada 21
Chile 33
China 43
Hong Kong, China 55
Indonesia 65
Japan 79
Korea 89
Malaysia 97
Mexico 109
New Zealand 123
Papua New Guinea 133
Peru 141
Philippines 155
The Russian Federation 167
Singapore 175
Chinese Taipei 183
Thailand 193
United States 203
Viet Nam 215

FOREWORD

We are pleased to present the *APEC Energy Demand and Supply Outlook – 5th Edition*. This Outlook is designed to provide a basic point of reference for anyone wishing to become more informed about the energy choices facing the APEC region.

Concerns about energy security, the impacts of energy on the economy, and environmental sustainability are becoming increasingly important drivers of policy in every APEC economy. The business-as-usual projections presented here illustrate the risks of the development path the APEC region is currently on. A new feature of this Outlook is the alternative scenarios, which examine options for increasing natural gas use and reducing energy demand in transportation.

Readers who desire a quick overview of our most important findings should read Chapter 1, "Summary of Key Trends". Readers who desire a quick overview of our business-as-usual projections should read Chapter 2, "APEC Energy Demand and Supply Overview". Because of the summaries provided in these two chapters, an Executive Summary would be redundant and is not included. Detailed tables of the model results are available on the APERC website http://aperc.ieej.or.jp/.

This report is the work of Asia Pacific Energy Research Centre (the 'we' used throughout this report). It is an independent study, and does not necessarily reflect the views or policies of the APEC Energy Working Group or individual member economies. But we hope that it will serve as a useful basis for discussion and analysis of energy issues both within and among APEC member economies.

I would like to express a special thanks to the many people outside APERC who have assisted us in preparing this report, as well as to the entire team here at APERC. We at APERC are, of course, responsible for any errors that remain.

I would especially like to acknowledge the contributions of my predecessor as APERC President, Kenji Kobayashi. Under Mr. Kobayashi's leadership, the *Outlook – 5th Edition* project was already well-organized and underway when I joined APERC in July 2012.

Takato Ojimi
President
Asia Pacific Energy Research Centre (APERC)

ACKNOWLEDGEMENTS

The development of the *APEC Energy Demand and Supply Outlook – 5th Edition* could not have been accomplished without the contributions of many individuals and organizations. We would like to thank all those whose efforts made this Outlook possible, in particular those named below.

We are very grateful to our sponsors. The Ministry of Economy, Trade and Industry, Japan, provided the primary funding for this project. The Petroleum Institute of Thailand funded the participation of Charothon Ung-Jinda and Nontaphorn Udomwadhanaphorn. The United States Department of Energy funded the participation of Monterey R. Gardiner.

We wish to express our appreciation to the APERC Annual Conference and Workshop participants who met with us and provided invaluable insights into the issues raised in the draft report.

We also would like to thank members of the APEC Energy Working Group (EWG), the APEC Expert Group on Energy Data and Analysis (EGEDA), and the APERC Advisory Board, along with numerous government officials, for their helpful information and comments.

PROJECT MANAGER

Ralph D. Samuelson

MAIN CONTRIBUTORS TO THIS VOLUME

Australia: Gayathiri Bragatheswaran

Brunei Darussalam: Aishah Mohd. Isa and Mardrianto Kadri

Canada: Gayathiri Bragatheswaran

Chile: Tran Thanh Lien and Juan Roberto Lozano Maya

People's Republic of China: Bing-Chwen Yang, Aishah Mohd. Isa and Du Bing

Hong Kong, China: Bing-Chwen Yang

Indonesia: Aishah Mohd. Isa, Mardrianto Kadri, and Chrisnawan Anditya

Japan: Goichi Komori and Kazumoto Irie

Republic of Korea: Dmitry Aleksandrovich Sokolov

Malaysia: Aishah Mohd. Isa and Chandran Sundaraj

Mexico: Juan Roberto Lozano Maya

New Zealand: Ralph D. Samuelson

Papua New Guinea: Dmitry Aleksandrovich Sokolov

Peru: Juan Roberto Lozano Maya

The Republic of Philippines: Elvira Torres Gelindon

The Russian Federation: Dmitry Aleksandrovich Sokolov

Singapore: Charothon Ung-Jinda and Aishah Mohd. Isa

Chinese Taipei: Bing-Chwen Yang

Thailand: Charothon Ung-Jinda and Aishah Mohd. Isa

United States: Luke Leaver

Viet Nam: Tran Thanh Lien

PUBLICATION

Aishah Mohd. Isa and Gayathiri Bragatheswaran

ENERGY DEMAND AND SUPPLY MODEL MANAGEMENT

Elvira Torres Gelindon

EDITORS

Naomi O'Connor and Lyn Fletcher

GRAPHICS

Charothon Ung-Jinda and Aishah Mohd Isa

ADMINISTRATIVE SUPPORT

Masatsugu Kamakura, Kaori Najima and Tomoyo Kawamura

COMPUTER SUPPORT

Ping Zhang

ACKNOWLEDGEMENT OF APERC ADVISORY BOARD MEMBERS

Institute of Energy Economics, Japan: Kenichi Matsui

Bureau of Resources and Energy Economics, Department of Resources, Energy and Tourism, Australia: Rupert Quentin Grafton

Canadian Energy Research Institute, Canada: Marwan Masri

Energy Research Institute of National Development and Reform Commission, China: Fengqi Zhou

Tsinghua University, China: Zongxin Wu

ASEAN Center for Energy, Indonesia: Hardiv Harris Situmeang

Institute of Energy Economics, Japan: Masakazu Toyoda

Korea Energy Economics Institute, Korea: Jin-woo Kim

Energy Systems Institute, Siberian Branch Russian Academy of Sciences, Russia: Nikolay I. Vorapay

Center for Energy-Environment Resources Development, Foundation for International Human Resource Development, Thailand: Thierry Lefevre

Lawrence Berkeley National Laboratory, USA: Mark Levine

ACKNOWLEDGEMENT OF EXPERTS OUTSIDE APERC

MODELLING CONSULTANTS

The Institute of Energy Economics, Japan Energy Data and Modelling Center, Japan: Kokichi Itoh, Shigeru Suehiro, Shen Zhungyuen, Naoko Doi, Yuji Matsuo and Satoshi Nakanishi

Stockholm Environment Institute: Victoria Clark and Charlie Heaps

AUSTRALIA

Department of Resources, Energy and Tourism, Australia: Micheal Gurner and Andrew Scally

BRUNEI DARUSSALAM

Energy Department, Prime Minister's Office, Brunei Darussalam: Noor Dina Zharina Binti Hj Yahya, Hj Amirul Ariffin Hj Mohd Salleh, Siti Hafsah Haji Abd Hamis and Ahmad bin Haji Mohamad

Brunei National Energy Research Institute: Weerawat Chantanakome

CANADA

Natural Resources Canada: Kristi Varangu and Susan Moir

Foreign Affairs and International Trade Canada: Michelle Campbell

CHILE

International Department, Ministry of Energy, Chile: Carlos Piña, Pia Suarez and Corissa Petro

CHINA

Department of International Cooperation, National Energy Administration, China: Sun Yang

Centre for International Energy Strategy Studies, Renmin University of China: Xu Qinhua

Energy Research Institute, National Development and Reform Commission of P.R. China: Angie An

HONG KONG, CHINA

Electrical and Mechanical Services Department, Government of the Hong Kong Special Administrative Region: Li Kwok-keung, Eddie W.K. Wu, Mak Ka Chun, Ming Sang Kam and Cho-Yee Ip

INDONESIA

National Energy Council of Indonesia: Farida Zed

Directorate General of New Renewable Energy and Energy Conservation: Maritje Hutapea, Dadan Kusdiana, and Edi Sartono

JAPAN

Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, Japan: Ryo Minami, Shinji Kakuno and Terumi Munetake

Institute of Energy Economics, Japan: Tomoko Murakami, Naoki Nishida Naoko Doi, Yuji Matsuo and Yoshiaki Shibata

KOREA

Korea Energy Economics Institute, Korea: Gue Jae Jeong and Woonam Seok

Korea National Oil Corporation: Joonbeom Lee

Ministry of Foreign Affairs and Trade, Korea: Eunji Han

MALAYSIA

Ministry of Energy, Green Technology and Water, Malaysia: Loo Took Gee, Anbalagan Kannan, Satish Ranggayah and Mohd Azlan bin Othman

Energy Section, Economic Planning Unit: Nik Adnan Nik Abdullah

Institute of Energy Policy Research, Universiti Tenaga Nasional, Malaysia: Leong Yow Peng

Corporate Strategic Planning Division, Petronas: Ridzuan Zulkifli

MEXICO

Ministry of Energy, Mexico: Leydi Barcelo Córdova

NEW ZEALAND

Ministry of Business, Innovation and Employment: Mark Hashimoto and Bryan Field

PAPUA NEW GUINEA

Department of Petroleum and Energy, Papua New Guinea: Vore Veve and Idau Kopi

PERU

Ministry of Energy and Mines, Peru: Luis Alberto Espinoza, Raul Bastidas, Maria del Rosario Castillo and Roxana Pareja

PHILIPPINES

Department of Energy, Philippines: Jesus T. Tamang and Victoria B. Capito

RUSSIA

Ministry of Energy, Russian Federation: Talyat Aliev and Svetlana Beznasyuk

SINGAPORE

Energy Planning and Development Division, Energy Market Authority, Singapore: Jonathan Goh, Faith Gan, Latha Ganesh, Pang Yan Wei, Agnes Koh, Haresh Mohanan and Dennis Tay

CHINESE TAIPEI

Bureau of Energy, Ministry of Economic Affairs, Chinese Taipei: Jerry J. R. Ou, Jyuung-Shiauu Chern, Yunn-Ming Wang and Su-fang Chen

Taiwan Institute of Economic Research: Lynn Wang, Feng-Shuo Yang and Grace Chung

THAILAND

International Energy Cooperation Office, Ministry of Energy of the Kingdom of Thailand: Chawalit Pantaros

Department of Alternative Energy Development and Efficiency, Ministry of Energy of the Kingdom of Thailand: Twarath Sutabutr, Prasert Sinsukpraset and Vinuchada Talangsri

Energy Policy and Planning Office, Ministry of Energy of the Kingdom of Thailand: Reukrit Kenharaj and Sittichod Wantawin

UNITED STATES

Office of Policy & International Affairs, U.S. Department of Energy: Phyllis Yoshida, Karen Alozie and Jeffrey Skeer and Antonio Ruiz

Pacific Northwest National Laboratory, United States: Cary N. Bloyd

VIET NAM

General Directorate of Energy, Ministry of Industry and Trade, Viet Nam: Cao Quoc Hung and Pham Thanh Tung

INTERNATIONAL ORGANIZATIONS

International Energy Agency: Fatih Birol, Amos G. Bromhead, Sharon Burghgraeve, Jean-Yves Garnier, Nigel Alan Jollands, Lisa Ryan, Peter Taylor and Akira Yanagisawa

HAPUA Secretariat, Association of South-East Asian Nations: Syaiful Bakhri Ibrahim

LIST OF ABBREVIATIONS

APEC ECONOMIES

AUS	Australia
BD	Brunei Darussalam
CDA	Canada
CHL	Chile
CT	Chinese Taipei
HKC	Hong Kong, China
INA	Indonesia
JPN	Japan
MAS	Malaysia
MEX	Mexico
NZ	New Zealand
PE	Peru
PNG	Papua New Guinea
PRC	People's Republic of China
ROK	Republic of Korea
RP	the Republic of the Philippines
RUS	the Russian Federation
SIN	Singapore
THA	Thailand
US or USA	United States of America
VN	Viet Nam

ORGANIZATIONS AND INSTITUTIONS

ADB	Asian Development Bank
APEC	Asia Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of South-East Asian Nations
CIA	Central Intelligence Agency (USA)
EDMC	Energy Data and Modelling Centre (of IEEJ)
EIA	Energy Information Administration (USA)
EWG	Energy Working Group (of APEC)
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of the Petroleum Exporting Countries
WTO	World Trade Organisation
UN	United Nations

TECHNICAL TERMS

BAU	business-as-usual
bcf	billion cubic feet
bcm	billion cubic metres
bpd	barrels per day
BRT	bus rapid transit
BTU	British thermal unit
CBM	coal bed methane
CCGT	combined cycle gas turbine
CCS	carbon capture and sequestration
CDM	Clean Development Mechanism
CNG	compressed natural gas
CO_2	carbon dioxide
CSP	concentrated solar power
DSM	demand-side management
EOR	enhanced oil recovery
EV	electric vehicles
FCV	fuel cell vehicles
FED	final energy demand
FDI	foreign direct investment
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gases
g/kWh	grams per kilowatt-hour (used to measure the emissions caused by the generation of one unit of electricity)
GNP	gross national product
GTL	gas-to-liquids
GW	gigawatt
GWh	gigawatt-hour
IGCC	integrated coal gasification combined cycle
IGFC	integrated coal gasification fuel cell
IOC	international oil companies
IPP	independent power producers
kgoe	kilogram of oil equivalent
km	kilometre
ktoe	thousand tonnes of oil equivalent
kW	kilowatt
kWh	kilowatt-hour
LEAP	Long-range Energy Alternatives Planning System
LHV	lower heating value
LNG	liquefied natural gas
LPG	liquefied petroleum gas
mbd	million barrels per day
mcm	million cubic metres
MEPS	minimum energy performance standards

Mmbls	million barrels
mmscf	million standard cubic feet
MBTU	million British thermal units
MOU	memorandum of understanding
MPa	megapascals
MRT	mass rapid transit
MSW	municipal solid waste
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWp	megawatts peak
NAFTA	North American Free Trade Agreement
NGV	natural gas vehicle
NRE	new renewable energy
NYMEX	New York Mercantile Exchange
NO_x	nitrogen oxides
PHV	plug-in hybrid vehicles
PJ	petajoules
PPP	purchasing power parity
PSC	production sharing contract
PV	(solar) photo-voltaic
R&D	research and development
R/P	reserves-to-production ratio
SO_x	sulphur oxides
SUVs	Sports Utility Vehicles
T&D	transmission and distribution
tcf	trillion cubic feet
tcm	trillion cubic metre
toe	tonnes of oil equivalent
TPES	total primary energy supply
TWh	terawatt-hours
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical (coal power generation technology)
USD	US Dollar

Tables of Approximate Conversion Factors

Crude Oil*

From	To: tonnes (metric)	kilolitres	barrels	US gallons	tonnes per year
	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US Gallons	0.00325	0.0038	0.0238	1	–
Barrels per day	–	–	–	–	49.8

* Based on worldwide average gravity

Products

	To convert: barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
Liquefied natural gas (LPG)	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.240
Gas oil/diesel	0.133	7.5	0.839	1.192
Fuel oil	0.149	6.7	0.939	1.065

Natural Gas (NG) and Liquefied Natural Gas (LNG)

	To: billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.74	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	0.021	1.01	0.19
1 million tonnes oil equivalent	1.11	39.2	1	0.82	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	1	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	0.021	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	0.11	5.41	1

Units

1 metric tonne	= 2204.62 lb = 1.1023 short tons
1 kilolitre	= 6.2898 barrels = 1 cubic metre
1 kilocalorie (kcal)	= 4.187 kJ = 3.968 Btu
1 kilojoule (kJ)	= 0.239 kcal = 0.948 Btu
1 British thermal	= 0.252 kcal unit (Btu) = 1.055 kJ
1 kilowatt-hour (kWh)	= 860 kcal = 3 600 kJ = 3 412 Btu

Calorific Equivalents

One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million British thermal units
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	See Natural Gas (NG) and Liquefied Natural Gas (LNG) table
Electricity	12 megawatt-hours

One million tonnes of oil or oil equivalent produces about 4400 gigawatt-hours (= 4.4 terawatt-hours) of electricity in a modern power station.

1 barrel of ethanol = 0.57 barrel of oil
1 barrel of biodiesel = 0.88 barrel of oil

Reproduced from the *BP Statistical Review of World Energy June 2012* with the kind permission of BP p.l.c.

AUSTRALIA

- *Australia's new Clean Energy Future package, which includes a carbon trading mechanism, is likely to see an increase in energy efficiency and decrease in overall CO_2 emissions in the long term.*
- *Due to its considerable coal seam gas reserves, Australia is likely to become a strategic producer of unconventional gas within the outlook period.*
- *Annual CO_2 emissions from fuel combustion are projected to decrease by 1.4% over the outlook period; this can largely be attributed to Australia's commitment to increasing the use of renewable energy, particularly in electricity generation as well as the switch from coal to gas.*

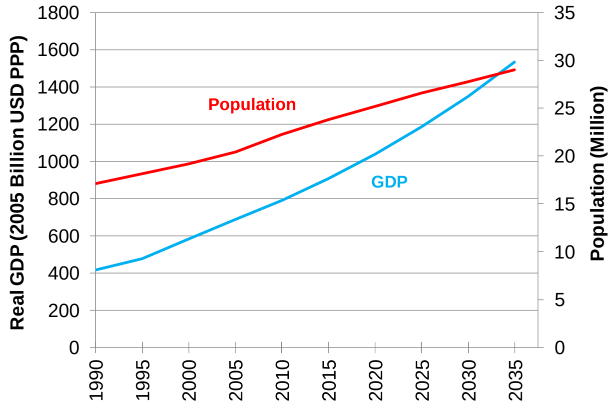
ECONOMY

Australia is the world's largest island economy, and the sixth largest economy (in land area) in the world. It lies in the southern hemisphere, between the Indian and Pacific Oceans. Its total land area of nearly 7.7 million square kilometres is made up of the mainland, the major island of Tasmania, and other small islands. Australia has no land boundaries with other economies; its ocean neighbours include Indonesia, East Timor, Papua New Guinea, the Solomon Islands, Vanuatu, New Caledonia, and New Zealand.

The Australian mainland is largely desert or semi-arid land. A temperate climate and moderately fertile soils are found in the southeast and southwest corners, while the far north is characterized by a tropical climate (warm all year) and a mix of rainforests, grasslands and desert.

As of June 2011, Australia's population was 22.6 million people, mostly concentrated along the eastern and south eastern coast, and some on the west coast. Across the total landmass the population density (three people per square kilometre) is one of the lowest in the world. Nearly 92% of the population live in urban areas; the average household is a family of no more than four.

Figure AUS1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Australia is rich in mineral resources and is a major world producer of bauxite, coal, gold, copper, nickel, zinc and iron ore—some concentrated in a particular region, others dispersed across its six states and two territories. The minerals sector is a substantial contributor to the Australian economy, with minerals production increasing over the past decade. Historically, mineral discoveries in Australia have been characterized by high-grade deposits and surface mineralization (Hogan, 2003); most of the surface mineralization has been developed and future mining activities are expected to be more energy intensive. The majority of Australia's resource production is exported, accounting for significant export earnings.

Australia has developed a world-class minerals processing industry to complement its mining industry; the three major areas are alumina refining, aluminium smelting, and iron-and steel-making.

Australia is one of the world's largest alumina producers with production estimated at 19.3 million tonnes in 2011–12 (BREE, 2012e).

Australia is also a significant exporter of iron ore, with the majority of exports going to China. Future iron ore production and exports are supported by a number of significant iron ore projects expected to be completed in the foreseeable future (BREE, 2012c). Other energy-intensive industries of note in the Australian economy include other non-ferrous metals processing (aluminium), non-metallic mineral production, and chemical and associated production.

Agriculture in Australia is a highly commercialized, technology-based, export-orientated industry, with exports such as dairy products, grain and live cattle going mostly to Southeast Asia and the Middle East. Agriculture and the associated industries of food, beverages and tobacco, wood, and pulp and paper are important contributors to the economy.

Australia's harsh and wide-flung geography makes road transport a crucial element in the economy; Australia has three to four times more road per capita than Europe, and seven to nine times more than Asia. The rail network is slighter than the road system, although train networks are established within cities and between states.

Air travel, domestic and international, has grown rapidly since the early 1990s, particularly with the emergence of budget airlines. Generally, while cars are the usual mode of travel between rural centres, and cars or train the mode between rural centres and state capitals, air transport is the most economic form of travel between state capitals.

ENERGY RESOURCES AND INFRASTRUCTURE

Australia has abundant coal reserves and is one of the world's leading coal producers and exporters. At the end of 2011, Australia's recoverable coal reserves stood around 86 billion tonnes (Geoscience Australia, 2011b), with estimated production in 2011–12 of 219.2 million tonnes (BREE, 2012e). Australia's economic reserves are sufficient to sustain current black coal production rates for nearly 100 years. Brown coal economic reserves are estimated to be able to sustain current production for over 500 years (BREE, 2012a). Coal is the dominant primary energy source in Australia; in 2008–09, it accounted for 39% of primary energy consumption in the economy (BREE, 2011, p. 30). Coal use is heavy in the power generation sector, where it currently accounts for more than 70% of the generation mix (BREE, 2011, p. 30). Over 80% of coal produced in Australia is exported.

Environmental issues, in particular climate change, are expected to have a strong influence on the future of Australian coal exports and domestic consumption. The industry is focused on the development and deployment of 'clean and green' coal conversion and storage technologies. In addition, the Australian Government's efforts in promoting coal-to-liquids technology and carbon sequestration could play an important role in shaping future domestic coal consumption, especially in meeting the rising domestic demand for transport fuels.

Natural gas has become the fastest growing fossil fuel in terms of production and consumption in Australia. According to the CIA's World Factbook, at the end of 2010 Australia had an estimated 3.115 trillion cubic metres of proven natural gas reserves, which places it within the top 15 of economies with proven natural gas reserves (USCIA, 2011).The majority of Australia's conventional gas resources are located off the northwest coast of Western Australia, which makes this the largest gas-producing region in Australia. However, the rise of non-conventional gas resources in the eastern region, such as coal seam gas reserves, means gas production is forecast to increase significantly in the east in the outlook period.

On average between 2010–11 and 2011–12 Australia's production of natural gas (including natural gas from coal seam methane projects) is estimated to be about 52.7 billion cubic metres (BREE, 2012e). About 35% of this production is exported as liquefied natural gas (LNG), mostly within the Asia–Pacific region (ABARES, 2011). Environmental concerns about energy use have provided a boost to natural gas use in Australia. Federal and state policy initiatives have encouraged the use of cleaner energy resources, including natural gas, which has a lower CO_2 emissions factor than coal or oil. Combined with its security of supply, natural gas will be the preferred choice for many Australian energy consumers. The power generation, manufacturing and mining sectors are all expected to significantly increase the share of natural gas in their energy mix in the medium and long term.

Australia has significant reserves of coal seam gas (CSG). As at the end of 2010, Australia had economic demonstrated resources of 35 055 petajoules (PJ), but only produced 175 PJ (0.5% of the economic demonstrated resources) in that year (Geoscience Australia, 2011a). Due to environmental risks associated with the extraction of CSG, such projects need to undergo a comprehensive and sometimes lengthy approvals process overseen by the respective state government. There are three LNG–CSG projects under construction currently, with environmental impact studies being conducted on two other CSG projects (BREE, 2012b). In 2011, CSG was produced only in Queensland and New South Wales, where it accounted for the majority of each state's total gas production. Production of CSG is expected to strengthen in the future with LNG plant plans already in place based on production and export from Queensland (BREE, 2012d).

As of the end of 2010, Australia's total oil economic demonstrated resources were estimated at 22 161 PJ—made up of 12 413 PJ of condensate, 5685 PJ of crude oil and 4063 PJ of liquefied petroleum gas (LPG) (BREE, 2012a). Australia's proven oil reserves are not as impressive as that of its coal, accounting for about 2% of the world's proven reserves. Most of Australia's oil reserves are located in the Carnarvon Basin, Gippsland Basin, Bonaparte Basin, Cooper–Eromanga Basin, and Bass Basin; these areas cover the north, west, southeast and southern regions of Australia. Australia is a net oil importer, in 2011 Australia's crude oil and condensate production was 425 614 barrels per day, with imports in the year around 554 270 barrels per day (BREE, 2012e). Australia's oil production has been declining since 2003—this is due to natural depletion (especially in the Cooper–Eromanga Basin and Gippsland Basin), lack of new exploration fields coming online, and higher exploration costs for unexplored resources located offshore (in deep water). There is some export of crude oil, particularly heavy crude from wells in the northwest.

Petroleum products are the main energy source for the transport and mining sectors in Australia. In 2008–09, they accounted for 35% of primary energy consumption in the economy, second only to coal. Within the transport sector there are a range of alternative low-carbon fuels that have the potential to complement or replace conventional oil, but they need further research, development and demonstration before they can be adopted (BREE, 2011). While hybrid and electric vehicles are available in Australia the price competitiveness of conventional vehicles generally beats out these forms of automobile transportation.

Australia has enormous potential renewable energy resources, especially wind, solar, geothermal and hydro. While in 2009–10 only 2% of total energy produced in Australia was from renewable sources (predominantly bio-energy), Australia's Clean Energy Future plan and its Renewable Energy Target (both discussed under 'Energy Policies') emphasize Australia's commitment to renewable energy and should therefore see its further development (BREE, 2012a). The National Electricity Market (NEM) was established in 1998 to allow the inter-jurisdictional flow of electricity between the Australian Capital Territory, New South Wales, Queensland, South Australia and Victoria (Tasmania joined the NEM in 2005). Western Australia and the Northern Territory are not connected to the NEM because of their distance from the rest of the market. The NEM comprises a wholesale sector and a competitive retail sector. All electricity dispatched must be traded through the central pool, where output from generators is aggregated and scheduled to meet demand.

ENERGY POLICIES

Australia enjoys a high level of energy security characterized by low-priced, reliable energy supplies and a significant natural endowment of energy resources, including coal, natural gas, crude oil and considerable potential for renewable energy. Underpinning Australia's natural resources are extensive infrastructure and well-functioning domestic and international energy markets.

The Australian Government released a draft Energy White Paper (EWP) on 13 December 2011. The consultation process included public forums in each state capital across Australia and 285 written submissions were received. The final Energy White Paper is due to be released at the end of 2012.

The EWP promotes well-functioning markets supported by efficient and effective regulatory frameworks to deliver competitively priced energy. The core objective is to build a secure, resilient and efficient energy system that provides accessible, reliable and competitively priced energy for all Australians; to enhance Australia's domestic and export growth potential; and to deliver clean and sustainable energy. The four key priority areas outlined in the draft EWP are strengthening the resilience of Australia's energy policy framework; delivering better energy market outcomes for consumers; developing Australia's critical energy resources—particularly gas resources; and accelerating clean energy outcomes.

An update to the 2009 National Energy Security Assessment (NESA) was released in December 2011. The 2011 NESA found that Australia's overall energy security situation is expected to remain adequate and reliable, but it will increasingly be shaped by the strength of new investment going forward and the price of energy, which are both materially influenced by global trends (DRET, 2011c). The 2011 NESA was a key input into the development of the draft Energy White Paper.

On 10 July 2011, the Australian Government announced the Clean Energy Future plan, which makes the move from the previous Clean Energy Initiative and other government programs to a comprehensive plan to reduce Australia's greenhouse gas emissions. The Clean Energy Future includes:

- the introduction of a carbon price
- the promotion of innovation and investment in renewable energy
- encouragement for energy efficiency
- the creation of opportunities in the land sector to cut pollution.

The carbon pricing mechanism establishes a fixed carbon price of AUD 23 (USD 24) per tonne (rising at 2.5% per year in real terms) for the period 1 July 2012 to 30 June 2015. The carbon price will apply to around 500 of Australia's largest greenhouse gas emitters. Around 60% of Australia's emissions will be directly covered by the carbon pricing mechanism, and around two-thirds will be covered by a combination of the mechanism and equivalent carbon pricing arrangements. From 1 July 2015, the carbon price will become flexible under a 'cap and trade' emissions trading scheme, with the price largely determined by the market. Emissions units will be able to be traded from 1 July 2015, and a lower and upper limit of emissions unit prices will apply for the first three years beyond 1 July 2015 (DCCEE, 2011a).

The Australian Government does not undertake or finance energy resource exploration or development. In the petroleum sector, the government relies on an annual acreage release to create opportunities for investment. The release, distributed worldwide, is a comprehensive package that includes details of the acreage, bidding requirements and permit conditions. All foreign investment proposals in Australia are subject to assessment and subsequent government approval through the Foreign Investment Review Board.

The approvals process for unconventional gas exploration is overseen by each responsible state government, under the Environment Protection and Biodiversity Conservation Act 1999. In this process each state assesses applications from each company looking to explore in their area, and then declines or grants access; this can be quite a lengthy process. Similarly, the assessment of safety requirements and environmental regulation for the coal industry is carried out by the state in which each project is based.

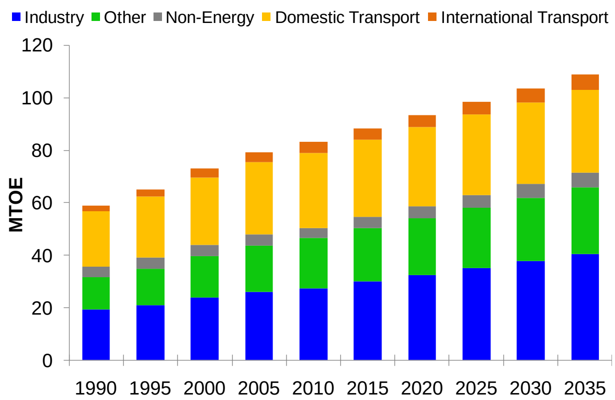
The Australian Government has a number of policies and programs in place to capitalize on the potential economic growth and emissions reduction resulting from improved energy efficiency within the industrial, transport, and residential and commercial sectors. There is also a suite of policies and initiatives introduced over the last few years to increase the role of renewable energy. This includes the Renewable Energy Target, which requires 45 000 GWh of electricity generation to be sourced from renewable energy by 2020. The Renewable Energy Target has been separated into a Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES), to provide greater certainty for households, for large-scale renewable energy projects and for installers of small-scale renewable energy systems. Combined, the new LRET and SRES are expected to deliver more renewable energy than the overall Renewable Energy Target (DCCEE, 2011b). Other measures promote low-carbon energy research, development, demonstration and deployment including the Global Carbon Capture and Storage Institute.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Final energy demand under business-as-usual (BAU) assumptions is expected to grow at an annual average rate of 1% over the outlook period. Most of this growth can be attributed to increases in energy consumption across all sectors, especially in the industrial and 'other' (residential, commercial and agricultural) sectors.

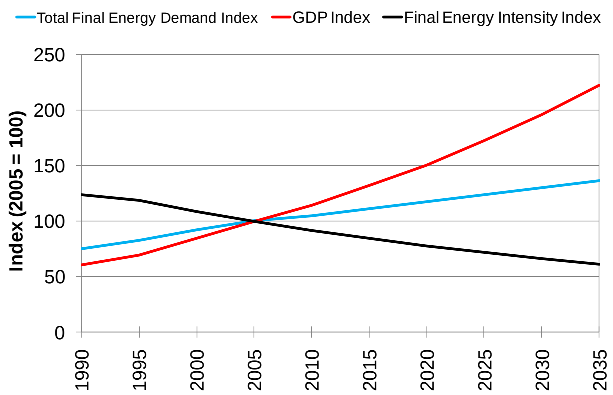
Figure AUS2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics2011* © OECD/IEA 2011

Despite this increase in final energy demand, final energy intensity (as shown in Figure AUS3) is expected to decline by 39% between 2005 and 2035.

Figure AUS3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industrial sector is projected to grow at an average annual rate of 1.6% between 2010 and 2035. This reflects the steady but relatively slow growth of Australia's industrial sector in general, along with Australia's focus on the services sector. However, given that Australia is experiencing a mining boom, energy consumption in this sector is expected to increase (on average 2.2% a year over the outlook period) in tandem with the rapidly growing industry.

Combustible fuels are expected to account for the majority of industrial energy demand, with consumption increasing by more than 45% over the outlook period.

Transport

Vehicle ownership in Australia has very nearly reached saturation level. The transportation energy demand of Australia is projected to grow by 10% over the outlook period.

Given the lack of incentives for consumers to shift to vehicles using alternative fuels, virtually all transport-based energy consumption will be of oil products. Conventional gasoline vehicles will account for a greater proportion of vehicles, comprising more than half of the light vehicle fleet by 2035. Conventional diesel vehicles will make up the second highest share of the light vehicle fleet (17%), while vehicles using alternative fuels will account for only a small share.

Other

Australia has many policies promoting energy efficiency within the residential and commercial sectors. Through building codes and standards Australia promotes energy efficiency within commercial buildings. In the residential space the government has retrofit programs promoting initiatives such as installation of energy-efficient lighting.

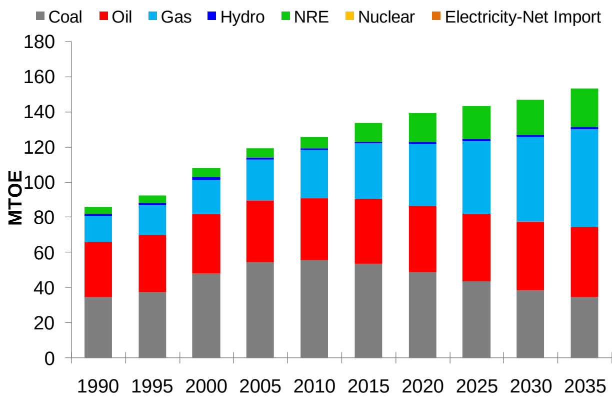
However, such efforts will be offset by a growing population and an increasingly consumer-driven society, which is likely to result in the use of more electrical gadgets and home appliances. Energy demand in the 'other' sector, which includes residential, commercial, and agricultural demand, is expected to grow at an average annual rate of 1.1% over the outlook period. Electricity is expected to continue to dominate the fuel mix in this sector, accounting for 55% of 'other' energy consumption in 2035.

PRIMARY ENERGY SUPPLY

Australia's primary energy supply between 2010 and 2035 is projected to grow at an average annual rate of 0.8%.

Given the potential for significant production of natural gas from unconventional sources, Australia is expected to increase its production of gas in the outlook period. Primary supply of gas is projected to nearly double between 2010 and 2035.

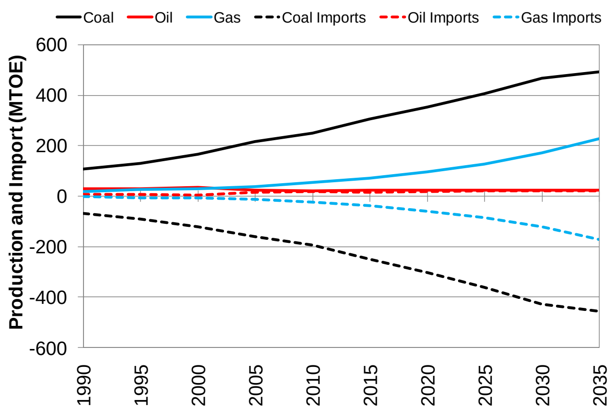
Figure AUS4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics2011* © OECD/IEA 2011

Coal will dominate energy supply in most of the first part of the outlook period (2010–2027), with an average share of 37% over those years. Although much of the gas produced will be exported as LNG, predominantly to economies in the Asian region, gas is expected to overtake coal in domestic energy supply in the latter half of the outlook period, accounting for 36% of primary energy supply in 2035.

Figure AUS5: BAU Energy Production and Net Imports

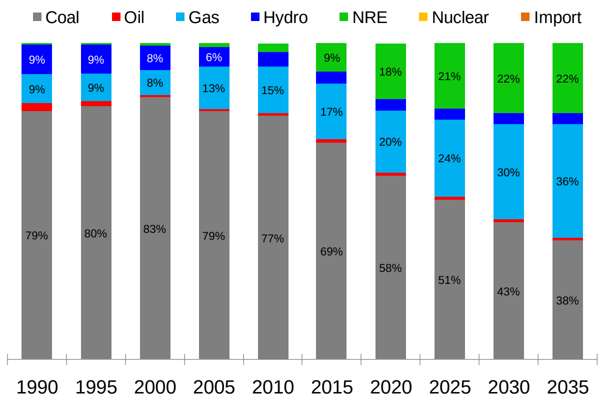


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics2011* © OECD/IEA 2011

ELECTRICITY

Australia's coal reserves mean this fuel will dominate the electricity generation mix in the outlook period. However, the Australian Government's commitment to energy efficiency and the promotion of renewable energy makes it highly likely that the economy will at least very nearly achieve its goal of 20% electricity sourced from renewable energy by 2020. This will bring about a reduction in the role of coal in the electricity generation mix over the outlook period, as with increased contribution from natural gas and NRE (predominantly wind).

Figure AUS6: BAU Electricity Generation Mix

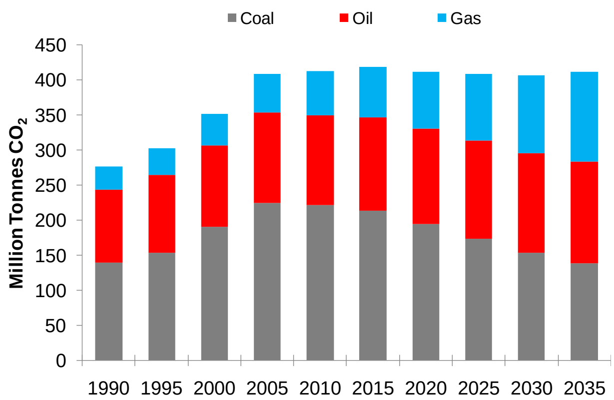


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics2011* © OECD/IEA 2011

CO_2 EMISSIONS

Over the outlook period Australia's total CO_2 emissions from fuel combustion are projected to decrease by 0.3 million tonnes from 2010 to 2035, to 412.3 million tonnes. This decrease in emissions can be attributable to Australia's policies promoting renewable energy in the household and commercial sectors. Most notable, however, is Australia's push to increase use of renewable energy sources in electricity generation; in particular wind power capacity is expected to increase by 30–35% over the outlook period. This structural change will be a key factor in emissions reduction.

Figure AUS7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

Table AUS1 indicates that emission increases due to GDP growth will be offset by a reduction in both the CO_2 intensity of energy (contributed by fuel switching from coal to gas and NRE) and energy intensity of GDP from effective energy efficiency measures, which will lead to a modest reduction in total CO_2 emissions over the outlook period.

Table AUS1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	0.4%	-1.7%	-0.8%	-0.7%	-0.5%
Change in Energy Intensity of GDP	-1.2%	-0.9%	-1.9%	-1.9%	-2.2%
Change in GDP	3.4%	2.7%	2.7%	2.7%	2.7%
Total Change	2.6%	0.2%	0.0%	0.0%	0.0%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual, the Australian energy outlook is steady. However, as demand for cleaner sources of fuel such as natural gas increases globally over the outlook period, Australia may wish to expedite regulation and exploration processes in order to maximize its sizeable natural gas resources.

ALTERNATIVE SCENARIOS

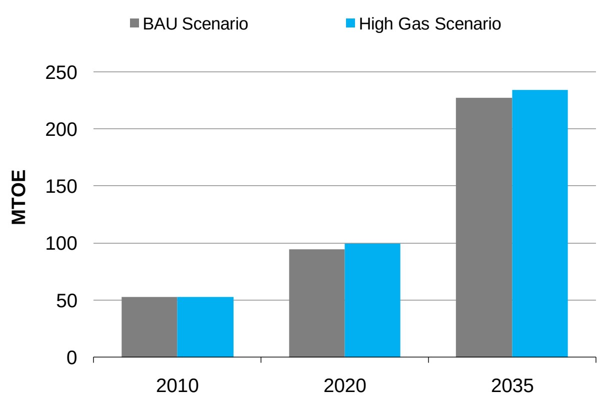
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Australia assumed the production increase shown in Figure AUS8, which equals 3% by 2035. This was based on expanding Australia's current unconventional and conventional gas development given its strong customer base in the Asia–Pacific region.

Figure AUS8: High Gas Scenario – Gas Production



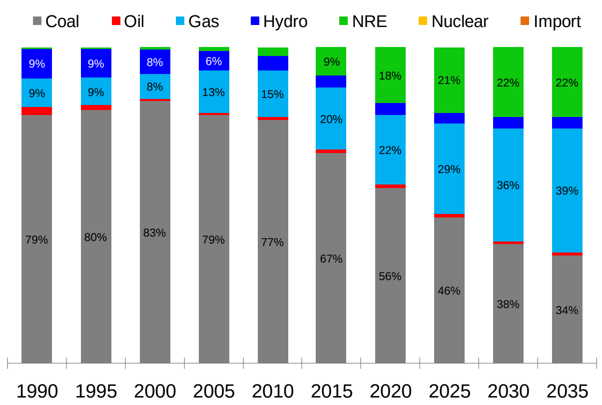
Source: APERC Analysis (2012)

Even under BAU assumptions, Australia's gas production is expected to increase significantly over the outlook period. The slight additional increase in gas production under the alternative scenario can be attributed to the assumption that the sometimes cumbersome and lengthy approvals processes will be improved and expedited to allow more gas projects to become operational.

Additional gas consumption in each economy in the High Gas Scenario depends not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. Given the perceived environmental benefits of gas over coal, a portion of the gas produced will be consumed locally. However, given Australia's modest population in terms of its gas reserves, the majority of the additional gas is expected to be exported.

Figure AUS9 shows the High Gas Scenario electricity generation mix for Australia. This graph may be compared with the BAU scenario graph in Figure AUS6. It can be seen the gas share has increased by 3% by 2035, while the coal share has declined by 4%. It is interesting to note that under the alternative scenario gas has a greater share than coal in the electricity generation mix by 2035. However, even under the BAU case, gas would only be 2% shy of the share of coal in the generation mix by 2035, a substantial change from 2010.

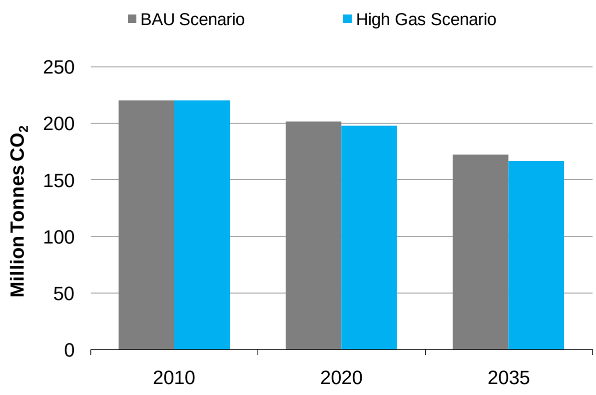
Figure AUS9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The additional domestically-consumed gas in the High Gas Scenario was assumed to replace coal in electricity generation. Since gas has roughly half the CO_2 emissions of coal per unit of electricity generated, this had the impact of reducing CO_2 emissions in electricity generation by nearly 5% in 2035. Figure AUS10 shows this CO_2 emission reduction which is significant given Australia's GDP growth.

Figure AUS10: High Gas Scenario – CO_2 Emissions from Electricity Generation



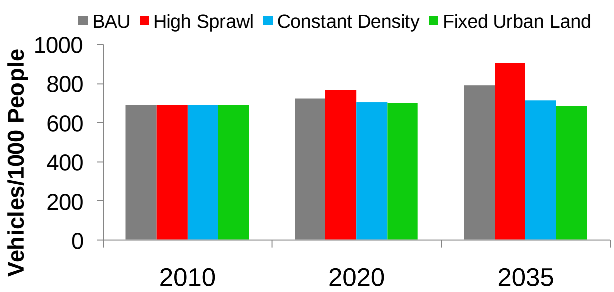
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure AUS11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. If Australia's cities were to stay at a constant population density it is expected that there will be a decrease in vehicle ownership of 10% in 2035 compared to the BAU case. The High Sprawl case would result in an expected 15% increase in vehicle ownership by 2035 compared to BAU.

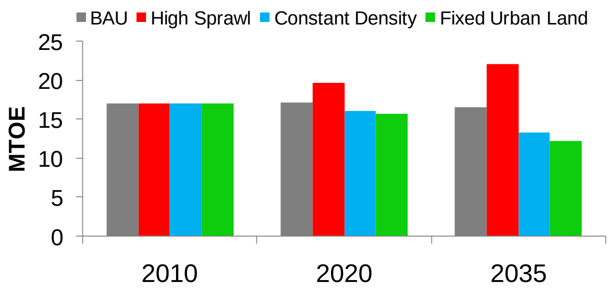
Figure AUS11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure AUS12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The High Sprawl scenario is likely to see 33% more light vehicle oil consumption in 2035 compared to BAU. Under the Constant Density and Fixed Urban Land scenarios, there were reductions in light vehicle oil consumption of 19% and 26% respectively in 2035 compared to BAU. This demonstrates the benefits of better urban planning.

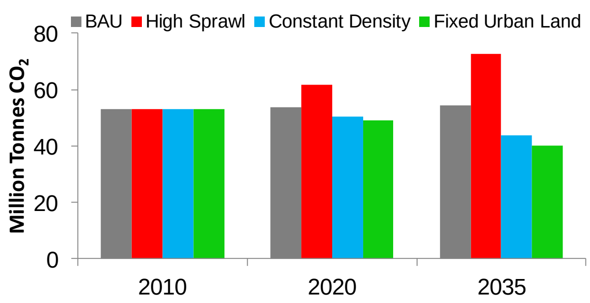
Figure AUS12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure AUS13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

Figure AUS13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



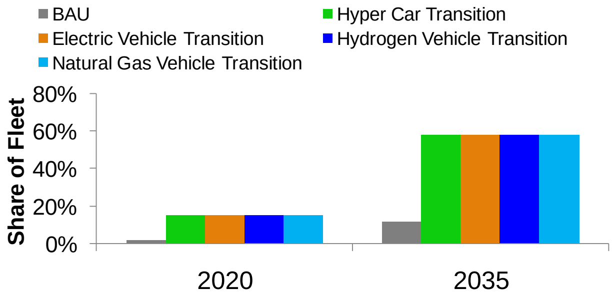
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure AUS14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 58% compared to about 11% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 42%, compared to about 89% in the BAU scenario.

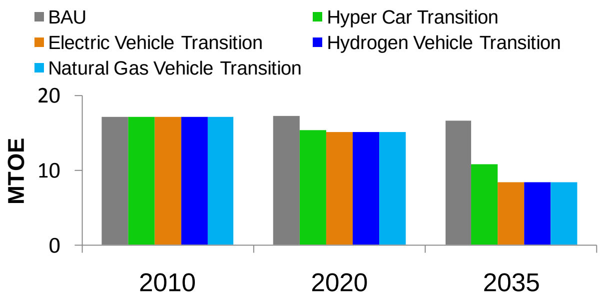
Figure AUS14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure AUS15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 35% by 2035—even though these highly efficient vehicles still use oil.

Figure AUS15: Virtual Clean Car Race – Light Vehicle Oil Consumption



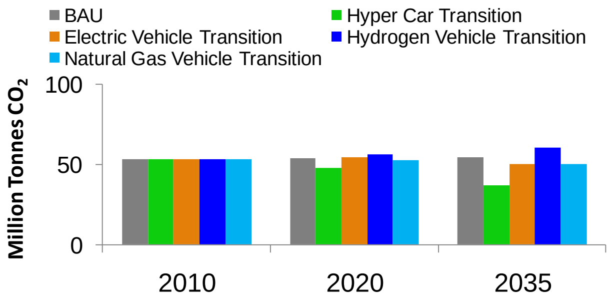
Source: APERC Analysis (2012)

Figure AUS16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Australia, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emission reduction, with an emission reduction of 33% compared to BAU in 2035. This is probably because hyper cars do better in economies like Australia where coal is more likely to be the marginal source of electricity generation. To facilitate fair comparisons, the Electric

Vehicle Transition scenario assumes no additional non-fossil electricity. The Electric Vehicle Transition scenario would rate second, offering a reduction of 9% compared to BAU in 2035. The Natural Gas Vehicle Transition scenario offers emission reductions of 8%, while in the Hydrogen Vehicle Transition scenario, emissions increase by 11% compared to BAU. This is likely due to the emissions associated with converting natural gas to hydrogen to fuel these vehicles.

Figure AUS16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

ABARES (Australian Bureau of Agriculture and Resource Economics and Sciences) (2011), *Australian Commodities June Quarter 2011*, http://adl.brs.gov.au/data/warehouse/pe_abares99010609/AC11.2_June_highres_REPORT_11b.pdf

BREE (Bureau of Resources and Energy Economics) (2011), *Australian Energy Projections to 2034–35*, www.bree.gov.au/documents/publications/energy/Australian-Energy-Projections-report.pdf

— (2012a), *Energy in Australia*, www.bree.gov.au/documents/publications/energy-in-aust/energy-in-australia-2012.pdf

— (2012b), *Mining Industry Major Projects*, April 2012, www.bree.gov.au/documents/publications/mimp/Mining-Industry-Major-Projects-.pdf

— (2012c), *Resources and Energy Quarterly*, March 2012, www.bree.gov.au/documents/publications/resources/REQ-Mar-2012.pdf

— (2012d), *Resources and Energy Quarterly*, June 2012, www.bree.gov.au/documents/publications/resources/REQ-Jun-2012.pdf

— (2012e), *Resources and Energy Quarterly*, September 2012, www.bree.gov.au/documents/publications/req/BREE_REQ_Sept2012.pdf

DCCEE (Department of Climate Change and Energy Efficiency) (2011a), *Clean Energy Act 2011*, www.comlaw.gov.au/Details/C2011A00131/Html/Text - _Toc308513393. See also www.climatechange.gov.au/government/submissions/closed-consultations/clean-energy-legislative-package/clean-energy-bill-2011.aspx

— (2011b), *Renewable Energy Target*, www.climatechange.gov.au/government/initiatives/renewable-target.aspx

DRET (Department of Resources, Energy and Tourism) (2011a), *Australia's Coal Industry*, www.ret.gov.au/resources/mining/australian_mineral_commodities/Pages/australia_coal_industry.aspx

— (2011c), *National Energy Security Assessment (NESA)*, December 2011, www.ret.gov.au/energy/energy_security/national_energy_security_assessment/Pages/NationalEnergySecurityAssessment.aspx

Geoscience Australia (2011a), *Australian Atlas on Minerals Resources, Mines and Processing Centres: Coal Seam Gas*, www.australianminesatlas.gov.au/aimr/commodity/coal_seam_gas.html - resources

— (2011b), *Minerals – Australia's Identified Mineral Resources Table 1*, www.ga.gov.au/minerals/mineral-resources/aimr/table-1.html

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

Hogan, L. (2003), *Public Geological Surveys in Australia*, ABARE eReport 03.15. Prepared for the Australian Government Department of Industry, Tourism and Resources, Canberra, www.abare.gov.au/publications_html/energy/energy_03/er03_geologicalsurveys.pdf

IEA (International Energy Agency) (2011) *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

USCIA (United States Central Intelligence Agency) (2011), *The World Factbook*, www.cia.gov/library/publications/the-world-factbook/rankorder/2179rank.html

BRUNEI DARUSSALAM

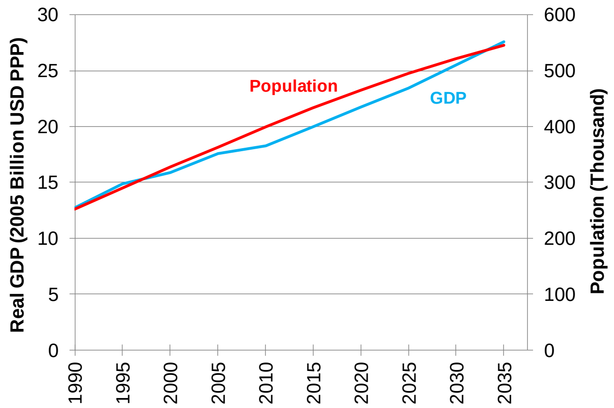
- *Brunei Darussalam has low GDP growth, but high macroeconomic stability.*
- *The economy is highly dependent on LNG and oil exports. The government's efforts to encourage diversification have met with limited success. This is set to change with the introduction of downstream oil and gas industries planned for the first half of the forecast period.*
- *The development of energy-intensive industries is expected to drive final energy demand in Brunei Darussalam, which is projected to increase by 39% from 2010 to 2035, reaching 1.7 Mtoe in 2035.*

ECONOMY

Brunei Darussalam is located on the north-west coast of the island of Borneo. It has a coastline of about 161 kilometres along the South China Sea and a land area of 5765 square kilometres, of which 75% is covered by primary forest. The economy is characterized by hilly lowlands in the west, rugged mountains in the east, and a swampy tidal plain along the coast. The climate is equatorial, with an average temperature of 28°C, high humidity, and heavy rainfall that ranges from 2500 mm to 7500 mm annually. The economy's only neighbour is the Malaysian state of Sarawak, which separates Brunei Darussalam into two parts.

Brunei Darussalam is a small economy with a total population of 423 000 in 2011, of which 27% were foreigners (DEPD, 2012, p. 4). The economy's population is projected to grow at an average annual rate of 1.3% over the forecast period, with the total population reaching about 550 000 by the year 2035. According to the United Nations, 75.6% of the population was urbanized in 2010; this figure is projected to increase to 80.4% by 2035 (United Nations, 2011).

Figure BD3: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

The majority of the population is concentrated in the capital, Bandar Seri Begawan, and in the oil refining area of Seria in the west. The remaining areas are sparsely populated and largely undisturbed. The economy is wealthy and capable of maintaining a welfare state that provides free higher education and healthcare to its citizens, and subsidized housing, food and fuel.

In 2009, Brunei Darussalam achieved a nominal GDP of USD 17.7 billion (in 2005 USD PPP) and a GDP per capita of USD 45 158, which is one of the highest in the world. Brunei Darussalam's GDP is projected to grow at a modest average annual rate of 1.7% over the outlook period, reaching USD 27.6 billion in 2035. Given the projected 1.3% average annual population growth, GDP per capita will remain high, increasing by about 10% to reach nearly USD 50 563 per capita by 2035.

The oil and gas sector is the backbone of Brunei Darussalam's economy, accounting for 67.7% of GDP and 95.6% of total exports in 2011 (DEPD, 2012, p. 8). Brunei Darussalam is the fourth-largest oil producer in South-East Asia and the ninth-largest exporter of liquefied natural gas (LNG) in the world (BEDB, 2011). The economy's non oil and gas sectors include agriculture, forestry, fishing, aquaculture and banking.

There is a rising awareness the economy is depleting its natural resources and subsequently it needs to diversify away from its over-reliance on upstream oil and gas production. The Wawasan Brunei 2035 (referred to here as the Vision Brunei 2035) formulates Brunei Darussalam's plans to upskill the labour force, reduce unemployment, strengthen the banking and tourism sectors, and widen the economic base beyond oil and gas by 2035 (BEDB, 2011). For the short term, the National Development Plan 2007–2012 supports the Vision Brunei 2035 by allocating BND 9.5 billion (around USD 6.6 billion) for 826 programmes and projects to strengthen the economy's human resources base, social services and infrastructure, and to support the development of competitive industries. Priority industries are finance, hospitality, agriculture, halal products (which includes food, pharmaceuticals and cosmetics) and software development (APERC, 2009).

One of the key initiatives under the Vision Brunei 2035 is to designate industry cluster-specific sites with supporting infrastructure and facilities. This will facilitate industrial development and promote industrial investments. The first site, established in 2007, was the Sungai Liang Industrial Park (SPARK), designed specifically for downstream petrochemical processing activities. Additionally, 1 trillion cubic feet (Tcf) (28.3 billion cubic meter (bcm)) of natural gas has been allocated for domestic downstream activities over an estimated 20-year span (FGE, 2010).

The first plant built at the SPARK site was a methanol plant developed by the Brunei Methanol Company. The plant began production in May 2010 and is capable of producing 850 000 tonnes of methanol each year. The next project in SPARK is an integrated chemical complex housing six plants that will use part of the allocated 1 Tcf (28.3 bcm) of natural gas as feedstock to produce ammonia, urea, di-ammonium phosphate, ammonium sulphate, melamine and caprolactam. The project is being developed by the Mitsui Consortium and is expected to begin operations in 2015 (Brunei Times, 2011).

The second industrial site is the Pulau Muara Besar (PMB) Island site, designed for the development of oil field support services, such as a marine supply base and fabrication yard, as well as further downstream activities (BEDB, 2012). The anchoring project will be a USD 2.5 billion oil refinery and aromatics cracker project to be developed by the Zheijiang Hengyi Group Co. Ltd. The project is expected to begin operations in 2015, with a production capacity of approximately 135 thousand barrels per day. The first phase will comprise the production of petroleum products such as gasoline, diesel and jet A-fuel, as well as paraxylene and benzene used mainly in textile production (BEDB, 2012). The feedstock for this plant will be locally-sourced crude oil and condensate.

Brunei Darussalam's largest export, after oil and gas, is its manufactured garments. It should be noted the total value of garments exported significantly decreased by about 80% from BND 56.7 million in 2009 to BND 8.2 million in 2010, due to a major trade agreement between the economy and the United States expiring in the same year (DEPD, 2012, p. 8). On the other hand, the economy's first methanol plant began exporting its products in May 2010, and other sectors like the agriculture, forestry and fishery sectors and the services sector showed a healthy growth rate of 3–4% from 2009 to 2010 (DEPD, 2012). This healthy growth in the non oil and gas sectors is consistent with the economy's efforts towards diversification, and is likely to continue in the short to medium term.

Bruneians enjoy a well-developed transport infrastructure; the quality of roads in Brunei Darussalam has been ranked seventh in Asia and third in South-East Asia (Brunei Press, 2011b, p. E89). The major population centres in the country are linked by a network of about 3127.4 kilometres of road (DEPD, 2012, p. 17). Brunei also has one of the highest car ownership rates in the world, with roughly one car for every 2.09 persons (Brunei Press, 2011a). This can be attributed to the limited public transport system, low import tax, inexpensive car maintenance and low unleaded petrol prices. With 170 000 licensed vehicles using the road network daily, the Brunei Darussalam Government is constantly maintaining, upgrading and extending its road network. In its National Development Plan 2007–2012, the government has allocated BND 568.5 million (USD 464 million) for this purpose (Brunei Press, 2011b, p. E89).

The Brunei International Airport (BIA) handles more than 20 000 flights annually. In 2011, 27 822 flights were recorded, including scheduled, non-scheduled, chartered and military flights (DEPD, 2012, p. 17). Brunei Darussalam's major port is at Muara. In 2011, the port handled a total of a little over 1 million freight tonnes of cargo (DEPD, 2012, p. 17). The port authority is continuing its efforts to attract and encourage more shipping lines to call at the port. The Ministry of Industry and Primary Resources is keen to develop the economy's tourism industry by capitalizing on Brunei Darussalam's rich cultural heritage and pristine natural rainforests. If the Ministry's initiative is successful, it is expected the energy demand for both aviation and maritime transport will increase in the coming years.

ENERGY RESOURCES AND INFRASTRUCTURE

Brunei Darussalam owes its current prosperity to its significant natural gas and oil resources. The existing and potential oil and gas reserves lie within the economy's northern landmass and extend offshore to the outer limits of its exclusive economic zone (EEZ). As of 1 January 2012, Brunei Darussalam's proven oil reserves stood at 1.1 billion barrels and its gas reserves were estimated at 13.8 Tcf (390 bcm) (OGJ, 2011). The oil reserves are expected to last about 25 years and the natural gas reserves 40 years. New recovery technologies as well as potential onshore and deepwater fields are expected to add to the lifespan of the reserves.

In 2010, the economy's major oil fields were the onshore Seria-Tali field, with 292 producing oil wells, and the offshore fields Champion (239 producing oil wells) and South West Ampa (152 producing oil wells) (OGJ, 2011). On average, Brunei's oil fields produced 160 100 barrels per day in 2010. Only a small fraction of the oil produced is refined at Brunei Darussalam's sole refinery in Seria, which has a distillation capacity of 15 000 barrels per day. The main products are motor gasoline, diesel oil and dual-purpose kerosene. These outputs are used almost exclusively for domestic consumption. The rest of Brunei Darussalam's crude oil is exported and refined elsewhere.

Brunei Darussalam's most prolific natural gas field is also its oldest offshore field, the South West Ampa field. It holds more than half of the economy's total natural gas reserves. Other sources include the gas wells in the Fairley, Gannet and Maharajalela-Jamalulalam fields (OBG, 2009). The production from these fields is piped to the Brunei LNG Plant in Lumut to be liquefied. Most of the LNG produced is exported to Japan and Korea (Brunei LNG, 2010).

Brunei Darussalam has an installed electricity capacity of 894 MW that produced 3723 GWh of electricity in 2011 (DEPD, 2012, p. 19). Given the abundance of natural gas available in the economy, almost all of its installed electricity capacity is natural gas-fired. The only exceptions are the diesel power station at Belingus and the demonstration 1.2 MW Tenaga Suria Brunei (TSB) solar energy plant. The solar plant is the largest-scale photovoltaic project in South-East Asia, and is capable of producing 1344 MWh of electricity each year (OBG, 2011). Brunei Darussalam has significant solar, hydro and biomass potential, but it has no concrete plans for exploiting this potential on a large scale due to environmental and cost constraints. Instead, in the near future, the economy will concentrate on reducing its energy intensity through energy efficiency and conservation initiatives.

As reported in the Brunei Key Indicators 2011, 99.9% of the population is already connected to the electricity grid, while the remaining 0.1% is served by stand-alone generators (DEPD, 2012, p. 19). The transmission network is divided into three separate grids, namely the Brunei-Muara network, the BPC network and the Temburong District network. The three grids are operated by two different utilities, the Department of Electrical Services (DES) and the Berakas Power Company Private Limited (BPC). The National Development Plan 2007–2012 proposes that all three of the economy's power grids are interconnected by 2012.

ENERGY POLICIES

Brunei Darussalam's energy policy is centred on its oil and gas industries. In 1981, the Oil Conservation Policy was introduced when oil production peaked at 261 000 barrels per day in 1979. The policy aimed to prolong the life of the economy's oil reserves by rationalizing its oil output. As a result, production gradually dropped to around 150 000 barrels per day in 1989. In November 1990, the government reviewed the policy and removed the production ceiling, resulting in the production of 219 000 barrels per day by 2006 (APERC, 2009). In 2011, oil production averaged 166 000 barrels per day (DEPD, 2012, p. 11).

In 2000, the Brunei Natural Gas Policy (Production and Utilization) was introduced. The policy aimed to maintain gas production at year-2000 levels to adequately satisfy export obligations, to open new areas for exploration and development, and to encourage increased exploration by new and existing operators. Under the policy, priority is always given to domestic gas use, especially for electricity generation.

Brunei Darussalam has set an economy-wide target to reduce its energy intensity by 45% by 2035, with 2005 as the base year. To ensure the 45% reduction target is met, Brunei Darussalam has identified a number of action plans for the generation, residential, industry, government and transport sectors. These action plans are designed to improve energy efficiency performance in these five sectors between 2010 and 2030. Some of the action plans identified include: restructuring the residential electricity tariff structure; improving the efficiency of new and existing power plants; formulating an economy-wide standard and labelling for air conditioning and lighting systems; initiating energy management programmes in government and industrial buildings; and introducing energy efficient vehicles like hybrid and electric vehicles into Brunei Darussalam's automotive market (APERC, 2012). These action plans will be formalized in the Energy White Paper to be published in early 2013.

Brunei Darussalam implements five-year economic development plans known as National Development Plans that also serve as guidance for its energy policies. Currently, the ninth National Development Plan 2007–2012 is in force. In line with this plan, the economy has launched a long-term development plan, the Vision Brunei 2035. The Vision aims to make Brunei Darussalam, by 2035, a nation which will be widely recognised "for the accomplishment of its educated and highly skilled people as measured by the highest international standards; quality of life that is among the top 10 nations in the world; and a dynamic and sustainable economy with income per capita within the top 10 countries in the world" (DEPD, 2008).

In May 2005, His Majesty the Sultan and Yang Di-Pertuan of Brunei Darussalam created the post of the Minister of Energy. The Energy Division at the Prime Minister's Office was also created, to be responsible for formulating the economy's energy policy as well as presiding over its energy matters. The Petroleum Unit, that oversees the development of Brunei Darussalam's natural gas and oil sector, and the Department of Electrical Services, that is tasked with managing and developing its electricity sector, come under this ministry. In 2011, the Energy Division and the Petroleum Unit merged to become the Energy Department under the Prime Minister's Office.

The Brunei Shell Petroleum Co. Sdn. Bhd. (BSP), jointly owned by the Brunei Darussalam Government and the Royal Dutch/Shell Group of the Netherlands, has been the dominant oil and gas production company in the economy. The only other concessionary is the French multinational oil company, Total E&P Deep Offshore B.V. In 2002, the Brunei National Petroleum Company Private Limited (PetroleumBRUNEI) was empowered to manage Brunei Darussalam's commercial interests in the oil and gas sector. PetroleumBRUNEI has been granted all mineral rights in eight petroleum exploration blocks, nominee shareholder status in the Brunei Methanol Company Private Limited, and one of its subsidiaries, PB Logistics, is a shareholder in the Brunei Methanol Tanker (BMT).

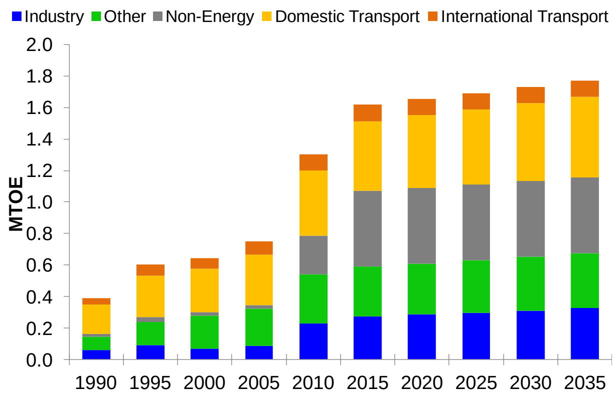
Currently, energy prices are heavily subsidised. Before 2012, the residential electricity tariff was priced at approximately BND 0.06 (USD 0.044) per kWh. A new tariff structure, which came into effect on 1 January 2012, was designed to encourage smart electricity use and to help the poor by rewarding low users and penalising heavy users of electricity. Motor fuel prices remain comparatively low, with petrol prices varying from BND 0.36 (USD 0.26) per litre for regular to a maximum of BND 0.53 (USD 0.38) per litre for premium unleaded (Lawrey and Pillarisetti, 2011). In an effort to address the challenges of increasing demands and depleting resources and to improve energy efficiency performance, the government of Brunei Darussalam has decided to implement progressively increasing electricity tariffs and to adopt European Union equivalent fuel economy regulations. These measures will be formalized in the economy's Energy White Paper to be published in early 2013.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

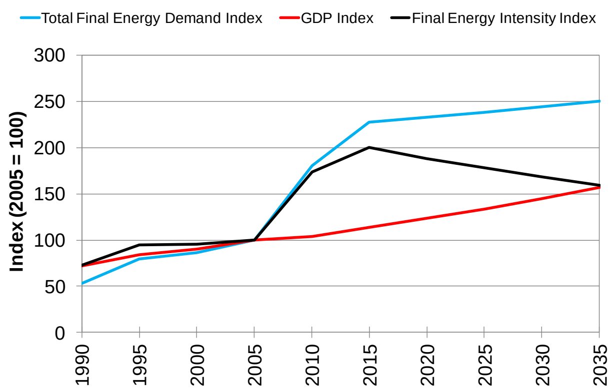
The total final energy demand for Brunei Darussalam is projected to almost double from 0.9 Mtoe in 2009 to 1.7 Mtoe in 2035. The industry and non-energy sectors begin to take up a much larger portion of final energy demand from 2010 onwards, compared to an almost negligible share before 2010. This is due to the methanol plant in SPARK beginning production in that year. The methanol plant will require massive amounts of natural gas as fuel, resulting in gas taking a large chunk of oil's dominant share of final energy consumption. By 2035, oil will still account for the largest share (46%), followed by gas (35%), electricity (19%) and NRE (0.6%).

Figure BD4: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure BD3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Under BAU scenario, Brunei Darussalam's final energy intensity is expected to increase by 60% between 2005 and 2030. This increase will be driven primarily by a growing demand for energy for the new industries in the industry and non-energy sectors. The energy efficiency action plans and measures to be initiated in the Energy White Paper may help to alleviate some of this increase.

Industry

The changes in the final energy demand depend on two aspects: the expansion of the energy-intensive industry sector and the start of methanol production at the SPARK site in 2010. Other industries proposed for the SPARK and Pulau Muara Besar industrial sites are not considered in this analysis—they are still in the early stages of planning and their definite time of entry has yet to be established.

The final energy demand for industry in Brunei Darussalam is projected to increase by 41% from 2010 to 2035, reaching 326 kilotonnes of oil equivalent (ktoe) by 2035. The industry sector's energy demand will be for oil (58%), electricity (22%) and gas (20%).

Transport

The domestic transport sector's demand for energy is projected to continue to increase during the forecast period, reaching 512 ktoe in 2035. Petroleum products are expected to remain the dominant transport energy source, but their growth will slow with the expected improvements in vehicle fuel efficiency.

Other

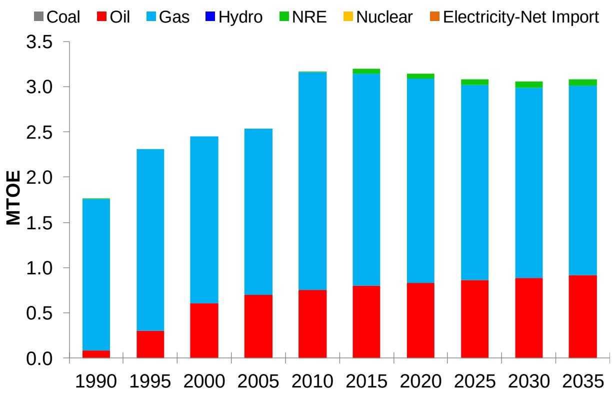
The final energy demand in the 'other' sector, which represents the residential, commercial and agricultural sectors, is projected to increase by 12.5% from 2010 to 2035, reaching 349 ktoe by 2035. This will be driven mostly by the residential sector. Electricity consistently holds a two-thirds share of energy demand for the 'other' sector throughout the outlook period.

PRIMARY ENERGY SUPPLY

Brunei Darussalam's primary energy supply is expected to remain fairly constant at about 3 Mtoe over the forecast period. Natural gas and oil will remain the dominant supply fuels for primary energy with small contributions from solar and biomass.

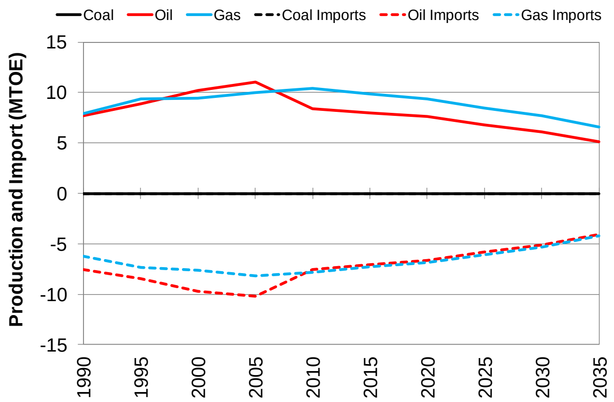
Natural gas production and oil production are forecasted to gradually decrease over the 2010–2035 period due to maturing reserves and the increasing complexity of resource exploration in the economy. Since domestic consumption is modest and priority is given to domestic use, it is expected that the decrease in production will be reflected in the amount of oil and gas exported each year. There is no coal production or coal consumption in this economy.

Figure BD4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure BD5: BAU Energy Production and Net Imports



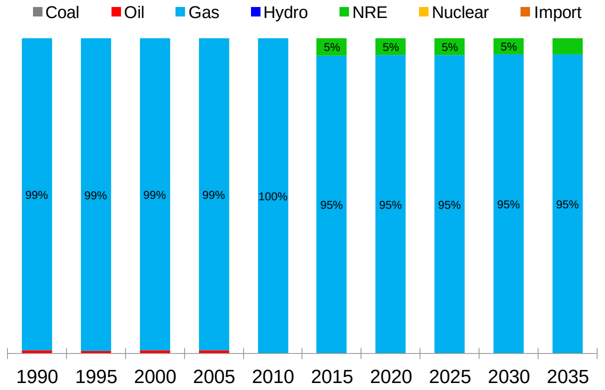
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

Brunei Darussalam is projected to continue to rely heavily on natural gas for electricity generation. The economy is expected to improve its conversion efficiency by replacing the existing single-cycle power plants with combined-cycle gas units and by ensuring all new power plant installations have over 45% efficiency (APERC, 2012).

Brunei Darussalam will also begin to diversify its energy resources by taking advantage of its available new renewable energy (NRE) potential. The economy already has a 1.2 MW solar power plant and will continue to develop more solar capacity during the outlook period. Another form of NRE capacity that will likely be introduced is biomass generation, using landfill gas as fuel. By 2035, NRE's contribution to total power generation will increase to 5%, compared to zero in 2009.

Figure BD6: BAU Electricity Generation Mix

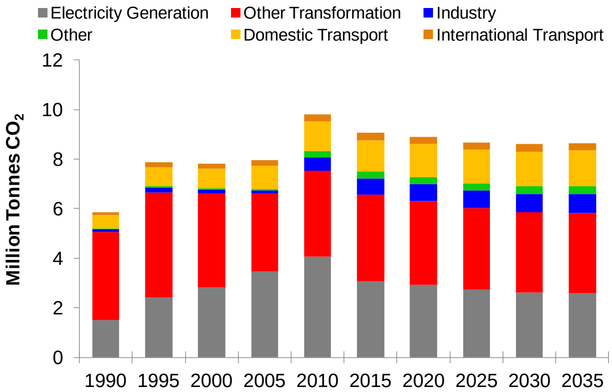


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Brunei Darussalam's annual CO_2 emissions from fuel combustion are projected to begin to decrease from 2010 onwards, reaching about 8.65 million tonnes of CO_2 in 2035. This compares to 5.9 million tonnes in 1990 and 8.0 million tonnes in 2005. The sudden increase in CO_2 emissions from the industry sector in 2010 can be attributed to production starting at the SPARK methanol plant. Improvements in power generation efficiency will contribute to reducing the CO_2 emissions from this sector over the next 25 years.

Figure BD7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis in Table BD1 shows that from 1990 to 2005, the growth in CO_2 emissions was underpinned by growing GDP, but from 2010 to 2035, total change in CO2 emissions will show a declining trend, driven by declining trends in CO_2 intensity and energy intensity.

Table BD1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.5%	-0.8%	-0.7%	-0.5%	-0.5%
Change in Energy Intensity of GDP	0.3%	3.7%	-0.7%	-0.9%	-1.7%
Change in GDP	2.2%	0.8%	1.5%	1.5%	1.7%
Total Change	2.1%	3.7%	0.1%	0.1%	-0.6%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

As a major oil and gas producer and exporter, Brunei Darussalam's economic and energy security is assured. Unfortunately, based on historical data, this abundance of wealth and resources has not created an environment conducive to energy efficiency and conservation measures.

Brunei Darussalam's Vision Brunei 2035, published in 2008, and the upcoming Energy White Paper, to be published in 2013, outline environmental policy directions and initiatives designed to minimize environmental impacts and to conserve existing oil and gas resources. These measures may help Brunei Darussalam meet its challenges to maintain economic and energy security as well as to improve environmental sustainability.

ALTERNATIVE SCENARIOS

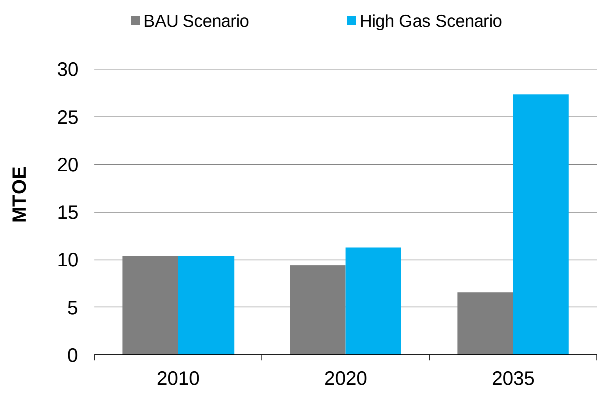
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario for Brunei Darussalam assumed the production increase shown in Figure BD8, which equals 315% by 2035. This is based on the draft for Brunei Darussalam's Energy White Paper, in which the economy proposes to explore deepwater offshore commercial blocks more aggressively and to review the potential of developing small and marginal fields that have previously been deemed infeasible. The success of these proposed initiatives will certainly increase Brunei Darussalam's gas production. The Energy White Paper provides estimates for the potential increase in gas production, and these estimates were adopted for the High Gas Scenario for this economy.

Figure BD8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. Since domestic power generation in Brunei Darussalam is almost fully gas-based, the additional gas production will likely be exported as LNG. As a result, no change is expected in the economy's electricity generation mix or in its CO_2 emissions. Thus, Figures BD9 and BD10 are not included for this economy.

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

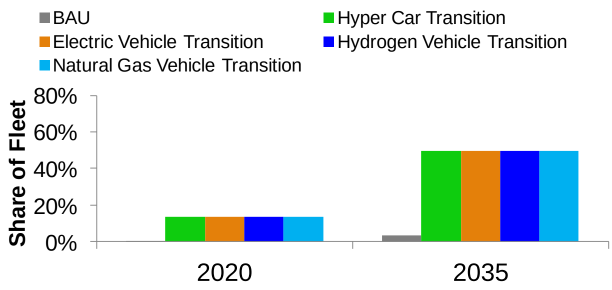
The alternative urban development scenarios evaluate potential transport energy savings from urban planning by modelling the relationship between travel distance, vehicle efficiency and vehicle ownership. Unfortunately, there is not sufficient data on urban land use available for Brunei Darussalam to run this scenario. Figures BD11–BD13 are therefore not included for this economy.

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure BD14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035, the share of the alternative vehicles in the fleet reaches around 50% compared to about 3% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 50%, compared to about 97% in the BAU scenario.

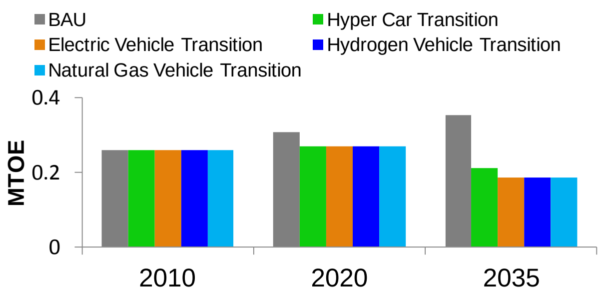
Figure BD14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure BD15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 47% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 39% by 2035—even though these highly-efficient vehicles still use oil.

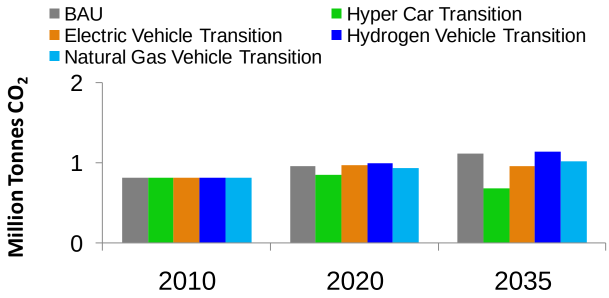
Figure BD15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure BD16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

Figure BD16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

In Brunei Darussalam, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reduction, with an emissions reduction of 39% compared to BAU in 2035. Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption. In the other alternative vehicles oil combustion is replaced by other fuels; namely electricity for electric vehicles, hydrogen for hydrogen vehicles and natural gas in natural gas vehicles. In Brunei Darussalam virtually all electricity generation comes from gas combustion, thus the additional demand for electricity and hydrogen generation would require more gas combustion, which in turn would produce more CO_2 emissions.

The runner-up in this race is the Electric Vehicle Transition scenario offering a 14% emissions reduction compared to BAU, followed by the Natural Gas Vehicle Transition scenario (8%). The Hydrogen Vehicle Transition scenario offers the least benefit, producing 3% more emissions compared to BAU in 2035.

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2009), *APEC Energy Demand and Supply Outlook 4th Edition – Brunei Economy Review*, www.ieej.or.jp/aperc/2009pdf/Outlook/Outlook_Volume_II_4E.pdf

— (2012), *Compendium of Energy Efficiency Policies of APEC Economies*, www.ieej.or.jp/aperc

BEDB (Brunei Economic Development Board) (2011), 'Economic Overview' website page, www.bedb.com.bn/why_ecoverview.html

— (2012), "Over US$2.5b investment in oil refinery and aromatics cracker project in Brunei", press release, www.bedb.com.bn/news_articles_details.php?id=123

Brunei LNG (2010), 'LNG Chain' website page, www.bruneilng.com/lng_chain.htm

Brunei Press (2011a), 'About Brunei' website page, www.bruneipress.com.bn/brunei/brunei.html

— (2011b), *Borneo Bulletin Yearbook 2011–Green Pursuits*, 12 April 2011, Brunei Press Sdn. Bhd.

Brunei Times (2011), "Spark Gets New Locator: $3.37 billion petrochem complex", 30 August 2011, www.bt.com.bn/news-national/2011/08/30/spark-gets-new-locator-3-37-billion-petrochem-complex

DEPD (Department of Economic Planning and Development, Brunei Darussalam) (2008), *Wawasan Brunei 2035*, January 2008.

— (2012), *Brunei Key Indicators 2011–2nd Release*, www.depd.gov.bn/download/BDKI2011_R2.pdf

FGE (Facts Global Energy) (2010), "Overview of Brunei's Gas Balance: Implications for LNG Exports", Issue #49, June 2010, www.fgenergy.com/?page=download&id=1989

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

Lawrey Roger and J. Ram Pillarisetti (2011), "Energy Subsidies versus Economic Efficiency: Practical and Theoretical Issues in the Case of Brunei Darussalam", *Journal of Asian Social Science*, Vol. 7 No 3, March 2011, www.ccsenet.org/journal/index.php/ass/article/download/7820/6986

OBG (Oxford Business Group) (2009), *Focus on efficiency: A push to maximise existing reserves and explore new resources*, www.oxfordbusinessgroup.com/news/focus-efficiency-push-maximise-existing-reserves-and-explore-new-resources

— (2011), *Let there be light: Delivering greener electricity more efficiently*, www.oxfordbusinessgroup.com/news/let-there-be-light-delivering-greener-electricity-more-efficiently

OGJ (Oil & Gas Journal) (2011), "Worldwide Look at Reserves and Production", Vol. 109 Issue 49, 5 December 2011.

United Nations (2011), *World Urbanization Prospects*, Department of Economic and Social Affairs, Population Division, http://esa.un.org/unpd/wup/unup/index_panel3.html

CANADA

- *Canada's commitment to energy efficiency through its policies will help the economy to keep its overall energy demand moderate in the long term.*
- *Canada will remain the world's largest oil sands producers, one of the largest shale gas producers, and a major energy exporting economy.*
- *Annual CO_2 emissions from fuel combustion are projected to increase by 20% over the outlook period. This can be attributed to Canada's projected strong growth in the resources sector fuelling economic growth and activity.*

ECONOMY

Canada's land area is the second largest in the world, after Russia. The economy is located in the northern part of North America, and has a widely varied climate, from temperate in the south to sub-arctic and arctic in the north. Canada's geography and climate contribute to its high energy consumption (about four times the APEC average) (APERC, 2009). The economy's high energy use is due in part to the demand for the transportation fuels required to travel its vast distances, and the space and water heating needed to cope with its cold weather.

Canada is made up of a Federal Government, 10 provincial governments and three territories. Roughly 90% of the land in Canada is Crown land (land held for the monarchy). The majority of this land is owned by the relevant provincial government. Under the Canadian Constitution, the provinces have ownership over the natural resources that lie within their provincial boundaries. Provincial governments manage the pace of energy resource development within their jurisdiction. Federal jurisdiction applies to territories north of 60 degrees, aboriginal and offshore frontier areas. Offshore areas are jointly managed by federal/provincial authorities. The federal government also regulates interprovincial and international energy trade.

Canada was demonstrating solid economic growth before the onset of the global recession in 2008 and its continuation into 2009. Between 1990 and 2009, GDP increased at an average of 2.4% per year. Although there was negative growth in Canada's economy in 2009, GDP is expected to recover, and to grow at an average of 2.4% per year over the outlook period.

The affluence of this economy translates into a high standard of living. Canada's car ownership rate is high for the APEC region. In 2009, there were nearly 21 million registered vehicles on the road—96% of these vehicles were up to 4.5 tonnes (light vehicles) (Statistics Canada, 2010a). Given the urban sprawl and the well constructed road network, automobiles are the dominant means of intercity passenger travel. Compared to other industrialized economies, the public transport system is less extensive and its market share is primarily limited to the larger cities. However, compared to its neighbour the United States (US), Canada's public transport is better funded and of a higher quality.

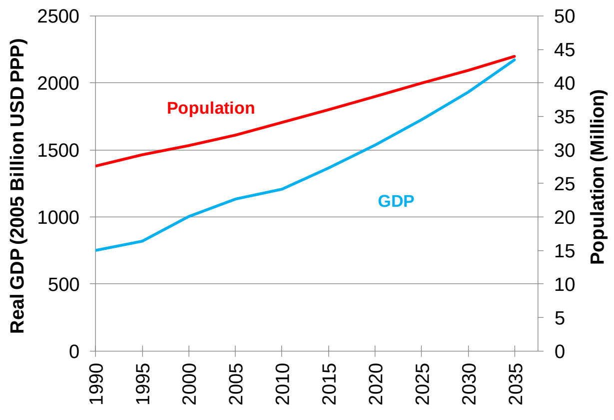
Canada is an advanced industrialized economy with a substantial services sector. Unlike many other developed economies, Canada's economy has a large natural resources producing component. This includes oil and natural gas, minerals and metals mining, forestry, and agricultural sectors. The mining and oil and gas extraction industries alone accounted for about 4.5% of GDP in 2010 (Statistics Canada, 2012).

Canada is moving toward a knowledge-based economy: the service industry employs three-quarters of the workforce and generated 72% of GDP in 2010. Manufacturing makes up 13% of GDP—this includes major industries producing transport equipment, food, chemicals, fabricated metal products, and machinery. Canada's economy is closely tied in with the US economy: in 2010, the US accounted for 73% of Canada's exports and 63% of its imports (Statistics Canada, 2012).

There is an extensive freight rail network across the southern part of Canada. Given Canada's large size, long distance trucking is quite common. Along with this, Canada has many sea ports along its Pacific Ocean and Atlantic Ocean coastlines.

In 2009, Canada had a population of 33.7 million, with the majority of the population living in urban areas. Given Canada's climate, most of the population lives in the southern region, avoiding the sparsely populated northern region that suffers from very cold temperatures. The population is estimated to reach 44.3 million by 2035, growing at an average of 1% per year. The median age of the Canadian population has been increasing over the last three decades: at 1 July 2010 the median age was 39.7 years. In the long term, this could have labour force implications (Statistics Canada, 2011, p. 352).

Figure CDA1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

ENERGY RESOURCES AND INFRASTRUCTURE

Canada is richly endowed with natural resources: oil, natural gas, coal, and uranium in its western provinces and huge hydropower resources in Quebec, British Columbia, Newfoundland, Ontario, and Manitoba. It also has offshore oil and gas reserves near Nova Scotia and Newfoundland. Installed electricity generation capacity was 130.5 gigawatts (GW) in 2010 (Statistics Canada, 2010b). Canada is the world's fifth-largest energy producer (behind the United States, Russia, China and Saudi Arabia). It is a major energy exporter, being the most important source for US energy imports (EIA, 2009).

Canada is the world's third largest hydroelectricity producer, after China and Brazil. Even though it is greatly used, there is still undeveloped hydropower potential available, more than double the current capacity, across all provinces and territories (technically, the potential for an additional 163 000 MW). There is roughly 25 000 MW of additional capacity in various planning stages (Irving, 2010).

Canada is endowed with huge oil potential. At 173 billion barrels, Canada's proven oil reserves are the third largest in the world, after Saudi Arabia and Venezuela. The oil sands account for 98% of Canada's oil reserves. 'Proven oil reserves' are the estimated remaining volume of oil that is economic to recover with current technology. This figure is known through drilling, testing and production.

As of 2011, Canada's remaining technically recoverable oil sands and conventional oil resources were estimated by the National Energy Board (NEB) at 343 billion barrels. The oil sands account for 90% of these oil resources. 'Technically recoverable oil' is the volume of oil that can be produced, and recovered from the subsurface, if costs are not considered a limiting factor.

There is much potential to add to Canada's proven oil reserves. Presently, non-conventional established oil reserves are only reported for Alberta. However, assessments are still underway to estimate the size of the oil sands bitumen resources in Saskatchewan. In future, Canada's proven oil reserves could grow as some of Saskatchewan's oil sands resources become recognised as proven oil reserves. Furthermore, the Grosmont carbonate formation is estimated to account for 21% of the oil sands resources in-place in Alberta but thus far has not been assigned any value as either a proven oil reserve, or even a technically recoverable resource.

The application of horizontal drilling and multi-stage hydraulic fracturing has given new life to previously low-producing or unproductive conventional oil reservoirs. The development of tight oil resources (also called shale oil) has already reversed the decline of conventional oil production in Canada and the United States. Since tight light oil extraction technology is still in its early stages of development in Canada, the ultimate impact on the resource potential is unclear. However, the successful development of Canada's tight oil resources could lead to a significant increase in the size of conventional oil reserves.

Canada is seeking to expand its oil pipeline infrastructure to enable it to export its growing oil production. In December 2011, the National Energy Board approved the Bakken Pipeline project. The pipeline will extend from Saskatchewan to Manitoba, connecting to the Enbridge Pipelines Inc. mainline system and will serve as a continuous, long-term source of light crude oil supply to the central Canadian and US mid-west markets. This will maintain the long-term competitiveness of refineries in those regions (APERC, 2012). In addition, Enbridge's Northern Gateway pipeline, a 525 000 barrel per day (26 Mtoe/year) project, is currently undergoing regulatory review and Kinder Morgan plans to twin its existing TransMountain pipeline, via a 450 000 barrel per day (22 Mtoe/year) expansion. It intends to seek regulatory approval in 2014 and anticipates the expanded pipeline system could be in service by 2017. These pipelines will enable Canada to expand oil exports to the Asia Pacific region (NRCan, 2012a).

Globally, Canada is the third largest producer of natural gas (behind Russia and the US) and fourth largest exporter (behind Russia, Norway and Qatar). Canadian natural gas production is expected to rise over the outlook period, driven by growth in unconventional natural gas production (NRCan, 2012a).

Most of the economy's conventional gas resources are located in western Canada. The Canadian Society for Unconventional Resources (CSUR) estimates Canada's marketable natural gas resources (conventional and unconventional gas resources) at 19.9 to 36.8 trillion cubic meters (131 000 to 242 000 Mtoe). These natural gas resources represent hundreds of years of supply. Unconventional natural gas (e.g. shale and tight gas) represents the largest component of Canada's natural gas resources, and most of these resources are located within the Western Canadian Sedimentary Basin. However, there are significant natural gas resources located in eastern Canada within the Utica and Maritime Basins (NRCan, 2012a).

Currently in the North American market, natural gas prices are depressed, largely due to excess supply. The US, like Canada, is rich in shale gas resources and while the US is looking at developing these resources, it is also looking at developing LNG (liquefied natural gas) export terminals, rather than import terminals. Nevertheless, the US (EIA, 2012) projects that Canada will remain a major exporter of natural gas into the US market up to the end of the reference period in 2035.

Canada, too, is looking at building LNG export terminals with proposed sites on the west coast. The development of these terminals will provide Canada with a larger market for its gas—other Asia Pacific economies such as Japan and Korea. There are several LNG terminals proposed for British Columbia:

- Douglas Channel LNG, a partnership between BC LNG Export Co-operative and Douglas Channel Energy Partnership, to liquefy 7.1 million cubic metres/day (2.3 Mtoe/year) of natural gas. The first phase to liquefy 3.5 million cubic metres/day (1.15 Mtoe/year) could be in-service in late 2013 or early 2014;
- Kitimat LNG, a partnership between Apache, EnCana and EOG Resources, to liquefy 36.8 million cubic metres/day (12.1 Mtoe/year) of natural gas, expected to be in-service in 2017;
- LNG Canada, a partnership between Shell, Mitsubishi Corp, Korea Gas Corp. and PetroChina Company Limited, to liquefy 96.3 million cubic metres/day (31.6 Mtoe/year) of natural gas, the first phase of which (48.1 million cubic metres/day or 15.8 Mtoe/year) is expected to be in-service in 2019;
- Two other LNG terminals are proposed for the Port of Prince Rupert in British Columbia, led by Petronas of Malaysia and the British Gas Group.

In oil sands operations in Alberta, natural gas is used to generate electricity and steam. Steam is used for in situ oil production and in the production of hydrogen to upgrade bitumen into synthetic crude oil blends. Gas consumption by the oil sands industry in 2011 was estimated to be approximately 10% of Canada's total natural gas production (NEB, 2011a).

As noted earlier, growing natural gas requirements in North America have prompted a major push in the construction of LNG export facilities on Canada's west coast. On Canada's east coast, the Canaport LNG terminal in Saint John, New Brunswick, began operating in June 2009 and is currently Canada's only operating LNG import facility. However, the focus is now on export terminals given Canada's considerable unconventional gas supply potential, especially in the form of shale gas and tight gas (NRCan, 2011b). Due to the shale gas supply revolution and low North American natural gas prices relative to world markets, almost all import proposals are on hold.

Most of Canada's coal reserves are located in western Canada. The consumption of domestic coal and thermal coal imports are expected to decline in the outlook period, largely due to the phasing out of coal fired power generation by 2015 in Ontario. However, coal production is expected to increase as a result of multiple projects coming online in western Canada, increasing the exportable amount of coal (NEB, 2011b).

Canada continues to be a leading producer of uranium, with nearly one-fifth of world production (9145 tonnes of uranium metal) in 2011. Canada's low-cost high-quality uranium resources are the third largest in the world, after those of Australia and Kazakhstan. As of January 1, 2012 Canada's total recoverable low-cost uranium resources were estimated at 466 300 tonnes of uranium metal. Recent exploration activity is expected to further increase these figures (NRCan, 2012a).

Hydropower dominated electricity generation in 2010 (59%), followed by coal (13%) and nuclear energy (15%). Nuclear generated power is most prominent in the province of Ontario, where it accounted for 54% of electricity generation in 2010.

Ontario has initiated plans to construct two new nuclear plants (1000 MW each). A clear timeline for their completion has not yet been announced. The Point-Lepreau Station in New Brunswick is expected to be back online in 2012. The Government of Quebec recently announced it will not continue with the refurbishment of the Gentilly-2 reactor and instead intends to close the nuclear generating station by the end of 2012 (NRCan, 2012a).

Canada is a net exporter of electricity. Given the increase in the production of clean and renewable energies, there is potential for significant extra electricity to be available for export. The US is the recipient of Canada's electricity exports. In 2011, Canada's electricity exports to the US totalled CAD 2.03 billion (NEB, 2011).

ENERGY POLICIES

The Canadian Government has a number of policies that promote energy efficiency and cleaner technologies, boost renewable energy supplies and aim to reduce greenhouse gas (GHG) emissions. Since 2006, the Government of Canada has invested more than CAD 10 billion to reduce greenhouse gas emissions and build a more sustainable environment through investments in green infrastructure, energy efficiency, clean energy technologies and the production of cleaner fuels. As part of the Copenhagen Accord, Canada pledged to set a goal to reduce emissions by 17% from 2005 levels by 2020; this was endorsed again through the Cancun Agreement and is in line with US goals.

The Energy Efficiency Act, which took effect in 1992, has been amended to expand its scope and increase its effectiveness (NRCan, 2009a). This includes provisions aimed at reducing standby power consumption, which is currently 10% of household electricity use in Canada. Provincial governments are also major contributors to energy efficiency in their respective provinces through the establishment of energy efficient building codes, equipment standards, etc.

Canada's energy policy, including for resource development, is market-based and incorporates a mix of domestic and foreign owned companies. As per the Canadian Constitution, the regulation of mining activities on publicly owned mineral leases falls under provincial or territorial government jurisdiction. Therefore, there is separate mining rights legislation for each of the 13 Canadian jurisdictions except Nunavut (the northern and eastern portions of the former Northwest Territories). Off-shore mineral rights are usually owned by the Canadian Federal Government (NRCan, 2011b).

Since the signing of Western Accord and the Agreement on Natural Gas Markets and Prices, in 1985, oil and natural gas prices in Canada have been deregulated. The agreements opened up the oil and gas markets to greater competition by permitting more exports, allowing users to buy directly from producers and unbundling production and marketing from transportation services. Oil and gas pipeline networks continue to be regulated as natural monopolies (NRCan 2009b; NEB 1996).

In most provinces, the electricity industry is highly integrated with the bulk of generation, transmission and distribution services provided by one or two dominant utilities. Although some of these utilities are privately owned, many are Crown corporations owned by the provincial governments. Independent power producers also exist, but rarely in direct competition with a Crown corporation. Exceptions include the provinces of Alberta, which has moved to full wholesale and retail competition, and Ontario, which has established a hybrid system with competitive and regulated elements. Retail electricity prices vary across the provinces, in terms of both their level and the mechanism by which they are set. Within the power sector, Canada has an accelerated capital cost allowance (CCA) program which gives a tax benefit for clean energy generation, allowing 50% CCA for projects that use renewable energy equipment or use fossil fuels efficiently, including co-generation (NEB, 2011). In addition, the federal government has invested CAD 1.5 billion to increase Canada's energy supplies from renewable sources, including solar, tidal, hydro, wind, biomass and geothermal through the ecoENERGY Renewable Initiative.

One policy measure that has proved successful in promoting energy efficiency and creating energy savings is the ecoENERGY Retrofit initiative. The program provided incentives for energy efficiency improvements in low-rise residential housing and in small and medium-sized organizations in the institutional, commercial and industrial sectors. The ecoENERGY Retrofit–Small and Medium Organizations component of the initiative ran from April 2007 to March 2011. This CAD 40 million program provided financial incentives to implement energy retrofit projects in buildings with up to 20 000 square metres of floor space and industrial facilities with fewer than 500 employees. Financial incentives stimulated almost 1300 energy retrofit projects. The ecoENERGY Retrofit–Homes component of the initiative was also launched in April 2007. The four year, CAD 745 million program provided federal grants to property owners for improving the energy efficiency of their homes. In

2011, an additional one-year investment of CAD 400 million was made, which allowed as many as 250 000 homeowners to participate in the programme. In total, ecoENERGY Retrofit–Homes helped over 640 000 Canadians increase the energy efficiency of their homes. Homeowners reduced their energy consumption by an average of 20% for ongoing savings of more than CAD 400 million a year (NRCan, 2012b).

In the transport sector, energy consumption growth rates have decreased in recent times. This could be attributable to federal, provincial and territorial programs that promote alternative fuel supply. These include funding programs that encourage investment in the biofuels industry as well as separate renewable fuel blending mandates. For instance, since 2010, Canada has had a 5% renewable fuel mandate. This mandate was expanded in July 2011 to include a 2% renewable fuel content requirement for diesel fuel and heating oil. Several provincial governments have set their own renewable fuel standards, some of which mandate a higher renewable fuel content, and some of which were implemented before the federal mandatory blending requirements (CRFA, 2010). Due to growing domestic supply, natural gas is also being promoted as a transportation fuel, particularly for medium and heavy duty vehicles in the freight sector.

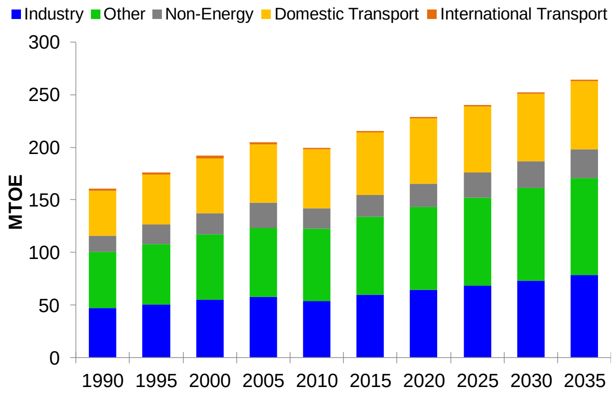
In addition to the above, in October 2011, light-duty vehicle greenhouse gas emission regulations came into force for model years 2011 to 2016, establishing a common Canada–US emissions standard for new vehicles.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow on average 1.1% per year over the outlook period.

Figure CDA2: BAU Final Energy Demand

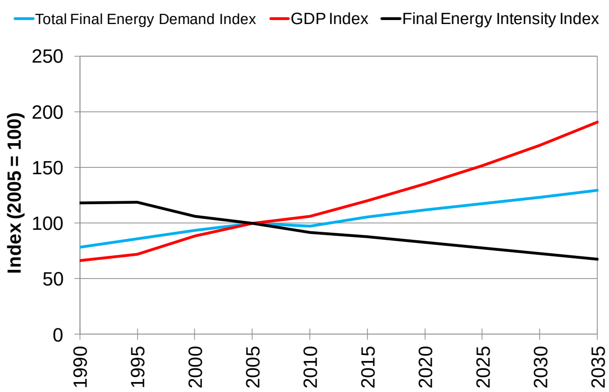


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

A majority of this increase can be attributed to increases in energy consumption across all sectors, especially in the industry and 'other' (residential, commercial and agricultural) sectors.

Despite this small increase in final energy demand, final energy intensity (Figure CDA3) is expected to decline by 32% between 2005 and 2035.

Figure CDA3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 1.5% between 2010 and 2035. Much of the energy demand will come from energy intensive industries such as iron and steel, aluminium, cement, chemicals and fertilisers, pulp and paper manufacturing, and oil and gas extraction.

Transport

On average over the outlook period, Canada's total transport energy demand (including international transport) is projected to grow by an average of 0.6% per year. This is a much smaller growth rate than between 1990 and 2009, when energy demand for transport averaged 1.3% a year.

To comply with the Federal Government's greenhouse gas emission policies (such as the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations) it is likely fuel economy will improve over the projection period. In April 2012, the Government of Canada released proposed on-road heavy-duty vehicle greenhouse gas emissions regulations for model years 2014 and beyond. Proposed regulations for new passenger cars and light trucks for the 2017 to 2025 model years are also under development. These regulations combined with the renewable fuel content mandate (discussed above) and an interest in natural gas vehicles for medium to heavy fleet trucks in the western provinces may bring about change in the types of energy sources demanded within the outlook period.

Conventional gasoline and diesel vehicles will account for most of the light vehicle fleet in the projection period, accounting for 84% of the fleet by 2035, with conventional hybrid gasoline and diesel vehicles accounting for another 5%. The dominant fuel source over the projection period and in 2035 for all domestic transport will be oil.

Other

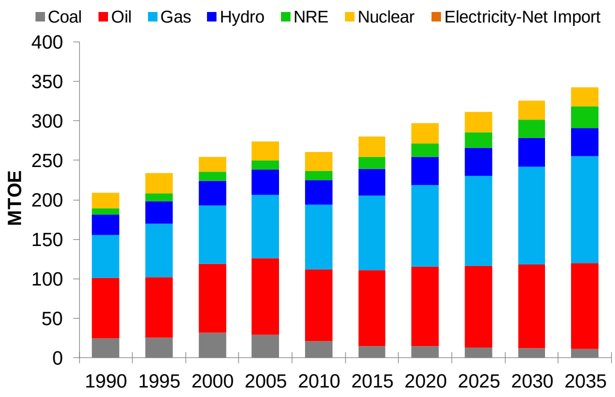
Canada has many policies promoting energy efficiency within the residential and commercial sectors (such as the ecoENERGY Retrofit programs).

However, these efforts will be offset by factors such as the growing population. Energy demand in the 'other' sector, which includes residential, commercial, and agricultural demand, is expected to grow on average 1.2% per year over the outlook period. Given Canada's cold climate, much of the residential and commercial energy use is linked to space and water heating in homes and commercial buildings. Electricity is expected to dominate the fuel mix in this sector throughout the projection period, accounting for 41% of the 'other' sector's energy consumption in 2035, followed closely by gas at 38%.

PRIMARY ENERGY SUPPLY

Canada's primary energy supply between 2010 and 2035 is projected to grow at an average annual rate of 1.1%, in line with the growth in energy demand. Primary energy intensity is projected to decline 34% between 2005 and 2035.

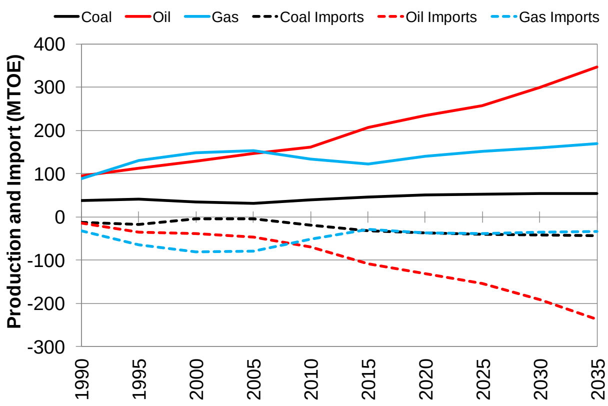
Figure CDA4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The primary supply of oil is projected to increase by 19% between 2010 and 2035, while gas production is projected to increase 27%. Conventional oil and gas production is expected to decline, while increases in production from unconventional resources (especially oil sands, tight oil, and shale gas) are expected to more than compensate (NEB, 2011a).

Figure CDA5: BAU Energy Production and Net Imports

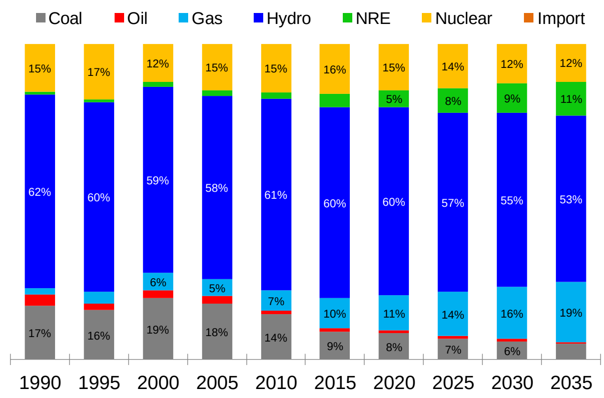


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

Hydropower will remain Canada's dominant source of electricity generation throughout the outlook period. After hydropower, gas is expected to be the largest contributor. In 2035, gas will account for 19% of the generation mix, an increase in share of 12% from 2010. This increase will be driven by higher gas production, and a significant reduction of coal use in electricity generation. The reduction in coal use is partly in response to combined efforts by the federal and provincial governments to reduce reliance on coal-fired electricity generation, especially Ontario's coal phase-out policy and the recently released federal regulations for reducing greenhouse gas emissions from the coal-fired electricity sector.

Figure CDA6: BAU Electricity Generation Mix



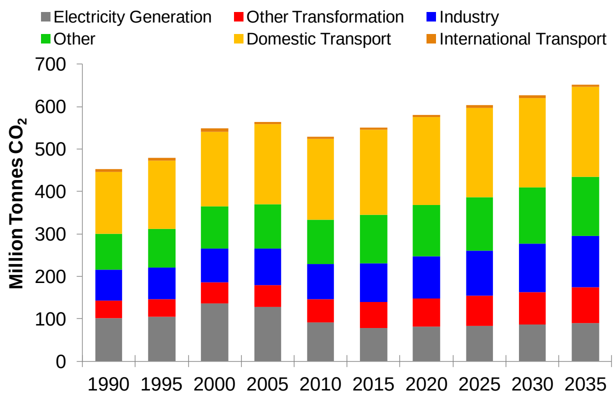
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Over the outlook period Canada's total CO_2 emissions from fuel combustion are projected to increase by 23% from 2010 to 2035, to reach

652.2 million tonnes. By fuel, most of the increase in emissions can be attributable to gas, closely followed by oil. By sector, emissions from electricity generation are projected to decline as a result of reductions in coal-fired generation, while emissions in other sectors will continue to grow.

Figure CDA7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

Table CDA1 shows that the growth in emissions that would have otherwise resulted from Canada's GDP growth are partly offset by reductions in the energy intensity of GDP and reductions in the CO_2 intensity of energy. Reductions in the energy intensity of GDP include improved energy efficiency and shifts to less energy-intensive industry. Reductions in the CO_2 intensity of energy include reductions in coal generation and increases in renewable energy generation.

Table CDA1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
Change in Energy Intensity of GDP	-1.0%	-2.2%	-1.4%	-1.4%	-1.2%
Change in GDP	2.8%	1.2%	2.2%	2.2%	2.4%
Total Change	1.5%	-1.3%	0.4%	0.5%	0.8%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual, Canada's opportunities as an energy exporting economy appear assured. The global demand for oil from secure sources and for natural gas, which has much lower CO_2 emissions than coal, is likely to grow over the Outlook period. Canada has abundant resources of both unconventional oil and unconventional gas, and should be in a good position to help meet this demand. It is, however, important to recognize that there is growing public concern over the environmental risks of unconventional oil and unconventional gas development. These concerns will need to be addressed through enlightened regulation if oil and gas development is to win the public confidence it will need for Canada to achieve its potential.

ALTERNATIVE SCENARIOS

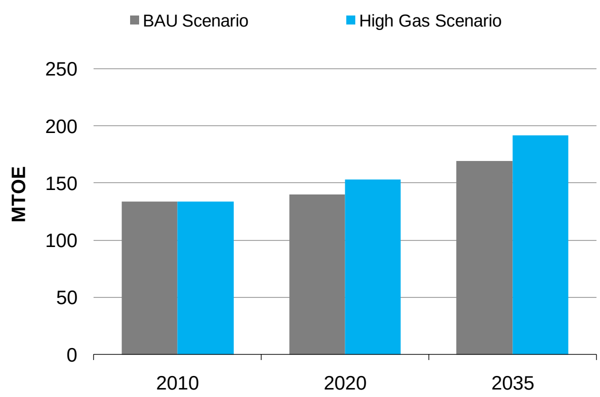
In order to address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts that higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU scenario prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario production for Canada assumed a production increase of 13.2% by 2035 compared to BAU, as shown in Figure CDA8. This assumption is based on Canada's prospective unconventional and conventional gas reserves. As noted above, even under the BAU scenario gas production is expected to increase significantly over the outlook period. Under the alternative scenario, it is assumed that opposition to some gas development projects can be overcome through more intensive engagement with stakeholders, and that the sometimes cumbersome and lengthy approvals processes will be streamlined to allow more gas projects to move ahead quickly.

Figure CDA8: High Gas Scenario – Gas Production

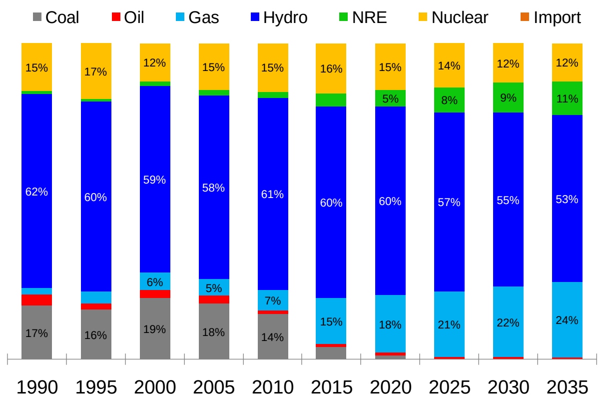


Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. While some of Canada's additional natural gas will be consumed domestically, it is likely that much will be exported. While currently there are no operational LNG export terminals in Canada, project proposals are under consideration and are assumed to come to fruition under the High Gas Scenario. There should be significant demand for natural gas in Asian economies such as China, Japan, and Korea.

The additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure CDA9 shows the High Gas Scenario Electricity Generation Mix.

Figure CDA9: High Gas Scenario – Electricity Generation Mix

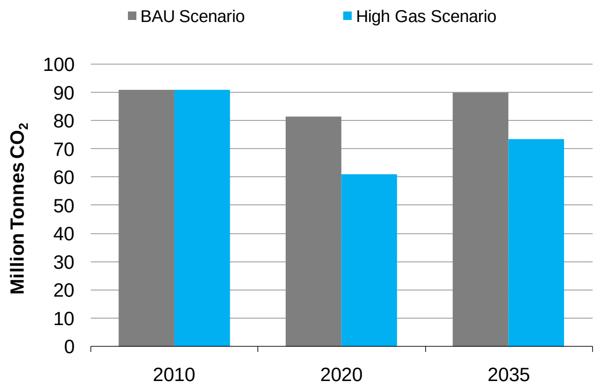


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

This graph may be compared with the BAU scenario graph shown in Figure CDA6 above. The gas share is 5% higher in 2035 compared to the BAU case, because coal has a 5% market share in the BAU case, the increased gas production thus displaces coal in power generation.

Since gas has roughly half the CO_2 emissions of coal per unit of electricity generated, this had the impact of reducing CO_2 emissions in electricity generation by a significant 24% in 2035. The reduction in emissions is comparatively large in percentage terms because the majority of Canada's electricity generation is from hydro and has no emissions. Figure CDA10 shows this CO_2 reduction.

Figure CDA10: High Gas Scenario – CO_2 Emissions from Electricity Generation



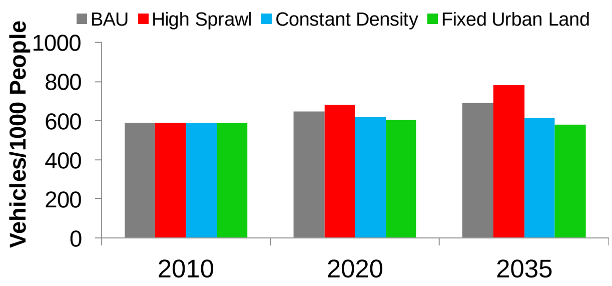
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CDA11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. It can be seen that better urban planning is likely to prove beneficial in Canada since under a High Sprawl scenario, vehicle ownership is projected to increase by 13% in 2035 compared to the BAU scenario, whereas under the Constant Density and Fixed Urban Land scenarios vehicle ownership declines 11% and 16%, respectively, compared to the BAU scenario.

Figure CDA11: Urban Development Scenarios – Vehicle Ownership

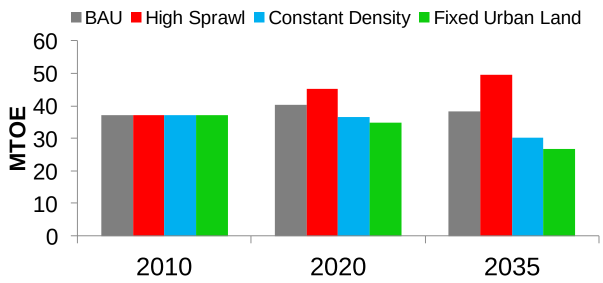


Source: APERC Analysis (2012)

Figure CDA12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Similar, but larger, effects than those seen in figure CDA11 can be seen in figure CDA12, since urban planning affects not only vehicle ownership, but also the distances driven.

Oil consumption is projected to increase 29% in 2035 under a High Sprawl scenario compared to the BAU scenario, whereas oil consumption is projected to decline 21% and 31% under the two other scenarios.

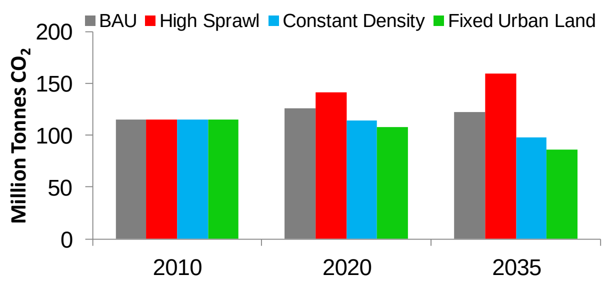
Figure CDA12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure CDA13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is the same in percentage terms as the impact of urban planning on oil consumption, since there is no significant change in the mix of fuels used under any of these scenarios.

Figure CDA13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



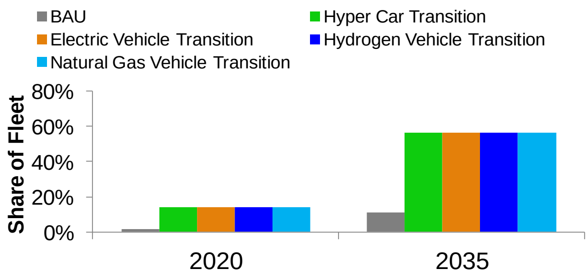
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CDA14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 57% compared to about 11% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 43%, compared to about 89% in the BAU scenario.

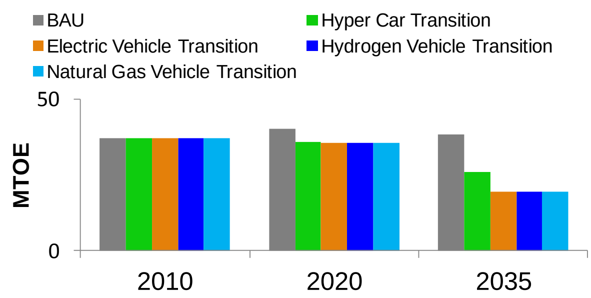
Figure CDA14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure CDA15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 34% by 2035—even though these highly-efficient vehicles still use oil.

Figure CDA15: Virtual Clean Car Race – Light Vehicle Oil Consumption



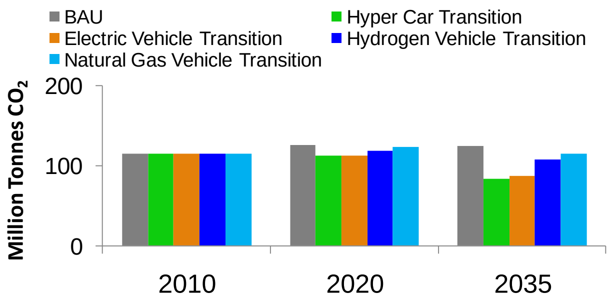
Source: APERC Analysis (2012)

Figure CDA16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, for the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Canada, the Hyper Car Transition scenario is the winner in terms of CO_2 emission reduction, with an emission reduction of 33% compared to BAU in

2035. The Electric Vehicle Transition scenario does almost as well, reducing emissions 30% compared to BAU in 2035, reflecting the fact that, in Canada, relatively low-emission natural gas is assumed to be the marginal source of electricity generation. A Hydrogen Vehicle Transition scenario would reduce emissions by 13% compared to BAU in 2035, while the Natural Gas Vehicle Transition scenario would reduce emissions by 7% compared to BAU in 2035.

Figure CDA16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2009), *APEC Energy Overview 2008*, www.ieej.or.jp/aperc/

— (2012), *APEC Energy Overview 2011*, www.ieej.or.jp/aperc/

CRFA (Canadian Renewable Fuels Association) (2010), 'Federal Programs' website page, www.greenfuels.org/en/public-policy/federal-programs.aspx

EIA (Energy Information Administration, United States) (2009), *Country Analysis Brief: Canada*, www.eia.gov/countries/cab.cfm?fips=CA

— (2012), *Annual Energy Outlook 2012*, www.eia.gov/forecasts/aeo/

Environment Canada (2011), *A Climate Change Plan for the Purposes of the Kyoto Protocol Implementation Act*, ec.gc.ca/doc/publications/cc/COM1410/p2-eng.htm

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

Jacob Irving (2010), *Hydropower in Canada: Canada's Number One Electricity Source*, presentation to the Standing Committee on Energy, the Environment and Natural Resources, Senate of Canada', 16 November 2010, www.canadianenergyfuture.ca/wp-content/uploads/2010/11/Hydro-EN1.pdf

National Energy Board (NEB) (1996), *Natural Gas Market Assessment: 10 years after deregulation,* www.neb.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/ntrlgs/ntrlgs-eng.html

— (2011a), *Canada's Energy Overview 2011*, July 2011, www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyvrvw/cndnnrgyvrvw2011/cndnnrgyvrvw2011-eng.html

— (2011b), *Canada's Energy Future: Energy Supply and Demand Projections to 2035*, www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2011/nrgsppldmndprjctn2035-eng.pdf

Natural Resources Canada (NRCan) (2009a), 'Modernized Energy Efficiency Act Receives Royal Assent' news release, 14 May 2009, www.nrcan.gc.ca/media/newcom/2009/200942-eng.php

— (2009b), *Energy Use Data Handbook,* Office of Energy Efficiency, http://oee.nrcan.gc.ca/Publications/statistics/handbook09/index.cfm?attr=0

— (2011a), *Canadian LNG Import and Export Projects Update*, www.nrcan.gc.ca/energy/sources/natural-gas/1156

— (2011b), *Mining Regulations*, www.nrcan.gc.ca/minerals-metals/policy/legislation-regulations/3707

— (2012a), 'Official Statistics from Natural Resources Canada', quoted from e-mails dated: 13/10/2012 and 23/10/2012 from Ms. Susan Moir, Senior Policy Advisor International Energy Division, Energy Sector.

— (2012b), *Improving Energy Performance in Canada: Report to Parliament Under the Energy Efficiency Act For the Fiscal Year 2010-2011*, http://oee.nrcan.gc.ca/publications/statistics/parliament10-11/index.cfm

Statistics Canada (2010a), *Canadian Vehicle Survey: Annual 2009*, http://publications.gc.ca/collections/collection_2010/statcan/53-223-X/53-223-x2009000-eng.pdf

— (2010b), Catalogue 57-206, Electric Power Generating Stations

— (2011), *Canada Year Book 2011*, Catalogue no. 11-402-X, www.statcan.gc.ca/pub/11-402-x/2011000/pdf/population-eng.pdf

— (2012), Summary Tables, www.statcan.gc.ca/tables-tableaux/sum-som/index-eng.htm

CHILE

- *Through promotion of energy efficiency and construction of LNG import terminals, Chile has responded in an effective and environmentally responsible fashion to the natural gas crisis of the early 2000s, which was precipitated by Argentina's restrictions on gas exports to Chile.*
- *Looking forward, however, the business-as-usual outlook suggests that Chile will face additional challenges, with CO_2 emissions more than doubling and oil imports rising 72% over the 25-year outlook period.*
- *Chile may have significant shale gas resources; however, further investigation is required to determine its economic viability there.*

ECONOMY

Chile is one of three Latin American members of APEC. The economy lies in South America, with Peru to the north and Bolivia and Argentina to the east. It is 4300 kilometres long and on average 175 kilometres wide; the total land area is 756 950 square kilometres. Chile is divided into 15 regions, which form the economy's first level of administration. Each region is headed by a governor appointed by the President. Regions are divided into provinces (the second level of administration), also each headed by a governor appointed by the President. There are 54 provinces in total. Provinces are further divided into communes, which are governed by municipalities.

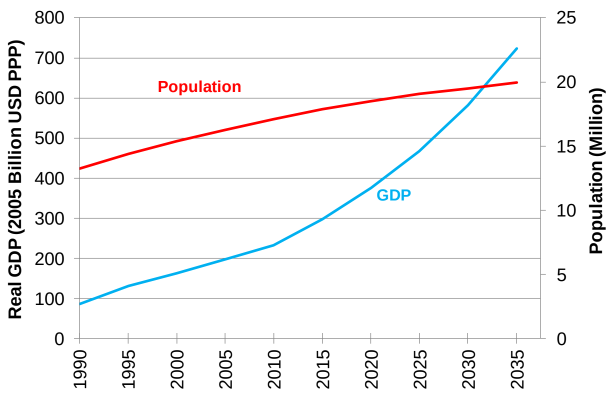
Chile has a greatly varied climate, covering at least seven major climatic subtypes. Temperatures are influenced by oceanic currents: in the south and centre, the Antarctic current produces cooler temperatures, while towards the north temperatures rise due to the effect of tropical currents. Average temperatures in central Chile range between summer peaks of 20°C and winter lows of 8°C. The climactic diversity causes regional differences in energy consumption patterns, such as use of air conditioning in the north, compared to demand for heating in the south.

Chile's population is projected to grow at an average annual rate of 0.6% over the outlook period, reaching over 20 million by 2035. Almost all of the 2035 population (99%) are expected to be living in urban areas—mainly in big cities such as Santiago, Valparaiso–Viña del Mar and Concepción.

In 2010, GDP per capita was USD 13 644 (in 2005 PPP) and during the outlook period, Chile's GDP growth is expected to be moderate, with an average annual growth rate of 4.6%. GDP in 2035 is estimated at USD 724 billion at 2005 USD PPP (or USD 36 259 per capita). This assumes continued expansion of the manufacturing industry, which has been a substantial contributor to Chile's GDP; the mining sub-sector, specifically copper, is also expected to continue to grow.

Chile's economy is based on five key areas: rich mineral resources, agriculture (which takes advantage of the wide variety of climatic conditions), rich fishing grounds, industry, and financial services. Chile has a market-oriented economy characterized by a high level of foreign trade, with export markets balanced among Europe, South America, North America and Asia. Chile has 25 trade agreements in place (MRE, 2008, p. 18), and is an active participant in international organizations such as the Asia-Pacific Economic Cooperation (APEC), the World Trade Organization (WTO), Southern Common Market (Mercado Común del Sur or Mercosur), European Free Trade Association (EFTA), Central American Common Market (CACM) and Latin American Energy Organization (Olade).

Figure CHL5: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Broken down by economic sectors, Chile's GDP in 2010 was composed of agriculture and mining (21%), manufacturing and industry (22%) and services, transport and communications (57%) (BCL, 2012). Copper extraction accounts for 92% of the mining GDP, and is one of the pillars of the Chilean economy; it attracts significant foreign private investment, since its production is well developed and oriented to exports.

There are four major energy demand sectors in Chile: industry, mining, transportation, and 'other' (residential, commercial and public) (APEC, 2009). The industry and mining sectors together used 37% of the 2009 final energy demand; this was driven by two subsectors in particular: copper, and pulp and paper. The major energy sources consumed in these sectors are petroleum products, biomass, and electricity.

The transport sector is also a major energy user, consuming 31% of the final demand. Chile's particular geography, high urbanization and low population density (in most centres other than greater Santiago) create the conditions for frequent long journeys. Road transportation is the predominant mode, accounting for 80% of the transport energy demand. Maritime and air transport together make up most of the remaining energy use, while the rail share of the transport energy demand is minimal, representing less than 1%.

In the medium and long term, vehicle sales growth is expected to be sustained by rising incomes and low prices. Light vehicle ownership will increase substantially from around 1.8 million cars in 2009 to 6.6 million cars in 2035. Most of the cars sold in Chile are made in Asia or elsewhere in South America by American and European automakers. There is no longer any automotive production in Chile—the last remaining local assembly plant in Chile, a General Motors plant in Arica that assembled pick-up trucks, closed in mid-2008.

Historically the railways have been important in Chile, but they now play a relatively small part in the economy's transport system. Rail's declining importance, including for freight transportation, is expected to continue through the outlook period.

Chile employs a concessions or public–private joint investment system to finance the construction, development and improvement of transport infrastructure such as highways, airports and urban transportation systems. The system is administered by the Ministry of Public Works (MOP). Between 1993 and 2008, USD 11.5 billion was invested in new, upgraded highways (such as Highways 5, 68, 78 and 57) as well as road maintenance and improvement of urban transportation, especially in Santiago (such as the Metro de Santiago bus system). By 2009, Chile had a total 81 000 km of roads, of which 21% was paved (MOP, 2009).

The 'other' sector, which covers the residential, commercial and public sub-sectors, consumed 28% of Chile's final energy demand in 2009; 79% of this use was in the residential sector. New renewable energy (NRE) accounts for 46% of total final energy consumption in the residential sub-sector—mostly of biomass for heating and cooking (APERC, 2009).

ENERGY RESOURCES AND INFRASTRUCTURE

Chile has limited domestic fossil energy resources. It is largely dependent on international energy markets, which means the economy is exposed to considerable risk in terms of security of supply and price fluctuations. The economy does produce some conventional energy resources, including crude oil, natural gas, coal, and renewable energy sources such as hydro, wind and biomass. Chile is considered to have three major domestic energy resources: wood/biomass for heating and electricity generation; water for hydroelectricity generation; and natural gas from the Magallanes region.

Chile's estimated proven crude oil reserve in January 2009 was 150 million barrels (equivalent to about 20 Mtoe) located mostly in the southern Magallanes region (Oil & Gas Journal, 2011). In 2009, production was 0.72 Mtoe (about 14 000 barrels/day), including gas liquids. By comparison, Chile's 2009 total primary oil supply was 15.6 Mtoe. Limited local production means dependency on imports is substantial and growing. The government-owned Empresa Nacional del Petróleo (ENAP) and privately owned GEOpark are the major oil producers and refiners in the economy. ENAP operates all three refineries in Chile, the largest of which is the 113 400 barrels/day Bio-Bio refinery, located south of the capital Santiago (ENAP, 2009).

Chile's natural gas production comes from onshore and offshore facilities in the Magallanes region. Proved reserves of natural gas were 98 billion cubic metres (or about 88 Mtoe) in 2011 (USEIA, 2011). However, Chile had limited gas production of about 1.5 Mtoe in 2009 (IEA, 2011). The economy is a net importer of natural gas, with imports accounting for 44% of the economy's total natural gas supply in 2009. There are indications Chile may have significant resources of shale gas (see Volume 1, Table 12.2), but utilization of this resource is not included in APERC's business-as-usual (BAU) projection because the initial studies on shale gas in the Magallanes region only began in 2009 and information is still incomplete.

Historically, Chile's main source of imported gas was Argentina, but Chile has faced restrictions on imports imposed by that economy since 2004 (see the 'Energy Policies' section below). Given the limited domestic gas production, Chile is pursuing other sources of imports in the form of liquefied natural gas (LNG). Two major LNG import facilities commenced full-scale operation in 2011. The first, located in Quintero Bay, has a total installed capacity of 5 million cubic metres per day. The second facility in Mejillones, in northern Chile, has an installed capacity of 2.5 million cubic metres per day. Both these terminals will be expanded in the future.

Natural gas distribution is carried out by eight companies: Metrogas, Gasvalpo, Innergy, GasSur, Intergas, Gasco Magallanes, Distrinor, and Lipigas. The biggest, Metrogas, supplies industrial and residential customers in Santiago. In Valparaíso City distribution is by Gasvalpo. In the south, Innergy handles industrial distribution while residential distribution is the responsibility of GasSur and Intergas. In the far south, industrial and residential distribution is by Gasco Magallanes. In the north, Distrinor supplies Antofagasta city and Lipigas distributes within Calama city.

Chile's recoverable coal reserves were estimated at 700 million tonnes in 2008 (CNE, 2008a), or 136 years of coal supply at 2005 demand levels. Domestic coal production is in two regions: Bio-Bio in Golfo de Arauco, and Pecket and Isla Riesco in Magallanes. Production of coal is expected to reach 5–6 million tonnes.

In terms of electricity generation potential, Chile is rich in hydropower energy sources. Chile's total electricity generation in 2009 was 60.7 TWh, with 51% of this coming from thermal power plants run on coal (25%), oil (20%) or gas (6%). The rest was almost all hydro (IEA, 2011). Public utilities accounted for 91% of total electricity generation, while the remainder was generated by independent producers.

Chile's electricity grid is made up of two main systems. The Central Interconnection System (SIC) supplies 90% of the population while the Northern Interconnection System (SING) provides electricity to northern regional consumers including the mining companies located there. The two grids are not connected. In addition, there are two smaller systems serving a very small proportion of the population; these are the Aysen Interconnection System and the Magallanes Interconnection System.

Renewable energy (hydro, wind, biomass and biogas) contributed 76% of Chile's domestic energy production in 2009 (7339 ktoe). Biomass in the form of wood is the largest source of domestic energy production (50% of total indigenous production and 70% of energy from renewable sources) with most wood used in the residential sector. The second largest renewable energy contributor is hydro. In 2009 Chile produced 2228 ktoe (25 990 GWh) of hydropower, which was 22% of total indigenous energy production. Chile also has a modest potential supply of biogas from biomass treatment of waste products such as poultry dung and urban solid waste. Chile began some production of biogas in 2009, producing a total of 6.9 ktoe (12 million cubic metres) (MINERGIA, 2010). Biofuels are just starting to emerge in the automotive sector.

No other energy sources, such as nuclear or geothermal, are currently being employed, although the potential of geothermal and photovoltaic resources in Chile's energy mix is promising.

ENERGY POLICIES

Chile's approach to the energy sector is based on the development of a free market economy. Since 1990, the economy has distinguished itself as a world leader in liberalizing the energy sector.

Chile's energy policy priority is to reduce the economy's dependence on energy imports and the associated exposure to supply shocks, which are heightened by the growing energy demand. A significant event in Chile's recent history, that has deeply influenced its subsequent energy policies, was the gas crisis that began in 2004. The background on the crisis is that in 1995, in an effort to diversify its energy supply, Chile signed a gas integration protocol with Argentina to set up a supply of competitively priced imported gas. The agreement led Chile's private sector to invest heavily in the economy's natural gas infrastructure. The gas share in Chile's power generation rose from 1% in 1996 to 33% in 2004. However, in 2004, Argentina began to unilaterally reduce energy exports, with severe impact on the gas trade with Chile, even cutting off gas exports completely in some periods during 2007 and 2008 (IEA, 2009).

In early 2012, the Chilean Government through its Ministry of Energy issued the National Energy Strategy 2012–2030 (ENE for its Spanish acronym). This document sets out long-term policy and objectives for the energy sector. It focuses on electricity issues, and on the supply of clean, competitively priced and reliable energy to Chile, to support the economy's development and to sustain economic growth. The ENE established six main goals (MINERGIA, 2012):

1. Economy-wide promotion of energy efficiency
2. Promotion of non-conventional renewable energy
3. Expansion of hydropower generation to reduce dependence on energy imports

4. A new institutional focus on electricity transmission
5. Modifications to the electricity market to make it more competitive
6. Development of electricity interconnections with neighbouring economies.

As the ENE was issued by the President and his Cabinet, it can be expected that most measures and targets in the strategy will be enforced, although there are certain parts of the ENE that depend on further regulation or legal modification, and so are less certain.

On the planning side, the ENE proposes the creation of power utility corridors that will be listed as facilities of 'national interest', improving small power producers with access to the grid, and the use of smart grid technology to promote the expansion of distributed generation.

On the operational side of the electricity sector, the ENE calls for more independence for existing independent power system operators in each of the two major electricity systems. This is to bring more even-handed treatment to all power producers. There is policy to introduce net metering into the Chilean market, so that families and small businesses have incentive to install renewable energy technologies with the possibility of being paid by the utility for surplus energy fed to the grid. In addition, the ENE proposes the development of electricity interconnections with Chile's neighbours, particularly with Argentina, while also advancing efforts with Peru, Bolivia and Ecuador. This is with the intent of preventing supply disruption.

Chile's oil and gas sector is centred on the National Petroleum Agency (ENAP), the government-owned company created in 1950 and unchanged by 1990s liberalization. ENAP presently controls the bulk of oil production and refining in the economy, supplying about 70% of Chile's oil product demand through an extensive network for transportation, storage and distribution of crude oil, natural gas and refined products (ENAP, 2011). Despite Chile's limited hydrocarbon resources, the economy has always aspired to securing energy supply and self-sufficiency. For this reason, ENAP carries out exploration and production activities overseas, including in Ecuador, Argentina and Egypt. Technically, Chile's oil and gas industry is open to private companies, but in practice few investors participate due to the economy's limited resources.

In the case of coal, domestic production is limited, accounting for little more than 5% of Chile's coal demand in 2010 (MINERGIA, 2010). The Isla Riesco project in the south of Chile is expected to significantly increase the domestic supply, with its annual output of approximately 6 million tonnes of coal. It is expected to start operation in the first half of 2013 (Mina Invierno, 2012a, 2012b).

Energy efficiency has become central to Chile's work towards its key goal of reducing dependence on imported fossil fuels. The government's dual approach in recent years—increasing the share of electricity produced from hydro and new renewable energy (NRE) sources while reducing demand growth through energy efficiency—has been strengthened through the ENE published in 2012.

The Energy Efficiency Agency (AChEE) is responsible for the promotion and enhancement of efficient energy use in the economy. This agency includes representatives of the Ministries of Finance and Energy and is responsible for implementing Chile's Action Plan on Energy Efficiency 2020 (PAEE 2020), which is listed as the first goal of the ENE. The main target of PAEE 2020 is a 12% reduction in the forecast energy demand for 2020, roughly equivalent to 1122 MW of capacity.

The Chilean Government through AChEE is carrying out several major projects in these areas:

- *Transport Sector*. One program was carried out in 2011, replacing 144 buses older than 20 years with new, energy-efficient units. Other lines of action are currently in 'pre-development': developing efficient driving workshops; providing incentives for improving energy efficiency standards and technological upgrades in existing vehicles; fostering implementation of economy-wide energy efficiency management; and developing information mechanisms to promote purchase of energy-efficient vehicles.
- *Residential, Commercial and Public Sectors*. Action in these sectors is at the planning stage. The plans include a pilot project for water heaters replacement; specialized training in energy efficiency management; the inclusion of energy efficiency criteria for new buildings; a special program to carry out energy efficiency measures in public buildings; and an energy efficiency certification scheme for current buildings.
- *Industry and Mining Sectors*. There are three projects in planning in these energy-intensive sectors. They include implementation of energy management systems through the implementation of the international standard ISO 50.001; promotion of and training in cogeneration; and the development of an economy-wide list of top-quality energy advisors.

- *Business Development.* Four programs are underway, including energy audits and diagnosis.
- *Measurement and Verification.* AChEE's project management, training and monitoring software are included in this area.
- *Education and Training.* This covers several projects with wide application, including strengthening energy efficiency research and innovation in higher education institutions, and increasing people's awareness of energy efficiency issues.

In terms of electricity production from renewable energy, new legislation proposed in April 2008 aims to provide an incentive for increased use of new renewable energy (NRE) in the economy's electricity systems. Law 20.257 (the Law of Non-Conventional Renewable Energy) took effect in 2010 (CNE, 2008b) and establishes that any new power supply contract (new consumption or new supply to existing consumption) must include at least a percentage of self-generated or outsourced NRE. The share starts at 5% for the period 2010–14 and gradually builds up to 10% of total energy production by 2024.

Since the ENE's publication in 2012, renewable energy has become a higher priority, and it is expected that its share in the Chilean electricity matrix will rise in the short and long term. The ENE proposes various strategies in support of this, such as improving bidding mechanisms; expanding hydropower generation; developing a geo-referenced atlas to provide accurate information that can support investment; implementing financing schemes; and developing and implementing differentiated policies for individual technologies, which will address specific technical and economic issues.

In addition, from May 2012 one of the six sectoral committees of Chile's Economic Development Agency (CORFO) has been exclusively devoted to energy issues. The Renewable Energy Centre is in charge of supporting access to finance, supporting project development, strengthening networking and stimulating innovation in the NRE area (CORFO–CER, 2012).

In Chile, prices for petroleum-based fuels are set by market conditions across all stages of the value chain, including retail sales at service stations. However, specific excise taxes (IEC in Spanish) are charged on transport fuels (gasoline, diesel, LPG and CNG). Although Chile does not employ direct energy subsidies, a mechanism was introduced in February 2011 to reduce uncertainty about domestic prices for oil products. This is the government's Consumers' Protection System for Volatility in International Oil Prices Volatility (SIPCO). Under this system, a price band is determined around the average price of a fuel over the past five months. If the price of the fuel rises or falls outside this band, the excise tax is varied to counteract the price change. Thus, significant variations in price are absorbed into the IEC excise tax system and consumer risk is minimized (CNE, 2012).

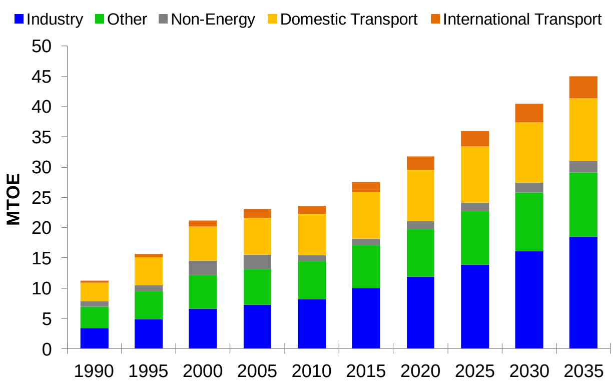
Chile is a signatory to the United Nations Framework Convention on Climate Change (1995), and ratified the Kyoto Protocol in 2002. In 2006, the government published a National Strategy on Climate Change to promote action in that area. In December 2008, to complement the strategy, Chile published the National Action Plan on Climate Change 2008–12. This action plan assigns institutional responsibilities for adapting, mitigating and strengthening Chile's response to climate change (CONAMA, 2008).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

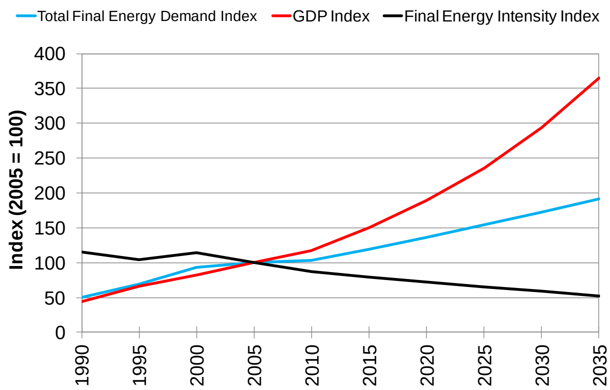
Chile's final energy demand (excluding the international transport sector) is expected to grow 88% over the outlook period, rising from 22.3 Mtoe in 2010 to 41.9 Mtoe by 2035 under business-as-usual (BAU) assumptions. By 2035 the sector with the greatest energy demand will be industry (44%), followed by 'other' (residential, commercial, and agriculture) with 26%, domestic transport with 25%, and the remaining 5% accounted by non-energy use.

Figure CHL6: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure CHL3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the Chilean industrial sector is expected to grow almost 130% over the outlook period, rising from 8.1 Mtoe in 2010 to 18.6 Mtoe by 2035. By 2035, the largest share of this demand will be for oil products (predominantly diesel) at 44%, followed by electricity at 39%. Renewable energy sources, mostly biomass in the pulp and paper industry, are expected to be the third major energy source for the sector with 14%, while coal is bound to account for less than 1%. The use of natural gas, mainly in the mining and petrochemical industries, is expected to remain minimal, with little change from 2010 levels (about 1% in 2035). While Chile's historically restricted gas supplies might have discouraged a more rapid expansion of natural gas in the industrial sector, this may change with the availability of more gas in the form of LNG. Our industrial gas projections could, therefore, be conservative.

Transport

Energy demand in Chile's domestic transport sector is expected to increase 52%, rising from 6.8 Mtoe in 2010 to 10.4 Mtoe in 2035. As with most economies, by 2035 the bulk of the sector's energy demand is expected to be met by petroleum-based fuels (gasoline and diesel) with 94%. Biofuels, gas (CNG) and electricity (for electric cars) could account for the remaining 6% of the transport sector demand in 2035.

Chile's light vehicle fleet is expected to double by 2035. Composition of the fleet at the end of the outlook period is expected to be mostly conventional gasoline and diesel-powered cars (81%), with conventional hybrid cars at 8%, plug-in hybrids at roughly 4%, CNG cars at 3%, and the remainder made up by LPG cars, motorcycles and and hydrogen fuel cell cars. With a current ownership level of less than 200 vehicles per 1000 people, Chile's vehicle ownership is far from saturation and is projected to grow steadily in line with the economy's increasing population, urbanization rate and per capita income.

Energy use in the transport sector will grow more slowly than light vehicle ownership. This reflects slower growth in energy demand for heavy vehicles and other transport modes, along with increasingly efficient vehicles.

Other

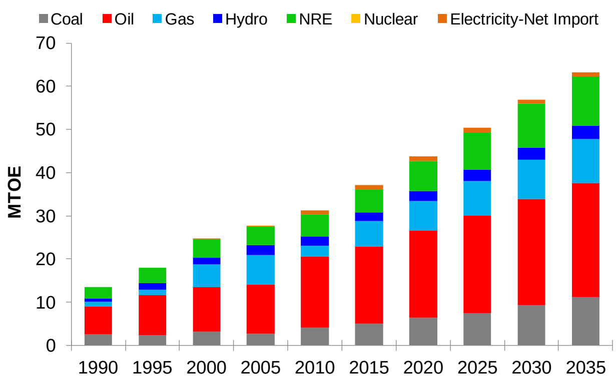
Energy demand in the residential, commercial and agriculture subsectors is expected to grow 76% in the outlook period, rising from 6.3 Mtoe in 2010 to 11.1 Mtoe by 2035. Projections indicate that all energy sources in this combined sector will experience a fairly similar growth over the period (expanding around 140% on the 2010 amount) with the exception of renewable energy, which is expected to remain flat.

PRIMARY ENERGY SUPPLY

Chile's primary energy supply is projected to double over the outlook period, from 31.3 Mtoe in 2010 to 63.6 Mtoe in 2035. Among the fossil fuels, natural gas will experience the largest growth, increasing four times from 2.5 Mtoe in 2010 to 10.3 Mtoe in 2035. This assumption is based on the planned expansion of the current LNG import terminals. The energy supply from petroleum products will grow 61%, rising from 16.6 Mtoe in 2010 to 26.7 Mtoe in 2035, while coal supply will grow 177% by 2035, reaching more than 11.2 Mtoe.

New renewable energy (NRE) supply is projected to more than double from 5.0 Mtoe in 2010 to 11.4 Mtoe in 2035—exceeding coal's share to become the second largest energy source in Chile's primary energy mix. The growth of NRE will be mainly driven by electricity generation demand growth.

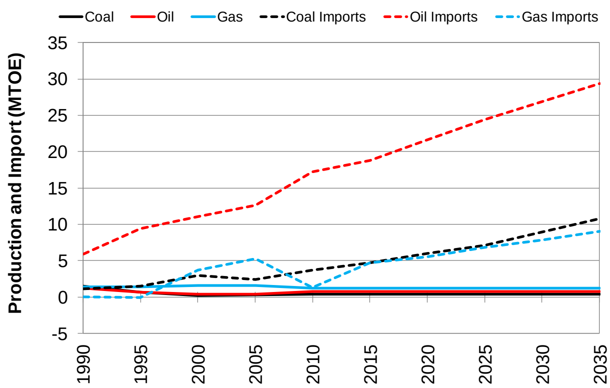
Figure CHL4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Oil will remain dominant, accounting for 42% of Chile's total primary energy supply in 2035, and will be predominantly used in transport and industry. Oil imports are expected to rise by about 72%, rising from 17.2 Mtoe in 2010 to 29.6 Mtoe in 2035. Without taking into account the possible impact of the Isla Riesco project on the domestic coal supply, coal imports are expected to reach 10.8 Mtoe in 2035, nearly triple its 2010 figure. Significant growth of gas imports is expected, increasing almost seven times over the outlook period from 1.3 Mtoe in 2010 to 9.1 Mtoe in 2035, as a result of the expansion of Chile's LNG terminals.

Figure CHL5: BAU Energy Production and Net Imports

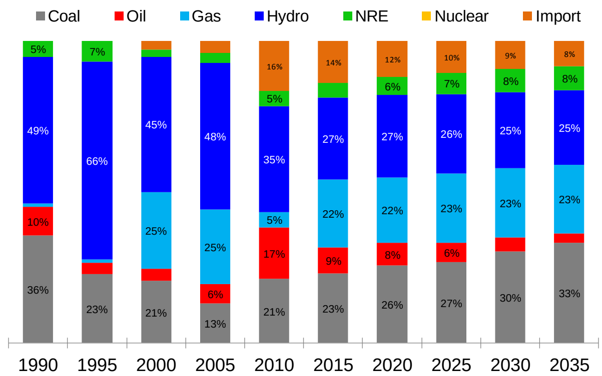


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

Total electricity generation in Chile is projected to grow 119% over the outlook period, increasing from 60 TWh in 2010 to 131 TWh in 2035. Coal-fired technology is expected to become a more important source, supplying 36% of the electricity generated in 2035, followed by hydro (27%) and natural gas (25%). Natural-gas-fired generation will have the largest increase, growing more than eight times in comparison to 2010 levels. At the same time, electricity generation from NRE is expected to more than triple. The increase in the use of gas for electricity generation reflects greater ability to import LNG following the expansion of the current import terminals.

Figure CHL6: BAU Electricity Generation Mix

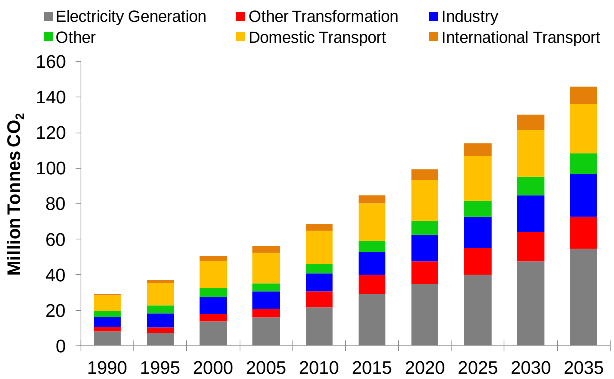


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Chile's total CO_2 emissions are projected to more than double over the outlook period, reaching 14 million tonnes of CO_2 in 2035 (including international transport) compared to nearly 69 million tonnes of CO_2 in 2010. By 2035, CO_2 emissions from the electricity generation sector are estimated to account for 37% of this (around 55 million tonnes), followed by domestic transport (19% or 28 million tonnes), and industry (16%, 24 million tonnes).

Figure CHL7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis reported in Table CHL1 shows GDP growth (at 4.6% per year) underlies much of the projected CO_2 emissions increase. The impact of this economic growth is partly offset by a reduction in the energy intensity of GDP of 1.6% per year, reflecting a shift toward less energy-intensive industry and greater energy efficiency economy-wide.

Table CHL1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.6%	1.8%	0.5%	0.4%	0.2%
Change in Energy Intensity of GDP	-0.6%	-1.0%	-1.4%	-1.5%	-1.6%
Change in GDP	5.6%	3.3%	4.4%	4.4%	4.6%
Total Change	4.4%	4.1%	3.4%	3.2%	3.1%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

With its efforts to promote energy efficiency and LNG imports, Chile has responded effectively to the security of supply challenges posed by the gas crisis, and has done so in an environmentally responsible fashion. Looking ahead, however, Chile's rapidly growing CO_2 emissions and increasing dependency on imported oil in the BAU scenario suggest additional challenges will need to be addressed in the future.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

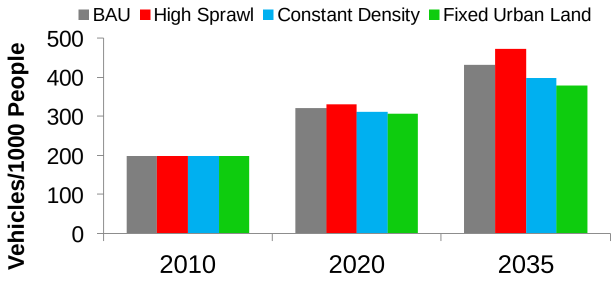
Significant increases in Chile's domestic gas production would require Chile to have significant unconventional natural gas potential. An analysis by the United States Energy Information Administration estimated that Chile has 64 Tcf (1600 Mtoe) of technically recoverable shale gas (see Volume 1, Table 12.2). However, further investigation will be required before the economic viability of this gas can be confirmed. Therefore, the High Gas Scenario was not run for Chile and Figures CHL8–CHL10 are not included here.

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were created: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CHL11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the scenarios is significant, with vehicle ownership about 10% higher in the High Sprawl scenario compared to BAU in 2035, and about 13% lower in the Fixed Urban Land scenario. This means that better urban planning will have a direct impact on vehicle ownership in the long run.

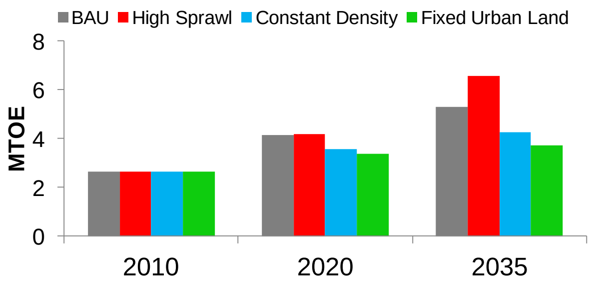
Figure CHL11: Urban Development Scenario – Vehicle Ownership



Source: APERC Analysis (2012)

Figure CHL12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Light vehicle oil consumption would be 31% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 26% lower in the Fixed Urban Land scenario.

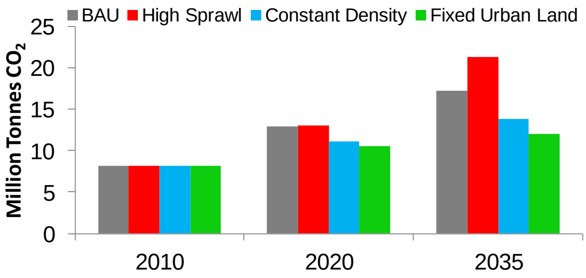
Figure CHL12: Urban Development Scenario – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure CHL13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO_2 emissions would be 31% higher in the High Sprawl scenario compared to BAU in 2035, and about 27% lower in the Fixed Urban Land scenario.

Figure CHL13: Urban Development Scenario – Light Vehicle CO_2 Emissions



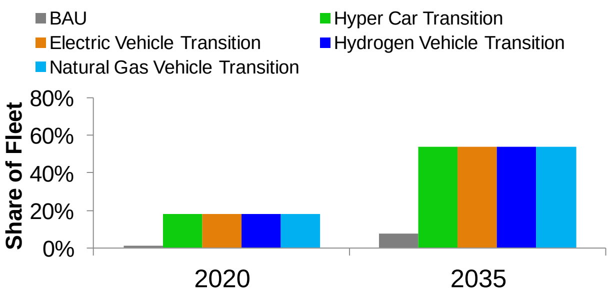
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CHL14 shows the evolution of the vehicle fleet under BAU and the four Virtual Clean Car Race scenarios. By 2035, the share of alternative vehicles in the fleet reaches about 55% compared to about 8% in the BAU scenario. The share of conventional vehicles in the fleet is only about 45%, compared to about 92% in the BAU scenario.

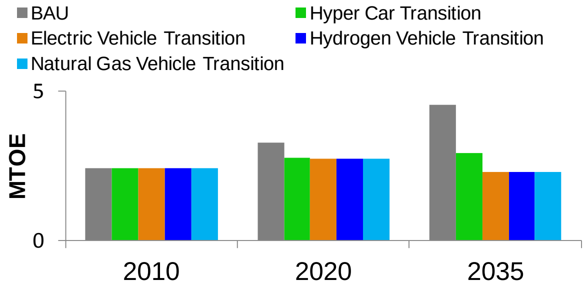
Figure CHL14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure CHL15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by about 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to the BAU scenario by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 35% by 2035—even though these highly efficient vehicles still use oil.

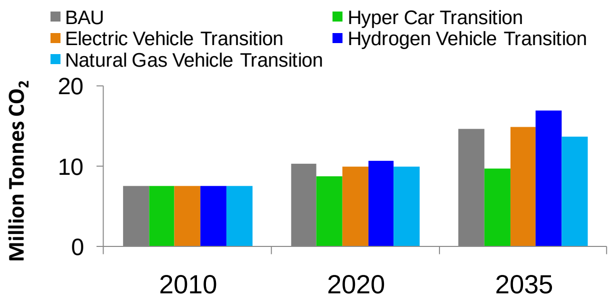
Figure CHL15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure CHL16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

Figure CHL16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

In Chile, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reduction, with emissions reduced by 34% compared to BAU in 2035. The Natural Gas Vehicle Transition scenario offers lower emissions reduction (7% compared to BAU), reflecting the lower emissions of natural gas compared to oil. The Electric Vehicle Transition scenario offers no significant emission reduction in Chile. This is probably because coal will be the largest marginal source for electricity generation in Chile in 2035, and coal combustion produces more CO_2 emissions than oil or natural gas combustion. The Hydrogen Vehicle Transition scenario offers no emission benefits, in fact producing 15% more CO_2 compared to BAU in 2035.

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2009), *Peer Review on Energy Efficiency in Chile, Final Report*, 14 April, Chile, www.ieej.or.jp/aperc/PREE/PREE_Chile.pdf

BCL (Banco Central de Chile) (2012), *Cuentas Nacionales 2008–2011*, www.bcentral.cl/publicaciones/estadisticas/actividad-economica-gasto/pdf/CCNN2008_2011.pdf

CNE (Comisión Nacional de Energía) (2008a), 'Gobierno duplica presupuesto en materia energética para 2009' press release, www.cne.cl

— (2008b), *Ley de Energías Renovables No Convencionales; Ley 20.257*, www.cne.cl

— (2012), *Sistema de Protección al Contribuyente ante las Variaciones en los Precios Internacionales de los Combustibles – SIPCO*, www.cne.cl/component/content/article/74-hidrocarburos-precios-de-paridad/504-sipco

CONAMA (Comisión Nacional del Medio Ambiente) (2008), *Plan de Acción Nacional de Cambio Climático 2008–2012,* www.conama.cl

CORFO–CER (Corporación de Fomento a la Producción – Centro de Energías Renovables) (2012), *Comités CORFO*, www.corfo.cl/sobre-corfo/estructura-corporativa/comites-corfo

ENAP (Empresa Nacional del Petróleo) (2009), *Memoria Anual 2008* (in Spanish), www.enap.cl

— (2011), *ENAP First Quarter Results 2011,* www.enap.cl/investor_relations/doc/presentaciones/ENAP_Presentacion1er_Trimestre2011.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2009), *Chile: Energy Policy Review 2009,* www.iea.org

— (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service. (Note that Chile's gas production figures here, and in APERC's tables, are actually from the *World Energy Statistics 2012,* as there was obviously a significant correction made to the historical data in 2012.)

MINERGIA (Ministry of Energy) (2010), *Balance Nacional de Energía 2010.*

— (2012), *Estrategia Nacional de Energía 2012–2030,* www.minergia.cl/estrategia-nacional-de-energia-2012.html

Mina Invierno (2012a), *Breve descripción del proyecto*, www.minainvierno.cl/servicios/acerca-del-proyecto

— (2012b), *Mina Invierno presenta más del 50% de avance en su construcción*, minainvierno.blogspot.jp/2012/07/mina-invierno-presenta-mas-del-50-de.html

MOP (Ministry of Public Works) (2009), *Chile: Opportunities in Infrastructure 2009-2010,* www.mop.cl/Documents/chile%20opportunities%20in%20infrastructure.pdf

MRE (Ministerio de Relaciones Exteriores) (2008), *Chilean International Economic Affairs – Figures 2008*, Dirección General de Relaciones Económicas Internacionales (DIRECON), Santiago, www.direcon.cl/documentos/Libro_Cifras_2008.pdf

Oil & Gas Journal (2011), "Worldwide look at reserves and production", Vol. 109 Issue 49, 5 December 2011.

USEIA (United States Energy Information Administration) (2011), *World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States,* www.eia.gov/analysis/studies/worldshalegas/

CHINA

- *Over the outlook period, rapid economic growth coupled with its efforts in energy efficiency and conservation will drive the moderate annual growth rate of 2.3% for China's final energy demand. This is compared with a GDP growth rate of 6.6% over the same period.*
- *The total primary energy supply is projected to grow 2.1% annually over the period. This includes average annual growth rates of 0.8% for coal, 2.7% for oil and about 7.7% for natural gas.*
- *The contribution of non-fossil fuels in the fuel mix for power generation will rise to 37% by 2035, up from 19% in 2009. This increase will be key to China limiting its CO_2 emissions over the outlook period.*
- *The increase in the gas share of power generation, from 1% in 2009 to 11% by 2035, also reflects China's efforts to limit its CO_2 emissions.*

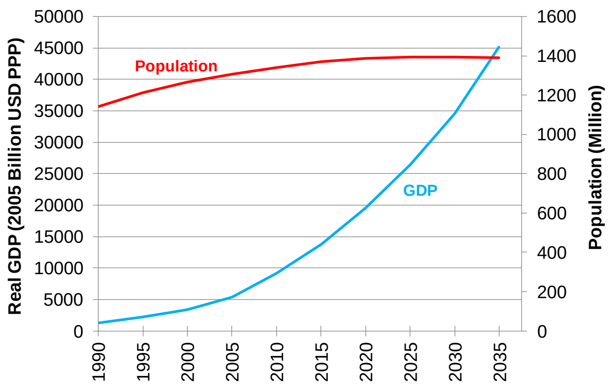
ECONOMY

China is the fourth-largest economy in geographic size in the world, after Russia, Canada, and the United States (US). Its land area covers 9.6 million square kilometres, and features a range of landscape types, including mountains, deserts and river basins. China has by far the largest population of any economy in the world. The economy's population growth will be restrained during the outlook period, growing 0.15% per year compared with the average annual growth rate of 0.82% from 1990 to 2009. The total population is expected to increase to about 1.39 billion by 2035, an increase of about 4.3% from the 2009 figure.

China is the third-largest economy in the world after the US and Japan with a real GDP of USD 8.26 trillion (in 2005 USD PPP) in 2009. It has sustained high rates of economic growth since the early 1990s; the average annual growth rate for the period 1990–2009 was 10.5%. It is projected the high economic growth rate will slow down as China's economy matures. The projected average annual growth rate is about 6.6% during the outlook period (2010–2035). This is similar to the target set in China's 12th Five-Year Plan (2011–2015) for a GDP growth rate of 7% during those five years (APCO Worldwide, 2010).

However, China's development so far has mostly focused on its coastal area due to the access it gives to the global market and the convenience it offers to communicate with foreign economies. Another concern is that the income of many citizens has not kept pace with the fast economic growth over the past decade. To eliminate imbalances and to share the wealth around the economy, China is putting considerable effort into encouraging investment in its western area (such as land credits, lower taxes and subsidies for manufacturers, etc.) and speeding up the construction of transport systems (such as high-speed rail, airports, highways, etc.) for both people and products. The goal is to try to balance the development around China's big territory.

Figure PRC1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Economic development has created increasing demands for air-conditioning, heating, lighting, other appliances, motorcycles, and vehicles to improve people's quality of life. This will boost the future requirements for energy infrastructure and energy consumption. The big challenge for China in the future will be to slow down the growth of energy consumption to protect the environment and to ensure the proper use of limited resources. In China's 12th Five-Year Plan for Energy Development, the projected primary energy consumption shows an annual growth rate of about 4.3% from 2011 to 2015. This represents a slowdown, compared with the 6.6% annual growth rate during the period 2005-2010 (SCC, 2013).

China is seeking to move away from its traditional role as the 'world's workshop' to being a centre of high-tech and high-value added industry. In China's 12th Five-Year Plan for National Economic and Social Development, the focus is on developing seven so-called 'strategic emerging industries' (SEIs). The aim is to increase the SEI's contribution from approximately 5% of GDP in 2009 to 8% by 2015 and 15% by 2020 (NPC, 2011). It is hoped these industries will become the backbone of China's economy over the next decade. These seven industries are biotechnology, new energy, high-end equipment manufacturing, energy conservation and environmental protection, new-energy vehicles, new materials, and next-generation IT. Four of the industries relate to low-carbon technology for a clean environment and sustainable development. China can therefore be expected to become a leader in the low-carbon energy field.

To reduce the dependence of its economy on exports, China is expected to strongly emphasize the importance of shifting to consumption-driven growth, with domestic consumption expected to rise from 35% of GDP in 2009 to around 50–55% of GDP by 2015. Another effort will be to enhance the contribution of service industries; they are expected to account for 47% of GDP by 2015, up 4% from the 2010 level. Other policies stressed in the 12th Five-Year Plan for National Economic and Social Development include raising the minimum wage, expanding the government-funded social welfare and health care system, and reducing the gap in the quality of life between the urban and rural areas. The urban population is expected to reach 51.5% by 2015, up 4% from 2010 (NPC, 2011).

In the past, China's energy demand was driven mainly by the rapid growth of industry. In 2009, industry as a whole accounted for 48% of final energy consumption. The main area of growth was in the rise of heavy industry and energy-intensive industry after 2001. Within this sector, energy use was dominated by iron and steel (29% of all industrial energy used in 2009), followed by non-metallic minerals including the cement industry (23%). However, with the economy's efforts to re-structure the industry sector and to introduce the SEIs in the 12th Five-Year Plan, it is expected the energy intensity and carbon emission levels for the industry sector will be significantly reduced.

The domestic transport sector accounted for around 11% of final energy consumption in 2009; this increased at 7.8% annually from 2000 to 2009. This growth in demand was driven mainly by road transport, which consumed 76% of this sector's energy use in 2009. Passenger vehicle numbers, including civil and private, grew at an average annual rate of 20% from 2000 to 2009. Private vehicle ownership is expected to continue to rise rapidly in the future (NBSC, 2012). Fast growth in the truck and domestic marine fleet is also expected.

Investment in China's transport infrastructure is about CNY 6.2 trillion (USD 976 billion) for the duration of the 12th Five-Year Plan, an increase of 32% over that in the 11th Five-Year Plan. The majority of the funds will be used in highway construction. According to 12th Five-Year Plan, the scale of the economy's highway network will continue to expand. The total road mileage is expected to reach 4.5 million kilometres, and the total mileage of high-speed divided highways is expected to reach 108 000 kilometres. This highway network will connect more than 90% of the towns and cities with populations of over 200,000 people. To slow down the growth in private vehicle use, China is also making massive investments in public transport, including high-speed rail and urban mass transit rail systems. The expansion of the domestic airport and flight fleet is another way the economy is trying to balance development between its eastern and western areas.

Most of the rural areas in China now have electricity; the 2010 electrification figure was 99.4% of households (CEPP, 2010). However, electricity blackouts are still a problem in some of the rural areas. The growth in residential energy demand is mainly due to increasing urbanization (36% in 2000, and expected to reach 71% by 2035) (UN, 2012). The increase in urbanization increases energy demand, as urban residents tend to be more dependent on electricity and commercial fuels than the rural population. The urban population is currently concentrated in the eastern areas due to more industrial development and more employment opportunities. However, it can be expected that more balanced development in the future will mean higher residential energy demand in the western and rural areas.

The 'other' sector, which is mainly residential and commercial use, accounted for 33% of the economy's final energy demand in 2009. Residential energy use dominates (73% of this sector's energy use in 2009), followed by commercial at 12% and agriculture at about 6%. However, the service industry will gradually contribute more to the overall GDP, so the commercial sector is expected to consume more energy in the future.

ENERGY RESOURCES AND INFRASTRUCTURE

China has significant energy resources, particularly coal. In 2010, China was the world's largest producer and consumer of coal, as well as its fifth-largest producer and second-largest consumer of oil (EIA, 2012; BP, 2011). Estimates put China's recoverable coal reserves at around 114.5 billion tonnes in 2010, enough to last 35 years at 2010 production levels; and 14.8 billion barrels of proven oil reserves as of December 2010, enough to last 9.9 years at 2010 production levels (BP, 2011). China's largest and oldest oilfields are located in the northeast region of the economy. China also had 2.8 trillion cubic metres (tcm) of proven natural gas reserves as of December 2010, enough to last 29 years at 2010 production rates (EIA, 2012; BP, 2011).

Investment in the exploration of energy resources was more than USD 17 billion in 2011 alone, 7% higher than in 2010. The potential new areas for oil and gas fields are the western basin area (such as Tarim Basin, etc.) and the offshore area in Bohai Bay (northeast China) (MLR, 2012). China has estimated exploitable shale gas resources of 36.1 tcm, in theory enough to meet China's gas needs for the next two centuries (EIA, 2012). It has launched a five-year plan (2011–2015) for the development of shale gas, aiming for 6.5 billion cubic metres (bcm) of shale gas production by 2015, which is equivalent to 2–3% of projected Chinese gas production in 2015; and more than 60 bcm of shale gas production by 2020. But the geological conditions are complex and will pose great technical and investment challenges.

China's fast economic development saw the economy shift from being a net oil exporter to a net oil importer in 1993. As of 2009, estimates place China as the second-largest net importer of oil. For environmental reasons, China is trying to slow down the growth rate of coal production and to limit coal consumption in the future. In the 12th Five-Year Plan for Energy Development, China will increase the share of gas in the primary energy consumption from 4.6% in 2010 to 7.5% by 2015 (SCC, 2013).

In addition to fossil fuel, China is endowed with 400 gigawatts (GW) of economic hydropower potential, more than any other economy. There is also a potential wind-based generation of 1500 GW, including 500 GW offshore and 1000 GW shore-based (CEC, 2011).

However, coal and oil resources have been used more extensively than natural gas and hydro for power generation and industrial development and this will continue into the near future. Most of the economy's existing power generation is coal based, with coal accounting for 79% of electricity production in 2009. In the 12th Five-Year Plan, China will increase the non-fossil fuel share of power generation from 8% in 2009 to 11.4% by 2015 and to 15% by 2020.

Much of the growth in China's domestic energy demand for crude oil and gas is being met by imports. The expansion of domestic crude oil production and refinery capacity has not been sufficient to match the rapid increase in demand for diesel and gasoline. China's increased energy imports from the global oil market have had a significant impact internationally, tightening the overall balance between demand and supply. Chinese oil companies are also trying to boost overseas investment levels to ensure stable supplies. China is also seeking to increase its gas supply via pipelines from foreign economies, such as Turkmenistan, Kazakhstan, Uzbekistan, Myanmar and Russia. Negotiations with some of these economies are still ongoing. Three liquefied natural gas (LNG) terminals will be operating by the end of 2011 and another six new LNG terminals are in the planning/construction stages (EIA, 2012).

After the enactment of the Renewable Energy Law in 2005, the installation of renewable electricity generating capacity (excluding hydro) has doubled every year, from being almost non-existent before 2005. China's total installed wind turbine capacity (with grid connection) reached 2% (or 17.6 GW) of total electricity generating capacity, with a 1% (or 27.6 TWh) share of total electricity generation in 2009. The share of biomass was 2% (or 14.1 GW) of capacity and 2% (or 64.8 TWh) of electricity generation in 2009 (IEA, 2011). In addition, China has been speeding up its installation of solar photovoltaic power generation: in early 2009, the installed capacity was 300 MW with another 500 MW under construction.

Total solar cell production in China in 2009 was 4011 MW, which accounted for 42% of the world's solar cell shipments. However, at the end of 2009, the accumulated installed capacity in China was only about 300 MW, with another 500 MW under construction. Installed capacity is expected to grow to 21 000 MW by the end of 2015 (SCC, 2013). China launched the Golden Sun program in 2010 encompassing 275 projects with a capacity of 640 MW, which is expected to rise to 1000 MW over the following three years (NEA, 2010).

ENERGY POLICIES

In a context of rising demand and constrained supply, China has made energy security the top priority in its energy policy objectives. The economy's 12th Five-Year Plan for National Economic and Social Development (2011–2015) sets out a program for the enhancement of energy security, with a strong emphasis on clean energy and energy efficiency. By 2015, China aims to have non-fossil fuels account for 11.4% of primary energy consumption, cut energy intensity by 16%, and reduce CO_2 emission per unit GDP by 17% from 2010 levels. By 2020, non-fossil energy will account for 15% of China's total primary energy consumption and CO_2 emission per unit GDP will be 40-45% lower than in 2005 (SCIO, 2012). A number of measures have been implemented to this end. These measures include the promotion of non-fossil fuel as an energy source as well as lower carbon energy sources (especially gas); the modernization of energy industries, with the closure of inefficient small coalmines, power plants, refineries, and iron-and-steel production plants; and the introduction of efficient technologies throughout the energy supply chain, i.e. from production and transport through to consumption.

In the 12th Five-Year Plan for Coal Industry, coal production is capped at 3.9 billion tonnes by 2015. China also introduced regulatory controls to limit environmental degradation, tax evasion, and mine accidents. It aims to reduce the number of coal enterprises from about 11 000 to 4000. Although state-owned coal mines dominate in China's coal industry, non-state-owned coal mines still play an important role. For the state-owned coal mines, ownership is divided between various central, provincial, and local government agencies. About 10 big coal companies are expected to account for nearly 60% of all China's coal production by 2015. Even though coal's share will decrease from 70% in 2010 to 65% in 2015, it will continue to be China's largest energy source and a major contributor to its environmental problems (NDRC, 2012c).

China's three major state-owned oil companies dominate the economy's oil industry, and have been aggressively expanding. China has two vertically integrated firms: the China National Petroleum Corporation (CNPC) and the China Petroleum and Chemical Corporation (Sinopec). The third player is the China National Offshore Oil Corporation (CNOOC). CNPC is the leading upstream player in China and, along with its publicly-listed arm PetroChina, accounts for roughly 60% and 80% of China's total oil and gas output, respectively. Sinopec, on the other hand, has traditionally focused on downstream activities, such as refining and distribution. These sectors have made up nearly 80% of the company's revenues since 2008 and Sinopec is gradually seeking to acquire more upstream assets.

China has been seeking to increase the security of its oil supply by encouraging Chinese companies to become involved in upstream investment activities abroad in cooperation with international or local companies, and by speeding up the build-out of its strategic petroleum reserve (SPR) (Zhang and Wu, 2010). China has traditionally protected its own oil and gas companies by not allowing foreign oil companies to operate in China. However, international oil companies (IOCs) have been granted greater access to offshore oil prospects, mainly through production sharing agreements, and they have made some progress in the Bohai Bay area (CNPC, 2012).

China's oil product prices are regulated by the government. However, it tries to align with the international crude oil market. In December 2008, China launched a fuel tax and reforms of its product pricing mechanism. This was done to tie retail oil product prices more closely to international crude oil markets, to attract downstream investment, to ensure profit margins for refiners, and to reduce energy misallocation caused by distortions in the market pricing.

Similarly, China's natural gas prices are regulated and generally well below international market rates. China has favoured manufacturing and fertilizer gas users by the relatively lower price these sub-sectors pay. To bolster investment in the natural gas sector, particularly by foreign participants, and to make domestic gas competitive with other fuels, the National Development and Reform Commission (NDRC) proposed linking gas prices indirectly to international crude oil prices, effectively raising prices. Industry analysts claim these price modifications are necessary to develop the gas market further. In mid-2010, the NDRC raised the onshore wellhead prices by 25%, and some Chinese cities have raised end-user prices in the industrial and power sectors (EIA, 2012).

Another way China seeks to secure its energy supply is by speeding up its efforts in shale gas exploration. China will seek international cooperation in this area. It will: encourage investment in US companies to learn the technology for exploring for shale gas; provide financial policies and subsidies for shale gas exploration, including price subsidies, preferential tax treatment and land subsidies; and encourage joint-ventures between local and foreign companies to explore for shale gas (NDRC, 2012b).

The 12th Five-Year Plan for Energy Development also specifies targets for the future development of nuclear and hydropower. The power generation capacity of hydropower plants will increase 47% by 2015, based on 2009 capacity. The number of nuclear energy power plants will increase from 11 in 2009 to 25 by 2015 (SCC, 2013).

Following the 2011 Fukushima Nuclear Accident in Japan, China immediately suspended approval of all new nuclear power projects and undertook a comprehensive safety review of existing and under-construction nuclear facilities—these include nuclear power plants, research reactors and fuel-cycle facilities. The safety inspection took over 9 months and concluded that the operating reactors conform to both China's nuclear safety laws and regulations and International Atomic Energy Agency (IAEA) standards. At the same time, several areas for improvement were identified. The Nuclear Power Safety Plan (2011–20) and the Nuclear Power Mid- and Long-Term Plan (2011–20) were developed to address these issues. With the approval of these plans in October 2012 by the State Council, China officially lifted the suspension on new nuclear power plant approvals and at the same time introduced more stringent safety standards and regulations (NDRC, 2012). For example, until 2015, China will reconsider the relocation of nuclear power plant projects proposed for inland provinces to coastal provinces and will re-evaluate the proposed sites in areas that have experienced or are prone to earthquakes (Zeng Ming, et al., 2012). The legal system related to nuclear power will be improved to optimize the nuclear safety management, supervision and inspection systems. An emergency mechanism for nuclear accidents has also been established to enhance the economy's emergency response capability (SCIO, 2012).

China's electricity generation sector is dominated by five major state-owned holding companies. They generate about half of China's electricity. Much of the remainder is generated by independent power producers (IPPs), often in partnership with the privately-listed arms of the state-owned companies. Deregulation and other reforms have opened the electricity sector to foreign investment, although this has so far been limited.

In 2002, the State Electricity Regulatory Commission (SERC) was established, which is responsible for the overall regulation of the electricity sector and for improving investment and competition to alleviate power shortages. However, the wholesale and retail electricity prices are determined and capped by the NDRC. The NDRC used to be responsible for determining the annual plan price at which coal companies are obligated to sell large quantities of coal to power producers, but this annual plan price was abolished according to a recent policy issued by the State Council in 2012 (SCC, 2012a). Typically, generators negotiate directly with coal companies for long-term contracts. The NDRC has made small changes to its pricing system and, in 2009, it allowed electricity producers and wholesale end-users such as industrial consumers to negotiate with each other directly. The latest power tariff changes were from June 2010 when the government raised rates for energy-intensive industries by 50–100% to achieve energy efficiency goals for the year (EIA, 2012).

To strengthen coordination and decision-making in the energy sector, China established a high-level body—the National Energy Committee—to be in charge of coordinating China's energy strategy and deliberations on major issues in energy security. In March 2008, the National Energy Administration (NEA) was formed, under the NDRC. The NEA is responsible for developing and implementing energy industry planning, industrial policies and standards, and for administering the energy sector. This responsibility covers coal, oil, natural gas, and electric power including nuclear energy, and new and renewable sources of energy (NRDC, 2012a). In 2009, the National Energy Conservation Centre was formed within the NDRC to provide technical support for the government's energy efficiency and conservation management initiatives.

An amended version of the Renewable Energy Law was endorsed by the Standing Committee of the National People's Congress in December 2009 and came into effect on 1 April 2010. It more clearly defines the responsibilities of power grid and power generation enterprises, and it emphasizes the firm contracts for the purchase of power from renewable energy sources and the establishment of a development fund for renewable energy.

The government has established energy-efficient design standards for both residential buildings and public buildings, and a code for acceptance inspections of energy-efficient building construction. Since 2007, China has issued 46 economy-wide minimum energy performance standards (MEPS). The standards cover home appliances, industrial equipment, and business equipment. By the end of October 2011, China had an energy-efficiency labelling program covering 25 product classes. There is also a voluntary energy-efficiency endorsement label in China, to encourage more enterprises to reach a higher level in energy-efficiency. The government has also promoted high-efficiency illumination products and air conditioners, energy-efficient motors and other energy-efficient products through government subsidies (APERC, 2012).

The government has established its own preferential procurement system for energy-efficient products, released a government procurement list of energy-efficient products, and ordered the mandatory procurement of nine kinds of energy-efficient products, including air conditioners, computers and illumination products. By the end of 2010, the market share of high-efficiency illumination products had reached 67%, and that of high-efficiency air conditioners, 70% (APERC, 2012).

To promote energy conservation activities in the industry sector, the China Government encourages energy service companies (ESCOs) through financial and tax incentives. ESCOs provide a total energy-efficiency solution (finance, technology, operation, maintenance, etc.) for industrial energy users. They generally operate under energy performance contracts which compensate them with a share of the savings they produce for their customers. From 2005–2010, the number of energy service companies increased from 80 to over 800, the number of employees in this sector increased from 16 000 to 180 000, and energy service industry revenues grew from CNY 4.7 billion to CNY 84 billion (USD 740 million to USD 13.2 billion) (APERC, 2012).

In the transport sector, China published its Development Plan for Energy Saving and New Energy Automobile Industry (2012–2020) to introduce more environment-friendly vehicles into the domestic market. The plan will focus on electrically-driven vehicles (EVs and FCVs) and plug-in hybrid vehicles (PHVs) to enhance the competitiveness of the economy's automobile industry, to increase energy efficiency and to reduce carbon emissions. The production and sales of EVs, FCVs and PHVs are expected to total 500 000 units by 2015, and more than 5 million units—with a 2 million unit production capacity—by 2020. Subsidies and tax exemptions are provided for EVs, FCVs and PHVs (SCC, 2012b). China is considering the introduction of a carbon tax in the future, which could provide another incentive. More than 2000 charging stations with 400 000 quick chargers for EVs will be provided by 2015. The economy is harmonizing charging methods to promote electrically-driven vehicles. EVs, FCVs and PHVs will be introduced gradually into the domestic market for both energy conservation and environmental protection (IEEJ, 2012).

China began regulating passenger vehicle fuel consumption in 2004 with the issuance of the National Standard GB 19578-2004 Limits of Fuel Consumption for Passenger Cars (UN, 2011). The standards are based on 16 weight classes and put a limit on fuel consumption by weight. To strengthen vehicle efficiency efforts, a fuel consumption testing and management mechanism was introduced in March 2011. Under this mechanism, China published a list of vehicle models that satisfied the fuel consumption standards in 2011 (CAA, 2011).

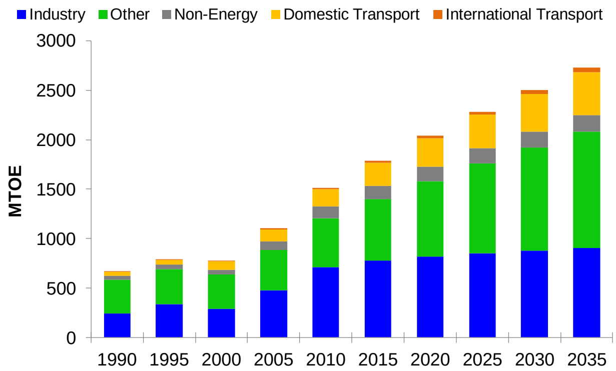
BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Over the outlook period (2010–2035), China's final energy demand is projected to grow 2.3% per year, which is a little slower than the average annual growth rate of 4.1% between 1990 and 2009.

The 'other' sector will be the biggest energy user by 2035, with a 43% share of final energy demand, followed by the industry sector (33%) and domestic transport (16%). However, the domestic transport sector has the highest average annual growth rate at 3.7%, followed by the 'other' sector at 3.5% and the industry sector at 0.9%.

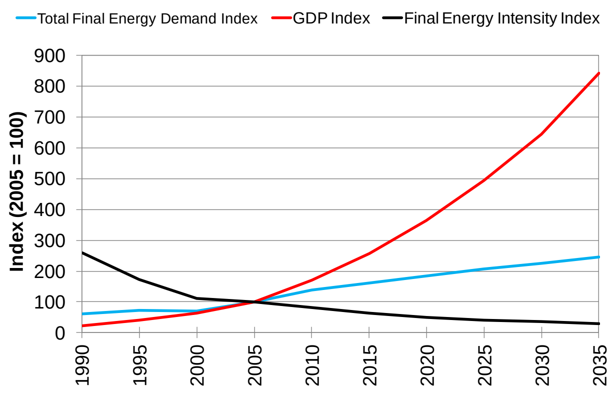
Figure PRC2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to decline by about 71% between 2005 and 2035.

Figure PRC3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

China's industry sector energy demand is projected to grow at an average annual rate of 0.9% during the outlook period. This is significantly slower than its average annual growth rate of 5.6% between 1990 and 2009.

During the outlook period, coal will still be the major source of energy in China's industry sector, although the share of other energy sources such as electricity and gas will increase. Coal's share of total industry energy demand is expected to decline to 46% by 2035, down from 59% in 2009. It is expected electricity will follow coal as the industry sector's most important energy source by 2035, accounting for 34% of China's industry energy demand. Industrial demand for gas is projected to grow very fast, at an average annual rate of 4.9% over the outlook period, but it will still account for only 6% of industry energy demand in 2035.

Within the industry sector, energy use is dominated by the iron and steel industry (25% of all industrial energy used by 2035), followed by the non-metallic minerals industry including cement (17%) and the chemical and petrochemical industry (16%). The projections also show the machinery industry will have the highest growth rate, followed by the pulp, paper and printing industry. Growth in industrial demand is limited by the overall shift from energy-intensive industries to high-value-added industries and by a bigger contribution from the service industry.

Transport

Chinese domestic transport energy demand is expected to grow 3.7% annually over the outlook period. Domestic aviation is projected to grow the fastest with an annual growth rate of 5.8% during the outlook period, followed by domestic shipping at 4.3%, and road transport at 3.6%. Road transport will still use 75% of the transport energy in 2035, due to an increase in the number of private vehicles and the need to transport domestic goods by heavy road vehicles. Light vehicles and heavy vehicles will each use about half of the energy consumed in road transport. Projections to 2035 show the number of light vehicles will grow to about four times the number of light vehicles in 2009, at an average annual growth rate of 5.6%. Vehicle ownership in the economy will begin to approach saturation level around 2020, so the growth in ownership will slow after 2020.

China will continue its efforts to reduce energy consumption in the domestic transport sector, such as promoting clean-energy vehicles, fuel efficiency standards and fuel-efficiency labeling, mass transport systems in urban areas, and high-speed railways for inter-city transportation.

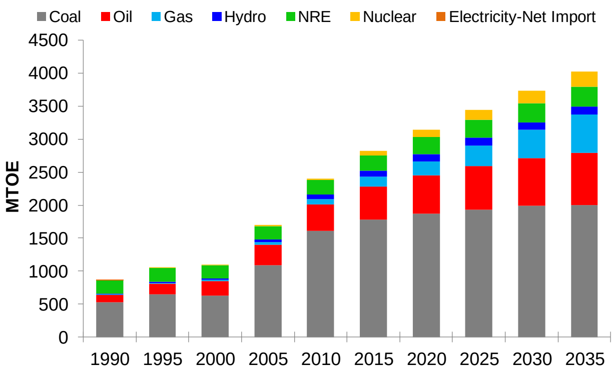
Other

Energy demand in the 'other' sector, which includes residential, commercial, and agricultural demand, is primarily driven by income growth, the improvement in living standards and the expansion of the service industry. China's 'other' sector energy demand is expected to grow at an average annual rate of 3.5% over the outlook period (2010–2035). Electricity is expected to continue to dominate the energy mix, accounting for 37% of 'other' sector energy consumption by 2035, followed by new renewable energy (NRE) at 19% and natural gas at 18%. Energy-efficiency improvements in the building sector (including appliances) are a major force slowing down energy demand growth in the 'other' sector.

PRIMARY ENERGY SUPPLY

China's total primary energy supply is projected to grow at an average annual rate of 2.1% over the outlook period. This is slower than the average annual growth rate of 5.2% from 1990–2009. This is mainly due to a projected slowdown in the GDP growth rate and efforts to improve energy efficiency.

Figure PRC4: BAU Primary Energy Supply

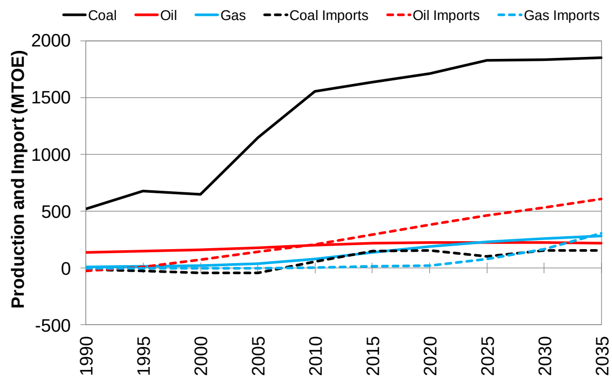


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Among the fossil fuels, natural gas will grow the fastest (8% per year), followed by oil (2.7%) and coal (0.9%). Hydro and nuclear energy are expected to play a key role in reducing China's CO_2 emissions. Projected annual growth rates are 2.3% for hydro and 10% for nuclear over the outlook period, while new renewable energy has a projected annual growth rate of about 1.4%.

If the exploration for shale gas is successful and major progress is made in the future, the share of gas in the primary energy mix will grow faster than the BAU case projection.

Figure PRC5: BAU Energy Production and Net Imports

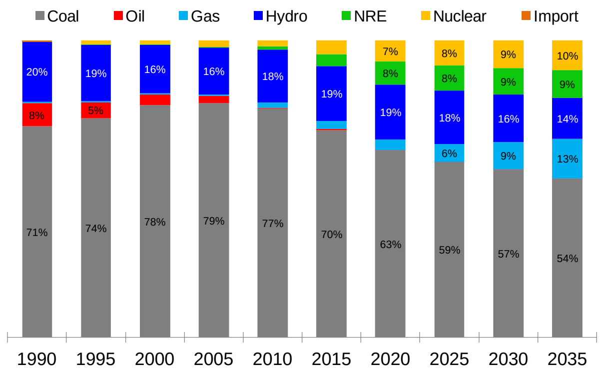


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

Electricity generation in China will increase by 3.3% per year over the outlook period. Non-fossil energy (such as NRE, nuclear, and hydro) will gradually increase its share in the fuel mix for power generation from 21% in 2009 to 33% by 2035.

Figure PRC6: BAU Electricity Generation Mix



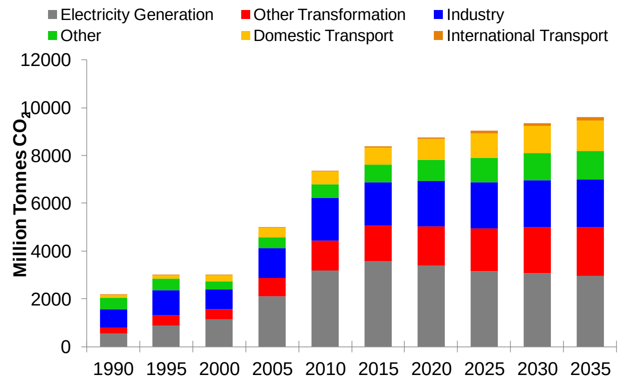
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Throughout the outlook period, coal will maintain its dominant share in the electricity generation mix. It is projected to provide around 54% of generation by 2035, down from 77% in 2010. Generation based on natural gas will provide about 13% of the total generation mix by 2035. In coastal areas, gas-fired generation will replace coal-fired generation, as a result of reforms aimed at reducing carbon emissions and air pollution.

CO_2 EMISSIONS

Over the outlook period, China's total CO_2 emissions are projected to increase from 6870 million tonnes of CO_2 in 2009 to 11 288 million tonnes by 2035. Of the 2035 emissions, 39% will come from the electricity generation sector (about 4145 million tonnes) and 18% from industry (1994 million tonnes).

Figure PRC7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis in Table PRC1 shows that the growth in China's GDP is largely decoupled from energy consumption and CO_2 emissions. Growth in GDP is largely offset by the declining energy intensity of GDP (due mainly to increasing energy efficiency and a shift away from energy-intensive industry) and the declining carbon intensity (due mainly to a declining share of coal in the energy mix).

Table PRC1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	1.1%	2.0%	-0.3%	-0.3%	-0.8%
Change in Energy Intensity of GDP	-5.1%	-4.8%	-4.5%	-4.5%	-4.4%
Change in GDP	10.2%	11.2%	7.7%	7.4%	6.6%
Total Change	5.7%	8.0%	2.5%	2.2%	1.1%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

China has significant energy resources, particularly coal, oil and hydro. The shale gas potential may play an important role in the future. However, the development of these energy sources is unlikely to meet the economy's growing demand for energy. In particular, net import dependency on oil is projected to increase from 57% in 2009 to 78% by 2035. The economy's growing import dependency, combined with depleting domestic resources, raise concerns about China's energy supply security. Even without significant supply shocks, such a high dependency on imported oil may impede China's economic growth due to the instability of energy prices.

China's new 12th Five-Year Plan and policy initiatives to promote energy efficiency are expected to reduce the economy's energy intensity significantly. However, China's continued economic growth, projected increases in living standards, and high reliance on coal, mean its greenhouse gas emissions are still expected to climb significantly.

Since China is likely to be the world's largest energy consumer in 2035, it will need to be a key player in worldwide efforts to reduce greenhouse gas emissions.

ALTERNATIVE SCENARIOS

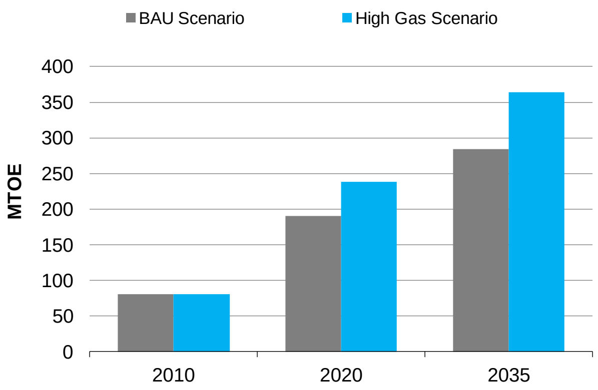
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The extra gas production for China in the High Gas Scenario comes mainly from the economy's development of its shale gas resources. China is one of the APEC economies possessing a major resource potential for shale gas. However, the development of shale gas in China will pose major technical and policy challenges. In this High Gas Scenario, we assumed China can overcome these challenges. Figure PRC8 shows an increase in gas production of 28% by 2035, compared with the BAU case.

Figure PRC8: High Gas Scenario – Gas Production

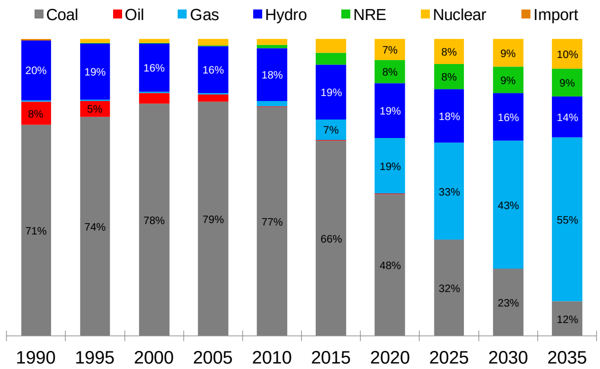


Source: APERC Analysis (2012)

Additional gas consumption in China in the High Gas Scenario will depend on the extra production of shale gas, as well as the LNG and pipeline natural gas imported from other economies. We also assumed all the additional gas would be used to replace coal in electricity generation. The electricity sector relied heavily on coal-fired power plants in the BAU case, so the sector has plenty of opportunity to replace coal by gas.

Figure PRC9 shows the fuel mix for power generation in this High Gas Scenario. This figure may be compared to Figure PRC6 above. The projection shows the share of gas in electricity generation in 2035 has increased by 42%, from 13% in BAU to 55% in the High Gas Scenario. At the same time, coal share has declined by the same amount to 12%.

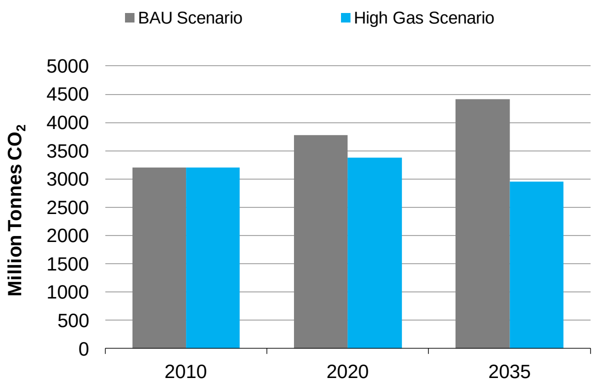
Figure PRC9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas has roughly half the CO_2 emissions of coal per unit of electricity generated, this had the impact of reducing CO_2 emissions in electricity generation by 33% in 2035. Figure PRC10 shows this CO_2 emissions reduction.

Figure PRC10: High Gas Scenario – CO_2 Emissions from Electricity Generation



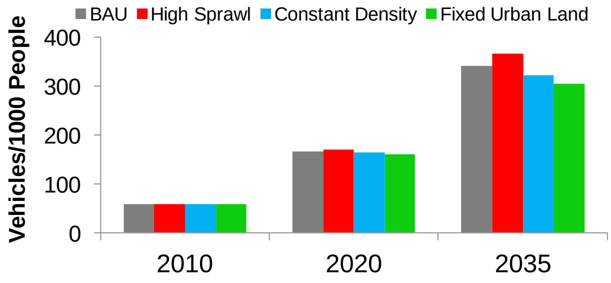
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impact of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PRC11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the cases is significant. By 2035, vehicle ownership would be about 7% higher in the High Sprawl scenario, compared with the BAU scenario, and about 6% and 11% lower in the Constant Density and Fixed Urban Land scenarios respectively. Given that China is still under a period of fast development, vehicle ownership has a lot of room to increase. This is especially true if sprawling development patterns make it difficult for people to live without a car. The model results suggest that better urban planning could significantly reduce the need for people to own vehicles.

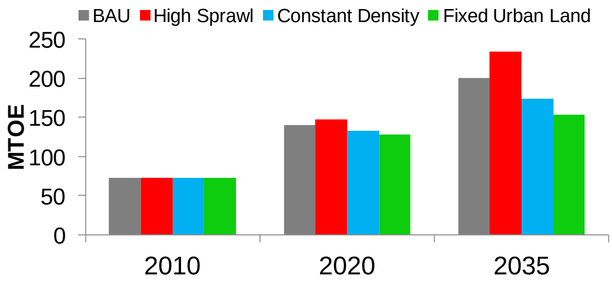
Figure PRC11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure PRC12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of better urban planning on light vehicle oil consumption is even more pronounced than on vehicle ownership—more compact cities reduce both the need for vehicles and the distances they must travel. In 2035, light vehicle oil consumption would be 17% higher in the High Sprawl scenario, compared with the BAU scenario, and about 13% and 24% lower in the Constant Density and Fixed Urban Land scenarios respectively.

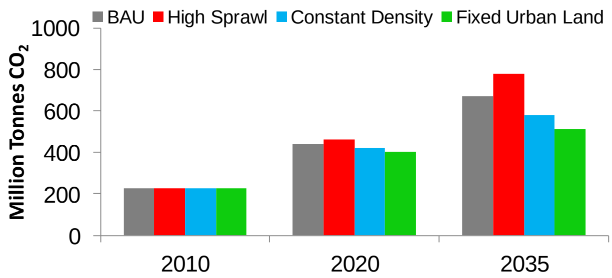
Figure PRC12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure PRC13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these cases. In 2035, light vehicle CO_2 emissions would be 17% higher in the High Sprawl scenario, compared with the BAU scenario, and about 13% and 24% lower in the Constant Density and Fixed Urban Land scenarios respectively.

Figure PRC13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



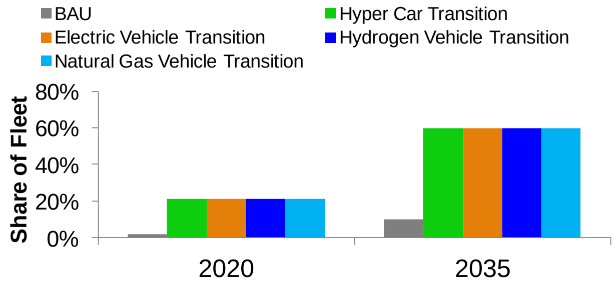
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PRC14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60% compared to about 10% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 90% in the BAU scenario.

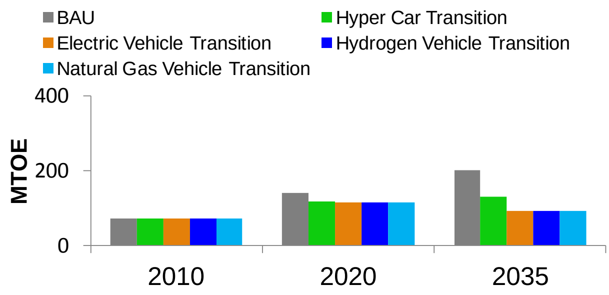
Figure PRC14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure PRC15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 54% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 36% by 2035—even though these highly-efficient vehicles still use oil.

Figure PRC15: Virtual Clean Car Race – Light Vehicle Oil Consumption



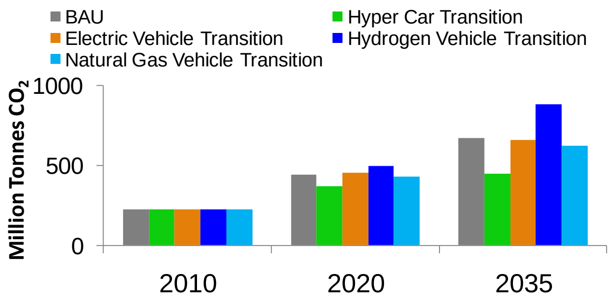
Source: APERC Analysis (2012)

Figure PRC16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In China, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reductions, with an emissions reduction of 33% compared with BAU in 2035. The Electric Vehicle Transition scenario offers an emissions reduction of about 2% and the Natural Gas Vehicle Transition scenario a reduction of about 7% compared with BAU in 2035. The limited reduction in the Electric Vehicle Transition scenario is principally because the marginal source for the added electricity demand is mainly coal, which is more carbon-intensive than oil. However, if introduction of electric vehicles were combined with a re-structuring of the fuel mix for the power sector, China could achieve a bigger emissions reduction.

The result for the Hydrogen Vehicle Transition scenario shows an increase of CO_2 emissions of 31% by 2035. This is mainly due to the way hydrogen is produced—from steam methane reforming of gas, a process which involves significant CO_2 emissions. However, the results would be more favourable if the hydrogen could be produced from a renewable or low-carbon energy source.

Figure PRC16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

APCO Worldwide (2010), China's 12th Five-Year Plan, www.apcoworldwide.com/content/pdfs/chinas_12th_five-year_plan.pdf

APERC (Asia Pacific Energy Research Centre) (2012), *APEC Energy Overview 2011*, www.ieej.or.jp/aperc/2012pdf/Overview2011.pdf

BP (British Petroleum) (2011), *BP Statistical Review of World Energy June 2011*, www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf

CAA (China Association of Automobile Manufacturers) (2011), *Implementation of Vehicle Fuel Economy Standards Access Policy*, Chinese version, www.caam.org.cn/zhengceyanjiu/20110415/2005054667.html

CEC (China Electricity Council) (2011), *China Electricity Industry Development Annual Report 2011*, Beijing, China, www.chinabookshop.net/china-electricity-council-m-165.html

CEPP (China Electric Power Press) (2010), *China Electric Power Yearbook*, Beijing, China, www.chinabookshop.net/china-electric-power-press-m-41.html?osCsid=v8dsbgf747njcok5nm6m0hb641

CNPC (China National Petroleum Corporation) (2012), *Annual report 2011*, http://161.207.8.13:82/gate/big5/lhyt.cnpc.com.cn/cn

EIA (Energy Information Administration, United States) (2012), "Countries: China" website page, http://205.254.135.7/countries/country-data.cfm?fips=CH#pet

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

IEEJ (The Institute of Energy Economics, Japan) (2012), *IEEJ e-Newsletter, No. 3*, http://eneken.ieej.or.jp/en/jeb/1206.pdf

MLR (Ministry of Land and Resources) (2012), *Mineral Resource for China*, Chinese version, http://big5.mlr.gov.cn/zygk/#

NBSC (National Bureau of Statistics of China) (2012), *China Statistical Yearbook 2011*, www.stats.gov.cn/tjsj/ndsj/2011/indexeh.htm

NDRC (National Development and Reform Commission) (2012a), "National Energy Administration" website page, http://en.ndrc.gov.cn/mfod/t20081218_252224.htm

— (2012b), *Shale Gas Development Plan (2011–2015)*, www.ndrc.gov.cn/zcfb/zcfbtz/2012tz/W020120316370486643634.pdf

— (2012 c), *The 12th Five-Year Plan for Coal Industry Development*, in Chinese, www.ndrc.gov.cn/zcfb/zcfbtz/2012tz/t20120322_468769.htm

NEA (National Energy Administration) (2010), *Status and Policies of PV in China*, www.scribd.com/doc/35456394/Status-and-Policies-of-PV-in-China

NPC (National People's Congress) (2011), *The 12th Five-Year Plan for National Economic and Social Development*, in Chinese, www.gov.cn/2011lh/content_1825838.htm

NRDC (Natural Resources Defense Council) (2012), "China moves to strengthen nuclear safety standards and moderate the pace of its nuclear power development" website page, http://switchboard.nrdc.org/blogs/alin/china_moves_to_strengthen_nucl.html

SCC (the State Council of China) (2012 a), *Guidance on Deepening the Reform of the Thermal Coal Market*, in Chinese, www.gov.cn/zwgk/2012-12/25/content_2298187.htm

— (2012b), *The Development Plan for Energy Saving and New Energy Automobile Industry (2012-2020)*, in Chinese, www.gov.cn/zwgk/2012-07/09/content_2179032.htm

— (2013), The 12th Five-Year Plan for Energy Development, in Chinese, www.gov.cn/zwgk/2013-01/23/content_2318554.htm

SCIO (Information Office of the State Council) (2012), *China's Energy Policy 2012,* www.scio.gov.cn/zxbd/wz/201210/t1233774.htm

UN (United Nations) (2011), *Global Overview on Fuel Efficiency and Motor Vehicle Emission Standards: Policy Options and Perspectives for International Cooperation*, Department of Economic and Social Affairs, www.un.org/esa/dsd/resources/res_pdfs/csd-19/Background-paper3-transport.pdf

— (2012), *World Urbanization Prospects, the 2011 Revision*, Department of Economic and Social Affairs, Population Division, http://esa.un.org/unup/CD-ROM/Urban-Rural-Population.htm

Zeng Ming, Chen Li-min, Xue Song, Wei Yang, and Wang Lei (2012), "Post-Fukushima Nuclear Power Development in China", *POWER Magazine*, 1 November, www.powermag.com/issues/features/Post-Fukushima-Nuclear-Power-Development-in-China_5094.html

Zhang, Liutong and Kang Wu (2010), "China works to double SPR capacity by 2013", *Oil & Gas Journal*, Vol. 108, No. 37, 10 April 2010, www.ogj.com/articles/print/volume-108/issue-37/transportations/china-works-to-double-spr-capacity-by-2013.html

HONG KONG, CHINA

- *Hong Kong, China's primary energy supply is projected to grow at an average annual rate of 1.3% over the outlook period. Most of the increase is due to the demand for gas for power generation; however, coal will still be the major primary energy supply fuel in 2035 with almost 40% share of the total primary energy supply, followed by gas with a 35% share.*
- *Hong Kong, China is expected to be increasingly dependent on imported energy from mainland China, with import levels almost doubling between 2010 and 2035.*
- *CO_2 emissions are projected to increase mainly due to oil consumption which accounts for 65% of total emissions. International transport will account for over half of total emissions by 2035.*

ECONOMY

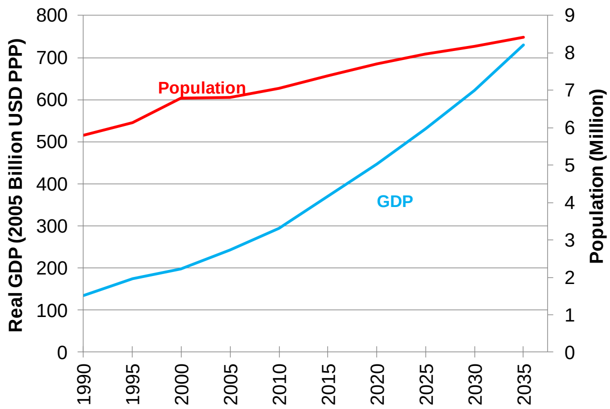
Hong Kong, China is one of the special administrative regions of the People's Republic of China. It borders Guangdong to the north and is surrounded by the South China Sea to the east, west and south. Hong Kong, China is an international financial centre, and has a highly developed free market economy.

Hong Kong, China has been transforming itself into an almost entirely services-based economy. Its GDP is expected to grow at an average annual rate of 3.7% over the outlook period (2010–2035); this is similar to the average annual growth of 3.8% between 1990 and 2009. Besides the economy's traditional strengths in the financial, logistics, property, tourism and services industries, Hong Kong, China's projected growth is based on an increase in knowledge-based and services industries (CSD, 2012).

Hong Kong, China has identified four key industries within the service sector; they are financial services, trading and logistics, tourism, and producer and professional services. These four industries contributed 58% of GDP (average annual growth rate was 5.5% from 2005–2010) and employed 48.2% of the total persons employed in 2010. Another six industries in the service sector are also identified as high potential development industries by the Hong Kong, China Government. These are cultural and creative industries, medical services, education services, innovation and technology, testing and certification services, and environmental industries. These six industries contributed 8.4% of GDP (average annual growth rate was 3.4% from 2008–2010) and employed 11.6% of the total persons employed in 2010. By 2035, it is expected that the services sector will contribute more than 95% of GDP, compared with 92.9% in 2010.

Hong Kong, China's population is expected to grow slowly at an average annual rate of 0.7% over the outlook period, reaching 8.4 million people in 2035. Among the APEC economies, Hong Kong, China ranks highly for GDP per capita and has a higher standard of living than many of the other economies. The economy has a high population density. Its high urban intensity and high-rise buildings have made it is appropriate to use advanced energy efficiency technology to reduce energy consumption in the commercial and residential sectors. However, it has also had a negative impact on the quality of the living environment, creating too much congestion and too little green space in the built up areas. A key issue for the Hong Kong, China Government will be to maintain a balanced '3-E' (economy, energy, and environment) development policy in the future.

Figure HKC1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Hong Kong, China's economy has a firm foundation in its strong financial services sector. It is expected to continue to shift towards higher-value-added services and a knowledge-based economy. To stay competitive and to attain sustainable growth, Hong Kong, China is attempting to restructure and reposition itself to face the challenges posed by globalization and closer integration with mainland China. The Mainland and Hong Kong Closer Economic Partnership Arrangement (CEPA) is an example of the opportunities the economy has under the 'One Country, Two Systems' relationship with mainland China. The liberalization of trade in goods under CEPA means all products of Hong Kong, China origin enjoy tariff-free access to mainland China—on application by local manufacturers, and if the CEPA rules of origin are satisfied.

The government's strategy is to move economic activity up the value chain by: speeding up structural transformation to a high-value, knowledge-based, and skill-intensive economy; pursuing reforms in education and population policy to achieve the talent pool required; and leveraging on the immense business opportunities available in mainland China. There are four economic sectors where Hong Kong, China has a competitive advantage over mainland China: trade and logistics, tourism, financial services, and professional services and other producer services.

In Hong Kong, China, the public transport systems (including rail, bus and ferry) are estimated to carry more than 90% of all person trips in 2008 (Transport Department, 2012b). The number of observed public transport boardings is about 11.65 million a day (Transport Department, 2012a). While road transport is highly visible in the city, the rail system plays a significant role in the transport sector, with more than 246 kilometres of routes and a carrying average of about 4.5 million passengers every day in 2010. Its ridership has increased at about 3% annually from 2001 to 2010, higher than the average annual growth rate of private vehicles at 2.2% (Transport Department, 2012a). The total franchised bus system has more than 578 lines with a daily ridership of about 2.3 million (Transport Department, 2012a). There are also about 7000 non-franchised buses providing transport services. This shows mass transportation is increasing in importance in Hong Kong, China.

As a regional aviation hub, as well as being the gateway to the Pearl River Delta (PRD) area of mainland China, Hong Kong, China's international airport has a significant throughput, serving more than 100 airlines and 53.9 million passengers in 2011 (Hong Kong International Airport, 2012). Hong Kong, China's energy use for international aviation is significant—petroleum products for international aviation accounted for about 89% of energy use in the whole transport sector in 2009. In the future, mainland China's increasing participation in global economic activities is expected to speed up the growth of passenger air travel between Hong Kong, China and mainland China.

The globalization of economic activities has also increased the freight volume of air and shipping transport. Hong Kong, China can handle more than 400 cargo ships a week from more than 80 international companies. The maximum handling capacity for containers is more than 2.3 million sets a year, being mainly import/export cargos for southern China. It is expected that international transport will account for the about 94.3% of the energy used in the transport sector in 2035.

Concerning final energy consumption (excluding international transport) in Hong Kong, China in 2009, the commercial sector used the most energy at 58%, followed by the residential sector at 25%. Due to its tropical climate, air conditioning is a significant part of residential energy use, accounting for about 20% of residential demand in 2009. The relatively slow growth of energy consumption by air conditioning in residential energy use (the overall growth from 1999–2009 was only 16.5%) appears to reflect market saturation for air conditioning units/systems. Similarly, there was almost no growth in air conditioning use in the commercial sector over the period 1999–2009 (EMSD, 2012).

ENERGY RESOURCES AND INFRASTRUCTURE

The absence of a domestic energy source has made Hong Kong, China a net importer of oil products (mostly from Singapore, which supplies about 80% of its motor gasoline requirements). The economy also imports natural gas—100% of this came from mainland China in 2010. Privately-owned electric and gas utilities service the economy's daily requirements.

Towngas and liquefied petroleum gas (LPG) are the two main types of fuel gas used throughout Hong Kong, China. Towngas is distributed by the Hong Kong and China Gas Company Limited. It is manufactured at plants in Tai Po and Ma Tau Kok, using both naphtha and natural gas (from October 2006) as the feedstock. LPG is supplied by oil companies and imported into Hong Kong, China through the five terminals on Tsing Yi Island.

In 2010, the total installed electricity generating capacity serving Hong Kong, China was 12 644 MW, including capacity in Guangdong, mainland China contracted to utilities in Hong Kong, China. All locally generated power is thermal fired. Electricity is supplied by CLP Holdings Limited (CLP) and Power Assets Holdings Limited (PAH). CLP supplies electricity from its Black Point (2500 MW), Castle Peak (4108 MW) and Penny's Bay (300 MW) power stations (CLP, 2012). Natural gas is the main fuel at Black Point, and coal the main fuel at Castle Peak. The natural gas is imported from the Yacheng 13-1 gas field off Hainan Island in southern China, via a

780 kilometre high-pressure submarine pipeline. CLP is contracted to purchase about 70% of the power generated at the two 984 MW pressurized-water reactors at the Guangdong Daya Bay Nuclear Power Station, to help meet the long-term demand for electricity in its supply area. It also has the right to use 50% of the 1200 MW capacity of Phase 1 of the Guangzhou pumped storage power station at Conghua, in mainland China.

Electricity for PAH is supplied from the coal and gas fired Lamma Power Station, which has a total installed capacity of 3736 MW (PAH, 2012). Natural gas used at this station is mainly imported through a submarine pipeline from the Dapeng LNG terminal in Guangdong.

ENERGY POLICIES

In its latest 2011–2012 policy address, the government of the Hong Kong Special Administrative Region (SAR) announced it will pursue two key energy policy objectives (Office of the Chief Executive, 2012). The first is to ensure the energy needs of the community are met safely, efficiently, and at reasonable prices. The second is to minimize the environmental impact of energy production and consumption, and to promote the efficient use and conservation of energy.

In keeping with the free market economic policy of Hong Kong, China, the government intervenes only when necessary to safeguard the interests of consumers, to ensure public safety, and to protect the environment. The government works with the power, oil and gas companies to maintain strategic reserves of coal, diesel, gas and naphtha. It monitors the performance of the power companies and other energy providers through the Scheme of Control Agreements, most recently revised in 2008, to encourage energy efficiency, quality services, and the use of renewable energy (Environment Bureau, 2012).

Hong Kong, China proposes to optimize its fuel mix to promote power generation with low carbon emissions. This will mean significantly reducing its reliance on fossil fuels, phasing out existing coal-fired generation units, and increasing the use of non-fossil, cleaner and low-carbon fuels, including renewable energy and imported nuclear energy. Its plan is that, by 2020, natural gas will account for about 40% of its fuel mix for power generation, coal no more than 10%, renewable energy about 3%–4%, and imported nuclear generated energy the remaining 50% (EPD, 2012). However, it faces a challenge from environmental groups, especially after the Fukushima nuclear disaster in Japan in March 2011. The role of clean energy in the future generation mix will be carefully re-evaluated to address their concerns.

Hong Kong, China will also endeavour to enhance energy efficiency, promote green buildings, encourage electricity savings, facilitate low-carbon transport and develop facilities to turn waste into energy. By implementing this strategy, the economy expects to: reduce energy intensity by 45% by 2035 and carbon intensity by 50%–60% by 2020 from 2005 levels; decrease its greenhouse gas (GHG) emissions by 19%–33% by 2020 compared with 2005; and lower its greenhouse gas emissions per capita from 6.2 tonnes in 2005 to 3.6–4.5 tonnes in 2020.

To help monitor the energy situation, Hong Kong, China has developed an energy end-use database. The database provides a useful insight into the energy supply and demand situation, including energy consumption patterns and trends, and the energy use characteristics of individual sectors and subsectors. A basic data set is publicly available on the internet. The government can use this data to analyse the current situation and to generate valuable policy/strategy revisions to implement in the future. The private sector can use the data to benchmark their energy efficiency so they can make further improvements in their energy consumption systems (EMSD, 2012).

A memorandum of understanding (MOU) signed by the Hong Kong, China Government and the National Energy Bureau of the People's Republic of China on 28 August 2008 ensures the long-term and stable supply of nuclear generated electricity, and the supply of natural gas from three different sources: offshore gas, piped gas and LNG (liquefied natural gas) from an LNG terminal built as a joint venture on a neighbouring mainland China site. Gas-fired power plants generated 28.8% of the economy's electricity in 2009. To improve air quality and to address the challenges posed by global warming, the government is exploring ways to gradually increase the use of clean energy. The inter-governmental MOU contemplates the delivery of gas for electricity generation in Hong Kong, China from three sources:

(a) New gas fields to be developed in the South China Sea.

(b) A second West-to-East gas pipeline, bringing gas from Turkmenistan through China.

(c) An LNG terminal located in Shenzhen, mainland China.

In 2009, the Hong Kong, China Government approved the extension of the contracts for CLP to purchase nuclear generated power from Guangdong

Daya Bay Nuclear Power Station from 7 May 2014 to 6 May 2034. These contracts will enable the continued supply of non-carbon emitting electricity to Hong Kong, China for another 20 years.

In Hong Kong, China, franchised buses are the major cause of roadside air pollution in busy corridors. The government's policy objective is to have zero-emission buses running across the territory in the long term. When the current bus franchises expire in the next few years, Hong Kong, China will impose additional requirements on the franchises. The bus companies will be required to switch to zero-emission buses or the most environmentally-friendly buses available when replacing existing ones, taking into account the feasibility and affordability for bus operators and passengers.

In terms of fuel consumption and other measures of environmental performance, hybrid buses are currently superior to ordinary diesel buses. In view of market availability and technical developments, hybrid buses have the potential to replace diesel buses on a large scale in the near future, before electric or fuel cell buses become available to the market. To reach its long-term goal for zero-emission buses, the government will provide financial support to bus companies that wish to test zero-emission buses, such as electric buses.

BUSINESS-AS-USUAL OUTLOOK

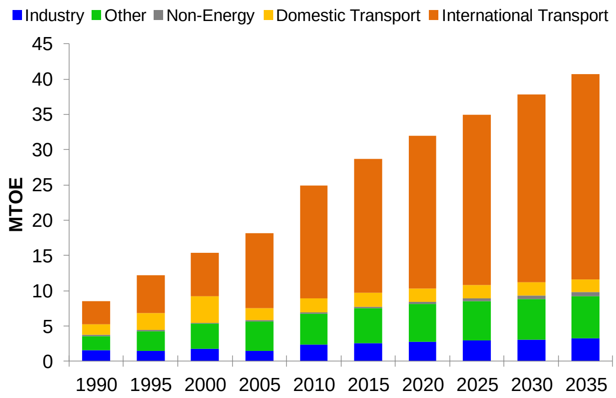
FINAL ENERGY DEMAND

In this business-as-usual (BAU) case, the new fuel mix for power generation proposed by the Hong Kong, China Government was not taken into account in our BAU simulation for the electricity supply system. This was due to the policy still being under debate, with no final decision reached at the time of this writing. The final results of our simulation may differ from those the government proposes. However, our BAU simulation does reflect the current energy policy of Hong Kong, China.

In the simulation, the final energy demand is expected to grow at only 1% a year over the outlook period (2010–2035). If the international transport sector is discounted, the 'other' sector (residential, commercial and agriculture) will account for the largest share of energy consumption at 6 Mtoe in 2035, followed by the industry sector at 3 Mtoe. However, the projection also shows international transport energy consumption has the potential to increase to about 29 Mtoe in 2035, compared with 15 Mtoe in 2009.

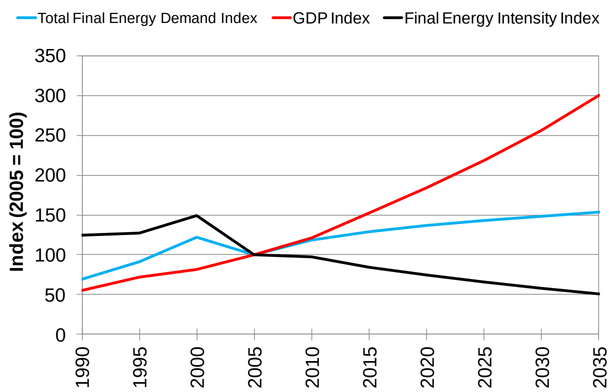
By implementing different measures for energy conservation in the building sector (including for appliances) and by continuing service-oriented GDP growth, the economy's final energy intensity is expected to decline by about 49% between 2005 and 2035.

Figure HKC2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure HKC3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 1.3% over the outlook period. This is lower than the average annual growth rate of 2.1% between 1990 and 2009. The slowdown in the energy demand growth rate is due to the slow growth in the value of industrial production expected in the future, and to the relocation of many industries, especially the energy-intensive and labour-intensive ones, to mainland China.

Transport

Transport sector energy demand (including international and domestic demand) is projected to increase by about 73% by 2035, based on the 2010 demand figures. Almost all the increase will come from the energy demand for international transport. Domestic demand is projected to decrease by 12.2%

in the same period. The dramatic increase of energy demand for international transport is due to Hong Kong, China's location at the gateway to the Pearl River Delta (PRD) area of mainland China and to its position as a regional aviation hub. The projection also shows international aviation demand grows by about 57% from 2010 to 2035. Marine demand grows even faster, at 95% over the same period. The result reflects Hong Kong, China's ambitions to be a regional transfer hub for both air and marine transport. The decrease in energy demand for domestic transport is probably due to a decline in vehicle numbers and the growing use of mass transport systems (both rail and bus). The policy to gradually increase the use of hybrid and electrical vehicles will also reduce energy consumption for domestic transport.

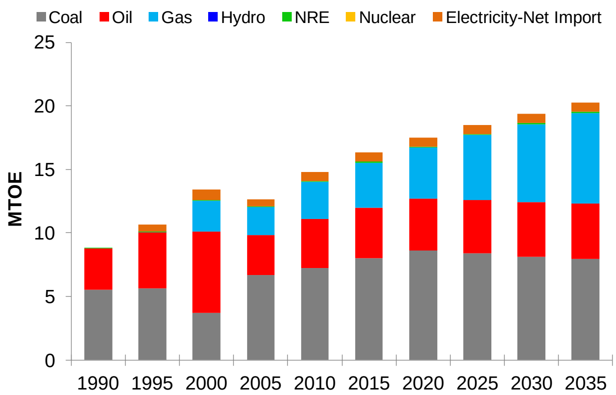
Other

The demand for energy in Hong Kong, China's 'other' sector is expected to grow at an average annual rate of 1.2% over the outlook period (2010–2035). Energy demand in the 'other' sector, which includes residential, commercial, agricultural and construction demand, is primarily driven by income growth. It appears most of the growth in the 'other' sector is commercial, reflecting the overall growth of this sector and particularly of service industries. Residential demand is growing slowly, reflecting Hong Kong, China's focus on improving energy efficiency. Energy efficiency improvements, such as the mandatory implementation of building energy codes, the mandatory/voluntary energy efficiency labeling schemes for appliances, the adoption of high-efficient lighting fixtures/systems, and the promotion and implementation of district cooling systems for the commercial sector are the major driving forces slowing down the energy demand growth rate in the 'other' sector. Electricity is expected to continue to dominate the energy mix, accounting for 76% of 'other' sector energy consumption in 2035.

PRIMARY ENERGY SUPPLY

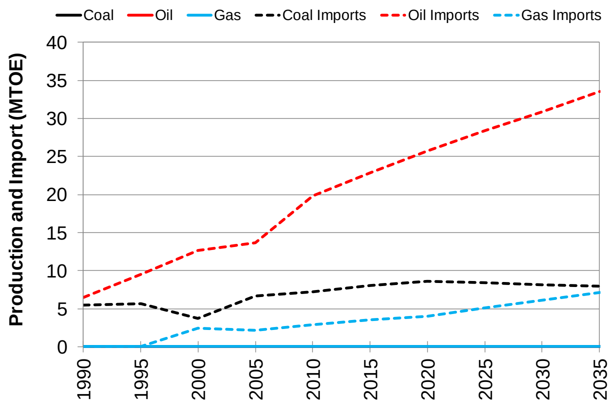
Hong Kong, China has no domestic energy reserves or petroleum refineries. The economy imports all of its primary energy needs. The total primary energy supply (excluding energy consumption for international transport) is projected to grow at an annual rate of 1.3% during the outlook period. The shift from coal to natural gas for power generation will result in a dramatic increase in the share of natural gas in the primary energy supply (excluding international transport) from 20% in 2010 to 35% by 2035. The share of coal will decrease from 49% in 2010 to 39% in 2035. During the outlook period, oil will show a minor increase, however, the share will decrease from 26% in 2010 to 22% in 2035. The results shown in Figure HKC4 do not include international transport, as fuel for international transport is not included in Primary Energy Supply. In this BAU case, the newly proposed fuel mix using an increasing amount of power imported from the nuclear energy power plant in mainland China is not included in this simulation.

Figure HKC4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure HKC5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

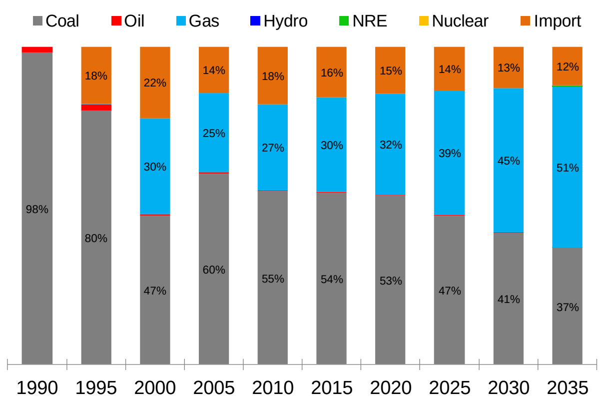
Hong Kong, China's electricity generation output is projected to increase at an average annual rate of 1.6%, reaching 61 TWh in 2035. The economy's commitment to reducing its GHG (greenhouse gas) emissions by 19%–33% by 2020 compared with 2005, means additions to the total installed electricity capacity are expected to be natural gas based, rather than coal fired. Coal's share of total electricity generation is expected to fall from 55% in 2010 to 37% in 2035.

Hong Kong, China's electricity supply is strongly dependent on power generated in mainland China.

Net imported electricity contributed to about 18% of electricity supplied in 2010. Most of the imported electricity comes from power generated at the Guangdong Daya Bay Nuclear Power Station; a small percentage comes from a storage hydropower plant in Guangzhou.

In this BAU scenario, the new proposed fuel mix for power generation is not included. The only consideration was to keep the net imported electricity amount from mainland China at the same level as in 2010, and to gradually increase the gas-fired power plants by phasing out the old coal-fired power plants. It means the increase of nuclear generated power imported from mainland China is not taken into account in this projection. Another uncertain issue in Hong Kong, China that needs to be clarified is the contribution of new renewable energy (NRE) to power generation. Considering the economy's land limitations, our BAU projection assumes NRE will be mostly demonstration projects, and its contribution will be small.

Figure HKC6: BAU Electricity Generation Mix



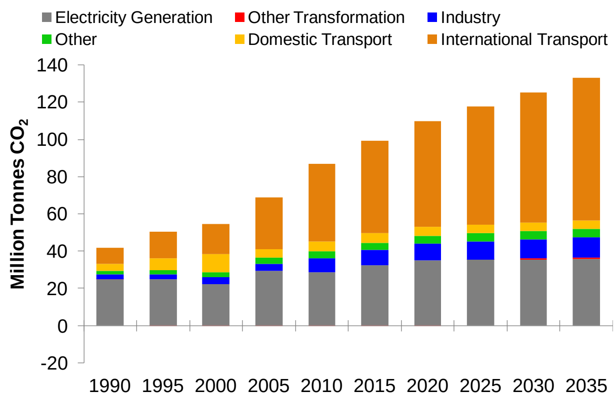
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Over the outlook period, Hong Kong, China's total CO_2 emissions from fuel combustion are projected to reach 133 million tonnes of CO_2, which is 53.3% higher than in 2010 and 217% higher than the 1990 level. The results show an increase of 59% in the period from 2005 to 2020, compared to the goal set by Hong Kong, China's government to reduce GHG emissions by 19%–33% in the same period. If the emissions from international transport are excluded, the projection shows a comparatively smaller increase of 29% in the same period (2005–2020). To meet the goal of Hong Kong, China's energy policy, more efforts to implement the proposed fuel mix for the power supply system should be considered. If Hong Kong, China goes ahead with its proposal to import additional nuclear generated power from mainland China, its emissions would be significantly reduced compared to our BAU case. The other option is to adopt cleaner coal technologies or carbon capture and storage (CCS) with coal-fired power plants to reduce their CO_2 emissions. Efficient coal technologies are discussed further in Volume 1, Chapter 13.

In 2035, international transport is expected to account for the largest share of total CO_2 emissions, at 58% or 76.4 million tonnes of CO_2, followed by the electricity generation sector at 27% (35.7 million tonnes of CO_2) and the industry sector at 8% (10.9 million tonnes of CO_2).

Figure HKC7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table HKC1 below suggests the growth in Hong Kong, China's GDP will be offset by a reduction in the energy intensity of GDP (improved energy efficiency and move to a service-oriented economy) and a minor reduction in the CO_2 intensity of energy (fuel switching from coal to natural gas).

Table HKC1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-1.1%	-1.0%	-0.3%	-0.3%	-0.2%
Change in Energy Intensity of GDP	0.5%	1.7%	-1.0%	-1.1%	-1.7%
Change in GDP	4.0%	4.0%	3.8%	3.7%	3.7%
Total Change	3.3%	4.8%	2.4%	2.2%	1.7%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Overall, the economy of Hong Kong, China is expected to continue to grow healthily. However, such growth will depend on energy security, as Hong Kong, China relies on imports for most of its energy supply.

With its lack of fossil energy resources, the economy is heavily dependent on imported oil, gas and electricity, especially to supply the large energy demands from both international aviation and its residential and commercial sectors. It is critical that Hong Kong, China improve its energy security, in particular to protect itself from fluctuations in the energy market. While the lack of indigenous resources means little can be done to improve the security of the supply of fossil fuels, electricity security could be greatly improved by ensuring the continuation of the contract with the Guangdong Daya Bay Nuclear Power Station. Although Hong Kong, China is almost entirely dependent on imported energy, the fact much of this energy is imported from mainland China, with which it has close political and economic ties, should help to reduce the risk of supply.

In terms of reducing its GHG emissions, the shift away from coal to gas for power generation will make a significant difference, but the reduction will not be enough to meet the goal set by the Hong Kong, China Government. Furthermore, the increasing energy demand, especially for electricity, will pose a more serious challenge to reducing the actual GHG emissions. The economy could help to reduce its GHG emissions by shifting to more imported electricity from nuclear or renewable energy sources, or by further increasing its energy efficiency at home. Government policies to increase vehicle fuel efficiency and to implement district cooling schemes should be continued, to further reduce the overall environmental impacts.

Further study of the future fuel mix proposed by the Hong Kong, China Government should be explored, to find a strategy to implement and potentially contribute to the reduction of GHG emissions.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

Hong Kong does not have any natural gas reserves and it is highly unlikely that any resource will be found in the economy in the future. It is also unlikely to be economic to replace coal in electricity generation with additional gas imports. Under BAU scenario, gas-fired power plants will account for more than 50% of electricity generation by 2035. Beyond this, Hong Kong, China has a long term policy to increase nuclear energy imports from mainland China. This policy is likely to be prioritized over gas power expansions.

For these reasons, the High Gas Scenario was not run for Hong Kong, China. Therefore, figures HKC8–HKC10 are not included here.

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

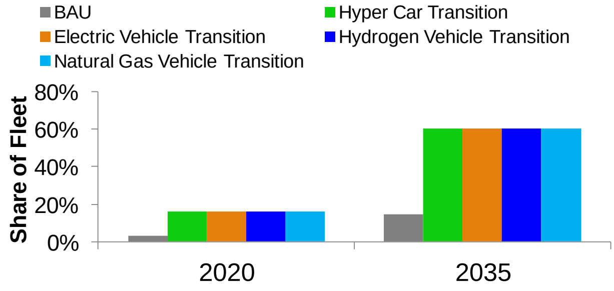
Hong Kong, China is already a compact city with high urban density and low energy consumption. Due to its natural geographical constraints, it would be impossible for Hong Kong, China to expand significantly in land area. For these reasons, the alternative urban development scenarios were not run for Hong Kong, China. Therefore, figures HKC11–HKC13 are not included here.

VIRTUAL CLEAN CAR RACE

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure HKC14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60% compared to about 15% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 85% in the BAU scenario.

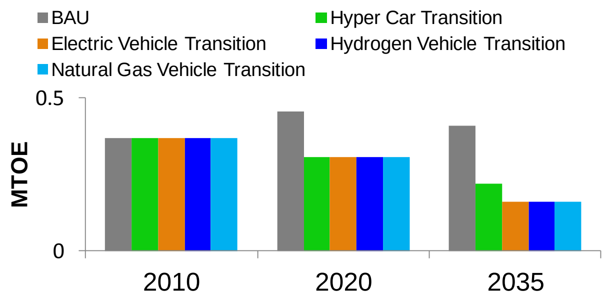
Figure HKC14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure HKC15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 49% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—31% by 2035—even though these highly-efficient vehicles still use oil.

Figure HKC15: Virtual Clean Car Race – Light Vehicle Oil Consumption

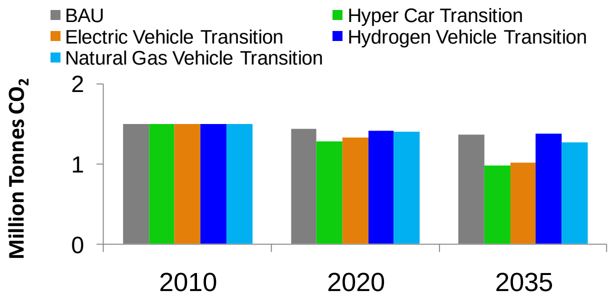


Source: APERC Analysis (2012)

Figure HKC16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Hong Kong, China, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions savings, with an emissions reduction of 28% compared to BAU in 2035. The Electric Vehicle Transition scenario is second, offering a 26% emissions reduction compared to BAU. Compared to most economies, electric vehicles do relatively well in Hong Kong, China, reflecting the economy's heavy reliance on natural gas rather than coal for electricity generation, and the economy's relatively efficient electricity generation. Natural Gas Vehicle Transition offers a reduction of about 7% while the Hydrogen Vehicle Transition does not change emissions.

Figure HKC16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

CLP (CLP Holdings Limited) (2012), *2010 Annual Report*, www.clpgroup.com/ourcompany/aboutus/resourcecorner/investmentresources/Pages/financialreports.aspx#tab2

CSD (Census and Statistic Department, Government of the Hong Kong Special Administrative Region of the People's Republic of China) (2012), *Hong Kong Statistic Table 036*, www.censtatd.gov.hk/hong_kong_statistics/statistical_tables/index.jsp?tableID=036

EMSD (Electrical and Mechanical Services Department, Government of the Hong Kong Special Administrative Region of the People's Republic of China) (2012), *Hong Kong Energy End-use Data 2011*, www.emsd.gov.hk/emsd/e_download/pee/HKEEUD2011.pdf

Environment Bureau (Government of the Hong Kong Special Administrative Region of the People's Republic of China) (2012), *Scheme of Control Agreement*, www.enb.gov.hk/en/resources_publications/agreement/index.html

EPD (Environmental Protection Department, Government of the Hong Kong Special Administrative Region of the People's Republic of China) (2012), *Hong Kong's Climate Change Strategy and Action Agenda*, www.epd.gov.hk/epd/english/climate_change/consult.html

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

Hong Kong International Airport (2012), 'Facts and Figures' website page, www.hongkongairport.com/chi/business/about-the-airport/facts-figures/facts-sheets.html

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

Office of the Chief Executive (Government of the Hong Kong Special Administrative Region of the People's Republic of China) (2012), *Policy Address 2011–2012*, www.policyaddress.gov.hk/11-12/eng/index.html

PAH (Power Assets Holdings Limited) (2012), *2010 Annual Report*, www.powerassets.com/pahWeb/IR/FinancialReports/AnnualReports/AnnualReport2010_en.htm

Transport Department (Government of the Hong Kong Special Administrative Region of the People's Republic of China) (2012a), *Annual Transport Digest 2011*, www.td.gov.hk/mini_site/atd/2011/tc/s1_p1.htm

— (2012b), *Hong Kong Transportation 40 Years (2008)*, www.td.gov.hk/filemanager/tc/publication/td-booklet-final-251108.pdf

INDONESIA

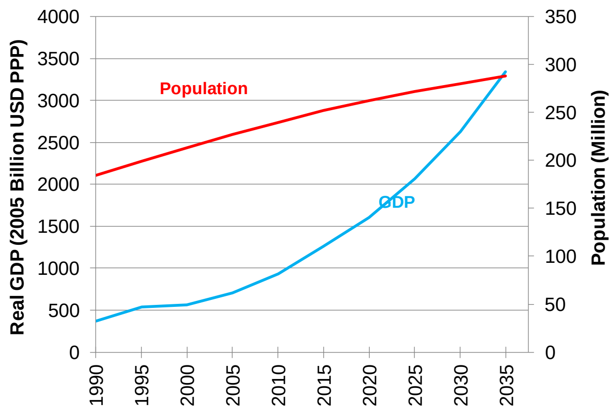
- *Under business-as-usual assumptions that include strong economic growth, Indonesia's primary energy demand (including biomass) is projected to increase at an average annual rate of 3% over the outlook period, to reach 429 Mtoe in 2035. This is in line with the expected improvements in economic and living conditions spurred by the implementation of the Masterplan for Acceleration and Expansion of Indonesia Economic Development (MP3EI).*
- *Coal production is expected to continue a dominant role in the economy throughout the outlook period, with exports of coal rising to 333 Mtoe in 2035. Indonesia is already a net oil importer, and is expected to become a natural gas importer during the outlook period.*
- *CO_2 emissions will almost triple over the outlook period, reaching 1031 million tonnes of CO_2 by 2035. However, Indonesia's final energy intensity is predicted to decrease by 52% from 2005 levels.*

ECONOMY

The Republic of Indonesia is a large archipelago located south-east of mainland South-East Asia. The economy covers about 1 910 931 square kilometres of land. It is made up of five large islands—Sumatra, Java, Kalimantan, Sulawesi and Irian Jaya—and over 17 000 smaller islands, of which only 7% are permanently inhabited. The terrain is mostly coastal plains with mountainous interiors, and the climate is characteristically tropical with abundant rainfall, high temperatures and high humidity. Indonesia shares land boundaries with Malaysia, Papua New Guinea and East Timor.

The population of Indonesia in 2010 was estimated to be 239.9 million, making it the world's fourth most populous economy. About half of the population still lives in rural areas and are involved mainly in agriculture-related activities. The UN predicts that 60.3% of the population will be urbanized by 2025 (UNPD, 2012). Most of the urban population lives on Java Island, making it the most populous island in the world, congregating in Indonesia's capital city Jakarta as well as the cities of Surabaya, Bandung and Semarang.

Figure INA1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Indonesia was profoundly affected by the 1997 Asian financial crisis. The economy's GDP growth plummeted from 7.8% in 1996 to negative 13% in 1998. In the past five years, Indonesia has revived its economy to achieve consistent growth of about 6% annually, and was even able to stay resilient during the 2009 global financial crisis. In 2010, Indonesia had the largest economy in ASEAN, with overall GDP of USD 930.7 billion (in 2005 USD PPP), although the per capita GDP of USD 3880 (in 2005 USD PPP) is much lower than that of other ASEAN countries like Thailand (USD 7674 per capita) or Singapore (USD 51 800 per capita). This outlook expects Indonesia's GDP to increase at an average annual rate of 5% over the outlook period, reaching USD 3340 billion (in 2005 USD PPP) by 2035. In 2011, Indonesia gained an international investment grade credit rating and hit a record of USD 19.3 billion in foreign direct investment (Wall Street Journal, 2012), almost four times higher than the 2009 foreign direct investment of USD 4.87 billion (The World Bank, 2012).

However, poverty remains a challenge and the unemployment rate is still relatively high at 6.3% in 2012 (Jakarta Post, 2012c). Access to the basic services of electricity, water, sewage, transport, trade, education and health is still limited (IEA, 2008). For instance, in 2010 only 48% of households had sustainable access to improved drinking water, 52% to basic sanitation and the electrification ratio was at 67.2% (BAPPENAS, 2010; DGE, 2011). Furthermore, in the past decade, Indonesia has been beset by a string of natural disasters, including the massive tsunami in 2004, several major earthquakes registering over seven on the Richter scale, and the Mt Merapi volcanic eruption in 2010.

In order to meet its manifold challenges, in 2011 the Indonesian Government issued the Masterplan for Acceleration and Expansion of Indonesia Economic Development (MP3EI). The MP3EI integrates three key objectives: to develop regional economic potential in six Indonesia Economic Corridors (Sumatra, Java, Kalimantan, Sulawesi, Bali-Nusa Tenggara, and Papua-Maluku Island); to strengthen economy-wide connectivity locally and internationally; and to strengthen human resource capacity and the economy's science and technology to support the development of programs in every economic corridor.

Indonesia's current economic structure is primarily focused on agriculture and industries that extract and harvest natural resources. With its vast natural resources, Indonesia has become a major global producer of a broad range of commodities. The economy is the world's largest producer and exporter of palm oil, and the second largest producer of coal, cocoa and tin. It is also a major producer of nickel, bauxite, steel, copper, rubber and fish products (CMEA, 2011). Under MP3EI, the economy aims to further develop its local resources to create a sustainable upstream and downstream activity chain; this includes biofuels and oleo-chemicals from palm oil, and tyres and gloves from rubber, as well as a steel-smelting industry from iron ore. To support the development of MP3EI's main economic activities, the Indonesian Government estimates a total investment of IDR 4012 trillion (USD 437 billion) (CMEA, 2011).

Indonesia's economic portfolio is fairly diverse. In 2010, the manufacturing sector accounted for the largest share of Indonesia's GDP at 24.82%, followed by the agricultural sector (15.34%), the mining sector (11.15%) and the services sector (10.19%) (MOI, 2011). Indonesia manufactures textiles and apparel, furniture, cement, fertilizer, steel and glassware. In the high technology area, Indonesia has the most sophisticated aircraft industry in South-East Asia and a growing range of automotive, shipping and electronic manufacturing capabilities. For instance, car manufacturers like Toyota, General Motors, Ford and Tata are not only increasing production in terms of output, but will also be rolling out new models to meet the increasing domestic demand (Jakarta Post, 2012a). The steel industry is also currently expanding its capacity, with several new steel mills expected to come online by 2015. These include the Krakatau Steel mill with an initial capacity of 3 million tonnes per year, the PT Meratus Jaya Iron Steel plant with production capacity of 315 000 tonnes per year and the PT Indoferro plant capable of producing 500 000 tonnes per year of steel billet (Kuo, 2012).

Vehicle ownership (excluding motorcycles) in this economy is still low at 79 vehicles per 1000 people (The World Bank, 2012). However, average annual growth of number of vehicles (excluding motorcycles) in Indonesia is very high at about 11% annually, and this trend is expected to continue in the mid-term. Motorcycles are by far the most popular choice of vehicle in Indonesia, accounting for 79.4% of the 76.9 million vehicles registered with the State Police of Indonesia in 2010 (BPS, 2012).

Indonesia has a total of 355 856 km of roads, of which 57% are paved and 0.2% are toll roads (MOT, 2010). The economy's rail network is still underdeveloped. There are currently only four rail networks: one in Java, which is passenger oriented, and three in Sumatra, which are mostly used for transporting goods like coal, cement and palm oil (The World Bank, 2011). In the capital city of Jakarta, urban public transportation consists of a range of bus services including public minibuses operated by Metromini and Kopaja, public minivans, and the TransJakarta bus rapid transit (BRT) system, as well as two- and four-wheeled taxis. A rail-based mass rapid transit (MRT) system is also under development and is expected to commence operation in 2016.

As an archipelago, Indonesia relies heavily on air and sea transport for inter-island transportation. As of 2010, the economy has more than 300 ports scattered over the archipelago, and each of the major islands has at least one significant port city. While inland waterways are also used as transport routes, this is limited to the river systems in Eastern Sumatra and Kalimantan. The domestic airline network is quite extensive, providing quick and affordable access to areas not serviced by water and land transport networks.

The Indonesian Government recognizes that connectivity within the region is important to support economic activities; thus strengthening local and global connectivity is one of the four main strategies of the MP3EI. Roughly 10% of the IDR 4012 trillion (USD 437 billion) investment in MP3EI is directed toward basic infrastructure provision, such as roads, seaports, airports, railways and power generation (CMEA, 2011). This translates to increasing demand for energy in the form of fossil fuel and electricity in the coming years.

ENERGY RESOURCES AND INFRASTRUCTURE

Indonesia has substantial coal and gas reserves but its oil reserves are depleting. According to the Handbook of Energy and Economic Statistics Indonesia 2011, as of January 2010, proven reserves of coal stood at 21.13 billion tonnes, proven reserves of crude oil at 4.23 billion barrels and proven reserves of natural gas at 3.07 trillion cubic metres (tcm) (108.4 trillion standard cubic feet) (ESDM, 2011, pp. 60, 66 and 78). At current production rates, Indonesia's coal reserves are sufficient for 77 years, oil reserves for 12 years and gas for 32 years.

About 60% of Indonesia's coal reserves are sub-bituminous while the rest are lignite coals (29%) and bituminous (11%) (Lucarelli, 2010). Kalimantan and Sumatra each holds roughly 49% of the coal reserves (CMEA, 2011); however, Kalimantan accounts for over 90% of Indonesia's coal production and export. This can be attributed to Kalimantan's higher quality coal, ease of extraction and transportation through navigable rivers and coastal areas, as well as its proximity to large power markets. Currently, about 20% of annual production is consumed domestically, while the rest is exported to coal-consuming countries like Japan, China, India, South Korea and other ASEAN countries (CMEA, 2011). Coal production in Indonesia is very attractive due to strong demand and strong reserves, and as such is projected to continue growing throughout the outlook period.

A very different situation can be observed in the Indonesian oil industry. Crude oil production has been on a downward trend for the past decade, culminating in Indonesia becoming a net oil importer in 2004. This can be attributed to natural maturation of producing oilfields combined with a slower reserve replacement rate and decreased exploration and investment in the industry. The economy actually has a fairly sizable oil reserve potential—the proven reserve in 2011 is 4.2 billion barrels, and out of the 128 estimated oil basins, only 38 have been extensively explored (PWC, 2011c). Most of the existing wells are in Sumatra and Kalimantan.

The Indonesian Government is promoting exploration further offshore and in frontier regions, providing incentives such as encouraging three-dimensional seismic surveys and agreeing to a change to the production-sharing contract—to increase oil companies' share from 15% to 35%. Other incentives also proposed include waiving land and building taxes as well as import duties for capital goods (Oil and Gas Technology, 2012). These incentives may improve Indonesia's oil outlook, but given that no new significant finds have been made in the past decade, and in the light of Indonesia's rapidly growing demand, the economy is expected to remain an oil importer in the long term.

Indonesia has the largest proven natural gas reserves in the Asia–Pacific region, estimated to be about 2% of the world's total estimated proven natural gas reserves (OGJ, 2011). The economy's major production sites are Arun in Aceh, Bontang in South Kalimantan, and Tangguh in Papua (Jakarta Globe, 2011).

Indonesia's archipelago geography and the distributed nature of its gas reserves complicate the transportation process; this is mitigated through a combination of LNG facilities and a localized pipeline network (Hutagalung et al., 2011). Indonesia has three LNG liquefaction facilities in operation, one under construction in Donggi–Senoro and another planned at Abadi (Global LNG Info, 2012). In anticipation of rising domestic demand, especially from islands without their own natural gas sources, three regasification terminals will be constructed: the Nusantara LNG FSRU terminal, the East–Central Java LNG FSRU terminal, and the Lampung LNG FSRU terminal (Global LNG Info, 2012). In 2011, Indonesia exported its LNG to Mexico, Chile, China, Japan, South Korea, Chinese Taipei and Thailand (BP, 2012).

Indonesia's natural gas pipeline network is operated by the government-owned Perusahaan Gas Negara (PGN). It consists of high-pressure transmission pipelines totalling 2160 km in length, and a distribution pipeline network stretching more than 3500 km (PGN, 2012a; PGN, 2012b). Natural gas pipelines connect the economy to its neighbours Singapore and Malaysia, enabling pipeline gas exports to these economies. There are plans to further extend and interconnect the existing pipeline network so that eventually the islands of Sumatra, Java and Kalimantan will be linked via a 4184-km pipeline.

Maturing gas fields and rapidly increasing domestic demand are issues that have led the Indonesian Government to support the exploitation of several large pockets of natural gas, including the Abadi gas field in the Masela block (estimated 65 bcm (2.3 tcf) of gas) and the East Natuna block (estimated 1.3 tcm (46 tcf) of gas) (Jakarta Globe, 2012). There are initiatives in place to promote the extraction of coal bed methane (CBM) gas and shale gas. Indonesia has an estimated 12.8 tcm (453 tcf) of CBM in place, which is one of the largest resources in the world. CBM production started in March 2011 from the Sanga-Sanga PSC, and is being exported from the Bontang LNG facility (CBM Asia, 2012).

Indonesia also has the largest geothermal energy capacity in the world, estimated to be equivalent to 29 038 MW of electricity and spread across more than 270 locations (ESDM, 2011, p. 94). Geothermal energy is a special focus of Indonesia's USD 400 million Clean Technology Fund, which is co-financed by the World Bank and the Asian Development Bank. By 2011, 1.2 GW of thermal capacity had been successfully installed (PWC, 2011a). In addition to geothermal energy, Indonesia possesses a variety of renewable energy resources, including up to 75 670 MW of potential hydropower, 769 MW of potential micro-hydro and 49 810 MW of potential biomass, as well as solar, wind and uranium capabilities (BPPT, 2011).

Indonesia's power sector recently began to make meaningful investment after a decade of delay due to the extended impact of the 1997 Asian financial crisis. The initial priorities are to end severe power deficiencies in all the regions, and to improve electricity access from the current electrification ratio of 67% in 2010 to 99% by 2020. With these priorities in place, the Indonesian Government has mandated the government-owned electric company Perusahaan Listrik Negara (PLN) to implement fast-track programs to accelerate development of generating facilities.

Phase I of the 10 000 MW Accelerated Power Program was launched in 2006. PLN was required to build 9551 MW of new coal-based generation capacity by the end of 2009. Due to several reasons, the Indonesian Government delayed the final completion date for Phase I of the 10 000 MW Accelerated Power Program to 2014 (ESDM, 2012a). By the end of November 2012, 4520 MW of power generation capacity had been successfully completed and begun operation.

In 2010, the government mandated PLN to implement Phase II of the program. In this second phase, it is intended that PLN add 11 144 MW of capacity, based on 68% coal, 19% geothermal, 10% combined cycle gas, and 3% hydropower (ESDM, 2010). The two-phase accelerated power development program is expected to rapidly increase generating capacity, encourage renewable energy utilization, and at the same time eliminate oil-based power plants, except in regions where there are no other competitive alternative energy sources.

The composition of the generation capacity mix for the Phase II of the 10 000 MW Accelerated Power Program is updated as and when required to better ensure sustainability and energy security. In 2012, the Ministry of Energy and Mineral Resources (MEMR) has announced the 10 000 MW Phase II will add 10 047 MW capacity, of which 49% will be developed from geothermal, 30% from coal, 17% from hydropower, 3% from gas, and 1% from gassified coal (ESDM, 2012a).

Currently, Indonesia's power network consists of a central system connecting the islands of Java, Bali and Madura, as well as several isolated and partially interconnected systems on other islands. Plans are already in place to connect the partially integrated power systems and isolated grids within the growing demand regions of Sumatra, Sulawesi, and Kalimantan. In 2012, PLN has begun initial construction for two transmission lines that will connect the Indonesia and Malaysia power grids. The first transmission line would be 122 km long, with a capacity of 275 kV, and will connect West Kalimantan to Sarawak in Borneo Island; it is expected to be completed by 2014. The second transmission line will be a 250-kV high voltage direct current (HVDC) subsea cable linking Sumatra to Peninsular Malaysia and is expected to begin operation in 2017 (Jakarta Post, 2012b).

ENERGY POLICIES

Indonesia's current National Energy Policy (KEN for its acronym in Indonesian) was formulated under the Presidential Decree No. 5 of 2006. At the core of the KEN are several policies setting out five key objectives: diversification, rational energy pricing, energy conservation, energy sector reform, and rural electrification. KEN sets economy-wide targets for the optimal energy mix in 2025, with the aim of reducing oil's share while increasing the coal and renewable energy shares. KEN also established an economy-wide target to reduce the energy elasticity target to less than 1—in this case, energy elasticity is defined as the rate of change of total primary energy over rate of change of GDP.

The National Energy Council (DEN for its acronym in Indonesian) has been mandated to formulate and monitor the implementation of the KEN as well as to lead responses to energy crises and emergency situations. The immediate responsibility for regulating Indonesia's energy sector lies with the Ministry for Energy and Mineral Resources (MEMR) and its sub-agencies.

Indonesia's oil and gas industry is currently undergoing regulatory changes. The industry was reformed in 2001 under the Oil and Gas Law (Law No. 21/2001). BP Migas and BPH Migas were created as regulatory bodies for upstream and downstream activities, respectively. Exploration and production activities were conducted based on a fiscal contractual system that relies mainly on production sharing contracts (PSC) between government and private investors, which may include foreign and domestic companies, as well as the government-owned Pertamina.

However, on 13 November 2012, the Constitutional Court declared the existence of BP Migas was in conflict with the Constitution of 1945 and ordered the dissolution of BP Migas. As at the time of writing, the government is drafting a new Oil and Gas Law that will determine the new industry structure. Until this law can be enacted, an Interim Working Unit for Upstream Oil and Gas Business Activities (SKSPMIGAS) has been established under MEMR to undertake all of BP Migas roles and responsibilities (ESDM, 2012b). SKSPMIGAS was later renamed to Working Unit for Upstream Oil and Gas Business Activities (SKKMIGAS) (EDSM, 2013).

The Indonesian mining sector is governed by the Constitution of 1945, which stipulates that Indonesia's natural resources are to be controlled by the government and must be used for the maximum benefit of the Indonesian people. Therefore, under the Law on Mineral and Coal Mining (Law No. 4/2009), the government holds the title to mining deposits and grants licenses for exploration and sale. The Mining Business Licenses are open to both Indonesian citizens and foreign investors who own Indonesian companies. To protect Indonesian interests, all license holders are required to pay production royalties to the government and to carry out coal processing and refining within Indonesia. License holders are also obligated to sell a percentage of coal production to the domestic market, which mostly consists of the power generation sector. This Domestic Market Obligation (DMO) percentage is determined annually by the MEMR, based on forecast domestic requirements. In 2010 the DMO percentage was set to 24.75%; in 2011 it was 24.17% (PWC, 2011b).

The industry was partially deregulated in 1985 when limited private participation in electricity generation was permitted in the form of Independent Power Producers (IPP). Electricity transmission and distribution remained a monopoly under the government-owned utility PLN, and IPPs were obliged to sell generated electricity exclusively to PLN. The new Electricity Law (Law No. 30/2009) enacted in September 2009, fully deregulated the power market by allowing IPPs to generate and sell electricity to end users. However, until 2011, PLN remained the sole owner of transmission and distribution assets and controlled over 80% of generation assets. The same law mandated central and regional government to regulate the electricity industry within their respective jurisdictions. This is done through these electricity regulatory authorities: the Directorate General of Electricity (DGE) and the Directorate General of New Energy, Renewable Energy and Energy Conservation (DGNREEC) under MEMR.

While subsidies on fuels for power generation and industry, and high-octane gasoline for transport, have been removed, substantial subsidies remain for lower-octane gasoline and diesel oil for transport, kerosene and a certain class of electricity use in households. In 2011, it was estimated that the Indonesian Government spent a total of IDR 137 trillion (USD 14.8 billion) on energy subsidies, including fuel and electricity subsidies (IISD, 2011). The Indonesian Government is making progress towards fuel subsidy reforms; this includes significantly reducing kerosene subsidies through the kerosene-to-LPG program introduced in 2007.

In May 2012, the Indonesian President announced five policies under the National Saving Program that restricts access to subsidized fuel and introduces new energy diversification and conservation measures (Republika Online, 2012). The policies are:

1. Subsidized fuel consumption will be monitored through automated data collection at every fuelling station.
2. Government vehicles will be prohibited from using subsidized fuel.
3. Vehicles owned by plantation and mining owners will also be banned from using subsidized fuel.
4. Natural gas will be introduced as an alternative fuel in the transportation sector; as a start 33 natural-gas fuelling stations will be constructed and 15 000 converter kits will be distributed to launch the program.
5. Water and electricity savings measures will be implemented at the central and district offices (BUMN and BUMD for the acronyms in Indonesian) as well as in street lighting.

A more comprehensive strategy is being formed to gradually phase out all fossil fuel subsidies while minimizing the social impact of that change (IISD, 2012).

The Indonesian Government is also looking at further reducing the effect of fuel subsidies by developing alternative fuels for transportation. To drive this initiative, Ministerial Regulation No. 32/2008 was enacted regarding the Supply, Use and Commerce of Bio-fuels as Other Fuel. This makes biofuel consumption mandatory from 2009 (APERC, 2011). So far, the initiative has been quite successful; as of 2010, there are several biofuel producers in the economy, capable of producing 4 506 629 kilolitres of biodiesel and 286 686 kilolitres bioethanol annually (DGNREEC, 2012).

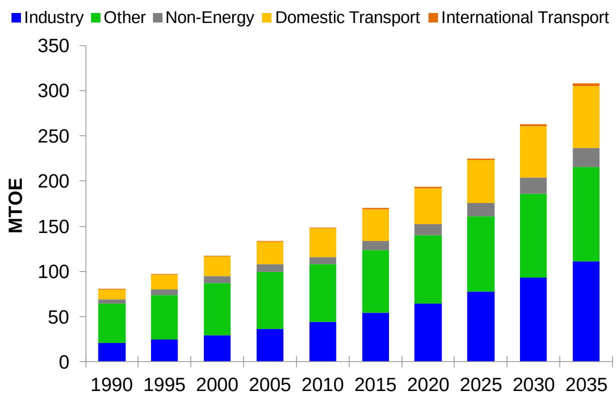
In 2009, during the G20 Finance Ministers and Central Bank Governors Summit at Pittsburgh and the COP15 forum in Copenhagen, Indonesian President Yudhoyono pledged to voluntarily and unilaterally cut carbon emissions by 26% relative to business-as-usual levels by 2020. Further emissions reductions of 41% are expected with international support (MOE, 2010). In line with this pledge, Indonesia's DEN is currently drafting a revised National Energy Policy (KEN). Early drafts propose that Indonesia will no longer build oil-fired power plants (ESDM, 2012c) and the renewable energy share of total primary energy consumption will be increased to around 25% by 2025, compared to the original target of 10% (Balia, 2011). The new policy also sees a paradigm shift to demand-side management with more emphasis on energy conservation to improve energy utilization. Through energy conservation measures, the DGNREEC expects to achieve a 17% reduction in final energy consumption by 2025, compared to consumption in 2009 (DGNREEC, 2012).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Indonesia's final energy demand under business-as-usual (BAU) assumptions is projected to increase at an average annual rate of 3% over the outlook period to reach 305 Mtoe in 2035 (International transport sector was excluded from this total). Demand is expected to increase across all sectors and all fuel types, with the exception of new renewable energy (NRE).

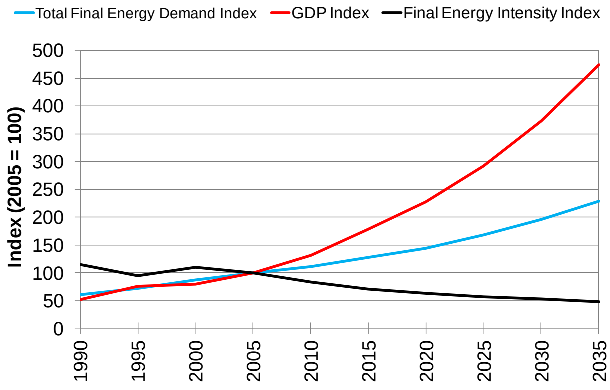
Figure INA2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to halve by 2035 compared to the final energy intensity in 2005. This is a positive indicator of the improving economic performance and better management of energy utilization in Indonesia.

Figure INA3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Based on current trends for capacity and productivity expansion in Indonesia, industrial energy demand in the economy is projected to experience strong growth, almost tripling from 43.3 Mtoe in 2009 to over 110 Mtoe in 2035. Each type of fuel experiences similar rates of growth from 2010 to 2035 (of about 3–5%), with the exception of NRE, which will decline from 6.5 Mtoe in 2009 to 3.8 Mtoe in 2035. This indicates that as Indonesia's industrial sector becomes more sophisticated, biomass will be replaced by other commercial fuel like electricity and natural gas. Industrial energy intensity is projected to reduce by 36% from 2005 to 2035.

Transport

Road vehicle ownership in Indonesia is far from saturation level, and given the economy's accelerating economic development, growth in vehicle ownership is expected to be very rapid. This will translate to a corresponding increase in energy demand in the transport sector. The same increasing energy demand growth can be expected in other types of transportation. In total, rail, road, aviation and water-based transportation will require about 71 Mtoe of energy by 2035, compared to 32 Mtoe in 2009. In 2009, virtually all of this demand was for oil, but with the introduction of alternative fuels and vehicles in the economy, demand for other fuels will gradually increase throughout the outlook period. By 2035, demand for other types of fuel will account for about 4% of the total demand. The gradual shift to more efficient fuel and transportation modes will contribute towards the expected 40% improvement in transportation energy intensity from 2010 to 2035.

Other

The 'other' sector (combining the agricultural, commercial and residential sub-sectors) is expected to experience strong growth in the 25 years from 2010 to 2035, given Indonesia's rapidly increasing economic and population growth. Each year should see an average growth of about 2% in the 'other' final energy demand, rising from 63.7 Mtoe in 2009 to 104 Mtoe by 2035.

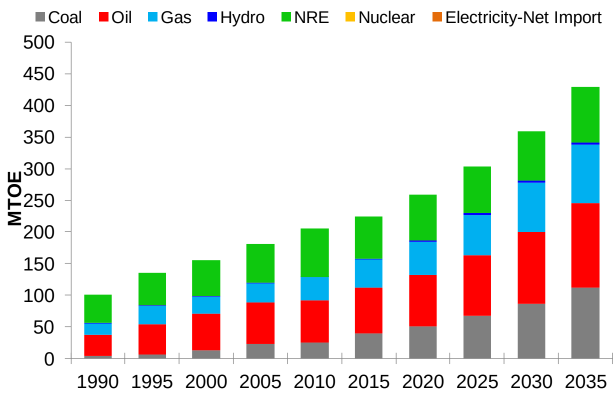
The demand will be primarily for NRE in the form of biomass, and for electricity and oil. This projection assumes that PLN is able to realize its target of improving the electrification ratio from 67.2% in 2010 to 99% in 2020. As a result, growth in electricity demand is expected to be the most rapid, at an annual average of 6%, as access to electricity will be complemented by increasing use of electrical appliances in both the commercial and residential sectors.

Energy intensity in the 'other' sector will improve significantly during the outlook period, achieving a 65% reduction from the 2005 to 2035. This can be attributed to the various energy efficiency and conservation measures currently in place in Indonesia. This includes the formation of government-owned service companies (ESCO); publication of energy benchmark and best practice guides for energy use in commercial buildings; updating of energy standards and labelling system for electrical appliances; subsidization of an energy-efficient lighting program in the residential sector; and promotion of research and development in energy efficiency and conservation.

PRIMARY ENERGY SUPPLY

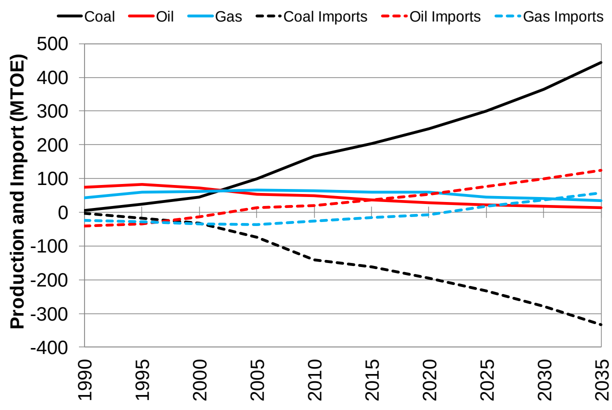
Indonesia's primary energy supply is expected to more than double during the outlook period, reaching 429 Mtoe in 2035. In 2035, the fuel mix will mostly be distributed among four fuels—oil (31%), coal (26%), natural gas (22%) and NRE (20%).

Figure INA4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure INA5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Indonesia will continue to produce coal, oil and gas; however, by the latter half of the outlook period, oil and gas production will begin to dwindle. Indonesia became a net oil importer in 2004, and unless new, viable natural gas resources can be developed, Indonesia will begin to import natural gas after 2020. On the other hand, given its substantial coal reserves and established coal industry, Indonesia will remain a major coal exporter throughout the 2010–2035 period.

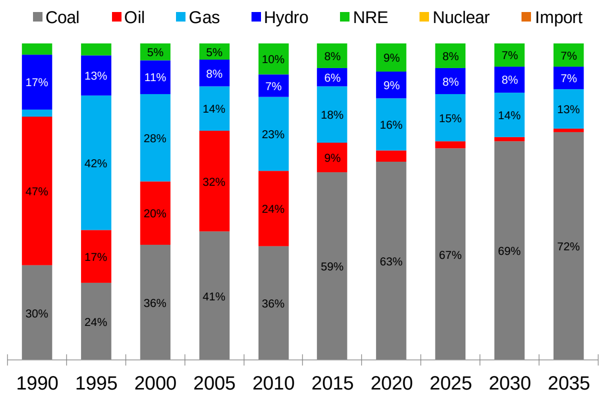
ELECTRICITY

Indonesia's electrification ratio and per capita electricity consumption were pretty low in 2010 at 67.2% of total households and 620 kWh per capita respectively (DGE, 2011, p. viii). There is much room for growth, and considering that annual electricity consumption growth has been high at 6–7%, it is not surprising Indonesian authorities have embarked on the two-phase 10 000 MW Accelerated Power Program to meet this anticipated surge in electricity demand.

This huge influx of capacity rapidly shrinks oil's share in power generation from 24% in 2010 to 1% by 2035. Coal and gas are the preferred investment choices for thermal power plants, especially coal since Indonesia has vast but under-utilized coal deposits. This will lead to coal dominating the generation mix from 2015 onwards.

In line with Indonesian government programs, it is projected that NRE (in the form of solar, wind, geothermal and biomass) will contribute an increasing share to the generation mix over the outlook period, reaching 7% by 2035. Most of this contribution will be from geothermal power plants, in which Indonesia has significant potential (estimated about 29 GW).

Figure INA6: BAU Electricity Generation Mix

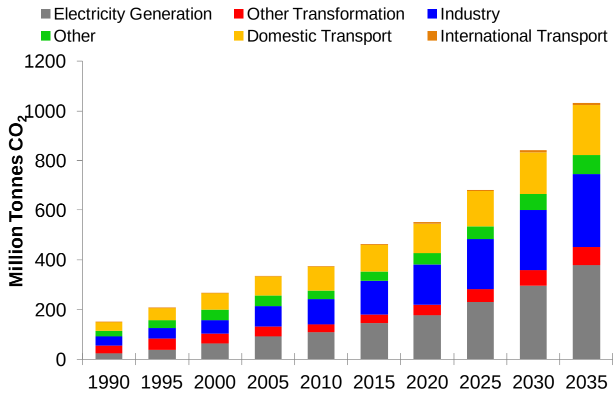


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Over the outlook period, Indonesia's CO_2 emissions from combustion of fossil fuels is projected to reach 1031 million tonnes of CO_2 in 2035, which is a 175% increase from 2010 emission levels. Fossil-fuel-based electricity generation is expected to be the main source of CO_2 emissions, followed by the industrial and domestic transport sectors.

Figure INA7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

Table INA1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	1.5%	-0.1%	1.0%	0.9%	1.1%
Change in Energy Intensity of GDP	-0.5%	-3.0%	-2.5%	-2.3%	-2.1%
Change in GDP	4.4%	5.7%	5.4%	5.3%	5.2%
Total Change	5.5%	2.4%	3.8%	3.8%	4.1%

Source: APERC Analysis (2012)

The decomposition analysis illustrated in Table INA1 shows that Indonesia's CO_2 emissions are affected most by economic growth, and to a lesser degree by the change in CO_2 intensity of energy (as a result of fuel switching, especially to coal). The total increase in CO_2 emissions will be moderated by the reduction in energy intensity of GDP (due to increased energy efficiency). The latter indicates overall better economic efficiency in terms of energy use.

CHALLENGES AND IMPLICATIONS OF BAU

Under BAU assumptions, Indonesia will continue to experience strong economic growth, which will lead to rapidly increasing domestic energy requirements. Indonesia has ample indigenous resources of coal and geothermal, and plans are underway to effectively harness these resources to meet growing demand. It is projected that under existing policies, Indonesia will likely reduce its final energy intensity by half from 2005 to 2035; however, the absolute amount of carbon emissions will almost triple during the same period. There remain significant opportunities for improving environmental sustainability, particularly in the power generation, industry and transport sectors.

ALTERNATIVE SCENARIOS

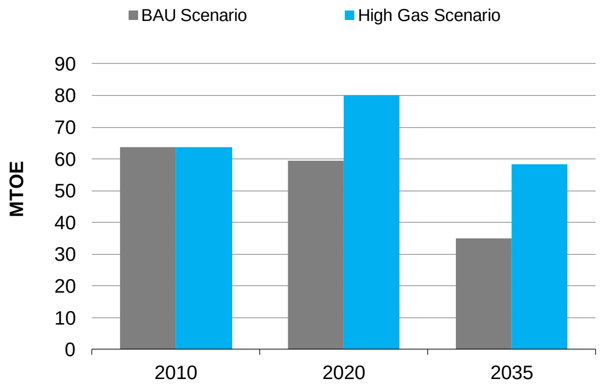
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Indonesia assumed the production increase shown in Figure INA8, which is 67% by 2035. Indonesia has ample natural gas resources, estimated to be the largest in the Asia–Pacific region, but limited technology and infrastructure for gas extraction and transport. For this High Gas Scenario, it was assumed that Indonesia was able to attract sufficient investment to overcome these challenges, which would spur construction of the necessary infrastructure and development of major gas projects such as the Natuna D-Alpha gas field. Note these estimates can be considered conservative as the potential for unconventional gas like shale gas and coal bed methane (CBM) was not included.

Figure INA8: High Gas Scenario – Gas Production

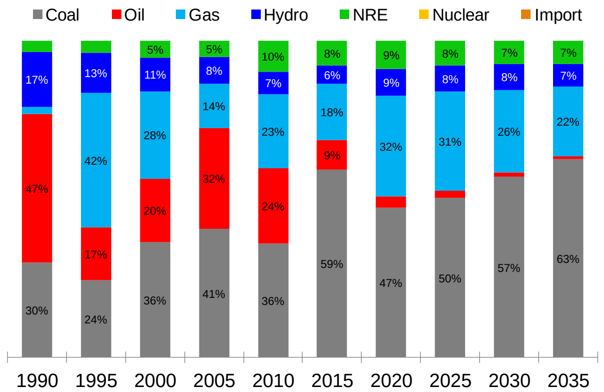


Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. For Indonesia, the economy would likely export most of the additional gas produced as LNG to maximise economic benefits, while the remainder will replace coal to reduce local air pollution and CO_2 emissions.

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure INA9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario shown in Figure INA6. It can be seen that the gas share has increased by 9% by 2035, while the coal share has declined by the same amount.

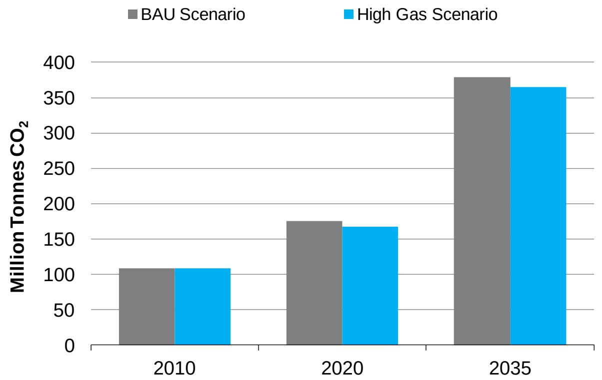
Figure INA9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas has roughly half the CO_2 emissions than coal per unit of electricity generated, this reduces CO_2 emissions in electricity generation by 3.8% in 2035. Figure INA10 shows this CO_2 emission reduction.

Figure INA10: High Gas Scenario –CO_2 Emissions from Electricity Generation



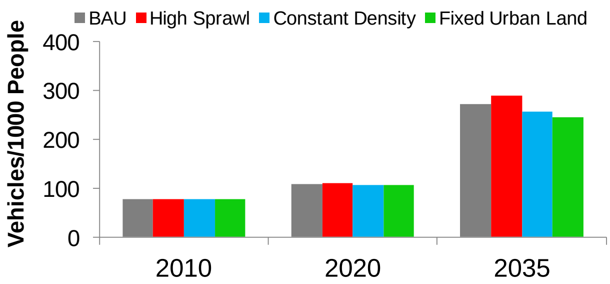
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure INA11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The impact of urban planning on vehicle ownership is relatively small. Since vehicle ownership is well below saturation level, vehicle purchasing will continue to grow almost regardless of urban planning. By 2035, vehicle ownership is about 6% higher in the High Sprawl scenario compared to the BAU, and about 10% lower in the Fixed Urban Land scenario.

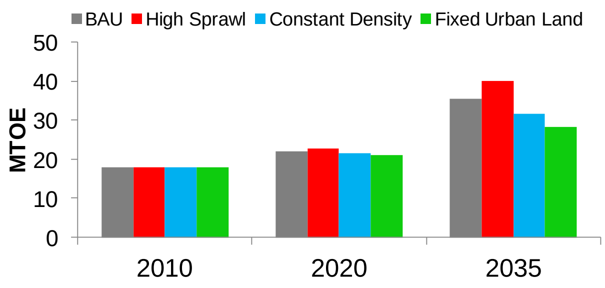
Figure INA11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure INA12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Better urban planning has a more pronounced impact on light vehicle oil consumption than on vehicle ownership because compact cities reduce both the need for vehicles and the distances they must travel. Light vehicle oil consumption would be 13% higher in the High Sprawl scenario compared to BAU in 2035, and about 20% lower in the Fixed Urban Land scenario.

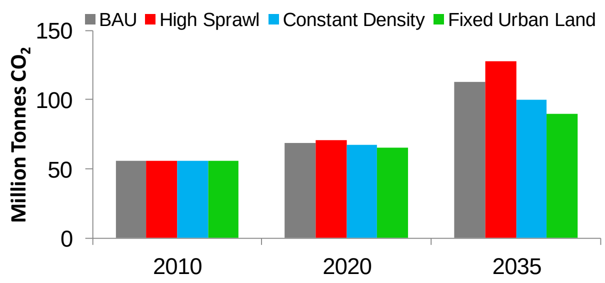
Figure INA12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure INA13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

Figure INA13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



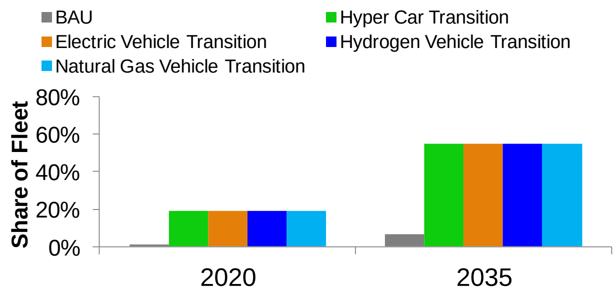
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure INA14 shows the evolution of the vehicle fleet under BAU and the four Virtual Clean Car Race scenarios. By 2035, the share of the alternative vehicles in the fleet reaches around 55% compared to about 6% under BAU. The share of conventional vehicles in the fleet is therefore only about 45%, compared to about 94% in the BAU scenario.

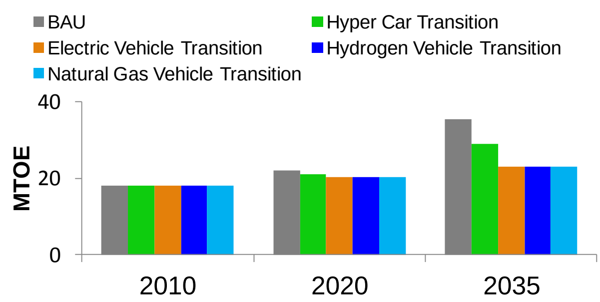
Figure INA14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure INA15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 36% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU in 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 23% by 2035—even though these highly efficient vehicles still use oil.

Figure INA15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

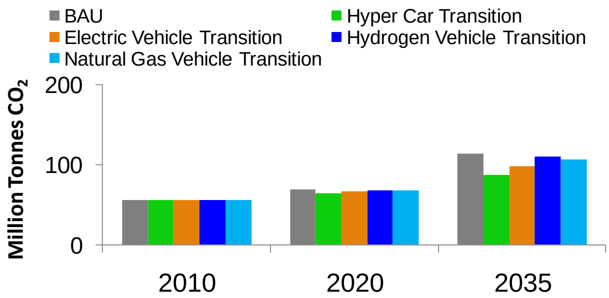
Figure INA16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Indonesia, the Hyper Car Transition scenario is the winner in terms of CO_2 emissions reduction, with an emission reduction of 23% compared to BAU in 2035. The Electric Vehicle Transition, Natural Gas Vehicle Transition and Hydrogen

Vehicle Transition scenarios offer lower emission reductions (13%, 6% and 3% respectively).

Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption. In the other alternative vehicles oil combustion is replaced by other fuels: electricity for electric vehicles, hydrogen for hydrogen vehicles and gas in natural gas vehicles. The additional demand for electricity and hydrogen generation would produce more CO_2 emissions and this offsets some of the benefits gained from oil replacement.

Figure INA16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2011), *APEC Energy Overview 2011 – Indonesia*, www.ieej.or.jp/aperc

Balia, Dr M. Lobo (2011), *Indonesia's National Energy Security Policy*, Presentation for KEEI–ACE Joint Research Workshop 2012, 2 May, http://energy-indonesia.com/03dge/Indonesia's%20National%20Energy%20Security%20Policy.pdf

BAPPENAS (Ministry of National Development Planning) (2010), *Report on the Achievement of the Millennium Development Goals Indonesia 2010*, www.undp.or.id/pubs/docs/MDG 2010 Report Final Full LR.pdf

BP (2012), *BP Statistical Review of World Energy June 2012*, www.bp.com/statisticalreview

BPPT (The Agency for the Assessment and Application Technology) (2011), *Outlook Energi Indonesia 2011: Energi Masa Depan di Sektor Transportasi dan Ketenagalistrikan,* http://perpustakaan.bappenas.go.id/lontar/opac/themes/bappenas4/templateDetail.jsp?id=112479&lokasi=lokal

BPS (Statistics Indonesia) (2012), *Transportation Statistics,* http://dds.bps.go.id/eng/aboutus.php?id_subyek=17&tabel=1&fl=1

CBM Asia (2012), 'CBM Asia Enters Indonesia Coalbed Methane Partnership With Continental Energy Corporation' press release, www.cbmasia.ca/Press-Releases/96

CMEA (Coordinating Ministry for Economic Affairs) (2011), *Masterplan: Acceleration and Expansion of Indonesia Economic Development 2011–2015.*

DGE (Directorate General of Electricity) (2011), *Statistics Book of Electricity and Energy Number 24-2011*, http://www.djlpe.esdm.go.id/modules/_website/files/1049/File/Statistik%202010%20DITJEN%20LISTRIK.pdf

DGNREEC (Directorate General of New Renewable Energy and Energy Conservation) (2012), *Policy Initiatives*, Presentation for Eurocham Green Economy Seminar, 22 March, http://energy-indonesia.com/03dge/POLICY%20INITIATIVE%20Regarding%20Green%20Economy%20Concept_March22%20DJEBTKE%20EuroCham%20JW%20Marriot%20r1.pdf

ESDM (Ministry of Energy and Mineral Resources) (2010), *Joint Decision of Minister of Industry, Minister of Energy and Mineral Resources, Minister of Manpower and Transmigration, Home Affairs Minister, Minister for State-Owned Enterprises No 16 Year 2010,* in Indonesian, http://prokum.esdm.go.id/permen/2010/Permen%20ESDM%2016%202010%20SKB.pdf

— (2011), *Handbook of Energy and Economic Statistics of Indonesia 2011*, http://prokum.esdm.go.id/Publikasi/Handbook%20of%20Energy%20&%20Economic%20Statistics%20of%20Indonesia%20/Handbook%20of%20Energy%20&%20Economic%20Statistics%20ind%202011.pdf

— (2012a), *Decision of Minister of Energy and Mineral Resources No 1 Year 2012*, in Indonesian, http://prokum.esdm.go.id/permen/2012/Permen%20ESDM%2001%202012.pdf

— (2012b), *Decision of Minister of Energy and Mineral Resources No 3135K/08/MEM/2012*, in Indonesian, http://prokum.esdm.go.id/kepmen/2012/Kepmen%20ESDM%203135%202012.pdf

— (2012c), 'Developers of New Generation Capacity Prohibited from Using Oil', in Indonesian, news archive, 18 May, www.esdm.go.id/berita/listrik/39-listrik/5728-pembangkit-listrik-baru-dilarang-gunakan-bbm.html

— (2013), *Decision of President No 9 Year 2013*, in Indonesian, http://prokum.esdm.go.id/perpres/2013/Perpres%209%202013.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

Global LNG Info (2012), *World's LNG Liquefaction Plants and Regassification Terminals*, www.globallnginfo.com/World LNG Plants & Terminals.pdf

Hutagalung, Aldi, with Maarten Arentsen and Jon Lovett (2011), "Regulatory Reform in the Indonesian Natural Gas Market", *Fourth Annual Conference on Competition and Regulation in Network Industries,* 25 November, www.crninet.com/2011/b6a.pdf

IEA (International Energy Agency) (2008), *Energy Policy Review of Indonesia*, http://iea.org/publications/freepublications/publication/Indonesia2008.pdf

— (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

IISD (International Institute for Sustainable Development) (2011), *A Citizen's Guide to Energy Subsidies in Indonesia*, www.iisd.org/gsi/sites/default/files/indonesia_czguide_eng.pdf

— (2012), *Indonesia's Fuel Subsidies: Action Plan for Reform,* March, www.iisd.org/gsi/sites/default/files/ffs_actionplan_indonesia.pdf

Jakarta Globe (2011), 'Oil Years Give Way to Era of Indonesian Natural Gas', 28 February, www.thejakartaglobe.com/business/oil-years-give-way-to-era-of-indonesian-natural-gas/501245

Jakarta Post (2012a), 'Indonesia on the road to becoming Thailand's rival', 24 May, www.thejakartapost.com/news/2012/05/24/indonesia-road-becoming-thailands-rival.html

— (2012b) 'RI–Malaysia electricity line begins construction', 29 September, www.thejakartapost.com/news/2012/09/29/ri-malaysia-electricity-line-begins-construction.html

— (2012c), 'Unemployment Rate in February Reached 6.32 percent', 7 May, www.thejakartapost.com/news/2012/05/07/unemployment-rate-february-reached-632-percent.html

Kuo, Chin S. (2012), *USGS 2010 Mineral Yearbook – The Mineral Industry of Indonesia*, January, http://minerals.usgs.gov/minerals/pubs/country/2010/myb3-2010-id.pdf

Lucarelli, Bart (2010), *The History and Future of Indonesia's Coal Industry: Impact of Politics and Regulatory Framework on Industry Structure and Performance*, Working Paper #93, Frogman Spogli Institute for International Studies, http://iis-db.stanford.edu/pubs/22953/WP_93_Lucarelli_revised_Oct_2010.pdf

MOE (Ministry for Environment) (2010), *Indonesia Second National Communication Under the United Nations Framework Convention on Climate Change (UNFCC)*, Jakarta, November.

MOI (Ministry of Industry) (2011), *Industry Facts and Figures 2011*.

MOT (Ministry of Transportation) (2010), *Transport Information Book,* http://118.97.61.233/pusdatin/images/bit%20english%202011.pdf

OGJ (Oil & Gas Journal) (2011), 'Worldwide Look at Reserves and Production', 5 December.

Oil and Gas Technology (2012), 'Indonesia Pushes for Deep-sea Exploration', 9 May, www.oilandgastechnology.net/upstream/indonesia-pushes-deep-sea-exploration

PGN (State Gas Company) (2012a), 'Natural Gas Transmission' website page, www.pgn.co.id/pages/default/our_operations/transmission/0

— (2012b),+ 'Natural Gas Distribution' website page, www.pgn.co.id/pages/default/our_operations/distribution/0

PWC (PricewaterhouseCoopers) (2011a), *Electricity in Indonesia – Investment and Taxation Guide*, www.pwc.com/id/en/publications/assets/Indonesian-Electricity-Guide_2011.pdf

— (2011b), *Mining in Indonesia – Investment and Taxation Guide,* May, www.pwc.com/id/en/publications/assets/Mining-Investment-And-Taxation-Guide-2011.pdf

— (2011c), *Oil and Gas in Indonesia – Investment and Taxation Guide,* 4th edition, August, www.pwc.com/id/en/publications/assets/Oil_and_Gas_Guide-2011.pdf

Republika Online (2012), 'SBY Keluarkan 5 Kebijakan Hemat Energy Nasional', 29 May, www.republika.co.id/berita/nasional/umum/12/05/29/m4sdc6-sby-keluarkan-5-kebijakan-hemat-energi-nasional

The World Bank (2011), *Transport in Indonesia*, http://go.worldbank.org/PF2AFG64V0

— (2012), *The World Bank Database*, http://data.worldbank.org

UNPD (United Nations Population Division) (2012), *World Urbanization Prospects*, http://esa.un.org/unpd/wup/unup/index_panel3.html

Wall Street Journal (2012), 'Foreign Direct Investment in Indonesia Soars', 20 January, http://online.wsj.com/article/SB10001424052970204616504577170160678124608.html

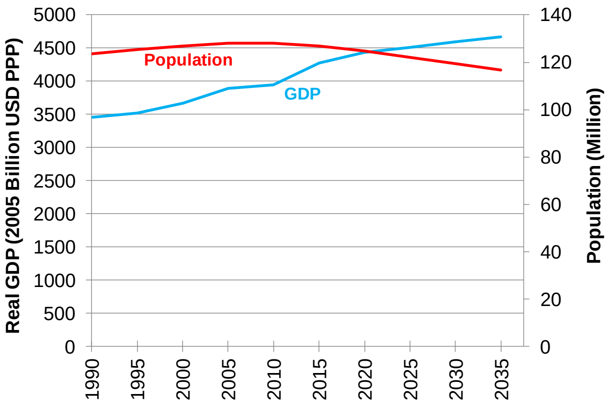
JAPAN

- *Japan's final energy consumption is expected to decrease at 0.6% per year over the outlook period as a result of Japan's slow GDP growth and declining final energy intensity.*
- *The future of nuclear power remains the largest uncertainty in Japan's energy outlook, as Japan has not yet reached a consensus on the role of nuclear power after the accident at the Fukushima Daiichi Nuclear Power Plant in March 2011. This Outlook assumes no new nuclear units are built, and that existing nuclear units will continue to operate, but will be phased out at the end of their 40-year life. The Japanese Government is considering three options for how much nuclear energy will contribute to the power generation mix in 2030, namely 0%, 15% or 20–25%, and has called for public comments on these options.*
- *Japan's CO_2 emissions are expected to decrease at 0.5% per year toward 2035, because of the decrease in final energy consumption and decline of final energy intensity.*

ECONOMY

Japan is located in East Asia and is made up of several thousand islands, the largest of which are Honshu, Hokkaido, Kyushu and Shikoku. It has a land area of about 377 800 square kilometres, most of it mountainous and thickly forested. In 2010 the population was 128.1 million people and the population density was 339.1 people per square kilometre.

Figure JPN1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Japan's population is expected to decrease to 117 million by 2035 (the annual average growth rate is decreasing at 0.4% for the period). In 2010 about 40% of the total population was concentrated in Tokyo Metropolitan Area and Kansai (Osaka, Kobe and Kyoto) Areas. The urbanization rate was 77.3% in 1990 and reached 90.5% in 2010. The urbanization rate is expected to reach 96.3% in 2025 (UN, 2012).

Japan's GDP per capita increased at an annual rate of 0.5% from USD 27 999 (2005 USD PPP) in 1990 to USD 30 807 in 2010. It is expected to increase at an annual rate of 1.1% from USD 30 807 in 2010 to above USD 40 000 in 2035. This low rate of annual growth of GDP can largely be explained by three factors:

- aging population combined with the diminishing number of children (decrease in domestic consumption)
- mature social infrastructure (decrease in domestic investment)
- relocation of production sites overseas by Japanese companies (decrease in export and increase in import).

Japan has diverse regional climates. On the Pacific Coast, summers are often rainy, while winters are generally dry; temperature averages are higher in the southern regions and lower in the north. On the coast of the Japan Sea, there is a lot of heavy snow in winter. In the Okinawa islands, off the coast of Kyushu, the climate is subtropical or tropical, with high temperatures throughout the year. In general, Japan faces heavy demands for electricity in summer (for cooling) and in winter (for heating).

In Japan, the major industries are iron and steel, chemical and petroleum, machinery, and non-metallic minerals. The share of final energy consumption by these four industries is about 65% of the total industry demand in 2009 (IEA, 2011). The iron and steel industry consume mainly coal and electricity, whereas the chemical and petroleum industry consume mainly oil products and electricity. These four major industries are expected to continue to play important roles into the future.

Road transport accounted for 66% of Japan's passenger-kilometres in 2012 (IEEJ, 2012, pp. 130–131). Japan has an extensive network of about 1.3 million kilometres of roads, including about 9000 kilometres of national expressway. Japanese roads are generally paved and well maintained (MLIT, 2012b).

Railways account for an unusually large share of passenger-kilometres at 29% (IEEJ, 2012, pp. 130–131). Japan is well known for its network of 'bullet trains' (*Shinkansen*) that provide high-speed service between major cities. All major Japanese cities have local railway and/or subway systems. Air transport accounts for most of the remaining non-road, non-rail domestic passenger-kilometres.

In freight transportation, road transport accounts for 64% of the tonne-kilometres. Water-based transport, mostly coastal shipping, accounts for another 32%. Japan has 23 'Specially Designated Ports', 105 'Major Ports', and many more small and medium-sized ones (MLIT, 2012a). In contrast to the large role of rail in passenger transport, freight transport by rail accounts for only about 4% of the freight tonne-kilometres (IEEJ, 2012, pp. 130–131).

Almost 99% of the passenger and freight vehicles used in Japan in 2009 were domestically produced. On the other hand, about 55% of the motorcycles in use in 2009 were domestically produced (MLIT, 2010 and MOF, 2010).

ENERGY RESOURCES AND INFRASTRUCTURE

Japan has very limited fossil fuel energy resources. Japan produces coal, crude oil and natural gas on a very small scale compared to its demand. Import dependency in 2009 for coal was 99%, crude oil almost 100%, and natural gas 96% (APEC, 2009).

Japan has no pipeline or electrical connections to other economies. All natural gas is imported in the form of LNG. Japan had 27 LNG receiving terminals as of 2009, with a total storage capacity of 15.09 million kilolitres. This is equivalent to about 9% of the total annual LNG import volumes. Japan will have seven more LNG receiving terminals by 2015 (JIE, 2011).

Japan has confirmed resources of methane hydrates equivalent to 1.1 trillion cubic metres of methane gas (about 1000 Mtoe) in the eastern Nankai Trough area. However, further research will be required before this resource can be developed. Japan started the Methane Hydrate Development Program in 2001 in order to utilize resources in the coastal waters of Japan. The program consists of three phases and will be completed in 2018 (METI, 2001).

Japan generated 1041.0 TWh of electricity in 2009. The sources of electricity generation are: coal 279.5 TWh (26.8%), oil 91.6 TWh (8.8%), gas 284.9 TWh (27.4%), hydro 75.2 TWh (7.2%), new renewable energy 30.0 TWh (2.9%), and nuclear 279.8 TWh (26.9%). Japan had 54 commercial nuclear units with about 49 GW of capacity prior to the Fukushima Nuclear Accident in March 2011 (IEEJ, 2012, p. 208). However, as discussed in the next section, all but two of these units were shut down at the time this Outlook was compiled.

Japan has already developed almost all of the sites suitable for large-scale hydro power plants. Therefore, hydro development must concentrate on sites suitable for small and medium-scale plants.

Japan has significant potential sources of renewable energy. These are as follows (NPU, 2011):

1. *Solar photovoltaic*
   - Residence: 91 GW
   - Non-residence:
     - Public buildings, other commercial and industry: 44 GW
     - Little-used and unused land (e.g. waste disposal sites, transport right-of-ways): 18 GW–39 GW
     - Fields and rice paddies that have been abandoned and are no longer cultivated: 3 GW–104 GW
2. *Wind*
   - Onshore: 290 GW
   - Offshore: 1500 GW
3. *Small and medium-sized hydro*: 20 GW
4. *Geothermal*
   - Hot water resources: 4.3 GW
   - Hot springs: 0.72 GW
5. *Biomass*: 0.73 GW.

There are constraints that may hinder the development of some of these resources. Most geothermal energy resources are in national parks where strict environmental rules and regulations may prevent or severely limit development. Biomass energy development must take into account competition for land with food supply, as well as potential environmental impacts.

ENERGY POLICIES

In 2007, the Japanese Government announced 'Cool Earth 50', a cooperative initiative with major greenhouse gas emitters to reduce worldwide emissions by 50% from current levels by 2050 (METI, 2008a). At the United Nations Summit on Climate Change in September 2009, the Japanese Prime Minister pledged that Japan would cut its greenhouse gas emissions by 25% from 1990 levels by 2020, provided that a fair and effective international framework, in which all major economies participate, had been established.

The Strategic Energy Plan, which was last revised in 2010, aims to fundamentally change the energy supply and demand system. It set these ambitious targets for 2030 (METI, 2010):

1. Doubling the energy self-sufficiency rate (18% in 2010) and the ratio for the self-developed fossil fuel supply (resources developed abroad by Japanese petroleum and gas companies, which were 26% in 2010), thereby raising Japan's 'energy independence ratio' to about 70% (38% in 2010).
2. Raising the ratio of zero-emission power sources (mainly nuclear) to about 70% (34% in 2010).
3. Halving CO_2 emissions from the residential sector.
4. Maintaining and enhancing energy efficiency in the industrial sector at the highest level in the world.
5. Maintaining or obtaining leading shares in global markets for energy-related products and systems.

However, after experiencing the Great East Japan Earthquake and Fukushima Nuclear Accident in March 2011, the Japanese Government decided to review the Strategic Energy Plan. This review process is underway at the time of writing, with the key issue being the share of nuclear power in the power supply mix, as discussed below.

Japan has a Law on the Rational Use of Energy (an energy conservation law). This law requires business organizations (such as manufacturers and service companies) with energy use equivalent to 1500 kilolitres or more per year of crude oil, to report annually on the amounts of energy they consume and to prepare and submit medium-term (3–5 years) plans for the rational use of energy, and to assign responsible people to energy management. The target for reducing energy consumption intensity is 1% or more per year on average over the medium term (APERC, 2011). Japan has no fossil fuel subsidies that would encourage wasteful consumption.

Japan has a Top Runner Program to improve energy efficiency of machinery and equipment. This program sets standard target values for energy-using machinery and equipment, and calls for manufacturers and importers to, on average, meet this standard in their products. Currently, 23 categories of products are designated in the program (APERC, 2011).

Japan's Building Energy Codes define two categories of buildings for their targets: Type 1 House/Building (with floor area of 2000 square metres or more), and Type 2 House/Building (with floor area of 300–2000 square metres). Owners of these types of houses and buildings are required to report their energy conservation measures prior to construction, and afterwards to report the state of maintenance of the house or building to the relevant authority regularly (every three years). For the Type 1 House/Building, penalties may be levied if the building is not able to achieve satisfactory energy performance (APERC, 2011).

In the transport sector, large common carriers (rail, truck, bus, taxi, ship, and air) are required to annually prepare and submit energy conservation plans, as well as an annual report on their energy consumption. Similar rules apply to organizations that privately travel 30 million tonne-kilometres per year of their own freight (APERC, 2011).

Japan has a tax incentive scheme to promote the purchase of energy-efficient equipment. When small and medium-sized companies purchase specified energy-conserving equipment, they are given a tax credit. Companies of all sizes are given a special depreciation allowance on purchase of the specified equipment (APERC, 2011).

Japan has a vehicle-greening tax scheme and an eco-car tax reduction scheme; these provide tax incentives for owners of low-emission and/or high-fuel-efficiency vehicles. At the same time, heavy taxes are levied on older vehicles that are becoming harmful to the environment (APERC 2011).

Japan will grant direct subsidies for several types of efforts promoting energy efficiency:

- to support business operators who introduce 'highly significant' energy-saving facilities
- to introduce high-efficiency energy systems in homes/buildings or building energy management systems (BEMS)
- for research and demonstration projects to develop energy conservation technology (APERC, 2011).

Since Japan has very scarce domestic oil and gas reserves, the Japanese Government has given financial support for oil and gas exploration, development and production outside Japan through the Japan Oil, Gas and Metals National Corporation (JOGMEC). This has taken the form of investment and loan guarantees to project companies. In November 2011 there were 135 Japanese oil and gas companies engaging in exploration and development of crude oil and natural gas in 41 economies. The share of equity crude oil and natural gas to total imports is 23% in 2009 (JPDA, 2011).

Japan has 10 vertically integrated, mainly privately owned General Electricity Utilities, which have traditionally managed generation, transmission and distribution of electricity on a regulated monopoly basis. In addition, Wholesale Electricity Utilities operate large power plants and sell the output to a General Electric Utility. With the gradual liberalization of the Japanese power market since 1995, three new types of firms have entered the market: Wholesale Suppliers such as Independent Power Producers, which sell electricity to a General Electric Utility on a smaller scale than a Wholesale Electric Utility; Power Producers and Suppliers, who sell electricity directly to large customers using a transmission wheeling service provided by a General Electric Utility, and Specified Electricity Utilities which generate, transmit and distribute electricity directly to customers using their own network.

Customers with contract volumes of less than 50 kW are still categorized as 'regulated'. On the other hand, customers with contract volumes of 50 kW or more are categorized as 'de-regulated', and may purchase their electricity from either their General Electric Utility or a Power Producer and Supplier (TEPCO, 2012).

Japanese gas utilities also have historically operated as regulated monopolies. They are mainly privately owned, although some are municipally owned. As with electric utilities, the market has been partially liberalized since 1995 (METI, 2008b). De-regulated gas customers negotiate with gas companies on prices, while regulated customers pay regulated prices. Since 2007, customers with consumption volumes of more than 100 000 cubic metres per year were de-regulated (METI, 2008b).

Japan's Nuclear Energy Policy is currently under review after the Fukushima Nuclear Accident. Over the months after the accident, each of the nuclear units still in operation in Japan was shut down for scheduled inspection—this is required by law at least once every 13 months. After the inspection shutdowns, the companies did not restart operations for two reasons. First, the then Prime Minister Naoto Kan announced the government would carry out additional 'stress tests' for confirming the safety of nuclear power plants. Secondly, the power companies could not easily get agreements to restart from the local governments where the nuclear power plants were located. (Although agreement from the local government is not stipulated in Japanese regulations as a necessary condition for restart of a nuclear power unit, in practice the power companies cannot ignore the will of the local governments.)

By early May 2012, all 50 remaining nuclear power units (four units of the Fukushima Daiichi Nuclear Power Plant were decommissioned in April 2012) had ceased operation; that meant no electricity was being generated from nuclear power. Without nuclear power, there was concern that Japan would experience power shortages and blackouts during the summer of 2012 (from July to September). In July 2012, then Prime Minister Yoshihiko Noda announced the restart of two units of the Ohi Nuclear Power Plant. That decision, along with stringent electricity conservation efforts, allowed Japan to make it through the summer of 2012 without major disruptions to electricity service.

Over the longer term, Japan continues to face much controversy over the future of nuclear power. The Japanese Government is considering three options for how much nuclear energy will contribute to the power generation mix in 2030, namely 0%, 15% or 20–25%, and has called for public comments on these options (EEC, 2012).

In September 2012, a Nuclear Regulation Authority was established with the aim of integrating several nuclear safety authorities, while achieving separation of nuclear safety regulation and nuclear energy promotion. The government has emphasised that the rules regarding the 40-year limitation of the operation of nuclear power plants will be strictly applied (NPU, 2012). This means that unless there is new construction of nuclear power plant units, Japan will phase out all nuclear power by the end of 2049.

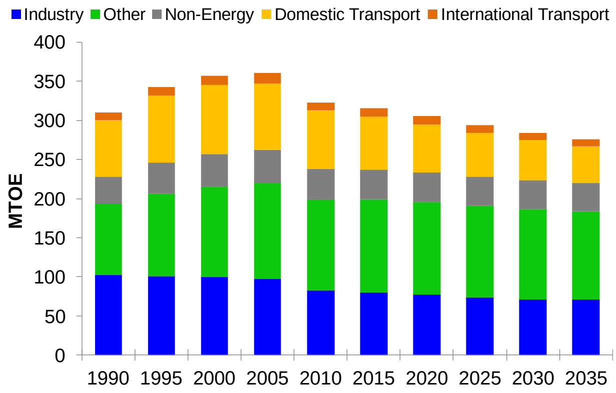
For the purposes of this Outlook, APERC assumed the existing nuclear units would resume operation once current safety reviews were completed, but each unit would be decommissioned at age 40 and there would be no newly built nuclear power units. The net effect of these assumptions is a gradual phase-out of nuclear power in Japan. APERC has also assumed that natural gas, coal and new renewable energy, such as wind, solar, biomass and other, would compensate for the decrease in electricity generation from nuclear energy. The current uncertainty regarding nuclear power is probably the largest uncertainty affecting Japan's business-as-usual energy outlook.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

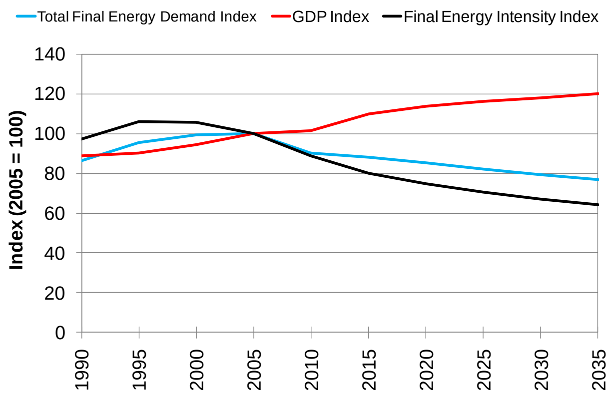
Japan's business-as-usual (BAU) final energy demand is expected to decrease at 0.6% per year over the outlook period (from 323.0 Mtoe in 2010 to 276 Mtoe in 2035). This decrease in final energy demand is caused by the slow growth of Japan's GDP and a decline in final energy intensity. The industry sector's share of the demand is expected to be about the same in 2010 and 2035, roughly 26%. However, the share taken up by the 'other' sector (which includes residential and commercial) is expected to increase from 36% in 2010 to 41% in 2035. The domestic transport share will decrease from 23% in 2010 to 17% in 2035. Final energy intensity is expected to decline by about 36% between 2005 and 2035.

Figure JPN2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure JPN3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Final energy demand in the industrial sector is projected to decrease at 0.6% per year, from 83 Mtoe in 2010 to 71 Mtoe in 2035. Slow GDP growth, relocation of production overseas by Japanese companies and improvement of energy efficiency are the reasons for the decrease.

Transport

Final energy demand in the domestic transport sector is projected to decrease at 1.8% per year, from 75 Mtoe in 2010 to 47 Mtoe in 2035. Improvement in vehicle energy efficiency contributes significantly to the decrease in the final energy demand for transport.

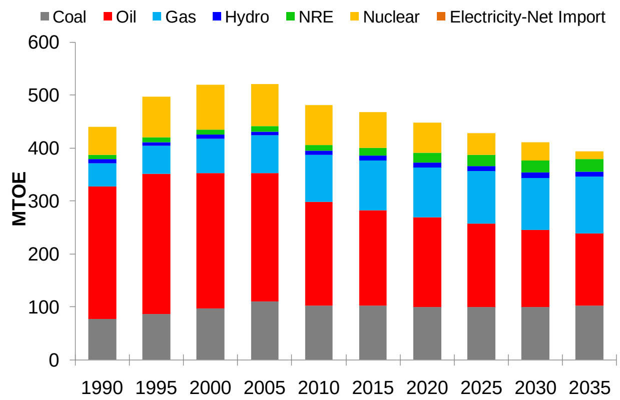
Other

Final energy demand in the 'other' sector is projected to decrease at 0.1% per year, from 115 Mtoe in 2010 to 113 Mtoe in 2035. Growing demand for various convenience appliances and equipment keeps energy demand from declining more quickly in this sector.

PRIMARY ENERGY SUPPLY

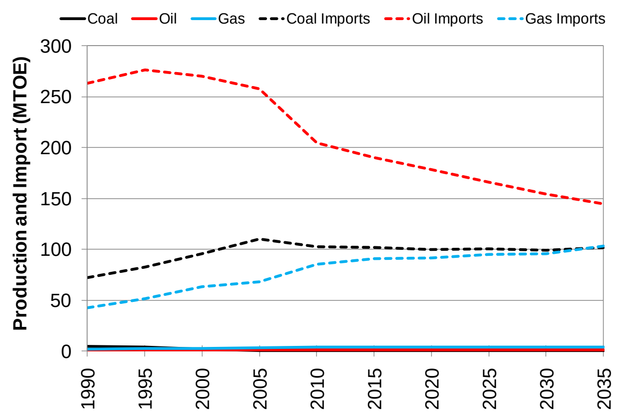
Japan's primary energy supply is projected to decrease at 0.7% per year, from 480 Mtoe in 2010 to 394 Mtoe in 2035. The new renewable share of the primary energy supply is projected to increase at 3.3% per year, while the nuclear share is projected to decrease at 6.2% per year. Fossil fuels (coal, oil and gas) are still expected to maintain a dominant role in the primary energy supply in 2035. Primary energy intensity is expected to decline by about 37% between 2005 and 2035.

Figure JPN4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure JPN5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

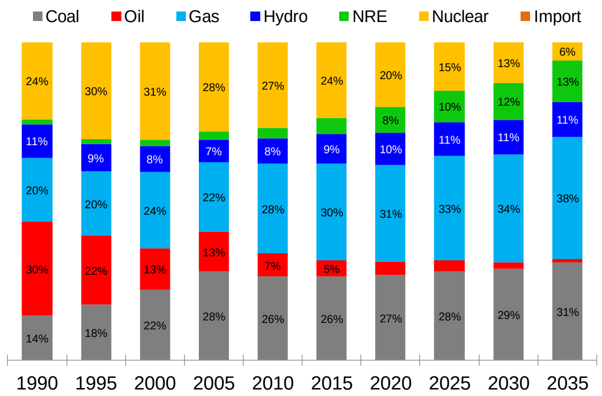
Both oil and gas production in Japan is expected to level off and then remain low throughout the period to 2035. While Japan has reasonable prospects of finding new oil and gas fields domestically, the economy faces depletion (decrease in production) of its existing oil and gas fields, and this would offset any increase in production from new fields.

Japan's net energy imports (coal, oil and gas combined) are projected to decrease at 0.4% per year over the outlook period, reflecting the decrease in the primary energy supply. Japan will continue to seek to import more equity oil and natural gas from overseas.

ELECTRICITY

Japan's BAU electricity generation is expected to decrease from 1071 TWh in 2010 to 1010 TWh in 2035; the average annual rate of this decrease is 0.2%. In 2010, coal, gas and nuclear are the main sources for electricity generation mix. Their share is 26%, 28% and 27% respectively. As discussed earlier, the share of nuclear is expected to decrease to 13% by 2035, while the share of coal and gas is expected to increase to 31% and 38%, respectively in 2035. The share of new renewable energy is expected to increase from 3% in 2010 to 13% in 2035.

Figure JPN6: BAU Electricity Generation Mix

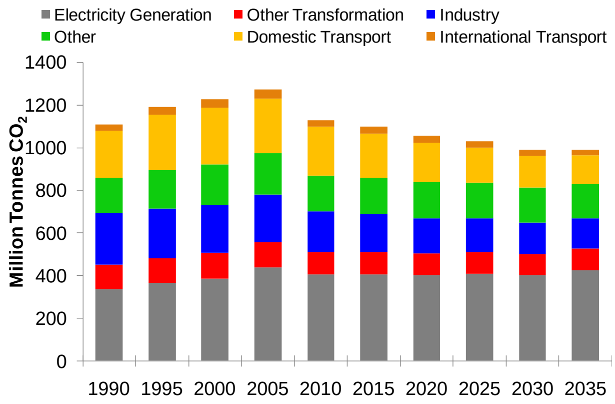


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Japan's BAU CO_2 emissions are projected to decrease at 0.5% per year, from about 1130 million tonnes of CO_2 in 2010 to 990 million tonnes of CO_2 in 2035. The decrease in the economy's final energy consumption and decline of final energy intensity are the main reasons for the decrease in CO_2 emissions.

Figure JPN7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

As shown in Table JPN1, Japan's 2010–2035 change in CO_2 emissions will be driven by a 1.5% per year reduction in the energy intensity of GDP (improvements in energy efficiency and a shift toward less energy-intensive industry). This reduction will be offset by 0.7% per year growth in GDP and a 0.3% per year growth in the CO_2 intensity of energy (declining use of nuclear power). The net result will be a 0.5% per year decline in CO_2 emissions.

Table JPN1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.2%	-0.7%	0.0%	0.1%	0.3%
Change in Energy Intensity of GDP	0.4%	-2.0%	-1.6%	-1.5%	-1.5%
Change in GDP	0.8%	0.3%	0.7%	0.6%	0.7%
Total Change	0.9%	-2.4%	-1.0%	-0.8%	-0.5%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Japan has scarce domestic energy resources and is highly dependent on imported energy. Although the economy's primary energy supply is expected to decrease between 2010 and 2035, the share of its energy supply coming from fossil fuels (coal, oil and gas combined) is expected to increase throughout the outlook period (80% in 2010 and 88% in 2035). Ensuring access to secure energy resources (including equity crude oil and natural gas) remains one of the most important challenges for Japan in this period. This challenge is compounded by the forecast reduction under BAU in the contribution of nuclear energy to electricity generation—from 27% in 2010 to 6% in 2035. This decrease in nuclear use for electricity generation raises concerns for both Japan's economic development and its environmental sustainability (in terms of CO_2 emissions). To pursue the best mix of energy resources will be a key focus for Japan.

ALTERNATIVE SCENARIOS

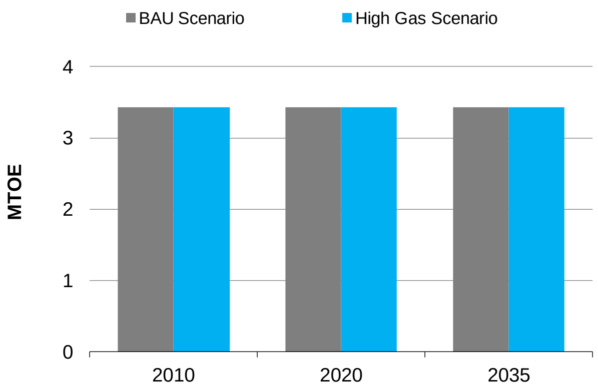
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU case prices or below, if constraints on gas production and trade could be reduced.

In the High Gas Scenario, no change was assumed in Japan's minimal domestic production, as shown in Figure JPN8.

Figure JPN8: High Gas Scenario – Gas Production

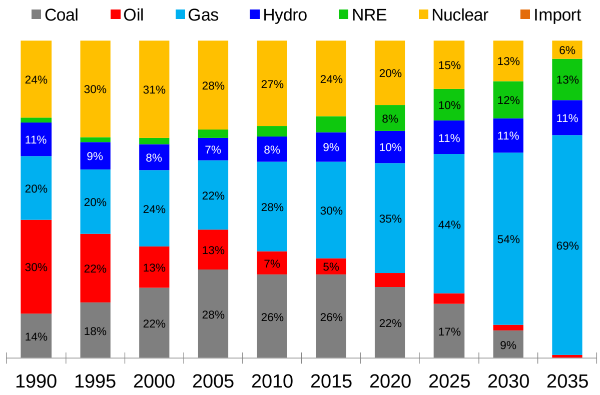


Source: APERC Analysis (2012)

However, under the High Gas Scenario, Japan would be able to import additional volumes of gas from other APEC economies at prices at or below BAU levels. Specifically, imports of gas would be up by 12% in 2020, by 25% in 2025, by 45% in 2030, and by 58% in 2035, compared to BAU. Japan would be importing an additional 49 Mtoe by 2035. It is assumed that Japan would use all of the additional gas imports for electricity generation, and that it would all be imported as LNG.

Figure JPN9 shows the High Gas Scenario Electricity Generation Mix. This graph may be compared with the BAU scenario shown in Figure JPN6. It can be seen that the gas share in 2035 has increased from 38% to 69%, while the coal share has declined from 31% to nil. So, under this scenario, Japan would be able to eliminate all of its coal-fired generation by 2035.

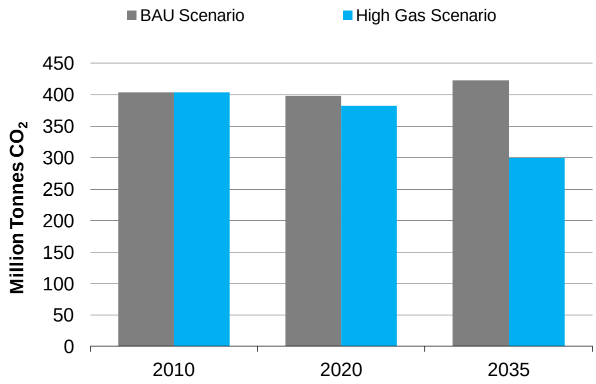
Figure JPN9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas has roughly half the CO_2 emissions per unit of electricity generated that coal has, this would have the impact of reducing CO_2 emissions from electricity generation by 30% by 2035. Figure JPN10 shows this CO_2 emissions reduction.

Figure JPN10: High Gas Scenario – CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

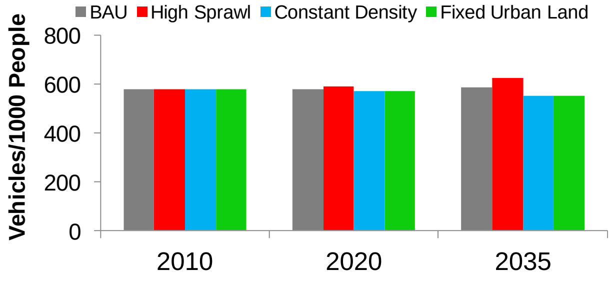
ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Since Japanese cities tend to be quite compact, and are unlikely to drop below the critical density at which transport energy demand starts to rise quickly under any scenario, the impact of better urban planning in Japan is fairly small.

Figure JPN11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. In the High Sprawl scenario, vehicle ownership is expected to be higher than in BAU by 7% in 2035. On the other hand, in both the Constant Density and Fixed Urban Land scenarios, vehicle ownership is expected to be smaller than in BAU by 6% in 2035.

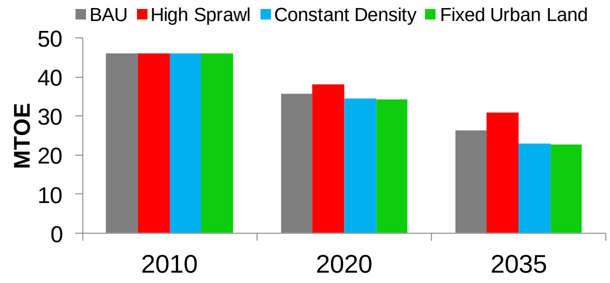
Figure JPN11: Urban Development Scenarios –Vehicle Ownership



Source: APERC Analysis (2012)

Figure JPN12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of urban planning is moderate, but still significant. In the High Sprawl scenario, light vehicle oil consumption is expected to be 17% higher than BAU in 2035. On the other hand, in the Constant Density and Fixed Urban Land scenarios, light vehicle oil consumption is expected to be smaller than BAU, by 13% and 14% respectively.

Figure JPN12: Urban Development Scenarios – Light Vehicle Oil Consumption

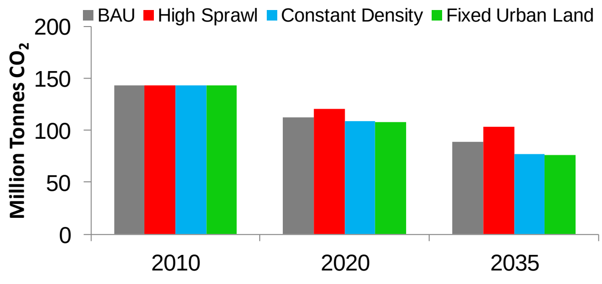


Source: APERC Analysis (2012)

Figure JPN13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

In the High Sprawl scenario, the figure for CO_2 emissions is 17% larger than BAU in 2035, whereas in the Constant Density and Fixed Urban Land scenarios, CO_2 emissions are smaller than BAU, by 13% and 14% respectively.

Figure JPN13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



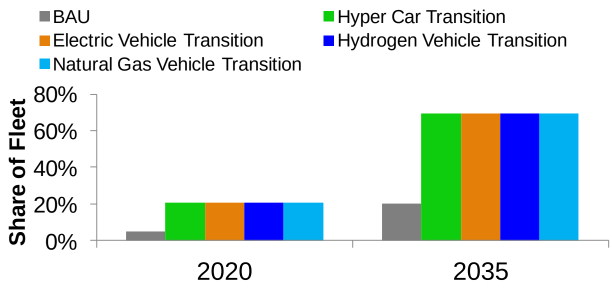
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure JPN14 shows the evolution of the light vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035, the share of alternative vehicles in the fleet is assumed to reach 69%, compared to about 20% under BAU. The share of conventional vehicles in the fleet is thus only about 31%, compared to about 80% in the BAU scenario.

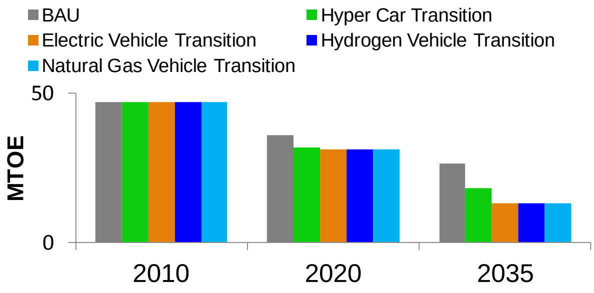
Figure JPN14: Virtual Clean Car Race – Shares of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

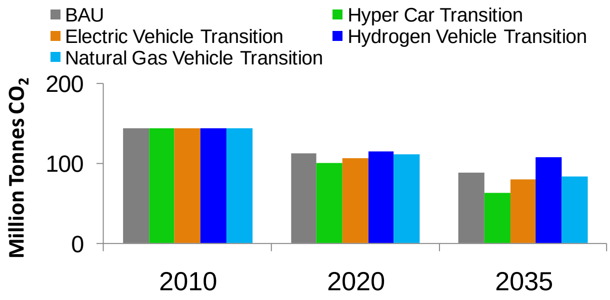
Figure JPN15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 51% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 31% by 2035, even though these highly efficient vehicles still use oil.

Figure JPN15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure JPN16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

Figure JPN16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impact of each scenario may differ significantly from their oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Japan, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reduction, with an emission reduction of 29% compared to BAU in 2035. The Electric Vehicle Transition scenario would also reduce emissions, but only by about 10% compared to BAU in 2035. The Electric Vehicle Transition scenario does not do as well as the Hyper Car Transition scenario in Japan because coal-fired generation is assumed to be the marginal source for much of the additional electricity required by the electric vehicles. The Natural Gas Vehicle Transition scenario would reduce emissions in 2035 by only 5%, reflecting the advances in conventional vehicle technology that are expected in Japan.

In contrast, the Hydrogen Vehicle Transition scenario would actually increase emissions by 21%, compared to BAU. This is mainly due to the way hydrogen is assumed to be produced—from steam methane reforming of gas, a process that involves significant CO_2 emissions.

REFERENCES

APEC (Asia–Pacific Economic Cooperation) (2009), *APEC Energy Statistics 2009,* October 2011, www.ieej.or.jp/egeda/database/

APERC (Asia Pacific Energy Research Centre) (2011), *Compendium of Energy Efficiency Policies of APEC Economies 2011*, www.ieej.or.jp/aperc/CEEP2011.html

EEC (Energy and Environment Council, Japan) (2012), *Options for Energy and the Environment: The Energy and Environment Council Decision on June 29, 2012*, www.npu.go.jp/policy/policy09/pdf/20120720/20120720_en.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

IEEJ (Institute for Energy Economics, Japan) (2012), *Handbook of Energy & Economic Statistics in Japan 2012*, Published by the Energy Data and Modelling Centre, Tokyo.

JIE (The Japan Institute of Energy) (2011), *Recommendations for Natural Gas Pipeline*, in Japanese. Published by Japan Industrial Publishing Co. Ltd.

JPDA (Japan Petroleum Development Association) (2011), *Data of Petroleum and Natural Gas Development*, in Japanese. Published by K.K. Sekiyu Tsushinsha.

METI (Ministry of Economy, Trade and Industry, Japan) (2001), *Methane Hydrate Development Plan*, www.eti.go.jp/topic/downloadfiles/e20205bj.pdf

— (2008a), *Cool Earth – Innovative Energy Technology Program*, www.meti.go.jp/english/newtopics/data/pdf/031320CoolEarth.pdf

— (2008b), 'The Status Quo of Gas Business Institution' website page, in Japanese, www.enecho.meti.go.jp/gasHP/genjo/index.html

— (2010), *The Strategic Energy Plan of Japan – Meeting Global Challenges and Securing Energy Futures,* www.meti.go.jp/english/press/data/pdf/20100618_08a.pdf

MLIT (Ministry of Land, Infrastructure and Transport, Japan) (2010), *Monthly Statistics on Automobile Transportation*, in Japanese.

— (2012a), *Specially Designated Port (23 ports)*, www.mlit.go.jp/kisha/kisha03/11/110319_2/110319_2_1.pdf

— (2012b), 'What is the total length of road in Japan?' website page, Road Bureau, www.mlit.go.jp/road/soudan/soudan_10b_01.html

MOF (Ministry of Finance, Japan) (2010), *Japan Exports & Imports: Commodity by Country*, published by Japan Tariff Association.

NPU (National Policy Unit, Japan) (2011), *Overview of Difference in Potential Survey on Power Generation Capacity using Renewable Energy by Each Ministry*, in Japanese, www.npu.go.jp/policy/policy09/pdf/20111221/hokoku_sankou3.pdf

— (2012), *Innovative Strategy for Energy and the Environment*, www.npu.go.jp/policy/policy06/pdf/20121004.en2.pdf

TEPCO (Tokyo Electric Power Company) (2012), 'The Electric Power Business in Japan', website page, www.tepco.co.jp/en/corpinfo/ir/kojin/jigyou-e.html

UN (United Nations, Department of Economic and Social Affairs Population Division, Population Estimates and Projections Sector) (2012), 'On-line Data: Country Profiles – Japan' website page, http://esa.un.org/unpd/wup/unup/index_panel3.html

KOREA

- *Korea's primary energy supply is projected to grow at an average annual rate of 0.5%, from 229 Mtoe in 2009 to 270 Mtoe in 2035.*
- *Energy demand growth will slow over the outlook period as a result of Korea's population growth tailing off and of the continued structural change in the economy toward less energy-intensive industries.*
- *The shift in Korea's energy policy toward sustainable development is expected to facilitate the replacement of oil with renewable and nuclear energies, improvements in energy efficiency, and the optimal diversification of the economy's energy supply.*

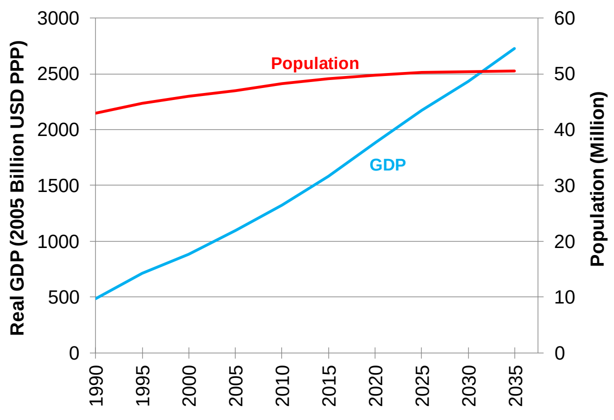
ECONOMY

The Republic of Korea is located in North-East Asia between China and Japan. The economy's geography is largely made up of hills and mountains, with wide coastal plains in the west and the south. The climate is relatively moderate with four distinct seasons. Air conditioning is commonly necessary during the tropical hot summers and buildings need to be heated during the bitterly cold winters.

Since the 1990s, Korea has been one of Asia's fastest growing and most dynamic economies. Gross domestic product (GDP) increased at a rate of 5.1% per year from 1990 to 2009, reaching USD 1244 billion (in 2005 USD PPP) in 2009. Per capita income in 2009 was USD 25 941, more than four times higher than it was in 1990 (Global Insight, 2012).

Korea's major industries include the semiconductor, shipbuilding, steel, automobile, petrochemicals, digital electronics, machinery, parts and materials industries.

Figure ROK1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Korea's population in 2009 was around 48 million people. The economy had an urbanization rate of 80% in 2010. Korea's population density is very high, with an average of more than 480 people per square kilometre. More than 20% of the population lives in Seoul, Korea's capital and its largest city.

The economy's population is projected to grow at an average annual rate of 0.2% during the outlook period and to exceed 50 million people by 2020. The projection for the period 2020 to 2030 is for no population growth (KOSIS, 2012). In addition, Korea's population is ageing rapidly. After 2030, 24% of the population will be over the age of 65 years—a substantial increase from 9% in 2005 (KOSIS, 2012). The effect of these population changes on the size and composition of the labour force will have an impact on future economic growth.

The fast development of Korea's economy was based on a world class public transport system.

There are eight international and six domestic airports connecting Korean cities with almost anywhere in the world. The Incheon Airport hub consolidates Korea's position as one of the main Asian aviation transport centres.

Since 2004, Korea's KTX high speed trains have connected the economy's main cities, and almost all its towns are served by regional bus services. Six of Korea's major cities have subway systems and, in combination with extensive city bus systems, they make getting around the economy's cities easy and cost effective.

Korea has the world's largest ship building industry and it is host to a vast system of ferry and cargo services to the public. There are four major ports in Korea: Incheon, Mokpo, Pohang and Busan.

The total length of Korea's roads in 2009 was 104.9 thousand kilometres (km), 79% of which was paved. The economy had 3776 km of highways connecting its major cities (KAMA, 2012). Further development of highways is planned to overcome the congestion around the economy's big cities due to the high rates of private vehicle ownership.

In 2011, Korea was in the global top five for motor vehicle production. The economy maintained its fifth place following China, Japan, the United States (US) and Germany. Vehicle production in 2011 hit a new record of 4.6 million units. Domestic vehicle sales were over 1.4 million units (including imported vehicles) in 2011 and the total number of registered vehicles in Korea reached 18.4 million units. Most of these were passenger cars (76.6%), 17.5% were trucks, 5.5% were buses, and 0.4% were other vehicles. Under a business-as-usual scenario, the number of registered vehicles in Korea will increase by 0.5–1% annually and by 2035 there will be around 23 million units (KAMA, 2012).

ENERGY RESOURCES AND INFRASTRUCTURE

Korea has few indigenous energy resources. To sustain its high level of economic growth, Korea imports large quantities of energy products. The economy imported 86% of its primary energy supply in 2009 on a net basis. By the end of the outlook period in 2035, Korea will import 72% of its primary energy supply on a net basis with long-term stategy aimed to promote nuclear and NRE energy.

The economy has no oil resources. Korea's total reliance on oil imports has led to a policy of securing its oil supply by long-term contracts (about 70% of supply), spot oil transactions and overseas development.

Korea's refining industry is efficient. It had a combined crude refining capacity of about 2.8 million barrels per day in 2012.

Korea has 3 billion cubic metres of offshore natural gas reserves. This allows the production of a small amount of natural gas, satisfying only about 2% of the annual demand. Korea will continue to rely on imported LNG (liquefied natural gas) for most of its natural gas consumption. LNG imported through the Korea Gas Corporation's (KOGAS's) existing terminals in Pyongtaek, Incheon and Tongyeong will continue to be the economy's main source of natural gas used as city gas and in electricity generation. A pipeline to provide a natural gas supply from Russia is under negotiation and may be introduced after 2016.

There are 326 million tonnes of recoverable coal reserves, mainly anthracite. Existing production capacities allow the production of only 2–2.5 million tonnes of anthracite annually or about 3% of Korea's coal demand in 2010. Korea imports all its bituminous coal (KEEI, 2012).

Given these limited indigenous energy resources, Korea uses a combination of thermal (oil, natural gas and coal), nuclear and hydro electricity generation capacities, and the facility mix has not changed much since the 1990s.

Nuclear energy has retained a high share (around 35%) of the power generation mix over the last two decades. Under a business-as-usual scenario, this is expected to increase to about 49% over the outlook period in response to climate change and energy security pressures.

New and renewable energy (NRE) sources have been widely introduced in Korea and the shares of those power sources will expand during the outlook period. Solar energy will expand for use in the residential sector, mostly for the production of hot water. Bioenergy will continue to be the largest NRE source in Korea. Bio gases will be used for electricity generation and heat production, and biodiesel will be widely used for transportation. There will be an increasing trend to use wind and geothermal energy, due to technology developments and the government's active support.

The economy-wide multi-loop electricity transmission grid has a high reliability, and Korea plans to accelerate the construction of new 765 kV large capacity transmission systems.

Korea's district heating market has expanded steadily, with about 13% of Korean households using it in 2010 (KEEI, 2012). The economy has ambitious plans for the expansion of district heating through its planning policy and tax incentives.

ENERGY POLICIES

In the past, Korea's energy policy focused on ensuring a stable energy supply to sustain economic growth. The government is now seeking a new direction in energy policy to support sustainable development that fully considers the 3Es (energy, economy and environment).

The responsibility for energy policy development and its implementation is divided between a number of government institutions. The Ministry of Knowledge Economy (MKE) is the primary government body for energy policy.

In August 2008, faced with high energy prices and rising concerns over climate change, Korea announced a long-term strategy that will determine the direction of its energy policy until 2035. The strategy suggests the orientation of energy policy towards a vision of Low Carbon, Green Growth.

The primary goals are to improve energy intensity by 47%, and to reduce the economy's dependence on fossil fuels based on the policy of Green Growth.

The nuclear industry is viewed as a realistic alternative to reduce import dependency and to improve greenhouse gas emissions. The government will need to strengthen international cooperation in safety measures and to increase social acceptance of nuclear energy power generation if it is to push forward its plans in a post-Fukushima environment.

The Korea Government plans to expand the share of NRE in the total primary energy supply from 2.2% in 2008 to 11–12% by 2030, focusing on solar, wind and bioenergy resources. It will do this by directly investing in R&D and NRE facilities construction and by providing incentives for businesses participating in NRE development (KEEI, 2012).

Heavy dependence on the Middle East for its crude oil supply has led the economy to a policy of diversifying its oil supply during the outlook period. The state-owned Korea National Oil Corporation (KNOC) will continue to be responsible for the economy's preparedness for an oil emergency situation by operating oil stockpiling facilities and pursuing stakes in oil projects around the world.

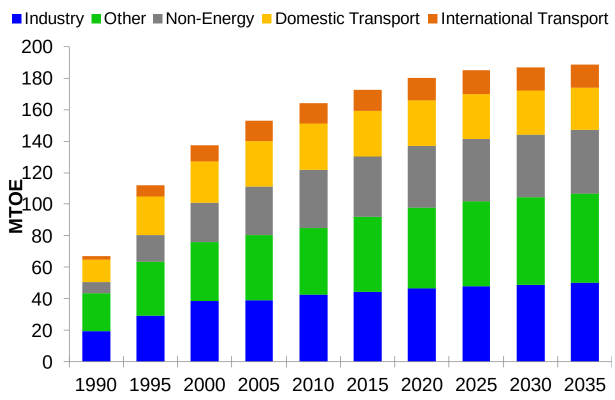
In the natural gas industry, the state-owned monopoly KOGAS will continue to be responsible for managing the import, storage, transmission and wholesale distribution of LNG. The electricity industry will continue to be dominated by the state-owned Korea Electric Power Corporation (KEPCO). It is possible there may be stages of restructuring and liberalization over the outlook period, allowing more private participation in the oil, gas and electricity industries.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Korea's total final energy demand is projected to grow at an average annual rate of 0.6% over the outlook period, led by the residential and commercial sectors.

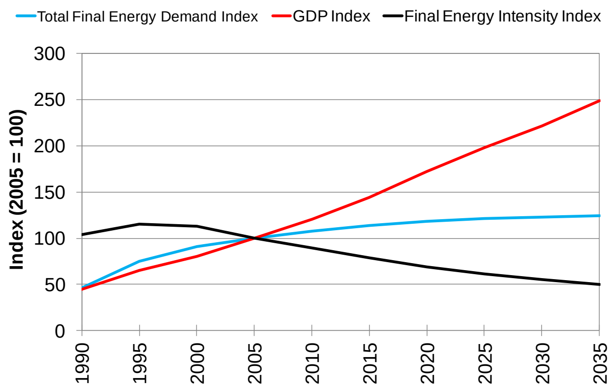
Figure ROK2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to decline by about 50% between 2005 and 2035.

Figure ROK3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 0.6% from 2010 to 2035. Electricity is the dominant energy source for the industry sector, although the sector's demand for natural gas is projected to increase substantially.

Transport

The domestic transport sector's final energy demand is projected to decline at an average annual rate of 0.3% over the outlook period. This is mainly because vehicle ownership is expected to level off as economic growth slows and as population growth begins to decline after 2018.

Well-developed public transport systems (such as subway and bus services), especially in Seoul, will also help to slow the growth in transport energy demand.

The international transport sector's final energy demand, however, will increase at an average annual rate of 0.6%, as Korea's airports provide an increasing number of international aviation services.

Other

The final energy demand in the 'other' sector, which includes commercial and residential users, is projected to increase at an average annual rate of 1.2% over the outlook period. The increased demand is based on an expected growth in high-value-added commerce within the commercial subsector.

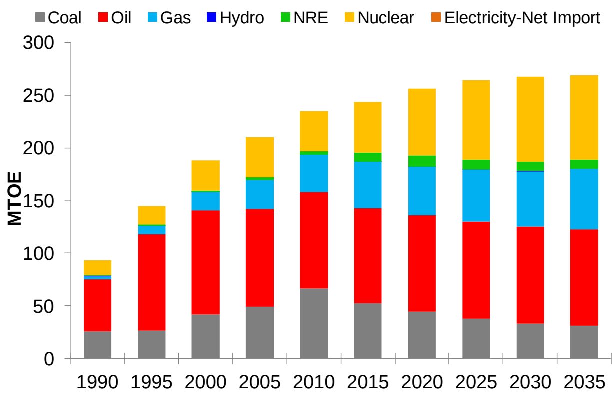
Electricity demand is expected to grow at an average annual rate of 1.6%. Demand will be driven by the spread of air conditioning and the introduction of a wider range of electrical appliances. It will be offset by the expected peaking of population growth.

Natural gas is expected to increase at an average annual rate of 0.7%. This will be driven by an increase in the demand for city gas, although that itself is expected to slow down over the outlook period compared with the growth witnessed from 1990 to 2010. That slowdown will be because the expansion of the trunk pipeline network is almost completed.

PRIMARY ENERGY SUPPLY

Korea's primary energy supply is projected to grow at an average annual rate of 0.5% over the outlook period. This growth rate is much lower than the growth rate of 5.6% between 1990 and 2005. The projected lower growth rate will be due to energy efficiency improvements and limited population growth.

Figure ROK4: BAU Primary Energy Supply

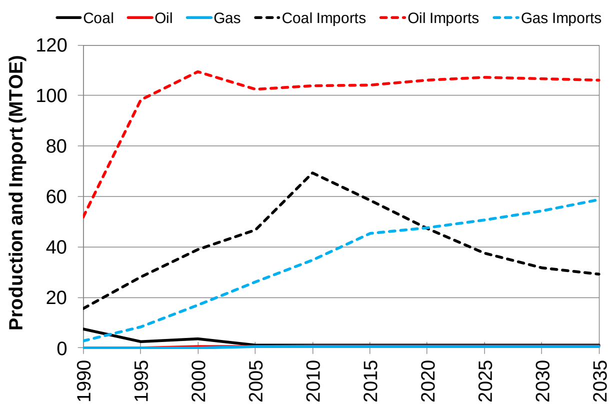


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Oil is expected to remain the dominant energy source through to 2035 but its share will stay constant at around 36%. About half of the oil demand will be for non-energy use by 2035. At the same time, natural gas is projected to increase its share from 14% in 2010 to 23% by 2035; it will grow at an average annual rate of 2.2%. Renewable energy is estimated to grow at a high average annual rate of 5% from 2010 to 2020, and at 2–3% from 2020 onwards, as a result of efforts to diversify energy resources to improve the economy's energy security. However, its share will continue to be small.

Korea will continue to import large quantities of energy products. By 2035, oil imports will be 105 million tonnes of oil equivalent (Mtoe), which is similar to the 2010 level, and natural gas 60 Mtoe. Securing a stable supply of oil and natural gas will be the main energy agenda for Korea over the outlook period. Coal imports will decline, mainly due to the ecological restriction on the use of coal for power generation.

Figure ROK5: BAU Energy Production and Net Imports



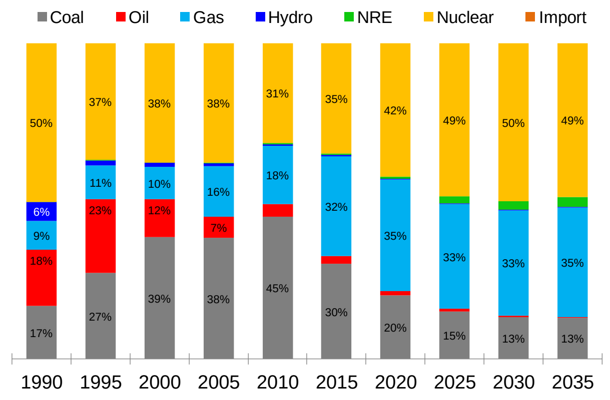
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

Korea's electricity demand is projected to grow at an average annual rate of 1.1% over the outlook period. This is much lower than the 9.3% annual growth recorded between 1990 and 2005. More than half of this demand growth is expected to come from the 'other' sector, followed by the industry sector.

The electricity generation mix is expected to change slightly if the government's 2008 long-term strategy is followed. The nuclear share will expand to 49% by 2035 from 31% in 2010, while oil will account for less than 1% (a substantial decrease from its 7% share in 2005). At the same time, natural gas is projected to increase from 18% in 2010 to 35% of the mix in 2035. Renewable energy is expected to grow the fastest, at an average annual rate of 8%, although its share will be less than 5% in 2035. There are no plans for the further development of hydro power in Korea due to a lack of suitable locations.

Figure ROK6: BAU Electricity Generation Mix

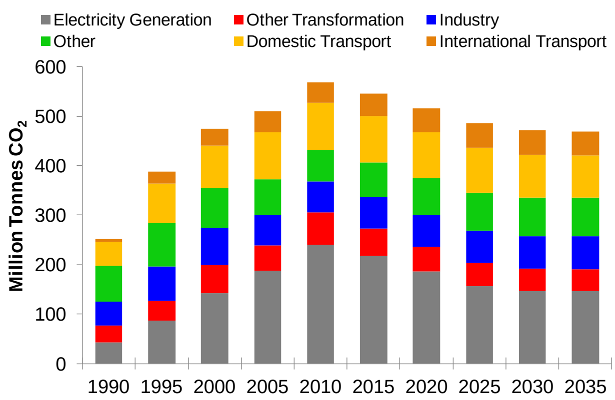


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Korea's CO_2 emissions are estimated to decline by 18% over the outlook period, from 570 million tonnes of CO_2 in 2010 to 470 million tonnes of CO_2 by 2035. This is because natural gas and nuclear energy are expected to increase their shares in the electricity generation mix by 2035.

Figure ROK7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

From the decomposition analysis shown in Table ROK1, it can be seen that economic growth underlies Korea's CO_2 emissions increase through the outlook period. This will be offset by a change in energy intensity (energy efficiency) and carbon intensity (fuel switching).

Table ROK1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-2.6%	10.3%	0.6%	0.5%	-1.4%
Change in Energy Intensity of GDP	0.0%	-2.0%	-2.2%	-2.2%	-2.3%
Change in GDP	5.5%	3.8%	3.2%	3.1%	2.9%
Total Change	2.8%	12.3%	1.6%	1.3%	-0.8%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Korea's energy policy shift towards sustainable development is expected to be maintained through to 2035. However, the achievement of a cleaner energy supply for the economy is less certain.

The expansion of nuclear energy power generation may not progress as planned, due to public opposition. Even though there is a good understanding of the importance of nuclear energy by the Korean public, the acceptance of a new power plant at a local level can still be a significant barrier. Delays in nuclear energy power plant construction may result in other energy sources being retained for power generation.

Furthermore, the achievement of the government's target for increasing renewable energy's contribution to the primary energy supply (11% after 2030) is also uncertain. Strong and constant government support for the efforts to increase renewable energy use will be essential if the target is to be achieved.

Energy security will remain a critical issue for any economy such as Korea that relies on imports for most of its energy resources. Even with an expanded share of the primary energy supply coming from nuclear and renewable sources, the projected continuing emphasis on coal for electricity generation, oil for transport use and LNG in the residential sector will leave Korea importing the majority of its energy resources. It is therefore assumed Korea will experience significant challenges in its efforts to better secure its energy supply.

ALTERNATIVE SCENARIOS

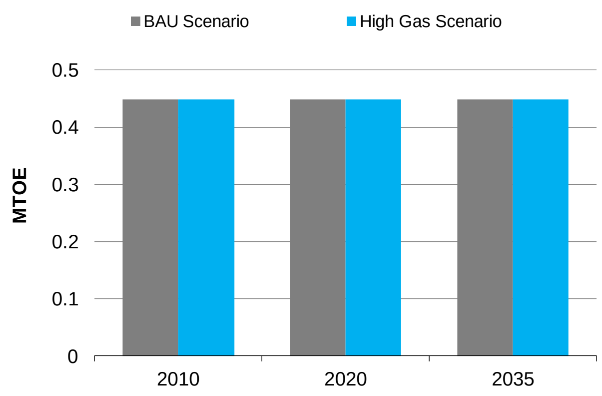
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies, including the Republic of Korea.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Korea assumed the production levels would be kept constant at 0.45 Mtoe, as shown in Figure ROK8, through to 2035. The High Gas Scenario assumption primarily removes the import restrictions, including for the possible pipeline supply from the Russian Federation.

Figure ROK8: High Gas Scenario – Gas Production

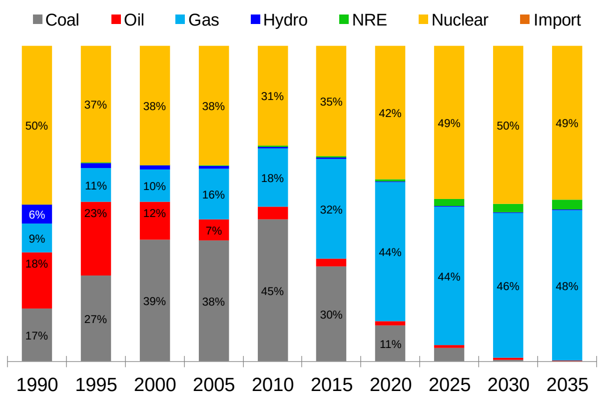


Source: APERC Analysis (2012)

Additional gas consumption in Korea in the High Gas Scenario will depend on the gas market situation in the APEC region. In a high gas availability situation, additional gas will be used to totally replace coal in electricity generation by 2035.

Figure ROK9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU case graph shown in Figure ROK6. It can be seen that the gas share has increased by 13% by 2035, while the coal share has declined from 13% to zero.

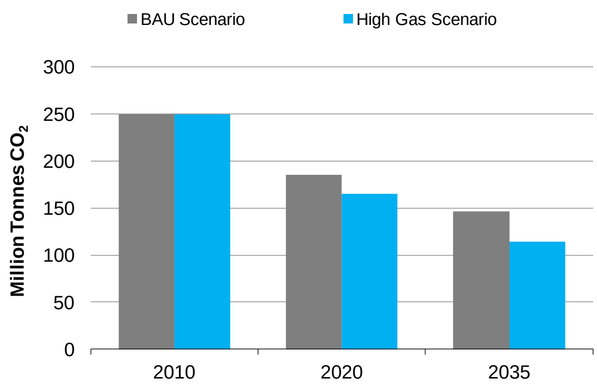
Figure ROK9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas has roughly half the CO_2 emissions of coal per unit of electricity generated, this had the impact of reducing CO_2 emissions in electricity generation by 21% by 2035. Figure ROK10 shows this CO_2 emissions reduction.

Figure ROK10: High Gas Scenario – CO_2 Emissions from Electricity Generation



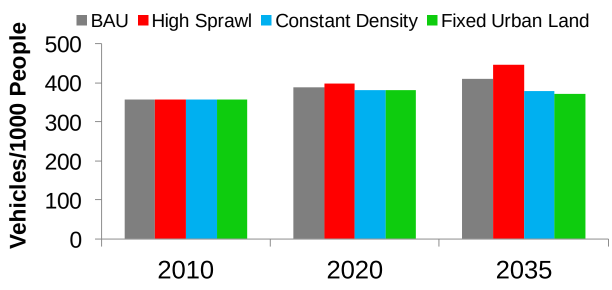
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure ROK11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Urban planning has a direct effect on the expected level of vehicle saturation on long-term vehicle ownership. Since vehicle ownership is near saturation in Korea, the impact of a change in urban planning on vehicle ownership for large Korean cities like Seoul, Busan and Daegu is significant.

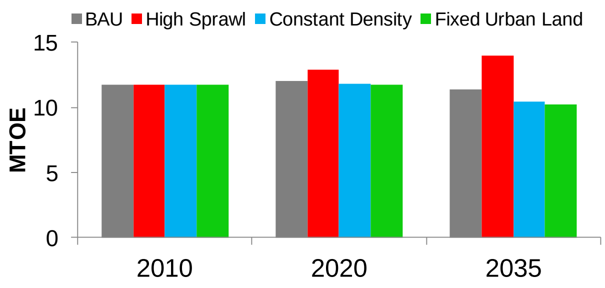
Figure ROK11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure ROK12 shows the change in light vehicle fleet oil consumption under BAU and the three alternative urban development scenarios. The impact on oil consumption from the change in the size of the light vehicle fleet is compounded by the change in the distance travelled per vehicle. In compact cities, modelled by the Fixed Urban Land scenario, travel distances per vehicle are typically lower than in sprawling cities modelled by the High Sprawl scenario. As a result, light vehicle oil consumption would be 23% higher in the High Sprawl scenario compared to BAU in 2035, and about 9% and 10% lower in the Constant Density and Fixed Urban Land scenarios respectively.

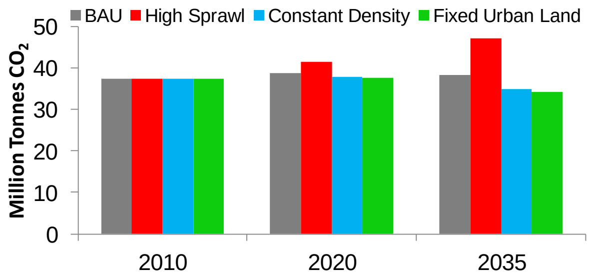
Figure ROK12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure ROK13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

Figure ROK13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



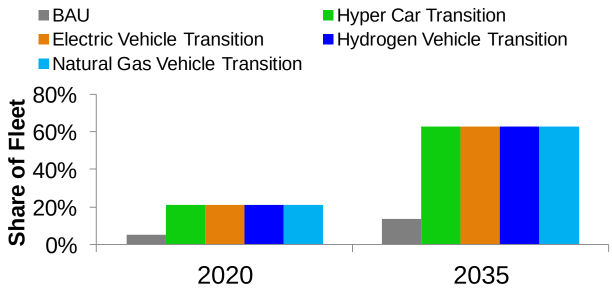
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure ROK14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60% compared to about 10% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 90% in the BAU scenario.

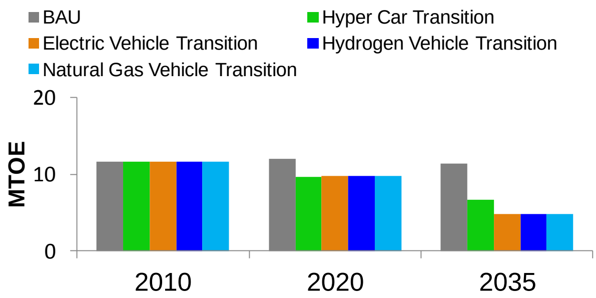
Figure ROK14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure ROK15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 53% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—30% by 2035—even though these highly-efficient vehicles still use oil.

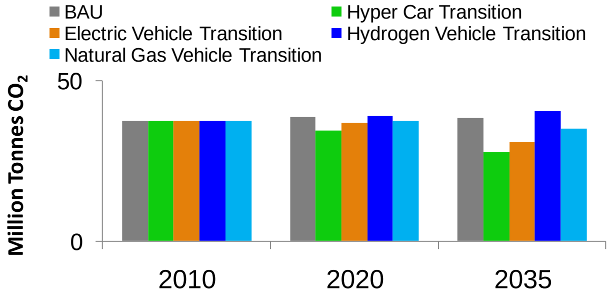
Figure ROK15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure ROK16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

Figure ROK16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

In Korea, the Hyper Car Transition scenario is the winner in terms of CO_2 emissions savings, with an emissions reduction of about 28% compared to BAU in 2035. Reflecting Korea's relatively low-carbon electricity generation, the Electric Vehicle Transition scenario comes in second, with an emissions reduction of 20% compared to BAU in 2035. Reflecting the lower carbon-intensity of natural gas compared to oil, the Natural Gas Vehicle Transition scenario achieves an emissions reduction of about 8% compared to BAU in 2035. Reflecting the inefficiency of producing hydrogen vehicle fuel from natural gas, then converting the hydrogen to electricity in the vehicle, the Hydrogen Vehicle Transition scenario would actually increase emissions by 6% compared to BAU in 2035.

REFERENCES

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

KAMA (Korea Automobile Manufacturers Association) (2012), *Reports and Statistics 2012*, www.kama.or.kr/eng/R&s/Rsoften_e?key=Production

KEEI (Korea Energy Economics Institute) (2012), *Yearbook of Energy Statistics, 2011*, www.keei.re.kr

KOSIS (Korean Statistical Information Service) (2012), *Statistical Database 2012*, http://kosis.kr/eng/database/database_001000.jsp?listid=Z

MALAYSIA

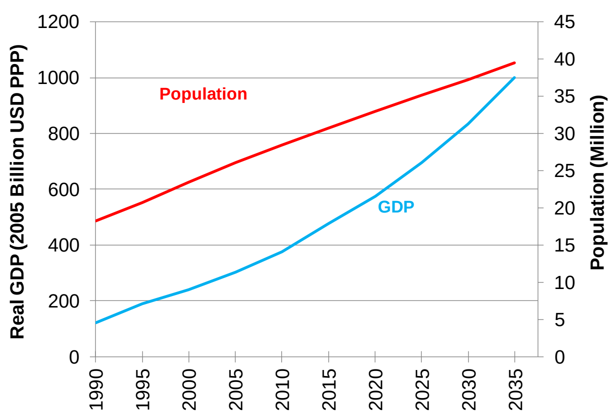
- *Malaysia's primary energy supply is projected to grow at 1.7% a year, to reach 103 Mtoe in 2035. The growth is driven mainly by demand for gas in the electricity generation sector and demand for oil in the transport sector.*
- *The oil and gas sectors have long been significant contributors to Malaysia's GDP and energy security, but this is likely to change due to rising domestic demand and maturing reserves. To meet this challenge, Malaysia will sustain production by rejuvenating existing fields and intensifying exploration activities while enhancing downstream growth and leveraging on its strategic location to become a regional hub for oilfield services.*
- *Electricity demand is expected to increase significantly from 96.3 TWh in 2009 to 206 TWh in 2035. To better manage this increasing demand, Malaysia aims to encourage efficient use of energy through initiatives like the Malaysia Green Labeling Program and Green Building Index, and to diversify its energy sources by building up solar capacity and tapping its vast hydroelectricity potential.*

ECONOMY

Malaysia is located in South-East Asia. Its territory covers an area of 330 803 square kilometres, spread across the southern part of the Malay Peninsula and the Sabah and Sarawak states on the island of Borneo. Malaysia's neighbours include Indonesia, Singapore, Thailand and Brunei Darussalam. Malaysia currently shares electricity interconnections with both Thailand and Singapore. Gas pipelines link Malaysia to Thailand, Singapore and Indonesia.

In 2009, Malaysia's total population was estimated to be about 28.3 million, with over 70% living in urban areas (DOS, 2011). Since its interior terrain is mostly forest-covered mountains, the Malaysian population is largely concentrated on the coastal plains. Malaysia's highest population densities are found in the peninsula cities of Kuala Lumpur, Penang and Putrajaya (DOS, 2011). The total population is projected to grow at an average annual rate of 1.3% over the outlook period, reaching just below 40 million by 2035.

Figure MAS1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Malaysia's GDP per capita in 2009 was estimated to be about USD 12 600 (in 2005 USD PPP), the third highest among the ASEAN economies. Based on current trends, Malaysia's annual GDP growth is predicted to be 4% for the next 25 years. Poverty has mostly been eradicated, and there is generally good access to water, electricity and telecommunications facilities.

Malaysia is an upper-middle-income developing economy with aspirations to achieve developed status by the year 2020. The Vision 2020 objective was first announced in 1991; since then several initiatives and programs have been put into place to drive economic growth. The latest, the Economic Transformation Programme (ETP), was launched in 2010 and is the most comprehensive initiative yet, incorporating active participation from the private sector and business community. Under the ETP, 131 Entry Point Projects (EPPs) were identified and categorized under 12 National Key Areas (NKEA) to provide focused economic growth. The 131 EPPs are high-impact projects, matched with specific ideas and actions, and are prioritized in government planning and fund allocation. By the end of 2011, 83% of the EPPs had either begun work or were currently in operation (PEMANDU, 2012). These accelerated EPPs are expected to stimulate economic growth, and this will be matched by corresponding growth in energy demand.

Manufacturing is a major contributor to the Malaysian economy, particularly the electrical and electronics, chemical products, and petroleum products manufacturing industries. Natural gas and electricity are the main energy sources used, while coal is used mostly by the cement, and iron and steel manufacturing industries.

Mining and agriculture are two other important economic activities; in 2009, each sector contributed

7.7% of the Malaysian GDP (MOF, 2011). Tin, oil and gas are the major natural resources of export significance in the mining sector. Other minerals mined in Malaysia include iron ore, bauxite, coal, ilmenite and gold. Overall, mining will continue to play a small but vital role in the economy.

The agricultural sector, which includes fisheries and forestry, has been identified as one of the NKEAs under the ETP and is currently undergoing rapid modernization and commercialization. As a result, the sector is expected to experience consistent economic growth in coming years. Some of these measures are already paying off: Malaysia is now one of the leading producers of palm oil worldwide and through concerted research initiatives, new applications of palm oil in biofuel production and biomass power generation have been successfully implemented.

In terms of passenger and freight volumes, road transport is the leading transportation mode in Malaysia (Ong et al., 2012). Malaysia has extensive road networks, totalling 157 167 km at the end of 2011, of which 81% are paved (EPU, 2012, p. 30). There are a total of 28 high-speed divided highways in the economy with a total length of 2137 km (LLM, 2012).

In 2009, there were about 19 million registered vehicles in Malaysia, and this is increasing at an average annual growth rate of 6.4% (RTD, 2010). Malaysian manufactured cars from Perodua and Proton currently dominate the economy's automobile market, although decreasing import taxes mean imported cars from Japan and Europe are gaining a greater share of the market each year. There is a mixture of new and rebuilt imported cars available in Malaysia, based on the economy's healthy rebuilt vehicle industry—there are eight rebuilt car manufacturers and nine rebuilt motorcycle manufacturers. Given the ease of obtaining car loans and subsidized fuel prices, car ownership is high among the population. According to the Malaysian Automotive Industry, based on historical trends it is unlikely that car ownership will reach saturation level in the near future, and car sales are expected to continue to grow at a moderate rate (MAI, 2011).

Rail transport, monorail and light rail transit systems also play significant roles in the land transport system, especially in Kuala Lumpur, Malaysia's capital city. Malaysia also has excellent marine port and airport infrastructure in key locations, which allows Malaysia to take advantage of its strategic position in the middle of the Trans-Asian route. In its Tenth Malaysian Plan, which covers 2011–2015, Malaysia has budgeted about MYR 13 billion (about USD 4.3 billion) to upgrade and enhance transportation access and connectivity (EPU, 2011). Some of the planned projects are to build road and rail links to major ports and airports, build electrified double-track rail lines, deepen port channels, upgrade marine ports and expand airport capacity.

Malaysia's equatorial climate has year-round average temperatures of 20–35°C and relative humidity of 80–90%; the timing of the rainy season on the peninsula coast varies. The tropical climate requires year-round space cooling in Malaysian buildings. On average, space cooling accounts for nearly 40% of the total building energy requirement. Malaysia is relatively safe from extreme natural disasters like earthquakes and hurricanes, although mild flooding does occur in certain regions, causing damage to properties but generally no loss of life.

ENERGY RESOURCES AND INFRASTRUCTURE

Malaysia is blessed with a variety of primary energy resources, including oil, natural gas, coal and renewable energy. According to the Malaysian Economic Planning Unit, as of 1 January 2011, there is an estimated 2.5 trillion cubic metres (89.9 trillion cubic feet) of natural gas and 5.9 billion barrels of oil reserves available, that will last 39 and 25 years respectively (EPU, 2011). The National Depletion Policy of 1980 aims to safeguard depleting reserves by restricting the production of hydrocarbons to 3% of 'oil initially in place'. This effectively limits the production of crude oil to 650 000 barrels per day and natural gas in Peninsular Malaysia to 2000 million standard cubic feet (56.6 million cubic metres) per day (KeTTHa, 2009). The economy also has about 1.9 billion tonnes of coal resources that are largely underexploited (Tse, 2011).

The majority of Malaysia's oil production comes from offshore fields in the Malay basin in the west, as well as the Sabah and Sarawak basins in the east. Malaysia's oil quality is generally high, but production has been declining in the past decade. To extend the reserves' lifetime, oil exploration activities are being expanded into deepwater—an activity which is significantly more challenging, both economically and technically. The Kikeh project was the first successfully developed deepwater oilfield in Malaysia, with two more deepwater fields under development in Gumusut/Kakap and Malikai (Rasheed Khan and Murzali, 2008).

There are five oil refineries in Malaysia with a combined capacity of 492 000 barrels per day—used for both domestic consumption and export (EC, 2012, p. 31). A sixth refinery will be added by 2014 under the Refinery and Petrochemical Integrated Development (RAPID) project in Pengerang, Johor. The refinery will have a capacity of 300 000 barrels per day and will supply feedstock for RAPID's petrochemical complex as well as produce gasoline and diesel that meet European specifications (Petronas, 2012b).

Like its oil reserves, the economy's natural gas reserves lie offshore of Peninsular Malaysia's east coast, Sabah and Sarawak. The three most active areas are the Malaysia–Thailand Joint Development Area (JDA), the SK309/SK311 area in offshore Sarawak, and Bintang area near Terengganu.

Malaysia has two gas pipeline networks. The Peninsular Gas Utilisation (PGU) network now includes over 2500 km of pipelines linking most cities in Peninsular Malaysia and it has cross-border interconnections to Singapore and Songkhla, Thailand. The PGU pipeline system incorporates six gas-processing plants with a combined capacity of 56.6 million cubic metres (2060 million standard cubic feet) per day, producing methane, ethane, butane and condensate (Gas Malaysia, 2012). The system receives gas from offshore Peninsular Malaysia fields as well as imported gas from JDA, West Natuna and PM3 CAA fields. About half the PGU system gas is consumed by the power sector while the rest goes to non-power industries or is exported to Singapore (Maybank, 2012).

The second gas pipeline linking the states of Sabah and Sarawak is under construction and expected to be completed by 2013. The Sabah–Sarawak Gas Pipeline (SSGP) will be approximately 521 km in length, and will deliver natural gas from Kimanis in Sabah to an LNG facility in Bintulu, Sarawak (OBG, 2012).

The economy operates extensive LNG export facilities and produces 13% of world LNG exports. As of 2010, Japan remained the largest importer of Malaysia's LNG, followed by Korea and Chinese Taipei (MLNG, 2011). To meet the anticipated shortfall of gas in the Malay Peninsula, Malaysia constructed its first LNG Regasification Terminal (RGT) in Malacca, which was completed in mid-2012. Once fully operational, the terminal will have the capacity to process and store up to 3.8 million tonnes per annum of LNG. A second RGT is being planned for the Pengerang Integrated Petroleum Complex (PIPC) in Johor (OBG, 2012) and a third RGT in Lahad Datu, Sabah.

Bituminous and sub-bituminous coals make up the bulk of coal reserves in Malaysia. Although the coal resource in Malaysia is substantial, domestic coal production has not been aggressively pursued because most of these coal deposits are far inland, where infrastructure is lacking and the extraction cost is high. Some locations, like the Maliau Basin in Sabah, have been designated as protected areas. Currently, coal mining is only conducted in Sarawak—production comes from the areas of Bintulu, Merit-Pila, Silantek and Tutoh. In Peninsular Malaysia, coal is used primarily for power generation, by the iron and steel industry, and by cement manufacturers. At present, coal is imported from Australia, Indonesia, South Africa and Viet Nam (Tse, 2011).

Renewable resources, especially hydropower and biomass, are in abundance in the economy. Malaysia's hydropower potential is assessed at 29 000 MW, mostly located in East Malaysia. In 2008, it was announced that several large hydroelectric projects will be developed under the Sarawak Corridor of Renewable Energy (SCORE); this will take over 20 years to develop and will generate a total of 20 000 MW when completed.

Small-scale generation from mini-hydro, biomass, solar and wind are already in place, totalling 773.6 MW. Of this figure, 15.3% is currently grid-connected while the rest is for self-generation in the industry sector. Over 90% is based on biomass power generation (EC, 2012). In 2011, the Malaysian Parliament approved a sophisticated system of feed-in tariffs that came into effect on 1 December 2011. This is expected to accelerate renewable energy development in the economy.

ENERGY POLICIES

Malaysia's National Energy Policy was first formulated in 1979 by the Economic Planning Unit under the Prime Minister's Department. The policy consists of three principal energy objectives:

1. *The Supply Objective.* To ensure the provision of adequate, secure and cost-effective supply of energy.
2. *The Utilization Objective.* To promote efficient utilization of energy and to discourage wasteful and non-productive patterns of energy consumption.
3. *The Environmental Objective.* To minimize the negative impacts of energy production, transportation, conversion, utilization and consumption on the environment.

These three principle objectives are instrumental in the development of Malaysia's energy sector. Subsequent policies are designed to support these objectives and their implementation.

The National Depletion Policy was formulated in 1980 to prolong and preserve the economy's oil and gas resources by setting a limit on the annual production of oil and natural gas. A year later, the economy introduced the Four-Fuel Diversification Policy, with the aim of diversifying the energy mix used in electricity generation. The initial focus of this policy was to reduce the economy's dependence on oil as the principal energy source, and it aimed for the optimization of the energy mix of oil, gas, hydro and coal used in generation of electricity. As a result, oil's domination of the electricity generation energy mix has been significantly reduced and replaced with gas and coal. In 2001, the Five-Fuel Diversification Policy was introduced to incorporate renewable energy as the fifth fuel after oil, gas, coal and hydro.

To diversify fuel use in non-power sectors, particularly the transportation sector, the National Biofuel Policy was introduced in 2006. The policy promotes the production of biofuel by the blending of processed palm oil (5%) with petroleum diesel (95%), it promotes biofuel consumption by establishing biodiesel pumps at selected stations, it ensures biodiesel quality by establishing an industry standard, and it encourages production by encouraging the establishment of biodiesel plants (MPICM, 2006).

At the 2009 Climate Change Summit in Copenhagen, Malaysia's Prime Minister pledged to "voluntarily reduce CO_2 emission intensity of GDP up to 40% by 2020 as compared to 2005 levels, conditional on financial and technological assistance from developed countries". Subsequently, the National Green Technology Policy was formulated, based on four pillars:

1. To attain energy independence and promote efficient utilization
2. To conserve and minimize environmental impacts
3. To enhance economic development through the use of green technology
4. To improve quality of life for all.

Four focus sectors were chosen—energy, buildings, waste and waste management, and transportation. As at mid 2012, several key initiatives have been introduced under the National Green Technology Policy. Government initiatives include the restructuring of the Malaysian Green Technology Corporation, the organization of the annual International Greentech and Eco Products Exhibition and Conference Malaysia (IGEM), the development of Putrajaya and Cyberjaya as pioneer townships in Green Technology, and establishing the Green Technology Fund Scheme (GFTS) which provides MYR 1.5 billion (USD 490 million) for green technology schemes.

The Malaysia Green Labelling Program (MGLP) has also been introduced—this includes the National Eco Labelling Program to certify eco-friendly domestically manufactured products, and the Energy Star Rating certification for energy-efficient home appliances. To promote green technology in the building sector, the Green Building Index (GBI) has been developed. To obtain a GBI certificate, the developer must ensure that the building meets six criteria: energy efficiency, indoor environmental quality, sustainable site planning and management, use of sustainable materials and resources, water efficiency, and innovation.

The National Renewable Energy Policy and Action Plan came into being in 2010. Its aim is to spur utilization of indigenous renewable energy resources to contribute towards Malaysia's electricity supply security and sustainable socio-economic development. Under this policy, two crucial Acts were established: the Renewable Energy Act 2011 and the Sustainable Energy Development Authority Act 2011, which together set up the framework for the new feed-in tariff mechanism.

The current five-year Malaysian plan, the Tenth Malaysian Plan 2011–2015, and its New Energy Policy aim to address several key issues to ensure economic efficiency and security of supply while still meeting social and environmental objectives.

One crucial issue is rationalizing fuel subsidies. Subsidies represent a substantial financial burden to the Malaysian Government. For instance, in 2009, fuel subsidies alone amounted to MYR 6.2 billion (USD 2 billion), which is almost 4% of government operating expenditure (MOF, 2011). Realizing that subsidies are unsustainable and may lead to sub-optimal resource allocation, as well as negatively impact market efficiency and impede long-term growth potential, the Malaysian Government has started taking steps to restructure subsidy allocations. Under the New Energy Policy, the price of gas to the power sector will be gradually raised by MYR 3 (USD 0.98) per million British thermal units every six months, eventually reaching the market price by 2016. At the same time, subsidy amounts will be itemized in consumer utility bills to increase awareness and encourage efficient energy use. Vehicle fuel subsidies remain unchanged.

The New Energy Policy addresses the energy security issue by developing alternative resources, with emphasis on renewable and clean carbon technology for the power generation sector, and biofuels for the transportation sector. Existing measures that encourage efficient use of energy, such as the Malaysia Green Labelling Program (MGLP) and Green Building Index (GBI) initiatives, will be extended and further enhanced under the New Energy Policy.

In Malaysia, the government-owned company Petronas holds exclusive ownership rights to all oil and gas exploration and production projects, and all foreign and private companies must operate through production sharing contracts (PSC). In terms of electricity production, the industry is dominated by three integrated utilities: Tenaga Nasional Berhad (TNB) serving Peninsular Malaysia, Sabah Electricity Berhad (SESB) in Sabah state and Sarawak Energy Berhad (SEB) in Sarawak state. TNB is publicly listed while SESB and SEB are privately owned, with the government owning some shares in each utility. The three utilities are complemented by various independent power producers (IPPs), dedicated power producers and co-generators. Under the New Energy Policy, both the gas and electricity sectors are slated for restructuring to raise productivity and improve business efficiency.

At the same time, under the Economic Transformation Programme (ETP), Malaysia has outlined 12 Entry Point Projects (EPPs) for the oil, gas and energy industries. The 12 EPPs are categorized under four main thrusts:

1. *Sustaining oil and gas production*. This involves extending the lifecycle of existing resources by optimizing exploration, development and production activities.
2. *Enhancing downstream growth*. The two EPPs under this thrust involve building a regional oil storage and trading hub, and unlocking gas demand in Peninsular Malaysia by providing better access to gas (through LNG imports and PGU infrastructure), thus encouraging industrial users to switch from diesel to competitively priced natural gas.
3. *Making Malaysia the number one Asian hub for oilfield services*. This thrust leverages on the economy's strategic location, to attract global operations and to build strategic partnerships and joint ventures for developing engineering, procurement and installation capabilities.
4. *Building a sustainable energy platform for growth*. The four EPPs under this thrust are designed to ensure energy security by improving energy efficiency and diversifying energy resources. This includes building up solar power capacity and tapping into Malaysia's hydroelectricity potential.

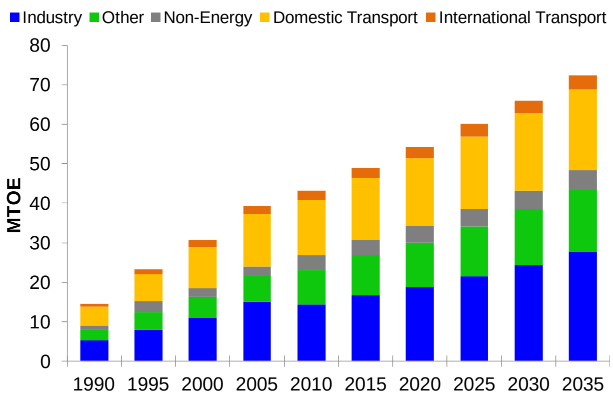
Deploying nuclear energy for electricity generation was one of the EPPs introduced under ETP, but after the Fukushima Nuclear Accident in May 2011, there has been growing public concern regarding the safety and increasing cost of nuclear power development. As of October 2012, the government has yet to decide on the construction of a nuclear power plant or its proposed location (The Star, 2012).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

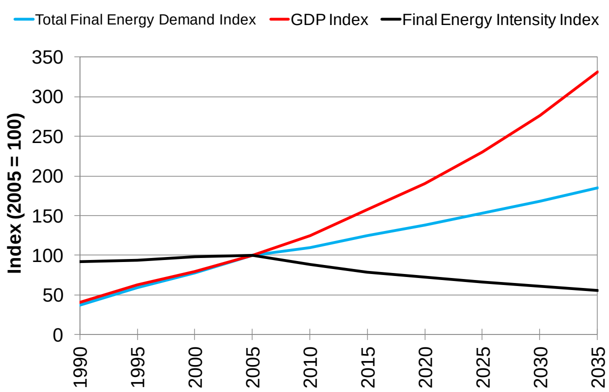
Malaysia's final energy demand (excluding the international transport sector) is projected to grow at an average annual rate of 2.1%, reaching 69 Mtoe by 2035 under business-as-usual (BAU) assumptions. The industry sector accounts for the largest portion with a share of 38% by 2035, followed by the domestic transport sector at 28%. Malaysia's final energy intensity is projected to decline by 44% between 2005 and 2035.

Figure MAS2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure MAS3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

By 2035, natural gas will account for the largest share of the final industry demand (33%), followed by electricity and oil, at 28% each. The final energy demand for the industrial sector is expected to nearly double over the outlook period, reaching 28 Mtoe in 2035. The energy intensity for the industrial sector, calculated as industrial demand divided by current GDP, is expected to reduce by 28% within the same time period. This reflects the sector's shift towards a structure that is less energy intensive as well as improvements in technical energy efficiency.

Transport

The transport sector energy demand is projected to increase in the outlook period by an average annual rate of 1.5% for domestic transport and 1.8% for international transport, reaching a total of 24 Mtoe in 2035. Petroleum products are expected to remain the dominant transport energy source, but other energy resources, especially natural gas and biofuels, are expected to contribute an increasing share over the outlook period, together accounting for about 3% of the total transport final energy demand in 2035. This would be in line with existing government incentives to encourage utilization of natural gas and biofuel in light vehicles. Currently, the fuelling stations for non-petroleum products are very limited and concentrated mostly within the Klang Valley. The contribution from natural gas would likely increase dramatically if the fuelling stations were more widespread across the economy.

Other

The final energy demand for the 'other' sector, which includes commercial, residential, and agriculture sub-sectors, is projected to grow at an average annual rate of 2.4%, reaching 16 Mtoe in 2035. Electricity constitutes the largest portion, with a share of about 62% (10 Mtoe) in 2035. This will be heavily driven by the need for space cooling. Generally, most urban dwellings are currently equipped with at least basic electrical home appliances such as televisions and refrigerators. Air conditioning is less common outside cities and townships as fans are deemed sufficient to cope with the humid weather. This moderate growth trend will likely continue throughout the outlook period unless there is a drastic change in climate.

PRIMARY ENERGY SUPPLY

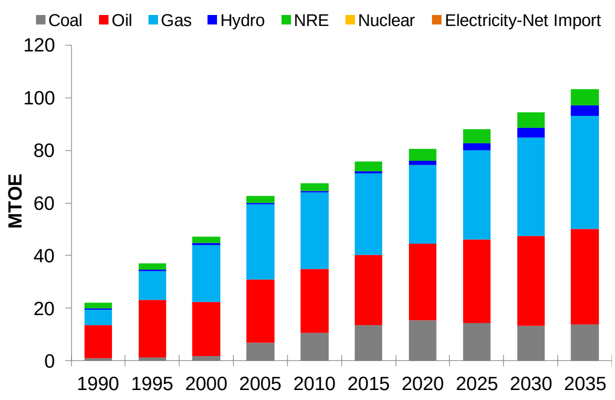
This outlook projects that Malaysia's primary energy supply will increase significantly from 66 Mtoe in 2009 to over 100 Mtoe in 2035, at an annual average rate of 1.7%. Fossil fuels will account for most of the primary energy supply in 2035, with oil at 35% and gas 42%.

In the medium term, it is expected that the economy will be able to sustain its oil production through the government's initiative under ETP to rejuvenate existing oilfields and explore new fields like the Kikeh deepwater field. However, given the economy's maturing oil reserves and the technical and economic issues involved in developing deepwater oilfields, it is likely that production will begin to decline and Malaysia will be a net oil importer by 2025.

Intensified exploration of natural gas fields under ETP has had some success: several new fields have been discovered including Block H off the coast of Sabah (MOC, 2012) and Block SK316 off the coast of Sarawak (Petronas, 2012a). This will lead to increased gas production in the mid-term, and consistent production up to 2030, after which production may begin to decline.

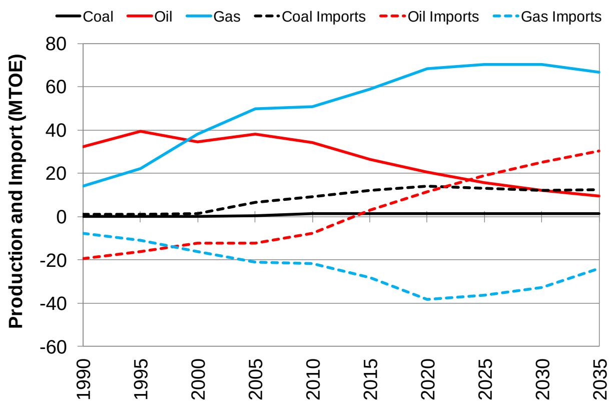
Coal production will remain minimal throughout the outlook period. Coal is mostly consumed by the electricity generation sector, and coal imports are expected to fluctuate according to the addition and retirement of coal power generation capacity throughout the period.

Figure MAS4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure MAS5: BAU Energy Production and Net Imports



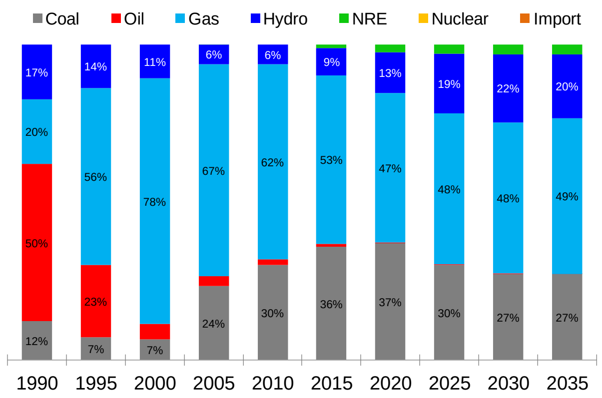
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

Electricity generation in Malaysia is projected to grow over the outlook period at an average annual rate of 2.8%, doubling from 105.1 TWh in 2009 to 217 TWh in 2035. A key goal for the economy is to create a more balanced generation mix. In order to achieve this, natural gas dependence will be reduced from 62% in 2010 to 49% in 2035. The reduced natural gas share will be taken up by hydro and new renewable energy (NRE).

Hydroelectric generation is projected to grow strongly during the outlook period, based on the development of large hydro projects in Sarawak under the SCORE initiative. NRE, mostly from biomass and solar sources, will also continue to grow from its currently negligible contribution to over 6 TWh in 2035 with the implementation of the feed-in tariff mechanisms.

Figure MAS6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

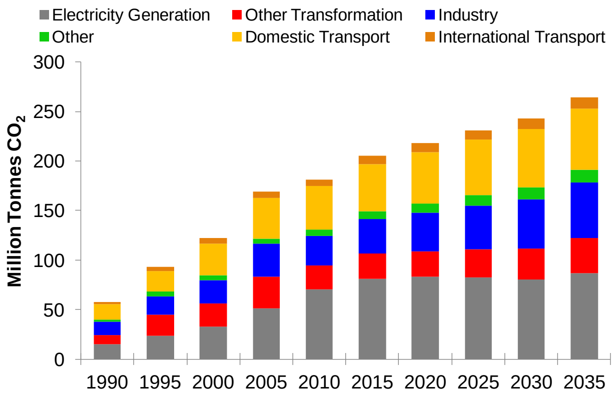
CO_2 EMISSIONS

Total CO_2 emissions from fuel combustion are projected to reach 264 million tonnes CO_2 in 2035, which is 46% higher than in 2010 and 360% higher than in 1990. By 2035, the biggest source of CO_2 emissions is the electricity generation sector (33%), followed by the domestic transport sector (24%) and the industry sector (21%).

Under BAU assumptions, Malaysia's CO_2 emission intensity of GDP will likely show a reduction of 32% from 2005 to 2020, compared to the goal set by the government to reduce CO_2 emission intensity of GDP by 40% in the same period. Further efforts are recommended to improve the economy's environmental sustainability, particularly in the power generation, transport and industry sectors.

The decomposition analysis in Table MAS1 indicates that prior to 2005 the total change in CO_2 emissions from fuel combustion was driven by change in GDP. From 2010 onwards, GDP impact on emissions will be offset by the decreasing energy intensity from energy efficiency measures in industrial structure.

Figure MAS7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

Table MAS1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	0.2%	-0.2%	-0.2%	-0.2%	-0.2%
Change in Energy Intensity of GDP	0.9%	-2.8%	-2.4%	-2.3%	-2.2%
Change in GDP	6.3%	4.5%	4.1%	4.1%	4.0%
Total Change	7.5%	1.4%	1.5%	1.5%	1.5%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Malaysia has achieved remarkable success in its economic development agenda, which is strongly underpinned by its energy sector, especially its oil and gas production. Malaysia's oil and gas reserves are modest in size and are gradually depleting. While efforts to discover and exploit new reserves are on-going and have yielded encouraging success, Malaysia continues to transform its economic portfolio by strategically developing its strengths in sectors other than oil and gas — priority areas include financial services, wholesale and retail, palm oil and rubber production and processing, tourism, electrical and electronics manufacturing, business services, agriculture and healthcare.

In order to ensure long-term energy security, the economy is implementing new, long-term solutions for its energy needs. This includes intensifying energy efficiency initiatives to ensure more productive and prudent use of the remaining reserves, and enhancing efforts to develop viable new renewable energy resources, such as solar, wind, and biofuel. These efforts would also mitigate environmental ill effects caused by the energy sector, especially from the projected 46% increase in total carbon emissions over the outlook period.

ALTERNATIVE SCENARIOS

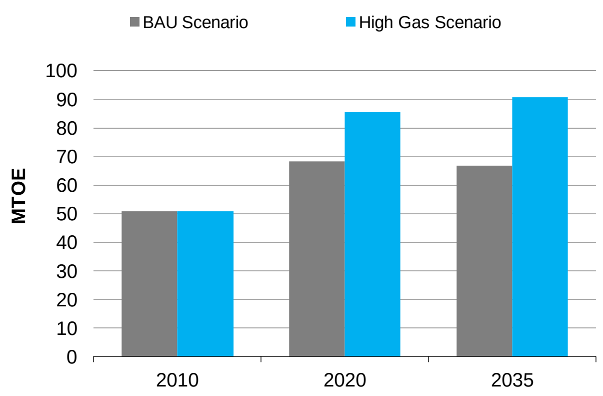
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario for Malaysia assumed the production increase shown in Figure MAS8, which is 36% by 2035. Two key assumptions were made in this scenario. First, a slight relaxation of the 3% restriction on gas production set under the National Depletion Policy 1980 to 4%. Second, successful commercialization of new natural gas discoveries—this includes Block SB303 in offshore Sabah (Lundin, 2012). These very recent gas discoveries were not included in the BAU assumptions.

Figure MAS8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

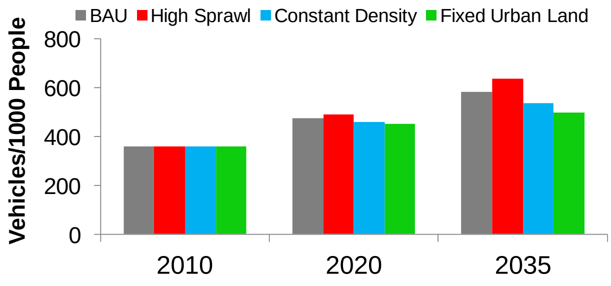
Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. The Malaysian Government aims to have a balanced electricity generation mix to avoid dependency on a single fuel. Figure MAS6 shows natural gas already occupies a large portion (62% in 2010) of the generation mix. In line with Malaysia's policies, this alternative scenario assumes that in a high gas availability situation the economy would seek to maximize economic benefits by exporting the additional gas via its LNG and pipeline facilities, rather than increasing natural gas utilization in the power sector. For this reason, Figures MAS9 and MAS10 (which show changes in electricity generation and the resulting change in emissions) were not included.

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure MAS11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. By 2035, the difference between the scenarios is significant, with vehicle ownership being about 9% higher in the High Sprawl scenario compared to BAU, and about 8% lower in the Constant Density scenario and 14% lower in the Fixed Urban Land scenario.

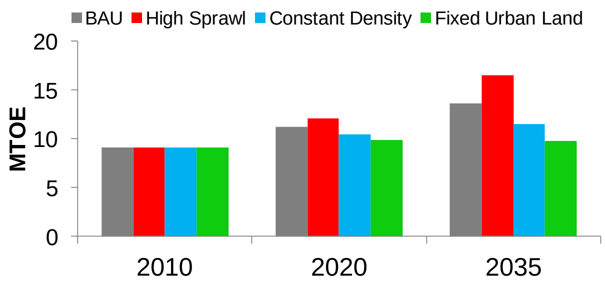
Figure MAS11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure MAS12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. Better urban planning has an even more pronounced impact on light vehicle oil consumption than on vehicle ownership because compact cities reduce both the need for vehicles and the distances they must travel. Light vehicle oil consumption would be 21% higher in the High Sprawl scenario compared to BAU in 2035, and about 16% and 28% lower in the Constant Density and Fixed Urban Land scenarios, respectively.

Figure MAS12: Urban Development Scenarios – Light Vehicle Oil Consumption

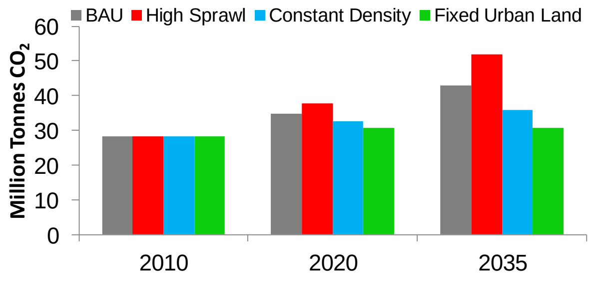


Source: APERC Analysis (2012)

Figure MAS13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

The benefits of urban planning in reducing the number of vehicles, oil consumption and CO_2 emissions are quite significant, and Malaysia as a developing economy would do well to incorporate energy saving urban designs in their city planning policies.

Figure MAS13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



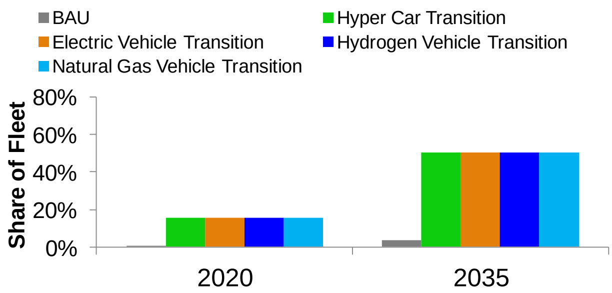
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure MAS14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 50% compared to about 4% in BAU. The share of conventional vehicles in the fleet is thus only about 50%, compared to about 96% in the BAU scenario.

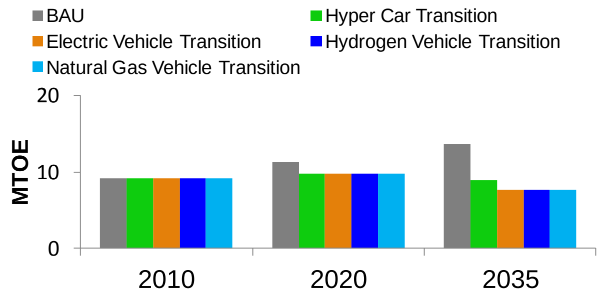
Figure MAS14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure MAS15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 44% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU in 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 27% by 2035—even though these highly efficient vehicles still use oil.

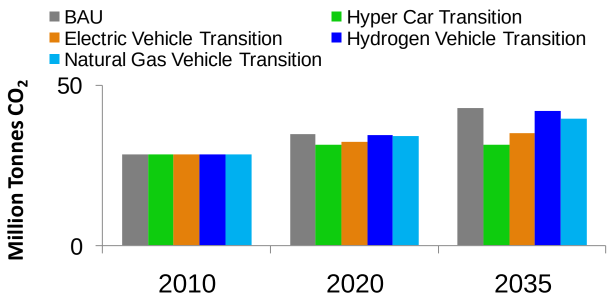
Figure MAS15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure MAS16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

Figure MAS16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

In Malaysia, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emission reduction, with an emission reduction of 27% compared to BAU in 2035. The Electric Vehicle Transition scenario would be second, offering a reduction of 18% compared to BAU in 2035. The Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios offer lower emission reductions (8% and 2% respectively).

Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption, while in the other alternative vehicles oil combustion is replaced by other fuels—namely electricity for electric vehicles, hydrogen for hydrogen vehicles and gas in natural gas vehicles. Thus, additional demand for electricity and hydrogen generation would produce more CO_2 emissions and this will offset some of the benefits gained from oil replacement. However, since Malaysia's electricity generation relies heavily on natural gas, electric vehicles tend to do better in terms of CO_2 emissions than they do in other economies that rely more on higher-emitting coal for electricity generation.

REFERENCES

DOS (Department of Statistics) (2011), 'Population and Housing Census, Malaysia 2010 (2010 Census)' website page, www.statistics.gov.my/portal/index.php?option=com_content&view=article&id=1215%3Apopulation-distribution-and-basic-demographic-characteristic-report-population-and-housing-census-malaysia-2010-updated-2972011&catid=130%3Apopulation-distribution-and-basic-demographic-characteristic-report-population-and-housing-census-malaysia-2010&Itemid=154&lang=en

EC (Energy Commission, Malaysia) (2012), *National Energy Balance 2010*, http://meih.st.gov.my/documents/10620/32f18652-5a27-4a8d-b812-417416191432

EPU (Economic Planning Unit) (2011), *Tenth Malaysian Plan*, www.epu.gov.my/rmkesepuluh

— (2012), *The Malaysian Economy in Figures 2012*, www.epu.gov.my/html/themes/epu/images/common/pdf/The-Malaysian-Economic-In-Figures-2012.pdf

Gas Malaysia (2012), 'Peninsular Gas Utilisation Project' website page, www.gasmalaysia.com/about_gas/peninsular_gas_utilisation_project.php

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

KeTTHa (Ministry of Energy, Green Technology and Water) (2009), 'Supply Objective' website page, www.kettha.gov.my/en/content/supply-objective

LLM (Malaysian Highway Authority) (2012), 'Operating Highways List' website page, www.llm.gov.my/beroperasi.aspx

Lundin (2012), 'Lundin Petroleum makes third gas discovery, offshore Sabah, Malaysia', press release, www.lundin-petroleum.com/Press/pr_malaysia_12-09-12_e.html

MAI (Malaysia Automotive Institute) (2011), *Malaysia Automotive Economy Trends and Outlook,* www.mai.org.my/ver1/index.php?option=com_content&view=article&id=487:latest-exclusive-download-malaysia-automotive-economy-trend-and-outlook-20102011&catid=36:rotate-content-design

Maybank (2012), *Oil and Gas Sector Update,* January 2012, www.maybank-ib.com/pdf/Oil and Gas Sector 2012.pdf

MLNG (Malaysia LNG) (2011), *Malaysia LNG – Major Export Markets*, www.mlng.com.my/Customers.html

MOC (Murphy Oil Corporation) (2012), 'Malaysia Exploration and Production Operations' website page, www.murphyoilcorp.com/operations/expro/malaysia.aspx

MOF (Ministry of Finance) (2011), *Economic Report 2010/2011*, www.treasury.gov.my/index.php?option=com_content&view=category&id=73&Itemid=174&lang=en

MPICM (Ministry of Plantation Industries and Commodities Malaysia) (2006), *The National Biofuel Policy.*

OBG (Oxford Business Group) (2012), 'Malaysia: Push for liquefied natural gas' website page, www.oxfordbusinessgroup.com/economic_updates/malaysia-push-liquefied-natural-gas

Ong, H.C, Mahlia, T.M.I, and Masjuki, H.H. (2012), "A review on energy pattern and policy for transportation sector in Malaysia", *Renewable and Sustainable Energy Reviews*, Vol 16 Issue 1, pp 532–542, 2012.

PEMANDU (Performance Management and Delivery Unit) (2012), *Economic Transformation Programme*, http://etp.pemandu.gov.my/default.aspx

Petronas (2012a), 'Petronas Discovers Gas Offshore Sarawak' press release, www.petronas.com.my/media-relations/media-releases/Pages/article/PETRONAS-DISCOVERS-GAS-OFFSHORE-SARAWAK_1AZ9TL.aspx

— (2012b), 'Petronas's RAPID Project Progresses as Scheduled' press release, www.petronas.com.my/media-relations/media-releases/Pages/article/PETRONAS%E2%80%99-RAPID-PROJECT-PROGRESSES-AS-SCHEDULED.aspx

Mohd Rasheed Khan and Murzali Mohd Ali (2008), *Kikeh Deepwater Block – Reenergizing Malaysia's Petroleum Industry*, www.azmilaw.com/archives/Article_12_Kikeh-Field_of_Firsts_00113094.pdf

RTD (Road Transport Department) (2010), 'Statistik Kenderaan dan Pemandu' website page, http://www.jpj.gov.my/statistics

The Star (2012), "PM: No decision yet on nuclear power plant", 3 October, http://thestar.com.my/news/story.asp?file=/2012/10/3/parliament/12116404&sec=parliament

Tse, Pui-Kwan (2011), *USGS 2009 Minerals Yearbook – The Mineral Industry in Malaysia*, February 2011, http://minerals.usgs.gov/minerals/pubs/country/2009/myb3-2009-my.pdf

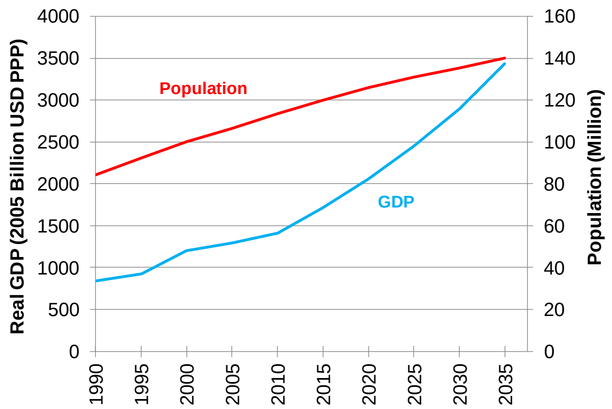
MEXICO

- *By sustaining its crude oil production, Mexico is likely to remain a large oil producer and exporter in the future.*
- *Even though Mexico is expected to be a net gas importer throughout the outlook period under business-as-usual assumptions, the full extent of Mexico's shale gas resources remains unknown. Better knowledge of these resources could change Mexico's gas outlook considerably.*
- *CO_2 emissions are projected to grow 56% in the outlook period with the economy's final use sectors accounting for 55% of those emissions by 2035. Mexico's CO_2 intensity is expected to decline much faster than its final energy intensity.*

ECONOMY

Mexico is legally constituted as a republic and politically divided into 31 states and one federal district. It is geographically located in North America and is one of APEC's three Latin American economies. Bordered by the United States (US) to the north and Belize and Guatemala to the south, the Mexican territory, of around 1.96 million square kilometres, is rich in resources. It encompasses a wide variety of climatic conditions, ranging from very dry with high temperatures in the north, to very humid with high temperatures in the south, to mild in the centre and warm on the coasts (SMN, 2011). Due to its abundant and complex ecosystems, Mexico is one of the 12 'megadiverse' economies in the world (UNEP, 2002).

Figure MEX1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

As depicted in Figure MEX1, the economy's total population of around 112 million in 2010 (Inegi, 2010) is projected to grow moderately, at an annual rate of 0.8%, to reach 140 million by 2035. Around 78% of Mexico's population live in urban areas and the remaining 22% live in rural areas (UN, 2009).

The largest urban areas are Mexico City, Guadalajara and Monterrey. While Greater Mexico City formed by the Capital City (Distrito Federal) and its surrounding metropolitan areas (Zona Metropolitana del Valle de México) represents only 0.1% of the Mexican territory, it accounts for as much as 25% of the economy's GDP. With a population close to 20 million, Mexico City is one of the top megacities in the world (UN, 2008).

Mexico's economic growth is expected to be moderate, with real GDP expanding at an average of 3.6% per year from 2010 to 2035 (see Figure MEX1). GDP per capita is expected to grow less dynamically, with a 2.8% average annual growth rate over the same period. In spite of being an OECD member since 1994, Mexico's GDP per capita was the lowest among the member economies in 2010 (IMF, 2011) and poverty reduction is one of the economy's major challenges—46% of Mexico's population are still considered poor and 10% live under extreme poverty conditions (Coneval, 2011). According to the United Nations Human Development Index (which measures progress in terms of human well-being rather than in pure economic terms) though, Mexico is considered a High Human Development economy, ranked 57th in the world and fifth in Latin America (UNDP, 2011).

Mexico is an export-driven economy, the second largest in Latin America and the 14th largest in the world (IMF, 2011). Roughly 80% of its total exports go to the US. Crude oil and manufactured goods (mostly machinery and vehicles) are Mexico's main exports. In 2010, crude oil, machinery and vehicle manufactures accounted respectively for 14%, 23.9% and 21.8% of Mexico's total exports (SE, 2011).

The energy sector, and particularly the oil industry, is critical to the economy. Revenues and taxes from the state-owned oil company provide nearly one-third of the total government revenue, from which Mexico's social development is mainly funded (Inegi, 2011; SHCP, 2011). In addition to exports, remittances from Mexicans working abroad are especially important. They not only constitute the second largest income source but, since 2009, have surpassed foreign direct investment inflows (Banxico, 2011).

The services sector is the main component of Mexico's GDP, accounting for 65% in 2010; industry and agriculture represent 31% and 4%, respectively. Along with the export-oriented industries described above, food products, chemicals, cement, beverages and tobacco are Mexico's most distinctive industries (Inegi, 2011). The most energy-intensive industries are iron and steel, cement, sugar, chemicals and mining; their joint energy demand amounts to half of the energy demand of Mexico's industry sector (Sener, 2011a).

Due to its location, Mexico is prone to natural disasters, with floods, hurricanes, droughts and even frosts being common. As the Mexican territory lies between several tectonic plates, the incidence of earthquakes is high, with most of the major ones stemming from the Pacific Coast (SSN, 2011). Moreover, Mexico has many volcanoes, several of them with little activity and close to major urban centres. An example is Popocatépetl, whose ash emissions have occasionally affected Mexico City's air quality, most recently during the second quarter of 2012 (Segob, 2012).

Road transport dominates passenger transport in Mexico, carrying more than 97% of all passenger trips. The remaining passenger transport is evenly split between air and (mostly short-distance) rail; marine transport has little significance. The economy has a comprehensive road infrastructure of almost 372 000 kilometres spread across the territory. Only 37% of the roads are paved (predominantly federal and state toll highways); the rest are gravel or unsurfaced (SCT, 2011).

As Mexico's vehicle ownership level of less than 300 units per 1000 people is well below saturation, it is expected that in the next few years vehicle growth will be robust due to increasing population and per capita income.

The recent expansion of bus-rapid-transit corridors, subway (metro) and local train systems in major urban centres such as León and Mexico City has helped to improve mass transport in the economy. However, most urban transport networks are still served by traditional systems where many small buses with drivers paid on a daily basis compete for customers. This has lead to an inefficient oversupply of obsolete vehicles that increase traffic congestion, commuting times, customer fares and greenhouse gas (GHG) emissions. Domestic freight transport is also dominated by road carriers, at around 85%; rail, marine and, marginally, air transport account for the remainder (SCT, 2012). The transport sector alone accounts for the majority of emissions in final energy demand—the sector is responsible for two-thirds of the emissions.

Mexico is one of the world's top 10 automobile manufacturers. Nonetheless, the majority of the vehicles produced are exported and only about 20% are sold domestically (BBVA, 2012), with most of Mexico's vehicle fleet being imported.

Although Mexico's weather conditions are diverse, most of its territory enjoys warm and consistent temperatures. The hottest areas in the territory are located in the humid south, along the coastlines and particularly in the dry north; and while they call for the intensive use of air conditioning and cooling equipment, their use is, still far from saturation. On the other hand, in spite of cold winters and occasional snowfalls in the north and high-altitude areas, the use of central heating in the economy's households is uncommon.

ENERGY RESOURCES AND INFRASTRUCTURE

Mexico's geographical position provides the economy with large energy resources including crude oil, natural gas, coal and uranium as well as hydro, wind and solar resources for power generation. In 2010, Mexico's proven primary energy reserves were 10.2 million barrels of crude oil (11.4 if gas liquids are included), 0.35 trillion cubic metres of natural gas, 1.21 billion tonnes of coal and 1.3 thousand tonnes of uranium (Pemex, 2011b; BP, 2011).

Mexico is among the top oil producer economies and is a net crude oil exporter. Around 53% of its total indigenous crude oil production of 2.56 million barrels per day is sent overseas, mainly to the US. In 2010, Mexico was the second largest oil exporter to that economy (USEIA, 2012; Pemex, 2011b).

By law, hydrocarbon resources are exclusively exploited by Petróleos Mexicanos (Pemex), the state-owned oil company, ranked as one of the largest in the world. The company is Mexico's sole upstream and downstream agent and is responsible for the final distribution of most oil products (liquefied petroleum gas, or LPG, is among the exceptions). At a broader level, Pemex is of the utmost importance as it represents Mexico's most significant taxpayer (Pemex, 2011a).

For its oil reserves Mexico is ranked 17th in the world. Its production, which comes primarily from its offshore southern regions, is characterised by a predominance of heavy (55%), light (32%) and extra-light (12%) oil types. One supergiant field, Cantarell, accounted for as much as 63% of Mexico's oil production at its peak production in 2004. However, due to its continuing natural decline, Pemex's efforts have been aimed at discovering and exploiting other fields to offset this output loss and the company's focus has shifted to production and investments in new areas in the oil-rich southern basins in an attempt to stabilise total crude oil output. Nonetheless, these new areas are more technically complex, such as the offshore Ku-Maloob-Zaap and onshore Chicontepec (Aceite Terciario del Golfo) fields. In addition, due to the permanent legal restriction on oil producers other than Pemex and to that company's severe budgetary constraints, the development of Mexico's oil resources has been hindered. This is the case with Mexico's considerable deepwater oil potential, whose production has been delayed and it is not expected to begin until 2015 (Pemex, 2012).

Even though Mexico is a big oil producer, the lack of sufficient domestic refining capacity forces the economy to be a major oil products importer, especially of gasoline. Nearly half of the total gasoline demand is met by imported stock.

Mexico is also an important natural gas producer of 0.20 billion cubic metres per day, of which roughly 65% is associated with crude oil and the remaining 35% is non-associated gas. For its natural gas reserves, Mexico was ranked 33rd in the world in 2010 (Pemex, 2011b). Historically, the Burgos Basin has been the main producer of non-associated natural gas; the offshore oil fields, including Cantarell, have been the most significant associated gas sources (Pemex, 2011b). In addition, with the recent release of a world assessment of shale gas resources by the US Department of Energy (USEIA, 2011), Mexico's shale gas potential has attracted domestic and international attention. Its shale gas resources were ranked fourth among the economies studied.

Despite being a significant gas producer, Mexico is not self-sufficient in natural gas. This is due to an increasing demand for natural gas in the oil industry, the electricity sector and the residential and commercial sectors for heating and cooking purposes. Expanding distribution grids for natural gas have helped it to replace other traditionally-used fuels like LPG. Nonetheless, some imports are necessary due to infrastructure and logistics reasons; Mexico's main natural gas pipeline connecting the production areas to the consuming centres does not extend to the north-west region. Natural gas imports from the US are required to meet that demand.

Unlike the oil industry, where all major activities are carried out by Pemex and its subsidiaries, the natural gas industry in Mexico allows private participation to some extent, namely in the import, export, transport, storage and distribution activities. This has helped to promote competition and infrastructure construction, including LNG (liquefied natural gas) terminals. Under the current regulations, the awarding of a distribution permit grants a single company exclusivity in a set area for a long-term period and is conditioned to the fulfilment of investment pledges. In an attempt to protect customers and to prevent vertical monopolies, companies cannot be awarded permits for both transport and distribution activities. So far, natural gas distribution grids are present in 20 areas of Mexico, including its major cities and many significant industrial clusters (Sener, 2010b).

To support and diversify its natural gas supply, Mexico has three LNG regasification facilities; one on the Gulf of Mexico and two on its Pacific Ocean coastline. In the northern Gulf of Mexico, the Altamira LNG Terminal, with a maximum regasification capacity of 21.5 million cubic metres per day (mcmd), supplies natural gas to combined-cycle public power plants. On the Pacific coastline of the Baja California State, close to the US, the Ensenada LNG Terminal (Energía Costa Azul) operates with a maximum regasification capacity of 36.8 mcmd. Mexico's third LNG terminal, Terminal KMS on the southern Pacific coastline at Manzanillo, Colima is under construction, with a maximum regasification capacity of 14.2 mcmd. It is expected to start operations during 2012, mainly to service public power plants. Once the three terminals are operating, Mexico's LNG storage capacity will amount to 72.5 million cubic metres per day (Sener, 2010b).

Coal consumption is relatively low in Mexico. Most of the economy's recoverable coal reserves of 1.21 billion tonnes are located in the north-eastern state of Coahuila, with some significant additional resources in Sonora (in the north-west) and Oaxaca (in the south). Around 70% of the recoverable reserves are of the anthracite and bituminous types, while 30% are sub-bituminous and lignite (BP, 2011). Coal production is around 11 million tonnes a year—more than 80% is thermal coal, the rest is coking coal. Mexico's main use for coal is as a fuel for thermal power plants (thermal coal). Coking coal is used for feeding the iron and steel industry's furnaces. Coal imports are required as production only meets about half the economy's demand (Sener, 2011a).

In the case of electricity, as in the oil sector, Mexico manages all its transmission, transformation, distribution and public service activities through the state-owned Power Federal Commission (CFE for its acronym in Spanish). On 11 October 2009, as part of the Mexican Government's action plan to improve energy efficiency in the power sector, the state-owned Luz y Fuerza del Centro electric power utility, which was responsible for servicing Mexico's central area including Mexico City and its metropolitan area, was abolished by presidential decree. Due to its poor efficiency and the considerable public financing required to support its operations, the utility had become a burden for Mexico's public budget and its energy sectors (DOF, 2009). As a result, the operation of its service territory was taken over by CFE, which now stands as the only public power utility in the economy.

CFE is in charge of the electricity sector's planning and manages all the electricity generated by itself and the independent power producers (IPPs) that operate in a segment of the industry open to the private sector. The Mexican Electricity System (SEN for its acronym in Spanish) is made up of three grids; the main one is comprehensive and spreads across most of the territory. The other two grids are located in the north and south of the Baja California State. Currently these three grids are isolated from each other although the northern Baja California grid is expected to be connected with the main grid by 2014 (CFE, 2011).

The northern Baja California grid is connected to the US at two points, allowing for electricity imports and exports depending on each economy's electricity needs. In addition to the US, Mexico exports electricity to the neighbouring economies of Belize and Guatemala. Exports and imports of electricity are modest and represent less than 1% of the economy's total electricity generation. Mexico's economy-wide reserve margins are over 40% due to planning decisions based on estimates that turned out to be above the actual demand (CFE, 2011), Thus, Mexico's electricity supply and SEN's reliability are considered strong.

Mexico's overall electrification rate is 97.7% of its total population, being 98.9% in the urban centres and 93.1% in rural areas (Sener, 2011b). As the legal framework mandates electricity supply to be universal except when economic or technical factors are present, in 2010 the government launched a project to bring electricity to Mexico's poorest communities through the installation of solar panels. The project, partially funded by the World Bank, looks forward to providing electricity over a 5-year span to 50 000 households in 2500 isolated communities located in Mexico's districts with the lowest Human Development Index values (Sener, 2010a).

The total installed electricity generation capacity for public service was 52 945 megawatts (MW) in 2010. Around 77.5% came from CFE, and the remaining 22.5% from IPPs, which sell their electricity to CFE to be supplied into the SEN. Roughly 74% of Mexico's power plant capacity is based on fossil fuels, with natural gas alone accounting for a little over half of that share. The remaining 26% is spread over nuclear, NRE (new renewable energy) and hydropower, the latter of which represents 22% of total capacity (Sener, 2011b).

SEN's concern with diversification of supply and sustainability issues has caused it to promote low-carbon technologies for power generation (especially more combined-cycle power plants and the replacement of fuel-oil based thermal power plants), the use of renewable energy, and some cogeneration opportunities. According to the SEN's expansion plan (CFE, 2011), Mexico's renewable-based electricity generation will increase in the next few years, building on the economy's promising potential for hydro, wind and geothermal electricity generation.

ENERGY POLICIES

Under the current legal framework, Mexico's Ministry of Energy (Secretaría de Energía, Sener for its acronym in Spanish) is responsible for the economy's energy policy. In 2007 and based on the National Development Plan 2007–2012, Sener launched the Energy Sector Program 2007–2012 to match the Presidential 6-year term. The main energy policy goals contained in the document aimed for the secure supply of the energy required for development at competitive prices, while minimising environmental impacts, operating at a high standard and promoting energy efficiency and diversification (Sener, 2007).

Considered the most significant recent development in Mexico's energy policy, the Energy Reform passed in 2008 included a set of laws and reform initiatives to strengthen the energy sector and to grant greater autonomy to Pemex.

With these reforms, a new document to guide energy sector policy in the long term was created. Mexico's National Energy Strategy (ENE for its acronym in Spanish) sets out the long-term vision for a 15-year span and is the reference point for all energy policies. The strategy focuses on three critical areas: energy security, economic efficiency and environmental sustainability. It also provides an insight into issues and topics that could shape the energy industry in the future. Although integrated and published annually by Sener, the ENE is developed through the collaboration of a number of governmental institutions, universities, research institutions, independent experts and representatives of Mexico's states and legislative powers, to ensure all relevant perspectives are reflected in the document.

The most recent edition of this document, issued in February 2012, explores several possible scenarios for Mexico's energy policy (business-as-usual, or BAU, and ENE-optimistic) and sets out several objectives covering the energy sector's major activities (hydrocarbons, electricity, renewable energy, energy efficiency, sustainability and technological research) to be achieved by 2026. By that year, its long-term policy aims for crude oil production of 3.4 million barrels per day, a replacement ratio of crude oil's proved reserves of more than 100%, natural gas production of 0.32 billion cubic metres per day, and a reduction in flaring and losses during gas extraction of 0.8% of the gas produced. In the downstream activities, the goals are to increase the natural gas transportation capacity and to boost petrochemicals production.

In comparison to previous documents, the latest edition of the ENE includes production from Mexico's shale gas resources by 2016. For this to happen, ENE assumes changes in the regulatory and business environment will be made to provide an incentive to develop this unconventional gas supply. While under the ENE's BAU scenario only one shale gas play will be developed with an output of 28 mcmd by 2026, its optimistic scenario considers developing another play providing an output of 92.9 mcmd by 2026 (Sener, 2012).

In compliance with these policies, Pemex defined the company's future priorities in its 2012–2016 Business Plan, including plans for several major projects it intends to carry out. Pemex looks forward to finding and developing new reserves, optimising its hydrocarbon and petrochemical production levels and ensuring their competitive and efficient supply in the economy (Sener, 2011b).

In the electricity sector, the economy's long-term energy policy calls for a reduction of total power losses from 11% in 2010 to 8% in 2026. For CFE to reduce its power losses, more aggressive measures against electric power theft will be needed. Power theft is not uncommon in Mexico, and represents one of the major causes of the economy's power losses. By 2026, Mexico's energy policy also aims to achieve a reduction in the reserve margin to 13%, and a 2.1% increase in the length of the power transmission network. This effort will include not only building new lines, but also replacing many of the existing ones that are reaching the end of their life cycle. Another objective is to improve energy efficiency enough to achieve a 15% or more energy savings over the government's BAU projection. This will be accomplished mainly through the allocation of more resources to strengthen the planned energy efficiency projects (Sener, 2012).

The long-term policy also demands an increase in the share of non-fossil-fuels electricity generation (NRE, large hydro and nuclear) from around 26% in 2010 to 35% by 2026. Natural gas based technologies have been favoured since the early 2000s for power generation, and this trend is expected to continue. However, other alternatives such as renewable energy and low-carbon technologies will play a significant role in Mexico's electricity generation in the future (Sener, 2012). Natural gas power plants have been preferred primarily due to relatively low prices and low emissions for natural gas, but also because of the increasing supply of natural gas in Mexico, the lower construction investment, and the higher thermal efficiency in comparison with other fuels (CFE, 2011).

Even though Mexico does not rule out nuclear energy for meeting its future electricity demands, the ENE only includes nuclear energy expansion in its alternative scenarios. Its BAU assumptions did not consider any additions to the economy's nuclear-generated power capacity, which consists of the Laguna Verde power plant.

To promote the use of renewable energy throughout the economy, Mexico developed a new regulatory framework as a result of the 2008 Energy Reform. This includes new legal and institutional provisions to promote renewable energy and biofuels, through several strategies. The passing of the Law for Renewable Energy Utilization and Energy Transition Funding lead to the creation of a National Strategy for Energy Transition and Sustainable Use. This strategy will promote policies, programs, actions and projects focusing on the increased use of low-carbon technologies, the promotion of energy sustainability and efficiency, and the reduction of Mexico's dependence on hydrocarbons. Created from a special tax levied on Pemex's revenue, the Law also provided for the creation of the Trust Fund for Energy's Transition and Sustainable Use. The fund's objective is to finance scientific and applied research projects dedicated to low-carbon technologies, the diversification of energy sources, renewable energy sources and energy efficiency.

The implementation of various other projects in collaboration with international organizations has helped to expand renewable energy in Mexico. In addition to the project for the electrification of poor communities mentioned above, with the aid of the German agency for International Cooperation, the program for solar water heating was launched in

2007. The objective of this program is to install 1.8 million square metres of solar collectors for water heating purposes in residential, commercial and agriculture sectors by providing the technical support, and by coordinating with the major stakeholders involved in the production and use of this technology.

Mexico has had energy efficiency programs since 1989 and has public institutions that encourage efforts in energy efficiency and conservation. The National Commission for the Efficient Use of Energy (Conuee) is responsible for promoting the programs and for providing technical advice in energy efficiency. Other institutions, such as the Trust Fund for Electricity Savings (FIDE), provide finance for energy audits and assessments, and facilitate the acquisition and installation of energy-efficient equipment.

Some of the energy efficiency policies currently being carried out by Mexico are: the Program for Energy-Saving Household Appliances Replacement, to replace freezer and air conditioning equipment at least 10 years old with energy-efficient new appliances through a preferential-rate loan from the Mexican Government repaid through the power utility bill; and the Program for Sustainable Light, to replace up to four traditional incandescent bulbs per household with four energy-efficient lamps free of charge. In addition, the Official Mexican Standards specify the minimum energy efficiency requirements for an electric product to be sold on the Mexican market.

To control the economy's inflation and to reduce the social impact of energy price increases, the Mexican Government subsidizes the fuels most used by families, such as electricity (restricted to low-consumption residential tariffs), LPG, gasoline and diesel. In the case of gasoline and diesel, the government applies a monthly slippage scheme. The scheme seeks to allow Mexico's prices to catch up with their US counterparts to avoid economic distortions, to reallocate subsidies to social projects, to promote lower imports through lower demand and to reduce emissions associated with fuels combustion. The slippage scheme works by increasing Mexico's gasoline and diesel prices by a few cents at a time, with the aim of gradually closing the gap between domestic and international prices (IISD, 2010). Since these fuel subsidies are general rather than targeted to the lowest-income population, they can promote inefficient or wasteful consumption, along with increased fuel demand and emissions without necessarily improving poor people's incomes. They also require the expending of considerable financial resources that could otherwise be directed to more urgent government priorities such as social programs.

Recognizing climate change as one of the major global and domestic challenges, the Mexican Government considers it to be a central policy concern. The economy introduced a National Climate Change Strategy (ENCC for its acronym in Spanish) in 2007 for mitigation and adaptation to climate change, and published the Special Climate Change Program 2009–2012 (PECC for its acronym in Spanish) in 2009.

As the energy sector is the main contributor of GHG emissions in Mexico, the PECC established actions to achieve the mitigation desired in two areas: oil and electricity production and final-demand efficiency and savings. In the short term, the PECC set a specific mitigation goal to be achieved by 2012—to avoid 50.6 million tonnes of carbon dioxide equivalent, with the energy sector accounting for 57% of those emissions. On the other hand, two ambitious aspirational long-term goals were also integrated in the document. These strive to reduce Mexico's total GHG emissions by 20% by 2020 and by 50% by 2050, compared with its emission levels in 2000 (Semarnat, 2009).

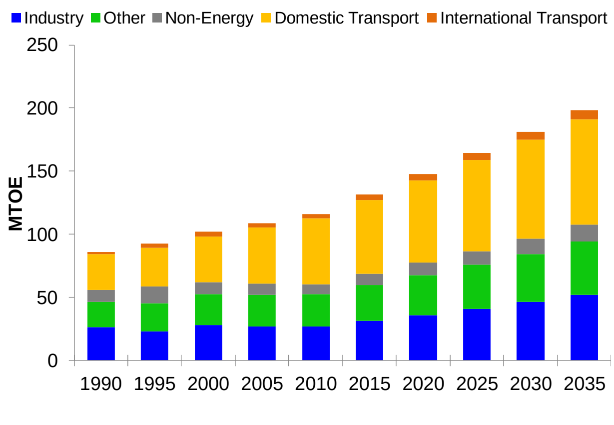
As an update to this document, it is worth mentioning that on 1 December 2012 Mexico had a new president, from a different political party than his last two predecessors and for the period up to 2018. While no formal plans had been announced at the time of closing this document, President Peña Nieto had announced the government's intentions of attaining a substantial reform in the energy sector, to turn it into an effective lever for Mexico's transformation (Presidencia de la República, 2012).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

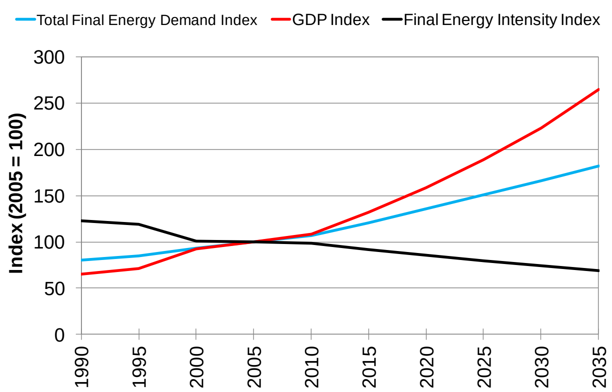
Under a BAU scenario, Mexico's final energy demand is expected to grow 70%, from 112 million tonnes of oil equivalent (Mtoe) in 2010 to 191 Mtoe by 2035. Sector shares are expected to remain fairly constant from 2010, with domestic transport accounting for the largest share of the demand (42%) followed by industry (26%), 'other' (residential, commercial and agriculture) (21%), non-energy (7%) and international transport (4%) in 2035. From 2005 to 2035, final energy intensity is expected to decline by 31%.

Figure MEX7: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure MEX3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

The industry sector's energy demand is projected to grow 92% over the outlook period, increasing from 27.1 Mtoe in 2010 to 52.1 Mtoe by 2035. By energy source, shares in 2035 will remain fairly similar to those in 2010, with decreasing contributions from oil and NRE and increasing contributions from gas and electricity.

Reflecting the predominance of machinery in Mexico's industry composition, electricity is expected to continue as the main energy source with almost 39% of the industry sector's energy demand by 2035. Natural gas is expected to have the second largest share, at 37%. Apart from oil, with an expected share of 19%, the remainder will be made up by coal and NRE. These latter two energy sources are mainly used in the most energy-intensive industries: coal, in the cement and steel industries and NRE (as biomass) in the sugarcane industry. Industry energy intensity is projected to decrease 27% from 2005 to 2035.

Transport

Domestic transport is expected to remain the largest energy demand sector in Mexico with roughly 42% of the total energy demand in 2035. From 2010 to 2035 this sector is estimated to grow 61%. Given the lack of incentives for the use of alternative vehicles, by 2035 nearly all the sector's energy demand (95%) will be based on oil fuels (gasoline and diesel). The future chances for developing significant demand for energy alternatives other than compressed natural gas (CNG) and NRE (biofuels) are small.

Energy demand for CNG and NRE (in the form of bioethanol and biodiesel) is expected to grow significantly, expanding 48 and 5 times respectively, by 2035. The growth assumptions for CNG are based on favourable expectations for the relative price of CNG compared to gasoline and on tighter environmental standards calling for cleaner fuels, especially in mass transport vehicles. Nonetheless, in spite of this dramatic growth, CNG's share in the transport energy mix by 2035 will still be small, accounting for around 1%. In the case of NRE in the form of biofuels, the Mexican Government plans to replace gasoline's conventional oxygenates with bioethanol in the city of Guadalajara, to comply with the mandatory 2.7% oxygenation blending (Semarnat, 2006). Along with the ongoing early development of biodiesel-based transport solutions across the economy, this plan will push forward biofuels' demand in the long term.

On the other hand, although the strategies in the National Program for Sustainable Use of Energy (Pronase) issued in late 2009 called for an increase in fuel efficiency and an improvement in best practices for new vehicles added to the national fleet, Mexico lacks mandatory fuel efficiency standards. The issuing of such standards during the outlook period would be helpful not only in driving down energy demand, but also in reducing gasoline imports and decreasing CO_2 emissions.

Other

The 'other' sector's energy demand is projected to increase 65%, from 25.4 Mtoe in 2010 to 41.8 Mtoe by 2035. By the end of the outlook period, the combined energy demands of the residential, commercial and agriculture sectors are expected to represent around 21% of the total final energy demand. Natural gas will be the fastest-growing energy source, with its demand almost doubling by 2035. This will be followed by electricity demand increasing by 87%, oil (mostly as LPG) by 85% and NRE (in the form of firewood) showing very little growth.

Unlike other sectors whose energy composition is projected to remain stable from 2010 to 2035, in this sector the shares of the various fuels are expected to change. While the shares for oil (in the form of LPG), natural gas and electricity will increase, the share of NRE in the 'other' sector's total energy demand is expected to decrease. By 2035, this sector's energy demand is estimated to be made up by oil (47%), electricity (33%) and natural gas (4%). NRE's share (as non-commercial firewood) will be gradually replaced by commercial energy options, and will represent only 16% of the energy demand in 2035, down from a 25% share in 2010. Unlike other APEC economies, Mexico depends heavily on oil products, mostly LPG, to meet the energy demand in the residential and commercial sectors.

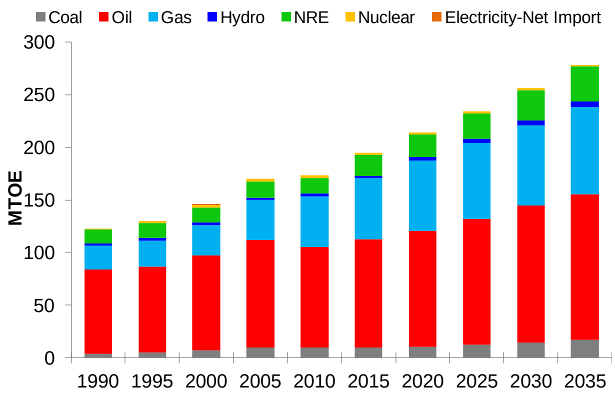
This situation is explained by a natural transition to more convenient energy sources. As new energy distribution infrastructure reaches more markets and more energy options are available for consumers, a shift away from non-commercial fuels is expected. In Mexico's case, these circumstances have historically favoured the wide distribution of LPG to replace firewood. Although the recent expansion of distribution grids has provided access to natural gas in more areas, their development is still limited and they have not significantly reduced the use of LPG.

It is worth noting that due to Mexico's energy efficiency programs and policies being especially focused on the residential sector in recent years, the 'other' sector's energy intensity reduction in the outlook period is expected to be slightly better than that in the industry and transport sectors, with a total improvement of 37% from 2005 to 2035.

PRIMARY ENERGY SUPPLY

Mexico's primary energy supply is expected to increase by 61% in the 2010–2035 outlook period. The predominance of fossil fuels is expected to continue, with coal, oil and gas jointly accounting for 86% of primary energy supply by 2035, with the rest provided by NRE (12%), hydro (2%) and nuclear (less than 1%). From 2005 to 2035, Mexico's primary energy intensity will decline 38%.

Figure MEX4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

As one of the world's major oil and gas producers and exporters, and given its potential resources for these products, Mexico's oil production is assumed to increase during the outlook period. Production is expected to reach its peak by 2025 with 200.4 Mtoe (3.3 million barrels per day) and to sustain this output until 2035. This represents an average annual growth of 1% from 2010 to 2035. It is expected the economy will remain a net oil exporter for the outlook period.

In contrast, Mexico will remain a net gas importer throughout the outlook period, with the import gap increasing from 2020 to 2035. This will occur in spite of an average annual growth of 1.4% in natural gas production from 2010 to 2035. However, additional shale gas production beyond the planned levels could affect these outcomes.

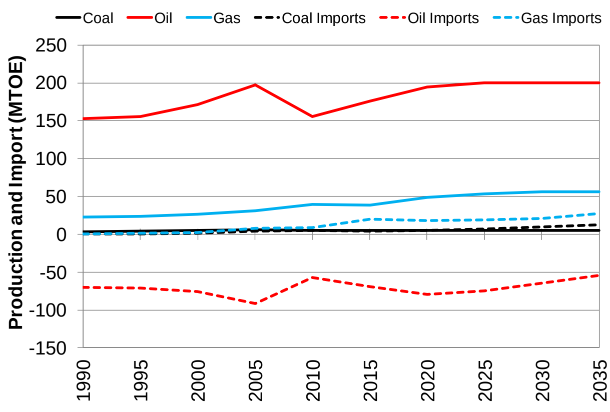
In this regard, the development of Mexico's shale gas resources poses several uncertainties. Although the economy is including one or two shale gas plays in its long-term energy policy, the available data on its resources is based on external information and Mexico still lacks its own studies to assess accurately the location and scale of its shale gas reserves. In addition, Pemex's budget is not only insufficient for addressing effectively all of its projects, but more than 90% of those financial resources are absorbed by its oil exploration and production activities. This leaves a very low share to be allocated for other operations and projects.

Aggravating this situation is the fact that hydrocarbons exploration in Mexico is exclusively reserved for the state. While private participants are currently undertaking some upstream activities under special contracting schemes, their operations are limited and the production planning and decisions are still carried out by Pemex. This limits flexibility, compared to standard practices in the global industry.

In contrast, a key factor for the booming shale gas production in the US is the existence of a plethora of predominantly small and mid-sized competing producers, site builders and service providers who can afford capital-intensive drilling and hydraulic fracturing in many wells dispersed across large areas (USDOE, 2009). This industry structure has allowed participants to bear higher capital costs compared with conventional gas production and to have greater organisational flexibility to come up with cost-effective technological solutions, to afford infrastructure construction, and to adapt to the market fluctuations.

The above conditions are totally the opposite to the ones prevailing in Mexico, where decisions tend to be centrally-made and politically-driven. As a result, budgets and project planning tend to favour conventional production, and to restrain investment in new technology and research and development. Unless policymakers are able to design a more competitive and attractive environment for shale gas production, it seems likely that Mexico's unconventional gas potential will not be fully developed. This in turn will hamper its aspirations to reverse its position as a gas importer in the future, restraining its energy security and the economic benefits that shale gas could bring.

Figure MEX5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

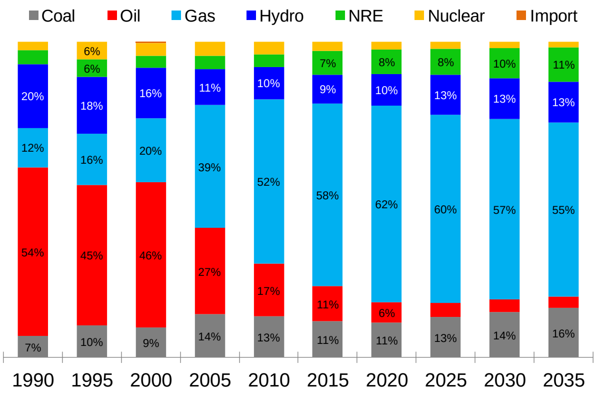
ELECTRICITY

Power generation in Mexico is projected to increase 72% in the outlook period. By 2035, it is expected that nearly three-quarters of the total electricity generation will remain based on fossil fuels, primarily natural gas. The rest will be supplied by hydro, NRE and nuclear energy power plants.

From 2010 to 2035, it is estimated that the largest growth by power generation source will be experienced by NRE at 356%. In contrast, oil-based generation is expected to drop by 63.5%. During the outlook period, NRE capacity will be based on wind, geothermal, mini-hydro and biomass. Based on SEN's expansion plan, solar energy growth is assumed to be limited, although particular projects carried out by private investors could be possible in the future.

Renewable energy and low-carbon technologies will play a growing role in Mexico's power generation over the coming years. Altogether, non-fossil sources (hydro, NRE and nuclear) are expected to expand their share in Mexico's power generation from 18% in 2010 to 25% by 2035. This is especially significant due to the projected growth in demand for the same period. However, this scenario suggests the Mexican Government's target of 35% of total electricity generation based on these technologies might not be accomplished. Technical issues as well as financial constraints (such as the higher costs of technology development and of the construction of needed transmission infrastructure) might limit NRE's output from growing to the targeted levels.

Figure MEX6: BAU Electricity Generation Mix



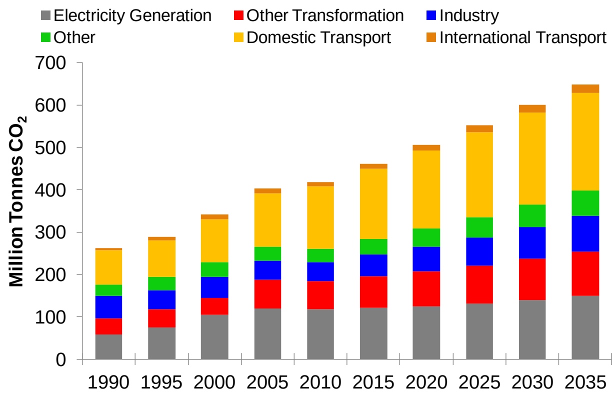
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

CO_2 emissions in Mexico's energy sector are projected to increase 55% from 2010, to reach around649 million tonnes of CO_2 by 2035. Final-use energy demand will contribute 58% of these emissions, and the economy's energy transformation sectors will account for the remaining 42%.

By fossil fuel, emissions from coal consumption are expected to have the largest increase in the outlook period (77%), followed by gas and oil (70% and 46%, respectively). The share of each of these sources in the total emissions is estimated to remain fairly constant over the outlook period. By 2035, emissions from oil consumption will make up the majority (nearly 60%) of the total emissions, followed by gas (30%) and coal (10%).

Figure MEX7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

From the results of these projections, shown in Figure MEX7, it seems that Mexico's long-term strategy towards lower-carbon electricity generation will pay off. The electricity sector's CO_2 emissions will grow only 26% in the outlook period, with their share in the total energy sector emissions dropping from 28% in 2010 to 23% by 2035. This may be explained by Mexico's long-standing policy to decrease oil-based power generation and to promote combined-cycle gas technologies. In this case, it is expected that the emissions from oil-based (diesel and fuel oil) power plants will decrease roughly 66% during the outlook period.

In contrast, in the final demand sectors, emissions will grow more quickly. Industry will have the fastest growth in emissions, 91% from 2010 to 2035, although the transport sector will account for 61% of final demand emissions by the end of the period.

As shown in Table MEX1, emissions resulting from Mexico's GDP growth will be partly offset by energy intensity reductions and small reductions in the CO_2 intensity of energy.

Table MEX1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	0.6%	0.4%	0.0%	-0.1%	-0.2%
Change in Energy Intensity of GDP	-0.6%	-1.3%	-1.6%	-1.6%	-1.6%
Change in GDP	2.9%	1.7%	3.3%	3.3%	3.6%
Total Change	2.9%	0.7%	1.6%	1.6%	1.8%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under the BAU scenario, Mexico's projected energy supply shows good potential. It is likely the economy will not only remain a large oil producer, but it will also sustain its crude oil exports into the future. Depending on the actual time and size of the development of its unconventional shale gas resources, the economy could also redefine its trade flows in the long term to become a net gas exporter.

In the electricity sector, the economy's target of 35% of its electricity generation to be based on carbon-free technologies by 2026 is not likely to be accomplished by that year, or even within the outlook period. Nonetheless, the projections suggest Mexico's efforts to fight climate change will achieve some success in the electricity sector as its CO_2 emissions are expected to increase at a slower pace than those of the final-demand sectors.

Although successful programs have been implemented in the residential and commercial sectors in recent years, Mexico will need more policies focused on energy efficiency, in particular ones focused on sectors such as transport and industry. In the light of the new government in Mexico and its priorities, the energy sector remains as one of the biggest challenges for improving economy-wide competitiveness and reducing CO_2 emissions.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the results from the business-as-usual (BAU) scenario, three sets of alternative scenarios were developed for most APEC economies.

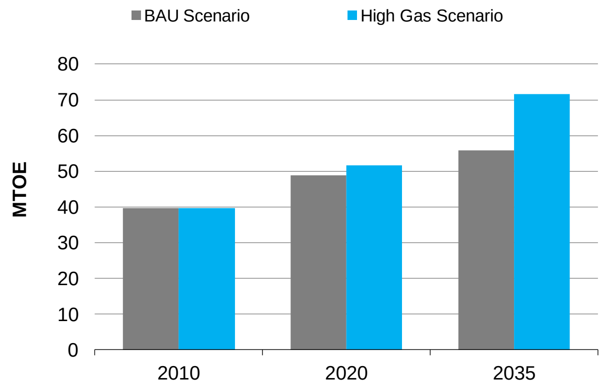
HIGH GAS SCENARIO

An alternative 'High Gas Scenario' was developed to consider the effects a higher gas output could have on Mexico's energy sector. The High Gas Scenario was built around estimates of gas production that could be available at BAU scenario prices or below if constraints on gas production and trade were reduced. The assumptions of the High Gas Scenario are further discussed in Volume 1, Chapter 12.

As shown in Figure MEX8, the High Gas Scenario for Mexico estimates an increase of 28% in gas production by 2035 in comparison with the BAU scenario. Assumptions of a larger output are based on the greater shale gas production that would result if an additional shale gas play were developed in the long term, as stated in the ENE's optimistic scenario.

Since ENE's outlook period only extends to 2026, it was assumed that the additional production achieved would be sustained afterwards, up to 2035.

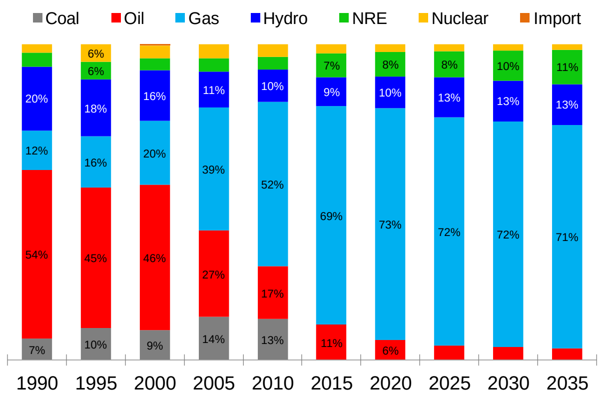
Figure MEX8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

The High Gas Scenario assumes that the main use for the additional gas will be as a replacement for coal in the electricity generation sector. The effects of higher gas utilization on Mexico's electricity generation mix are presented in Figure MEX9 and may be contrasted with the BAU electricity generation mix shown in Figure MEX6. It can be seen that, by 2035, gas-based electricity generation will completely replace all coal-based generation and account for 71% of the total electricity generation mix in Mexico. This compares to a projected 55% share under BAU.

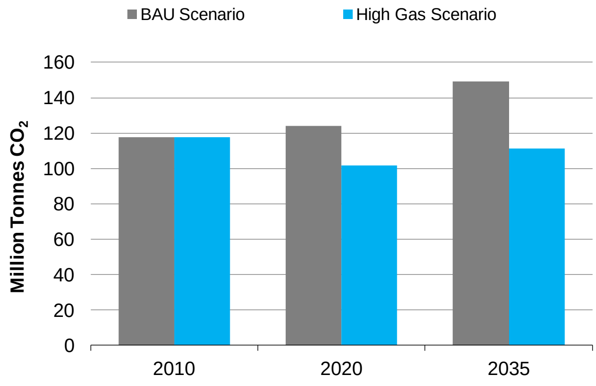
Figure MEX9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas produces roughly half of the CO_2 emissions of coal per unit of electricity generated, in Mexico this substitution would reduce CO_2 emissions in electricity generation by 25% in 2035, as depicted in Figure MEX10.

Figure MEX10: High Gas Scenario – CO_2 Emissions from Electricity Generation



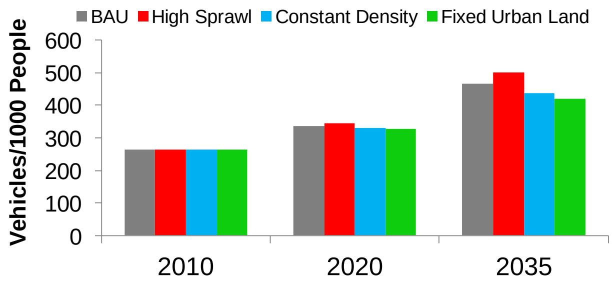
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To better appreciate the impact of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in more detail in Volume 1, Chapter 5.

Figure MEX11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. In comparison to BAU, it is estimated that by 2035 the High Sprawl scenario would expand the number of vehicles per 1000 people by 7%, while in the Constant Density and Fixed Urban Land scenarios, decreases of 6% and 10% respectively are expected.

Figure MEX11: Urban Development Scenarios – Vehicle Ownership

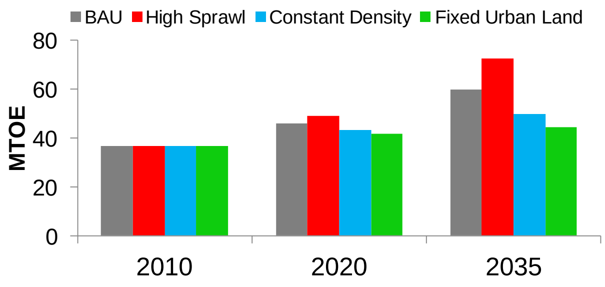


Source: APERC Analysis (2012)

Figure MEX12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of these scenarios on oil consumption is larger than it is on vehicle ownership. In comparison to BAU, it is estimated that by 2035 the High Sprawl scenario would expand the light vehicle oil consumption by 21%, while in the Constant Density and Fixed Urban

Land scenarios, decreases of 16% and 26% respectively, are expected.

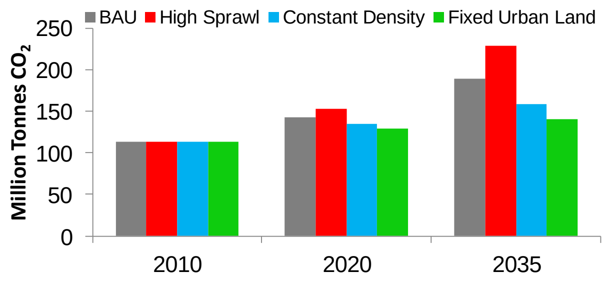
Figure MEX12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure MEX13 shows the impact of these urban planning alternatives on CO_2 emissions, which is similar to the impact of the urban planning alternatives on oil consumption, as there is no significant change in the mix of fuels used in any of these scenarios.

Figure MEX13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



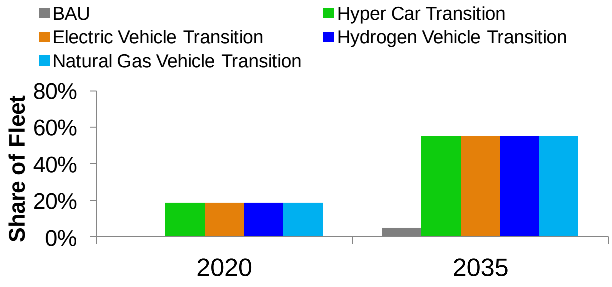
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To assess the possible impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The main assumptions behind these scenarios are discussed in more detail in Volume 1, Chapter 5.

Figure MEX14 shows the evolution of the vehicle fleet under BAU and the four Virtual Clean Car Race scenarios. By 2035, the share of the alternative vehicles in the fleet would reach 55% compared to about 5% in the BAU scenario. Therefore, the share of conventional vehicles in the fleet under the alternative scenarios decreases to 45% in contrast to the 95% share projected for the BAU scenario.

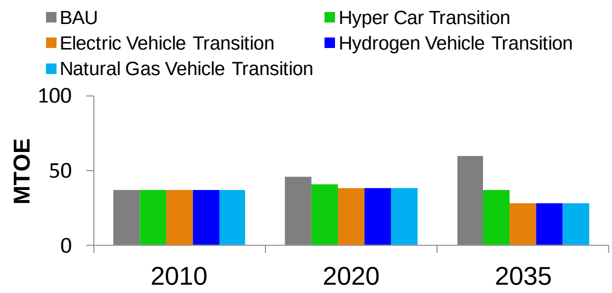
Figure MEX14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

In Figure MEX15, the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios is presented. Oil consumption drops by 53% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 38% by 2035—even though these highly-efficient vehicles still use oil.

Figure MEX15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

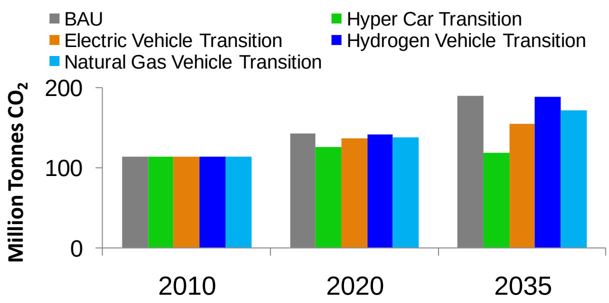
Finally, Figure MEX16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, the change in CO_2 emissions in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios is defined as the variations in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different emission factor per unit of energy.

In comparison to BAU, the results suggest the Hyper Car Transition scenario is the best option for Mexico in terms of reducing CO_2 emissions, with a 37% decrease by 2035. The Electric Vehicle Transition scenario would be second, offering a reduction of 18%, while the Natural Gas Vehicle

Transition scenario would offer a reduction of 10%. Although electric vehicles produce no CO_2 directly, the electricity consumed is assumed to be produced from fossil fuels, limiting their emissions reduction potential. Natural gas is, of course, a fossil fuel whose combustion emits CO_2, although in modestly lower quantities than oil.

The Hydrogen Vehicle Transition scenario offers little CO_2 emissions reduction benefits, emissions are unchanged compared to BAU in 2035. Like electric vehicles, hydrogen vehicles produce no CO_2 directly, however, the hydrogen consumed is assumed to be produced from fossil fuels, with a second transformation of hydrogen to electricity taking place in the vehicle. The conversion losses involved in these two transformation processes negate the emissions reduction potential of hydrogen vehicles.

Figure MEX16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

Banxico (Banco de México) (2011), *Balanza de Pagos*, www.banxico.gob.mx/politica-monetaria-e-inflacion/index.html

BBVA (Banco Bilbao Vizcaya Argentaria – Research) (2012), *Industria automotriz: Clave en el crecimiento económico de México*, www.bbvaresearch.com/KETD/fbin/mult/120125_PresentacionesMexico_81_tcm346-285045.pdf

BP (2011), *Statistical Review of World Energy 2011*, www.bp.com/statisticalreview

CFE (Comisión Federal de Electricidad) (2011), *Programa de Obras e Inversiones del Sector Eléctrico (POISE) 2011–2025*, http://aplicaciones.cfe.gob.mx/aplicaciones/otros/POISE2011_2025%20WEB.ZIP

Coneval (Consejo Nacional de Evaluación de la Política de Desarrollo Social) (2011), *Pobreza en México y en las Entidades Federativas 2008–2010*, http://web.coneval.gob.mx/Informes/Interactivo/Medicion_pobreza_2010.pdf

DOF (Diario Oficial de la Federación) (2009), *Decreto por el que se extingue el Organismo Descentralizado Luz y Fuerza del Centro*, 11 October 2009, www.energia.gob.mx/webSener/res/Acerca_de/DE_LFC_11102009.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

IISD (International Institute for Sustainable Development) (2010), *Implementation of Subsidy Reform in Mexico*, www.iisd.org/gsi/sites/default/files/ffs_gsiunepconf_sess3_ovela.pdf

IMF (International Monetary Fund) (2011), *World Economic Outlook Database – GDP per capita, current prices in U.S. Dollars*, September 2011, www.imf.org/external/pubs/ft/weo/2011/02/weodata/index.aspx

Inegi (Instituto Nacional de Estadística y Geografía) (2010), *Censo de Población y Vivienda 2010. Cuadro Resumen*, www.inegi.org.mx/Sistemas/temasV2/Default.aspx?s=est&c=17484

— (2011), *Banco de Información Económica*, http://www.inegi.org.mx/sistemas/bie/

Pemex (Petróleos Mexicanos) (2011a), *Acerca de Pemex*, www.pemex.com/index.cfm?action=content&sectionid=1

— (2011b), *Memoria de Labores 2010*, www.pemex.com/files/content/Version_completa_memoria_de_labores_2010.pdf

— (2012), P*alabras del Director General de Petróleos Mexicanos, Dr. Juan José Suárez Coppel, durante la ceremonia conmemorativa del 74 aniversario de la expropiación de la industria petrolera*, www.pemex.com/index.cfm?action=news&sectionid=8&catid=42&contentid=26266

Presidencia de la República (2012), *Mensaje a la Nación del Presidente de los Estados Unidos Mexicanos*, www.presidencia.gob.mx/articulos-prensa/mensaje-a-la-nacion-del-presidente-de-los-estados-unidos-mexicanos/

SCT (Secretaría de Comunicaciones y Transportes) (2011), *Estadística de Bolsillo 2011*, www.sct.gob.mx/uploads/media/EB-2011.pdf

— (2012), North American Transportation Statistics Database, http://nats.sct.gob.mx/index_en.html

SE (Secretaría de Economía) (2011), *Diagnóstico de la Economía Mexicana*, www.economia.gob.mx/files/diagnostico_economia_mexicana.pdf

Segob (Secretaría de Gobernación) (2012), *Sistema Nacional de Protección Civil*, www.proteccioncivil.gob.mx/en/ProteccionCivil

Semarnat (Secretaría del Medio Ambiente y Recursos Naturales) (2006), *Norma Oficial Mexicana NOM-086-SEMARNAT-SENER-SCFI-2005, Especificaciones de los combustibles fósiles para protección ambiental*, www.ordenjuridico.gob.mx/Federal/PE/APF/APC/SEMARNAT/Normas/Oficiales/2006/30012006%281%29.pdf

— (2009), *Programa Especial de Cambio Climático 2009–2012*, www.semarnat.gob.mx/programas/semarnat/Paginas/PECC.aspx

Sener (Secretaría de Energía) (2007), *Programa Sectorial de Energía 2007–2012*, www.sener.gob.mx/res/0/Programa%20Sectorial%20de%20Energia%202007-2012.pdf

— (2010a), *Cuarto Informe de Labores 2010*, www.sener.gob.mx/res/0/CuartoInformeLaboresSENER2010.pdf

— (2010b), *Prospectiva del Mercado de Gas Natural 2010–2025*, www.sener.gob.mx/res/PE_y_DT/pub/perspectiva_gas_natural_2010_2025.pdf

— (2011a), *Balance Nacional de Energía 2010*, www.sener.gob.mx/res/PE_y_DT/pub/2011/Balance%20Nacional%20de%20Energ%C3%ADa%202010_2.pdf

— (2011b), *Quinto Informe de Labores 2011*, www.sener.gob.mx/res/0/SENER_5.pdf

— (2012), *Estrategia Nacional de Energía 2012–2026*, www.energia.gob.mx/res/PE_y_DT/pub/2012/ENE_2012_2026.pdf

SHCP (Secretaría de Hacienda y Crédito Público) (2011), *Criterios Generales de Política Económica 2011*, www.hacienda.gob.mx/POLITICAFINANCIERA/FINANZASPUBLICAS/Paginas/CriteriosGralesPolEco.aspx

SMN (Sistema Meteorológico Nacional) (2011), *Clima en México*, http://smn.cna.gob.mx/index.php?option=com_content&view=article&id=103&Itemid=68

SSN (Sistema Sismológico Nacional) (2011), *El SSN y la Sismicidad de México*, http://secre.ssn.unam.mx/SSN/Doc/Mx_sismo/mhist.htm

UN (United Nations) (2008), *State of the World's Cities 2010/2011. Bridging the Urban Divide*, United Nations Human Settlement Program, www.unhabitat.org/pmss/getElectronicVersion.aspx?nr=2917&alt=1

— (2009), *World Urbanization Prospects: The 2009 Revision Population Database*, Department of Economic and Social Affairs, Population Division, esa.un.org/unpd/wup/unup/

UNDP (United Nations Development Programme) (2011), *Human Development Report 2011*, hdr.undp.org/en/media/HDR_2011_EN_Complete.pdf

UNEP (United Nations Environment Programme) (2002), *Cancun Declaration of Like-Minded Megadiverse Countries*, www.pnuma.org/deramb_ing/CancunDeclaration.php

USDOE (United States Department of Energy) (2009), *Modern Shale Gas Development in the United States: A Primer*, www.netl.doe.gov/technologies/oil-gas/publications/epreports/shale_gas_primer_2009.pdf

USEIA (United States Energy Information Administration) (2011), *World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States*, www.eia.gov/analysis/studies/worldshalegas/pdf/fullreport.pdf

— (2012), *U.S. Total Crude Oil and Products Imports*, www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbblpd_a.htm

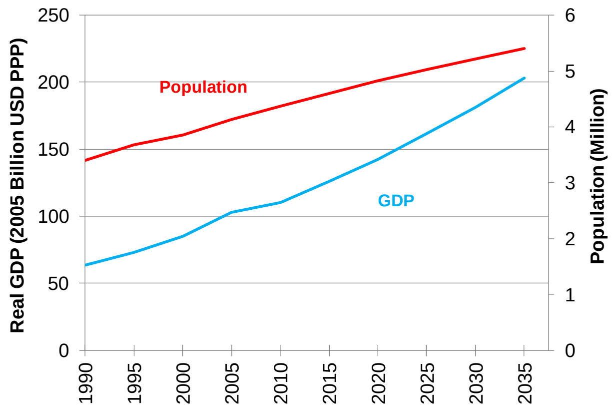
NEW ZEALAND

- *New Zealand policies aggressively promote energy efficiency; as a consequence, New Zealand's energy demand is likely to grow slowly if at all over the 2010–2035 time period.*
- *New Zealand's gas market is totally isolated, with no pipeline connections or LNG terminals; consequently, the level of future gas discoveries poses major uncertainties for New Zealand's energy outlook*
- *While annual CO_2 emissions from fuel combustion are projected to remain stable at around 35 million tonnes over the 2010–2035 time period, emissions per capita of about 8 tonnes/person in 2010 are still higher than some other wealthy economies and higher than the levels required worldwide to avoid damaging climate change.*

ECONOMY

New Zealand is an island economy in the South Pacific, consisting of two main islands—the North Island and the South Island—and a number of smaller outer islands. In land area it is a bit smaller than Japan or the Philippines, but larger than the United Kingdom. The relatively small population of about 4.3 million in 2010 is, however, comparable only to a medium-size Asian city. New Zealand's location is remote from other major economies. There are no electricity or pipeline connections to other economies.

Figure NZ1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

New Zealand is a mature economy, whose population is expected to increase only modestly to about 5.4 million by 2035. About 86% of this population is urban, with the Auckland region alone accounting for about one-third of the 2009 population (United Nations, 2009).

Economic growth will be similarly modest, with GDP increasing by an average of about 2.5% per year in real dollars between 2010 and 2035. New Zealand's per capita GDP of about USD 25 000 puts it at the low-end of the OECD economies. However, New Zealand generally rates high in most 'quality of life' surveys. New Zealanders are generally very environmentally conscious, and take pride in the 'clean and green' condition of their land, water, and air.

Most of New Zealand is hilly or mountainous. The climate is mostly cool and wet. Winters are generally not extreme, with snow and ice unusual except in the far south and at higher elevations. However, winter heating of buildings is still necessary and almost universal. Summer cooling of buildings is, however, less common, and mostly limited to large commercial structures. New Zealand is geologically prone to earthquakes, tsunamis, and volcanic eruptions; several earthquakes in 2010 and 2011 caused fatalities and major damage in the Canterbury/Christchurch area.

New Zealand's economy is heavily dependent on agriculture and associated food processing. Major agricultural activities include the raising of dairy cattle, sheep, and other grazing livestock, as well as the cultivation of orchards and vineyards. Other major export industries include tourism, fishing, coal mining, forestry, and forest products processing.

Because its climate is ideal for pastures, New Zealand is the world's largest dairy exporter, and has been described as the 'Saudi Arabia of Milk' (Wall Street Journal, 2008). The dairy processing industry is particularly energy intensive, as much of New Zealand's dairy exports must be dried or condensed.

Another energy-intensive export industry is the aluminium smelter located at Bluff, which accounts for about 12% of New Zealand's electricity consumption (Covec, et al., 2006). New Zealand has two plants that convert natural gas into methanol, mostly for export. These methanol plants are currently only partially utilized, and their future operation will depend upon the availability of gas and the spread between local gas prices and international methanol prices. There is also one integrated steel mill, one oil refinery, and one chemical plant that converts natural gas into urea (mostly for fertilizer), all of which serve mostly domestic markets.

Although Auckland and Wellington have small commuter rail systems, and all cities have local bus services, the automobile is the dominant mode of local passenger transportation. The automobile and air travel dominate the intercity passenger market, although there are some intercity bus services. Intercity rail services are limited to three routes, mostly served only once a day in each direction. New Zealand has only a few short motorways. Highways and local roads are well maintained, but often narrow and twisty. All of this is unlikely to change very much by 2035 under current policies.

Domestic freight transport is also dominated by road transport, although the railways (re-acquired by the government in 2008) have a role, especially in moving container freight, coal, and other commodities. Due to New Zealand's remote location, New Zealand is heavily dependent on overseas air and ship transport for both freight and tourism.

The majority of New Zealand's automobile fleet is imported used from Japan. There is no domestic automobile manufacturing industry.

ENERGY RESOURCES AND INFRASTRUCTURE

Although New Zealand has a modest oil and gas producing industry, New Zealand was 63% dependent on imports of oil and oil products in 2009. New Zealand also produces a significant quantity of natural gas, which is used for electricity generation, directly in homes and businesses, and in the methanol and urea plants mentioned above. However, only the North Island has a natural gas pipeline and distribution network. New Zealand's gas market is totally isolated from the rest of the world, as there are no facilities for importing natural gas on either island. All of New Zealand's gas is currently domestically produced.

New Zealand's gas and domestic oil come primarily from the Taranaki Basin, where there are several offshore fields. The largest of these fields, Maui, is in depletion, and there has been concern that New Zealand's gas supply could be inadequate in future years. Proposals have been made to build a liquefied natural gas (LNG) terminal to allow the importation of LNG. However, private investors have not been willing to finance such a major investment without government backing, and the government thus far has not been willing to provide the necessary support.

Despite the immediate concerns about gas supply, New Zealand's long-term prospects for finding more domestic gas, and oil as well, are excellent. To quote the website of New Zealand Petroleum & Minerals, the agency that manages New Zealand's oil and gas resources:

> "Taranaki Basin, covering an area of about 330,000 km^2, is currently the only producing basin in New Zealand. … The basin remains under-explored compared to many comparable rift complex basins of its size and there remains considerable potential for further discoveries.
>
> The rest of New Zealand is severely under-explored. Nevertheless, frontier basins drilled to date have all yielded discoveries confirming viable petroleum systems. Given many untested structures mapped have closures bigger than the Maui field (New Zealand's largest field), there is considerable potential for commercial hydrocarbon discoveries under New Zealand's largely untouched seabed." (NZP&M, 2012)

The last few years have indeed seen a series of small discoveries in the Taranaki Basin.

Why the lack of exploration? First, oil is the big prize that most exploration firms seek, and New Zealand's geology is widely viewed as gas-prone. Indeed, much of New Zealand's current 'oil' production is actually natural gas liquids. Second, New Zealand's gas infrastructure is underdeveloped. A modest discovery outside the Taranaki Basin would require the construction of a gas pipeline system to reach the New Zealand market. A really major gas discovery would swamp the New Zealand market and require the construction of an LNG export facility. Either way, the cost of the investment would reduce the value of the gas at the wellhead. Third, many of the best potential drilling sites are distant from shore, in deep water, and exposed to severe sea conditions, making drilling difficult and expensive (Samuelson, 2008). However, each of these barriers is likely to be overcome as technology improves and oil prices rise.

With historically abundant hydro resources, New Zealand is heavily dependent on electricity. Many homes and businesses in New Zealand have electric space heating and electric water heating. About 55% of New Zealand's electricity is generated by hydro. However, the best sites for hydro plants have been largely developed, and there is strong environmental opposition to developing the remaining sites. While some small additional hydro projects may be possible, major new hydro projects are unlikely. New Zealand's heavy dependence on hydro for electricity generation leaves its electricity supplies subject to fluctuations in precipitation. Dry years in New Zealand have historically resulted in electricity supply crises.

New Zealand has only one major coal electricity generation plant, Huntly, commissioned in 1987 (NZMED, 2012, Table G3.C). While there is only one coal plant, it operates as a baseload facility and accounted for about 8% of New Zealand's electricity production in 2009. Although New Zealand has significant domestic coal resources, there is strong opposition to new coal plants because of their greenhouse gas emissions. Although Huntly will probably continue to operate for some time, it is unlikely that a new coal plant could be built in New Zealand without carbon capture and storage.

Gas accounted for about 21% of New Zealand's electricity production in 2009. While there is environmental opposition to new gas plants on the basis of their greenhouse gas emissions, the opposition is less strong than it would be for coal. Gas has the advantages of a relatively low capital cost, a short construction and approval cycle, and an ability to avoid transmission constraints (since gas plants can be built close to major markets and existing transmission infrastructure). So gas is an attractive option for new electricity generation.

Geothermal electricity accounted for about 13% of New Zealand's electricity production in 2009, and there is significant potential for more. It is worth noting that, in accordance with New Zealand's statistical standards, we assume geothermal energy has a conversion efficiency of only 15%. This means it takes roughly seven units of primary geothermal steam energy to produce one unit of electricity. As a result, our figures for primary energy from new renewable energy (NRE) for New Zealand are quite large, perhaps deceptively so.

Wind power, which currently accounts for about 4% of New Zealand's electricity production in 2009, could also be expanded significantly. Unlike most economies, New Zealand's windy climate often allows wind farms to be developed without subsidy.

New Zealand has only one small oil-fired generation plant, which serves as a reserve resource. Due to high costs and concerns about the security of supply, oil is probably New Zealand's least-preferred option for electricity generation.

ENERGY POLICIES

New Zealand has adopted an economy-wide target for a 50% reduction in New Zealand's carbon-equivalent net emissions, compared with 1990 levels, by 2050. New Zealand is willing to commit to reducing greenhouse gas emissions by between 10% and 20% below 1990 levels by 2020, if there is a comprehensive global agreement and certain conditions are met (NZMED, 2011).

The Climate Change Response (Emissions Trading) Amendment Act 2008 established New Zealand's emissions trading scheme. The scheme places a price on greenhouse gas emissions to provide an incentive to reduce the volume of overall emissions. Six gases covered under the Kyoto Protocol are covered under the scheme—carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (CCINZ, 2011).

In August 2011, the government released the *New Zealand Energy Strategy 2011–2021: Developing Our Energy Potential* (NZMED, 2011) to replace the 2007 New Zealand Energy Strategy. The new strategy focuses on four priorities: diverse resource development; environmental responsibility; the efficient use of energy; and secure and affordable energy. As part of the Energy Strategy, the New Zealand Government retains the target of 90% of electricity to be generated from renewable sources by 2025, provided security of supply is maintained.

New Zealand has a relatively long tradition of promoting energy efficiency, having passed an Energy Efficiency and Conservation Act in the year 2000, which led to the first National Energy Efficiency and Conservation Strategy, as well as the establishment of the Energy Efficiency and Conservation Authority (EECA) to spearhead the implementation of the strategy. The Energy Strategy includes a revised New Zealand Energy Efficiency and Conservation Strategy 2011–2016. The overall goal of the new strategy is for New Zealand to continue to improve its energy intensity (energy used per unit of GDP) by 1.3% per year to 2016. New Zealand has no fossil fuel subsidies that would encourage wasteful consumption.

New Zealand's oil and gas exploration and production activities are largely in private ownership and open to competition. New Zealand generally welcomes investments in oil and gas exploration by foreign firms. Electricity generation and marketing is also largely open to competition, but three of the five major generators are state-owned firms, as is the transmission grid operator. The New Zealand Electricity Authority oversees the rules of the electricity market, but does not regulate electricity prices.

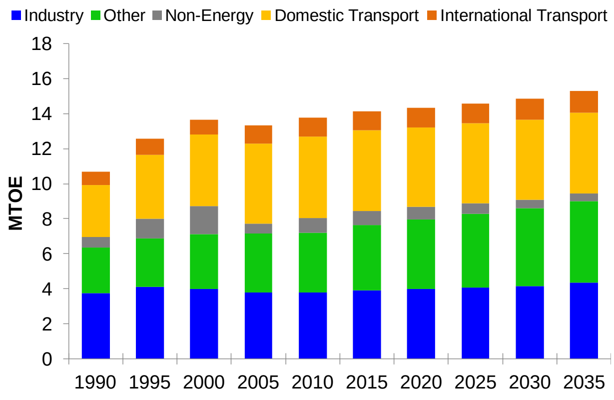
The coal mining industry in New Zealand is dominated by a large state-owned firm, although there are private operators as well.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

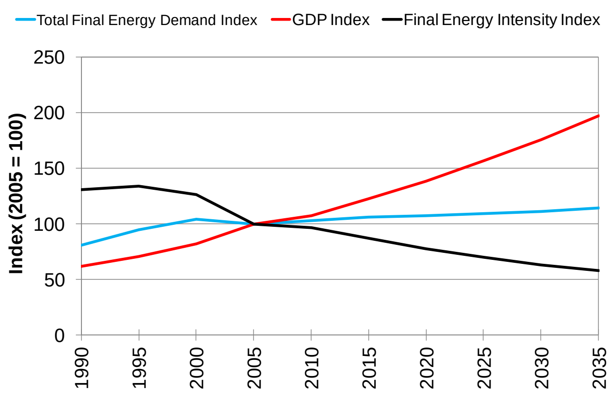
Business-as-usual (BAU) final energy demand is expected to grow at 0.4% per year over the outlook period. The 'other' sector (covering residential, commercial, and agriculture uses) will account for 91% of the growth. Demand is more or less evenly split between industry, transport and 'other'. Final energy intensity is expected to decline by about 42% between 2005 and 2035.

Figure NZ2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011a

Figure NZ3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 0.5% until 2035, reflecting the slow growth of New Zealand industry generally. New Zealand's heavy industry is dominated by a few big firms. The aluminium and chemical industries may be viewed as a way of exporting surplus energy. Their future will depend on the availability of low-cost electricity and gas respectively. The other industries have competitive advantages in their local or export markets, so their demand is expected to be stable. Some growth in light industry is expected, but it is unlikely to be energy intensive.

Industrial electricity use is projected to increase from 1.2 Mtoe in 2010 to 1.5 Mtoe in 2035, accounting for the fastest growth, both in absolute industrial energy demand and in percentage terms, at an average annual rate of 0.8%.

Transport

Vehicle ownership in New Zealand has already reached saturation level. Over the outlook period, the domestic transportation energy demand of New Zealand is projected to remain almost unchanged. Rising vehicle kilometres travelled will be offset by increasingly efficient vehicles. Higher vehicle fuel efficiency will be stimulated by stricter fuel efficiency standards in Japan, from which the majority of New Zealand's vehicles are imported in used form, as well as by New Zealand's own vehicle efficiency labelling scheme.

Although New Zealand currently exempts electric vehicles from road user charges, almost all transport energy demand is likely to be for oil products. Conventional diesel vehicles will be increasingly common, comprising about one-quarter of the light vehicle fleet by 2035.

Other

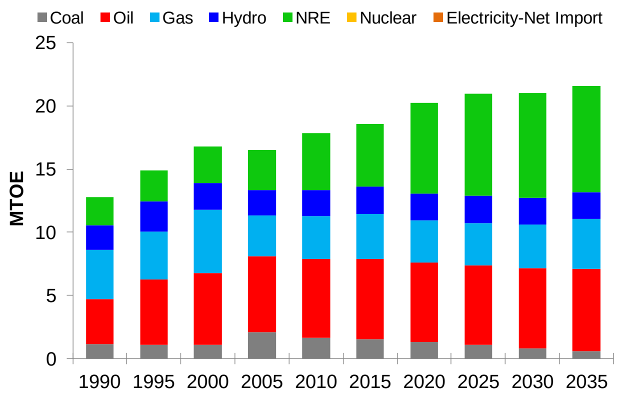
New Zealand's energy efficiency building codes, minimum efficiency performance standards for appliances, and assistance for home insulation and clean heating retrofits will help to hold down the growth of residential energy demand.

However, these efforts will be offset by a growing population, larger homes, and more appliances. Energy demand in the 'other' sector, which includes residential, commercial, agricultural and construction demand, is expected to grow at 1.3% per year over the outlook period. Electricity is expected to continue to dominate the fuel mix in this sector, accounting for 62% of 'other' energy consumption in 2035.

PRIMARY ENERGY SUPPLY

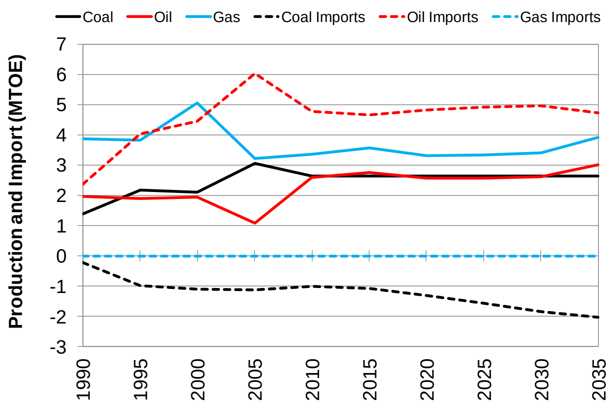
New Zealand's primary energy supply in the 2010–2035 period is projected to grow at an annual rate of 0.8%.

Figure NZ4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011a

Figure NZ5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011a

Given the isolated nature of New Zealand's gas market, the amount of gas that will be available is perhaps the greatest uncertainty in New Zealand's energy outlook. In APERC's view, the evidence suggests that additional gas supplies are likely to be found. As noted above, the geological prospects are good. And the market seems to be responding, with exploration and development activity continuing at historically high levels. New Zealand's Energy Data File 2012 notes that NZD 6.8 billion has been spent in the most recent five years (2007–2011) on oil and gas exploration and development. By comparison, from 2002 to 2006 a total of NZD 2.7 billion had been spent (NZMED, 2012, Table H.1).

The availability of gas is likely to allow New Zealand to continue to generate electricity from gas, and to meet any gap between electricity demand growth and new renewable energy (NRE) generation with domestic gas. It is also likely New Zealand can continue to produce methanol for export from gas.

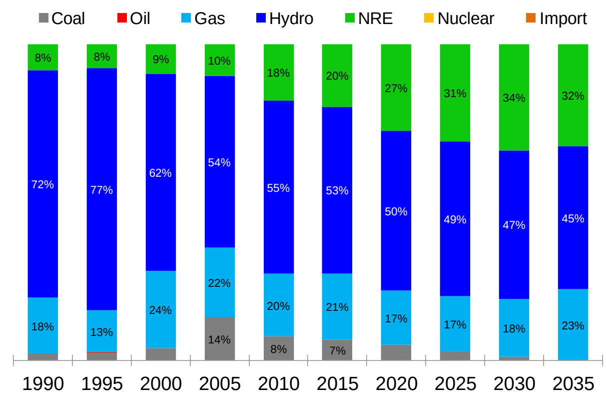
Oil production is subject to similar uncertainties and similar good prospects. Given New Zealand's very small projected increase in oil demand to 2035, any increase in oil production could reduce New Zealand's dependence on oil imports. APERC projects a very slight decline in oil imports from about 4.8 Mtoe in 2010 to about 4.7 Mtoe in 2035, but these are highly uncertain figures.

ELECTRICITY

The availability of gas and renewables should make it possible to gradually phase out New Zealand's only coal-fired generation plant, Huntly. Electricity production from hydro is likely to remain fairly constant, given the lack of attractive sites for new projects and the opposition to hydro development at the sites that are available. However, other forms of renewable generation, including wind and geothermal, are likely to more than double between 2010 and 2035, reflecting both available resources and existing supportive government policies.

Given the many uncertainties, especially regarding gas discoveries, it is difficult to say if New Zealand will reach its goal of 90% renewable electricity by 2025. Given the isolated nature of the New Zealand gas market, if significant amounts of additional gas are discovered, as APERC assumes, it will probably be priced to be competitive with renewables in the electricity generation market, since it has nowhere else to go.

Figure NZ6: BAU Electricity Generation Mix

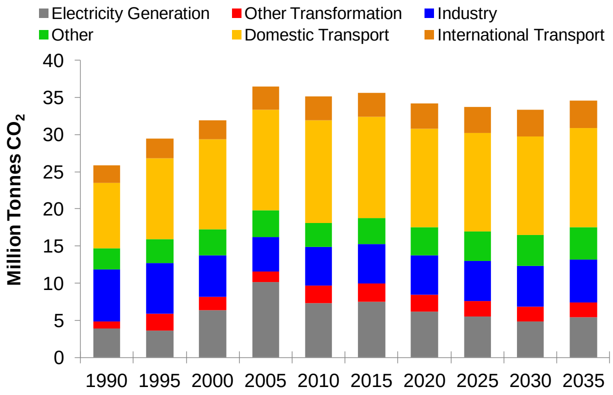


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011a

CO_2 EMISSIONS

Over the outlook period New Zealand's total CO_2 emissions from fuel combustion are projected to remain approximately stable at around 35 million tonnes. This result is explained by the stable use of oil in the transport sector, the declining use of coal in electricity generation offset by a modest increase in the use of gas, the stable demand for fossil fuels in the industrial sector, and only a small increase in demand in the residential/commercial/agricultural ('other') sector.

Figure NZ7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table NZ1 below suggests the growth in New Zealand's GDP will be offset by a small reduction in the CO_2 intensity of energy (fuel switching) and a small reduction in the energy intensity of GDP (energy efficiency).

It should be noted that New Zealand is unusual among developed economies in that total greenhouse gas emissions from agriculture have historically slightly exceeded emissions from energy (NZMFE, 2011).

Table NZ1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	0.6%	-2.3%	-1.3%	-1.0%	-0.8%
Change in Energy Intensity of GDP	-1.5%	0.1%	-1.3%	-1.4%	-1.7%
Change in GDP	3.3%	1.4%	2.3%	2.3%	2.5%
Total Change	2.3%	-0.8%	-0.4%	-0.2%	-0.1%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

By comparison with most economies, New Zealand's business-as-usual energy outlook is reasonably good. CO_2 emissions from fossil fuels may be stable over the 2010–2035 time period, while oil imports may decline. However, at around 8 tonnes/person each year, New Zealand's CO_2 emissions per person from fossil fuel consumption remain relatively high on a world scale, higher for example than the 2009 emissions of France, Sweden, or Switzerland (IEA, 2011b, p. 97), and far above the level which must be achieved worldwide to avert damaging climate change (see Volume I, Chapter 16).

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts that higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU scenario prices or below if constraints on gas production and trade could be reduced.

New Zealand's gas market is, however, a rather exceptional case for two reasons. First, with no pipeline connections to other economies, and no LNG terminals, New Zealand's gas market is totally isolated from other economies. Second, while an increase in New Zealand's gas production beyond BAU levels is a definite possibility, it would probably cause New Zealand's CO_2 emissions to increase rather than decrease. This is because, in APERC's BAU scenario, the only major coal-fired electricity generation plant will be phased out. So rather than competing with coal, gas competes primarily with renewables including wind and geothermal.

So, unlike other APEC economies, increased gas production in New Zealand would likely have negative, rather than positive, environmental impacts. The only exception would be if the increase in New Zealand's gas production were so huge that it made the construction of an LNG export terminal economic. In this event, New Zealand could export gas to other APEC economies where it could be used to replace coal. Given the underexplored nature of much of New Zealand's territory, large future gas discoveries are a possibility. However, the currently known gas resources in New Zealand would not allow for LNG exports at the present time.

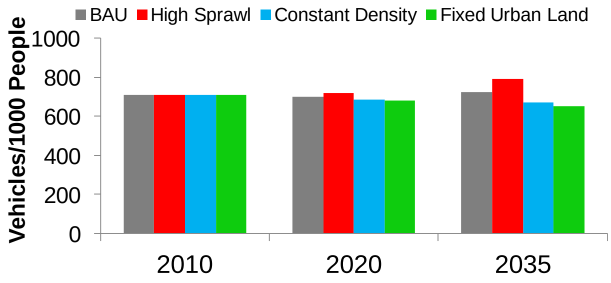
For these reasons, the High Gas Scenario was not run for New Zealand. Figures NZ8–NZ10 are, therefore, not included here.

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure NZ11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the scenarios is significant, with vehicle ownership being about 9% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 10% lower in the Fixed Urban Land scenario. Given that New Zealand is a relatively wealthy economy with vehicle ownership at close to saturation levels, the model results suggest better urban planning could modestly reduce the need for people to own vehicles. New Zealand's cities, especially Auckland, are currently characterized by a high level of 'sprawl'.

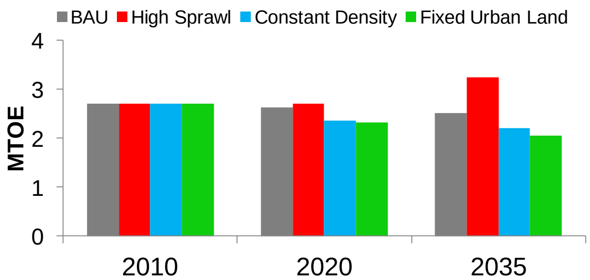
Figure NZ11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure NZ12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of better urban planning on light vehicle oil consumption is more pronounced than on vehicle ownership, as more compact cities reduce both the need for vehicles and the distances they must travel.

Figure NZ12: Urban Development Scenarios – Light Vehicle Oil Consumption

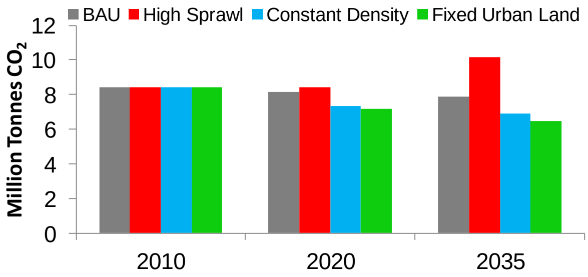


Source: APERC Analysis (2012)

Light vehicle oil consumption would be 29% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 18% lower in the Fixed Urban Land scenario.

Figure NZ13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO_2 emissions would be 29% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 18% lower in the Fixed Urban Land scenario.

Figure NZ13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



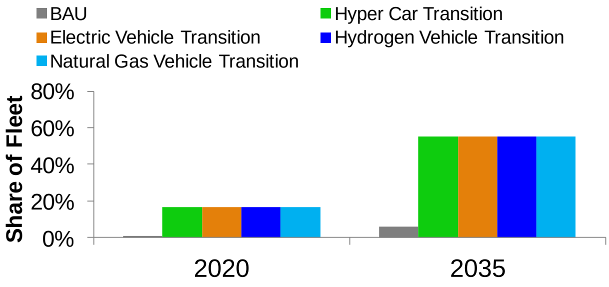
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure NZ14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035, the share of the alternative vehicles in the vehicle fleet is assumed to reach about 55% compared to about 6% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 45%, compared to about 94% in the BAU scenario.

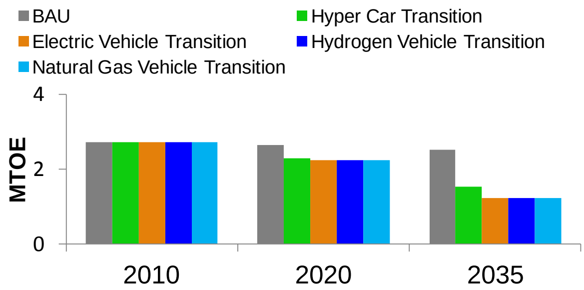
Figure NZ14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure NZ15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—40% by 2035—even though these highly-efficient vehicles still use oil.

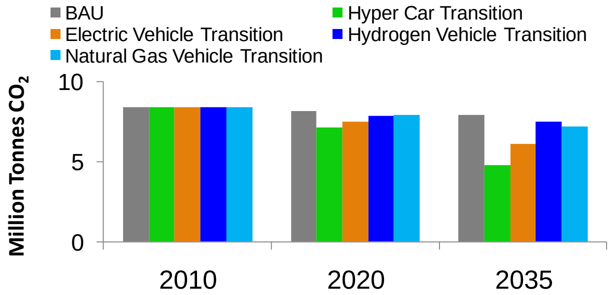
Figure NZ15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure NZ16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition Scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

Figure NZ16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

In New Zealand, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reductions with emissions reduced 39% compared to BAU in 2035. This figure is roughly in line with their reduction in oil demand. The Electric Vehicle Transition scenario comes in second, offering a 22% reduction. Electric vehicles offer a significant reduction because in New Zealand the additional electricity for electric vehicles would be generated with gas rather than the coal that would be used in many APEC economies (to facilitate fair comparisons, the Electric Vehicle Transition scenario assumes no additional renewable generating capacity). The Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios offer considerably less emissions reductions (9% and 5%, respectively).

REFERENCES

CCINZ (Climate Change Information New Zealand) (2011), *Emissions Trading Scheme Basics*, www.climatechange.govt.nz/emissions-trading-scheme/basics.html

Covec, Hale & Twomey, and Exergi Consulting (2006), *Heavy Industry Energy Demand*, www.covec.co.nz/sites/covec.tst/files/Heavy%20Industry%20Energy%20Demand_0.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011a), *World Energy Statistics 2011*, CD-ROM Edition.

— (2011b), *CO_2 Emissions from Fossil Fuel Consumption Highlights*, www.iea.org/media/statistics/CO2highlights.pdf f

NZMED (New Zealand Ministry of Economic Development) (2011), *New Zealand Energy Strategy 2011–2021: Developing Our Energy Potential*, www.med.govt.nz/sectors-industries/energy/strategies

— (2012), *New Zealand Energy Data File 2012*, www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-data-file/new-zealand-energy-data-file-2012

NZMFE (New Zealand Ministry for the Environment) (2011), *New Zealand's Greenhouse Gas Inventory 1990–2009*, www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2011-snapshot/greehouse-gas-inventory-2011-snapshot.pdf

NZP&M (New Zealand Petroleum & Minerals) (2012), 'Petroleum Basins' website page, www.nzpam.govt.nz/cms/petroleum/petroleum-basins

Samuelson, Ralph D. (2008), *Oil: An Introduction for New Zealanders*, Ministry of Economic Development, www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/oil-an-introduction-for-new-zealanders

United Nations (2009), *World Urbanization Prospects: The 2009 Revision Population Database*, Department of Economic and Social Affairs, Population Division, http://esa.un.org/wup2009/unup/

Wall Street Journal (2008), "'Saudi Arabia of Milk' Hits Production Limits", 8 May 2008, http://online.wsj.com/article/SB121018928727674565.html

PAPUA NEW GUINEA

- *Papua New Guinea will become a major LNG exporter with the start-up of LNG export projects after 2014.*
- *Papua New Guinea's total primary energy supply is projected to increase from 2.2 Mtoe in 2010 to 6.7 Mtoe in 2035; fuel gas for LNG liquefaction accounts for a significant portion of this increase.*
- *Papua New Guinea may shift from a net oil exporter to a net oil importer after 2020 unless new reserves of oil are found.*
- *Papua New Guinea has a significant hydroelectric and geothermal potential. The government plans to either build or upgrade 800 MW of hydro electricity and over 500 MW of geothermal generating capacity within the next 10–15 years to provide a reliable and affordable electricity supply.*

ECONOMY

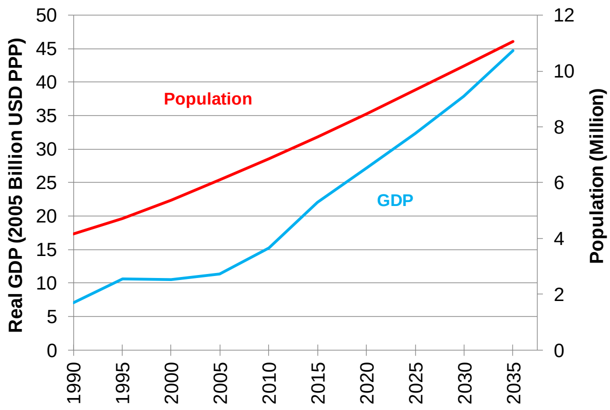
Papua New Guinea is located in the south-western Pacific Ocean, just south of the equator. It is made up of over 600 islands, including the eastern half of New Guinea—the world's second-largest island—as well as the Bismarck Archipelago, the D'Entrecasteaux island group, and the three islands of the Lousiade Archipelago. New Guinea and the larger islands are mountainous and rugged, with a string of active volcanoes dotting the north part of the mainland and continuing to the island of New Britain.

Papua New Guinea's population was 6.7 million in 2009, with more than 80% living in rural areas. Most of the rural population are dependent on subsistence farming. Only 13% of households have access to electricity (DNPM, 2010a).

The population is expected to grow at an average annual rate of 1.9% over the outlook period. The population in Papua New Guinea's major cities and towns is expected to double by 2035, to reach 2 million people as a result of the high rural-urban migration to the National Capital District and other major towns like Madang, Mt Hagen, Lae, Kimbe and Rubail. Rural provinces such as Chimbu, East Sepik, Milne Bay, Oro, Gulf and Munus are expected to experience an out-migration of people as a result of a lack of services and income opportunities.

Papua New Guinea has achieved moderate economic growth and government surpluses since 2003. Economic growth has primarily been aided by high commodity prices. The real GDP growth rate between 2005 and 2010 was 6%. GDP is expected to continue to expand at an average annual rate of 4.4% over the outlook period.

Figure PNG1: GDP and Population



Sources: USDA ERS (2012) and APERC Analysis (2012)

The economy of Papua New Guinea can be separated into subsistence non-market and market sectors. The market economy is dominated by large-scale resource projects, particularly mining, oil and gas. Agriculture currently accounts for 13% of GDP and supports more than 75% of the population (DNPM, 2010a). The economy's primary cash crops are coffee, palm oil, cocoa, copra, tea, rubber and sugar. Some of the rural population are involved in smallholder cash cropping of coffee, cocoa and copra. Operations in Papua New Guinea's mining, timber, and fishing sectors are largely foreign owned.

Papua New Guinea is endowed with substantial mineral resources, including gold, copper and natural gas. Government revenue depends heavily on minerals exports and after 2014 it will benefit from the start of liquefied natural gas (LNG) exports. The remainder of Papua New Guinea's industry sector is made up of light industries and agricultural processing industries.

Papua New Guinea's economic development will require considerable growth in the coverage and quality of its state transport network. Currently, Papua New Guinea has one of the lowest road densities in the world. The total road network is

30 000 kilometres (km), of which 8460 km are state roads. Only 28% of the 8460 km of state roads were in a good condition in 2010. A comprehensive program of rehabilitating existing roads and constructing new roads would expand the state road network to 25 000 km by 2035 (DNPM, 2010a, p. 66). Congestion on roads in the urban areas will be a growing issue as the number of passenger vehicles is expected to increase rapidly with rising income levels.

About 60% of Papua New Guinea's population depends on water transportation including for the delivery of goods and services. The water transport system's services and infrastructure will also require upgrading. Port Moresby, Lae and Kimbe are the economy's busiest seaports, accounting for more than 80% of its cargo. Between 2010 and 2035 it is projected the cargo throughput at all Papua New Guinea's ports will increase five-fold under rapid development (DNPM, 2010a).

The aviation industry will continue to play a vital role. For many remote parts of Papua New Guinea, air transport is their only possible link with the main centres. However, the economy's regional airports do not meet international standards and need to be developed to handle larger planes and increased passenger numbers.

ENERGY RESOURCES AND INFRASTRUCTURE

The Papuan Basin in the south-eastern part of Papua New Guinea is the most explored and developed oil and gas region in the economy—particularly the Papuan Fold Belt and Papuan Foreland areas. There has also been exploration in the North New Guinea basin, and the Cape Vogel, New Ireland and Bougainville basins.

Papua New Guinea's proven hydrocarbon reserves consist primarily of natural gas (440 billion cubic metres (bcm)), followed by oil (0.660 billion barrels) and gas condensates (0.262 billion barrels). The inclusion of inferred, mean-risk reserves would increase oil reserves by an additional 1 billion barrels, and natural gas by more than 283 bcm (PNG CMP, 2012).

Oil development started in 1991 with crude oil production at the Kutubu fields. Production at the Kutubu fields peaked in 1993, but has been declining. The fields are projected to be depleted by 2026 (DNPM, 2010a).

In 2005, Papua New Guinea's first oil refinery started production, sourcing crude oil from both local oil fields and imports. In 2008, 5.8 million barrels of crude oil were processed (DNPM, 2010a). The capacity of the existing refinery, with expansion, could reach 9 million barrels by 2035.

Papua New Guinea's ExxonMobil-led LNG export project is expected to start up in 2014, with a capacity of 6.6 million tonnes per year. Consideration is being given to adding a third train (ExxonMobil, 2010). InterOil has obtained government approval for its plans to develop another LNG project at Elk-Antelope with construction starting after 2014. Its project would be similar in size to the ExxonMobil-led LNG export project (Platts, 2012). The project's final investment decision should be reached in 2013. These projects can greatly stimulate Papua New Guinea's economy. In general, Papua New Guinea is considered to be underexplored for gas.

Papua New Guinea has a significant hydroelectric potential. Its land area includes nine large hydrological drainage divisions (basins). The largest river basins are the Sepik (catchment area of 78 000 square kilometres (sq km)), the Fly (61 000 sq km), the Purari (33 670 sq km), and the Markham (12 000 sq km). There are other catchments of less than 5000 sq km, in areas that are very steep. On the mainland, the mean annual rainfall ranges from less than 2000 mm to 8000 mm in some mountainous areas, while the island groups receive a mean annual rainfall of 3000–7000 mm. The gross theoretical hydropower potential for Papua New Guinea is 175 terawatt-hours (TWh) per year (Encyclopedia of Earth, 2008). By 2035, 800 MW of hydro electricity generating capacity is planned to be either built or upgraded (DNPM, 2010a).

The Geothermal Energy Association estimates Papua New Guinea's geothermal potential at 21.92 TWh. The association also categorizes Papua New Guinea as an economy that could, in theory, meet all its power needs from geothermal sources alone, well into the future (GEA, 2010).

The government in partnership with the private sector will pursue the development of renewable sources, including geothermal. By 2035, about 500 MW of new geothermal electricity generating capacity could be put into operation in the economy (DNPM, 2010a).

Papua New Guinea has three large regional electricity power grids. The Port Moresby system serves the National Capital District and surrounding areas in the Central Province. The main source of generation is the Rouna system consisting of four hydro stations on the Laloki River, controlled water storage in the Sirinumu Reservoir, and a small generator at the toe of the Sirinumu dam. The total generation capacity from the Rouna power stations is

62.2 MW. A thermal power station at Moitaka, outside Port Moresby, has a generation capacity of 30 MW based on diesel and gas turbines. A privately-owned diesel power station at Kanudi has a capacity of 24 MW (JOGMEC, 2011).

The Ramu system serves the load centres of Lae, Madang and Gusap in the Momase Region and the Highlands centres of Wabag, Mendi, Mt Hagen, Kundiawa, Goroka, Kainantu and Yonki. The main source of generation is the Ramu Hydro Power Station with an installed capacity of 75 MW, comprising five units of 15 MW each. Additional hydro energy is supplied by Pauanda, a 12 MW run-of-river station in the Western Highlands Province. Power is also purchased when required from the privately owned Baiune Hydro Power Station at Bulolo in the Morobe Province, and varies between 1 MW to 2 MW depending on availability. There are diesel plants at Madang, Lae, Mendi and Wabag. These plants serve as stand-by units.

The Gazelle Peninsula system serves the townships of Rabaul, Kokopo and Keravat and the system is powered by the 10 MW Warangoi hydro plant, the 8.4 MW Ulagunan diesel plant, and the 0.5 MW Kerevat diesel plant (PPL, 2012).

In addition to these three grids there are also oil-based power stations serving various isolated communities.

ENERGY POLICIES

The Papua New Guinea Government has jurisdiction over energy matters. The Papua New Guinea National Energy Policy and the Rural Electrification Policy are under review by the Government Task Force on Policy. The exploration and development of petroleum resources are authorised and administered by the Department of Petroleum and Energy.

The Papua New Guinea Government has initiated the Papua New Guinea Vision 2050 (NSPT, 2010) which has seven 'pillars'; natural resources, climate change and environmental sustainability are among the areas of focus. In the Vision 2050, the Papua New Guinea Government notes the economy can make a significant contribution to reducing global greenhouse gas (GHG) emissions with good forest management and through the development of its hydroelectric and geothermal potential.

In its Copenhagen Accord response of 2 February 2010, Papua New Guinea stated it was seeking to "decrease GHG emissions at least 50% before 2030 while becoming carbon neutral before 2050", subject to certain conditions (UNFCCC, 2010).

In March 2010, the Papua New Guinea Government announced the Development Strategic Plan 2010–2030 (DNPM, 2010a), which has five pillars—one of which is 'natural resources and environment'.

In October 2010, the Papua New Guinea Government announced its Medium Term Development Plan (MTDP) 2011–2015 (DNPM, 2010b). The MTDP 2011–2015 will focus on increasing access to electricity for all households in the economy. A comprehensive analysis of the cost effectiveness of various alternative sources of power will be required.

Petromin PNG Holdings Limited (Petromin), a state-controlled company, holds the economy's oil and gas assets and seeks to maximise indigenious ownership and revenue in the petroleum and gas sectors. It will do this through proactive investment strategies either alone or in partnership with resource developers (PNG CMP, 2012).

The state-owned PNG Power Ltd (PPL) is a fully integrated power authority responsible for the generation, transmission, distribution and retailing of electricity throughout Papua New Guinea and for servicing individual electricity consumers.

PPL services customers in almost all urban centres throughout the economy, encompassing the industrial, commercial, government and domestic sectors. The company also has a regulatory role in approving licences for electrical contractors, providing certification for electrical equipment and appliances to be sold in Papua New Guinea, and providing safety advisory services and checks for major installations.

PPL is regulated under a price control mechanism known as the maximum average price (MAP). Under MAP, for each of the tariffs PNG Power Ltd charges to the different classes of its consumers (Industrial, General Supply, Domestic Customers and Public Lighting) the average price of those tariffs must not exceed the MAP determined by the Papua New Guinea Government (PPL, 2012).

The Papua New Guinea Government has been successful in attracting major international oil and gas companies to the economy with its very open oil and gas industry structure.

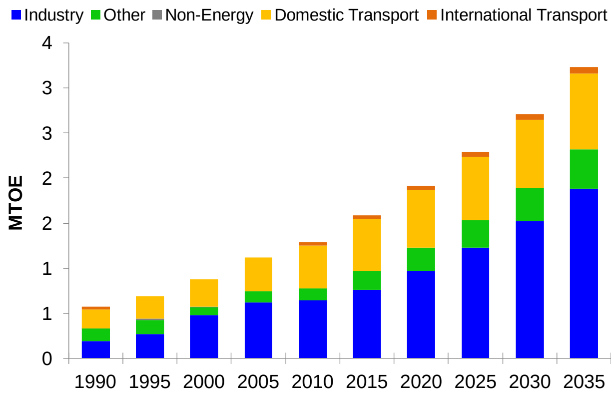
A key strategic objective for the Papua New Guinea Government's energy policy is to provide access to electricity to at least 70% of households by 2030 (DNPM, 2010a).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow at 3.8% per year over the outlook period. The industry sector will account for 59% of final demand in 2035, driven by the development of LNG projects.

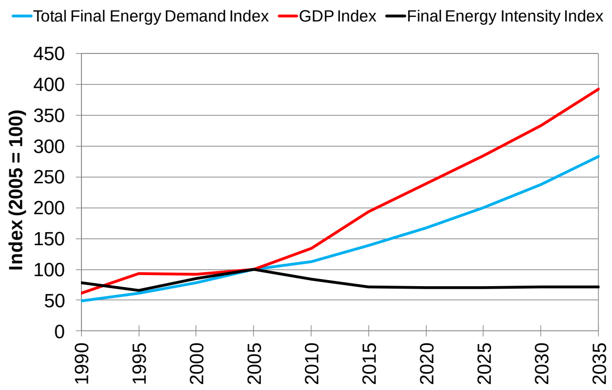
Figure PNG8: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: APEC (2011)

Final energy intensity is expected to decline by about 28% between 2005 and 2035, with the industry, transport and services sectors projected to see a substantial improvement in their energy intensity.

Figure PNG3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

This outlook assumes Papua New Guinea's industry sector will retain its current structure, which consists mainly of mining, light manufacturing and agricultural processing. However, the scale of production of these industries is expected to grow.

Final industry energy demand is projected to increase at an average annual rate of 4.4%, from 0.6 Mtoe in 2010 to 1.9 Mtoe in 2035.

Transport

Final energy demand in the transport sector is expected to increase at an average annual rate of 2.3% over the outlook period. This demand will be met almost entirely by oil-derived fuels.

Other

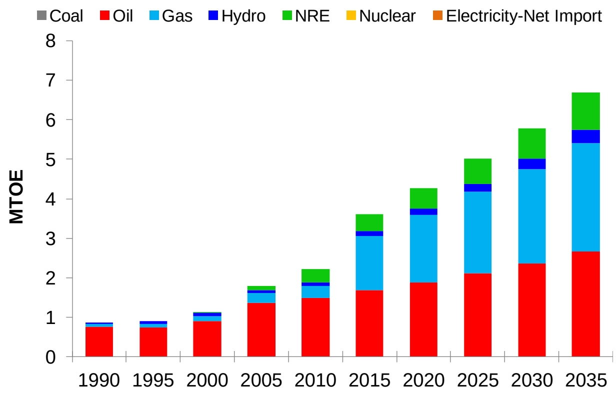
The final energy demand in the 'other' sector, which includes residential, commercial and agricultural users, is projected to increase at an average annual rate of 4.8% over the outlook period. In the 'other' sector, commercial energy demand will be primarily for electricity, kerosene and LPG (liquefied petroleum gas). There are currently no plans for the construction of a gas distribution network for residential and commercial customers.

The projection for the 'other' sector includes only the final demand for commercial energy, due to inadequate information about non-commercial energy use in Papua New Guinea. The economy's consumption of non-commercial biomass is projected to remain significant over the outlook period.

PRIMARY ENERGY SUPPLY

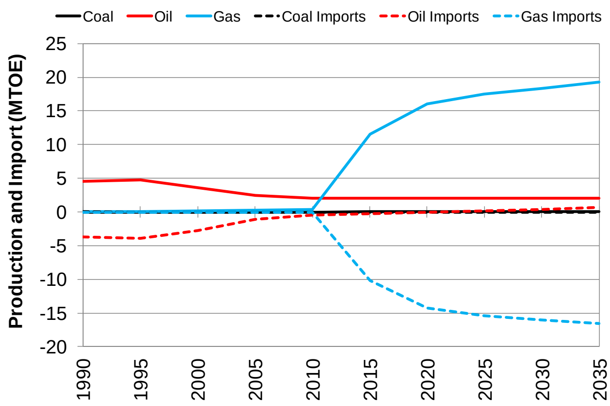
Papua New Guinea's primary energy supply in the 2010–2035 period is projected to grow at an annual rate of 4.5%. Oil, which was the predominant form of energy before 2010, will be increasingly supplemented with natural gas and new renewable energy (NRE) (mainly geothermal). Papua New Guinea has historically been a modest oil exporter, but could become an oil importer after 2020.

Figure PNG4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: APEC (2011)

Figure PNG5: BAU Energy Production and Net Imports



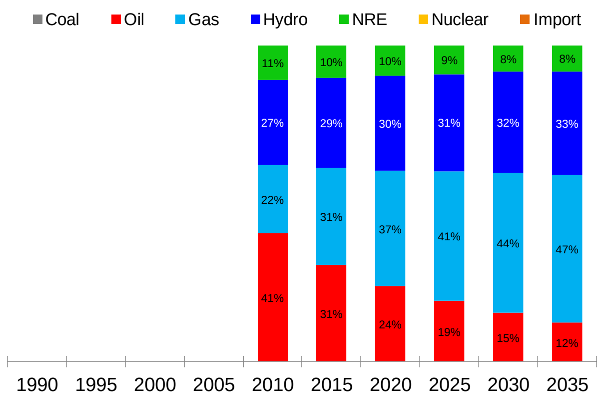
Source: APERC Analysis (2012)
Historical Data: APEC (2011)

Although not part of final energy demand, about 25% of Papua New Guinea's primary energy supply in 2035 will be used to produce and liquefy natural gas for export. And, although not part of either primary energy supply or final energy demand, about 86% of Papua New Guinea's natural gas production will be exported.

ELECTRICITY

Electricity generation is projected to grow by 4.9% annually over the outlook period and to reach 12.2 TWh in 2035.

Figure PNG6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)
Historical data is not available for Papua New Guinea.

Natural gas electricity generation is expected to increase over 700% between 2010 and 2035 as a result of a natural gas supply becoming available in the Port Moresby area.

Diesel and heavy oil generated electricity have been the main contributors to the high cost structure in the economy's electricity sector. After 2015, diesel and heavy oil generators will be phased out and retained mainly for back-up purposes.

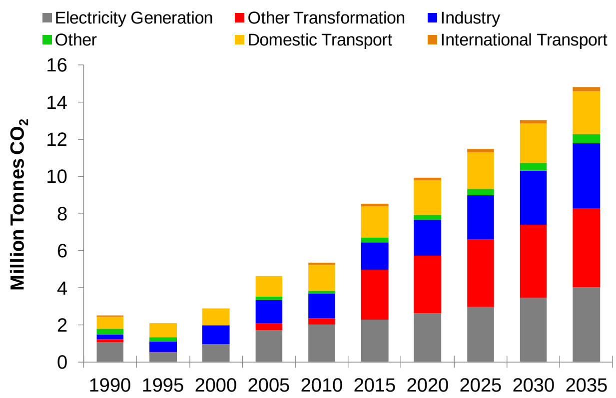
Papua New Guinea has no plans to use coal for power generation.

CO_2 EMISSIONS

Papua New Guinea's CO_2 emissions from the combustion of fuels are projected to reach 14.8 million tonnes in 2035, which is almost a 2.8 times increase from the 2010 level of 5.5 million tonnes.

In 2035, electricity generation and other transformation (primarily own-use in LNG liquefaction plants) are projected to contribute the largest shares of CO_2 emissions (4.0 million and 4.2 million tonnes, respectively), followed by industry (3.6 million tonnes) and transport (2.5 million tonnes).

Figure PNG7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

From the decomposition analysis shown in Table PNG1, it can be seen that economic growth at an annual rate of 4.4% through the outlook period drives the growth in Papua New Guinea's CO_2 emissions. This will be offset by modest reductions in energy intensity and carbon intensity (in particular, the shift away from oil).

Table PNG1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.8%	-1.1%	-0.7%	-0.6%	-0.5%
Change in Energy Intensity of GDP	1.7%	-1.1%	-0.4%	-0.5%	-0.3%
Change in GDP	3.3%	6.0%	4.9%	4.7%	4.4%
Total Change	4.2%	3.6%	3.9%	3.5%	3.5%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Given the success of Papua New Guinea's efforts to attract investment in gas exploration and development, the economy should be able to achieve the significant growth in natural gas production we project throughout the outlook period. Our business-as-usual projection, however, shows Papua New Guinea will become a net oil importer before 2035 unless significant new oil reserves are found.

There is a great potential to replace oil in electricity generation. Papua New Guinea is fortunate to have a diversity of lower-carbon options, including the greater use of geothermal and hydropower resources. The development of these resources will have high upfront investment costs. However, they may well be more economic in the long run, compared to the more readily available option of gas-fired electricity generation.

The needs for specialised expertise and considerable financial resources mean Papua New Guinea's development will depend on a transparent, stable, and fair incentive regime for foreign investors.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies, although only two could be developed for Papua New Guinea.

HIGH GAS SCENARIO

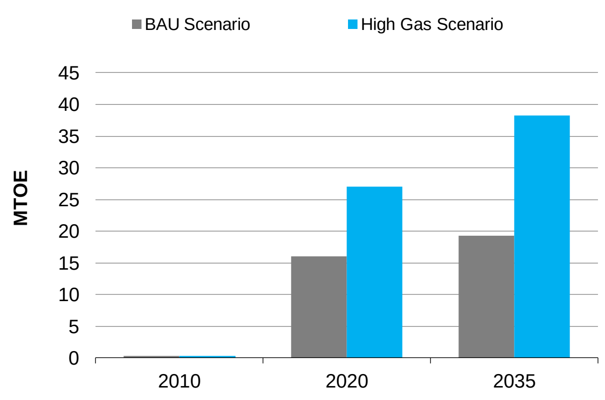
To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU case prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario production for Papua New Guinea assumed a production increase almost double the BAU levels, as shown in Figure PNG8. Papua Guinea has the potential for increasing production based on resources which are believed to exist, but this will require significant investment in both production and LNG infrastructure. The High Gas Scenario assumes a continuing transparent, stable, and fair incentive regime for foreign investors, which will enable greater investment in gas production for LNG exports to international markets.

The major impact of this scenario would be to enable Papua New Guinea to increase its LNG exports to other APEC economies, thereby enabling them to replace more coal with natural gas in electricity generation. Papua New Guinea itself uses no coal in electricity generation, even in the BAU scenario, so we assume no change in the generation mix. Hence Figures PNG9 and PNG10 are not shown.

There may be an additional potential for Papua New Guinea to replace some of the remaining oil used in electricity generation with natural gas. However, oil generation may be needed to serve remote communities where natural gas would not be available. Due to data limitations, this option was not examined.

Figure PNG8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

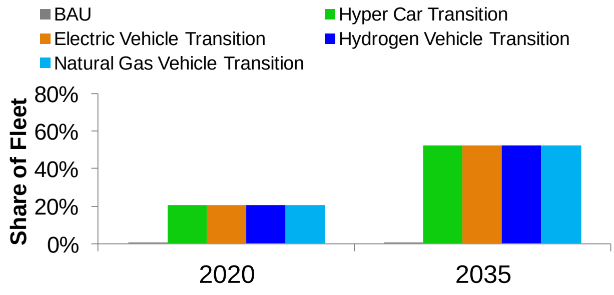
The three alternative urban development scenarios were not examined for Papua New Guinea due to a lack of adequate data. Hence Figures PNG11 to PNG13 are not shown.

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PNG14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035, the share of alternative vehicles in the fleet reaches around 51% compared to about 1% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 48%, compared to about 99% in the BAU scenario.

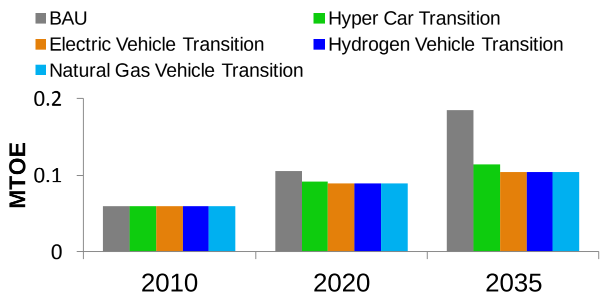
Figure PNG14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure PNG15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 38% by 2035—even though these highly-efficient vehicles still use oil.

Figure PNG15: Virtual Clean Car Race – Light Vehicle Oil Consumption

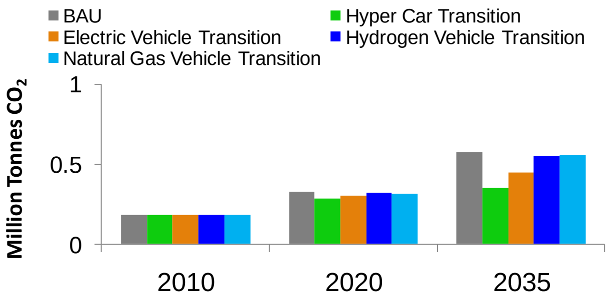


Source: APERC Analysis (2012)

Figure PNG16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impact of each scenario may differ significantly from its oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Papua New Guinea, the Hyper Car Transition scenario is the winner in terms of CO_2 emissions savings, with an emissions reduction of 38% compared to BAU in 2035. The Electric Vehicle Transition scenario would offer a reduction of 22% in emissions in 2035, larger than in many other economies due to the assumption none of the additional electricity would be generated from coal. The Hydrogen Vehicle Transition scenario would reduce emissions by 4% and the Natural Gas Vehicle Transition scenario would decrease emissions by 3% compared to BAU in 2035.

Figure PNG16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

APEC (2011), *APEC Energy Statistics 2009*, October 2011, www.ieej.or.jp/egeda/database/

DNPM (Department of National Planning and Monitoring, Papua New Guinea) (2010a), *Development Strategic Plan 2010–2030*, www.treasury.gov.pg/html/publications/files/pub_files/2011/png-development-strategic-plan.2010-2030.pdf

— (2010b), *Medium Term Development Plan 2011–2015*, www.undp.org.pg/docs/publications/MTDP.pdf

Encyclopedia of Earth (2008), 'Water profile of Papua New Guinea' website page, www.eoearth.org/article/Water_profile_of_Papua_New_Guinea

ExxonMobil (2010), "Papua New Guinea LNG Project Clears Final Conditions to Proceed", 12 March 2010, www. news.exxonmobil.com/press-release/papua-new-guinea-lng-project-clears-final-conditions-proceed

GEA (The Geothermal Energy Association) (2010), *Data on PNG*, www.geo-energy.org/pdf/reports/gea_international_market_report_final_may_2010.pdf

JOGMEC (Japan Oil, Gas and Metals National Corporation) (2011), *Study on Economic Partnership Projects in Developing Countries in FY2010: Study on the Gas Conversion and Optimization of Thermal Power Stations in the Outskirts of the Capital of the Independent State of Papua New Guinea: Final Report*, March 2011, prepared for the Ministry of Economy, Trade and Industry by JOGMEC and Japan Petroleum Exploration Co., Ltd., www.meti.go.jp/meti_lib/report/2011fy/E001610.pdf

NSPT (National Strategic Plan Taskforce) (2010), *Papua New Guinea Vision 2050*, www.treasury.gov.pg/html/publications/files/pub_files/2011/2011.png.vision.2050.pdf

Platts (2012), "Papua New Guinea government aims to deliver InterOil LNG project: Governor General", 22 August 2012, www.platts.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/7999958

PNG CMP (Papua New Guinea Chamber of Mines and Petroleum) (2012), 'Petroleum in PNG' website page, http://pngchamberminpet.com.pg/petroleum-in-png/

PPL (PNG Power Ltd) (2012), 'Tariffs & Rates' website page, www.pngpower.com.pg/index.php/tariffs-a-rates

USDA ERS (United States Department of Agriculture, Economic Research Service) (2012), *International Macroeconomic Dataset*, www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx

UNFCCC (United Nations Framework Convention on Climate Change) (2010), Letter from Kevin M. Conrad, Special Envoy and Ambassador for Environment & Climate Change, Department of Prime Minister and National Executive Council, Papua New Guinea, 2 February 2010, http://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/pngcphaccord_app2.pdf

PERU

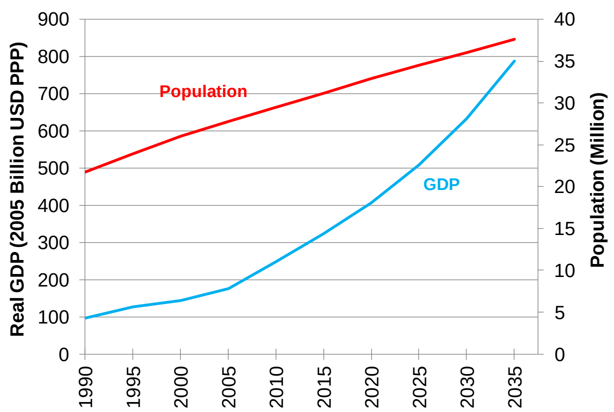
- *Although Peru is expected to remain a net gas exporter into the future, there is some uncertainty whether long-term production from the Camisea gas project will meet the economy's demand and export commitments, especially in the final years of the outlook period.*
- *The expected reduction in hydropower's contribution to electricity production, as fossil fuel use rises, will be the fastest growing source of CO_2 emissions over the outlook period.*
- *Peru has considerable potential for improving its energy efficiency; however, this will require the expansion of effective large-scale measures into the more energy-intensive sectors such as transport and electricity generation.*

ECONOMY

Peru is a developing economy in South America and one of the three APEC Latin American economies. It has a land area of around 1.28 million square kilometres along the Pacific coast of the continent, bordering Ecuador and Colombia to the north, Brazil and Bolivia to the east, and Chile to the south. Peru's economic resources and climatic conditions are diverse; its climate zones range from tropical humidity in the Amazon rainforests, dry and cold in the Peruvian Andes' highlands, to hot and humid along the coast. Its complex biodiversity has led to Peru being listed as one of the 12 mega-diverse economies in the world (UNEP, 2002).

Peru is politically divided into 25 regions and the Lima Municipality, which is considered an autonomous region containing Lima, the capital city. With roughly nine million people, Lima is also the economy's largest urban and financial centre and is ranked fifth among Latin American urban centres (UN, 2008), containing 31% of the total Peruvian population (INEI, 2011b). Other important cities in the economy are Arequipa, Trujillo and Chiclayo.

Figure PE1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Peru's urbanization in recent decades has been rapid, with an annual growth rate of 2.1% since 1990. As of 2010, around 77% of Peru's population is considered urban, while 22% is still living in rural areas (UN, 2009). Peru's population, close to 29.5 million, is expected to grow at an average annual rate of 1%, reaching 37.6 million people in 2035.

Peru's economic growth since 2000 has been significant, with its GDP in constant currency terms increasing at an average annual rate of 5.7% from 2000 to 2010. Peru is the seventh largest economy in Latin America and the fifty-first in the world (IMF, 2011).

The main contributor to the economy is the services sector, which accounts for nearly 62% of Peru's GDP, followed by industry with 24% and agriculture with the remaining 14% (INEI, 2011a). The Peruvian economy is expected to grow considerably between 2010 and 2035, with GDP increasing at an annual average rate of 4.8%.

Growth in GDP per capita is expected to be less dynamic, with a projected annual growth rate of 3.7% over the same period, to reach almost USD 21 000 by 2035. Although Peru is considered a 'High Human Development' economy, placed eightieth in the world and eighth in Latin America on the basis of the United Nations' Human Development Index, the economy faces major challenges in terms of improving quality of life for its people. These challenges include increasing the proportion of the population with access to water and sanitation (Peru's rate is among the lowest in Latin America), as well as reducing the proportion of the urban population living in slums (currently about one-third) (UNDP, 2011; UN, 2008). In spite of some success in poverty reduction in the five years to 2011, Peru still struggles to improve general conditions, with 31% of its population considered poor and 10% considered extremely poor (INEI, 2011b).

Peru is a commodity export economy, with minerals, natural gas, fish and produce accounting for nearly 78% of its total exports. The mining sector is critical to the Peruvian economy, as it constitutes 4.3% of GDP, provides 61% of exports and is a key destination for foreign direct investment in the economy, attracting 23% of the total (INEI, 2011a; MINCETUR, 2011; Proinversión, 2011). Peru is the world's top producer of silver, second of copper and zinc, third of tin, fourth of lead and mercury and sixth of gold (MINEM, 2010c).

After mining, the energy (oil and gas) industry is the most important in Peru, accounting for almost 1.4% of its GDP, making up almost 10% of its exports and representing 16% of the total foreign direct investment (INEI, 2011a; MINCETUR 2011; Proinversión, 2011). The remainder of Peruvian exports are mainly agricultural and fishing products.

Owing to Peru's diverse geography and climate, the economy is also exposed to several natural hazards. Earthquakes, tsunamis, volcano activity, droughts, and floods are not uncommon. In particular, Peru has been affected by the periodic climatic phenomena known as 'El Niño' and 'La Niña'—this sudden increase (El Niño) or decrease (La Niña) of equatorial ocean water temperature approximately every five years—that give rise to abnormal rainfall patterns that can go way above or below the norm, with severe economic consequences. The Peruvian Government estimated the economic losses caused in 1997 and 1998 by El Niño at over USD 3.5 billion (INDECI, 2010; NASA, 2011).

Transport systems in Peru are insufficient to keep up with demand growth and there are few options other than road transport, which is the dominant mode. Air transport infrastructure is limited, with most passenger and freight traffic going through Lima airport. The rail network is also fairly limited, and most traffic is for freight only. Water-based transportation is only employed in the Amazon river areas (MTC, 2005; MTC, 2011a).

The economy's road infrastructure comprises a total of 126 000 kilometres of roads maintained by three levels of government (central, state and local). The overall quality is poor, with less than 20% of Peruvian roads being paved (MTC, 2011c). In rural and poor areas such as in the Andes mountains, the roads' poor quality, or their absence, hinders economic growth by isolating populations from access to social centres and markets. With the help of the World Bank, a road construction program for the economy's poorest areas was implemented from 1995 to 2011. It is estimated that 3.5 million people benefited from this program, which included the construction of rural vehicle roads, pedestrian paths and fluvial corridors in the Amazon region (WB, 2010).

Bus services are the main public transport option across Peru, and small-sized vans (combis) and minibuses (micros) provide most of the conventional passenger service in Lima. The informality and disorganization prevalent in their operations is not only responsible for their general inefficiency, but also for significant emissions (MTC, 2007). In the city of Lima, however, the 2010 introduction of an urban train line and a bus-rapid-transit (BRT) corridor (with vehicles operating on compressed natural gas) has significantly reduced the number of conventional vehicle commuter trips.

Peru's total vehicle fleet reached 1.8 million units in 2010, with nearly two-thirds of these in the Lima region (MTC, 2011b). In a move to benefit Peruvian families, car purchases were boosted in the 1990s by reducing import restrictions. This facilitated the importing of used cars, which has had an impact on the economy's vehicle fleet's renewal rate and average age—the fleet is considered old, with an average age of 17 years.

With no domestic vehicle manufacturers, all Peruvian vehicle sales come from imported stock, whether new or used. Most used units come from Japan and South Korea, requiring special facilities (CETICOs) to convert the right-wheeled Asian cars to the Peruvian left-hand-drive mode (BBVA, 2010).

In 2001, the government set maximum allowable vehicle emissions limits, calculated according to the vehicle's technology and fuel. The license required to import a vehicle now has stricter conditions applying to used cars, such as gasoline-fuelled vehicles not being older than five years, and diesel vehicles not being older than two. These criteria have reduced used car sales as well as their share in the economy's total car sales, falling from 83% in 2001 to 20% by 2010 (MTC, 2011a). By the end of 2012, the removal of the fiscal benefits granted to some CETICOs in combination with the reduction of taxes on the sales of new cars seems likely to reduce further the share of used cars into the Peruvian car fleet over the next few years (Gestión, 2013).

ENERGY RESOURCES AND INFRASTRUCTURE

Peru possesses a variety of natural resources, including a range of energy sources. Proved energy reserves total 582 million barrels of crude oil (1.24 billion barrels if natural gas liquids (NGL) are included), 0.35 trillion cubic metres of natural gas, 21.4 million tonnes of coal and 1800 tonnes of uranium located in the Puno region (MINEM, 2010a; MINEM, 2011). Of particular significance, the economy's natural gas reserves are the largest in South America after Brazil and Argentina (OGJ, 2011).

Peru produced 72 700 barrels per day (B/D) of crude oil and 84 500 B/D of NGL in 2010 (MINEM, 2010a). The economy's oil-refining capacity, which totals 213 300 B/D, is spread across six refineries (Conchán, El Milagro, Iquitos, La Pampilla, Pucallpa and Talara) (Petroperu, 2011; Repsol, 2011). Production of petroleum products in 2010 reached 74 620 million barrels, with gasoline and diesel making up half of the total output. Peru is a net oil importer. Not only is the domestic production insufficient to meet domestic demand, but most crude produced is of extra-heavy type, which cannot be processed in many of Peru's refineries. Of around 55 million barrels of total crude oil processed in Peru's refineries in 2010, the proportion of indigenous feedstock was 36%, while the remaining 64% was imported, mainly from Ecuador and Nigeria (MINEM, 2010a).

In contrast with its modest oil profile, Peru is considered a major South American gas producer. The Camisea project is the economy's major gas production area and is by far the most important energy project ever undertaken in Peru (Pluspetrol, 2011). This project began with the San Martín and Cashiriari gas fields, commonly known as 'Block 88', in the Ucayali basin in south-eastern Peru along the Camisea River. Although they were discovered in the 1980s, it was not until 2000 that a 30-year production contract was signed between the government and production companies, with development starting in 2004. In 2010 Peru produced around 7.2 billion cubic metres (255.6 billion cubic feet) of natural gas, a remarkable increase of 108.4% over the previous year. This was mainly due to the addition of Block 56 to the project; this block's output represented almost 40% of total production (MINEM, 2010a).

Although the initial aim of the Camisea project was to provide natural gas for domestic use, gas production increased rapidly since 2004, which has allowed the development of a liquefied natural gas (LNG) export market (MINEM, 2010a; PlusPetrol, 2011). In 2010, Peruvian LNG exports from its Melchorita plant amounted to 3.59 bcm, representing approximately half of Peru's total production (Perupetro, 2011).

Coal production in Peru is limited and the economy is a net importer. Peru's coal needs are met by 87% imports and 13% domestic production. Reserves amount to about 21 million tonnes and are located in the La Libertad, Ancash and Lima regions, with nearly all of them (95%) of anthracite type; bituminous coal makes up the rest (MINEM, 2011).

Peru's electricity infrastructure is based on the National Interconnected System (SEIN for its acronym in Spanish), which covers most of Peru—SEIN was created by interconnection of Peru's northern and southern power grids in 2001. There are also isolated power systems in areas where an extension of SEIN is not technically or economically feasible. Roughly 20% of the Peruvian population still lacks of access to electricity (MINEM, 2010d).

Of Peru's total installed power capacity of 8612 MW in 2010, about 85% goes into public service via SEIN and 15% is used by on-site power systems isolated from the main grid, servicing municipalities and private users (MINEM, 2010b). Several private companies participate in electricity generation, transmission and distribution on SEIN and a remarkable proportion of the economy's electricity generation is based on hydroelectricity (approximately 46%). The rest comes from thermal power plants, which are fuelled by natural gas (33% of total electricity production), diesel and fuel oil (19%) and coal (2%). Increasing gas production and availability in recent years has stimulated gas use within thermal plants.

New renewable energy (NRE) sources for electricity generation, such as biomass and wind, represent only 0.3% of the total capacity (MINEM, 2010b, 2010d). However, the Ministry of Energy and Mines' (MINEM) projections for Peru's NRE-based power generation are promising. The potential contributions are estimated at 77 GW from wind energy and 60 GW from biomass. In addition, while there has been no formal assessment of geothermal energy potential in Peru, initial studies suggest sufficient resources to allow power generation projects. At the same time, potential resources of hydropower (which is not counted as a 'new' renewable energy source) has been estimated at 177 MW.

Peru's SEIN system has one international link with Ecuador. While further interconnections with electricity networks in Brazil and Colombia are planned in the near future, interconnection with Chile and Bolivia is prevented by the use of different frequencies in their electricity systems (MINEM, 2010d).

ENERGY POLICIES

In Peru, the Ministry of Energy and Mines (MINEM) is responsible for development of energy policies and for guidance of the energy sector, as well as for addressing mining policies and issues. This reflects the major importance of these two sectors to the Peruvian economy.

MINEM is responsible for environmental issues concerning energy and mining activities. Through its different departments, the ministry covers all major areas of influence in the energy sector, oversees their activities and promotes investment to achieve sustainable development across the economy. In addition to MINEM, an autonomous regulatory organization created in 1996, Organismo Supervisor de la Inversión en Energía y Minería (Osinergmin) is in charge of setting electricity tariffs and gas transportation rates. Its goal is promoting efficiency in the power and gas sectors at the lowest possible cost for the customer.

In November 2010, MINEM issued Peru's Energy Policy Proposal 2010–2040. The goal of the policy is to meet Peru's energy demand in a safe, sustainable, reliable and efficient way, supported by planning, research and technological innovation. Its main objectives are achieving a diversified and competitive energy matrix with emphasis on renewable energy and energy efficiency; a competitive energy supply; universal access to energy supply; the highest possible efficiency levels in the energy production and utilization systems; self-sufficiency in energy production; and developing an energy sector with minimal environmental impact and low carbon emissions, as part of sustainable development (MINEM, 2010e).

In particular, the policy strives to develop the natural gas industry and extend its use in the residential, commercial, transport and industrial sectors as well as for efficient power generation. It also calls for strengthening institutions involved in the energy sector and joining regional energy markets in order to achieve Peru's long-term vision (MINEM, 2010e).

As Peru's economy has become gradually more open, free-market mechanisms such as competition and private operation have been implemented in industries such as mining, electricity, hydrocarbon and telecommunications. Several new laws have established a regime where domestic and foreign investments are subject to equal terms and this has encouraged foreign companies to participate in almost all economic sectors. Overall, Peru aims to ensure proper conditions to attract and retain investment by granting foreign investors equal treatment with Peruvians. Most activities are unrestricted, and there are a variety of schemes available under which investment can be made.

Under this regime, oil and gas upstream activities in Peru are conducted by private companies under licence or on service contracts granted by the government. In addition to MINEM, the government-owned company Perupetro is in charge of assessing the technical aspects of the contracts granted. The government guarantees that the tax law in effect on the agreement date will remain unchanged throughout the contract term. Under a licence contract, the investor pays a royalty; whereas under a service contract, the government pays remuneration to the contractor. In both cases, the distribution of the economic rent (either as royalty or remuneration) is determined using two methodologies: production scales and economic results (Ernst & Young, 2011).

Before Camisea came online, Peru had developed only the Aguaytía gas field in its central region and some others in the northern department of Piura. Camisea, as one of the biggest gas reserves in South America and source of nearly all (more than 95%) of the natural gas in Peru, has been the basis of major development of the domestic natural gas industry (Osinergmin, 2008; MINEM, 2010a). The development is based on a model that aims for an open market with free competition in the production sector—with some government-set goals that participating companies have to meet. There is some government regulation of the transport and distribution activities, especially regarding tariffs (Osinergmin, 2008).

Electricity is a major issue within Peru's energy profile. When economic reforms began in 1992, one of the main targets of the Peruvian Government was the liberalization of the market to create an efficient, competitive and reliable electricity sector. This sector is now divided into three areas: generation, transmission, and distribution, with many private and government-owned power utilities participating in all of them. By law, electric energy dispatch and planning are carried out by the Electric Energy Operation and Dispatch Committee (COES for its Spanish acronym), which is a private and independent operator. To foster efficiency and competition, the legal framework prevents the participating companies from creating trusts and monopolies.

Peru's policies in the electricity sector have these objectives:

- reducing the economy's exposure to price volatility and helping ensure that consumers receive more competitive electricity tariffs
- reducing administrative intervention in generation price determination to promote market solutions
- creating effective competition in the generation market

- introducing a mechanism of compensation between SEIN and the isolated systems so that prices in the separate systems incorporate the benefits of natural gas production while reducing their exposure to the volatility of fuel markets.

Under this framework, there are regulated and non-regulated electricity prices, depending on the size of individual demand. 'Free' users are exempt from regulated prices due to their large demand (usually equal or more than 2500 kWh on their maximum annual demand), while users under 2500 kWh are subject to the regulated prices scheme.

Peru also has policy goals to increase use of renewable energy sources and support their development. The government aims to diversify renewable-based electric generation from the current significant reliance on hydropower. Modifications to the regulatory framework in 2008 added new features, including a five-year target for the share of domestic power consumption generated from renewable energy sources (excluding hydropower plants larger than 20 MW installed capacity); a firm price guaranteed for up to 20 years for successful bidders for energy supply contracts; and priority in dispatch and access to networks.

To achieve the renewable energy policy goals, MINEM established open auctions for renewable energy supply in order to ensure competitive conditions for electricity generators and customers. The first auction, finished in March 2010, added 411 MW in renewable energy capacity to SEIN; this was awarded in 26 projects using wind, solar, biomass or mini-hydro (Osinergmin, 2011b). From a second auction, open in the second half of 2011, another 210 MW of capacity was added to SEIN. This consists of 102 MW small hydro, 90 MW wind power, 16 MW solar and 2 MW biomass from urban waste (Osinergmin, 2011a).

In regard to biofuels, Peru's regulatory framework also establishes a mandatory fuel blending of 7.8% of bioethanol in gasoline (this mix is known as gasohol) and 5% of biodiesel in traditional diesel (this mix is known as diesel B5).

Although Peru does not use nuclear energy for power generation, a government-run nuclear program has been in operation since 1975. In late 2009, Peru's Nuclear Energy Institute (IPEN, for its acronym in Spanish) presented its Institutional Strategic Plan 2010–2016. This plan encompasses three main objectives, including the promotion of power generation based on nuclear energy (IPEN, 2009). In addition, Peru's Energy Policy Proposal 2010–2040 considers nuclear energy development as an integral part of the economy's energy matrix in the long term.

To promote energy efficiency, in 2009 MINEM published a Referential Plan for the Efficient Use of Energy 2009–2018. This document outlines the actions required in each sector to achieve the economy's energy efficiency goals. The key goal is to reduce energy consumption by 15% from 2007 levels by 2018, through implementation of energy efficiency measures.

Subsequently, in May 2010, the Peruvian Government created the General Directorate of Energy Efficiency (DGEE) within the Vice-Ministry of Energy (through Supreme Decree No. 026–2010–EM). DGEE serves as the technical regulatory body in charge of the proposal and assessment of energy-efficient use and production, and non-conventional renewable energy issues. It also leads the economy's energy planning, and is in charge of developing the National Energy Plan, which must incorporate actions for electricity sector development, in line with economy-wide development policies and the 2010–2040 Energy Policy framework.

Energy prices in Peru are partially subsidized. To strengthen macroeconomic development, the Peruvian Government created the Fund for Price Stabilization of Oil-derived Fuels in 2004. This aims to avoid price increases for final consumers resulting from high volatility in international oil prices. Using this mechanism, the government sets upper and lower price limits for producers and importers, to ensure the price stays within that range in spite of changing market conditions. In the case of fluctuations that drive the price above the limit, the difference is covered by the fund, through transfers to producers and importers; in the opposite situation, these parties will pay to the fund the difference between the actual price and the band's lower limit (El Peruano, 2010). As of early 2012, the fund was still operating, with considerable benefit for retail LPG, regular gasoline (84 and 90 octane), gasohol, diesel B5 and industrial fuel oil used for power generation (El Peruano, 2012).

As one of the economies most vulnerable to climate change, Peru has looked forward to implementing an effective and sustainable strategy for adapting and mitigating its effects. After the United Nations Climate Change Conference of Parties (COP16) held in Cancun, Mexico in late 2010, Peru submitted its Nationally Appropriate Mitigation Action (NAMA), which proposes to reduce the economy's emissions by working towards several objectives. These objectives include reduction to zero of net deforestation of natural or primary forests;

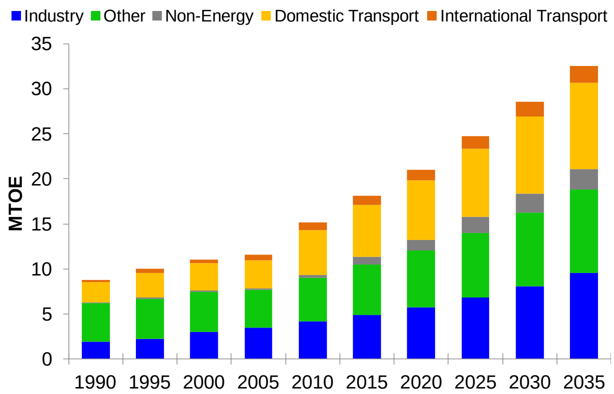
modification of the current energy grid, so that renewable energy (nonconventional energy, hydropower and biofuels) represents at least 33% of the total energy use by 2020; and implementation of measures to reverse the inappropriate management of solid waste (UN–FCCC, 2011).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Peru's final energy demand (excluding the international transport sector) is expected to grow at an average rate of 3.1% per year, from 14.3 million tonnes of oil equivalent (Mtoe) in 2010 to 30.6 Mtoe by 2035 in the business-as-usual (BAU) scenario. In the long term, the most significant change is expected in the industry sector, which will expand its energy demand 130%, rising to 9.6 Mtoe in 2035. In 2035 the domestic transportation and industry sectors are expected to share the lead with a 31% share each, closely followed by the 'other' sector with 30%, and non-energy with 7%.

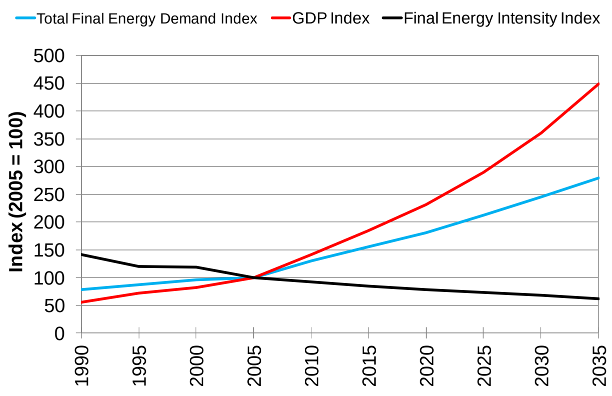
Figure PE2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

From 2005 to 2035, Peru's final energy intensity is expected to decline considerably, by 38% in comparison to 2005 levels.

Figure PE3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Reflecting its energy-intensive nature, Peru's industrial energy demand is expected to increase at an average annual rate of 3.4% from 2010 to 2035. Gas demand is expected to experience the biggest increase over the outlook period, growing 243% from 2010, followed by electricity (141%) and oil (128%), while coal use is expected to slightly decrease (4%) in the same period.

Projections indicate that fuel shares in 2035 will remain fairly similar to 2010. The main changes are an increase in gas from 15% to 22% and decrease in coal from 15% to 6%. Although the share of natural gas in the Peruvian industrial energy demand is expected to grow, this will ultimately depend on the development of distribution networks to reach potential customers beyond Lima, which currently stands as the most important market. Energy intensity in this sector is expected to decrease by 38% from 2005 to 2035.

Transport

As in other developing economies, Peru's transport energy demand remains the largest of the final-use sectors. Due to a projected expansion of the economy's total vehicle fleet by nearly 250% from 2010 to 2035, it is expected that energy demand in this sector will grow 92% in the same period (equivalent to an annual average growth of 2.6%). By 2035, energy demand will reach 9.6 Mtoe (11.5 Mtoe if international transport is included).

Road transport is expected to account for nearly all the transport demand, with oil-based fuels (gasoline, diesel and LPG) being the dominant energy sources. Biofuels demand is also expected to increase based on the growth of oil-based fuels, given Peru's mandatory blending of gasoline with bioethanol and diesel with biodiesel. Development of other fuels and/or technologies in this sector seems unlikely and is not considered in the projection.

Some of the main factors that will affect the transport energy demand in the outlook period are:

- the expiration of import licenses for used cars, which will make for greater efficiency in the vehicle fleet as more new cars are sold—and which could ultimately promote the introduction of new technologies
- the building and expansion of CNG infrastructure and the success of the current CNG projects, such as the Lima BRT corridor
- aggressive transport policies that could call for construction of new mass transportation systems

- tighter environmental standards that might allow development of new technologies or setting of higher biofuels blending targets.

Other

Reflecting the increased urbanization in Peru in the outlook period, energy demand growth in the 'other' sector (which covers residential, commercial and agriculture use) is expected to be moderately rapid, with an annual average growth of 2.6% reaching 9.3 Mtoe by 2035.

Electricity is the source expected to experience the fastest growth in 'other' sector demand (162%), closely followed by oil (mainly as LPG, 158%) and natural gas (138%). As Camisea gas production rises, natural gas and its by-product LPG are expected to increase their availability. While natural gas distribution grids are expected to expand in Lima and Callao replacing existing LPG and electricity demand there, in turn LPG's greater distribution is expected to replace demand for less convenient fossil fuels (such as coal and kerosene) or non-commercial biomass.

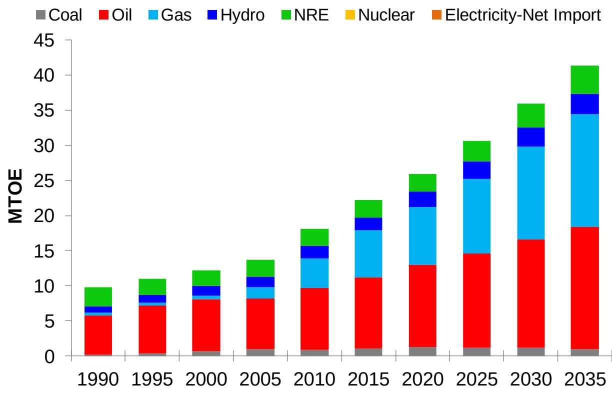
In contrast, the demand growth in the 'other' sector for new renewable energy (NRE) is expected to be much lower. As non-commercial biomass is still widely used in Peruvian households for heating and cooking purposes in the form of firewood, dung and yareta (a dried moss-type plant), it is likely demand will decrease as more convenient energy options become available. Other commercial NRE sources such as solar may also come into production but on a small scale.

Nonetheless, the expected decrease in energy intensity in the 'other' sector will be greater than in Peru's industry and transport sectors. Under the legal framework set by the Peruvian Reference Plan for the Efficient Use of Energy, several programs will operate until 2018, including replacement of incandescent bulbs by high-efficiency lamps, replacement of traditional electric boilers by solar technology in households, and replacement of stoves running on firewood and kerosene by new appliances based on natural gas and LPG. As a result, energy intensity in the 'other' sector is expected to improve significantly, decreasing 51% from 2005 to 2035.

PRIMARY ENERGY SUPPLY

Peru's primary energy supply is projected to increase by 129% in the outlook period, rising from 18.0 Mtoe in 2010 to 41.3 Mtoe in 2035. Fossil fuels (coal, oil and gas) are expected to remain the main energy sources, mainly due to the anticipated expansion in domestic supply of natural gas, with their combined share of the primary supply expected to increase from 77% in 2010 to nearly 84% in 2035. The remainder of the energy supply will come from hydro and NRE. While gas supply growth is expected to grow most rapidly, increasing 282% from 2010 to 2035, growth from coal will be the lowest, expanding 15.1% in the same period.

Figure PE4: BAU Primary Energy Supply

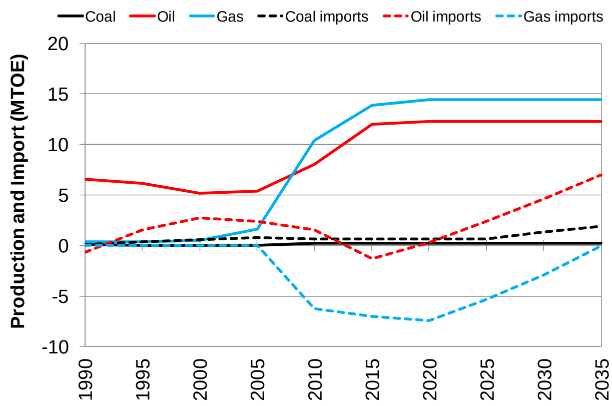


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Under BAU assumptions, Peru is expected to continue as a net gas exporter based on its proven natural gas reserves, production and demand. However, as the Peruvian Government's production forecasts are restricted to a 10-year span, gas production beyond that period is somewhat uncertain. In this regard, the assumptions made in this Outlook are that gas output will peak in 2016, and will be sustained around that level until 2035. The projection therefore indicates gas imports will be required in the last years of the outlook period to meet growing demand and whether gas imports are needed or not will ultimately depend on Peru's capacity to strengthen its exploration and production and maximize Camisea's output.

Projections indicate that Peru will remain an oil importer throughout the outlook period. Given its scarce oil reserves and limited production in comparison to expected demand, net oil imports are expected to grow 352%. In addition, since no major coal mining projects seem likely in the near future, coal imports will continue to be required to meet most of its demand.

Figure PE5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

From 2005 to 2035 Peru's primary energy intensity will decrease by 33%. This is of special importance to Peru's energy security given its role as a growing oil importer.

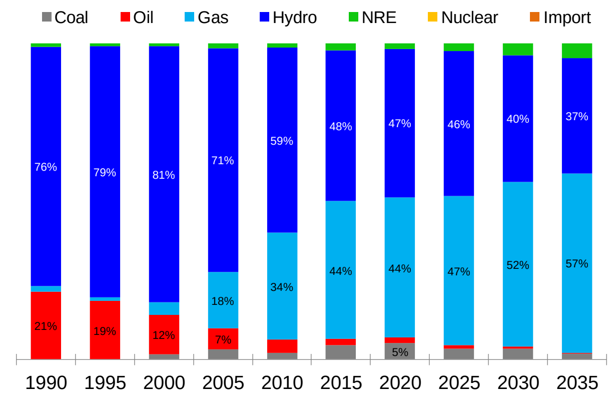
ELECTRICITY

Electricity generation is projected to increase at an annual average growth rate of 3.7% from 2010 to 2035, reaching 92 TWh by 2035. As shown in Figure PE6, while the hydrocarbon share of the power generation mix in 2010 amounted to 40%, by 2035 it is expected to represent as much as 60% of total generation, with hydroelectricity and a much smaller share of NRE making up the remainder.

The increase in gas production is expected to support considerable growth in combined-cycle power technologies. In this case, power generation based on gas is projected to grow significantly, increasing 320% from 2010 to 2035, followed by coal (125%) and hydro (56%). Demand for oil-based fuels such as diesel and fuel oil is expected to decrease 87% by 2035, as the use of these fuels for electricity generation will largely be limited to areas where gas distribution or hydropower is unavailable.

The Peruvian Government's efforts to raise the NRE contribution to the electricity generation mix will pay off in the long term. With an expected remarkable growth of 740% over the outlook period, NRE-based generation technologies will be the fastest growing energy source. The NRE share of total generation is expected to increase from 1% in 2010 to 5% by 2035. The mostly likely NRE development will be wind and biomass-fuelled power plants.

Figure PE6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

This projection does not consider any growth in international trade in electricity with Peru's neighbours. With only one existing arrangement with Ecuador, further discussions in progress on interconnections with Brazil and Colombia will influence Peru's future electricity supply.

CO_2 EMISSIONS

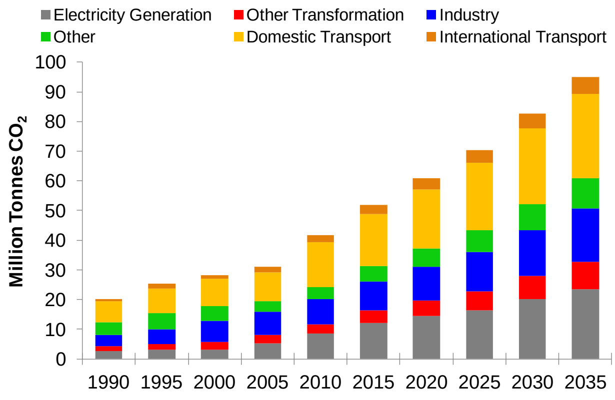
CO_2 emissions associated with the energy sector in Peru are projected to grow 128% from 2010 to 2035, from 41.8 million tonnes of CO_2 equivalent to 95.1 million tonnes of CO_2 equivalent. In 2035, final-use energy sectors are expected to make up most of these emissions (59%), followed by electricity generation (25%), refineries and energy sector own-use (10%) and international transport (6%).

Owing to the expected increase in natural gas use, especially in power generation, the projection indicates that oil's share of total emissions will decrease, from 68% in 2010 to 60% in 2035, coal will reduce from 8% to 4% and the gas share will grow from 24% to 36%.

Even though Peru is seeking to diversify its power generation mix by promoting NRE and replacing fuel oil and diesel power plants, the expected reduction in hydropower contribution and increasing reliance on gas-fired technologies is expected to raise the share CO_2 emissions from electricity generation between 2010 and 2035 from 20% to 25%.

In terms of final-use sectors, the largest increases in emissions from 2010 to 2035 are expected to be in the 'other' sector (157%), industry (110%) and domestic transport (86%).

Figure PE7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

Table PE1 shows that from 2010 to 2035, Peru's emissions will grow at about 3.3% per year. This will mainly be driven by GDP growth of 4.7% per year, offset declining energy intensity of GDP (improved energy efficiency and a shift to less energy-intensive industry) of 1.3%. The CO_2 intensity of energy will remain unchanged.

Table PE1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	0.5%	0.4%	0.1%	0.0%	0.0%
Change in Energy Intensity of GDP	-1.6%	-1.3%	-1.2%	-1.3%	-1.3%
Change in GDP	4.0%	7.2%	5.3%	5.1%	4.7%
Total Change	2.9%	6.2%	4.0%	3.8%	3.3%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Although the Camisea project has helped Peru to achieve gas self-sufficiency and become a significant player in the international gas market scene as the only source of LNG exports in South America, the long-term evolution of the project is unclear. It is uncertain whether Peru will be able to continue to satisfy domestic demand and international export contracts.

There would appear to be an opportunity to develop policies to improve Peru's energy efficiency, especially in the final demand sectors, given expected large increases in consumption and emissions. Energy intensity improvements implemented by the Peruvian authorities would provide numerous advantages to the economy. Energy security enhancement, reduction of growth in oil imports, maximization of gas value, increased productivity and ultimately, greater reductions in CO_2 emissions are some of the benefits Peru could gain by developing more ambitious energy efficiency policies.

ALTERNATIVE SCENARIOS

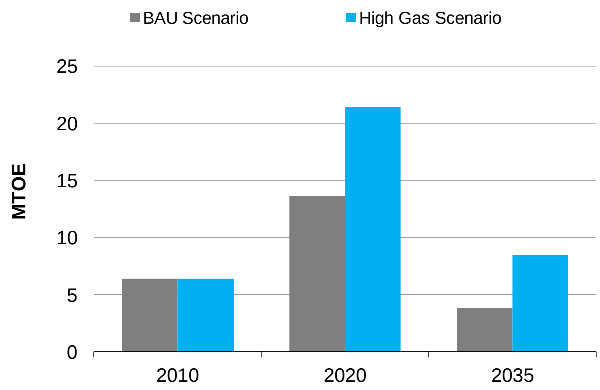
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies including Peru.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the Peruvian energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12.

This scenario was built around estimates of gas production that might be available at BAU scenario prices or below, if constraints on gas production and trade could be reduced. As shown in Figure PE8, under the High Gas Scenario gas production in Peru would be 121% larger in 2035 than under BAU.

Figure PE8: High Gas Scenario – Gas Production



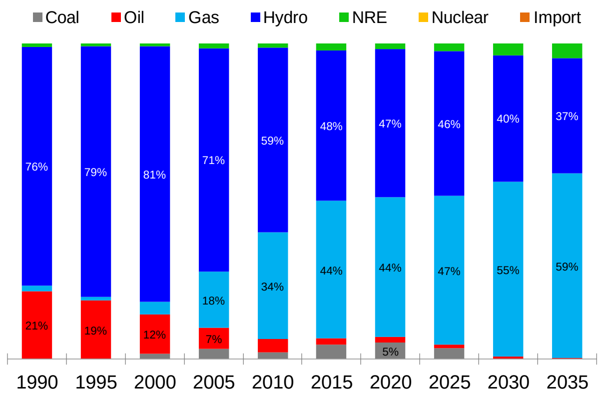
Source: APERC Analysis (2012)

Assumptions about gas production were based on information provided by Peru's MINEM on the total gas reserves (proved, probable and possible) from Blocks 56, 57, 58 and 88 of the Camisea gas project. While the BAU scenario only considers the development of proved gas reserves, the High Gas Scenario includes the probable reserves potential, resulting in much higher gas production. The High Gas Scenario assumptions also incorporate additional gas output from Block 58 coming online by 2025.

Under this High Gas Scenario, additional gas consumption in each economy will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. Irrespective of the significant investments required to develop the gas potential at Camisea, higher gas consumption in Peru's domestic market entails considerable expansion in the pipeline network to reach consumption centres beyond Lima. For this reason, it is probable that some portion of the additional gas production will be allocated for exports through Peru's LNG plant, which may be expanded in the future.

The High Gas Scenario assumes that the main use for the additional gas production will be in the electricity generation sector as a replacement for coal. The effects of a larger gas contribution to Peruvian electricity generation are presented in Figure PE9. Since the BAU electricity generation mix shown in Figure PE6 already included a significant increase in gas-based electricity generation, raising it to 57% of total generation and replacing most coal generation by 2035, the gas share under the High Gas Scenario is only slightly larger. By 2035 gas would account for 59% of the total electricity generation mix in Peru, completely eliminating coal-based generation.

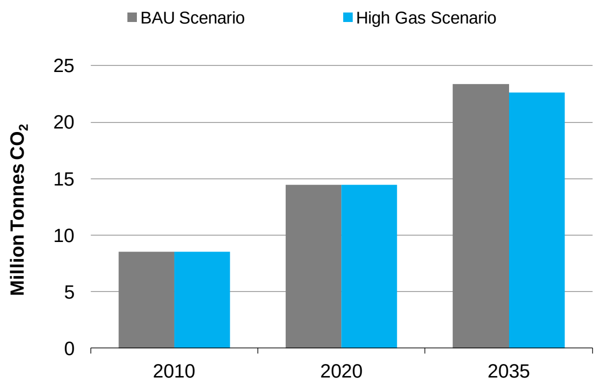
Figure PE9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

As gas has roughly half the CO_2 emissions of coal per unit of electricity generated and the expected increase in the gas-based electricity generation is very moderate in comparison with BAU, CO_2 emissions would only reduce 3% in 2035. Figure PE10 shows this CO_2 emissions reduction.

Figure PE10: High Gas Scenario – CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

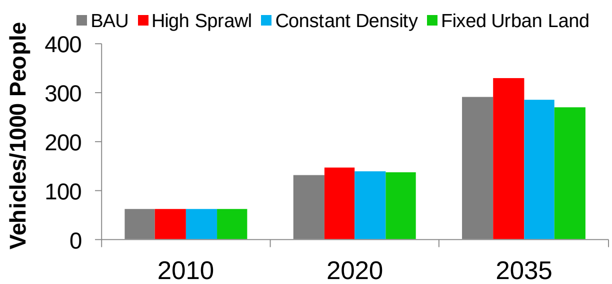
ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PE11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. By 2035, the High Sprawl scenario shows an increase of 14% compared to BAU, while the Constant Density and Fixed Urban Land scenarios showed a reduction of 2% and 7%, respectively.

In developing economies like Peru, the impact of urban planning tends to be relatively small. As vehicle ownership is still far from the saturation level, it will grow rapidly irrespective of urban planning. However, it should be noted that after 2035, there might still be significant impacts.

Figure PE11: Urban Development Scenarios – Vehicle Ownership

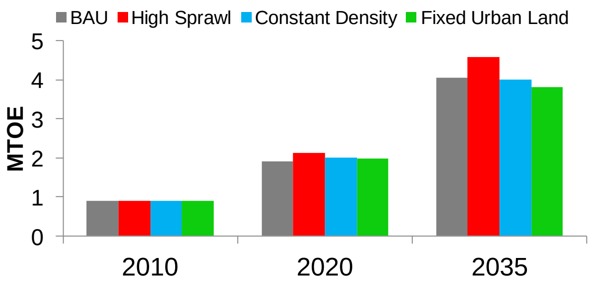


Source: APERC Analysis (2012)

Figure PE12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The results are similar to Figure PE11, with the highest variation being the

13% increase in 2035 compared to BAU occurring under the High Sprawl scenario, while the Constant Density and Fixed Urban Land scenarios showed a reduction of 1% and 6%, respectively..

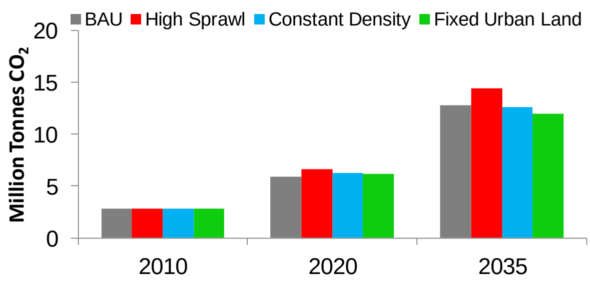
Figure PE12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure PE13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

Figure PE13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



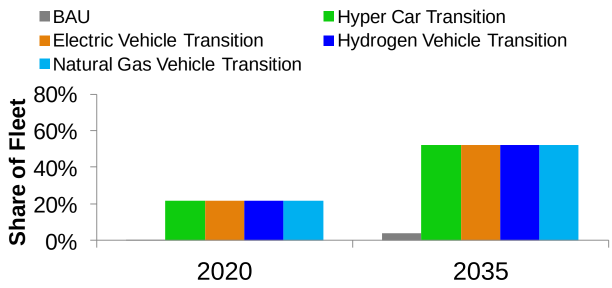
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure PE14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 52% compared to about 4% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 48%, compared to about 96% in the BAU scenario.

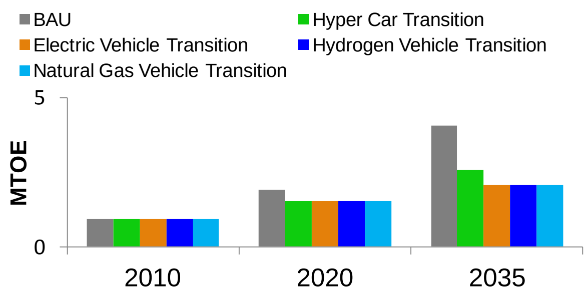
Figure PE14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure PE15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 49% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 37% by 2035—even though these highly efficient vehicles still use oil.

Figure PE15: Virtual Clean Car Race – Light Vehicle Oil Consumption

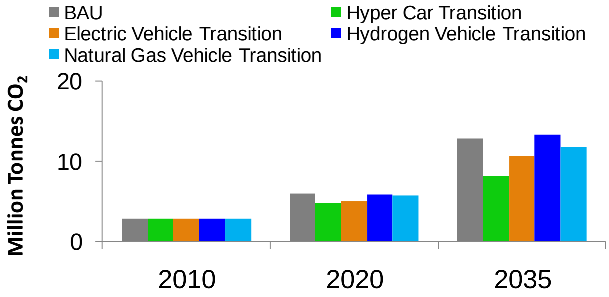


Source: APERC Analysis (2012)

Figure PE16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impact of each scenario may differ significantly from their oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Peru, the Hyper Car Transition scenario appears to be the best option in terms of CO_2 emissions savings, with an emissions reduction of 36% compared to BAU in 2035. The next best reductions are the Electric Vehicle Transition (17%) and Natural Gas Vehicle Transition (8%) scenarios. Although hyper cars consume conventional fuels, their efficiency levels would significantly reduce the amount of fuel required. In Peru, electric vehicles would also offer significant reductions because natural gas-fired generation would probably be the marginal source of the electricity. The Hydrogen Vehicle Transition scenario offers the least benefits, and in fact actually increases CO_2 emissions by 4% compared to BAU in 2035. Although hydrogen vehicles have little direct carbon impact, hydrogen fuel production is energy intensive, entailing significant indirect CO_2 emissions.

Figure PE16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

BBVA (Banco Bilbao Vizcaya Argentaria – Research) (2010), Peru: Automobile Market Outlook, www.bbvaresearch.com/KETD/fbin/mult/automobile_market_outlook_peru_tcm348-259266.pdf?ts=832012

El Peruano (2010), *Decreto de Urgencia No. 027-2010*, www2.osinerg.gob.pe/preciosreferencia/TarPreciosBanda/Decreto_UrgenciaNº027-2010.pdf

— (2012), *Decreto de Urgencia No. 005-2012*, www.mef.gob.pe/index.php?option=com_docman&task=doc_download&gid=8761&Itemid=100599&lang=es

Ernst & Young (2011), *Global Oil and Gas Tax Guide 2011*, June 2011, www.ey.com/oilandgas

Gestión (El Diario de Economía y Negocios de Perú) (2013), *La venta de autos nuevos alcanzó nuevo récord*, gestion.pe/economia/venta-autos-nuevos-marco-nuevo-record-2012-2055795

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

IMF (International Monetary Fund) (2011), *World Economic Outlook Database*, September 2011, www.imf.org/external/pubs/ft/weo/2011/02/weodata/index.aspx

INDECI (Instituto Nacional de Defensa Civil del Perú) (2010), *Atlas de Peligros del Perú 2010*, www.indeci.gob.pe/atlas_10/index_final2.html

INEI (Instituto Nacional de Estadística e Informática) (2011a), *Información Económica*, www.inei.gob.pe/web/aplicaciones/siemweb/index.asp?id=003

— (2011b), *Perú en cifras. Indicadores Demográficos—Población*, www.inei.gob.pe

IPEN (Instituto Peruano de Energía Nuclear) (2009), *Plan Estratégico Institucional 2010–2016,* www.ipen.gob.pe/site/transparencia/transp_2012/plan_org/pei2010_2016.pdf

MINCETUR (Ministerio de Comercio Exterior y Turismo) (2011), *Cierre 2010 Exportaciones*, www.mincetur.gob.pe/newweb/Default.aspx?tabid=2315

MINEM (Ministerio de Energía y Minas) (2010a), *Anuario de Hidrocarburos 2010*, www.minem.gob.pe/publicacion.php?idSector=5&idPublicacion=403

— (2010b), *Anuario Estadístico de Electricidad 2010*, www.minem.gob.pe/publicacion.php?idSector=6&idPublicacion=405

— (2010c), *Anuario Minero 2010*, www.minem.gob.pe/publicacion.php?idSector=1&idPublicacion=382

— (2010d), *Perú Sector Eléctrico 2010*, Documento Promotor, www.minem.gob.pe/publicacion.php?idSector=6&idPublicacion=52

— (2010e), *Propuesta de Política Energética de Estado 2010–2040*, www.minem.gob.pe/prepublicacionesSectorDown.php?id=99

— (2011), *Balance Nacional de Energía 2010*, www.minem.gob.pe/publicacion.php?idSector=12&idPublicacion=418

MTC (Ministerio de Transportes y Comunicaciones) (2005), *Plan Intermodal de Transporte 2004–2023*, www.mtc.gob.pe/portal/logypro/plan_intermodal/principal.html

— (2007), *Especificaciones Técnicas para la conservación de Carreteras*, *Diagnóstico del Sector Transporte*, http://transparencia.mtc.gob.pe/idm_docs/normas_legales/1_0_2951.pdf

— (2011a), *Estadísticas de transportes*, www.mtc.gob.pe/estadisticas/index.html

— (2011b), *Parque vehicular estimado según departamento o región 2002–2011*, www.mtc.gob.pe/estadisticas/archivos/ESTADISTICA items/1-TRANSPORTES/4.CARRETERO/3.A.2.xls

— (2011c), *PPPs and CREMA contacts on National Roads*, www.proviasnac.gob.pe/Archivos/file/Documentos de Interes/NRN PERU RTT engl %28jun2011%29.pdf

NASA (US National Space Aeronautics and Space Administration – Earth Observatory) (2011), *El Niño, La Niña, and Rainfall*, earthobservatory.nasa.gov/Features/WorldOfChange/enso.php

OGJ (Oil & Gas Journal) (2011), *Worldwide Report,* Pennwell, Houston, USA, 5 December.

Osinergmin (Organismo Supervisor de la Inversión en Energía y Minería) (2008), *Regulación del Gas Natural en el Perú*, www2.osinerg.gob.pe/Infotec/GasNatural/pdf/Regulacion Gas Natural Peru.pdf

— (2011a), *Acta de Adjudicación de la Segunda Subasta de Suministro de electricidad con Recursos Energéticos Renovables*, www2.osinerg.gob.pe/EnergiasRenovables/contenido/Actas/Acta-Adjudicacion y Buena Pro.pdf

— (2011b), *Resultados Primera Subasta*, www2.osinerg.gob.pe/EnergiasRenovables/contenido/Resultado1raSubasta.html

Perupetro (La Agencia Nacional de los Hidrocarburos) (2011), Embarques de gas natural para fines de exportación, www.perupetro.com.pe/RelacionExportacion/relacion.jsp

Petroperú (2011), *Instalaciones*, www.petroperu.com.pe/portalweb/Main.asp?Seccion=74

PlusPetrol (2011), *Proyecto Camisea*, www.pluspetrol.net/camisea.html

Proinversión (Agencia de Promoción de la Inversión Privada) (2011), *Inversión extranjera directa en Perú por sector de destino*, www.proinversion.gob.pe/0/0/modulos/JER/PlantillaStandard.aspx?ARE=0&PFL=0&JER=1744

Repsol (2011), *Refinería La Pampilla*, www.repsol.com/pe es/corporacion/complejos/refineria-la-pampilla/

UN (United Nations) (2008), *State of the World's Cities 2010/2011: Bridging the Urban Divide,* United Nations Human Settlement Program, www.unhabitat.org/pmss/getElectronicVersion.aspx?nr=2917&alt=1

— (2009), *World Urbanization Prospects: The 2009 Revision Population Database*, esa.un.org/unpd/wup/unup/

UNDP (United Nations Development Programme) (2011), *Human Development Report 2011*, hdr.undp.org/en/media/HDR 2011 EN Complete.pdf

UNEP (United Nations Environment Programme) (2002), *Cancun Declaration of Like-Minded Megadiverse Countries*, www.pnuma.org/deramb ing/CancunDeclaration.php

UN–FCCC (United Nations Framework Convention on Climate Change) (2011), C*ompilation of information on nationally appropriate mitigation actions to be implemented by Parties not included in Annex I to the Convention,* unfccc.int/resource/docs/2011/awglca14/eng/inf01.pdf

WB (The World Bank) (2010)*, Peru Rural Road Program: Bringing Access to the Rural Poor,* siteresources.worldbank.org/NEWS/Resources/PeruRuralRoadProgram4-11-10.pdf

PHILIPPINES

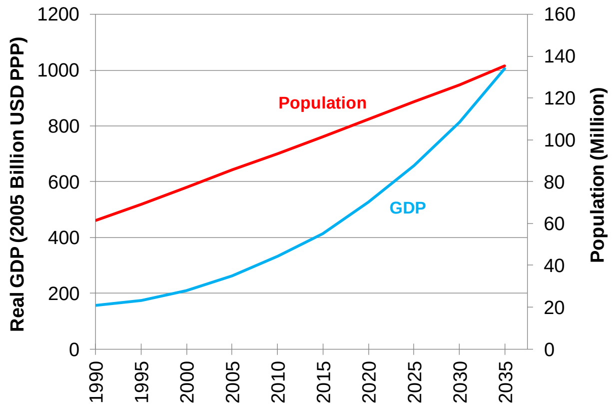
- *The Philippines is an economy which relies heavily on imported fossil fuel. The harnessing and use of renewable energy (RE) is a critical component of the Philippine Government's energy supply security strategy. The passing of the Renewable Energy Act of 2008 will ensure this challenge is addressed and the necessary RE polices put into action.*
- *Through its guiding vision, Energy Access for More, the Philippines Government hopes to put into action its national commitment to move energy access higher up the political and development agendas to become a key priority of the government.*
- *The government and the private sector will continue to forge strong partnerships to ensure the delivery of secure, sustainable, sufficient, quality and environment-friendly energy to all sectors of society.*

ECONOMY

The Philippines is an archipelago of 7107 islands surrounded by South-East Asia's main bodies of water. It covers a total land area of 300 000 square kilometres, including inland bodies of water, spread over the three main island groups: Luzon, Visayas and Mindanao. Its total population in 2010 reached 93 million, with only 49% living in urban communities.

The population will continue to grow at 1.5% annually, reaching 135.2 million by 2035. An estimated half of the population lives in Luzon, the largest of the three major island groups and home of the Philippines capital, Manila. The growth for this outlook period is slower than the 2.2% rate during the period 1990–2005. During this earlier period, more than half of the total population was rural: by 2035, 61% of the total population will be urban.

Figure RP1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

The Philippines economy grew a remarkable 7.6% in 2010 and will continue to show positive growth over the next 25 years—on average, 4.5% annually in real US dollars. This translates to real GDP of USD 1006 billion and a per capita GDP of USD 7450 by 2035. Overtaking Thailand, the second-largest economy in the Association of Southeast Asian Nations (ASEAN), the Philippines is seen as one of the fastest growing economies in the ASEAN region over the outlook period (Ward, 2012). However, its high population growth rate will be a challenge in the economy's fight against poverty.

The industry sector is likely to continue to propel the growth in the economy, backed by a revived and strong manufacturing sector and renewed construction projects in the private sector. Growth in the manufacturing sector will remain robust due to export demand. The food industry will continue to experience a high growth rate due to the improved performance in the agriculture sector.

Most industries are concentrated in the urban areas around metropolitan Manila. The economy's biggest export processing zones are located within the Cebu metropolitan area and in some parts of Luzon. These processing zones provide the economy with a promising future in international markets. Electronics as well as semi-conductor materials, woodcraft and furniture, apparel and clothing accessories are the economy's top exports. These are assembled and/or manufactured in these processing zones.

The Philippines is primarily an agricultural economy. Its main agricultural crops are rice, corn, coconut, sugarcane, bananas and other tropical fruits. However, the rapid rates of urbanization and economic expansion have resulted in deforestation and the indiscriminate conversion of agriculture land for residential, industrial and commercial uses. This may undermine the economy's food security and forest resources, and has prompted the formulation of the Philippine Strategy for Sustainable Development. One of the strategies identified includes the "integration of environmental considerations in decision making, proper resource pricing, property rights reform, conservation of Biodiversity, rehabilitation of degraded ecosystem, strengthening of residual management (pollution control), control of population growth and human resources development, inducing growth in rural areas, promotion of environmental education and strengthening of citizens participation" (PA 21, 1989).

The Philippines is located within the circum-Pacific belt, which means the economy frequently experiences seismic and volcanic activities. The volcanic nature of the economy is beneficial for the successful harnessing of geothermal energy resources.

The Philippines has a tropical maritime climate which is usually hot and humid, especially during the summer. This has the result of increasing electricity consumption due to the extensive use of air conditioning units and other cooling devices. The Philippines also sits astride the typhoon belt. This means the economy experiences torrential rains and thunder storms, some of which prove costly and damaging, destroying lives and property. The economy's tropical climate, however, sustains a rich biodiversity, one of the richest in the world. Its lush forests, tropical islands, white sand beaches, lakes, rivers and mountains serve as the economy's major tourist attractions.

The economy relies heavily on its road network to handle most of its passenger and freight movements. Large parts of the road network continue to be in a poor condition and only a small part of the total network is paved (such as the national roads and thoroughfares). Inadequate connectivity and the lack of a sustainable road safety strategy reduce the efficiency of the road network in promoting growth and providing safe access. This is likely to improve in the future, with the current administration's vision of providing the public with quality infrastructure facilities by 2030 (DPWH, 2011).

Public transport services—mostly buses, jeepneys (the popular and inexpensive mass transport vehicles, originally made from US military jeeps left over from World War II and now part of the economy's culture), tricycles (motorcycles with sidecars) and taxis—are predominantly privately owned and operated. The economy will continue to produce a number of light vehicles locally. However, imported used cars fuelled with gasoline and diesel will continue to form a significant part of the economy's vehicle counts over the next 25 years. These imported used vehicles came mostly from Japan and Hong Kong, China which are converted to left-hand-drive vehicles in conversion bays and freeport zones in the municipality of Subic.

Three light rail transit lines provide some convenience to the riding public within the Manila metropolitan areas. The economy is attempting to revitalize its ailing heavy rail transit, but an inefficient ticketing system and rundown stations have resulted in its poor ridership (World Bank, 2011).

There are eight international airports in the Philippines. The premier gateway to other parts of the world is the Ninoy Aquino International Airport in Manila. The other international airports are located in Clark, Subic, Laoag, Cebu, Davao, General Santos, and Zamboanga.

Being an island nation, water transport plays a major role in the movement of people and commodities. The economy has seven international seaports located in Manila (South and North Harbour), Batangas, Puerto Princesa and Subic (Luzon), Cebu (Visayas), Davao and Zamboanga (Mindanao). Inter-island passenger vessels ferry passengers to the different islands of the Philippines, while cruise liners call regularly into the port of Manila (DOT, 2009).

ENERGY RESOURCES AND INFRASTRUCTURE

The Philippines has modest indigenous energy resources, accounting for the total production of 24 million tonnes of oil equivalent (Mtoe) in 2010 and projected to expand to 31.6 Mtoe in 2035. One-third of these resources are fossil fuels—3.5 Mtoe of coal (mainly lignite), 3 Mtoe of natural gas and 0.9 Mtoe of crude oil. The economy's local crude oil production comes mostly from four oilfields: the Nido, Matinloc, North Matinloc and Galoc fields. The economy, through the Department of Energy (DOE), is gearing up to drill 25 oil wells every five years or a total of 100 wells by 2030. Hence, in addition to its current indigenous resources, the expected discoveries could mean the production of an additional 2.4 million barrels of oil per year by 2025 (DOE, 2010b).

The Philippines, however, imports most of its oil and is likely to continue to do so during the outlook period, to sustain the economy's total petroleum requirements of 27.9 Mtoe by 2035.

The offshore Malampaya field is the largest producing gas field and the main source of gas in the economy, with an estimated daily production capacity of 450 million standard cubic feet (13 million cubic meters). It is also the main source of gas for the three large natural gas fired power plants in the Philippines. While gas production from this field is expected to be stable up to 2025, a potential gas discovery of 635 billion cubic feet (18.3 billion cubic meters) in the Sulu Sea is assumed to be developed and to produce gas during the same period.

While the demand for natural gas is mainly met by domestic production, efforts to ensure energy security will be enhanced. The economy will import natural gas to augment the projected demand beyond the production capacity from the Malampaya gas field. Feasibility studies are underway for potential locations for liquefied natural gas (LNG) import terminals (JICA, 2012, pp. 1–3).

Indigenous coal production accounted for 14% of the economy's demand for coal in 2010, and is estimated to reach 6.9 Mtoe by 2035. Domestic coal comes mainly from Semirara Island through the economy's only large-scale privately-owned coal producer, Semirara Mining Corporation. Indonesia is the economy's most significant coal trading partner, accounting for 96.7% of the total coal imported.

The Philippines' installed electricity generating capacity stood at 16 GW in 2010, and is projected to increase to over 58 GW by 2035. Fossil fuels will continue to dominate the economy's total power generation; coal thermal alone is expected to provide almost 70% of its electricity generation by 2035, followed by natural gas with a 16% share.

In view of the economy's abundant renewable resources, by 2035 more than 50% of its indigenous energy resources are expected to come from renewable energy, such as hydro and geothermal as well as other new and renewable energy (RE) sources. Other RE sources include biomass (like fuelwood and bagasse, the fiber left after juice has been squeezed from sugarcane stalks, etc.), which is mainly used in household and commercial applications. The Philippines benefits from its tropical maritime climate with its wind and solar sources of energy, and the economy is looking at the possibility of its first ocean energy facility by 2018 (Layug, 2012).

Among the renewable energy sources, geothermal energy is expected to provide the biggest contribution over the next 25 years. The economy's installed geothermal generating capacity of 1966 MW in 2010 placed the economy as the second-largest geothermal producer in the world behind the United States (US) (IGA, 2010). The passage of the Renewable Energy Act of 2008 (RE Act) will provide the direction for the economy to harness and utilize its renewable energy. A firm commitment from the private sector, particularly on funding, will likely provide the economy with an additional capacity of 9.2 GW from geothermal, hydro, biomass, wind, solar and ocean sources by 2035.

In 2010, the electrification level of the economy at a household connection level was 68% (NSO, 2010); at a barangay level (a village, district or ward, i.e. the basic political unit) it had reached 99.89%. The economy envisions a 90% household electrification level by 2017. Due to its geography, the economy has a complex energy system. Major power grids are separated according to its three major islands, Luzon, Visayas and Mindanao. In the Luzon grid, more than half of its capacity is coal-fired; Visayas is home to the economy's vast geothermal resources; while more than 50% of the Mindanao grid's energy requirement is sourced from hydro. The interconnection of the three major grids is not expected in the near future. Smaller islands are interconnected to the major island grids to provide service to remote areas. Where it is not economical to connect a small island to a major grid, separate local systems are being established around small generating plants (NGCP, 2011).

ENERGY POLICIES

The Philippines, through collaborative efforts with key economic development agencies, will continue to formulate plans and programs to maintain its positive growth for the next 25 years. The implementation of infrastructure projects by the Department of Public Works and Highways (DPWH) and the Department of Transportation and Communication (DOTC) will help to promote the economy's growth. Assuming the industry sector continues to show good performances over the outlook period, the economy will achieve its economic objectives (Navarro and Yap, 2012).

As the major instrument for realizing the energy sector's vision of achieving energy independence, the Department of Energy (DOE) is currently crafting the 2012–2030 Philippine Energy Plan (PEP). The 20-year plan will reflect the government's mission to ensure the delivery of secure, sustainable, sufficient, affordable and environment-friendly energy to all economic sectors. The energy sector's guiding vision, Energy Access for more, will ensure a larger population has access to reliable and affordable energy services, most importantly for local productivity and economy-wide development. With this guiding vision, the economy hopes to put into action its national commitment to move energy access higher up the political and development agendas to become a key priority of the government (DOE, 2010a).

To attract more investors into the exploration and development of its indigenous oil and gas resources, the economy conducts an annual Philippine Energy Contracting Round (PECR) or energy contracting round mechanism. As of 2009, 34 service contracts (SCs) have been supervised and monitored by the DOE and the number is likely to increase to 117 by 2030. Private companies enter SCs with the DOE for the exploration of oil concession areas and natural gas deposits and for the development of geothermal resources and certain coal areas in the economy, subject to sharing their net proceeds with the government.

The economy hopes to achieve a production level of 8.59 million barrels of oil, 294 billion cubic feet (8.49 billion cubic metres) of gas and 87.58 million barrels of condensate by the end of 2030. Assuming these targets are realized, hydrocarbon resources level will reach 45% by 2035 from the 2010 production level of 30%. The economy has 16 sedimentary basins, the majority of which are in Luzon, particularly in Palawan.

Through the PECR, and the conversion of existing coal operating contracts from the exploration to the development stage, the entry of more investors is anticipated. Considering private coal exploration investors and the state-owned Philippine National Oil Company Exploration Corporation (PNOC EC) together, the economy's indigenous coal production is likely to increase from its 2010 level of 3.5 Mtoe to 6.9 Mtoe by 2035.

The Philippines is projected to rely heavily on imported fossil fuel, even after 25 years. The RE Act will ensure this challenge will be addressed and the necessary RE polices will be put into action. Through its National Renewable Energy Program, the economy's current RE based grid-connected installed capacity of 5440 MW is targeted to triple by 2030. Most of this capacity will come from hydro and wind power (DOE, 2011). The RE Act will likewise address possible bureaucratic constraints in developing RE by streamlining the registration process and promoting transparency and open competition. Future policy requirements to commercialize RE, such as the formulation of a feed in tariff (FIT) and bidding for its allocation, are being developed.

The Philippines' downstream oil industry was deregulated in 1998 and is currently dominated by two major oil refining and marketing companies; Petron Corporation and Pilipinas Shell. A third oil refiner and marketer, Caltex Philippines Inc., converted its 86 500 barrels per day refinery into an import terminal in 2003 and now operates as a marketing and distributing company under the name Chevron, but maintains its Caltex brand. Petron Corporation was jointly owned by PNOC, a state-owned company, and the Aramco Overseas Company, but it was privatized in 2010.

The Downstream Oil Industry Deregulation Act of 1998 allows oil companies to set their own unregulated prices based on competition in local markets. Oil deregulation does not guarantee lower prices but does guarantee fair prices. As mandated, the DOE monitors the prices of both the raw material crude oil and the refined petroleum products in the international market.

As embodied in the Electricity Power Industry Reform Act (EPIRA), the economy's electricity supply industry has been restructured paving the way for the privatization of the state-owned National Power Corporation (NPC). The restructuring calls for the separation of the different components of the power sector namely, generation, transmission, distribution and supply. Transmission and distribution exhibit natural monopoly characteristics which make the regulation of them appropriate. The generation and retail sale of electricity, on the other hand, can be efficient in the competitive environment as a result of the reforms introduced by the EPIRA. The privatization of NPC involves the sale of the state-owned power generation and transmission assets (e.g. power plants and transmission facilities) to private investors.

While oil pricing is deregulated, electricity pricing is a regulated energy commodity. The price for electricity is set by the Energy Regulatory Commission (ERC). Alongside the implementation of the EPIRA is the unbundling of electricity rates. The individual charges for providing specific electric services to any end-user, for generation, transmission, distribution and supply, are identified and separated. The ERC determines the rate-setting methodology taking into account the relevant considerations that will enable a specific entity to operate viably, with the end view of providing a reasonable price for electricity. Part of the EPIRA law is the birth of the Wholesale Electricity Spot Market (WESM) which serves as a venue where electricity made by power-producing companies is centrally coordinated and traded like any other commodity in a market of goods. After several months of trial operations, in June 2006 the WESM started commercial operations in the Luzon grid. Four years into its commercial operations in Luzon, the Visayas grid was integrated into the WESM and it commenced commercial operations in that grid in December 2010. The establishment of the WESM creates a level playing field for the trading of electricity among WESM participants; hence third parties are granted access to the power system. Although prices are still governed by commercial and market forces, customers may have the option to buy energy at a price lower than the regulated rate (WESM, 2012).

By virtue also of EPIRA, the energy sector through the DOE is mandated to formulate the Power Development Plan (PDP) which is integrated into the PEP. The PDP outlines a strategic roadmap for the power sector to ensure and secure the delivery of a reliable and quality electricity supply in the short-term, medium-term and long-term planning periods.

In view of the Philippines' wide-ranging geographical situation, to fully connect the entire population to the national grid is a significant hurdle. Servicing the most remote and difficult to electrify rural areas will require significant resources; hence achieving a 100% electrification level over the outlook period remains a challenge for the economy. The government through DOE and other private and government agencies spearheads the development of various innovative service delivery mechanisms designed to increase access to electricity services. One of its efforts is the Expanded Rural Electrification Program which aims to at least provide some access to electricity for the marginalized and other off-grid areas. This will be done through decentralized energy systems such as battery charging stations (BCS), individual solar home systems, micro-hydro systems, and wind turbine energy systems (Salire and Muhi, 2010).

The National Electrification Administration (NEA), an attached agency of the DOE, is the economy's prime mover in rural electrification and the DOE's arm in the implementation of the decentralized energy systems. NEA currently supervises 96 electric cooperatives by providing quality financial, institutional and technical services to franchise areas not covered by the Manila Electric Company, the economy's biggest privately-owned utility.

Meanwhile, NPC remains as an economy-wide government-owned and controlled corporation which performs the missionary electrification function through the Small Power Utilities Group (SPUG). SPUG is responsible for providing power generation and its associated power delivery systems in areas not connected to the transmission system.

The Biofuels Act of 2006 provides the economy with a way of hedging against escalating oil prices and of reducing the economy's dependence on imported fossil fuels. The Act currently mandates a minimum 1% biodiesel blend in diesel and a 5% bioethanol blend in gasoline. The economy hopes to increase this to 20% coco methyl ester (CME) in diesel and 20% ethanol in gasoline by 2030. CME is domestically produced from coconuts, while 80% of the bioethanol supply will be sourced from imports due to the limited domestic production capacity.

Alongside its efforts to curb the economy's dependence on imported oil, the Philippines Government considers the use of alternative fuels in the transport sector a priority. As well as its target to replace the current number of conventionally fuelled vehicles with alternative technologies and fuels by 2035, the economy expects to add more infrastructure such as natural gas pipelines, refilling stations for CNG (compressed natural gas) buses and charging stations for electric vehicles. Operators who participate in the natural gas vehicle (NGV) program receive incentives such as an income tax holiday and a 0% rate of duty on imported NGVs, NGV engines and other NGV industry items. There is a proposal to enhance the existing incentives for the program to encourage more participants. Over the next 25 years, the economy has a target to increase the number of vehicle engines running on higher percentages of biofuels, while electric vehicles in both private and public transport will become mainstream.

Mass transport systems in some of the economy's biggest cities are likely to improve in the future. For example, a feasibility study on a bus rapid transit (BRT) system for Cebu is being done with the help of the World Bank and AusAID (DOTC, 2010).

The government also aims to attain a better interconnection between the economy's islands, to open up new economic opportunities, to reduce transport costs and to increase access to social services. Priority infrastructure projects include: the completion of the nautical highway system (an integrated network of highway and vehicular ferry routes), with several projects that will spread development and provide new opportunities for growth in other regions to decongest metropolitan Manila; better access to tourist sites; and improvements in underdeveloped regions and roads (World Bank, 2011).

Economic growth and increasing energy use clearly indicate the economy is likely to face the realities of high oil prices and greater competition for energy resources in the long term. As a way of hedging against the high cost of oil, the National Energy Efficiency and Conservation Program (NEECP) is seen as an essential strategy in rationalizing the economy's demand for petroleum products and eventually lessening the impact of escalating prices on the economy (DOE, 2009).

Through the NEECP, the energy sector will work on developing and promoting new technologies. It will also conduct a major information campaign to promote the practice of sensible energy habits in homes, businesses and motor vehicles. Specifically, activities under the program include: the Fuel Economy Run (which involves participating private vehicle manufacturers and assemblers showcasing the fuel efficiency of their vehicles); the provision of awards to establishments observed to achieve significant energy savings in their operations; and educational campaigns in schools, households, and municipalities. To ensure wider coverage the economy conducts tri-media campaigns, with the hope of achieving an annual 10% reduction in its total energy demand by 2030 (Reyes, 2012).

In addition, the economy is implementing the Philippine Energy Efficiency Project which aims to demonstrate the societal benefits of a series of energy efficiency projects in the different sectors—such as the public, commercial and residential sectors. The project's key targets include: the retrofit of 135 government buildings with energy efficient lighting systems; the economy-wide distribution of compact fluorescent lamps (CFL) totalling 8.6 million CFL units; and the retrofit of public lighting (street and traffic lights) using light emitting diode (LED) lamps in three major cities. The project quantification of economic and environmental benefits showed a 243 MW deferment of power generating capacity additions, a reduction of oil imports by 83.1 kilotonnes of oil equivalent (ktoe), and the avoidance of 172 kilotonnes of CO_2 emissions.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

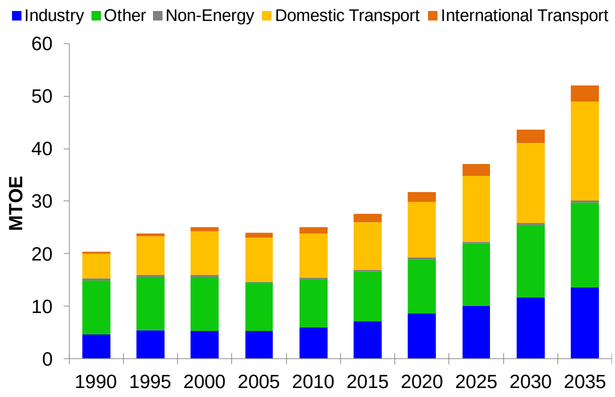
The Philippines' final energy demand is expected to expand at an average annual rate of 2.9% from 2010 to 2035. This translates to a total final energy demand of 49 Mtoe by 2035, from the 2010 level of 23.8 Mtoe.

Together with the economy's fast-paced growth, the industry and domestic transport sectors are both projected to grow at an average annual rate of 3.3% over the next 25 years. Growth in the industry sector will be driven by the projected expansion of the machinery industry, whose energy demand will increase by 5% annually during the same period.

The transport sector (includes international transport sector) is expected to dominate total final energy demand over the outlook period, accounting for a 42% share by 2035. The 'other' and industry sectors' energy demands are estimated to account for 26% and 31%, respectively, of the economy's final energy demand by 2035. The non-energy sector's demand is very small, with only a 1% share of the total final energy demand in 2035.

While oil consumption is projected to continue to dominate the economy's final energy demand through to 2035, gas consumption shows a positive boost of 4.8% annually over the 25-year outlook period.

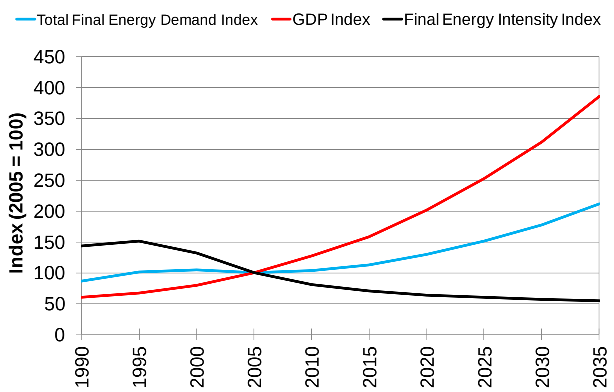
Figure RP2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to reduce by 45% from 2005–2035.

Figure RP3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

The industry sector's fuel consumption of 6 Mtoe in 2010 will reach 14 Mtoe by 2035, which is almost one-third of the economy's final energy requirement in 2035. Heavy-use industries are dominated by food and tobacco products and non-metallic minerals—they are expected to collectively use more than 60% of the industry energy demand by 2035.

The demand for natural gas in the industry sector will grow the fastest, at an annual rate of 4.8% in the next 25 years. Coal consumption, which dominated the industry sector's energy demand in 2010, is likely to be displaced by a demand for electricity by 2035. It is estimated that electricity use will grow at a rate of 3.6% annually over the outlook period.

Transport

Energy demand in the domestic transport sector will grow alongside that in the industry sector.

Transport energy demand will absorb more than one-third of the economy's total fuel requirement during the 25-year outlook period. The sector's total demand will expand to 19 Mtoe by 2035 from the 2010 level of 8.4 Mtoe. Petroleum consumption in the sector is not expected to respond strongly to oil price increases. It accounts for 67% of the economy's total oil requirement by 2035.

The light vehicle fleet is expected to increase significantly, with an annual growth rate of 3.4% over the outlook period. By 2035, the fleet is projected to be made up of 40% conventional gasoline and 19% diesel vehicles, and about 6% all other types of vehicles, mainly LPG and conventional hybrids. The remaining 35% of the light vehicle fleet will be motorcycles.

Other

The 'other' sector will account about one-third of the economy's total energy demand and will grow at an average annual rate of 2.3% during the outlook period. This translates to an increase from the 2010 demand level of 9.2 Mtoe to 16 Mtoe by 2035. Electricity will be the dominant fuel used and it will grow the fastest, at an average annual rate of 4.4% over the next 25 years. It is assumed this growth will reflect the changing fuel preferences over the outlook period, as traditional biomass use in the sector contracts rapidly at a rate of 6% annually.

The residential sector's energy demand (60%) is likely to remain the main contributor in the 'other' sector's total energy consumption. This is due to the continuing growth of the economy's population and GDP in the next 25 years. Energy demand in this sector is expected to grow 1.7% annually during the outlook period.

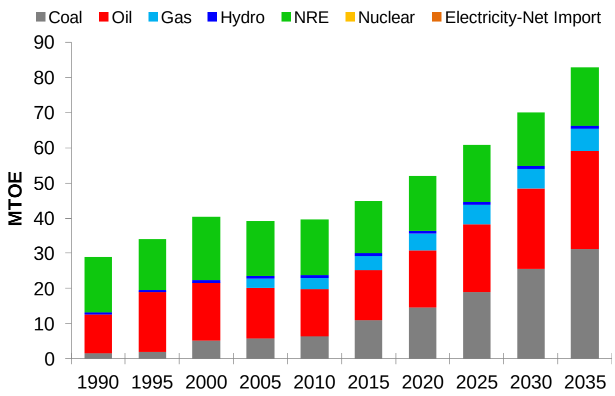
The commercial sector is projected to be one of the drivers of the Philippines economy due to the continuing expansion in the number of business process outsourcing companies (such as call centres) taking place in the economy (PhilBPO, 2011). With this in view, the energy requirement in this sector is likely to grow faster than that in the residential sector, at 3.5% annually over the next 25 years.

Agriculture plays a significant role in the Philippines economy. Its produce, such as fruits, vegetables and other crops as well as livestock and poultry, is projected to post strong export performances over the next 25 years (PIDS, 2009). The modest increase (1.9% annually) in energy consumption for the sector during the outlook period is driven by an increase in the demand for petroleum products, used mainly for farm machinery and implements, and for electricity, used largely in the livestock and poultry sub-sectors.

PRIMARY ENERGY SUPPLY

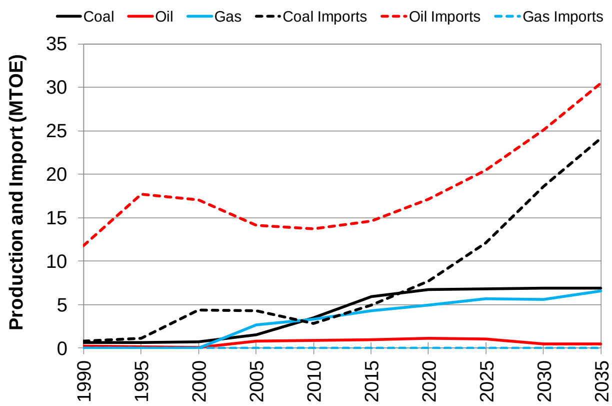
Oil will continue to dominate the economy's energy mix from 2010–2025, accounting for one-third of its total primary energy supply. This is mostly driven by the transport sector which will consume more than 60% of the economy's total oil supply during the period. In terms of growth, coal will grow the fastest at an average annual rate of 6.5% during the outlook period. By end of 2025, coal is likely to exceed oil in the primary energy supply, mainly as a result of coal use for electricity generation.

Figure RP4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure RP5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The Philippines' total primary energy supply is projected to grow moderately at an annual rate of 3% over the next 25 years. This translates to the 2010 supply level of 39.6 Mtoe expanding to 83 Mtoe by 2035. Its modest domestic production of energy resources will not sustain the economy's fuel requirements over the outlook period. Hence, the economy will continue to rely mostly on imports.

While new gas finds and other potential indigenous coal and renewable energy sources are projected to come into production within the outlook period, more than half of the economy's requirements will be imported. Consequently, most of the economy's oil supply will be imported, reaching 30 Mtoe of oil imported by 2035, from its 2010 level of 13.7 Mtoe.

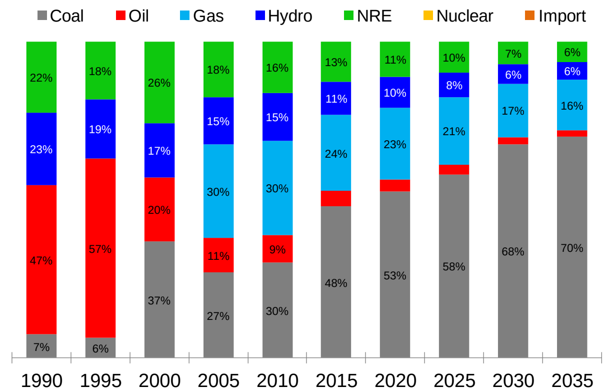
Due to the significant contribution of coal in the economy's energy mix, particularly with coal generation reaching about 70% of total electricity generation by 2035, a total of 28 Mtoe of coal will be needed over the outlook period. Indigenous coal production is estimated to increase at an average annual rate of 2.7% from its current level, to reach 7 Mtoe by 2035. However, the economy's coal imports will continue to grow over the outlook period.

The economy's new renewable energy (NRE) supply is expected to continue to contribute significantly to the total primary energy supply. Despite a modest annual growth rate of 0.2%, NRE will likely account for about 20% of the economy's total primary energy supply by 2035.

ELECTRICITY

The economy's total power generation will increase by 4.2% during the outlook period. This translates to an increase from the 2010 level of 67 TWh to 187 TWh by 2035.

Figure RP6: BAU Electricity Generation Mix



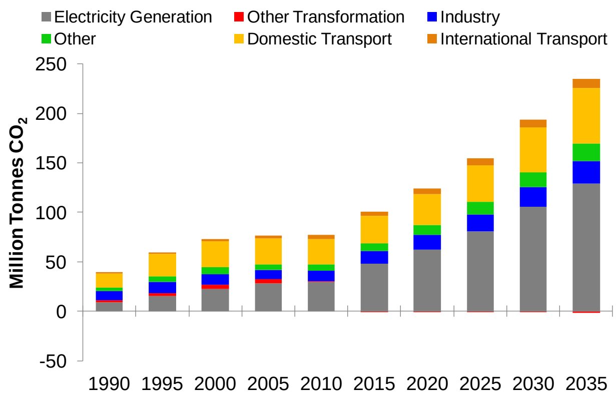
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Electricity output from coal is likely to dominate power generation, accounting for more than half of the economy's total gross generation by 2035. The output from coal generation will reach 130 TWh by 2035, up from 20 TWh in 2010. Electricity generated from hydro and NRE will increase modestly by less than 1% annually from 2010 to 2035, posting a combined output of 22 TWh by 2035. Currently, natural gas accounts for almost 30% of the economy's power generation and is expected to increase moderately by 1.7% annually over the next 25 years.

CO_2 EMISSIONS

APERC's projection showed the economy's CO_2 emissions increasing 4.5% annually during the outlook period. This translates from CO_2 emission levels of 75.9 million tonnes in 2010 to 230.2 million tonnes by 2035. This is due to the projected increase in fossil fuels consumption, especially in coal for power generation. Emissions from electricity generation grow by 6% per year and from coal-fired generation by 7.4% per year.

Figure RP7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The Table RP1 shows the total change in CO_2 emissions from fuel combustion will be influenced largely by the change in GDP, and the reduction in energy intensity of GDP (energy efficiency) will be mostly offset by the CO_2 intensity of energy (fuel switching to increase the use of fossil fuels, especially coal).

Table RP1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	2.4%	-0.2%	1.3%	1.2%	1.5%
Change in Energy Intensity of GDP	-1.3%	-4.3%	-2.1%	-1.9%	-1.5%
Change in GDP	3.4%	4.9%	4.6%	4.6%	4.5%
Total Change	4.6%	0.3%	3.8%	3.8%	4.5%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual assumptions, the Philippines projections reflect positive economic growth, in line with the economy's own projections. This will be matched by a corresponding growth in energy demand. The Philippines Government has a vision to achieve energy independence, and a goal to ensure the delivery of secure, sustainable, sufficient, affordable and environment-friendly energy to all economic sectors.

The birth of a natural gas industry brings the Philippines closer to the government's goal, and has earned the economy a place alongside other significant Asian economies in the APEC region's natural gas markets. It remains to be seen whether the extent of the economy's natural gas supply will be sufficient for its domestic requirements. The Philippines' natural gas industry can still be considered young, meaning there is a vast opportunity for developing policies to ensure the full achievement of its goal.

Despite its low per capita emissions of 1.7 tonnes of CO_2 by 2035, the BAU projection indicates that the growth rate of CO_2 emissions in the Philippines will be high at 4.5% annually from 2010–2035. This alarming rate should spur the economy into taking measures to ensure environmental sustainability. Since the electricity sector has the highest emissions growth, it is proposed that improvement measures should focus on this sector. This will happen by improving energy efficiency in the electricity generation, transmission and distribution sub-sectors as well as intensifying the implementation of the RE Law which would consequently reduce fossil fuels consumption.

ALTERNATIVE SCENARIOS

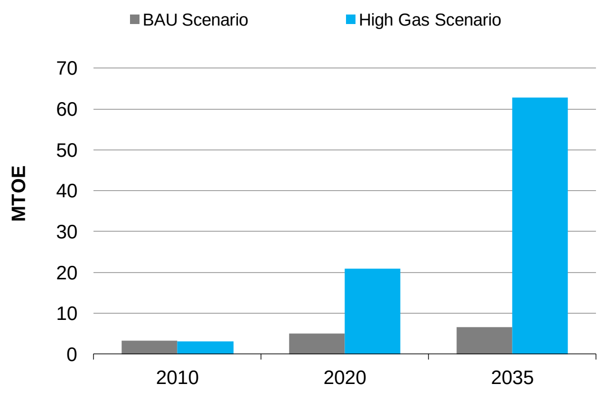
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU scenario prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario in the Philippines assumed natural gas production would reach 62.7 Mtoe in 2035, 10 times more than the production level under BAU (see Figure RP8). This potential production scenario was taken from a joint study done in cooperation with the Japan International Cooperation Agency (JICA, 2012). The increase in production will begin to take place in 2017, with production levels twice those under the BAU scenario in that year. This additional gas production will mostly likely come from the Malampaya gas fields.

Figure RP8: High Gas Scenario – Gas Production



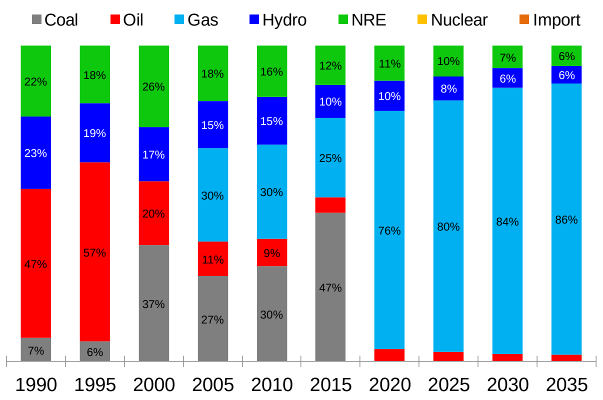
Source: APERC Analysis (2012)

An increase in natural gas production will likely spur the development of additional infrastructure, such as the expansion of natural gas fired power generation capacity, LNG (liquefied natural gas) terminals and several pipelines to extend the use of gas in other sectors, and the construction of additional CNG refueling stations for natural gas vehicles (NGVs).

In the High Gas Scenario, additional gas production will not be exported through gas pipelines. For gas pipeline exports to take place, the Philippines will need to commit to the Trans-ASEAN gas pipeline project requirements (ASCOPE, 2010).

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation in the Philippines from 2019. As shown in Figure RP9, the electricity generation from the assumed gas production will reach 161 TWh in 2035, which is 86% of the total electricity output of the economy.

Figure RP9: High Gas Scenario – Electricity Generation Mix

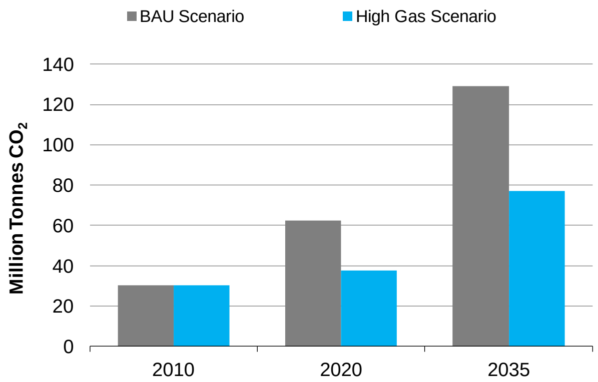


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure RP9 may be compared with the BAU case graph in Figure RP6. It can be seen that the gas share has reached more than 70% of the total electricity generation input by 2035, completely displacing the coal share in the Philippines electricity generation mix.

Since gas has roughly half the CO_2 emissions of coal per unit of electricity generated, this had the impact of reducing CO_2 emissions in electricity generation by 40% by 2035. This is compared to the BAU emissions level of 129 million tonnes CO_2 (see Figure RP10).

Figure RP10: High Gas Scenario – CO_2 Emissions from Electricity Generation



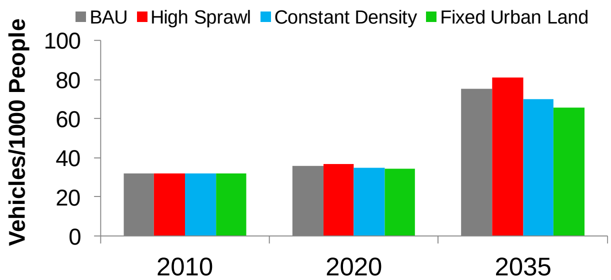
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

As urbanization in the Philippines increases rapidly in the next 25 years, so will vehicle ownership. Figure RP11 shows this change in vehicle ownership under BAU and the three alternative urban development scenarios.

Figure RP11: Urban Development Scenarios – Vehicle Ownership

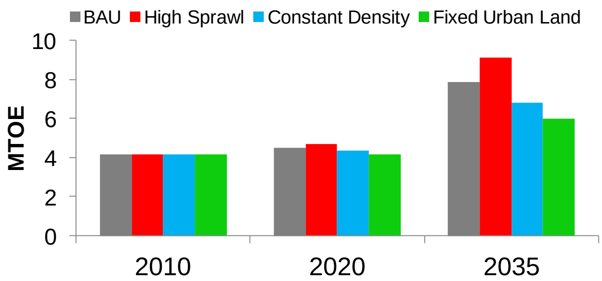


Source: APERC Analysis (2012)

Vehicle ownership in the High Sprawl scenario will be 8% higher than BAU in 2035, but 13% lower than BAU in the Fixed Urban Land scenario. This means that significant urban planning would have a direct effect on vehicle ownership in the long run, specifically in metropolitan Manila which was identified by the World Bank as one of 120 largest cities in the world.

Consequently, the oil consumption of light vehicles changed considerably under BAU and the three alternative urban development scenarios. Figure RP12 shows light vehicle oil consumption will be noticeably higher in the High Sprawl scenario, at 16% compared to BAU in 2035. On the other hand, light vehicle oil consumption in the Fixed Urban Land scenario is 24% lower than BAU by 2035, as travel distances per vehicle and vehicle ownership in more compact cities are both significantly reduced.

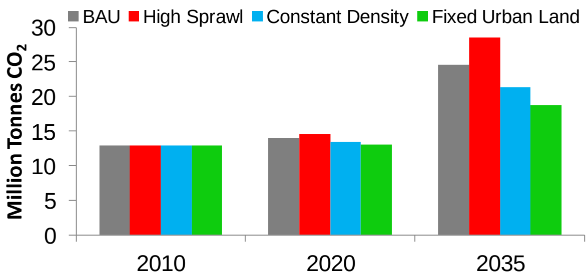
Figure RP12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure RP13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO_2 emissions would be 16% higher in the High Sprawl scenario compared to BAU in 2035, and about 24% lower in the Fixed Urban Land scenario.

Figure RP13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



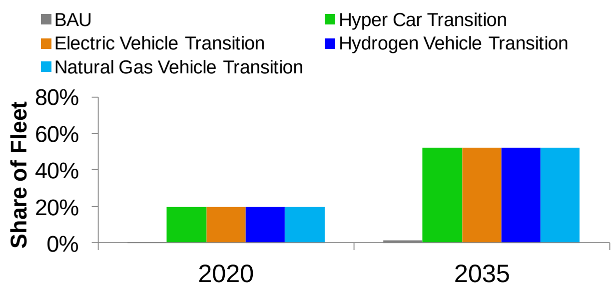
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure RP14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035, the share of the alternative vehicles in the vehicle fleet is assumed to reach about 52% compared to about 1.6% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 48% compared to about 98.4% in the BAU scenario.

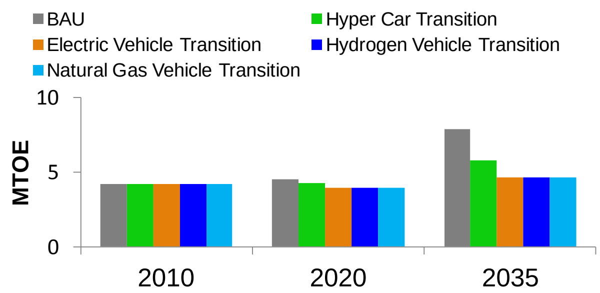
Figure RP14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure RP15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops significantly by 41% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to the BAU scenario. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced by 26% compared to BAU by 2035, even though these highly-efficient vehicles still use oil.

Figure RP15: Virtual Clean Car Race – Light Vehicle Oil Consumption

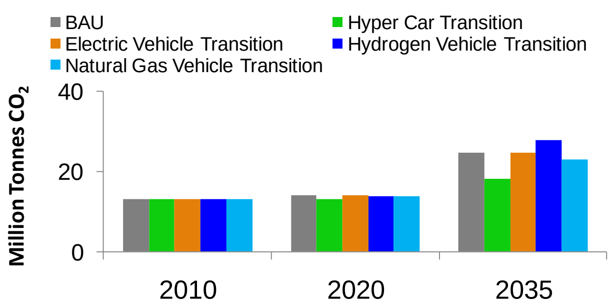


Source: APERC Analysis (2012)

Figure RP16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In the Philippines, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reduction with emissions reduced by 26% compared to BAU in 2035. The Natural Gas Vehicle Transition scenario reduced emissions slightly, by 6% compared to BAU. The CO_2 emissions from the Electric Vehicle Transition scenario showed no difference compared to BAU in 2035. This may be caused by the high prevalence of coal in the electricity generation mix. The Hydrogen Vehicle Transition scenario offers no emissions reduction benefits—emissions increased by 13% compared to BAU in 2035. (To facilitate fair comparisons, the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios assumed no additional non-fossil utilization for their energy production.)

Figure RP16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

ASCOPE (ASEAN Council on Petroleum) (2010), 'Trans ASEAN Gas Pipeline Project (TAGP)' website page, http://ascope.org/projects.html

DOE (Department of Energy) (2009), *The National Energy Efficiency and Conservation Program*, www.doe.gov.ph/EE/Efficiency.htm

— (2010a), 'Energy Reform Agenda' website page, www.doe.gov.ph/era.htm

— (2010b), *The Philippine Energy Plan 2009–2030*, www.doe.gov.ph/PEP/default.htm

— (2011), *National Renewable Energy Program*, www.doe.gov.ph/nrep/index.asp?opt=execSummary

DOT (Department of Tourism) (2009), 'Getting There' website page, www.tourism.gov.ph/SitePages/GettingAround.aspx

DOTC (Department of Transportation and Communication) (2010), *RA008-02: Formulating a National Transport Plan*, www.dotc.gov.ph/index.php?option=com_k2&view=item&id=128:ntp&Itemid=89

DPWH (Department of Public Works and Highways) (2011), 'Department of Public Works and Highways' website page, www.dpwh.gov.ph

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

IGA (International Geothermal Association) (2010), 'Installed Generating Capacity' website page, www.geothermal-energy.org/226,installed_generating_capacity.html

JICA (Japan International Cooperation Agency) (2012), *Study on Collecting Information and Verification in Promotion of Utilization of Clean Energy Sources*, draft report, January 2012.

Layug, Jose M. (2012), *Renewable Energy Towards Sustainable Future*, presentation at the 12th APERC Annual Conference, Japan, 14 February 2012.

Navarro, Adoracion M. and Yap, Josef T. (2012), "The Philippine economy in 2011 and prospects for 2012", *Development Research News*, Vol. XXX No. 1, January–February 2012, http://dirp4.pids.gov.ph/ris/drn/pidsdrn12-1.pdf

NGCP (National Grid Corporation of the Philippines) (2011), *Transmission Development Plan 2011*, www.ngcp.ph/tdp.asp

NSO (National Statistics Office) (2010), 'Population and Housing' website page, www.census.gov.ph/tags/population-and-housing

PA 21 (Philippine Agenda 21) (1989), *Philippine Strategy for Sustainable Development*, www.psdn.org.ph/agenda21/pssd.htm

PhilBPO (Philippines Business Process Outsourcing) (2011), 'KPO Philippines – An Emerging Reason Why Many Outsource to the Philippines' website page, www.philippinesbpo.com/kpo-philippines-an-emerging-reason-why-many-outsource-to-the-philippines

PIDS (Philippine Institute for Development Studies) (2009), "A vision for Philippine agriculture", *Development Research News*, Vol. XXVII No. 6, November–December 2009, http://dirp4.pids.gov.ph/ris/drn/pidsdrn09-6.pdf

Reyes, Evelyn N. (2012), *Energy Efficiency and Conservation Roadmap*, presentation at the Peer Review on Energy Efficiency (PREE), Philippines, 6–10 February 2012.

Salire, Salvador M. Jr. and Muhi, Pamela Grace C. (2010), "The Role of Decentralized Energy Systems in Rural Electrification: The Philippines Experience", *Asia-Pacific Tech Monitor*, May–June 2010, www.techmonitor.net/tm/images/1/13/10may_jun_sf4.pdf

Ward, Karen (2012), "The World in 2050 – From the Top 30 to the Top 100", *HSBC Global Research*, January 2012, www.research.hsbc.com/midas/Res/RDV?ao=20&key=hCmm8WiQC0&n=317638.PDF

WESM (Wholesale Electricity Spot Market) (2012), 'About Us' website page, www.wesm.ph/inner.php/about_us

World Bank (2011), 'Transport in the Philippines' website page, http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/EXTEAPREGTOPTRANSPORT/0,,contentMDK:20458729~menuPK:2066318~pagePK:34004173~piPK:34003707~theSitePK:574066,00.html

THE RUSSIAN FEDERATION

- *Russia will maintain its position as a top global energy exporter with a more diversified mix of products exported and a more varied mix of product destinations; frontier and offshore hydrocarbon resources should replace depleting fields in the traditional oil and gas regions.*
- *Russia will need to invest heavily in oil and gas exploration and development in new frontier areas, and in the development of the accompanying energy infrastructure needed to service both existing markets in Europe and new markets in Asia–Pacific. The inflow of investment into the energy sector would be facilitated by improved investor confidence in the stability of Russian institutional arrangements and by domestic energy price liberalization.*
- *Despite the Fukushima Nuclear Accident, Russia's nuclear energy industry remains a focus of Russia's development: nuclear energy will take a larger share in power generation in the domestic market, while the industry will expand abroad. Russia will remain a key player in the practical implementation of improved nuclear fuel technology.*
- *Significant energy conservation and economic restructuring efforts would reduce Russia's high level of energy intensity, allowing it to conserve its energy resources and to reduce greenhouse gas emissions.*

ECONOMY

With a land area of more than 17 million square kilometres, the Russian Federation is geographically the world's largest economy. It is the only APEC economy located in both Europe and Asia, and is bordered by the Arctic and the North Pacific oceans. Its terrain is characterized by broad plains west of the Urals, vast coniferous forests in Siberia, tundra along the Arctic seaboard, and uplands and mountains in the southern regions. The Russian Federation has a vast natural resource base that includes major deposits of coal, natural gas, oil and other minerals. Despite its land area advantage, the economy lacks an optimal climate for agriculture—most of its area has a continental climate, and is either too cold or too dry. Central heating is common for up to 6–8 months of the year, while cooling during the summer is not widely used.

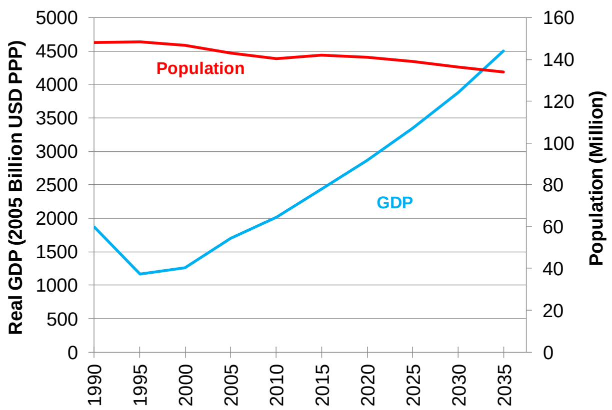
In 1999, after a decade of economic contraction (about 40% compared to the 1990 GDP level), the Russian economy began to grow again. The recovery was triggered by a devaluation of the rouble in the aftermath of the 1998 financial crisis, and its positive impact on the economy's competitiveness. In parallel, soaring world prices of oil and natural gas also drove the recovery.

Russia's major industries include the oil and gas production, petroleum refining, mining, iron and steel, chemicals, machinery and motor vehicles industries.

GDP increased at a rate of 4.8% per year from 2000 to 2009, reaching USD 1931 billion (in 2005 USD PPP) in 2009. Per capita income in 2009 was USD 13 712, 60% more than in 2000. Over the outlook period, Russia's GDP is expected to continue to grow, although at a slower average annual rate of 3.3%, to reach USD 33 600 per person (2005 USD PPP) by 2035.

Russia's population in 2011 was around 142.8 million people. Russia's population is projected to decline at an average annual rate of 0.2% during the outlook period and is expected to be 134 million people by 2035.

Figure RUS9: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

The urbanization rate in 2011 was 74% and it has not changed much since 1989. Russia's average population density of only 8.4 people per square kilometre is very low, with the majority of the population living in the European part of the economy (GKS, 2012).

Russia's economy faces challenges due to the underdevelopment of its transport infrastructure. In particular, the current condition of Russian airports and air transport facilities provides insufficient capacity for and slows the performance of air transportation services. Further modernization of air and rail transport is planned in connection with Russia's programs for hosting the 2014 Winter Olympic Games, the 2018 Football World Cup, and the 2020 World Expo.

The total length of Russian roads in 2009 was 983 000 kilometres (km), 80% of which was paved. The country had only 29 000 km of high-speed divided highways connecting big cities (GKS, 2012). Further development of highways will be necessary if the big cities are to be connected.

Russia has a state railway system with a total length of 83 000 km, but only some cities have high-speed train services. Almost all towns in Russia regardless of size are served by regional bus services. Subway systems have been introduced in seven of Russia's major cities, and all cities have extensive city bus systems.

Russia's pipeline transport is underdeveloped relative to the potential oil and gas supply. The total length of the pipeline system in the economy was 233 000 km in 2010, 167 000 km of which was gas pipeline, 49 000 km was oil pipeline, and 16 000 km was oil products pipeline.

Russia maintained its place in the top three automobile markets in Europe, following Germany and the UK. Vehicle production in 2011 was 1.7 million units.

ENERGY RESOURCES AND INFRASTRUCTURE

In terms of proven reserves, the Russian Federation holds 21.4% of the world's gas, 5.3% of its oil reserves, 18.2% of its coal reserves, and about 14% of its uranium ore reserves (BP, 2012). Even more resources remain to be discovered, but the formidable obstacles of climate, terrain and distance hinder their exploitation.

The Russian energy sector is very important for the security of the global energy supply. The economy is the world's largest exporter of energy overall, and also the largest exporter of natural gas, and the second-largest exporter of oil. In addition, Russian-labelled nuclear fuel is used at 74 commercial reactors (17% of the global market) and 30 research reactors in 17 economies worldwide, and the economy provides over 40% of the world's uranium enrichment services (ME, 2012).

However, Russia's oil resources in the traditional oil producing regions are believed to be heavily depleted, with more than 50% of the economically-recoverable resources already produced. In the Urals and Volga regions, resource depletion is believed to exceed 70%. The share of remaining resources that is hard-to-recover is constantly growing. Almost 80% of Russia's oil production comes from large fields with remaining lives of 8–10 years. Newly developed resources are often concentrated in middle-size and small-size deposits (ME, 2012). Without the development of new fields in remote areas, oil production is likely to peak at 550 million tonnes of oil equivalent (Mtoe) per year by 2020 and then decline to 400 Mtoe per year by 2035.

The refining industry in Russia includes about 30 major refineries with a total capacity for primary processing of about 254 million tonnes of crude oil per year (ME, 2012). Most of these refineries are older facilities that do not meet modern standards for energy efficiency or environmental protection. During the outlook period, the refinery industry of Russia will need to undergo modernization, with priority given to the cracking processes needed to produce the lighter fuels (such as gasoline, diesel, and jet fuel) most in demand in the market. The Russian Government's export policy favours the export of petroleum products rather than crude oil, which implies that Russia will need a large expansion of refinery capacity by 2035.

The oil sector is heavily controlled by the Russian Government and this control will increase after the state-owned Rosneft takeover of TNK-BP. The merger will create the world's largest listed oil company with a daily output of 4.6 million barrels in oil-equivalent terms (Reuters, 2012).

The gas industry of Russia has a more favourable resource situation than the oil industry. The proved natural gas resources in Russia, estimated at 44.6 trillion cubic meters (BP, 2012), should be adequate to meet both domestic market and export demands in the outlook period. Russia will continue to be a major gas supplier to Europe and planning is in progress for major export projects to serve the Asia–Pacific region.

About 79% of the gas production in 2009 was from Gazprom, a state-controlled corporation. Gazprom is also the owner of Russia's pipeline network. The company is the main gas supplier to domestic and export markets, and is the owner of most of the basic infrastructure of the Russian natural gas business.

The remaining reserves of coal in Russia amount to more than 190 billion tonnes or 18% of the world reserves. At current rates of coal consumption in the economy, these reserves will be sufficient for 800 years. Unlike the oil and gas sector, the coal industry has no large state-controlled company and is almost 100% privatized.

As of 2010, the generation of electricity and heat in Russia from thermal sources was provided by six wholesale generating companies, which operate without regard to territorial boundaries, and 14 territorial generating companies. These companies are mostly privately-owned with some state participation. RusHydro operates most of Russia's hydropower stations. Rosatom operates all Russia's nuclear energy power plants. Both of these companies are state controlled.

Russia has the world's largest and oldest district heating system with centralized heat production and distribution networks in most major cities. The system has a high number of combined heat and power (CHP) installations. Given the obsolescence of the Russian district heating infrastructure, a considerable amount of energy can be saved through relatively accessible technologies and cost-effective energy saving practices (IES, 2010).

During the outlook period, the development of Russia's electricity infrastructure will be determined by the State Program of Long Term Development of Installed Capacity and Forecast of Construction of New Capacities in the Russian Federation for the Period till 2030 (IES, 2010). Our business-as-usual projections are based primarily on this document.

ENERGY POLICIES

The adoption of the Energy Strategy of Russia for the period up to 2020 in August 2003 (IES, 2010) was a milestone in Russia's energy sector development. The strategy identifies the economy's long-term energy policy and the mechanisms for its realization. A revised version of the strategy was adopted by the government in November 2009—the Energy Strategy of Russia for the period up to 2030, (Energy Strategy 2030) (IES, 2010). The new version of the strategy was updated to take into account the new realities and priorities in the energy sector as affected by the global recession. The strategy is a framework within which more detailed industry-oriented medium-term and short-term programs can be developed.

The strategic objective of Russia's external energy policy is to use its energy potential effectively to maximize its integration into the world's energy markets, to strengthen Russia's position in those markets, and to maximize the benefits of energy resources to the economy.

To achieve this, Russia will implement a number of measures to improve the security of domestic energy consumption and energy export obligations, and will make efficiency improvements along the entire energy supply chain. This will include the development of new hydrocarbon provinces in remote areas and offshore. It will also include the rehabilitation, modernization and development of energy infrastructure, including the construction of additional trunk oil and gas pipelines, to enhance the economy's energy export capacity.

To better integrate Russia into world energy markets, export delivery markets will be diversified. At least 27% of Russia's total energy exports in 2030 should be delivered to the Asia–Pacific region (IES, 2010).

Despite the Fukushima Nuclear Accident, Russia's nuclear energy industry remains a focus of Russia's development. Nuclear energy will take a larger share in power generation domestically, while the industry will expand abroad. Russia will remain a key player in the practical implementation of improved nuclear fuel technology.

Despite the existing programs for renewable energy development in the Energy Strategy 2030, the economic potential of renewable energy in Russia is low. Fossil fuels in Russia are so abundant that renewables have difficulty competing.

The Energy Strategy 2030 calls for a reduction in the energy intensity of the economy by 40% by 2030 (IES, 2010). Decreasing Russia's relatively high energy intensity (about 335 tonnes of oil equivalent per million USD PPP in 2009) needs to be a main objective of Russian energy policy. Without significant progress in this area some industries may not be globally competitive, thus impeding Russia's economic development.

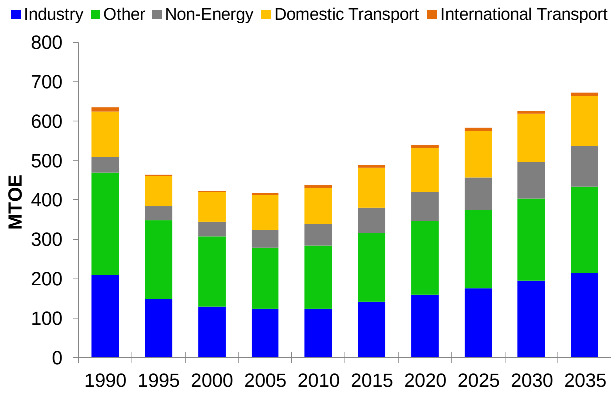
Perhaps the most important measures in the Energy Strategy 2030 are directed toward developing energy market institutions, such as fair pricing mechanisms and transparent trading principles, and making sure there is sufficient energy transportation infrastructure. State participation in the energy sector development will consist mainly of supporting innovative developments in the energy sector, as well as providing a stable institutional environment for the effective functioning of the sector (IES, 2010).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

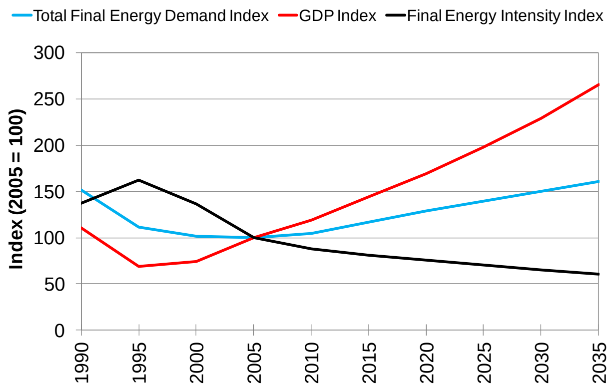
Russia's final energy demand is expected to grow at 1.7% per year over the outlook period, but will not exceed 1990 levels until after 2030. Growth is expected in all sectors. Final energy intensity is expected to decline by about 39% between 2005 and 2035.

Figure RUS10: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure RUS3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Russia's industrial energy demand is projected to grow at an average annual rate of 2.2% until 2035, with industrial growth driven by infrastructure project development in the economy. The anticipated technological retrofitting of industrial facilities is expected to contribute to improvements in energy efficiency. Moreover, a firmly implemented policy to reduce energy subsidies and link domestic energy prices with world benchmarks is expected to provide a major stimulus for energy efficiency improvements in the long term.

Transport

Transport energy demand increases of 1.3% annually are expected over the outlook period. Rising incomes will gradually increase passenger vehicle ownership, from around 230 per 1000 people in 2005 to about 660 per 1000 in 2035.

Road transport will continue to consume the largest share of the energy used in the transport sector over the outlook period. The improvement in living standards and increased vehicle ownership will lead to a shift from public transport to individual passenger vehicles for commuting.

Other

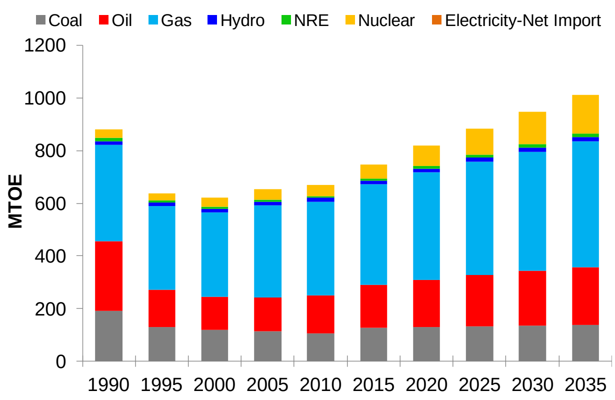
Energy consumption in the 'other' economic sectors (residential, commercial, and agriculture) is expected to grow by 1.2% annually over the outlook period. Due to Russia's frigid climate, space heating accounts for a large share of this demand. Russia's district heating systems will meet 43% of 'other' sector energy demand in 2035, while gas will account for another 22%. However, the current energy efficiency of heat generation and use in the residential and commercial sectors is low. A gradual shift to more energy-efficient apartment and office buildings is expected over the outlook period, encouraged by government programs. Coal and renewable energy (mainly biomass) will maintain shares of 5% and 1% respectively, mainly due to their importance in rural and remote areas.

PRIMARY ENERGY SUPPLY

Russia's total primary energy supply is expected to reach 1009 Mtoe in 2035. Nuclear energy is projected to grow the fastest at an average annual rate of 5% per year, followed by new renewable energy (NRE) at 3.2%. However, NRE's share of the total primary energy supply will still be only about 1.4% in 2035. Of the fossil fuels, oil will grow the fastest at 1.7% per year, driven by a growing transport demand. At the same time natural gas will grow by 1.2% per year, while coal will grow by 1.1% per year. Hydro output will be virtually unchanged over the outlook period.

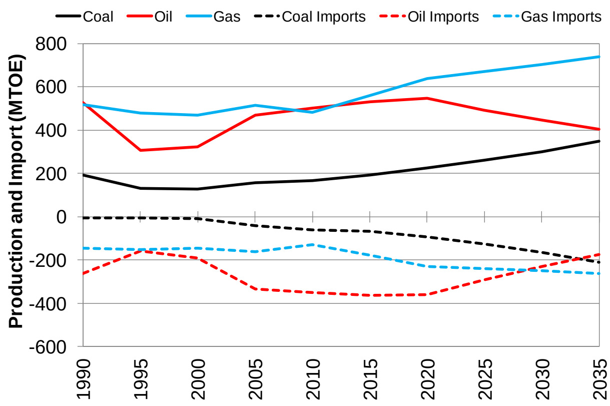
Although there are huge untapped hydro resources in the Russian Far East, their remote location and lack of local markets makes them unlikely to be developed during the outlook period.

Figure RUS4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure RUS5: BAU Energy Production and Net Imports



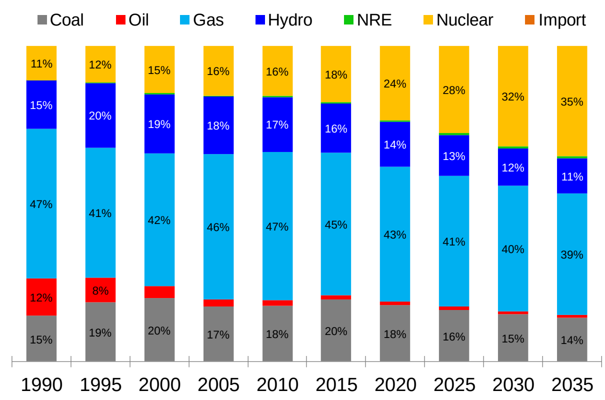
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Significant growth is expected in coal and gas production and exports. However, oil exports will experience a contraction over the outlook period, as domestic demand will grow and (after 2020) production may decline.

ELECTRICITY

Electricity demand is projected to grow at an average annual rate of 2.5%. This will require an increase in installed generation capacity from 237 GW in 2010 to 335 GW by 2035 or, in other words, the construction of more than an average 4 GW of new capacity each year within the outlook period.

Figure RUS6: BAU Electricity Generation Mix



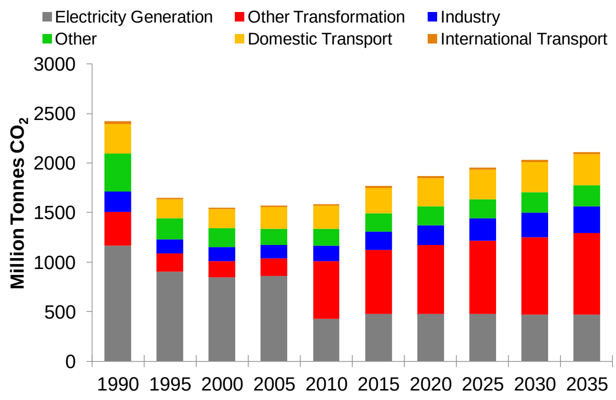
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Natural gas will be the main input fuel for electricity generation in 2035 (39% share), followed by nuclear (35%), coal (14%) and hydro (11%). Electricity generation from renewable sources is expected to increase robustly at an average annual rate of 5.9%; however, its share will remain less than 1%. Petroleum products will likewise account for less than 1% of electricity generation, but they will be the major fuel for electricity generation in isolated areas, in particular for the northern regions in the Russian Far East.

CO_2 EMISSIONS

Over the outlook period, Russia's total CO_2 emissions from the energy sector are projected to reach 2113 million tonnes of CO_2, which is still lower than the 1990 level of 2424 million tonnes. The emissions from electricity and district heating production will contribute 50% of the total CO_2 emissions in 2035. (Note, in Figure RUS7, CO_2 emissions from heat production shift from Electricity Generation to Other Transformation after 2010 due to data limitations.)

Figure RUS7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The major factor restraining the growth of Russia's CO_2 emissions is the expected decline in energy intensity of GDP at an average annual rate of 1.7% per year (see Table RUS1 below).

Table RUS1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.9%	0.4%	-0.2%	-0.3%	-0.4%
Change in Energy Intensity of GDP	-1.3%	-3.5%	-2.0%	-2.0%	-1.7%
Change in GDP	-0.7%	3.5%	3.4%	3.3%	3.3%
Total Change	-2.9%	0.2%	1.0%	1.0%	1.2%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Russia is one of the most energy-intensive economies in the world because of a) its frigid climate; b) the disproportionally large shares of energy-intensive industries in contrast to the much lower shares of less energy-intensive industries and services; and c) the high proportion of technologically obsolete assets within industry and the energy supply infrastructure.

In the energy sector, a refurbishment of the refining industry in Russia is urgently required to meet tightening fuel quality standards and to drastically increase the yield of light products (which is the lowest of all APEC member economies). Russia will need to invest heavily in oil and gas exploration and development in frontier areas and offshore, and in the development of the accompanying energy infrastructure needed to service both existing markets in Europe, and new markets in Asia–Pacific. An inflow of investment into the energy sector would be facilitated by improved investor confidence in the stability of Russian institutional arrangements and by domestic energy price liberalization.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

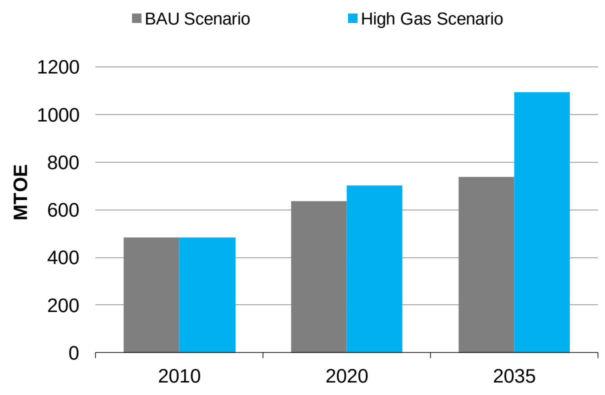
HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below if constraints on gas production and trade could be reduced.

The High Gas Scenario production for Russia assumed the production increase shown in Figure RUS8, which equals 48% by 2035 compared with BAU. Russia has vast resources of gas in frontier areas of production like Yamal, Eastern Siberia and the Far East, which require significant investment in both production and pipeline transport infrastructure.

The High Gas Scenario would remove the restrictions on the use of the export pipeline system by private gas producing companies. This would enable greater investment in offshore gas production for liquefied natural gas (LNG) exports from both the Northern Shelf and the Far East, as well as in the onshore development of Eastern Russian gas basins for pipeline transportation to international markets, including pipeline supply to China, Korea and possibly Japan.

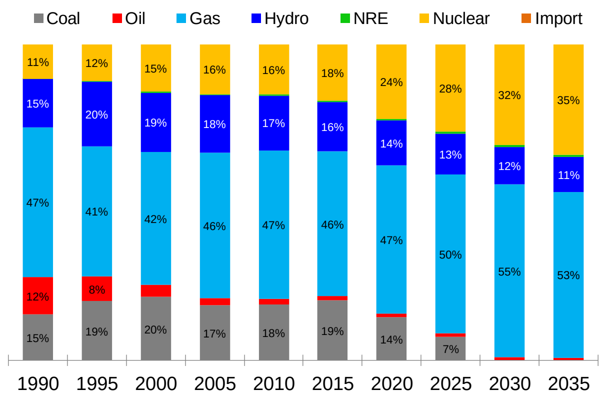
Figure RUS8: High Gas Scenario – Gas Production



Source: APERC Analysis (2012)

The additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure RUS9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario graph in Figure RUS6. It can be seen that the gas share has increased by 14% by 2035, while the coal share has declined by a corresponding amount.

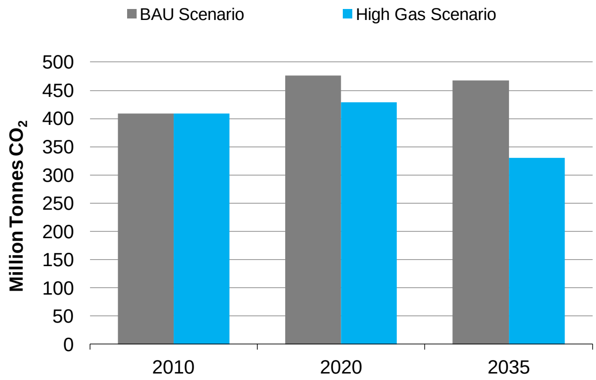
Figure RUS9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

A higher gas share in the electricity generation mix is projected to reduce the CO_2 emissions in electricity generation by 10% by 2020 and by 29% by 2035, since gas has roughly half the CO_2 emissions of coal per unit of electricity generated. In addition to lowering CO_2 emissions, the High Gas Scenario would boost Russian economic growth, especially in the remote eastern regions of the economy.

Figure RUS10: High Gas Scenario – CO_2 Emissions from Electricity Generation



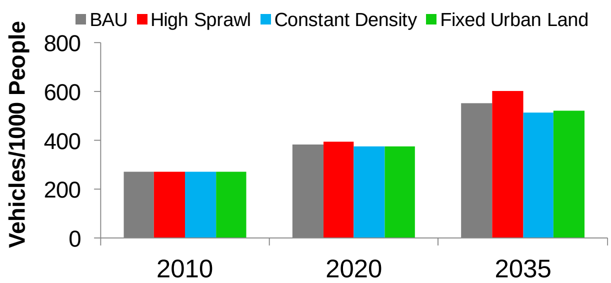
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure RUS11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Urban planning has a direct effect on the expected level at which the long-term saturation of vehicle ownership is reached. In the High Sprawl scenario, vehicle ownership would be about 9% higher than BAU by 2035, while in the Constant Density scenario, it would be about 7% below BAU. Note, in most economies the Fixed Urban Land scenario has a population density higher than the Constant Density scenario, and therefore a lower vehicle ownership. However, due to Russia's expected population decline, this is not the case for Russia.

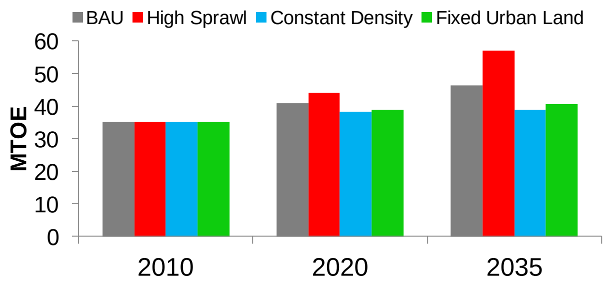
Figure RUS11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure RUS12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact on oil consumption in the light vehicle fleet is compounded by the change in vehicle travel, since in compact cities the travel distances per vehicle are typically lower than those in sprawling cities. Consequently, in the High Sprawl scenario light vehicle oil consumption would be 23% higher than BAU, while in the Constant Density scenario it would be 16% lower than BAU.

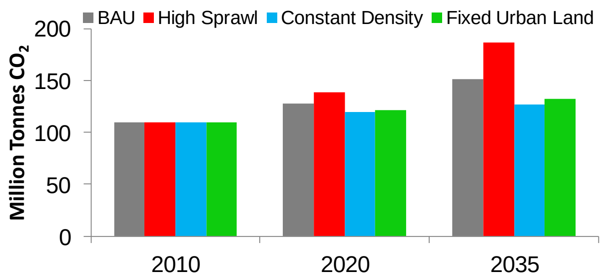
Figure RUS12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure RUS13 shows the change in light vehicle CO_2 emissions in Russia under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these cases.

Figure RUS13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



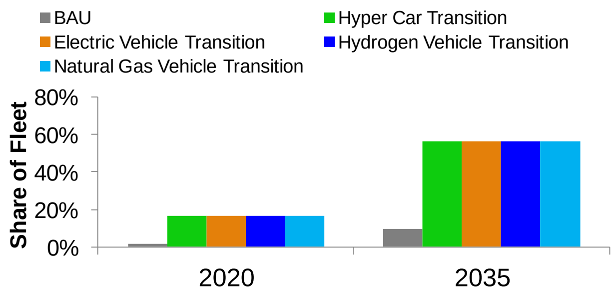
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure RUS14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 56% compared to about 10% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 44%, compared to about 90% in the BAU scenario.

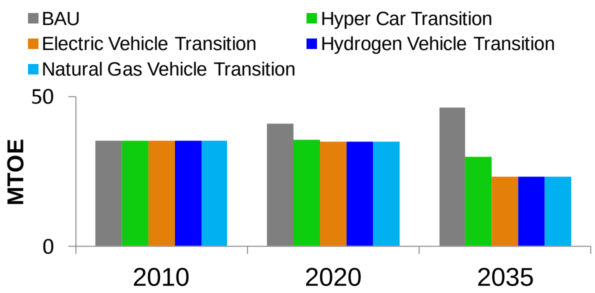
Figure RUS14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Feet



Source: APERC Analysis (2012)

Figure RUS15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by about 50% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 36% by 2035—even though these highly-efficient vehicles still use oil.

Figure RUS15: Virtual Clean Car Race – Light Vehicle Oil Consumption

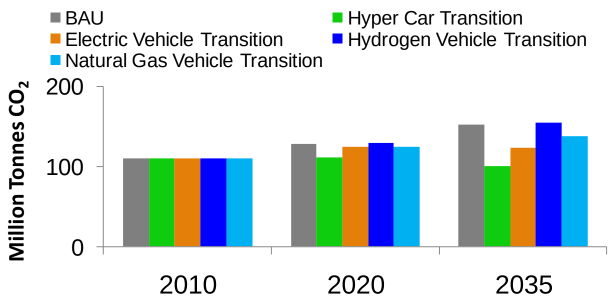


Source: APERC Analysis (2012)

Figure RUS16 shows the change in light vehicle CO_2 emissions in Russia under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Russia, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reductions, with an emissions reduction of 34% compared to BAU in 2035. The Electric Vehicle Transition scenario would reduce emissions by about 19%, reflecting our assumption that in Russia the additional electricity required by electric vehicles would be generated primarily from natural gas. The Natural Gas Vehicle Transition scenario would reduce emissions by about 9% compared to BAU. The Hydrogen Vehicle Transition scenario would increase emissions by about 2%. This is mainly due to the way hydrogen is produced—from the steam methane reforming of gas, a process which involves significant CO_2 emissions.

Figure RUS16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

BP (British Petroleum) (2012), *BP statistical review of world energy June 2012*, www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481

GKS (Federal State Statistics Service) (2012), *Russia in figures 2011*, www.gks.ru/wps/wcm/connect/rosstat/rosstatsite.eng/figures/population/

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

IES (Institute of Energy Strategy) (2010), *Energy Strategy of Russia for the period up to 2030*, www.energystrategy.ru/projects/docs/ES-2030_(Eng).pdf

ME (Ministry of Energy of the Russian Federation) (2012), *The Russian Federation Energy Data 2011*, in Russian, www.minenergo.gov.ru/activity/

Reuters (2012), "Mixed feelings over Rosneft-BP alliance", 25 October 2012, www.reuters.com/article/2012/10/25/russia-putin-rosneft-idUSL5E8LPNUR20121025

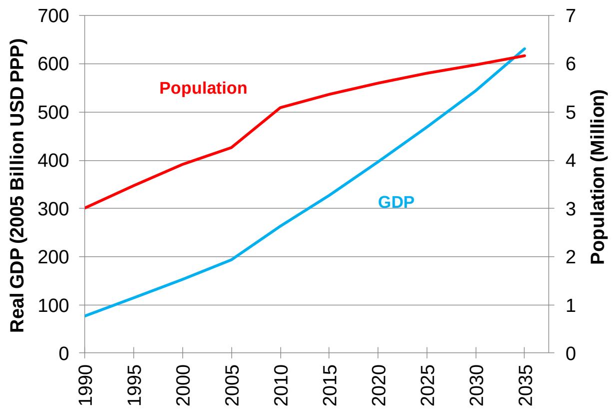
SINGAPORE

- *Singapore's primary energy supply is projected to grow at an average annual rate of 1.1% over the outlook period, dominated by an increasing demand for oil in the transport sector.*
- *As a major logistics hub for the South-East Asia region, Singapore's international transport sector is expected to continue to dominate final energy demand. The domestic transport sector's final energy demand will continue to decline at 0.4% annually.*
- *Final energy intensity is projected to decrease by 38% from 2010 to 2035; however, the absolute amount of CO_2 emitted will continue to grow at 1.8% annually over the same period.*

ECONOMY

The Republic of Singapore is an island city-state located off the southern tip of the Malay Peninsula. It is situated south of the Straits of Malacca on a major shipping route, well-located for the energy industry with regard to international oil refining and trading. It is also an emerging leader in the biotechnology industry. Its total land area is 710 square kilometres (km^2) and it had a population of 4.8 million in 2009, of which 1.2 million were non-residents. The economy's population density is about 7126 persons per km^2. Despite its small land area and population, Singapore is one of the most highly industrialized and urbanized economies in South-East Asia. The climate is hot and humid, with an average temperature ranging from 20 to 35 degrees Celsius and a relative humidity ranging from 80% to 90% throughout the year.

Figure SIN1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Singapore is a mature economy. Its population is expected to grow slightly at 0.8% per year over the projection period. In 2035, the total population is expected to be about 6.2 million.

Singapore is a highly developed and vibrant free-market economy. It is the pricing centre and leading oil trading hub in Asia. In 2011, the service industry contributed 69% of GDP, while manufacturing accounted for 27% (MTI, 2012). Most of the manufacturing output is for export. The top two exports in 2011 were electronic components and parts (31%) and refined petroleum products (26%) (MTI, 2012). Between 2010 and 2035, GDP is projected to grow moderately, at about 3.6% per year or 140% in total growth. By 2035, Singapore's GDP will grow to about USD 632 billion (in 2005 USD PPP) or about USD 102 588 per capita.

Singapore has grown into one of Asia's and the world's leading and most cost effective locations for petrochemical industries. The key for this success is Jurong Island, a collection of seven small islands that is home to three major oil refineries. Singapore is the third-largest oil and oil products trading hub in the world (EDB, 2011). It has a complex refining and petrochemical integration with a refining capacity of about 1.385 million barrels of oil per day (BP, 2012).

Domestic transport energy demand in Singapore mainly comes from road transport. The total length of roads in Singapore is 3411 km and the per capita car ownership rate is about 110 cars per 1000 people (LTA, 2012b). Singapore has been motivated to reduce car ownership and to encourage people to use public transport. Private car ownership has been moderated through the use of various measures, such as mandatory car ownership quotas by limiting the number of vehicle ownership certificates; electronic road pricing on congested roads; a green vehicle rebate to encourage more fuel-efficient vehicles; and trials of green technologies such as diesel hybrid buses and electric vehicles.

Rail transport plays a significant role in the economy. The total length of the mass rapid transit (MRT) and the light rail transit (LRT) systems as of 2011 is 138 km and they handle an average daily ridership of about 2.4 million passengers (LTA, 2012b). The Land Transport Authority of Singapore has targets to expand the rail network to 278 km by 2020, and to increase the rapid transit system (RTS) density from 31 km per million population to 51 km per million population (LTA, 2012a).

Singapore is the busiest sea port in the world in terms of shipping tonnage, with some 120 000 vessel calls annually, and the economy is connected to more than 600 ports in over 120 countries worldwide (MPA, 2009). Singapore's Changi Airport is ranked the seventh busiest international airport. Each week, more than 6200 flights land or depart from Changi Airport, with more than 46.5 million passengers passing through the airport in 2011 (CAG, 2012).

ENERGY RESOURCES AND INFRASTRUCTURE

Singapore has negligible indigenous energy resources, either in fossil fuels or in alternative energy sources. Singapore imports nearly all the fuel it requires for its energy needs, except for a small portion of energy produced from incinerating municipal waste. In 2009, 146.1 Mtoe (million tonnes of oil equivalent) of energy products were imported, mainly consisting of petroleum products, crude oil and natural gas liquids (NGLs), and natural gas that accounted for 61.8%, 33.2% and 5% of energy imports, respectively (EMA, 2011, p. 10). Singapore exported 84 Mtoe of energy products in the same year, consisting mostly of refined petroleum products (EMA, 2011, p. 10).

Oil is mainly imported from the Middle East, and it is mainly used by the transport and industry sectors. Natural gas is imported from Malaysia and Indonesia. Imported natural gas is transported via four offshore pipelines—two pipelines from Indonesia (9.2 million standard cubic metres per day from West Natuna and 9.9 million standard cubic metres per day from South Sumatra) and two pipelines from Malaysia (supplying 4.2 and 2.8 million standard cubic metres per day).

About 80% of Singapore's electricity demand is produced from natural gas as fuel (EMA, 2011, p. 14). As Singapore's demand for gas is expected to exceed supply via pipeline in the near future, Singapore is planning to import LNG (liquefied natural gas). The construction of Singapore's first LNG receiving terminal began in March 2010 on Jurong Island (EMA, 2010). The LNG receiving terminal is expected to begin operations in the second quarter of 2013. It will have an initial capacity of 3.5 million tonnes per year, which will be increased to 6 million tonnes per year by the end of 2013 (EMA, 2010).

Singapore has limited land area and lacks the natural endowments necessary to make use of non-fossil energy alternatives to meet its needs. As such, Singapore is recognized as 'alternative energy-disadvantaged' under the United Nations Framework Convention on Climate Change (UNFCCC) (NEA, 2010, p. 11). The economy does not have any hydro or geothermal resources, and average wind speeds are too low to generate power efficiently or economically. Wave and tidal technologies have limited application as much of Singapore's sea space is used for ports, anchorage and shipping lanes.

Despite these disadvantages, Singapore is keen to adopt renewable energy solutions to improve its energy security. To this end, the Singapore Government has begun to harness energy from solar photovoltaic (PV), waste incineration and bio-gas for power generation. By 2010, 3% of Singapore's electricity generation came from these renewable resources (EMA, 2011, p. 14).

Singapore does not have a nuclear energy industry. However, nuclear energy is considered by the government as a long-term energy supply option for Singapore 20–30 years down the road.

ENERGY POLICIES

The Singapore Government published the National Energy Policy Report in 2007. The report contains a robust national energy framework aimed at meeting the economy's objectives for economic competitiveness, energy security and environmental sustainability (MTI, 2007). Under the policy, the economy has defined the following key energy strategies:

1. Promote competitive energy markets
2. Diversify energy supplies
3. Improve energy efficiency
4. Build an energy industry and invest in energy research and development
5. Promote greater regional and international cooperation
6. Develop a whole-of-government approach.

In 2009, Singapore voluntarily committed to a 16% reduction in emissions below 2020 business-as-usual (BAU) levels, contingent on a legally binding global agreement on climate change in which all countries implement their commitments in good faith (NEA, 2010, p. 37). The Sustainable Singapore Blueprint (SSB) was developed based on this commitment. It details several other energy goals to be achieved by 2030, including reducing energy intensity (per SGD GDP) by 35% from 2005 levels; setting a cap for sulphur dioxide (SO_2) levels at 15 micrograms per cubic metre ($\mu g/m^3$); and improving the recycling rate to 70% (NEA, 2010, p. 5).

The Energy Market Authority (EMA), under the Ministry for Trade and Industry, is mandated to regulate the electricity and piped gas industries and the district cooling services in designated areas. Both the electricity and gas industries have been liberalised—the electricity industry since 1995 and the gas industry since 2008. The gas pipeline network is owned and operated by PowerGas Ltd.

The electricity industry is divided into contestable and non-contestable sectors. The non-contestable consumers constitute 25% of the total electricity sales in Singapore and purchase their electricity from SP Services Ltd at a regulated tariff. Generation companies compete to sell electricity to the National Electricity Market of Singapore (NEMS), established in January 2003. Electricity is then transmitted through the grid network operated by the EMA.

The EMA has launched several initiatives to spur the development of more diverse and sustainable energy solutions. These initiatives include setting up the Electric Vehicles Test Bed for electric vehicles (EVs) that provides an open platform for industry players to test EV prototypes and vehicle charging technologies; setting up the Pulau Ibin Micro-grid Test Bed to assess the feasibility and scalability of electricity supply from a micro-grid infrastructure using an intermittent renewable energy supply; and the Intelligent Energy System (IES) pilot to test and evaluate new smart grid applications and technologies. These initiatives will transform Singapore's energy landscape into something more dynamic, and will enable the economy to spearhead the adoption of new, smart technologies in the region.

Energy efficiency is an integral part of Singapore's energy policy and the Energy Efficiency Programme Office (E^2PO) was established to promote and facilitate the adoption of energy efficiency in Singapore. E^2PO focuses on a sectoral approach to energy efficiency, targeting five sectors namely power generation, industry, transport, building and household. The following outlines some of the ongoing and planned programmes:

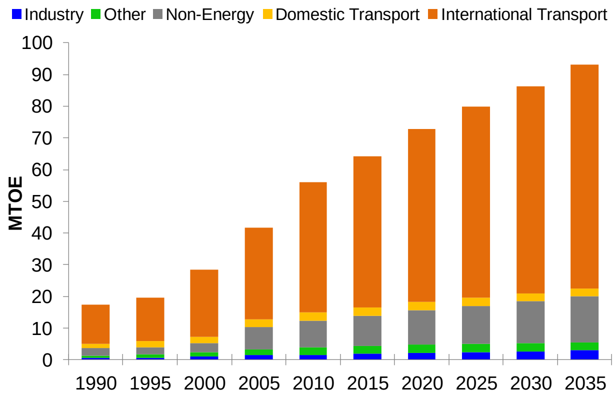
- *Power generation sector*. Market competition in Singapore's electricity industry acts as a natural incentive for power generation companies to be energy efficient. The government aims to further maximize efficiency in this sector by encouraging more co-generation and tri-generation facilities—these facilities produce two to three utilities (like electricity, steam, chilled water) from a single integrated system.
- *Industry sector*. A SGD 10 million (USD 8.1 million) Energy Efficiency Improvement Assistance Scheme (EASe) was launched in 2005 to provide financial assistance to Singapore's companies to conduct energy appraisals for buildings and industrial facilities. To equip facility owners and technical staff with the necessary knowledge and skills to manage energy services within their facilities, a Singapore Certified Energy Manager Training Grant was introduced. Investment in energy efficient equipment is encouraged through the Investment Allowance Scheme (IAS).
- *Transport sector*. The Fuel Economy Labelling Scheme (FELS) was launched to provide buyers of passenger cars and light goods vehicles with fuel economy information at point of sale. The Green Vehicle Rebate (GVR) encourages the purchase of green vehicles by providing green passenger cars and electric motorcycle rebates of 40% and 10% of the open market prices. The Vehicle Quota System (VQS) and Electronic Road Pricing (ERP), on the other hand, limit car ownership and usage, and promote the use of public transport.
- *Building sector*. The Energy Smart Labels are awarded to existing buildings with good energy performances. The Green Mark Buildings rating system evaluates new buildings on their environmental impact and performance, and awards Certified, Gold, GoldPlus or Platinum ratings depending on the points scored on a set of criteria. The EASe scheme for the industry sector also applies to buildings.
- *Household sector*. To encourage energy efficient purchases, the Mandatory Energy Labelling Scheme (MELS) and the Minimum Energy Performance Standards (MEPS) were introduced for energy intensive appliances like air conditioners and refrigerators. In 2008, the government launched the 10% Energy Challenge, a national public awareness campaign challenging households to reduce their electricity consumption by at least 10% by adopting simple energy saving habits.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow at 1.6% per year over the outlook period, from about 56 Mtoe in 2010 to over 22.5 Mtoe by 2035 (This figure includes demand from international transport sector). If we discount demand from international transport sector, by 2035 over 75% of the final energy demand will be for oil, followed by electricity and natural gas. Demand for new renewable energy (NRE) will grow the fastest at 5.3% annually; however the share for NRE in 2035 will still be comparatively low at 0.3%.

Figure SIN2: BAU Final Energy Demand

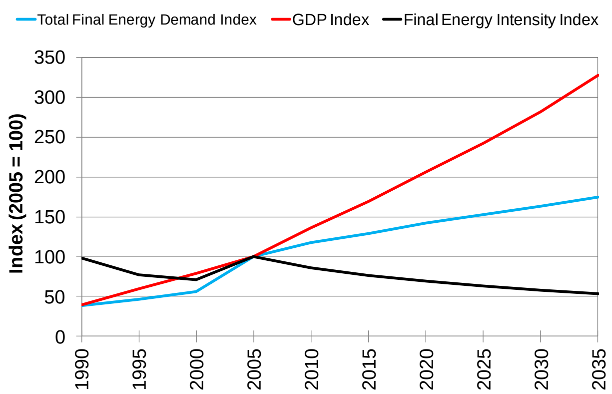


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

As a major trading and oil refining hub, international transport and the non-energy sector dominate Singapore's final energy demand, taking up 76% and 16% respectively of the total final energy demand by 2035. With the exception of the domestic transport sector, all sectors will show growth from 2010 to 2035. Domestic transport sector demand is expected to decline at the rate of 0.4% annually from 2010 to 2035; this can be attributed to the comprehensive energy efficiency measures expected in the transport sector.

For Singapore, final energy intensity is likely to decline by 47% between 2005 and 2035. Please note that for the purpose of calculating final energy intensity, international transport is excluded so only domestic energy demand is considered.

Figure SIN3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 2.5% until 2035, reflecting the growth of Singapore's industries. Industrial electricity demand will consistently account for the largest share from 2010 to 2035 at about 65%, while industrial gas demand will see the highest growth, by 87% to 0.8 Mtoe by 2035.

Transport

Domestic transport demand is projected to decrease from 2010 to 2035 by 0.4% annually, to 2.5 Mtoe by 2035. The oil share in total domestic transport demand will decline from 96% in 2010 to 88% by 2035. The rest will be taken up by natural gas (5%), electricity (4%) and bio-fuel (3%). With less oil combustion, energy intensity for this sector will decrease by over 60% from 2010 to 2035.

This positive trend could probably be attributed to the many initiatives the government has put in place to reduce and diversify energy use in the transport sector, particularly its initiatives to promote the use of alternative vehicles and public transport.

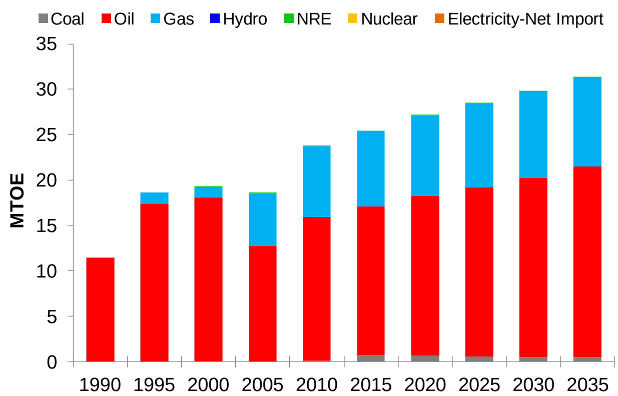
Other

Energy demand in the 'other' sector, which includes residential, commercial, agricultural, and construction demand, is expected to grow at 0.5% per year over the outlook period. Electricity is expected to continue to dominate the fuel mix in this sector, accounting for about 90% of 'other' energy consumption from 2010 to 2035.

PRIMARY ENERGY SUPPLY

Singapore's primary energy supply is projected to grow at an annual rate of 1.1% per year over the projection period, from 24 Mtoe in 2010 to 31 Mtoe by 2035.

Figure SIN4: BAU Primary Energy Supply

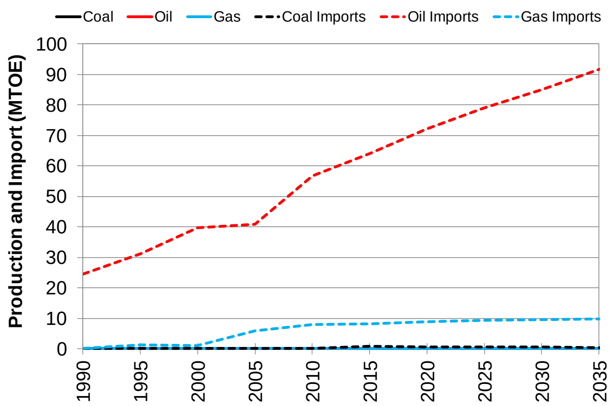


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Oil will dominate the primary energy mix accounting for 64–68% of primary energy supply from 2010 to 2035, most likely to meet the demand of the international transport sector. Natural gas, coal, and NRE will constitute the remaining share of supply at 31%, 1.4% and 0.4% respectively by 2035.

Singapore's first 160 MW biomass clean coal (BMCC) co-generation plant, developed as part of the Tembusu multi-utilities complex on Jurong Island, is expected to begin operations by the end of 2012. This will contribute to the introduction of coal fuel and biomass into the primary energy supply mix from 2012 onwards.

Figure SIN5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

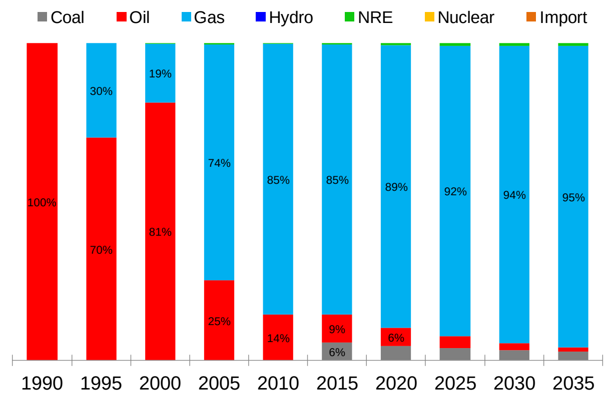
Singapore has negligible indigenous energy resources, either in fossil fuels or in alternative energy sources. The economy imports nearly all the fuels it requires for its energy needs, particularly oil. The supply of imported gas via pipelines is likely to remain constant. The future demand for natural gas (for electricity generation) will probably be supplied by imported LNG once the LNG import terminal on Jurong Island begins operations in 2013.

ELECTRICITY

Singapore's final electricity demand is projected to increase slightly by 38% from 37 TWh in 2010 to 51 TWh by 2035. Singapore is a mature economy that employs various incentives and regulations to promote energy efficiency measures; hence the small growth compared to its developing neighbours Malaysia (103%) and Indonesia (293%).

On the supply side, Singapore will begin to diversify its electricity generation mix from 2012 with the introduction of coal and NRE (in the form of solar and biomass) into the supply mix. However, natural gas will continue to be the dominant fuel throughout the outlook period.

Figure SIN6: BAU Electricity Generation Mix

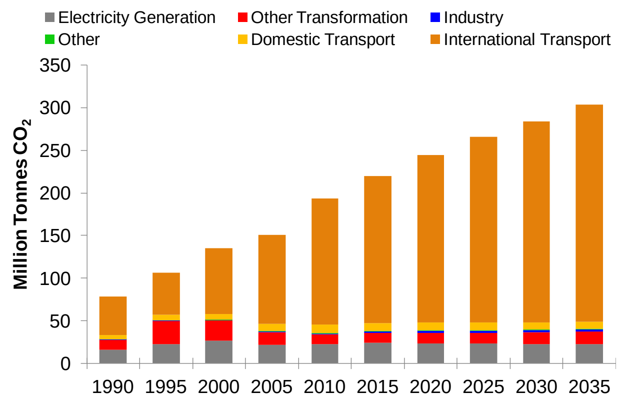


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Over the outlook period Singapore's total CO_2 emissions from fuel combustion are projected to increase 1.8% annually to reach 304 million tonnes of CO_2 by 2035, compared to 194 million tonnes of CO_2 in 2010. While the international transport sector will continue to be the largest contributor to CO_2 emissions in Singapore, emissions from the domestic transport sector will show a 14% emissions reduction from 2010 to 2035. The industry sector will show the highest growth rate at 2.5% annually from 2010 to 2035.

Figure SIN7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table SIN1 below suggests that, from 2010 to 2035, the total change in carbon emissions is affected by Singapore's GDP growth, offset by the reduction in energy intensity (energy efficiency) and CO_2 intensity of energy (fuel switching).

Table SIN1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.2%	-1.2%	-0.2%	-0.2%	0.0%
Change in Energy Intensity of GDP	-1.6%	0.1%	-1.3%	-1.4%	-1.7%
Change in GDP	6.4%	6.4%	4.2%	4.0%	3.6%
Total Change	4.4%	5.2%	2.6%	2.4%	1.8%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

As a small economy without any significant energy resources, Singapore is totally dependent on imported energy to meet its energy needs. Energy security is a main challenge, along with economic competitiveness and environmental sustainability.

Singapore continues to take various measures to meet these challenges, intensifying its efforts in energy diversification to enhance the security of supply, and energy efficiency to reduce demand and mitigate carbon emissions. Research and development is another important part of Singapore's energy strategy. The economy is likely to capitalize on its strength in this area to develop innovative and sustainable solutions to address Singapore's energy needs.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

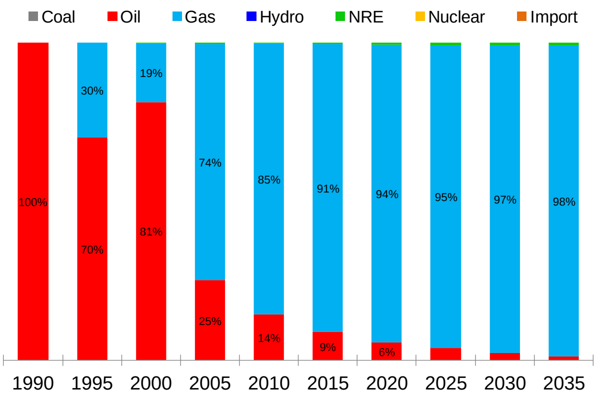
HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced. Singapore does not produce natural gas, so Figure SIN8 is not included for this economy.

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. Singapore currently imports natural gas from Malaysia and Indonesia via pipelines, and will soon import LNG through the new LNG import terminal on Jurong Island. In a situation where there is more gas available, Singapore will likely choose to import additional gas via LNG.

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure SIN9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario graph shown in Figure SIN6. It can be seen that the gas share has increased by 3% by 2035, while the coal share has declined by an equal amount.

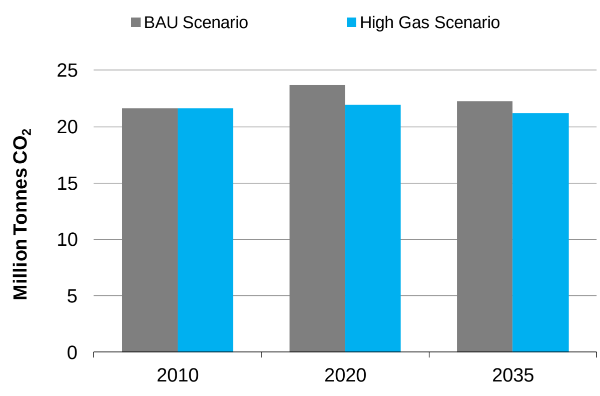
Figure SIN9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas has roughly half the CO_2 emissions of coal per unit of electricity generated, this had the impact of reducing CO_2 emissions in electricity generation by 5% by 2035. Figure SIN10 shows this CO_2 emissions reduction.

Figure SIN10: High Gas Scenario – CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

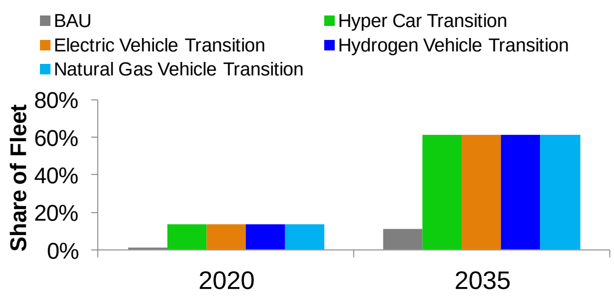
The Alternative Urban Development Scenarios are not performed for Singapore since it is already a compact city with high urban density and low energy consumption. Therefore, Figures SIN11–SIN13 are not included here.

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure SIN14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 62% compared to about 11% in BAU. The share of conventional vehicles in the fleet is thus only about 38%, compared to about 89% in the BAU scenario.

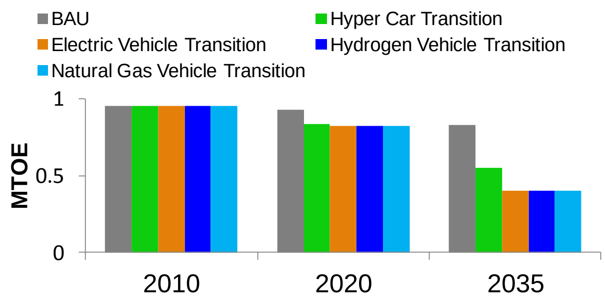
Figure SIN14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure SIN15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 35% by 2035—even though these highly-efficient vehicles still use oil.

Figure SIN15: Virtual Clean Car Race – Light Vehicle Oil Consumption



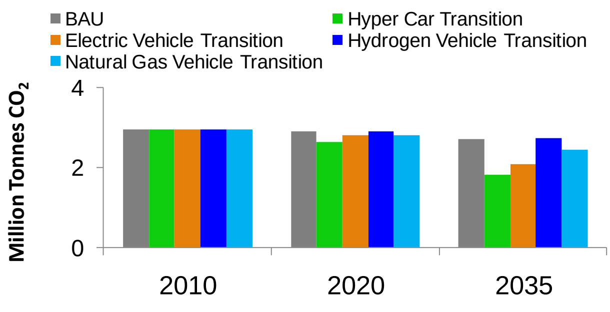
Source: APERC Analysis (2012)

Figure SIN16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change emissions from electricity and hydrogen generation. The impact of each scenario on emission levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Singapore, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions reductions, with an emissions reduction of 33% compared to BAU in 2035. Hyper cars rely on their ultra-light carbon fibre bodies and other energy-saving features to reduce oil consumption. In the other alternative vehicles oil combustion is replaced by other fuels; namely electricity for electric vehicles, hydrogen for hydrogen vehicles and natural gas for natural gas vehicles. In Singapore, electricity generation mostly comes from thermal combustion; thus additional demand for electricity and hydrogen generation would produce more CO_2 emissions, offsetting some of the benefits gained from oil replacement.

The Electric Vehicle Transition, Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios offer less emissions reductions (23%, 10% and 0% respectively).

Figure SIN16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

BP (British Petroleum) (2012), *Statistical Review of World Energy 2012*, www.bp.com/statisticalreview

CAG (Changi Airport Group) (2012), 'Who we are' website page, www.changiairportgroup.com/cag/html/the-group/index.html

EDB (Economic Development Board) (2011), Energy Factsheet 2011: Singapore – Asia's Energy Hub, www.edb.gov.sg/content/dam/edb/en/resources/pdfs/factsheets/Energy%20Factsheet.pdf

EMA (Energy Market Authority) (2010), 'LNG Terminal Development' website page, www.ema.gov.sg/LNG/LNG-terminal-development/

— (2011), *Singapore Energy Statistics 2011*, www.ema.gov.sg/media/files/publications/SES2011.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

LTA (Land Transport Authority) (2012a), 'MRT and LRT Trains' website page, www.lta.gov.sg/content/ltaweb/en/public-transport/mrt-and-lrt-trains.html

— (2012b), *Singapore Land Transport Statistics in Brief 2012*, www.lta.gov.sg/content/dam/ltaweb/corp/PublicationsResearch/files/FactsandFigures/Stats_in_Brief_2012.pdf

MPA (Maritime and Port Authority of Singapore) (2009), 'Premier hub port' website page, www.mpa.gov.sg/sites/maritime_singapore/what_is_maritime_singapore/premier_hub_port.page

MTI (Ministry of Trade and Industry) (2007), *National Energy Policy Report: Energy for Growth*, www.mti.gov.sg/ResearchRoom/Documents/app.mti.gov.sg/data/pages/885/doc/NEPR%202007.pdf

— (2012), *Economic Survey of Singapore 2011*, www.mti.gov.sg/ResearchRoom/SiteAssets/Pages/Economic-Survey-of-Singapore-2011/FullReport_AES2011.pdf

NEA (National Environment Agency) (2010), *Singapore's Second National Communication – Under the United Nations Framework Convention on Climate Change*, http://app.nccs.gov.sg/data/resources/docs/SINGAPORE'S%20SECOND%20NATIONAL%20COMMUNICATIONS%20NOV%202010.pdf

CHINESE TAIPEI

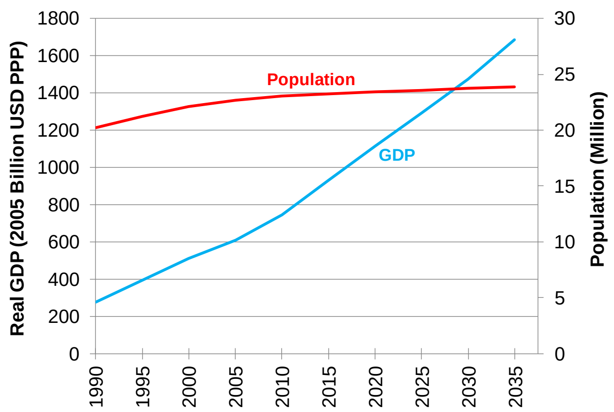
- *Chinese Taipei's primary energy supply is projected to grow at an average annual rate of 0.4% over the outlook period; this is due mainly to demand growth in the 'other' sector which consists of the residential, commercial, and agricultural sectors.*
- *The economy aims to reduce its total CO_2 emissions by changing its energy mix, specifically increasing imports of natural gas, developing renewable energy sources, and employing cleaner coal technologies and carbon capture and storage (CCS).*
- *The Renewable Energy Development Act (2009) has been introduced to speed up the development of clean energy. The share of electricity generated from renewable energy sources is expected to rise from 1% of total electricity generation in 2005 to about 8% in 2025.*
- *Government policy goals in the energy sector include reducing the economy's energy intensity by 50% by 2025 (from 2005 levels) and returning CO_2 emissions to 2000 levels by 2025.*

ECONOMY

Chinese Taipei is located in the middle of a chain of islands stretching from Japan in the north to the Philippines in the south. Its position, just 160 kilometres off the southeastern coast of China, makes it a natural gateway to East Asia.

The economy is made up of the islands of Taiwan, Penghu, Kinmen, Matsu, and several islets, with a total area of about 36 188 square kilometres. Only one-quarter of the land is arable, although the subtropical climate permits multi-cropping of rice and year-round cultivation of fruit and vegetables.

Figure CT11: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

The population of Chinese Taipei is expected to increase at a slow average annual rate of 0.15% over the outlook period, from 23.04 million in 2010 to 23.9 million in 2035. However, according to the economy's own projections, negative population growth is likely by the 2020s, due to a low birth rate and negative net immigration (CEPD, 2012a).

Chinese Taipei's GDP is expected to grow at an average annual rate of 3.3% over the outlook period; however, the projection also shows that the rate of growth in GDP is expected to slow during the period. The projected average rate for 2010–2035 is below the high average annual GDP growth rate of 4.7% in the 1990–2009 period, indicating that Chinese Taipei is becoming a highly developed economy. At the same time, GDP per person is projected to grow from USD 29 200 in 2009 to USD 70 611 by 2035, at an average annual growth rate at 3.2%. These GDP per capita figures also show a gradually decreasing trend when compared with the 1990–2009 period.

The rapid economic development since 2000 has resulted in substantial changes to the economic structure of Chinese Taipei, with the emphasis moving from industrial production to the service sector. In 2010, 67.1% of domestic production was in the service sector, with industry accounting for 31.3% and agriculture 1.6% (CEPD, 2012b). In comparison, in 1990 services made up 57.0% of production, and industry 38.9%. This gradual change in the economic structure over last two decades is expected to continue in the future. Future challenges will include further restructuring of the economy's traditional manufacturing industry into high-value-added industry, and expansion of the information and communication technology (ICT) and service industry sectors.

Chinese Taipei's main industries are electronics, petrochemicals, metals, and mechanical equipment. Within the manufacturing sector itself there has also been structural change, from energy-intensive industries to industries that are non-energy-intensive. The non-energy-intensive and high-tech industries now produce the majority of exports: electronic products, machinery, electrical equipment, information and communication products, and precision instruments accounted for about 52.1% of the economy's total exports in 2010 (IDB, 2011).

Chinese Taipei imports almost all the crude oil required for its refining and petrochemical industries.

The economy's total refining capacity has reached 1.26 million barrels per day, which exceeds the domestic demand for petroleum products—Chinese Taipei is a net exporter of refined petroleum products (BOE, 2012a).

The industry sector (including non-energy use) is the single greatest consumer of energy in the economy, accounting for about 64% of final demand in 2010. It was followed by domestic transportation at 18%, residential at 9% and commercial at 6%; agriculture and non-specified demand account for the balance. Energy use in industry is dominated by chemical and petrochemical processing (about 37% in 2010), while iron and steel production used about 15%.

Chinese Taipei has developed a comprehensive domestic transport system including two freeways and one high-speed railway running north–south across the island of Taiwan. Transport sector energy consumption totalled about 15.6 Mtoe in 2010—most of this was used in road transportation (about 11.3 Mtoe or 73%), with international aviation using about 2.0 Mtoe (13%). Chinese Taipei has been striving to reduce its automobile dependency (in 2010 there were about 5.9 million passenger cars in the economy) and to encourage the use of public transport (CEPD, 2012b). The public transport systems include a high-speed rail system, which runs 345 km from Taipei to Kaohsiung, and rail rapid transit systems in Taipei city (110 km), in Kaohsiung city (39 km), and in Hsinchu city (11 km) (MOTC, 2012). There are plans for construction of further rail rapid transit systems in urban centres, including in Taipei, Taichung and Kaohsiung.

The policies encouraging a shift to public transport have been successful in Taipei city, with the daily ridership increasing at an average annual rate of 18.74% from 1998 to 2011 (MOTC, 2012). In 2011 the Taipei Metro served, on average, 1.55 million passengers per day (TRTC, 2012). In 2010 the total number of registered vehicles (including heavy vehicles) was around 7.05 million, with 78% of those domestically produced (TTVMA, 2012). Between 2002 and 2011, the total number of vehicles increased only 19.1%, with motorcycles increasing by 26.7% over that period (MOTC, 2012).

As the majority of the population is concentrated in major cities, electricity is the main source of energy for almost all homes; the electricity demand has grown at an average annual rate of 4.2% from 1995 to 2010. Air conditioning in the summer season is a major source of residential electricity demand.

ENERGY RESOURCES AND INFRASTRUCTURE

Chinese Taipei has very limited indigenous energy resources: domestic natural gas provides just 0.1% of the economy's primary supply, while hydro provides 0.3%, and geothermal, solar and wind power combined provide 0.2%.

Instead, Chinese Taipei relies on imports for most of its energy requirements and is a net importer of fossil fuels—in 2010 its import dependency was 99%. On an energy equivalent basis, oil formed the biggest part of the imports, at about 50% (coming mainly from Saudi Arabia, Kuwait and Iran); coal made up 38% (mainly from Australia, Indonesia and China), while imported LNG, mainly from Indonesia and Malaysia, made up 12%.

Two LNG terminals with a total capacity of 10.44 million tonnes were operating in Chinese Taipei in 2010. More LNG terminals are planned to meet the economy's projected growth in demand for natural gas. In addition to LNG terminals, Chinese Taipei has an extensive gas transmission and distribution network. This infrastructure means 44.1% of the economy's population has direct natural gas supply (BOE, 2012b).

In 2012 when this outlook was prepared, there were three nuclear power plants in Chinese Taipei, each with two units, creating a total installed capacity of 5144 MW. A fourth nuclear power plant (also with two units) is under construction; these two new units are scheduled to begin commercial operation in 2014 and 2016, adding 1350 MW of capacity per unit (AEC, 2012). A revision of nuclear energy policy following the Fukushima accident in Japan means older plant decommissioning will begin when the fourth plant becomes operational—see 'Energy Policies' below.

Chinese Taipei's total electricity generation in 2010 was 247 TWh (TPC, 2011). Fossil fuels are the basis of 78% of all electricity generated: coal provides about 52%, LNG 22%, and oil 4%. Nuclear power accounted for about 18% of total electricity generation in 2010, with the remainder coming from hydro and new renewable energy sources.

ENERGY POLICIES

Chinese Taipei's Energy Commission, which was established in 1979 under the Ministry of Economic Affairs (MOEA), became the Bureau of Energy in 2004. The Bureau is responsible for formulating and implementing the economy's energy policy. Policy development since 2008 has included the establishment of a suite of energy-related regulations defining the rules for markets in renewable energy, petroleum products, natural gas, and electricity. The aim is to create a better energy business environment.

The fundamental goal of Chinese Taipei's energy policy is to promote energy security, supported by secure imports of oil, natural gas and coal as well as the development of domestic energy resources including nuclear, fossil fuels, and new renewable energy sources.

On 5 June 2008, the Ministry of Economic Affairs released the *Framework of Taiwan's Sustainable Energy Policy* (BOE, 2012c). This presents a 'win-win-win' solution for energy, the environment and the economy. The framework addresses the constraints that Chinese Taipei faces in terms of its insufficient natural resources and limited environmental carrying capacity. It states that sustainable energy policies should support the efficient use of the economy's limited energy resources, the development of clean energy, and the security of energy supply. The framework establishes three goals:

- Reductions in energy intensity from 2005 levels—by 20% by 2015 and by 50% by 2025.
- Reductions in total CO_2 emissions, so that total emissions return to the 2008 level between 2016 and 2020, and are further reduced to the 2000 level by 2025; at the same time, the share of low-carbon energy in the electricity generation system will be increased from the current 40% to 55% by 2025.
- Secure and stable energy supply, achieved by building a secure energy supply system to meet economic development goals, specifically 6% average annual GDP growth rate from 2008 to 2012, and USD 30 000 per capita income by 2015.

To achieve these goals, Chinese Taipei has set these energy conservation targets and strategies:

- *Industry sector*: raise boiler efficiency, expand cogeneration, and increase the share of high-value-added industries
- *Power sector*: replace old coal-fired and gas-fired units with high-efficiency generating units and reduce line losses by improving power dispatch and transmission facilities
- *Transportation sector*: raise the fuel efficiency standard for private vehicles by 25% (compared to 2005 levels) by 2015
- *Residential and commercial sectors*: raise appliance efficiency standards to a range of 10% to 70% in 2011; completely eliminate incandescent lights and replace them with LED lighting by 2025.

In terms of electricity supply, Chinese Taipei aims to have an electricity supply that provides a reserve capacity of 16%, based on peak demand. Until 1998, the government-owned Taiwan Power Company (TPC) was the only power company operating in Chinese Taipei. Because of environmental issues and a complex official approval process, the construction of new power plants by TPC fell behind schedule; this resulted in the total reserve capacity falling below the government requirement between 1990 and 2004. Reserve capacity remained under 8% between 1990 and 1996. In order to stabilize the power supply, Chinese Taipei's electricity market was opened to independent power producers (IPPs) in 1998. TPC contracted with IPPs for a capacity of around 5000 MW to lift the target reserve capacity above 16%—a target which has been achieved since 2004 (TPC, 2011). In 2010, the total IPP capacity was 7707 MW, about 18% of the economy's total. The power produced by the IPPs is currently sold to TPC for distribution through TPC's transmission lines.

In another move to avoid electricity shortages, TPC was required to adopt new management systems, including demand-side control, increasing the purchase of electricity from cogeneration systems, providing price incentives for electricity demand reduction and other energy conservation measures. The Ministry of Economic Affairs has also announced it will open a fifth round of bidding to IPPs if the reserve capacity falls below 16% in the future.

In line with the government's overall goal of privatizing TPC and promoting the liberalization of the domestic power market, the Electricity Act was approved by Chinese Taipei's Legislative Yuan in early 2011. This enables IPPs to build and invest in transmission and distribution facilities. In addition, IPPs will be able to sell power to consumers directly, which means the market structure will no longer be a monopoly.

Following the 2011 Fukushima Daiichi Nuclear Power Plant Accident in Japan, Chinese Taipei reviewed its energy policy. On 3 November 2011, President Ma announced a new policy to "Steadily Reduce Nuclear Dependency, Gradually Move Towards a Nuclear-free Homeland, and Create a Low-carbon Green Energy Environment" (BOE, 2012d). The main aspects of the revised nuclear energy strategy are:

- To conduct a comprehensive safety examination of nuclear power plants to ensure nuclear safety
- To steadily reduce nuclear energy dependence by actively reducing electricity demand and peak

load, and by promoting alternative energy sources to ensure stable power supply

- No extension to the lifespan of the three existing nuclear power plants (six units), with the expected first decommissioning to begin in 2018 and all six existing units to be decommissioned by 2025
- The safety of the fourth nuclear power plant (currently in construction) must be ensured prior to its commercial operation
- If the two reactor units of the fourth nuclear power plant are operating securely before 2016, the decommissioning of the oldest nuclear power plant will begin immediately (ahead of the planned 2018 date).

To implement the new energy policy, Chinese Taipei has set a goal for the total installed capacity based on renewable sources to reach 9952 MW by 2025 and 12 502 MW by 2030. This will come from wind power (4200 MW), solar photo-voltaic (3100 MW), hydro (2502 MW), waste (1369 MW), ocean (600 MW), fuel cell (500 MW), and geothermal/bio-gas (231 MW). The installed renewables capacity is also expected to contribute about 10% of the economy's overall power requirement by 2030.

Chinese Taipei's Renewable Energy Development Act (2009) also set up the incentives for private investment in renewable energy which are provided through a feed-in tariff (FIT) mechanism, under which TPC purchases power from renewables generators on contracts involving preferential rates and guaranteed grid connections. The overall aim is to secure the market for electricity generated from renewable energy.

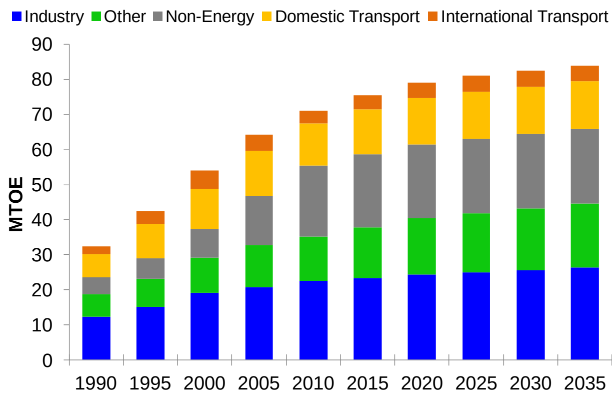
Overall, Chinese Taipei is expected to continue to import almost all of its energy requirements throughout the outlook period due to its lack of indigenous energy sources. To minimize the impact of any oil supply disruptions, Chinese Taipei maintains an oil stockpile of no less than 60 days' supply. The economy has also tried to diversify its energy supply mix by switching from oil to natural gas, coal and renewable energy. In addition, it has started to secure international joint venture agreements to acquire captive supply sources (BOE, 2012e).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

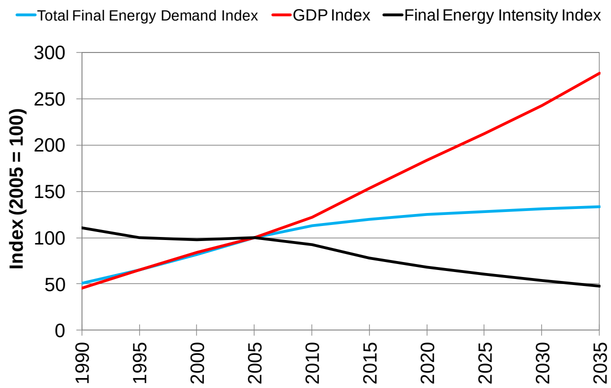
Chinese Taipei's final energy demand is expected to grow 0.7% per year over the outlook period. The slowing of demand growth compared to earlier periods is due to energy conservation efforts in all sectors and the economy's overall industry restructuring. The 'other' sector (which includes commercial, residential, and agricultural use) shows the highest annual growth rate of 1.5%, followed by industry at 0.6%. The economy's final energy intensity is expected to decline by about 52% between 2005 and 2035.

Figure CT2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure CT3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industrial sector is projected to grow at an average annual rate of 0.6% over the outlook period; this is lower than the average annual growth rate of 2.5% between 1990 and 2009. This reduction in demand growth is due to structural shift in the industrial sector, from energy-intensive to non-energy-intensive industries, as well as improvements in energy efficiency. The current dominance of the petrochemical industry makes the Chinese Taipei industrial sector highly energy intensive. This energy intensity will reduce, as will the rate of increase in the sector's energy demand, as the electronics and ICT industries are expected to grow more quickly than the petrochemical industry.

The energy mix for the industrial sector over the outlook period shows a slow increase for coal and oil, accompanied by a much more rapid increase in the use of electricity and gas. This energy consumption trend matches the structural change from high-energy-intensive industry to high-value-added electronic or ICT-based industry. Energy intensity in this sector is expected to decline by 1.5% per year over the outlook period.

However, the projection also shows a continued growth in non-energy demand for fossil fuels. Petrochemicals will continue to play a major role in industry and in the economy's overall GDP growth, and Chinese Taipei will remain a larger exporter of petroleum products.

Transport

Chinese Taipei's transport energy consumption has grown in parallel with its economic development, improvement in living standards, and upgrades in transportation infrastructure. The steep growth of the recent decades is expected to slow over the outlook period. While all domestic transport sub-sectors showed substantial average annual growth of 3.0% between 1990 and 2009, growth is expected to be slower between 2010 and 2035. Projections for the annual growth rate in number of passenger vehicles in use (less than 1.9%), and for motorcycles in use (less than 1.6%) are low, while the number of heavy vehicles (including buses) will grow a little faster (more than 2%).

Total transport energy demand (domestic and international) is expected to grow slowly over the outlook period at an average annual rate of about 0.6%. This is due to improvement in public transportation systems and increases in vehicle energy efficiency. Energy use for domestic transportation has a projected annual growth rate of 0.5%, lower than the international transportation annual growth rate of 0.7%. The growth in international aviation energy demand is based on exports of high-value-added manufacturing products, and the increase in direct air travel between Chinese Taipei and mainland China. To accommodate the predicted growth in air transport, Chinese Taipei has converted Songshan Airport in Taipei city to an international airport, expanded the freight handling capacity at Kaohsiung Airport, and is planning a third terminal at Taoyuan Airport.

Over the outlook period, rail transit systems are expected to gradually replace buses and passenger vehicles for city travel, while high-speed railways are expected to continue to replace passenger vehicles for inter-city travel. As a result, transport oil demand is expected to grow at an average annual rate of only 0.4% over the outlook period. By contrast, transport electricity consumption is expected to grow at an average annual rate of 5.5%, matching the growth in public transportation systems. However, even in 2035, electricity use in transport will remain small compared to oil use.

Other

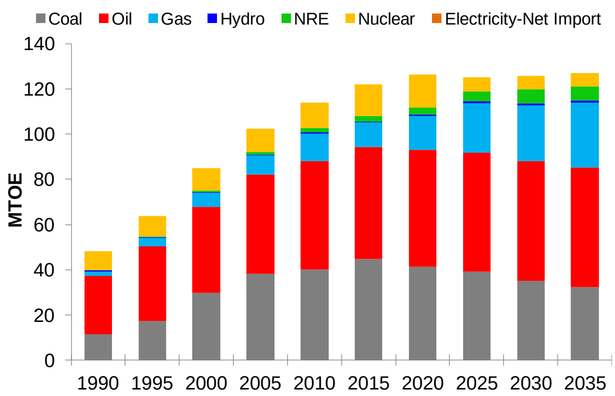
Energy demand in the 'other' sector, which includes residential, commercial, and agricultural demand, is primarily driven by income growth and the improvement in living standards. The 'other' sector energy demand will grow at an average annual rate of 1.5% over the outlook period. Electricity is expected to continue to dominate the energy mix, accounting for 68% in 2035.

However, the annual growth rate for this sector is expected to slow in the long term, based on the adoption of many energy conservation measures, such as increased energy efficiency in appliances and other equipment, replacement and improvement of lighting, as well as incentives for energy conservation. The promotion of zero-energy (and zero-emission) construction will also make a contribution to reducing future energy consumption in the commercial and residential sectors.

PRIMARY ENERGY SUPPLY

To reduce carbon emissions, Chinese Taipei is gradually reducing coal's share in its primary energy supply (from 38% in 2009 to 25% by 2035).

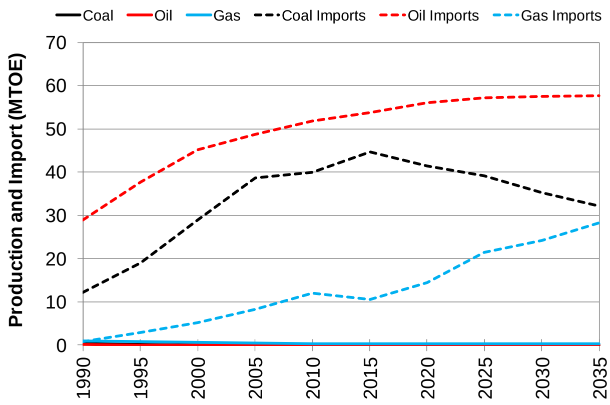
Figure CT4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Another recent policy initiative requires reduction in dependence on nuclear energy. The reduction in the use of coal and nuclear power will require an increase in the gas share of the primary supply (from 10% in 2009 to 23% by 2035) and more aggressive exploitation of renewable energy sources (from 1% in 2009 to 5% by 2035). The reduction in coal imports and fast growth in gas imports are shown in Figure CT5.

Figure CT5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

ELECTRICITY

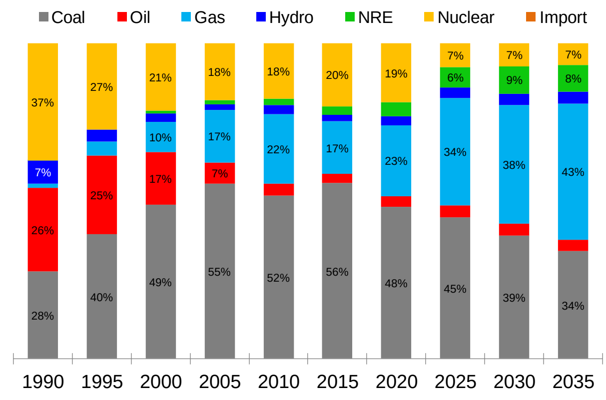
This business-as-usual (BAU) projection takes into account the November 2011 revision of energy policy, which announced the gradual phase-out of existing nuclear power plants.

By 2035, Chinese Taipei's total installed capacity is expected to reach 73.0 GW. The majority of this will be thermal (76%); this is made up of coal (33% of total generation capacity), natural gas (38%) and oil (5%). Other generation capacity at the end of the outlook period will be from nuclear (4%), NRE (13%), and hydro (7%).

Chinese Taipei's total electricity generation is projected to increase from 226 TWh in 2009 to 336 TWh in 2035, growing at an average annual rate of 1.2%. Efforts to reduce the economy's CO_2 emission intensity will mean the share of coal will decrease from 55% in 2009 to 34% in 2035; it will be replaced by increased generation from natural gas and NRE sources. The natural gas share will increase significantly from 20% in 2009 to 43% in 2035.

Nuclear's share is expected to decrease from 18% in 2009 to only 7% in 2035, as a result of the decision not to extend the lifespan of existing plants. The share of electricity generation supplied by hydro is projected to increase from 2% in 2009 to around 4% in 2035. At the same time, as a result of government policy to promote the development of new and renewable energy sources (mainly wind power), the NRE share will increase from 2% in 2009 to 8% in 2035.

Figure CT6: BAU Electricity Generation Mix



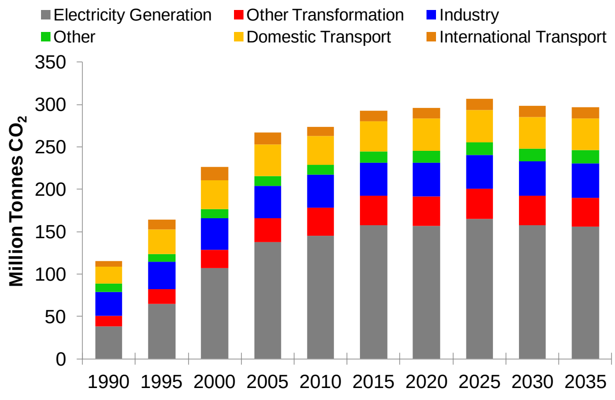
Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Chinese Taipei's total CO_2 emissions from fuel combustion are projected to reach 297 million tonnes of CO_2 in 2035, which is 15% higher than in 2009 and 158% of the 1990 level. Total CO_2 emissions are expected to peak at 307 million tonnes in 2025. In 2008, Chinese Taipei set a policy goal of a zero increase on 2000 levels (historically 219.4 million tonnes of CO_2 (IEA, 2009, p. III.42))—this projection in 2025 shows an overall increase of 40% on those 2000 levels. This outcome is a consequence of the 2011 change in energy policy to avoid extending the lifespan of existing nuclear power plants and to increase the use of coal- and gas-fired power plants to fill the gap. For Chinese Taipei to meet its own CO_2 emission reduction targets, more development of NRE will be necessary. Current development plans have identified offshore wind turbines and geothermal as potential sources. Another option to reduce CO_2 emissions is adoption of cleaner coal technologies and carbon capture and storage (CCS) in the economy's coal-fired power plants. Efficient coal technologies are discussed further in Volume 1, Chapter 13.

The electricity generation sector is expected to account for the largest share of CO_2 emissions in 2035 at 52% of total CO_2 emissions (156 million tonnes of CO_2). The industry sector is the next highest contributor, at 14% (41 million tonnes of CO_2), followed by the domestic transportation sector at 12% (37 million tonnes of CO_2).

Figure CT7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table CT1 suggests the growth in Chinese Taipei's GDP will be offset by a reduction in the energy intensity of GDP (energy efficiency and change in industrial structure) and a small reduction in the CO_2 intensity of energy (fuel switching).

Table CT1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	0.6%	-1.4%	-0.3%	-0.3%	-0.1%
Change in Energy Intensity of GDP	-0.2%	-2.1%	-2.7%	-2.7%	-2.8%
Change in GDP	5.3%	4.1%	3.6%	3.5%	3.3%
Total Change	5.8%	0.5%	0.5%	0.4%	0.3%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

With limited domestic energy resources, the security of Chinese Taipei's energy supply is central to its energy policy goals of meeting a growing energy demand while reducing CO_2 emissions. The economy will have to look to low-carbon energy sources, in particular replacing coal with natural gas and renewable energy. Chinese Taipei has already moved to promote renewable energy with the 2009 introduction of the Renewable Energy Development Act, which uses preferential feed-in tariffs and guaranteed grid connections to encourage NRE-based generation.

To decouple energy consumption and GDP growth, the service sector needs to be promoted and expanded and the industry sector needs to move to a less energy-intensive structure. For example, promoting knowledge-based industries in the Green Silicon Island, and other high-value-added and low-energy-intensive scientific industry parks, could be one way to foster a less energy-intensive economy. At the same time, energy efficiency efforts need to be promoted throughout the economy.

The establishment of international stockpiling through regional cooperation could be an important way of stabilizing domestic energy supply, as could the acquisition of equity in international energy resource developments by the government-owned oil company.

ALTERNATIVE SCENARIOS

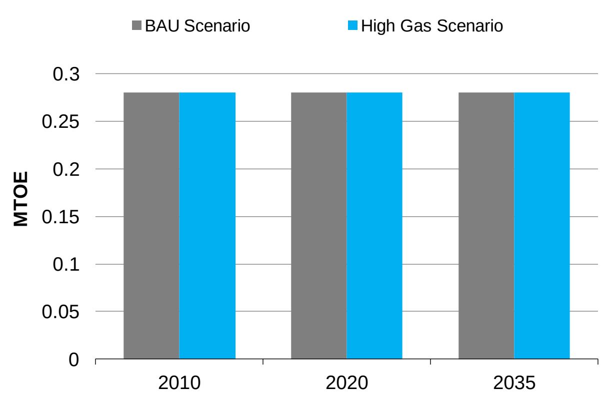
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

However, as Chinese Taipei's gas resources are very limited, the High Gas Scenario assumes no domestic production increases—as shown in Figure CT8.

Figure CT8: High Gas Scenario – Gas Production

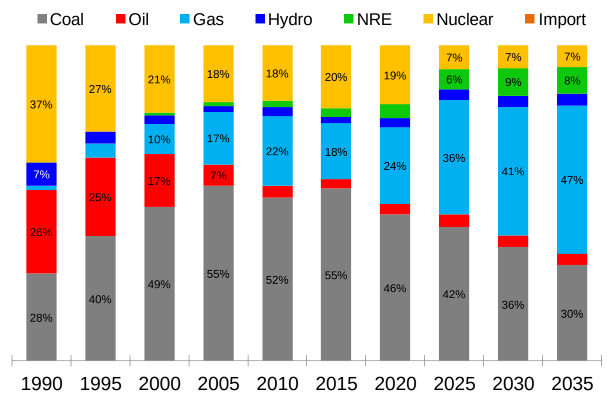


Source: APERC Analysis (2012)

Additional gas consumption in Chinese Taipei in the High Gas Scenario will be a result of increased gas imports, as a result of the improved gas market situation in the APEC region. It will require the expansion of LNG terminals in the economy. Given Chinese Taipei's aspirations to reduce CO_2 emissions, this High Gas Scenario assumes the additional imported gas would be used to replace coal in electricity generation, as gas generally has less than half the CO_2 emissions of coal when used for electricity generation.

Figure CT9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU case graph shown in Figure CT6. It can be seen that the gas share has increased by 4% by 2035, while the coal share has declined by an equal amount.

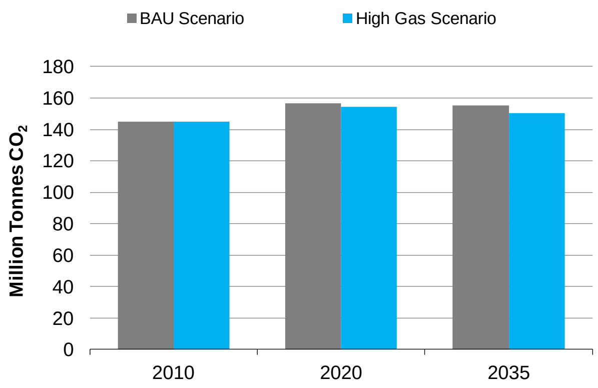
Figure CT9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The resulting reduction in CO_2 emissions from electricity generation for Chinese Taipei is shown in Figure CT10. By 2035 there would be a 3.3% reduction compared to BAU scenario emissions.

Figure CT10: High Gas Scenario – CO_2 Emissions from Electricity Generation



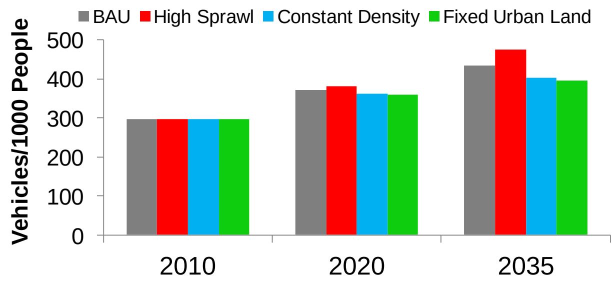
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impact of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CT11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the scenarios is significant, with vehicle ownership being about 9% higher in the High Sprawl scenario compared to BAU in 2035, and about 8% and 9% lower in the Constant Density and Fixed Urban Land scenarios respectively. The model results suggest that better urban planning could significantly reduce the need for people to own vehicles.

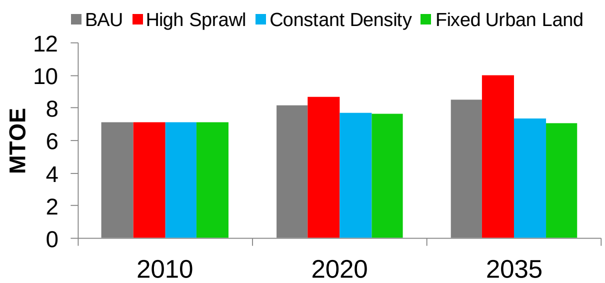
Figure CT11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure CT12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of better urban planning on light vehicle oil consumption is even more pronounced than on vehicle ownership, as more compact cities reduce both the need for vehicles and the distances they must travel. Light vehicle oil consumption would be 18% higher in the High Sprawl scenario compared to BAU in 2035, and about 14% and 17% lower in the Constant Density and Fixed Urban Land scenarios respectively.

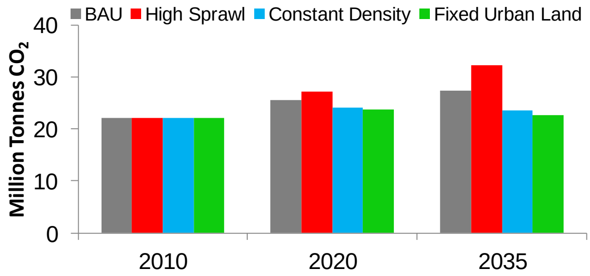
Figure CT12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure CT13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO_2 emissions would be 18% higher in the High Sprawl scenario compared to the BAU scenario in 2035. They would be about 14% and 17% lower in the Constant Density and Fixed Urban Land scenarios respectively.

Figure CT13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



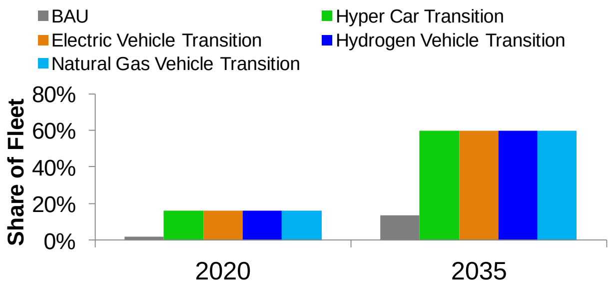
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure CT14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 60% compared to about 14% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 40%, compared to about 86% in the BAU scenario.

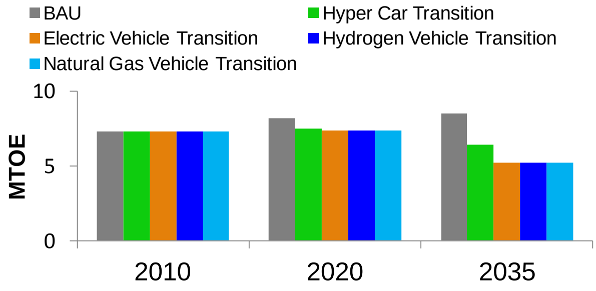
Figure CT14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure CT15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 39% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 25% by 2035—even though these highly efficient vehicles still use oil.

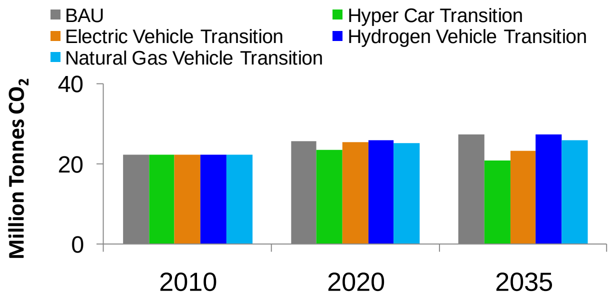
Figure CT15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure CT16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from its oil consumption impact, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

Figure CT16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

In Chinese Taipei, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emission reductions, with an emissions reduction of 24% compared to BAU in 2035. The Electric Vehicle Transition scenario offers emission reductions of about 15%. The Electric Vehicle Transition scenario does not do as well as the Hyper Car Transition scenario in Chinese Taipei because in this economy coal-fired generation would be the marginal source for much of the additional electricity required by the electric vehicles.

Under the Natural Gas Vehicle Transition scenario, 2035 emissions would be reduced by about 5%, reflecting the slightly lower carbon intensity of natural gas and the slightly higher efficiency of natural gas vehicles compared to conventional vehicles. The Hydrogen Vehicles Transition scenario would have no reduction in emissions. This is mainly due to the way the hydrogen is assumed to be produced—from steam methane reforming of gas, a process that involves significant CO_2 emissions.

REFERENCES

AEC (Atomic Energy Council) (2012), Atomic Energy Annual Report – 2011, www.aec.gov.tw/www/service/other/files/annual_100/index.html

BOE (Bureau of Energy, of Chinese Taipei Ministry of Economic Affairs) (2012a), *2010 Energy Statistical Hand Book*, www.moeaboe.gov.tw/

— (2012b), *BOE Annual Report, 2010*, www.moeaboe.gov.tw/opengovinfo/Plan/all/energy_year/main/EnergyYearMain.aspx?PageId=default

— (2012c), *Framework of Taiwan's Sustainable Energy Policy*, www.moeaboe.gov.tw/English/english_index.aspx?Group=4

— (2012d), *New Energy Policy of Taiwan*, www.moeaboe.gov.tw/English/english_index.aspx?Group=4

— (2012e), *Petroleum Administration Law*, law.moj.gov.tw/Eng/LawClass/LawAll.aspx?PCode=J0020019

CEPD (Council for Economic Planning and Development) (2012a), *Population Projection for Chinese Taipei from 2012–2060, 2011*, www.cepd.gov.tw/m1.aspx?sNo=0000455

— (2012b), *Taiwan Statistical Data Book – 2011*, Executive Yuan, Chinese Taipei, www.cepd.gov.tw/

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IDB (Industrial Development Bureau, of Chinese Taipei Ministry of Economic Affairs) (2011), *Major Indicators of Manufacturing Sector in 2009,* www.moeaidb.gov.tw

IEA (International Energy Agency) (2009), *CO_2 Emissions from Fuel Combustion—2009 Edition.*

— (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

MOTC (Ministry of Transportation and Communication, Chinese Taipei) (2012), *2010 Traffic Year Book*, www.motc.gov.tw/motchypage/hypage.cgi?HYPAGE=yearbook.asp&mp=1

TPC (Taiwan Power Company) (2011), *2010 Taiwan Power Company Annual Report,* www.taipower.com.tw/

TRTC (Taipei Rapid Transit Corporation) (2012), "Traffic Statistics" website page, in Chinese, www.trtc.com.tw/ct.asp?xItem=1366864&CtNode=27643&mp=122031

TTVMA (Taiwan Transportation Vehicle Manufacturers Association) (2012), "Vehicle Statistics" website page, in Chinese, www.ttvma.org.tw/cht/information.php

THAILAND

- *Thailand's final energy demand is expected to grow at an average annual rate of 2.6% over the outlook period. This is driven mainly by increased demand in the 'other' sector (which covers residential, commercial and agricultural use) and in the non-energy sector.*
- *Energy imports are expected to keep growing through to 2035; oil, gas and electricity will all be imported to meet demand.*
- *Thailand's known domestic oil and gas resources are limited; diversification of supply through the use of renewable and/or alternative energy resources may provide an effective option for improving energy security.*

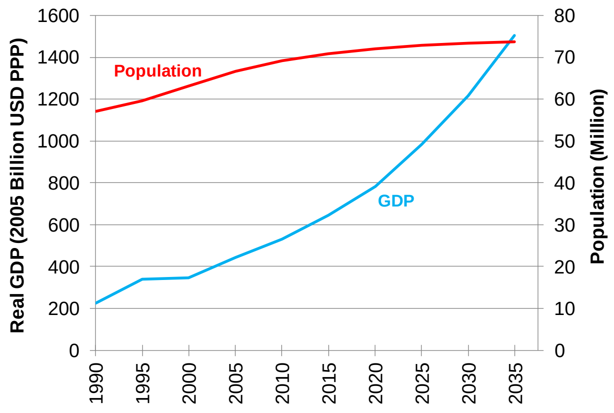
ECONOMY

Thailand is located in South-East Asia. It is bounded to the west by Myanmar, to the north by Myanmar and Lao People's Democratic Republic (Lao PDR), to the east by Lao PDR and Cambodia, and to the south by Malaysia. It has an area of 513 115 square kilometres and had a population of about 69 million at the end of 2010. The climate is generally hot and humid.

Thailand is the second largest economy in the Association of South East Asian Nations (ASEAN). It is a newly industrialized economy, and heavily export dependent. Its total GDP in 2010 was USD 530 billion (in 2005 USD PPP) or about USD 7675 per person.

Thailand's population is expected to increase at the slow annual average rate of 0.3%, to about 73.8 million by 2035. About half will be living in Bangkok, which is both the capital and the most populous city. Thailand's economy is expected to grow moderately at an annual average growth rate of 4.3% to about USD 1500 billion (in 2005 USD PPP), or about USD 20 390 per person by 2035.

Figure THA1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

The World Bank ranks Thailand the fourth easiest place in Asia to do business and seventeenth in the world (The World Bank, 2012). Thailand is a diversified economy dominated by agriculture and international trade. It is the world's leading exporter of rice and a major exporter of shrimp. Other crops include coconuts, corn, rubber, soybeans, sugarcane and tapioca. The economy is also an automotive and electronics goods exporter.

In 2010 the major energy consumers were the manufacturing and transportation sectors, at 36% and 35% respectively. For the manufacturing sector, most of the demand was for coal (32.6%), followed by renewable energy (27.5%) and petroleum products (10.3%) (DEDE, 2010b, pp. 16–17).

Thailand's transport sector energy consumption is dominated by road transport, which uses 89.4% of transport energy consumption in 2009 (MOT, 2009, p. 14). Thailand's road network is 204 425 kilometres (km) long, of which 30% is classified as national highways. The motorway network is quite small, 226 km at present (NESDB, 2012). The railway network covers a total distance of 4119 km; of this 94% is single-track and 6% (234 km) is double-track (NEDSB, 2012). In 2009, 11 million tonnes of freight and 47 million passengers were transported by the rail network (MOT, 2009, p. 15).

Mass rapid transit (MRT) has become an increasingly significant mode of urban passenger transport, carrying 10% of domestic passengers. In 2011, there were two MRT lines in operation in Bangkok: BTS–Sky Train and MRT–Blue Line, which transport about 600 000 and 190 000 daily passengers respectively (BTS, 2012, p. 31; MRTA, 2012, p. 81). The current total length for these two MRT lines is about 58 km. A bus rapid transit (BRT) system complements the MRT system. The BRT was opened in May 2010 and consists of five bus routes covering 110 km; it can accommodate 50 000 passengers a day (Link Technologies, 2011).

Water transportation plays an important role in Thailand and can be categorized into either inland waterway transportation or coastal transportation. The Mekong River flows through Thailand, allowing international cargo delivery with China, Burma and

Lao PDR. Main domestic inland water routes include the Chaopraya River, Pasak River, Bangpakong River, Mae Klong River and Tha Chin River. Within Bangkok, canals provide an alternative service to the capital's traffic-congested roads.

There a total of 57 airports in Thailand, of which nine are international airports. In 2010 there were an average 84 450 person-trips per day and 303 ton per day of air cargo delivery (OTP, 2011).

Thailand has formulated an ambitious and comprehensive Transport and Traffic Development Master Plan (2011–2020) with six goals emphasizing sustainability and connectivity. Indicators have been developed to ensure that plans are on track. A total of THB 1862 trillion (USD 60 trillion) has been budgeted for the master plan and will cover all modes of transport.

One key project under this master plan is to develop four routes for high-speed trains that will originate from Bangkok's main terminal: to Chiang Mai in the north, to Nong Kai in the north-east, to Rayong in the east and to Huahin in the south. The plan is to complete the 1915-km high-speed train network by 2032 (NESDB, 2012). A second key project is the metropolitan mass rail transit development project that will consist of 12 routes covering a distance of 495 km and 308 stations. Other measures listed under the Transport and Traffic Development Master Plan are to upgrade the Laem Chabang Port to a world class green port, improve accessibility to public boat transport, and to expand the capacity and upgrade domestic and international airports to be able to handle more customers in a more efficient and sustainable manner (OTP, 2011).

At the end of 2010, Thailand had a total registered gasoline vehicle fleet of 20.5 million units, and diesel fleet of 7.0 million. Motorcycles accounted for 84% of registered gasoline vehicles. Pick-up trucks accounted for 66% of registered diesel vehicles while public buses and trucks accounted for another 11% of the diesel fleet (DLT, 2011). About 90% of all vehicles are domestically produced; the remaining 10% are imported from many economies, mostly from the European Union or United States (DLT, 2011). The consumption of diesel is 2.5 times higher than gasoline due to the significant number of diesel light vehicles in the economy.

In 2010, 98.4% of villages and 86.8% of households in Thailand had access to the electricity network (DEDE, 2010a, p. 5). The use of residential biomass (in the form of charcoal and fuel wood) accounted for 59% of total residential final energy demand in 2010 (DEDE, 2010b, p. xi). It is expected that this use of biomass for cooking in rural areas will decline as the population increasingly becomes more urbanized.

ENERGY RESOURCES AND INFRASTRUCTURE

Thailand is highly dependent on energy imports, which accounted for 46% of the total primary energy supply in 2009. Imports accounted for 72% of oil demand and 28% of gas demand the same year (IEA, 2011). Oil was mainly imported from the Middle East via tanker, while gas was imported from Myanmar via pipeline.

At end of 2011, the Department of Mineral Fuel reported proven reserves of petroleum both onshore and offshore at 215 million barrels of crude oil, 239 million barrels of condensate, and 284 billion cubic metres (10.06 trillion cubic feet) of natural gas (DMF, 2011, p. 79). Based on 2011 production rates, crude oil reserves will last another four years, condensate reserves another seven years, and natural gas reserves will be depleted in less than 15 years. Although Thailand's coal reserves are large, most of the proven coal reserves are lignite coal of low calorific value. There has been to date no significant assessment of Thailand's unconventional oil and gas resources.

Conservative assumptions suggest that Thailand will need to continue to increase imports of oil and gas from neighboring economies. Thailand has had gas pipeline interconnections with Myanmar since 1999 and Malaysia since 2005; these were constructed as a part of the on-going Trans-ASEAN Gas Pipeline (TAGP) project (ASCOPE, 2010). Within Thailand, the total natural gas network covers 4056 km and natural gas is distributed to power generators, including the Electricity Authority of Thailand (EGAT), independent power producers (IPP) and small power producers (SPP), as well as to 272 industrial users (PTT, 2011a).

Because of the economy's faster than expected growth in demand for natural gas, and the limited scope of its reserves, Thailand is actively seeking new gas resources. It is also seeking to improve security of energy supply by diversifying its power generation fuel mix, through increased use of renewable resources, particularly solar, wind, hydro and biomass.

Liquefied natural gas (LNG) has also been used as a fuel for electricity generation since 2011. The Map Ta Phut LNG Terminal, Thailand's first LNG re-gasification terminal, was inaugurated in Rayong province in September 2011. The terminal has an initial capacity of 5 million tons per annum, extendable to 10 million tons a year (PTT, 2011b). The anticipated growth in demand for natural gas has led the government to consider building a second LNG terminal, possibly in the south of Thailand to avoid the current freight traffic congestion around Rayong.

Thailand has good potential for generating electricity from renewable energy. Assessments from Thailand's Ministry of Energy estimated that about 57.3 GW of renewable energy capacity may be available, mostly from solar, biomass and wind energy. As of 2010, only 1750 MW of renewable energy capacity had been installed in Thailand, of which 92% was fuelled by biomass (EGAT, 2010, p. 99).

ENERGY POLICIES

Thailand's energy policy aims for sustainable energy management so the economy has sufficient energy to meet its needs. Currently, it is based on these five strategies:

1. Energy security.
2. Promoting the use of indigenous energy resources including renewable and alternative energy.
3. Monitoring energy prices and ensuring prices are at competitive levels and appropriate for the wider economic and investment situation.
4. Effectively promoting energy conservation and efficiency.
5. Supporting energy development domestically and internationally while simultaneously protecting the environment.

Thailand's energy policy also seeks to build an energy self-sufficient society; achieve a balance between food and energy security; build a knowledge-based society; promote Thailand's role in the international arena; and enhance economic links with other economies in the region to facilitate harmonious cooperation in energy and other sectors.

To improve energy security, Thailand's government has adopted a range of comprehensive measures covering the oil, gas and electricity sectors. The policy development includes comprehensive and careful study of nuclear energy as another option for increasing the stability of the economy's future electricity supply. According to the original Power Development Plan 2010 (PDP 2010), the Electricity Generating Authority of Thailand (EGAT) has estimated that nuclear power could contribute up to 10% of the economy's total electricity generation from 2023 (EGAT, 2010). However, public acceptance of nuclear energy is a major challenge in Thailand, and an effective communication strategy will be needed to reduce the public's fear of nuclear power and increase recognition of the benefits it would offer to the community. The latest version of the PDP 2010 released in June 2012 reflects this sentiment, and limits the share of nuclear to less than 5% of total generation capacity.

The same revision of PDP 2010 stipulates that Thailand's reserve margin should not be less than 15% of peak power demand and reduces the allowable share for foreign power purchase from neighboring countries from 25% to 15% of total generating capacity.

The Renewable and Alternative Energy Development Plan (2012–2021) sets a framework for Thailand to increase the share of renewable and alternative energy to 25% of total energy consumption by 2021 (DEDE, 2011). The plan states the Thai government will encourage the use of indigenous resources including renewable and alternative energy (particularly for power and heat generation), and supports the use of transport biofuels such as ethanol-blended gasoline (gasohol) and biodiesel. The plan also strongly promotes community-scale alternative energy use, by encouraging the production and use of renewable energy at a local level, through appropriate incentives for farmers. It also rigorously and continuously promotes research and development of all forms of renewable energy.

Thailand has adopted a 20-year Energy Efficiency Development Plan 2011–2030 (EEDP) (EPPO, 2011). This plan sets a target of 25% reduction in the economy's energy intensity by 2030, compared to 2005 levels. In 2011, the EEDP targets were revised to meet the new target declared by APEC Leaders at the APEC Summit 2011. Thailand now aims to achieve a 25% reduction of energy intensity by 2030, compared with 2010 levels (APERC, 2012). The focus for energy efficiency measures is on transport and industry sectors. If the energy conservation measures can be successfully implemented, energy elasticity (the percentage change in energy consumption to achieve a 1% change in the economy's GDP) will be reduced from an average of 0.98 in the past 20 years to 0.7 in the next 20 years. Implementation of the EEDP will result in cumulative final energy savings of about 289 000 ktoe by 2030 (or an average of 14 500 ktoe per year), and avoided CO_2 emission of 976 million tons (EPPO, 2011). The EEDP employs these strategies:

1. *Mandatory Requirements via Rules, Regulations and Standards.* This includes the enforcement of Minimum Energy Performance Standards

(MEPS), mandatory energy efficiency labelling and enforcement of the Energy Conservation Promotion Act.

2. *Energy Conservation Promotion and Support*. This includes measures for incentives to encourage voluntary energy efficiency labelling, promotion for travelling by mass transit systems, and financial support for Energy Services Companies (ESCO).
3. *Public Awareness Creation and Behavioural Change*. This includes public relations and provision of knowledge about energy conservation to the general public, promoting activities related to the development of a low carbon society and low carbon economy, and the determination of energy prices as a tool to foster public awareness and change energy consumption behaviour.
4. *Promotion of Technology Development and Innovation*. This includes measures to promote research and development to improve energy efficiency and reduce the technological costs, promote demonstrations of technically proven energy efficiency technologies and support for wide commercial deployment of viable technologies.
5. *Human Resources and Institutional Capability Development*. This includes support measures to build professional and institutional capabilities for planning, supervising and implementing energy efficiency conservation measures.

Liquid petroleum gas (LPG) and natural gas vehicle (NGV) fuel prices have been subsidized at below cost levels in Thailand since the 1980s. The price subsidy for LPG and NGV is now being removed, through a gradual increase in price that began in January 2012. The subsidy for transport LPG and NGV will be gone by the end of 2012; the removal of the subsidy for LPG and natural gas for residential, industrial and other sectors will follow more slowly. There will be some government assistance in the residential sector, to offset the increase in the cost of living, before the residential LPG subsidy is completely removed.

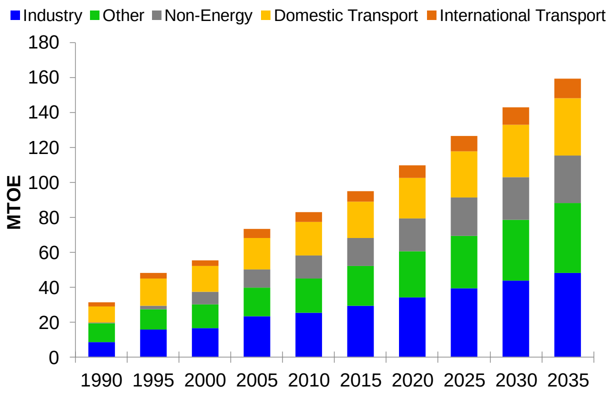
Foreign investment in the energy sector is covered by the Foreign Business Act 1999. There is no restriction on foreign investment in businesses involved in energy (oil, gas, electricity) exploration and production. However foreign equity is limited to minority shares of transmission and distribution service businesses. This means foreign companies seeking to operate transmission, trading or distribution services in Thailand require a local joint venture partner. For natural gas transmission and distribution, third parties are able to gain direct access to the network, but there are currently no third party companies doing this (APEC, 2011, p. 392).

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

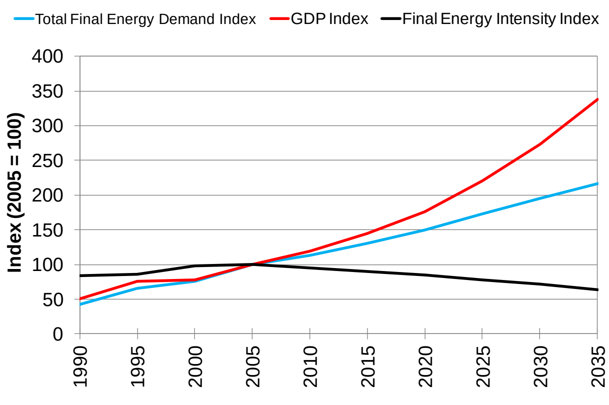
The final energy demand is expected to grow under business-as-usual (BAU) assumptions at an average annual rate of 2.6% over the outlook period (a 92% growth in total). In 2035, industry and non-energy use together will account for 48% of the total final energy demand, while transport will account for 27% and 'other' sector demand for 25%, as shown in Figure THA2. More than half of the final energy demand will be for oil. Natural gas demand will be the most rapidly growing energy source, at an annual average rate of 4.4% per year from 2010 to 2035.

Figure THA2: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics* 2011 © OECD/IEA 2011

Figure THA3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Thailand's final energy intensity is expected to decrease by over 25% between 2010 and 2030, and over 35% between 2005 and 2035, as shown in Figure THA3. This should meet the economy's own target of 25% energy intensity reduction by 2030, compared to 2010 levels, as set in the Energy Efficiency Development Plan (EEDP).

Industry

Industry's energy demand is expected to grow by 2.6% per year over the outlook period. This is due to growth in the manufacturing subsector, particularly in food and beverages, chemicals and non-metallic minerals. Coal and electricity are expected to be the largest industrial energy sources. The fastest growing, however, will be oil, which is expected to grow at an average annual rate of 5%, from 2.7 Mtoe in 2009 to 10 Mtoe in 2035.

Transport

Domestic transport demand is expected to grow by 2.1% per year over the outlook period, due to increasing vehicle numbers (which are still far below saturation level) and the increase in vehicle kilometres travelled. Demand will be moderated by the gradual shift in transport modes in urban centres (to rapid transit systems) and a modest increase in the use of biofuels and alternative vehicles.

The light vehicle fleet in Thailand will be more diverse by 2035. Hybrids and plug-in hybrid vehicles will account for 4% of the fleet, while vehicles running on LPG and CNG will account for 7%.

Other

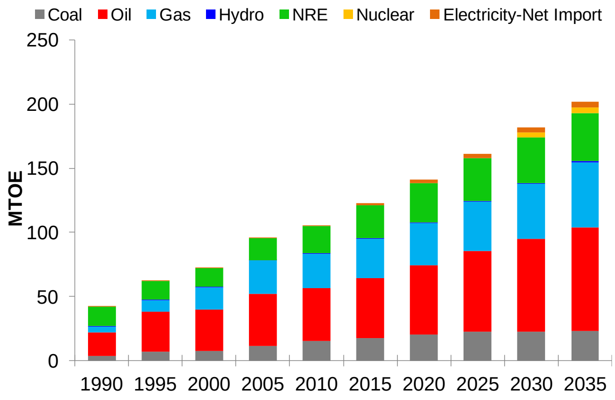
Energy demand in the 'other' sector, which includes the residential, commercial and agricultural subsectors, is expected to increase at an annual average of 3.0% over the outlook period, to 40 Mtoe in 2035. A large percentage of 'other' sector demand will be for electricity in the commercial subsector and for oil in the agricultural subsector.

The likely increase in home appliance ownership, and its impact on residential demand, varies between types of home appliance. In 2010, air conditioners were owned by only 15.6% of the households, which is a long way below saturation level. In comparison television and fan ownership levels are much higher: 96% of households own a television and 97% own fans (NSO, 2011). Thailand is promoting energy conservation and efficiency through various measures, including building codes and minimum efficiency performance standards for appliances, and this is expected to moderate electricity demand in this sector.

PRIMARY ENERGY SUPPLY

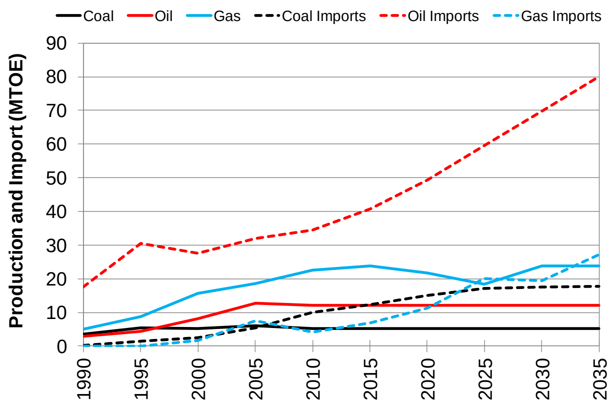
Thailand's total primary energy supply is projected to grow at an annual average of 2.6% over the outlook period. Figure THA4 shows oil and gas will dominate the mix, and in 2035 will account for over 65% of total primary energy supply. New renewable energy sources (NRE) are expected to grow by 77% over the period, and will account for 19% of the 2035 total. In this BAU projection, Thailand will likely introduce nuclear energy into the primary energy fuel mix from 2027 onwards. However, as noted in the 'Energy Policies' section above, there is still much uncertainty about the future of nuclear in Thailand.

Figure THA4: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure THA5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Over the outlook period Thailand is expected to remain highly dependent on energy imports, particularly for oil, as seen in Figure THA5. Oil imports are expected to grow at an average annual rate of 3.4%, to 80 Mtoe in 2035. This is to meet the projected demand for oil, especially in the domestic transport and non-energy sectors over the outlook period.

Increasing demand for natural gas, especially for electricity generation, and Thailand's limited gas production will require the economy to increase its gas imports almost four-fold from 7.5 Mtoe in 2009 to 27 Mtoe in 2035. Coal imports are expected to grow at an annual average of 2.3% from 2010 to 2035, mostly serving the industrial sector and electricity generation.

ELECTRICITY

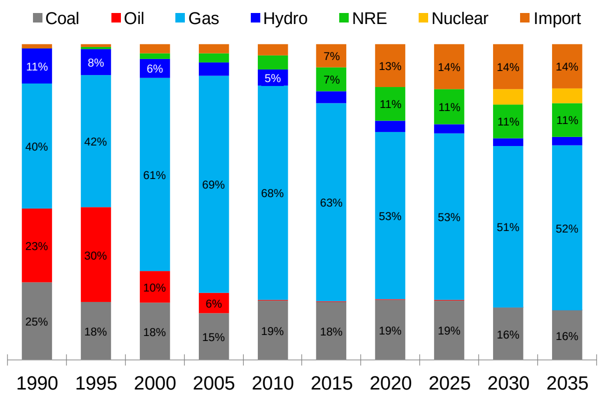
Figure THA6 shows Thailand's electricity generation fuel mix will remain heavily dependent on natural gas throughout the outlook period. By 2010, oil-fuelled power plants had mostly been removed from use; as a result, the oil share in the total generation mix is almost negligible throughout the outlook period. During the same time, the coal share will be maintained at about 16–19%.

After the Fukushima Nuclear Accident, the Ministry of Energy postponed construction of a proposed nuclear power project and reduced the plant's final capacity from four 1000 MW units to two: one unit to commence operation in 2026 and the next unit in 2027 (EGAT, 2012). With this latest proposal incorporated, our BAU scenario projects that nuclear energy will contribute about 5% of the electricity generation mix from 2027 onwards. This may still change depending on Cabinet endorsement and public acceptance, as well as the results of feasibility and safety review assessments of Thailand's nuclear readiness.

The share of electricity generation based on hydro and NRE sources will increase from 9.5% in 2010 to 13.4% in 2035. As a tropical economy with strong agricultural sector, most of Thailand's NRE will be in the form of biomass, biogas and solar energy.

Thailand has signed a number of Memoranda of Understanding (MOU) with Lao PDR, Myanmar and China to develop power generation projects over the next 20 years to enable Thailand to import electricity from these economies (EGAT, 2010, p. 22). Most are hydroelectric and renewable energy projects. The associated transmission systems are already under construction. As these power purchase projects come online, Thailand's electricity imports will increase and account for at least 14% of the total electricity generation mix from 2025 onwards.

Figure THA6: BAU Electricity Generation Mix

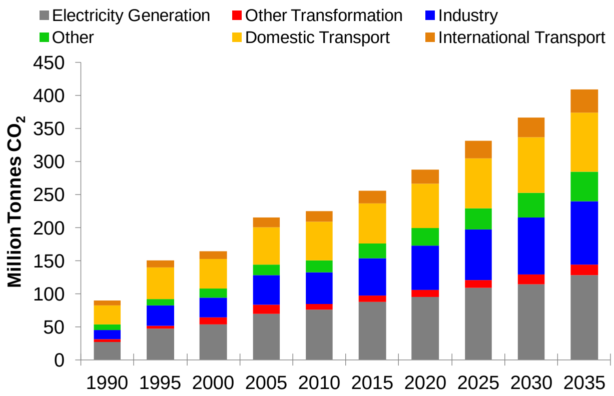


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Thailand's level of CO_2 emissions is expected to increase throughout the outlook period, across all sectors, as shown in Figure THA7. The average annual rate of increase for the whole economy is 2.4%. Electricity generation, industry and domestic transport will be the main contributors.

Figure THA7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis in Table THA7 shows Thailand's growth in GDP drives the total change in CO_2 emissions, offset by reductions in CO_2 intensity of energy (fuel switching) and energy intensity of GDP (energy efficiency and industry structure).

Table THA1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	0.4%	-1.0%	-0.4%	-0.4%	-0.2%
Change in Energy Intensity of GDP	0.9%	-1.6%	-1.5%	-1.6%	-1.5%
Change in GDP	4.7%	3.6%	4.1%	4.1%	4.3%
Total Change	6.1%	0.9%	2.1%	2.2%	2.4%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual assumptions, Thailand's final energy demand will double within the next 25 years, and with its limited resources, the economy will likely remain a net energy importer to meet its increasing energy demands. The BAU scenario also indicates Thailand's high dependency on fossil fuels will likely result in the further increase of CO_2 emissions and environmental pollution.

To improve energy security and alleviate the climate change problem, the economy is actively pursuing initiatives in biofuels and natural gas for vehicles, and nuclear and renewable energy in the power sector, as well as diversifying its imported energy resources. The economy already has a 20-year Energy Efficiency Development Plan 2011–2030 in place—this should accelerate energy efficiency and conservation measures in the economy, with the result of reducing energy intensity by 25% from 2010 to 2030.

ALTERNATIVE SCENARIOS

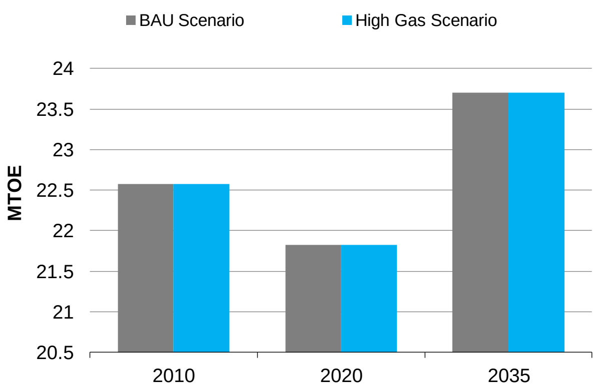
To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

Due to natural gas resource depletion (DMF, 2010), gas production under the High Gas Scenario for Thailand is likely to be the same as for BAU, as shown in Figure THA8.

Figure THA8: High Gas Scenario – Gas Production

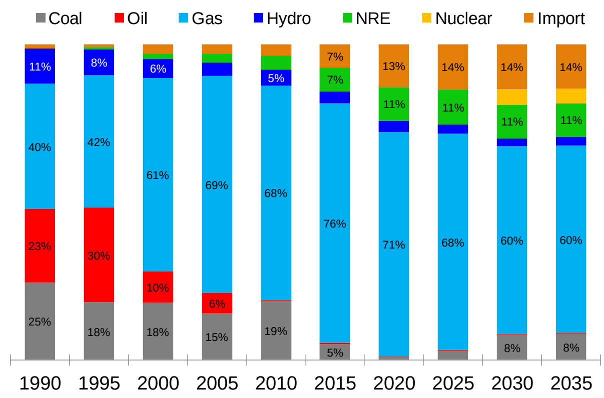


Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. In Thailand, natural gas demand for electricity production is projected to increase over the outlook period; therefore, in a situation of high gas availability, Thailand can be expected to import more gas via pipeline and as LNG to meet the growing demand. The proportion of imported gas will depend on the market situation.

Additional imported gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure THA9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario shown in Figure THA6. It can be seen that the gas share has increased by 8% by 2035, while the coal share has declined by an equal amount.

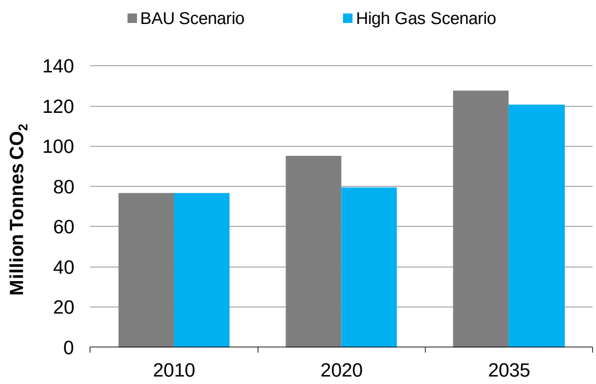
Figure THA9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Since gas has roughly half the CO_2 emissions per unit of electricity generated than coal, this had the impact of reducing CO_2 emissions in electricity generation by 6% by 2035 as shown in Figure THA10.

Figure THA10: High Gas Scenario – CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

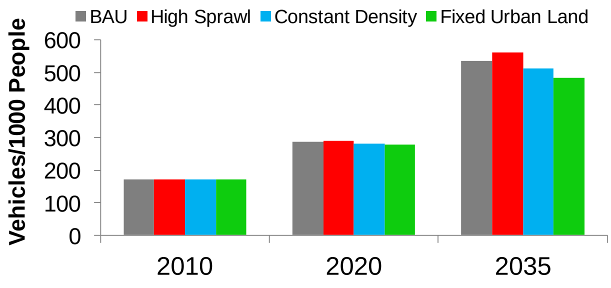
The CO_2 emissions reduction in the High Gas Scenario could contribute towards Thailand's Energy Efficiency Development Plan (EEDP) target to achieve cumulative avoided CO_2 emissions of 976 million tons from 2010 to 2030 (EPPO, 2011, p. 8)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure THA11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. The difference between the High Sprawl scenario and BAU is moderate: vehicle ownership is 5% higher in the High Sprawl scenario. However, there is a significant shift in the Fixed Urban Land scenario, where vehicle ownership is 9% lower than BAU. The impacts of improved urban planning are likely to be more significant in the years after 2035, as vehicle ownership approaches saturation levels typical of wealthy economies.

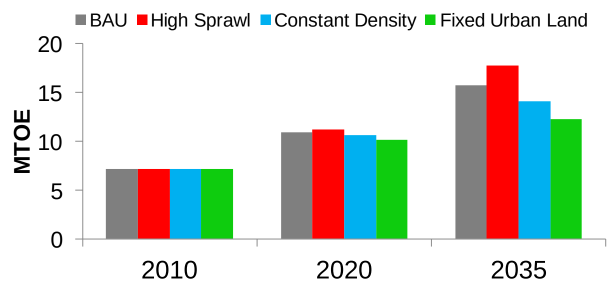
Figure THA11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure THA12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The different urban development scenarios have greater impact on light vehicle oil consumption than they did on vehicle ownership figures. In addition to reducing vehicle ownership, denser urban development also reduces the length of vehicle trips. Light vehicle oil consumption in the High Sprawl scenario is 13% higher than BAU, while in the Constant Density and Fixed Urban Land scenarios, it is 10% and 22% lower, respectively.

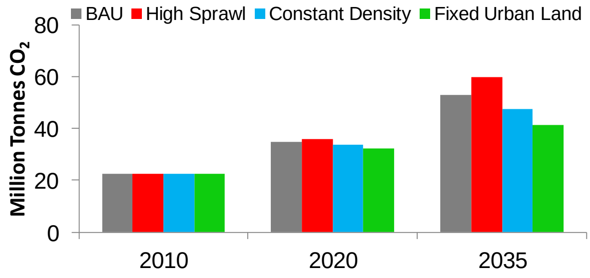
Figure THA12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure THA13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios. Light vehicle CO_2 emissions would be 13% higher in the High Sprawl scenario compared to BAU in 2035, and about 10% and 22% lower in the Constant Density and Fixed Urban Land scenarios, respectively.

Figure THA13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



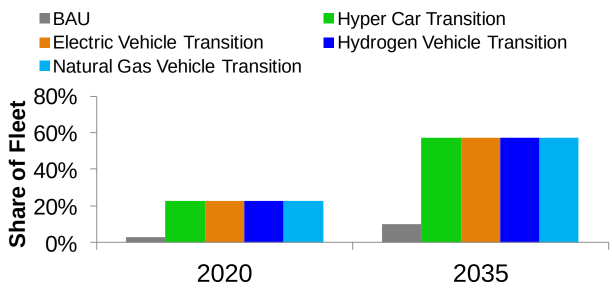
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure THA14 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios.

Figure THA14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet

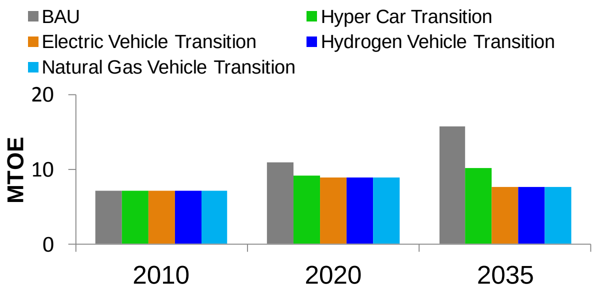


Source: APERC Analysis (2012)

By 2035 the share of the alternative vehicles in the fleet reaches around 57% compared to about 9% in the BAU scenario. The share of conventional vehicles in the fleet is thus only about 43%, compared to about 91% in the BAU scenario.

Figure THA15 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 51% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU: down 35% by 2035, even though these highly efficient vehicles still use oil.

Figure THA15: Virtual Clean Car Race – Light Vehicle Oil Consumption



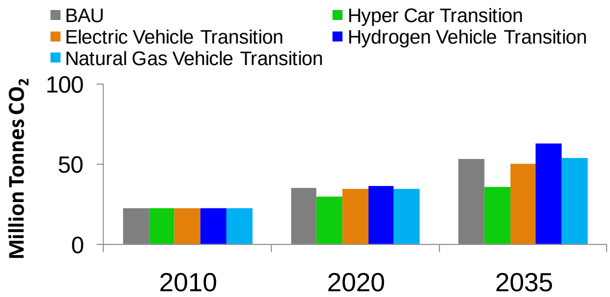
Source: APERC Analysis (2012)

Figure THA16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios, the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In Thailand, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emission reduction, with an emission reduction of 32% compared to BAU in 2035. This is because of the higher fuel efficiency in hyper cars reduces the oil consumption per kilometre travelled. The Electric Vehicles Transition scenario would be second, offering a reduction of 6% compared to BAU in 2035. While electric vehicles and the power plants that supply them use energy more efficiently than conventional vehicles, this scenario assumes they still rely on fossil-fuel generated electricity, which in Thailand is mainly from natural gas.

In contrast, the Natural Gas Vehicle Transition and Hydrogen Vehicle Transition scenarios would actually increase emissions level, by 2% and 18% respectively, compared to BAU in 2035. Thailand has a large proportion of diesel and LPG light vehicles, which are more efficient than light vehicles using regular petrol or natural gas as fuel. This means there is actually a drop in efficiency when switching to natural gas vehicles, which causes a small increase in emissions for the Natural Gas Vehicle Transition scenario. The large increase in emissions for the Hydrogen Vehicle Transition scenario reflects the conversion losses in producing hydrogen from gas which involves significant CO_2 emissions. The results would be more favourable if hydrogen could be produced from a renewable or low carbon energy source.

Figure THA16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

APEC (Asia–Pacific Economic Cooperation) (2011), *The Impacts and Benefits of Structural Reforms in the Transport, Energy and Telecommunications Sectors in APEC Economies*, APEC Policy Unit, http://publications.apec.org/publication-detail.php?pub_id=1113

APERC (Asia Pacific Energy Research Centre) (2012), *Compendium of Energy Efficiency Policies of APEC Economies: Thailand,* www.ieej.or.jp/aperc/CEEP/2011/Thailand_2011.pdf

ASCOPE (ASEAN Council on Petroleum) (2010), 'Trans ASEAN Gas Pipeline Project (TAGP)' website page, http://ascope.org/component/content/article/6-projects/28-tagp.html

BTS (BTS Group Holdings Public Company Limited) (2012), *Annual Report 2011/2012*, http://bts.listedcompany.com/misc/ar/AR2011-EN.html

DEDE (Department of Alternative Energy and Efficiency, Thailand) (2010a), "Electric Power in Thailand" in *Annual Report 2010*, www.dede.go.th/dede/images/stories/060554_circular/report_electric_2553_3.pdf

— (2010b), "Thailand Energy Situation" in *Annual Report 2010,* www.dede.go.th/dede/images/stories/6may54_circular/energy_53_2.pdf

— (2011), *The Renewable and Alternative Energy Development Plan for 25 Percent in 10 Years (AEDP (2012–2021),* www.dede.go.th/dede/images/stories/dede_aedp_2012_2021.pdf

DLT (Department of Land Transport, Thailand) (2011), 'Transport Statistic Sub-division, Planning Division' website page, in Thai, http://apps.dlt.go.th/statistics_web/statistics.html

DMF (Department of Mineral Fuel, Thailand) (2011), *Annual Report 2011*, www.dmf.go.th/resources/annualReport/annual/en/PDF Ministry 2011Eng.pdf

EGAT (Electricity Generating Authority of Thailand) (2010), *Summary of Thailand Power Development Plan 2010–2030,* System Planning Division, www.egat.co.th/en/images/stories/pdf/Report PDP2010-Apr2010_English.pdf

— (2012), *Summary of Thailand Power Development Plan 2012–2030 (PDP2010: Revision 3)*, www.egat.co.th/en/images/stories/pdf/PDP2010-Rev3-Eng.pdf

EPPO (Energy Policy and Planning Office, Ministry of Energy, Thailand) (2011), *Thailand 20-Year Energy Efficiency Development Plan 2011–2030* (EEDP), www.eppo.go.th/encon/ee-20yrs/EEDP_Eng.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

IEA (International Energy Agency) (2011), *World Energy Statistics 2011,* retrieved from OECD/IEA CD-ROM Service.

Link Technologies (2011), *Bangkok BRT Project – Case Study,* http://assets.exandas-gis.com/eshop/pdf/BangkokEN_Light.pdf

MOT (Ministry of Transport, Thailand) (2009), *Transport Statistic*, www.news.mot.go.th/motc/portal/graph/index_transtat.html

MRTA (Mass Rapid Transit Authority of Thailand) (2012), "Summary of Operating Results in the fiscal year 2011" in *Annual Report 2011*, www.mrta.co.th/news/Annual_report/2554/14.pdf

NESDB (Office of the National Economic and Social Development Board) (2012), *Thailand's Infrastructure Development Plan and Opportunities,* www.nesdb.go.th/LinkClick.aspx?fileticket=GNUKLT3q0Rg%3d&tabid=427&mid=1083

NSO (National Statistic Office of Thailand) (2011), *Household Energy Consumption Survey 2010*, in Thai, http://service.nso.go.th/nso/nsopublish/themes/files/energyImp53.pdf

OTP (Office of Transport and Traffic Policy and Planning, Thailand) (2011), *The Study on Transport and Traffic Development Master Plan – Executive Summary Report,* www.otp.go.th/images/stories/7-projectotp/2552/21/Executive%20Summary%20Report/Executive%20Summary%20Report.pdf

PTT (PTT Public Company Limited) (2011a), 'Gas Transmission Pipeline (GTM)' website page, www.pttplc.com/en/about-ptt-business-operations-gas-unit-transmission-pipeline.aspx

— (2011b), 'Minister of Energy inaugurates sixth gas separation plant and LNG terminal' press release, www.pttplc.com/en/news-energy-fact-business-social-news-detail.aspx?K=NDMyMA==

The World Bank (2012), *Thailand – Doing Business*, www.doingbusiness.org/~/media/fpdkm/doingbusiness/documents/profiles/country/THA.pdf

UNITED STATES

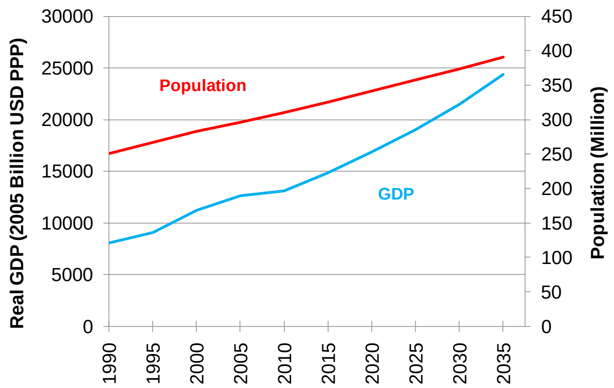
- *Economic recovery and population growth combined with aggressive energy efficiency policies will see the US energy demand grow slowly over the 2010–2035 outlook period.*
- *The US has uncovered vast shale oil and gas reserves which will see domestic production dramatically reverse its long standing decline and accelerate US energy security and economic growth.*
- *Coal use will decline quickly in the electricity sector. Total annual CO_2 emissions from fuel combustion will decline to around 5050 million tonnes in 2035 or 13% lower than in 2005. However, emissions per capita will still be higher than most other wealthy economies and above the level required worldwide to avoid damaging climate change.*

ECONOMY

The United States (US) is the world's largest economy. In land area, it is geographically diverse and resource rich.

The US population was about 310 million in 2010 and continues to increase steadily as a result of positive immigration, a stable replacement birth rate (about 2.05 births per woman) and a positive ratio of births to deaths (CIA, 2011). The population is expected to grow to around 391 million over the outlook period. About 82% of the population is urban—this is projected to increase in share to 88% by 2035 (UN, 2011).

Figure US1: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

Economic growth in real GDP will be moderate, with a growth rate averaging 2.5% per year between 2010 and 2035. By 2035, total GDP is expected to reach USD 24.3 trillion in real 2005 dollars

The average per capita income in real 2005 dollars was USD 42 200 in 2010, which using purchasing power parity (PPP) per capita places the US comfortably in the top 10 wealthy economies in the world (IMF, 2011). However, the distribution of wealth in the US is among the most unequal for a mature and developed economy (CIA, 2011). The percentage of people below the defined poverty line was approximately 15% in 2010, the highest level since 1993 (US Census Bureau, 2011b).

Owing to its geographical size the US has a diverse climate and landscape. The vast majority of the US has a moderate climate which supports its large tracts of arable and fertile land. However, the southwestern states tend to be very dry, and their agriculture depends on artificial irrigation. Almost all areas typically experience heat waves during summer; the northern regions experience severe cold and snow storms during winter. Summer cooling and winter heating of buildings are almost universal. The western US states are geologically prone to earthquakes; the states in the mid-west and in the Gulf of Mexico are also prone to severe weather events such as tornados and hurricanes.

The US enjoys one the highest standards of living in the world. The economy relies on domestic consumption, which accounted for 70% of total GDP during the decade up to 2010 (Hubbard and Navarro, 2010). The US economy is highly service based, and supported by a productive and educated workforce. The US has a net trade deficit which equated to about 3.4% of GDP in 2010 (US Census Bureau, 2011c). Other key sectors include agriculture, manufacturing and mining.

The industry sector is one of the major energy consumers in the US economy. This sector is made up of energy intensive industries, such as those that produce aluminium, chemicals, paper and steel. The US has a growing high-tech industry which is less energy intensive than the older 'smokestack' industries. A shift toward less energy intensive industries has also been driven by growing global competition for low-tech industrial production. This has led to the gradual shift to a service based economy.

US cities were developed during the advent of cheap energy and an ample supply of land. Consequently, US cities have high levels of urban sprawl which has led to high per capita vehicle ownership. The US also has the world's largest interconnected highway system and a comprehensive network of urban and intercity motorways. The combination of high vehicle ownership, an extensive highway network and low attention to energy efficiency has led to especially high transport energy use per capita. The economy's dependence on automobile mobility is unlikely to change by 2035.

Automobiles and air transport are the dominate means of intercity passenger travel. US public transport is typically of fair to poor quality relative to other industrialized economies, and its market share is relatively small outside of a few cities with compact central business districts (such as New York). The public transport system is heavily subsidized with ticket revenue comprising only about 38% of operational costs in 2010. However, since 1995, public transport has seen sustained growth with total transit trips increasing over 30% between 1995 and 2010. This growth was more than twice the rate of population growth over the same time (APTA, 2012).

The US has a diverse freight transport industry which includes many kinds of highway carriers, ocean and inland waterway shipping, and domestic and international air freight. Most interesting, from an energy perspective, is the US rail freight system. It is largely unsubsidized and considered to be one of the world's most productive and efficient rail freight systems (The Economist, 2010). In terms of ton-miles, rail freight accounted for about 37% of total freight volumes in 2009 (RITA|BTS, 2012).

The US has a particular endearment for sport utility vehicles and pick-up trucks which represented a 43% share of the total light vehicle fleet in 2011 (USDOE, 2012). The rapid rise in oil prices since the early 2000s combined with the onset of the financial crisis in 2008 has caused a severe downturn for US automobile companies. From 1998 to 2010, the light vehicle market share of the three major US automobile companies, General Motors, Ford and Chrysler has declined from 70% to less than 50% (Motor Intelligence, 2011). The US does not import used automobiles, but exports used vehicles, largely to its southern neighbour, Mexico.

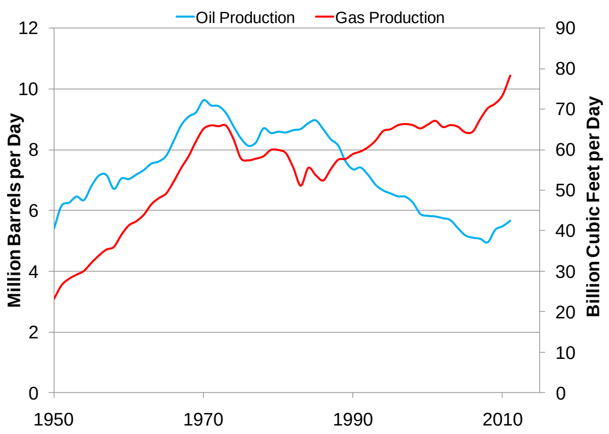
ENERGY RESOURCES AND INFRASTRUCTURE

The US energy scene has changed remarkably. The economy historically ranked as APEC's second largest oil and gas producer (after Russia). However, until recently, it was widely viewed as being on a long-term path to growing oil and gas import dependency as a result of declining oil production and stagnant gas production. This outlook has changed dramatically as a result of the exploitation of new technology for producing unconventional gas and oil, most notably 'shale gas' and 'shale bearing oil'. These technologies are discussed in Volume 1. The US has been the world leader in the development and exploitation of these technologies and their impact on the US oil and gas supply outlook has been significant.

The new technologies have resulted in an increasing production of natural gas and a precipitous drop in gas prices since 2008. The economy is believed to have huge unconventional gas resources with recoverable reserves from shale basins across the US estimated at 482 trillion cubic feet (13.6 trillion cubic metres) (EIA, 2012a). It is likely the US, historically a modest gas importer, will become a modest gas exporter in the 2010–2035 outlook period. The access to plentiful gas supplies and at relatively low prices will unlock further demand in transport, for new electricity generation and directly in industry applications.

Oil production has similarly reversed its decline, aided by rising world oil prices. In addition to shale bearing oil, the US is likely to have significant resources of deep water offshore oil, which can also be exploited using new technology. Although this technology suffered a setback with the Deepwater Horizon oil spill in the Gulf of Mexico in 2010 (see 'Energy Policies' below), the long-term prospects remain solid. The US is a net oil importer—the economy imported a peak of 60% of its demand in 2006 but this dropped steadily to less than 50% of its demand in 2010.

Figure US2: Domestic Oil and Natural Gas Production



Source: Adapted from EIA, 2012b and 2012c

The US is the world's second largest coal producer (after China). US coal reserves are immense, equating to more than one-quarter of the global coal reserves in 2010 and over 200 years of supply at current rates of production (BP, 2011).

Although fossil fuels still dominate the US primary energy mix, new and renewable energy (NRE) resources are growing fast. US biofuel is supplied almost exclusively by corn-ethanol distillers, but cellulosic feedstocks are a promising technology for the future. The economy's capacity to sustainably supply biomass feedstocks for energy use is estimated to exceed 1 billion tonnes per year, which might displace 30% of its current petroleum consumption (USDOE, 2011). Since 2000, following the push to reduce US foreign oil dependency, US biofuel production has risen almost 10-fold to 13.3 billion US gallons (320 million barrels) in 2010 (EIA, 2011). The sustained growth in biofuel production was supported by generous federal subsidies. Currently, in the face of high oil prices and rising budget deficits the federal government is debating whether to continue biofuel subsidies at current levels. The future growth in biofuel production is likely to slow as a result of supply constraints on corn feedstock and of the high cost of using more abundant cellulosic feedstocks.

Wind and solar energy, like biofuels, have a large development potential and have experienced rapid growth in recent years. In 2010 alone, the total wind energy capacity installed was 5116 MW, and from 2007 to 2010 wind installations accounted for over 35% of all new US electricity generating capacity (AWEA, 2010). Solar photovoltaic and thermal systems are also growing rapidly. In 2010, solar installations by capacity reached 956 MW or almost double that in 2009. However, subsidies and state regulations are key mechanisms that have supported NRE and its future growth is dependent on this support continuing in the short term.

The US geothermal capacity is less than 4 GW, with planned capacity additions totalling a further 5 GW (NREL, 2011). Geothermal energy provides largely baseload power using the energy potential of high temperature fluids, located in shallow and extractable geological formations underground. The limited number of drilling locations with high temperature underground resources at shallow depths has restricted new generation capacity. The future of geothermal will largely be limited outside of the planned capacity additions. However there is a lot of potential in the commercialization of technology for deep enhanced geothermal extraction, where the US has vast untapped resources.

The US has the world's largest nuclear generating capacity with 104 nuclear plants, providing nearly 20% of the economy's electricity generation. The last new reactor to join the fleet was brought online in 1996. The high initial cost of nuclear plants, regulatory uncertainties, low demand growth, safety concerns, and the unresolved issue of waste disposal are the major obstacles to adding new reactors. Several new nuclear reactors (largely within existing nuclear facilities) are awaiting the approval of the NRC (Nuclear Regulatory Commission) with four recently approved for construction. The US federal government provides generous financial incentives including tax credits, loan guarantees, insurance protection, waste disposal and funding support for advanced reactor technology (WNA, 2012). Growth in nuclear energy is likely to be slow, with competition from low-cost natural gas posing a major threat.

ENERGY POLICIES

The US has a provisional target to reduce total GHG (greenhouse gas) emissions by about 17% below a 2005 baseline, by 2020 (USDOE, 2009). The US did not ratify the Kyoto Protocol, but many states have adopted legislation intended to limit GHG emissions. Twenty-two states, collectively home to nearly half the US population, have adopted GHG emission reduction targets, although the stringency of these varies considerably (Pew Centre, 2012). It is unlikely the US will agree to binding targets or will adopt a carbon tax in the immediate future, due to strong opposition to such measures.

Many states have adopted policies to increase the share of renewable energy in the electricity generation mix. Twenty-eight states have adopted a mandatory renewable portfolio standard (RPS). Such policies require a certain share of retail electricity sales to be provided by renewable generation by a specified year. The share and the year vary state by state, as do other provisions, such as the eligible technologies and the trading of renewable energy credits. For example, the Pennsylvania RPS requires 8% 'Tier 1' renewables by 2020 and defines methane from coalmines as an eligible resource, while the California RPS targets a 33% share of renewables by 2020 and has a more common definition of renewable energy (NCSU, 2007). In California the RPS is proving effective at stimulating NRE development. Since 2003, 2871 MW of eligible NRE capacity has been installed under the RPS mandate, and several compliance targets on the path to the 2020 target have been met. A further 2500 MW of NRE is expected to be commissioned by the end of 2012 (CPUC, 2012).

There are three policies likely to have a substantial impact on both US energy consumption and emissions. These are the new emission standards on pollutants and toxins issued by the Environmental Protection Agency (EPA), the revised corporate average fuel economy (CAFE) standards and the

EPA's proposal to introduce a restriction on carbon emissions in the power sector.

Firstly, the new EPA emission standards on mercury and toxic pollutants will be incrementally applied from 2012. The strict emission standards will be fully enforced by 2015. This will have a major impact on reducing toxic emissions from coal, primarily in the electricity sector (EPA, 2012b). The new standards will require expensive technological retrofits to existing facilities, and will affect almost half the coal generating capacity. Most of the affected coal facilities are over 40 years old and the new standards are likely to result in extensive capacity retirements which may exceed 50 GW.

Secondly, the revised CAFE standards are expected to be finalised in mid-2012. These require new passenger cars and trucks to meet higher fuel economy standards in the years ahead. Specifically, new passenger vehicles and light trucks are required to achieve an annualized fuel economy improvement of 5% and 3.5% per year, respectively, until 2025. For passenger vehicles, the new standard aims to increase the average new vehicle fuel economy from 27.5 miles per gallon in 2010 to 54.5 miles per gallon (23.2 kilometres per litre) by 2025, and to the 'maximum feasible standard' after that (NHTSA, 2011). The new standards have several loopholes which may inhibit their effectiveness. The chief concern is the use of a size weighted average fuel economy, where larger vehicles have lower fuel efficiency targets. This policy was included to eliminate penalties which favour the sales of small vehicles over large vehicles. However, sales of larger vehicles may increase in market share and reduce real fuel efficiency improvements. A published study suggests average vehicle sizes, particularly for light trucks, may increase between 2% and 32% under the new standards. This would result in a net reduction in the average fuel economy of between 1 and 4 miles per gallon (between 0.4 and 1.7 kilometres per litre) (Whitefoot and Skerlos, 2011). Other uncertainties which may reduce the standards' effectiveness include low fees for non-compliance, overstated fuel economy ratings and low targets for heavy trucks. These negative effects are expected to be limited and real efficiency improvements are likely to accelerate under these rules, but perhaps at a less than anticipated rate.

Finally, the EPA is proposing to limit CO_2 emissions in the power sector. The proposed standard restricts CO_2 emissions to a limit of 454 kilograms (1000 lb) for every megawatt-hour of electricity produced. These proposed restrictions only apply to new generating units and exclude existing units in operation or under construction. The regulation is aimed at limiting climate change by enforcing the use of modern and more efficient fossil fuel generation technologies (EPA, 2012a). The carbon restriction will essentially require new coal plants to operate using the latest high efficiency technology or to employ carbon sequestration. However, at the time of writing, the proposed standards are still under appeal thus adding uncertainty to whether the restrictions will become law.

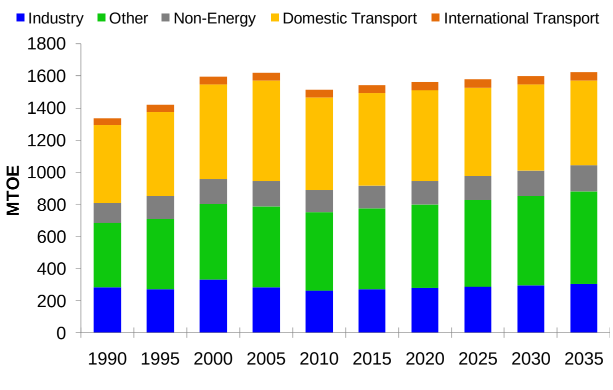
Oil exploration suffered a major setback in the wake of the deep water BP oil spill in the Gulf of Mexico in July 2010. A moratorium on new deep water exploration was initially enforced, but lifted in October 2010 with improved safety regulations on future deep water drilling operations. The US has an extensive, efficient, diverse and long standing oil and gas exploration industry. The oil and gas industry is entirely privately owned and foreign investment is generally welcomed. Tax breaks for major exploration companies are under political scrutiny: however, the industry is supported by robust growth in unconventional oil and gas exploration.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Business-as-usual (BAU) final energy demand is expected to grow at only 0.3% per year over the outlook period. The largest component of demand growth will be from the 'other' sector (residential, commercial, and agriculture). Growth in transport will remain flat.

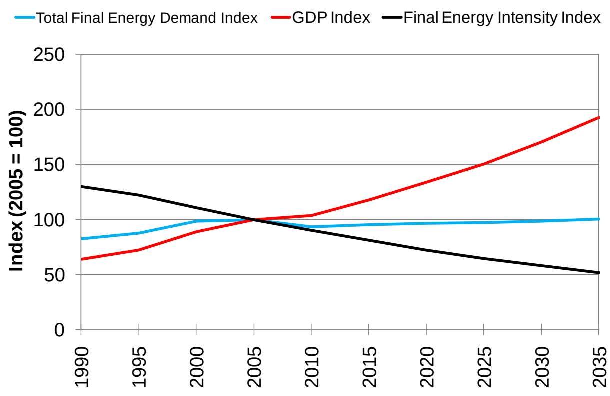
Figure US3: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Final energy intensity is expected to decline by about 42% between 2005 and 2035.

Figure US4: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Energy demand in the industry sector is projected to grow at an average annual rate of 0.6% until 2035. Productivity per worker will continue to rise in manufacturing due to increasing global competition from developing economies. The same competition is also driving improvements in energy efficiency. As the US shifts towards an increasingly service based economy, manufacturing growth will be flat with light industry growth robust. Growth in energy intensive raw product industries such as aluminium, paper, chemicals, cement and steel will be robust with the supply of cheap energy from shale gas. Energy consumption in the industry sector will increase from about 260 Mtoe in 2010 to 300 Mtoe by 2035.

Transport

Over the outlook period, transport energy demand is projected to decline slightly, with an annual decline rate of 0.3%. Energy demand in the international aviation and shipping sector will rise modestly, but the reduction in the domestic transport sector will be more substantial.

For domestic transport, vehicle ownership in the US has reached saturation level. The US automobile fleet will continue to increase slowly in line with population growth, but improved vehicle fuel efficiency combined with consumer response to increasing oil prices will offset the effect of a growing population. Additionally, alternative vehicles will have a modest entry into the market by 2035, with more funding going into R&D and with the support of tax credits and subsidies. With rising oil prices the share of more efficient conventional vehicles such as diesel and CNG (compressed natural gas) vehicles will also modestly increase. Conventional hybrid vehicles (gasoline and diesel) will make up about 13% of the fleet by 2035, with plug-in hybrids accounting for around 10% and hydrogen fuel cell and fully electric vehicles less than 3%.

Other

Energy demand in the 'other' sector, which includes residential, commercial and agricultural demand, is expected to grow the most of all sectors at 0.7% per year over the outlook period. Electricity is expected to remain the main fuel source in this sector, accounting for about 50% of its energy consumption throughout the outlook period.

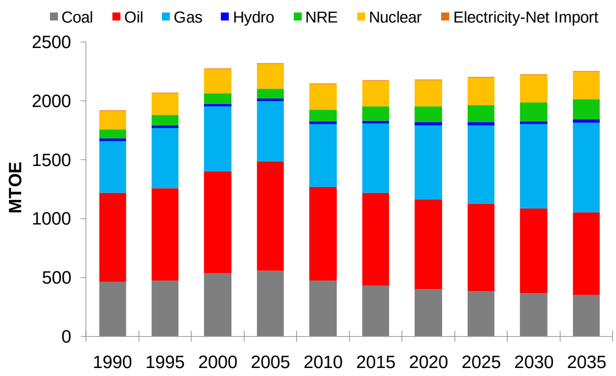
The US median residential floor area increased 36% on average between 1980 and 2010 (US Census Bureau, 2011a). Following the financial crisis in 2008, house sizes have stabilized. With rising urbanization and rising energy prices, floor spaces are expected to remain stable in the outlook period with the demand for small inner city homes outpacing the demand for outer city homes.

The US has a regulatory framework to provide rebates, incentives and R&D in energy efficiency measures. Energy efficiency is a key innovation tool for economic growth. The slight growth in 'other' sector energy demand will be driven by a robust growth in agriculture and by the growth in population. This will offset any energy efficiency improvements.

PRIMARY ENERGY SUPPLY

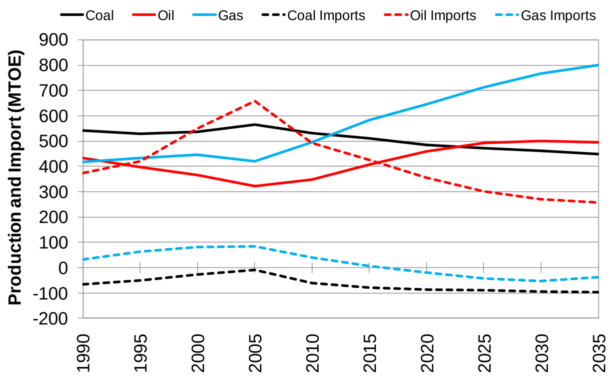
The US primary energy supply in the 2010–2035 period is projected to grow at an annual rate of about 0.2%. The economy will undergo a structural change in primary energy supply fuels, with the share of low carbon fuels increasing rapidly.

Figure US5: BAU Primary Energy Supply



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Figure US6: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

The Obama administration announced a target to reduce US foreign oil imports by one-third by 2025 (Reuters, 2011). In fact, US oil imports are likely to decline over the outlook period to 2035. Under a BAU scenario, a 33% reduction in oil imports from 2010 levels is likely to be achieved at or before the target of 2025. Additionally, the US has aggressively increased its production of biofuel as a direct substitute for oil. The future growth of biofuel is largely dependent on cellulosic feedstock (2nd generation) technology. Cellulosic biofuel is still in the infancy stages—high costs and the need for further advances in technology inhibit its commercialization. Therefore the growth of biofuels is likely to be slow in the medium term until the technology and economics are firmly established.

The acute shortage of domestic natural gas from as early as 1990 led to growing LNG (liquefied natural gas) imports. This equation has changed with unconventional gas production and, assuming government approval, the US is likely to become a modest LNG exporter perhaps as soon as 2017. This is based on an assumption the federal government will not unduly withhold granted export exemptions. At the same time, reduced coal use in electricity generation combined with a strong global coal demand will increase US coal exports. Net domestic coal production will gradually decline.

The medium term outlook for reducing the economy's import dependency is relatively certain, but the long term outlook is not. Unconventional oil and gas technologies are still developing and therefore the ultimate potential of these resources is uncertain. Since the start of commercial shale gas production, technically recoverable shale gas reserve estimates have steadily increased, but recent estimates for 2012 have reduced shale gas reserve estimates 42% from those made in 2011. Technically recoverable shale gas estimates for 2012 stand at 482 trillion cubic feet (or 13.6 trillion cubic metres) but these estimates are uncertain (EIA, 2012a). A further reduction in both the developable unconventional oil and gas resources may see energy dependency reverse its trend in the long term outlook.

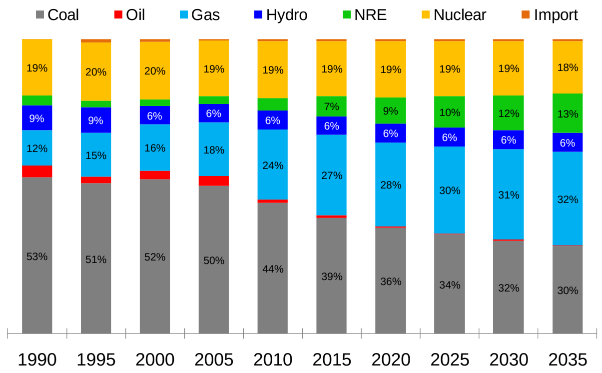
ELECTRICITY

The US electricity sector will also undergo significant changes in the outlook period. In 2011, the EPA (Environmental Protection Agency) issued strict new emission standards for mercury and toxic pollutants (EPA, 2011). The new standards require half of the existing coal generation facilities to either undergo expensive retrofits or to shut down to comply. At the same time, the proposed limits on CO_2 emissions in the power sector add much uncertainty to the economics and regulatory environment of new coal generation. Accompanying the raft of regulatory restrictions, low natural gas prices and subdued electricity demand are putting more pressure on the economics of coal generation. The reduction of capacity by retirements and the diminishing use of coal will result in coal's share of electricity generation dropping from 45% in 2010 to 30% by 2035.

Low cost shale gas and supply security will underpin the growth of high efficiency CCGT (combined-cycle gas turbine) capacity. The share of natural gas generation will increase from 24% in 2010 to 32% by 2035. Additionally, the contribution of NRE will increase over three-fold from about 4% to 13%. Growth in NRE will be led by wind and solar generation, due to reducing installation costs, the attractiveness of the resources and continuing regulatory state and federal incentives. The vast majority of the nuclear energy generating facilities are assumed to extend their operating life to 60 years. Slow capacity growth occurs by up-rating investments in existing reactor facilities. New nuclear reactor additions are unlikely as a result of weak demand growth and low-cost natural gas undermining the capital intensive economics of new nuclear facilities.

The long term stability of natural gas prices and the eventual size of proved shale gas reserve estimates are uncertain. Higher natural gas prices could limit natural gas generation uptake. This in turn is likely to reduce the retirements in coal generation facilities and to improve the growth in NRE and nuclear generation. Additionally, the introduction of a carbon cap, trade or tax is a highly uncertain policy measure with major implications. A moderate carbon pricing policy will significantly improve the growth of NRE and nuclear generation, chiefly at the expense of coal growth and modestly at the expense of natural gas growth.

Figure US7: BAU Electricity Generation Mix

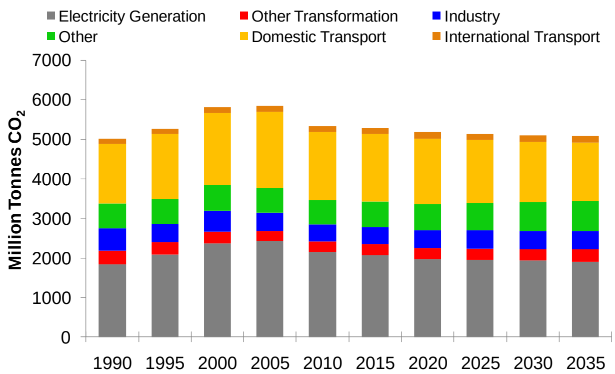


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

CO_2 EMISSIONS

Total CO_2 emissions from fuel combustion reached a peak of about 5850 million tonnes in 2005. It is projected total CO_2 emissions will steadily decrease to around 5100 million tonnes or some 13% lower than the historical peak. Electricity generation emissions will lead the decline with reducing coal generation and growing contributions from natural gas and NRE. However, increasing energy demand from both the industry and 'other' sectors will limit the rate at which emissions reduce. Transport sector emissions will remain the same due to the stable use of oil.

Figure US8: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table US1 below suggests the growth in GDP will be more than offset by both a reduction in the CO_2 intensity of energy (fuel switching) and a reduction in the energy intensity of GDP (energy efficiency).

Table US1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	-0.3%	-0.4%	-0.4%	-0.4%	-0.4%
Change in Energy Intensity of GDP	-1.7%	-2.2%	-2.2%	-2.2%	-2.3%
Change in GDP	3.1%	0.7%	2.2%	2.2%	2.5%
Total Change	1.0%	-1.8%	-0.6%	-0.5%	-0.2%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under business-as-usual, the US energy outlook is reasonably positive. Energy security and per capita GDP will increase, while CO_2 emissions will stabilize at a level 13% lower than in 2005. US per capita CO_2 emissions from fossil fuels remain stubbornly high at about 17.2 metric tonnes per capita in 2010. By 2035, per capita CO_2 emissions from fossil fuels are expected to decline to about 13.0 metric tonnes per capita. However, the US still has significant room to reduce emissions which far exceed the global average needed to prevent damaging climate change. Owing to its status as the world's largest economy and the world's third largest by population, the US is a vital player in any global emissions reduction agreement. The introduction of a carbon tax will have a substantial impact on US CO_2 emissions. In particular, electricity generation is likely to respond to carbon pricing by reducing coal use.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

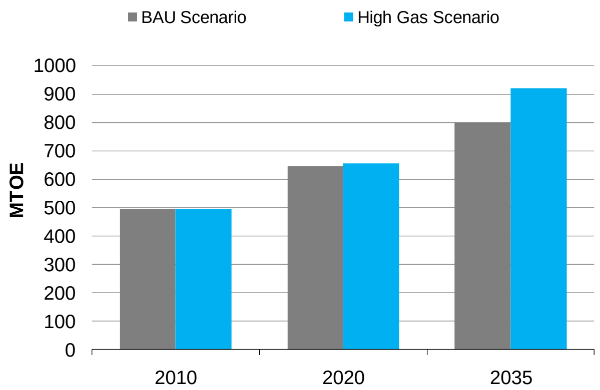
HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

The High Gas Scenario production for the US assumed the production increase shown in Figure US9, which equals 15% by 2035. The US has vast reserves of shale gas which require significant investment in both production and transport infrastructure. The High Gas Scenario assumption primarily removes the restrictions on exports to non free trade economies (which currently require government approval). In turn, this enables greater investment into shale gas production for LNG exports from both the Gulf of Mexico and the West

Coast basins to international markets. The High Gas Scenario also assumed the vast conventional North Slope gas reserves in Alaska are incrementally developed with the project economics supported by improved access to key Asian markets such as Japan and China.

Figure US9: High Gas Scenario – Gas Production

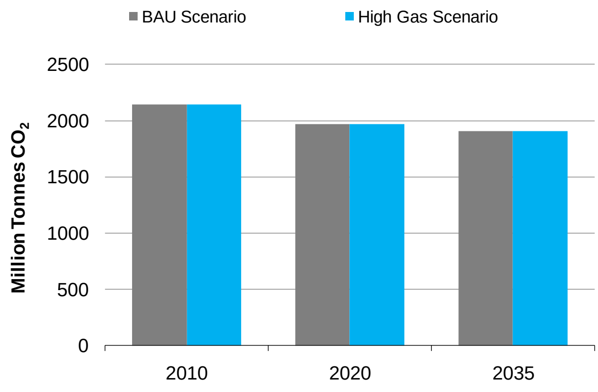


Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario depends not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. The limiting factor for US gas production is the limited domestic consumption. Under BAU, domestic gas consumption reaches saturation in all sectors. Therefore, all additional gas production above BAU must be exported as LNG. Exports via pipeline are unlikely since both the neighboring economies of Mexico and Canada are net exporters of gas to the US. Owing to the large capital investment for LNG, the long development horizon and the lack of existing infrastructure, gas production does not materially increase under the High Gas Scenario until after 2020. Increasing gas production would seek to boost US economic growth.

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Gas has roughly half the CO_2 emissions of coal per unit of electricity generated. Since the US electricity sector has no room for further gas utilization there is no domestic benefit in reducing CO_2 emissions. However, significant CO_2 emissions reductions exist for LNG importing economies within APEC (see China High Gas Scenario). With a more abundant LNG supply at no additional cost there is much potential for coal to gas switching in the power sector for the LNG importing economies within APEC. Figure US10 shows the CO_2 emissions under the High Gas Scenario are unchanged from BAU.

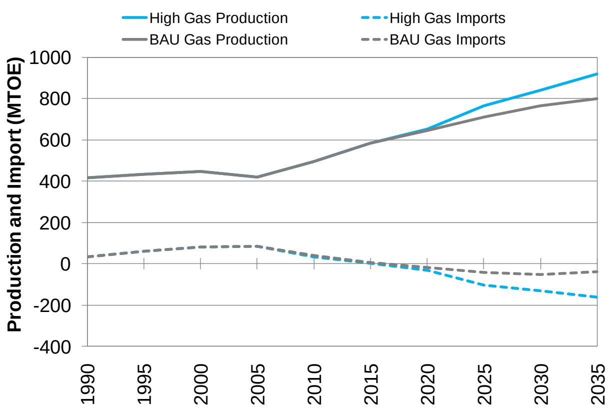
Figure US10: High Gas Scenario – CO_2 Emissions from Electricity Generation



Source: APERC Analysis (2012)

Figure US11 shows the High Gas Scenario production and imports. Gas exports increase from 30 Mtoe under BAU to around 155 Mtoe by 2035.

Figure US11: High Gas Scenario – Production and Imports



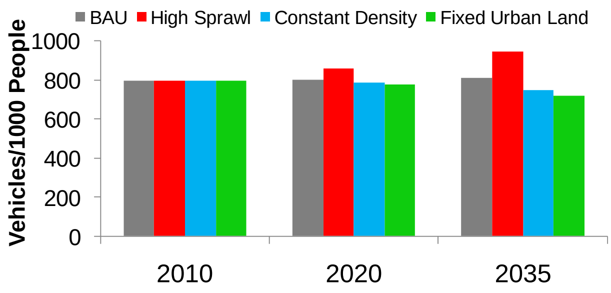
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure US12 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Urban planning has a direct effect on the expected level of vehicle saturation in long term vehicle ownership. Under BAU, US vehicle ownership is near saturation. The change in vehicle ownership under the different urban planning scenarios is significant.

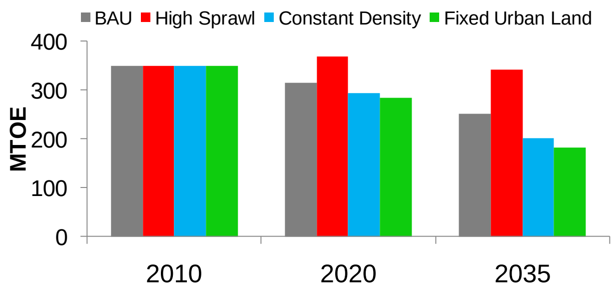
Figure US12: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure US13 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact on oil consumption in the light vehicle fleet is compounded by a change in urban living and in the distances vehicles travel. In compact cities, travel distances per vehicle are typically lower than in sprawling cities.

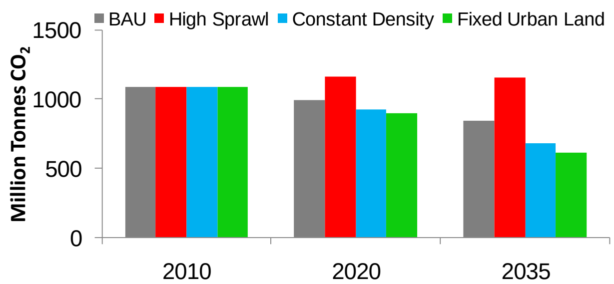
Figure US13: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure US14 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these cases.

Figure US14: Urban Development Scenarios – Light Vehicle Wheel-to-Tank CO_2 Emissions



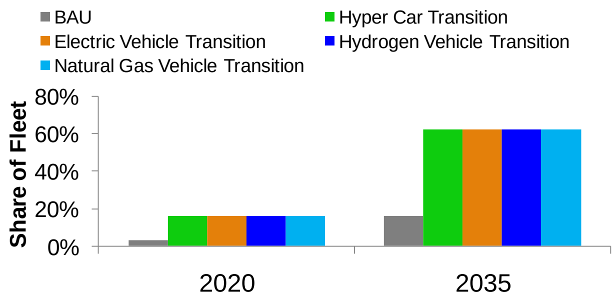
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impact of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure US15 shows the evolution of the vehicle fleet under BAU and the four 'Virtual Clean Car Race' scenarios. By 2035 the share of the alternative vehicles in the fleet reaches around 62% compared to about 16% in BAU scenario. The share of conventional vehicles in the fleet is thus only about 38%, compared to about 84% in BAU scenario.

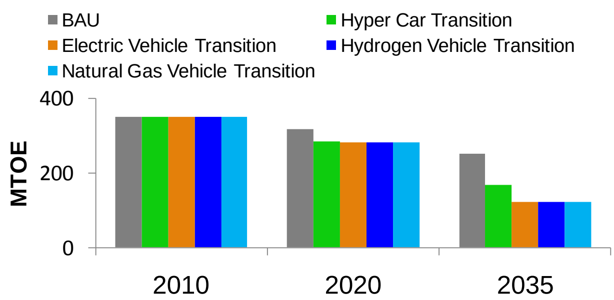
Figure US15: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure US16 shows the change in light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 52% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU by 2035. The drop is large as these alternative vehicles use no oil. Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—down 34% by 2035—even though these highly-efficient vehicles still use oil.

Figure US16: Virtual Clean Car Race – Light Vehicle Oil Consumption

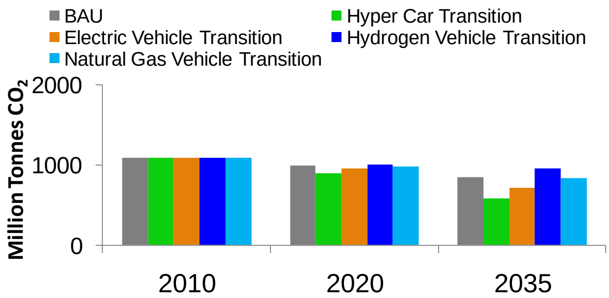


Source: APERC Analysis (2012)

Figure US17 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The emissions impacts of each scenario may differ significantly from their oil consumption impacts, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

In the US, the Hyper Car Transition scenario is the clear winner in terms of CO_2 emissions savings, with an emissions reduction of 31% compared to BAU in 2035. In addition, both Electric Vehicle Transition and Natural Gas Vehicle Transition scenarios offer savings in emissions of 15% and 2% respectively compared to BAU in 2035. In contrast, the Hydrogen Vehicle Transition scenario increases emissions 12%. This is principally because hydrogen production from steam methane reforming (from hydrocarbon fuels) has high emissions from the fuel production and distribution process. (To facilitate fair comparisons, the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios assumed no additional non-fossil utilization for their energy production.)

Figure US17: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

REFERENCES

APTA (American Public Transportation Association) (2012), *Public Transportation Fact Book*, www.apta.com/resources/statistics/Documents/FactBook/APTA_2012_Fact%20Book.pdf

AWEA (American Wind Energy Association) (2010), *U.S. Wind Industry Annual Market Report Year Ending 2010*, www.midatlanticwind.org/files/Events_Webinar_20110610_AWEA.pdf

BP (British Petroleum) (2011), *BP statistical review of world energy June 2011*, www.gpo.gov/fdsys/pkg/FR-2012-02-16/pdf/2012-806.pdf

CPUC (California Public Utilities Commission) (2012) *Renewables Portfolio Standard Quarterly Report: 1st and 2nd quarter 2012*, www.cpuc.ca.gov/NR/rdonlyres/2060A18B-CB42-4B4B-A426-E3BDC01BDCA2/0/2012_Q1Q2_RPSReport.pdf

CIA (Central Intelligence Agency) (2011), *The World Factbook*, https://www.cia.gov/library/publications/the-world-factbook/geos/us.html

EIA (Energy Information Administration) (2011), *Annual Energy Review 2011*, http://205.254.135.24/totalenergy/data/annual/

— (2012a), *Annual Energy Outlook 2012: Early Release Overview*, www.eia.gov/forecasts/aeo/er/pdf/0383er%282012%29.pdf

— (2012b), *Crude Oil Production*, http://205.254.135.7/dnav/ng/ng_prod_sum_dcu_NUS_a.htm

— (2012c), *Natural Gas Gross Statistics*, http://205.254.135.7/dnav/ng/ng_prod_sum_dcu_NUS_a.htm

EPA (Environmental Protection Agency) (2011), *Mercury and Air Toxic Standards*, www.epa.gov/mats/

— (2012a), *Carbon Pollution Standard for New Power Plants*, http://epa.gov/carbonpollutionstandard/index.html

— (2012b), *Federal Action: Final Rule*, www.gpo.gov/fdsys/pkg/FR-2012-02-16/pdf/2012-806.pdf

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

Hubbard, G. and Navarro, P. (2010), "America's Four Growth Drivers Stall and Our Economy Stagnates", www.ftpress.com/articles/article.aspx?p=1622406&seqNum=1

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, CD-ROM edition.

IMF (International Monetary Fund) (2011), *World Economic Outlook Database, September 2011*, www.imf.org/external/pubs/ft/weo/2012/update/01/index.htm

Motor Intelligence (2011), *New Vehicle Sales*, www.motorintelligence.com/m_frameset.html

NCSU (2007), Database of State Incentives for Renewables and Efficiency, North Carolina State University, Accessed: 9 March 2009, www.dsireusa.org/

NHTSA (National Highway Traffic Safety Administration) (2011), *CAFE – Fuel Economy*, www.nhtsa.gov/fuel-economy

NREL (National Renewable Energy Laboratory) (2011), 'Geothermal power generation' website page, www.nrel.gov/gis/geothermal.html

Pew Center (2012), Greenhouse Gas Emissions Targets, Last updated: 5 July 2012, www.pewclimate.org/what_s_being_done/in_the_states/emissionstargets_map.cfm

REUTERS (2011), "Obama calls for deep cuts in US oil imports", 30 March 2011, www.reuters.com/article/2011/03/30/us-obama-energy-idUSTRE72S3C820110330

RITA|BTS (Research and Innovative Technology Administration|Bureau of Transportation Statistics) (2012), *National Transportation Statistics, Table 1-50*, www.bts.gov/publications/national_transportation_statistics/#chapter_1

The Economist (2010), "High-speed railroading: America's system of rail freight is the world's best", 22 July 2010, www.economist.com/node/16636101

UN (United Nations) (2011), *World Urbanization Prospects*, Department of Economic and Social Affairs, Population Division, http://esa.un.org/unup/pdf/WUP2011_Highlights.pdf

US Census Bureau (2011a), *Median and Average Square Feet of Floor Area in New Single-Family Houses Completed by Location*, www.census.gov/const/C25Ann/sftotalmedavgsqft.pdf

— (2011b), *Poverty data sources*, www.census.gov/hhes/www/poverty/poverty.html

— (2011c), *U.S. International Trade in Goods and Services*, www.census.gov/foreign-trade/www/press.html

USDOE (US Department of Energy) (2009), EERE News: "President Obama Sets a Target for Cutting U.S. Greenhouse Gas Emissions", 02 December 2009, http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=15650

— (2011), *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: US billion-ton update*, http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf

— (2012), *Transportation Energy Data Book*, *Table 4.11*, http://cta.ornl.gov/data/index.shtml

Whitefoot, K. and Skerlos, J. (2011), *Design Incentives to Increase Vehicle Size Created from the US Footprint-based Fuel Economy Standards*, http://designscience.umich.edu/alumni/katie/Whitefoot_Skerlos_Footprint.pdf

WNA (World Nuclear Association) (2012), 'US Nuclear Power Policy' website page, www.world-nuclear.org/info/inf41_US_nuclear_power_policy.html

VIET NAM

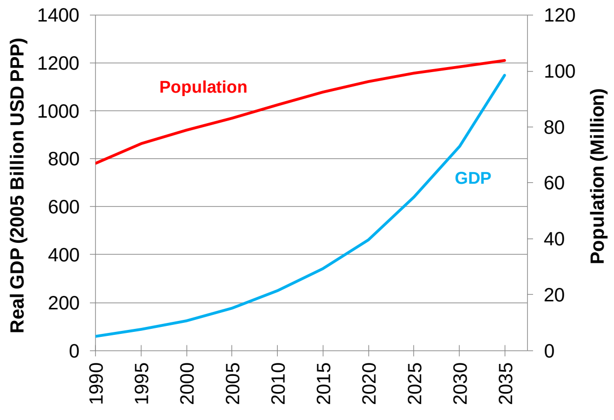
- *Viet Nam's final energy demand is expected to grow at an average annual rate of 3.5% over the outlook period, from 55.6 Mtoe in 2009 to 138.7 Mtoe in 2035. The 'other' sector (consisting of the residential, commercial and agricultural subsectors) will account for the biggest share of the total demand (57%) in 2035.*
- *Viet Nam is expected to become a net importer of energy from 2020 and the economy's energy import dependency is projected to reach 54% by 2035.*
- *CO_2 emissions from fuel combustion are projected to reach 466 million tonnes of CO_2 by 2035.*

ECONOMY

Viet Nam is located in South-East Asia. It shares borders with Cambodia and the Lao People's Democratic Republic (Lao PDR) to the west, and China to the north; while to the east and south it borders the Gulf of Tonkin, the Eastern Sea (also known as the South China Sea) and the Gulf of Thailand. Viet Nam's total land area is 330 958 square kilometres, spread out in an elongated 'S' shape; this also gives it an extensive marine exclusive economic zone along its 3260-kilometre coastline.

Viet Nam lies in the tropical monsoon zone. The typical features of this zone include warmth, humidity and abundant seasonal rainfall. In the north there are four seasons, while in the centre and in the south it is hot all year round with just two seasons, rainy and dry.

Figure VN12: GDP and Population



Sources: Global Insight (2012) and APERC Analysis (2012)

In 2010, Viet Nam's population was 87.9 million. Economic growth and rising household incomes mean the use of air conditioning for cooling interiors is growing in Viet Nam. In 2012 it is common in commercial buildings and also in private urban homes, and the demand for air conditioning is expected to continue to increase over the outlook period. In contrast, the use of biomass fuels for cooking in rural areas (and for home heating in mountainous areas) will decrease.

Market-oriented reforms since 1986 and rapid economic development have transformed the economy of Viet Nam over recent decades. The economic growth rate for the period 1990–2010 was an annual average of 7.4%, with GDP increasing from USD 60 billion in 1990 to USD 250 billion in 2010 (figures in 2005 USD PPP).

In 2010, Viet Nam had an income per capita of about USD 2850 (in 2005 USD PPP). The government has set a target of GDP growth between 6.5% and 7.0% per year over the period 2010–2015 (PMVN, 2011b). The government also expects population growth to be under 1.2% over the same period. This outlook, which takes into consideration the current global economic context and Viet Nam's future economic prospects, projects an average annual GDP growth rate of 6.3% over the outlook period, and a population growth rate of 0.7% per year over the same period, with the total reaching 104 million people by 2035. The rate of urbanization growth is higher, at an average annual rate of 1.9%; this means over 50% of the population is expected to be living in urban centres by 2035. GDP per capita (in 2005 USD PPP) is expected to exceed USD 11 000 by 2035, comparable to the equivalent figure for Malaysia in 2005 (USD 11 570).

Viet Nam's economy is dependent on exports and on agriculture, including fisheries. Major export products include coal, crude oil, textiles, footwear, rice, fish and agricultural products, and electronic products (GSO, 2009, p. 459i). The sector making the highest contribution to GDP is industry, at over 35% of the total share in 2009.

The industry sector is expected to grow quickly over the outlook period, based on growth in food processing, iron and steel, and textiles and leather. Most industry is concentrated in and around Viet Nam's big cities, including Ho Chi Minh City, Dong Nai, Bien Hoa, Hai Phong, Quang Ninh and

Ha Noi. While energy use for industry will grow at a slower rate over the outlook period than it did during 2000–2009, energy-intensive industries, such as iron and steel factories and cement and chemical plants, are still expected to account for nearly 40% of the economy's total energy use in the industry in 2035.

The economy relies heavily on its road networks, which are used for 80% of passenger trips and more than half of the freight movements. Other transportation modes in use are rail and waterways.

Most public transport services in Viet Nam are privately owned and operated, using buses, taxis, and motorbike taxis. In 2009, there were 23 million motorbikes in the economy, compared to 0.8 million cars. However, car ownership is expected to increase much more rapidly than motorbike ownership over the outlook period — the share of motorbikes in the total vehicle fleet will probably be drastically reduced by 2035. Most car ownership will be private, as the Vietnamese Government is phasing out the purchase of new cars and imported second-hand cars for government use.

Traffic congestion is already an issue in urban areas, particularly in Ha Noi and Ho Chi Minh cities, where the existing road networks do not have the capacity for the growing traffic volumes. To address congestion and also to reduce CO_2 emissions, the government of Viet Nam has developed policy to promote the use of public bus systems in these cities. At the same time, mass transit systems including subways and sky trains are being constructed in stages in both Ha Noi and Ho Chi Minh. Most of the systems are expected to be operational by the end of the outlook period.

The government's long-term aim is to improve the land-based connection between Ha Noi and Ho Chi Minh cities, and in doing so to reduce the air traffic between them. A high-speed railway between the two cities has been proposed—a revised plan is to be submitted to the National Assembly after the initial proposal was rejected on cost reasons. The revised proposal will prioritise the construction of two segments: Ho Chi Minh–Nha Trang, and Ha Noi–Vinh (not the entire Ha Noi–Ho Chi Minh route proposed initially). The intent is to shift traffic to rail from road, and therefore reduce the economy's demand for petroleum fuel.

ENERGY RESOURCES AND INFRASTRUCTURE

Viet Nam has diverse fossil energy resources, including oil, gas and coal, as well as renewable energy resources such as hydro, biomass, solar and geothermal. Natural gas and crude oil are found mainly offshore in the southern region, while coal reserves (mostly anthracite) are located in the north.

Over the period 1995–2010, oil production and exports grew at an average annual rate of 10.4%. In 2012, Viet Nam has 14 oil-producing fields: Bach Ho, Rong, Dai Hung, Rang Dong, Ruby, Emerald, Su Tu Den, Bunga Kekwa, Bunga Raya, Bunga Tulip, Ca Ngu Vang, Phuong Dong, Song Doc, and Cendor. Five of these are new fields, explored only since 2008. Most oil exploration and production activities occur off the southeast coast in the Cuu Long and Nam Con Son basins. Before 2009, Viet Nam did not have its own refinery, so all crude oil production was exported and petroleum products were imported. However, since February 2009, a refinery with a capacity of about 150 000 barrels per day has been in operation in Quang Nam province. The refinery provides around 6.5 million tonnes of petroleum products annually for domestic consumption (Petrovietnam, 2012).

Gas resources are found in many parts of Viet Nam, with the largest found in offshore basins. As well as the large gas fields discovered in the Cuu Long and Nam Con Son basins, there is the Malay–Tho Chu basin offshore of the southwest region and the Song Hong basin in the north. The Cuu Long basin is one of the developed natural gas production areas, with most of its gas produced in association with crude oil production (Petrovietnam, 2012).

Natural gas demand in Viet Nam, especially for electricity generation, has increased rapidly since 1995, and it is expected to continue to rise over the outlook period. At the same time, the current proved reserve is not very large compared with the reserves estimated in neighbouring economies, and local oil and gas experts' studies show a big gas discovery is unlikely. The reports suggest only the current annual supply of about 7–8 billion cubic metres (6.3–7.2 Mtoe) is assured from 'proven plus probable' (2P) reserves. To achieve annual production over 20 billion cubic metres (18 Mtoe) after the year 2020 will require the 'proven plus probable plus possible' (3P) reserves to move into the 'proven' category by means of further successful exploration and development (World Bank, 2010). Overall, natural gas imports are expected to be required after 2020. Unconventional gas has not been considered in Viet Nam so far.

Viet Nam has two large coalfields located in the north, in Quang Ninh province and the Red River Delta. As at the end of 2008, Viet Nam's coal reserves excluding peat were estimated at 6141 million tonnes. Of this geological reserve, 70%

is anthracite, and is deposited in Quang Ninh province. Most of the remainder is sub-bituminous coal, including deposits of 1580 million tonnes (26%) in the Khoai Chau region of the Red River Delta, and 96 million tonnes of fat coal deposits, which are used for making coke (MOIT and Vinacomin, 2008). In 2009, Viet Nam exported over 20 million tonnes of coal, a record amount, and exports made up nearly 50% of the coal industry's sales that year. Major export destinations included China, Japan, Korea, Chinese Taipei, Thailand and India.

Coal production changes expected in the outlook period include a shift from open cut mining to underground mining, as the producing coal seams in the Quang Ninh mines get deeper. In addition, the commercial development of the sub-bituminous coal of the Red River Delta is scheduled to begin after 2015. However, while the volume of coal production will keep growing, to reach 75 million tonnes by 2030 and will plateau from 2030 onwards, this will not match the increasing coal demand. Viet Nam is expected to import coal after 2020 under business-as-usual (BAU) conditions.

The rapid expansion of Viet Nam's economy between 1995 and 2009 meant electricity demand increased dramatically in the same period. The average annual rate of growth between 1995 and 2009 was 13%: the 2009 electricity demand of 83 200 GWh was nearly six times greater than the 1995 figure of 14 648 GWh. Peak demand increased more than four times during this period, rising to 13 800 MW compared to 3200 MW in 1995. The potential peak demand was even higher than reported, as power shortages led to load shedding and cuts in electricity supply during peak hours.

In 2009, power generation in Viet Nam was based on these sources: gas (43%), hydro (32%), coal (23%) and oil (2%). The construction of new electricity plants using nuclear, hydro and renewable energy sources is constrained by the availability of resources and construction sites and by high generation costs. As a result, the relatively more flexible resources of coal and natural gas make up the majority of the electricity generation mix throughout the outlook period—accounting for more than 70% of generation between them.

Some development of hydro and nuclear power plants will still take place to meet the demand growth and this will contribute to the projected five-fold increase of electricity supply by 2035. However, the limits to hydro development, and the long lead-time required to mobilize technology and funding for nuclear plant construction, mean the majority of the electricity demand increase in the outlook period will be supplied by thermal generation, based on coal and natural gas.

ENERGY POLICIES

The key points of Viet Nam's National Energy Development Strategies include:

- Diversified and effective exploitation of domestic natural resources, in combination with a reasonable import–export balance, with the gradual reduction of primary energy exports, conserving fuels and ensuring energy security for the future.
- Development of energy in line with natural resource protection and environmental protection, ensuring sustainable development of the energy sector.
- Increasing the share of rural households using commercial energy to 80% by 2020. By 2020, 100% of rural households will have access to electricity.
- Increasing the share of renewable energy in the total commercial primary energy supply to 5% by 2025 and to 11% by 2050.
- Reducing dependence on energy imports.
- Nuclear power development plan.
- Enhancing international cooperation in the energy sector (PMVN, 2007).

To reach the targets set for increasing the share of renewable energy sources in power generation, the government of Viet Nam has, since 2008, been developing policy to support renewable energy use. Government documents in this area include the Decision by the Minister of Industry and Trade on "Regulation on avoided cost electricity tariff schedule and standard power purchase agreement" (MOIT, 2008), and the Decision by the Prime Minister on "Mechanism for supporting wind power development" (PMVN, 2011a). The key elements of the decision on wind power development are the provision of incentives for capital investment, and provisions about related land use, transmission fees and electricity tariffs.

As an agriculture economy, Viet Nam has good biomass resources, including fuel wood, waste residues from crops, and other organic wastes. However, currently these sources are mostly used as non-commercial energy for households. To better harness this potential, the government is actively encouraging the production of biomass-based electricity. A number of rice-husk power plants are under development in the Mekong River delta, with support from local authorities. The use of solar power, however, is limited in Viet Nam by high development costs, and is restricted to a few projects supported by the government.

The development of nuclear power has been actively pursued in Viet Nam since the mid 1990s. It formed an important part of the National Energy Research Program for 1995–2000, run by a group of organizations including the Institute of Energy (IE), the Ministry of Industry and Trade (MOIT), Atomic Energy Research Institutes, and the Ministry of Science and Technology (MOST), with the assistance of foreign companies and the governments of Japan, France, Korea, Canada, and Russia. Through this program, a number of engineers, researchers and policymakers from Viet Nam have engaged in study and offshore training in various areas related to nuclear power. The research program concluded that nuclear power needed to be included as a key item in the economy's energy policy development in coming years. Since 2000, the government has been developing legal and policy frameworks, and technical and human infrastructures, to facilitate the development of nuclear power These include the Atomic Energy Law (Government of Viet Nam, 2008), the "Strategy for utilization of atomic energy for peace in Viet Nam" (MOST, 2006), and a pre-feasibility study and a human resource development program for the first nuclear power plant (MOIT and IE, 2005 and 2009; MOST, 2006).

These preparations have laid the groundwork for the first unit of Viet Nam's first nuclear power plant, scheduled to begin operations in 2020. The share of nuclear power in the economy's energy mix is then expected to increase gradually, to reach 20–30% of the total electricity production by 2050. However, after the Fukushima Daiichi Nuclear Power Plant accident in Japan, safety issues in the development and operation of nuclear power plants, already a high priority for Viet Nam, now mean the program's timeframe is under review.

The Vietnamese Government has recognized the need to improve energy efficiency in parallel with its efforts to develop energy resources. In 2006, the Ministry of Industry and Trade (MOIT) launched the National Energy Efficiency Program (VNEEP) for the period 2006–2015. This is the most comprehensive and effective of a variety of initiatives undertaken in this area since 1995 (PMVN, 2006b). VNEEP sets targets to reduce the economy's total energy consumption by 3–5% annually from 2006 to 2010, rising to 5–8% annually during 2011–2015 (compared to BAU levels). The program includes six packages with 11 actions (projects) covering key areas of energy efficiency. These key areas include: the legal framework; education and information dissemination; high-efficiency equipment and appliances; energy efficiency and conservation in industry; and the building code. A State Steering Committee (chaired by the MOIT) has been established, to oversee the implementation and monitoring of the program alongside the Energy Efficiency and Conservation Office, which has the role of coordinating the contribution of other governmental organizations (PMVN, 2006b).

There are no specific policies promoting the use of unconventional vehicle fuels (such as LPG, CNG, electricity and bio-fuel). In 2012, 100% of road transport fuels are oil-based, and are expected to remain so until 2035.

Viet Nam is in the process of reducing some of its fuel price regulations and subsidies. At times the government has required the Vietnam National Coal Mineral Industries Group (Vinacomin) to supply coal for power generation at below cost price, and oil and gas prices are also regulated by the government. While the coal subsidy has supported the development of industries using coal-based power, it also affects Vinacomin's profit and re-investment levels. The government has begun the gradual reduction of regulation of the domestic coal price, and is preparing a strategy for the gradual removal of subsidies for coal used in power generation.

The Petrovietnam Oil and Gas Group (PVN) is a government-owned company. Its functions include implementing sector management on behalf of the government, investing in gas pipelines, negotiating Product Sharing Contracts (PSCs) with exploring and producing companies, as well as monitoring those contracts. PVN is made up of four businesses, which together hold 100% of the company's assets: the Petroleum Exploration and Production Corporation, the Gas Corporation, the Electricity Production and Trading Corporation, and the Oil Refining and Petrochemical Corporation. PVN also encompasses other companies, enterprises and training organizations.

Viet Nam's gas and oil upstream sector is open to all, while the downstream functions such as transmission, distribution, and marketing are almost all within the PVN monopoly. Oil and gas production is carried out by PVN and private companies, including foreign companies and joint ventures with PVN, but all are required to sell through PVN.

The Electricity Law sets out the key principles for change in the power market (PMVN 2006a). It established the Electricity Regulatory Authority of Viet Nam (ERAV) to assist the Minister for Industry and Trade in implementing regulatory activities in the electricity sector; to contribute to a market that is safe and stable, and provides a high-quality supply of electricity; to foster the economical and efficient consumption of electricity; and to uphold the equity and transparency of the sector in compliance with the law. Under this legislation, Viet Nam's power market is to develop in three stages:

- Level 1 (2005–2014): a competitive generation power market will replace the current monopoly and subsidized power
- Level 2 (2015–2022): the establishment of a competitive wholesale power market
- Level 3 (after 2022): the realization of a competitive electricity retail market.

Electricity of Vietnam (EVN) is one of the important players in these changes, in its role coordinating the development, management and operation of the economy's electric power industry assets. There are also Build-Operation-Transfer (BOT) and Independent Power Producer (IPP) schemes run in partnership with private investors. In 2009, 32% of the electricity supply system in Viet Nam was owned by companies other than EVN. In terms of electrification, 95.5% of villages in rural areas have access to electricity (GSO, 2011).

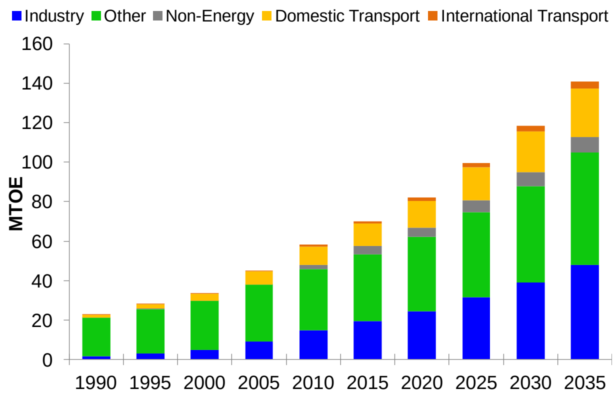
Work to enhance international cooperation in the energy field has included numerous agreements and projects that have been established and implemented within a framework of cooperation at a regional level. These include the ASEAN Power Grid, Trans-ASEAN Gas Pipeline, and Regional Power Trade in the Greater Mekong subregion. Viet Nam also has bilateral agreements on energy trade with neighbouring economies. In 2000, the governments of Viet Nam and Lao PDR signed an energy cooperation accord. Under this accord, Viet Nam will import about 2000 MW of electricity from Lao PDR (APERC, 2009). The governments of Viet Nam and Cambodia have also signed an energy cooperation agreement, under which Viet Nam has supplied 80–200 MW of electricity to Cambodia via a 220 KV transmission line since 2009 (APERC, 2009). In the future, when Cambodia builds hydro power plants and starts participating in the regional electricity market, Viet Nam will in turn buy electricity from Cambodia. In 2009, Viet Nam bought over 4.1 billion KWh of electricity from China and this annual amount will continue to increase. By 2020, a 500 KV transmission line between the two economies will be completed. Similar cooperative activities are underway in the coal, oil and gas sectors.

BUSINESS-AS-USUAL OUTLOOK

FINAL ENERGY DEMAND

Based on our business-as-usual (BAU) assumptions under the current economic conditions, total final energy demand for Viet Nam will continue to rise at an average annual rate of about 3.6% over the outlook period. This is less than the projected GDP growth for the economy. As a result, the total final energy demand in 2035 will reach about 140 Mtoe, which is a more than two-fold increase on 2010 levels. Energy consumption will increase in every sector of the economy, including the residential and commercial sectors, which are influenced by growing modernization within Viet Nam. The strongest growth, however, is in the industry and transport sectors.

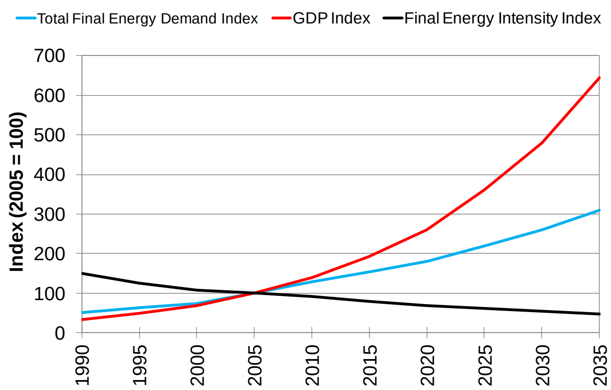
Figure VN13: BAU Final Energy Demand



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

By the end of the outlook period, oil is expected to represent the largest share of the final energy demand (34%), followed by electricity (24%) and coal (22%). Between 2010 and 2035, the consumption of gas is projected to grow the fastest, at an average annual rate of 7%. Final energy intensity is expected to decline by about 52% between 2005 and 2035.

Figure VN3: BAU Final Energy Intensity



Source: APERC Analysis (2012)

Industry

Industry is the sector that will consume the third largest amount of energy (after the Other and Non-Energy sectors) in Viet Nam by the end of the outlook period, accounting for 35% of the total final energy consumption in 2035. This is higher than the sector's 25% share in 2010.

Energy demand in the industry sector is projected to grow at an average annual rate of 5.0% until 2035, reflecting the rapid growth of Viet Nam industry generally. Viet Nam's heavy industry is dominated by iron and steel, and non-metallic minerals. However, the growth in heavy industry's energy demand will be significantly slower than in 2000–2009. This is due to the removal of the electricity price subsidies after 2015 and to increased regulation to reduce environmental pollution. The energy demand growth rate for other industries is expected to match that in the 2000–2009 period.

The industrial use of gas is projected to increase from 0.3 Mtoe in 2010 to 1.8 Mtoe in 2035, which at 7.3% is the fastest annual growth rate for fuels.

Transport

The share of the final energy demand taken up by the transport sector (includes both international and domestic transport sectors) is expected to increase over the outlook period, from 17.8% in 2010 to 20% in 2035. It will increase at an average annual rate of 4.1% over this period.

After 2000, vehicle ownership in Viet Nam began to rapidly increase; however, the motorbike will remain the most popular means of passenger transport. Over the outlook period, the growth in motorbike ownership is expected to slow, peaking at 27 million units in 2030. In contrast, the ownership of four-wheel vehicles will grow significantly to 2035, as incomes rise and the road infrastructure improves.

Because there are no government incentives to switch to alternative fuels and vehicles, the demand for conventional fuel for transportation, such as diesel, gasoline and fuel oil, is expected to continue rising.

Other

The energy used in the 'other' sector (which includes the residential, commercial and agriculture subsectors) is expected to increase from 31 Mtoe in 2010 to 57 Mtoe in 2035, rising at an average annual rate of 2.4%. This includes a high growth in the demand for electricity (6.5%), supported by strong GDP growth, rising household incomes and high rates of urbanization during the outlook period.

PRIMARY ENERGY SUPPLY

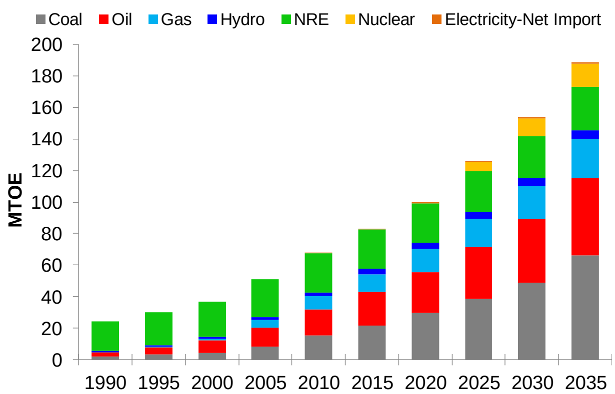
Viet Nam's primary energy supply is projected to increase almost three-fold over the outlook period, from 68 Mtoe in 2010 to about 188 Mtoe in 2035. This is based on an average annual increase of 4.2%. The proportion of non-commercial energy sources (biomass such as firewood) in the mix will decrease gradually. In 2010, non-commercial energy sources made up 37% of the primary energy supply; in 2035 they will provide just over 15%, as rising household incomes and the shift to urban centres prompts a shift to commercial energy sources.

Since 1990, Viet Nam has been a net energy exporter, with crude oil and coal as its main energy exports. However, from 2020 Viet Nam is expected to become a net importer of energy, as a result of its high energy demand growth and the limitations on available energy resources. The economy's oil import dependency is expected to start from 2014, reaching 66% in 2035.

The 2035 petroleum product demand in Viet Nam is forecast to be three times greater than the current level, and this demand will not be able to be met from domestic resources. In addition, the revenue from crude oil exports is diminishing, while the cost of energy imports is increasing. This means it is crucial for Viet Nam to use its indigenous resources as efficiently as possible and to minimize its imports.

Viet Nam is expected to reduce primary energy intensity by nearly 43% between 2005 and 2035—from 286 tonnes of oil equivalent (toe) per unit of GDP (in 2005 USD million PPP) to 164 toe per unit of GDP.

Figure VN4: BAU Primary Energy Supply

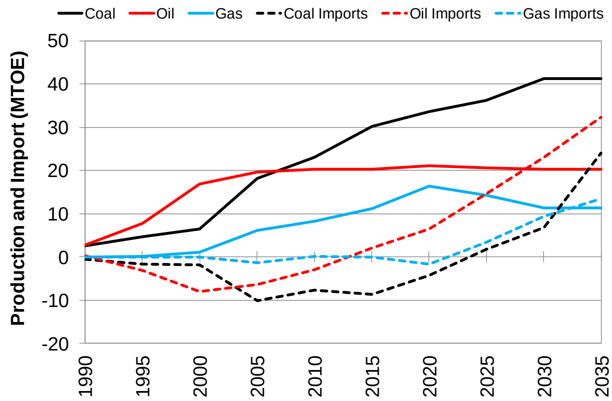


Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Viet Nam's first oil refinery successfully started production in early 2009. A second refinery with the same capacity is expected to be in action by 2015. This outlook also assumes a third refinery, with a

150 000 barrel per day capacity, will start operations after 2020. In the final decade of the outlook period, 20–25 million tonnes of domestic petroleum products from the new refineries (accounting for about 50% of total supply) should be reaching the market. This will significantly contribute to the reduction of petroleum product imports to Viet Nam.

Figure VN5: BAU Energy Production and Net Imports



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

Coal will replace oil to form the largest share of the total primary energy supply. Coal demand growth will be driven mainly by the rapid development of the electricity and industry sectors, accounting for 35% of primary energy supply in 2035. After 2020, coal and natural gas demand are expected to exceed indigenous supply.

Oil will make up the second largest share of the primary energy supply, accounting for 26% in 2035. It is mainly used in the transport and industry sectors. In 2009, Viet Nam was an exporter of crude oil, but a net importer of oil products. As oil reserves decline over the outlook period, Viet Nam's oil import dependency is expected to increase to 66% in 2035.

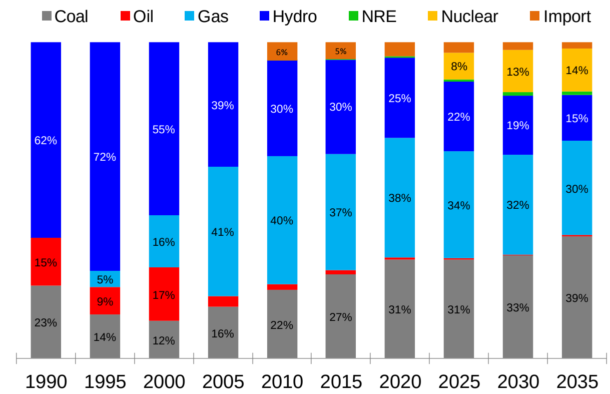
Electricity imports are expected to increase by 2020 and will account for 0.4% of the primary energy supply by 2035.

Excluding large-scale hydro, other types of renewable energy such as mini-hydro, wind, biomass, geothermal, and municipal solid waste landfill gas, will continue to be promoted. Together they will contribute 15% of the primary energy supply in 2035. Nuclear energy—based on it coming online after 2020—is expected to provide 8% of the total primary energy supply in 2035.

ELECTRICITY

The current high electricity elasticity to GDP (1.9 in the period 2005–2010) is expected to drop to 1.1 by 2035. The electricity demand forecast in the government's Master Plan on Power Development (MOIT and IE, 2011) is substantially higher than in this APERC outlook—the differences between our analysis and the Vietnamese Government's projections can be explained by our expected drop in electricity elasticity.

Figure VN6: BAU Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

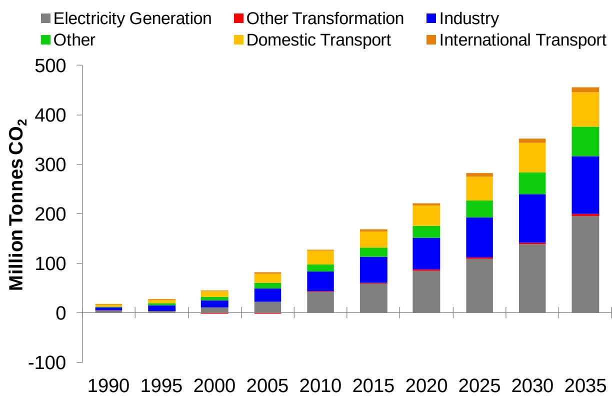
Plans for two nuclear power plants with a total capacity of 2000–4000 MW in Ninh Thuan province, in central Viet Nam, are currently at feasibility study stage. This BAU projection assumes the nuclear power plants will have started commercial operations by 2022. In 2035, the sources for electricity generation in Viet Nam are expected to be, in descending order, coal, gas, hydro, nuclear, renewable energy and fuel oil.

Electricity generation is projected to increase at an average annual rate of 6.1%, reaching 409 TWh in 2035. Over the outlook period, the hydro share of electricity production will decrease considerably, from 30% to 15%, as most potential locations for big and medium hydro plants become fully developed. By contrast, coal-fired generation will substantially increase, and will have the biggest share in 2035 (39%). The share provided by gas-fired plants is projected to decrease to 30% by 2035. Meanwhile, the nuclear share will increase from zero in 2009 to 14% in 2035. In addition, as the government continues to pursue its goal of increasing the use of domestic resources, new renewable energy sources (NRE) are expected to contribute to electricity generation, especially in remote areas where connection with the grid is not economically feasible. NRE's share will increase from zero in 2009 to 1% in 2035.

CO_2 EMISSIONS

Viet Nam is currently one of the lowest per capita CO_2 emitters in APEC; 2010 levels were 1.5 tonnes of CO_2 per person. CO_2 emissions from fuel combustion are projected to grow at an average annual rate of 5.2% over the outlook period, reaching about 466 million tonnes of CO_2 in 2035. Emissions are expected to increase to relatively high levels as Viet Nam industrializes and the economy uses more carbon-intensive energy sources. This particularly applies to coal used for power generation.

Figure VN7: BAU CO_2 Emissions by Sector



Source: APERC Analysis (2012)

The decomposition analysis shown in Table VN1 suggests the growth in Viet Nam's CO_2 emissions from fuel combustion is driven largely by economic growth, moderated by the declining energy intensity of GDP (energy efficiency measures).

Table VN1: Analysis of Reasons for Change in BAU CO_2 Emissions from Fuel Combustion

(Average Annual Percent Change)

	1990-2005	2005-2010	2005-2030	2005-2035	2010-2035
Change in CO_2 Intensity of Energy	5.5%	3.2%	1.4%	1.4%	1.0%
Change in Energy Intensity of GDP	-2.3%	-0.9%	-1.8%	-1.8%	-2.0%
Change in GDP	7.6%	7.0%	6.5%	6.4%	6.3%
Total Change	11.0%	9.4%	6.0%	5.9%	5.2%

Source: APERC Analysis (2012)

CHALLENGES AND IMPLICATIONS OF BAU

Under BAU, Viet Nam's energy outlook is reasonably positive, considering the domestic and global aspects of this economy. From 2010–2035, energy security and per capita GDP will increase, while the average annual growth rate of CO_2 emissions (at 5.2%) will be less than the GDP growth rate of 6.3%. This emission growth rate is also much lower than the recorded CO_2 emission growth rate during 1990–2009 (10.4%). However, there are still significant opportunities for improved environmental sustainability; particularly in the power generation, transportation and industry sectors.

ALTERNATIVE SCENARIOS

To address the energy security, economic development, and environmental sustainability challenges posed by the business-as-usual (BAU) outcomes, three sets of alternative scenarios were developed for most APEC economies.

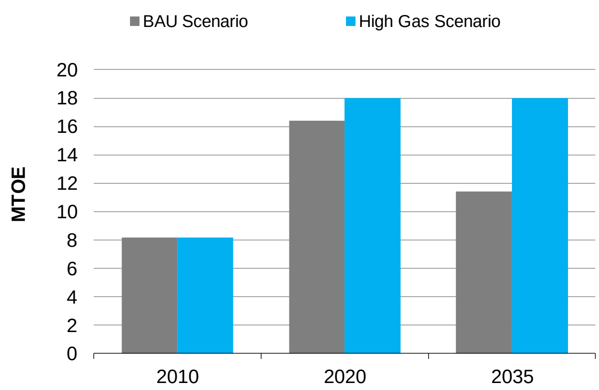
HIGH GAS SCENARIO

To understand the impacts higher gas production might have on the energy sector, an alternative 'High Gas Scenario' was developed. The assumptions behind this scenario are discussed in more detail in Volume 1, Chapter 12. The scenario was built around estimates of gas production that might be available at BAU prices or below, if constraints on gas production and trade could be reduced.

Viet Nam has no known reserves for unconventional gas, but there is potential for offshore deep water conventional natural gas. Realizing this potential requires a significant investment in exploration, production and transportation infrastructure. The High Gas Scenario for Viet Nam assumes sufficient investment is available for additional gas extraction from these new, more challenging gas fields.

Under these assumptions, the High Gas Scenario for Viet Nam assumed the production increase shown in Figure VN8, which is 57% higher than BAU by 2035. Production is expected to increase gradually to reach its peak in 2025. Due to the retirement of old, existing gas fields, production will begin to decrease again and will plateau from 2030 onwards at the 2020 production level.

Figure VN8: High Gas Scenario – Gas Production



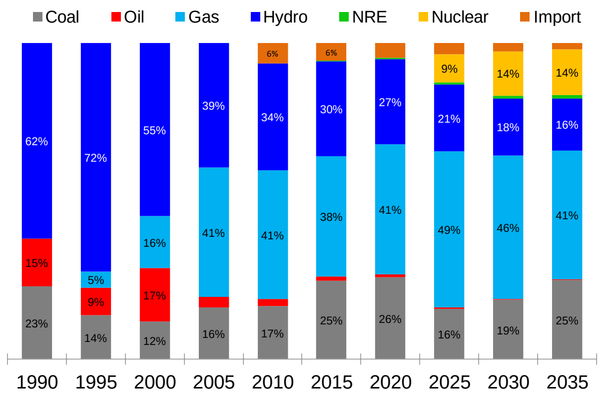
Source: APERC Analysis (2012)

Additional gas consumption in each economy in the High Gas Scenario will depend not only on the economy's own additional gas production, but also on the gas market situation in the APEC region. For Viet Nam, the additional gas production provides an opportunity to reduce local air pollution and CO_2

emissions by burning less coal. Any remaining amount of gas will be exported via the Trans-ASEAN Gas Pipeline (TAGP).

Additional gas in the High Gas Scenario was assumed to replace coal in electricity generation. Figure VN9 shows the High Gas Scenario electricity generation mix. This graph may be compared with the BAU scenario graph in Figure VN6. It can be seen that the gas share has increased by 11% by 2035, while the coal share has declined by 14%.

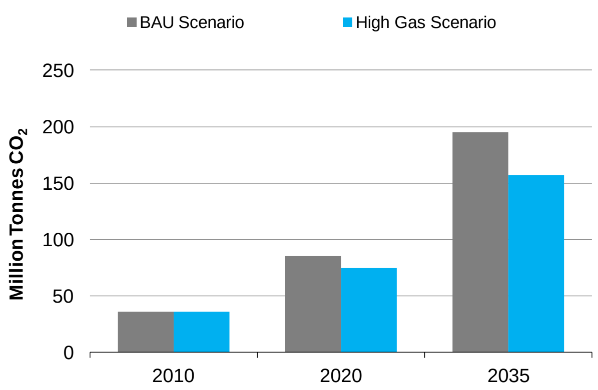
Figure VN9: High Gas Scenario – Electricity Generation Mix



Source: APERC Analysis (2012)
Historical Data: *World Energy Statistics 2011* © OECD/IEA 2011

A higher gas share in the electricity generation mix is projected to reduce the CO_2 emissions in electricity generation by 20% by 2035, since gas has roughly half the CO_2 emissions per unit of electricity generated of coal. Figure VN10 shows this CO_2 emissions reduction.

Figure VN10: High Gas Scenario – CO_2 Emissions from Electricity Generation



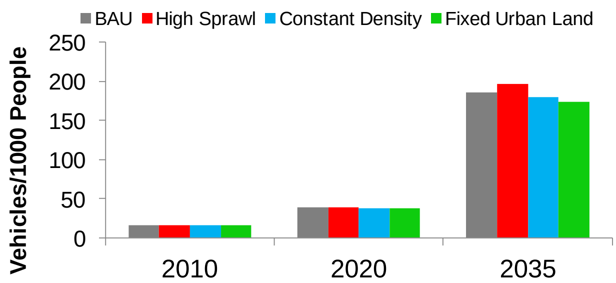
Source: APERC Analysis (2012)

ALTERNATIVE URBAN DEVELOPMENT SCENARIOS

To understand the impacts of future urban development on the energy sector, three alternative urban development scenarios were developed: 'High Sprawl', 'Constant Density', and 'Fixed Urban Land'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure VN11 shows the change in vehicle ownership under BAU and the three alternative urban development scenarios. Since vehicle ownership is still well below saturation point in Viet Nam, the impact of urban planning on vehicle ownership is barely discernible in 2020, but by 2035 the difference between the four scenarios are more pronounced. In 2035, vehicle ownership will be about 6% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 7% lower in the Fixed Urban Land scenario.

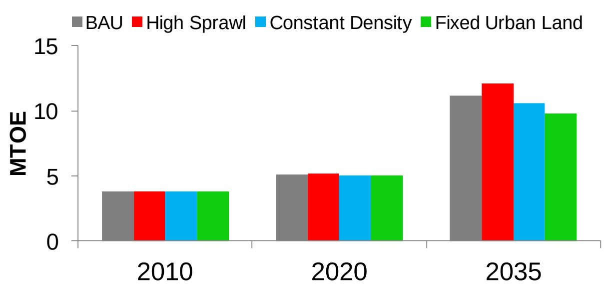
Figure VN11: Urban Development Scenarios – Vehicle Ownership



Source: APERC Analysis (2012)

Figure VN12 shows the change in light vehicle oil consumption under BAU and the three alternative urban development scenarios. The impact of urban planning on light vehicle oil consumption is relatively small and similar to that on vehicle ownership. Light vehicle oil consumption will be 8% higher in the High Sprawl scenario compared to the BAU scenario in 2035, and about 12% lower in the Fixed Urban Land scenario.

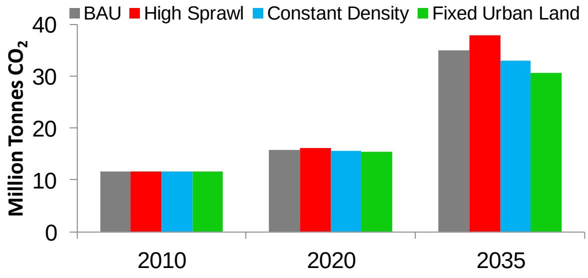
Figure VN12: Urban Development Scenarios – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure VN13 shows the change in light vehicle CO_2 emissions under BAU and the three alternative urban development scenarios. The impact of urban planning on CO_2 emissions is similar to the impact of urban planning on energy use, since there is no significant change in the mix of fuels used under any of these scenarios.

Figure VN13: Urban Development Scenarios – Light Vehicle Tank-to-Wheel CO_2 Emissions



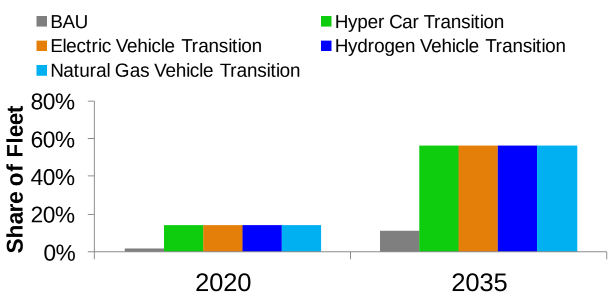
Source: APERC Analysis (2012)

VIRTUAL CLEAN CAR RACE

To understand the impacts of vehicle technology on the energy sector, four alternative vehicle scenarios were developed: 'Hyper Car Transition' (ultra-light conventionally-powered vehicles), 'Electric Vehicle Transition', 'Hydrogen Vehicle Transition', and 'Natural Gas Vehicle Transition'. The assumptions behind these scenarios are discussed in Volume 1, Chapter 5.

Figure VN14 shows the evolution of the four-wheel light vehicle fleet under BAU and the four alternative 'Virtual Clean Car Race' scenarios. By 2035, the share of alternative vehicles in the four-wheel fleet reaches around 53% compared to about 4% in the BAU scenario. The conventional vehicles in the fleet is thus only about 47% compared to about 96% in the BAU scenario.

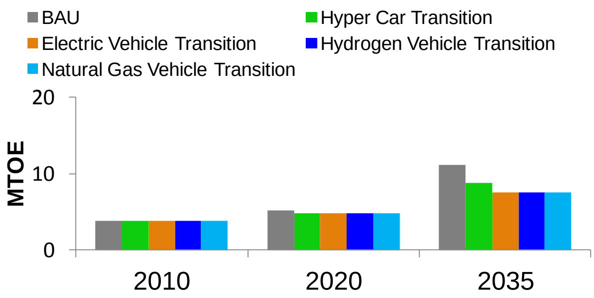
Figure VN14: Virtual Clean Car Race – Share of Alternative Vehicles in the Light Vehicle Fleet



Source: APERC Analysis (2012)

Figure VN15 shows the change in all light vehicle oil consumption under BAU and the four alternative vehicle scenarios. Oil consumption drops by 32% in the Electric Vehicle Transition, Hydrogen Vehicle Transition, and Natural Gas Vehicle Transition scenarios compared to BAU, as these alternative vehicles do not use oil. (In this graph, motorbikes are also included in the light vehicle fleet. Viet Nam is somewhat unique in that they will account for a significant share—about 35% of light vehicle oil consumption in 2035 under BAU. Motorbike energy demand does not change in the alternative vehicle scenarios.) Oil demand in the Hyper Car Transition scenario is also significantly reduced compared to BAU—23% by 2035.

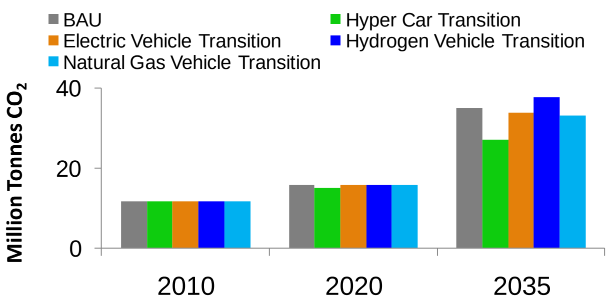
Figure VN15: Virtual Clean Car Race – Light Vehicle Oil Consumption



Source: APERC Analysis (2012)

Figure VN16 shows the change in light vehicle CO_2 emissions under BAU and the four alternative vehicle scenarios. To allow for consistent comparisons, in the Electric Vehicle Transition and Hydrogen Vehicle Transition scenarios the change in CO_2 emissions is defined as the change in emissions from electricity and hydrogen generation. The impact of each scenario on emissions levels may differ significantly from its impact on oil consumption, since each alternative vehicle type uses a different fuel with a different level of emissions per unit of energy.

Figure VN16: Virtual Clean Car Race – Light Vehicle CO_2 Emissions



Source: APERC Analysis (2012)

In Viet Nam, the Hyper Car Transition scenario is the clear winner with an emissions reduction of 22% compared to BAU in 2035. Both the Electric Vehicle Transition and Natural Gas Vehicle Transition scenarios offer less emissions reductions (3% and 5%, respectively). This is principally because the marginal source for added electricity demand is coal-fired generation, which has an adverse impact on the emissions of electric vehicles. The Hydrogen Vehicle Transition scenario produces 8% more emissions compared to BAU in 2035. Higher emissions for this scenario can be attributed to the process of hydrogen production from steam methane reforming of natural gas.

REFERENCES

APERC (Asia Pacific Energy Research Centre) (2009), *APEC Energy Overview 2008*, Tokyo, Japan, www.ieej.or.jp/aperc

Global Insight (2012), *World Industry Services*, retrieved from IHS Global Insight Data Service.

Government of Viet Nam (2008), *The Atomic Energy Law*.

GSO (General Statistics Office of Vietnam) (2009), *Statistical Yearbook of Vietnam*, www.gso.gov.vn

— (2011), "Initial report on rural survey in Viet Nam", December 2011 (in Vietnamese), www.gso.gov.vn/default.aspx?tabid=382&idmid=2&ItemID=12127

IEA (International Energy Agency) (2011), *World Energy Statistics 2011*, retrieved from OECD/IEA CD-ROM Service.

MOIT (Ministry of Industry and Trade, Viet Nam) (2008), "Decision 18/2008/QD-BCT on Regulation on avoided cost electricity tariff schedule and standard power purchase agreement, 18/07/2008".

MOIT and IE (Ministry of Industry and Trade, and Institute of Energy, Viet Nam) (2005, 2009), "The Pre-Feasibility Study on 1st Nuclear Power Plant in Vietnam" (2005 version and updated version in 2009).

— (2011), "Master Plan on Power Development (PDP7)".

MOIT and JICA (Ministry of Industry and Trade, and Japan International Cooperation Agency, Viet Nam) (2008), "The Study on National Energy Master Plan in Vietnam".

MOIT and Vinacomin (Ministry of Industry and Trade, and Vinacomin) (2008), "Strategy on Coal Development for Vietnam in Period 2008–2015 with expectation to 2025".

MOST (Ministry of Science and Technology, Viet Nam) (2006), "Strategy for utilization of atomic energy for peace in Viet Nam".

Petrovietnam (2012), www.pvn.com.vn

PMVN (The Prime Minister of Viet Nam) (2006a), Decision 26/2006/QD-TTg on "Approving the development of a competitive electricity market", 26 January 2006.

— (2006b), Decision 79/2006/QD-TTG on approval of "National Energy Efficiency Program 2006–2015".

— (2007), "Decision on National Energy Development Strategy of Vietnam for the Period up to 2020 with Outlook to 2050 (EDS)", December 2007.

— (2011a), Decision 37/2011/QD-TTG on approval of "Mechanism for supporting wind power development".

— (2011b), "Report of the Prime Minister Nguyen Tan Dung to National Assembly", 20 August 2011, http://thutuong.chinhphu.vn/Home/Thu-tuong-Nguyen-Tan-Dung-bao-cao-Quoc-hoi-ve-kinh-texa-hoi/201110/12770.vgp

World Bank (2010), *Vietnam – Gas Sector Development Framework: Final report*, January 2010, http://documents.worldbank.org/curated/en/2010/01/12342721/vietnam-gas-sector-development-framework-final-report

Published by
Asia Pacific Energy Research Centre (APERC)
Institute of Energy Economics, Japan
Tokyo, JAPAN
E-mail: master@aperc.ieej.or.jp
Website: http://aperc.ieej.or.jp

Produced for
APEC Secretariat
35 Heng Mui Keng Terrace, Singapore 119616
Telephone: (65) 68 919 600
Fax: (65) 68 919 690
E-mail: info@apec.org
Website: www.apec.org

APEC# 213-RE-01.5 ISBN 978-4-931482-45-6