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Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region

APEC Energy Working Group

November 2022

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Project: EWG 04 2019A

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APEC#222-RE-01.15

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1. Executive Summary

To speed up the implementation and reach the APEC Double Renewable Energy and 45% Energy Efficiency goals, EWG encourages collaborative work between the expert groups, EGNRET and EGEE&C. The joint projects in RE&EE will provide co-benefits technically and economically. This project addresses the co-benefitting opportunities for renewable energy and energy efficiency project for power generation and distribution, transportation, and buildings sector so that cost can be shared to promote project with both renewable energy and energy efficiency benefits. It focuses on sharing of best practices with the development of criteria, framework, and guideline of the joint project evaluation in the future. In addition, capacity building activities for project developers and stakeholders are on project designing and planning for transportation sector.

The participants in this project are from various sectors in the APEC member economies. They contribute to the sharing of best practice on opportunities and developing roadmap or guideline for co-benefitting joint RE&EE project. This will benefit the APEC Secretariat to evaluate the future project submissions.

This project aims to examine and analyze joint RE&EE projects among developed and developing APEC economies for guidelines in assessing future joint RE&EE projects to support both APEC RE&EE goals in a more economical way through cost-sharing project implementation. Key actions are:

- ✓ To share best practices of successful joint projects for RE&EE implementation with co-benefit in power generation and distribution, transport, and buildings sectors, as shown in Chapter 3;
- ✓ To develop guideline with criteria and framework for joint RE&EE projects with co-benefit technically and economically from extensive literature review with inputs from both workshops, as shown in Chapter 4 and Annex 1 & 2, in addition to recent change of Energy Efficiency, Low Carbon and Energy Resiliency Measures (EELCER) Sub-Fund criteria and guideline approved during 60th meeting of the APEC Energy Working Group (EWG60) in Brunei Darussalam on June 21-25, 2021;
- ✓ To share example of cost benefit analysis (CBA) on successful projects (for example, RE&EE in transport sector - EV & biofuel), as shown in Annex 2;
- ✓ To build capacity and network for co-benefitting project developers in designing, planning, and assessing potential RE&EE joint project, as shown in Annex 1 & 2.

Way forward to mainstream projects with co-benefitting in renewable energy and energy efficiency can be implemented with future APEC proposals submitted to the Energy Efficiency, Low Carbon and Energy Resiliency Measures (EELCER) Sub-Fund being scored according to technical criteria in Table 3, as well as monitoring the occurrence frequencies of the keywords in Table 3 in future proposals with follow-up evaluation on the contribution of those proposals to the two APEC energy goals.

2. Project Background

Currently, many APEC economies are facing issues in implementing policies and projects to reach two ultimate key APEC goals of 45% energy intensity reduction by 2035 and doubling the share of renewable energy by 2030. To speed up the implementation and achieve these goals, EWG encourages collaborative work between the expert groups, EGNRET and EGEE&C. The joint projects in Renewable Energy and Energy Efficiency (RE&EE) will provide co-benefits technically and economically since state-of-the-art technologies nowadays can address both energy efficiency and renewable energy issues with economic benefit in cost-sharing. Presently, there were very few joint RE&EE project submission to APEC Secretariat. Hence, this proposed project will identify and illustrate opportunities and best practices in joint RE&EE projects with technical and economical co-benefit, where guidelines for future joint APEC project could be developed for the benefits of APEC economies to work collaboratively with synergy. Promoting energy efficiency in transportation sector and promoting renewable energy usage in this sector to enhance energy security and sustainability for the economy. For example, Thailand has a campaign to promote energy efficiency in transportation sector by using EVs, and to promote using biofuel for transportation sector.

This project addresses the co-benefitting opportunities for RE&EE project implementation with a focus on sharing best practices to develop criteria/framework for future joint APEC project guideline, as well as giving capacity building for potential project developers and stakeholders in APEC economies. In addition, capacity building objective of this project seeks to strengthen the skills in designing, planning, and assessing the co-benefits of joint RE&EE project for potential project developers from both government (as supporters' role) and private sectors (as implementers' role). Examples on commercially available technologies in developed APEC economies can be showcased to available resources in developing APEC economies, where cross-border transactions on project development are promoted. Hence, two workshops are planned as follows.

Although 1st workshop was originally planned to align with Hawaii Energy Conference (HEC), where participants can learn from energy industry leaders and policy makers from around the world, COVID-19 pandemic has changed the original plan to have 1st workshop as a separate virtual event but with speakers from Hawaii Natural Energy Institute (HNEI), the co-organizer of HEC, instead. Originally, 2nd workshop was planned to be in Thailand to learn from actual RE&EE projects, where step-by-step approach will be walked through using example in the transportation sector since disruptive electric vehicle technology clearly illustrates energy efficiency performance with ability to accommodate renewable energy. Nonetheless, on-going COVID-19 pandemic has changed the original plan to have virtual event but still retaining the original purpose as much as possible.

The project outputs are divided into two following chapters: review of projects and activities co-benefitting renewable energy and energy efficiency, and proposed criteria for joint projects co-benefitting renewable energy and energy efficiency. The report also includes the Summaries of key findings from 1st Workshop and 2nd Workshop, and also the summary of evaluation tool to assess co-benefitting projects in transportation sector and hands-on practice in the annexes.

3. Review of Projects and Activities Co-Benefitting Renewable Energy and Energy Efficiency

In the process of reviewing projects/activities that co-benefit renewable energy and energy efficiency, reports and literature related projects/activities in APEC economies that aim to support introduction or popularization of renewable energy or promotion of energy efficiency in transportation sector, power generation and distribution sector, and building sector are first listed. Documents related to renewable energy are scanned to ensure whether the project/activities could benefit energy efficiency or not, and vice versa. Finally, documents reporting projects/activities outside APEC economies are also visited, though limitedly, to gain additional insights that would help design activities that co-benefit renewable energy and energy efficiency. The projects/activities are listed under one of the three sectors in which they can best fit in. For each project/activity, a summary including a brief description of the project/activity, contributions to renewable energy and to energy efficiency, driving mechanisms for policy recommendation, good practices, and lessons learned are provided. These pieces of information will be used to develop criteria for joint projects co-benefitting renewable energy and energy efficiency in the next step.

3.1. Transportation Sector

Projects/activities under transportation sector can be divided into four sub-categories as shown in Figure 1. The subcategories include electric/hybrid/fuel cell vehicles, fuel-related measures, traffic management, and efficiency improvement. Projects/activities listed under this sector are low carbon bus in People's Republic of China and Republic of Korea, smart EV charging stations in United States of America, and several European Union members, China’s Clean Diesel Action Plan, biofuel promotion in Southeast Asia, Smart Park ICT Re-Engineering Initiative in Chinese Taipei, and usage of waste heat in Czech Republic.

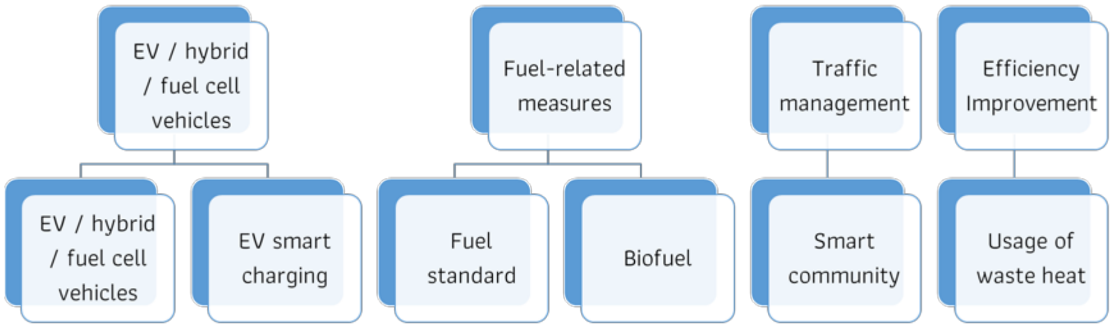

Figure 1 Past projects and activities co-benefitting renewable energy and energy efficiency in transportation sector

Low Carbon / Electric Buses

APEC Economies: People's Republic of China; Republic of Korea

Description

China aims to replace fuel-powered buses (targeting a 100% in most cities) with low-carbon buses (LCBs): plug-in hybrid and hybrid buses in order to decrease urban air pollution and greenhouse gas (GHG). LCBs use about four times less energy than fuel-powered units and could save on average 20% fuel. However, hybrid buses have an additional investment of 20-150% compared to fuel-powered units[1]. Similar approach can be seen in Seoul that encourages use of public transportation by increasing the expansion of median bus-only lanes in major cities and replace 50% of total buses in the city with low-carbon/electric buses[2].

Contribution to Renewable Energy

The contribution to renewable energy depends on the resources for the generation of electricity being used in electric buses[1].

Contribution to Energy Efficiency

Hybrid and plug-in hybrid buses could help reduce the usage of fuel by 20%[1] Fuel efficiency can also be improved by using lightweight carbon fiber composite materials for vehicle body shell[2].

Driving Mechanism for Policy Implementation

LCBs were supported by a number of policies in China, e.g., up-front purchase subsidies that cover bus size, pure electric drive range, bus efficiency, and technology, as well as, a series of interim rules issued in February 2018 tasking electric vehicle (EV) manufacturers to take responsibility for recovery of vehicle batteries by setting up recycling channels and services.[1] The relevant approaches also appear in other economies, for example, Germany, United Kingdom, and The United States[1].

The approach in Seoul was different. The government set up a meeting with CEOs of companies across economies, introducing Advanced Purchase Commitment System and cooperated with private sector through an Agreement on Joint Development of Electric Bus[2].

Good Practices

To optimize the usage of electric buses, configurations of electric bus technology, battery size, and charging technology, as well as other relevant parameters, such as route distance, bus performance in different seasons, battery reserve rate and battery capacity, need to be determined.[1]

Eco-friendly electric buses in Seoul were introduced under the framework of promoting zero emissions and resolving noise problem[2].

Lesson Learned and/or Obstacles

Electric vehicles are expected to produce zero direct emissions; however, it is irrelevant when emissions are caused at upstream due to energy production or transport. Furthermore, in economies that are dominated by fossil-fuel power plants, EVs only make significant contribution toward increased energy efficiency and improved air quality. Hybrid buses result in additional investment though they have lower operational expenditures. In contrast, battery electric buses have lower maintenance costs but higher tire usage.[1]

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[1] Asia Development Bank (2018), *Sustainable Transport Solutions: Low-Carbon Buses in the People's Republic of China*, Asian Development Bank, Manila.

[2] ESCI KSP (n.d.). Making Clean Future Seoul with Eco Friendly Vehicles. *Energy Smart Communities Initiative.* Retrieved from https://www.esci-ksp.org/wp/wp-content/uploads/2012/05/Making-Clean-Future-Seoul-with-Eco-Friendly-Vehicles-Seoul-Electric-Bus-Project.pdf

## Smart EV Charging Stations	**APEC Economies:** People's Republic of China; The United States **Non-APEC Economies**: Denmark; Germany; Norway; Sweden

Description

Electric Vehicles (EVs) Smart Charging helps minimize load impact from EVs by integrating shares of variable renewable energy (VRE) into power systems. EVs: unidirectional (V1G), bidirectional vehicle-to-grid (V2G), and vehicle-to-home/-building (V2H/B) adapt charging pattern to flatten peak demand, fill load valleys, balance the grid load in real-time, and manage energy resources based on distribution constraints and customer's preferences. However, the development requires major investment, and several technical challenges remain in some projects[3].

Contribution to Renewable Energy

EV charging can be a viable opportunity to the usage of integrating renewable energy sources (solar and wind power) to decarbonize transport practically and cost-effectively[3].

Contribution to Energy Efficiency

Smart charging can flatten the peak demand by switching to renewable energy (RE) sources (solar/wind power) according to the demand. In other words, charging intensity is adjusted during nighttime which requires a longer time than morning/afternoon. This prevents additional investments for high peak capacity[3].

Driving Mechanism for Policy Implementation

To develop charging station, its infrastructure requires major investment and appropriate regulations, such as

- Grant schemes or funding for the installations or incentives for EV grid services,
- Cooperation between automotive and power industries,
- Supportive policies for e-mobility and smart charging[3,]
- Tax increase for internal combustion engine (ICE) vehicles or ban on sales of fossil-fuel cars,
- Expansion of electric charging network infrastructure[4].

Good Practices

To facilitate Smart Charging station, an online app with functions of charging activities, time-of-use, and pricing should be introduced in order to interact with customers. An optimization system which could choose to supply electricity back to the grid when the vehicle is sufficiently charged can be added (vehicle-to-grid: V2G).[3]
Considering the low sales number of EVs to date, consumers may accept of EVs with increasing driving range, availability of charging stations, speed of charging, health of EV batteries.

Lessons Learned and/or Obstacles

Even though several economies have proved that smart charging can serve its purpose to integrate different RE sources to decrease peak load, some economies may confront following impediments:

- Technical requirements
- Regulations and policies
- Stakeholder role and responsibilities[1]

[3] IRENA (2019), *Innovation landscape brief: Electric-vehicle smart charging,* International Renewable Energy Agency, Abu Dhabi.
[4] IRENA (2019), *Innovation outlook: Smart charging for electric vehicles,* International Renewable Energy Agency, Abu Dhabi.

Biofuel	**APEC Economies:** Indonesia; Malaysia; The Philippines; Thailand; Viet Nam

Description

The study presents the renewable energy (RE) research & development (R&D) efforts on policies and activities, particularly, bioenergy, solar, wind, geothermal power, and hydropower technologies, and connections between the ten (10) ASEAN Member States (AMSs) as well as RE development targets in the region. The study shows that biomass, including biofuel, and hydropower offer better cost competitiveness compared to other energy forms[5].

Contribution to Renewable Energy

The contribution of AMSs to the RE target can be achieved by using biofuel to fully or partially substitute conventional fossil fuel.

Contribution to Energy Efficiency

Along with the promotion of biofuel, most AMSs introduces more stringent fuel standards to improve the fuel economy.

Driving Mechanism for Policy Implementation

To promote the usage of RE, governments in ASEAN issued and applied RE-related policies, funding, and global grants in following ways:

1. Increase R&D budget to promote research via government funding, private-public partnership, and global collaboration
2. Formulate and encourage R&D policy
3. Apply research funding/R&D commercialization support
4. Set up RE-related pilot projects
5. Establish research centers

Good Practice

There are similar types of resources available in region which makes it possible for AMSs to support each other's R&D. Many AMSs also build a framework to connect R&D players, governments, and private sectors to promote understanding in the RE priorities and make the R&D efforts relevant.

Lesson Learned and/or Obstacles

Despite the output of publication, patents, and commercialization, obstacles differ based on government structure, infrastructure, funding schemes, direction of research priorities. A lack of inter-stakeholder engagement is also identified as an important challenge. Furthermore, insufficient data, information, knowledge with respect to RE R&D can hinder the progress of RE implementation.

[5] ASEAN-German Energy Programme (2019), *Research and Development (R&D) on Renewable Energy in ASEAN*, ASEAN Centre for Energy (ACE), Jakarta.

<table>
<tr><td>Smart Community: Smart Park ICT Re-engineering Initiative</td><td>APEC Economy: Chinese Taipei</td></tr>
<tr><td>Description
Smart Park ICT Re-Engineering Initiative aims to transform several science parks into innovative and sustainable digital eco-communities by reducing carbon emissions produced by private vehicles. To reach the goals, a combination of smart traffic control, parking, digital signage, e-shuttle buses, and a transportation app were introduced. Furthermore, a best practice in encouraging installation of PV systems in public and private buildings, factories, and agricultural facilities in Tainan over past six years had been noted[6].</td><td></td></tr>
<tr><td>Contribution to Renewable Energy
The park's objectives include increasing RE use, reducing diesel power generation, and providing low-carbon power. Installation of PV energy system on buildings and factories was the main mean to increase the RE share.</td><td>Contribution to Energy Efficiency
The digital platform leads to a decrease in usage of fuel and carbon emissions through an integrated bus system: traffic control, parking, digital signage, transportation app, and e-shuttle buses. Furthermore, the use of electricity generation forecasting, remote monitoring and control system for three phase equilibrium of AC power were adopted to predict load demand.</td></tr>
<tr><td colspan="2">Driving Mechanism for Policy Implementation
The projects were encouraged and fostered by local governments and local green technology industry.</td></tr>
<tr><td>Good Practices
According to the Ministry of Science and Technology, the aim of the project lies in reducing carbon emission produced by private vehicles. Since 2011, the projects contributed to the reduction of carbon emissions by 960 tons and save over 100,000 liters of fuel. Over past six years, the installation of PV systems expended continuously, making the supporting local government the first government to claim gold award in Low Carbon Models Town category.</td><td>Lesson Learned and/or Obstacle
N/A</td></tr>
</table>

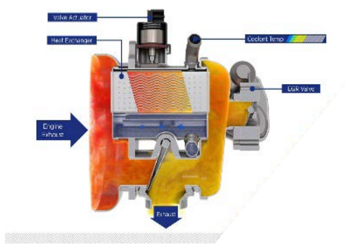
[6]New Southbound Policy Portal (2017). The Smart Park Information and Communication Technology Re-engineering Initiative and Great Tainan. *New Southbound Policy Portal.* Retrieved from https://nspp.mofa.gov.tw/nsppe/print.php?post=114369

Usage of Waste Heat: Waste Heat Energy Harvesting for Improving Vehicle Efficiency

Non-APEC Economy: Czech Republic

Description

In this Exhaust Heat Recovery System (EHRS), heat emitted by exhaust systems can be captured and used to increase vehicle efficiency. Heat exchanger concept is primarily designed to capture heat from different locations and transfer the energy for passenger heating or cooling. It can even provide supplement for train power efficiencies. The process led to a shorter heating time and rapidly increased temperature after start-up, resulting in fuel saving in hybrid vehicles[7].



Contribution to Renewable Energy

Waste heat that can be captured by exhaust systems is considered renewable energy. The heat can be fed into EHRS and help heating up the vehicle more rapidly, reducing power demand and enabling the vehicles to travel further on electronic motors.

Contribution to Energy Efficiency

Utilization of the waste heat can increase the fuel economy of the vehicle. Even under the worn-up condition, vehicles with EHRS demonstrated improvement of fuel economy. Similar finding applies to the hybrid powertrains which allow increased fuel economy under cold engine temperature conditions.

Driving Mechanism for Policy Implementation

N/A

Good Practice

EHRS is considered very effective and efficient in extracting heat from powertrains from underfloor position. Its capability is more flexible when switching to by-pass mode where heat can be collected within the exhaust system and coolant temperature is minimized when it rises during operation. In the next generation powertrain with EHRS installed, there is potential to extract larger quantity of heat which can be transferred to passenger cabin and/or powertrain fluids.

Lesson Learned and/or Obstacle

N/A

[7] Chiew, L., Clegg, M., Willats, R., Delplanque, G., & Barrieu, E. (2011). Waste Heat Energy Harvesting for Improving Vehicle Efficiency. *SAE International Journal of Materials and Manufacturing, 4*(1), 1211-1220. Retrieved March 2, 2021, from http://www.jstor.org/stable/26273853

3.2. Power Generation and Distribution Sector

Projects/activities under power generation and distribution sector can also be divided into four sub-categories as shown in Figure 2. The sub-categories include energy storage, smart grid, heat generation, and hydrogen generation. There are two examples for energy storage: one in Germany focusing on the development of battery, the other in France focusing on the modelling of electricity generating system that includes energy storage. As for smart grid, a project aiming for smart main grid in Hawaii, and several projects on renewable mini-grids in the US; Australia and Nepal are introduced. Co-generation projects in various economies around the world, and a landfill gas capture project in China are the examples for heat generation. Finally, an integration of renewable energy and hydrogen generation in Japan are shown as an example for hydrogen generation.

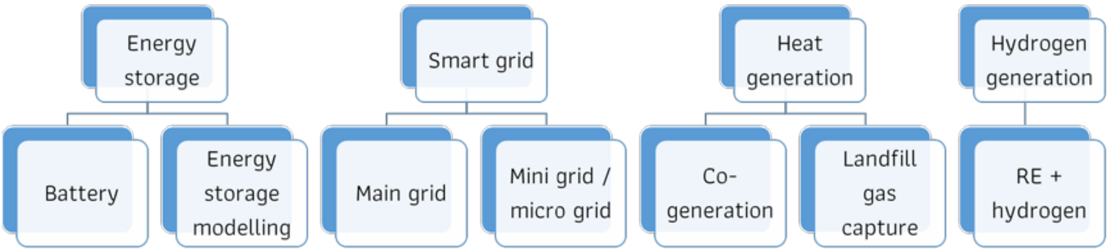


Figure 2 Past projects and activities co-benefitting renewable energy and energy efficiency in power generation and distribution sector

Energy Storage: Battery

Non-APEC Economy: Germany

Description

Stationary battery storage system (BSS) has grown in the global market for several years. BSS applications provide wide support from ancillary service, reduction in power prices and increase in solar capacity at private homes. However, the young markets run its course without assumptions about prices and battery dimensions. Germany addressed this issue by building database on wide capacity and power range of the storage systems. Lithium-ion technologies had influenced storage system market with high share for years, and currently its price has significantly fallen which makes it more affordable[8].

Contribution to Renewable Energy

Large-scale storage system (LSS) and industrial storage system (ISS) developments can play a critical role in increase RE share as the capacity being installed is normally large. Home storage system (HSS) tends to be more reliable in smaller-scale systems to support integrating a mix of renewable energy sources and increase the share of RE usage.

Contribution to Energy Efficiency

BSS with lithium-ion batteries can be used to store excessive energy to be used when the RE system cannot produce energy. It helps decrease specific system prices, and lead to higher energy efficiencies and longer lifetimes compared to lead-acid batteries in cyclic applications.

Driving Mechanism for Policy Implementation

To gather database on HSS market, funding support was provided by Federal Ministry for Economic Affairs and Energy in collaboration with banking group. The attendants of the programs were required to register HSS in an online questionnaire developed by the fund provider in order to receive the subsidy. As for ISS data, it was difficult to gather through the abovementioned approach. The data was collected via evaluation of press releases and direct contact to companies.

Good Practice

- Most ISS uses lithium-ion batteries and can be used for self-consumption. They can also be introduced as a part of smart grid. Their size depends on projects purposes and PV or wind power plant they are connected to.
- HSS manufacturers may provide ancillary services to support the usage of the customers.

Lesson Learned and/or Obstacle

- Individual HSS requires complex measurement technology, and the cost are currently unlikely to be compensated by the income.
- Site-specific conditions such as existing grid connection and developed location, cycle life and efficiency should be taken into account before consider installing LSS.

[8] Figgener, Jan & Stenzel, Peter & Kairies, Kai-Philipp & Linssen, Jochen & Haberschusz, David & Wessels, Oliver & Robinius, Martin & Stolten, Detlef & Sauer, Dirk. (2020). The development of stationary battery storage systems in Germany - status 2020. The Journal of Energy Storage. 33. 10.1016/j.est.2020.101982.

<table>
<tr><td colspan="2">Energy Storage: Energy Storage Modelling</td><td>Non-APEC Economy: France</td></tr>
<tr><td>Description
To supply electricity to remote areas in isolated regions, Artelia's solution: hybrid energy systems and energy storage is proposed as a key to address the problem. Through setting up of autonomous power plants powered by renewable energy (solar and wind energy) or hybrid systems, users' demand can be responded. The solution also includes a wide range of service facilitating the integration of RE sources into power grids[9].</td><td colspan="2"></td></tr>
<tr><td>Contribution to Renewable Energy
Hybrid energy system is an optimal option to use available RE at local level as sources to generate electricity in remote area and distribute it through micro-grids. The energy storage included in the system facilitates the integration of renewable energy sources into the grids</td><td colspan="2">Contribution to Energy Efficiency
Energy storage can be accurately modelled to store excessive energy generated by RE to be used when the system cannot produce energy.</td></tr>
<tr><td colspan="3">Driving Mechanism for Policy Implementation
The hybrid energy system and energy storage are currently developed by Arteria Group. The system primarily uses RE that can generate electricity locally as its power sources.</td></tr>
<tr><td>Good Practices
The system is an optimal solution for remote area to access to electricity. By using local RE resources for power generation and micro-grid for power distribution, it can timely respond to users' demand.</td><td colspan="2">Lesson Learned and/or Obstacle
N/A</td></tr>
</table>

[9] Hybrid energy systems and energy storage (n.d.). *Artelia*. Retrieved December 20, 2020, from https://www.arteliagroup.com/en/expertise/markets/energy/hybrid-energy-systems-and-energy-storage

Smart Grid (Main Grid): Jump Smart Maui

APEC Economy: The United States

Description

To respond to high demand of electricity from over 60,000 customers, large solar power systems and wind turbines were deployed in the island of Maui. However, the increase in RE generation systems negatively impacted grid operation and stability. Therefore, advanced smart grid technologies were introduced to address the issues.

Contribution to Renewable Energy

The project uses PV and wind as the main energy sources to flatten the peak demand in the island of Maui. Together with advancement of smart technologies and management, demand of electricity can be effectively supplied.

Contribution to Energy Efficiency

The advanced smart technologies and distributed and hierarchical architecture facilitate more efficient grid operation and better balance customers' demand.

Driving Mechanism for Policy Implementation

JUMP Smart Maui is a smart community project where global stakeholders from leading private and public organizations play a significant role in its initiatives as well as additional essential activities:

- Energy policies to support adoption of EVs and gasoline use in vehicles
- Subsidies to aid on high costs grid services
- Raising awareness of RE to overcome dependence on imported oil
- Active involvement of locals

Good Practice

- The smart technologies are considered as a barrier breaker for grid operation and distributed energy system. To respond to high demand of electricity and dependence on costly imported oil, rapid and continuous installation of RE generation system is not only a way out, but also the support of operational technologies. Demand and supply can be balanced.
- EVs were considered one of important power sources in isolated place, since it can sufficiently supply electricity both, home appliance and grids. Therefore, bi-directional EV charging development should be furthered.

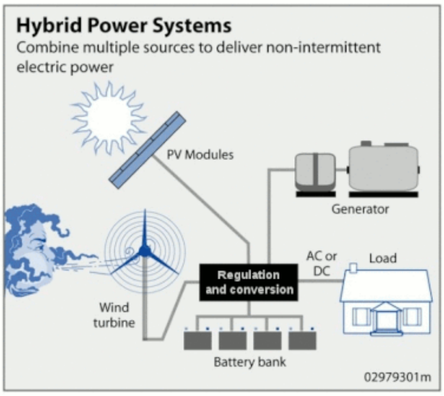
Lesson Learned and/or Obstacle

Operational issues can occur from a large-scale deployment of RE generation systems at a time, causing negative impact to customers. In order to address the issues, advancement of smart technologies and proper management, for example, virtual power plant with grid control system and distributed architecture, should be put in place.

Smart Grid (Mini-Grid / Micro-Grid): Renewable Mini-Grids	**APEC Economies:** Australia; The United States **Non-APEC Economy:** Nepal

Description

Renewable energy mini-grids enable greater shares of variable renewable energy (VRE), especially solar and wind energy, by connecting them to the main grid. The interconnected mini-grids increase flexibility of the main grid for greater integration of VRE by helping balance power grid, feeding any excess power into larger regional or domestic grids, and using a resilient system which do not require physical operator, to intelligently and systematically control the integrated infrastructure. However, there is a need to development quality assurance mechanisms and access to finance and long-term investment for its development[10].



Contribution to Renewable Energy

Different RE sources are used by mini-grids which are connected to main grid, to generate electrical power. RE mini-grids not only enable flexibility in power system, but also improve cost effectiveness and make users less dependent on fossil fuel.

Contribution to Energy Efficiency

Interconnection between RE mini-grids and main grids provide stable conditions to the energy consumption. During peak load, mini-grids containing different RE sources can be aggregated and transfer the power into main grid to serve high power consumption.

Driving Mechanism for Policy Implementation

Interconnected renewable mini-grid has proved a great contribution and potential to main grid in terms of energy management. This is attributed to stable policies and access to private investment, such as:

- Enabling policies and regulatory structures for interconnected mini-grid
- Standardization of renewable mini-gird
- Grid connection readiness and technical innovation availability
- Access to funding and long-term investment

Good Practice

Renewable mini-grids provide key services to the main grid in different ways. They help alleviate the imbalance of power grid, through several mechanisms, such as frequency control, stability congestion management, system restoration, and enhanced power quality. They can also supply excess power to domestic and regional main grids when they are in their sites. Aggregation of mini-grids can transfer the power into one single unit then distribute to the main grid in which it supports the main grid when the user's demand rises.

Lesson Learned and/or Obstacle

Investment in development of renewable mini-grid remains challenging since the return on investment is uncertain. In some economies, financing schemes and subsidies are required to fulfill the initial capital investment. Furthermore, it is necessary to balance the long-term costs of energy and infrastructure upgrade.

[10] IRENA (2019), *Innovation landscape brief: Renewable mini-grids*, International Renewable Energy Agency, Abu Dhabi.

Heat Generation: Cogeneration for RE

APEC Economies: People's Republic of China; Indonesia; Japan; Republic of Korea; Malaysia; Russian; Thailand; The United States
Non-APEC Economies: Denmark; Finland; India

Description
Combined heat and power generation (CHP) is a proven cost-effective technology developed to address energy security and economically unstable situations. CHP can increase energy efficiency in short and middle terms by delivery of hot water, space heating, hot air/steam for industrial processes, power generation. It produces less GHG emission compared to conventional power plants[11].

Contribution to Renewable Energy
CHP offers a variety of benefits to RE sector, e.g., beneficial use of local energy resource, reduced CO_2 emissions and other pollutants, and reduced need for transmission and distribution network. Renewable CHP includes, biomass, geothermal cogeneration, solar power, steam turbine, gas turbine, reciprocating engine, microturbine, and fuel cells.

Contribution to Energy Efficiency
CHP considerably increases energy efficiency. By combining electrical power and thermal energy. The system could increase its output by up to 70-90% compared to conventional systems.

Driving Mechanism for Policy Implementation
In terms of state support for cogeneration development, policies, instruments elaborated for its development should be planned. Policies towards development of CHP technologies and its share in domestic energy balance and trading and other regulation/agreement for combined technologies/connection to domestic grid are significantly noted. Other policies or incentives includes financial and fiscal support (up-front investment, R&D funding), utility supply obligations, local infrastructure and heat planning, climate change mitigation, and interconnection measure.

Good Practice
In APEC region, several economies such as Japan; People's Republic of China; Republic of Korea; and Singapore successfully introduced and popularized CHP. Regulatory support to aid its market is inevitable.
There are different strategies for CHP application:

- CHP investment attractiveness, reflecting more CHP-friendly approach (Japan);
- Good prospect on CHP market development (China);
- Government long-term plans to boost production of RE (Korea);
- CHP market opportunities (Singapore).

Lesson Learned and/or Obstacle
To successfully utilize cogeneration technologies, the study suggested following criteria to be met:

- A reliable power requirement;
- Relatively steady electrical and thermal demand patterns;
- Higher thermal energy demand than electricity;
- Long operating hours in the year;
- Inaccessibility to the grid or high price of grid electricity.

Currently, several barriers toward CHP can be noted:

[11] Russian Fund of Education Programs (2013), *Combined Heat and Power Technologies for Distributed Energy Systems*, APEC Secretariat.

Heat Generation: Cogeneration for RE	**APEC Economies:** People's Republic of China; Indonesia; Japan; Republic of Korea; Malaysia; Russian; Thailand; The United States **Non-APEC Economies:** Denmark; Finland; India
	- Economics and market barrier (cost for heat and electricity produced by CHP systems); - Regulatory barrier in according to access and interconnection between CHP and other RE resources (appeared in Slovenia; Belgium; Spain; Italy; Ireland); - Social and political awareness and knowledge about benefits of CHP; - Uncertainty of economic stability due to vary natural gas price (appeared in Slovenia; Greece; Belgium); - Locational and environmental rules; - High capital cost of heating infrastructure.

Heat Generation: Landfill Gas Capture

APEC Economy: People's Republic of China

Description

The city of Tianjin has implemented a project to recover landfill gas (LFG) and improve solid waste disposal. The project aims to: 1) reduce methane emissions and other non-methane organic compounds to the atmosphere; 2) utilize biogas from treatment process as fuel for electrical power source, and 3) use a stand-by flare unit to neutralize excess methane and other air pollutants from factories. The project benefits revenues from electricity sold to domestic grids, and enhanced safety from reducing risk of explosion from high methane concentrations[12].

Contribution to Renewable Energy

The LFG project in Tianjin was considered as alternative method to use wasted landfill gas (RE), consisted of methane and other gas such as carbon dioxide and methane organic compounds, primarily to produce electrical power through LFG collection, electricity generation and flaring system.

Contribution to Energy Efficiency

The LFG project offers an alternative source of electrical power in which it helps reduce usage of electrical power generated by conventional system.

Driving Mechanism for Policy Implementation

The implementation of following incentives aids the project to successfully demonstrate its operation for LFG recovery and electricity generation.

The project was:

- Initiated by government with investment;
- Implemented and operated by specially created entity with the support by local resources and global experts;
- Registered as a Clean Development Mechanism (CDM) project under domestic protocol which reached an agreement with World Bank to purchase the certified emission credits from the project.

Good Practice

After launched in 2008, the project utilized and recovered over 50% of methane in the area which helps:

- Increase revenue to municipality from electricity sold to grid under a purchase agreement with World Bank;
- Reduce local and regional pollution;
- Enhance safety from explosion from high methane concentration;
- Create local jobs;
- Improve site management on threat to local groundwater

Lesson Learned and/or Obstacle

The followings can be challenges to the project:

- Need for collaboration with private and public sectors in implementation and operation;
- Technical problems and complexity during operating stages (to some developing economies);
- Need for reconstruction of landfill and set-up for LFG recovery systems, leading to major investment and long-term operation and maintenance cost

[12] ESMAP. (2009). *Good Practices in City Energy Efficiency: Tianjin, China - Landfill Gas Capture for Electricity Generation.* ESMAP Energy Efficient Cities Initiative. Washington, DC: World Bank.

	- Need of financing by World Bank load and register an agreement to purchase emission credits which ensures revenues

RE + Hydrogen: Fukushima Hydrogen Energy Research Field (FH2R)	**APEC Economy:** Japan

Description

hydrogen produced from RE can respond to the increase of energy consumption and to the total decarbonization of power generation sector. Hydrogen can replace fossil fuel-based feedstocks. For example, it can combine with carbon dioxide to feed up to 100% syngas into the gas grid. In transport, hydrogen fuel cell offers driving performance comparable to conventional vehicles. Lastly, hydrogen produced from RE facilitate the integration of VRE into energy system through the use of electrolyzer allowing the system a flexible load and grid balancing services[13].

Contribution to Renewable Energy

Hydrogen can be used to store energy produced by VRE, e.g., solar, wind, and can be used in sectors that electrification is difficult, such as transport, building, and industry.

Contribution to Energy Efficiency

Key hydrogen technologies (ALK, PEM, SOEC) contribute its efforts to EE through large-scale application and minimal infrastructure requirements.

Driving Mechanism for Policy Implementation

For the potential to materialize, initial stage of hydrogen application and scaling up remains concerns to policy makers. Following mechanisms can be used to stimulate the introduction of hydrogen application:

1. Stable and supportive policy framework to encourage private investment;
2. Technology-neutral instruments, including carbon pricing, emissions restrictions, specific mandates for RE content;
3. Measures to cover initial cost difference (in case of vehicle application)
4. Specific instrument to de-risk infrastructure investment and improve economics of supply chain (related to carbon market)

Good Practice

- In transport, hydrogen can help overcome battery limitations by being complementary to electric vehicles and replacing diesel in rail transport and on-board/onshore power supply in shipping and aviation sectors.
- In industry, power-to-hydrogen using electricity from RE helps industries in its production and helps end-use sector in reducing fossil fuel dependency.
- In gas grid sector, hydrogen from renewable power fed into gas grid represents a potential upside revenue to improve power-to-hydrogen's economics.

Lesson Learned and/or Obstacle

Deployment of hydrogen end-use applications requires a joint hydrogen supply chain including capacity for production, purification, and pressuring for transport. However, supply chain can be influenced and varied by following factors:

- Sufficient existence of hydrogen sources;
- Certain consumption threshold;
- Investment in new large-scale production capacity.

[13] IRENA (2018), *Hydrogen from renewable power: Technology outlook for the energy transition,* International Renewable Energy Agency, Abu Dhabi.

3.3. Building Sector

Projects/activities under building sector can be divided into two sub-categories: nearly/net zero energy building (NZEB), and heating and cooling, as shown in Figure 3. There are examples of building codes, awards and funds that helped accomplish NZEB in various economies. As for heating and cooling, an example of district heating network in China and projects on renewable power-to-heat in People's Republic of China; Denmark; Germany; and United Kingdom are introduced.

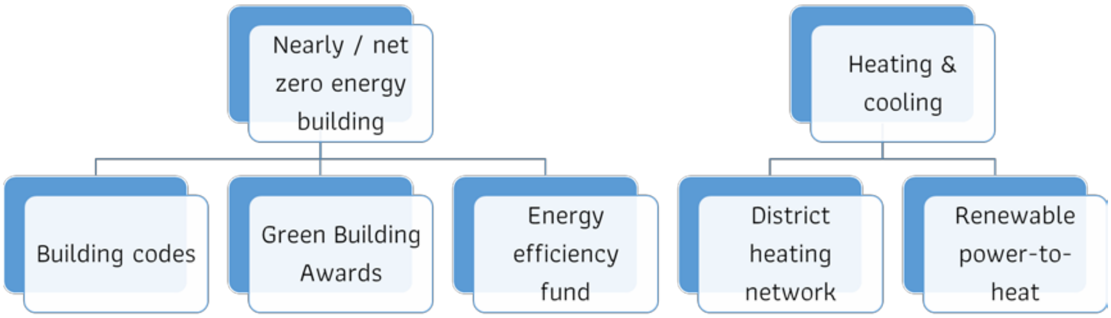


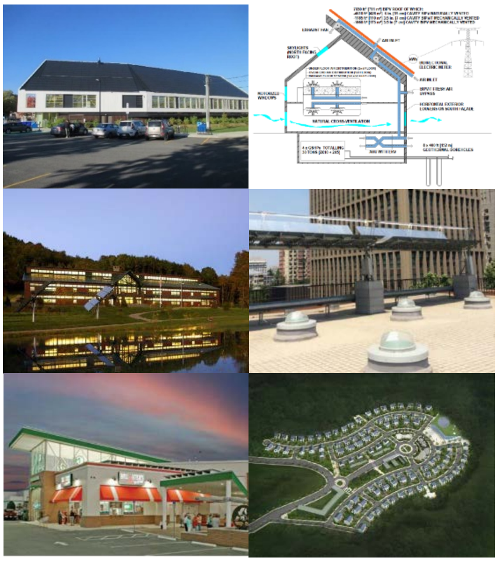
Figure 3 Past projects and activities co-benefitting renewable energy and energy efficiency in building sector

Nearly / Net Zero Energy Building: Building Codes / Awards

APEC Economies: Australia; Canada; People's Republic of China; Hong Kong; China; Japan; Republic of Korea; Chinese Taipei; The United States

Description

The project carried out professional in-depth comparative research with the detailed information of best practice net zero energy building (NZEB) pilot buildings, to showcase how energy reduction could be achieved by integration design, advanced technology utilization and NZE oriented management & commissioning in buildings. An extensive investigation and comparative study of different NZEB best practices which includes commercial building and residential building in all climate regions among APEC economies were carried out and 100 NZEB best practices from 8 economies were collected[14].



Contribution to Renewable Energy

NZEB is technically defined as a measure of a building's energy performance, whereby it produces as much or more RE as it uses over the course of a year in operation. Therefore, NZEBs basically use RE as the main energy source. The renewable energy generation systems and technologies that integrated in NZEB commonly refer to solar power system, solar thermal system, wind power system, combined heat and power system, and the heat pump system.

Contribution to Energy Efficiency

To increase the energy performance of the building, various energy efficiency measures are applied in NZEB. Passive approaches include high performance building envelope, passive heating, passive cooling, and passive lighting. Active approaches include energy-efficient heating and cooling sources, HVAC system, lighting, and advanced control.

Driving Mechanism for Policy Implementation

Each economy combined different mechanisms to drive the accomplishment of NZEB in both public and private sectors. For example[15]:

- Laws, regulations and technical guidelines;
- Building codes and standards;
- Funding for research, development, and demonstration projects, some of which are specific to NZEB, though the rest are for all clean energy or low carbon innovations;
- Other fiscal incentive policies of building energy efficiency, including subsidization;
- Nearly/net zero energy building certifications;
- Self-funded or industrial-led initiatives.

[14] Wei, X., & Zhang, S. (2017). APEC 100 Best Practice Analysis of Nearly/Net Zero Energy Building. ASEAN-German Energy Programme (2019), *Best Practices in Energy*

[15] ASEAN-German Energy Programme (2019), *Best Practices in Energy Efficiency and Conservation*, ASEAN Centre for Energy (ACE), Jakarta.

Nearly / Net Zero Energy Building: Building Codes / Awards	**APEC Economies:** Australia; Canada; People's Republic of China; Hong Kong; China; Japan; Republic of Korea; Chinese Taipei; The United States
Good Practice Governments used both carrots and sticks to facilitate the accomplishment of NZEB. To create the first move, fiscal incentive policies worked well, while certifications, regulations, standards, and codes are useful means to sustain the NZEB projects. Interestingly, some private companies autonomously accomplished NZEB, and others get together and formed industrial led initiatives.	**Lesson Learned and/or Obstacle** The incremental cost of NZEB is the biggest obstacle for the dissemination of the concept. According to the investigation, one third of the projects can control the increment cost within 50%, and there are 6 out of 100 projects whose increment cost are over 100% of the typical buildings.

Municipal Energy Efficiency Fund

APEC Economy: The United States

Description

Establishment of long-term Municipal Energy Efficiency Fund in the City of Ann Arbor is able to overcome the land of readily available energy efficiency (EE) financing. The fund has financed EE projects in several sectors and demonstrated that EE can pay for itself in the long-term condition[16].

Contribution to Renewable Energy

The article indicates no contribution to RE sector. However, one of energy plan's directives aims to increase use of RE such as, solar, wind and hydroelectric energy technologies. Other example outreach projects are also focusing on RE with possible longer payback.

Contribution to Energy Efficiency

The fund supported financing to initiate several EE projects. Its management and method to allocate budget demonstrates that EE projects can foster itself in long-term condition. Projects assisted by the fund have cumulatively resulted in providing EE cost reduction and energy saving.

Driving Mechanism for Policy Implementation

By recognizing need for local energy conservation, energy steering committees were appointed to develop energy plan and its directives which emphasized several areas for energy conservation. The following methods were used to allocate fund to any project:

- Subproject eligibility criteria (total energy saving potential, improvement of facility environment and educational or demonstrational value of project);
- Fund administration (fund under the city's energy office supervision).

Good Practice

- The key to cost-effective reduction is the combination of capital availability and staff expertise. The success was demonstrated through making small but dedicated financial and human resource available for activities on energy conservation which can lead to significant impact for the city.
- The fund provided upfront capital to municipal EE projects which aim to retrofit facilities in the city. It finally collected revenue from energy saving which was 80 percent of the upfront capital within five years. Therefore, the fund becomes financially sustainable and fully repay the bond obligations within ten years.

Lesson Learned and/or Obstacle

It is essential to make sure that the followings are available in the initial stage: an initial funding source, and dedicated staff to support and coordinate the activities. More importantly, the fund does not guarantee the savings from subprojects, but relies on its repayments which could differ from the initial estimates when the subprojects were approved.

[16] ESMAP. (2011). *Good Practices in City Energy Efficiency: Ann Arbor, Michigan (USA) - Municipal Energy Efficiency Fund*. ESMAP Energy Efficient Cities Initiative. Washington, DC: World Bank.

District Heating Network

APEC Economy: People's Republic of China

Description

The project proposes coal-free energy efficient small-scale district energy systems in eight different locations in Qingdao city. Without coal, the city relies on the use of mix of energy sources such as natural gas, extracted heat and solar thermal for the city's peak demand. The mix of sources combined with highly EE district energy system help reduce the GHG emissions and other air pollutants in the city[17].

Contribution to Renewable Energy

A mix of RE sources (especially heat sources) was used instead of coals for peak demand shaving. With the combined renewable heat sources such natural gas, waste heat, wastewater, geothermal heat pump and solar heat pump, the system could significantly reduce GHG emissions and other air pollutions in the area.

Contribution to Energy Efficiency

The project proposed nine components of the system with energy-efficient and low-emissions design features. The fully completed system achieved an energy intensity far below the Chinese average.

Driving Mechanism for Policy Implementation

Requirements under the environmental impact assessment (EIA) were used to monitor the fulfillment of the environmental laws and regulations. The project cost was supported by Chinese government and partially by the loan from Asian Development Bank (ADB).

Good Practice

Instead of conventional large-scale heating system, the project purposely used a wider range but smaller scale heating systems in dispersed areas. Small-scale systems facilitated the introduction of different clean and renewable resources, and co-generation or tri-generation to fulfill end-users' needs. Compared to equivalent energy production of conventional systems (coal-fired sources), this system contributes to energy saving, reduces annual emissions and improves air quality in the area.

Lesson Learned and/or Obstacle

- To set up small-scale heating systems in several different areas, it becomes quite challenging to respond to domestic environmental laws, domestic assessment guidelines, global agreements, domestic environmental standards and ADB policies (in case of loan).
- To ensure that the project will not result in significant adverse environmental, social and health impacts, mitigation measures should be applied and implemented in initial stage as well.
- During its construction and operation phases, ongoing outbreak of coronavirus disease took place in the area causing a challenge in collaborations, face-to-face meetings, human gathering, and public activities.

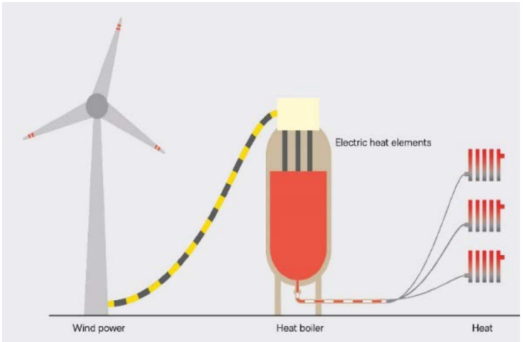
[17] Qingdao Municipal Government and Qingdao Energy Group Co. Ltd. (2020). *People's Republic of China: Qingdao Smart Low Carbon District Energy Project.* Asian Development Bank, Manila.

Renewable Power-to-Heat

APEC Economy: People's Republic of China,
Non-APEC Economies: Denmark; Germany; United Kingdom

Description

Renewable power-to-heat plays an important role in increasing the share of RE in building and industrial heating sectors. Renewable power-to-heat applications can be used as energy storage medium for VRE sources. Power-to-heat systems including centralized and decentralized heating systems and support VRE integration in terms of reducing RE curtailment, increasing flexibility through load shifting, storing energy, providing grid services via aggregators, and increasing self-consumption from local renewable-based generation[18].



Contribution to Renewable Energy

Various renewable sources such as waste, solar thermal, geothermal are used to generate heat to feed into and aid in industry’s production process. Through heat generation process, RE sources can be used effectively in two different ways: 1) by direct conversion of RE sources to heat and 2) by using electricity generated from RE sources to produce heat.

Contribution to Energy Efficiency

Rapidly increasing number in switching from coal-fired boilers to electric heat pumps can give an immediate effect on overall energy efficiency and pollution from household heating. The process of load shifting with energy management system also helped balance energy demand of buildings in Sweden, reduced 78% energy required for heating system and reduced customer’s energy bills by almost 20%.

Driving Mechanism for Policy Implementation

Policy and regulatory support can be a significant drive to deployment of power-to-heat technologies:

- Limiting or banning the use of fossil fuel;
- Introducing requirement for RE building model;
- Initiating a change in taxation levels on fossil fuel usage reduction;
- Incentivizing energy efficiency to boost power-to-heat applications;
- Enabling interconnection of heating and electricity markets;
- Categorizing different consumer segments and types of building;
- Market design that allows revenue stacking.

Good Practice

Power-to-heat technology in several economies receives government and private subsidies in different ways based on the economies policies and regulations. In China, government subsidies have encouraged consumer to switch from coal-fired boiler to electricity-based heat pumps, resulting in over a million heat pumps being sold in 2014. In Canada and Denmark, the government attempted to adopt government-owned heating and cooling plants.

Lesson Learned and/or Obstacle

Domestic-level networks of stakeholders need to be appointed to promote power-to-heat technologies and provide better understanding to public.

[18] IRENA (2019), *Innovation landscape brief: Renewable power-to-heat*, International Renewable Energy Agency, Abu Dhabi

3.4. Preliminary Summary of Driving Mechanisms for Policy Recommendation

From the review of over fifteen projects/activities co-benefitting renewable energy and energy efficiency in three different sectors, it can be seen that there are different types of policy that could enable or expedite such projects/activities in other APEC economies. Policies enabling increase in renewable energy sharing tend to focus on supply side, trying to help renewable energy producers gain the competitiveness in order to be able to participate in energy market. On the other hand, policies facilitating reduction in energy intensity tend to focus on demand side, seeking for the way to help users decrease the energy usage while maintaining the same level of activities.

Policies to accelerate the introduction of renewable energy typically include the full financial support for demonstration projects or subsidization to help the investment in new systems. Some governments sign agreements with private sectors to facilitate their investment in renewable energy while others introduce policy incentives that ease private investment, e.g., tax deduction. In addition, regulations that aim to reduce the usage of non-renewable energy, e.g., fossil fuels, in the forms of increase in taxation of fossil fuels or carbon pricing can in turn expedite the usage of renewable energy. Policies to facilitate the improvement in energy efficiency also include fiscal incentives and support to research and development projects. Supporting policies can also be in terms of awards or certification to prove that those users are consuming energy efficiently. Same as the case of renewable energy, restriction, or limitation of carbon emission, e.g., emission standards, carbon tax or increase in taxation of fossil-fuel-related products also result in promotion of energy efficiency. Self-funded or industrial-led initiatives from the user side can also be observed since they help demonstrate the greenness of the industrial sector.

For these particular projects, it turned out that policies that aimed to promote renewable energy by supporting the supply side could also benefit the demand side and consequently the improvement in energy efficiency, and vice versa. For example, subsidy to an energy storage system in a solar power system aiming to facilitate the photovoltaic penetration in energy market can also help increase the efficiency of the photovoltaic system by storing the excessive electricity generated during the day to use at night. Promotion of net zero emission building which aims to maximize the energy efficiency of the energy usage inside the building will also result in installation of renewable energy systems which help reduce the carbon emission. However, knowing that there are various ways to simultaneously facilitate the renewable energy and the energy efficiency, it would be more beneficial if the viewpoints of both supply side and demand side can be taken into account when designing the policy, referring to abovementioned examples.

However, it could also be observed that many of the activities relied on financial support from the government. One important reason to this is that some of the technologies, e.g., energy storage system, electric vehicles, are not yet economically feasible in some of the APEC economies. During this stage, subsidy can be given to demonstration projects to familiarize the public with the technologies in order to have smooth transition when the technology cost goes down to acceptable level.

4. Proposed Criteria for Joint Projects Co-Benefitting Renewable Energy and Energy Efficiency

4.1. Review of Criteria Being Used Currently

This section reviews existing criteria being used to evaluate energy-related projects. The list in Table 1 comprises of reports and publications containing 1) common quality criteria generally used to assess APEC projects 2) criteria for evaluation of energy-related projects or research, development, and demonstration projects in Thailand, and 3) criteria to assess energy-related proposals in other economies. Documents in Table 1 were used as the resources for the review.

The extracted criteria were counted as they appear in the documents as the frequency would represent the significance of them. The criteria were ranked by the counts in Table 2 to understand the prioritization. APEC common quality criteria were among those frequently found, including relevance, effectiveness, impact, efficiency, and sustainability. This set of criteria is used by APEC project overseers work with APEC Secretariat to achieve satisfactory quality according to the criteria. Therefore, the same set of criteria should also be used to evaluate the projects leading to co-benefits to renewable energy and energy efficiency.

Some other criteria in Table 2 occasionally appear in the documents. Some of them emphasize on project procurement and qualification of grant applicants which do not fit to the objective of this project. The rest are technical requirements which could be important success factors to achieve co-benefits on renewable energy and energy efficiency. These technical requirements will be revisited in the next section where the key success factors are discussed.

Table 1 Criteria Documents and Categories

No.	Document	Category
1	Selection Criteria for Flagship 2020 (translated)	APEC
2	Co-benefits of Smart and Sustainable Energy District Projects: An Overview of Economic Assessment Methodologies	Co-benefit Indicator
3	Guideline, Criteria, Condition and Priority for Fund Spending to Promote Energy Conservation in Fiscal Year 2021 (translated)	Eligibility of Grant Applicants
4	Guidelines for the Monitoring, Evaluation and Design of Energy Efficiency Policies	Evaluation of Energy Efficiency Policies
5	APEC Scoring Template	APEC
6	APEC Project Proposal – Quality Assessment	APEC
7	Final Report Evaluation for Agricultural Research Project (translated)	Eligibility of Grant Applicants
8	Eligibility Criteria and Guidelines for Accessing the Energy Efficiency and Low Carbon Measures Sub-Fund	APEC
9	Evaluation of Renewable Energy Projects in Europe – Synthesis Report	APEC
10	Guideline for Grant Applicants on SWITCH Asia II - Promoting Sustainable Consumption and Production	Eligibility of Grant Applicants
11	Guidebook on APEC Projects Edition 15	APEC
12	Proposal Evaluation Form for Educational Funding and Research Development on Energy Conservation Technology in Fiscal Year 2016 (translated)	Eligibility of Grant Applicants

Table 2 Criteria Being Used Currently and Their Counts

No.	Criteria	Count
1	Relevance	8
2	Effectiveness	7
3	Impact	6
4	Efficiency	5
5	Sustainability	3
6	Financial value added	2
7	Management of project cycle	2
8	Design of action	2
9	Energy performance standards for buildings, cars or appliances	1
10	Mandatory targets/tradable permits certificates for (demand-side) energy (for certified energy savings) for energy companies	1
11	Labelling of appliances, cars, buildings	1
12	Information/knowledge transfer/education/training	1
13	Energy audits	1
14	Co-operative or public procurement program	1
15	Supports the priorities of the APEC Fund to which it is applying	1
16	Quality appears strong	1
17	Supports economy's priorities	1
18	Supports capacity building	1
19	Supports cross fora collaboration and benefits to multiple economies	1
20	Worthiness in research investment	1
21	Other contribution	1
22	Research team composition	1

4.2. Extraction of Key Success Factors

Important keywords that appeared in the review of projects and activities co-benefitting renewable energy and energy efficiency in Section 1 were extracted to determine the key success factors to the achievement of the co-benefits. They generally involve technical characteristics that can potentially lead to the increase in share of renewable energy and the decrease in energy intensity. The keywords were carefully picked up one by one from each project in all sectors, and then assorted into categories. The categories along with the keywords representing success factors are presented in Table 3.

To prioritize the categories of the key success factors, the categories were ranked based on the number of keywords belonged to the categories. Two of the categories: cost effectiveness and sustainability, synchronize with the APEC quality criteria in the previous section. Therefore, no additional actions are required for these criteria. The rest of the criteria represent technical characteristics of the projects or activities that can contribute to the APEC goals on renewable energy and energy efficiency. They can be used as additional criteria for the proposals under the Energy Efficiency and Low Carbon Measures Sub-Fund.

It is also worth mentioning that there are only few similarities in keywords in Table 3 and technical criteria in Table 2. This is because the existing criteria aims to evaluate whether the project will help achieve either the goal for renewable energy or the goal for energy efficiency. This indicates the necessity of having additional criteria if APEC EWG would like to fund the projects that can simultaneously benefit both APEC Energy Goals.

Table 3 Key Success Factors for Projects or Activities Co-benefitting Renewable Energy and Energy Efficiency

No.	Category	Keywords	Count
1	Flattening peak demand	Load impact minimization, Peak demand reduction, Avoiding peak load, Peak demand shaving, Load shifting, Integration of VRE, V2G, V2H, V2B, Reducing RE curtailment, Storage of energy produced by VRE, Energy storage for VRE, Flexibility, Balancing power grid, Alleviating imbalance, Flexible load, Grid balancing, Ancillary service, Frequency control	16
2	Low carbon	Zero emission, Carbon emission reduction, Frequency fluctuation mitigation, Less GHG emission, Emission reduction, Emission restriction, GHG emission reduction, Clean Development Mechanism (CDM)	8
3	Digital	Online app, Monitoring and control, Forecasting, Integrated Distribution Management system (DMS), Optimization system, Control of integrated infrastructure	6
4	Electricity/electrification	Increasing self-consumption, Hybrid, V2G, V2H, V2B	5
5	Cost effectiveness	Reduction in power price, Return of investment, Carbon pricing	3
6	Fuel standards	Improvement of fuel economy, Emission restriction, Fossil fuel replacement	3
7	Local context	Use of local energy resources, Local needs	2
8	Sustainability	Sustainable, Eco	2

4.3. Initial Proposal of Renewable Energy and Energy Efficiency Co-benefits Criteria

A proposal for the set of criteria that APEC EWG can use to evaluate future project proposals to ensure that the projects will co-benefit renewable energy and energy efficiency was presented at the 1st Workshop (see Annex 1) in March 2021.

The review of criteria being used currently in Section 4.1 indicated that Quality Criteria for Assessing APEC Project including Relevance, Effectiveness, Impact, Efficiency, and Sustainability are frequently used, and are well-defined since they also appear in other documents. Therefore, they should continue to be used as key aspects that the evaluators need to consider during the evaluation of the project proposals.

Taking a closer look at the eligibility criteria and guidelines for accessing the Energy Efficiency and Low Carbon Measures (EELCM) Sub-Fund, the important parts are the *eligibility criteria* and the *priority for funding*. Based on the abovementioned findings, the following slight modification of the eligibility criteria is proposed in ***italic***.

"To be eligible, projects must:

- **Have at least 4 co-sponsoring economies from the project's originating forum, as confirmed by the APEC Secretariat; and**

- ***Focus on activities which will contribute to achieving:***
  1) APEC's aggregate energy intensity reduction goal of 45% by 2035 which was agreed at the APEC Leaders Meeting in Honolulu in 2011; and
  2) ***contribute to achieving the goal of doubling the share of renewables by 2030 which was endorsed by the APEC Leaders Meeting in Beijing in 2014;*** **and**

- **Demonstrate that the proposed project will meet capacity building needs for APEC developing economies; and**

- **In case of Category 2 projects, have a total APEC-funded budget of USD 100,000 or less."**

The proposed eligibility criteria explicitly require the proposal to contribute to achieving both APEC energy goals instead of achieving either of them. Since the project contractor is required to fulfill both APEC energy goals, even if the project aims just only on reduction of energy intensity, the project contractor will need to consider the ways that the project can contribute to introduction of clean energy.

As for the priority for funding, the technical key success factors extracted from Section 4.2 could help ensure that the priority is given to the project that will lead to improvement of energy efficiency in accompany with accelerating deployment of renewable energy. Below is the proposal to add the technical key success factors as another priority for funding. The proposed modification is shown in ***italic***.

> **"Support for the projects listed in Category 1 are the top priority of the EELCM Sub-Fund and as such, subject to EWG endorsement, a maximum of 1 project per year would be funded from Category 1 project applications, before all other projects applying for the sub-fund. Therefore, the highest scoring Category 1 Concept Note will be funded first before any Category 2 Concept Notes are recommended for funding:**
>
> - **Low-Carbon Model Town (LCMT) as reflected in the official APEC LCMT Concept approved by all EWG members, including through policy making and dissemination of APEC low-carbon towns. This concept may continue to evolve and improve over time on the basis of lessons learned from previous phases and feedback from EWG members; or**
>
> - ***Projects that supports both RE&EE APEC goals through at least two of following six technical criteria:***
>   **1)** ***Flattening peak demand;***
>   ***2) Low carbon,***
>   ***3) Digital;***
>   ***4) Electricity/electrification;***
>   ***5) Fuel standards;***
>   ***6) Local context."***

There is a scoring sheet where APEC economies are requested to provide scores according to the guiding questions for each criterion. The aforementioned technical criteria can be used when an economy evaluate whether the proposal supports the priorities of the sub-fund.

4.4. Final Proposal of Renewable Energy and Energy Efficiency Co-benefits Criteria

During the 60th meeting of the APEC Energy Working Group (EWG60) in Brunei Darussalam on June 21-25, 2021, the name of the Energy Efficiency and Low Carbon Measures (EELCM) Sub-Fund was changed to the Energy Efficiency, Low Carbon and Energy Resiliency Measures (EELCER) Sub-Fund along with the eligibility criteria and guideline. This is to align the funding from the sub-fund with the Energy Resiliency Principle and the initiative to Enhance Energy Access in APEC, which were endorsed by the APEC EWG in 2020.

The essence of the proposal for the modifications of the eligible criteria of the sub-fund remains valid even though the name of the sub-fund was changed to the Energy Efficiency, Low Carbon and Energy Resiliency Measures (EELCER) Sub-Fund, though the recommendation needs to be amended to suit the modified eligibility criteria. The proposed modification is shown in ***italic***.

"To be eligible, projects must:

- **Have at least 4 co-sponsoring economies from the project's originating forum, as confirmed by the APEC Secretariat; and**

- ***Focus on activities which will contribute to achieving:***
    1) ***APEC's aggregate energy intensity reduction goal of 45% by 2035 which was agreed at the APEC Leaders Meeting in Honolulu in 2011; and***
    2) ***contribute to achieving the goal of doubling the share of renewables by 2030 which was endorsed by the APEC Leaders Meeting in Beijing in 2014; and/or***

- **Focus on activities which will contribute to enhance energy resiliency, which was highlighted the importance at APEC Energy Ministerial Meeting in 2015; and/or**

- **Focus on activities which will contribute to enhancing energy access, which was underlined by APEC leaders in 2016, 2017 and 2020.**

- **Demonstrate that the proposed project will meet capacity building needs for APEC developing economies; and**

- **In case of Category 2 projects, have a total APEC-funded budget of USD 100,000 or less."**

From the change in the name of the sub-fund to incorporate the new priority for funding, it could be assumed that the proposal to alter the priority for funding seems not to be feasible. However, the technical criteria listed in Table 3 can still be used by the economy to evaluate the contribution of the project proposal towards the two APEC energy goals which should align well with most economies' priorities.

4.5. Way towards Mainstreaming Projects Co-benefitting Renewable Energy and Energy Efficiency

Figure 4 shows the plan to promote joint renewable energy and energy efficiency projects under APEC EWG. With the 1st Workshop (Annex 1) where economies shared best practices of successful joint projects for renewable energy and energy efficiency implementation with co-benefits, and the 2nd Workshop (Annex 2) where the evaluation tools to assess co-benefitting projects were introduced to economies along with hands-on practice, participated economies have realized the needs to design project proposals that can co-benefit renewable energy and energy efficiency, and have learned the way to design and evaluate them.

The proposal to the eligibility criteria of the Energy Efficiency, Low Carbon and Energy Resiliency Measures (EELCER) Sub-Fund seems to be insignificant in terms of the written criteria. However, this slight modification will require the project contractor to find the ways to meet both APEC energy goals on renewable energy and energy efficiency, and he/she can refer to the list of the key success factors for the project to co-benefit renewable energy and energy efficiency in Table 3 which will help ensure that the project will result in co-benefits. The implementation will be even more efficient if the economies refer to this list during the project scoring. In addition, a number of co-benefits evaluation tools are available for usage of any economies, which would facilitate the design of the joint RE&EE project with co-benefits.

It is a good idea to have a monitoring program to monitor whether the modification of the eligibility criteria and the introduction of the technical criteria for proposal scoring really lead to co-benefits to renewable energy and energy efficiency. This can be done by monitoring the occurrence frequencies of the keywords in Table 3 in future proposals and evaluate the contribution of those proposals to the two APEC energy goals.

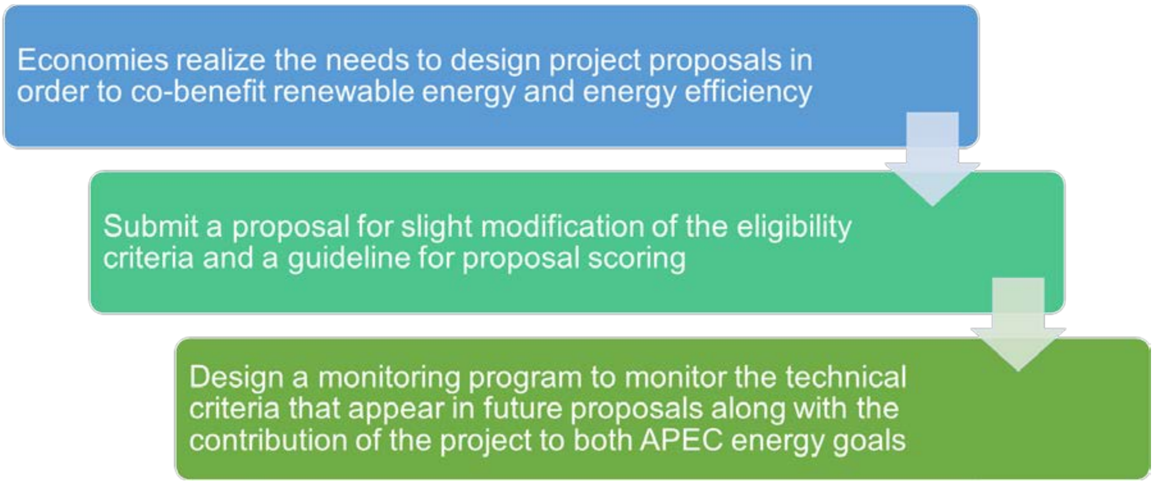


Figure 4 Steps to mainstream projects co-benefitting renewable energy and energy efficiency in APEC EWG

Annex

1. Summary of 1st Workshop

The 1st APEC Workshop on Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region was scheduled to hold in virtual-hybrid manner during 18-19 March 2021 in Pathum Thani, Thailand, with the objectives to share best practices of successful joint projects for RE&EE implementation with co-benefit in power generation and distribution, transport, and building sector, as well as to discuss criteria and framework for joint RE&EE projects with co-benefit technically and economically. As shown in the agenda in Table 4, the 1st day workshop started with a welcome speech and a short introduction to the event by Dr Aree Thanaboonsombut, Deputy Executive Director, National Metal and Materials Technology Center (MTEC), Thailand, valuing the co-benefits for renewable energy and energy efficiency, which is expected to be the opportunities to strengthen economic benefits for APEC economy and respond to APEC energy goals. Afterwards, opening speech was delivered by Dr Prasert Sinsukprasert, Director General, Department of Alternative Energy and Efficiency (DEDE), Ministry of Energy, Thailand, pointing out that global collaboration is a key to overcome currently appeared global disasters and to achieve APEC vision on renewable energy and energy efficiency which is consistent to the Alternative Energy Development Plan 2018 (AEDP2018) of Thailand.

Table 4 Agenda for the 1st Workshop

The 1st APEC Workshop on Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region

Date: 18-19 March 2021 at MTEC (https://goo.gl/maps/HAyRpn85pCJSwyi3A)
Room M506 & online; Time zone: GMT+7

18 March 2021 (Thursday) - Virtual Workshop	
08:30 – 09:00	Registration and Reception (Online)
09:00 – 09:10	**Welcome Remark & Introduction-Workshop overview and goals** 1. Instructions for online workshop 2. A short introduction to the event: workshop objective, expectation and agenda ***Dr Julathep Kajornchaikul****, Executive Director, National Energy Technology Center (ENTEC) (Thailand)*
09:10 – 09.20	**Opening Ceremony** Opening Speech by ***Dr Prasert Sinsukprasert,*** *Director General, Department of Alternative Energy and Efficiency, Ministry of Energy (Thailand)*
	Group Photo
   09:20 – 09:40 09:40 – 10:00	**Sharing of Best Practices for the RE&EE Projects** Sharing best practices in the perspective of project conceptualization and design, financing, procurement, construction and operation, obstacles & overcomes **Best Practice of RE&EE Co-benefit in Power Generation & Distribution Sector** ***Dr Richard Rocheleu****, Director of Hawaii Natural Energy Institute, University of Hawaii (United States)* **Best Practice of RE&EE Co-benefit in Transportation Sector**

18 March 2021 (Thursday) - Virtual Workshop	
10:00 – 10:20	***Mr Bert Fabian**, UN Environment Programme (UNEP)* **Best Practice of RE&EE Co-benefit in Building Sector** ***Prof Dr Wen-Pei Sung**, National Chin-Yi University of Technology (Chinese Taipei)*
10:20 – 10:30	Digital Break
10:30 – 12:00	**<u>Brainstorming Activities</u>** **Development of criteria and framework for joint RE&EE projects with co-benefit technically and economically** In this session, government representatives, investors, developers, and academia will brainstorm on the criteria of possible co-benefit projects for RE&EE through interactive activities with expected outcomes as follows: • Define linkages and commonalities between the co-benefit RE&EE Projects between power generation and distribution, transport, and buildings sectors **<u>Facilitator:</u>** ***Dr Worajit Setthapun**, Dean of Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University (Thailand)* **Activities:** 1. Introduction to Brainstorming activities format **2. Presentation on Preliminary studies of best practices, guideline, criteria, and framework for successful RE&EE joint projects in power generation & distribution, transport, and buildings sector** ***Dr Kampanart Silva**, National Energy Technology Center (ENTEC) (Thailand)* 3. **Discussion of linkages and commonalities** between the co-benefit RE&EE Projects between power generation and distribution, transport, and buildings sectors a) Joint Project Commonalities/Differences b) Co-benefit on economical and technical aspect and justifications c) Obstacles and Overcomes 4. **Wrap up – Day 1**

19 March 2021 (Friday) - Virtual Workshop	
08:30 – 09:00	Registration and Reception (Online)
09:00 – 09:20	**<u>Recap of Day 1 and Introduction of Day 2 Goal & Expectations</u>** ***Dr Worajit Setthapun**, Dean of Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University (Thailand)*
09:20 – 09:40 09:40 – 10:00	**<u>Policy Perspective to facilitate Co-benefit RE&EE Projects</u>** **Policy Best Practices in 100% RE Goal for Hawaii** ***Mr Mark Glick**, Energy Policy & Innovation Specialist, Hawaii Natural Energy Institute, University of Hawaii at Manoa (United States)* **JUMP Smart Maui Project** ***Mr Leon Roose,** Hawaii Natural Energy Institute, University of Hawaii (United States)*

19 March 2021 (Friday) - Virtual Workshop	
10:00 – 10:20 10:20 – 10:40	**Demonstration on Production and Utilization Technology for Hydrogen Energy Carrier** ***Dr Kinya Sakanishi****, Assistant Director General, Department of Energy and Environment, National Institute of Advanced Industrial Science and Technology (Japan)* **District Cooling & District Heating (China)** ***Dr Vivia Luo****, Yunnan Academy of Scientific & Technology Information (China)*
10:40–10:50	Break
10:50 – 11:50	**<u>Brainstorming Activities</u>** **Development of criteria and framework for joint RE&EE projects with co-benefit technically and economically** In this session, government representatives, investors, developers, and academia will brainstorm on the criteria of possible co-benefit projects for RE&EE through interactive activities with expected outcomes as follows: • RE&EE project development criteria, framework and guideline of the joint project to be applicable for granting agencies **<u>Facilitator:</u>** ***Dr Nuwong Chollacoop****, Project Manager, National Energy Technology Center (ENTEC) (Thailand)* **Activities:** 1. Introduction to Brainstorming activities format 2. **Discussion of joint RE&EE project development criteria, framework and guideline** a) Possible type of joint projects with economic and technical co-benefit b) Criteria and Framework for RE&EE Joint project c) Selection Guideline for granting agencies d) Possible Policy support for joint projects 3. **Wrap up – possible way forward and collaborations**
11:50 – 12:00	**<u>Closing Remarks</u>**

Table 5 List of Participants to 1st APEC Workshop

No.	APEC Member Economy	Title	Name	Gender	Organization	E-mail
1	Thailand	Dr	Prasert Sinsukprasert	Male	Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy	prasert_s@dede.go.th
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3	People's Republic of China	Dr	Vivia Luo	Female	Yunnan Academy of Scientific & Technology Information	vivialuo@hotmail.com

No.	APEC Member Economy	Title	Name	Gender	Organization	E-mail
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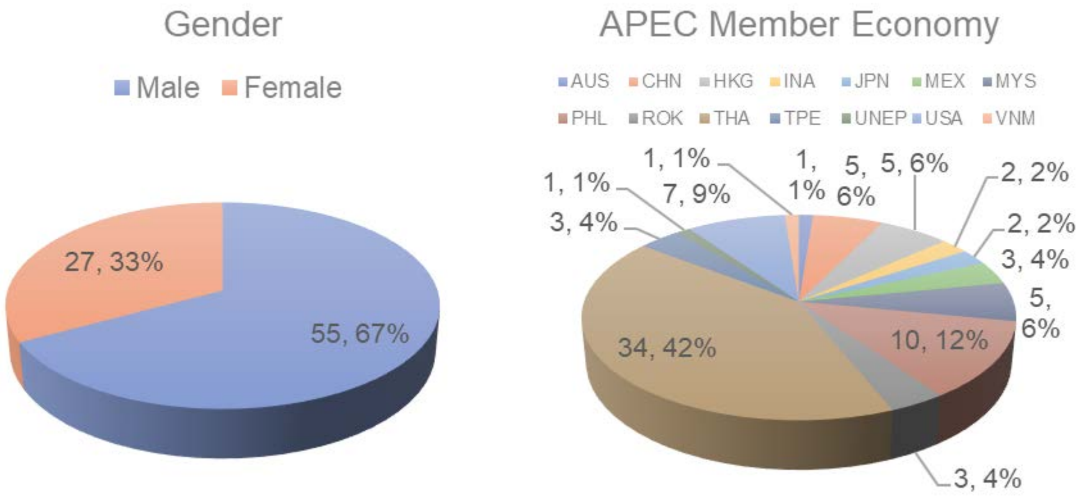

Figure 5 Breakdown statistics

1.1. 1st Workshop Participants

As shown in Figure 5 and detailed in Table 5, the 1st workshop was attended a total of 82 participants from 13 APEC member economies and 1 global organization with a female-to-male ratio of 33% (27 women and 55 men). As usual, the virtual-hybrid meeting was highly participative, with Dr Nuwong Chollacoop, project manager from Thailand, taking on the role of overall facilitator.

1.2. 1st Workshop Presentation and Discussion

The 1st workshop was a hybrid workshop with local participants attending on-site, and foreign participants attending online. It was structured for two days with the first day composed of sharing of best practices of renewable energy (RE) and energy efficiency (EE) co-benefits in power generation and distribution sector, transportation sector and building sector, followed by brainstorming activities to discuss the criteria and framework for joint RE&EE projects with co-benefits, proposed by the project team based on literature survey of past projects with RE&EE co-benefits. The second day focused on policy perspective to facilitate projects co-benefitting RE&EE, again followed by a brainstorming session to recap driving mechanisms and enabling policies for joint RE&EE projects. Experience shared by top runners in respective sectors confirmed the opportunities in designing projects to serve both APEC energy goals on RE&EE, and successfully implement the projects with policy support from government sector. This aligns with the proposed criteria and framework for joint RE&EE projects, which suggested technical criteria for bridging the gap between RE and EE, and various policies that serve as a driving force for the projects. Participating APEC Member Economies also provided feedback and comments on the proposed criteria, which enhanced the coverage of the criteria and helped finalize the guideline for projects co-benefitting RE&EE. Figure 6 shows various presentations and discussion on the first day; whereas Figure 7 shows presentations on policy perspective on the second day with final discussion to wrap up the workshop. Presentation files are shared at: https://drive.google.com/drive/folders/1iOAow_FNILxIwei1jPhx1H4UB3YgWb-a and records of both days are available at https://www.facebook.com/mtecnstda/videos/845546132844307 and https://www.facebook.com/mtecnstda/videos/236199754860988

Figure 6 Presentation and Discussion of the first day of workshop

Figure 7 Presentations on Policy Perspective on the second day of workshop

The first session on best practices for RE&EE projects started with the presentation by Dr Richard Rocheleu, who is the Director of Hawaii Natural Energy Institute (HNEI), USA, covering the best practices of RE&EE in power generation based on past experience of Hawaii Natural Energy Institute. With 100% clean energy goal, Hawaii has been used as a test bed for advanced energy technology to inform decision makers on cost effective pathways to the goal. As the prices of solar panels and batteries had significantly fallen recently, Hawaii Electric is considering increasing the share of dispatchable renewable energy, e.g., photovoltaic (PV) plus energy storage, and standalone storage. Stochastic analysis of resource adequacy shows that PV plus storage can effectively provide capacity reserves which mitigates risk of large coal power plant retirement in 2022. The analysis also shows that standalone storage increases the reliability of the system. Even at significant penetration level, there is a near equivalence between PV plus storage, standalone storage, and demand response as a replacement for dispatchable thermal generation.

Next was the presentation by Mr Bert Fabian from the United Nations Environment Programme (UNEP), which focuses on RE&EE co-benefits in the transportation sector. RE&EE projects in transportation sector provides co-benefits not only in enhancing energy security and diversity in energy sources, but also in non-energy-related sectors, e.g., providing jobs and enabling green growth, improving public health through better air quality, and improving resilience to disasters and climate change vulnerabilities. Co-benefits can be quantified by estimating the savings from the aforementioned co-benefits from RE&EE-related transport interventions when compared with the cases without interventions. Several examples of transport interventions that impacts EE&RE were introduced, including policies to promote efficient and light-duty EVs in 65+ regions under the Global Fuel Economy Initiative (GFEI), policies, regulations, and pilot projects in East Africa and Southeast Asia to promote electric two- and three- wheelers, and policies, regulations, and pilot projects to integrate e-buses.

The last presentation in this session was given by Prof Wen-Pei Sung from National Chin-Yi University of Technology, Chinese Taipei, using Taichung city to showcase energy-saving strategy for building during urban renewal. Converting abandoned old railway into Green Sky Gallery provides sufficient lighting and comfortable temperature to the walking corridor by design with no additional energy usage. Old houses were reformed to be shops and department stores, with energy-efficient lighting and air-conditioning. Livable architecture was introduced to Taichung city to raise the green cover rate of the city aiming to mitigate the urban heat island effect. This includes building greening (vertical greening) and green belts across the city. The construction of the new park also considered the use of reclaimed water and man-made river to improve air quality and ensure comfort environment.

Prior to the discussion on criteria and framework for joint RE&EE projects with co-benefits, Dr Kampanart Silva from National Energy Technology Center (ENTEC), Thailand, presented an overview of the literature review conducted by the project team on projects and activities co-benefitting RE&EE in power generation and distribution sector, transportation sector, and building sector. Key technical criteria that can help design projects with co-benefits were extracted from the review to develop a proposal of criteria for joint projects co-benefitting RE&EE. The project team proposed six categories of technical criteria for co-benefits to RE&EE, including:

1) Flattening peak demand;
2) Low carbon;
3) Digital;
4) Electricity/electrification;

5) Fuel standards;
6) Local context.

The project team proposed modifications of eligibility criteria and priority for Energy Efficiency and Low Carbon Measures (EELCM) Sub-Fund, and additional consideration during the scoring of the projects by APEC Member Economies' representatives detailed below.

1) Slight modification of eligibility criteria for EELCM Sub-Fund: the project must focus on activities which contribute to both RE&EE APEC goals (Figure 8).
2) Modification of priority for EELCM Sub-Fund: In addition to Low-Carbon Model Town (LCMT), projects that support both RE&EE APEC goals through at least two of six aforementioned technical criteria should be recommended for funding as Category 1 Projects (Figure 9).
3) Scoring by APEC Member Economies' representatives: six aforementioned technical criteria should be considered during the scoring of Criteria 1 (Relevance), which evaluates whether the project supports the priorities of the APEC Fund to which it is applying (Figure 10).

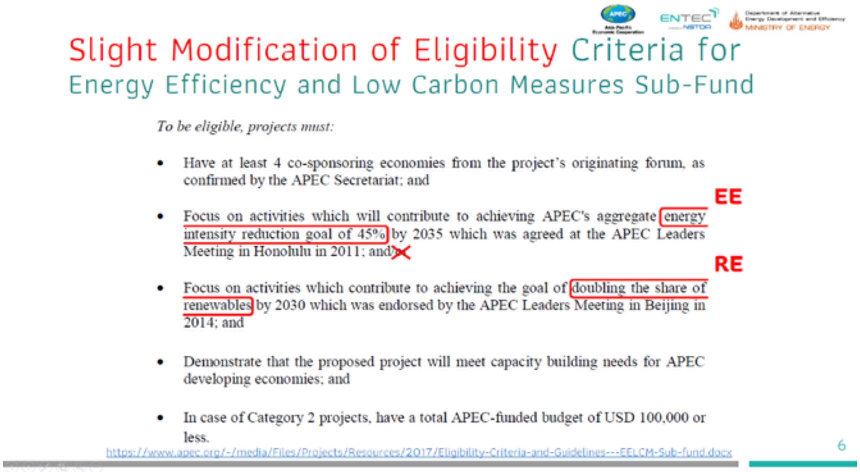

Figure 8 Slight modification of eligibility criteria for EELCM Sub-Fund

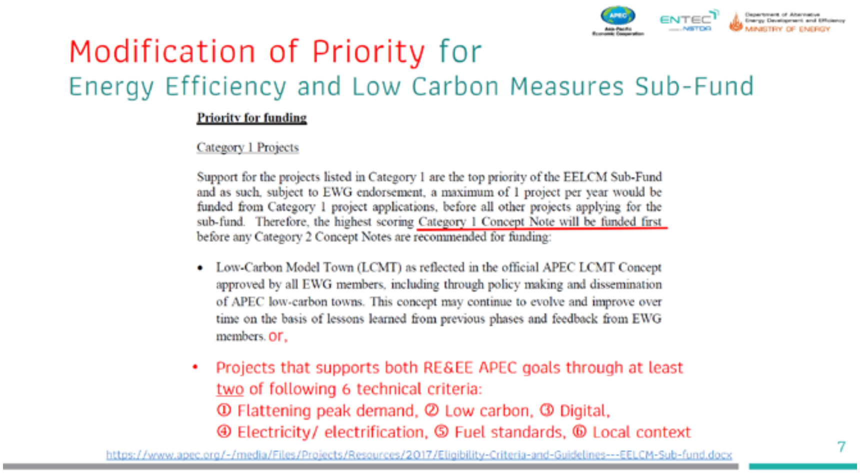

Figure 9 Modification of priority for EELCM Sub-Fund

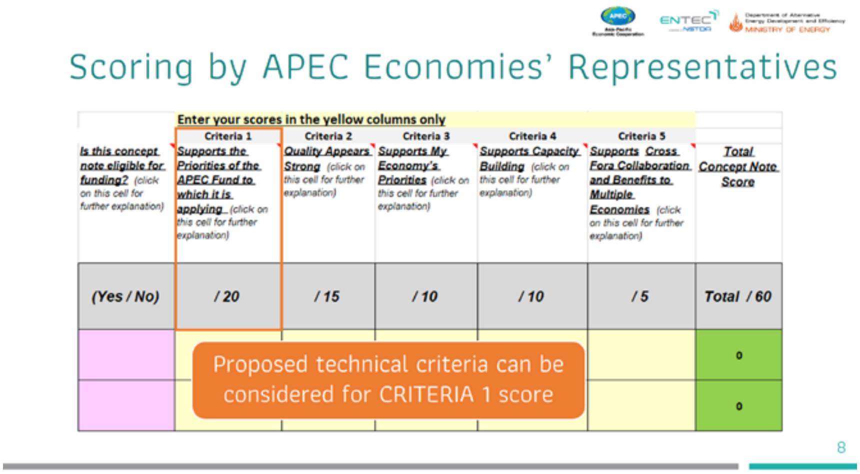

Figure 10 Scoring by APEC Member Economies' representatives

The discussion focused on how the proposed technical criteria can fit in current APEC quality criteria. Each participating APEC member economy responded to the criteria in different ways. Importantly, it is suggested by Dr Naoko Doi, the Institute of Energy Economics, Japan (IEEJ), to involve cost effectiveness as one of the technical criteria and advised that driving forces such as stakeholder engagement should be included into the framework. It is then suggested that creating prosperity for communities is also crucial in encouraging investment. Dr Yaowateera Achawangkul, Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand added that community engagement can be achieved through a push to actualize community energy services and increase proportion of local material purchase, estimated to be up to 60%.

The 2nd day of the workshop starts with recap of first day workshop with comment by Dr Cary Bloyd, Senior Staff Scientist at Electricity Infrastructure and Buildings Division of Pacific Northwest National Laboratory, USA, that to achieve low carbon emissions, it is necessary that decision making at city or state level should be firstly and fundamentally made. Since energy efficiency by now has reached its goal, increasing share of renewable energy to a higher level should be set as the priority to achieve net zero emissions. Further, it is also suggested that a good combination of renewable energy usage can lead to the APEC ultimate goals where a case study of New York City's Roadmap can be taken into consideration for the development of the proposed criteria. As the second day, the workshop focuses on policy perspective to facilitate co-benefit RE&EE projects. The session started with the presentation from Mr Mark Glick from Hawaii Natural Energy Institute (HNEI), USA, on Hawaii best practices toward 100% renewable energy goal by 2045. Hawaii Clean Energy Initiative (HCEI) was initiated in 2008, starting from issuing the strategic plans, institutionalizing the financial, policy and regulatory mechanisms for energy transition, and developing the stakeholder alliance which was critical to HCEI's success. Strategic planning was achieved across all sectors by setting sectoral goals that are consistent with each other: 40% renewable energy for electricity generation by 2030, 30% energy efficiency improvement by 2030, displacement of 70% petroleum fuel in transportation sector by 2030, and meeting in-state demand for renewable fuels. Several acts were issued to facilitate energy transformation, including Act 37 that accelerates retirement of utility fossil generation, Act 164 which modifies, revises, and clarifies State Building Code, and Act 97 which sets 100% renewable energy in electricity sector as a goal of the state. As a result, Hawaii Electric reached 34.5% renewable energy in December 2020, and a number of PVs and energy storage projects were approved by the Hawaii Public Utilities Commission. Honolulu Healthy & Resilient Building Initiative was also started which led to significant electricity cost savings. Finally, as for the transportation sector, the International Council on Clean Transportation (ICCT) is carrying out analysis and convening stakeholders to develop a set of actionable tactics to reduce petroleum-based fuels.

Next was the presentation by Mr Marc Matsuura from Hawaii Natural Energy Institute (HNEI), USA, which introduced JUMP Smart Maui project. The project presented new approaches to flexibility of energy system, aiming to lower currently high electricity costs derived by dependence on fuel and cost of oil. In 2015, Maui was facing issues on daily high load of 200 MW from over 63,000 customers. There were attempts to shape the load through utilization of generation mix of large installed solar and wind systems. However, the rapidly increasing growth of renewable energy generation caused negative impacts on grid operation and grid reliability. Advanced smart grid technologies were applied to enhance grid stability as well as balance high demand. Furthermore, the project also promote deployment of EVs and use of gasoline in Hawaii area, DC fast charging network, autonomous optimization of distributed system, and Hawaii virtual power plan demonstration.

Next was the presentation by Dr Kinya Sakanishi from National Institute of Advanced Industrial Science and Technology (AIST), Japan, describing the demonstration of production and utilization technology for hydrogen energy carrier. Fukushima Renewable Energy Institute, AIST (FREA) was established in April 2014 to be the global R&D base for RE and to promote RE-based industry in the area. Apart from expanded introduction of RE, FREA also support the realization of hydrogen-based society. The institute is responsible for technology development for distribution and utilization of imported hydrogen, and domestic hydrogen production to utilize surplus RE. There are various energy carriers that enable distribution and utilization of hydrogen. Ammonia energy carrier is one of them which is synthesized from hydrogen (both imported and produced domestically) and used to generate power or heat with gas turbine, engine, or fuel cell. Under the concept of carbon recycling, hydrogen can be used with carbon dioxide (CO_2) that is captured from thermal power plants and reduced to carbon monoxide (CO) to generate methane (methanation), which leads to fuels as the final products. In addition, FREA is demonstrating the hydrogen energy system to be used in buildings. It also possesses the first commercial hydrogen station for fuel cell vehicles using RE-based hydrogen. Finally, research on hydrogen production from biomass with carbon capture and storage was introduced.

The final presentation of this session was by Dr Vivia Luo from Yunnan Academy of Scientific & Technology Information, People’s Republic of China, focusing on district heating and cooling using RE. Keywords for district heating and cooling are energy efficiency improvement (through heat pumps and ice storage) and green (though usage of solar energy). Recent trends of cooling and heating technology include combining solar energy with other energy sources, integrating refrigeration with heat storage technology, and using solar energy in heating and cooling. A number of district heating systems in People’s Republic of China were introduced. For example, solar power is used to replace coal for heating in Saga, Tibet which is 4,600 meters over sea level, and natural gas along with distributed PV are used to provide heating and cooling in hotels in Hainan. In order to facilitate district heating and cooling with RE, owners need to apply for financial support from government and conduct thorough survey to determine the specifications of the system. On the other hand, government needs to build more demonstration sites and projects.

The discussion on the second day focuses on the policy aspect of the criteria and framework for joint RE&EE projects. Dr Kampanart Silva from National Energy Technology Center (ENTEC), Thailand, recapped the proposed criteria presented on the first day, and added the information on driving mechanisms and enabling policies for the joint RE&EE projects. Example policies include financial supports, incentives, standards and regulations, stakeholder engagement, and self-funded or industrial-led initiatives. It was also found that policies that aimed to promote EE could also benefit the improvement of RE, and vice versa.

In the course of the second day of discussion on the proposed criteria and framework for joint RE&EE projects, it was summarized by Mr Harry Lai, Deputy Director of the Electrical and Mechanical Services Department, Hong Kong, China that to bring the criteria into effect, a new energy saving target for government buildings should be set in an appropriate and acceptable number and Feed-in-Tariff scheme must be presented publicly. At the end of discussion, closing speech was given by Ms Munlika Sompranon, Department of Alternative Energy Development and Efficiency (DEDE). She expected that the 1st APEC Workshop on Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region would lead to beneficial outcomes to joint RE&EE APEC proposals in the future and looked forward to seeing the contribution from the 1st Workshop to the 2nd Workshop.

2. Summary of 2nd Workshop

The 2nd APEC Workshop on Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region was scheduled to hold in a fully virtual manner during 19-20 July 2021 with the objectives to share best practices of successful joint projects for RE&EE implementation with co-benefit in power generation and distribution, transport, and building sector, as well as to discuss criteria and framework for joint RE&EE projects with co-benefit technically and economically.

As shown in the agenda in Table 6, the first day of the 2nd workshop started with a welcome speech and a brief introduction to the event by Dr Julathep Kajornchaiyakul, Acting Executive Director of the National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA), Thailand. He expressed his expectation on contributions from RE&EE experts all over the region to the achievement of APEC RE&EE goals among APEC economies throughout future development of co-benefits. Thereupon, the opening speech was delivered by Dr Prasert Sinsukprasert, Director General, Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand pointing out that co-benefits of deployment of renewable energy and enhancement of energy efficiency take their role to effectively mitigate and address climate change effects. Therefore, it is crucial to understand this role throughout implementing guideline for co-benefit assessment of renewable energy and energy efficiency. For the reason, Thailand and APEC economies can achieve APEC goals on renewable energy and energy efficiency, which is consistent to the Alternative Energy Development Plan 2018 (AEDP2018) of Thailand.

Table 6 Agenda for the 2nd Workshop

The 2nd APEC Workshop on Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region

Date: 19 – 20 July 2021

(https://zoom.us/j/98589211685?pwd=ZGF4WUVxT3lIQVBQMFhMS2dYak45UT09)

Time zone: GMT+7

19 July (Monday) - Virtual Workshop	
08:30–09:00	Registration and Reception (Online)
09:00–09:10	**Introduction** **Workshop overview and goals** 3. Instructions for online workshop 4. A short introduction to the event: workshop objective, expectation and agenda ***Dr Nuwong Chollacoop****, Project Manager, National Energy Technology Center (ENTEC) (Thailand)*
  09:10–09.20 09:20–09.30	**Opening Ceremony** Welcome Speech by ***Dr Julathep Kajornchaiyakul,*** Acting Executive Director of the National Energy Technology Center (ENTEC) *(Thailand)* Opening Speech by ***Dr Prasert Sinsukprasert,*** Director General, Department of Alternative Energy and Efficiency, Ministry of Energy *(Thailand)*
09:30–09.40	**Virtual Group Photo**

09:40–10:00 10:00–10:20	**Summary of Best Practices for the RE&EE Projects** Sharing the results from the 1st APEC Workshop on Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region: - Summary of best practices of RE&EE projects - Drafted criteria, framework and evaluation tool to assess and develop successful co-benefitting projects ***Dr Worajit Setthapun**, Dean of Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University (Thailand)* ***Dr Kampanart Silva**, National Energy Technology Center (ENTEC) (Thailand)* **Criteria, framework and evaluation tool to assess co-benefitting projects in transportation sector** Tentative framework includes how accumulative benefit could derive from using renewable fuel for energy-efficient vehicle, renewable electricity for electric vehicle ***Dr Kampanart Silva**, National Energy Technology Center (ENTEC) (Thailand)*
10:20–10:30	Break
  10:30–10:50 10:50–11:10 11:10–11:30	**<u>Examples of RE&EE Co-benefit Assessment Tools</u>** **Co-benefits and Trade-Offs of Green and Clean Energy** ***Dr Venkatachalam Anbumozhi**, Economic Research Institute for ASEAN and East Asia (ERIA)* **Mainstreaming Transport Co-benefits Approach: A Guide to Evaluating Transport Projects** ***Prof Atsushi Fukuda**, Nihon University* Q&A
11:30–12:00	**Summary and Wrap up Day 1**
20July (Tuesday) - Virtual Workshop	
08:30–09:00	Registration and Reception (Online)
09:00–09:10	**<u>Recap of Day 1 and Introduction of Day 2 Goal & Expectations</u>** ***Dr Worajit Setthapun**, Dean of Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University (Thailand)*
09:10–9:30	**Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments** ***Mr Colby Tucker**, US Environmental Protection Agency (EPA) (USA)*
09:30–10:00	**Cost Benefit Analysis in Transport Sector** ***Dr Peerawat Saisirirat**, National Energy Technology Center (ENTEC) (Thailand)*

10:00–10:40	**Hands-on Practice with Evaluation Tool to Assess Co-benefitting Projects in Transportation Sector** ***Dr Peerawat Saisirirat**, National Energy Technology Center (ENTEC) (Thailand)*
10:40–10:50	Break
10:40–11:50	**Discussion on Potential Use of Co-benefitting Assessment Tool** ***Dr Nuwong Chollacoop**, Project Manager, National Energy Technology Center (ENTEC) (Thailand)*
11:50–12:00	**Closing Remarks**

Table 7 List of Participants to 2nd APEC Workshop

No.	APEC Member Economy	Title	Name	Gender	Organization	E-mail
1	Thailand	Dr	Prasert Sinsukprasert	Male	Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy	prasert_s@dede.go.th
2	Thailand	Dr	Julathep Kajornchaiyakul	Male	National Metal and Materials Technology Center (MTEC)/National Energy Technology Center (ENTEC)	julathep@mtec.or.th
3	Indonesia	Dr	Venkatachalam Anbumozhi	Male	Economic Research Institute for ASEAN and East Asia	v.anbumozhi@eria.org
4	Japan	Prof	Atsushi Fukuda	Male	Department of Transportation Systems Engineering, College of Science and Technology, Nihon University	drwpsung@gmail.com
5	United State of America	Mr	Colby Tucker	Male	US Environmental Protection Agency	Tucker.WilliamC@epa.gov
6	Chinese Taipei	Mr	Hsieh	Male	Industrial Technology Research Institute	zackhsieh@itri.org.tw
7	Malaysia	Mr	Ishamuddin Mazlan	Male	Sustainable Energy Development Authority (SEDA Malaysia)	Ishamuddin@seda.gov.my
8	Malaysia	Mr	Ir Gopinathan Muthaiyah	Male	Sustainable Energy Development	gopinathanm@seda.gov.my

No.	APEC Member Economy	Title	Name	Gender	Organization	E-mail
					Authority (SEDA Malaysia)	
9	Mexico	Mr	Heberto Barrios Castillo	Male	Ministry of Energy of Mexico	hbarrios@energia.gob.mx
10	Mexico	Ms	Andrea Ytuarte Orantes	Female	Ministry of Energy of Mexico	aytuarte@energia.gob.mx
11	Mexico	Dr	Rosa Isela Gomez García	Female	Ministry of Energy of Mexico	rgomezg@energia.gob.mx
12	Peru	Mr	Felix Bernabel Badillo	Male	Ministry of Energy and Mines	fbernabel@mine.gob.pe
13	Peru	Mr	Elvis Tello Ortiz	Male	Ministry of Energy and Mines	etello@minem.gob.pe
14	Peru	Ms	Maria Del Pilar Ocampo Moreno	Female	Ministry of Energy and Mines	mocampo@minem.gob.pe
15	Peru	Mr	Alberto Agurto Saldana	Male	Ministry of Energy and Mines	temp_dgh97@minem.gob.pe
16	The Philippines	Mr	Artemio P. Habitan	Male	Department of Energy	ahabitan@yahoo.com
17	The Philippines	Mrs	Norita C. Froilan	Female	Department of Energy	froilanorie_cube@yahoo.com
18	The Philippines	Mr	Dante L. Castillo	Male	Department of Energy	dcastillo@doe.gov.ph
19	Thailand	Mr	Sarunyu Phongpitchayapa	Male	Electricity Generating Authority of Thailand (EGAT)	592300@egat.co.th
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21	Thailand	Miss	Wipaporn Pongpiriyakijkul	Female	Electricity Generating Authority of Thailand (EGAT)	596059@egat.co.th
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24	Thailand	Ms	Krittiya Petsee	Female	Ministry of Energy of Thailand	krittiya.psed4@gmail.com
25	Thailand	Ms	Yanisa Lertanantrakoon	Female	Ministry of Energy of Thailand	yanisale@energy.go.th
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27	Thailand	Ms	Munlika Sompranon	Female	Department of Alternative Energy Development and	mu21bm@hotmail.com

No.	APEC Member Economy	Title	Name	Gender	Organization	E-mail
					Efficiency (DEDE), Ministry of Energy	
28	Thailand	Dr	Yaowateera Achawangkul	Female	Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy	yaowateera@gmail.com
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41	Thailand	Dr	Nuwong Chollacoop	Male	National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA)	nuwong.cho@entec.or.th
42	Thailand	Dr	Peerawat Saisirirat	Male	National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA)	peerawat.sai@entec.or.th
43	Thailand	Dr	Kampanart Silva	Male	National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA)	kampanart.sil@entec.or.th
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45	Thailand	Mr	Kampanat Thapmanee	Male	National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA)	kampanat.tha@entec.or.th
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No.	APEC Member Economy	Title	Name	Gender	Organization	E-mail
					(ENTEC), National Science and Technology Development Agency (NSTDA)	
47	Thailand	Mr	Pidpong Janta	Male	National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA)	man.picyr@gmail.com
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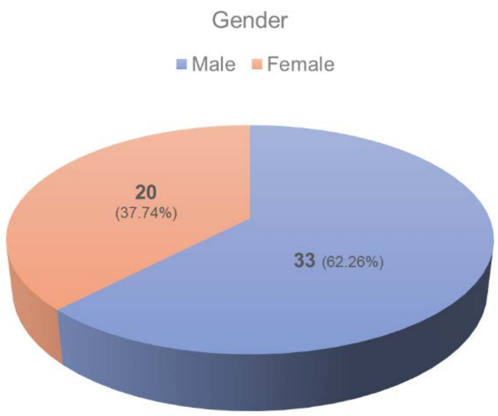
49	Thailand	Ms	Supreeya Teerapimonchan	Female	National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA)	supreeya.tee@entec.or.th
50	Thailand	Ms	Natthaya Patlakfa	Female	National Metal and MaterialsTechnology Center (MTEC), National Science and Technology Development Agency (NSTDA)	nattaya@nstda.or.th
51	Thailand	Mr	Ragkiat Niyomvanicha	Male	National Metal and MaterialsTechnology Center (MTEC), National Science and Technology Development Agency (NSTDA)	ragkiat.niy@mtec.or.th
52	Thailand	Dr	Worajit Setthapun	Female	Asian Development College for Community Economy and Technology (adiCET) Chiang Mai Rajabhat University	worajit@cmru.ac.th
53	Thailand	Dr	Hathaithip Sintuya	Female	Asian Development College for Community Economy and	hathaithip.nin@gmail.com

No.	APEC Member Economy	Title	Name	Gender	Organization	E-mail
					Technology (adiCET) Chiang Mai Rajabhat University	



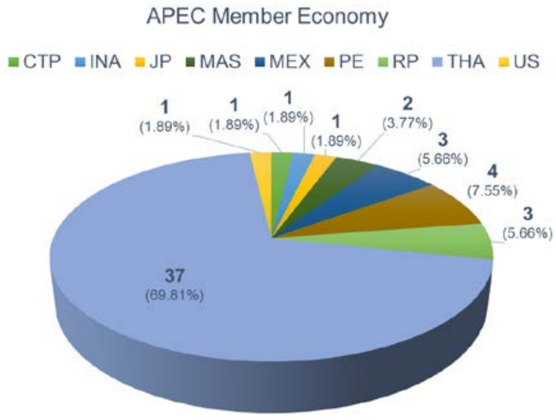


Figure 11 Breakdown statistics

2.1. 2nd Workshop Participants

As shown in Figure 11 and detailed in Table 7, the 2nd workshop was attended by a total of 53 participants from 9 APEC economies with a female-to-male ratio of 37.74% (20 women and 33 men). As usual, the virtual meeting was highly participative, with Dr Nuwong Chollacoop, project manager from ENTEC, NSTDA, Thailand taking on the role of overall facilitator.

2.2. 2nd Workshop Presentation and Discussion

The 2nd workshop was structured for two days. The first day composed of recap of the 1st workshop and sharing of examples of RE&EE co-benefit frameworks and assessment tools by experts from APEC Economies. The recap of the 1st workshop included the summary of the best practices of past RE&EE projects and the drafted criteria and framework to assess and develop successful co-benefitting projects while the sharing session covered the introduction of tools and framework proposed and used by Economic Research Institute for ASEAN and East Asia (ERIA) and Institute for Global Environmental Strategies (IGES). The second day started with a sharing session of the co-benefit evaluation framework and tool of the US Environmental Protection Agency (EPA), followed by a hands-on session of the cost-benefit analysis of co-benefitting projects in transportation sector using the Fuel Economy Policies Implementation Tool (FEPIT) of the International Energy Agency (IEA). All co-benefit assessment framework and tools help grasp a big picture of co-benefits of renewable energy and energy efficiency in important domains, e.g., energy production and consumption, environment, economic and social, and help quantify those co-benefits in order to ease the communication with policy makers and help justify the co-benefitting projects. Participating APEC economies also provided feedback and comments which contribute to refinement of the proposed criteria and pave the way to the actual use of cost-benefit analysis to quantify co-benefits of the RE&EE projects to each other and to other relevant domains. Figure 12 and Figure 13 show various presentations and discussion on the first day and the second day, respectively. Presentation files are shared at:

https://drive.google.com/drive/folders/10EICavFhzX8bJFAOUS7kKOwTREFKlwmP and records of both days are available at https://www.facebook.com/mtecnstda/videos/534900737632773 and https://www.facebook.com/mtecnstda/videos/310301564211211

Figure 12 Presentation and Discussion of the first day of workshop

Figure 13 Presentations on co-benefit assessment on the second day of workshop

The recap of the first workshop was presented by Dr Worajit Setthapun, the Dean of Asian Development College for Community Economy and Technology (adiCET), Chiang Mai Rajabhat University (CMRU), Thailand and Dr Kampanart Silva from ENTEC, NSTDA, Thailand. Best practices and driving mechanisms that facilitate achievement of RE&EE co-benefits in power generation and distribution sector, transportation sector, and building sector were introduced. Based on the abovementioned best practices and the survey of criteria being used in APEC region, The project team proposed modifications of eligibility criteria and priority for Energy Efficiency and Low Carbon Measures (EELCM) Sub-Fund, and additional consideration during the scoring of the projects by APEC Member Economies' representatives. The proposal includes, the suggestions to focus on projects that contribute to both RE&EE APEC goals (instead of contributing to either of the goals); to give priority to projects that meet many of the six technical criteria for co-benefits to RE&EE: (1) flattening peak demand, (2) low carbon, (3) digital, (4) electricity/electrification, (5) fuel standards, (6) local context; and to consider the aforementioned technical criteria during the scoring of Criterion 1: Relevance.

During the Q&A session, Dr Cary Bloyd from the Pacific Northwest National Laboratory, USA suggested the project team to consider the overall impact when assessing the co-benefits. Not only benefits to RE&EE, but also other benefits, e.g., reduction in environmental impact, optimization of overall services should be taken into consideration, and contribution to mitigation and adaptation to climate change should be set as one of the priorities. Mr Harry Lai from the Electrical and Mechanical Services Department, Hong Kong, China, advised the project team to update the information on the priority of the EELCM Sub-Fund which has been updated during the 61st APEC Energy Working Group (EWG) Meeting on June 21-25, 2021, in Brunei Darussalam. The new priorities include “energy resiliency” which was proposed by Japan.

Next was the presentation by Dr Venkatachalam Anbumozhi from Economic Research Institute for ASEAN and East Asia (ERIA), Indonesia which covered co-benefits and trade-offs of renewable energy and energy efficiency. He started his talk by emphasizing the need to identify co-benefits to meet triple challenges: accelerating economics growths, enhancing energy and human security, and reducing pollutions and emissions. There are different types of co-benefits of RE&EE, such as harnessing carbon market, increasing tax revenues, openness to trade and investment in green goods and services, and energy connectivity. The talk also introduced various ways to maximize co-benefits, for example, using externalities (carbon tax and removal of fossil fuel subsidies), increasing government’s spending on innovation, enhancing technology transfer, and making use of natural capital through allocation of property rights and enforcement of environmental quality standards and regulations. Barriers of investment on RE&EE were identified, including regulatory and permitting procedures, proximity to existing infrastructure, and environmental impacts, along with the solutions to overcome the barriers, including optimization and adjustment of co-benefits, development of a comprehensive investment roadmap, earmarking financial resources, and establishment of regionally coordinated volunteer principles and monitoring guideline.

The other presentation was given by Prof Atsushi Fukuda from Nihon University, Japan who introduced the outcome of the Institute for Global Environmental Strategies (IGES)’ study on Mainstreaming Transport Co-benefits Approach: A Guide to Evaluating Transport Projects which aimed to quantify co-benefits of clean investment in transportation sector. He pointed out that the unit cost for carbon emission has always been underestimated compared to damages derived by climate change. As a result, benefits other than emission credits have been required to make emission reduction activities feasible. Apart from greenhouse gas reduction, user benefits (such as reduction of accident loss, travel time saving, vehicle operating cost saving), air pollution reduction, and alleviation of global warming can be used to assess co-benefits. The presentation ended with two important key issues to be addressed: (1) necessity in preparing emission factors, and (2) necessity in determining a proper price for greenhouse gas emission.

Discussion after the talks was centered on the ways to facilitate projects with co-benefits to RE, EE and other aspects, especially carbon emission reduction. As for the quantification of benefits in carbon reduction, Prof Fukuda emphasized the need of effort in putting a price tag to carbon. As for the promotion of projects co-benefitting RE&EE, Dr Ambumozhi stressed the necessity to formulate regional coordination framework, to think of the way to put green technologies into a business model, and to identify and address issues in technological and financial windows.

The second day started with a presentation by Mr Colby Tucker from the US Environmental Protection Agency (EPA), USA which introduced the USEPA’s co-benefit evaluation guide entitled Quantifying the Multiple Benefits of Energy Efficiency and Renewable

Energy: A Guide for State and Local Governments[19]. The document describes the multiple benefits of EE and RE, explains the value of quantifying benefits, and finally describes how to quantify those benefits. The framework starts from identifying benefits of RE&EE, and then extend the scope to cover benefits in enhancing electricity system, reducing emission, and improving health, and boosting economy. The analytical framework for quantification of co-benefits include: (1) determining scope and strategy; (2) determining direct electricity impacts; (3) quantifying multiple benefits from direct electricity benefits; (4) using benefit information to support informed decision-making. A step-by-step guide for quantifying emissions and health benefits were also introduced. The steps to be followed are: (1) develop and project a baseline emissions profile; (2) quantify expected emissions reductions; (3) estimate air quality changes from reductions: (4) quantify health and related economic effects. Tools, data resources and case studies to facilitate further study were also provided.

Next was the presentation by Dr Peerawat Saisirirat from ENTEC, NSTDA, Thailand which was divided into two parts. The first part summarized the aspects to be considered before performing cost-benefit analysis in transportation sector which were introduced through the actual examples of opportunities and barriers of RE&EE for transportation sector in Thailand. Fuel economy improvement in Thailand has been driven by Nationally Determined Contribution (NDC) and Energy Efficiency Plan (EEP). Government uses excise tax and eco sticker as the means to urge improvement of fuel economy. The aspirational goal of light-duty vehicles' fuel consumption goal in Thailand is to reduce the fuel consumption by 3.1% in 2030 comparing to 2016. On the other hand, Thai government promotes both electric vehicles and biofuel to increase the share of renewable energy in transportation sector.

The second part is the hands-on practice session for assessment of co-benefits in transportation sector. The Microsoft Excel-based Fuel Economy Policy Implementation Tool (FEPIT) of the International Energy Agency (IEA) was introduced for the demonstration. Excise tax, annual circulation rate and fuel tax were used to calculate the benefits. Passenger cars and pickup trucks were taken into consideration. Based on the Alternative Energy Development Plan 2018 (AEDP 2018), the blending ratio of ethanol in gasoline and of biodiesel in diesel was set to 20%. From the customer viewpoint, the target scenario (fuel economy improvement only) gave lower cost that the business-as-usual (BAU) scenario for the passenger cars, and the cost became even lower when biofuel was accounted for due to the subsidy. As for pickup trucks, government incentives were needed to keep the customer's cost of the target scenarios (both with and without biofuel) lower than the BAU scenario. From the government viewpoint, the biofuel compensation made the revenue of the target scenario with biofuel became much lower than the target scenario without biofuel due to biofuel compensation, though it was still by far higher than the BAU scenario. As a conclusion, when the framework was properly designed, the customers will pay less in the target scenario due to biofuel subsidization. Government will also receive higher revenue through the increase in annual registration tax and fuel excise tax. In this calculation, 38% of the target carbon emission reduction in transportation sector can be achieved. Furthermore, the increase in biofuel fraction can also help reduce fossil fuel import. Figure 14 shows the hands-on practice session. Further detail of FEPTI and the hands-on practice are documented in Annex 3.

Right after the hands-on practice session, there was a question from Rosa Isela Gomez García, Ministry of Energy of Mexico, Mexico on biofuel compensation, which was later clarified by Dr Saisirirat that it is the subsidy for bioethanol and biodiesel to reduce the

[19] United States Environment Protection Agency (n.d.). EPA. Retrieved June 21, 2021, from https://www.epa.gov/statelocalenergy/quantifying-multiple-benefits-energy-efficiency-and-renewable-energy-guide-state

selling price of biofuel. There was also a question from Mr Felix Bernabel Badillo, Ministry of Energy and Mines, Peru on the RE&EE planning in transportation sector in Thailand. Dr Silva responded that promotions of RE&EE are both under supervision of Department of Alternative Energy Development and Efficiency (DEDE). However, when it comes to transportation sector, Ministry of Transport plans the RE&EE targets in association with the NDC which is looked after by Office of Natural Resources and Environmental Policy and Planning (ONEP).

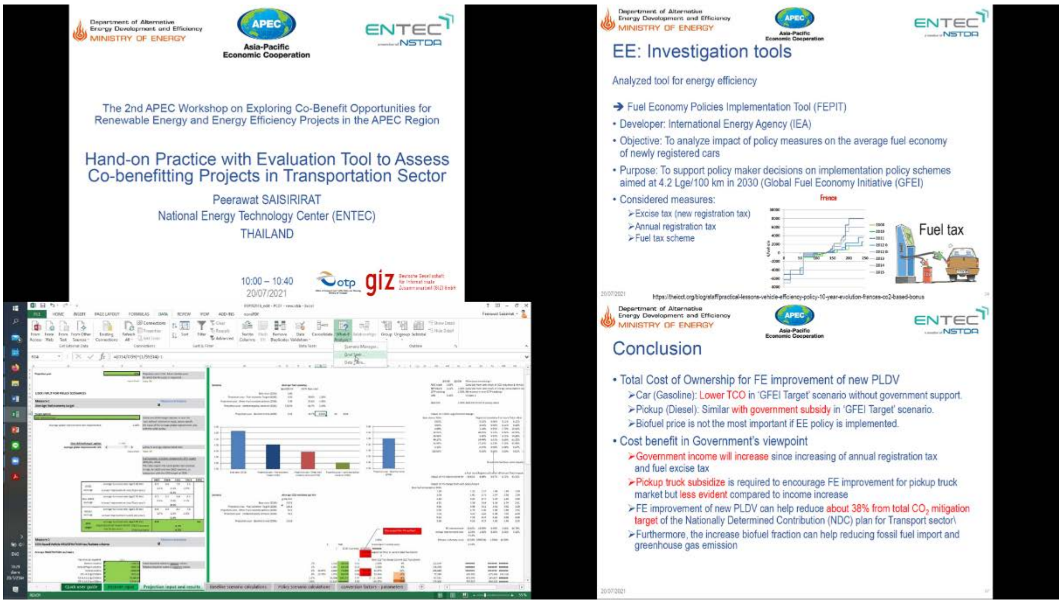


Figure 14 Co-benefit assessment hands-on practice session

In the discussion session, Dr Setthapun introduced the APEC Workshop on University Collaboration to Support Data Gathering and Analysis in Energy Efficiency and Renewable Energy (EWG-06-2019A) which was virtually held on June 8-9, 2021, to show that the academia is also working on data collection and analysis to support the quantification of multiple benefits of RE&EE. Dr Yaowateera Achawangkul, DEDE, Thailand then joined the discussion and shared his view that Thailand started from the promotion of biomass and biofuel decades ago, and though it has plenty of reserve, it has been putting efforts in increasing the efficiency. The best practice from the success cases could be useful for the real implementation. The discussion then moved toward to co-benefits of RE&EE in contribution to carbon neutral at which most APEC economies are aiming. Ms Munlika Sompranon, DEDE, Thailand informed the meeting that Thailand is moving toward carbon neutral, and the target year will be announced at the UN Climate Change Conference (COP26). Dr Chollacoop wrapped up that we should extend the promotion of co-benefits in RE&EE in this workshop toward greenhouse gas reduction.

The discussion on the second day focuses on policy aspects of the criteria and framework for joint RE&EE projects. Dr Kampanart Silva from ENTEC, Thailand, recapped the proposed criteria presented on the first day, and added the information on driving mechanisms and enabling policies for the joint RE&EE projects. Example policies include financial supports/incentives, standards and regulations, stakeholder engagement, and self-funded or industrial-led initiatives. In was also found that policies that aimed to promote EE could also benefit the improvement of RE, and vice versa. At the end of the discussion session, closing speech was given by Ms Sompranon, DEDE, Thailand. She appreciated all the participants for their highly active engagement in the 1st and 2nd APEC Workshops on Exploring Co-Benefit Opportunities for Renewable Energy and Energy Efficiency Projects in the APEC Region. The outcome of discussion would value co-benefits of renewable energy and energy efficiency as an explicit potential that should be taken into consideration beyond direct benefits.

3. Summary of Evaluation Tool to Assess Co-benefitting Projects in Transportation Sector and Hands-on Practice

The hands-on practice aims to demonstrate the way that a project can co-benefit energy efficiency and renewable energy. The example used in the activity was a part of the Global Fuel Economy Initiative (GFEI) that aims to increase the energy efficiency in transportation sector through the improvement of fuel economy. However, with the introduction of biofuel and electric vehicle (EV) into the program, the project can also contribute to increase in the share of renewable energy. Fuel Economy Policies Implementation Tool (FEPIT) was used to quantify the benefits of the measures from both vehicle owners' and government's viewpoints.

3.1. Background

In 2030, the Global Fuel Economy Initiative (GFEI) has set a target to improve the average fuel economy (FE) at 4.4 L_{ge}/100 km. To reach the goal, it is important to understand how the policy implementation affect RE&EE from the perspectives of both customers and the government. Fuel Economy Policies Implementation Tool (FEPIT), a benefit analysis tool was used to evaluate the change in customers' and government's expenditures by electric vehicle deployment and increase in usage of biofuel in order to demonstrate the co-benefits in RE&EE from the policies.

Figure 15 shows aspirational Light Duty Vehicle (LDV) fuel consumption goals in various economies, with the average FE roadmap target of 4.4 L_{ge}/100 km expected to be achieved by 2030. In comparison to Thailand's fuel economy, the annual improvement rate of new vehicle must decrease by -3.1% per year. This report demonstrates the execution of FEPIT, and also the way to use the results to help achieve the GFEI target of a 3.1% annual improvement rate of FE.

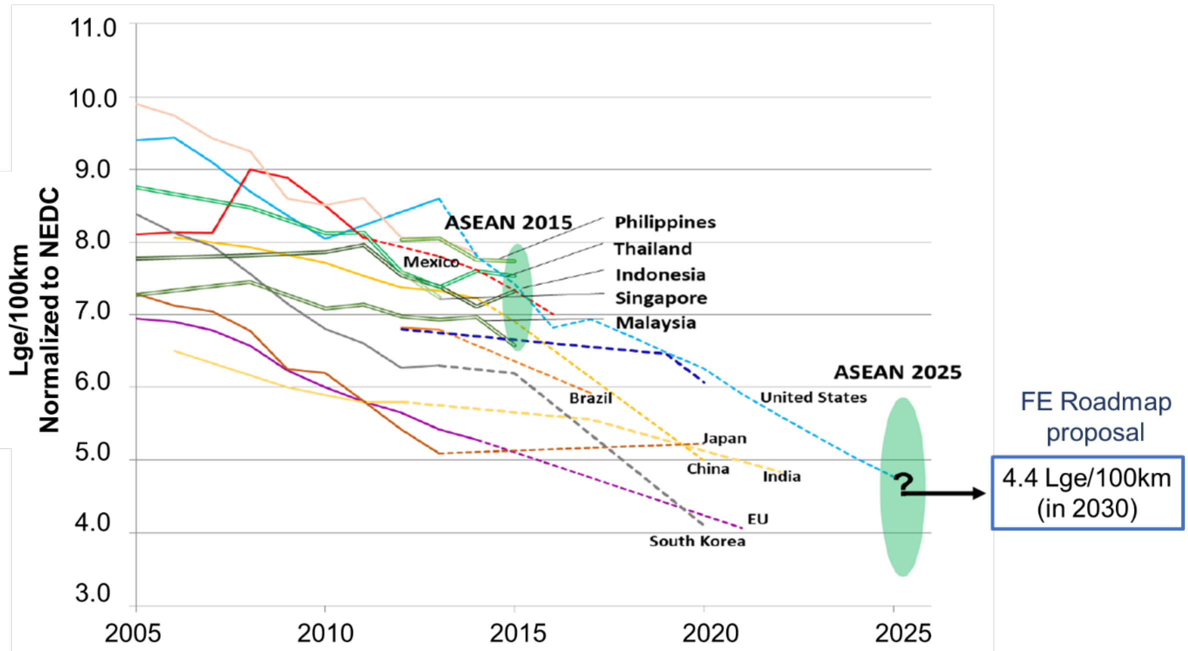


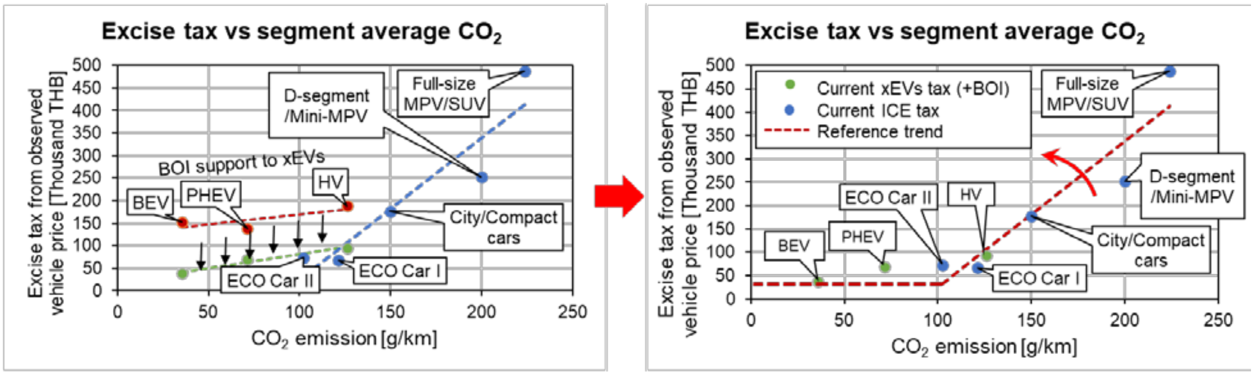
Figure 15 Aspirational LDV Fuel Consumption Goal

3.2. Fuel Economy Policies Implementation Tool (FEPIT)

Fuel Economy Policies Implementation Tool (FEPIT)[20] consists of a Microsoft Excel file including six worksheets, a user guide, and a methodology report. It is used to analyze potential outcomes of different policy measures on the average fuel economy of newly registered cars in various scenarios. FEPIT can be used to assess the impact of four different policy measures: fuel economy target, CO_2-based vehicle registration tax/feebate scheme, CO_2-based vehicle circulation tax/feebate scheme, and fuel taxation.

3.3. Measures to Achieve GFEI Target of -3.1% Annual Improvement Rate

FEPIT's calculation requires certain user's input data. The first input data focuses on how registration rate (excise tax) changes with CO_2. Figure 16(a) depicts the excise tax and segment average CO_2 of respective vehicle segments. A new trend line (green dashed line) created by electric vehicle promotion by the Board of Investment (BOI) in Thailand offers lower excise taxes to a more environmentally friendly and more fuel economy option. Referring to the existing CO_2-based excise tax for internal combustion engine (ICE) vehicles in Figure 16 (a), the slope can be steeper to penalize polluted vehicles as shown in Figure 16(b) (current ICE CO_2-based excise tax is about 3,145 THB/(gCO_2/km).



(a) (b)

Figure 16 Revision of registration rate (excise tax) and segment average CO_2

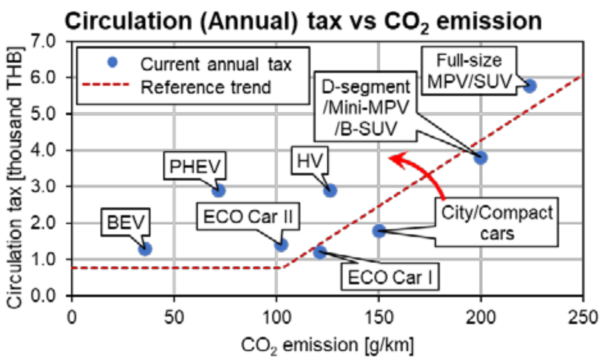


Figure 17 Revision of annual circulation tax and segment average CO_2

[20] Global Fuel Economy Initiative (2015), Fuel Economy Policies Implementation Tool (FEPIT), User's Guide, International Energy Agency, France.

The second input data in Figure 17 shows how an annual circulation tax changes with CO_2. Again, a steeper slope leading to more intense penalty on polluted vehicles can be introduced. Other input data are fuel price and fuel excise tax. In the Business as Usual (BAU) scenario, fuel price is assumed to be constant. As a result, the additional increment of BAU fuel price is defined based on the benefit from fuel excise tax.

FEPIT is used to analyze the impact of policy measures on the average fuel economy of newly registered cars. Measures considered by FEPIT include excise tax, annual registration tax, and fuel tax scheme. Cars and pickup trucks were chosen as the targets due to their large shares (see Figure 18). Table 8 shows the government's new criteria of CO_2-based excise tax in order to improve FE. From RE perspective, Thailand has a domestic Alternative Energy Development Plan 2018 (AEDP2018) which promotes biofuel utilization in vehicles, such as promoting Gasohol E20 as the main fuel for gasoline engine users and discontinuing Gasohol E10-ON91 (ongoing), promoting Diesel B10 as the main fuel for diesel engine users (success), and reducing biofuel price compensation.

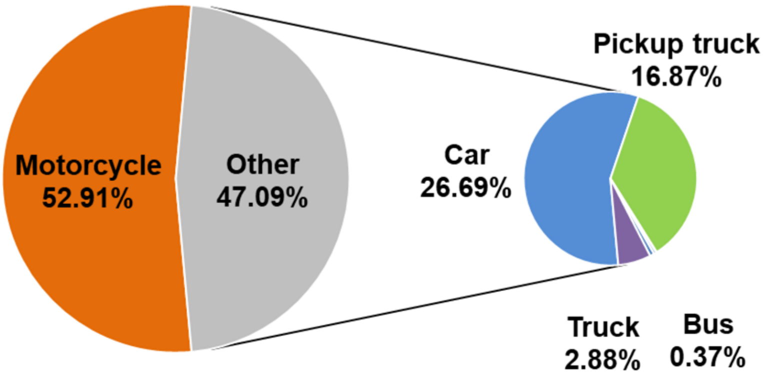


Figure 18 Vehicle share in Thailand

Table 8 Current vehicle tax structure

Vehicle type	Current tax structure			
	CO_2	Tax rate (%)		
		E10/E20	E85/NGV	Hybrid/BOI
Passenger car -Lower than 10 passenger seats	≤100 g/km	25*	20*	8*/4*
	101-150 g/km			16/8
	151-200 g/km	30	25	21/10.5
	>200 g/km	35	30	26/13
	>3,000 g/km	40	40	40
PPV/ DC/ Space Cap/ Pickup	Hybrid/BOI <175 g/km	18*/8 and 6 (Euro 5/B20)		
	≤200 g/km	20*/10/4/2.5,15 and 9/3/2 (Euro 5/B20)		
	>200 g/km	25/13/6/4 and 12/5/3 (Euro 5/B20)		
	>3,250 CC	40		
Eco Car /E85,B10	≤100 g/km	12*/10*		
	101-120 g/km	14		
Electric Vehicle, Fuel Cell/EV (BOI)		8/2 (2019-2022)		

Remark: *Active safety standard for passenger car with lower than 10 seats which has CO2 <150 g/km/ PPV which has CO2 < 200 g/km / Eco car which has CO2 <100 g/km

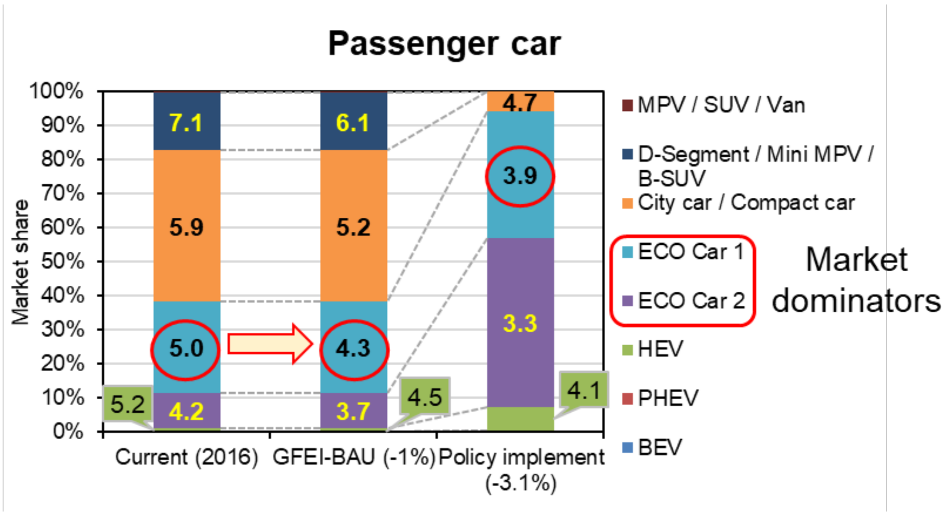
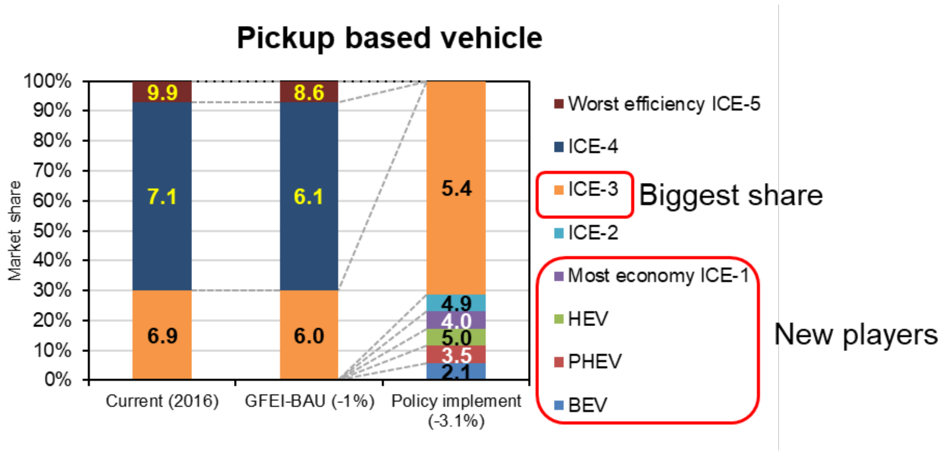


Figure 19 Prediction of new passenger car mix and average fuel economy in 2030



Remark: ICE classified by the amount of CO_2 emission.

Figure 20 Prediction of pickup truck mix and average fuel economy in 2030

Figure 19 shows the FEPIT's prediction of new passenger car mix (bar charts) and segment average fuel economy (numbers; L_{ge}/100 km). Improvement in average fuel economy can be observed in all vehicle segments. Target policy implementation significantly reduced fuel economy when compared to the BAU scenario (1% decrease in GFEI). The figure also revealed rises in the market share of city cars, eco-cars, and xEVs as a result of increase in registration tax, annual circulation tax, and fuel price. The average fuel economy for passenger cars has decreased from 5.68 L_{ge}/100km in 2016 (the current scenario) to 3.91 L_{ge}/100 km in 2030 (the future target scenario). Consequently, the eco-car 1 and eco-car 2 have become more dominant in the market due to improved fuel economy. It is evident that policy implementation can push forward vehicle share shifts to better fuel economy segments, and segment average fuel economy improvement in all classes.

Figure 20 shows the FEPIT's prediction of new pickup truck mix (bar charts) and segment average fuel economy (numbers; L_{ge}/100 km). Fuel economy of the pickup trucks has decreased from 7.67 L_{ge}/100km in 2016 (the current scenario) to 5.22 L_{ge}/100 km in 2030 (the future target scenario). The improvement of fuel economy is not as distinctive as the case of passenger cars. This indicates that low emission pickup trucks, such as ICE-1, ICE-2, and xEVs should be encouraged.

3.4. Customer's Viewpoint (Total Cost of Ownership)

Figure 21 and Figure 22 shows the total cost of ownership for passenger cars and pick trucks, respectively. It is important to note that the vehicle prices were averaged from market surveys, except for the xEVs, which followed the in-house EV study. The battery cost was around 22% of the vehicle's gate price and scheduled for replacement every 8 years. The maintenance cost of ICE comes from the engine overhauling expense, which is 50,000 THB every 10 years. Energy expense equals to fuel expense, referring to the considered fuel price, including electric charging for BEV and PHEV (4 THB/kWh). Figure 21 shows that the target scenario with biofuel (RE&EE co-benefits scenario) best reduces excise taxes and total energy expenses while maintenance costs remain stable. Figure 22 illustrates decreasing trends in excise taxes and total energy expenses, similar to the case of passenger cars. However, to reach the GFEI objective in 2030, the pickup truck segment requires government incentives in terms of subsidies for the promotion of RE&EE.

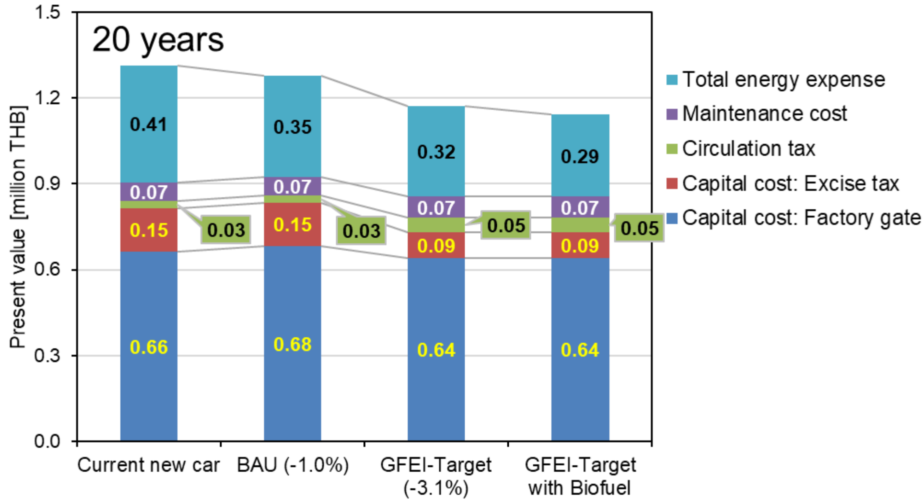


Figure 21 Total cost of ownership for passenger cars

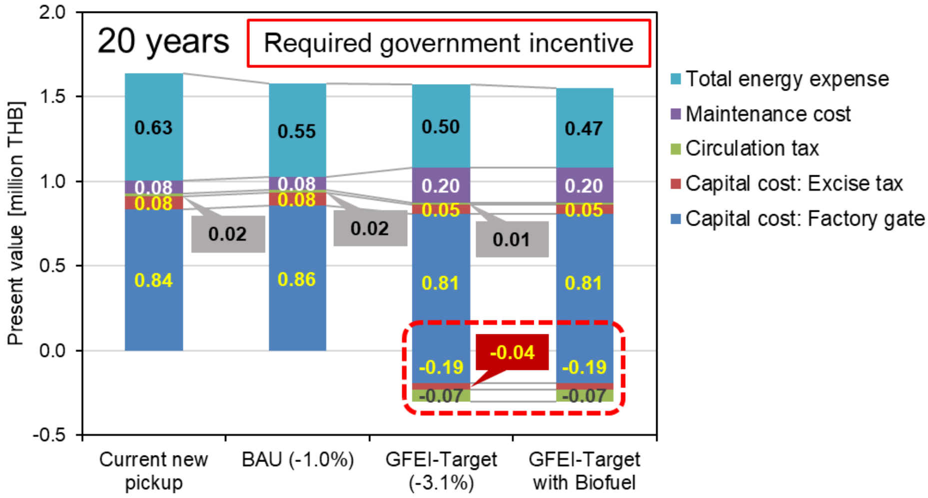


Figure 22 Total cost of ownership for pickup trucks

3.5. Government's Viewpoint (Benefit of the Economy)

Figure 23 shows FEPIT's results from the government's perspective. The revenue from fuel tax has dramatically increased by GFEI Target (3.1%). It is assumed that decrease in the accumulative cost of fuel demand resulted in a rise in the fuel tax. Figure 24 shows that the accumulative cost of fuel demand in the GFEI target (-3.1%) case and the GFEI target with biofuel case reduced by 0.44 and 1.73 trillion baht, respectively. Improved fuel economy contributes to lower fuel prices, which encourages vehicle owners to purchase more eco-cars or zero-emission vehicles. However, it is still difficult to lower the fuel consumption of the whole economy, and this becomes the rationale for raising the fuel tax. Nevertheless, the pickup truck requires government incentives in terms of reduction in excise tax so that the government can gain benefits from fuel economy policies. In relation to renewable energy, it also requires the support from government compensation for biofuel prices in order to promote the utilization.

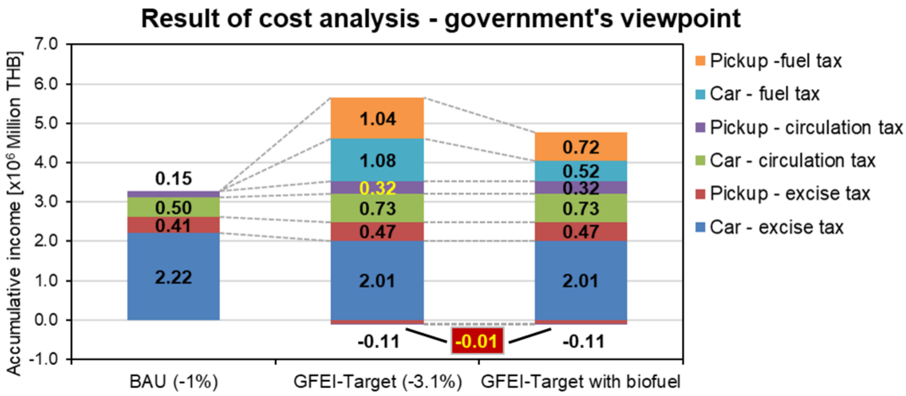


Figure 23 Cost analysis of government's viewpoint

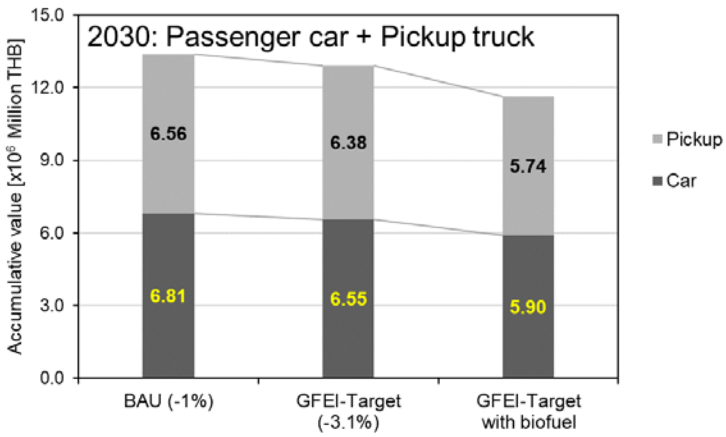


Figure 24 Cost of fuel demand in different scenarios

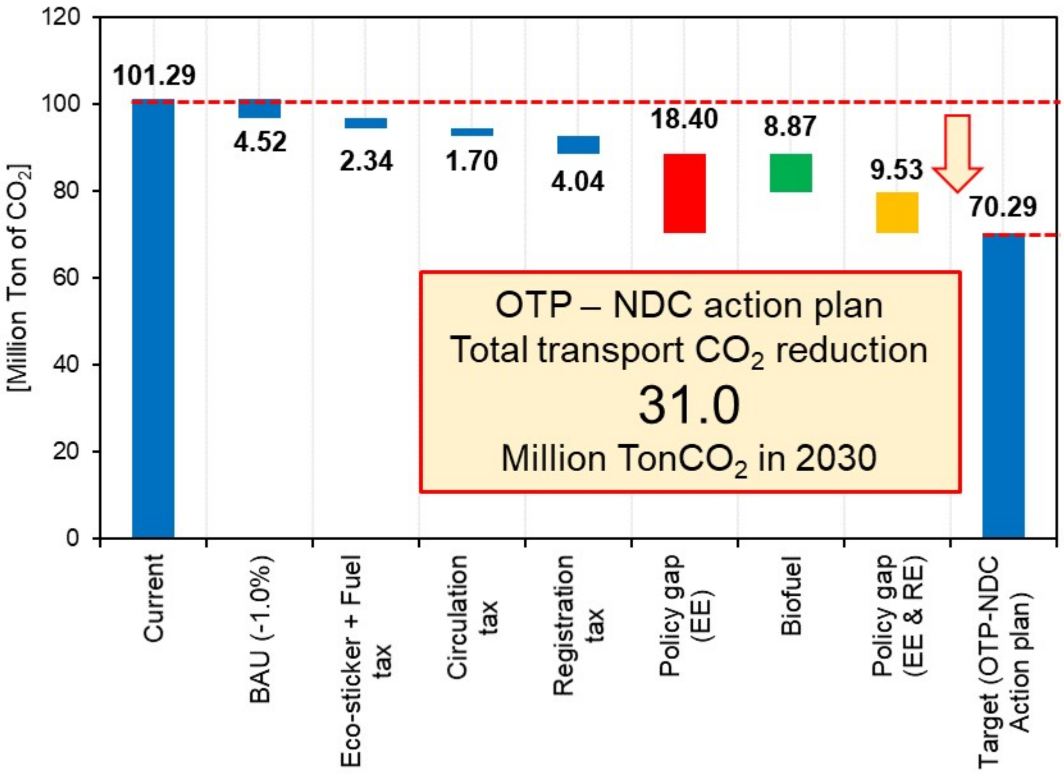


Figure 25 Projection of CO_2 emission and policy impact in 2030

Figure 25 shows the projection of CO_2 emissions under different policy scenarios. Combining the contribution from eco-sticker, fuel tax, circulation tax, and EE&RE can reduce CO_2 emissions by 21.47 million ton. There is still a gap of 9.53 million ton to reach the 2030 reduction target under the Thailand's Nationally Determined Contribution (NDC) action plan.

3.6. Summary of Hand-on Practice with FEPIT

FEPIT demonstrated the benefits of RE&EE policies in transportation sector in terms of cost reduction, revenue generation, and CO_2 emission reduction. FEPIT computes not only a fuel economy target, but also a CO_2-based vehicle registration tax, which includes a circulation tax and fuel charges. It can also assess the change in total cost of ownership from the perspective of the customer, as well as the opportunity cost of government. Therefore, this tool can assist users in understanding how to simultaneously promote fuel efficiency and renewable energy through policy implementation.