

Promoting Energy Efficiency Enhancement in Electricity Generation

Workshop Summary Report

APEC Energy Working Group

November 2025



**Asia-Pacific
Economic Cooperation**



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APEC Project: EWG 211 2023A

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APEC#225-RE-04.10

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1 Background

APEC accounts for 68% of world electricity generation and 60% of global carbon emissions. According to the 8th Edition APEC Energy Demand and Supply Outlook, APEC's electricity generation nearly doubled between 2000 and 2018. Two-thirds of the increase came from coal- and gas-fired power plants. Accelerating the phase-out of unabated fossil fuels and energy efficiency in electricity generation play a crucial role in providing affordable, resilient and accessible energy, supporting economic growth and energy security, accelerating the energy transition, and reducing carbon emissions.

In alignment with APEC's Putrajaya Vision 2040, Aotearoa Plan of Action, and Bio-Circular-Green Economy goals, Hong Kong, China, conducted the project "Promoting Energy Efficiency Enhancement in Electricity Generation" (EWG_211_2023A). This project encompasses a detailed study summarizing high-efficiency electricity generation standards, targets, and indicators, along with strategies for phasing out unabated fossil fuels. Additionally, it includes a workshop aimed at exchanging best practices and policies to advance energy transition and drive innovation in emerging technologies, complemented by a Workshop Summary Report documenting key insights and discussions.

By leveraging supportive policies, regulatory frameworks, practical energy efficiency benchmarks, and cutting-edge technologies, APEC member economies can chart out energy transition policies and roadmaps. This collaborative endeavor seeks to engage APEC member economies by sharing knowledge and experiences and providing a platform for dialogue among government officials, utilities, experts, academia, and stakeholders. The primary focus is on achieving APEC's prioritized clean energy transition and energy intensity reduction objectives, aligning with APEC's Putrajaya Vision 2040 and Aotearoa Plan of Action to address climate challenges effectively.

2 Objective

2.1 Project Objectives

This project aimed to promote accelerating the phase-out of unabated fossil fuels and energy efficiency enhancement in electricity generation through implementing effective policy and boosting innovative and technological improvements to pursue strong, balanced, secure, sustainable and inclusive growth in the APEC region.

2.2 Workshop Objectives

The workshop “APEC Workshop on Promoting Energy Efficiency Enhancement in Electricity Generation” that came alongside this project with one day session on 8 April 2025 aimed to encourage member economies to exchange the study, best practices and policies to boost energy transition and drive emerging technologies.

The workshop provided a capacity-building opportunity for APEC members, especially the developing economies, to enhance their advanced technologies knowledge and skills in electricity transition. among APEC members, international organisations and academia. More than 60 delegates and experts from 15 APEC member economies attended the workshop to exchange views on the best practices, challenges, and the application of innovative technology in enhancing energy efficiency in electricity generation and facilitating the phase-out of unabated fossil fuels.



Photo of the Workshop on Promoting Energy Efficiency Enhancement in Electricity Generation was held in Hong Kong, China on 8 April 2025

3 Workshop Summary

3.1 Welcoming Remarks of Workshop

Presenter: Mr. Raymond POON, Director of Electrical and Mechanical Services, Hong Kong, China

Mr. Raymond POON delivered the welcoming remarks at the APEC Workshop on Promoting Energy Efficiency Enhancement in Electricity Generation, expressed his honor and enthusiasm in hosting all distinguished guests in Hong Kong. He opened by referencing the season of spring, drawing a parallel between the renewal symbolized by blossoming flowers and the workshop's focus on sustainable energy practices.

Mr. Poon provided context for the workshop by highlighting the significant role of the APEC region in global electricity generation and carbon emissions, referencing data from the 8th Edition APEC Energy Demand and Supply Outlook. He noted that APEC accounts for 68% of world electricity generation and 60% of global carbon emissions, with a near doubling of electricity demand between 2000 and 2018, driven largely by coal and gas. This situation underscores the urgency of phasing out unabated fossil fuels and enhancing energy efficiency to support economic growth, energy security, and carbon reduction.

Mr. Poon outlined the objectives of the workshop and the broader APEC project, which is being carried out with the involvement of EGEEC and EGCFC. Mr. Poon stressed the importance of promoting effective policy and fostering technological innovation to support balanced, sustainable, and inclusive growth across APEC.

Discussing the diverse energy supply system within APEC, Mr. Poon acknowledged the foundational role of various energy sources in supporting economic and social development, while noting the challenges posed by continued reliance on coal. He presented Hong Kong, China's transition from coal to natural gas in electricity generation, highlighting the environmental and technological advantages of natural gas and the adoption of combined-cycle gas turbine (CCGT) technology, which has significantly improved efficiency.

Mr. Poon also addressed global trends in hydrogen blending and the critical role of digital innovation, including digital twins and artificial intelligence, in optimizing power generation. Mr. Poon emphasized Hong Kong, China's position as a "super connector" in the region, referencing ongoing projects and upcoming international events that demonstrate the city's commitment to fostering collaboration and dialogue in the energy sector. He concluded by encouraging participants to experience Hong Kong, China's vibrant culture and to engage in meaningful discussions throughout the workshop.

3.2 Session 1 - Overview of Energy Efficiency in Electricity Generation and APEC Goal on the Phase-Out of Unbated Fossil Fuels

Sharing 1.1: Efficiency in Fossil Fuel Electricity Generation

Presenter: Mr. Carlos Fernández ALVAREZ, Senior Analyst of Gas, Coal and Power Markets Division, International Energy Agency (IEA) (pre-recording)

Mr. Carlos Fernández ALVAREZ presented the ongoing significance of fossil fuels in global energy systems, emphasizing that they currently account for 80% of primary energy consumption, a modest decline from 87% in the 1970s. He stressed that this enduring dominance makes enhancing the efficiency of fossil fuel-based electricity generation a critical priority during the energy transition.

Focusing on power generation, Mr. Alvarez noted that fossil fuels, primarily coal and natural gas, provide nearly 60% of global electricity, with coal contributing about 35%. He highlighted data showing that while the average efficiency of gas-fired power plants has improved to around 48%, coal plant efficiency has stagnated at approximately 36% globally.

Mr. Alvarez explained the technical reasons behind these efficiency differences, particularly how combined-cycle gas turbine systems achieve significantly higher efficiency by utilizing waste heat from the gas turbine to generate additional electricity through a steam turbine. This technology can reach nearly 60% efficiency in modern installations, compared to 35-40% for simple-cycle plants.

For coal plants, he detailed the thermodynamic limitations of the steam cycle, where only about 39% of input energy typically converts to electricity, with major losses occurring in condensers (52%) and boilers (5.5%). He discussed how supercritical and ultra-supercritical technologies can push efficiency to 46-48% by operating at higher temperatures and pressures, although most global coal capacity still relies on less efficient subcritical systems.

Mr. Alvarez identified various operational factors impacting real-world efficiency, including fuel quality variations, combustion conditions, heat exchanger performance, and maintenance practices. He emphasized that even small efficiency improvements are significant, as each 1% gain in efficiency translates to a more than 2% reduction in CO₂ emissions.

He also addressed the challenges of accurately measuring and reporting efficiency across different regions and standards, noting significant variations in calculations using higher or lower heating values. Mr. Alvarez stressed the need for standardized assessment protocols to enable meaningful international comparisons of power plant performance.

Optimizing fossil fuel efficiency represents a crucial opportunity to reduce emissions and resource consumption during the multi-decade energy transition, advocating for operational best practices, performance monitoring, and workforce training to bridge the gap between design specifications and actual plant efficiency.

Sharing 1.2: APEC's Electricity Mix and Efficiency: Progress, Challenges, and Opportunities

Presenter: Ms Yasmin FOULADI, Researcher, Asia Pacific Energy Research Centre (APERC)

Ms. Yasmin FOULADI presented her analysis focusing on three key areas: electricity generation fuel mix, generation efficiency, and transmission/distribution efficiency across APEC member economies.

First, she highlighted that APEC's electricity production has more than doubled since 2000, increasing from 9,300 to 19,000 terawatt-hours. Fossil fuels continue to dominate the region's power mix, accounting for 63% in 2022, only slightly down from 67% in 2000. While coal remains the primary generation source, its share has gradually declined as renewables, particularly solar and wind, have gained traction since 2010.

Ms. Fouladi emphasized the substantial diversity in generation mixes across APEC members, economies like Canada; Chile; New Zealand; and Viet Nam benefit from significant hydropower resources, while others, such as Papua New Guinea, rely heavily on oil for electricity generation. Notably, China and the United States together account for 70% of APEC's total electricity generation, with China alone responsible for 46% of regional output in 2022.

Looking ahead, preliminary APERC modeling projects continued electricity demand growth across APEC at approximately 2% annually under current policy trajectories. Ms. Fouladi noted that more detailed projections, including policy scenarios, would be available in APERC's forthcoming Outlook publication later this year.

Transitioning to generation efficiency, she explained the standard methodology for calculating power plant efficiency involves determining the percentage of input energy converted into delivered electricity. Across APEC, fossil fuel plants average about 40% efficiency, with significant variation based on fuel type, plant technology, age, and operational practices. These variations indicate substantial potential for efficiency improvements through technology upgrades and better operational management.

Ms. Fouladi highlighted Combined Heat and Power (CHP) systems as an underutilized efficiency opportunity, capturing waste heat from electricity generation for productive uses, which can increase overall system efficiency. When heat is factored in, the efficiency of fossil fuel plants in the APEC Region rises to 50%. She also discussed combined cycle gas turbine technology, explaining how these systems achieve higher efficiencies by using gas and steam turbines sequentially.

Finally, she outlined that grid losses represent a critical component of overall power system efficiency, noting that APEC member economies have generally reduced these losses between 2010 and 2022, though significant variation remains across members. Ms. Fouladi cautioned against direct comparisons, emphasizing that geographic factors and system scale create inherent differences in loss potentials.

3.3 Section 2 - Policies and Challenges of Energy Efficiency in Electricity Generation and Phase-Out of Unbated Fossil Fuels

Sharing 2.1: China's Experience on Energy Transition and Energy Efficiency Enhancement in Electricity Generation

Presenter: Ms. ZHANG Yue, National Energy Administration, People's Republic of China

Ms. ZHANG Yue presented an insightful overview of China's energy transition and efforts to enhance energy efficiency in electricity generation. She outlined China's goals and policies, emphasizing President Xi Jinping's energy security strategy, which includes commitments to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. The focus is on constructing a new energy system that is clean, low carbon, safe, and efficient, supported by the Energy Law released in 2024.

Ms. Zhang highlighted impressive statistics showcasing China's significant progress in clean energy adoption. By 2024, the share of clean energy consumption is expected to exceed 28%, accompanied by a notable decline in coal consumption. Advancements in renewable energy infrastructure are evident, with wind and solar capacities surpassing 1,400 gigawatts. Technological innovations, such as mature wind turbine manufacturing and advancements in solar photovoltaic technology, are propelling China towards a sustainable energy landscape.

She discussed the development of a unified, territory-wide interconnected power grid, including the West-to-East Transmission Corridor, which has a transmission capacity exceeding 300 GW, and ultra-high voltage direct current lines capable of delivering over 50% of renewable energy electricity. Ms. Zhang noted advancements in large-scale wind turbines (up to 18 MW), deep-sea floating wind projects, and high-efficiency photovoltaic technologies, such as N-type and heterojunction cells. Energy storage technologies, including lithium-ion and flow batteries, are diversifying, and coal-fired power plant efficiency has improved, with average coal consumption dropping to 303.2 grams per kWh. Meanwhile, new energy storage technologies have achieved diversified development.

She identified four main challenges: rapid electricity demand growth, increased weather dependence due to renewables, system stability risks as traditional generators are replaced, and heightened needs for flexibility across time scales. In response, Ms. Zhang outlined measures such as the new power system action plan, emphasizing system stability, smart grids, and comprehensive charging infrastructure. She stressed the importance of optimizing energy storage deployment, developing supportive power sources like hydro, nuclear, and advanced coal, and innovating in standards, technology, and market mechanisms.

Regarding coal-fired power, Ms. Zhang stated that while coal will remain necessary for some time, its role will diminish. Carbon reductions will be achieved by co-firing with low-carbon fuels, improving plant efficiency, and deploying carbon capture technologies. She described efforts to accelerate renewables, including large-scale wind and solar bases, distributed photovoltaic systems, offshore wind, hydropower, and geothermal energy, alongside integration with sectors like transportation and

agriculture. The expansion of green electricity certificates was noted as a way to promote renewable consumption.

Ms. Zhang shared insights on grid reinforcement and the integration of renewables, explaining that efforts are underway to upgrade the West-to-East Transmission Corridor and modernize the distribution network to support distributed energy and new loads, such as electric vehicle charging. The development of smart grid technologies is central to enabling intelligent scheduling and real-time operations, while improvements in system flexibility—including advanced energy storage, demand response, and virtual power plants—are essential to accommodating the variability of wind and solar power. These comprehensive measures are vital for ensuring that China's energy system can meet growing demand, maintain stability, and achieve its ambitious climate and efficiency goals.

Q&A for session 2.1

Question 1: What are the developing directions of China's power grid in the context of promoting the construction of a new power system?

Ms. ZHANG explained that the grid is crucial for linking supply and demand. China will continue reinforcing the territory-wide interconnected grid, emphasizing west-to-east transmission, regional interconnections, and upgrades to the distribution network for more distributed generation and new loads like EV charging. Microgrids and multi-energy systems are being developed to enhance local balancing.

Question 2: How can China promote collaboration in electricity generation with APEC member economies to advance clean energy initiatives?

Ms. ZHANG highlighted the opportunities for cooperation with APEC member economies in policies, technology innovation, and industrial chain development. She emphasized the importance of communication, sharing technology progress, and collaborating in the industrial chain to build a competitive clean energy industry collectively.

Sharing 2.2: Thailand's Energy Efficiency Policies and Phase-Out of Fossil Fuels in Power Generation

Presenter: Mr. Wuttipong APICHONNABUTR, Civil Engineer, Senior Professional Level, Department of Alternative Energy Development and Efficiency (DEDE), Thailand

Mr. Wuttipong APICHONNABUTR presented a comprehensive overview of Thailand's energy landscape and its transition strategies. He began by outlining the current energy situation, where petroleum products dominate at 49% of total consumption, followed by non-renewable electricity at 22%. Renewable energy accounts for 7% of total consumption but represents 29.6% of power generation, primarily from biomass (63.5%) and hydropower (16.9%).

The transportation sector is Thailand's the largest energy consumer at 39.7%, closely followed by industry at 37.1%. Domestic natural gas supplies 39.4% of energy production, while renewables contribute 32.9%. Mr. Apichonnubutr highlighted the success of energy efficiency measures, demonstrating through comparative graphs how these policies have contained energy demand growth between 2010 and 2023 despite economic expansion.

Thailand has committed to ambitious climate targets, including a 40% reduction in greenhouse gas emissions by 2030, carbon neutrality by 2050, and net-zero emissions by 2065. These goals are supported by five integrated territory-wide energy plans covering power development, energy efficiency, alternative energy, gas, and oil. The Energy Efficiency Plan (EEP) aims to reduce energy intensity by 36% by 2037, targeting savings of 35,000 ktoe through initiatives across various sectors, including industry, buildings, transportation, agriculture, and residential areas.

Mr. Apichonnubutr detailed Thailand's three-pronged approach to energy efficiency: compulsory measures like building energy codes for structures over 2,000 sqm; voluntary programs offering financial incentives for efficient equipment; and complementary efforts in workforce development and public awareness. He emphasized the importance of standards and labeling for appliances and the promotion of smart technologies like IoT and AI in industrial applications.

A case study of the Kiridharn Hydro hydropower project illustrated practical implementation strategies. This 12.4 MW facility in eastern Thailand serves dual purposes of power generation and agricultural water management. Recent upgrades, including an Automatic Line Voltage Control system, reduced powerhouse electricity costs by 20%. The project now incorporates floating solar (20 MW) and rooftop PV, with plans to expand solar integration to 25 small hydropower plants by 2030.

Mr. Apichonnubutr explained that the Alternative Energy Development Plan (AEDP) aims to increase renewable energy to 36% of total final consumption by 2037, with renewables projected to supply 61% of electricity generation. He noted that solar power would lead this transition at 20.6% of planned capacity, followed by imported hydropower at 15.4%. He indicated that the share of fossil fuels in power generation is planned to decrease to 39% by 2037, with a complete phase-out expected by 2065.

Q&A for session 2.2

Question: Are there efforts to combine photovoltaics with pumped storage hydropower to stabilize solar output, beyond simple hybrid systems?

Reply: Mr. Apichonnubutr acknowledged the Electricity Generating Authority of Thailand (EGAT) has implemented pumped storage hydropower in northeastern Thailand and floating solar projects. While not directly familiar with specific large-scale PV-pumped storage hybrids, he offered to follow up with EGAT for detailed information on such initiatives.

Sharing 2.3: Chile's experience on energy transitions

Presenter: Ms. Adelaida BAERISWYL, Advisor, International Affairs Office, Ministry of Energy, Government of Chile, Chile

Ms. Adelaida BAERISWYL presented Chile's comprehensive approach to energy transition, emphasizing coal phase-out strategies and just transition principles. She described Chile's energy landscape, highlighting its exceptional renewable energy potential—estimated at 80 times the current installed capacity—concentrated in solar-rich northern regions and wind-abundant southern areas. This situation contrasts sharply with Chile's complete dependence on imported fossil fuels for coal and gas generation, making renewable energy development both an environmental and energy security imperative.

She explained that Chile has established long-term energy policies that transcend political cycles, starting with the 2015 Energy Policy aimed at 2050, which is updated every five years. The most recent iteration, the Initial Agenda for the Second Stage of Energy Transition (2023), addresses new challenges arising from Chile's successful first transition phase. While initial renewable energy penetration has been achieved, the current focus has shifted to supporting technologies like energy storage and grid flexibility to ensure system reliability.

Ms. Baeriswyl traced Chile's energy evolution since 1970, when hydropower dominated the matrix. She noted that severe droughts beginning in 1998 and natural gas supply cuts from Argentina in 2004 exposed vulnerabilities in this model, prompting diversification into imported fuels. Since 2010, however, Chile has proactively planned its energy future through the 2050 Energy Policy, capitalizing on its abundant renewable resources rather than reacting to external shocks. This forward-looking approach has led to significant results, with renewable generation expanding from 34% in 2010 to a projected 80% by 2030.

She outlined Chile's coal phase-out program, initiated through a 2019 voluntary agreement with power plant operators targeting complete phase-out by 2040. While about two-thirds of plants can be retired relatively smoothly, she acknowledged that the final third presents greater technical challenges requiring advanced storage solutions and grid modernization. Ms. Baeriswyl emphasized that the coal phase-out extends beyond energy policy, directly impacting six cities where power plants are the primary economic activity.

She also discussed Chile's innovative Just Energy Transition Strategy, which addresses socioeconomic dimensions through extensive participatory processes, including workshops and public consultations. This strategy focuses on four pillars: health, human capital and employability, environment, and sustainable local development. Ms. Baeriswyl highlighted the Ministry of Energy's central role in operationalizing just transition principles across all energy policies, stressing that overcoming remaining technical challenges requires coordinated efforts between government, industry, and communities.

Sharing 2.4: Republic of Korea's Initiatives Toward Carbon Neutral

Presenter: Ms. Jieun HEO, Assistant Manager, Korea Energy Agency (KEA), Republic of Korea (ROK)

Ms. Jieun HEO presented the Republic of Korea's (ROK) comprehensive strategy to achieve carbon neutrality by 2050. She outlined the economy's energy challenges as an energy-intensive economy with high import dependency. Ms. Heo explained that ROK has set increasingly ambitious climate targets, raising its 2030 National Greenhouse Gas Reduction Targets (NDC) from a 26.3% to a 40% reduction from 2018 levels. She noted that ROK's 2022 energy policy established five key directions: addressing climate change, enhancing security, fostering innovation, establishing a new energy mix (32.4% nuclear and 21.6% renewables by 2030), and improving market-based efficiency.

She presented a dual-track approach that combines supply-side renewable energy expansion with demand-side efficiency measures. Ms. Heo emphasized the need to address generation, transmission, and consumption efficiency holistically. The Comprehensive Plan for Energy Demand-Side Efficiency aims for a 25% improvement by 2027 through ten priority tasks across industrial, building, and residential sectors.

Initiatives in the industrial sector include voluntary agreements with major energy consumers, which feature public performance disclosures and incentives. ROK plans to implement an Energy Efficiency Resource Standard (EERS) requiring energy suppliers to support customer efficiency gains, while reforming equipment standards into a tiered labeling system to drive innovation. For buildings, programs like Energy Cashback and Green Building certification promote efficiency from design through operation.

Ms. Heo highlighted how the 11th Basic Plan for Electricity Supply and Demand strengthens these demand-side measures, with the Korea Energy Agency (KEA) targeting a 2.6 GW peak demand reduction by 2038. The plan also accelerates coal phase-out by prohibiting new coal plants and replacing retired capacity with renewables and nuclear. Projections indicate that renewables will generate nearly triple coal's output by 2038, with solar and wind capacity reaching 74 GW by 2030, accounting for 21.7% of generation.

ROK's renewable energy policies have driven significant growth, with installed capacity reaching 30 GW in 2023. Ms. Heo described the government's May 2023 roadmap to rebalance the solar-wind mix from 87:13 to 60:40 by 2030 through 16 key tasks, including reforms to the Renewable Portfolio Standard (RPS) system to enhance cost-effectiveness. She concluded with ROK's latest Renewable Energy Expansion and Supply Chain Enhancement strategy, which addresses implementation challenges like grid constraints and high costs.

Sharing 2.5: Policies of Electricity Generation in the Phase-Out of Fossil Fuels

Presenter: Mr. Takeda IKEDA, Executive Economist from The Institute of Energy Economics, Japan (IEEJ) (pre-recording)

Mr. Takeda IKEDA presented Japan's goal of achieving carbon neutrality by 2050 and introduced the Seventh Strategic Energy Plan launched in February 2025. He explained that Japan aims to balance economic growth, energy security, and environmental concerns by emphasizing safety and efficiency. To achieve stable energy supply and decarbonization, Japan will maximize renewable energy as its primary power source and promote balanced power generation. The economy plans to enhance energy efficiency and fuel switching in manufacturing while maximizing decarbonized sources like renewables and nuclear power, both crucial for energy security.

Mr. Ikeda highlighted the importance of public acceptance, cost-efficiency, managing energy intermittency, encouraging innovation in renewable energy supply chains, and enhancing the use of solar power materials. Upgrading power grid systems is also seen as crucial to support more renewable energy.

Mr. Ikeda also emphasized the need to shift away from fossil fuels towards cleaner options like hydrogen and ammonia in power production to reduce carbon emissions. He shared Japan's efforts to blend these cleaner fuels with natural gas or coal to make power plants cleaner.

Additionally, he mentioned government support to promote the use of hydrogen through economic bonds and laws like the Hydrogen Society Promotion Act. Japan is also offering subsidies to encourage the use of hydrogen and ammonia as energy sources.

In terms of international collaboration, Mr. Ikeda discussed Japan's advancements in transporting hydrogen, including successful tests with large ships. He explained how Japan is exploring new methods, like using Methyl Cyclohexane (MCH), to transport and extract hydrogen efficiently.

In conclusion, Mr. Ikeda highlighted Japan's commitment to transitioning to renewable energy sources and reducing its dependence on fossil fuels. In introducing renewable energy as a major power source, Japan would work to integrate renewable energy into the electricity market and minimize integration costs for society as a whole associated with grid development and balancing power. His insights showcased Japan's efforts towards a cleaner and more sustainable energy future.

3.4 Section 3 - Deployed Technologies for Transitioning to Cleaner Fossil Energy

Sharing 3.0: Findings from Pre-Workshop Study

Presenter: Prof. XU Zhao, Professor, The Hong Kong Polytechnic University, Hong Kong, China

Prof. XU Zhao presented the rapid growth in global energy demand and the significant role of the electric power industry as a major carbon emitter, accounting for nearly 40% of total annual global carbon emissions according to an International Energy Agency (IEA) report. He emphasized that achieving sustainability in power generation is crucial for both economic and societal development. The primary objective of the APEC project is to phase out fossil fuel-based technologies while enhancing energy efficiency to promote a balanced, secure, and sustainable energy future across the APEC region.

In his analysis of power plant efficiencies, Prof. Xu reviewed various technologies currently in use. Coal-fired power plants typically operate at 35–42% efficiency, with energy losses occurring during combustion (6–10%), thermal-to-mechanical conversion (40–45%), and mechanical-to-electrical conversion (1–3%). Gas-fired plants show higher efficiency (40–60%), though they also experience losses in combustion (5–10%) and turbine operations (30–45%). Nuclear plants, while low in efficiency (30–34%), face challenges due to lower operating temperatures and pressures compared to coal plants. Renewable energy sources such as hydropower (87–92% efficiency) demonstrate minimal losses, whereas wind (32–42%) and solar (12–19%) technologies exhibit lower efficiency due to energy conversion limitations.

Prof. Xu then discussed retrofitting options for existing coal and gas-fired power plants. For coal plants, upgrading boilers to supercritical or ultra-supercritical systems can increase efficiency to 47%. Combined Heat and Power (CHP) integration can actually have the highest efficiency, can be up to 70-90% of efficiency. low-temperature economizers, and condenser optimization offer additional efficiency gains (5–10%). A particularly innovative approach involves converting coal plants into Carnot Battery systems, where excess renewable energy is stored as thermal energy for later use, a concept already implemented in China's Shanxi province. While Magnetohydrodynamic (MHD) power generation was mentioned as a theoretical but immature technology, Prof. Xu noted its potential for direct thermal-to-electrical conversion.

For gas-fired plants, retrofitting strategies include combined cycle power generation, upgrading turbines to higher efficiency classes (e.g., H-class, J-class), and optimizing combustion through wet compression, staged combustion, and burner design improvements. Cooling system enhancements can further improve efficiency by 5–7%. Prof. Xu emphasized that while combined cycle retrofits require significant investment, they yield substantial efficiency improvements, whereas combustion optimizations offer cost-effective but incremental gains.

The presentation also explored emerging technologies for high-efficiency power generation. In coal plants, Integrated Gasification Combined Cycle (IGCC) and fluidized bed combustion represent cleaner and more efficient alternatives. Gas-fired plants benefit from advanced turbine designs (e.g.,

H-class, J-class) and Kalina cycle systems, which use ammonia-water mixtures to recover low-temperature waste heat. Hydrogen and ammonia co-firing were highlighted as promising decarbonization strategies.

For nuclear energy, Prof. Xu discussed Generation IV reactors, small modular reactors (SMRs), and spent fuel recycling as innovations improving safety, efficiency, and waste reduction. Hydropower advancements include variable-speed pumped storage and hydrokinetic turbines, which harness tidal energy without dams. Solar technology is evolving with high-efficiency materials like N-type silicon and passivated emitter and rear cell (PERC) designs, while wind energy innovations focus on taller turbines, longer blades, and wake steering to optimize wind farm performance.

Prof. Xu concluded the importance of transitioning from coal-based generation to low-carbon alternatives, investing in efficient power generation and storage, and promoting a diversified energy mix. He emphasized that these technological advances must remain affordable, flexible and easily accessible to support economic growth and energy security while accelerating emissions reductions.

Sharing 3.1: CLP Power Energy Transition Journey in Power Generation

Presenter: Mr. CHANG Fan, Director - Business Strategy/Generation, CLP Power Hong Kong Limited, Hong Kong, China

Mr. CHANG Fan presented the company's comprehensive energy transition strategy spanning over three decades. As one of Hong Kong, China's two major power companies with operations across Asia Pacific, CLP has reduced emissions by over 90% since the 1980s while increasing electricity supply by 90%, achieving a 60% reduction in carbon intensity.

He outlined CLP's diversified Hong Kong generation portfolio including the coal-dominant Castle Peak Power Station (3,058MW), gas-fired Black Point Power Station (3,850MW), nuclear imports from Daya Bay Nuclear Power Station (1,577MW), Guangdong, pump storage imports, and landfill gas generation. Mr. Chang highlighted key decarbonization milestones, beginning with nuclear power imports from the Daya Bay Nuclear Power Station starting in 1994, which now supplies 80% of its electricity output to Hong Kong, China and avoids 7.5 million tonnes of CO₂ annually.

Mr. Chang explained that a major transition pillar for CLP has been the shift to natural gas, which began in 1996 with the installation of eight F-class combined cycle gas turbines (CCGT) at Black Point Power Station, achieving 50% efficiency. He detailed how CLP enhanced these units through retrofits in 2022 and added two advanced H-class CCGT units between 2020 and 2024. These new units feature annular combustion systems and optimized blade designs that increase efficiency to 60%. The commissioning of Hong Kong, China's first offshore LNG terminal in 2023 improved supply security and price competitiveness through diversified global LNG sourcing.

Regarding the remaining coal generation, Mr. Chang described CLP's emission control retrofits at Castle Peak Power Station, which include Selective Catalytic Reduction for NO_x reduction, Boosted

Over-Fire Air systems, and Flue Gas Desulfurization for sulfur oxides (SO_x) removal. He noted that these investments enabled compliance with tightening environmental standards while maintaining coal's role in the energy mix during the transition.

Mr. Chang stated that CLP aims to reduce its carbon intensity from 0.8 kg CO₂/kWh in 2007 to 0.26 kg CO₂/kWh by 2030 and achieve net-zero emissions by 2050. Key strategies include a complete coal phase-out by 2035 and increasing zero-carbon energy to 60-70% of the mix by that same year, alongside regional energy cooperation. He emphasized that natural gas alone cannot deliver net-zero emissions, prompting CLP to explore hydrogen blending trials at Black Point Power Station.

The hydrogen pilot involves modifying two units to accommodate 5% hydrogen-natural gas blends, which requires specialized receiving stations for pressurized hydrogen delivery. Mr. Chang acknowledged the challenges posed by hydrogen's current cost and supply limitations in Southern China. Additionally, Mr. Chang reported that his company was reviewing carbon capture technologies and hydrogen derivatives like ammonia as potential long-term solutions.

He demonstrated how CLP's phased, technology-driven approach balances emission reductions with energy security and affordability. The company's transition leverages both infrastructure upgrades, such as gas turbine retrofits and emission controls, and fuel switching, including nuclear imports and hydrogen trials, while maintaining operational reliability during Hong Kong, China's energy transformation.

Sharing 3.2: Deployed Technologies for Transitioning to Cleaner Fossil Energy at Lamma Power Station

Presenter: Mr. Ray WU, Chief Mechanical Engineer, The Hongkong Electric Co., Ltd., Hong Kong, China

Mr. Ray WU introduced Lamma Power Station in Hong Kong, China, highlighting its total installed capacity of 3,082 megawatts. He noted that the station features a mix of gas-fired combined cycle units, coal-fired units scheduled for retirement by 2035, emergency gas turbines, and renewable energy sources such as solar and wind power, along with ongoing expansion projects aimed at increasing gas generation capacity.

Mr. Wu discussed the deployment of advanced gas-fired combined cycle units, including Lamma 10, 11, and 12, as well as the future Lamma 13. He explained that these units have a thermal efficiency of up to 58.5% and utilize a single-shaft arrangement that integrates a gas turbine generator and a steam turbine for enhanced efficiency.

He highlighted key technologies in the CCGT units, including a Dry Low NO_x combustion system and a Selective Catalytic Reduction (SCR) system designed to minimize nitrogen oxide emissions. By adopting advanced combustion and post-combustion gas treatment systems, Lamma Power Station has successfully reduced emissions to stringent levels, significantly contributing to environmental sustainability.

Mr. Wu elaborated on the utilization of ammonia for nitrogen oxide reduction through a selective catalytic reduction system, complemented by a Urea-to-Ammonia Conversion (UTAC) system to ensure safe and efficient ammonia handling. He stated that these technologies have enabled Lamma Power Station to achieve low nitrogen oxide emission levels of less than 5 mg/Nm³, effectively meeting regulatory standards.

Discussing decarbonization efforts, Mr. Wu highlighted the phased retirement of coal-fired units and the strategic shift towards gas-fired generation. He noted that the implementation of advanced gas turbine technologies, along with emission control systems, has led to significant improvements in environmental performance, showcasing the station's commitment to sustainability.

He also outlined future plans to retire coal-fired units by 2035 and explore decarbonization strategies that incorporate renewable energy and hydrogen technologies. Collaborative efforts with HK Electric and China Light and Power to develop an offshore LNG terminal have bolstered gas supply security and price competitiveness, further supporting the transition to cleaner energy sources.

In response to a question about utilizing the cold energy of LNG to enhance the energy efficiency of gas turbines, Mr. Wu explained that the LNG terminal uses seawater to warm up and vaporize liquefied natural gas to gaseous form. He also emphasized ongoing efforts to recover other waste heat to improve thermal efficiency at Lamma Power Station.

Sharing 3.3: Innovative Methods to Enhance Power Plant Design and Operation Efficiency Using Artificial Intelligence

Presenter: Ms. CHENG Xiaohong, Deputy Director of Dept. of International Cooperation, State Power Investment Corporation (SPIC), China

Ms. CHENG Xiaohong presented the important role of Artificial Intelligence (AI) and renewable energy sources in shaping the future of energy. She illustrated that SPIC plays a significant role in China's energy sector, boasting a total installed capacity of 265 GW, with a focus on smart technology to effectively manage renewable and new energy power plants.

In 2023, SPIC initiated the Smart Plant initiative, which organized power plants into prevention centers and large-scale plants to optimize operational management. By leveraging smart technology and district-level structures, the initiative aims to enhance operational efficiency and safety across renewable energy projects.

Ms. Cheng detailed several innovative methods deployed by SPIC to boost power plant design and operational efficiency using AI. She noted that intelligent recognition systems, deep learning, and multisource data improved site selection efficiency by over 90%, streamlining data extraction for wind and photovoltaic (PV) power projects. Additionally, an automated resource analysis system reduced repetitive work by over 80%, enabling automated layout design of wind turbine positions and

increasing design efficiency by more than 90%.

She explained that the integration of Geographic Information Systems (GIS) and AI technologies streamlined the inspection process for key overhead line equipment, boosting inspection efficiency by over 50% and reducing labor costs by approximately 20%. Furthermore, intelligent design software automatically generates all necessary drawings during the planning process, enhancing engineering design quality and efficiency.

Ms. Cheng also highlighted that an Intelligent Flexible Control device optimized electricity consumption at PV power plants, resulting in a 90% reduction in off-grade electricity consumption and increased energy savings. The implementation of AI technologies in the intelligent operation and management platform enabled identification of power generation status, predictive maintenance, and remote monitoring, which reduced operation and maintenance costs by 10% and enhanced equipment reliability and operational efficiency.

She emphasized the importance of embracing new technological advancements to shape a sustainable future. Her presentation underscored how AI is revolutionizing power plant operations, paving the way for a more efficient and sustainable energy landscape.

3.5 Section 4 - Energy source and Gender issue for Electricity Generation

Sharing 4.1: Efficiency Enhancement in Nuclear Electricity Generation

Presenter: Prof. ZHAO Jiyun, Professor, Department of Mechanical Engineering, City University of Hong Kong, Hong Kong, China

Prof. ZHAO Jiyun presented the significance of nuclear power within the global energy landscape, emphasizing its role as the second-largest source of low-emission electricity, following hydropower. With 413 operational nuclear reactors worldwide in 2023, nuclear energy has played a crucial role in reducing CO₂ emissions and meeting energy demands across various member economies.

Exploring the technical efficiency of nuclear energy, Prof. Zhao emphasized the importance of temperature in enhancing efficiency. By comparing different cooling methods like water, gas, and liquid metal, he showcased how advanced systems like fast breed reactors and fourth-generation nuclear reactors have the potential to achieve higher efficiency levels, surpassing traditional pressurized water reactor systems.

Prof. Zhao discussed the cost-effectiveness of nuclear electricity generation, particularly through long-term operating strategies and lifetime extensions of nuclear power plants. By extending the operational lifespan of reactors beyond their original design, nuclear power has demonstrated cost competitiveness, as evidenced by lower levelized costs of electricity compared to other technologies like fossil fuels and renewables.

He also highlighted the reliability of nuclear energy, exemplified by high-capacity factors and reduced refueling periods in modern reactors, leading to improved operational efficiency and reduced downtime. Prof. Zhao presented data showcasing nuclear power's reliability as a consistent and dependable source of electricity generation, with high-capacity factors outperforming many alternative energy technologies.

In terms of environmental efficiency, Prof. Zhao emphasized the low carbon footprint of nuclear energy, characterized by minimal greenhouse gas emissions per kilowatt-hour compared to fossil fuels, and renewables like solar, wind and hydropower. He also shared the environmental benefits of nuclear power in terms of toxic emissions, mineral and metal requirements, and land use efficiency, positioning nuclear energy as an environmentally friendly option.

Drawing upon international projections and investments in nuclear energy, Prof. Zhao outlined a positive trajectory for nuclear power, with a significant increase in capacity and investment expected by 2050. The commitments made by member economies and international organizations underscore the growing importance of nuclear energy in the global energy transition.

Prof. Zhao presentation provided a comprehensive overview of the efficiency enhancements in nuclear electricity generation, highlighting the technical, economic, and environmental considerations

that shape the future of nuclear energy.

Sharing 4.2: Renewable Energy: A Gender Perspective

Presenter: Ms. Celia GARCÍA-BAÑOS, Programme Officer, International Renewable Energy Agency (IRENA) (pre-recording)

Ms Celia GARCÍA-BAÑOS presented an overview of the agency's gender-focused work within the context of the global energy transition. She introduced IRENA as an intergovernmental organization nearing global membership, dedicated to promoting renewable energy from a people- and planet-oriented perspective.

Ms. García-Baños described IRENA's efforts over more than a decade to evaluate job growth in the renewable energy sector. She noted that the latest assessment in 2023 revealed the highest employment figures to date, with a significant increase attributed to expanded renewable energy capacity. Solar photovoltaic (PV) technology led in job creation, followed by bioenergy and hydropower. However, she pointed out the uneven distribution of these jobs across regions. She projected that, if aligned with the Paris Agreement and supported by appropriate policies, renewable energy jobs could grow from 16 million to 30 million globally by 2030.

She presented the gender composition of the renewable energy workforce, detailing IRENA's survey-based research, which found that women represent about 32% of the workforce in renewables—higher than in oil and gas (22%) but lower than the economy-wide average (45.9%). Further analysis revealed significant differences between technologies: wind energy employs only about 20% women, similar to oil and gas, while solar PV performs better, with around 40% women. Despite these averages, Ms. García-Baños highlighted that women were concentrated in administrative roles and remain underrepresented in Science, Technology, Engineering, and Mathematics (STEM) positions, as well as in management roles. For instance, in wind energy, women occupy just 13% of management and 8% of senior management positions.

She outlined barriers preventing women from entering, remaining, and advancing in the sector, identifying cultural and social norms as primary challenges influencing hiring and promotion practices. Other significant barriers included limited transparency in internal policies, lack of flexible work arrangements, insufficient parental leave, and absence of on-site childcare, particularly relevant during childbearing years. She emphasized that these obstacles are not due to a lack of skills or qualifications.

In areas with limited energy access, Ms. García-Baños observed opportunities for women in planning, construction, and operations at the community level, though these were hindered by insufficient skills training and persistent cultural barriers. To address these challenges, she advocated for mainstreaming gender perspectives in all policies and programs, recommending mentorship, clear targets for gender diversity, inclusive workplace policies, and monitoring of wage equality. She concluded that improving women's representation in renewable energy is vital for a more diverse and

inclusive workforce.

3.6 Closing Remarks of Workshop

Presenter: Mr. Marsden KONG, Project Overseer, Assistant Director/Electricity and Energy Efficiency of the Electrical and Mechanical Services Department; Hong Kong, China

Mr. Marsden KONG expressed his sincere gratitude to all speakers and participants . Mr. Kong noted that the case studies and presentations delivered by these experts provided a comprehensive overview of the policies, challenges, technologies, and opportunities relevant to enhancing energy efficiency and advancing the transition to cleaner electricity generation across the APEC region. He emphasized the importance of the insights shared, highlighting their role in helping participants better understand the current energy landscape and future prospects of energy transition within the region.

In addition to acknowledging the speakers, Mr. Kong thanked all workshop participants, both those who attended in person. He recognized the value of their active participation, which enriched the workshop's discussions and contributed to the identification of practical solutions for advancing shared energy goals. Mr. Kong conveyed a strong message of collaboration and innovation, urging all stakeholders to work together towards a sustainable energy future.

4 Conclusion

The workshop provided a valuable platform for international scholars and engineers to share their expertise on energy transition, emphasizing the importance of effective policies, best practices, and innovative technologies. The discussions highlighted the urgent need to enhance energy efficiency in electricity generation, particularly within the APEC region, where the impact of carbon emissions is significant. Participants recognized that promoting energy efficiency and phasing out unabated fossil fuels are not merely environmental imperatives but also essential for achieving sustainable economic growth and energy security.

Key takeaways from the workshop included a comprehensive technical review of various power plant efficiencies, showcasing the potential for improvement across different technologies. Recommendations such as prioritizing retrofits, integrating hybrid systems, and utilizing digital twins for performance optimization were well-received, demonstrating a clear path forward for enhancing energy generation efficiency.

Moreover, the workshop addressed the strengths and limitations of innovative technologies in the energy transition. While advancements in renewable energy and combined-cycle systems present significant opportunities, challenges such as high implementation costs and the need for skilled labor remain critical obstacles. The discussion around hydrogen blending and digital innovations further emphasized the necessity for ongoing research and development to facilitate their large-scale deployment.

Best practices for developing effective energy transition policies emerged as a focal point of the workshop. Establishing ambitious goals, fostering collaboration among stakeholders, and promoting technological innovation were identified as essential strategies for successful policy implementation. Additionally, addressing gender perspectives within energy policies emerged as a crucial element for enhancing workforce diversity and overall sector performance.

In conclusion, the workshop served as an enriching platform for APEC member economies, particularly developing economies, to exchange knowledge and experiences. The collaborative spirit fostered during the event is expected to strengthen regional cooperation and intensify efforts to reduce energy intensity while tackling pressing environmental challenges. By implementing the insights and strategies discussed, APEC member economies can navigate the complexities of the energy transition effectively, paving the way for a sustainable and equitable energy future.

Appendix A – Agenda

Date : 8 April 2025

Time : 09:00 -16:20

Venue : Kowloon Room, Mezzanine Floor, Kowloon Shangri-La,
Tsim Sha Tsui, Hong Kong, China

Time	Activities
09:00 – 09:30	Registration
09:30 – 09:40	Welcoming Remarks Mr Raymond POON, Director of Electrical and Mechanical Services, Hong Kong, China
09:40 – 09:45	Photo Taking
Session 1: Overview of Energy Efficiency in Electricity Generation and APEC Goal on the Phase-Out of Unbated Fossil Fuels	
09:45 – 10:25	- “Efficiency in Fossil Fuel Electricity Generation” by Mr. Carlos Fernández Alvarez, Senior Analyst of Gas, Coal and Power Markets Division, International Energy Agency (IEA) (pre-recording) - “APEC’s Electricity Mix and Efficiency: Progress, Challenges, and Opportunities” by Ms. Yasmin FOULADI, Researcher, Asia Pacific Energy Research Centre (APEREC)
10:25 – 10:40	Break
Session 2: Policies and Challenges of Energy Efficiency in Electricity Generation and Phase-Out of Unbated Fossil Fuels	
10:40 – 12:00	- “China’s Experience on Energy Transition and Energy Efficiency Enhancement in Electricity Generation” by Ms. ZHANG Yue, National Energy Administration, People's Republic of China - “Thailand’s Energy Efficiency Policies and Phase-Out of Fossil Fuels in Power Generation” by Mr. Wuttipong APICHONNABUTR, Civil Engineer, Senior Professional Level, Department of Alternative Energy Development and Efficiency (DEDE), Thailand - “Chile’s experience on energy transitions” by Ms. Adelaida BAERISWYL, Advisor, International Affairs Office, Ministry of Energy, Government of Chile - “Korea’s Initiatives Toward Carbon Neutral” by Ms. Jieun HEO, Assistant Manager, Korea Energy Agency
12:00 – 13:15	Lunch
13:15 – 13:30	Registration

Time	Activities
Session 2 (continue)	
13:20 – 13:35	- “Policies of Electricity Generation in the Phase-Out of Fossil Fuels” by Mr. Takeda IKEDA, Executive Economist from The Institute of Energy Economics, Japan (IEEJ) (pre-recording)
Session 3: Deployed Technologies for Transitioning to Cleaner Fossil Energy	
13:35 – 13:55	Findings from Pre-Workshop Study by Prof. XU Zhao, Professor, the Hong Kong Polytechnic University, Hong Kong, China
13:55 – 15:00	- “CLP Power Energy Transition Journey in Power Generation” by Mr. CHANG Fan, Director - Business Strategy/Generation, China Light and Power Company Limited (CLP), Hong Kong, China - “Deployed Technologies for Transitioning to Cleaner Fossil Energy at Lamma Power Station” by Mr. Ray WU, Chief Mechanical Engineer, The Hongkong Electric Co., Ltd., Hong Kong, China - "Innovative Methods to Enhance Power Plant Design and Operation Efficiency Using Artificial Intelligence", by Ms. CHENG Xiaohong, Deputy Director of Dept. of International Cooperation, State Power Investment Corporation (SPIC), China
15:00 – 15:30	Break
Session 4: Energy source and Gender issue for Electricity Generation	
15:30 – 16:10	- “Efficiency Enhancement in Nuclear Electricity Generation” by Prof. Zhao Jiyun, Professor, Department of Mechanical Engineering, City University of Hong Kong, Hong Kong, China - “Renewable Energy: A Gender Perspective” by Ms. Celia García-Baños, Programme Officer, IRENA (pre-recording)
16:10 – 16:15	Closing Remarks Mr Marsden KONG, Assistant Director/Electricity and Energy Efficiency, Electrical and Mechanical Services Department, Hong Kong, China
16:15 – 16:20	Photo Taking
16:20	End of workshop