APEC Workshop on Energy Modelling

Workshop Summary Report

Hong Kong, China | 8 August 2023

APEC Energy Working Group

February 2024

Asia-Pacific
Economic Cooperation

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In conjunction with this project, the "APEC Workshop on Energy Modelling" was held via video conference in Hong Kong, China, on 8 August 2023. The workshop brought together approximately 90 experts and delegates from eight APEC member economies and five organisations. The participants shared their valuable experiences on the utilisation of energy modelling for forecasting energy consumption, tracking progress in low-carbon transitions, and shaping energy policies. We extend our heartfelt gratitude to the speakers, experts, and attendees for their invaluable contributions and support throughout the event.

Contents

1. Background

Climate change is an existential threat to the whole world. COP26 concludes a more substantial commitment from all parties to limit global temperature rises. Meanwhile, The Asia-Pacific Economic Cooperation (APEC) accounts for 65% of global carbon emissions. APEC has set the aspirational goals of reducing the aggregate energy intensity by 45% from 2005 levels by 2035 and doubling the share of renewable energy in APEC's overall energy mix by 2030 (over the 2010 levels).

APEC member economies must plan and monitor their energy policies and energy consumption substantially and evaluate the effectiveness of the energy efficiency policies implemented for low carbon transition and transforming the fuel mix to endeavour the APEC goals.

Energy modelling is indispensable for forecasting energy consumption and tracking low-carbon transition progress. Economies have their unique energy profiles based on their economic activities. In this connection, numerous energy models with notable strengths in the market that APEC member economies have adopted. The energy profile of economic activities keeps evolving with the latest technologies applied in daily life. Keeping the energy model up to date can facilitate the policymakers to identify the potential areas for energy savings and monitor the progress of the target achievement.

2. Objective

2.1. Project Objective

Hong Kong, China (HKC) proposed a project which aimed to analyse various energy modelling to identify their strengths and limitations, including the complexity of the model updating, the level of data details required, and the impact of the latest technological advancement on adopting a new form of renewable energy to facilitate the delivery of the APEC goals.

HKC collaborated with EGEE&C and EGEDA to organise a capacity-building workshop to share current and best practices, case studies, and recommendations on adopting energy modelling.

2.2. Workshop Objective

The workshop that comes alongside this project was held in Hong Kong, China via video conference on 8 August 2023. Around 90 experts and delegates from eight APEC member economies and five organisations attended the workshop to share their experiences on the utilisation of energy modelling in forecasting energy consumption and tracking low carbon transition progress, as well as for formatting the energy policies.

The workshop provided a capacity-building opportunity for APEC members to share current and best practices, case studies, and recommendations on adopting energy modelling. It also supported collaboration between APEC fora, the Energy Working Group (EWG) and its Sub-fora, and international and external organisations with experience sharing and direct dialogue to meet APEC’s energy intensity reduction goal and double renewable energy goal.

The Workshop Summary Report summarised the insights from the speakers and participants during the workshop as recommendations for APEC member economies. This aimed to strengthen the joint efforts in moving towards the APEC goals and APEC 2022 priorities.

3. Workshop Summary

3.1. Opening Remarks

Speaker:
Mr TSE Chin-wan, Secretary for Environment and Ecology, Hong Kong, China

Mr TSE Chin-wan discussed APEC's Energy Intensity Reduction Goal, considering the significant role APEC economies play in global energy consumption, accounting for around 60 per cent of the total. Recognising the rising energy consumption and associated emissions due to rapid economic development and recovery from the pandemic, APEC has set a target to reduce the region's aggregate energy intensity by 45 per cent by 2035 compared to the 2005 level. This goal emphasises the urgent need for APEC members to accelerate their energy transition and adopt more environmentally friendly frameworks to secure a climate-safe future.

He highlighted HKC's commitment to becoming carbon neutral by 2050, as outlined in its Climate Action Plan 2050. The plan focuses on four main decarbonisation strategies and measures: net-zero electricity generation, energy saving and green buildings, green transport and waste reduction. To effectively address climate change and achieve carbon neutrality, HKC has reformed its “Council for Sustainable Development” into the “Council for Carbon Neutral and Sustainable Development”. Additionally, the "Office of Climate Change and Carbon Neutrality" has been established to enhance coordination and drive thorough decarbonisation efforts. These organisations will develop strategies, policies, and action plans to support carbon neutrality.

Mr TSE Chin-wan acknowledged that achieving carbon neutrality within 27 years is a challenging goal that requires robust policy support and cross-sector cooperation. Energy modelling plays a crucial role in projecting the energy consumption and tracking the progress in low-carbon transitions. Each APEC economy has a unique energy profile influenced by its economic activities and the adoption of new technologies. Energy models enable policymakers to identify energy-saving opportunities and track progress towards meeting APEC's energy intensity reduction target.

He emphasised that addressing climate change is a global issue that necessitates global solutions. Building a carbon-neutral future requires collaborative efforts from all APEC member economies. Energy modelling tools provide valuable insights into energy consumption trends, enabling informed decision-making in pursuit of energy goals. By sharing experiences, adopting energy modelling practices, and strengthening collaboration, APEC participants can work together to shape a greener tomorrow.

3.2. Project Summary

Speaker:
Ms Elaine YIP, Project Officer of this APEC project and Engineer of the Electrical and Mechanical Services Department (EMSD), Hong Kong, China

Ms Elaine YIP discussed energy modelling, highlighting its purpose and significance in process systems engineering and energy economic analysis. Energy system modelling, specifically, involves building computer models of energy systems to simulate future outcomes related to energy demand, supply, policy implementation, technology choices, and renewable energy applications.

She mentioned that almost all APEC member economies have adopted energy modelling. Additionally, the study examined the models used by the Asia Pacific Energy Research Centre (APERC) and the International Energy Agency (IEA). The study identified 29 energy system models developed by APEC member economies, categorized into 14 technologies. The Integrated MARKAL-EFOM System (TIMES model) and the Low Emission Analysis Platform (LEAP model) were the most commonly adopted energy modelling technologies, with approximately 33% and 29% adoption rates, respectively.

These technologies can be classified into three basic approaches: top-down, bottom-up, and hybrid. Ms YIP noted that more economies have embraced the bottom-up approach, while others have opted for a hybrid approach. She explained the differences between these approaches.

Top-down models focus on macro-level parameters and drivers, allowing policymakers to assess macroeconomic impacts such as energy and climate policy effects on unemployment rates and inflation. However, top-down models do not delve into the technical details, behaviour, and interaction of individual components within the energy systems, making it challenging to assess the impacts of specific policies and technological advancements.

The bottom-up approach, on the other hand, is an engineering approach that provides a detailed representation of energy system components. It aims to achieve a balance between energy supply and demand and requires more technical details and energy data for model formulation.

Hybrid models combine elements of both top-down and bottom-up approaches. They can analyze the impacts of technology-specific changes and policies on the energy system, as well as the economy, or vice versa. Hybrid models can extract data from separate models through soft or hard links, depending on their compatibility.

Ms YIP mentioned that there are numerous energy models in the market, each with notable strengths, which have been adopted by APEC member economies.

3.3. Session 1: Development of Energy Modelling

3.3.1. Presentation 1 - Energy Modelling in the APEC Energy Outlook

Speaker:
Dr Manuel Antonio HEREDIA MUNOZ, Senior Researcher, Asia Pacific Energy Research Centre (APERC)

Dr Manuel Antonio HEREDIA MUNOZ discussed misconceptions and complexity in energy modelling, emphasising the need to address these misconceptions and strike a balance between complexity and practicality. He highlighted the purpose and benefits of energy models in decision-making, including their ability to provide insights into energy system interactions, inform policies, and aid in identifying optimal strategies and solutions.

He further explained the role of energy modelling in the APEC Energy Outlook, a publication that analyses energy systems in 21 APEC economies. The Outlook monitors progress towards APEC's energy objectives, such as increased renewable energy deployment and reduced emissions. The modelling process involves methodology determination, system boundary establishment, data gathering, stakeholder involvement, and iterative modifications. Conversations with APEC representatives help clarify ideas and consider implications, ensuring informed decision-making and energy policy development.

The APEC Energy Outlook utilises a modelling approach that considers the demand, transformation, and supply sides of energy systems It employs the Open Source energy MOdelling SYStem (OSeMOSYS) for long-term planning, enabling analysis of complex interconnected systems and supporting infrastructure investments, energy mix evaluation, and emissions analysis. Through energy modelling, the APEC Energy Outlook provides comprehensive insights and facilitates policy development and decision-making within and between APEC economies.

Overall, energy modelling is a crucial tool in the APEC Energy Outlook, enabling informed decision-making, sustainable energy strategies, and policy analysis in the Asia-Pacific region.

3.3.2. Presentation 2 - Strengths and Constraints of Energy Modellings

Speaker:
Ms Becky CHIM, Engineer, EMSD, Hong Kong, China

Ms Becky CHIM discussed the purpose of energy models and their main functions. She explained that energy models are designed to serve specific purposes, including simulation, equilibrium analysis, and optimisation. Simulation involves projecting future energy demand and simulating policy impacts to track progress towards targets. Equilibrium analysis examines the long-term behaviour of the energy system and the impact of factors such as energy prices and policies. Optimisation identifies the most cost-effective technology set to meet demand under given constraints, aiding planning and investment decisions.

She highlighted the types of data required for energy models. These include macroeconomic data (such as Gross Domestic Product (GDP), population, and energy import and/or export), sectoral data (covering residential, commercial, industrial, transport, and agriculture sectors), end-use data (specific categories in each sector), and energy technology data (sources, processes, transformations, and electricity generation).

Ms CHIM discussed different model technologies commonly used in energy modelling amongst APEC member economies. They were the Low Emissions Analysis Platform (LEAP), the Integrated MARKAL-EFOM System (TIMES), the Asia-Pacific Integrated Model (AIM), and the Energy Policy Simulator (EPS). She explained that these models have different strengths and requirements. LEAP is a bottom-up model used for simulation and requires a relatively low amount of initial data. TIMES requires detailed design and extensive data, with separate procedures for macroeconomic and data updates. AIM and EPS are hybrid models focusing on policy impact analysis on greenhouse gas emissions. EPS has a simple user interface and low data requirements, while AIM provides more comprehensive technology-level analysis with extensive data requirements.

She also shared the experience of Hong Kong, China (HKC) on the utilisation of the LEAP model. HKC annually updated the LEAP model with support from departments on providing macroeconomic and energy consumption data. In order to maintain the model with the up-to-date energy consumption trend, HKC scheduled energy consumption surveys across a survey cycle for collecting data from different sectors and segments which cover fuel type consumption, as well as end-use technologies. The user-friendly interface feature of LEAP allows the modeller of HKC to keep evolving the existing LEAP model to reflect the latest situation in HKC. It also facilitated the evaluation of energy-saving plans and tracked progress towards targets in building energy efficiency and carbon neutrality.

Ms CHIM discussed the best practices in energy modelling, including model component extension, the development of new modules, and the creation of a technology-rich database. Enhancements in data input and analysis involve regular data review, standardised maintenance, and the use of program tools for data cleaning. Sharing data and projection results among economies promotes knowledge exchange. The expertise of international organisations supports the development of energy modelling.

In summary, Ms CHIM provided insights into the purpose and functions of energy models, the types of data required, different model technologies, a case study on Hong Kong, China's utilisation of the LEAP model, and best practices in energy modelling.

3.4. Session 2: Best Practice & Experience Sharing on Utilisation of Energy Modelling

3.4.1. Presentation 1 - Building a Government Energy Modelling Team

Speakers:
Mr Justin PLANT, Acting Director – Energy Modelling, Department of Climate Change, Energy, the Environment and Water (DCCEEW), Australia; and
Ms Ashley DING, Senior Analyst – Energy Modelling, Department of Climate Change, Energy, the Environment and Water (DCCEEW), Australia

Mr Justin PLANT and Ms Ashley DING discussed key energy and climate policies in Australia and the establishment of an in-house energy modelling team at the Department of Climate Change, Energy, the Environment and Water (DCCEEW) in Australia.

The Australian government is committed to decarbonising its economy and has set ambitious targets. They aim to reduce greenhouse gas emissions by 43% from 2005 levels by 2030, as updated in their *Nationally Determined Contribution* in June 2022. Additionally, Australia aims to achieve net-zero emissions by 2050 through legislation. To support these goals, Australia is modernising its energy networks and targeting 82%

renewable energy in the economy-wide electricity market by 2030.

The DCCEEW established an energy modelling team in 2020, initially focusing on the electricity market. In 2022, a gas market model was added to the group, which was impacted by governmental reform. The team's primary role is to conduct routine monitoring programs, provide advice to agencies, and assist in defining energy policy. They specialise in maximizing capacity and determining the optimal generation mix. The team utilises modelling programs like PLEXOS to simulate and analyse the electricity market. They also provide emission forecasts and track progress towards reduction targets. Additionally, the team maintains a Python-based model of the East Coast gas market to assess supply and infrastructure needs.

Building an in-house energy modelling team has provided valuable insights for the DCCEEW. Here are the key lessons learned:

1. Clearly define the scope of energy modelling: It is essential to focus on specific aspects, such as electricity and gas markets, rather than attempting to cover the entire energy sector.
2. Choose model platforms wisely: Consider factors like cost and support when selecting model platforms In the case of the DCCEEW, they utilise PLEXOS for electricity modelling and have developed an in-house model for gas markets.
3. Leverage existing work and datasets: Take advantage of publicly available models and data to save time and costs. The team benefits from utilising models and data provided by the Australian Energy Market Operator (AEMO).
4. Seek expertise from experienced professionals: Enhance modelling capabilities by seeking input from experienced professionals, both within the organisation and from the private sector.
5. Foster continuous talent development: Keep up with the latest developments in energy modelling through continuous learning and growth. This skill set is in high demand and presents valuable opportunities for the team.

Over the past three years, the DCCEEW has experienced significant benefits from establishing an internal energy modelling team. The in-house team provides greater agility, flexibility, and responsiveness compared to relying solely on consultants and contractors. This has resulted in quicker turnaround times and lower external costs. The team has also gained a deeper understanding of the electricity and gas markets and energy modelling methods, enabling them to provide knowledgeable advice to other departmental teams. Their internal knowledge helps in identifying key assumptions and developing sound policy decisions.

Overall, the DCCEEW's in-house energy modelling team has proven to be a valuable asset in supporting energy and climate policies in Australia, providing expertise, and facilitating informed decision-making.

3.4.2. Presentation 2 - Annual Energy Outlook 2023 with Projections to 2050

Speaker:
Dr Sauleh SIDDIQUI, Chief Energy Modeller, Energy Information Administration (EIA), United States

Dr SIDDIQUI presented the role of the U.S. Energy Information Administration (EIA) in energy policy analysis and provided an overview of the Annual Energy Outlook (AEO) for 2023.

The EIA serves as the statistical and analytical agency of the U.S. Department of Energy, providing independent energy information. The AEO, published annually in March, plays a crucial role in informing policymakers, business experts, and the general public about energy trends in the United States. It presents accurate information and analysis based on extensive research conducted by the EIA.

To ensure objectivity, the EIA incorporates current policies into its models and, when requested, reviews other policies. The AEO goes beyond an isolated reference case and presents a range of results using additional cases to account for the uncertainty of the future.

In the 2023 energy outlook, the EIA introduced updates and enhancements. It includes a narrative to provide context and aid in interpretation, as well as technical notes for more detailed information. The EIA acknowledges the evolving nature of policies and technologies, which may affect the projections extended until 2050.

To address uncertainties, the EIA considers additional cases that take into account factors such as economic growth, global oil prices, domestic oil and gas supply, and costs of zero-carbon technologies. These additional cases aim to capture a broader range of potential outcomes.

For AEO2023, EIA combined economic growth cases with zero carbon technology cost cases to explore the interplay between demand-side and supply-side factors. By examining different scenarios resulting from the interaction of these variables, the EIA presents four additional scenarios derived from these combinations.

The AEO 2023 highlights four key messages derived from a range of scenarios. First, a decrease in energy-related carbon dioxide emissions across all cases due to increased electrification, higher equipment efficiencies, and greater generation of zero-carbon electricity. Second, renewable generating capacity grows in all regions of the United States, supported by the growth of installed battery capacity. Third, technological advancements and electrification contribute to projected decreases in demand-side energy intensity. Finally, the United States remains a net exporter of petroleum products and natural gas through 2050 in all cases explored in the AEO 2023.

Overall, Dr SIDDIQUI emphasized the role of the EIA in providing independent and comprehensive energy information, and the AEO 2023's ability to capture a range of scenarios and key trends in the U.S. energy landscape.

3.5. Session 3: Latest Trend and Insights from Global Energy Modelling and Women Participation

3.5.1. Presentation 1 - World Energy Transitions Outlook 2023 – 1.5°C Pathway

Speaker:
Dr Mengzhu XIAO, Programme Officer, International Renewable Energy Agency (IRENA)

Dr Mengzhu XIAO discussed the key findings of the World Energy Transitions Outlook (WETO) 2023 Volume 1 report and highlighted the transformation pathways for achieving the 1.5°C climate goal by 2050. The WETO analysis focuses on various sectors of the global energy system, both from the demand and supply sides, including industry, transportation, buildings, power generation, heat production, sustainable biomass and renewable fuels.

The WETO analysis highlights the importance of immediate actions to meet the 1.5°C climate target. Dr XIAO emphasised that all sectors, including power and heat plants, industry, buildings, and transportation, need to reduce their emissions. The WETO analysis suggests a range of decarbonization strategies, such as utilising low-cost renewable energy sources, improving energy efficiency, promoting electrification, advancing clean hydrogen production, and implementing carbon abatement measures.

To achieve the 1.5°C climate goal by 2050, the WETO analysis points out that the total global renewable power capacity must triple by 2030 to over 11 TW. Electrification driven by renewable energy and increased efficiency is expected to dominate final energy consumption in 2050. Dr XIAO highlighted the significance of renewable hydrogen and the modern use of sustainable biomass in the energy mix in 2050.

However, the current climate commitments fall short of achieving net-zero emissions. The power industry needs to transform with renewable energy sources dominating generation. Dr XIAO discussed the need to significantly increase the production of clean hydrogen. Furthermore, reducing the use of inefficient traditional biomass is necessary for achieving sustainable development goals.

The WETO analysis also addresses the importance of efficient energy use in the industry sector and envisions a shift in infrastructure to achieve negative emissions. In the building sector, the share of electricity needs to increase, and smart, energy-efficient buildings powered by renewables are envisioned. The transport sector requires accelerated deployment of low-carbon solutions, including electrification, renewable fuels, energy efficiency, and technological innovations.

Dr XIAO stressed the need for scaling up energy transition investments in the coming decades. Energy investment decisions should simultaneously drive the transition to reduce the risk of stranded assets. The WETO analysis estimates an average additional investment of USD1.7 trillion per year until 2050 to reach the 1.5°C climate target compared to the Planned Energy Scenario. Renewable energy, efficiency improvements, and electrification are identified as key investment priorities.

Transforming the power sector under IRENA's 1.5°C Scenario would require an average of more than USD2.2 trillion per year through 2050, which includes investments both in renewable power generation technology as well as grids and flexibility measures (e.g. storage). In the building sector, investments in energy efficiency dominate, while significant funding is allocated to electric charging infrastructure in the transport sector. The industry sector focuses on energy efficiency and circular economy practices, with investments in electrolysers to produce green hydrogen, supply infrastructures and renewables-based feedstocks.

In summary, Dr XIAO highlighted the key findings of the latest WETO analysis and emphasised the importance of immediate actions, increased investments towards faster deployment of renewables, various efficiency improvement measures and electrification, and a comprehensive transformation across various sectors of the entire energy system to achieve the 1.5°C climate goal by 2050.

3.5.2. Presentation 2 – The Road to Net Zero Emission

Speaker:
Ms Olivia CHEN, Energy Modeller, World Energy Outlook, International Energy Agency (IEA)

During the presentation, Ms Olivia CHEN provided an overview of the International Energy Agency (IEA)'s work on long-term outlooks and highlighted the modelling results from the *World Energy Outlook* and its related reports. The IEA's mission is to ensure a secure and sustainable energy future for all. The *World Energy Outlook*, one of the IEA's flagship reports, serves as a valuable resource for understanding global energy supply and demand dynamics and what they mean for energy security, environmental protection and economic development.

Ms CHEN acknowledged that while the COVID-19 pandemic led to a reduction in energy-related greenhouse gas emissions, in the face of challenges such as price shocks, emissions reached a record high of 36.8 Gt CO_2-eq in 2022. Nonetheless, clean energy technologies have played a significant role in mitigating emissions growth in recent years. Sales of electric vehicles, heat pumps, and capacity additions of solar PV, wind, and nuclear capacity contributed to emissions savings, as did energy efficiency improvements.

To achieve the ambitious goal of limiting global warming to 1.5°C, it is crucial to significantly scale up ambition on clean energy. Ms CHEN explained that the IEA employs forward-looking modelling to develop three main scenarios: the Stated Policies Scenario, the Announced Pledges Scenario, and the Net Zero Emissions by 2050 Scenario.

The Stated Policies Scenario shows that policies in place today are sufficiently strong to produce a distinct peak in fossil fuels demand before 2030, and a projected decline afterwards. The Stated Policies Scenario envisions a significant reduction in the proportion of fossil fuels in the global energy mix, declining from around 80% today to 60% by 2050. The power sector leads the decarbonization efforts, as solar PV capacity surpasses coal before 2030. Electricity generation from low-emissions energy sources is anticipated to surpasses that of fossil fuels by 2030.

Both the Announced Pledges Scenario and the Net Zero Emissions by 2050 Scenario exhibit accelerated development in renewable energy and carbon reduction. In the Net Zero Emissions by 2050 Scenario, key actions to achieve rapid emissions reductions include tripling renewables power capacity to reach 11,000 GW, doubling annual energy intensity improvements, and reducing methane emissions from fossil fuel operations by 75% by 2030. Overcoming barriers to renewable energy expansion, by speeding up permitting and enhancing grid connectivity is critical. Announced plans to strengthen manufacturing capacity for solar PV and batteries already show promise to match levels needed to meet climate targets, while other clean energy technologies' pipelines need to see accelerated growth.

Ms CHEN emphasised that achieving universal energy access remains a challenge, with 880 million people lacking access to electricity and 2.4 billion people lacking access to clean cooking. In the Net Zero Emissions by 2050 Scenario, universal access to modern energy is achieved by 2030, requiring a step up in investment. Emissions inequality is also evident, with the top 10% of emitters having emissions over 200 times higher than the bottom 10%. Swift action from high-emitting countries is crucial.

Gender equity in the energy sector is another area of concern. Women are underrepresented, particularly in traditional energy sectors. However, clean energy start-ups show higher levels of gender balance. Clean energy transitions present an opportunity to improve gender equity in the sector if efforts are made to enhance female representation in senior management and boost gender balance in the industry.

Ms CHEN's presentation shed light on the IEA's work and the modelling outcomes from the *World Energy Outlook*, providing valuable insight into the necessary actions for achieving a secure, sustainable, and equitable energy future.

3.6. Closing Remarks

Speaker:
Mr Barry CHU, Deputy Lead Shepherd of APEC's EWG and Assistant Director (Electricity and Energy Efficiency) of EMSD, Hong Kong, China

Mr CHU expressed his satisfaction with the workshop, highlighting the valuable contributions made by esteemed speakers and moderators. The workshop's main focus was on exploring the latest advancements in energy modelling, facilitating the exchange of experiences in energy formulation and projection, and sharing global energy modelling practices. It successfully translated policy directions from APEC Economic Leaders and Ministers into practical measures, aligning with the goals of the APEC-funded Project "Promoting Energy Modelling in APEC Region."

During the workshop, participants gained valuable insights from economies sharing on the practical application of energy modellings, as well as in Australia's power supply formulation and the Energy Modelling System in the United States. Presentations by the IEA and IRENA emphasised the global significance of energy modelling, showcasing its role in scenario analysis and supporting energy transitions worldwide. APERC's presentation on the APEC Energy Outlook highlighted the integration of cutting-edge technologies and the application of new and renewable energy sources.

The discussions among participants were highly constructive, fostering further exploration of energy modelling as a means to reduce energy intensity and promote renewable energy integration. Attendees received up-to-date information, insightful analysis, and innovative suggestions that contribute to advancing APEC objectives and addressing climate concerns through energy modelling technology.

Recognising the importance of energy modelling in achieving APEC's ambitious goals, Mr CHU encouraged participants to utilise this tool to expedite progress towards APEC's energy targets. By leveraging energy modelling, APEC member economies can enhance their efforts in combating climate change and transitioning to low-carbon energy systems.

4. Summary of Discussion

4.1. Session 1: Development of Energy Modelling

Moderator:
Prof. William CHUNG, Associate Professor, Department of Management Sciences, City University of Hong Kong, Hong Kong, China

Q1: What are some notable achievements and considerations in the evolution of the energy system model, as shared by Dr. Manuel Antonio HEREDIA MUNOZ from APERC?

A1: Regarding the evolution of the energy system model, Dr Manuel Antonio HEREDIA MUNOZ shared APERC's experience and considerations. Integration of variable renewable energy sources, which have a substantial influence on overall performance, is one noteworthy achievement. The long-term limits created by this integration become increasingly obvious as the system evolves and develops over time. The modelling strategies for certain industries are also influenced by the rising integration of variable renewable energy, such as electric cars and time-dependent elements. Additionally, consideration is given to new energy sources like, hydrogen to be used as a fuel source and in the electrical industry. APERC continuously monitors these elements and works to include them in its long-term models. They tried to deal with limitations that can develop as a result of pressing issues. However, it was anticipated that in the near future, dealing with the interplay between these components may call for various strategies and methods. Understanding that short-term problems could have long-term consequences is crucial for finding successful solutions. Dr HEREDIA also shared that APERC initially analysed the potential effects of such scenarios. The modeller may not immediately integrate the scenarios into the main model but instead, simplify the model to capture time dependencies and relevant factors. The approach taken depends on the type of policy under consideration. Extensive discussions are conducted amongst experts or member economies to explore different possibilities. One approach is to establish relationships between dynamic scenarios and specific time frames as pre or post-interactions. The choice of approach depends on the specific policy being evaluated.

Q2: How does energy modelling support policy formulation?

A2: Regarding the role of energy modelling in supporting policy formulation, Ms Becky CHIM explained that energy data and modelling projections in HKC, serve as references for government departments in developing energy-saving policies and targets. For example, energy consumption projections served as one of the references for the extension of the Mandatory Energy Efficiency Labelling Scheme (MEELS). Gas appliances used for cooking and water heating were identified as potential contributors to energy savings and would be included in MEELS from September 2023. This demonstrates how energy modelling could support policy formulation.

Q3: What skills and mindset are necessary for constructing and operating energy models?

A3: Dr HEREDIA also shared his view that modeller or analyst should have a mathematical mentality and the capacity to deconstruct reality into digestible questions which are essential skills for the construction and operation of energy models. He advised that simplifying complicated circumstances and concentrating on the most important model components that apply to the models are crucial. In order to attain the best outcomes with the fewest resources, one might eventually discover the importance of eliminating unnecessary components and aiming for simplicity and elegance. Dr HEREDIA pointed out that experience was necessary to develop the mentioned modelling ability while the modeller or analyst should also keep an open mind and make an effort.

Q4: What is the minimum data and data type required for each sector when developing an energy model using a bottom-up approach?

A4: In considering the minimum data and data type required for each sector on developing the energy modelling base on bottom-up approach, Dr HEREDIA shared the specific data requirements could vary greatly depending on the complexity and granularity of the model, as well as the specific goals of the exercise. Typically, for industry which requires energy consumption data by fuel and sectors, equipment data including equipment stock, industrial processes data, production data, technology data, and fuel prices. For buildings, that include residential, the following data were typically required: energy consumption data, building characteristics, household size, constructed area. Appliances and Equipment technical specifications and stock, income per household, commercial activities, and fuel prices.

Q5: How can evolving and dynamic policy scenarios be incorporated into a system energy model?

A5: For the second question on how to incorporate evolving and dynamic policy scenarios into a system energy model, Dr HEREDIA advised this could be a complex task. In the APERC Energy Outlook, they started by identifying and analysing relevant key policies. This step helped to understand goals, expected effects, timeframe, and other relevant factors that could be transformed into mathematical parameters and constraints when modeling a specific scenario. Some policies may lead to feedback loops to ensure that results capture expected effects.

Other important aspect of evolving policies scenarios was uncertainty that grows over time. For that reason, sensitivity analysis and different scenarios are necessary to understand the robustness of the model under different conditions.

It was important to understand that energy modeling is usually an iterative process, that requires not only the mathematical analysis but also expert knowledge and judgement to ensure the value of the results.

Q6: Can you provide an example of the data required to evaluate the impact of an energy efficiency policy in energy modeling? How is the energy intensity calculated in HKC?

For the first question on providing example of data required to evaluate the impact of the energy efficiency policy in the energy modelling, Ms CHIM shared that a baseline energy consumption projection should be first developed. The baseline energy consumption projection might base on the various macroeconomic or activity data available in the economies, as different member economy might have its own specific energy system profile. For example, growth of the household number could be one of the possible activities for projecting the energy consumption of the residential sector.
For the second question on the calculation of the energy intensity in HKC, Ms CHIM advised the energy intensity is represented by the ratio of "energy end-use" to "Gross Domestic Product".

4.2. Session 2: Best Practice & Experience Sharing on Utilisation of Energy Modelling

Moderator:
Ir Edward CHOW, Head of Carbon and Environmental Excellence, Hong Kong Productivity Council, Hong Kong, China

Q1: How does the EIA manage to collect vast amounts of data, and how is the data incorporated into energy models?

A1: Regarding data collection challenges, Dr Sauleh SIDDIQUI shared that EIA manages to collect vast amounts of data due to its resources and authority provided by the federal government. They work with varied teams, collect particular data from stakeholders through surveys and measurements, and coordinate with other U.S. agencies. The use of data sources does not indicate bias, and EIA continues to be policy neutral. It might be difficult to incorporate the gathered data into energy models; this requires making assumptions and estimates that are annually checked for correctness.

Q2: What is the role of the EIA's short-term model, and how does it complement long-term models?

A2: With regard to the requirement for short-term models, Dr SIDDIQUI advised that the EIA's short-term model enables projection over a time frame of one to two years. By concentrating on immediate decisions and offering more precise projections based on current data and events, it complements long-term models. The short-term model assumes certain policies remain unchanged, leveraging data-dependent and econometric models. EIA values the expertise of area specialists and modelers who can incorporate political, geopolitical, and market factors into the projections. The short-term model also serves as a benchmarking tool for the long-term model.

Q3: How does the Australian Energy Market Operator (AEMO) manage and utilise large volumes of data for energy modelling? What are the challenges and opportunities for energy modelling in supporting the energy transition?

A3: Regarding data for energy modelling, Mr Justin PLANT considered that network analysis is crucial alongside data. Informing decision-makers in meaningful ways supports purposeful decision-making. The AEMO has an online platform sharing real-time updates on consumption and reliable energy penetration. Utilising those large volume data for setting scenarios in electricity and gas market modelling requires best practices and recommendations. To manage this data volume effectively and extract meaningful insights, two approaches are employed.

1. Third-party aggregators collect and provide the data in usable formats for download, analysis, and visualisation. The transparent nature of the market allows access to information on generator bids and operations, facilitating this process.
2. Robust data pipeline is established, ensuring the necessary hardware and virtual environments for efficient data handling. Optimizing this process enhances speed and efficiency in ingesting, storing, and manipulating the data, supporting modelling platforms and data science solutions.

Moving to the challenges and opportunities for energy modelling in supporting the energy transition, Ms Ashley DING shared that eligibility plays a crucial role in government decision-making. Due to differences in goals, resources, and skills across municipal, state, and federal governments, there are issues with present modelling techniques that often concentrate on single-scale initiatives and ignore the multi-scale nature of central governance. It becomes difficult to develop a modelling strategy that supports projects with several scales. On the other side, as open-source energy modelling frameworks, open data platforms, and visualisation tools become more accessible, possibilities present themselves. These advancements offer cost-effective multi-scale modelling options for the government, enabling faster responses to internal requests, benchmarking with other public analyses, and delivering work at a lower cost. However, these advancements also raise important questions for the government to address.

4.3. Session 3: Latest Trend and Insights from Global Energy Modelling and Women Participation

Moderator:
Ms Jovian CHEUNG, APEC EGEEC Vice Chair

Q1: What is the Flextool introduced by IRENA, and how is it used for energy system modelling?

A1: Regarding the Flextool applied by IRENA, Dr XIAO explained that it was used for supporting the flexibility analysis of the renewables dominated power system. A bottom-up energy system modelling tool developed by the REmap team has been used to estimate energy flows based on activity metrics. The tool takes into account technical elements from various sectors, subsectors, and energy services. Though model coupling, it also makes it possible to evaluate high-share variable renewable power systems, such as cross-border power exchanges, and analyse flexibility requirements. IRENA models worldwide hydrogen commerce and production, particularly for the hydrogen sector has been published in IRENA specific global hydrogen trade to meet the 1.5°C climate goal report in 2022. For the social-economic analysis of energy transition pathways, IRENA works with consulting firms to apply macroeconomic models for evaluating the socioeconomic advantages of renewable energy transitions.

Q2: How does the IEA incorporate diverse policy plans and programs into its energy modelling for producing the annual energy outlook?

A2: Regarding the incorporation of diverse policy plans and programs into its energy modelling for producing the annual energy outlook, Ms CHEN explained that energy modelling in the IEA's annual energy outlook takes into account a rigorous member-by-member and sector-by-sector tracking of energy and climate policies and programs, including for different economies in the APEC regions. It identifies policy and technology solutions that benefit the entire energy system within each region, including the optimal deployment sequence for technologies. Comparisons of different mitigation measures' respective impacts on energy emission savings can assist policymakers in identifying priorities for clean energy transitions. The goal is to align modelling with policy making, supporting decision-making processes.

Q3: What initiatives do the IEA and IRENA have in place to promote gender equality in the energy sector?

A3: Both IEA and IRENA have implemented initiatives to promote inclusivity and encourage the participation of women. Regarding the IEA's work on gender equality, Ms Chen emphasised that the organisation collects and publishes gender-disaggregated data on energy sector employment, management, innovation, and financing in its online Gender and Energy Data Portal. This data helps to inform policies to enhance gender diversity. The IEA also serves as the secretariat for the Equality in Energy Transitions Initiative to accelerate gender equality in the energy sector by 2030 through the sharing of best practices among 15 participating governments, among other gender-focused programming. Dr XIAO highlighted the organisation's efforts to incorporate a gender perspective into the renewable energy sector. The latest gender perspective series report focuses on gender equality in the solar PV sector. It examines women's participation in the solar workforce, identifies barriers they face, and discusses pathways to achieve a more inclusive solar PV workforce.

Q4: What expertise and training are important for professionals in the field of energy modelling?

A4: Regarding expertise and training in energy modelling, Dr XIAO shared her personal experience which involved pursuing a Doctor of Engineer (Dr.-Ing) under Energy Scenario School from Helmholtz Association. She learned about subjects including energy scenario construction, assessment and impact through research schools, cooperation with researchers, and participation in various multiple disciplinary international conferences. In IRENA, Dr XIAO worked with colleagues to analyse global energy transition pathways, improve modelling approach, investigate cutting-edge innovation technologies such as green hydrogen utilizations, and the bottleneck issues for energy transition. She stressed the importance of teamwork involved in modelling an energy system and consultancy with stakeholders when developing energy scenarios. Ms CHEN shared her experience. Her team comprises both engineers and economists, enabling diverse perspectives and contributions. She advised that interdisciplinary knowledge spanning geology, environmental science, engineering, economics, finance, and the history of the energy industry, can be useful for energy modelling. In terms of energy modelling skills, Ms CHEN highlighted the value of a strong mathematics background, experience handling large datasets, and programming languages.

Q5: How Energy Efficiency will play a key role in the transportation sector in the context of achieving reduction target of greenhouse gas emissions?

A5: Dr XIAO shared that stringent efficiency standards for all transportation modes are crucial for sectoral transformation, along with behavioural changes. Decarbonisation can be supported through structural changes in the delivery of mobility services. A modal shift from private passenger cars to collective transport, and from passenger aviation and road-based freight to rail, is highly possible but would require developing the necessary infrastructure. This could reduce the energy intensity of the transport sector. Despite an increase in transport demand, the sector's final energy consumption would decrease by 13% by 2050 compared with 2020 levels or by 25% compared with 2019 levels under IRENA's 1.5°C Scenario. A combination of low-carbon approaches would reduce transport emissions to just 0.6 Gt CO_2 annually by 2050, a 91% reduction compared with 2020. These include measures in electrification, scale-up of renewable fuels, and energy efficiency and technological innovation measures across all transportation modes.

5. Conclusion

In the APEC Workshop on Energy Modelling, experts and delegates shared their experiences on the utilisation of energy modelling in forecasting energy consumption and tracking low carbon transition progress, as well as for formatting the energy policies.

During the workshop, the purpose and benefit of Energy Models are recognised. Energy models offer insights into energy system interactions and their impacts. With energy models, optimal strategies and solutions that align with energy goals will be easier to identify. APERC reported that the APEC Energy Outlook used energy modelling to evaluate policy impacts on member economies. Results enable comparisons within and between APEC regions, aiding policy development. It avoids isolating individual economies, providing comprehensive insights for decision-making.

Reference made to the sharing from Australia; Hong Kong, China; and United States, it was observed that different economies have varying data availability and objectives for energy models. To utilise the energy models, the modelling process is iterative and involves gathering data, involving stakeholders, and making modifications. Regular data review, enhancement in data input, and developing new modules for extending the functions of an energy model are considered the best practices for utilising energy modelling. Moreover, training for manpower to support energy modelling works is important. expertise from experienced professionals shall be able to enhance modelling capabilities and continuously develop talent through learning and growth to stay updated and contribute value to the team. This skill set is in high demand and offers opportunities.

Four major types of energy models were introduced in the workshop, i.e. LEAP, TIMES, AIM, and EPS. AIM and EPS are hybrid models focusing on policy impact analysis on greenhouse gas emissions. EPS has a simple user interface and low data requirements, while AIM provides more comprehensive technology-level analysis with extensive data requirements. LEAP is a bottom-up model used for simulation, requiring relatively less initial data. TIMES requires detailed design and extensive data, with separate macroeconomic and data update procedures. It was suggested by the speaker that APEC member economies shall choose model platforms wisely, considering cost and support, and leverage existing work and datasets to save time and costs.

There is a range of scenarios that can be considered to be reviewed by an energy model, such as energy-related CO_2 emissions, growth in renewable generating capacity, and technological advancements and electrification drive projected decreases in demand-side energy intensity. With sharing by APERC, IRENA and IEA, the advantages of adopting energy modelling were well discussed in the workshop and as a reference for different APEC member economies.

Appendix A – Agenda

APEC Workshop on Energy Modelling (EWG 05 2022A)
8 August 2023 09:00-12:05 (GMT+8)

HKC Time (GMT+8)	Duration (mins)	Sessions
09:00 - 09:30	30	Registration & Test Run
09:30	-	**Start of Workshop**
09:30 - 09:40	10	**Opening Remarks** *Mr TSE Chin-wan, Secretary for Environment and Ecology, Hong Kong, China*
09:40 - 09:45	5	**Photo-taking**
09:45 - 09:50	5	**Project Summary** *Ms Elaine YIP, Engineer (Project Officer), Electrical and Mechanical Services Department (EMSD), Hong Kong, China*
Session 1: Development of Energy Modelling *Moderator: Prof. William CHUNG, Associate Professor, Department of Management Sciences, City University of Hong Kong, Hong Kong, China*		
09:50 - 10:10	20	**Energy Modelling in the APEC Energy Demand and Supply Outlook** *Dr Manuel Antonio HEREDIA MUNOZ, Senior Researcher, Asia Pacific energy Research Centre (APERC)*
10:10 - 10:25	15	**Strengths and Constraints of Energy Modellings** *Ms Becky CHIM, Engineer, Electrical and Mechanical Services Department (EMSD), Hong Kong, China*
10:25 - 10:30	5	**Q&A**
10:30 - 10:35	5	**Break**
Session 2: Best Practice & Experience Sharing on Uilitsation of Energy Modelling *Moderator: Ir Edward CHOW, Head of Carbon and Environmental Excellence, Hong Kong Productivity Council, Hong Kong, China*		
10:35 – 10:50	15	**Building a Government Energy Modelling Team** *Mr Justin PLANT, Acting Director, Energy Modelling, Department of Climate Change, Energy, the*

		Environment and Water (DCCEEW), Australia *Ms Ashley DING, Senior Analyst, Energy Modelling, Department of Climate Change, Energy, the Environment and Water (DCCEEW), Australia*
10:50 – 11:05	15	**Annual Energy Outlook 2023 with Projections to 2050** *Dr Sauleh SIDDIQUI, Chief Energy Modeller, Energy Information Administration (EIA), United States*
11:05 - 11:15	10	**Q&A**
11:15 - 11:20	5	**Break**
Session 3: Latest Trend and Insights from Global Energy Modelling and Women Participation *Moderator: Ms Jovian CHEUNG, APEC EGEEC Vice Chair*		
11:20 - 11:35	15	**World Energy Transitions Outlook 2023, 1.5°C Pathway** *Dr Mengzhu XIAO, Programme Officer, International Renewable Energy Agency (IRENA)*
11:35 - 11:50	15	**The Road to Net Zero Emissions** *Ms Olivia CHEN, Energy Analyst and Modeller, World Energy Outlook, International Energy Agency (IEA)*
11:50 - 12:00	10	**Q&A**
12:00 - 12:05	5	**Closing Remarks**
12:05	-	**End of Workshop**

Appendix B – Polling result

Q1. How familiar you are with the definition of energy system modelling?

Options for answer	No. of vote
Very familiar	4
Moderately familiar	17
Neutral	8
Slightly familiar	0
New to me	15
Total no. of response	**44**

Q2. How familiar you are with the types of energy system modelling (e.g., bottom up, hybrid approach)?

Options for answer	No. of vote
Very familiar	3
Moderately familiar	12
Neutral	11
Slightly familiar	16
New to me	16
Total no. of response	**58**

Q3. How many numbers of 21 APEC member economies do you guess adopted energy system modelling?

Options for answer	No. of vote
0-20%	5
21-40%	14
41-60%	22
61-80%	6
>80%	0
Total no. of response	**47**

Q4. Do you know how to apply an energy system model?

Options for answer	**No. of vote**
Yes	14
No	44
Total no. of response	**58**

Q5. Do you know how to form an energy system model?

Options for answer	**No. of vote**
Yes	13
No	45
Total no. of response	**58**

Q6. Apart from this workshop, have you participated in any other workshops or training sessions related to energy modelling in the past 12 months?

Options for answer	**No. of vote**
Yes – Online mode	7
Yes – Physical mode	5
Yes – Hybrid mode	3
No	43
Total no. of response	**58**

Q7. Please select the most important factor you believe for adopting the energy system model in policy formulation.

Options for answer	**No. of vote**
Availability of quality data	19
Clear objectives for the analysis	20
Maturity of modelling tools in market	2
Complexity of the model's operation	1
Availability of data processing tools (for massive data manipulation)	3
Stakeholder support	1
Financial support	2
Total no. of response	**48**

Q8. Please select the most important factor you think can enhance women's participation in energy-related industries.

Options for answer	**No. of vote**
Education and training opportunity	16
Feasible work arrangement	19
Promotion opportunity	7
Total no. of response	**42**