Asia-Pacific Economic Cooperation

Including New and Renewable Energy Technologies into Economy-Level Energy Models

Prepared by DecisionWare, Inc.,
an Affiliate of International Resources Group,
for Asia-Pacific Economic Cooperation (APEC)
September 30, 2002

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EXECUTIVE SUMMARY

Numerous Asia-Pacific Economic Cooperation (APEC) Member Economies turn to national-level energy–economic models to examine the potential role of evolving technologies and pressing policy issues related to the interactions between energy, the environment, and economic activity. Among the various models available to the APEC economies, the MARKAL model is used or is under development in no less than 15 of them. This puts MARKAL in a unique position of being able serve as a common analytic platform for examining issues of interest to the APEC Economies.

One issue increasingly discussed is the potential role that renewable energy can play in promoting environmentally sensitive economic development. This role was highlighted at the World Summit on Sustainable Development (WSSD), where substantial discussions were undertaken about adopting policies to achieve a goal of 10% primary energy coming from renewable sources. While the WSSD did include a statement to "encourage diversification of fuel supply"—which would help to promote renewable energy technologies—no targets were set. While this study was planned a year before the WSSD, it shows how a consistent analytic framework can be used to assess the security, environmental, and economic implications that would arise from the establishment of renewable electricity generation goals in the form of minimum percent electricity generation from non-hydro renewable technologies in the participating APEC Member Economies.

The objective of this work was to enhance the energy-modeling capabilities in APEC Member Economies with respect to renewable energy technologies and to work with the participating Member Teams to perform case studies regarding the effects of different penetration rates of renewable technologies. The MARKAL modeling teams from Australia, China, Japan, and the United States agreed to participate in the study, and the first step in the work involved reviewing each country model to assess its suitability in regard to the study's objectives. All four Member Economy models were found to be suitable for inclusion in the assessment.

As part of this effort, we built a generic database of renewable technology characterizations that may be used by other APEC member countries, as well as non-member economies. These tasks will enhance the detail on renewable and energy efficient technologies in the MARKAL framework and test various hypotheses about the effects of different penetration rates of renewable and energy efficient technologies on energy supply mix and energy consumption patterns in APEC member economies.

In the next step, we examined the characterization (technical performance and costs) of renewable electric-generating technologies currently used in the participating-Member MARKAL models. We also compiled the most recent information on the prospects for a host of renewable electric technologies available from the United States Department of Energy (US DOE). The DOE characterizations fell toward the optimistic end but were generally within the range of what was found in the various Member models. The renewable technology characterizations to be used in the assessment were then assembled into a database (APECR, see section 5.1), refined for local conditions in each of the Member Economies, and structured for being conveniently incorporated into the existing Member MARKAL models.

A series of scenarios looking to establish increasing percentages of electric generation from renewables were run, with and without modest reductions in future carbon dioxide (CO_2) emissions. Owing to the cost effectiveness of the APECR technologies (especially after 2020), some level of adoption of these technologies was seen even without imposing any renewable portfolio goals. Over the entire model period, the overall impact on the energy system of modest renewable targets was an initial increase in costs, but the cost impact was surprisingly small, as shown in Figure ES-1. In addition, MARKAL results with the APECR technology characterizations showed the following benefits to each of the Economies:

1. Improvement in long-term energy security, as characterized by lower energy imports;
2. Slight change in economic conditions, as characterized by modest increases in total system cost over the modeling horizon;
3. A lower cost of meeting any CO_2 reduction targets; and
4. Reduced environmental pollution—both in CO_2 and in local air pollutants.

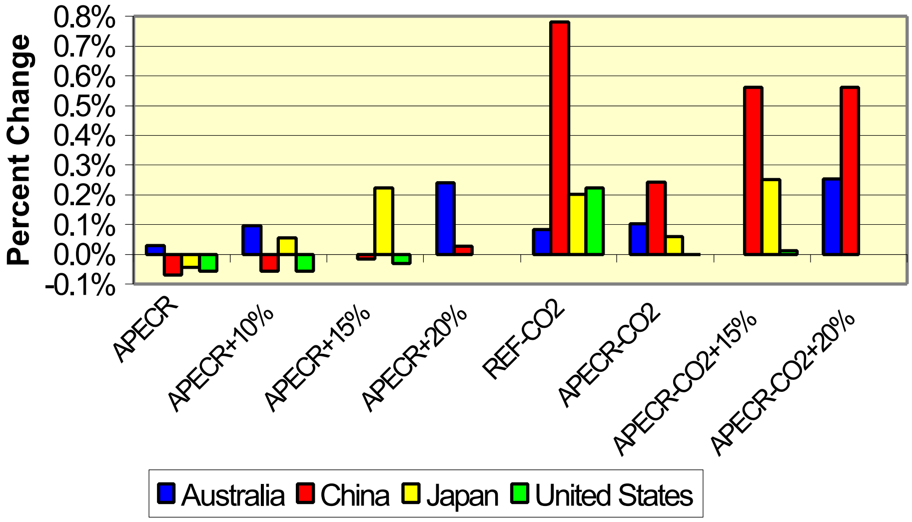

Figure ES-1. Change in Total System Cost

This assessment highlights the potential role of renewable resources and energy technologies within selected APEC Economies and demonstrates the merits of using a common framework to examine APEC Member-Economy issues. However, as discussed in Section 6.6.2 Consideration for APEC Future Analyses, it represents only an initial foray into this area.

The APECR technology characterizations are available for other APEC Member Countries to utilize. The potential benefits to APEC leveraging the extensive coverage provided by the MARKAL models for analysis of possible policy options for APEC Member Economies deserve serious consideration.

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1.0 INTRODUCTION

1.1 Background

The increased use of renewable energy resources can contribute, both economically and socially, to the well being of the Economies included in the Asia-Pacific Economic Cooperation (APEC) region. Continued economic growth within the region will require satisfying the increasing demand for energy, both in urban and rural areas. However, the forecasted demand for energy, particularly electricity, cannot be met adequately through exclusive reliance on conventional sources. As an alternative, new and renewable energy technologies can augment current resources.[1] For example, China has successfully established a grid-connected wind electricity generation program. Similarly, Thailand and Malaysia have developed extensive freestanding biomass cogeneration projects. For the Thai sugar industry alone, over 700 megawatt electricity (MWe) have been developed. Although these successes are encouraging, renewables have failed to penetrate other markets as a result of various factors affecting the policy and planning environments.

The APEC Energy Working Group (EWG)/Expert Group on New and Renewable Energy Technologies (EGNRET, formerly the Expert Group on Technology Cooperation) was established by the EWG to promote and facilitate the expanded use of new and renewable energy, where cost effective. As part of this charge, the EWG established an initiative to examine "Modeling Renewable and Energy Efficient Technologies in APEC Member Countries – Including New and Renewable Energy Technologies in Economy-Level Energy Models." Building upon previous APEC studies of renewable technologies and economy-level energy modeling, the initiative examined the maximum cost-effective levels for new and renewable technologies using a consistent modeling framework.

To increase understanding of renewable energy sources and the methods required to include these options in the planning process, the initiative aimed to leverage off other work on the incorporation of renewables into the planning and policy formulation processes. One of these, the Asia Least-Cost Greenhouse Gas Emission Abatement Strategy (ALGAS) program, identified more than 70 projects in 11 Asian nations, most APEC Member Economies, which could be implemented to reduce greenhouse gas (GHG) emissions, many of which involve renewable energy technology deployment.[2]

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[1] For the purpose of this study, "new and renewable technologies" correspond to what is included among the APEC portfolio (e.g., not hydroelectricity).

[2] *Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS) Program Performed for the Asian Development Bank, Global Environment Facility, and the United Nations Development Program* by Alternative Energy Development, Inc. (now a Division of International Resources Group). ISBN #971-561-186-9, ADB published in Manila, The Philippines, September 1998.

1.2 Modeling energy systems using MARKAL

A previous APEC study[3] concluded that MARKAL ranks as a top model for evaluating the penetration of renewable technologies in Member Economies.

MARKAL is a generic model tailored by the input data to represent the evolution over a period of usually 20 to 50 years of a specific energy-environment system at the national, regional, state or province, or community level. As shown in figure 1, the system is represented as a network, depicting all possible flows of energy from resource extraction, through energy transformation and end-use devices, to demand for useful energy services. Each link in the network is characterized by a set of technical coefficients (e.g., capacity, efficiency), environmental emission coefficients (e.g., CO_2, sulfuric acid [SO_x], nitrous oxides [NO_x]), and economic coefficients (e.g., capital costs, date of commercialization). Many such energy networks or Reference Energy Systems (RES) are feasible for each time period. MARKAL finds the "best" RES for each time period by selecting the set of options that minimizes total system cost over the entire planning horizon.

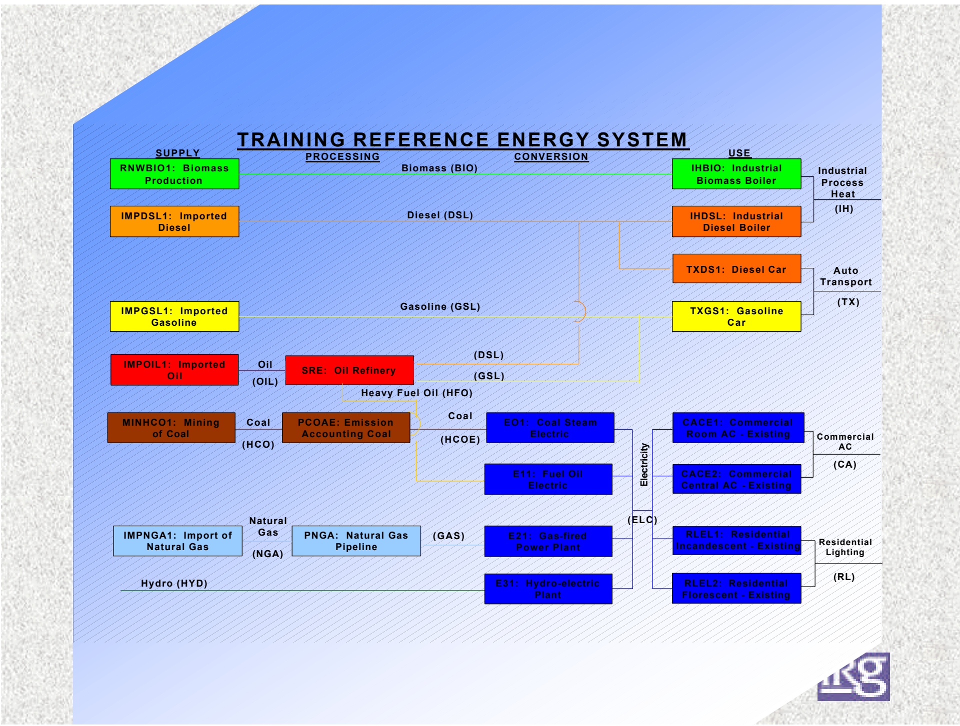

Figure 1. Simplified Reference Energy System (RES)

The MARKAL family of models is among the most widely used tools in energy–environmental analysis. Current users of the model total more than **90 institutions in some 40 countries**. Because of its flexibility, the model has been applied for local energy planning (at the municipality/utility/state levels), as well as for policy analysis at the regional, national, and global

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[3] *Development of Analytic Methodologies to Incorporate Renewable Energy in Domestic Energy and Economic Planning,* Duangjai Intarapravich, APEC Secretariat, Report # 99-RE-01.2, Singapore, October 1999.

levels. The directly comparable results produced by the model allow multi-national analysis for international cooperation. Some uses of MARKAL include:

- Identifying least-cost energy systems and investment strategies;
- Identifying cost-effective responses to restrictions on environmental emissions and wastes under the conditions of sustained development;
- Evaluating new technologies and priorities for research and development (R&D);
- Evaluating the effects of regulations, taxes, and subsidies;
- Establishing baselines and evaluating additionality issues and assessing project impacts ([GHG savings) in the context of Kyoto Protocol joint implementation (JI), Clean Development Mechanism (CDM), and emissions trading (ET) opportunities, and
- Determining the value of regional and international cooperation.

To facilitate the use of the model, a user-friendly data handling and analysis system, ANSWER, is employed. ANSWER oversees all aspect of working with the model—data preparation, RES network diagramming, scenario management, submitting model runs, and reviewing the model results. Figure 2 shows some of these capabilities.

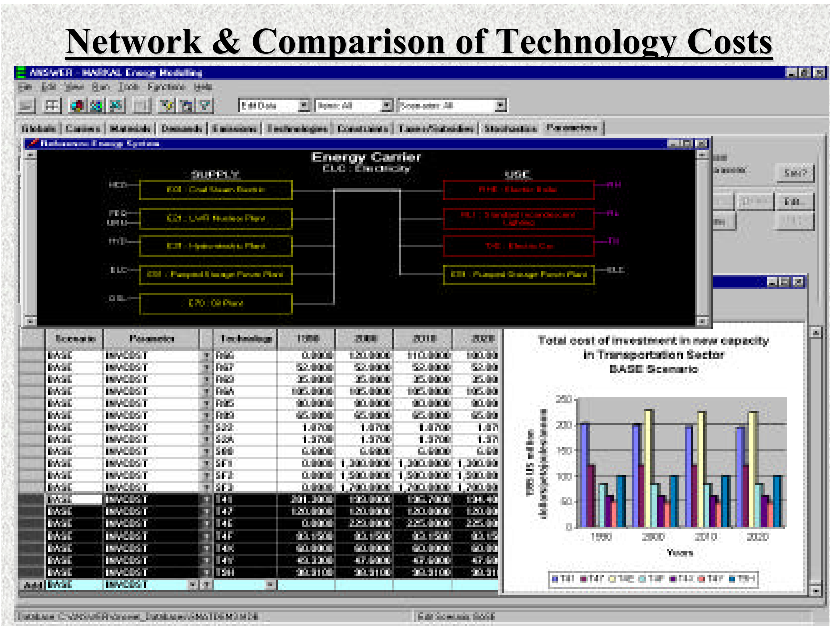

Figure 2. ANSWER Data Handling, RES Diagramming and Analysis Graphics

As MARKAL can be used to determine the impact on total energy system costs, changes in energy intensity economy wide and for the electrical system, changes in emissions levels, price of electricity and meeting demands, and changes in other characteristics of the energy system resulting from the implementation of renewable technologies, it is well suited for the APEC assessment. Since MARKAL models the entire energy system, it can capture the benefits arising from renewables penetrating the electric generation sector while freeing up conventional commercial energy sources for other uses. These characteristics can be determined for existing commercial renewable and energy efficient technologies, as well as for those under development.

2.0 PROJECT ORGANIZATION

Project organization consisted of a Project Team and Member Teams from each of the APEC Member Economies that participated. The Project Team was charged with coordinating all activities and providing the common framework for conducting and comparing the various project activities. This included templates for the current renewable characterizations in the participating nation models, a database with best available information on costs and performance of new and renewable technologies used for the assessment, defining the scenario and procedures for conducting the assessment, and providing templates for gathering the results and summaries.

The Project Team was complemented by Member Teams—MARKAL experts who steward the models of the participating APEC Member Economies. These individuals are responsible for and fully familiar with the Member Economy models, so their involvement was central to project success.

2.1 Member involvement with the MARKAL model

MARKAL models have been implemented previously in a number of APEC Member Economies. Many of the developing Economies in the region received model development support from the US Country Study Program (USCS), the ALGAS program, and the Australian Agency for International Development (AUSAID) Association of South Eastern Asian Nations (ASEAN) GHG mitigation project. Many of the Organization for Economic Cooperation and Development (OECD) APEC members (including the US, Canada, Japan, South Korea, New Zealand and Australia) have developed MARKAL infrastructure independently.

Table 1. APEC Member Economies and MARKAL Capabilities

Economy-level MARKAL models	MARKAL models under development	No MARKAL Models
Australia	Malaysia	Brunei Darussalam
Canada	New Zealand	Chile
China	Thailand	Papua New Guinea
Hong Kong, China	Viet Nam	Peru
Indonesia		The Russian Federation
Japan		Singapore
Korea		
Mexico		
Philippines		
Chinese Taipei		
United States		

Table 1 indicates that, of the 21 APEC Member Economies, more than two-thirds (15) have or are developing Economy-level MARKAL models. In addition, several cities and provinces in China (including Shanghai and Hong Kong, Guangzhou) have developed local energy planning frame-works using MARKAL. A number of China's other major municipalities and provinces have expressed strong interest in similar undertakings. With this established network of users and Member Economy models, improved renewables and energy efficient technology characterizations should enhance the energy system planning activities currently in progress in the APEC region. However, the lack of information on the technological and economic performance of these technologies, along with many MARKAL users being unfamiliar with how to appropriately incorporate these energy technologies into the framework, have led to renewable and energy efficient technologies often being underrepresented in planning efforts.

2.2 Guiding the project

MARKAL plays a prominent planning role in 15 APEC Member Economies. Thus, APEC selected DecisionWare, Inc., the company charged by the International Energy Agency (IEA) Energy Technology Systems Analysis Programme (ETSAP) with the global responsibility for the continued development and support of the MARKAL family of models, to perform the core activities and guide the project. DecisionWare, with its in-depth familiarity with MARKAL and global reputation, is affiliated with International Resources Group, a leader in renewable energy technologies. DecisionWare's relationship with the MARKAL modeling teams in the various APEC economies proved quite valuable during the recruiting of members' economies for participation in the undertaking.

2.3 Team activities and responsibilities

Table 2 describes the basic activities and responsibilities charged to the Project and Member Teams.

Table 2. Project and Member Team Tasks, Activities, and Deliverables

Task	Project Team		Member Team	
	Activity	**Deliverable**	**Activity**	**Deliverable**
Assess existing MARKAL models in APEC Member Economies and select four economies for inclusion in the study (see Sections 3 and 4)	Invitation letter soliciting expressions of interest to participate sent to Member APEC Coordinators and MARKAL host institutions A letter elaborating the guidelines for the review and the conditions imposed upon the Project team with respect to the use of the databases Review individual Member Economy models provided by the Member Teams Prepare a template for elaborating and evaluating the renewable technologies currently in Member databases Submit recommendation to APEC as to the countries to be considered for inclusion in the project. Inform the Member teams of their selection or not Contract with the selected Member teams for their contribution to the project, where necessary	Memo summarizing the review of the individual models and recommending involvement or not in the project Memo summarizing the current status of the existing technologies in the APEC Member databases Provide an overview of the new and renewable technologies in the APEC economy databases (Section 4.1.3 and Annex 2)	Provide a current production database for review and evaluation by the Project Team.[4] Respond fully to technical questions put forth as part of preparing the Model Review memo provided for APEC (provided previously), and any other detailed questions about the database that may arise	Provide their existing renewable technologies in a spreadsheet format distributed by the Project Team Return signed contract, where appropriate Supporting documentation, as requested by the Project team. Timely response via email when technical issues arise requiring clarification

[4] Note that only the China, US, and Indonesia models (the latter ultimately not participating in the project) were submitted to the Project Team for review. When Australia, Japan, and the US elected to participate, the supporting documentation as to official use was taken as an indication that the models met the basic criteria for inclusion in the project.

Task	Project Team		Member Team	
	Activity	Deliverable	Activity	Deliverable
Find the best available data on renewable energy technologies	Develop the APECR technology characterizations, organize into a transparent database, and write the procedures for incorporating it into Member models	Distribute the proposed APEC database of new and renewable technologies to the Member teams, along with Guidelines for including said technologies in their models	Review and refinement of the new and renewable technology characterizations developed by the Project Team	
Work with the selected Economies to include the APECR technologies in their MARKAL models (see Section 5)	Guide the inclusion of the APECR import and integration process by responding to Member Team inquiries	Distribute the final APEC database of new and renewable technologies to the Member teams, along with Guidelines for including said technologies in their models (Section 5 and Annex 3)	Augment the APECR technology characterizations for country specific circumstances/adjustments Inclusion of the new and renewable technology characterizations, along with any necessary RES adjustments, into the country model. Development of biomass supply curves for country-relevant biomass feed stocks, including the potential for energy crop, if time permits.	Working model incorporating the APECR technologies as alternatives to those originally in the Member models.
Develop case studies and assess the maximum cost-effective implementation of new and renewable energy technologies in each the Economies (see Section 6)	Develop assessment guidelines and templates for compiling the results. Oversee Member Team assessment activities Review of the results submitted from each Member Team	Provide the scenario guidelines and results templates to the Member Teams	Development of scenarios for evaluating the potential penetration of renewable energy technologies, and analysis of the preliminary runs, including interpretation of model behavior with respect to the new technologies. In parallel with the Project Team conduct the assessment, exchanging observations and recommendations	Timely and detailed comments to support incorporation of the renewable technology characterizations, the development of scenarios, and conducting the analysis Complete the results templates provided by the Project Team and provide a summary of said results

Task	Project Team		Member Team	
	Activity	Deliverable	Activity	Deliverable
Prepare a presentation of the results of the study to be given to APEC members	Prepare a presentation summarizing the results and submit to Member Teams for review Prepare a short MARKAL tutorial as well	Presentation of results at a venue designated by APEC	Provide comments on the presentation	
Provide a final report summarizing the findings of the assessment to the APEC Energy Working Group	Compile the project materials and results of the assessment and prepare a summary and the final report. (Section 6 and Annex 4)	Submit final report to APEC	Review and comment on the draft evaluation of the results of the model runs prepared by the Project Team. Review and comment on the draft and final reports as prepared by the Project Team.	Timely review and comment on the write-up of the results.

3.0 SELECTION OF PARTICIPATING MEMBER ECONOMIES

The project's effectiveness lay partly in involving an adequate number of Member Economies that had, or were developing, consistent modeling framework to examine modeling renewable and energy efficient technologies. In this case, MARKAL became the standard, since the MARKAL family of models can be used to examine the maximum cost-effective levels for new and renewable technologies and was already widely employed throughout the region.

The MARKAL Project Team sent an initial invitation to the APEC coordinators and MARKAL hosts of five Member Economies with sufficiently mature MARKAL models. Of these, only China and the United States opted to take part in the initiative; Indonesia, Mexico, and Philippines could not fully engage at this time owing to other commitments that limited the availability of the key people or the developing nature of the current model database. The Project Team then approached Japan and Australia, who agreed to participate. Thus, along with China, the Member Teams included three other institutions—the Australia Bureau for Agriculture and Resource Economics (ABARE); the Japan Atomic Energy Research Institute (JAERI); and, for the United States, Brookhaven National Laboratory (BNL)—that have for many years been involved with the MARKAL model for their governments and happen to be also very active in ETSAP.

Member Team Selection Criteria

- A working, calibrated MARKAL model
- The database, along with a summary of the most recent model sector update and a reference to the most recent database use
- Thorough documentation on the source of the data used in the model (e.g., government reports, utility documents, etc.) [Important]
- A track record on the use of the model within the country for official and/or academic purposes [Strength]
- The degree of coverage of the energy sector and the richness of the technology characterizations depicted in the database
- Country experience with and knowledge of MARKAL, as demonstrated by response to questions during the evaluation process

All four participating Member Economies had highly experienced MARKAL teams that completed the study and took an active role from the outset. It should be noted that the Australia, Japan, and US Member teams contributed in-kind resources to participate in the project. China was provided a modest stipend from the project budget.

4.0 REVIEW OF EXISTING MARKAL MEMBER ECONOMY MODELS

Defining the assessment context required examining and summarizing the nature and breadth of existing MARKAL models. This consisted of two main activities. For the first, the Project Team provided a series of templates to the Member Teams, who then completed summary reports on their models. (These tables are described later in this section.) The Renewable Energy (RE) Existing Tech Data spreadsheet (Annex 2) resulted from this activity and provides details of each member's MARKAL model and the depiction of renewable energy technologies (other than hydro).

4.1 Summary of model characteristics

This section reports the principal characteristics of the APEC-member national MARKAL models that are participating in the project. For each Member Economy, the Member Team MARKAL directly provided the information, presented side-by-side in the following tables, for each of the four Member Economies.

- Table 3 compares the general model parameters such as units, analysis period, regionality, demand representation, and quality control.
- Table 4 provides an overview of the model's basic structure and component and indicates the number of energy carriers, demand sectors, the nature of the resource supply representation, and the number of technologies by class.
- Table 5 gives a brief overview of how renewables are handled in the current model.
- Table 6 provides insight into the behavior of the reference model to which the APEC renewables will be introduced.

4.1.1 Overview of Member Economy models

Table 3 provides an overview of the global parameters used in the model. All the models use Petajoules (PJ) for the standard energy unit, PJ/a for capacity outside the power sector, and Gigawatts (GW) for capacity within the power sector. However, for some demands employ different units. Each of the models are in convenient monetary units, but will all be converted to a common unit (e.g., US$1995) using purchasing power parity information provided by the Member Teams.

Each model employs a prevailing social discount rate. For the purpose of this study, the original discount rates will be used, as these most likely best represent the situation in each economy. The seasonal representation used in each model is obviously member specific.

The models run from 1990 to 2050, but with some only starting in 1995 and one ending in 2040. Thus, while the individual Member Teams will run their models for the full horizon depicted in each model, this study only reports results for the period 2000 to 2040.

All the models have “clean” quality control reports, indicating that they properly conform to what MARKAL expects in terms of attributes and parameters used to describe the energy system, to the extent to which the quality control routine can assure.

Table 3. General Model Characteristics

	Australia	China	Japan	United States
Units				
Energy	PJ	PJ	PJ	PJ
Renewable Energy	PJ	PJ	PJ	PJ
Capacity	PJ/a, GW	PJ/a, GW	PJ/a, GW	PJ/a, GW
Demands	PJ, except for transport (000 pass. Km; '000 tonne km)	PJ for all except five major industries (steel, cement, ammonia, aluminum and paper) and transportation. Activity levels defined for those sectors.	Million tons for steel, cement, pulp, and paper. PJ for other industries, residential and commercial sectors. Billion passenger-km or billion ton-km for transportation.	PJ for all e industries. Lighting in Billion lumen-second, heating/cooling PJ, Billion vehicle miles traveled (VMT) for highway transport (passenger and truck), Billion passenger miles traveled (PMT) for air travel, most rest PJ.
Emissions	Million tonne	Thousand tons	Thousand tons	Million tons CO2, thousand tons other
Monetary Convert to1995 M$US (multiplier)	2000 $A 0.5751	1995 Million US$ 1	1995 Billion Japanese yen 0.0058824	1999 Million US$ 0.9346
Discount Year	2000	1995	1990	1995
Discount Rate	8 %	10%	5%	5%
Modeling Periods; Length	2000–40; 5 years/period	1995–2050; 5 years/period	1990–2050; 5 years/period	1995–2050; 5 years/period
Seasonal Shape	I-D 0.2778 I-N 0.1389 S-D 0.2222 S-N 0.1111 W-D 0.1667 W-N 0.0833 That is: day = 18 hours; intermediate = 5 months; summer = 4 months; winter = 3 months	I-D 0.2500 I-N 0.2500 S-D 0.1250 S-N 0.1250 W-D 0.1250 W-N 0.1250	I-D 0.2200 I-N 0.1960 S-D 0.1400 S-N 0.1120 W-D 0.1470 W-N 0.1850	I-D .25 I-N .25 S-D .125 S-N .125 W-D .125 W-N .125
Online Documentation	Little	Very little	None	Partial, being updated and expanded

	Australia	China	Japan	United States
Regionality	6 distinct regions—New South Wales (NSW), Victoria (Vic.), Queensland (Qld), Western Australia (WA), South Australia (SA), Tasmania (Tas). Exchanges of energy carriers: Gas pipelines numerous Electric grid Inter-connections (in both directions between N↔V; N↔S; N↔Q; V↔S; V↔T)	Single region model with no imports/exports of electricity and no net imports of coal.	Single region model with no imports/exports of electricity.	Four regional residential heating/cooling sectors
Demand Representation	Industrial, Commercial, Residential—mostly regionally disaggregated across 6 States Transportation—not regionally disaggregated, but road passenger transport is disaggregated between metropolitan and non- metropolitan Many fuel options for most demands	Industrial, Commercial, Urban and Rural Residential, Transportation and Agriculture Five major industries and transportation use activity levels Other industries, along with Commercial, Residential and Agriculture use final energy Many fuel options for most demands	Industries are divided into steel, cement, pulp, paper, glass, chemicals, and others. They are subdivided into motor, boiler, furnaces. Both residential sector and commercial sector have sub-sectors; lighting and appliances, space heating, water heating, air conditioning. Transportation sector is split into railways, automobiles, air, and ship. New fuel or technology options are included for many demands.	Industries are divided into steel, aluminum, process heat, process steam, mechanical drive, feedstock. Both residential sector for heating/cooling by region and single/multi-family building type, lighting, water heating, refrigeration, appliances. Commercial sector heating/cooling, lighting, water heating, office equipment, appliances. Transportation sector is split into rail, light-duty vehicles, light trucks, heavy trucks, bus, air, and ship. New fuel or technology options are included for many demands.

	Australia	China	Japan	United States
Quality of adhering to general modeling principles	Overall very good. Quality control log shows no violations.	Overall very good Quality control log shows a few reminders and warnings that can be easily resolved Vintaging assumed based on average group improvement for classes of technologies Order of magnitude: 10^4 All demands range from 1.8 to 16,150	Overall very good Quality control log shows some warnings most of which relate with modeling of wastes or recovered energy carriers Order of magnitude: 10^4 All demands range from 0.8 to 3807	Overall very good Quality control log shows only minor warnings which are not a problem Heavy use of vintaging for all groups of improvement for classes of technologies. Order of magnitude: Range from 10 to 10,000, with the exception of commercial lighting 100,000 (to be rescaled)

4.1.2 Overview of energy system modeled in each Member Economy

Table 4 summarizes the energy system characterization for each model by describing the energy carriers, emission indicators, resource options, conversion and process technology options, and demand devices.

All the models contain a wide range of energy carriers, with the Australian model being particularly diverse owing to its multi-region structure. In the US model, particular attention is paid to the sulphur content of the coal. In terms of supplying basic energy into the system, the Australian and US models have a rather robust set of resource supply curves, while the China model has very limited supply curves, and the Japanese model relies on imports.

Emission tracking is done in all the models at the technology level, which permits sector levels and fuel totals to be easily derived. The China and US models track both CO_2 and local air pollutants, while the others only monitor CO_2 emissions.

The Japanese model has approximately half as many power plant options in as the others, and, in the Australian model, the typical 47 options in each region are similar to the number in China and the US, although the total is six times that to cover all regions. In the Australian model, electric transmission options between the various regions are permitted, when appropriate. All the models have only a limited number of coupled heat and power plants (about 4, not taking into consideration regionalization of the Australia model). The Australian model has no heating plants, while the Japanese model employs over a dozen (mostly nuclear).

The Australian model has a rather sophisticated refinery representation, while the others have, at most, two-stage refineries depicted. The Australian model also has a quite detailed natural gas representation, including pipelines between the various regions.

The demand representation in the models is quite similar at the sector level, with the Japanese model more robust in the industrial sectors than the others. The device level shows a wide variation in the number of options, with the Australian and US models employing +500 technologies, while the China and Japanese models make available 100 and 150 demand devices, respectively. However, much of the bulk in the Australian and US model can be attributed to their full and partial (residential heating and cooling) regionalization.

Table 4. Overview of Model Data by Energy System Component

	Australia	China	Japan	United States
Energy Carriers	Electricity: (NSW, Vic, Qld, S.A., W.A., Tas.) Coal - black coal, brown coal, lignite, briquettes), coke Biomass - firewood, non-crop biomass used in electricity generation, biomass for ethanol production, energy crops, crop residues, crop residues for methanol; oil seeds for diesel production, Ethanol, methanol Crude oil (imports; domestic); Petroleum Products - Alkylate, butanes, cracker feed, condensate, catalytic gasoline, isomerate from refinery, LPG, refinery fuel, heavy distillate, light distillate, straight run naphtha, gasoline (leaded) kero (heating oil; jet fuel); lube base stocks; gasoline (unleaded); catalytic reformate; shale synthetic (syn)crude; hydrogenation syncrude Shale oil Low temperature heat Natural gas; compressed natural gas Process heat: biomass-based (NSW;SA; WA; Tas; Vic); Solar, wind, hydroelectric; Energy conservation (dummy); home insulation (dummy);	Electricity Heat – two types: low temp directly produced and as by-product of electric production, and high-temp modeled as by-product of electric production Coal – raw and washed; tracked to different demand sectors Coke –2 supply steps, then direct use Coal gas, liquids Coal Bed Methane – 2 sources Natural Gas – good, rather detailed distribution network Liquified petroleum gas (LPG)/Dimethyl ether(DME) Crude Oil – 2 refineries: one fixed refinery and one limit Diesel, gasoline, kerosene Ethanol and Methanol Hydrogen Biomass – Ag residues, firewood and biogas Hydro, geothermal, wind, solar Uranium Other – non-energy products (lubricants & feedstocks) Conservation – 5 carriers	Electricity Heat – low temp, medium temp, high temp, waste heat of several types Coal – steam coal, coking coal, and coal for oversee liquefaction; coke, coke oven gas, synthetic gas from gasification process, liquids Natural Gas – domestic gas and liquefied natural gas (LNG) with low price and high price Crude Oil – flexible outputs with hydro-cracking of heavy distillates Petroleum Products – LPG, gasoline, naphtha, kerosene, diesel, and heavy Town gas Synthetic Fuel – hydrogen, methanol, synthetic gasoline Renewables – hydro, geothermal, wind, solar, biomass Nuclear – uranium, plutonium, nuclear fuel Wastes – pulp waste, iron & steel off-gas, municipal waste, municipal waste heat Others – conservation, lubricant	Electricity Heat – low temp, high temp Coal – by heat con tent and sulphur, plus coking coal Coal Products – coke, coke oven gas, synthetic gas from gasification process, liquids Natural Gas – detail supply curve for all domestic and import options Crude Oil – detail supply curve for all domestic and import options. Flexible refineries with secondary cracking Petroleum Products – LPG, gasoline, naphtha, kerosene, diesel, jet fuel, and heavy Synthetic Fuel – hydrogen, alcohol-based Renewables – hydro, geothermal, wind, solar, biomass Nuclear – uranium, plutonium, nuclear fuel Wastes –municipal waste Others – conservation by sector

	Australia	China	Japan	United States
Emission Indicators	CO_2 Emission coefficients are attributed to technology in which combustion occurs (not the resource)	CO_2, NO_x, SO_2, PM_{10} CO_2 tracked by resource, and modified for sequestering technologies; Others tracked at sector and technology levels	CO_2 only. Tracked both by resource and at sector and technology levels	CO_2, NO_x, SO_2, PM_{10}, VOC All tracked by sector and technology levels
Resource Supply Options, by type and energy carrier	By primary energy carrier, and indication of Mining (MIN) – brown coal (Vic); lignite (SA); Black coal ((NSW, Qld 4 cost categories in each case), WA, Tas); crude oil (existing and undiscovered); condensates; shale oil mining; LPG; natural gas (by 9 Basins 4 of which are split by commercial / undeveloped-undiscovered) Imports (IMP) – crude oil; natural gas (Papua & New Guinea) Exports (EXP) – two black coal (NSW & Qld) with fixed bounds; LNG (NW Shelf); LPG (Gippsland and Cooper Basin) Renewable (RNW) – 10 categories— most inputs to electricity generation + 3 for biofuels (biomass for ethanol, methanol, oil seeds for biodiesel)	By primary energy carrier, and indication of MIN – coal, natural gas, and uranium = 1 supply step each; oil = 2 steps (normal and EOR); CBM = 2 steps (normal and CO_2 enhanced) IMP – refined oil products (gasoline, diesel and kerosene), LPG, natural gas and crude oil EXP – only coal, and with upper bound RNW – 17; see below	By primary energy carrier, and indication of MIN – coal, natural gas, and oil IMP – coal (stream coal, coking coal, and for oversea liquefaction), crude oil, refined oil products (LPG, gasoline, naphtha, kerosene, diesel and heavy), LNG, natural uranium EXP – none RNW – 17; see below	By primary energy carrier, and indication of MIN – coal, natural gas, oil, natural gas liquids; each with detailed supply/cost step curves with typically 14 steps IMP – coking coal, oil, petroleum products, natural gas, LNG, electricity EXP – coal, petroleum products RNW – 17; see below

	Australia	China	Japan	United States
Power-sector – Electric Power Plants (ELE)	211 electricity generation technologies + 14 interstate transmissions links, for example, NSW has 47 such technologies of which: 23 are fossil fuel; 24 are renewable; 11 are existing (ie installed or expanded), 35 are new (ie not yet installed ands with different characteristics from existing technologies) and 1 is refurbished. Black coal is the major base-load fuel in NSW and Qld; brown coal in Victoria. SA and WA use lignite and black coal (respectively) and natural gas in existing base-load stations. Tasmania is hydro. NSW and Vic rely on hydro for emergency and peak load supplies. Ample gas supplies are available in all states (or in Tasmania potentially so) for future electricity supply base-load or otherwise and technologies are included in the database accordingly. The database has a wide variety of traditional and new renewable electricity supply technologies	Total = 44 11 Coal Combustion 13 Coal Gasification/ Polygeneration 2 Oil 5 Natural Gas 1 Nuclear 2 Hydro 1 Geothermal 5 Biomass 2 Solar photovoltaic (PV) 2 Wind	Total = 26 3 Coal Combustion 5 Oil (incl. re-powering) 4 Natural Gas (incl. re-powering) 3 Nuclear 1 Hydro 2 Geothermal 2 Solar PV 1 Wind 4 Others (wastes)	Total = 55 8 Coal Combustion 3 Coal Gasification 3 Oil 11 Natural Gas 5 Nuclear 2 Hydro 3 Geothermal 3 Biomass 4 Solar 9 Wind 4 Syn fuel (e.g., hydrogen, methanol)
Power-sector – Coupled Heat and Power (CPD)	5 biomass (bagasse) based cogeneration (2 NSW; 3 Qld) 12 natural gas based cogeneration (2 each in all states)	1 Biomass 2 Coal combustion 1 Natural Gas Fuel Cell 1 Hydrogen Fuel Cell	1 Conventional gas 2 Natural Gas Fuel Cell	2 Gas 1 Coal 1 Oil 1 biomass 1 Syn fuel
Power-sector – Heating Plants (HPL)		2 coal combustion	1 Conventional gas 1 Geothermal 11 Nuclear heat	1 Gas 1 geothermal 1 Coal

	Australia	China	Japan	United States
Non power-sector	Oil refining (described by 32 process technologies) Natural gas pipelines (currently 45 including variants such as: existing, existing + compression, new, new + compression) Natural gas processing (8 technologies, one for each basin) Natural gas top methanol (2 technologies) Compressed natural gas production (3 natural gas sources) Black coal washing (one technology) Syngas from black coal (3 technologies) Shale oil to syncrude Coke ovens (one technology) Brown coal products (4 technologies) Liquid biomass fuel production (7 technologies: 2 methanol feedstocks, 1 biodiesel from oil seeds, 4 ethanol from sucrose or starch feedstocks of progressively increasing unit cost) Methanol processed to gasoline Blending of biomass fuel with gasoline (methanol and ethanol)	4 Biomass (2 liquid & 2 gas) 1 Coal Washing 1 Coke Making 6 Coal to Liquid Fuels 4 Coal to Synthesis Gas and hydrogen (H_2) 4 Natural Gas to Liquid Fuel 2 Natural Gas to H_2 2 Oil Refineries Multiple dummy/accounting processes	Oil refineries = 8 Coke oven Coal gasification = 2 Coal liquefaction = 5 LNG = 4 Biomass alcohol Nuclear fuel cycle = 6 CO2 recovery and disposal = 3 Delivery of fuel = 19	1 Coke Making 3 Coal to alcohol, Gasoline 2 Coal to Synthesis Gas (high/low BTU) 1 Coal to H_2 1 Natural Gas to H_2 2 Biomass to liquids 3 biomass to gas MSW to gas 2 Oil Refineries 3-stage gas pipelines (main, distribution and delivery) numerous emission reduction options Multiple dummy/accounting processes
Demand Sectors	Industrial - 7 (37 including regionalized) Transportation - 9 (except for electric vehicles not regionalized) Commercial - 6 (14 including regionalized) Non-energy - 3 General with fixed “fuel” shares (6 including regionalized) Residential - 11 (39 including regionalized)	Industrial – 8 Commercial - 3 Urban Residential - 4 Rural Residential - 3 Transportation – 10 (5 passenger and 5 freight) Agriculture - 4	Industry = 18 Commercial = 4 Residential = 4 Transportation = 12	Agriculture - 1 Commercial - 7 Industrial – 6 Petrochemicals - 1 Residential – 20 (some regionalized) Transportation – 8

	Australia	China	Japan	United States
Demand devices	Industrial in each region 134 technologies Residential in each region 286 technologies Commercial in each region 70 technologies Non-Energy in each region 6 technologies Transportation 105 technologies urban and non-urban road passenger (cars and buses) light coml., light truck, heavy truck aircraft, shipping, heavy mobile (agr., minerals, construction) rail Total technologies all regions = 599	16 Industrial Processes 4 Other Industry Process Heat 1 Other Industry Electric 1 Other Industry Non-Fuel 6 Commercial Space Heat 6 Commercial Air Conditioning 5 Urban Cooking & Water Heating 2 Urban Air Conditioning 7 Urban Space Heating 3 Lighting And Appliances 6 Rural Cooking & Water Heating 7 Rural Space Heat 4 Agricultural 12 Passenger Transport 8 Freight Transport	70 Industrial processes 11 Iron & steel 3 Cement 8 Glass 8 Pulp & paper 18 Chemicals 22 Other industries 15 Industrial conservation processes 25 Commercial devices 21 Residential devices 16 Domestic passenger transport. 10 Domestic freight transport. 5 International transportation	Agriculture - 2 Commercial - 58 Industrial – 24 Petrochemicals - 4 Residential - 334 Transportation – 97

4.1.3 Current renewable energy technology characterization in Member Economy models

Table 5 provides a preliminary assessment of the renewable energy technology characterization in each of the models, including renewable energy carriers, resource supply steps, conversion and process technology types, and demand devices. The actual data from each model associated with the power sector renewable technologies can be found in the RE Existing Technology Data_Part4.XLS spreadsheet (Annex 2).

Each of the models uses a similar set of renewable energy carriers. The biomass supply curve in the Australia model is handled by means of a set of electric technologies, while in the US a rather robust traditional supply step curve is represented. The other models have minimal biomass supply information at this time. Looking at the Australian model at the single-region level, with the exception of a robust set of wind options in the US, the two models are similar. The China and Japan models have more modest representations of power sector renewable technologies. The Australian model currently lacks any commercial solar options; otherwise, all the models permit solar water and photovoltaic (PV) at the demand locations.

As illustrative of the relationship of the APEC renewable technology characterizations used for the assessment, and those that existed in the model previously, figure 3, shows that the costs are right about in the middle of the range.

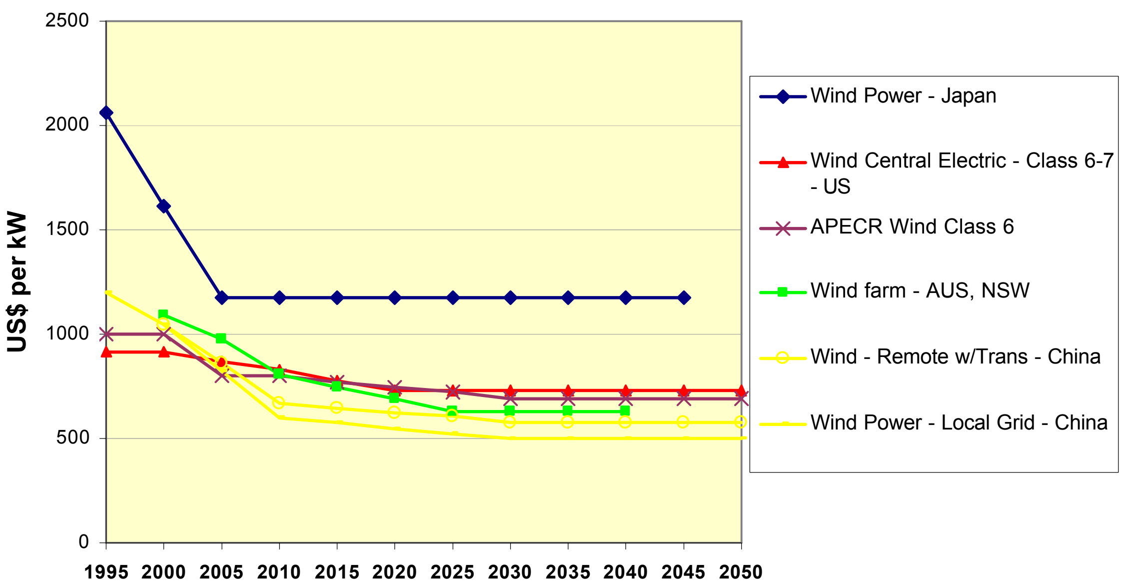

Figure 3. Wind Technology Investment Costs

As shown in figure 4, Capacity Factors revealed a more pronounced difference, with the APEC technology characterizations showing better performance than that typically used in the individual national models. Nevertheless, the APEC values do fall within the range currently in use.

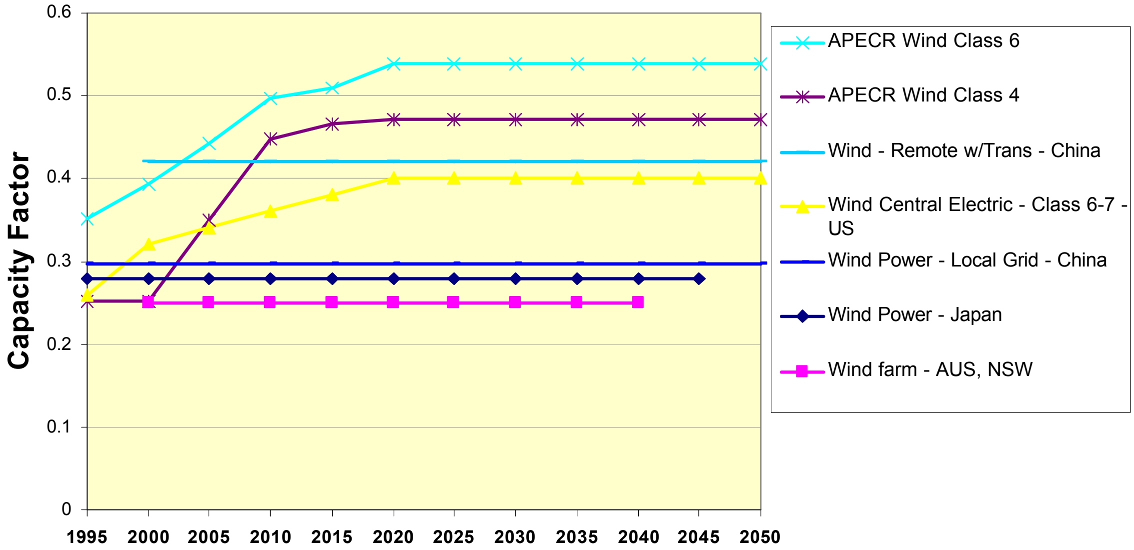

Figure 4. Wind Technology Capacity Factors

Table 5. Renewable Technology Representation

	Australia	China	Japan	United States
Number of renewable energy carriers	Electricity resources: both non-biomass (i.e., solar, wind) and biomass: (grain, crop residues, bagasse) are tracked by renewable energy carriers, but do not bear a cost which is instead incorporated in the cost of the electricity supply technology Other renewable resources are specified with unit costs: eg firewood (used by end-use sectors) and liquid fuel biomass resources (biomass for ethanol, methanol and biodiesel production).	Solar, wind and geothermal resources are not tracked by a renewable energy carrier, but they are tracked by technology. Two biomass resources: agricultural residues and firewood.	Hydro, solar, wind, geothermal are tracked by a renewable energy carrier. Biomass includes conventional domestic wood and imported wood.	Hydro, solar, wind, geothermal are tracked by a renewable energy carrier.
Number of biomass supply steps	Biomass-based electricity supply steps …	Each biomass resource has one supply step. Both resources have fixed upper bounds based on current estimates of available resource.	One	14 basic supply steps, plus MSW, and crops
Number of each type of renewable conversion technology				

	Australia	China	Japan	United States
Electric only	Total renewable electricity technologies in all 6 states is 86 Biomass (51 varying between 6 to 11 per state) Hydro (14 varying between 1-5) Solar (13 varying between 0-3) Wind (8 varying between 1-2) Tidal (1)	5 Biomass (3 utility scale, 2 village scale) 1 Geothermal 2 Hydro (small and large) 2 Solar (residential PV and central PV) 2 Wind (local grid and remote w/ long distance transmission	1 Hydro 2 Geothermal (low and high cost) 2 Solar (low and high cost) 1 Wind	2 Hydro (large scale and pumped storage) 3 Geothermal (liquid, flushed steam, binary cycle) 3 Biomass (MSW, gasification combined cycle, direct firing) 4 Solar (PV, central solar power[CSP]) 9 Wind (Class 4, 5, 6/7) 4 Syn fuel (e.g., hydrogen, methanol)
Coupled Heat & Power	Bagasse, wood	1 Biomass	none	none
Processes	none	3 Biomass	2 Biomass	2 Biomass to liquids 3 biomass to gas MSW to gas
Number of each type of renewable demand technology				
Industrial	none	none	none	biomass direct process steam
Transport	none	none	none	Hydrogen fuel cell Alcohol-based vehicles
Agriculture	none	none	1 Solar	none
Commercial	none	2 Solar (space heating and cooling both with gas backup)	2 Solar (for water heating and for multi-purpose)	2 Solar (for water heating, PV, space heating)
Residential (Urban for China)	Solar water heaters House insulation	3 Solar (water heating, cooling and space heating all with gas backup)	2 Solar (for water heating and for multi-purpose)	2 Solar (for water heating, PV) Wood for space heating

	Australia	China	Japan	United States
Rural Residential (China only)		4 Biomass (two cooking and two space heating) 3 Solar (one cooking with gas backup and two space heating with coal backup)		

4.2 Overview of current reference scenario (REF) results

This cursory summary of the Reference Scenario results offers insight, however limited, into the basic behavior of the models. This undertaking focuses more strongly on how the reference case responds to the introduction of the APEC renewable technologies options. Table 6 summarizes the model behavior, including the degree of calibration to existing data, the impact of resource bounds, energy carrier marginal cost behavior, and the current use of renewable energy technologies.

All these models have been carefully calibrated against official publications described the current energy system of each Member Economy. Thus, the energy demands, fuel supply mix, existing technology mix, emissions levels, and energy prices all replicate both the current situation and track anticipated near- to mid-term development paths.

With regard to the role of renewable technologies pertinent to this study, the following situations exist:

- In Australia, outside of hydro (which is not considered in this study), only some biomass options enter the reference solution. Note that the Australia MARKAL team has previously used their model to assess various mandated levels of electricity to come from renewable technologies, and those insights are incorporated into this assessment.

- In the China model, many of the currently available renewable technology options, other than central solar/wind and some biomass, are heavily used up to the limits on growth in the model. The costs and penetration level limits in the China model will be careful reviewed when setting up for the APEC assessment.

- Japan exhibits a mix of constrained (e.g., tradition biomass, solar water heating, wind), and unused (e.g., PV) renewable technologies. These limits will be careful reviewed when setting up the APEC assessment.

- In the US, wind Class 6/7 and MSW are used to their limits, while other technologies are floating (e.g., biomass, geothermal) or not used (e.g., solar).

With regard to overall model statistics, the China and Japan model are about the same size (<10,000 rows), as are the Australian and US models (~20,000 rows). This is not surprising owing to the full/partial regional representation in the latter two models, as well as the large number of emission reductions options available in the US model.

Table 6. Cursory Review of Reference Scenario Results

	Australia	China	Japan	United States
Roll of hard bounds				
Resource Options	Arbitrary upper or fixed limits are placed on exports of hard black coal (NSW and Qld), natural gas (LNG) and LPG Positively-sloped supply curves are specified for: NSW black coal Qld black coal	Coal exports are constrained by an at upper limit A minimum level of Oil import are maintained by a lower limit Mined resources have upper limits. Model wants more coal bed methane and natural gas Biomass use constrained by upper limits; model wants more	In the reference scenario where CO2 emissions are moderately controlled, imports of oil and coking coal are reduced substantially. Steam coal maintains its level of import, while use of natural gas expands much with time. Use of Nuclear and renewable energy increases significantly.	Supply curves smoothly selected as needed.
Smoothness of energy carrier marginals	Electricity prices generally (eg summer-day) quite smooth but increasing over time (with the exception of Tasmania which falls from a high price in the initial period); in the mandatory renewable target (RET) a minor peak occurs 2010	Generally quite smooth Some drops (up to factor of 2) for refined oil products after initial period	Generally smooth. In the 1st time period where demand and supply balances are strictly controlled with external constraints, prices of some energy carriers (gasoline, LPG, electricity, and so on) are very large.	Very smooth, with energy prices calibrated to AEO2002

	Australia	China	Japan	United States
Technologies	88 / 170 renewable electricity technologies have upper bounds on capacity; 28 have RESIDs and 5 (also) have lower bounds on capacity in the first period (2000) time dependent availability factors for PVs, solar thermal and pumped storage PEAK *fraction of capacity in peak load' varies	Most renewable energy technologies have a growth rate limit Nuclear lower bound reflects minimum political commitment Electric heating and cooling technologies forced into commercial sector Model would like more geothermal and large-scale wind	Technical changes are limited by external constraints until 2010. But after 2010, substantial changes allowed in electric power generation and in end-use sectors. This might cause unrealistic changes in the fuel mix of some end-use sectors. Model is conservative for the possibility of future drastic changes in the transportation fuel mix, but enough flexible for the changes of power generation technologies.	Technology choices calibrated nicely to AEO2002 based upon technology characterizations, not very constrained in this regard. Heavy use of investment growth rate limits based upon manufacturing capacity. Sectoral "hurdle rates" are used.
Degree calibrates to published statistics in the initial period(s)				
Primary Energy Use	Model data assumptions calibrated to 1999 data published in Projections of Australian Energy 1999 (ABARE)	Model output calibrated to 1995 data published in China Energy Statistical Yearbook	Model output calibrated to 1990, 1995, and 2000 data of Energy Balance Tables published by the Institute of Energy Economics, Japan.	Model is calibrated to AEO2002 demand services til 2020, by matching fuel use and technology choice.
Total Emissions	Base year CO_2 emissions in the model (363 mtonne CO_2) compare closely to latest available inventory data for 1999 energy sector emissions (365 mtonne CO_2)	1995 SO_2 emissions agree with 1995 data	69878 tons CO2 over the entire (65 years) modeling horizon.	CO2 emissions calibrated to AEO2002, air pollutants constrained to the levels mandated in the Clean Air Act
Final Energy Use	Model data assumptions calibrated to 1999 data published in Projections of Australian Energy 1999 (ABARE)	Model output calibrated to 1995 data published in China Energy Statistical Yearbook	Model output calibrated to 1990, 1995, and 2000 data of Energy Balance Tables published by the Institute of Energy Economics, Japan	Model is calibrated to AEO2002 demand services til 2020, by matching fuel use and technology choice.

	Australia	China	Japan	United States
Role of existing renewable technologies in the present Reference scenario	Biomass - bagasse sugar mills, municipal biomass and forestry biomass are each 3-4 percent. With the 2% target in place, bagasse increases to 13 percent and municipal biomass to 9 percent and wind to 4.5 percent. Hydro - in the absence of '2%' mandatory target conventional hydro share of renewable electricity technologies falls slightly to 88 percent of total renewable electricity by 2010 Solar - no significant role for solar thermal or PVs is suggested by MARKAL modeling in the absence of much stronger CO_2 abatement policy Wind - more recent data not yet incorporated in the database suggests a significantly stronger role for wind reflecting both 'green energy' policies and the target.	Biomass - traditional biomass used for cooking throughout analysis period, but used for space heat only in first half of period. Gasification-based electricity & DME production used up to the resource limit starting in 2010. Biomass firewood resource use drops to less than half of resource limit. Village biomass cooking gas systems not used. Ethanol from biomass not used.Biogas from digester used to technology limit for rural space heat Geothermal - used up to the resource limit Hydro (large & small) - used at the lower bound limit only Solar - solar (w/ gas backup) used for commercial space heating at the technology growth rate limit. Solar (w/ gas backup) used for urban space heating at the technology growth rate limit. Solar with coal backup used for rural space heat at technology growth rate. Central and distributed solar power plant not used Wind - local wind farm not used except for residual. Large, remote wind farm with long-distance transmission used at upper bound limit.	Biomass - traditional biomass use reduces with time following the upper limit. Alcohol conversion not used at all. Geothermal - low-cost geothermal used up to the limit, but high cost only after 2035. Hydro - used up to the limit. Solar - low-cost solar PV used substantially, but not up to the limit. Conventional solar water heating, both for residential and commercial use, used up to the limit. High cost solar PV and advanced solar system, both for residential and commercial use, not used at all. Wind - used up to the limit.	Biomass - supply used to 30% of potential available in the model. MSW used to its limit Geothermal - flash steam used, but with slack. Hydro -used to its current installed capacity with no new additions permitted. Solar - does not penetrate Wind - class 6/7 used to their limit

	Australia	China	Japan	United States
Model Statistics				
Equations	20,258	7,977	8,384	17,054
Variables	27,105	10,041	10,337	22,626
Non-zeros	192,550	63,525	60,432	159,753
Objective function value (Total discounted system cost)	1,821,100 (M$A2000)	2,877,412.55 (M$1995)	1,636,338.70 (B1995 yen)	136,838,866 (M$1999)

5.0 APEC RENEWABLE ENERGY TECHNOLOGY CHARACTERIZATIONS—DATABASE DESCRIPTION AND GUIDELINES FOR USE

5.1 Renewable technology characterization data sources

The data for the APEC renewable energy technology characterizations was developed from a US DOE/Electric Power Research Institute (EPRI) Topical Report 109496: *Renewable Energy Technology Characterizations*, published December 1997. Updates to this information were provided by Princeton Energy Research Institute (PERI) and National Renewable Energy Laboratory (NREL) and were based on internal DOE planning documents. For the rest of this document these technologies and the associated MARKAL dataset (scenario) are referred to as APECR.

An important aspect of the APECR data is that it reflects the role of technology evolution and learning expected to occur in renewable technologies over the next 50 years. This is accomplished by means of decreasing values for some of the cost parameters (e.g., investment cost) and improving values for some of the technical parameters (e.g., capacity factors, particularly as better associated storage technologies develop) characterizing the APECR technologies over time.

5.2 Corresponding renewable technologies in existing Member models

As part of gaining a fuller understanding of the current representation of renewables in the various economy models, each Member Team provided the characterization of those renewable technologies that correspond to those in the APECR scenario in a common Excel workbook format (see the Excel file, RE Existing Technology Data_Part4 in Annex 2). The Excel workbook is organized into three types of spreadsheets:

1. **Index sheet**—contains a list by renewable technologies by type for each Member Economy as hyperlinks that allow quick access to any particular set of the individual technology characterizations on the corresponding source data technology sheets.

2. **Source Data sheets**—are provided for each renewable group and contain the actual technology characterizations from the Member databases.

3. **Comparison Data sheets**—contain some comparison tables for investment costs and capacity factors for selected technologies to give a feel for how the characterizations vary and compare with the APECR values.

5.3 Overview of the APECR database

The APECR technology characterization database is organized in a workbook of spreadsheet templates that serve several purposes (see the Excel file, RE Technology Data_V10a in Annex 3). The templates provide the most recent information available in the US for cost and performance information on the group of renewable technologies contained in the database. Linked templates facilitate unit conversion and data transformation, allowing users to incorporate such technologies and move from the original source data to the form needed by their model. Further, for usefulness to individual MARKAL models, the data is collected and formatted for bulk loading into the ANSWER data handling system for MARKAL.

The Excel workbook is organized into seven types of spreadsheets. Each group of sheets is briefly described here:

1. **Index sheet**—contains hyperlinks to allow quick access to any particular set of the individual technology characterizations on the corresponding technology sheets. The technology sheets are organized by type of renewables.

2. **Source Data sheet**—contains the actual technology characterizations from the DOE/ERPI report and other sources.

3. **Units&Convert**—contains unit and conversion information that is applied to the Source Data to transform it into that required by a particular Member Team model.

4. **Capacity Factor (CF) & Peak Calc**—contains a worksheet to help modelers determine appropriate estimates of the capacity factor and peak contribution to be assigned to particular technologies based by local conditions. Instructions for using this tool are described in Section 5.5.4.

5. **Energy Carriers sheet**—lists the individual energy carriers employed in the technology characterizations.

6. **Technology characterization spreadsheet series**—contain the transformed data organized by renewables type, except solar, which is split into Photovoltaics (PV) and Solar Thermal-Electric (Sol-Th) technology sheets. A Country Factor column is provided on each technology characterization sheet that will allow each Member Team to modify the generic data to account for relative capital cost, labor costs, productivity, or other differences between the US and their economy, or other local conditions as deemed necessary by the analyst.

7. **ANSWER bulk load sheets**—a series of three sheets where the final data is collected for direct loading into ANSWER[5].

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[5] *ANSWER MARKAL Energy Modelling for Windows, User Manual,* The Australian Bureau of Agricultural and Resource Economics, Section 2.10, 2001.

The individual workbook sheets are all linked so that any change made on one of the master forms propagates through to all the others. Basically, Source Data is transformed according to the information provided on the Units&Convert sheet and the Country Factor column on each technology characterization sheet, with the resulting values stored in the technology characterization spreadsheets. Likewise, these values cascade to the ANSWER bulk load sheets. Thus, if new Source Data becomes available and is introduced appropriately, it will automatically be applied to the associated technology sheets along and the final bulk load sheet. The same mechanism is in place if a user decides that a different short name or description is desired for any energy carrier, emission, or technology. A change on the appropriate source sheet will propagate throughout the spreadsheet.

5.4 Naming conventions

On the Energy Carrier (and Emissions) sheet, the short name and description for each energy carrier involved in the renewables Reference Energy System sub-system is depicted by data maintained in the spreadsheet. No particular convention has been employed when naming these commodities; however, 3-character names will be reflected in the technology names (as noted below). The user may either accept the ones found there or change them, as desired. If such commodities already exist in one MARKAL database, the user may want both to use the same names and, thus, inhibit reloading the commodity into the database (see ANSWER Bulk Load Sheets, below).

The Source Data sheet names the individual technologies. Because all are electric conversion technologies, the first letter of each has been chosen as 'E'. The next 3 letters correspond to the default name of the primary energy carrier feeding the technology, followed by a 2- or 3-character indicator of the nature of this particular technology. If the user ends up deciding to have more than one instance of a particular technology (e.g., multiple wind sites), then use the next character position as instance index once loaded into ANSWER, as discussed below in the Replicating Instances Section 5.8. The final 2 characters correspond to the year in which the technology initially becomes available. This component of the name may thus be adjusted if different vintages of a technology are required owing to changes in the technology characterization (other than investment cost) over time, as discussed in the Replicating Instances section.

5.5 Organization of the database spreadsheet

As noted, the spreadsheet is divided into seven groups of individual sheets. Each group is discussed in more detail below.

The content on each of the sheets corresponds to either descriptive (MARKAL) text, source data, labels, links to the source data on other sheets, the ANSWER bulk load specification and data, and, finally, user input. All fields for which the user may provide input are colored magenta. For the most part, such fields are either name or description fields, unit conversion values, member-specific adjustment factors, or "override" values for time-independent data (TID). In general, the user is encouraged to make all changes in these fields. If a hard override of a particular value is desired, it is suggested that the user does that in ANSWER after loading. It should be noted that the spreadsheets have very few input fields.

The basic structure of the various sheets and individual technology characterizations should not be altered. The user is strongly encourage to make all adjustments to the names or data by means of these input cells so as to retain all the links established in the integrated spreadsheet. *[Provisions could be added later to allow for convenient adding of new technologies and/or rows of data, but not in this initial iteration of the database.]*

Wherever deemed appropriate, comments have been added to certain cells to clarify aspects of the underlying information.

5.5.1 Index

The Index sheet serves both to identify the technologies characterized in the spreadsheet and to provide hyperlinks to allow quick access to any group of renewable technology characterizations. The header contains the database version and the date of its last update.

5.5.2 Source Data

The Source Data sheet—the heart of the database—contains all the raw data, along with full references to the sources of the data.

The sheet is organized by technology group, each containing tables of the associated individual technologies. Each row has a short description of the data, along with an indication of the units.

The only input fields are the name and description fields associated with the individual technologies.

5.5.3 Units&Converts

The first entry on the Units&Converts sheet is the <country name>. ANSWER supports multi-region models, and the Member Economy name will be designated as the region in ANSWER. It will also serve as documentation as to where a particular instance of the database is being used. This will help other countries with similar Country Factors to easily establish a relevant initial instance of the database for their own use.

The Units&Convert form identifies the units of the source data for each type of information. The user then provides the corresponding units for each component (as expected by their model), and the factor to be applied to convert source data to model data.

See the comments for explanation and reminders on certain entries. Note, for example, that any unit entry in the My IDs column MUST be pre-established in ANSWER prior to attempting the bulk load.

5.5.4 CF and PEAK Calc

This sheet is provided to assist the user in determining the appropriate season/day-night capacity factors for the solar technologies CF calculation requires several steps, but the calculation is straightforward if the steps are followed correctly.

First, the seasonal fractions (IF, SF, & WF) are determined based on the number of months per season. In the example in the spreadsheet, a typical temperate season breakdown is used.

Second, the hours of day and night are entered into the day-hour and night-hour columns according to the hours of peak and off-peak electricity demand, respectively. The resulting day-night fractions (DF & NF) should be the same as the MARKAL fractions of the year (QHR fractions) that are already defined for an existing MARKAL model. In the spreadsheet example, the day-night split is based on the solar day for a mid-latitude location.

Third, the average seasonal solar plant output is entered as a fraction of the nominal plant output for every hour of the day. These seasonal outputs are technology-specific values, usually developed from plant simulation models that determine the actual plant output using hourly values of solar input. The hourly outputs for each day of a season can then be averaged to produce the seasonal average values needed for the CF calculation. For a solar PV technology, as is used in the spreadsheet example, the solar output is directly proportional to the available sunlight, which approximately follows a cosine shape. For a solar thermal technology with storage, such as the power tower, the solar plant output can extend long into the night, depending upon the amount of energy storage. Storage gives the plant operator flexibility to shift the plant output into the peak (or high-value) times. To assist the user, the CF & Peak Calc spreadsheet provide examples of typical plant outputs. These can be adopted by the user, if no plant simulation data is available, to generate reasonable, member-specific CFs

The parameter PEAK(CON) specifies the fraction of a conversion technology that can be counted on to be available to meet peak demand and reserve margin requirements. This sheet automatically calculates this parameter after all the CF data has been input by seasonally averaging the day fraction CF values for the technology.

5.5.5 Energy Carriers (and Emissions)

The energy carriers and emissions (pending) sheet simply contains the short names and descriptions for each of the energy carriers (and emissions) involved in the renewables sub-system depicted by the technologies in the APECR database. The analyst may adjust the text, if desired, to match it up with already existing names in the model database. As noted earlier, 3-character short names are encouraged so that the primary energy carrier name can be imbedded into the technology name as part of organizing the sub-system. Note, however, that if the short names are changed, then the user is left the task of adjusted the related technologies names.

For electricity, the overall grid efficiency may also be provided. However, if the grid and associated efficiency already appears in the Member Economy database, then the ANS_Items and ANS_T sheets should be adjusted (as discussed later) to prevent duplicate data loading. The same holds true with respect to not re-loading the name for any other energy carrier that already exists in the Member Economy database. If left in the spreadsheet and loaded, these can easily be removed from the APECR scenario. This is strongly encouraged, to avoid both confusion and possible error, such as unintentionally overriding a BASE scenario electric efficiency.

5.5.6 Technology Group Sheets

Each of the five groups of renewable technologies is contained on a separate sheet in the workbook. The individual sheets are discussed briefly after the general layout and principles embodied in these sheets are explained. These are considered the Country Sheets, where all transformation of the original data to that expected by the APEC Member model is performed.

For each technology, a small table provides the data to fully characterize it to MARKAL, in conjunction with the Set membership specifications contained on the ANS Items sheet for each technology. The name and description of each technology are presented at the top of the table, taken from the Source Data sheet. The header of each table identifies the parameter name, the energy carrier (and time-slice for seasonal CFs), the units (as taken from the Units&Convert sheet according to the nature of the parameter), and the time independent (TID) and period-based information.

Most of the individual rows correspond to the rows of the Source Data sheet, though identified according to their MARKAL parameter name as defined below in table 7. Some are additional to complete the MARKAL specifications, most notably PEAK and OUT(ELC)_TID. In the case of VAROM, where the source data places the entire operations and maintenance (O&M) cost in the FIXOM, a placeholder row has been included in the tables. This will allow the user to add a member-specific value in the event that it may be warranted. To do this, the user is encouraged to us the Country Factor to indicate the % of the FIXOM (e.g., .8 fixed), then either put the absolute value of the VAROM in said row, or better yet “program” each VAROM cell to be the (1. - %FIXOM) * Source Data Fixed O&M.

Table 7. Country Sheet Data Attributes

MARKAL Attribute Name	Description
AF/CF or CF(Z)(Y) if seasonal[6]	Availability/Capacity Factor
FIXOM	Fixed Operating and Maintenance Cost
INP(ENT)c	Input Energy Carrier/Efficiency/FEQ[7]
INVCOST	Capital cost
PEAK	Peak contribution[8]
VAROM	Variable Operating and Maintenance Cost
LIFE	Technical lifetime
OUT(ELC)_TID	Grid connection[9]
START	Year first available

As noted earlier, the analyst is encouraged to MAKE CHANGES ONLY by means of the magenta input fields under the Country Factor column so as to retain all linked inter-dependencies in the spreadsheets.

5.5.7 ANSWER Bulk Load Sheets

Three sheets encompass all the data that ANSWER needs as part of the bulk load procedure. The ANS_Items sheet provides all the details associated with naming and assigning the energy carriers and technologies to the various MARKAL characterization Sets. It is also where the unit information is provided for each component. The ANS_TID sheet contains all the TID, notably the LIFE, START and grid connection. The ANS_T sheet contains the bulk of the time series data that actually characterize the operational and financial aspects of each technology.

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[6] For a discussion on how to calculate the CF(Z)(Y)s, see the section above on the CF & PEAK Calc sheet.

[7] The efficiency is provided as the amount of input energy carrier needed for a unit of electricity out, and thus represents 1/efficiency. Note that for renewable technologies for which no physical energy carrier is involved, the fossil equivalent (FEQ) value is provided (from the Units&Convert sheet) for the purposes of reporting the contribution of the renewables in terms of primary energy equivalent. The FEQ value should be expressed as the average efficiency of all installed fossil-fired power plants. Note that the energy carrier name is not found on the Source Data sheet, but taken from the Energy Carrier sheet, as appropriate.

[8] MARKAL maintains a peaking constraint that strives to ensure that enough "excess" capacity is available to meet the moment of highest electricity demand. The constraint is based on the total level of installed capacity, where it is assumed that all the installed capacity could, if necessary, be available to meet the peak at the crucial moment. However, as one cannot guarantee that the wind will be blowing or the sun shining, some deflator must be introduced so as not to over-credit the role of such technologies toward meeting peak capacity requirement. Initial estimates of this are provided in the country sheet, without a corresponding entry on the Source Data sheet, to encourage refinement to the situation in each country.

[9] Energy carrier name not found on the Source Data sheet; take from the Energy Carrier sheet as appropriate.

For the most part, the user is strongly discouraged from making any changes to the information contained in these sheets, with one exception. If the user wishes to inhibit loading of a particular component of the ANS_Items sheet, as said entity already exists in the target database, then simply insert an '*' as the first character in the A-cell in each of the 3 rows that describe the entity. Similarly, if for some reason actual data entries are not to be transferred to the database, insert an '*' as the first character in the A-cell of any row not wanted (e.g., TE(ENT) for ELC electricity).

One other adjustment might be necessary for the user if the model years do not correspond to those found on the ANS_T sheet. If the model starts after 1995, or ends before the 2050, those columns need to be deleted from the sheet before proceeding with the actual load operation.

5.6 Procedure for ANSWER bulk load

Once the member-specific adjustments, if any, have been introduced in the spreadsheet, the complete ANSWER bulk load information is collected on the ANS_* sheets. The only other thing the user needs to ensure is that all units referred to on the Units&Convert sheet exist in the target ANSWER database prior to performing the load operation.

To actually mode the data into your existing model:

- Open your existing model database
- Create a New alternate scenario for the APEC renewable technologies (APECR)
- Select File/Import/Model Data from Excel
- Identify where the RE Technology Data XLS can be found
- Proceed with the load.

Upon completion of the load, the APECR scenario will contain all the information necessary for including the sub-system in the Member Economy model. When accessing the energy carrier and technologies tabs, all the items appearing in this alternate scenario will have a status tag of 'M' if the item exists in the BASE scenario as well as APECR, or 'SM' if it only appears in APECR. For energy carriers tagged with 'SM' it is suggested that these be deleted from the APECR scenario to avoid duplicate entries in the database.

The analyst should check that the RES connectivity is properly established for the APECR technologies by selecting the scenario for editing and drawing the RES for the ELC sub-system.

5.7 Deciphering errors during the ANSWER load procedure

While the analyst is not likely to encounter any problems during the ANSWER load process, the possibility exists that, if some links or cells were inadvertently changed, something may be wrong. A short list of considerations and actions to guide the user through the task of straightening things out is provided here.

- Start by requesting view of the load Log if ANSWER reports any problems.
    - If the log indicates that some item is not known/defined, then most likely a short name was changed in the wrong place and did not cascade through all the necessary dependent entries in the spreadsheet. This can be seen if an item appearing on the ANS_TID/T sheets, but not on the ANS_Items sheet.
    - Another common problem might be that a unit name is not declared in ANSWER prior to the load. Either make sure that the unit IDs on the Units&Convert sheet are exactly the same as those in the database (including case), or add the Units via the ANSWER Edit/Units menu option.
- Do not proceed with the load until all errors are resolved. If you do load prematurely, delete the APECR scenario, then recreate it.
- Try again after correcting all problems.[10]

5.8 Replicating instances of the technologies in ANSWER

An analyst could have several reasons to want more than one instance of one of the APECR technologies in their model. For example, the three most obvious ones involve 1) reflecting some geographic aspect of the energy system; 2) the model supporting multiple electric grids; or 3) desiring to carefully manage changing values in the technology data by introducing vintages of technologies.

In all cases, a single instance of the technology should be loaded into the APECR scenario. To handle the multiple instances to reflect geographic or similar issues, insert a simple one-character indicator just before the year designator. If multiple grids are involved, use the first letter of the electricity energy carrier grid name in the same position.

The vintaging decision can cause a bit more difficulty. In the MARKAL model, the variables that track investments in new capacity (INV), total installed capacity (CAP), and activity (ACT, TEZY, etc.) have only a single period index. Thus, the latter two represent the capacity and activities of all technologies available to the model in a given period, regardless of when they were actually built. When the input data, other than INVCOST, changes over time, the analyst must decide whether these changing values represent the "presumed" average mix due to both old and new investments and thereby use a single technology, or if the difference is substantial enough that separate technologies should be represented in the model. The latter is encouraged most of the time and here, in particular, as performance and cost changes become substantial over time. To do this, the initial 2000 technologies should be copied to <rootname>YY, where YY corresponds to the year the technology will initially become available. Then, an investment bound row (IBOND) should be added with a value of 0 for all periods from which no new investment using these technical and economic characteristics will be permitted, forcing the model to use one of the similar vintaged technology instead. Obviously, the START for these vintaged technologies must also be adjusted.

5.9 Preparing for sensitivity analyses

To complete the process of preparing to introduce (selectively for certain model runs) and use the new technology characterizations, any corresponding "old" technology in the database will have to be "removed" when including the new technologies descriptions. This is easily done by introducing a BOUND(up) = 0 row for such technologies in the APECR scenario, and copying the RESIDs (for any existing capacity in place) to the equivalent APECR technology. Also, any market penetration bounds imposed on the original BASE technology, as well as any other attribute, need to be applied to its APECR counterpart.

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[10] If problems persist, contact Gary Goldstein, ggoldstein@irgltd.com, for assistance.

6.0 POTENTIAL OF RENEWABLE ENERGY TECHNOLOGIES

6.1 Overview of assessment

Utilizing the new APEC renewable energy (APECR) technology profiles, each Member Team ran a series of case studies to identify the maximum cost-effective implementation of renewable technologies in each APEC economy. These case studies, designed to represent the setting of renewable portfolio standards, resulting in implementation of different penetration levels for non-hydro renewable energy technologies in the power sector, aimed to determine their impact relative to reducing GHG emissions.

This section describes assessment approach and methodology and summarizes each Member's results. Each Member Economy model reflects the best current information on existing and planned renewable technology installations in that economy, projected growth in demand for power generation capacity and installations, availability and costs of competing energy options, and experience relative to possible market penetration rates for new energy technologies. This APECR characterization-based assessment of potential RE technology implementation looks at the benefits of possible common approaches for achieving regional goals related to climate change mitigation.

6.2 Methodology and approach

Upon receiving the new APECR technology profiles, each team prepared its economic model for the assessment runs. This process consisted of the following steps:

1. Review of new technology characterizations, relative to technologies currently found in the database, to determine which complement the current technologies and which one will substitute for current technologies.

2. "Removal" of current technologies that are being replaced by new technology descriptions by introducing a BOUND(up) = 0 row for such technologies in the APECR scenario and copying the RESIDs (for any existing capacity in place) to the equivalent APECR technology.

3. Review and adjust new technology characterizations to ensure that they meet necessary member-specific constraints and that costs for equipment and labor are corrected to local conditions, performance is proportional to the strength of the resource, start dates are defined for technology implementation, and upper bounds reflect the potential size of the resource.

To achieve a consistent and cohesive set of assessments by each Member Team, the Project Team prepared analysis guidelines, designed specific scenarios for each team to run, and created a template format for presenting analysis results to facilitate cross comparison. These draft guidelines, scenarios, and format were circulated in draft form to all the teams for review and comment prior to implementation.

First, each Member Team ran its model with the current renewable energy technologies to establish the reference case for the analysis. Then, the APECR scenario was run to determine the basic level of non-hydro renewable energy implementation using the APECR technologies.

Using scenarios that simulate the impact of a mandatory implementation policy or renewable portfolio standards, each team ran scenarios that would force additional implementation of non-hydro renewable energy technologies. Employing the standard MARKAL ADRATIO facility, the teams defined constraints that allowed them to specify the percentage of electricity from renewable energy technologies that should be implemented in each model period. This corresponds to establishing a renewable energy portfolio standard for electricity generation.

Because the Member Economy models reported significantly different levels of RE technology implementation in their Reference cases, these renewable portfolio standard scenarios were designed to force the same incremental percentage of renewable energy technologies above that of the Reference case. The initial three levels of renewable energy penetration proved to be too modest, and three new percentage levels (10%, 15% and 20%[11]) were defined for the year 2030. These were treated as *incremental* percentages. In addition, this constraint was phased in on a linear basis starting in 2005. Therefore, if the Reference case reported 5% renewable energy technologies in 2030, the 10% incremental mandatory renewable energy scenario (APECR+10%) would specify a 3% incremental constraints starting in 2010 that increased 3% each period to reach 15% (5% + 10%) in 2030. The constraint was maintained constant thereafter.

APECR Assessment Procedures

- Each **Member Team** would run their model over the currently existing modeling periods (Australia 2000–2040, China 1995–2050, Japan 1990–2050, and US 1995–2050), and the model results would be reported only for the period 2000 to 2040 by decades.
- Cumulative for the entire model period, along with some results by decade, would be reported, with a comparison of relative changes in these results.
- Each **Member Team** would review the world prices for coal, oil and natural gas from the AEO2002 (provided by the Project Team) and decide whether to work with current country values or to update according to the AEO2002 projections. [In all cases the profiles already in the country models were used.]
- Each **Member Team** would document any changes to their reference scenario necessary to allow for inclusion of the APEC renewable technologies.
- All cost results would be reported in US$1995.
- Each **Member Team** would analyze its scenario run results, input these into the results table, and summarize the conclusions of their analysis.
- The Project team would combine and analyze the complete set of results.

The third step in the analysis involved running several scenarios that applied a CO_2 emissions cap to the energy system that was 10% below the CO_2 emission levels reported in the Reference case for each period from 2015 onward. Both the Reference case and the APECR case were run with the constraint. In addition, some Member Teams ran the Reference case with a 10% incremental

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[11] The 20% incremental renewables case was only feasible in the Australia and China models.

renewable energy mandate, and others ran the APECR scenario with both the 10% CO_2 emission constraint and the 20% incremental renewable energy mandate.

6.3 Scenario descriptions

The requirement imposed by the APECR technology requiring that a certain percentage of total electricity generation be produced by renewable technologies corresponds to the establishment of a renewable portfolio standard policy with the Member Economies. Table 8 shows the scenario descriptions used in this assessment:

Table 8. Description of Assessment Scenarios

Case	Description[12,13]
REFerence	Member base case with any existing renewable energy technologies included
APECR	Base case with APECR renewable energy technologies added/substituted for initial member renewable energy technologies
APECR +10%	APECR technologies with a 10% renewable electric portfolio standard
APECR +15%	APECR technologies with a 15% renewable electric portfolio standard
APECR +20%	APECR technologies with a 20% renewable electric portfolio standard
REF - CO_2	Base case with only Member Economy renewable technologies and 10% CO_2 emission reduction
REF +10%RE	Base case with only Member Economy renewable technologies and with a 10% renewable electric portfolio standard
APECR - CO_2	APECR technologies with 10% CO_2 emission reduction
APECR - CO_2+10%	APECR technologies with 10% CO_2 emission reduction and 10% renewable electric portfolio standard
APECR - CO2+15%	APECR technologies with 10% CO_2 emission reduction and 15% renewable electric portfolio standard
APECR - CO2+20%	APECR technologies with 10% CO_2 emission reduction and 20% renewable electric portfolio standard

Not all scenarios were run by every Member Team—only those scenarios that "sense" were run (or reported). The assessment approach relied heavily on the Member Team analysts' capabilities.

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[12] Renewable electric portfolio standard, as defined for the APECR assessment, corresponds to "mandatory" incremental electric production of x percent above the REF case from non-hydro renewable technologies.

[13] 10% CO_2 reduction starting in 2015 is against the projected levels obtained in the REF base case run.

Therefore, each analyst made specific decisions (i.e., whether or not to harmonize world energy prices and economic growth assumptions) and had some leeway regarding reporting results.

6.4 Summary of Member Economy results

This preliminary look at the potential for advanced renewable energy technologies in APEC member economies does offer APECR technology characterizations that reflect the latest RE technology improvements. However, these APECR technologies represent only a subset of the electric conversion technologies. The other electric conversion technologies in each member MARKAL model were not updated, so the assessment does not provide for their uniform handling. Thus, results show somewhat of a relative “advantage” to non-hydro renewable technologies.

The individual results from each Member Team are summarized below, and the spreadsheets in Annex 4 contain the detailed results generated by each Member Team.

The marginal price simply reflects the cost of the last unit of electricity introduced to the system in the most expensive season and day-night slice. This is not the delivered price, which would be much lower. In the case of meeting the renewable portfolio standards and carbon constraints, the marginal cost indicates how much less expensive the total discounted system cost would be if one less unit of renewable electricity or carbon reduction were imposed on the system.

Assessment Results Reported in Annex 4

- Total discounted system cost
- Primary or fossil energy mix (2030)
- Amount of electricity produced (2030)
- Electric generation percentage by power plants type, with non-hydro renewables broken out, in 2030
- Total CO_2 emissions and power sector CO_2 emissions
- Marginal price of electricity for the peak season-day period in 2030
- Marginal cost of adding the mandatory percentages of electricity from renewable energy portfolio requirement
- Marginal cost of meeting any carbon emission constraint

6.5 Member Team reports

6.5.1 Australia experience[14]

Australia has introduced a mandatory target policy for renewable electricity that does allow some increases in hydro beyond a given base level. This Mandatory Renewable Energy Target Scheme

[14] The renewable technology characterizations in Australian model were recently updated by ABARE, and those technologies were used when conducting the runs for this study. Also, the Australian Team felt it was important to distinguish whether or not hydroelectric plants were included in the renewable portfolio or not. Thus a separate set of case names were employed for their runs.

MRETS[15] serves as the MARKAL scenario REFMRETS. The scenarios modeled in MARKAL here also include an MRETS-like variant in which hydro output is not permitted to exceed the hydro output in the reference case (REFMRETH). That same upper bound on hydro output is also applied to all other cases modeled, including those with a CO_2 constraint (except those CO_2-constrained cases corresponding to the reference case and MRETS).

The CO_2-constrained cases all have a limit on time-dependent CO_2 emissions after 2015 that has an absolute value equal to 90 percent of the emissions in the Reference case. Hence, the CO_2 constraint becomes relatively less binding as the effect of the new renewables target is ramped up.

The mandatory targets are 3%, 10%, and 20% over and above the MRETS case but exclude any increase in hydro beyond the reference case output.

Objective value differences

The objective value is calculated using a discount rate of 8% real. The costs as presented in the table are measured relative to the Reference case, but these can be adjusted to an alternative reference point, for example, MRETS. It is argued that the objective value in itself is not meaningful because it reflects some arbitrary conventions in the use of technology-specific costs. Hence, the% increases relative to this objective value (in the reference case) are not meaningful for the same reason. Much more policy relevant, the $ value differences relative the to reference case objective value[16] are listed in the summary table. They range from $323 million to $2,591 million in the pure renewable target cases and $885 to $2,732 million in the mixed cases also incorporating the CO_2 constraint. In comparing the CO_2-constrained cases with their corresponding 'pure target' cases, in the most stringent target case (20% + MRETS), the CO_2 target is still binding but not tightly so.

Cost of emissions abatement

The cumulative emission level over the period 2000 to 2040 reflects the total CO_2 emissions. If the difference in discounted cost is divided by the reduction in cumulative emissions (here, relative to the reference case), a useful indicator of cost-effectiveness of CO_2 abatement (unit discounted cost of cumulative abatement) results. For pure target cases, its value increases in the range of $8 to $11 per tonne of cumulative CO_2 (contained carbon basis). A further indicator assumes that the pure carbon-penalties approach is optimal for reducing emissions. Here, normalizing on the case REFAP10C implies that the mandatory target cases are more costly in reducing CO_2 emissions by factors in the range 2.9 to 4.3.

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[15] The Mandatory Renewable Energy Target Scheme involves a tradable certificate scheme actually confined to renewable electricity but, because of its political history, also includes solar water heaters. Full documentation on the scheme can be found on the site of the Office of the Renewable Energy Regulator, http://www.orer.gov.au/index.htm

[16] From this can be calculated another indicator, namely the percentage ratio of this discounted cost difference relative to the value of projected GDP over the same projection period also discounted at the same rate (here 8 percent). This value is not included in the attached table.

As noted, the CO_2 constraint, as defined, becomes relatively less binding as the effect of the new renewables target is ramped up. Likewise, the marginal cost of meeting the CO_2 constraint falls—for example, in the 2030 time sub-period, decreasing from $35/tonne CO_2 to $17/tonne CO_2.

Impact of renewables targets on other electricity technologies

Coal-fired electricity generation is dominant in Australia except for Tasmania (hydro) and South Australia and, to a lesser extent, Western Australia (gas). However, gas—particularly Combined Cycle Gas Turbine (CCGT) capacity—also offers an important future option even in the more populous eastern states with access to low-cost coal (NSW, Victoria, and Queensland).

In the case of the pure mandatory targets for renewables, the reduction in coal-fired electricity varies in the range 0% to 21% as the target is ramped up. In absolute terms, these reductions exceed those in gas-fired electricity, but only by a factor of around two. This contrasts markedly with the optimal carbon penalties cases in which gas-fired electricity expands and results in a more radical fall in coal-fired output. This greater role for gas explains much of the greater cost-effectiveness of the pure carbon-penalty approach. However, the mixed 20% target case shows no difference in the role of gas compared with the corresponding pure targets approach.

Ramping up the new renewables target creates minimal impact on hydro and corresponds to the way that the target is defined—that is, excluding hydro but by subjecting hydro output to a simple upper bound identical to that of the reference case, in all cases. If mandatory targets clearly aim to abate CO_2 emissions, it seems inappropriate for these targets to squeeze hydro, especially when electricity can be produced at low marginal cost from existing capacity. This is particularly the case in Australia, where little scope exists for investment in major new hydroelectric capacity.

Role of particular new renewable technologies induced by the targets and CO_2 constraints

The renewable technology characterizations in the Australian MARKAL model were recently updated, and those characterizations were used rather than the APECR technologies. A comparison of the existing technology characterizations (see Annex 2) shows that, while the Australian wind technology has a similar investment cost profile, the capacity factor is far below that currently anticipated in the near future. Furthermore, these technologies were available to the reference scenario. Thus, the Australian runs do not exhibit as strong and efficient adoption of the renewable portfolio as the other country models do.

The wind power share of new renewable electricity technologies increases from 13 to 26% (2025) as the mandatory target is ramped up from 3 to 20% above the existing 2% target. The CO_2 constraint entails 17% wind in the presence of the existing MRETS target.

Photovoltaics do not appear until 2030 and even then are confined to either the most stringent renewable target (20+2%) or its combination with the CO_2 constraint, at only 3% of total new renewables excluding hydro. Solar thermal does not appear in any case modeled here.

Various forms of biomass-based electricity are important and account for the remainder, with bagasse-based electricity being initially the most important. Bagasse-based electricity grows in absolute terms as the target becomes more stringent, and it accounts for 35% of new renewables

(2030) in the reference case. However, this share declines to 22% (2030) at the most stringent target. Other biomass-based renewables featured in target cases include black liquor, landfill gas, sewage gas, and wood waste.

6.5.2 China experience

The China model was used last year in a major study for the China Council for International Cooperation on Environment and Development, and all the electric conversion technology characterizations (renewable and non-renewable) were updated as part of that study.[17] The renewable energy technologies are already attractive in the Reference Chinese model, with wind and biomass technologies contributing 10.7% of electricity generation in 2030. When the APECR technologies were integrated into the model, the non-hydro RE contribution increased to 19.1%. Therefore, three cases were developed that would increase the minimum percentage of renewable energy in 2030 to approximately 10%, 15% and 20% above the REF case. Specifically, the targets in 2030 were 20.7%, 25.7%, and 30.7%, respectively, and these were ramped in from 2010 on a linear basis.

The model shows that the APECR technologies can contribute significantly to CO_2 reductions by replacing coal-fired power technologies in the electric sector. The cost of achieving CO_2 reductions with the APECR technologies is approximately 60% of the equivalent cost using the renewable energy technologies in the Reference scenario. The model also shows that the APECR technologies can help reduce imports of oil and gas (28.8% in the Reference case to 18.3% in the APECR+20% case). Some of the APECR technologies are economical enough to compete with existing and new fossil-fired technologies. Many of the others can be introduced without any significant economic impacts, particularly when aiming to control CO_2 emissions. However, these preliminary results also show that significant CO_2 emission reductions will require attention to non-electric sectors.

Several APECR technologies are quite cost-effective in the 2010 to 2040 time frame, and their introduction reduces the discounted system cost by 0.07% compared to a cost increase of 0.24% for the same renewable energy mandate without the APERC technologies (REF+10%RE). As the APECR technology contribution is increased, this 0.07% cost savings is reduced until the APECR+20% case (31% total renewable energy contribution), where the system cost increases 0.03% above the REF case. In the REF-CO_2 case, the system cost increase is 0.78%, but in the APECR-CO_2 case, the cost increases only 0.56%.

For the APECR+ cases, the peak marginal cost of electricity decreases slightly with the introduction of the APECR technologies, because, starting in about 2020, APECR technologies are more cost-effective than the coal technologies they displace. With the REFCO_2 case, coal use does not change much, but it shifts from combustion to gasification. The gasification technology has higher capital costs but lower operating costs, thus reducing the peak marginal. For APECR-CO_2, the shift from coal combustion to gasification is less than in the REF-CO_2 case, and the reduction in the peak electricity marginal is less.

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[17] "Future Implications of China's Energy-Technology Choices," Wu Zongxin, Pat DeLaquil, Eric Larson, Chen Wenying, and Gao Pengfei, *Energy For Sustainable Development,* **5** (4), December 2001.

The marginal cost of introducing APECR technologies (above the 10.7% Reference case contribution) is less than half the cost per Gigajoule (GJ) of adding a similar increment of renewable energy technologies, and the APECR marginal cost is flat or decreases with time. In addition, the REF+10%RE case, the marginal introduction cost increases significantly over time. The cost of reducing CO_2 emissions in the Reference case (REF-CO_2) is generally about 60% higher than it is in the APECR cases.

In Reference case, large wind-farm and village-scale biomass gasification systems are the major non-hydro renewable energy contributors. Addition of the APECR technologies increases the wind energy contribution, adds solar power tower technology to the electricity mix, and reduces coal use in the electric sector. When additional renewable energy technologies are mandated into the energy economy, biomass gasification technology is added because the APECR wind and solar power tower technology are limited by upper resource bounds, and coal use in the electric sector is further reduced. If CO_2 constraints are imposed in REF-CO2, coal gasification technology with CO_2 sequestration is used to meet the constraint. If the CO2 constraint is applied with the APECR technologies (APECR-CO_2), biomass gasification and combustion technologies are added, and less coal gasification with CO_2 sequestration is used. The renewable energy contribution in the electric sector increased to 31%.

In the Reference case, coal use is 63.5% of total primary energy. With the addition of the APECR technologies, overall coal use remains constant, but oil consumption (and oil imports) are reduced as electricity from renewable energy technologies increases. This trend holds for all cases where the renewable energy contribution is increased. In the REF-CO_2 case, coal use in electric sector is basically the same, but coal use in other sectors decreases and is replaced by natural gas (mostly) and oil (slightly). This is consistent with the shift in coal use from combustion to gasification with CO_2 sequestration. When the CO_2 constraint is imposed with the APECR technologies available, both coal use and natural gas use are reduced relative to the REF-CO_2 case.

The APECR technologies contribute to an important reduction in CO_2 emissions, achieving a 1.5% reduction in cumulative emissions simply through their introduction (APECR case), and achieving up to 2.3% reduction in the APECR+20% case. However, the model shows that, while coal in the electric sector is reduced, overall coal use is not necessarily reduced. By contrast, the REF-CO_2 case achieves 31% renewable energy in the electric sector (same as the APECR+20% case), but it achieves an 8.5% reduction in cumulative CO_2 emissions, which is 3.7 times higher than the APECR+20% case. In the REF-CO_2 case, the model employs CO_2 sequestration from coal gasification technologies, both to further reduce emissions from the electric sector and to use synthetic gas products to displace coal in non-electric sectors.

All three APECR biomass technologies were incorporated into the model, direct-fired starting from 2000, co-fired and gasification from 2005. No changes were made to the Chinese biomass technologies, except to lower the starting (2010) upper bound on EBL02 (electricity and DME production) In the REF case, the two preferred technologies are EBL02 and EBV03 (village-scale biomass gasification coupled heat and power [CHP]) In the APECR+ cases, the APECR biomass gasification and direct combustion technologies are selected. The model prefers the gasification technology, the constraint used to limit the technology growth rate required that some biomass direct combustion technology be employed.

All three APECR geothermal technologies were incorporated into the model. Flashed steam starting from 2005, binary from 2010, and hot dry rock from 2015. The Chinese technology was left in the model, and the same upper bound (0.85 GW) was applied to all technologies. Because the geothermal resource for power generation in China is small, these APECR technologies, while being selected, do not have much impact on the electricity supply or CO_2 emissions.

All four PV technologies, central station (high and average sunlight) and residential (high and average sunlight) were incorporated into the model, both starting from 2000. Each was given a growth constraint but no upper bound. Two solar thermal technologies—power tower and solar dishes—were also incorporated into the model, both available from 2010. Each was given an upper bound proportional to the size of the resource and the expected maximum penetration rate. No investment was permitted on the solar technologies in the original China model for the time period 2005 to 2050. The model selects the solar power tower as the preferred solar technology in the APECR case up to the amount allowed by the resource upper bound. No other solar technology is selected.

Both APECR wind turbine technologies were incorporated into the model, starting from 2000. No investment was permitted on the local wind farm technology in the original China model. Investment was permitted in the remote wind farm technology with long-distance transmission, and the potential resource (320 GW) was partitioned between the three wind technologies according to data on Class 4-5 and Class 6-7 wind resources. The APECR cases have about 60% more installed wind farms in 2030 relative to the reference scenario. The contribution of renewable resources used in electric generation for the period 2030 is shown in Figure 5.

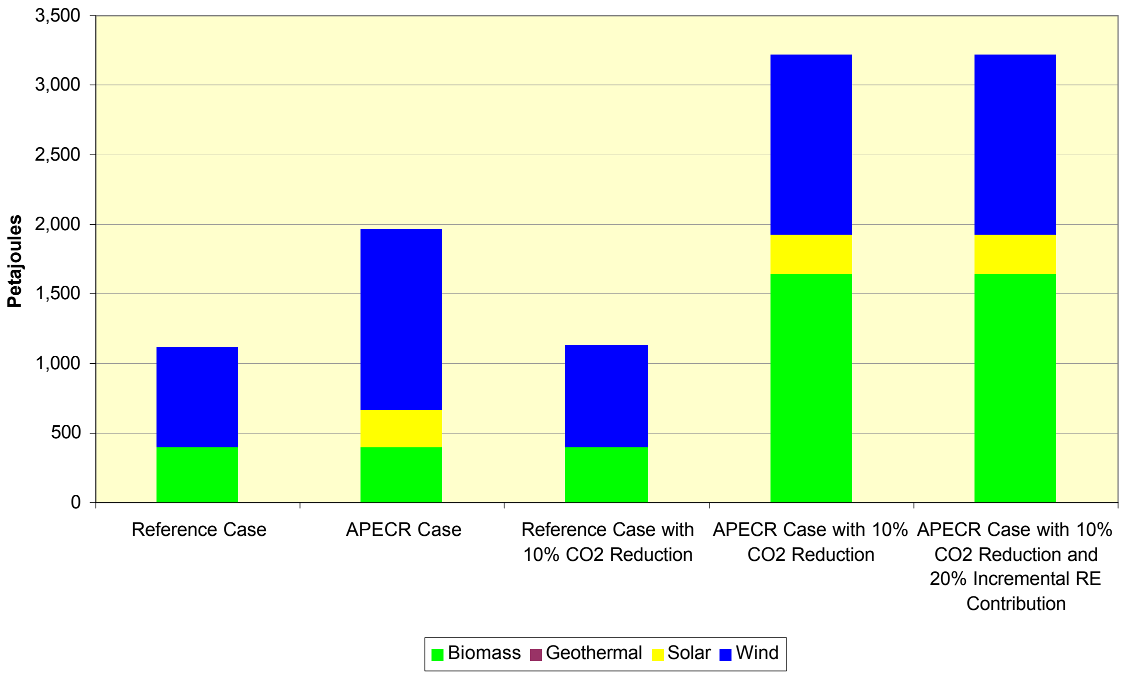

Figure 5. Contribution of Renewable Resources to Electric Generation for China in 2030

The China model contains two distributed CHP fuel cell technologies: one that uses natural gas and one that uses hydrogen from coal or biomass. The model selects only the natural gas fuel cell technology.

6.5.3 Japan experience

In the case study of Japan, the original cost data of APECR technologies were multiplied by a factor 1.3 in order to adjust for the costs of energy facilities or equipments installed in United States compared to those installed in Japan. First of all the ppp-adjusted currency exchange rate reported by OECD was used for general currency conversion.[18] Next the cost of energy facilities or equipments based on productivity, based on sector-specific productivity, must be averaged with the weight of goods and services input to the associated facilities or equipments.[19] An average factor of 1.3 (an approximate inverse of 0.78) compensates for the difference of productivity.

In the both solar PV and wind power systems, some machinery components might be produced at lower costs than the estimated costs using a factor 1.3. But, looking at the costs of the entire system, I believe a multiplication factor 1.3 will give good estimation.

Even with the productivity adjustment, some APECR technologies are economically attractive compared with existing and future power technologies using fossil fuel. Even in the case without lower constraints on its activity, APECR contributed 3.8% of total electricity production in 2030, and 6.5% in 2050. When CO_2 emissions were controlled, the introduction of APECR technologies was accelerated. In the case where the emissions were lowered by 10% from the reference case, APECR electricity production in 2030 and 2050 increased to 7.8% and 10.0% of the total, respectively.

APECR technologies applied for the Japanese model are categorized from the viewpoint of economic attractiveness into three groups:

- ***Most attractive technologies:*** Biomass co-fired, geothermal (flashed steam and binary), and solar thermal (power tower) were introduced up to the upper limits in almost all cases. Wind power (class 6) was used up in all but the Ref+APECR case.

- ***Least attractive technologies:*** Biomass (direct-fired and gasification), geothermal (hot dry rock), PV (central station-average), and solar thermal (solar trough) were, in general, not selected in the cases without lower constraints on APECR activities and were invested only in the first half of the planning time period, even when the lower constraints were applied.

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[18] 170 yen/$ as reported by OECD.

[19] According to a Nov. 2000 report by the Japanese Policy Research Institute, Ministry of Finance, the average labor productivity of Japan is 78% of US based on PPP exchange rate. In most industry sectors it is below the level of US. The worst is agriculture and fishing with only 23.5%. Electric power sector (including gas and water supply) is 60.5% resulting in much higher electricity prices in Japan. In order to convert the costs of energy facilities or equipments based on the productivity, sector specific productivity must be averaged with the weight of goods and services input to the associated facilities or equipments.

- ***Conditionally attractive technologies:*** Wind power (class 4) was not introduced in the Ref+APECR case, but it was invested up to the limits until 2030 in other cases. PV (residential-average) was used up to the limits when 15% lower constraint was applied, but much less in other cases.

When introduced in the energy systems, APECR gave some impacts to the energy supply pattern in the future. Currently, Japan depends heavily on fossil fuel, most of which is imported. Fossil fuel occupies 82% of primary energy in 2000. In the reference case, it was projected that the dependency on fossil fuel be decreased to 74% in 2030 by the development of nuclear energy. When APECR was used, the share of fossil was further decreased to 70% (10% constraint case) or 67% (15% constraint case). Since APECR replaced mainly coal-fired power technologies, coal imports were reduced most significantly, although imports of oil and natural gas were also reduced in the cases without CO_2 emission control.

The influence of APECR to the final energy consumption was trivial. When APECR was introduced to the system by using lower constraints, electricity consumption decreased slightly due to the increases of marginal electricity production costs. In replacement of electricity, the consumption of petroleum products and town gas increased.

The overall economic impacts of APECR were not significant; the increases of discounted system costs over 1990 to 2050 were within the range of 0.25% even including the cases with 15% lower constraints. Looking at the detail, APECR reduced the costs of importing fossil fuel, but increased the technology costs. In 2030 the reduction of fuel import costs was about 5% in the cases with the 15% constraint. While, in the same cases and year the investment costs of supply technologies increased by around 6%, and the O&M costs decreased by 1.2 to 1.8%. It should be noted that the O&M costs decreased in all cases where APECR was introduced, indicating that the O&M costs per Gigawatt generation (GWe) of APECR technologies are much lower than those of coal-fired technologies.

APECR quite effectively reduces CO_2 emissions, since it replaces mainly coal-fired technologies, as mentioned above. In the 15%-constraint cases, the total emissions were reduced by 9%, and the power sector emissions by 29% over the time period 1990 to 2050. Looking at the year 2050, the total emissions were reduced by 15%, and the power sector emissions by 45%. It should also be noted that APECR contributes to the reduction of emission control costs. With the CO_2 emission constraint, total cumulative cost increased by 0.20% without APECR; however, in the APECR case with the 10% constraint, the increase remained 0.11%. Thus, although some of APECR technologies have a disadvantage in production costs, they might also be introduced to the future energy systems without any significant economic impacts, particularly when CO_2 emissions are to be controlled.

6.5.4 United States experience

MARKAL has been in use at US-DOE for the past 10 years. The current US MARKAL model is applied most often to support DOE Energy Efficiency and Renewable Energy (EERE) under the auspices of Phillip Tseng. John Lee at Brookhaven National Laboratory oversees the US model database development, calibration, and application. Most recently, the model has been used to examine issues related to GHG emissions and for DOE obligations under the Government Performance and Results Act (GPRA).

The REF scenario was not altered for the APEC assessment. The APECR technologies were incorporated (and their REF counterparts eliminated), and the market potential limits reconstructed from the more optimistic estimates of the various DOE program offices in the various APECR runs. Note that, for some technologies, these estimates were higher than that reflected in the REF scenario. The APECR technology characterizations proved much more attractive than those found in the REF scenario, even though some fell below those assumed by the corresponding DOE program offices. Thus, while optimistic, the APECR characterizations did not exceed what the DOE views as reasonable—unsurprisingly, since the APECR and DOE used technology characterizations from the same NREL/EPRI source.

Setting up and conducting the assessment went extremely smoothly, as the APECR workbook was adjusted to bring all the costs to US$1999. The energy carriers feeding the APECR technologies were then changed to match those of the REF scenario, where necessary, and all the energy carriers "removed" from the APECR scenario in ANSWER. A mapping then identified which REF technologies corresponded to which APECR scenario, with the former bounded out and the compound bounds used for the APECR to limit the market potential.

The APECR technologies cost/performance characteristics are clearly very attractive—even without encouragement, they are taken up to about 10% of electric generation level. Overall APECR portfolio impact without a CO_2 limit is positive with respect to the (marginal) cost of electricity and level of emissions. Though higher electric investment costs are incurred early, the reduction in fossil fuel consumption for power generation over time results in an overall positive impact on electricity costs. In the constrained cases, the cost of meeting CO_2 limit declines steeply over time for all cases, but the APECR portfolio is much less disruptive in the initial years, and the long-term costs to the energy system are much less than without them. The APECR technologies accomplish the slowing of CO_2 growth at a cost of 54% to 81% less than the REF case, and, by 2045 with the modest CO_2 limits examined, this is met without additional marginal investment.

The primary shift for the non-CO_2 cases is about a 7.5% drop of electricity from both coal and gas generation. In the CO_2-constrained case, the coal sector takes a 20% "hit" on generation without the APECR technologies, but just 16% with them. CO_2 limits with the APECR technologies showed no abandonment of existing coal capacity, which did occur in the REF case. However, the picture for gas differs substantially. Gas generation must rise by 16% without the APECR technologies, but remains pretty much constant when the APECR technologies are introduced. Total electric generation moves down slightly in most cases, along with a slower and somewhat reduced uptake of the AGCC and little gas turbine systems (which are in heavy demand for REF) when the APECR technologies are available. Note that the REF CO_2-limited case needs advanced nuclear power sources to be built during the 2025 to 2040 timeframe. For all runs, biomass does not climb the elaborate 13-step supply curve past the first few steps, except when the renewable portfolio standards forces it a bit higher. This limited use is primarily due to the 5% per year limit on the expansion of the biomass gasification technology.

Outside of the shifts discussed with respect to electric generation mix, overall final energy consumption remains about the same. There are some shifts with respect to an increase in gas for commercial cooling and residential heating, particularly in the CO_2-limited scenarios where gas is forced lower without the APECR technologies. Also, in the CO_2-limited scenario, the level of residential conservation rose by 33% in the REF case, whereas it remained fairly constant when the APECR technologies were available.

With respect to the cost of meeting the modest CO_2 limit required here, the cost declines steeply over time in all scenarios including the REF. Thus the initial cost depends heavily upon whether or not the system is prepared for the necessary changes. To this end, the APECR technologies and the required 18% renewable portfolio are particularly beneficial and much less disruptive in the initial years, as they have prepared the system in advance for the anticipated CO_2 reduction. Furthermore, meeting the CO_2 limit with the APECR+portfolio is 54% to 81% less expensive for the constrained time periods. Finally, the cost drops to $0 in 2045 if renewable portfolio standards are in place; in the REF case, though it eases somewhat in 2040, it rises again to more than $200 in 2050.

In terms of the individual APECR technologies, the geothermal technologies reach their full market potential in all cases. Not all biomass or solar technologies are taken up until forced by the requirement to reach higher renewable portfolio levels or when CO_2 limits are imposed. The wind technology options are fully exploited, and more is highly desired in all instances. The contribution of renewable resources used in electric generation for the period 2030 is shown in Figure 6. Clearly the updated APECR technology characterizations show much greater contributions, especially from solar and wind.

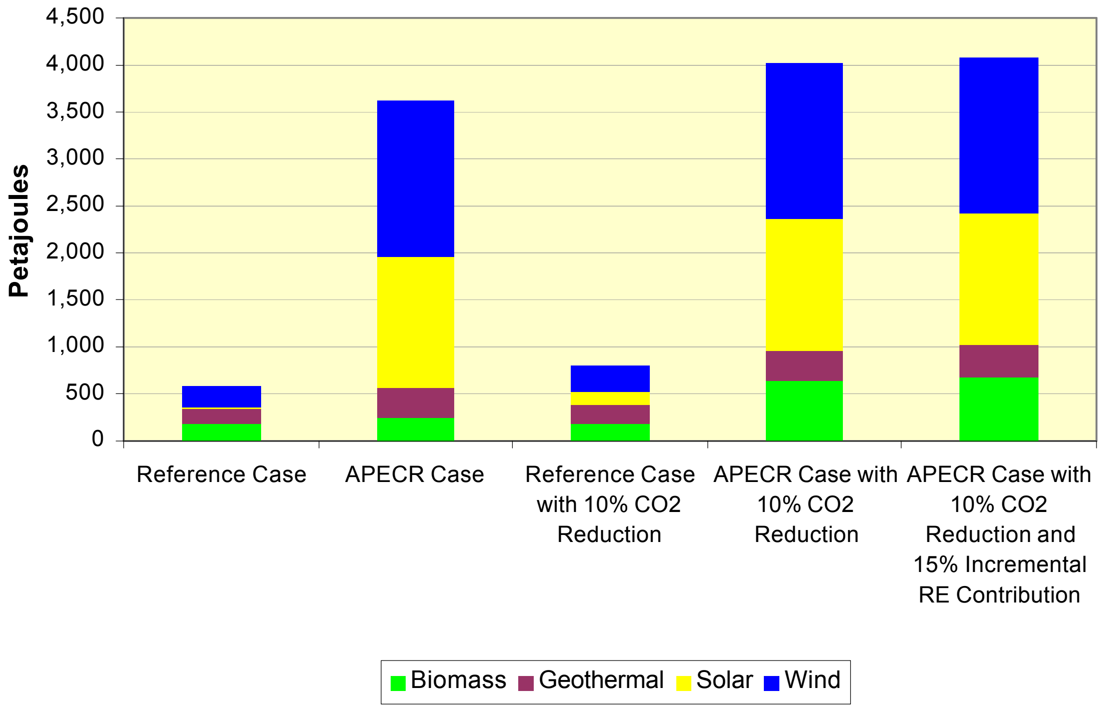


Figure 6. Contribution of Renewable Resources to Electric Generation for the US in 2030

The bottom line: Modest renewable portfolio standards can be rather easily accomplished, and these point to highly positive long-term results. This is particularly true given any need to consider possible future GHG emission limits.

6.6 Conclusions

This analysis clearly shows that the updated non-hydro renewable energy technology characterizations embodied in APECR technologies hold significant economic potential. In addition, establishing renewable portfolio standards to encourage higher penetrations of these technologies into the economy as a CO_2-reduction hedging strategy seems to result in only a very slight increase in the discounted system cost.

The scenarios evaluated in the study relate directly to the kinds of proposals put forth at the World Summit on Sustainable Development (WSSD) with respect to renewable energy. At the WSSD, substantial discussion ensued about adopting policies to achieve a goal of an increasing the share of primary energy coming from renewable energy. While the WSSD did include a statement to "encourage diversification of fuel supply"—which would help to promote renewables—no targets were set. Perhaps further studies like this assessment would help encourage policymakers to see the security, environmental, and potential economic benefits that would be realized.

Since this assessment is only preliminary, additional work should be performed to further examine the potential for renewable energy technologies based on these encouraging results.

6.6.1 Common results

As discussed in Section 6.5 for each APEC Member Economy, the APECR technology characterizations result in a significant increase in the economically attractive uptake of non-hydro renewable energy. Figure 5 shows the specific changes that resulted from the replacement of the old renewable energy characterizations with the APECR characterizations for the US, Japan and China. Australia was not included in this figure because, as noted above, that country team used their MRETS characterizations rather than the APECR characterizations.

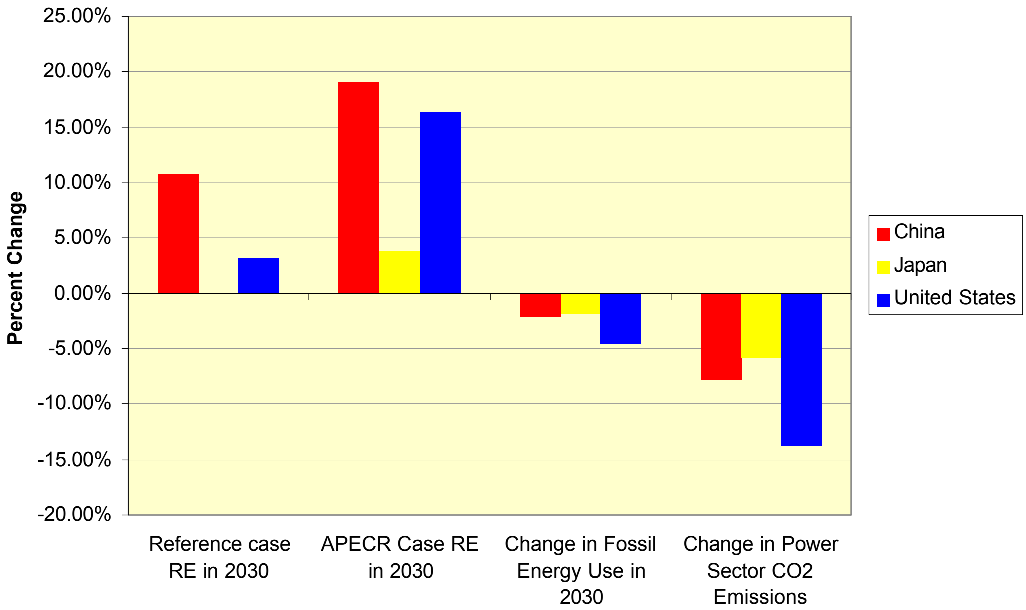


Figure 7. Changes between Reference Case and APECR Case

The increases in renewable energy (RE) penetration and the change in fossil energy use are given for the year 2030 while the change in power sector CO2 emissions is a cumulative value over the analysis period. For Japan, several of the APECR technologies are cost-effective by the 2030 time frame, and result in a 3% penetration, where there was no penetration in the reference case. For China, the approximately 90% increase in cost-effective renewable energy utilization is significant given that their reference case used the most recently updated renewable energy characterizations. However, the over 5-fold increase for the US is most significant, and shows that it is possible, without economic penalty to reduce fossil fuel consumption by almost 5% and power-sector CO2 emissions by almost 15% over the 2000 to 2050 time period. The economic impact is positive, meaning that the total system cost decreases, but the change, at less than 0.07%, is insignificant for all three countries.

Figure 6 gives a highly aggregate view of the impact on total discounted system cost, the MAKRAL objective function, for several scenarios. The +15/20% scenarios simulate the impact of imposing a renewable electric portfolio standard in concert with the APECR technology characterizations. The –CO2 scenarios simulate the impact of imposing a 10% limit on CO_2 emissions for each of the Member Economies with and without imposing a renewable energy portfolio standard. The overall implications of these scenario runs is that over the +50 years of the model runs the overall cost of both encouraging higher levels of renewable energy and achieving significantly lower CO2 emissions results in an insignificant cost to the energy system of the Member Economies studied.

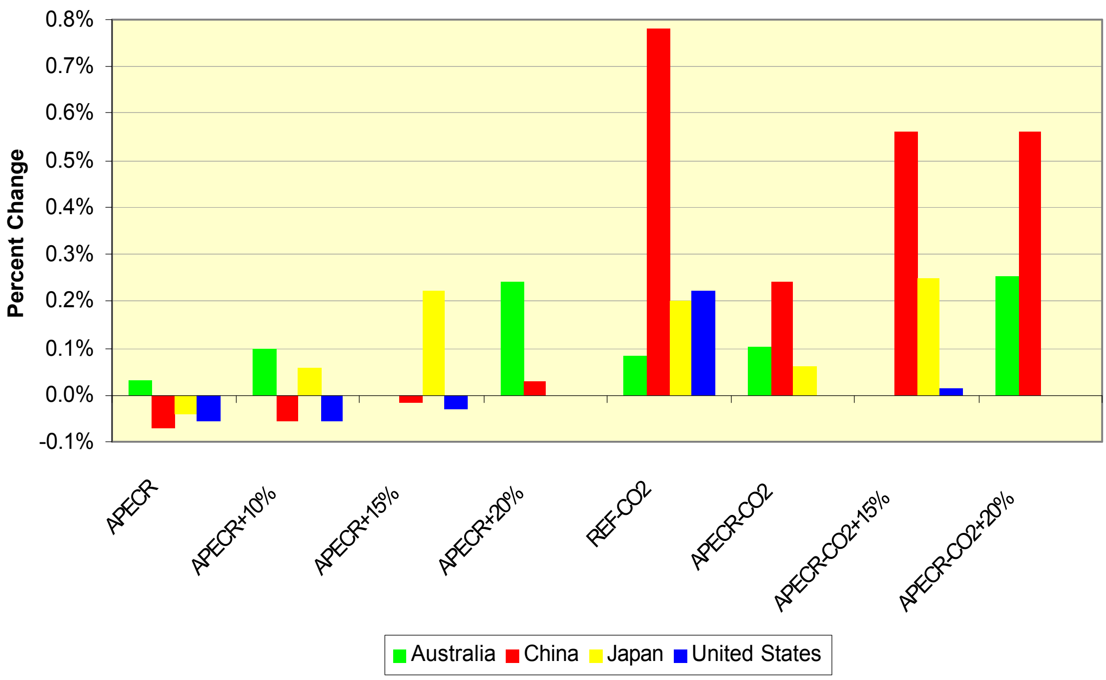


Figure 8. Change in Total Discounted System Cost

Not surprisingly, a careful look at the details reveals that the years when renewable portfolio standards are introduced show increased investment costs in new technologies. However, the long-term fuel cost savings from the use of renewable technologies more than offset these investments. In Japan and Australia, the renewable technologies are not as favorable, but a modest portfolio requirement of 10% has less than a 1% impact on the total system cost. Taking into consideration the air emission and security benefits that would also arise (which MARKAL tracks), such a standard clearly makes good economic sense.

In the CO_2-constrained cases, the availability of the APECR technologies results in more than a 15% or 20% renewable contribution for the United States and China. However, it should also be noted that phasing in a renewable portfolio standard prior to the period in which emission limits are imposed is more costly than delaying such actions as long as possible—mainly because the cost/performance of APECR technologies improves assuming continuing technological progress. Thus, in the APECR-CO_2 runs, these technologies only begin to come in heavily once the CO_2 constraint is imposed when the technology is supposed to have matured and is relatively attractive. This may a bit unrealistic, as technology improvement is a function of deployment, and it may be difficult to reach levels suggested by APECR data without the portfolio standards to get them going.

Figure 7 shows the cumulative CO2 emissions from only the power sector over the analysis period. The economic introduction of the APECR technologies decreases CO_2 emissions by between 5% and 15%. Mandatory introductions of the technologies can result in emission reductions of 15% to 20%, with increases in the total discount system cost of much less than 1%.

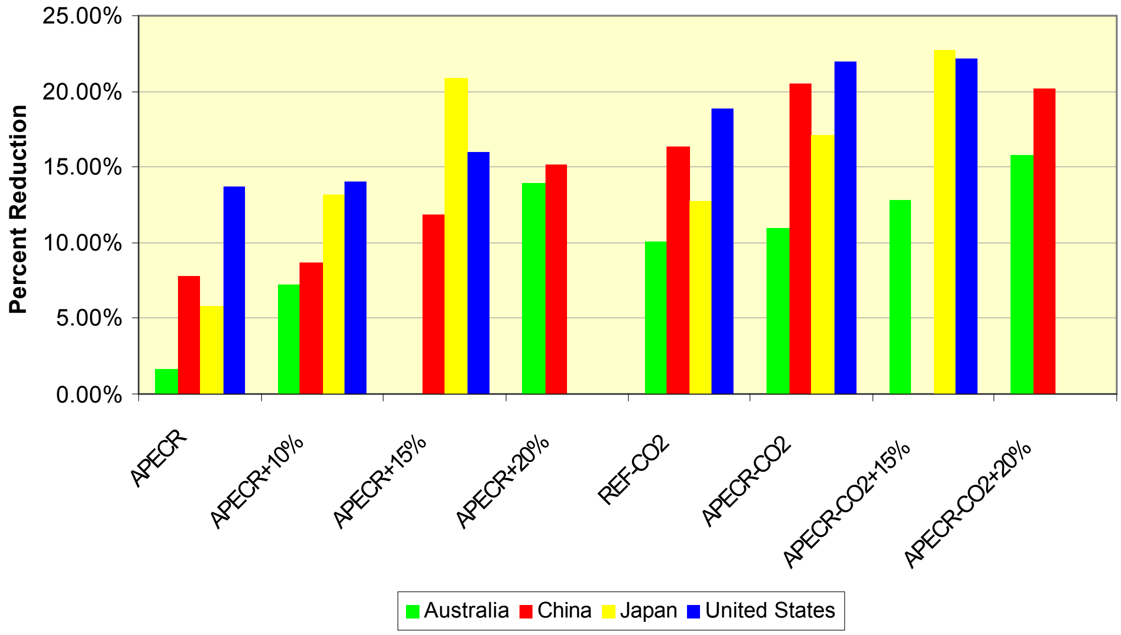


Figure 9. Change in Cumulative Power Sector CO_2 Emissions

When mandatory reductions in CO_2 emissions were investigated, the marginal cost of CO_2 reductions was significantly lower (approximately 25% to 60%) when the APECR technologies were available to the model. This is further shown in Table 9.

As APECR technologies are cost effective to begin with and directly displace fossil fuel use, which lowers CO2 levels, their availability dramatically reduces the cost of achieving reductions in CO2 emissions. Note that for the US and Japan, a 15% mandatory renewable contribution was imposed, but for China and Australia, a 20% mandatory renewable energy contribution was used. Analysis of the details shows that when the renewable energy contribution is forced to begin in 2005 and ramp up to +15/20%, the impact on the economy to adapt to the lower CO2 levels is less, except in Japan where a slightly lower portfolio requirement does result in higher overall system cost. Of course in 2005-10 there are higher investment costs arising from the requirement to achieve the portfolio level earlier than the model would have done otherwise (in APECR).

Table 9. Cost of CO2 Reductions in US$/ton of Carbon

Country / Scenario	REF-CO2	APECR-CO2	APECR-CO2+15%
United States			
2020	310	137	143
2030	198	40	38
2040	159	37	37
Japan			
2020	91	91	54
2030	101	54	0
2040	65	0	0
China			APECR-CO2+20%
2020	14	13	13
2030	19	12	12
2040	52	32	32
Australia			
2020	32	32	12
2030	35	35	17

6.6.2 Considerations for APEC future analyses

As a result of this work, the APECR technology characterizations have now been developed for easy implementation into any APEC Member Economy MARKAL model, as well as for wider use. The preliminary assessment performed as part of this work has produced very encouraging results, such as the relatively high rate of economic penetration of the APECR technologies and their relatively low cost of introduction.

However, this has only been a preliminary assessment, and much future work needs to be performed.

- Because only the APECR technology characterizations were updated, the other electric conversion technologies should be updated to balance the treatment of this sector in the energy economy.

- It is important to note that the APERC technologies are generic cost estimates, and should be adjusted for economy specific cost and renewable energy resource considerations.

- As observed with the Australian model runs, careful consideration needs to be given to what is and is not included in the business-as-usual (BAU) reference case against which sensitivity runs are compared. Allowing more renewables in the BAU, as the APECR showed they are cost-effective, would of necessity dampen the level of the changes observed in the alternate scenarios.

- Estimates of the resource potential relative to the APECR technology characterizations should be further examined. Several Member Teams reported that APECR technologies were constrained by upper bounds or by technology growth constraints.

- While the degree of harmonization of sensitive model drivers (e.g., World Oil Price, GDP growth rate) is perhaps not as important as the skill of Member Teams to know and properly apply their models, coordinated studies such as this one would benefit from aligning such assumptions.

- As noted previously, the APECR technologies assume favorable technology progress. However, as mentioned above, this may a bit unrealistic as technology improvement is a function of deployment. The MARKAL-ETL variant endogenizes technology learning, correlating the investment cost of such technology with deployment, but using it was outside the scope of this work. Conducting an assessment using MARKAL-ETL, along with a broader set of competing technologies characterized, would offer insights regarding the timing for and levels at which to establish renewable technology portfolio standards.

Note that Member participation in this project depended heavily upon in-kind contributions by the Member Team institutions in Australia, Japan, and the US. At times, this slowed project progress, since the undertaking had a lower priority than other work. However, there has been interested expressed by ~~Taiwan~~ Chinese Taipei; Hong Kong, China; ~~South~~ Korea, and Canada to participate in a 2nd APECR-type study. In addition, perhaps timing and the recent renewed MARKAL interest and efforts in The Philippines, Indonesia and Mexico could also result in engaging those Economies in such an undertaking, if appropriate resources are made available.

This assessment indeed served to demonstrate both the availability of expert teams and quality models that can be called upon to provide insight into pressing issues confronting the APEC Economies. Some such areas that could benefit from the coordinated application of Member MARKAL models might include:

- Assessment of the security and air quality implications arising from promoting the use of alternate fueled transportation vehicles and related policies;

- Expansion of the coverage of the renewable technologies being considered to the entire energy system, not just the power sector, and

- Examination of "green permit" trading as a cooperative means for further promoting renewable technologies by establishing a framework that encourages the least-cost deployment of such technologies throughout the region.

- Evaluation of the cross-border impacts of common policies/strategies to promote early commercial adoption of renewable and other clean energy technologies.

The APEC Energy Working Group should consider taking full advantage of the experienced MARKAL teams and established models found in most APEC Economies. In particular, if an ETSAP-like "voluntary" collaboration forum were established within APEC, it would serve as a valuable resource that could be more fully exploited. Such a group could focus on harmonizing technology characterizations and subjecting models to peer review with an eye toward conducting creditable "common" assessments that could directly benefit participating APEC Economies.

ANNEX 1:
ACRONYMS AND ABBREVIATIONS

ABARE	Australia Bureau for Agriculture and Resource Economics
ALGAS	Asia Least-Cost Greenhouse Gas Emission Abatement Strategy
APEC	Asia-Pacific Economic Cooperation
APECR	Renewable energy technology characterization data used for APEC
ASEAN	Association of South Eastern Asian
AUSAID	Australian Agency for International Development
BAU	Business-as-usual
BNL	Brookhaven National Laboratory
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CHP	Coupled heat and power
CF	Capacity Factor
CO_2	Carbon dioxide
DME	Dimethyl ether
DOE	Department of Energy
EERE	Energy Efficiency and Renewable Energy
EGNRET	Expert Group on New and Renewable Energy Technologies (formerly Expert Group on Technology Cooperation)
EPRI	Electric Power Research Institute
ET	Emissions trading
ETSAP	Energy Technology Systems Analysis Programme
EWG	Energy Working Group
EXP	MARKAL Export indicator
FEQ	Fossil equivalent
GJ	Gigajoule
GHG	Greenhouse gas
GPRA	Government Performance and Results Act
GW	Gigawatts
GWe	Gigawatt generation
H_2	Hydrogen

IEA	International Energy Agency
IMP	MARKAL Import indicator
JAERI	Japan Atomic Energy Research Institute
JI	Joint implementation
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
	Remove (MCFC or SOFC) from the last sentence of 6.5.2
MIN	MARKAL Mining indicator (may want to simply state Mining in text and get rid of the acronym).
MRETS	Mandatory Renewable Energy Target Scheme
MWe	Megawatt electricity
NO_x	Nitrous oxides
NREL	National Renewable Energy Laboratory
NSW	New South Wales
OECD	Organization for Economic Cooperation and Development
O&M	Operations and maintenance
PERI	Princeton Energy Research Institute
PJ	Petajoules
PMT	Passenger Miles Traveled
PV	Photovoltaic
QHR	MARKAL fractions of the year.
Qld	Queensland
R&D	Research and development
REF	Reference scenario
RES	Simplified Reference Energy System
RNW	Renewable
SA	South Australia
SO_x	Sulfuric acid
Sol-Th	Solar Thermal-Electric
Syn fuel	Synthetic Fuels
Tas	Tasmania
TID	Time-independent data
US	United States
USCS	US Country Study Program
Vic	Victoria

VMT	Vehicle Miles Traveled
WA	Western Australia
WSSD	World Summit on Sustainable Development

Annex 2:
APEC Existing Member Renewable Technology Characterizations[1]

Table A2-1. Existing Member Data—Index

Current Technology Characterization by Country

Conversion Technologies

	China					Australia					Japan					USA				
Resource	CODE	NAME	START	LIFE	DICS-RATE	CODE	NAME	START	LIFE	DICS-RATE	CODE	NAME	START	LIFE	DICS-RATE	CODE	NAME	START	LIFE	DICS-RATE
Biomass	EBC01	Biomass Fluid Bed Combustion	2000	30	0.1	ENBC1	Biomass co-firing	2000	40		S31	Biomass Methanol Conversion	2005	20	0.05	E0B	MSW -Mass Burning-Electricity	1995	30	0.1
	EBLO1	Biomass Electricity & FTL	2010	30	0.1	ENBL1	Black Liquor	2000	35		S36	Conventional Biomass Conversion	1990	5	0.05	E33	Biomass Gasfication Combine-Cycle	1995	30	0.1
	EBL02	Biomass Electricity & DME	2010	30	0.1	ENCW1	Crop Wastes	2000	30							E3D	Industrial Cogeneration - Biomass	1995	30	0.1
	EBV01	Biomass Village Elec & Town gas	2000	20	0.1	ENEC1	Energy Crops	2000	35							E96	Biomass Direct Fired Electric	1995	30	0.1
	EBV02	Biomass Village Microturbine CHP	2005	20	0.1	ENFR1	Forestry Residues and Wood Waste	2000	30							E3E				
	EBV03	Biomass Village SOFC & MT Hybrid	2015	20	0.1	ENFW1	Wet Waste	2000	35											
						ENGJ1	Bagasse	2000	35											
						ENGJ2	Bagasse & Wood Waste/Cane Trash/ Stored Bagasse	2000	35											
						ENLG1	Landfill Gas	2000	20											
						ENMS1	MSW Combustion	2000	35											
						ENMW1	Municipal Wastewater	2000	35											

[1] The Excel Workbook, RE Existing Technology Data_Part4.XLS, is available from the APEC Secretariat or the authors.

Geo-thermal	EG01	Geothermal Power Generation	1995	15	0.1					E32	Geothermal Power (Conventional)	1990	20	0.05	E32	Geothermal Electric, Liquid	2010	30	0.08
										E33	Geothermal Power (Binary)	2010	20	0.05	E3A	Geothermal Flashed Steam Electric	1995	30	0.1
										E7C					E4M	Geothermal Binary Cycle	2000	30	0.1
Solar	EPV01	Central PV Power Plant	1995	20	0.1	ENST1	Solar thermal (Solar only)	2000	30	E4C	Solar PV (Low Cost)	1995	20	0.05	E34	Solar Central Thermal Electric	1995	30	0.1
	EPV02	Residential PV Systems	1995	20	0.1	ENSV1	Photo voltaics	2000	30	E4D	Solar PV (High Cost)	2015	20	0.05	E3D	Central Photovoltaic	1995	30	0.1
						ENSVR	PV RAPS	2000	30						E4B	Photovoltaic Buildings – Der	1995	20	0.1
															E36				
Wind	EW01	Wind Power Generation, Local grid	1995	20	0.1	ENWW1	Wind farm	2000	25	E38	Wind Power	2000	20	0.05	E35	Wind Central Electric - Class 6-7	1995	30	0.1
															E35A	Wind Central Electric - Class 6-7 - Post 2006	2010	30	0.1
	EW02	Wind Power Gen, Remote wind park	2000	20	0.1										E35B	Wind Central Electric - Class 6-7 - Post 2030	2030	30	0.1
															E37	Wind Central Electric - Class 5	1995	30	0.1
															E37A	Wind Central Electric - Class 5 - Post 2006	2015	30	0.1
															E39	Wind Central Electric - Class 4	1995	30	0.1
															E39A	Wind Central Electric - Class 4 - Post 2006	2025	30	0.1
															E39B	Wind Central Electric - Class 4 - Post 2030	2030	30	0.1
															E4C	Wind Electric - Der	1995	20	0.1
Fuel Cells															E93	Hydrogen Fuel Cell	NA		
															E95	Methanol Fuel Cell	2000	20	0.1
															E98	MCFC Fuel Cell - CHP	NA		
															E99	MCFC Fuel Cell - Elec	NA		

=US$1995	1.00	0.5751	5.882353	0.9346

{Multiplier to convert Country monetary values to common US$1995 applied to all cost comments on the COST sheet.}

=US$2000	In $1995 now	0.65	6.16	In $1999 now

{Multiplier to convert Country monetary values to common US$2000 applied to all cost comments on the COST sheet.}

Table A2-2. Existing Member Data— Biomass Characterizations

Biomass Fluid Bed Combustion – China

Scenario	Parameter	Technology	Commodity	Bound	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	EBC01	-	-	-		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BASE	ENV_ACT	EBC01	NOX	-	kt/PJ		0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374
BASE	ENV_ACT	EBC01	NOXE	-	kt/PJ		0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374
BASE	ENV_ACT	EBC01	PME	-	kt/PJ		0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
ADVTECH	IBOND(BD)	EBC01	-	UP	-		100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	1E+05
BASE	IBOND(BD)	EBC01	-	UP	-		0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	EBC01	BIE	-	-		6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06
BASE	INP(ENT)c	EBC01	BIU	-	-		6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06
BASE	INVCOST	EBC01	-	-	-		427	427	427	427	427	427	427	427	427	427	427
BASE	PEAK(CON)	EBC01	-	-	-		1	1	1	1	1	1	1	1	1	1	1
BASE	VAROM	EBC01	-	-	-		8.71	8.71	8.71	8.71	8.71	8.71	8.71	8.71	8.71	8.71	8.71

Biomass Electricity & FTL – China

Scenario	Parameter	Technology	Commodity	Bound	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	EBL01	-	-	-				0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BASE	ENV_ACT	EBL01	CO2B	-	Mt/PJ				-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
BASE	ENV_ACT	EBL01	NOX	-	kt/PJ				0.0448	0.0448	0.0448	0.0448	0.0448	0.0448	0.0448	0.0448	0.045
BASE	ENV_ACT	EBL01	NOXE	-	kt/PJ				0.0448	0.0448	0.0448	0.0448	0.0448	0.0448	0.0448	0.0448	0.045
BASE	ENV_ACT	EBL01	PME	-	kt/PJ				0.0772	0.0772	0.0772	0.0772	0.0772	0.0772	0.0772	0.0772	0.077
BASE	FIXOM	EBL01	-	-	-				33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2
ADVTECH	IBOND(BD)	EBL01	-	UP	-				100000	100000	100000	100000	100000	100000	100000	100000	1E+05
BASE	IBOND(BD)	EBL01	-	UP	-				0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	EBL01	BIE	-	-				5.07	5.07	5.07	5.07	5.07	5.07	5.07	5.07	5.07
BASE	INP(ENT)c	EBL01	BIU	-	-				5.07	5.07	5.07	5.07	5.07	5.07	5.07	5.07	5.07
BASE	INVCOST	EBL01	-	-	-				1659	1659	1659	1659	1659	1659	1659	1659	1659
BASE	OUT(ENC)c	EBL01	FTL	-	-				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
BASE	PEAK(CON)	EBL01	-	-	-				1	1	1	1	1	1	1	1	1
BASE	VAROM	EBL01	-	-	-				1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32

Biomass Electricity & DME – China

Scenario	Parameter	Technology	Commodity	Bound	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	EBL02	-	-	-				0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BASE	BOUND(BD)	EBL02	-	UP	-				5								
BASE	ENV_ACT	EBL02	NOX	-	-				0.541	0.541	0.541	0.541	0.541	0.541	0.541	0.541	0.541
BASE	ENV_ACT	EBL02	NOXE	-	-				0.541	0.541	0.541	0.541	0.541	0.541	0.541	0.541	0.541
BASE	ENV_ACT	EBL02	PME	-	-				0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
BASE	FIXOM	EBL02	-	-	-				44.8	44.8	44.8	44.8	44.8	44.8	44.8	44.8	44.8
BASE	GROWTH	EBL02	-	-	-				1.3	1.3	1.2	1.15	1.15	1.1	1.1	1.1	1.1
ADVTECH	IBOND(BD)	EBL02	-	UP	-				100000	100000	100000	100000	100000	100000	100000	100000	1E+05
BASE	IBOND(BD)	EBL02	-	UP	-				0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	EBL02	BIE	-	-				6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12
BASE	INP(ENT)c	EBL02	BIU	-	-				6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12
BASE	INVCOST	EBL02	-	-	-				2141	2141	2141	2141	2141	2141	2141	2141	2141
BASE	OUT(ENC)c	EBL02	DME	-	-				2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
BASE	PEAK(CON)	EBL02	-	-	-				1	1	1	1	1	1	1	1	1
BASE	VAROM	EBL02	-	-	-				1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78

Biomass Village Elec & Town gas – China

Scenario	Parameter	Technology	Commodity	Item3	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	EBV01	-	-	-		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BASE	ENV_ACT	EBV01	NOX	-	-		0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372
BASE	ENV_ACT	EBV01	NOXE	-	-		0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372
BASE	FIXOM	EBV01	-	-	-		128.7	128.7	128.7	128.7	128.7	128.7	128.7	128.7	128.7	128.7	128.7
BASE	INP(ENT)c	EBV01	BIE	-	-		14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99
BASE	INP(ENT)c	EBV01	BIU	-	-		14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99
BASE	INVCOST	EBV01	-	-	-		4336	3686	3133	2819	2819	2819	2819	2819	2819	2819	2819
BASE	OUT(ENC)c	EBV01	BIG	-	-		3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84
BASE	PEAK(CON)	EBV01	-	-	-		1	1	1	1	1	1	1	1	1	1	1
BASE	VAROM	EBV01	-	-	-		8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7

Biomass Village Microturbine CHP – China

Scenario	Parameter	Technology	Energy	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	EBV02	-	-	-			0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BASE	FIXOM	EBV02	-	-	-			71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3
ADVTECH	IBOND(BD)	EBV02	-	UP	-			100000	100000	100000	100000	100000	100000	100000	100000	100000	1E+05
BASE	IBOND(BD)	EBV02	-	UP	-			0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	EBV02	BIE	-	-			5.1	5.1	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76
BASE	INP(ENT)c	EBV02	BIU	-	-			5.1	5.1	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76
BASE	INVCOST	EBV02	-	-	-			2827	2677	2427	2013	2013	2013	2013	2013	2013	2013
BASE	PEAK(CON)	EBV02	-	-	-			1	1	1	1	1	1	1	1	1	1
BASE	REH	EBV02	-	-	-			1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
BASE	TRNEFF(Z)(Y)	EBV02	-	-	I-D			1	1	1	1	1	1	1	1	1	1
BASE	TRNEFF(Z)(Y)	EBV02	-	-	I-N			1	1	1	1	1	1	1	1	1	1
BASE	TRNEFF(Z)(Y)	EBV02	-	-	S-D			1	1	1	1	1	1	1	1	1	1
BASE	TRNEFF(Z)(Y)	EBV02	-	-	S-N			1	1	1	1	1	1	1	1	1	1
BASE	TRNEFF(Z)(Y)	EBV02	-	-	W-D			1	1	1	1	1	1	1	1	1	1
BASE	TRNEFF(Z)(Y)	EBV02	-	-	W-N			1	1	1	1	1	1	1	1	1	1
BASE	VAROM	EBV02	-	-	-			6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55	6.55

Biomass Village SOFC & MT Hybrid – China

Scenario	Parameter	Technology	Energy	Bound	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	EBV03	-	-	-					0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BASE	FIXOM	EBV03	-	-	-					41.2	37.8	34.4	34.4	34.4	34.4	34.4	34.4
ADVTECH	IBOND(BD)	EBV03	-	UP	-					100000	100000	100000	100000	100000	100000	100000	1E+05
BASE	IBOND(BD)	EBV03	-	UP	-					0	0	0	0	0	0	0	0
BASE	INP(ENT)c	EBV03	BIE	-	-					2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12
BASE	INP(ENT)c	EBV03	BIU	-	-					2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12
BASE	INVCOST	EBV03	-	-	-					1649	1511	1374	1374	1374	1374	1374	1374
BASE	PEAK(CON)	EBV03	-	-	-					1	1	1	1	1	1	1	1
BASE	VAROM	EBV03	-	-	-					1.74	1.6	1.45	1.45	1.45	1.45	1.45	1.45

Biomass Methanol Conversion – Japan

Scenario	Parameter	Technology	Commodity	Item3	Units	1990	1995	2000	2005
BASE	AF	S31	-	-	-				0.9
BASE	ENV_ACT	S31	CDE	-	-				-15.5
BASE	FIXOM	S31	-	-	yen/(MJ/y)				0.128
BASE	INP(ENT)c	S31	BIM	-	-				0.725
BASE	INP(ENT)c	S31	BIO	-	-				0.725
BASE	INP(ENT)c	S31	ELX	-	-				0.024
BASE	INP(ENT)c	S31	STM	-	-				0.246
BASE	INP(ENT)c	S31	XG0	-	-				0.029
BASE	INVCOST	S31	-	-	yen/(MJ/y)				2.17
BASE	OUT(ENC)c	S31	MTL	-	-				0.262

Conventional Biomass Conversion – Japan

Scenario	Parameter	Technology	Commodity	Item3	Units	1990	1995	2000	2005
BASE	AF	S36	-	-	-	1	1	1	1
BASE	BOUND(BD)	S36	-	UP	PJ/y	4.5	4.5	4.5	3.8
BASE	ENV_ACT	S36	CDE	-	-	-92.5	-92.5	-92.5	-92.5
BASE	INP(ENT)c	S36	BIM	-	-	1	1	1	1
BASE	INP(ENT)c	S36	BIO	-	-	1	1	1	1
BASE	OUT(ENC)c	S36	COD	-	-	1	1	1	1
BASE	VAROM	S36	-	-	yen/MJ	0.0969	0.0969	0.0969	0.0969

AUS, New South Wales

Scenario	Parameter	Technology	Commodity	Bound	Units	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Biomass co-firing – AUS, NSW																
BASE	AF	ENBC1	-	-	-	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		
BASE	BOUND(BD)	ENBC1	-	UP	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06		
BASE	DELIV(ENT)	ENBC1	BAI	-	-	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4		
BASE	INP(ENT)c	ENBC1	BAI	-	-	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8		
BASE	INP(ENT)c	ENBC1	BAQ	-	-	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8		
BASE	INVCOST	ENBC1	-	-	-	380	380	380	380	380	380	380	380	380		
BASE	PEAK(CON)	ENBC1	-	-	-	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		
BASE	VAROM	ENBC1	-	-	-	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39		
Black Liquor – AUS, NSW																
BASE	AF	ENBL1	-	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
BASE	BOUND(BD)	ENBL1	-	UP	-	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02		
BASE	DELIV(ENT)	ENBL1	BAI	-	-	0	0	0	0	0	0	0	0	0		
BASE	FIXOM	ENBL1	-	-	-	30	30	30	30	30	30	30	30	30		
BASE	INP(ENT)c	ENBL1	BAI	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENBL1	BAQ	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENBL1	-	-	-	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00		
BASE	OUT(ENC)c	ENBL1	PHO	-	-	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36		
BASE	PEAK(CON)	ENBL1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
Crop Wastes – AUS, NSW																
BASE	AF	ENCW1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
BASE	BOUND(BD)	ENCW1	-	UP	-	0.012	0.088	0.198	0.264	0.33	0.33	0.33	0.33	0.33		
BASE	DELIV(ENT)	ENCW1	CPR	-	-	5	5	5	5	5	5	5	5	5		
BASE	FIXOM	ENCW1	-	-	-	30	30	30	30	30	30	30	30	30		
BASE	INP(ENT)c	ENCW1	CPA	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENCW1	CPR	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENCW1	-	-	-	3,200.00	3,000.00	2,800.00	2,700.00	2,600.00	2,600.00	2,600.00	2,600.00	2,600.00		
BASE	PEAK(CON)	ENCW1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		

Scenario	Parameter	Technology	Commodity	Bound	Units	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
	Energy Crops – AUS, NSW															
BASE	AF	ENEC1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
BASE	BOUND(BD)	ENEC1	-	UP	-	0.008	0.1	0.26	0.5	0.8	1.5	2.5	3.5	4.5		
BASE	DELIV(ENT)	ENEC1	CEP	-	-	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5		
BASE	FIXOM	ENEC1	-	-	-	20	20	20	20	20	20	20	20	20		
BASE	INP(ENT)c	ENEC1	CEA	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENEC1	CEP	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENEC1	-	-	-	3,000.00	3,000.00	2,800.00	2,700.00	2,600.00	2,600.00	2,600.00	2,600.00	2,600.00		
BASE	PEAK(CON)	ENEC1	-	-	-	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6		
	Forestry Residues and Wood Waste – AUS, NSW															
BASE	AF	ENFR1	-	-	-	0.6	0.7	0.75	0.85	0.85	0.85	0.85	0.85	0.85		
BASE	BOUND(BD)	ENFR1	-	LO	-	0.017										
BASE	BOUND(BD)	ENFR1	-	UP	-	0.057	0.152	0.247	0.342	0.437	0.437	0.437	0.437	0.437		
BASE	DELIV(ENT)	ENFR1	BAI	-	-	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4		
BASE	FIXOM	ENFR1	-	-	-	30	30	30	30	30	30	30	30	30		
BASE	INP(ENT)c	ENFR1	BAI	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENFR1	BAQ	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENFR1	-	-	-	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00		
BASE	PEAK(CON)	ENFR1	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		
	Wet Waste – AUS, NSW															
BASE	AF	ENFW1	-	-	-	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		
BASE	BOUND(BD)	ENFW1	-	UP	-	0.01	0.038	0.07	0.104	0.14	0.14	0.14	0.14	0.14		
BASE	DELIV(ENT)	ENFW1	BAI	-	-	0	0	0	0	0	0	0	0	0		
BASE	FIXOM	ENFW1	-	-	-	50	50	50	50	50	50	50	50	50		
BASE	INP(ENT)c	ENFW1	BAI	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENFW1	BAQ	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENFW1	-	-	-	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00		
BASE	PEAK(CON)	ENFW1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		

Scenario	Parameter	Technology	Commodity	Bound	Units	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
	Bagasse – AUS, NSW															
BASE	AF	ENGJ1	-	-	-	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15		
BASE	BOUND(BD)	ENGJ1	-	UP	-	0.015	0.015	0	0	0	0	0	0	0		
BASE	DELIV(ENT)	ENGJ1	BAI	-	-	0	0	0	0	0	0	0	0	0		
BASE	FIXOM	ENGJ1	-	-	-	20	20	20	20	20	20	20	20	20		
BASE	INP(ENT)c	ENGJ1	BAI	-	-	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7		
BASE	INP(ENT)c	ENGJ1	BAQ	-	-	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7		
BASE	INVCOST	ENGJ1	-	-	-	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00		
BASE	OUT(ENC)c	ENGJ1	PHO	-	-	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61		
BASE	PEAK(CON)	ENGJ1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
BASE	RESID	ENGJ1	-	-	-	0.015	0.015	0	0	0	0	0	0	0		
	Bagasse & Wood Waste/Cane Trash/ Stored Bagasse – AUS, NSW															
BASE	AF	ENGJ2	-	-	-	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		
BASE	BOUND(BD)	ENGJ2	-	UP	-	0.03	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
BASE	DELIV(ENT)	ENGJ2	BAI	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
BASE	FIXOM	ENGJ2	-	-	-	30	30	30	30	30	30	30	30	30		
BASE	INP(ENT)c	ENGJ2	BAI	-	-	4	4	4	3.5	3	3	3	3	3		
BASE	INP(ENT)c	ENGJ2	BAQ	-	-	4	4	4	3.5	3	3	3	3	3		
BASE	INVCOST	ENGJ2	-	-	-	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00		
BASE	OUT(ENC)c	ENGJ2	PHO	-	-	0.61	0.46	0.36	0.33	0.3	0.3	0.3	0.3	0.3		
BASE	PEAK(CON)	ENGJ2	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
	Landfill Gas – AUS, NSW															
BASE	AF	ENLG1	-	-	-	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		
BASE	BOUND(BD)	ENLG1	-	LO	-	0.016										
BASE	BOUND(BD)	ENLG1	-	UP	-	0.033	0.048	0.083	0.094	0.094	0.094	0.094	0.094	0.094		
BASE	DELIV(ENT)	ENLG1	BAI	-	-	0	0	0	0	0	0	0	0	0		
BASE	FIXOM	ENLG1	-	-	-	40	40	40	40	40	40	40	40	40		
BASE	INP(ENT)c	ENLG1	BAI	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENLG1	BAQ	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENLG1	-	-	-	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00		

Scenario	Parameter	Technology	Commodity	Bound	Units	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	PEAK(CON)	ENLG1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
BASE	RESID	ENLG1	-	-	-	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013		
	MSW Combustion – AUS, NSW															
BASE	AF	ENMS1	-	-	-	0.8	0.8	0.85	0.85	0.85	0.85	0.85	0.85	0.85		
BASE	BOUND(BD)	ENMS1	-	UP	-	0.008	0.043	0.078	0.095	0.112	0.112	0.112	0.112	0.112		
BASE	DELIV(ENT)	ENMS1	BAI	-	-	0	0	0	0	0	0	0	0	0		
BASE	FIXOM	ENMS1	-	-	-	50	50	50	50	50	50	50	50	50		
BASE	INP(ENT)c	ENMS1	BAI	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENMS1	BAQ	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENMS1	-	-	-	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00		
BASE	OUT(ENC)c	ENMS1	PHO	-	-	0	0	0	0	0	0	0	0	0		
BASE	PEAK(CON)	ENMS1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
BASE	RESID	ENMS1	-	-	-	0	0	0	0	0	0	0	0	0		
	Municipal Wastewater – AUS, NSW															
BASE	AF	ENMW1	-	-	-	0.8	0.8	0.85	0.85	0.85	0.85	0.85	0.85	0.85		
BASE	BOUND(BD)	ENMW1	-	UP	-	0.005	0.01	0.02	0.026	0.035	0.035	0.035	0.035	0.035		
BASE	DELIV(ENT)	ENMW1	BAI	-	-	0	0	0	0	0	0	0	0	0		
BASE	FIXOM	ENMW1	-	-	-	50	50	50	50	50	50	50	50	50		
BASE	INP(ENT)c	ENMW1	BAI	-	-	4	4	4	4	4	4	4	4	4		
BASE	INP(ENT)c	ENMW1	BAQ	-	-	4	4	4	4	4	4	4	4	4		
BASE	INVCOST	ENMW1	-	-	-	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00	2,400.00		
BASE	OUT(ENC)c	ENMW1	PHO	-	-	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36		
BASE	PEAK(CON)	ENMW1	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
BASE	RESID	ENMW1	-	-	-	0	0	0	0	0	0	0	0	0		

MSW-MASS BURNING-ELECTRICITY – US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	BOUND(BD)	E0B	-	FX	-	2.87	2.84	3.522	3.88	4.18	4.3								
BASE	BOUND(BD)	E0B	-	UP	-						4.3	5.0125	5.725	6.4375	7.15	7.8625	8.575	9.288	10
BASE	CF(Z)(Y)	E0B	-	-	I-D	0.744	0.751	0.758	0.765	0.772	0.779	0.786	0.793	0.8	0.8	0.8	0.8	0.8	0.8
BASE	CF(Z)(Y)	E0B	-	-	I-N	0.744	0.751	0.758	0.765	0.772	0.779	0.786	0.793	0.8	0.8	0.8	0.8	0.8	0.8
BASE	CF(Z)(Y)	E0B	-	-	S-D	0.744	0.751	0.758	0.765	0.772	0.779	0.786	0.793	0.8	0.8	0.8	0.8	0.8	0.8
BASE	CF(Z)(Y)	E0B	-	-	S-N	0.744	0.751	0.758	0.765	0.772	0.779	0.786	0.793	0.8	0.8	0.8	0.8	0.8	0.8
BASE	CF(Z)(Y)	E0B	-	-	W-D	0.744	0.751	0.758	0.765	0.772	0.779	0.786	0.793	0.8	0.8	0.8	0.8	0.8	0.8
BASE	CF(Z)(Y)	E0B	-	-	W-N	0.744	0.751	0.758	0.765	0.772	0.779	0.786	0.793	0.8	0.8	0.8	0.8	0.8	0.8
BASE	DELIV(ENT)	E0B	MSW	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	FIXOM	E0B	-	-	-	20.536	20.5357	20.5357	20.5357	20.5357	20.5357	20.5357	20.5357	20.5357	20.5357	20.536	20.54	20.54	20.54
BASE	INP(ENT)c	E0B	MSA	-	-	4	4	4	4	4	4	4	4	4	4	4	4	4	4
BASE	INP(ENT)c	E0B	MSW	-	-	4	4	4	4	4	4	4	4	4	4	4	4	4	4
BASE	INVCOST	E0B	-	-	-	1708	1708	1395	1395	1395	1395	1395	1395	1395	1395	1395	1395	1395	1395
BASE	PEAK(CON)	E0B	-	-	-	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
BASE	RESID	E0B	-	-	-	2.87	2.3917	1.9133	1.435	0.9567	0.4783	0	0	0	0	0	0	0	0
BASE	VAROM	E0B	-	-	-	-14.27	-14.2663	-14.2663	-14.2663	-14.2663	-14.2663	-14.2663	-14.2663	-14.2663	-14.2663	-14.27	-14.27	-14.3	-14.3
BIOMASS GASFICATION COMBINE-CYCLE – US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	AF	E33	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
BASE	ENV_ACT	E33	NOE	-	-	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8
BASE	FIXOM	E33	-	-	-	45	45	44.5718	44.5718	44.5718	44.5718	44.5718	44.5718	44.5718	44.5718	44.572	44.57	44.57	44.57
BASE	GROWTH	E33	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BASE	IBOND(BD)	E33	-	UP	-							2							
BASE	INP(ENT)c	E33	BIT	-	-	2.7	2.7	2.7	2.7	2.7	2.7	2.67	2.67	2.52	2.52	2.52	2.52	2.52	2.52
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	INP(ENT)c	E33	BIU	-	-	2.881	2.9025	2.924	2.9455	2.967	2.967	2.967	2.967	2.967	2.967	2.967	2.967	2.967	2.967
BASE	INVCOST	E33	-	-	-	2880.2	2001.18	1800	1797.775	1643.68	1489.585	1386.855	1284.125	1284.125	1284.125	1284.1	1284	1284	1284
BASE	PEAK(CON)	E33	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
BASE	VAROM	E33	-	-	-	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.005	0.005	0.005

INDUSTRIAL COGENERATION – BIOMASS – US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	AF	E6D	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
BASE	BOUND(BD)	E6D	-	FX	-	5.8	5.8	6.4	7.1	8.1	8.9								
BASE	BOUND(BD)O	E6D	-	FX	-	98	119	133	148	169	187								
BASE	DELIV(ENT)	E6D	BIT	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	E6D	BIT	-	-	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83
BASE	INP(ENT)c	E6D	BIU	-	-	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83
BASE	INVCOST	E6D	-	-	-	3261.5	3261.471	3261.471	3261.471	3261.471	3261.471	3261.471	3261.471	3261.471	3261.471	3261.5	3261	3261	3261
BASE	OUT(ENC)c	E6D	PRH	-	-	5.291	5.291	5.291	5.291	5.291	5.291	5.291	5.291	5.291	5.291	5.291	5.291	5.291	5.291
BASE	PEAK(CON)	E6D	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	RESID	E6D	-	-	-	5.8	5.8	5.6711	5.5422	5.4134	5.2845	5.1556	5.0267	3.77	2.5133	1.2567	0	0	0
BASE	VAROM	E6D	-	-	-	2.1626	2.1626	2.1626	2.1626	2.1626	2.1626	2.1626	2.1626	2.1626	2.1626	2.1626	2.163	2.163	2.163
BIOMASS DIRECT FIRED ELECTRIC – US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	AF	E3E	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
BASE	BOUND(BD)	E3E	-	FX	-			1.68	2.04	2.33	2.37	2.5	2.8	3.1					
BASE	ENV_ACT	E3E	NOE	-	-	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8
BASE	INP(ENT)c	E3E	BIT	-	-	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
BASE	INP(ENT)c	E3E	BIU	-	-	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12
BASE	INVCOST	E3E	-	-	-	2803.7	1919.436	1699.589	1479.742	1358.947	1238.151	1238.151	1238.151	1238.151	1238.151	1238.2	1238	1238	1238
BASE	PEAK(CON)	E3E	-	-	-	0.899	0.899	0.899	0.899	0.899	0.899	0.899	0.899	0.899	0.899	0.899	0.899	0.899	0.899
BASE	RESID	E3E	-	-	-	1.91	1.39	1.1583	0.9267	0.695	0.4633	0.2317	0	0	0	0	0	0	0
BASE	VAROM	E3E	-	-	-	15.872	15.872	15.872	15.872	14.7487	13.6253	13.6253	13.6253	13.6253	13.6253	13.625	13.63	13.63	13.63

Table A2-3. Existing Member Data— Geothermal Characterizations

Geothermal Power Generation - China

Scenario	Parameter	Technology	Energy	Bound	Item4	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	EG01	-	-	-	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
BASE	BOUND(BD)	EG01	-	UP	GW	0.03	0.04	0.05	0.06	0.08	0.1	0.12	0.14	0.15	0.16	0.17	0.18
BASE	FIXOM	EG01	-	-	$/kW	30	28.5	27	25.8	24.5	23.3	22	22	22	22	22	22
BASE	INP(ENT)c	EG01	GEO	-	-	1	1	1	1	1	1	1	1	1	1	1	1
BASE	INVCOST	EG01	-	-	$/kW	2000	1902	1809	1720	1636	1556	1479	1479	1479	1479	1479	1479
BASE	PEAK(CON)	EG01	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
BASE	RESID	EG01	-	-	GW	0.0288	0.0288	0.0288	0.0144	0	0	0	0	0	0	0	0
BASE	VAROM	EG01	-	-	$/GJ	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014

Geothermal Power (Conventional) - Japan

Scenario	Parameter	Technology	Energy	Bound	Unit	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	E32	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
BASE	BOUND(BD)	E32	-	UP	GW	0.2	0.38	0.53	0.62	0.7	0.9	1.1	1.3	1.5	1.65	1.8	1.9	2
BASE	BOUND(BD)	E32	-	LO	GW	0.19	0.37	0.52										
BASE	FIXOM	E32	-	-	yen/W	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
BASE	IBOND(BD)	E32	-	UP	GW					0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BASE	INP(ENT)c	E32	GEO	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1
BASE	INVCOST	E32	-	-	yen/W	600	600	600	600	600	550	500	450	400	400	400	400	400
BASE	PEAK(CON)	E32	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1
BASE	RESID	E32	-	-	GW	0.18	0.18	0.09	0	0	0	0	0	0	0	0	0	0
BASE	VAROM	E32	-	-	yen/MJ	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Geothermal Power (Binary) - Japan

Scenario	Parameter	Technology	Energy	Bound	Unit	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	AF	E33	-	-	-					0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
BASE	BOUND(BD)	E33	-	UP	GW					0	0.1	0.2	0.35	0.5	1	1.5	2.25	3
BASE	FIXOM	E33	-	-	yen/W					26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
BASE	IBOND(BD)	E33	-	UP	GW						0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
BASE	INP(ENT)c	E33	GEO	-	-					1	1	1	1	1	1	1	1	1

BASE	INVCOST	E33	-	-	yen/W				900	825	750	675	600	600	600	600	600		
BASE	PEAK(CON)	E33	-	-	-				1	1	1	1	1	1	1	1	1		
BASE	VAROM	E33	-	-	yen/MJ				0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297		
GEOTHERMAL ELECTRIC, LIQUID - US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	AF	E32	-	-	-	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
BASE	BOUND(BD)	E32	-	UP	-	1	1.325	1.65	1.975	2.3	2.625	2.95	3.275	3.6	3.9573	4.35	4.7816	5.2561	5.7777
BASE	FIXOM	E32	-	-	-	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
BASE	INP(ENT)c	E32	GEO	-	-	7.97	7.97	7.97	7.97	7.97	7.97	7.97	7.97	7.97	7.97	7.97	7.97	7.97	7.97
BASE	INVCOST	E32	-	-	-	2086.1	1708	1665	1763	1759	1759	1759	1759	1759	1759	1759	1759	1759	1759
BASE	PEAK(CON)	E32	-	-	-	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175	0.8175
BASE	VAROM	E32	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GEOTHERMAL FLASHED STEAM ELECTRIC - US																			
	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	AF	E3A	-	-	-	0.87	0.87	0.87	0.87	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
BASE	BOUND(BD)O	E3A	-	FX	-	52.8	54	57	91	92	92	92	92	92	92	92	92	92	92
BASE	FIXOM	E3A	-	-	-	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
BASE	INP(ENT)c	E3A	GEO	-	-	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07
BASE	INVCOST	E3A	-	-	-	2086.1	1708	1665	1763	1759	1759	1759	1759	1759	1759	1759	1759	1759	1759
BASE	PEAK(CON)	E3A	-	-	-	0.622	0.622	0.622	0.622	0.622	0.622	0.622	0.622	0.622	0.622	0.622	0.622	0.622	0.622
BASE	RESID	E3A	-	-	-	3.02	2.85	2.375	1.9	1.425	0.95	0.475	0	0	0	0	0	0	0
BASE	VAROM	E3A	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GEOTHERMAL BINARY CYCLE - US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	AF	E4M	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
BASE	BOUND(BD)	E4M	-	UP	-	1	1	1.1429	1.2857	1.4286	1.5714	1.7143	1.8571	2	2.1539	2.3196	2.4981	2.6904	2.8974
BASE	FIXOM	E4M	-	-	-	54.757	54.7566	54.7566	54.7566	54.7566	54.7566	54.7566	54.7566	54.757	54.757	54.757	54.757	54.757	54.757
BASE	INP(ENT)c	E4M	GEO	-	-	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07
BASE	INVCOST	E4M	-	-	-	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2	2278.2
BASE	PEAK(CON)	E4M	-	-	-	0.635	0.635	0.635	0.635	0.635	0.635	0.635	0.635	0.635	0.635	0.635	0.635	0.635	0.635
BASE	VAROM	E4M	-	-	-	3.6916	3.6916	3.5235	3.3554	3.3554	3.3554	3.3554	3.3554	3.3554	3.3554	3.3554	3.3554	3.3554	3.3554

Table A2-4. Existing Member Data— Photovoltaic Characterizations

Central PV Power Plant - China

Scenario	Parameter	Technology	Energy	Bound	TimeSlice	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	CF(Z)(Y)	EPV01	-	-	I-D		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BASE	CF(Z)(Y)	EPV01	-	-	I-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	EPV01	-	-	S-D		0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
BASE	CF(Z)(Y)	EPV01	-	-	S-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	EPV01	-	-	W-D		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
BASE	CF(Z)(Y)	EPV01	-	-	W-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	FIXOM	EPV01	-	-	-	$/kW	140	120	60	37.5	27	15	12	10	10	10	10	10
BASE	GROWTH	EPV01	-	-	-	-	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
ADVTECH	IBOND(BD)	EPV01	-	UP	-	GW	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
BASE	IBOND(BD)	EPV01	-	UP	-	GW	0	0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	EPV01	SOL	-	-	$/kW	7000	6000	4000	2500	1800	1500	1200	1000	1000	1000	1000	1000
BASE	INVCOST	EPV01					0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
BASE	PEAK(CON)	EPV01																
BASE	VAROM	EPV01	-	-	-	$/GJ	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019

Residential PV Systems – China

Scenario	Parameter	Technology	Energy	Item3	TimeSlice	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	CF(Z)(Y)	EPV02	-	-	I-D		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BASE	CF(Z)(Y)	EPV02	-	-	I-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	EPV02	-	-	S-D		0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
BASE	CF(Z)(Y)	EPV02	-	-	S-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	EPV02	-	-	W-D		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
BASE	CF(Z)(Y)	EPV02	-	-	W-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	FIXOM	EPV02	-	-	-	yen/W	240	150	86.3	60	48.8	25	18.5	12	12	12	12	12
BASE	GROWTH	EPV02	-	-	-	GW	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
BASE	INP(ENT)c	EPV02	SOL	-	-		1	1	1	1	1	1	1	1	1	1	1	1
BASE	INVCOST	EPV02	-	-	-	$/kW	12000	7500	5750	4000	3250	2500	1850	1200	1200	1200	1200	1200
BASE	PEAK(CON)	EPV02	-	-	-		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
BASE	RESID	EPV02	-	-	-	GW	0.0288	0.0216	0.0144	0.0072	0	0	0	0	0	0	0	0
BASE	VAROM	EPV02	-	-	-	$/GJ	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019

Solar PV (Low Cost) – Japan

Scenario	Parameter	Technology	Energy	Bound	TimeSlice	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	BOUND(BD)	E4C	-	UP	-	GW	0.1	0.29	2.45	4.6								
BASE	BOUND(BD)	E4C	-	LO	-	GW		0.28	1.39	2.5								
BASE	CF(Z)(Y)	E4C	-	-	I-D		0.25	0.25	0.275	0.3	0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35
BASE	CF(Z)(Y)	E4C	-	-	I-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	E4C	-	-	S-D		0.25	0.25	0.275	0.3	0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35
BASE	CF(Z)(Y)	E4C	-	-	S-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	E4C	-	-	W-D		0.25	0.25	0.275	0.3	0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35
BASE	CF(Z)(Y)	E4C	-	-	W-N		0	0	0	0	0	0	0	0	0	0	0	0
BASE	FIXOM	E4C	-	-	-	yen/W	10	8	7	6	5	4	3.5	3	3	3	3	3
BASE	IBOND(BD)	E4C	-	UP	-	GW				6	7.5	10	12.5	15	17.5	20	22.5	25
BASE	INP(ENT)c	E4C	SOL	-	-		2.383	2.326	2.279	2.231	2.184	2.136	2.089	2.041	2.041	2.041	2.041	2.041
BASE	INVCOST	E4C	-	-	-	yen/W	1500	900	750	600	500	400	350	300	300	300	300	300
BASE	PEAK(CON)	E4C	-	-	-		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Solar PV (High Cost) – Japan

Scenario	Parameter	Technology	Energy	Bound	TimeSlice	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	CF(Z)(Y)	E4D	-	-	I-D						0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35
BASE	CF(Z)(Y)	E4D	-	-	I-N						0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	E4D	-	-	S-D						0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35
BASE	CF(Z)(Y)	E4D	-	-	S-N						0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	E4D	-	-	W-D						0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35
BASE	CF(Z)(Y)	E4D	-	-	W-N						0	0	0	0	0	0	0	0
BASE	FIXOM	E4D	-	-	-	yen/W					6	5	5.5	4	4	4	4	4
BASE	IBOND(BD)	E4D	-	UP	-	GW					1	5	6.5	8	9	10	12.5	15
BASE	INP(ENT)c	E4D	SOL	-	-						2.184	2.136	2.089	2.041	2.041	2.041	2.041	2.041
BASE	INVCOST	E4D	-	-	-	yen/W					600	500	450	400	400	400	400	400
BASE	PEAK(CON)	E4D	-	-	-						0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Scenario	Parameter	Technology	Commodity	Bound	Units	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Solar thermal (Solar only): AUS, NSW																
BASE	AF(Z)(Y)	ENST1	-	-	I-D	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22		
BASE	AF(Z)(Y)	ENST1	-	-	I-N	0	0	0	0	0	0	0	0	0		
BASE	AF(Z)(Y)	ENST1	-	-	S-D	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22		
BASE	AF(Z)(Y)	ENST1	-	-	S-N	0	0	0	0	0	0	0	0	0		
BASE	AF(Z)(Y)	ENST1	-	-	W-D	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22		
BASE	AF(Z)(Y)	ENST1	-	-	W-N	0	0	0	0	0	0	0	0	0		
BASE	BOUND(BD)	ENST1	-	UP	-	0.005	0.02	0.03	0.1	0.4	1.2	3	10	30		
BASE	FIXOM	ENST1	-	-	-	10	10	10	10	10	10	10	10	10		
BASE	INP(ENT)c	ENST1	SOL	-	-	1	1	1	1	1	1	1	1	1		
BASE	INP(ENT)c	ENST1	SPH	-	-	1	1	1	1	1	1	1	1	1		
BASE	INVCOST	ENST1	-	-	-	3,600.00	2,700.00	2,100.00	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00	2,000.00		
BASE	PEAK(CON)	ENST1	-	-	-	1	1	1	1	1	1	1	1	1		
Photo voltaics: AUS, NSW																
BASE	AF(Z)(Y)	ENSV1	-	-	I-D	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27		
BASE	AF(Z)(Y)	ENSV1	-	-	I-N	0	0	0	0	0	0	0	0	0		
BASE	AF(Z)(Y)	ENSV1	-	-	S-D	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27		
BASE	AF(Z)(Y)	ENSV1	-	-	S-N	0	0	0	0	0	0	0	0	0		
BASE	AF(Z)(Y)	ENSV1	-	-	W-D	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27		
BASE	AF(Z)(Y)	ENSV1	-	-	W-N	0	0	0	0	0	0	0	0	0		
BASE	BOUND(BD)	ENSV1	-	UP	-	0.024	0.168	0.552	1.44	4.32	12	30	100	300		
BASE	FIXOM	ENSV1	-	-	-	5	5	5	5	5	5	5	5	5		
BASE	INP(ENT)c	ENSV1	SOL	-	-	1	1	1	1	1	1	1	1	1		
BASE	INP(ENT)c	ENSV1	SPH	-	-	1	1	1	1	1	1	1	1	1		
BASE	INVCOST	ENSV1	-	-	-	14,000.00	8,000.00	4,500.00	4,000.00	3,500.00	3,100.00	3,100.00	3,100.00	3,100.00		
BASE	PEAK(CON)	ENSV1	-	-	-	1	1	1	1	1	1	1	1	1		

PV RAPS: AUS, NSW															
BASE	AF	ENSVR	-	-	-		0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
BASE	BOUND(BD)	ENSVR	-	UP	-		0.002	0.004	0.012	0.018	0.024	0.024	0.024	0.024	0.024
BASE	FIXOM	ENSVR	-	-	-		10	10	10	10	10	10	10	10	10
BASE	INP(ENT)c	ENSVR	SPH	-	-		1	1	1	1	1	1	1	1	1
BASE	INVCOST	ENSVR	-	-	-		14,000.00	8,600.00	5,300.00	5,000.00	4,700.00	4,400.00	4,400.00	4,400.00	4,400.00
BASE	PEAK(CON)	ENSVR	-	-		1	1	1	1	1	1	1	1	1	

SOLAR CENTRAL THERMAL ELECTRIC - US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	BOUND(BD)	E34	-	LO	-			0.09	0.21	0.37	0.54	0.7	0.9	1.1					
BASE	BOUND(BD)	E34	-	UP	-	0.36	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9
BASE	CF(Z)(Y)	E34	-	-	I-D	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
BASE	CF(Z)(Y)	E34	-	-	I-N														
BASE	CF(Z)(Y)	E34	-	-	S-D	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
BASE	CF(Z)(Y)	E34	-	-	S-N														
BASE	CF(Z)(Y)	E34	-	-	W-D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BASE	CF(Z)(Y)	E34	-	-	W-N														
BASE	FIXOM	E34	-	-	-	46.9	46.9	46.9	46.9	46.9	40.0667	33.2333	26.4	26.4	26.4	26.4	26.4	26.4	26.4
BASE	INP(ENT)c	E34	SOL	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008
BASE	INVCOST	E34	-	-	-	3805	3425.7521	2488	2488	2488	2488	2488	2377	2377	2377	2377	2377	2377	2377
BASE	PEAK(CON)	E34	-	-	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
BASE	RESID	E34	-	-	-	0.36	0.27	0.18	0.09	0	0	0	0	0	0	0	0	0	0
BASE	VAROM	E34	-	-	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

CENTRAL PHOTOVOLTAIC - US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	CF(Z)(Y)	E3D	-	-	I-D	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447
BASE	CF(Z)(Y)	E3D	-	-	I-N	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
BASE	CF(Z)(Y)	E3D	-	-	S-D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BASE	CF(Z)(Y)	E3D	-	-	S-N	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
BASE	CF(Z)(Y)	E3D	-	-	W-D	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344
BASE	CF(Z)(Y)	E3D	-	-	W-N														

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	FIXOM	E3D	-	-	-	20	15	9.7	8.36	7.02	5.68	4.34	3	3	3	3	3	3	3
BASE	IBOND(BD)	E3D	-	UP	-	0	0.5	0.5	1	1	1	2	2	2	2	2	2	2	2
BASE	INP(ENT)c	E3D	SOL	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008
BASE	INVCOST	E3D	-	-	-	3855.8	3855.783	3754	3214.2	2674.4	2134.6	1594.8	1055	1055	1055	1055	1055	1055	1055
BASE	PEAK(CON)	E3D	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BASE	RESID	E3D	-	-	-	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0

PHOTOVOLTAIC BUILDINGS - DER

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	BOUND(BD)	E4B	-	UP	-	0.8	5.4	10	11.6667	13.3333	15	16.6667	18.3333	20	21.8182	23.802	25.966	28.33	30.9
BASE	CF(Z)(Y)	E4B	-	-	I-D	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BASE	CF(Z)(Y)	E4B	-	-	I-N														
BASE	CF(Z)(Y)	E4B	-	-	S-D	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
BASE	CF(Z)(Y)	E4B	-	-	S-N														
BASE	CF(Z)(Y)	E4B	-	-	W-D	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
BASE	CF(Z)(Y)	E4B	-	-	W-N														
BASE	FIXOM	E4B	-	-	-	124.3	74.5305	44.0905	44.0905	32.735	32.735	32.735	32.735	32.735	32.735	32.735	32.735	32.74	32.74
BASE	IBOND(BD)	E4B	-	LO	-	0	0	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
BASE	INP(ENT)c	E4B	SOL	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008
BASE	INVCOST	E4B	-	-	-	12488	7775.4672	5327.552	4600.848	3740.786	3352.068	3222.092	3092.116	2962.14	2769.712	2577.3	2384.9	2192	2000
BASE	PEAK(CON)	E4B	-	-	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Table A2-5. Existing Member Data— Wind Characterizations

Wind Power Generation, Local grid – China

Scenario	Parameter	Technology	Energy	Bound	TimeSlice	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	BOUND(BD)	EW01	-	UP	-			1	1.8	2.6	3.8	5	7	9	11.5	14	17	20
BASE	CF(Z)(Y)	EW01	-	-	I-D		0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297
BASE	CF(Z)(Y)	EW01	-	-	I-N		0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297
BASE	CF(Z)(Y)	EW01	-	-	S-D		0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297
BASE	CF(Z)(Y)	EW01	-	-	S-N		0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297
BASE	CF(Z)(Y)	EW01	-	-	W-D		0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297
BASE	CF(Z)(Y)	EW01	-	-	W-N		0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297
BASE	FIXOM	EW01	-	-	-	$/kW	18	15.3	15.3	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
BASE	GROWTH	EW01	-	-	-	-	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.15	1.15	1.15	1.15	1.15
BASE	INP(ENT)c	EW01	WND	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
BASE	INVCOST	EW01	-	-	-	$/kW	1200	1050	825	600	575	550	525	500	500	500	500	500
BASE	PEAK(CON)	EW01	-	-	-	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
BASE	RESID	EW01	-	-	-	GW	0.0377	0.0377	0.0377	0.0377	0	0	0	0	0	0	0	0
BASE	VAROM	EW01	-	-	-	$/GJ	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556

Wind Power Gen, Remote wind park - China

Scenario	Parameter	Technology	Energy	Bound	TimeSlice	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	BOUND(BD)	EW02	-	UP	-			1	5	10	20	32	52	84	132	186	237	300
BASE	CF(Z)(Y)	EW02	-	-	I-D			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
BASE	CF(Z)(Y)	EW02	-	-	I-N			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
BASE	CF(Z)(Y)	EW02	-	-	S-D			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
BASE	CF(Z)(Y)	EW02	-	-	S-N			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
BASE	CF(Z)(Y)	EW02	-	-	W-D			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
BASE	CF(Z)(Y)	EW02	-	-	W-N			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
BASE	FIXOM	EW02	-	-	-	$/kW		7	6	5	5	5	5	5	5	5	5	5
BASE	GROWTH	EW02	-	-	-	-		1.3	1.3	1.2	1.2	1.2	1.2	1.15	1.15	1.15	1.15	1.15
ADVTECH	IBOND(BD)	EW02	-	UP	-	GW		100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
BASE	IBOND(BD)	EW02	-	UP	-	GW		0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	EW02	WND	-	--			1	1	1	1	1	1	1	1	1	1	1

BASE	INVCOST	EW02	-	-	-	$/kW		1050	860	670	646	625	604	580	580	580	580	580
BASE	PEAK(CON)	EW02	-	-	-	-		0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
BASE	VAROM	EW02	-	-	-	$/GJ		0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556	0.556

Wind Power - Japan

Scenario	Parameter	Technology	Energy	Bound	TimeSlice	Units	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BASE	BOUND(BD)	E38	-	UP	-	GW		0.15	0.5	1	3	6	9	11	11.5	12	12	12
BASE	CF(Z)(Y)	E38	-	-	I-D			0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
BASE	CF(Z)(Y)	E38	-	-	I-N			0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
BASE	CF(Z)(Y)	E38	-	-	S-D			0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
BASE	CF(Z)(Y)	E38	-	-	S-N			0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
BASE	CF(Z)(Y)	E38	-	-	W-D			0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
BASE	CF(Z)(Y)	E38	-	-	W-N			0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
BASE	FIXOM	E38	-	-	-	yen/W		3.5	2.75	2	2	2	2	2	2	2	2	2
BASE	IBOND(BD)	E38	-	UP	-	GW					3	3	3	3	3	3	3	3
BASE	INP(ENT)c	E38	WWO	-	-	-		2.326	2.279	2.231	2.184	2.136	2.089	2.041	2.041	2.041	2.041	2.041
BASE	INVCOST	E38	-	-	-	yen/W		350	275	200	200	200	200	200	200	200	200	200
1	1	E38	-	-	-	-				1	1	1	1	1	1	1	1	1

Scenario	Parameter	Technology	Commodity	Bound	Units	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Wind farm: AUS, NSW																
BASE	AF	ENWW1	-	-	-		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
BASE	BOUND(BD)	ENWW1	-	LO			0.0154									
BASE	BOUND(BD)	ENWW1	-	UP			0.05	0.075	0.15	0.17	0.2	1	2	3	4	
BASE	FIXOM	ENWW1	-	-			5	5	5	5	5	5	5	5	5	
BASE	INP(ENT)c	ENWW1	WND	-			1	1	1	1	1	1	1	1	1	
BASE	INP(ENT)c	ENWW1	WPH	-			1	1	1	1	1	1	1	1	1	
BASE	INVCOST	ENWW1	-	-			1,900.00	1,700.00	1,400.00	1,300.00	1,200.00	1,100.00	1,100.00	1,100.00	1,100.00	
BASE	PEAK(CON)	ENWW1	-	-			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	

WIND CENTRAL ELECTRIC - CLASS 6-7 - US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	BOUND(BD)	E35	-	LO	-	1.84	4	7											
BASE	BOUND(BD)	E35	-	UP	-	1.84	4												
BASE	CF(Z)(Y)	E35	-	-	I-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35	-	-	I-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35	-	-	S-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35	-	-	S-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35	-	-	W-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35	-	-	W-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	FIXOM	E35	-	-	-	26	26	26	26	26	26	26	26	26	26	26	26	26	26
BASE	IBOND(BD)	E35	-	UP	-			3.5	0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	E35	WIN	-	-	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
BASE	INVCOST	E35	-	-	-	983	983	934	885	835	786	786	786	786	786	786	786	786	786
BASE	PEAK(CON)	E35	-	-	-	0.26	0.4	0.45	0.46	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
BASE	RESID	E35	-	-	-	1.84	2.42	2.0167	1.6133	1.21	0.8067	0.4033	0	0	0	0	0	0	0
WIND CENTRAL ELECTRIC - CLASS 6-7 - POST 2030 - US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	CF(Z)(Y)	E35B	-	-	I-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35B	-	-	I-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35B	-	-	S-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35B	-	-	S-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35B	-	-	W-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35B	-	-	W-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	FIXOM	E35B	-	-	-	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
BASE	IBOND(BD)	E35B	-	UP	-								2	2	2	2	2	2	2
BASE	INP(ENT)c	E35B	WIN	-	-	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
BASE	INVCOST	E35B	-	-	-	983	983	934	885	835	786	786	725	725	725	725	725	725	725
BASE	PEAK(CON)	E35B	-	-	-	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

WIND CENTRAL ELECTRIC - CLASS 5 – US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	BOUND(BD)	E37	-	UP	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	E37	-	-	I-D	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37	-	-	I-N	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37	-	-	S-D	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37	-	-	S-N	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37	-	-	W-D	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37	-	-	W-N	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	FIXOM	E37	-	-	-	26	26	26	26	26	26	26	26	26	26	26	26	26	26
BASE	INP(ENT)c	E37	WIN	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.01	3.01
BASE	INVCOST	E37	-	-	-	983	983	934	885	835	786	786	786	786	786	786	786	786	786
BASE	PEAK(CON)	E37	-	-	-	0.26	0.35	0.4	0.41	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43

WIND CENTRAL ELECTRIC - CLASS 5 - POST 2006 - US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	CF(Z)(Y)	E37A	-	-	I-D	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37A	-	-	I-N	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37A	-	-	S-D	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37A	-	-	S-N	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37A	-	-	W-D	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	CF(Z)(Y)	E37A	-	-	W-N	0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BASE	FIXOM	E37A	-	-	-	26	26	26	26	26	26	26	26	26	26	26	26	26	26
BASE	IBOND(BD)	E37A	-	UP	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	E37A	WIN	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.01	3.01
BASE	INVCOST	E37A	-	-	-	983	983	934	885	835	786	786	786	786	786	786	786	786	786
BASE	PEAK(CON)	E37A	-	-	-	0.26	0.35	0.4	0.41	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43

WIND CENTRAL ELECTRIC - CLASS 4 - US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	BOUND(BD)	E39	-	UP	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	CF(Z)(Y)	E39	-	-	I-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39	-	-	I-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	CF(Z)(Y)	E39	-	-	S-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39	-	-	S-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39	-	-	W-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39	-	-	W-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	FIXOM	E39	-	-	-	26	26	26	26	26	26	26	26	26	26	26	26	26	26
BASE	INP(ENT)c	E39	WIN	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.01	3.01
BASE	INVCOST	E39	-	-	-	983	983	934	885	835	786	786	786	786	786	786	786	786	786
BASE	PEAK(CON)	E39	-	-	-	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38

WIND CENTRAL ELECTRIC - CLASS 4 - POST 2006 - US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	CF(Z)(Y)	E39A	-	-	I-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39A	-	-	I-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39A	-	-	S-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39A	-	-	S-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39A	-	-	W-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39A	-	-	W-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	FIXOM	E39A	-	-	-	26	26	26	26	26	26	26	26	26	26	26	26	26	26
BASE	IBOND(BD)	E39A	-	UP	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	E39A	WIN	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.01	3.01
BASE	INVCOST	E39A	-	-	-	983	983	934	885	835	786	786	786	786	786	786	786	786	786
BASE	PEAK(CON)	E39A	-	-	-	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38

WIND CENTRAL ELECTRIC - CLASS 4 - POST 2030 - US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	CF(Z)(Y)	E39B	-	-	I-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39B	-	-	I-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39B	-	-	S-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39B	-	-	S-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39B	-	-	W-D	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	CF(Z)(Y)	E39B	-	-	W-N	0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
BASE	FIXOM	E39B	-	-	-	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060

BASE	IBOND(BD)	E39B	-	UP	-								5	5	5	5	5	5	5
BASE	INP(ENT)c	E39B	WIN	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.01	3.01
BASE	INVCOST	E39B	-	-	-	983	983	934	885	835	835	835	829	829	829	829	829	829	829
BASE	PEAK(CON)	E39B	-	-	-	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38

WIND ELECTRIC - DER - US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	BOUND(BD)	E4C	-	UP	-	1													
BASE	CF(Z)(Y)	E4C	-	-	I-D	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
BASE	CF(Z)(Y)	E4C	-	-	I-N	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
BASE	CF(Z)(Y)	E4C	-	-	S-D	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
BASE	CF(Z)(Y)	E4C	-	-	S-N	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
BASE	CF(Z)(Y)	E4C	-	-	W-D	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
BASE	CF(Z)(Y)	E4C	-	-	W-N	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
BASE	FIXOM	E4C	-	-	-	8.9385	8.9385	8.9385	8.9385	8.9385	8.9385	8.9385	8.9385	8.9385	8.9385	8.9385	8.9385	8.94	8.94
BASE	IBOND(BD)	E4C	-	UP	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BASE	INP(ENT)c	E4C	WIN	-	-	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.008	3.01	3.01
BASE	INVCOST	E4C	-	-	-	983	936	793	744	733	722	722	722	722	722	722	722	722	722
BASE	PEAK(CON)	E4C	-	-	-	0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
BASE	RESID	E4C	-	-	-	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0

WIND CENTRAL ELECTRIC - CLASS 6-7 - POST 2006 - US

Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	CF(Z)(Y)	E35A	-	-	I-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35A	-	-	I-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35A	-	-	S-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35A	-	-	S-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	CF(Z)(Y)	E35A-		-	W-D	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE-+	CF(Z)(Y)	E35A	-	-	W-N	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BASE	FIXOM	E35A	-	-	-	26	26	26	26	26	26	26	26	26	26	26	26	26	26
BASE	IBOND(BD)	E35A	-	LO	-					2	2	2	2	2	2	2	2	2	2
BASE	IBOND(BD)	E35A	-	UP	-				0	2	2	2	2	2	2	2	2	2	2
BASE	INP(ENT)c	E35A	WIN	-	-	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
BASE	INVCOST	E35A	-	-	-	983	983	934	885	835	786	786	786	786	786	786	786	786	786
BASE	PEAK(CON)	E35A	-	-	-	0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

METHANOL FUEL CELL - US																			
Scenario	Parameter	Technology	Commodity	Bound	TimeSlice	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BASE	AF	E95	-	-	-	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
BASE	DELIV(ENT)	E95	ALC	-	-	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159	4.9159
BASE	FIXOM	E95	-	-	-	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177	8.8177
BASE	GROWTH	E95	-	-	-	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
BASE	IBOND(BD)	E95	-	UP	-			0	0	0	0	1	2	3	4	5	6	7	8
BASE	INP(ENT)c	E95	ALC	-	-	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
BASE	INVCOST	E95	-	-	-	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191	1244.191
BASE	PEAK(CON)	E95	-	-	-	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
BASE	VAROM	E95	-	-	-	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035	3.5035

Table A2-6. Existing Member Data— Investment Cost Comparison

Technology	Units ($1995/kW) unless otherwise noted	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
China															
Geothermal - China		2000	1902	1809	1720	1636	1556	1479	1479	1479	1479	1479	1479		
Biomass Electric - China			427	427	427	427	427	427	427	427	427	427	427		
Biomass Electricity & FTL - China					1659	1659	1659	1659	1659	1659	1659	1659	1659		
Biomass Electricity & DME - China					2141	2141	2141	2141	2141	2141	2141	2141	2141		
Biomass Village Elec & Town gas - China			4336	3686	3133	2819	2819	2819	2819	2819	2819	2819	2819		
Biomass Village Microturbine CHP - China				2827	2677	2427	2013	2013	2013	2013	2013	2013	2013		
Biomass Village SOFC & MT Hybrid - China						1649	1511	1374	1374	1374	1374	1374	1374		
Wind Power - Local Grid - China		1200	1050	825	600	575	550	525	500	500	500	500	500		
Wind - Remote w/Trans - China			1050	860	670	646	625	604	580	580	580	580	580		
Japan															
Biomass Methanol Conversion - Japan	(in PJ}			12.765	12.765	12.765	12.765	12.765	12.765	12.765	12.765	12.765	12.765		
Conventional Biomass Conversion - Japan	{no INVCOST}	???	???	???	???	???	???	???	???	???	???	???	???		
Geothermal Power (Conventional) - Japan		3529.4	3529.4	3529.4	3529.4	3235.3	2941.2	2647.1	2352.9	2352.9	2352.9	2352.9	2352.9		
Geothermal Power (Binary) - Japan					5294.1	4852.9	4411.8	3970.6	3529.4	3529.4	3529.4	3529.4	3529.4		
Solar PV (Low Cost) - Japan		8823.5	5294.1	4411.8	3529.4	2941.2	2352.9	2058.8	1764.7	1764.7	1764.7	1764.7	1764.7		
Solar PV (High Cost) - Japan						3529.4	2941.2	2647.1	2352.9	2352.9	2352.9	2352.9	2352.9		
Wind Power - Japan			2058.8	1617.6	1176.5	1176.5	1176.5	1176.5	1176.5	1176.5	1176.5	1176.5	1176.5		
Australia															
Biomass co-firing - AUS, NSW			218.54	218.54	218.54	218.54	218.54	218.54	218.54	218.54	218.54				
Black Liquor - AUS, NSW			1437.8	1437.8	1437.8	1437.8	1437.8	1437.8	1437.8	1437.8	1437.8				
Crop Wastes - AUS, NSW			1840.3	1725.3	1610.3	1552.8	1495.3	1495.3	1495.3	1495.3	1495.3				
Energy Crops - AUS, NSW			1725.3	1725.3	1610.3	1552.8	1495.3	1495.3	1495.3	1495.3	1495.3				
Forestry Residues and Wood Waste - AUS, NSW			1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3				
Wet Waste - AUS, NSW			1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3				
Bagasse - AUS, NSW			862.65	862.65	862.65	862.65	862.65	862.65	862.65	862.65	862.65				
Bagasse & Wood Waste/Cane Trash/ Stored Bagasse - AUS, NSW			862.65	862.65	862.65	862.65	862.65	862.65	862.65	862.65	862.65				
Landfill Gas - AUS, NSW			1380.2	1380.2	1380.2	1380.2	1380.2	1380.2	1380.2	1380.2	1380.2				

Australia														
MSW Combustion - AUS, NSW		1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3				
Municipal Wastewater - AUS, NSW		1380.2	1380.2	1380.2	1380.2	1380.2	1380.2	1380.2	1380.2	1380.2				
Solar thermal (Solar only) - AUS, NSW		2070.4	1552.8	1207.7	1150.2	1150.2	1150.2	1150.2	1150.2	1150.2				
Photo voltaics - AUS, NSW		8051.4	4600.8	2588	2300.4	2012.9	1782.8	1782.8	1782.8	1782.8				
PV RAPS - AUS, NSW		8051.4	4945.9	3048	2875.5	2703	2530.4	2530.4	2530.4	2530.4				
Wind farm - AUS, NSW		1092.7	977.67	805.14	747.63	690.12	632.61	632.61	632.61	632.61				
USA														
MSW -Mass Burning-Electricity - US	1596.3	1596.3	1303.8	1303.8	1303.8	1303.8	1303.8	1303.8	1303.8	1303.8	1303.8	1303.8	1303.8	1303.8
Biomass Gasfication Combine-Cycle - US	2691.8	1870.3	1682.3	1680.2	1536.2	1392.2	1296.2	1200.1	1200.1	1200.1	1200.1	1200.1	1200.1	1200.1
Industrial Cogeneration - Biomass - US	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2	3048.2
Biomass Direct Fired Electric - US	2620.3	1793.9	1588.4	1383	1270.1	1157.2	1157.2	1157.2	1157.2	1157.2	1157.2	1157.2	1157.2	1157.2
Geothermal Electric, Liquid - US	1949.7	1596.3	1556.1	1647.7	1644	1644	1644	1644	1644	1644	1644	1644	1644	1644
Geothermal Flashed Steam Electric - US	1949.7	1596.3	1556.1	1647.7	1644	1644	1644	1644	1644	1644	1644	1644	1644	1644
Geothermal Binary Cycle - US	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2	2129.2
Solar Central Thermal Electric - US	3556.2	3201.7	2325.3	2325.3	2325.3	2325.3	2325.3	2221.5	2221.5	2221.5	2221.5	2221.5	2221.5	2221.5
Central Photovoltaic - US	3603.6	3603.6	3508.5	3004	2499.5	1995	1490.5	986	986	986	986	986	986	986
Photovoltaic Buildings – Der - US	11671	7267	4979.1	4300	3496.1	3132.8	3011.4	2889.9	2768.4	2588.6	2408.7	2228.9	2049	1869.2
Wind Central Electric - Class 6-7- US	918.71	918.71	872.92	827.12	780.39	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6
Wind Central Electric - Class 6-7 - Post 2006 - US	918.71	918.71	872.92	827.12	780.39	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6
Wind Central Electric - Class 6-7 - Post 2030 - US	918.71	918.71	872.92	827.12	780.39	734.6	734.6	677.59	677.59	677.59	677.59	677.59	677.59	677.59
Wind Central Electric - Class 5 - Post 2006 - US	918.71	918.71	872.92	827.12	780.39	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6
Wind Central Electric - Class 5 - Post 2006 - US	918.71	918.71	872.92	827.12	780.39	734.6	734.6	734.6	734..6	734.6	734.6	734.6	734.6	734.6
Wind Central Electric - Class 4 - US	918.71	918.71	872.92	827.12	780.39	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6
Wind Central Electric - Class 4 - Post 2006 - US	918.71	918.71	872.92	827.12	780.39	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734.6	734. 6
Wind Central Electric - Class 4 - Post 2030 - US	918.71	918.71	872.92	827.12	780.39	780.39	780.39	774.78	774.78	774.78	774.78	774.78	774.78	774.78
Wind Central Electric - Der - US	918.71	874.79	741.14	695.34	685.06	674.78	674.78	674.78	674.78	674.78	674.78	674.78	674.78	674.78
Methanol Fuel Cell - US	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8	1162.8
APECR Data														
APECR Wind Class 6	1000	1000	800	800	770	750	720	695	695	695	695	695		

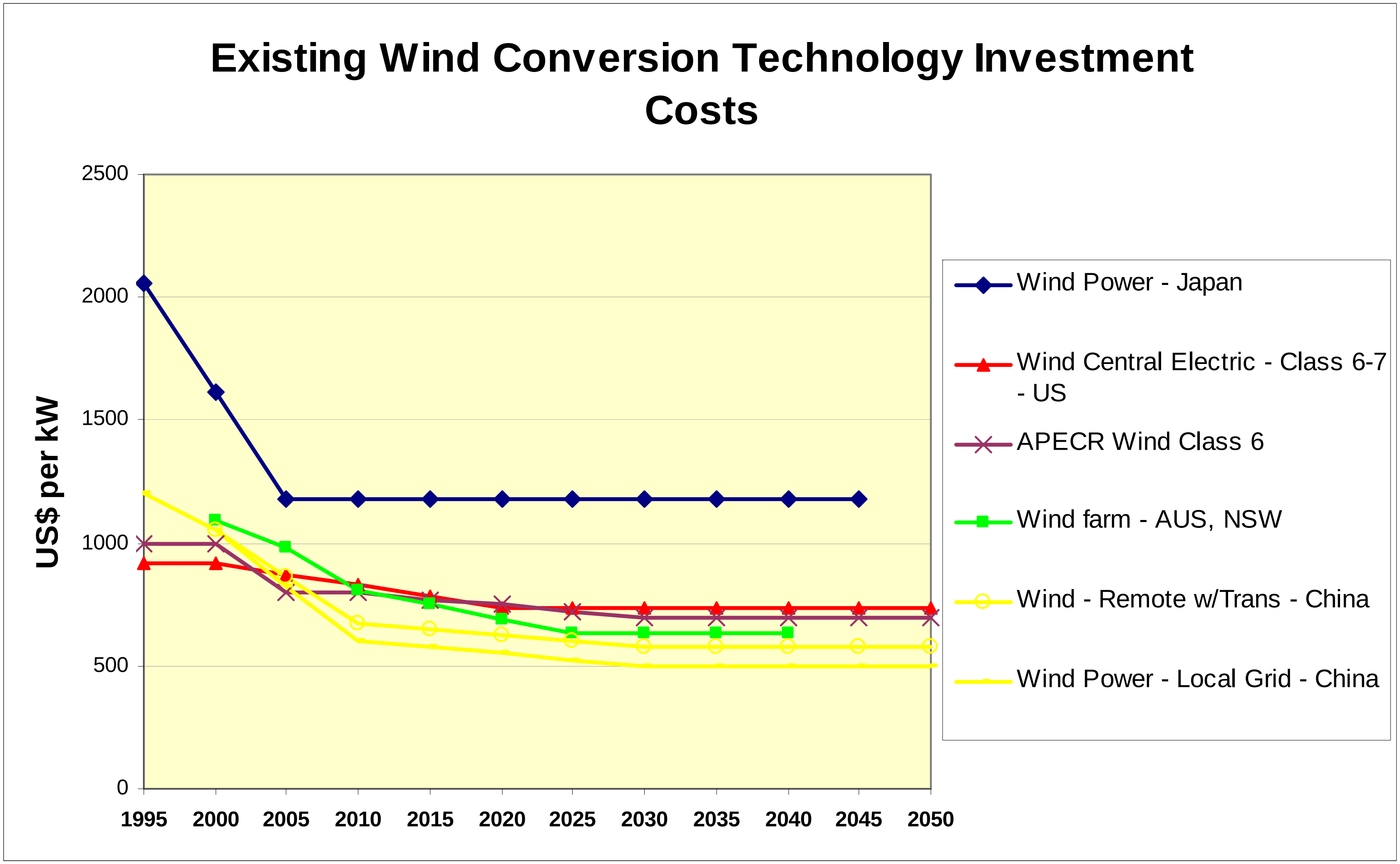

Existing Wind Conversion Technology Investment Costs
US$ per kW
2500
2000
1500
1000
500
0
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Wind Power - Japan
Wind Central Electric - Class 6-7 - US
APECR Wind Class 6
Wind farm - AUS, NSW
Wind - Remote w/Trans - China
Wind Power - Local Grid - China

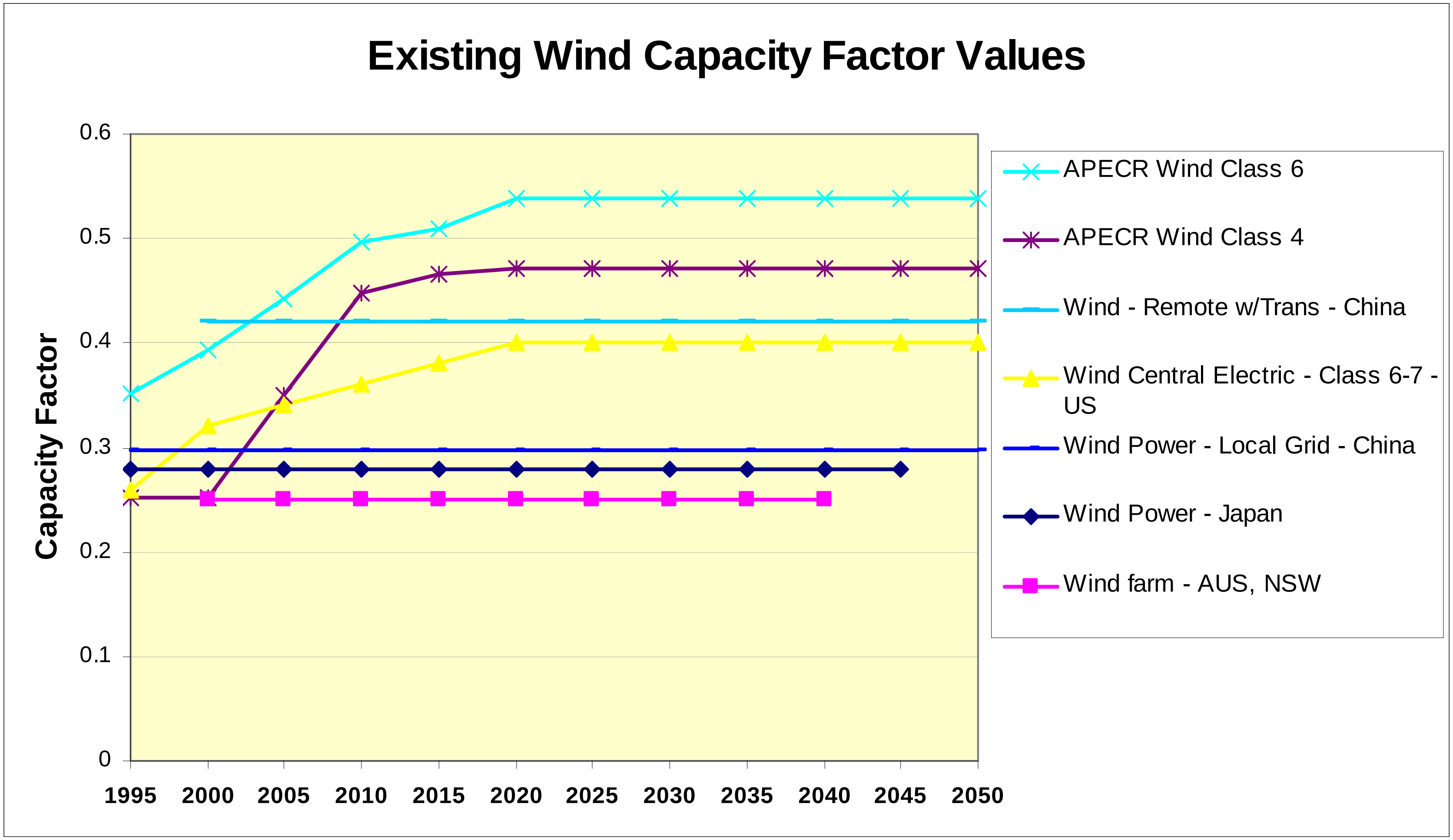
Table A2-7. Existing Member Data— Capacity/Availability Factor Comparison

Technology	Units (fraction)	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
China															
Geothermal - China		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85		
Biomass Electric - China			0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85		
Biomass Electricity & FTL - China					0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85		
Biomass Electricity & DME - China					0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85		
Biomass Village Elec & Town gas - China		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85			
Biomass Village Microturbine CHP - China			0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85			
Biomass Village SOFC & MT Hybrid - China					0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85			
Wind Power - Local Grid - China		0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297	0.297		
Wind - Remote w/Trans - China			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42		
Japan															
Biomass Methanol Conversion - Japan				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		
Conventional Biomass Conversion - Japan	1	1	1	1	1	1	1	1	1	1	1	1			
Geothermal Power (Conventional) - Japan		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		
Geothermal Power (Binary) - Japan					0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		
Solar PV (Low Cost) - Japan		0.25	0.25	0.275	0.3	0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35		
Solar PV (High Cost) - Japan						0.325	0.35	0.35	0.35	0.35	0.35	0.35	0.35		
Wind Power - Japan			0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28		

Australia														
Biomass co-firing - AUS, NSW		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9				
Black Liquor - AUS, NSW		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
Crop Wastes - AUS, NSW		0.5	1725.3	1610.3	1552.8	1495.3	1495.3	1495.3	1495.3	1495.3				
Energy Crops - AUS, NSW		0.5	1725.3	1610.3	1552.8	1495.3	1495.3	1495.3	1495.3	1495.3				
Forestry Residues and Wood Waste - AUS, NSW		0.6	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3				
Wet Waste - AUS, NSW		0.9	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3	1725.3				
Bagasse - AUS, NSW		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15				
`Bagasse & Wood Waste/Cane Trash/ Stored Bagasse - AUS, NSW		0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8				
Landfill Gas - AUS, NSW		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9				
MSW Combustion - AUS, NSW		0.8	0.8	0.85	0.85	0.85	0.85	0.85	0.85	0.85				
Municipal Wastewater - AUS, NSW		0.8	0.8	0.85	0.85	0.85	0.85	0.85	0.85	0.85				
Solar thermal (Solar only) - AUS, NSW		0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22				
Photo voltaics - AUS, NSW		0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27				
PV RAPS - AUS, NSW		0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22				
Wind farm - AUS, NSW		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25				
USA														
MSW -Mass Burning- Electricity - US	0.744	0.751	0.758	0.765	0.772	0.779	0.786	0.793	0.8	0.8	0.8	0.8	0.8	0.8
Biomass Gasfication Combine-Cycle - US	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Industrial Cogeneration - Biomass - US	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Biomass Direct Fired Electric - US	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Geothermal Electric, Liquid - US	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Geothermal Flashed Steam Electric - US	0.87	0.87	0.87	0.87	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

USA															
Geothermal Binary Cycle - US		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Solar Central Thermal Electric - US	ID]	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Solar Central Thermal Electric - US	[SD]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Solar Central Thermal Electric - US	[WD]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Central Photovoltaic - US	[ID]	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447
Central Photovoltaic - US	[SD]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Central Photovoltaic - US	[WD]	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344	0.344
Photovoltaic Buildings – Der - US	[ID]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Photovoltaic Buildings – Der - US	[SD]	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Photovoltaic Buildings – Der - US	[WD]	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Wind Central Electric - Class 6-7 - US		0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Wind Central Electric - Class 6-7 - Post 2006 - US		0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Wind Central Electric - Class 6-7 - Post 2030 - US		0.26	0.32	0.34	0.36	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Wind Central Electric - Class 5 - US		0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Wind Central Electric - Class 5 - Post 2006 - US		0.26	0.29	0.31	0.33	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Wind Central Electric - Class 4 - US		0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Wind Central Electric - Class 4 - Post 2006 - US		0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Wind Central Electric - Class 4 - Post 2030 - US		0.22	0.26	0.28	0.3	0.32	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Wind Electric - Der - US		0.22	0.3	0.35	0.36	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Methanol Fuel Cell - US		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

APECR Data												
APECR Wind Class 4	0.252	0.252	0.3495	0.447	0.465	0.471	0.471	0.471	0.471	0.471	0.471	0.471
APECR Wind Class 6	0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538	0.538	0.538	0.538	0.538



Annex 3: APEC New and Renewable Technology Database[2]

Table A3-1. Technology Data—Index

Renewable Energy Technology Characterizations for APEC	
Resource	NAME
Biomass	Biomass Co-fired
	Biomass Direct-fired
	Biomass Gasification
Geothermal	Geothermal, Binary
	Geothermal, Flashed steam
	Geothermal, Hot dry rock
Photovoltaics	PV Central station-average sunlight
	PV Central station-high sunlight
	PV Residential-average sunlight
	PV Residential-high sunlight
Solar Thermal	Dish Engine-Hybrid
	Power Tower
	Solar Trough
Wind	Wind Central Electric, Class 4
	Wind Central Electric, Class 6

[2] The complete spreadsheet workbook, RE Technology Data_V10a.XLS, can be obtained from the APEC Secretariat or the author, which includes the full ANSWER load sheets.

Table A3-2. Technology Data—Source Data

Renewable Technology Characterizations

This data was compiled predominantly from the DOE/EPRI *Renewable Energy Technology Characterizations*, 1997. Some data (as commented) was revised by PERI and by NREL based on internal DOE planning documents.

ID	Description		TID	1995	2000	2005	2010	2015	2020	2025	2030
				Time Series Data							
Biomass											
EBIOCF00	Biomass - cofire	Capital Cost ($/kW)			255.5	240.5	230.3	223.5	216.7	212.2	207.6
		Capacity Factor			0.85	0.85	0.85	0.85	0.85	0.85	0.85
		Fixed O&M ($/kW-yr			10.11	9.81	9.61	9.50	9.33	9.24	9.15
		Variable O&M (c/kWh)			0.16	0.16	0.16	0.16	0.16	0.16	0.16
		Efficiency			32.7%	32.5%	32.5%	32.5%	32.5%	32.6%	32.7%
		Input-coal			2.75	0 2.61	2.61	2.61	2.61	2.61	2.61
		Input-biomass			0.31	0.46	0.46	0.46	0.46	0.46	0.46
		Lifetime	30								
		Year first available	2000								
	Biomass - Direct fire	Capital Cost ($/kW)		1,796	1,571	1,364	1,211	1,080	1,004	1,004	1,004
		Capacity Factor		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
		Fixed O&M ($/kW-yr)		60.00	60.00	60.0	60.0	55.0	49.0	49.0	49.0
		Variable O&M (c/kWh)		0.70	0.70	0.70	0.70	0.64	0.57	0.57	0.57
		Efficiency		27.7%	27.7%	27.7%	27.7%	27.7%	33.9%	33.9%	33.9%
		Input-biomass		3.61	3.61	3.61	3.61	3.61	2.95	2.95	2.95
		Lifetime	30								
		Year first available	1995								
EBIOGA00	Biomass - gasificationl	Capital Cost ($/kW)			1,892	1,650	1,464	1,350	1,258	1,185	1,111
		Capacity Factor			0.80	0.80	0.80	0.80	0.80	0.80	0.80
		Fixed O&M ($/kW-yr)			43.4	43.4	43.4	43.24	43.4	43.4	43.4
		Variable O&M (c/kWh)			0.52	0.52	0.52	0.52	0.52	0.52	0.52
		Efficiency			36%	37%	37%	37%	41.5%	0.43	45%
		Input-biomass			2.78	2.70	2.70	2.70	2.41	2.31	2.22
		Lifetime	30								
		Year first available	1995								

Geothermal											
EGEOBI00	G eohermal Binary	Capital Cost ($/kW)		2,112	1,994	1,875	1,754	1,700	1,637	1,575	1,512
		Capacity Factor (%)		89.0	92.0	93.0	95.0	95.0	96.0	97	97
		Fixed O&M ($/kW-yr)		87.4	78.50	66.80	59.50	55.00	52.40	51	50.5
		Lifetime	30								
		Year first available	1995								
EGEOFS00	Geothermal Flashed Steam	Capital Cost ($/kW)		1,444	1,372	1,250	1,194	1,145	1,100	1,068	1,036
		Capacity Factor (%)		89.0	92.0	93.0	95.0	95.0	96.0	96.5	97.0
		Fixed O&M ($/kW-yr)		96.4	87.1	74.8	66.3	62.0	58.2	56.5	54.7
		Lifetime	30								
		Year first available	1995								
EGEOHR00	Geothermal Hot Dry Rock	Capital Cost ($/kW)			5,176	4,756	4,312	3,794	3,276	2,984	2,692
		Capacity Factor (%)			81.0	82.0	83.0	84.0	85.0	86	87
		Fixed O&M ($/kW-yr)			207.0	191.0	179.0	171.0	163.0	157.5	152.0
		Lifetime	30								
		Year first available	2000								
Photovoltaics											
ESOLPCA	PV Central Station average	Capital Cost ($/kW)		7,000	5,300	2,900	1,500	1,300	1,100	990	880
		Capacity Factor		20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70
		Fixed O&M ($/kW-yr		18.00	13.75	5.75	3.56	1.78	2.38	2.31	2.25
		Lifetime	30								
		Year first available	1995								
ESOLPCH00	PV Central Station-high	Capital Cost ($/kW)		7,000	5,300	2,900	1,500	1,300	1,100	990	880
		Capacity Factor		26.40	26.40	26.40	26.40	26.40	26.40	26.40	26.40
		Fixed O&M ($/kW-yr)		18.00	13.75	5.75	3.56	1.78	2.38	2.31	2.25
		Lifetime	30								
		Year first available	1995								
ESOLPRA00	PV Residential-average	Capital Cost ($/kW		6270	5340	4040	3050	2410	1770	1405	1040
		Capacity Factor		20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
		Fixed O&M ($/kW-yr)		17.40	15.38	14.29	13.33	12.9	12.50	12.1	11.76
		Lifetime	30								
		Year first available	1995								

ESOLPRH00	PV Residential-high	Capital Cost ($/kW)		6720	5340	4040	3050	2410	1770	1405	1040
		Capacity Factor (%)		26.30	26.30	26.30	26.30	26.30	26.30	26.30	26.30
		Fixed O&M ($/kW-yr)		17.40	15.38	14.29	13.33	12.9	12.50	12.1	11.76
		Lifetime	30								
		Year first available	1995								
Solar Thermal											
ESOLDE00	Dish Engine-hybrid	Capital Cost ($/kW)		12,000	5,691	3,231	1,690	1,579	1,467	1,396	1,324
		Capacity Factor (%)		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
		Variable O&M (c/kWh)		21.00	3.70	2.30	1.10	1.08	1.05	1.05	1.05
		Efficiency		30%	30%	30%	33%	35%	36%	36%	36%
		Input-natural gas		1.67	1.67	1.67	1.52	1.45	1.39	1.39	1.39
		Lifetime	30								
		Year first available	1995								
ESOLPT00	Power Tower	Capital Cost ($/kW)		3,805	2,875	2,129	2,381	2,262	2,144	2,088	2,032
		Capacity Factor (%)		0.43	0.43	0.44	0.65	0.71	0.77	0.77	0.77
		Fixed O&M ($/kW-yr)		67.0	67.0	23.0	30.0	27.5	25.0	25.0	25.0
		Lifetime	30								
		Year first available	1995								
ESOLST00	Solar Trough	Capital Cost ($/kW)		3,972	2,883	2,731	2,528	2,347	2,123	2,123	2,123
		Capacity Factor (%)		0.333	0.333	0.417	0.512	0.512	0.512	0.512	0.512
		Fixed O&M ($/kW-yr)		107	63	52	43	48	34	34	34
		Lifetime	30								
		Year first available	1995								
WIND											
EWNDC	Wind Class 4	Capital Cost ($/kW)		1,000	1,000	915	910	880	860	818	775
		Capacity Factor (%)		0.252	0.252	0.350	0.447	0.465	0.471	0.471	0.471
		Fixed O&M ($/kW-yr)		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
		Variable O&M ($/GJ)		1.38	1.38	0.72	0.50	0.47	0.44	0.44	0.44
		Lifetime	30								
		Year first available	1995								
EWNDC600	Wind Class 6	Capital Cost ($/kW)		1,000	1,000	800	800	770	750	720	695
		Capacity Factor (%)		0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538
		Fixed O&M ($/kW-yr)		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
		Variable O&M ($/GJ)		1.56	1.39	0.57	0.50	0.47	0.44	0.44	0.44
		Lifetime	30								
		Year first available	1995								

Central-average CF(Z)(Y)			Central-high CF(Z)(Y)			Residential-ave CF(Z)(Y)			Residental-high CF(Z)(Y)		
SF	0.25		SF	0.25		SF	0.25		SF	0.25	
DF	0.58	0.65	DF	0.58	0.74	DF	0.58	0.65	DF	0.58	0.74
NF	0.42	0	NF	0.42	0	NF	0.42	0	NF	0.42	0
IF	0.5		IF	0.5		IF	0.5		IF	0.5	
DF	0.5	0.35	DF	0.5	0.5	DF	0.5	0.34	DF	0.5	0.5
NF	0.5	0	NF	0.5	0	NF	0.5	0	NF	0.5	0
WF	0.25		WF	0.25		WF	0.25		WF	0.25	
DF	0.42	0.24	DF	0.42	0.3	DF	0.42	0.24	DF	0.42	0.29
NF	0.58	0	NF	0.58	0	NF	0.58	0	NF	0.58	0
Annual CF		0.207	Annual CF		0.264	Annual CF		0.205	Annual CF		0.263

Solar Dish CF(Z)(Y)			1995-2005 Tower CF(Z)(Y)			2010 Tower CF(Z)(Y)			2015 Tower CF(Z)(Y)		
SF	0.25		SF	0.25		SF	0.25		SF	0.25	
DF	0.58	0.9	DF	0.58	0.75	DF	0.58	0.85	DF	0.58	0.9
NF	0.42	0.2	NF	0.42	0.4	NF	0.42	0.62	NF	0.42	0.7
IF	0.5		IF	0.5		IF	0.5		IF	0.5	
DF	0.5	0.85	DF	0.5	0.65	DF	0.5	0.8	DF	0.5	0.8
NF	0.5	0.15	NF	0.5	0.24	NF	0.5	0.5	NF	0.5	0.6
WF	0.25		WF	0.25		WF	0.25		WF	0.25	
DF	0.42	0.8	DF	0.42	0.45	DF	0.42	0.75	DF	0.42	0.8
NF	0.58	0.1	NF	0.58	0.1	NF	0.58	0.4	NF	0.58	0.5
Annual CF		0.50	Annual CF		0.435	Annual CF		0.650	Annual CF		0.71

2020 Tower CF(Z)(Y)			2000 Trough CF(Z)(Y)			2005 Trough CF(Z)(Y)			2010 Trough CF(Z)(Y)		
SF	0.25		SF	0.25		SF	0.25		SF	0.25	
DF	0.58	0.9	DF	0.58	0.8	DF	0.58	0.85	DF	0.58	0.9
NF	0.42	0.8	NF	0.42	0	NF	0.42	0.25	NF	0.42	0.35
IF	0.5		IF	0.5		IF	0.5		IF	0.5	
DF	0.5	0.9	DF	0.5	0.655	DF	0.5	0.7	DF	0.5	0.75
NF	0.5	0.7	NF	0.5	0	NF	0.5	0.15	NF	0.5	0.25
WF	0.25		WF	0.25		WF	0.25		WF	0.25	
DF	0.42	0.8	DF	0.42	0.5	DF	0.42	0.52	DF	0.42	0.7
NF	0.58	0.5	NF	0.58	0	NF	0.58	0	NF	0.58	0.145
Annual CF		0.77	Annual CF		0.333	Annual CF		0.417	Annual CF		0.512

Table A3-3. Technology Data—Units&Converts

Conversions from Source Data Template to Individual Technology Sheets

Country Name <My Country>

Unit Type	Orig Unit IDs	My Unit IDs	Convert Factor
Monetary	1995$US	1995$US	1.000
Capacity	$/kW	m$/GW	1.000
Activity	¢/kWh	m$/PJ	2.778
	$/kWh	m$/PJ	277.8
Capacity	GW	GW	1.000
Activity	PJ	PJ	1.000
Energy	PJ	PJ	1.000
Emissions			
CO2	kt/PJ	kt/PJ	1.000
NOx	t/PJ	t/PJ	1.000
Cap-2-Energy	GW	PJ	31.536

Renewable Fossil Equivalent for Reporting	3.125

Table A3-4. Technology Data—CF & Peak Calculations

Intermediate Season

Time	Day hours	Night hours	Solar output	Day output	Night output
0 -1		1	0	0	0
1-2		1	0	0	0
2 -3		1	0	0	0
3 -4		1	0	0	0
4 -5		1	0	0	0
5 -6		1	0	0	0
6 -7		1	0	0	0
7 -8	1		0.100	0.100	0
8 -9	1		0.248	0.248	0
9 -10	1		0.373	0.373	0
10 -11	1		0.423	0.423	0
11 -12	1		0.472	0.472	0
12 -13	1		0.487	0.487	0
13 -14	1		0.487	0.487	0
14 -15	1		0.472	0.472	0
15 -16	1		0.423	0.423	0
16 -17	1		0.373	0.373	0
17 -18	1		0.248	0.248	0
18 -19	1		0.100	0.100	0
19 -20		1	0.000	0	0
20 -21		1	0.000	0	0
21 -22		1	0.000	0	0
22 -23		1	0.000	0	0
23-24		1	0	0	0
Total	12	12			
DF=	0.50			0.350	
NF=		0.50			0.000
IF-	0.5	6 months per year			

Summer Season

Time	Day hours	Night hours	Solar output	Day output	Night output
0 -1		1	0	0	0
1-2		1	0	0	0
2 -3		1	0	0	0
3 -4		1	0	0	0
4 -5		1	0	0	0
5 -6		1	0	0	0
6 -7	1		0.175	0.175	0
7 -8	1		0.435	0.435	0
8 -9	1		0.650	0.650	0
9 -10	1		0.740	0.740	0
10 -11	1		0.825	0.825	0
11 -12	1		0.850	0.850	0
12 -13	1		0.875	0.875	0
13 -14	1		0.875	0.875	0
14 -15	1		0.850	0.850	0
15 -16	1		0.825	0.825	0
16 -17	1		0.740	0.740	0
17 -18	1		0.650	0.650	0
18 -19	1		0.435	0.435	0
19 -20	1		0.175	0.175	0
20 -21		1	0.000	0	0
21 -22		1	0.000	0	0
22 -23		1	0.000	0	0
23-24		1	0.000	0	0
Total	14	10			
DF=	0.58			0.650	
NF=		0.42			0.000
SF=	0.25	3 months per year			

Winter Season

Time	Day hours	Night hours	Solar output	Day ouput	Night output
0 -1		1	0	0	0
1-2		1	0	0	0
2 -3		1	0	0	0
3 -4		1	0	0	0
4 -5		1	0	0	0
5 -6		1	0	0	0
6 -7		1	0	0	0
7 -8		1	0	0	0
8 -9	1		0.074	0.074	0
9 -10	1		0.185	0.185	0
10 -11	1		0.275	0.275	0
11 -12	1		0.315	0.315	0
12 -13	1		0.353	0.353	0
13 -14	1		0.353	0.353	0
14 -15	1		0.315	0.315	0
15 -16	1		0.275	0.275	0
16 -17	1		0.185	0.185	0
17 -18	1		0.074	0.074	0
18 -19		1	0.000	0	0
19 -20		1	0.000	0	0
20 -21		1	0	0	0
21 -22		1	0	0	0
22 -23		1	0	0	0
23-24		1	0	0	0
Total	10	14			
DF=	0.42			0.240	
NF=		0.58			0.000
WF	0.25	3 months per year			

Country Values for CF(Z)(Y)		
CF(Z)(Y)	I-N	0.00
CF(Z)(Y)	S-D	0.65
CF(Z)(Y)	S-N	0.00
CF(Z)(Y)	W-D	0.24
CF(Z)(Y)	W-N	0.00

Check on Annual Average CF			
IF		0.5	
	DF	0.50	0.35
	NF	0.50	0.00
SF		0.25	
	DF	0.58	0.65
	NF	0.42	0.00
WF		0.25	
	DF	0.42	0.24
	NF	0.58	0.00
Annual CF			0.207

PEAK(CON) Calculation
0.40

Example PV Plant Output - Ave sunlight			
Time	IF	SF	WF
0 -1	0	0	0
1-2	0	0	0
2 -3	0	0	0
3 -4	0	0	0
4 -5	0	0	0
5 -6	0	0	0
6 -7	0	0.175	0
7 -8	0.100	0.435	0
8 -9	0.248	0.650	0.074
9 -10	0.373	0.740	0.185
10 -11	0.423	0.825	0.275
11 -12	0.472	0.850	0.315
12 -13	0.487	0.875	0.353
13 -14	0.487	0.875	0.353
14 -15	0.472	0.850	0.315
15 -16	0.423	0.825	0.275
16 -17	0.373	0.740	0.185
17 -18	0.248	0.650	0.074
18 -19	0.100	0.435	0
19 -20	0	0.175	0
20 -21	0	0	0
21 -22	0	0	0
22 -23	0	0	0
23 -24	0	0	0

Example Solar Trough Plant Output			
Time	IF	SF	WF
0 -1	0	0	0
1-2	0	0	0
2 -3	0	0	0
3 -4	0	0	0
4 -5	0	0	0
5 -6	0	0	0
6 -7	0	0.000	0
7 -8	0.000	0.450	0
8 -9	0.260	0.700	0.000
9 -10	0.500	0.800	0.250
10 -11	0.750	0.900	0.500
11 -12	0.900	0.950	0.750
12 -13	0.900	0.950	0.750
13 -14	0.900	0.950	0.750
14 -15	0.900	0.950	0.750
15 -16	0.900	0.950	0.750
16 -17	0.750	0.950	0.500
17 -18	0.600	0.950	0.000
18 -19	0.500	0.950	0
19 -20	0	0.750	0
20 -21	0	0	0
21 -22	0	0	0
22 -23	0	0	0
23 -24	0	0	0

Example Solar Tower Plant Output			
Time	IF	SF	WF
0 -1	0	0.2	0
1-2	0	0	0
2 -3	0	0	0
3 -4	0	0	0
4 -5	0	0	0
5 -6	0	0	0
6 -7	0	0.000	0
7 -8	0.000	0.000	0
8 -9	0.000	0.400	0.000
9 -10	0.450	0.750	0.000
10 -11	0.750	0.850	0.000
11 -12	0.825	0.900	0.300
12 -13	0.825	0.950	0.550
13 -14	0.825	0.950	0.700
14 -15	0.825	0.950	0.700
15 -16	0.825	0.950	0.750
16 -17	0.825	0.950	0.750
17 -18	0.825	0.950	0.750
18 -19	0.825	0.950	0.750
19 -20	0.825	0.950	0.650
20 -21	0.825	0.950	0
21 -22	0.825	0.950	0
22 -23	0.400	0.950	0
23 -24	0	0.950	0

Table A3-5. Technology Data—Energy Carriers

Energy Carriers

		Transmission Efficiency
Electric Grid	ELC	1
Biomass	BIO	
Coal	COA	
Geothermal	GEO	
Solar	SOL	
Wind	WND	

Emissions

Better NOx emission data is needed for biomass.

Reference source gave 4.3 g/GJ for direct fire technology and 64.5 g/GJ for gasification technology.

WEA Table 8.1 gives 3.47 g/kWh (EAI data for 1997) for average coal combustion plants. This = 0.96 kg/GJ. It gives 0.87 g/kWh as BACT, which is 24.2 g/GJ .

Assume biomass direct fired 80% of coal NOx emissions due to lower flame temps and same ave eff (.33) gives 771 g/GJ

WEA Table 8.1 gives 0.092 g/kWh for NGCC, which is 26 g/GJ for 54.1% eff. Adjusting BIGCC for eff (.42) gives 33.5 g/GJ.

Table A3-6. Technology Data—Biomass

Biomass Technologies

Name	EBIOCF00		Description		Biomass - cofire											Country Factor
Parameter	Energy	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
AF					0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	1
FIXOM		m$/GW			10.11	9.81	9.61	9.5	9.33	9.24	9.15	9.15	9.15	9.15	9.15	1
INP(ENT)c	BIO				0.31	.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	1
INP(ENT)c	COA				2.75	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	1
INVCOST		m$/GW			256	241	230	224	217	212	208	207.6	207.6	207.6	207.6	1
PEAK(CON)					1	1	1	1	1	1	1	1	1	1	1	1
VAROM		m$/PJ			-0.453	-0.453	-0.453	-0.453	-0.453	-0.453	-0.453	-0.453	-0.453	-0.453	-0.453	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			2000													

Note: Because of the changing FIXOM, this technology should have separate characterization for each period until 2030

Name	EBIODF00		Description		Biomass - direct fire											Country Factor
Parameter	Energy	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
AF		-		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	1
FIXOM	-	m$/PJ		60.0	60.0	60.0	60.0	55.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	1
INP(ENT)c	BIO	-		3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST	-	m$/GW		1,796	1,571	1,364	1,211	1,080	1,004	1,004	1,004	1004	1004	1004	1004	1
PEAK(CON)	-	-		1	1	1	1	1	1	1	1	1	1	1	1	1
VAROM	-	m$/PJ		1.945	1.945	1.945	1.945	1.764	1.583	1.583	1.583	1.583	1.583	1.583	1.583	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing AF, FIXOM & VAROM, this technology should have separate characterization for 1995, 2015 and 2020

Name	EBIOGA00			Description		Biomass - gasification										Country Factor
Parameter	Energy	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
AF					0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.8	0.8	0.8	0.8	1
FIXOM		m$/GW			43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4	1
INP(ENT)c	BIO				2.78	2.70	2.70	2.70	2.41	2.31	2.22	2.22	2.22	2.22	2.22	1
INVCOST		m$/GW			1892	1650	1464	1350	1258	1185	1111	1111	1111	1111	1111	1
PEAK(CON)					1	1	1	1	1	1	1	1	1	1	1	1
VAROM		m$/PJ			1.445	1.445	1.445	1.445	1.445	1.445	1.445	1.445	1.445	1.445	1.445	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			2000													

Note: Because of the changing INP(ENC) this technology should have separate characterization for 2000, 2005, 2020, 2025, and 2030

Table A3-7. Technology Data—Geothermal Technologies

Geothermal Technologies

Name	EGEOBI00			Description		Geothermal Binary										Country Factor
Parameter	Energy	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	1
AF				0.89	0.92	0.93	0.95	0.95	0.96	0.965	0.97	0.97	0.97	0.97	0.97	1
FIXOM		m$/GW		87.4	78.5	66.8	59.5	55	52.4	51.45	50.5	50.5	50.5	50.5	50.5	1
INP(ENT) c	GEO			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		2112	1994	1875	1754	1700	1637	1575	1512	1512	1512	1512	1512	1
PEAK(CON)				1	1	1	1	1	1	1	1	1	1	1	1	1
VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing AF & FIXOM, this technology should have separate characterization for each period until 2030

Name	EGEOFS00			Description		Geothermal Flashed Steam										Country Factor
Parameter	Energy	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	1
AF				0.89	0.92	0.93	0.95	0.95	0.96	0.97	0.97	0.97	0.97	0.97	0.97	1
FIXOM		m$/GW		96.40	87.10	74.80	66.30	62.00	58.20	56.45	54.70	54.70	54.70	54.70	54.70	1
INP(ENT)c	GEO			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		1,444	1,372	1,250	1,194	1,145	1,100	1,068	1,036	1,036	1,036	1,036	1,036	1
PEAK(CON)				1	1	1	1	1	1	1	1	1	1	1	1	1
VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing AF & FIXOM, this technology should have separate characterization for each period until 2030

Name	EGEOHR00			Description		Geothermal Hot Dry Rock										Country Factor
Parameter	Energy	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
AF					0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.87	0.87	0.87	1
FIXOM		m$/GW			207	191	179	171	163	157.5	152	152	152	152	152	1
INP(ENT)c	GEO				3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW			5176	4756	4312	3794	3276	2984	2692	2692	2692	2692	2692	1
PEAK(CON)					1	1	1	1	1	1	1	1	1	1	1	1
VAROM		m$/PJ			0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			2000													

Note: Because of the changing AF & FIXOM, this technology should have separate characterization for each period until 2030

Caution: Hot dry rocks is advanced technology that is included as an option for country teams to consider including if their country contains a suitable geological resources and has technical skills appropriate to the technology risks.

Table A3-8. Technology Data—Solar Photovoltaic Technologies

Solar Photovoltaic Technologies

Name	ESOLPCA00			Description		PV Central Station-average										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	
CF(Z)(Y)	I-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	S-D			0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	
CF(Z)(Y)	S-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	W-D			0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	
CF(Z)(Y)	W-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
FIXOM		m$/GW		18.00	13.75	5.75	3.56	1.78	2.38	2.31	2.25	2.25	2.25	2.25	2.25	1
INP(ENT)c	SOL			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		7,000	5,300	2,900	1,500	1,300	1,100	990	880	880	880	880	880	1
PEAK(CON)				0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1
VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_ TID	ELC		1													
START			1995													

Note: Because of the changing FIXOM, this technology should have separate characterization for each period until 2030

Average sunlight corresponds to 1800 kWh/m2/yr

Name	ESOLPCH00			Description		PV Central Station-high										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
CF(Z)(Y)	I-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	S-D			0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	
CF(Z)(Y)	S-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	W-D			0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	
CF(Z)(Y)	W-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
FIXOM		m$/GW		18.00	13.75	5.75	3.56	1.78	2.38	2.31	2.25	2.25	2.25	2.25	2.25	1
INP(ENT)c	SOL			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		7,000	5,300	2,900	1,500	1,300	1,100	990	880	880	880	880	880	1
PEAK(CON)				0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1
VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													

START			1995													
Note: Because of the changing FIXOM, this technology should have separate characterization for each period until 2030																
High sunlight corresponds to 2400 kWh/m2/yr																
Name	ESOLPRA00			Description		PV Residential-average										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	
CF(Z)(Y)	I-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	S-D			0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	
CF(Z)(Y)	S-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	W-D			0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	
CF(Z)(Y)	W-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
FIXOM		m$/GW		17.40	15.38	14.29	13.33	12.92	12.50	12.13	11.76	11.76	11.76	11.76	11.76	1
INP(ENT)c	SOL			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		6,720	5,340	4,040	3,050	2,410	1,770	1,405	1,040	1,040	1,040	1,040	1,040	1
PEAK(CON)				0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1
VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													
Note: Because of the changing FIXOM, this technology should have separate characterization for each period until 2030																
Average sunlight corresponds to 1800 kWh/m2/yr																
Name	ESOLPRH00			Description		PV Residential-high										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
CF(Z)(Y)	I-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	S-D			0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	
CF(Z)(Y)	S-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CF(Z)(Y)	W-D			0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	
CF(Z)(Y)	W-N			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
FIXOM		m$/GW		17.40	15.38	14.29	13.33	12.92	12.50	12.13	11.76	11.76	11.76	11.76	11.76	1
INP(ENT)c	SOL			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		6,720	5,340	4,040	3,050	2,410	1,770	1,405	1,040	1,040	1,040	1,040	1,040	1
PEAK(CON)				0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1

VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing FIXOM, this technology should have separate characterization for each period until 2030
High sunlight corresponds to 2400 kWh/m2/yr

Table A3-9. Technology Data—Solar Thermal Concentrating Technologies

Solar Thermal Concentrating Technologies

Name	ESOLDE00			Description	Dish Engine-hybrid											Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	
CF(Z)(Y)	I-N			0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
CF(Z)(Y)	S-D			0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
CF(Z)(Y)	S-N			0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	
CF(Z)(Y)	W-D			0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	
CF(Z)(Y)	W-N			0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
FIXOM		m$/GW		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
INP(ENT)c	SOL			1.5625	1.5625	1.5625	1.5625	1.5625	1.5625	1.5625	1.5625	1.5625	1.5625	1.5625	1.5625	1
INP(ENT)c	NGS or DSL			1.6667	1.6667	1.6667	1.6667	1.6667	1.6667	1.6667	1.6667	1.6667	1.6667	1.6667	1.6667	1
INVCOST		m$/GW		12,000	5,691	3,231	1,690	1,579	1,467	1,396	1,324	1,324	1,324	1,324	1,324	1
PEAK(CON)				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1
VAROM		m$/PJ		58.34	10.28	6.39	3.06	2.99	2.92	2.92	2.92	2.92	2.92	2.92	2.92	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing FIXOM, this technology should have separate characterization for each period until 2030

Name	ESOLPT00			Description		Power Tower										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.65	0.65	0.65	0.80	0.80	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
CF(Z)(Y)	I-N			0.24	0.24	0.24	0.50	0.60	0.70	0.70	0.70	0.70	0.70	0.70	0.70	
CF(Z)(Y)	S-D			0.75	0.75	0.75	0.85	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
CF(Z)(Y)	S-N			0.40	0.40	0.40	0.62	0.70	0.80	0.80	0.80	0.80	0.80	0.80	0.80	
CF(Z)(Y)	W-D			0.45	0.45	0.45	0.75	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	
CF(Z)(Y)	W-N			0.10	0.10	0.10	0.40	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
FIXOM		m$/GW		67.00	67.00	23.00	30.00	27.50	25.00	25.00	25.00	25.00	25.00	25.00	25.00	1
INP(ENT)c	SOL			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		3,805	2,875	2,129	2,381	2,262	2,144	2,088	2,032	2,032	2,032	2,032	2,032	1
PEAK(CON)				0.5	0.6	0.6	0.75	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1

VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing CF and FIXOM, this technology should have separate characterization for 1995, 2005, 2010, 2015 and 2020

Name	ESOLST00			Description		Solar Trough										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.66	0.66	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	
CF(Z)(Y)	I-N			0.00	0.00	0.15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
CF(Z)(Y)	S-D			0.80	0.80	0.85	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
CF(Z)(Y)	S-N			0.00	0.00	0.25	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	
CF(Z)(Y)	W-D			0.50	0.50	0.52	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	
CF(Z)(Y)	W-N			0.00	0.00	0.00	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
FIXOM		m$/GW		107.00	63.00	52.00	43.00	48.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	1
INP(ENT)c	SOL			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		3,972	2,883	2,731	2,528	2,347	2,123	2,123	2,123	2,123	2,123	2,123	2,123	1
PEAK(CON)				0.5	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1
VAROM		m$/PJ		0	0	0	0	0	0	0	0	0	0	0	0	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing CF and FIXOM, this technology should have separate characterization for each period until 2020

Table A3-10. Technology Data—Wind Technologies

Windpower Technologies

Name	EWNDC400			Description		Wind Class 4										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.252	0.252	0.350	0.447	0.465	0.471	0.471	0.471	0.471	0.471	0.471	0.471	
CF(Z)(Y)	I-N			0.252	0.252	0.350	0.447	0.465	0.471	0.471	0.471	0.471	0.471	0.471	0.471	
CF(Z)(Y)	S-D			0.252	0.252	0.350	0.447	0.465	0.471	0.471	0.471	0.471	0.471	0.471	0.471	
CF(Z)(Y)	S-N			0.252	0.252	0.350	0.447	0.465	0.471	0.471	0.471	0.471	0.471	0.471	0.471	
CF(Z)(Y)	W-D			0.252	0.252	0.350	0.447	0.465	0.471	0.471	0.471	0.471	0.471	0.471	0.471	
CF(Z)(Y)	W-N			0.252	0.252	0.350	0.447	0.465	0.471	0.471	0.471	0.471	0.471	0.471	0.471	
FIXOM		m$/GW		8.00	13.75	5.75	3.56	1.78	2.38	2.31	2.25	2.25	2.25	2.25	2.25	1
INP(ENT)c	WND			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		1,000	1,000	915	910	880	860	818	775	775	775	775	775	1
PEAK(CON)				0.25	0.25	0.35	0.45	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	1
VAROM		m$/PJ		1.38	1.38	0.72	0.50	0.47	0.44	0.44	0.44	0.44	0.44	0.44	0.44	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing CF and VAROM this technology should have separate characterization for each period until 2020

Name	EWNDC600			Description		Wind Class 6										Country Factor
Parameter	Energy/TD	Units	TID	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	
CF(Z)(Y)	I-D			0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538	0.538	0.538	0.538	0.538	
CF(Z)(Y)	I-N			0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538	0.538	0.538	0.538	0.538	
CF(Z)(Y)	S-D			0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538	0.538	0.538	0.538	0.538	
CF(Z)(Y)	S-N			0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538	0.538	0.538	0.538	0.538	
CF(Z)(Y)	W-D			0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538	0.538	0.538	0.538	0.538	
CF(Z)(Y)	W-N			0.352	0.394	0.443	0.496	0.509	0.538	0.538	0.538	0.538	0.538	0.538	0.538	
FIXOM		m$/GW		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	1
INP(ENT)c	WND			3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	1
INVCOST		m$/GW		1,000	1,000	800	800	770	750	720	695	695	695	695	695	1
PEAK(CON)				0.35	0.39	0.44	0.50	0.51	0.54	0.54	0.54	0.54	0.54	0.54	0.54	1

VAROM		m$/PJ		1.56	1.39	0.57	0.50	0.47	0.44	0.44	0.44	0.44	0.44	0.44	0.44	1
LIFE			30													
OUT(ELC)_TID	ELC		1													
START			1995													

Note: Because of the changing CF and VAROM this technology should have separate characterization for each period until 2020

Table A3-11. Technology Data—ANS Items (Sample)

*** ITEMS ***	<My Country>					
* Note that items that already exist in the BASE scenario may be removed prior to loading if desired by						
*	putting an * in the 1st position of each row assoicated with said item, or deleting the rows					
*						
*	Energy					
*						
Item:	E	ELC	Electric Grid			
Sets:	ENT	ELC				
Units:	COMM=	PJ				
Item:	E	BIO	Biomass			
Sets:	ENT	ENC	ERN			
Units:	COMM=	PJ				
Item:	E	COA	Coal			
Sets:	ENT	ENC	EFS	SLD		
Units:	COMM=	PJ				
Item:	E	GEO	Geothermal			
Sets:	ENT	ENC	ERN			
Units:	COMM=	PJ				
Item:	E	SOL	Solar			
Sets:	ENT	ENC	ERN			
Units:	COMM=	PJ				
Item:	E	WND	Wind			
Sets:	ENT	ENC	ERN			
Units:	COMM=	PJ				
*						
*	Technologies					
*						
Item:	T	EBIOCF00	Biomass - cofire			
Sets:	TCH	CON	ELE	CEN	BAS	RNT
Units:	TACT=	PJ	TCAP=	GW		
Item:	T	EBIODF00	Biomass - direct fire			

Table A3-12. Technology Data—ANS-TID (Sample)

*** TID DATA ***	<My Country>				
*					
CAPUNIT	EBIOCF00	-	-	-	31.536
LIFE	EBIOCF00	-	-	-	30
OUT(ELC)_TID	EBIOCF00	ELC	-	-	1
START	EBIOCF00	-	-	-	2000
*					
CAPUNIT	EBIODF00	-	-	-	31.536
LIFE	EBIODF00	-	-	-	30
OUT(ELC)_TID	EBIODF00	ELC	-	-	1
START	EBIODF00	-	-	-	1995
*					
CAPUNIT	EBIOGA00	-	-	-	31.536
LIFE	EBIOGA00	-	-	-	30
OUT(ELC)_TID	EBIOGA00	ELC	-	-	1
START	EBIOGA00	-	-	-	2000
*					
CAPUNIT	EGEOBI00	-	-	-	31.536
LIFE	EGEOBI00	-	-	-	30
OUT(ELC)_TID	EGEOBI00	ELC	-	-	1
START	EGEOBI00	-	-	-	1995
*					
CAPUNIT	EGEOFS00	-	-	-	31.536
LIFE	EGEOFS00	-	-	-	30
OUT(ELC)_TID	EGEOFS00	ELC	-	-	1
START	EGEOFS00	-	-	-	1995
*					
CAPUNIT	EGEOHR00	-	-	-	31.536
LIFE	EGEOHR00	-	-	-	30
OUT(ELC)_TID	EGEOHR00	ELC	-	-	1
START	EGEOHR00	-	-	-	2000

Table A3-13. Technology Data—ANS-T (Sample)

*** TS DATA ***	<My Country>															
* Parameter	Technology	Energy	-null-	TD	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
*																
*	Energy															
*																
TE(ENT)	-	ELC	-	-	1	1	1	1	1	1	1	1	1	1	1	1
TE(ENT)	-	BIO	-	-	1	1	1	1	1	1	1	1	1	1	1	1
TE(ENT)	-	COA	-	-	1	1	1	1	1	1	1	1	1	1	1	1
TE(ENT)	-	GEO	-	-	1	1	1	1	1	1	1	1	1	1	1	1
TE(ENT)	-	SOL	-	-	1	1	1	1	1	1	1	1	1	1	1	1
TE(ENT)	-	WND	-	-	1	1	1	1	1	1	1	1	1	1	1	1
*																
*	Technologies															
*																
AF	EBIOCF00	-	-	-	0	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
FIXOM	EBIOCF00	-	-	-	0	10.11	9.81	9.61	9.5	9.33	9.24	9.15	9.15	9.15	9.15	9.15
INP(ENT)c	EBIOCF00	BIO	-	-	0	0.306153	0.461056	0.461056	0.461056	0.461056	0.461056	0.461056	0.461056	0.461056	0.461056	0.461056
INP(ENT)c	EBIOCF00	COA	-	-	0	2.752424	2.612653	2.612653	2.612653	2.612653	2.612653	2.612653	2.612653	2.612653	2.612653	2.612653
INVCOST	EBIOCF00	-	-	-	0	255.5	240.5	230.3	223.5	216.7	212.15	207.6	207.6	207.6	207.6	207.6
PEAK(CON)	EBIOCF00	-	-	-	0	1	1	1	1	1	1	1	1	1	1	1
VAROM	EBIOCF00	-	-	-	0	-0.45281	-0.45281	-0.45281	-0.45281	-0.45281	-0.45281	-0.45281	-0.45281	-0.45281	-0.45281	-0.45281
*																
AF	EBIODF00	-	-	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
FIXOM	EBIODF00	-	-	-	60	60	60	60	55	49	49	49	49	49	49	49
INP(ENT)c	EBIODF00	BIO	-	-	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125
INVCOST	EBIODF00	-	-	-	1796	1570.5	1363.5	1211.4	1080	1003.5	1003.5	1003.5	1003.5	1003.5	1003.5	1003.5
PEAK(CON)	EBIODF00	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
VAROM	EBIODF00	-	-	-	1.9446	1.9446	1.9446	1.9446	1.76403	1.58346	1.58346	1.58346	1.58346	1.58346	1.58346	1.58346
*																
AF	EBIOGA00	-	-	-	0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
FIXOM	EBIOGA00	-	-	-	0	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4
INP(ENT)c	EBIOGA00	BIO	-	-	0	2.777778	2.702703	2.702703	2.702703	2.409639	2.312139	2.222222	2.222222	2.222222	2.222222	2.222222
INVCOST	EBIOGA00	-	-	-	0	1892	1650	1464	1350	1258	1184.5	1111	1111	1111	1111	1111

Annex 4: APEC MARKAL New and Renewable Technologies Study Assessment[3]

Table A4-1. APEC New and Renewable Technologies Assessment – Index and Overview of Results

	Australia	China	Japan	US
Approach & Procedures				
Analysis Period	2000-2040	1995-2050	1990-2050	1995-2050 in 1999 US$
Monetary Convert to US$1995	2000$A (conversion factor = 2000$A1.739 / 1995US$)	1 (Model uses US$ 1995)	0.17 (from billion 1995ye to million 1995US$)	0.934579439
Approach & Procedures				
Com**modity Prices**	Original fossil fuel price projections were used	Original fossil fuel price projections were used.	Original fossil fuel price projections were used.	Original fossil fuel price projections were used.
Incorporation of APECR Technology Characterizations	used standard Australian MARKAL database which has recently been revised with respect to REs	Used ANSWER bulk load of APECR from the XLS, and adjusted.	Used ANSWER bulk load of APECR from the XLS, and adjusted.	Used ANSWER bulk load of APECR from the XLS with convert 1995 to 1999 $.
	Australia has introduced a mandatory target policy for renewable electricity which does allow some increases in hydro beyond a given base level (the scenario REFMRET). The scenario REFMRETH is a hypothetical variant of this existing policy in which hydro	Renewable energy technologies are already attractive in the Reference Chinese model, with wind and biomass technologies contributing 10.7% of electricity generation in 2030. When the APECR technologies were integrated into	Runs APECR-1and 2 correspond to minimum APECR electricity production shares 10%/15% in 2030 and thereafter. In the both cases, 2000=0%, 2005=1%, 2010=2%, and for time periods between 2010-2030	APECR technologies cost/performance characteristics are clearly very attractive as without encouragement they are taken up to about the 10% of electric generation level. So the 3/7% constraints were non-binding and dropped, and constraints forcing 10% and

[3] The complete spreadsheet workbook, RE Technology Assessment _1.XLS, can be obtained from the APEC Secretariat or the author.

APECR RENEWABLE ELECTRIC % RUNS	output is not permitted to exceed the hydro output in the reference case (REFAPEC) in which there is no mandatory target at all for NRE technologies. The additional mandatory targets undertaken here are 3, 10 and 20 per cent over and above the REFMRET case but exclude any increase in hydro beyond the reference case output. The CO2-constrained cases (acronyms ending '...10C') are all subject to a limit on time-dependent CO2 emissions after 2015 that has an absolute value equal to 90 per cent of the emissions in the Reference case, REFAPEC). Hence, the CO2 constraint becomes relatively less binding as the effect of the new renewables target is ramped up.	the model, the non-hydro RE contribution increased to 19.1%. Therefore, three cases were developed that would increase the minimum percentage of RE in 2030 to approximately 10%, 15% and 20% above the REF case. Specifically, the targets in 2030 were 20.7%, 25.7% and 30.7% respectively, and these were ramped in from 2010 on a linear basis.	linear interpolation was made. In the reference (REF) case, new investment on renewable technologies is not made after the year 2000 except for hydropower and district heating technologies. Thus, in APECR-1 and APECR-2 cases, the contribution by APECR technologies is explicitly indicated in comparison with the REF case.	15% over the 3% REF case levels (that is 13/18%) were used. These constraints were phased in beginning from the 3% BASE levels in 2005 until the target level is achieved in 2030 and held constant after that. Note that with the currently imposed limit on potential of these technologies the model is just infeasible at the 20% level. The market potential limits imposed on the model for the APECR technologies were taken from the most favorable estimates available from the US DOE.

	Australia	China	Japan	US
Analysis Period	2000-2040	1995-2050	1990-2050	1995-2050 in 1999 US$
Summary of Conclusions				
OVERALL MESSAGE	Runs indicate that the NRE technologies can contribute significantly to CO2 reductions especially by replacing coal-fired power technologies in the electric sector. Some replacement of gas also occurs. If the difference in discounted cost is divided by the reduction in cumulative emissions (here, relative to the reference case) we have a useful indicator of cost-effectiveness of CO2 abatement—that may be referred to as the 'unit discounted cost of cumulative abatement'. On this basis, the cost of achieving CO2 reductions with the NRE technologies present but applying the constraint directly to CO2 emissions, the additional system cost is approximately 25-35% of the equivalent additional cost due to use of the mandatory targets for the NRE technologies alone but without CO2 constraints. Additional NREs induced by the mandatory targets do not reduce fossil fuel imports in Australia given that it is major exporter of steaming coal (and LNG).	The model shows that the APECR technologies can contribute significantly to CO2 reductions by replacing coal-fired power technologies in the electric sector. The cost of achieving CO2 reductions wit the APECR technologies is approximately 60% of the equivalent cost using the renewable energy technologies in the REF scenario. The model also shows that the APECR technologies can help reduce imports of oil and gas (28.8% in the REF case to 18.3% in the APECR+20% case). Some of the APECR technologies are sufficiently economic to compete with existing and new fossil-fired technologies. Many of the others can be introduced without any significant economic impacts, particularly when CO2 emissions are to be controlled. However, these preliminary results also show that significant reductions in CO2 emissions will require attention to non-electric sectors of the economy.	APECR technologies will contribute, by replacing coal-fired power technologies, to alleviate the current heavy dependence on imported fossil fuel and the reduction of CO2 emissions. Some of them are enough economical to compete with existing and new fossil-fired technologies. Most of others might also be introduced to the future energy systems without any significant economic impacts, particularly when CO2 emissions are to be controlled.	APECR technologies cost/performance characteristics are clearly very attractive as without encouragement they are taken up to about the 10% of electric generation level. The overall impact of the APECR portfolio without a CO2 limits is positive with respect to the (marginal) cost of electricity and level of emssions. These technologies compete most directly with gas. As a result gas use shifts up somewhat in the residential and commercial sectors resulting in about the same levels of overall fossil fuel use. In the constrained cases, the cost of meeting CO2 limit declines steeply over time for all cases, but the APECR portfolio is much less disruptive in the initial years and the long-term costs to the energy system is much less than without it.

	Australia	China	Japan	US
Analysis Period	**2000-2040**	**1995-2050**	**1990-2050**	**1995-2050 in 1999 US$**
COSTS (TOTAL, ELECTRIC & EMISSIONS)	**(1) Differences in objective value relative to the reference case are in the range \$323 million to \$2591 million in the pure renewable target cases and \$885 to 2732 million in the mixed cases that also incorporate the CO2 constraint. (2) For the pure target cases, value of the 'unit discounted cost of cumulative abatement' increases in the range \$8–11 / tonne of cumulative CO2 (contained carbon basis). (3) the CO2 constraint as defined, becomes relatively less binding as the effect of the new renewables target is ramped up. Hence, the marginal cost of meeting the CO2 constraint also falls as this target is ramped up—for example, in the 2030 time sub-period, decreasing from \$35 / tonne CO2 to \$17 / tonne CO2.**	**1) Several of the APECR technologies are quite cost-effective in the 2010 to 2040 time frame, and their introduction reduces the discounted system cost by 0.07% compared to a cost increase of 0.24% for the same renewable energy mandate without the APERC technologies (REF+10%RE). As the APECR technology contribution is increased, this 0.07% cost savings is reduced until the APECR+20% case (31% total renewable energy contribution) where the system cost increase 0.03% above the REF case. In the REF-CO2 case, the system cost increase is 0.78%, but in the APECR-CO2 case, the cost increases only 0.56%. 2) For the APECR+ cases, the peak marginal cost of electricity decreases slightly with the introduction of the APECR technologies because starting in about 2020 they are more cost-effective than the coal technologies that they are displacing. With the REFCO2 case, the coal use does not change much, but it shifts from combustion to gasification. The gasification tech has higher capital costs by lower operating costs, thus the reduced the peak marginal. In the APECR-CO2 case, the shift from coal combustion to gasification is less than in the REF-CO2 case, and the reduction in the peak electricity marginal is less. 3) The marginal cost of introducing the APECR technologies (above the 10.7% REF case contribution) is less than half the cost per GJ of add a similar increment of renewable energy technologies, and the APECR marginal cost is flat or decreases with time. In the REF+10%RE case, the marginal introduction cost increases significantly over time 4) The cost of reducing CO2 emissions in the REF-CO2 case is generally about 60% higher than it is in the APECR cases.**	**Some of APECR technologies are economically well competitive with existing fossil technologies. Thus, without lower constraints APECR produced 3.8% of total electricity in 2030, and 6.5% in 2050. By this, as a cumulative value over 1990-2050, fuel import cost was reduced by 0.4%, although total cost was reduced by only 0.04%. When lower constraints were applied, APECR technologies with higher production costs were also introduced in the system resulting in the increase of total costs. However, the rate of the increase was quite modest such as 0.06% with the 10% constraint or 0.22% with the 15% constraint. With the CO2 emission constraint, total cumulative cost increased by 0.2% without APECR, however in the APECR case with the 10% constraint the increase remained 0.11% indicating that the introduction of APECR up to this scale will contribute to lower the cost of CO2 emission control.**	**1) Total system cost indicates that the APECR technologies do require higher investment in the electric sector, but the total system cost over the entire modeling horizon drops owing to the drop in total fossil fuel consumption and higher availability of the renewable technologies than assumed in the REFerence scenario. 2) It is a bit surprising to see the marginal cost of the electricity drop with the introduction of the APECR technologies. It re-asserts the attractiveness nature of the APECR assumptions, perhaps a bit overly so . However, even slightly more pessimistic assumptions would not impact the basic nature of the results. Also, note that the high electric marginal in REF+C is due to the need to abandon coal-fired capacity in favor on nuclear power or more advanced gas combined cycle. 3) The APECR technologies accomplish the slowing of CO2 growth at a cost of 54-81% less than the REF case alone.**

	Australia	China	Japan	US
Analysis Period	2000-2040	1995-2050	1990-2050	1995-2050 in 1999 US$
POWER SECTOR SHIFTS	Coal-fired electricity generation is dominant in Australia except for Tasmania (hydro) and South Australia and to a lesser extent Western Australia (gas). However gas, and CCGT capacity in particular, is also an important future option even in those more populous eastern states with access to low cost coal (NSW, Victoria and Queensland). In the case of the pure mandatory targets for renewables, the reduction in coal-fired electricity varies in the range 0-21 per cent as the target is ramped up. In absolute terms, these reductions are greater than those in gas-fired electricity but only by a factor of around two. This contrasts markedly with the optimal carbon penalties cases in which gas-fired electricity expands and the fall in coal-fired output has then to fall more radically. This greater role for gas explains much of the greater cost-effectiveness of the pure carbon penalty approach. However, by the time we reach the mixed 20 percent target case there is no difference in the role of gas compared with the corresponding pure targets approach. The impact on hydro as the new renewables target is ramped up is minimal, corresponding the way that the target is defined—that is, excluding hydro but by subjecting hydro output to a simple upper bound identical to that of the reference case, in all cases. If an important objective of the mandatory targets is to abate CO2 emissions, it does not seem appropriate that these targets be defined to as to squeeze hydro. This is especially so given that electricity can be produced at low marginal cost from existing capacity. This is particularly the case in Australia, where little scope exists for investment in major new hydroelectric capacity.	The REF case has 10.7% of electric generation from renewable energy. Large wind-farms and village-scale biomass gasification systems are the major contributors. Addition of the APECR technologies increases the wind energy contribution, add solar power tower technology to the electricity mix, and reduces coal use in the electric sector. When additional renewable energy technologies are forced into the energy economy, biomass gasification technology is added because the APECR wind and solar power tower technology are limited by their upper bounds. Coal use in the electric sector further reduced. If CO2 constraints are imposed in the REF case, coal gasification technology with CO2 sequestration is used to meet the constraint. If the CO2 constraint is applied with the APECR technologies, biomass gasification and combustion technologies are added, and less coal gasification with CO2 sequestration is used. The renewable energy contribution in the electric sector increased to 31%.	Coal fired plants were most affected. Electricity generation by both conventional and IGCC plants reduced with the increase of APECR contribution. Integrated gasification-MCFC plants, introduced from 2030 in the reference case, were not used at all in APECR cases. Oil-fired power plants, including auto generation with oil and/or waste fuel, were affected next. Influences to gas-fired, nuclear, and hydropower were quite small. When CO2 emissions were controlled, gas and hydro increased much to meet the constraints, however, their increases were much lower if APECR was introduced in the system.	The primary shift for the non-CO2 cases is about a 7.5% drop each in coal and gas generation. In the CO2 constrained case the coal sector takes a 20% "hit" on generation without the APECR technologies, but just 16% with them. But the picture for gas is quite different. Gas generation must raise by 16% without the APECR technologies, but remains pretty much constant when the are available. Total electric generation moves down slightly in most cases. Under the CO2 limits w/ APECR technologies the coal sector takes much less of a hit and there is no abandonment of existing capacity as there is in the REF case. Also slower and somewhat reduced uptake of the AGCC and little gas turbine systems (which are in heavy demand for REF) when the APECR technologies are available. Note that in the REF CO2 limited run advanced nuclear needs to be built during the 2025-40 timeframe.

	Australia	China	Japan	US
Analysis Period	**2000-2040**	**1995-2050**	**1990-2050**	**1995-2050 in 1999 US$**
ENERGY USE PATTERNS	Total energy use declines slightly in response to the mandatory NRE target, by as much as 2 % in the MRETS+20% case (2020) but negligibly by 2030. The declines in primary energy due to the CO2 target are more significant (again as at 2020) in the range 2.6 to 5.4 % relative to REFAPEC.	In the REF case, coal use is 63.5% of total primary energy. With the addition of the APECR technologies, overall coal use remains constant, but oil consumption in reduced as electricity from renewable energy technologies increases. Oil imports are reduced. This trend holds for all cases where the renewables contribution is increased. In the REF-CO2 case, coal use in electric sector is basically the same, but coal use in other sectors decreases and is replaced by natural gas (mostly) and oil (slightly). This is consistent with the shift in coal use from combustion to gasification with CO2 sequestration. When the CO2 constraint is imposed with the APECR technologies available, both coal use and natural gas use are reduced relative to the REF-CO2 case.	In primary energy fossil fuel is dominant now with a share of 82% in 2000. This is projected in the REF case to decrease to 74% in 2030 assuming substantial contribution by nuclear energy. In the APECR cases, the dependence on fossil fuel in 2030 reduced to 70% (10% constraint) or to 67% (15% constraint). Among fossil fuel, the reduction of coal was particularly large. In the cases without CO2 constraints, oil and natural gas decreased in addition to coal, but with much modest rates. No remarkable changes were found in the fuel mix of final energy consumption.	Outside of the shifts discussed with respect to electric generation mix, overall final energy consumption remains about the same. There are some shifts with respect to an increase in gas for commercial cooling and residential heating, particularly in the CO2 limited scenarios where gas is forced lower without the APECR technologies. Also, in the CO2 limited scenario the level of residential conservation raised by 33% in the REF case, whereas it remains about constant when the APECR technologies are available.

	Australia	China	Japan	US
Analysis Period	**2000-2040**	**1995-2050**	**1990-2050**	**1995-2050 in 1999 US$**
IMPACT ON EMISSIONS	In the pure mandatory target cases for NRE, reductions in cumulative CO2 emissions increase from 1.3 % to 5 % relative to REFAPEC. With the introduction of the CO2 abatement target as well, the actual cumulative CO2 abatement increases from 6.9 % in the case with no mandatory target for NRE to 7.2 - 7.5 % in the case of mandatory targets 3-20 above the MRET case	The APECR technologies contribute to an important reduction in CO2 emissions, achieving a 1.5% reduction in cumulative emissions simply through their introduction (APECR case), and achieving up to 2.3% reduction in the APECR+20% case. However, the model shows that while coal in the electric sector is reduced, overall coal use is not necessarily reduced. By contrast, the REF-CO2 case achieves 31% renewable energy in the electric sector (same as the APECR+20% case), but it achieves an 8.5% reduction in cumulative CO2 emissions, which is 3.7 times higher than the APECR+20% case. In the REF-CO2 case, the model employs CO2 sequestration from coal gasification technologies, to both further reduce emissions from the electric sector, and to use syn gas products to displace coal in non-electric sectors.	APECR contributes to substantial reduction of CO2 emissions. In the 15% constraint cases, the total emissions were reduced by 9%, and the power sector emissions by 29% over the time period 1990-2050. Looking at the year 2050, the total emissions were reduced by 15%, and the power sector emissions by 45%. Comparing its share in electricity generation, the rate of CO2 emission reduction is much larger because APECR replaces mainly coal-fired electric power generation technologies.	The model is run with US Clean Air Act limits on NOX and SOX in place (by sector where appropriate). Not surprisingly the shift away from coal and oil in the CO2 limited cases reduces associated releases of NOx, SOx, PM10 from both the power sector and industry, as well as to a lesser degree in the residential sector. Interestingly with the APECR technologies available the SOx limit on the power sector remain active, but when the CO2 limit is active for the Reference scenario the heavy drop in coal/gas use results in slack on this constraint. The power sector CO2 emissions are about 14% lower when the APECR technologies are available. Reference scenario power sector CO2 emissions drop almost 19% while with the APECR technologies available the total cumulative CO2 emissions drop over 22% when the CO2 limit is imposed.

	Australia	China	Japan	US
Analysis Period	**2000-2040**	**1995-2050**	**1990-2050**	**1995-2050 in 1999 US$**
Renewables Electric Technology Inputs and Results				
BIOMASS	Various forms of biomass-based electricity account for the bulk of new renewables, with bagasse-based electricity being initially the most important. It grows in absolute terms as the target becomes more stringent and accounts for 35 per cent of new renewables (2030) in the reference case. However, this share declines to 22 per cent (2030) at the most stringent target.	ALL three APECR biomass technologies were incorporated into the model, direct-fired starting from 2000, co-fired and gasification from 2005. No changes were made to the Chinese biomass technologies, except to lower the starting (2010) upper bound on EBL02 (electricity & DME production) In the REF case, the two preferred technologies are EBL02 and EBV03 (village-scale biomass gasification CHP.) In the APECR+ cases, the APECR biomass gasification and direct combustion technologies are selected. The model prefers the gasification technology, the constraint used to limit the technology growth rate required that some biomass direct combustion technology be employed.	ALL three APECR biomass technologies were incorporated into the model, co-fired and direct-fired starting from 2005, and gasification from 2015. No investment was permitted on the biomass technologies in the original Japan's model for the time period 2005-2050. In the results of analysis, co-fired technology was introduced up to the limits in all cases, however contribution by direct-fired and gasification technologies was very limited even in the cases with CO2 emission control. This is due to the assumption that the main source of biomass fuel will be imported wood, and will remain high price. Since economic attractiveness of biomass energy depends highly on the price of biomass fuel, contribution of direct-fired and gasification technologies will be more substantial if much cheaper biomass fuel than assumed here is available in the future.	Small adjustment permitting higher GROWTH and 2000 start for gasification. The amount of direct fire generation is fixed, as all future biomass electric is assumed to use gasification. The biomass gasification ends up not being fully used for the Reference CO2 run owing to the release of NOx, but the other APECR technologies enable it to max out when needed. The only decentralized options are industrial co-generation. The total biomass potential is identical in the REF and APECR scenarios. But the elaborate supply curves (13steps in all) do not move above the 3rd step ($2.77m/Pj) except to help meet the PCTRNW 18% constraint. This limited use is primarily due to the 5%/yr limit on the expansion of the biomass gasification technology.
GEOTHERMAL	no geothermal in Australian MARKAL database	All three APECR geothermal technologies were incorporated into the model. Flashed steam starting from 2005, binary from 2010, and hot dry rock from 2015. The Chinese technology was left in the model, and the same upper bound (0.85 GW) was applied to all technologies. Because the geothermal resource for power generation in China is small, these APECR technologies, while being selected, do not have much impact on the electricity supply or CO2 emissions.	All three APECR geothermal technologies were incorporated into the model, flashed steam starting from 2005, binary from 2010, and hot dry rock from 2015. No investment was permitted on the geothermal technologies in the original Japan's model for the time period 2005-2050. Flashed steam and binary technologies were introduced up to the limits in almost all cases of this assessment, but the use of hot dry rock was very limited because of its high investment and O&M costs. These results are consistent with those obtained in the past studies.	In all cases, other than the Reference case, the geothermal maxs out at its limits and is strongly sought. For the PCTRNW and CO2 runs this is to be expected.

	Australia	China	Japan	US
Analysis Period	**2000-2040**	**1995-2050**	**1990-2050**	**1995-2050 in 1999 US$**
SOLAR	Photovoltaics do not appear until 2030 and either the most stringent renewable target (20+2 per cent) or its combination with the CO2 constraint, at 3 per cent of new renewables excluding hydro. Solar thermal does not appear in any case.	All four PV technologies, central station (high and average sunlight) and residential (high and average sunlight) were incorporated into the model, both starting from 2000. Each was given a growth constraint, but no upper bound. Two solar thermal technologies, power tower and solar dishes were also incorporated into the model, both available from 2010. Each was given an upper bound proportional to the size of the resource and the expected maximum penetration rate. No investment was permitted on the solar technologies in the original China model for the time period 2005-2050. The model selects the solar power tower as the preferred solar technology in the **APECR case up to the amount allowed by the resource upper bound. No other solar technology is selected.**	Two PV technologies, central station (average sunlight) and residential (average sunlight) were incorporated into the model, both starting from 2050. Two solar thermal technologies, power tower and solar trough, were also involved in the model, both available from 2010. No investment was permitted on the solar technologies in the original Japan's model for the time period 2005-2050. The analytical results showed that power tower is most attractive and PV residential is next. Solar trough and PV central were used only when lower constraints were given to APECR technologies. Since the development of solar thermal technologies is not active in Japan, the original data were used for them. Economic attractiveness of power tower is due to the assumption on its high availability.	Solar as represented in the Reference scenario is only of interest under the CO2 limited run. For the APECR cases the various central station plants were made available to limited degrees, but only the high PV options were introduced. Without the PCTRNW constraints only the central PV is of interest, or when a CO2 limit is imposed.

	Australia	China	Japan	US
Analysis Period	**2000-2040**	**1995-2050**	**1990-2050**	**1995-2050 in 1999 US$**
WIND	Wind share of NRE increases from 13 to 26 per cent as the mandatory target is ramped up from 3 to 20 per cent above the existing 2 per cent target (2025). The CO2 constraint entails 17 per cent wind in the presence of the existing mandatory target.	Both APECR wind turbine technologies were incorporated into the model, both starting from 2000. No investment was permitted on the Local Wind Farm technology in the original China model. Investment was permitted in the Remote Wind Farm technology with long-distance transmission, and the potential resource (320 GW) was partitioned between the three wind technologies according to data on Class 4-5 and Class 6-7 wind recourses. The APECR cases have about 60% more installed wind farms in 2030 relative to the	All two APECR wind turbine technologies (class 4 and 6) were incorporated into the model, both starting from 2005. No investment was permitted on the wind turbine technology in the original Japan's model for the time period 2005-2050. In the results of the study class 6 was very promising, but class 4 was less attractive because of higher investment cost and lower availability. Different from other APECR technologies, the original cost data of wind power seems rather pessimistic as compared with those in Japan's model, although the investment cost of wind power depends heavily on its location.	The US model was split into Class 4, 5 and 6/7. As Class 5 was not broken out in the APECR scenario the Class 5 information that was provided by the DOE was used for all runs. Wind Class 4 was not permitted until 2030, under the assumption that the more attractive 5/6/7 sites would be used first. Note surprisingly there is a lot of pressure for more Class 6/7 as the PCTRNW constraint is increased, as well as on 4/5 when CO2 limits are introduced.
FUEL CELLS	no fuel cells in Australian MARKAL database	The China model contains two distributed CHP fuel cell technologies: one that uses natural gas (MCFC or SOFC) and one that uses H2 from coal or biomass. Model selects only the natural gas fuel cell technology.	No fuel cells using synfuels from renewable energy.	Fuel cells were characterized in the reference scenario and available to all scenarios. They are of little interest, except when from methane/hydrogen and the PCTRNW constraint is pushing the system.

Table A4-2. APEC New and Renewable Technologies Assessment: Australia

		REFAPEC	REFMRET	REFMRETH	MRET03H	MRET10H	MRET20H	REFAP10C	MRETS10C	MRETH10C	MRE3H10C	MR10H10C	MR20H10C
Scenario		Reference case	MRETS not excluding hydro	MRETS excluding hydro	MRETS + 3 per cent, excluding hydro	MRETS + 10 per cent, excluding hydro	MRETS + 20 per cent, excluding hydro	Reference case	MRETS not excluding hydro	MRETS excluding hydro	MRETS + 3 per cent, excluding hydro	MRETS + 10 per cent, excluding hydro	MRETS + 20 per cent, excluding hydro
								plus 10 per cent reduction in CO2 after 2015, relative to Reference case					
Total system cost	1995US$ m	1076774	1077097	1077106	1077256	1077817	1079366	1077659	1077876	1077889	1077947	1078286	1079507
(difference rel. to ref case)	1995US$ m	0	323	331	482	1043	2591	885	1102	1115	1173	1511	2732
(difference rel. corr. Case without CO2 constraint)	1995US$ m	0	0	0	0	0	0	885	779	784	691	469	141
(difference rel. to MRETS case not excluding hydro)	1995US$ m	-323	0	8	159	719	2268	562	779	792	849	1188	2409
Change in Total System Cost (%change			0.0300%	0.0308%	0.0448%	0.0968%	0.2407%	0.0822%	0.1023%	0.1036%	0.1089%	0.1404%	0.2537%
Change is Total System Cost from Bau=REFMRET (%change					0.0147%	0.0668%	0.2106%	0.0522%	0.0723%	0.0735%	0.0789%	0.1103%	0.2237%
Change in primary energy mix (%change	2020	0.0	-0.6	-0.7	-1.6	-3.4	-7.1	-5.0	-5.0	-5.0	*-5.1*	*-6.3*	*-8.7*
	2030	0.0	-0.1	-0.1	-1.3	-3.4	-4.1	-4.7	-4.7	-4.7	*-4.8*	*-6.0*	*-4.8*
Amount of electricity produced (%change	2020	0.0	0.0	-0.1	-0.5	-0.9	-2.1	-2.6	-2.5	-2.5	*-2.3*	*-2.7*	*-5.4*
	2030	0.0	0.0	-0.1	-0.7	-0.5	0.0	-0.6	-0.6	-0.6	*-0.5*	*-0.6*	*-0.3*
Total percent electricity from renewables	2020	10.6	12.5	12.5	14.9	20.5	28.5	14.4	14.6	14.5	15.2	20.5	28.5
	2030	15.6	15.9	15.9	18.9	25.9	35.9	18.3	18.4	18.3	18.9	25.9	35.9
rel. to Ref. Case (percentage points	2020	0.0	1.9	1.9	4.3	9.9	17.9	3.9	4.0	4.0	4.6	9.9	17.9
	2030	0.0	0.3	0.3	3.3	10.3	20.3	2.7	2.8	2.7	3.3	10.3	20.3
Total percent electricity from (non-hydro) renewables	2020	1.3	3.3	3.3	5.7	11.2	19.1	5.0	5.0	5.2	5.8	11.3	18.7

		2030	6.0	6.3	6.3	9.3	16.2	26.3	8.6	8.7	8.8	9.4	16.2	26.3
rel. to Ref. Case (percentage points)		2020	0.0	2.0	2.0	4.4	9.9	17.8	3.7	3.8	3.9	4.5	10.0	17.5
		2030	0.0	0.4	0.4	3.3	10.3	20.3	2.6	2.7	2.8	3.4	10.3	20.3
Power plants output displaced owing to the increased renewable electric power generation options	PJ levels													
	coal	2020	531.2	518.7	519.6	517.2	496.3	432.6	429.7	430.6	430.7	433.2	427.9	412.2
		2025	495.2	493.1	493.6	486.9	467.3	410.1	399.8	401.0	400.6	401.3	397.2	391.5
		2030	395.1	395.0	394.1	379.3	360.3	315.9	310.6	310.0	309.9	309.7	306.7	308.8
	gas	2020	18.5	16.4	16.0	13.8	11.6	11.6	23.3	22.0	21.8	19.3	11.6	11.6
		2025	19.1	17.4	17.0	14.6	10.0	10.0	58.3	57.1	58.4	56.6	36.6	10.0
		2030	37.3	35.2	35.9	30.8	9.4	0.8	103.7	103.0	103.8	100.9	55.8	0.8
	hydro	2020	61.8	62.2	61.5	61.8	61.5	61.8	61.8	62.3	61.6	61.3	60.4	61.8
		2025	61.8	62.3	61.6	61.2	61.8	61.8	61.5	61.7	61.1	61.3	60.0	61.8
		2030	61.8	62.3	61.7	61.4	61.8	61.8	61.3	61.6	61.0	61.0	61.8	61.8
	PJ differences from Ref. Case													
	coal	2020	0.0	-12.6	-11.6	-14.1	-34.9	-98.6	-101.5	-100.6	-100.5	-98.0	-103.3	-119.0
		2025	0.0	-2.0	-1.6	-8.2	-27.8	-85.1	-95.3	-94.1	-94.6	-93.8	-98.0	-103.7
		2030	0.0	-0.1	-1.0	-15.8	-34.8	-79.2	-84.5	-85.1	-85.2	-85.4	-88.4	-86.3
	gas	2020	0.0	-2.1	-2.5	-4.7	-6.9	-6.9	4.8	3.5	3.3	0.8	-6.9	-6.9
		2025	0.0	-1.7	-2.1	-4.4	-9.0	-9.0	39.2	38.0	39.4	37.5	17.6	-9.0
		2030	0.0	-2.1	-1.4	-6.5	-27.9	-36.5	66.5	65.7	66.5	63.6	18.5	-36.5
	hydro	2020	0.0	0.4	-0.3	0.0	-0.3	0.0	0.0	0.5	-0.2	-0.4	-1.4	0.0
		2025	0.0	0.4	-0.3	-0.6	0.0	0.0	-0.3	-0.2	-0.8	-0.6	-1.9	0.0
		2030	0.0	0.5	-0.1	-0.4	0.0	0.0	-0.6	-0.2	-0.9	-0.8	0.0	0.0
	(% change)													
	coal	2020	0.0	-2.4	-2.2	-2.6	-6.6	-18.6	-19.1	-18.9	-18.9	*-18.5*	*-19.4*	*-22.4*

		2025	0.0	-0.4	-0.3	-1.7	-5.6	-17.2	-19.3	-19.0	-19.1	*-18.9*	*-19.8*	*-20.9*
		2030	0.0	0.0	-0.3	-4.0	-8.8	-20.0	-21.4	-21.5	-21.6	*-21.6*	*-22.4*	*-21.9*
	gas	2020	0.0	-11.5	-13.6	-25.5	-37.2	-37.2	25.9	19.2	17.9	*4.5*	*-37.2*	*-37.2*
		2025	0.0	-8.7	-10.9	-23.2	-47.5	-47.5	206.0	199.5	206.7	*196.9*	*92.1*	*-47.5*
		2030	0.0	-5.7	-3.6	-17.3	-74.9	-97.9	178.3	176.2	178.4	*170.7*	*49.7*	*-97.9*
	hydro	2020	0.0	0.7	-0.4	0.0	-0.4	0.0	0.0	0.8	-0.3	*-0.7*	*-2.3*	*0.0*
		2025	0.0	0.7	-0.4	-1.0	0.0	0.0	-0.5	-0.3	-1.2	*-0.9*	*-3.1*	*0.0*
		2030	0.0	0.7	-0.2	-0.7	0.0	0.0	-0.9	-0.3	-1.4	*-1.3*	*0.0*	*0.0*
Total cumulative emissions CO2 (contained carbon)	m tonne		4952	4923	4922	4888	4820	4702	4610	4594	4593	4594	4591	4580
absolute change	m tonne		0	-29	-30	-64	-132	-250	-342	-358	-359	-358	-361	-372
(%change)			0	-0.6	-0.6	-1.3	-2.7	-5.0	-6.9	-7.2	-7.2	*-7.2*	*-7.3*	*-7.5*
power sector cumulative emissions (CO2	m tonne		1974	1943	1941	1905	1831	1699	1774	1757	1757	1753	1720	1661
absolute change	m tonne		0	-31	-32	-68	-142	-275	-200	-217	-217	-220	-254	-312
(%change)			0.0	-1.6	-1.6	-3.5	-7.2	-13.9	-10.1	-11.0	-11.0	*-11.2*	*-12.9*	*-15.8*
unit discounted cost of cumulative abatement (A/B)	1995US$ / tonne cum CO2			11	11	8	8	10	3	3	3	3	4	7
relative to 'pure carbon penalty' case (REFAP10C) = 1				4.3	4.3	2.9	3.1	4.0	1.0	1.2	1.2	1.3	1.6	2.8
	1995US$ GJ													
Price of electricity (NSW, I-D)		2020	9.0	9.3	9.5	8.7	7.8	9.5	10.4	10.4	10.4	10.1	9.2	10.1
		2025	11.3	11.1	11.1	11.0	10.4	11.4	10.5	10.5	10.5	10.5	10.9	11.8
		2030	14.3	14.4	14.4	14.3	14.3	18.5	17.0	16.7	16.7	16.5	15.7	18.8
	(%change)													
		2020	0	4	6	-3	-13	6	16	15	15	13	3	*13*
		2025	0	-2	-2	-2	-8	1	-7	-7	-7	-7	-3	*5*
		2030	0	0	0	0	0	29	18	16	16	15	10	*31*
	1995US$													

Marginal value on the PCTRNW ADRATIO constraint		2020	0.0	7.0	1.3	13.4	13.9	37.7	0.0	0.0	0.0	3.4	7.8	30.9
		2025	0.0	1.8	1.8	5.9	16.0	37.8	0.0	0.0	0.0	0.0	12.0	33.8
		2030	0.0	0.0	0.6	11.3	21.8	59.5	0.0	0.0	0.0	3.2	22.0	52.7
	1995US$ tonne CO2 (as contained carbon)													
Marginal cost of meeting any carbon emission constraint		2020	0.0	0.0	0.0	0.0	0.0	0.0	-31.8	-31.7	-31.7	-29.4	-20.9	-11.5
		2025	0.0	0.0	0.0	0.0	0.0	0.0	-20.4	-20.9	-20.9	-20.8	-13.1	-6.4
		2030	0.0	0.0	0.0	0.0	0.0	0.0	-35.2	-35.0	-35.0	-31.8	-15.6	-17.1
<u>Notes:</u>														
discount rate = 8 % real														
projection period, 2000-40														
upper limit imposed on output of hydro technologies based on results from reference case (REFAPEC)														

Table A4-3. APEC New and Renewable Technologies Assessment: China

Scenario Results		Reference	APECR	APECR+10%	APECR+15%	APECR+20%	REF-CO2	REF+10%RE	APECR-CO2	APECR-CO2+20%
Scenario Description		Base case with Chinese renewable energy (RE) technologies	Base case with APECR technologies added/substituted for Chinese technologies	APECR technologies with mandated incremental electric production of 10%	APECR technologies with mandated incremental electric production of 15%	APECR technologies with mandated incremental electric production of 20%	Reference case Chinese RE technologies and 10% CO2 emission reduction starting in 2015	Reference case Chinese RE technologies and 10% RE technology mandate	APECR technologies with 10% CO2 emission reduction starting in 2015	APECR technologies with 10% CO2 emission reduction and 20% mandated share
Total Discounted System Cost (billion 1995 US$)		2,816.1	2,814.2	2,814.6	2,815.7	2,816.9	2,838.1	2,823.0	2,831.9	2,831.9
% Change from Reference			-0.07%	-0.06%	-0.02%	0.03%	0.78%	0.24%	0.56%	0.56%
Fossil Energy (EJ)	2010	52.40	52.23	52.12	52.10	52.07	50.44	52.25	49.07	49.04
	2020	65.02	64.35	64.00	63.47	62.99	60.63	64.09	59.49	59.48
	2030	76.41	74.73	74.53	73.70	72.74	70.85	74.58	69.36	69.50
	2040	84.31	81.97	81.83	81.70	81.23	77.75	83.80	77.12	77.07
2030 % Change from Reference			-2.20%	-2.46%	-3.55%	-4.80%	-7.27%	-2.40%	-9.22%	-9.04%
Fossil Energy Breakdown in 2030 (EJ)	Coal	52.55	52.55	52.55	52.55	52.55	49.15	52.35	48.33	48.60
	CBM	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99
	Natural gas	5.29	5.29	5.29	5.29	5.01	7.06	5.29	6.40	6.26
	Crude oil	8.77	8.64	8.64	8.44	8.45	8.64	8.64	8.63	8.63
	ROP	5.81	4.27	4.07	3.44	2.75	2.02	4.31	2.02	2.02
Ratio of Oil & Gas Imports in 2030		28.8%	23.5%	22.8%	20.7%	18.3%	21.8%	23.6%	19.3%	18.8%
Electricity Produced in 2030 (EJ)		10.42	10.37	10.32	10.28	10.25	10.38	10.24	10.43	10.43
% Change from Reference			-0.49%	-0.99%	-1.33%	-1.63%	-0.40%	-1.71%	0.08%	0.10%
Electric Output in 2030 by Fuel Type (EJ)	Coal	6.62	5.78	5.50	4.99	4.48	6.57	5.48	4.58	4.58

		Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Gas	1.03	0.97	1.00	0.97	0.94	1.02	0.99	0.97	0.98
		Nuclear	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
		Hydro	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
		Non-hydro Renewables	1.12	1.98	2.17	2.67	3.18	1.14	2.12	3.23	3.23
	% Non-hydro Renewables		10.7%	19.1%	21.1%	26.0%	31.0%	11.0%	20.6%	31.0%	30.9%
Total CO2 Emissions (10^6 ton C) cumulative over period			91,943	90,581	90,447	90,153	89,840	84,137	91,289	84,134	84,134
	% Change from Reference			-1.48%	-1.63%	-1.95%	-2.29%	-8.49%	-0.71%	-8.49%	-8.49%
Total Power Sector Emissions (10^6 ton CO2) cumulative over period			25,722	23,722	23,492	22,677	21,818	21,514	24,537	20,458	20,544
	% Change from Reference			-7.78%	-8.67%	-11.84%	-15.18%	-16.36%	-4.61%	-20.46%	-20.13%
Peak Marginal Price of Electricity ($/GJ) in 2030			20.70	19.66	19.62	19.63	20.74	17.42	22.27	19.62	19.62
	% Change from Reference			-5.02%	-5.22%	-5.17%	0.19%	-15.85%	7.58%	-5.22%	-5.22%
Marginal value on the PCTRNW ADRATIO constraint ($/GJ)		2010	-	-	2.87	2.40	2.39	-	5.52	-	0
		2020	-	-	1.19	2.52	2.52	-	6.63	-	0
		2030	-	-	1.49	1.94	2.65	-	10.93	-	0
		2040	-	-	0	0	0	-	0	-	0
Marginal cost of meeting any carbon emission constraint ($/ton C)		2015	-	-	-	-	-	66.47	-	46.82	46.87
		2020	-	-	-	-	-	13.91	-	13.11	13.2
		2030	-	-	-	-	-	18.67	-	11.66	11.59
		2040	-	-	-	-	-	51.62	-	31.59	31.58

Notes: 1. "Total" means cumulative values over 60 years from 1992.5 to 2052.5

2. Marginal values are the added cost to the system of one more unit of electricity, or the savings if one less unit CO2 reduction or "forced" renewable energy output)

3. ROP means refined oil products

Table A4-4. APEC New and Renewable Technologies Assessment: Japan

Scenario Results			Reference	APECR	APECR+10%	APECR+15%	REF-CO2	APECR-CO2	APECR-CO2+10%	APECR-CO2+15%
Scenario description			Base case without non-hydro renewable technologies	Base case with APECR technologies	Minimum APECR electric production : 10% or more than total electricity	Minimum APECR electric production : 15% or more than total electricity	Reference case with 10% CO2 emission reduction starting in 2015	Ref+APECR case with 10% CO2 emission reduction starting in 2015	APECR-1 case with 10% CO2 emission reduction starting in 2015	APECR-2 case with 10% CO2 emission reduction starting in 2015
Total discounted system cost (billion 1995US$)			9327.4	9323.4	9332.6	9348.2	9346.3	9333.0	9338.1	9350.8
	%change from Reference			-0.04%	0.06%	0.22%	0.20%	0.06%	0.11%	0.25%
Fossil Energy (EJ)		2010	16.95	16.90	16.78	16.69	16.66	16.74	16.73	16.68
		2020	16.31	16.14	15.71	15.37	15.38	15.26	15.17	15.09
		2030	15.92	15.63	14.97	14.46	14.94	14.72	14.69	14.32
		2040	15.32	14.84	14.29	13.78	14.32	14.02	14.01	13.66
	2030 % Change from Reference			-1.85%	-5.99%	-9.20%	-6.14%	-7.54%	-7.73%	-10.03%
Fossil Energy Breakdown in 2030 (EJ)		Gas	2.64	2.60	2.52	2.55	3.56	2.93	2.81	2.56
		Liquid	7.99	7.99	7.98	7.92	7.69	7.80	7.91	7.99
		Solid	5.30	5.04	4.48	3.98	3.69	3.99	3.98	3.77
Amount of electricity produced in 2030 (EJ)			4.664	4.668	4.666	4.647	4.625	4.667	4.662	4.647
	%change from Reference			0.08%	0.03%	-0.36%	-0.84%	0.06%	-0.05%	-0.37%
% Electric Output in 2030 by Fuel Type		Coal	32.05%	28.56%	23.55%	18.68%	23.10%	22.44%	21.67%	18.36%
		Oil	5.37%	5.29%	4.78%	4.32%	5.82%	5.29%	5.42%	4.32%
		Gas	8.30%	8.10%	7.42%	7.52%	14.02%	8.48%	8.03%	7.84%
		Nuclear	45.08%	45.05%	45.07%	45.24%	46.08%	45.66%	45.10%	45.25%
		Hydro	7.81%	7.80%	7.80%	7.84%	9.58%	8.98%	8.39%	7.84%
		Non-hydro Renewables	0.00%	3.83%	10.00%	15.00%	0.00%	7.76%	10.00%	15.00%

	Others (Wastes)	1.38%	1.38%	1.38%	1.40%	1.40%	1.38%	1.38%	1.39%
Total CO2 emissions (10^6 ton C) cummulative over period		21,221	20,888	20,382	19,927	19,888	19,872	19,863	19,666
%change from Reference			-1.57%	-3.95%	6.10%	-6.28%	-6.36%	-6.40%	-7.33%
Power sector emissions (10^6 ton CO2) cummulative over period		7,007	6,601	6,088	5,546	6,112	5,811	5,760	5,416
%change from Reference			-5.79%	-13.11%	-20.85%	-12.77%	-17.07%	-17.79%	-22.70%
Marginal electricity prices in winter/day ($/GJ)	2020	12.27	12.30	14.03	36.25	16.36	16.31	17.33	43.37
	2030	14.43	12.88	11.34	12.93	17.68	14.90	14.71	12.94
	2040	12.15	11.86	11.00	10.74	15.61	11.00	11.00	10.28
Marginal value on the PCTRNW ADRATIO constraint ($/GJ)	2020	-	-	26.47	251.41	-	-	21.00	317.12
	2030	-	-	1.94	15.88	-	-	1.47	15.94
	2040	-	-	0.00	1.00	-	-	0.00	0.88
Marginal cost of meeting any carbon emission constraint ($/ton C)	2020	-	-	-	-	90.59	90.59	90.59	53.92
	2030	-	-	-	-	101.37	53.92	45.29	0.00
	2040	-	-	-	-	64.71	0.00	0.00	0.00
Any other relevant insights			When APECR was forced into the system, marginal electricity prices of winter-day, a little or much higher in 2020, became even lower than REF after 2020.					After 2020, CO2 constraints (10% below REF levels from 2015 on) can be met at much lower costs when APECR were in the system.	

Notes: 1. "Total" means cumulative values over 60 years from 1992.5 to 2052.5

2. Marginal values are the added cost to the system of one more unit of electricity, or the savings if one less unit CO2 reduction or "forced" renewable energy output)

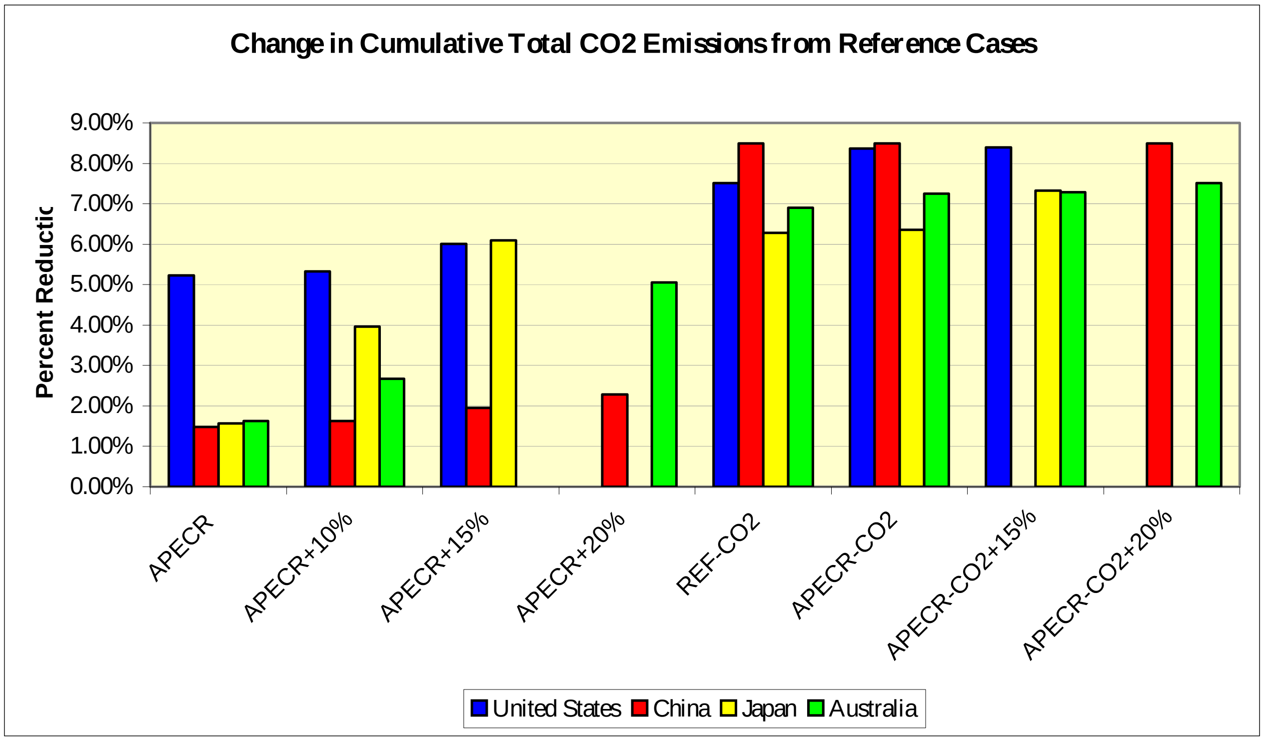
Table A4-5. APEC New and Renewable Technologies Assessment: US

Scenario Results				Reference	APECR	APECR+10%	APECR+15%	REF-CO2	APECR-CO2	APECR-CO2+15%
Scenario description		ANSWER Parameter (note you can also go to the energy/ emissions tab for CO2/ELC)		Base case with US RE technologies	Base case with APECR technologies added/substituted for US technologies	APECR technologies with "forced" renewable electric production of 10% more than Reference	APECR technologies with "forced" renewable electric production of 15% more than Reference	Base case RE technologies with 10% CO2 emission reduction starting in 2015	APECR technologies with 10% CO2 emission reduction starting in 2015	APECR @ +15% renewables with 10% CO2 emission reduction starting in 2015
Total discounted system cost (billion 1995 US$)		T01-D.TOTCOST		130,245.7	130,171.3	130,173.4	130,205.1	130,536.5	130,243.8	130,263.4
	%change from Reference				-0.0572%	-0.0555%	-0.0312%	0.2233%	-0.0014%	0.0136%
Fossil Energy (EJ)		T03-TOT.SUPFOS	2010	106.15	105.24	105.08	104.79	104.76	103.99	104.00
			2020	120.38	117.77	117.49	115.96	114.52	113.12	113.25
			2030	135.40	129.16	128.89	127.91	128.65	125.52	125.44
			2040	150.46	140.11	139.91	139.16	142.74	137.31	137.23
	2030 % Change from Reference				-4.60%	-4.81%	-5.53%	-4.98%	-7.29%	-7.35%
Fossil Energy Breakdown in 2030 (EJ)		T03-TOT.SUPFOS.GAS	Gas	44.96	42.69	42.42	42.13	51.43	43.86	43.62
		T03-TOT.SUPFOS.LIQ	Liquid	60.63	60.50	60.50	60.56	60.74	60.52	60.63
		T03-TOT.SUPFOS.SLD	Solid	29.80	25.98	25.96	25.21	16.49	21.15	21.19
Electricity produced in 2030 (EJ)		T04-OUTELC.TOT		23.00	23.07	23.15	22.84	23.07	22.85	22.85
	%change from Reference				0.33%	0.68%	-0.67%	0.33%	-0.65%	-0.65%
% Electric Output in 2030 by Fuel Type		T04 - OUTELC.CEN +DCN+STG+CPD (using VEDA)	Coal	43.7%	36.6%	36.5%	35.9%	24.0%	29.6%	29.6%
			Gas	40.9%	34.6%	33.8%	33.1%	57.0%	39.2%	39.0%

			Hydro	4.7%	4.9%	5.3%	4.7%	5.3%	4.7%	4.7%
		T04-IMPELC.TOT-EXPELC.TOT	Import	0.1%	0.0%	0.0%	0.0%	0.6%	0.5%	0.5%
		T04 - OUTELC.CEN +DCN+STG+CPD (using VEDA)	Nuclear	7.4%	7.4%	7.3%	7.4%	8.3%	7.4%	7.4%
			Oil	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
			Renewables	3.2%	16.3%	17.0%	18.6%	4.5%	18.4%	18.6%
Total CO2 emissions (10^6 ton C) cumulative over period		T01-EMISSION.TOT		126,431	119,822	119,705	118,835	116,932	115,848	115,825
	%change from Reference				-5.2%	-5.32%	-6.01%	-7.51%	-8.37%	-8.39%
Total Power Sector Emissions (10^6 ton CO2) cumulative over period		T27ENV-EMISSION.L		47,498	40,971	40,847	39,874	38,541	37,069	36,994
	%change from Reference				-13.74%	-14.00%	-16.05%	-18.86%	-21.96%	-22.11%
Peak Marginal Price of Electricity ($/GJ) in 2030		T09-FUEL.ELC.M		13.24	11.66	11.66	12.65	23.09	13.57	13.72
	%change from Reference				-11.93%	-11.93%	-4.46%	74.40%	2.49%	3.63%
Marginal value on the PCTRNW ADRATIO constraint ($/GJ)		T09-EMISSION.M	2010				15.18			14.9
			2020			9.23	563.98			510.19
			2030				4.87			1.63
			2040							
Marginal cost of meeting any carbon emission constraint ($/ton C)		T11-EQ.ADRATIO.M	2015					1507.00	378.94	321.78
			2020					309.70	136.56	142.51
			2030					198.12	39.56	37.68
			2040					158.86	37.03	37.03
Notes:	1. "Total" means cumulative values over 60 years from 1992.5 to 2052.5.									
	2. Marginal values are the added cost to the system of one more unit of electricity, or the savings if one less unit CO2 reduction or "forced" renewable energy output)									

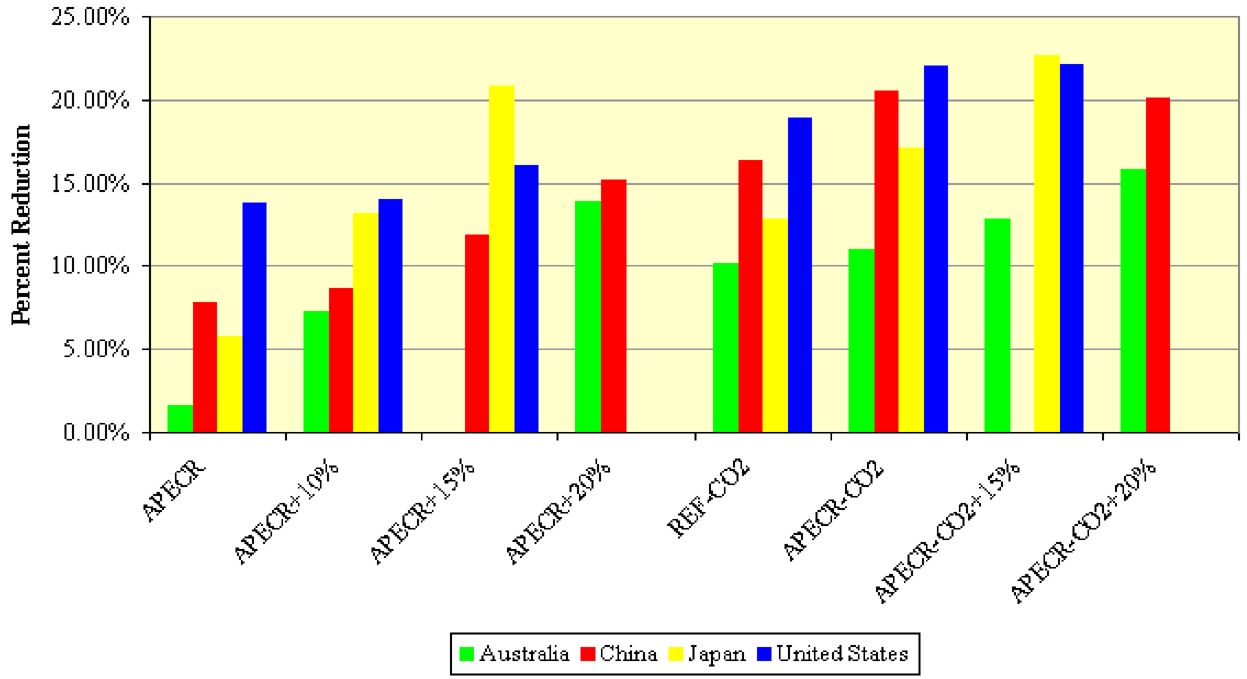
Country | **Cumulative Total Emissions (Million tons CO2)**

	APECR	APECR+10%	APECR+15%	APECR+20%	REF-CO2	APECR-CO2	APECR-CO2+15%	APECR-CO2+20%
Australia	1.63%	2.67%		5.05%	6.91%	7.25%	7.29%	7.51%
China	1.48%	1.63%	1.95%	2.29%	8.49%	8.49%		8.49%
Japan	1.57%	3.95%	6.10%		6.28%	6.36%	7.33%	
United States	5.23%	5.32%	6.01%		7.51%	8.37%	8.39%	



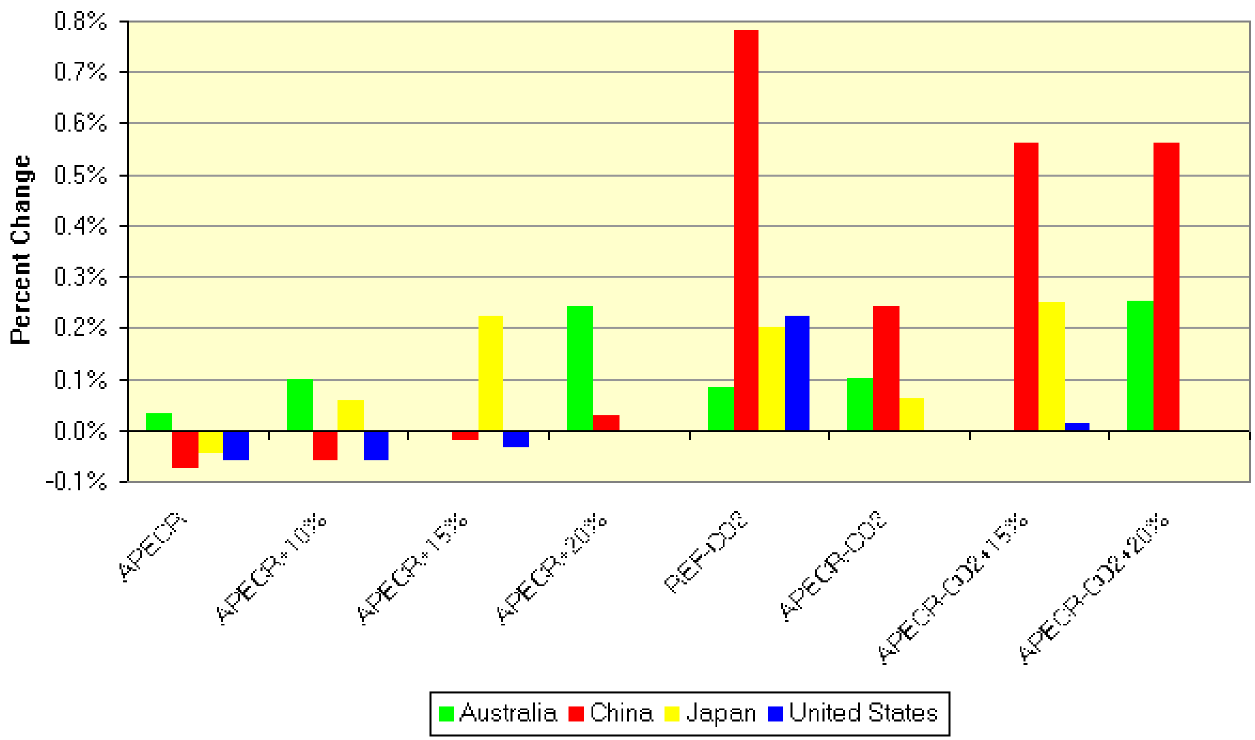
Country **Change in Cumulative Power Sector Emissions from Reference Cases**

	APECR	APECR+10%	APECR+15%	APECR+20%	REF-CO2	APECR-CO2	APECR-CO2+15%
Australia	1.63%	7.22%		13.93%	10.12%	11.00%	12.87%
China	7.78%	8.67%	11.84%	15.18%	16.36%	20.46%	
Japan	5.79%	13.11%	20.85%		12.77%	17.07%	22.70%
United States	13.74%	14.00%	16.05%		18.86%	21.96%	22.11%



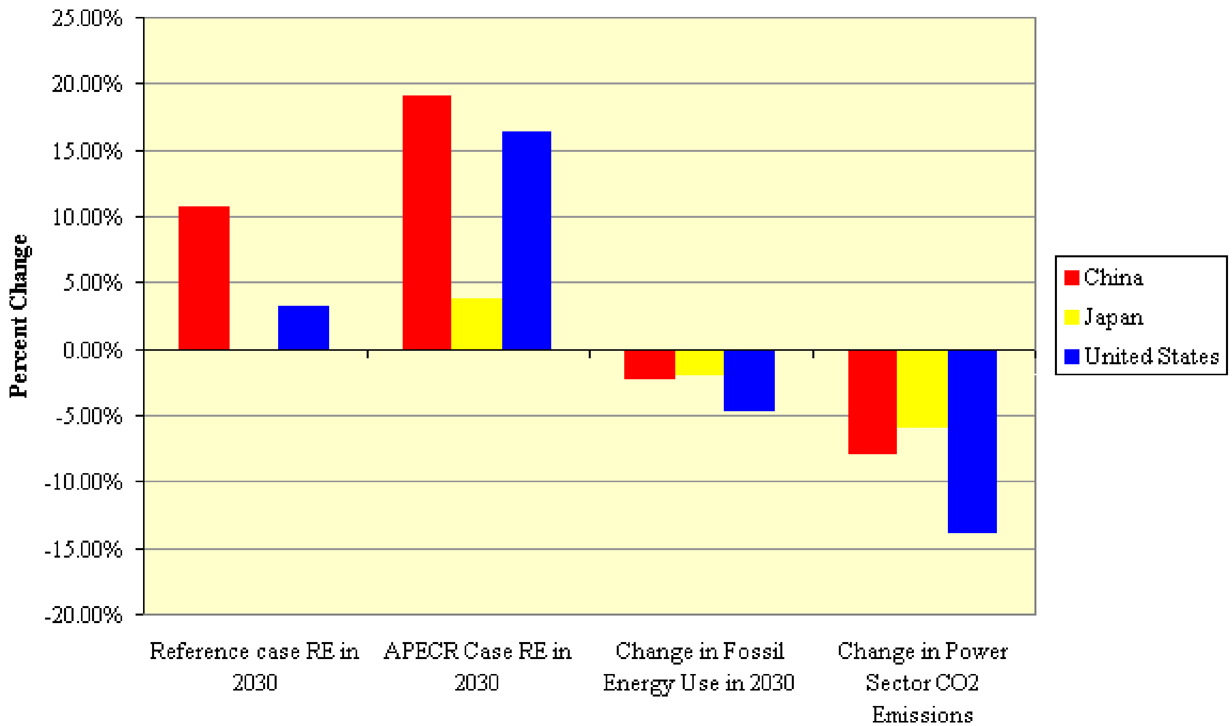
Country — **Cumulative Change in Total Discounted System Cost**

	APECR	APECR+10%	APECR+15%	APECR+20%	REF-CO2	APECR-CO2	APECR-CO2+15%	APECR-CO2+20%
Australia	0.031%	0.097%		0.241%	0.082%	0.104%		0.254%
China	-0.070%	-0.056%	-0.016%	0.029%	0.781%	0.243%	0.561%	0.561%
Japan	-0.043%	0.056%	0.223%		0.202%	0.060%	0.250%	
United States	-0.057%	-0.055%	-0.031%		0.223%	-0.001%	0.014%	



Country **Changes between REF and APECR Cases**

		Reference case RE in 2030	APECR Case RE in 2030	Change in Fossil Energy Use in 2030	Change in Power Sector CO2 Emissions
Australia					
China	10.71%	19.06%		-2.20%	-7.78%
Japan	0.00%	3.83%	-1.85%	-1.85%	-5.79%
United States	3.16%	16.31%	-4.60%	-4.60%	13.74%



Country **CO2 Reduction Cost**

	REF-CO2	APECR-CO2	APECR-CO2+15%	APECR-CO2+20%
United States				
2020	309.70	136.56	142.51	-
2030	198.12	39.56	37.68	-
2040	158.86	37.03	37.03	-
Japan				
2020	90.59	90.59	53.92	-
2030	101.37	53.92	0.00	-
2040	64.71	0.00	0.00	-
China				
2020	13.91	13.11	-	13.2
2030	18.67	11.66	-	11.59
2040	51.62	31.59	-	31.58
Australia				
2020	31.8	31.7	-	11.5
2030	35.2	35.0	-	17.1

So the story line something like: Much more expensive without APECR. As APECR were cost effective to begin with, and directly address lessen CO2 levels, easier across the board with the "best" characterization information. But note also that when forced beginning 2005 to ramp up to +15/20% to meet APECR the impact on the economy to adapt to the lower CO2 levels is less, except in Japan where a slightly lower requirement does . Of course in 2005-10 higher investment costs owing to the forced requirement to invest in the APECR.

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