Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

Achieving Carbon Neutrality through Bio-Circular-Green Economy Principle in APEC Region

APEC Energy Working Group

November 2023

Asia-Pacific
Economic Cooperation

Achieving Carbon Neutrality through Bio-Circular-Green Economy Principle in APEC Region

APEC Energy Working Group

November 2023

APEC Project: EWG 10 2021A

Produced by

Mrs. Munlika Sompranon, Dr. Kampanart Silva and Dr. Nuwong Chollacoop
Department of Alternative Development Energy Development and Efficiency
Ministry of Energy, 17 Rama I Road, Kasatsuk Bridge, Pathumwan, Bangkok 10330 Thailand

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

APEC#223-RE-01.14

Executive Summary

In October 2021, global leaders made a commitment at the 26th United Nations Climate Change Conference (COP26) in the United Kingdom to keep the global temperature increase to 1.5 ℃ by achieving carbon neutrality by 2050. Many APEC economies pledged to attain carbon neutrality or even net zero greenhouse gas (GHG) emissions by 2050 while some economies have rather limited climate mitigation capacity resulting in the commitment at a later stage. Only some economies have clear pathways for respective sectors to reduce GHG emissions while other economies do not. It would be very helpful for economies with no clear pathways towards carbon neutrality to make use of best practices and lessons learned from top-runner economies that have clear carbon neutral strategy and policy framework. This project aims to review methodology and framework of carbon neutral plans of APEC and non-APEC economies in power, transport, and building sectors, share best practices/lessons learned and build capacity on carbon neutral policy formulation, and examine how Bio-Circular-Green (BCG) Economy Model can contribute to the achievement of carbon neutrality.

The project picks up ten case studies of outstanding decarbonization technologies and corresponding policy actions from nine APEC economies: Canada; Chile; People's Republic of China; Japan; Republic of Korea; New Zealand; Chinese Taipei; Thailand; the United States; and one non-APEC economy, Sweden. Case studies in the power generation sector include RE100 island, coal phase-out, peer-to-peer trading platform, and wind power island. Case studies in the transportation sector include city-scale deployment of new energy vehicles, hydrogen energy demonstration project, and well-planned electric vehicle subsidies. Case studies in the building sector include retrofitting building to achieve net-zero carbon emission, homes of the future, and first carbon-zero house. BCG Economy Model is introduced along with the Bangkok Goal that Thailand proposed at APEC 2022 to promote BCG Economy Model at regional level. Three case studies are introduced to demonstrate the contribution of BCG Economy Model to the attainment of carbon neutrality commitment, including smart microgrid and energy trading platform, innovation-driven hub for sustainable and low carbon transformation, and a bamboo-powered rural community. Steps to drive an economy towards carbon neutrality is proposed based on the observation of the case studies, and the Thailand case study is used to qualitatively and quantitatively demonstrate how policy actions can be designed to reduce carbon dioxide emission and how BCG Economy Model can help achieve carbon neutrality.

The case studies serve as a useful reference for emerging economies to realize how low carbon technologies can be selected, how policy actions can be designed. BCG Economy Model case studies show how local context can be taken into account in carbon neutral policy formulation, and how just transition towards carbon neutrality could be ensured. Qualitative and quantitative considerations of emission reduction potential in the Thailand case study help realize how stakeholders at different levels may react to the proposed policy tools, how likely the policy actions would contribute to the reduction of carbon emissions and to what extent.

List of Contents

List of Figures

List of Tables

1. Introduction

1.1. Background

In 2015, United Nations announced the Sustainable Development Goals to be achieved by 2030[1]. Goal 13: Climate Action is among the goals being focused on by a number of economies in APEC and around the world due to its urgency and its potential to contribute to the fulfillment of other goals. The goal has received even more attention lately due to the commitment of global leaders at the 26th United Nations Climate Change Conference (COP26) in the United Kingdom in October 2021 to keep the global temperature increase to 1.5℃ by achieving carbon neutrality by 2050[2]. In accordance with this commitment, many APEC economies pledged to inject all efforts to attain carbon neutrality or even net zero greenhouse gas (GHG) emissions by 2050. Yet, some economies have rather limited climate mitigation capacity resulting in the commitment at a later stage, e.g., 2060, 2070. Only some economies have clear pathways for respective sectors to reduce GHG emissions while other economies have no distinct indication on how they are going to meet the GHG emission reduction goal that they promised at COP26.

APEC set its energy goals to reduce energy intensity by at least 45% by 2035 (against 2005 level) and double the share of renewable energy by 2030 (with 2010 as base year)[3], both of which could largely contribute to GHG emission reduction. However, as the global leaders decided to put more efforts to achieve carbon neutrality at an earlier date, there would be a necessity to revisit the goals and revise them to more stringent ones. APEC Energy Working Group (EWG) started examining the co-benefits of renewable energy deployment and improvement of energy efficiency in three major sectors, namely power sector, transport sector, and building sector, in its previous project from 2019-2022 to leverage the economies' undertakes to fulfill APEC energy goals[4]. It was found that low carbon (or more aggressively carbon neutrality) is among the top key success factors to achieve the co-benefits. Obviously, there are interlinkages among attainment of carbon neutrality, increasing renewable energy share, and improvement of energy efficiency, which are worth exploring further.

APEC launched 'Carbon Neutral' effort since 2008[5] followed by Low Carbon Model Towns Task Force (LCMT-TF) in 2010. However, different economies have different progress in achieving carbon neutrality[6]. Canada; Chile; Japan; Republic of Korea; New Zealand; and the Russian Federation have net zero emissions commitment in law; Australia; People's Republic of China; Hong Kong, China[7]; Peru; Singapore; Chinese Taipei[8]; and the United States have policy documents on net zero emissions, Malaysia; Thailand; and Viet Nam pledged for carbon neutrality, Indonesia; Mexico; and Papua New Guinea are in discussion or have proposed carbon neutral goals, and Brunei Darussalam and the Republic of the Philippines are still under consideration on how they can contribute to global carbon neutrality goal. It would be very helpful for economies with no

1 https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981
2 https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf
3 https://www.apec.org/docs/default-source/Publications/2019/5/APEC-Energy-Demand-and-Supply-Outlook-7th-Edition---Volume-I/219_EWG_APEC-Energy-Demand-and-Supply-Outlook-7th-edition_Vol-I.pdf
4 https://aimp2.apec.org/sites/PDB/Lists/Proposals/DispForm.aspx?ID=2457
5 https://www.apec.org/Press/News-Releases/2008/0825_pe_sme_carbon
6 https://eciu.net/netzerotracker
7 https://www.hk2050isnow.org/
8 https://www.ndc.gov.tw/en/Content_List.aspx?n=B927D0EDB57A7A3A

clear pathways towards carbon neutrality to make use of best practices and lessons learned from Japan and other economies that have clear carbon neutral strategy and policy framework.

Thailand is among the APEC economies that pay close attention to GHG emission reduction and made an ambitious pledge at COP26[9] to cut off GHG emissions by 40% by 2030, become carbon neutral by 2050, and achieve net zero emissions by 2065 as shown in Figure 1[10]. However, it has not updated the plans in each sector to carry through the aforementioned milestones. On the other hand, Thailand has been promoting the Bio-Circular-Green Economy or BCG Economy Model[11] which is in line with APEC 2022 priority on 'Sustainable and Inclusive Growth.' Energy is one of the important pillars of BCG Economy. Therefore, it would be worthwhile to use Thailand as a case study to investigate the ways to use lesson learned, best practices and low-carbon technology foresight of economies that have clear carbon neutral policy implication to design GHG emission reduction plan in each sector of the remaining APEC economies, referring to the BCG Economy model.

Figure 1 Thailand's Long-term Greenhouse Gas Emission Roadmap

9 https://www.mfa.go.th/en/content/cop26-glasgow?page=5d5bd3cb15e39c306002a9ac&menu=5d5bd3cb15e39c306002a9ad
10 https://globalcompact-th.com/news/detail/602
11 https://www.bcg.in.th/eng/

1.2. Objectives

The objectives of this project are:

- To review methodology and framework of carbon neutral plans from all around the world especially APEC economies in power, transport, and building sectors
- To share best practices and lessons learned on carbon neutral policy formulation under Bio-Circular-Green (BCG) Economy Principle
- To build capacity on carbon neutral policy formulation with a balanced integration of RE/EE technologies and regulation with an aim to have Thailand as case study.

1.3. Structure of the Report

The introduction of the project in Chapter 1 covers the background and the objectives of the project. Chapter 2 includes the case studies on decarbonization technologies in power generation, transport and building sectors, and supporting carbon neutral policies, with lessons learned/best practices from APEC and non-APEC economies. Chapter 3 recaps Bio-Circular-Green (BCG) Economy Model along with case studies on how BCG Economy Model can contribute to achievement of carbon neutrality. Chapter 4 picked up Thailand as a case study to demonstrate how an economy can move towards carbon neutrality through BCG Economy Model. Chapter 5 includes conclusions and further steps to be taken. Finally, the Annex contains the minutes of the interviews and the details of the workshop.

2. Case studies on Decarbonization Technologies and Policy Tools for Carbon Neutrality

2.1. Landscape of Carbon Neutrality Plans in APEC

APEC initiated its efforts towards carbon neutrality in 2008 when the APEC Small and Medium Enterprises Working Group decided to offset the carbon footprint of its meeting through the purchase of equivalent carbon credits of a Chinese wind power project[5]. This was followed by the Low Carbon Model Towns Task Force (LCMT-TF) of the APEC Energy Working Group (EWG) launched in 2010. After the Glasgow Climate Pact with a commitment of global carbon neutrality by 2050[12] was reached at the 2021 United Nations Climate Change Conference (COP26) in October 2021, APEC Economies have made significant progress to go carbon neutral. Figure 2 shows various stages of advancement of carbon neutral movement in respective APEC Economies. Though not as progressive as Sweden and Germany which decided to have net zero carbon emissions by 2045, Canada; Chile; Japan; Republic of Korea; and New Zealand have enacted a law for carbon neutral commitment by 2050. It is a decade later for the Russian Federation. Australia; Hong Kong, China; Peru; Singapore; Chinese Taipei; and the United States have policy documents with a carbon neutral goal by 2050, while People's Republic of China's goal is by 2060. Several APEC Economies in Southeast Asia, namely Malaysia; Thailand; and Viet Nam, have pledged to go carbon neutral by 2050 at COP26, and are now preparing their laws or policy documents. Though there is no official announcement, Mexico and Papua New Guinea are proposing to have net zero carbon emissions by 2050, and Indonesia by 2060.

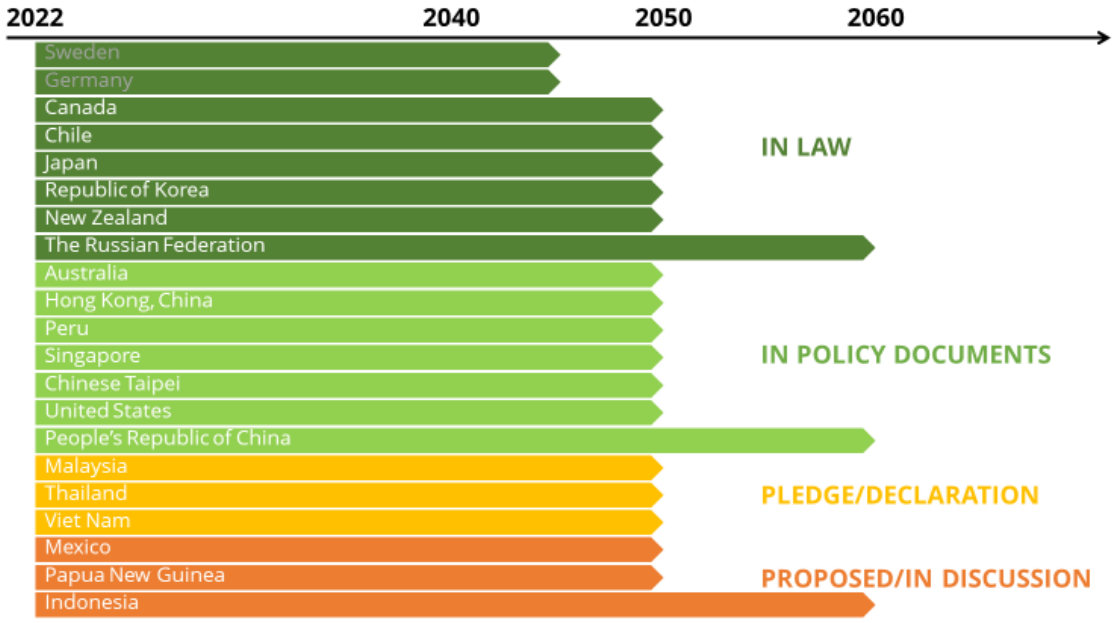


Figure 2 APEC Economies' efforts towards carbon neutrality[6-7]

12 https://unfccc.int/sites/default/files/resource/cop26_auv_2f_cover_decision.pdf

It will be beneficial to the APEC community if we can extract lessons learned and best practices, especially promising decarbonization technologies and supporting policy tools, and specify their contributions to the achievement of the carbon neutral targets in the APEC economies that successfully introduced clear pathways toward carbon neutrality whether in their law or policy documents.

According to the International Energy Agency (IEA), the energy related carbon dioxide emissions concentrate in power, transport, industry, and building sectors (Figure 3). Power, transport, and building sectors are the three key sectors where strategies and actions to further reduce carbon emissions are actively discussed in APEC EWG. The following process was adopted to derive lessons learned and best practices in achieving carbon neutrality. Once the carbon neutrality goals of respective APEC Economies are confirmed, the targets and milestones of the three key sectors along with decarbonization strategies are reviewed focusing on the Economies with carbon neutral commitment in law or in policy documents. Then decarbonization technologies that have large potential in reducing carbon emissions in each sector are listed. For each Economy, the sector where the particular economy is doing well is chosen, and the decarbonization technologies that have great potential in carbon emission reductions are selected. Finally, the policy tools to support that particular technology are listed, and the case study that can demonstrate the success of the policy tool(s) is described in detail. Note that a case study from a non-APEC Economy can also be selected if it is proved to be promising.

The following subsections consist of case studies from ten Economies (four cases in energy sector, three cases in transport sector, and three cases in building sector). The carbon neutral goal, the sectoral target, milestones, and strategies, along with the justification of the selection of that particular case study are also presented.

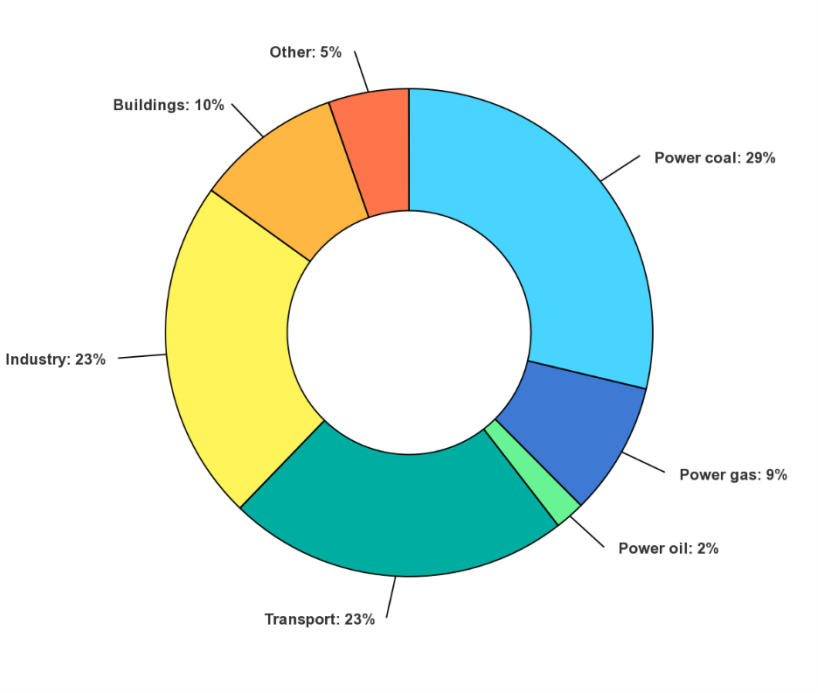


Figure 3 Global energy-related carbon dioxide emissions by sector[13]

13 https://www.iea.org/data-and-statistics/charts/global-energy-related-co2-emissions-by-sector

2.2. Power Generation Sector

2.2.1. RE100 Island[14]

Economy
Chinese Taipei

Carbon emission reduction target
In March 2022, Chinese Taipei announced its pathway to net-zero emission in 2050[15]. It amended the Greenhouse Gas Reduction and Management Act[16] which determined the pathway to decrease GHG emissions by half in 2050 compared to the base year. The pathway is based on four major transition strategies, including energy transition, industrial transition, lifestyle transition, and social transition, as well as two governance foundations, including technology R&D and climate legislation.

Targets, milestones, and strategies of power generation sector
Since power sector significantly contributes to GHG emissions in Chinese Taipei (approximately half), and electrification of transportation and industries will lead to further electricity demand, the majority of 12 key strategies to its net-zero transition shown in Figure 4 are related to power generation. Those directly connected to power generation are wind and solar PV, hydrogen, innovative energy, power systems and energy storage, energy saving and efficiency.

Outstanding decarbonization technology
To phase out from nuclear power generation in 2025, Chinese Taipei will be relying heavily on solar PV and offshore wind. Solar PV is expected to increase from 7.7GW in 2021 to 20GW in 2025 (8 GW rooftop and 12GW ground-mounted). As offshore wind power is more costly, the goal is set lower than solar PV at 5.6GW by 2025. However, the capacity will be increased to 20.6GW by 2035, and 35-50GW by 2050, as it is likely to be economically feasible by then.

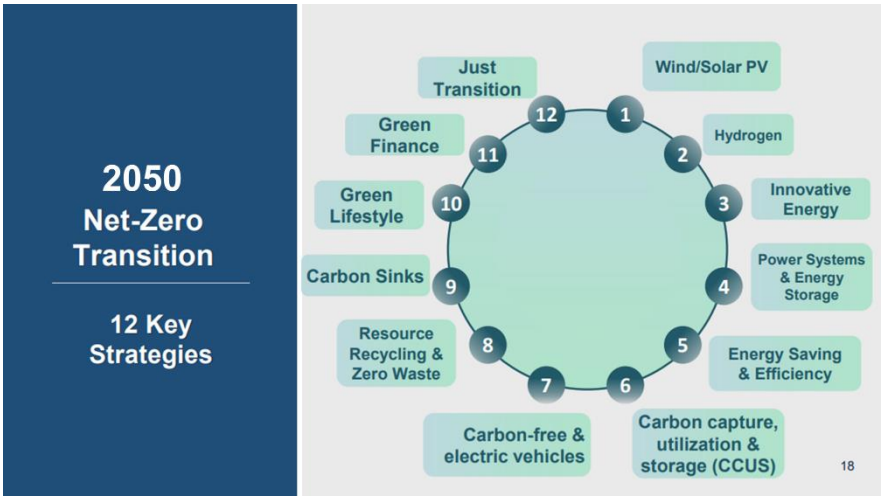


Figure 4 Chinese Taipei's net-zero transition strategies

14 In-depth information is obtained from the interview of delegates from Bureau of Energy and National Penghu University of Science and Technology on 21 November 2022.
15 https://www.ndc.gov.tw/en/Content_List.aspx?n=B154724D802DC488
16 https://law.moj.gov.tw/Eng/LawClass/LawAll.aspx?PCode=O0020098

Selected enabling policy tool

To enable rapid expansion of solar PV and offshore wind, several policies are planned. Solar PV pathway focuses on battery R&D, grid integration, and recycling, to prepare for economy-wide deployment of solar systems. Offshore wind starts with a demonstration incentive program in the initial phase to deal with the high price and will then move to zonal development which will involve capability review and bidding process to enhance competitivity and diversity. Additionally, to demonstrate the feasibility of using large share of variable renewable energy in the grid system, Penghu County is designed to be fully supplied by renewable energy systems (RE100) to see how solar PV and wind power generation would affect the central grid. Power generation in Penghu County was supported by a wide range of stakeholders including a governmental agency, a state-owned company, and the local government. The central government supports renewable power plant installation in the county by providing financial schemes and works closely with the state-owned company for technology deployment. The state-owned company is responsible for plant operation and maintenance over the plants' lifetime. The local government also plays a critical role in facilitating installation of the technologies and connecting public and private sectors to develop a joint venture.

Case study: Penghu Islands

Penghu county is a municipality in Chinese Taipei composed of multiple islands, located around 50km from the main island of Chinese Taipei. It has been relying on submarine cables of maximum capacity of 400MW for electricity in the county. There is now significant amount of solar and wind-based electricity generation (18.2MW solar and 19.2MW wind against approximately 50MW load as of 2022), though the islands still need to rely on the submarine cable when the renewable energy systems cannot produce the electricity. There are ongoing construction projects for solar and wind power systems which can potentially turn the city into a RE100 city. The city will possess 150.6MW and 222MW of solar and wind capacity, respectively, when all power plants are commissioned. With the combination of these power plants with energy storage systems and demand response strategies, Penghu Islands can be turned into RE100 islands. The locations of the power plants are shown in Figure 5.

There would be a number of challenges to turn Penghu islands into RE100 islands. First is the design of power dispatching when both demand and generation can fluctuate, including the management of energy storage. Second is on how to keep the entire energy system stable when there is a power outage on the main grid. Third is the modeling and verification of bi-direction power flow and power storage charge/discharge control which are very different from the conventional power distribution system. To cultivate knowledge, know-hows, and skills to deal with these challenges, National Penghu University of Science and Technology are conducting several demonstration projects, including the grid-connected 100kW PV power and Li-ion battery storage hybrid power system to study the interactions between the system and the main grid, and 10kW BIPV+ Li-ion battery system decentralized power plant to study the characteristics of the decentralized variable renewable energy system with energy storage.

The demonstration projects can help turn Penghu islands into sustainable and robust RE100 city, and Penghu County itself can serve as a testing ground for the Economy which aims to achieve large share of variable renewable energy so that it can clarify the challenges that it may face and find the solutions to address them.

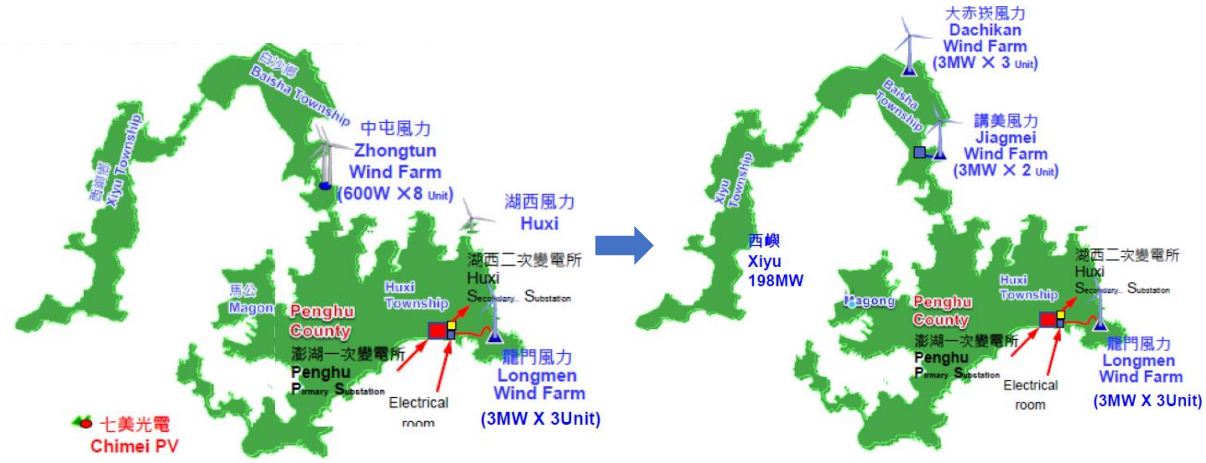


Figure 5 Renewable projects in Penghu County

2.2.2. Coal Phase-out

Economy
Chile

Carbon emission reduction target
Chile targets to reach maximum GHG emissions by 2025. Afterward, it aims to reduce 30% emission intensity below 2007 levels by 2030 under unconditional Nationally Determined Contributions (NDC). And they aim to reduce emission intensity around 35-45% below 2007 levels by 2030 under conditional NDC. Chile plans to achieve carbon neutrality by 2050[17].

Targets, milestones, and strategies of power generation sector
Chile has made good progress in power generation sector. The energy sector in Chile is responsible for 78% of the CO_2 emissions, of which electricity production alone accounts for 32%[18]. Since the 1990s Chilean economic growth has led to a steady increase in energy demand[19]. To guarantee sufficient energy supply and avoid energy crisis, many new coal-fired thermal power plants were constructed. As a result, 40% of Chile's electricity generation is currently based on coal. Chile needs to phase out those coal power plants and substitute them by renewable energy in order to achieve their carbon neutral target. President Piñera unveiled a plan to close all 28 of the economy's coal-fired power plants by 2040[20].

Outstanding decarbonization technology
The geolocation of the Economy will benefit not only solar but also wind power generation which make the production considerably cheap[21]. Moreover, Chile has some of the highest potential for solar in the world, especially around Atacama Desert[22]. Price competitiveness of solar over wind is another advantage for solar to be considered for power generation sector. According to

17 https://www.ndcs.undp.org/content/ndc-support-programme/en/home/our-work/geographic/latin-america-and-caribbean/chile And Chile NDC 2020, https://unfccc.int/sites/default/files/NDC/2022-06/Chile%27s_NDC_2020_english.pdf
18 https://ptx-hub.org/decarbonization-of-the-chilean-energy-sector/
19 https://www.energypartnership.cl/newsroom/coal-phase-out-in-chile/
20 https://www.wartsila.com/insights/article/chile-pledges-to-go-carbon-neutral-by-2050
21 https://www.wartsila.com/insights/article/chile-pledges-to-go-carbon-neutral-by-2050
22 https://energytransition.org/2018/07/is-an-energy-revolution-underway-in-chile/

Renewable Power Generation Costs of IRENA published in 2017, the installed costs of utility-scale solar PV projects fell by 68% (73% with Levelized Cost of Electricity (LCoE) methodology) between 2010 and 2017[23]. The total installed cost of newly commissioned Concentrated Solar Power (CSP) projects fell by 27% (33% with LCoE methodology) during the period.

Selected enabling policy tool

The Law No. 20.257, also known as Non-Conventional Renewable Energy Law, was enacted on 1 April 2008 aiming to fulfill future energy requirements by developing non-conventional renewable energy sources, such as geothermal, wind, solar, tidal, biomass and small hydroelectric plants[24]. 5.5% of all energy removed from the system shall be subject to this mandate in 2015, 6% in 2016, and so on, until reaching the goal of 10% by 2024. This will facilitate the steady transition towards renewable energy sources. Apart from this policy, the Chilean government has developed a long-term energy public policy, the Energy Agenda 2050. It was presented in 2014, including goals, new rules for the public sector, CO_2 tax, and abundant legislative agenda. To enforce the Non-Conventional Renewable Energy Law and the Energy Agenda 2050, a committee consists of relevant parties: government agencies, private companies, NGOs, academia, and municipalities, responsible for reinforcing the policy tools, was set up to steadily transform into renewable energy-based supply. Government agencies would play a role in introducing Non-Conventional Renewable Energy Law to engage relevant sectors to promote use of renewable energy and facilitate the transition. The private sector could align organizational goals with the Energy Agenda 2050 where goals to new rules should be adopted to facilitate decommissioning of coal-fired power plants. NGOs, academia, and municipalities could make scientific contributions on energy transition and the policy tools, while cooperating with both government and private sectors. The transition plan towards renewable energy will accelerate coal-fired power plant decommissioning and enable meeting its plan in 2040.

Case study: Decarbonization through coal phase-out

Chilean Ministry of Energy and Ministry of Environment has launched a project name "Decarbonization of the Chilean Energy Sector" from 2019 to 2022 to reduce the emission from power sector. The project is intended to help Chile achieve its ambitious climate change mitigation goals. The project wants to make sure innovative and sustainable approaches are being pursed for the alternative use of the existing infrastructure of coal-fired power plant that will be decommissioned in the future[25].

The project started during COP25 as GIZ supported the Chilean government in organizing the UN Climate Change Conference. At that time, GIZ also proposed new approaches to supply energy. Consequently, coal phase-out will be addressed, and they also include social compatibility of the shutdown of coal-fired power plants, development of necessary infrastructure for the introduction of a carbon market, and a regular exchange between the Chilean Ministry of Environment and the Ministry of Energy.

The expected effects of the project are to further expand the use of renewable energy, and to contribute to the complete decarbonization of the energy sector. It is expected that the emission

23 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf
24 https://climate-laws.org/geographies/chile/laws/law-no-20-257-on-non-conventional-renewable-energies https://www.iea.org/policies/4853-non-conventional-renewable-energy-law-law-20257
25 https://4echile.cl/wp-content/uploads/2020/08/Decarbonization-of-the-Chilean-energy-sector.pdf

value will be reduced to around 0.05tCO_2eq/MWh by 2022[25] combined with an increased share of non-conventional renewable energy (ERNC) in electricity production to 25%. This should result in at least 13MtCO_2 avoided GHG emissions by project completion.

Chile is well on the way to phase out coal from its energy mix, expecting to have decommissioned 18 out of 28 power plant, equivalent of 65% of the coal capacity by 2025[26]. Enel Chile is the first company in Chile to shut down its entire coal fleet 18 years ahead of the decarbonization target set in 2019[27]

The power supply of Chile is interesting as most of the power production currently relies on coal power plant. The transition towards non-coal power plants is still undergoing discussion in many Economies as alternative power generation sources such as solar, wind may not be sufficiently reliable for a large-scale generation. The journey that Chile takes to phase out its coal power plant can be considered as an alternative for several Economies being put under similar circumstances.

Figure 6 Enel Chile decommissioning plant

26 https://www.energypartnership.cl/newsroom/coal-phase-out-in-chile/
27 https://www.enel.com/media/explore/search-press-releases/press/2022/10/enel-becomes-the-first-company-in-chile-to-stop-using-coal-for-electricity-generation

2.2.3. Peer-to-peer trading platform

Economy
Thailand

Carbon emission reduction target
Thailand made a pledge at COP26 to cut off GHG emissions by 40% comparing to 2005 level by 2030 subject to foreign technological and financial support, achieve carbon neutrality by 2050, and have net zero emissions of all GHGs by 2065[9]. It has updated Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) in November 2022 which expect significant contribution from energy sector to carbon emission reduction, especially the power generation sector[28].

Targets, milestones, and strategies of power generation sector
The two energy plans that governs the emission reduction in Thailand are the Alternative Energy Development Plan 2018[29] that aims to increase to proportion of renewable energy in electricity generation to 30% by 2037 and the Energy Efficiency Plan 2018 that aims to reduce the energy intensity by 30% comparing to 2010 by 2037[30]. However, the government is launching a new National Energy Plan that integrates five key energy plans, including the Power Development Plan, the Alternative Energy Development Plan, the Energy Efficiency Plan, the Gas Plan, and the Oil Plan. This plan will include a target of over 50% of renewable energy share in power generation by 2050[28]. The Ministry of Energy comes up with 4D1E strategy, consisting of digitalization, decarbonization, decentralization, de-regulation, and electrification, to achieve this target and other ambitious targets set forth by the government[31].

Outstanding decarbonization technology
As can be seen in Figure 7, the plan to significantly increase the share of renewable energy relies on biomass, biogas, solar, and wind at first, and will later increase dependency on solar or wind with battery storage. It is anticipated that solar and wind together would account for 65% of total electricity generation by 2060[28]. This would perfectly synchronize with the 4D1E strategy, as the decentralized solar or wind power plants connected to digital platform would contribute to decarbonization of power generation and electrification of other sectors, particularly the transport sector. De-regulation is then inevitable to materialize this idea at an economy scale.

Selected enabling policy tool
De-regulation is needed to enable an economy-wide introduction of renewable energy, and Thailand would need to gradually shift from enhanced single buyer model to a more flexible electricity market[32]. However, as there could be various risks associated with this transition, the Energy Regulatory Commission of Thailand (ERC) approved 25 projects under the ERC Sandbox to demonstrate various innovative and smart business models to introduce more decarbonization technologies. Peer-to-peer and bilateral energy trading are among the categories that caught most

28 https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf
29 https://www.dede.go.th/download/Plan_62/20201021_TIEB_AEDP2018.pdf
30 https://www.dede.go.th/ewt_w3c/ewt_dl_link.php?filename=index&nid=54495
31 http://www.eppo.go.th/index.php/th/component/k2/item/17090-news-040864-1
32 https://iea.blob.core.windows.net/assets/19f9554b-f40c-46ff-b7f5-78f1456057a9/ThailandPowerSystemFlexibilityStudy.pdf

attention from the stakeholders, with 137 submitted projects and eight approved projects[33]. ERC Sandbox facilitates regulation lifts under specified conditions, and thus, it needs a wide range of stakeholders to facilitate the implementation. Government agencies related to energy regulations could design ERC Sandbox schemes for energy industry to demonstrate renewable energy trading within and among communities. Actors in the energy industry, such as system developers, plant owners and operators, make use of the ERC Sandbox to improve the energy trading scheme and system, and develop a flexible electricity market for future energy users and consumers. Though service providers do not engage in energy trading scheme development, they could play a critical role at a later stage on a larger-scale implementation. Additionally, energy trading under the ERC Sandbox offers an opportunity for energy producers and users to become prosumers which produce and consume energy at an optimal price. Exercises of energy trading by prosumers would support the demonstration of decentralized systems and de-regulation.

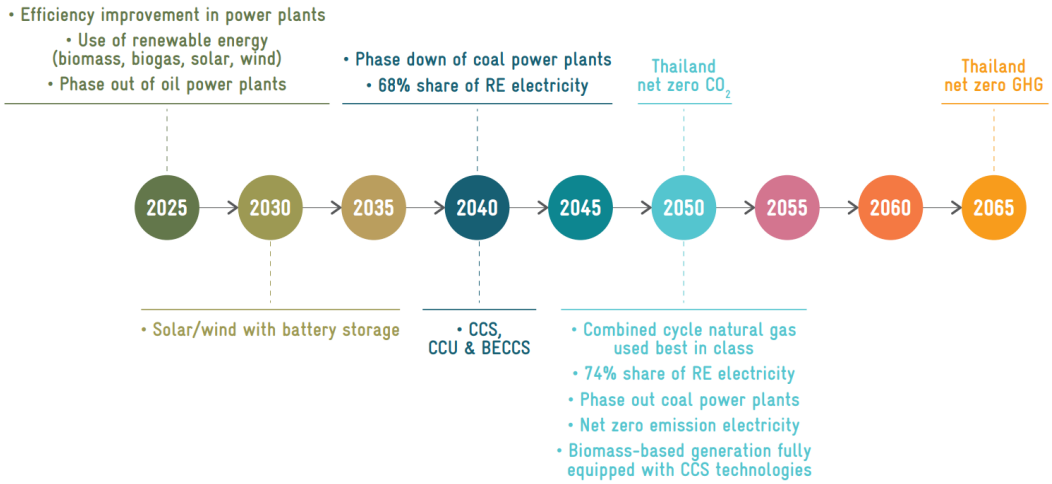


Figure 7 Net zero GHG emission timeline for Thailand's power generation[28]

33 https://www.asiacleanenergyforum.org/wp-content/uploads/2020/07/phimsupha_kokchang_acef-2020-dg-ddw_thailand-final-version.pdf

Case study: Town Sukhumvit 77 (T77)[34]

Figure 8 T77 community[35]

Town Sukhumvit 77 (T77) is one of the peer-to-peer (P2P) energy trading projects under the ERC Sandbox. Solar panels were installed on the rooftop of the prosumers with the main aim for internal use. Since the power use may differ depending on the prosumers' demand, the excess electricity can be sold to other prosumers and consumers via the P2P energy trading platform using blockchain.

In the T77 project, solar panels of BCPG Public Company Limited with a total capacity of 635kW were installed on the rooftops of three prosumers, including Bangkok Prep International School, Habito Community Mall, and Park Court Grand Apartment. The Dental Hospital joined the project as a consumer in this phase. Trading of electricity among these stakeholders is enabled by blockchain operated by Power Ledger. Installed capacity and demand of each stakeholder is summarized in Table 1.

According to the trading data in 2020, Bangkok Prep International School exported significant amount of electricity generated by its solar system since the school uses considerably less electricity during Saturdays and Sundays which can fulfill the demands of Habito Community Mall, Park Court Grand Apartment, and Dental Hospital. This model could make use of excess electricity generated by solar or other variable renewable energy (VRE) systems. Solar energy consumption of the whole system is reported to rise from 17.8% to 20.2% due to P2P trading. In 2021, Sansiri Head Office and Hasu Haus Condominium joined the platform, which made the system a little more complicated. Even with Sansiri Head Office as an additional electricity exporter during weekends, the electricity trading continued with negligible amount of electricity being returned to the grid.

34 Most information is based on the interview of BCPG Public Company Limited on 23 November 2022.
35 https://www.t77community.com/en/

Table 1 Installed capacity and demand of prosumers and consumer in T77 project

Prosumer/consumer	Installed capacity (kW)	Demand (kW)
Bangkok Prep International School	413	200-800
Habito Community Mall	54	300-500
Park Court Grand Apartment	168	150-300
Dental Hospital	–	150-250

This project demonstrated the ability of P2P trading using blockchain to facilitate electricity trading within decentralized power systems. With this kind of platform, more renewable energy sources can be introduced to the electricity mix with less capacity of energy storage system while limiting the amount of excess electricity as it can be exported to other prosumers in need of electricity. This P2P platform sandbox project is a crucial step towards a deregulated electricity market in Thailand.

2.2.4. Wind Power Island

Economy
The United States (US)

Carbon emission reduction target
The White House has launched the federal sustainability plan aiming to achieve a 65% emission reduction from federal operations by 2030 and net zero carbon emission by 2050[36]. New York State's Climate Act is among the most ambitious climate laws (Climate Act) in the Economy and requires New York to reduce economy-wide greenhouse gas emissions 40% by 2030 and no less than 85% by 2050 from 1990 level[37].

Targets, milestones, and strategies of power generation sector
The US government introduced eight actions that need to be accomplished by 2030 in order to reach net-zero carbon emission by 2050[38]. The action plan covers various sectors such as power sector, transport sector, building sector, and even the R&D plan for future technologies. In this section, only the action plans that are related to the power sector are introduced. First, they aim to increase solar and wind capacity by 3.5 times, to 500GW and eliminate most electricity generation from coal. However, the natural gas power generation is maintained to utilize for reliability reason.

36 https://www.whitehouse.gov/ceq/news-updates/2021/12/13/icymi-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/
37 Climate Action Council Draft Scoping Plan (2021) https://climate.ny.gov/resources/draft-scoping-plan/#:~:text=The%20Climate%20Action%20Council%20was,than%2085%20percent%20by%202050.
38 https://www.unsdsn.org/carbon-neutral-pathways-for-the-united-states

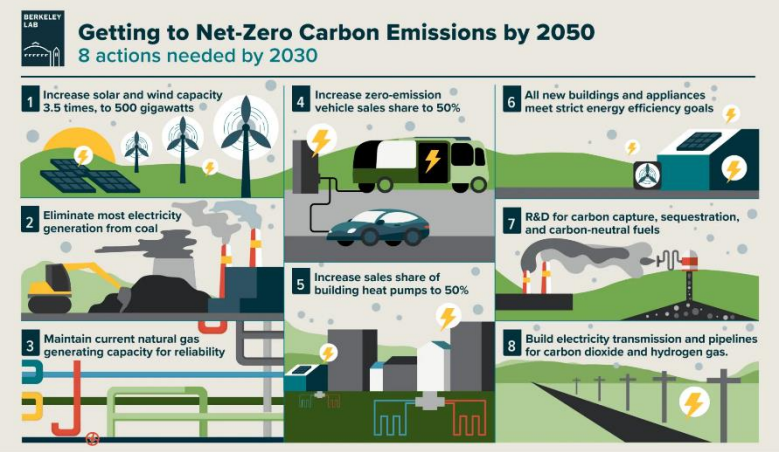


Figure 9 Eight actions needed by 2030 to get net-zero carbon emission[38]

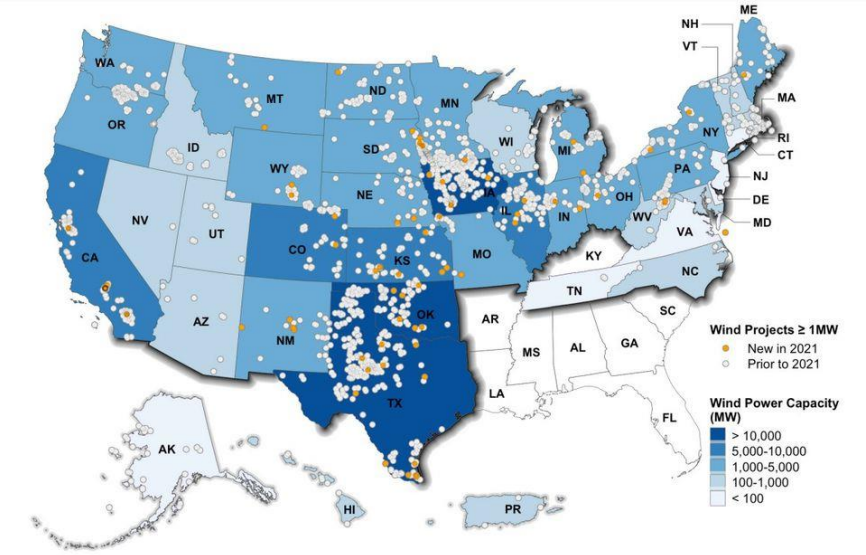


Figure 10 Location of the US wind power capacity in 2021[39]

The White House recently aims to have 80% clean power on its grid by 2030[40] and fully clean electricity generation by 2035[41]. This is a crucial foundation to attain net zero emissions no later than 2050. 13 mayors sent a letter to support this power sector target[42]. The Economy's grid is currently just 40% clean, but it is expected to reach 80% by 2030 with existing technologies at no additional cost to ratepayers in every region because the cost of renewables and batteries have significantly decreased[40].

New York's climate target is divided into several steps as shown in Figure 11. Not only renewable energy but also energy storage is introduced to decarbonize the power sources. New York plans to achieve 70% electricity from renewable energy and 100% zero-emission electricity by 2040.

39 Department of Energy's, Land-based wind market report, August 2022.
40 https://energyinnovation.org/publication/2030-report-powering-americas-clean-economy/
41 https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf
42 https://www.cnbc.com/2021/04/26/white-house-pushing-for-80percent-clean-us-power-grid-by-2030.html

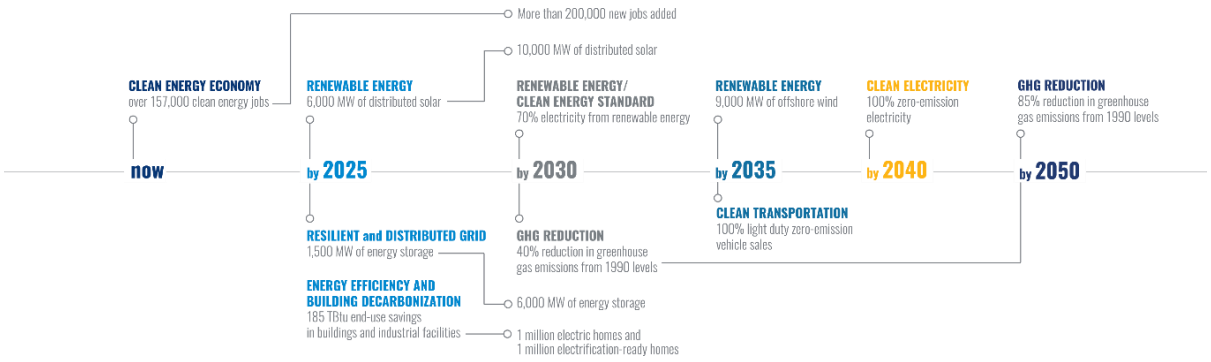


Figure 11 New York's climate targets

Outstanding decarbonization technology

Renewable energy is a great source to supply energy in the zero-emission society as it does not release pollutants. Renewable energy consists of wind energy, solar energy, hydropower, bioenergy, and geothermal energy[43]. Appropriate forms of energy should be selected to benefit from the advantage of geolocation. Wind energy have been widely utilized in several states of the United States. The US is the second largest producer of wind energy in the world[44]. Wind shares major proportion in renewable energy sources in the US (379.77 billion kWh in 2020 while solar is only 114.68 billion kWh in the same year). Wind has been implemented across the Economy with the support from governmental subsidies.

Selected enabling policy tool

The Inflation Reduction Act (IRA)[45] extends tax credits for wind and solar for the next ten years and allows standalone energy storage projects to qualify for the first time. "The IRA unlocks these possibilities of going bigger and also going to other places where you might have not thought of before," said Marcelo Ortega, a renewable analyst at Rystad Energy[46]. The bill also includes tax credits for the manufacturing of wind and solar components. IRA allocates USD11.7 billion for Initial Public Offering (LPO) to support issuing new loans, increase existing loan program authority by approximately USD100 billion, allocates USD5 billion for a new loan program. Besides, the Energy Infrastructure Reinvestment (EIR) program allows up to USD250 billion in loans. The Inflation Reduction Act could promote wind and solar technology deployment at a large scale, contributing to GHG emission reduction in the economy, though it requires several stakeholders to carry out the implementation and distribute financial support from the central government to state governments and private enterprises. The central government is an important stakeholder to inject billions to ensure energy security and address climate change in accordance with the Act. Further than that, the central government puts the Act into force, engages state governments and provides both loans and tax credits for wind and solar technology and budget for administrative expenses to attract private enterprises' investment. In this sense, actors at the state government level facilitate the enforcement of the Inflation Reduction Act and loans and tax credits distribution to private enterprises. With the cooperation among the central government and actors at state

43 Renewable Energy (Office of Energy Efficiency and Renewable Energy) https://www.energy.gov/eere/renewable-energy
44 https://www.power-technology.com/features/us-wind-energy-by-state/
45 https://www.energy.gov/lpo/inflation-reduction-act-2022
46 https://www.reuters.com/business/energy/us-tax-credits-set-spur-bigger-wind-farms-new-siting-strategies-2022-10-20/

government level, private enterprises obtain an opportunity to access the credits provided under the Act.

Case study: South Fork Wind

South Fork Wind will be New York's first offshore wind farm which is a centerpiece of New York's ambitious offshore wind energy goal[47]. There are 12 turbines along East Hampton beaches which started the construction in early 2022[48]. Because the wind farm just recently started the construction, the project receives the tax credit and benefit from the Inflation Reduction Act that set to spur bigger wind farms.

South Fork Wind develops offshore wind farm as a 50/50 partnership between Ørsted and Eversource. Ørsted is a global leader in offshore wind and a global leader in climate action, and Eversource is a domestic energy leader with homegrown expertise in regional energy transmission, including more than 100 years of experience delivering power to the region. The 132MW offshore wind farm will produce enough power for 70,000 homes. And the farm will reduce the GHG emission equivalent to taking 60,000 cars off the road.

The reason behind the construction of South Fork Wind is to respond to power demand on Long Island due to the fast growing of its population. South Fork is the one out of the 20 proposals that can tackle the problem in the most cost-effective manner. South Fork Wind aim will help the Town of East Hampton meet its 100% renewable energy goals and help New York to realize its vision of becoming a leader in clean energy.

The wind farm will be more beneficial if integrated with energy storage. This will increase the reliability of the energy and the additional cost can be facilitated by the inflation reduction act.

Figure 12 The location of South fork wind farm[49]

47 https://orstedcdn.azureedge.net/-/media/www/docs/corp/us/south-fork-wind/sfw-factsheet-202107.ashx?rev=86e07837726b488cb268b784b328e0ce&hash=21D3FC83A948A60DACC6BD1AC2124EAD
48 https://southforkwind.com/
49 https://southforkwind.com/about-south-fork-wind

2.3. Transportation Sector

2.3.1. City-scale Deployment of New Energy Vehicles

Economy

People's Republic of China

Carbon emission reduction target

People's Republic of China pledged to achieve carbon neutrality by 2060. Being the world's biggest producer and consumers of energy with 28% of global total carbon emissions[50], People's Republic of China announced to reach its peak for carbon emissions before 2030 and gradually reduce to the set target. To achieve carbon peaking and carbon neutrality goals, the economy has to maximize the deployment and the use of renewable energy. This implies significant changes in how the economy produces and consumes energy. Though the coal share in the economy's energy mix declines around 10% between 2012 and 2019, coal remains the primary source of energy in the economy[51]. Indicated by IRENA, the economy aims for direct and indirect electrification of three main sectors, namely building, industry and transport, along with sustainable use of bioenergy, hydrogen, and synthetic fuels[51].

Targets, milestones, and strategies of transportation sector

According to the New Energy Vehicle Industrial Development Plan for 2021 to 2035[52] (hereinafter referred to as "the Plan"), People's Republic of China attempts to strengthen and build competitiveness for its auto industry to stand at the front line of the world. The Plan is solely developed for new energy vehicles (NEVs)[53]. People's Republic of China determines crucial targets for development of electric vehicles in near-, mid-, and long-terms. It promotes the NEV market by setting sale penetration target for 100% electrification of the stock of public fleet and makes battery electric vehicles (BEVs) the mainstream of the new vehicle sales.

Outstanding decarbonization technology

As can be seen in Table 2, NEV is the key technology that the economy aims to deploy on streets and address economy's challenges in oil conservation, air pollution reduction, and climate mitigation. By 2020, the fleets of NEVs accounted for 4.92 million which almost reach the NEV sales target set in, the former NEVs development plan, Energy-Saving and New Energy Vehicles Industry Development Plan for 2012 to 2020[54,55]. Continuing the momentum, People's Republic of China progresses the Plan for further enhancement of auto industry and contribution to its carbon neutrality goal.

---

50 https://www.irena.org/publications/2022/Jul/Chinas-Route-to-Carbon-Neutrality

51 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_China_Carbon_Neutral_2022.pdf?rev=8ab20715805140dcb8ff28f1c064b94d

52 https://theicct.org/wp-content/uploads/2021/12/China-new-vehicle-industrial-dev-plan-jun2021.pdf

53 In Chinese context, NEVs refer to battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs, also included extended-range electric vehicles), and fuel cell electric vehicles (FCVs).

54 https://policy.asiapacificenergy.org/sites/default/files/Energy-Saving%20and%20New%20Energy%20Automobile%20Industry%20Development%20Plan%20%282012-2020%29.pdf

55 https://policy.asiapacificenergy.org/sites/default/files/节能与新能源汽车产业发展规划（2012—2020年）.pdf

Table 2 Targets in New Energy Vehicle Industrial Development Plan for 2021 to 2035[52]

	Starting in 2021, near term	By 2025, mid term	By 2035, longer term
NEV market	≥ 80% NEVs in new or renewal public fleets (e.g., buses, taxis, and delivery vehicles) in pilot zones and key air pollution regions		100% electrification of the stock of public fleets
	—	~20% NEV annual sales	BEVs become the mainstream of new vehicle sales
Key technology breakthrough	—	Average electricity consumption of new passenger BEVs = 12.0 kilowatt hours (kWh)/100 kilometers (km)	NEV core technologies reach world-class levels
Autonomous driving	—	Commercialize autonomous driving in specific areas and scenarios	Scale-up the application of highly autonomous intelligent and connected vehicles
FCV	—	—	Commercialize FCVs
Charging and refueling	—	Significantly improve charging and battery swapping services	Build the foundation for a hydrogen fuel supply system Build efficient and convenient charging and battery swapping networks

Selected enabling policy tools

To achieve the targets in the Plan, People's Republic of China previously focused on establishing core regulatory standards and test procedures for NEVs, their parts, and their infrastructure in the NEVs development plan for 2012-2020. However, the current Plan expands the regulatory and technical requirements to include smart driving and shared mobility. Regulations and incentives have been set in the Plan to accommodate NEV development. Among strategic tasks and policy enhancement set under the Plan, crucial enabling policy actions are shifting from direct subsidies for NEVs to taxation exemptions, charging subsidies, and parking incentives, and incentivizing research and development investment from state-owned enterprises, and enhancing the NEV mandate policy and exploring its integration with the carbon trading mechanism. Regulations and incentives for NEVs provided by central government could lead to large-scale development of electric vehicles and charging stations, though it needs government agencies to implement regulations and actors at different levels to distribute incentives and maximize benefits. The central government is involved in regulation and standard setups. The city government works closely with the finance commission of the municipality to give out incentives for NEVs and establish core regulations and standards, while the local association and committee connect electric vehicle private enterprises or joint ventures with government agencies to engage in the incentive program. Private enterprises or joint ventures could play a critical role in supplying electric vehicles and developing charging stations based on the incentives received. Cooperation among the central government, government agencies, the local association and committee, and private enterprises could maximize the use of regulations and incentives.

Case study: People's Republic of China's first EV taxi fleet in Shenzhen

Transport sector becomes one of the largest carbon emission contributors in People's Republic of China. Shenzhen, a city in southern China's Guangdong province, has been spending resources to phase out diesel vehicles serving populations of over 12 million in the city. Supported by United Nations Human Settlements Programme (UN-Habitat)[56], Shenzhen government planned to turn itself into a green city by introducing electric vehicle and conducted a program for the deployment under the name "People's Republic of China's first EV taxi fleet in Shenzhen". The program aims

56 https://unhabitat.org/sites/default/files/download-manager-files/Module%206%20-%20Annexure%20E%20case%20study%20Shenzhen.pdf

for 24,000 electric vehicle deployments and 12,000 charging station installations by 2012. At the beginning, the central government of People's Republic of China subsidized each purchase of electric vehicle (EV) taxi with up to CNY60,000 and the first batch of 100 EV taxis operated by Pengcheng Electric Vehicle Taxi company limited (a joint venture between a Chinese car manufacturer and the Shenzhen Bus Group) ran on the street of the city.

It is claimed that running an EV taxi for 100km costs CNY30 while a traditional taxi consumes 12l of gas which costs more than CNY60 with the same distance. This program sets a high expectation on deployment of an EV taxi as it can reduce local emissions of 5.18t each year when compared to a traditional taxi. However, Shenzhen later faced real obstacle in commercializing EV taxis as the nature of EV taxi involves higher vehicle price, management cost, maintenance and repair costs, and infrastructure cost. The central and local government developed strong policies[57] to accelerate the industrial growth by subsidizing manufacturers and consumers for upfront cost. This resulted in the success of EV taxi deployment. In 2019, traffic authority of Shenzhen reported that EV taxis have a share of over 70% of vehicles on the street. The entire EV fleet is estimated to cut carbon emissions by 856,000t a year for Shenzhen alone[58].

This program reveals that deployment of EV in the city where transport sector is the largest contributor to carbon emission, can result in a large volume of emission reduction. Direct subsidies drove the customer demand to the level that it can continue to thrive without the program [59]. Thus, the People's Republic of China's central government shifted to taxation exemptions as the subsidies with high growth rate of EV usage becomes a financial burden for the government. Tax exemption will remain as an important driver to push NEV sales in the city and the economy.

Figure 13 EV Taxi Fleet in Shenzhen

57 https://theicct.org/sites/default/files/publications/China-green-future-ev-jan2021.pdf
58 https://techcrunch.com/2019/01/04/shenzhen-electric-taxis-push/
59 https://www.china-briefing.com/news/china-considers-extending-its-ev-subsidies-to-2023/

2.3.2. Hydrogen Energy Demonstration Project

Economy
Japan

Carbon emission reduction target
Japan aims to reduce greenhouse gas emissions by 46% in fiscal year 2030 from its fiscal year 2013 levels, equivalent to reducing emission to 760MtCO_2, while continuing strenuous efforts in meeting the lofty goal of cutting its emission by 50%. Like many other economies, Japan wants to achieve carbon neutral by 2050[60].

Targets, milestones, and strategies of transportation sector
According to Green Growth Strategy 2020, for automobile industry, Japan aims for 20-30% of new vehicle sales to be electrified by 2030 and achieve 100% of new passenger vehicle sales being vehicles that are electrically driven by 2035[61]. Vehicle electrification can be done by using either battery electric vehicle or hydrogen fuel cell. As Japan is one of the leading economies when it comes to hydrogen technology and industry, the government plans to install 1,000 of hydrogen stations in optimal locations by 2030 in order to promote the usage of fuel cell electric vehicles.

Outstanding decarbonization technology
There are currently quite a number of decarbonizing technologies available in the transportation sector. Japan is one of the economies that have been investing not only on R&D but also have considerable experience in implementing the technology when it comes to hydrogen. There are 729 hydrogen refueling stations being operated across the economy[62]. The government issued JPY12.5 billion (USD114 million) to build hydrogen refueling stations and EV charging stations to support zero emission vehicle (ZEV) deployment. In the first National Hydrogen Strategy issued in 2017, Japan seeks to decarbonize itself by leveraging hydrogen energy use in not only transportation but also industry, power production, and other fields.

Selected enabling policy tool
Green Growth Strategy is announced in 2020 to achieve carbon neutrality in 2050. The strategy sets out 14 promising fields in which future growth is expected, and where efforts are essential for achieving the reduction of greenhouse gas emissions[63]. Automobile/battery industry is located under transportation/manufacturing-related industries.

60 https://unfccc.int/sites/default/files/NDC/2022-06/JAPAN_FIRST%20NDC%20%28UPDATED%20SUBMISSION%29.pdf
61 https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/05_automobile.pdf
62 https://www.meti.go.jp/english/policy/energy_environment/global_warming/roadmap/innovation/thep.html
63 Kizuna (2021) Japan's Green Growth Strategy Will Accelerate Innovation, Link: https://www.japan.go.jp/kizuna/2021/09/green_growth_strategy.html

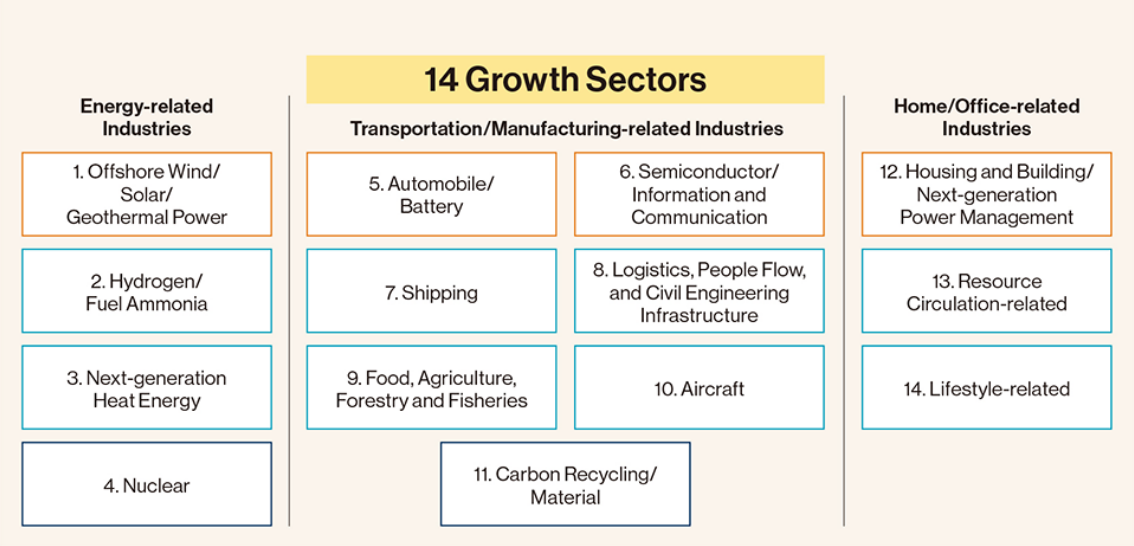


Figure 14 Green growth strategy[64]

The strategy lays out several steps essential for the hydrogen industry. The strategy is to focus first on increasing the volume of hydrogen introduced in society. Making hydrogen power generation turbines and fuel cell trucks into marketable products is one of the urgent tasks specified in the strategy. It also puts emphasis on measures to strengthen hydrogen supply and storage by developing pilot projects that can represent the actual business cases. The progress in hydrogen energy development lies in cooperation between stakeholders ranging from the central government, local governments, state-owned companies, to private companies. Setting up the hydrogen energy research field requires financial support. The central government is the key organization to allocate a large portion of budget to develop the research field. Local governments, such the metropolitan government, accommodate land acquisition for the development of hydrogen energy research field. The state-owned enterprise is responsible for transporting hydrogen energy produced in the research field to hydrogen stations and should join hands with private enterprises to develop the hydrogen stations to meet the required standards for commercial use. Private enterprises develop hydrogen-based technology such hydrogen power generators and hydrogen-fueled vehicles to demonstrate the application of hydrogen energy. The cooperation among stakeholders from an early stage to a later stage of hydrogen energy development could fulfill the aim of Green Growth Strategy to expand the volume of the domestic introduction to 3Mt in 2030 and 20Mt in 2050 while reducing its cost to JPY30/Nm^3 (less than 1/3 of current level) by 2030 and JPY20/Nm^3 (which is below gas-fired power plant costs) by 2050[65].

Case study: Fukushima Hydrogen Energy Research Field (FH2R)

Japan is highly focused on securing access to hydrogen feedstocks. Therefore, it has begun to test various options for sourcing hydrogen. Fukushima Hydrogen Energy Research Field (FH2R) has consistently been ranked as one of the world's largest projects of its kind and also served as hydrogen production plant and hydrogen refueling station. Fuel cell buses operated by Tokyo Metropolitan Government are also powered by the hydrogen generate from this plant[66]. The

64 https://www.japan.go.jp/kizuna/2021/09/green_growth_strategy.html
65 The International Trade Administration, US Department of Commerce (2021) Japan focuses on hydrogen as a key renewable energy source
66 https://www.japan.go.jp/kizuna/2022/06/clean_energy_strategy.html

buses have been developed and marketed by Toyota Motor Corporation in 2017[67]. The provincial government plans to increase the use of fuel cell buses as part of its strategy to contribute to the hydrogen society. The bus return route is from Tokyo Station, Marunouchi South Exit to Tokyo Big Sight.

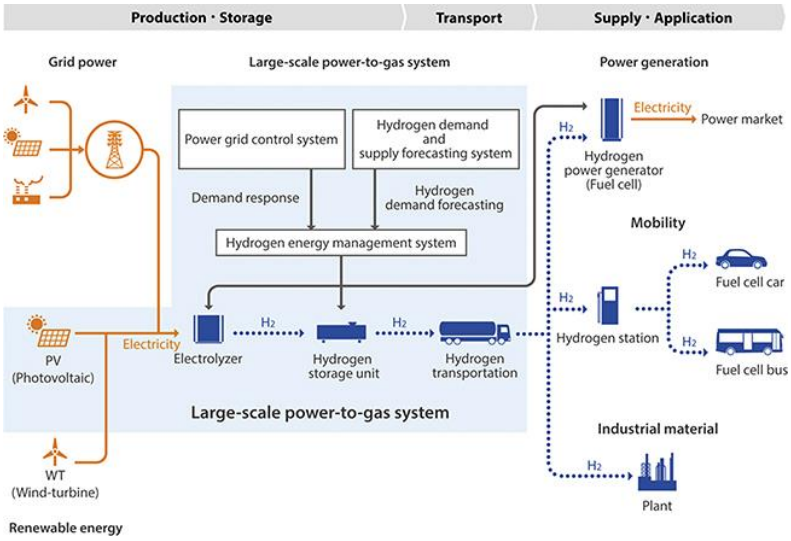


Figure 15 FH2R production, store, and supply diagram[68]

FH2R uses a 20MW solar PV array built on a 180,000m^2 site along with grid electricity to power a single stack 10MW alkaline water electrolysis which is developed by Asahi Kasei. The plant can produce, store, and supply up to 1,200Nm^3/h of hydrogen at rated power operation[69]. Toshiba, which served as the project's leading engineering, procurement, and construction (EPC) provider, is today responsible for the management of the project, as well as the overall hydrogen energy system. There are two important project goals: (1) to develop commercial strategies for utilizing hydrogen; (2) to implement demand-based hydrogen.

As the plant relies on renewable energy of which the output is subject to large fluctuation, FH2R is still figuring out to adjust to supply and demand in the power grid in order to maximize utilization of this energy while enabling low-cost and green hydrogen production technology. The key objective is to test a hydrogen energy management system to achieve the optimal combination of production and storage of hydrogen and power grid supply-demand balancing adjustments without using storage batteries. The selling price of the hydrogen out of this plant is not publicly available but the government state in the basic hydrogen strategy in 2017 that the retail price of hydrogen is currently around JPY100/m^3[70].

67 https://www.metro.tokyo.lg.jp/ENGLISH/TOPICS/2017/170224.htm
68 https://www.chemengonline.com/japans-new-technology-development-project-focused-on-green-hydrogen/?printmode=1
69 https://www.powermag.com/fukushima-hydrogen-energy-research-field-demonstrates-hydrogen-integration/
70 https://www.ifri.org/sites/default/files/atoms/files/nagashima_japan_hydrogen_2018_.pdf

Figure 16 The Fukushima Hydrogen Energy Research Field[71]

Figure 17 Hydrogen electrolysis of 10MW Fukushima plant[72]

71 https://www.powermag.com/fukushima-hydrogen-energy-research-field-demonstrates-hydrogen-integration/
72 https://www.energy-storage.news/hydrogen-electrolysis-using-renewable-energy-begins-at-10mw-fukushima-plant/

2.3.3. Well-planned Electric Vehicle Subsidies

Economy

Republic of Korea

Carbon emission reduction target

Republic of Korea (ROK) aims to reduce its greenhouse gas (GHG) emission by 40% by 2030 from the 2018 level[73] and attain carbon neutrality by 2050. Republic of Korea has already taken two significant steps towards achieving these goals[74]. The economy has passed the new legislation to become carbon neutral by 2050 under Carbon Neutrality Act[75]. In addition, both central and provincial governments are developing their own implementation plans to reduce carbon emission under the law.

Targets, milestones, and strategies of transportation sector

Transportation sector emission alone accounted for 14% of Republic of Korea's total emission in 2017[76]. Fuel economy improvement, battery and fuel cell electric vehicles, hybrid/plug-in hybrid electric vehicles, and carbon free fuel hydrogen or ammonia are technologies enabling carbon neutral transition in transportation sector. Republic of Korea plans to utilize electricity and hydrogen to decarbonize the energy use in the transportation sector. The Government has issued Nationally Determined Contributions (NDC) specifically for the transportation sector. The report mentioned that Republic of Korea aims to cut the emission about 37.8% by 2030 compared with the peak emission in 2018. The emission will be further reduced by scenario A and B in 2050. Scenario A will reduce the emission by about 2.8Mt by 2050 by utilizing the pure electric vehicle around 80% and hybrid electric vehicle 17%. Scenario B will help reduce the emission by about 9.2Mt by utilizing not only the electric vehicle and hybrid electric vehicle but also other the remaining vehicle that use conventional fuel to e-fuel. The diagram of the steppingstone in decarbonization in transportation sector is available in Figure 18.

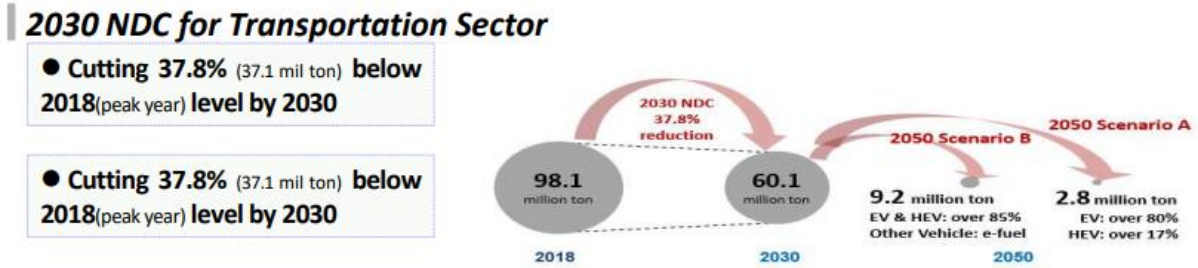


Figure 18 The 2030 NDC for transportation sector[77]

73 https://unfccc.int/sites/default/files/NDC/2022-06/211223_The%20Republic%20of%20Korea%27s%20Enhanced%20Update%20of%20its%20First%20Nationally%20Determined%20Contribution_211227_editorial%20change.pdf

74 https://keia.org/the-peninsula/2021-in-review-south-koreas-push-to-become-carbon-neutral/

75 http://eng.me.go.kr/eng/web/board/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=461&orgCd=&boardId=1516150&boardMasterId=522&boardCategoryId=&decorator=

76 https://unfccc.int/sites/default/files/resource/LTS1_RKorea.pdf

77 https://olc.worldbank.org/system/files/Presentation1.KOTI%20CRO%20Dr.Ye%202050%20Carbon%20Neutral%20Transport_TT2022_03232022.pdf

Outstanding decarbonization technology

Republic of Korea has seen a rapid increase in sales of electric light commercial vehicle (LCV), reaching 28,000 in 2021 up from just 1,500 two years earlier. This increase is attributed to the innovative policy in Republic of Korea that incentivizes the adoption of EVs for commercial use[78]. The Global EV Outlook 2022 also illustrated that Republic of Korea has a considerable share of highly technical cathode and anode material production capacity. Moreover, Republic of Korea almost tripled eligible funding in 2022 compared with 2021 to meet EV and charging infrastructure targets. Republic of Korea is a perfect candidate to showcase GHG reduction technologies in the transportation sector.

Selected enabling policy tool

Republic of Korea currently relies on transport tax to support the development and maintenance of this sector. The fund from fuel-based tax has contributed to transport infrastructure and public transport[79]. Subsidy is considered in transportation which is supported by the budget from transportation tax. Subsidy scheme and budget allocation are considered crucial means to support the development and expansion of electric vehicles. Several stakeholders ranging from ministries, private enterprises, to local governments should take part in the process. It is important for the subsidy scheme to be jointly designed by relevant ministries; for example, Ministry of Environment and Ministry of Finance, using transportation tax to maximize expected benefits for actors in transportation industry. Private enterprises play a key role in supplying electric vehicles based on market demand and purchase, and benefit from growing sales volume of electric vehicles. The local government facilitates private enterprises in deployment of charging stations.

Case Study: Electric vehicle subsidies

Government subsidies play an important role in rapid increment of the number of electric vehicles in the Economy. Total government funding for electric LCV subsidies increased from KRW210 billion (USD184 million) in 2020, to KRW400 billion (USD349 million) in 2021 and KRW574 billion (USD502 million) in 2022[78]. In 2022, full subsidies were limited to cars priced less than KRW55 million (USD48,100), and only cars priced below KRW85 million (USD74,300) were eligible for 50% of the subsidy amount. The ceiling for 100% of the central government subsidy was brought down to KRW55 million (USD48,077 USD) from the previous ceiling of KRW60 million[80]. Lower cost EV car models benefited from these changes. Republic of Korea extended its subsidy scheme until 2025 in hopes to meet its vehicle electrification targets. Depending on the model, LCVs can receive between KRW9 million and KRW27 million (USD7,900 and USD23,600) in 2022[81].

The subsidies play an essential role in increasing the number of electric vehicles. The increment slope from 2019 to 2021 was significant because electric vehicles started to gain popularity among users, and the government increased the subsidy as well. Figure 19 represents the trend of electric vehicle in Republic of Korea from year 2013 to 2021.

78 IEA, Electric Vehicles Initiative, and Clean Energy Ministerial (2022) Global EV Outlook 2022 Securing supplies for an electric future.

79 https://olc.worldbank.org/system/files/Presentation1.KOTI%20CRO%20Dr.Ye%202050%20Carbon%20Neutral%20Transport_TT2022_03232022.pdf

80 https://pulsenews.co.kr/view.php?year=2022&no=62959

81 https://www.hyundaimotorgroup.com/story/CONT0000000000001680

Even though subsidies play a significant role in expanding the EV market volume, the government needs to spend a huge amount of budget to support the program. Once the scheme for subsidy is established, it is challenging for the government to suddenly stop it as this will make the selling price of those vehicles unattractive to the final consumers. Republic of Korea aims to gradually reduce the subsidy to ensure smooth transition. This gives more time for the car makers to develop technologies to reduce the production cost of electric vehicles.

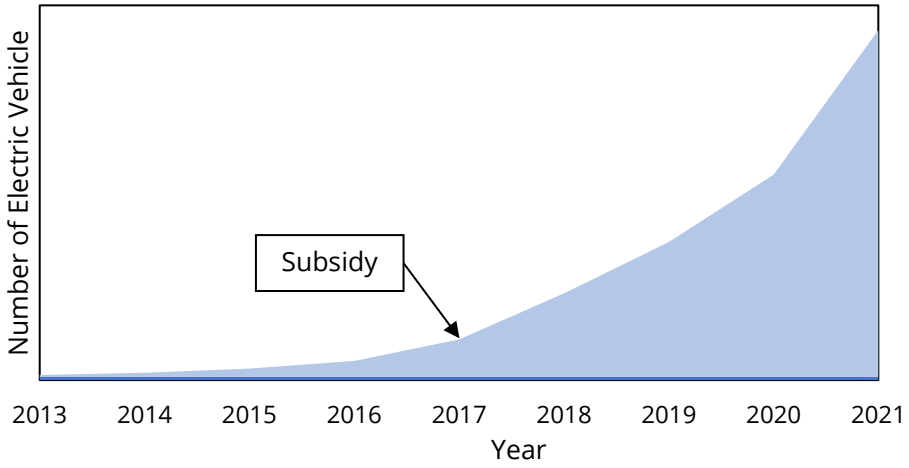


Figure 19 Electric vehicle registered in Republic of Korea[82]

82 https://www.statista.com/statistics/1097976/south-korea-total-registration-number-of-electric-vehicles/

2.4. Building Sector

2.4.1. Retrofitting Building to Achieve Net-zero Carbon Emission

Economy
Canada

Carbon emission reduction target
Canada has joined the growing list of economy commitments to achieve net-zero emissions by 2050. To reach the target, Canada passed an act, the Canadian Net-Zero Emissions Accountability Act, on 29 June 2021, to enshrine the commitment, ensure transparency and accountability of the progress, and encourage public participation. Canada also set actions on three main plans[83], namely, Canada's Strengthened Climate Plan, the Pan-Canadian Framework, and the 2030 Emissions Reduction Plan to provide a roadmap for emission reduction by 40-45% from 2005 levels by 2030.

Targets, milestones, and strategies of building sector
A Healthy Environment and a Healthy Economy plan[84], released in 2020, (hereinafter referred to as the Environment Plan) is a Canadian plan that aims to achieve environmental and economic goals, emphasizing clean air, clean water, and long-term secure jobs. The Environment Plan indicates key five pillars where job employments, climate action and clean growth are considered cornerstones. One of the five pillars, Making the Places Canadians Live and Gather More Affordable by Cutting Energy Waste, presents directions for homes and buildings in the economy in which energy efficient homes and buildings are to be comfortable and cost less. According to Federal Action for a Clean Growth Economy[85] (hereinafter the Federal Actions), homes and buildings are highlighted a key sector as heating, cooling, and lighting systems in Canada building accounted for 12% of the emission. The Government of Canada attempts to react with the carbon emissions from building sector and take an action to develop a "net-zero energy ready" model building code by 2030.

Outstanding decarbonization technology
Paving the Road to 2030 and Beyond: Market transformation roadmap for energy efficient equipment in the building sector[86], released in 2018, focuses on three key energy-using technologies including residential windows, space heating, water heating. The space heating in Canada is the largest source of energy consumption which accounts for 64% of energy used in homes and 56% of energy used in commercial buildings. A variety of space heating technologies are utilized in the economy to provide and maintain comfortable indoor temperature. Currently, heating equipment for residential use is condensing technology and 10% of sales of electrical systems are heat pumps. Development of heat pumps and integration of renewable resources with condensing technology is considered crucial for emissions reduction.

83 https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html
84 https://www.canada.ca/en/environment-climate-change/news/2020/12/a-healthy-environment-and-a-healthy-economy.html
85 https://www.canada.ca/content/dam/themes/environment/documents/weather1/20170119-en.pdf
86 https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/2018/en/18-00072-nrcan-road-map-eng.pdf

Selected enabling policy tool

According to the Environment Plan, the Government introduces 64 new measures and USD15 billion investments, in addition to Canada Infrastructure Bank's USD6 billion for clean infrastructure, which involves financial and implementing supports for efficient homes and buildings. In the Environment Plan, Canada shows efforts to introduce an enabling factor to increase energy efficiency in building sector through a new model called retrofit code for existing buildings issued in 2022. The retrofit code was developed and enforced by Canadian government. The government needs to demonstrate and ensure actual exercises on zero-carbon building retrofit to attract participants and investors. The retrofit code could be implemented in a way that the government agencies collaborate with local governments in provinces and territories to deploy the retrofit code. Private enterprises play a significant role in providing and constructing zero-carbon buildings that meet the required standards. Local governments accommodate both residents in the community and private enterprises in implementing the retrofit code for existing buildings. The central government can extend the retrofit code practices through collaboration with provinces and territories to have this code in place by 2025. With the retrofit code, more buildings in the economy can contribute to carbon emission reduction.

Case study: The Phenix[87]

The Phenix, located in Montreal, Quebec, is a zero-carbon building with a certified retrofit approach. The building, originally built in 1950 and used for industrial purposes, is transformed into an experimental laboratory for testing out new sustainable concepts and approaches. The Phenix is known for its health-promoting, energy-efficient and innovative characteristics. The building decreased a large amount of carbon emissions through upgrading of previous structure instead of a new build. It resulted in an 86% reduction of carbon emission.

The project is designed to minimize the use of new materials by conserving structural concrete of building's floors and original brick walls. This leads to the recognition of Zero Carbon Building Standard certification approved by Canada Green Building Council. Features to reduce its carbon emissions and achieve the standard certification include an upgrade of building's thermal performance which reduces energy consumption related to heating and air conditioning, improvement of advanced LED lighting systems, and integration of solar wall and solar photovoltaic panels. Further than energy efficiency aspect, the Phenix building promotes green transportation as it provides bicycle parking and presents user's health and wellness. The building adopts a combination of natural ventilation and low-emission materials, high-efficiency mechanical system and sensors that provides heating and cooling when required.

87 https://www.cagbc.org/green-building-showcase/green-building-spotlight/case-studies/the-phenix/

Figure 20 The Phenix[88]

With effective approach to upgrade and retrofit old building, adaptive reuse of structure, and diverse sustainability measures, the Phenix is considered one of the most successful cases to introduce energy-efficient building standards with retrofit approach. Apart from reducing greenhouse gas emissions, it also contributes to the reduction of environmental impacts from construction materials at a large scale.

2.4.2. Homes of the Future

Economy
New Zealand

Carbon emission reduction target
New Zealand has committed to achieve carbon neutrality by 2050 and stated the target in its law. The economy set Climate Change Response (Zero Carbon) Amendment Act 2019[89] to take actions to meet the ambition. The Act provides a framework under which New Zealand can contribute to the global effort under the Paris Agreement and allow the economy to prepare for and adapt to the effects of climate change. The New Zealand's carbon emissions reduction target[90] include reduction of net emission of all greenhouse gas (except biogenic methane) to zero by 2040 and reduction of emission of biogenic methane to 10% below 2017 level by 2030, and to 24-47% below 2017 level by 2050.

Targets/milestones and strategies of building sector
According to Aotearoa New Zealand's First Emissions Reduction Plan[91] (hereinafter referred to as Emissions Reduction Plan), New Zealand aims to contribute to the global effort to limit global warming to 1.5°C through setting targets for net-zero long-lived gases[92] by 2050, and a minimum 10% reduction in biogenic methane emissions by 2030 and a reduction of 24-47% in biogenic

88 https://clean50.com/projects/lemay-converts-a-1950s-era-warehouse-into-offices-and-a-laboratory-for-innovations-in-sustainability-and-design-the-phenix-rises-to-save-83-of-annual-energy-costs/
89 https://www.legislation.govt.nz/act/public/2019/0061/latest/LMS183736.html
90 https://environment.govt.nz/acts-and-regulations/acts/climate-change-response-amendment-act-2019/
91 https://environment.govt.nz/assets/publications/Aotearoa-New-Zealands-first-emissions-reduction-plan.pdf
92 In New Zealand context, long-lived gases refer to carbon dioxide and nitrous oxide.

methane by 2050 (compared with 2017 level). Building and Construction sector plays an important role in contributing to the long-term vision of the Emissions Reduction Plan, and New Zealand sets the target for building-related emissions to be near zero and for buildings to provide healthy places to work and lives for present and future generations.

Outstanding decarbonization technology

In 2018, building and construction sector in New Zealand contributes to emission of nearly 7.4Mt CO_2 equivalent. This represents 9.4% of domestic emissions. To reduce the emissions in the sector, New Zealand adopts photovoltaic array as one of the technologies in an initiative 'Homes of the Future'. 24kW_p rooftop photovoltaic array, which requires an area of 105m^2 per building, is claimed to generate sufficient electricity to meet the total demand and achieve Net Zero Energy status. A life cycle assessment conducted for the initiative indicates that the system can eliminate approximately 275t operational emissions over the building lifespan of 90 years[93]. Bi-directional rooftop system can be utilized to support central grid operation to balance demand and supply instantaneously if the building can import and export electricity.

Selected enabling policy tool

In order to reduce emissions from the building sector, New Zealand presents a focus area[94] under the second objective of the Emission Reduction Plan called "improving building energy efficiency" to increase energy efficiency, improve power quality, and drive down energy costs. The focus area is on amendments of the building code to improve new buildings' operational efficiency and encourage emissions reduction of existing buildings. Implementing amendments to Building Code Clause H1 (energy efficiency) compliance pathways and introducing mandatory energy performance certificates for buildings are key initiatives to support existing and new buildings to become low emissions. A wide range of stakeholders can be involved in implementing the Building Code Clause H1. Relevant ministries, such as Ministry of Building and Construction, Ministry of Business, Innovation and Employment, and Ministry of Housing and Urban Development collectively develop Building Code Clause H1, indicating key actions to lead the construction and building sector in implementing Building Code Clause H1. Private enterprises in the sector and target communities jointly design buildings to meet the objective, performance design, functional requirements and limits on application appeared on the Clause H1. The central government funds and finances the projects. This results in effective deployment and implementation of the Building Code Clause H1 in the building and construction sector.

Case study: Ngā Kāinga Anamata (Homes of the Future)[95]

Ngā Kāinga Anamata, literally Homes of the Future, is a sustainability-driven pilot project aiming for carbon emissions reduction in New Zealand's building sector. The core focus of the project is to achieve New Zealand's carbon emission target and contribute to the change in the built environment of the economy. Apart from climate change mitigation, the project also strives to

93 https://www.beehive.govt.nz/sites/default/files/2021-10/Attachment%20-%20Nga%20Kainga%20Anamata%20%285%20Systems%29%20-%20COP26%20-%20Sustainability%20Report%20Final_0.pdf

94 https://environment.govt.nz/assets/publications/Aotearoa-New-Zealands-first-emissions-reduction-plan.pdf

95 https://www.beehive.govt.nz/sites/default/files/2021-10/Attachment%20-%20Nga%20Kainga%20Anamata%20%285%20Systems%29%20-%20COP26%20-%20Sustainability%20Report%20Final_0.pdf

address underlying problems in the sector, including construction sector productivity, energy hardship, and sick building syndrome.

The concept of the project is that each building uses a different structural system for its construction, providing sustainability insights to be collected for further development which is in line with the enabling policy to amend the building code. The project prioritizes three key factors, trifecta, on cutting lifecycle carbon emissions, including low carbon materials, operational energy efficient solutions, and local renewable energy generation. The three key factors allow the buildings to achieve Passive House certification[96] and become net-zero energy through the use of photovoltaic rooftop system. This is in line with the enabling policy in New Zealand that introduces mandatory requirements for energy efficient buildings.

The lifecycle carbon emissions of the whole building were assessed. It resulted in carbon reduction of around 74% less than common apartment construction with the base year of 2020. This project is expected to accelerate decarbonization in the building and construction sector. This is considered a great start of the economy response towards climate mitigation, and the project was one of the global showcases in the COP26 Build Better Now pavilion. New Zealand sets the initiative of Homes of the Future to be the leading project in its plan for transformation of building and construction sector and transition to a 1.5°C net zero carbon economy.

Figure 21 Ngā Kāinga Anamata

96 A voluntary standard for energy efficiency in a building, which reduces ecological footprint.

2.4.3. First Carbon-zero House

Economy
Sweden

Carbon emission reduction target
Sweden's long-term target is to have net zero greenhouse gas emission by 2045 at the latest[97]. Greenhouse gas emission from activities in Sweden should be at least 85% lower than in 1990 by that time. The remaining 15% can be achieved through supplementary measures such as increase carbon sequestration in forest and land, carbon capture and storage technology (CCS), and emission reduction efforts outside of Sweden. The government has issued the climate act which describes steppingstones that the economy needs to follow in order to accomplish this ambitious goal.

Targets/milestones and strategies of building sector
Sweden is one of the European economies that make significant progress in reducing emissions from building and moving to a more sustainable and low-carbon economy. The emission from the building sector comes from various sources, especially the raw materials required to complete the construction. As of 2022, 90% of buildings and nearly 20% of individual houses are connected to the heating networks that is heavily relying on renewable energy[98]. In the same year, the first building was certified as carbon neutral by the Sweden Green Building Council. The first shipment of steel which is the main component for building sector without the use of fossil fuel was also achieved. Hydrogen Breakthrough Ironmaking Technology (HYBRIT) claims that by eliminating fossil fuels from the steelmaking process, it could reduce Sweden's total CO_2 emissions by "at least" 10%[99].

Outstanding decarbonization technology
Swedish Government has put in place several measures including tax on carbon emission and investment in renewable energy projects to support their goal of becoming carbon neutral by 2045. The economy employs two methods: energy saving and switching to renewable energy. According to the High Council on Climate, the economy introduced demanding energy performance standards, particularly to the construction of new buildings to increase energy efficiency. For example, thick layers of insulation, triple glazing, can be used for this purpose. The heat needed in Sweden is provided by a healthier heating system which is powered mostly by renewable sources. The share of oil in residential energy end use has fallen from 72% in 1970 to 7% in 2019. The significant change happened due to the two oil crises. Carbon neutrality in construction is introduced by launching the program on carbon footprint of construction machinery and materials. Two steel companies and an electricity company joined forces in 2016 to produce carbon-free steel[100]. They did not rely on CO_2 capture and storage, but on a new

97https://www.government.se/articles/2021/03/swedens-climate-policy-framework/#:~:text=New%20climate%20goals&text=goals%20for%20Sweden.-,By%202045%2C%20Sweden%20is%20to%20have%20zero%20net%20emissions%20of,percent%20lower%20than%20in%201990.
98 https://www.up-to-us.veolia.com/en/energy/sweden-decarbonisation-building-CO2-emissions-construction-energy
99 https://www.sei.org/projects-and-tools/projects/hybrit/
100 https://www.forbes.com/sites/davidrvetter/2021/08/19/how-sweden-delivered-the-worlds-first-fossil-fuel-free-steel/?sh=1fdae1a6b553

industrial process, involving a colossal investment: instead of smelting the ore in coal-fired blast furnaces, they plan to use electric furnaces running on renewable energy.

Selected enabling policy tool

The NOllCO$_2$ Certification will not only cover the whole building sector but also indirectly benefit other sectors, e.g., industrial sector. The NOllCO$_2$ consists of two main criteria [101]. First, it mandates the building's greenhouse gas emission reduction by setting limit values for greenhouse gas emission, building component production, construction process, and indirectly by setting a limit for the building's energy use. The second element is zero CO_2 which requires the building to balance out remaining climate impacts with climate measures to achieve net zero, such as production of renewable energy (including solar panels that Villazero has chosen to use). To mandate the NOllCO2 Certification, Swedish Green Building Council, a non-profit organization, plays a key role in developing the certification system to accommodate energy efficient building projects to meet a set of requirements. The Council does not only work closely with private enterprises on approving certification to build carbon-zero houses, but also provides practical guidelines to local governments to encourage carbon-zero house construction in their areas. Collaboration among architects, construction enterprises and local government could lead to sustainable implementation of the NOllCO2 Certification.

Case study: Villazero

Villazero is the first building to be certified as carbon neutral by the Sweden Green Building Council, and also the world's first carbon neutral house[102]. The construction of this project started in autumn 2021 and finished in 2022[103] and was done exclusively by women. According to Pai Stoll, a senior expert at the Sweden Green Building Council, Villazero is the first certified detached house project by NOllCO$_2$ and has been a pilot in the development of the certification. The goal of this project is to build a carbon neutral single-family house with the most sustainable construction technology and building materials of the future. This can be considered as the initial step proofing that achieving carbon neutral in building sector is possible.

The project chose not only to focus on reducing carbon dioxide emissions but also to raise gender equality in the construction industry. As mentioned earlier, the building is certified with two conditions. Villazero is built on wooden foundation which can reduce the emission to approximately 30%. The wooden board is insulated by four layers of EPS insulation to protect the house against moisture from below. Moreover, the walls and ceiling are also made of wood. It was not painted to reduce the emission but instead treated with silicon to resist moisture and rot. The building utilizes solar photovoltaic panels to supply the necessary power required within the house. As one of the certificate requirements is to have the house pay off the carbon dioxide debt within 50 years, solar energy on the roof was proved to pay the debt within approximately ten years which is a much shorter timeframe.

101 Sweden Green Building Council, https://www.sgbc.se/certifiering/nollco2/

102 https://www.globenewswire.com/en/news-release/2022/07/08/2476592/0/en/The-world-s-first-carbon-neutral-house-is-located-in-Sweden.html

103 https://se.ostberg.com/2021/12/02/villazero-sveriges-forsta-koldioxidneutrala-smahus/#

The project has been characterized by the spirit of the future with innovative solutions and sustainable material choices. It also has a vision to influence and propagate NOllCO$_2$ certificate throughout the construction industry. The house contributes to a sustainable future with forward-thinking of the feasible solution to decarbonize the building sector inside the economy.

Figure 22 Villazero – Sweden's first carbon dioxide-neutral detached house[104]

Figure 23 Villazero exterior with solar panels located in Borlänge, Sweden[105]

104 https://se.ostberg.com/2021/12/02/villazero-sveriges-forsta-koldioxidneutrala-smahus/#
105 https://www.globenewswire.com/en/news-release/2022/07/08/2476592/0/en/The-world-s-first-carbon-neutral-house-is-located-in-Sweden.html

3. Case studies of lessons learned and/or best practices on the BCG Economy Model contributing to achievement of carbon neutrality

3.1. BCG Economy Model

On 19 January 2021, the Thai Cabinet endorsed the proposal to declare the Bio-Circular-Green Economy or BCG Economy model the domestic agenda from 2021 onwards[106]. BCG Economy is an *integration* of bioeconomy, circular economy and green economy. Bioeconomy involves the production of renewable biological resources and the conversion of these resources into value added products. Circular economy aims at reusing and recycling materials to maximize the value of limited resources. Green economy determines to keep economy, society and the environment in balance, leading to sustainable development[107]. Therefore, the BCG Economy model serves as a *people-centric strategy*[108] to drive sustainable development, ensuring a balance between social, environmental, and economic objectives.

Thai Government established the Committee of Bio-Circular-Green Economy which consists of 11 sub-committees (Figure 24). The sub-committee that can significantly contribute to the achievement of carbon neutrality is the Sub-Committee on Energy Material and Chemical Biology which contributes to both power and transport sectors. It supports the promotion of renewable energy that maximize the usage of renewable resources in the local area which nurture the development of bioenergy and strengthen the local community, and also fosters and adds values to the supply chain of biofuels which would contribute to the advancement of the agricultural sector. Therefore, this sub-committee will need to work closely with the Sub-Committee on Agriculture. The Sub-Committee on Circular Economy aims to enhance resource efficiency which perfectly synchronizes with the net-zero building movement. These are among the outstanding examples of the contribution of BCG Economy towards carbon neutrality. Note that if other greenhouse gases (GHG) are considered, the agricultural and food waste-based biomass and biogas plants can also considerably contribute to the reduction of methane emissions[109].

Figure 24 The Committee of Bio-Circular-Green Economy and its sub-committees[110]

106 https://www.bcg.in.th/eng/wp-content/uploads/2022/07/3-Book-BCG-Action-Plan-Eng-compressed.pdf
107 https://www.nstda.or.th/en/images/pdf/BCG_Booklet1.pdf
108 https://thaipublica.org/2022/11/suvit-maesincee-bcg-in-action/
109 https://www.bcg.in.th/bcg-action-plan/
110 https://www.bcg.in.th/eng/executive-committee-subcommittee/

During APEC 2022 Thailand[111] during 18-19 November 2022, Thailand, as the Host Economy, successfully had the Bangkok Goals on BCG Economy adopted[112]. Tailoring the goals to match the context of APEC Economies, the link between the Bangkok Goals on BCG Economy and the carbon neutral commitment becomes more evident. The Bangkok Goals and the key areas[113] include:

1) Supporting global efforts to comprehensively address all environmental challenges, including climate change, extreme weather and natural disasters, for a sustainable planet, particularly in terms of climate mitigation, adaptation and resilience;
2) Progressing sustainable and inclusive trade and investment and ensuring that they are mutually supportive with our environmental policies;
3) Promoting environmental conservation, sustainable use and management of natural resources, as well as halting and reversing biodiversity loss;
4) Advancing resource efficiency and sustainable waste management towards zero waste.

Advancing the transition to clean and low carbon energy, and phasing out fossil fuels subsidies are included as the aspirational targets under the first key area. Advancing concrete initiatives on responsible business conduct in the transport and logistics sector is an aspirational target under the second key area. Finally, increasing efficient energy usage in the building sector will also contribute to the last key area. Three case studies below demonstrate how the BCG Economy model can contribute to the attainment of carbon neutrality of the key sectors in APEC community while balancing between social inclusion, environmental consideration, and economic development. Note that as the contribution to the power and transport sector and more prominent, the case studies will focus on these two sectors.

3.2. Smart Microgrid and Energy Trading Platform in a Rural Community

3.2.1. Summary of the Case Study

Smart Micro Grid and Energy Trading Platform is a pilot project developed by Electricity Generation Authority of Thailand (EGAT) under the Energy Regulatory Commission (ERC) Sandbox. The project aims to unlock the enhanced single buyer (ESB) model which limits investment promotion, and provide access to the central transmission system to a private electricity generating system[114]. The project is located in a rural area, Sisaengtham, approximately 800km away from Bangkok Metropolitan Region (BMR) and has no access to electricity. The concept relies on a prosumer model where an individual plays both roles of consumers and producers of electricity generated in the networked community. In the early phase of the project, the project installed rooftop solar panels, a battery energy storage system, and an energy trading platform. The development is centralized on management and balancing energy in the microgrid (both in demand and supply sides), testing grid operating modes (grid connected and islanding modes), data monitoring and evaluation for further development, maintenance and expansion of electricity generation and transmission system, and peer-to-peer (P2P) electricity trading scheme.

The development in the second phase focuses on adoption of P2P trading in the electricity network. Electricity is managed by the energy management system which is attached to the energy

111 https://www.apec2022.go.th/
112 https://www.mfa.go.th/en/content/apec-brief-2
113 https://www.bangkokgoals.apec.org/
114 https://www.nedo.go.jp/content/100945222.pdf

trading platform. Integration of solar power systems into electricity generation in conjunction with promotion of agricultural production reduces costs, maximizes local benefits, and creates more income for communities. In case of emergency, energy supply is secured by utilizing resources in communities where waste to energy and biomass/biogas can be utilized.

3.2.2. Contribution to Strategic Outcomes of BCG Economy

Smart Micro Grid and Energy Trading Platform is consistent with several goals and targets in the Bangkok Goals on BCG Economy[115]. The relevant goals and targets include:

Goal on Environmental Challenges

The pilot project contributes to global efforts including Goal 13: Climate Action of the 2030 Agenda for Sustainable Development and the goal under Paris Agreement on addressing climate change issues, as it reduces carbon emissions by (1) utilizing electricity generated by renewable energy sources, (2) strengthening resilience by adopting energy storage system to enhance community energy security, (3) advancing development on cost-effective and low emission technologies, and (4) supporting energy transition as being a promising example for low carbon society with distinct conditions.

Goal on Trade and Investment

Smart Micro Grid and Energy Trading Platform project contributes to grid stability enhancement and connectivity improvement. It will become a role model for thousands of communities to adopt the project conceptual ideas which will increase clean investment in rural areas.

Goal on Environment and Natural Resources, including Biodiversity

The project promotes environmental conservation and sustainable use of natural resources as it produces and consumes self-generated electricity which prevents degradation of natural resources.

3.2.3. Potential contribution to achievement of carbon neutrality:

Sisaengtham is considered a role model for future energy systems in which smart grid facilitates energy independence and becomes a learning center for the community, enabling sustainable development in accordance with BCG Economy model. This integration of low carbon technology adoption and BCG Economy model presents the local community efforts to contribute to carbon neutrality in the power sector through the use of green technologies and enhancement of grid stability using the concept of prosumer. Contributing to carbon neutrality through BCG Economy, a variety of stakeholders are involved in the action. Starting from the development of trading scheme that supports BCG actions, government agencies, such as Energy Regulatory Commission of Thailand (ERC), play a significant role in developing the ERC Sandbox scheme and approve qualified projects under the scheme. ERC also collaborates with existing service providers, namely Electricity Generating Authority of Thailand (EGAT) and Provincial Electricity Authority (PEA), to engage them in the decentralized system installation and investment, and cultivate new energy trading practices. Local governments aid in the implementation by coordinating between the service providers and the target local communities. While research institutes contribute to the project by studying potential energy trading mechanisms with use of digital technology platform and creating academic value to the case study, local entities cooperate in land allocation and

115 https://www.bangkokgoals.apec.org/goals-and-targets.html

provide supports on system installation and long-term maintenance. Local entities as the host of the demonstrated system could benefit from the electricity generated under the ERC Sandbox scheme.

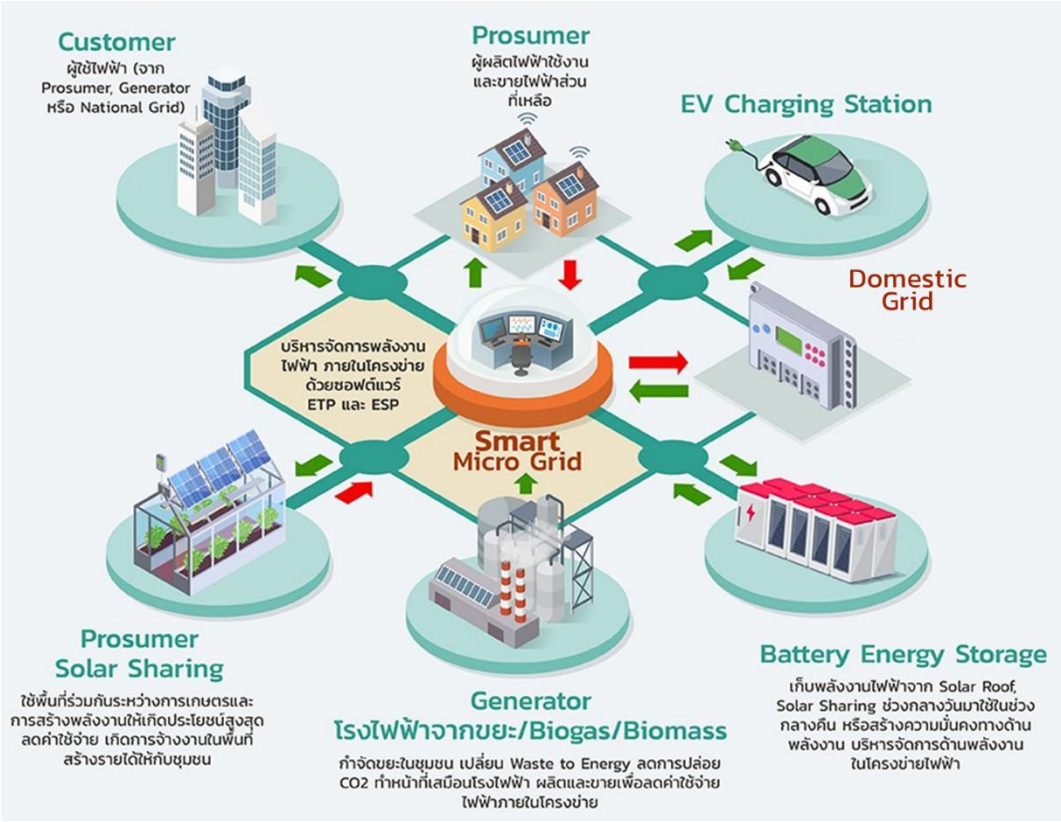


Figure 25 Sisaengtham smart microgrid

3.3. Innovation-driven Hub for Sustainable and Low-Carbon Transformation

3.3.1. Summary of the case study[116]

The Eastern Economic Corridor of Innovation (hereinafter referred to as EECi), located in Wangchan Valley, Rayong, is Thailand's initiative launched in 2017 to drive investment and assist manufacturing sector in creating a sustainable value chain through preparation of necessary research and development infrastructure and promotion of innovation and technology. In conjunction with BCG strategy, the initiative demonstrates how several sectors can work together towards digitalization in a balanced and sustainable manners.

Figure 26 Connection between EECi and BCG Economy Model

As EECi's mission is to drive Thailand's industries towards a sustainable economy, it provides publicly accessible research infrastructure which supports localization and commercialization of technologies. Shown in Figure 26, the initiative focuses on three main tasks, namely adding value to agricultural sector, facilitating industry transformation, and supporting new industry development. For example, EECi strives to add value to agricultural products by providing a biotechnology platform to facilitate conversion of biomass into fuels, power, chemical and other beneficial products. The corridor also provides infrastructure for interesting businesses at every scale to research 21st century technologies, e.g., connected and autonomous vehicle testing ground (without barriers on regulatory issues) and alternative battery pilot plant (prototype production). EECi also supports future industries and paves ways for people's wellness. Aircraft and unmanned aerial vehicles are developed and tested under a sandbox before entering into the market. Genomics is also a field that EECi pays attention to. Infrastructures in relation to manufacturing medical devices, advanced machined and tools for telemedicine are provided.

3.3.2. Contribution to strategic outcomes of BCG Economy

Towards BCG Economy strategy, EECi enables supports for businesses at every scale and provides access to advanced infrastructure and testing lab. This is in line with the goals and targets under Bangkok Goals on BCG Economy.

116 https://sudsesc.nida.ac.th/main/images/books/Thailand%E2%80%99s%20BCG%20Transformation.pdf

Goal on Trade and Investment

EECi accommodates initiatives on business conducts and industrial practices that complies with environment, social and governance approach through providing essential infrastructure, advanced manufacturing environment, and access to low carbon and digital technologies, for research and development toward technology localization and commercialization. Furthermore, it supports micro, small, and medium enterprises (MSMEs) by building capacity and providing opportunity to enhance competitiveness in regional and global markets.

Goal on Resource Efficiency and Sustainable Waste Management

EECi strives to eliminate wastes from human and industrial activities through building waste-to-energy power plants[117]. This is expected to reduce a large volume of waste landfilling, thereby reducing carbon emissions.

3.3.3. Potential contribution to achievement of carbon neutrality:

As EECi aims to support Thailand's transformation to enhance quality of life and go towards sustainability, it contributes to carbon emissions reduction in two main sectors: power sector and transport sector. In the power sector, EECi provides a power grid with robust energy storage capacity where the energy is produced and consumed by itself. With carbon credits and energy trading mechanisms, it can accelerate the movement towards carbon neutrality. In the transport sector, EECi facilitates development and testing innovative vehicles and provides sites for prototype production to advance high-security batteries to be competitive in regional and global market. Through cooperation with domestic corporates and foreign entities, EECi is able to pioneer innovative approaches and technologies in target industries towards carbon neutrality. Furthermore, BCG Economy Model can benefit the progress of attaining carbon neutrality by cooperating with the domestic and foreign entities, though it needs to consider a wide range of relevant actors. EECi is developed in accordance with Thailand's transformation which is in line with BCG Economy Model. Relevant actors include government agencies, private enterprises, service providers, and academic institutes. Since EECi establishment requires large domestic and foreign investments, Board of Investment is a crucial actor. Government agencies, such as National Science and Technology Development Agency (NSTDA), is a driving actor in its development phase. Private enterprises are significant stakeholders who invest the capital in EECi development and could benefit from the investment and use of EECi's advanced infrastructure, expecting expansion and growth in their business. Service providers, such as Provincial Electricity Authority (PEA) would associate in the energy technology development and innovation and could help accelerate of target industries. Academic institutes which are located within EECi could benefit from collaboration on research and academic value creation of potential technologies and innovations.

117 https://permanent-jakarta.thaiembassy.org/en/content/thailand-s-eec-spearheads-partnerships-for-sustain

3.4. A Bamboo-powered Rural Community

3.4.1. Summary of the case study[118]

Pha Pang Community Foundation is an exemplary display of BCG actions in Thailand. The community, located in a watershed area laying near a mountain in Lampang province, is full of bamboos. Many inhabitants in nearby communities migrated to the cities for work, leaving the Pha Pang community with approximately a thousand of elderly and children. As the nature of a rural community with low population and ample natural resources, As the population number do not meet the requirement to form a subdistrict, the foundation's director thought of an initiative to utilize the abundant resource in the community as a green energy source to contribute to the circular economy. This case study utilized the advantage of bamboo which produces 35% more oxygen than other tropical plants and absorbs 75% more carbon dioxide. Bamboo is one of the materials that can be turned into clean, efficient, and cheap gas. The synthesis gas self-sufficiently powered the low population by providing energy for local usage, such as cooking and food processing. Later, the foundation attempted to expand the idea of circular economy and set up a learning center and homestay to receive tourists to learn how Pha Pang can sustainably achieve its energy security. The foundation further brought benefits to the community by encouraging the villagers to plant their own bamboo trees and produce synthesis gas to power the community's facilities. This considers alternating solar power by using bamboo as a material to produce synthesis gas for electricity generation.

3.4.2. Contribution to strategic outcomes of BCG Economy

The Pha Pang case study contributes to the BCG Economy in the aspects of adding values to products, production of biogas from local resources, capacity building by providing employment and sharing knowledge, and support of local tourism in rural areas.

Goal on Environmental Challenges

This case supports global efforts, such as 2030 Agenda for Sustainable Development and Paris Agreement, as it uses natural resources in local community to produce synthesis gas and electricity, ensuring security and affordability of energy. Pha Pang Community Foundation equips local residents with capacity on resource utilization and awareness of circular economy and environmental issues.

Goal on Environment and Natural Resources, including Biodiversity

Pha Pang community promotes environmental conservation as the foundation supports bamboo re-plantation in agricultural areas and uses the products in a sustainable manner. The project also ensures protection of the environment and natural resources for long-term use.

Goal on Resource Efficiency and Sustainable Waste Management

The Pha Pang community takes advantage of utilization of bamboo to produce more oxygen and absorb more carbon while generating usable gas and electricity for household activities. Waste from gas generation process is also used as fertilizer for agricultural purposes.

118 https://sudsesc.nida.ac.th/main/images/books/Thailand%E2%80%99s%20BCG%20Transformation.pdf

3.4.3. Potential contribution to achievement of carbon neutrality

The initiative conducted by Pha Pang Community Foundation uses renewable energy to power facilities and increases energy independence through the production of biogas from abundant local resources. This not only responds well to BCG Economy Model but also the target of carbon neutrality, as the community is independent from the central grid system and depending on self-produced renewable energy. To actualize the use of renewable energy and promote the BCG Economy in the community, cooperation of stakeholders is considered an important process to nurture the the community while participating in carbon neutrality progression. Pha Pang Community Foundation, a local entity, is an important actor who initiates the model and demonstrates the utilization of local resources. The entity works closely with social enterprises in the community to add values to farm products and waste from agriculture. Private sector, such as Small and Medium Enterprise Development Bank of Thailand, could finance projects derived from the model that use local resources to promote sustainability in the community. Government agencies could assist in setting up a micro power plant to ensure energy security and internet access for the community. Furthermore, Provincial Electricity Authority (PEA) could play a supportive role in maximizing the potential of the model by implementing the model in other remote areas.

4. Steps towards Carbon Neutrality: A Case Study of Thailand

4.1. Steps to Drive an Economy towards Carbon Neutrality

APEC Economies are paving their pathways towards carbon neutrality and net zero GHG emissions through dissemination of the economy level climate commitment which was generally set in line with the global goal to responsible actors in respective sectors. At COP21, most Economies adopted the Paris Agreement and set their **Nationally Determined Contribution (NDC)** to be consistent with collective global efforts to address climate change impacts. After updating the NDCs several times to synchronize with the changes in the global target, **Long-term Low Emissions and Development Strategies (LT-LEDS)** are developed and submitted to UNFCCC, laying out essential climate policies, priorities, and measures. According to Figure 27, the LT-LEDS acts as the economy's strategic direction to encounter climate crisis. Built upon the LT-LEDS, the government determines its **Sectoral Plans** to frame the scope of actions and distribute responsibilities in GHG emission reduction to target sectors. Sectoral plans are then formulated as the economy's policy frameworks to guide relevant agencies towards transformational changes and incorporate sectoral decarbonization targets in accordance with the LT-LEDS. Sector plans consider possible scenarios in decarbonizations based on current circumstances, determine key mitigation actions, and propose **Key Technologies** to achieve the committed targets. **Policy Actions** and supports are put in place to maximize the capability of the key technologies and enlarge profitability from technology deployment to the Economy. Contributions of key technologies equipped with policy actions and supports serves their purposes in addressing responsibilities in sectoral plans, to achieve committed targets in LT-LEDS, and finally fulfill the NDC to achieve carbon neutrality and net-zero GHG emissions, respectively. Contribution to GHG emission reduction of each policy actions can be traced back through the pathway shown with red arrows in Figure 27 up to the NDC.

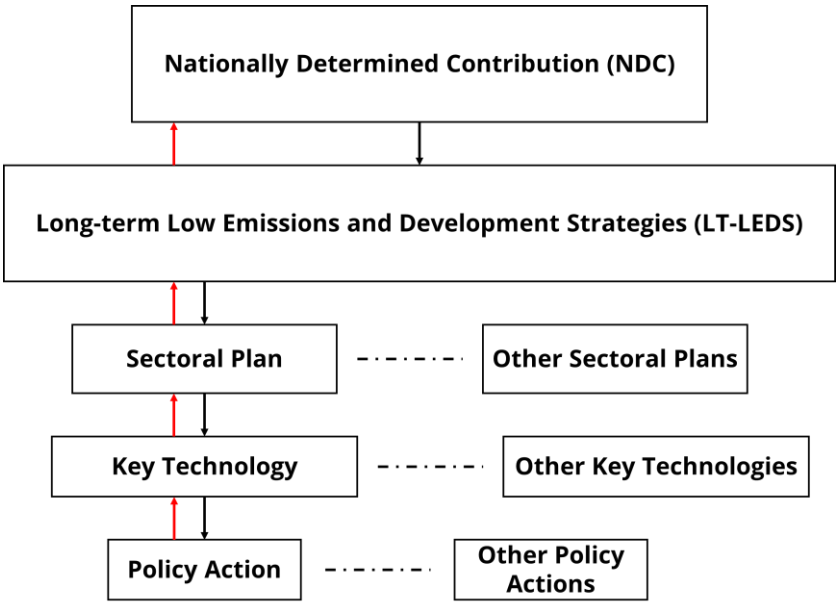


Figure 27 Flow for dissemination of climate commitment at economy level to key sectors

4.2. Potential Technologies, Corresponding Policy Actions, and Potential Contribution to Emission Reduction

In order to assess the contribution of potential low-carbon technologies, it is important to know what policy action(s) are designed to deploy those technologies, and how would they synchronize with the local context of respective economies. Table 3 summarizes promising low-carbon technologies combined with enabling policy actions of the case studies introduced in the previous chapter. Rather than trying to quantify the CO_2 emission reduction potential which is the common practice[119], this report will try to point out any constraints that can be avoided or alleviated by the policy actions to support that particular low-carbon technology (see the last column of Table 3). These potential contributions will be overlaid with the local context of Thailand in the next sub-section to confirm the applicability of applying low-carbon technology and associated policy action in each case study to Thailand and see how they complement each other. This approach will allow the readers to understand how each step should be conducted in order to evaluate the potential contribution of each technology and action to their carbon neutrality goal.

Table 3 Summary of low-carbon technologies and associated policy actions in respective case studies, and their potential contribution to CO2 emission reduction

Case study	Low-carbon technology	Description of policy action	Potential contribution to CO2 emission reduction
1. RE100 island (Chinese Taipei)	100% RE is achieved by using solar and offshore wind and connect them to the existing power grid. This concept is also applicable to other RE, such as hydropower, geothermal, and bioenergy.	High tariff is set by the government to support large-scale deployment of RE in a specific island (city) as a demonstration project.	The model can be applied to all islands and rural areas with limited grid access where the electricity price is higher. The reduction potential is larger for economies with many islands. Yet consideration must be taken for land use in heavily populated islands[120].
2. Coal phase-out (Chile)	Phase-out high emission (fossil fuel based) power generation, e.g., coal power plants, and replace by clean power sources.	Government issues the law to support renewable energy and the decommission plan for coal-fired power plants.	Clear milestones to phase out fossil fuel power plants and introduce renewable energy being bound by law will ease market entry and equalize playing field for renewable energy[121], ensuring steady

119 https://unfccc.int/sites/default/files/resource/2022_LRs_BP_Assessment_of_2020_Target.pdf
120 https://transrisk-project.eu/sites/default/files/Documents/4.4.6_Land-use%20impacts%20from%20renewable%20energy%20policies.pdf
121 https://www.ucsusa.org/resources/barriers-renewable-energy-technologies

Case study	Low-carbon technology	Description of policy action	Potential contribution to CO2 emission reduction
			transition towards cleaner energy mix.
3. Peer-to-peer trading platform (Thailand)	Peer-to-peer renewable electricity trading platform is used to facilitate sales and purchase of excess renewable energy of prosumers.	Government allocates budget for several sandbox projects on a peer-to-peer trading platform which creates opportunity to the prosumers to sell their excess electricity.	Enabling trading among small scale prosumers will accelerate the increase in renewable energy share. It can also address power system stability issue by facilitating decentralization of the power systems[122,123].
4. Wind power island (United States)	Wind power installed on an isolated island is used to supply electricity to existing power grid in another island. Energy storage can also be installed. The model is also applicable to other variable renewable energy.	Wind farm receives support through tax credit and benefit from inflation reduction act if the power plant is equipped with energy storage	For a heavily populated island/area, supplying clean electricity from a neighboring island can be a way to decarbonize power generation. In addition, for a large-scale renewable power system, especially when it is equipped with energy storage system which increases the unit cost, tax credits or subsidies can help alleviate financial barriers and risks[124].
5. City-scale deployment of new energy vehicles (People's Republic of China)	EV is used for the entire taxi fleet of a city to make BEVs the mainstream of new vehicles.	An ambitious EV deployment target is determined by the government in New Energy Industrial Development Plan along with the subsidy to support all taxis to use EV.	100% usage of EV for taxi fleet in major cities will largely contribute to CO2 emission reduction in transportation sector. It also addresses the issue of charging stations[125] as the EV will be concentrated in specific cities. However, this may lead to the issue of grid

122 https://www.sciencedirect.com/science/article/pii/S2211467X20300924
123 https://www.sciencedirect.com/science/article/pii/S0306261922000460
124 https://energypedia.info/wiki/Barriers_and_Risks_to_Renewable_Energy_Financing
125 https://www.exro.com/industry-insights/barriers-to-ev-adoption-part-2

Case study	Low-carbon technology	Description of policy action	Potential contribution to CO2 emission reduction
			overload[126], thus, it requires planning of charging schedule.
6. Hydrogen energy demonstration project (Japan)	Renewable energy sources are used to produce hydrogen in a large scale demonstration project.	Japan Green Growth Strategy includes hydrogen as one of the 14 industries to be focused in order to achieve carbon neutrality. Government financially supports the hydrogen production and refueling stations.	Hydrogen production with fuel cell vehicles will complement EV in achieving carbon free transportation. It is more suitable for heavy duty vehicles[127,128], e.g., long-haul trucks than EV. However, well-planned R&D needs to be in place to significantly reduce the cost.
7. Well-planned electric vehicle subsidies (Republic of Korea)	ROK plans to utilize electricity and hydrogen to decarbonize the transportation sector.	The government issued a dedicated NDC for the transportation sector. This leads to extensive EV subsidy resulting in fast expansion of EV.	Subsidies and incentives are important means to promote electric and fuel cell vehicles at the initial stage when they are still more expensive than ICE vehicles[129]. They must be well-planned to ensure sustainable growths of both types of vehicles when the subsidies are toned down after they become competitive with ICE vehicles[130].
8. Retrofitting building to achieve net-zero carbon emission (Canada)	Building retrofit is introduced as another way to contribute to net-zero carbon emission in the building sector.	The government introduced Environment Plan which includes building retrofitting as one of the new	Building retrofit is an important strategy to achieve net zero emission in building sector as the majority of the existing buildings will still be in use in 2050[131]. The

126 https://www.weforum.org/agenda/2022/01/the-ev-revolution-obstacles-solutions/
127 https://www.ornl.gov/news/heavy-duty-vehicles-ideal-entry-hydrogen-fuel-cell-use
128 https://newscenter.lbl.gov/2021/04/08/hydrogen-offers-promising-future-for-long-haul-trucking-industry/
129 https://www.bangkokpost.com/business/2056259/south-korea-ups-subsidies-for-eco-friendly-cars-to-speed-up-green-push
130 https://www.sciencedirect.com/science/article/pii/S2352484720313196
131 https://www.netzerocarbonguide.co.uk/guide/early-decisions/retrofit-or-new-build/summary

Case study	Low-carbon technology	Description of policy action	Potential contribution to CO2 emission reduction
		measures for clean infrastructure.	investment is also expected to pay back which makes it attractive to private sector[132].
9. Homes of the Future (New Zealand)	Ngā Kāinga Anamata (Homes of the Future) is a sustainability driven pilot project to make building-related emissions to be near zero through enhancement of energy efficiency.	Emission reduction from building sector is a focus area in Emission Reduction Plan of New Zealand. Building Code Clause H1 introduces requirements for a building's energy efficiency.	Another approach being focused lately to accelerate net-zero movement in housing sector is to enlarge the scope from net-zero home to net-zero community[133]. This can also decrease carbon footprint for indigenous, rural, and under-resourced communities[134].
10. First carbon-zero house (Sweden)	The home is built using sustainable construction material and utilizes a highly efficient heating system supplied by renewable energy.	Carbon-zero houses are supported by the introduction of the building certificate (NOllCO2 Certificate, Tax on Carbon Emission) to encourage the use of renewable energy and low carbon materials.	Net-zero houses focus not only on increasing efficiency of heating and electrical systems, but also reduce embodied carbons by using low carbon materials[135]. This can largely contribute to carbon emission reduction in residential sector
11. BCG (Smart microgrid and energy trading platform in a rural community)	The project integrates rooftop solar panels with battery energy storage and a demonstrative energy trading platform.	The project contributes to BCG Economy goals on: Environmental Challenges, Trade and Investment, and Environmental and Natural Resources,	With policy support to address energy inequality, rural microgrid can be a great tool to increase energy access for rural communities, and simultaneously contribute to GHG emission reduction[136].

132 https://www.mckinsey.com/capabilities/sustainability/our-insights/spotting-green-business-opportunities-in-a-surging-net-zero-world/transition-to-net-zero/buildings
133 https://www.ase.org/sites/ase.org/files/net-zero-communities.pdf
134 https://www.nrcan.gc.ca/energy-efficiency/homes/toward-net-zero-homes-and-communities/24522
135 https://www.ctc-n.org/technologies/carbon-sink-and-low-carbon-building-materials
136 https://www.sciencedirect.com/science/article/pii/S2211467X19301166

Case study	Low-carbon technology	Description of policy action	Potential contribution to CO2 emission reduction
		including biodiversity.	
12. BCG (Innovation-driven Hub for Sustainable and Low-Carbon Transformation)	The innovation-driven hub assists the manufacturing sector in creating a sustainable value chain while eliminating waste. It also provides a power grid with energy storage capacity. Carbon credits and energy trading mechanism will also be tested in the hub.	The innovation hub is under BCG Economy goals on: Trade and Investment, Resource Efficiency, and Sustainable Waste Management.	A demonstration city is a good idea to promote an initiative and lead to adoption by stakeholders. EEC or other innovation-driven sustainable and low-carbon cities[137] can induce carbon neutral movements in other government and private agencies, which consequently accelerate the CO2 emission reduction.
13. BCG (Bamboo-powered rural community)	The community generates sustainable energy from synthesis gas using bamboo. Bamboo trees can also absorb carbon. Waste can be turned into fertilizer for agricultural purpose.	The community aligns with BCG Economy goals on: Environmental Challenges, Environment and Natural Resources, including Biodiversity, and Resource Efficiency and Sustainable Waste Management	BCG economy model that capitalizes the strength to create additional values for the community can be referred to when an Economy wants to drive the communities towards carbon neutrality[138].

137 https://netzerocities.eu/
138 https://thaiembdc.org/bio-circular-green-bcg/

4.3. Thailand's Current Status on Decarbonization

4.3.1. Thailand's Nationally Determined Contribution (NDC)

At COP21, the Paris Agreement was adopted by 196 Parties and entered into force later in 2016. Thailand, as an Economy that experiences impact of climate change, showed its ambition to participate in limiting global warming to below 2°C by committing to reduce GHG emissions by 20-25% in 2030 in its first Nationally Determined Contribution (NDC). Due to the strong global movement to achieve the climate neutral world by mid-century at COP26, Thailand updated its NDC with greater targets to reduce GHG emissions by 30-40% in 2030 in order to attain carbon neutrality by 2050 and net zero GHG emissions by 2065.

4.3.2. Thailand's Long-term Low Greenhouse Gas Emission Development Strategy (LT-LEDS)

Towards fulfillment of the NDC, Thailand developed a key mitigation policy document called Long-term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) and submitted to UNFCCC in 2021 and later revised the plan in 2022 with greater targets where Thailand will strive towards carbon neutrality and net zero GHG emissions goals. This strategy navigates Thailand to a transition to the goals considering direction and patterns of local and global development as well as identifying potential mitigation actions to support Thailand's decarbonization opportunities. By fully integrating all actors and balancing consideration of responsibility distribution among sectors, the revised LT-LEDS highlights five key sectors that contribute to long-term mitigation actions, namely, energy sector, industrial processes and product use sector, waste sector, agriculture sector, and forestry sector. As the achievement of carbon neutrality and net zero GHG emissions depends heavily on energy sector which is the largest contributor to direct GHG emissions in the economy (69% as of 2018), relevant sub-sectors including power generation sub-sector, transport sub-sector, and building sub-sector (which consists of residential sub-sector and commercial building sub-sector), play critical roles in supporting decarbonization in energy sector.

4.3.3. Sectoral Roadmaps

<u>Power generation sector</u>

Power generation sector is considered an important sector that can introduce large volume of renewable sources in the economy's energy mix. Thailand heavily depends on renewable energy to achieve carbon neutrality, where the share of renewable electricity is estimated to be 68% of the total electricity generation in 2040, and 74% in 2050. Figure 28 shows the timeline for long-term mitigation actions in power generation. By 2025, the Economy continues to improve energy efficiency in power plants and consider phasing out oil power plants and phasing down coal power plants. Thailand also considers the use of solar and wind systems with battery storage, and/or equipped with CCS, CCU, and BECCS. In 2050, Thailand attempts to reach carbon neutrality by increasing share of renewable energy electricity to 74% and phasing out coal power plants to becomes net zero GHG emissions in 2065.

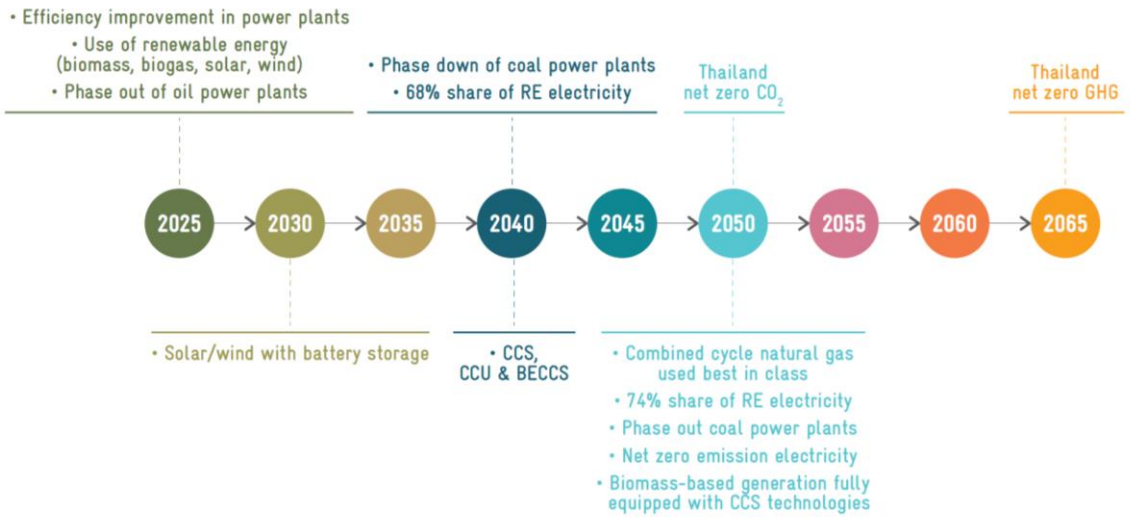


Figure 28 Carbon neutrality and net zero GHG emissions timeline for power generation sector

Transportation sector

Transportation sector in Thailand depends mainly on fossil fuels and is attributed to a large share of GHG emissions. To reach carbon neutrality and net zero GHG emissions, Thailand needs to shift its transport sector from fossil fuel-based to bio-based combustion or electrification to limit GHG emissions. Electric vehicles, fuel cell vehicles and biofuels are promising solutions. According to Figure 29, Thailand proposes a timeline for the transport sector to decarbonize and move towards the goals. By 2025, clean fuels, such as E10, E20, E85, B10, B20, and B100 are planned to be used in public fleets. In 2030, the Economy attempts to introduce a concept of 30@30, where 30% of public fleets are electrified by 2030, phase down ICE, and develop most efficient ICE vehicles. In 2045, Thailand aims to develop most efficient ICE vehicles with biofuels, significantly increase the share of electric vehicles and introduce fuel cell vehicles in the fleet.

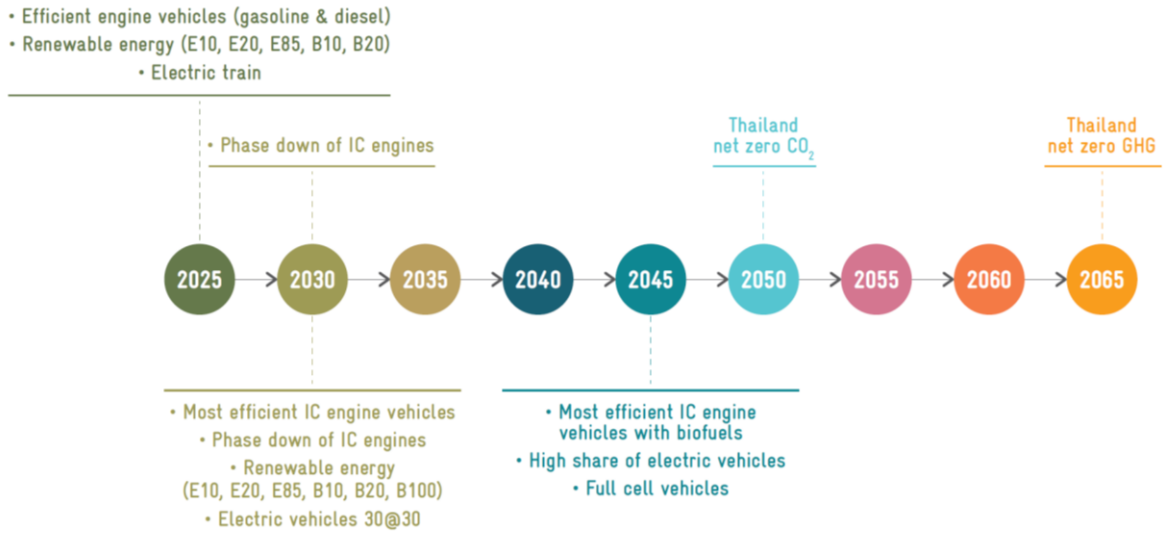


Figure 29 Carbon neutrality and net zero GHG emissions timeline for transportation sector

Building sector

The building sector in Thailand is separated to residential sector and commercial building sector. The sector mainly uses energy from electricity, LPG, and biomass. Decarbonization opportunities in the sector include improvement of energy efficiency and use of clean electricity in daily activities. As shown in Figure 30 and Figure 31, residential sector and commercial building sector share similarities in the timeline towards carbon neutrality and net zero GHG emissions. By 2025, building sector in Thailand will improve efficiency for lighting technologies, and electric devices and appliances. In 2030, efficient LPG application and solar-powered water heaters will be taking place in the sector and efficient appliances continue to grow. In 2035, residential sector in Thailand will maximize the usage of electrical devices, appliances, and solar-powered heaters.

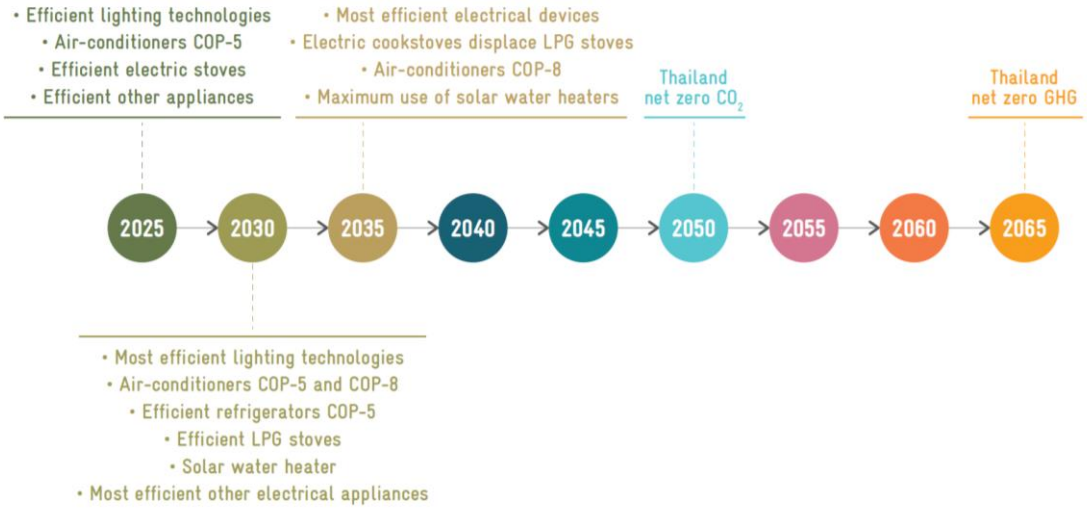


Figure 30 Carbon neutrality and net zero GHG emissions timeline for residential sector

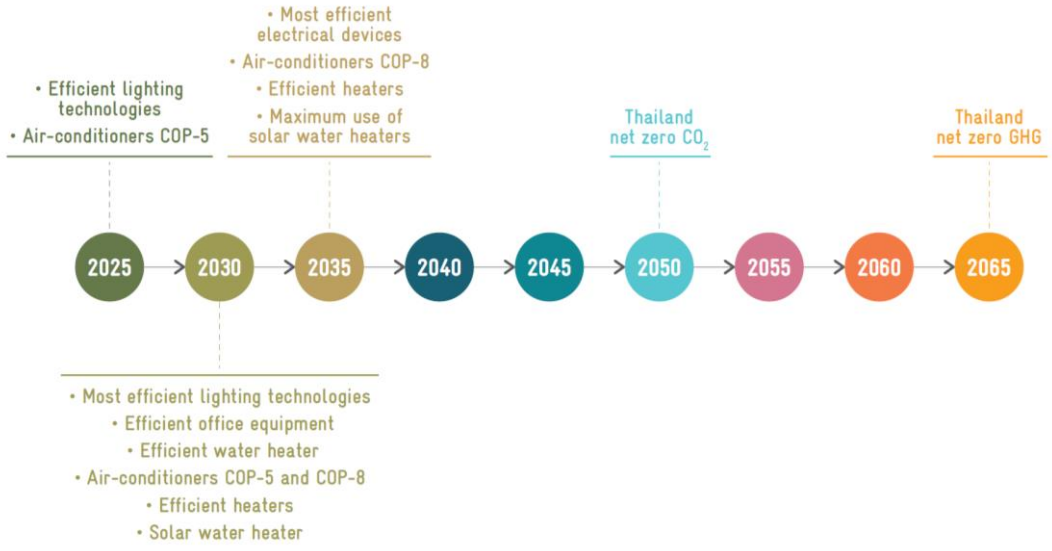


Figure 31 Carbon neutrality and net zero GHG emissions timeline for commercial building sector

4.3.4. Low Carbon Technologies in Power Generation, Transport, and Building Sectors

According to LT-LEDS, Thailand implements green technologies and innovations in power generation, transport, and building sectors, along with the improvement of energy efficiency to reach carbon neutrality and net zero GHG emissions. Table 4 shows in-use and target technologies in the three sectors.

Table 4 Current and planned low carbon technologies in power generation, transport, and building sectors in Thailand

Sectors		
Power Generation	**Transport**	**Building**
In use: • Solar PV • Wind turbine • Biomass cogeneration plants • Biogas turbines **Additional technologies:** • Solar PV with battery storage • Hydro-floating solar hybrid system • Fossil- and biomass-based power plants equipped with CCS/CCUS technologies • Fuel-cell power plants • Gas turbines using a natural gas/hydrogen blend and 100% green hydrogen	**Cleaner and more efficient technologies:** • Hybrid electric vehicles • Plug-in hybrid electric vehicles • Fuel cell electric vehicles • Fuel cell technology for long-haul truck	**Efficiency improvements:** • Cooling technologies (air-conditioners, refrigeration) • Electrical devices • Lighting technologies • Shifting from LPG cooking to electric cooking • Solar energy for water heating

4.3.5. Gaps in Policy Actions to Enable Low Carbon Technologies in Target Sectors

Technologies in use: solar PV, wind turbines, biomass cogeneration plants, and biogas turbines has been developed and implemented in Thailand for decades. In the earlier stage of the implementation, Thai government offers financial support in terms of subsidy and tariff, which led to a significant increase of renewable-based power plant in the economy. Since these power plants require a large piece of land nearby the central grid (for solar PV and wind turbines), supply of raw materials (biomass cogeneration plants and biogas turbines), and availability of transmission lines, the deployment of the technologies can somehow be restricted. Existing regulations may become hurdles for a renewable-based power plant to enter the power generation market which may decelerate the increase in the share of renewables.

Battery storage has shown remarkable progress in recent years. The technology sees continuous development along with the rise in renewable energy share in the central energy mix, contributing to stability in energy supply and energy security. The storage industry continues to evolve and develop new battery technologies with a higher level of efficiency. Though other

existing renewable energy power plants have become more affordable, the battery price is still high compared to its capacity to ensure stable supply of clean energy. Though the price of battery is expected to continue to fall[139], rising raw materials and component costs increased its price for the first time in 2022[140]. This requires appropriate industrial support from the government. Thailand Board of Investment (BOI) attempted to work closely with private sector in designing policy and incentives to support the development and introduced several tax exemption schemes to promote domestic and foreign investments. Detailed policy actions are yet to be explored to sustain sufficient interest of key private actors domestically and globally and alleviate impacts from upfront cost for the technology development.

Both *CCS/CCUS and fuel-cell power plants* can play a critical role in energy transition, especially in heavy industries. As the technologies are under development, requiring additional advancement and subsequent demonstration in actual conditions, BOI, Ministry of Energy, and Ministry of Natural Resources and Environment are working together to consider supporting policies, incentives, regulations, as well as prepare for a mandate to actualize the technologies. Thailand needs to plan for a tangible transition with actions to mitigate impacts from foreseeable issues by setting a clear policy direction, efficient regulations, and benchmarking and adoption of standards, particularly for CCS/CCUS.

Hydrogen blend and 100% green hydrogen are the next generation technologies that can increase renewable energy deployment, through its advantageous characteristics as a transportable and movable energy carrier. It enhances the ability of renewable energy to respond to the electricity consumption profile. Though the development of hydrogen goes well so far, technological advancement and economic feasibility remain as challenges. To actualize the utilization of hydrogen, government may need to adopt supportive law and regulations to enable a better research and development environment. Furthermore, as foreign investment in hydrogen can accelerate the deployment of the technology, the government can consider working closely with BOI[141] to participate in incentive packages to attract investment from foreign companies.

Electric vehicles play a critical role in transport sector in Thailand to reduce fossil fuel dependence. Increase in the share of EVs in public fleet, support new EV purchase in the market, and phase out of ICE vehicles present a great decarbonization opportunity for the sector. Thailand introduces 30@30 Policy, which targets zero emission vehicles to account for at least 30% of total automotive production by 2030 through a three-phase development plan: phase 1 (2021-2022), phase 2 (2023-2025), and phase 3 (2026-2030). Thai government injects financial and tax incentives and sets standards to accelerate the increase in EV share. Although the 30@30 Policy is expected to promote deployment of zero emission vehicles and support their critical infrastructure, it could only create a strong wave of demand and interest at the earlier stage. Since carbon neutrality and net zero GHG emissions are committed to be achieved by 2050 and 2065, respectively, additional policy actions and supports are required to sustain the momentum of EV deployment and manufacture after the end of phase 3 of the plan.

Efficiency improvement in the building sector is considered an important goal, that needs to be achieved. Currently, Thailand has enforced Building Energy Code (BEC) on new buildings with

139 https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/
140 https://www.bloomberg.com/professional/blog/race-to-net-zero-pressures-of-the-battery-boom-in-five-charts/
141 https://www.boi.go.th/un/boi_event_detail?module=news&topic_id=133211

an aim for net zero *energy* building in the sector. The requirements in the BEC are planned to be tightened by decreasing the floor areas of the applicable buildings which will gradually increase the number of concerned buildings. For smaller buildings, application of technologies and installation of equipment may increase the upfront cost for the newly built infrastructure. Furthermore, there are only few technologies, such as air-conditioners, refrigeration, efficient lighting, and electrical appliances, that are supported by Thailand's LT-LEDS. Thai Government needs to consider a systematic framework to implement the BEC, e.g., net-zero emission building, develop practical standards that public can adopt and follow, and introduce supportive regulations that cover technology and equipment utilization, especially for small buildings.

4.4. Qualitative Consideration of Emission Reduction Potential in Power Generation, Transport, and Building Sectors

This section presents qualitative consideration of emission reduction potential for case studies in power generation, transport, and building sectors. Case studies in power generation sector comprised of RE100 Island, Coal Phase-out, Peer-to-Peer Trading Platform, and Wind Power Island have a great potential to reduce greenhouse gas emission since it contributes to large increase in renewable energy share in energy mix. In transport sector, City-scale Development of New Vehicles, Hydrogen Energy Demonstration Project and Well-planned Electric Vehicle Subsidies are with promising strategic finance schemes, where electric vehicles are promoted by top-down and bottom-up approaches. Building sector relies on increase in energy efficiency of existing and newly constructed buildings which Retrofitting Building to Achieve Net-zero Carbon Emission, Homes of the Future and First Carbon-zero House are among cases that contribute to improvement of energy efficiency.

4.4.1. RE100 Island

Policy Information ①

Policy action: financial support
Technology/approach: solar, wind, other RE
Implemented area: large islands, remote areas

Possibility, Contribution and Caution ③

Possibility: Doable with strong top-down policy
Contribution: Support RE in large islands and remote areas (rather limited in Thailand)
Caution: Need to account for tourism perspective

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Increase in contribution to emission reduction in power sector Increase in energy security	YES
State-owned enterprises	Provide access to islands and remote areas	YES
Local government	Benefit from electricity generated from renewable energy [1]	YES
Tourism industry	Access to green electricity [2] RE infrastructure may disturb scenic landscape	YES NO ②

Figure 32 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for RE100 Island

Chinese Taipei has demonstrated a fully renewable energy-powered island which solar and off-share wind power and grid-connected system are promising contributors. Financial support provided by central government is a key enabling policy to deploy large-scale renewable energy technologies in the island. This approach is not only applicable for island areas, but also remote rural areas with limited energy access and uneconomical energy prices. Thus, emission reduction potential becomes larger for economies with many islands and remote areas. In

Thailand context, several stakeholders could enjoy benefits from the approach. Government agencies, such as Ministry of Energy could enjoy contribution to emission reduction in power generation sector. State-owned enterprises could provide energy security and access to rural remote areas and islands. Local government would benefit from electricity generated from renewable energy technologies[142]. Essentially, tourism industry uses generated electricity for tourism activities[143]. Adopting the approach, Thai stakeholders could gain benefits and contribute to emission reduction considerably. However, the enabling policy and the approach demonstrated in island context meet constraints. Due to the facts that Thailand largely depends on economic growth from tourism sector[144] and large islands in Thailand are developed for tourism purposes, implementation of renewable energy technologies in the areas requires actions to incorporate with tourism perspectives, particularly scenic landscape issues. To actualize the approach, government would need a strong top-down policy to develop renewable energy technologies in tourism-purposed areas and keep balance between use of technologies and a beauty of a natural destination which turning into a low-carbon and green tourism destination is strongly suggested[145].

4.4.2. Coal Phase-out

Policy Information ①

Policy action: Act and supporting policy
Technology/approach: all clean energy technologies
Implemented area: entire power sector

Possibility, Contribution and Caution ③

Possibility: Doable and ongoing in the Economy
Contribution: Significant contribution in facilitating increase in RE share
Caution: Need good compensation for state-owned enterprise, coal industries and surrounding communities

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Good alignment with National Energy Plan to avoid fossil fuels [1]	YES
State-owned enterprises	Demand/supply fluctuation due to large RE share [2]	NO
Private sector	Coal industry will not be able to continue the operation Opportunity to build new RE power plants [3]	NO YES
Local community	Loss of opportunity from compensation for power plant siting	NO ②

Figure 33 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for Coal Phase-out

Coal phase-out strategy in power generation towards carbon neutrality is an aim for numerous economies in which the strategy also exists in Chile and Thailand due to it has a great potential to reduce emissions. Chile has promoted Non-Conventional Renewable Energy Law[146] with strong effort to phase down and out coal-fired power plants, while Thailand's Long-term Low Emission Development Strategy and 4D1E (digitalization, decarbonization, decentralization, de-regulation, electrification) strategy supports phase-out and down of coal-fired power plants[147]. The strategy could lead to a significant contribution to emission reduction and provide benefits to relevant stakeholders. Government agencies could fulfill the Long-term Low Emission

142 https://www.taipeitimes.com/News/biz/archives/2017/11/24/2003682799
143 https://issuu.com/penghubaytw/docs/penghubaytwmag201710en
144 https://thailandpolicylab.com/en/building-a-nation-upon-sustainable-tourism/
145 https://www.eco-business.com/news/penghu-keen-on-renewable-resources-low-carbon-tourism/
146 https://www.energia.gob.cl/sites/default/files/energyagendaweb.pdf
147 https://www.thailand-energy-academy.org/assets/upload/coursedocument/file/E106%20Part%201%20Thailand%20Energy%20Pathway%20to%20Achieve%20Carbon%20Neutrality.pdf

Development Strategy and the 4D1E accordingly. Renewable energy industry receives business opportunity to build new renewable energy power plants[148]. However, decommissioning of coal-fired power plants could also lead to conflicts. Residents in communities nearby the operating coal-fired power plants either receive compensation for pollution damage from local government or live with better air quality as coal-fired power plants decommissioned. State-owned enterprise such as Electricity Generation Authority of Thailand needs to deal with high demand and supply of renewable energy and to stabilize an increase of renewable energy in the economy's power system and energy fluctuation[149]. Though there are conflicts left to manage and a critical resolve needs to be made, Thailand could use the approach as a practical action to contribute to emission reduction in power generation sector. Thailand has planned to replace decommissioned coal-fired power plants with gas-fired power plants with carbon capture utilization and storage technology[150]. Additionally, ammonia co-firing system is considered one of promising technology for a sustainable energy transition in Thailand[151]. Integrated these approaches, Thailand could incorporate abovementioned conflicts and largely contribute to carbon neutrality achievement.

4.4.3. Peer-to-Peer Trading Platform

Policy Information ①

Policy action: regulatory sandbox
Technology/approach: decentralized RE systems
Implemented area: communities with prosumers

Possibility, Contribution and Caution ③

Possibility: Doable with enabling environment
Contribution: Contribution in facilitating increase in RE share
Caution: Need regulatory support and consideration of wheeling charge

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Need for regulatory framework development Energy access for rural areas and improvement of grassroot economy [1]	YES
State-owned enterprises	Departing from enhanced single buyer model Burden on electricity transmission and/or distribution [2]	NO
Private sector	Opportunity to gain revenue by introducing trading platforms, products, and services [3]	YES
Prosumer/user	Sale/purchase of RE at right time and optimal price	YES ②

Figure 34 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for Peer-to-Peer Trading Platform

Peer-to-peer trading platform promotes decentralized systems in the power sector. The platform facilitates management of renewable energy surplus and enables a trading mechanism for prosumers in networked communities. Since decentralized systems allows participation of isolated communities to contribute to decarbonization[152], Energy Regulatory Commission of Thailand (ERC) has promoted the approach through setting up a new regulatory sandbox. Several demonstration projects were conducted under the regulatory sandbox, enlightening capability to reduce emissions in isolated areas. The regulatory sandbox could act as an enabling policy to support peer-to-peer trading platform and provide advantages to private sector and

148 https://www.greenpeace.org/thailand/publication/21396/climate-coal-phase-out-coal-thailand-report/
149 https://www.eria.org/RPR_FY2016_No.5_Chapter_1.pdf
150 https://www.pinsentmasons.com/out-law/news/thailand-to-replace-coal-fired-plants-with-gas-fired-complex
151 https://www.banpupower.com/wp-content/uploads/2023/01/Press-Release_BPP-MOU-for-BLCPs-Ammonia-Co-firing-CCUS-Feasibility_EN_FINAL_19012023.pdf
152 https://www.unescap.org/sites/default/files/14.%20FS-Decentralized-energy-system.pdf

prosumers/users. Private enterprises could take opportunity to introduce trading platforms, products, and services to the public and gain additional revenue from trading platform subscription and transaction fees[153]. Prosumers/users could purchase renewable energy at the right time and optimal price and obtain financial benefits from trading surplus of self-generated electricity. Essentially, peer-to-peer trading platform provide energy access locally in isolated areas[154]. This approach not only contributes to potential emission reduction in communities, but it also aligns well with Thailand's BCG actions as an economy-wide agenda[155]. Trading platform with decentralized systems has economic potentials for the economy and communities in which it addresses energy challenge on high energy consumption and grid stability[156] and enables energy access and security to rural communities where grassroot economy is improved through technology utilization[157]. Thus, the approach, enabled by the policy action, is applicable to Thailand's context with abovementioned reasons in which communities benefit from the platform with regulatory sandbox and largely contribute to emission reduction in power generation sector towards carbon neutrality achievement. However, the trading platform has certain constraints. Regarding supporting policies, regulations, and laws, ERC needs to develop a framework to govern trading mechanism among prosumers and communities in order to actualize the approach at larger scale after expiration of regulatory sandbox. Trading platform incurs Electricity Generation Authority of Thailand, Provincial Electricity Authority and Metropolitan Electricity Authority transmission utilities for energy transaction[158]. Wheeling charge for third party access becomes an issue for energy transaction among prosumers in communities. Since decentralized systems causes decreasing Electricity Generation Authority of Thailand's role of enhanced single buyer, wheeling charge should be incorporated properly.

153 https://www.mdpi.com/1996-1073/15/3/1229
154 https://www.unescap.org/sites/default/files/14.%20FS-Decentralized-energy-system.pdf
155 https://sdgs.nida.ac.th/home/outreach/outreach-65067
156 http://www.scadaautomation.co.th/?p=1906
157 https://www.nstda.or.th/en/images/pdf/bcg_action_plan.pdf
158 https://www.researchgate.net/publication/322819630_Price_Determination_of_Electricity_Supply_in_Thailand_based_on_Externalities_Wheeling_Charges_and_Losses

4.4.4. Wind Power Island

Policy Information ①

Policy action: tax credit and exemption
Technology/approach: wind and other RE
Implemented area: large islands

Possibility, Contribution and Caution ③

Possibility: Doable with strong top-down policy
Contribution: Significant contribution from tax-related measures, but limited contribution from offshore wind
Caution: Need consideration of wheeling charge and compensation to local fishing industry

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Align with existing measures to promote RE and EE [1,2]	YES
State-owned enterprises	Demand/supply fluctuation due to large RE share [2]	NO
Private sector	Financial support from government for RE projects	YES
Tourism industry	Impacts on tourism seems to be negligible	MAYBE
Local fishing industry	Local fishing industry may be affected by offshore wind farms [3]	NO ②

Figure 35 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for Wind Power Island

South Fork Wind Farm is a successful offshore wind farm showing New York's ambitious energy goal towards carbon neutrality. The wind farm located about 35mi east of a main island can supply energy to more than 70,000 New York households[159] and reduce emission equivalent to taking 60,000 cars of the road. The implementation of wind farm greatly responds to the State's emission reduction target to reduce 40% by 2030 where Inflation Reduction Act plays a critical role to support the wind farm's approval and construction. The act provides tax credit and exemption for renewable energy projects, expecting to receive private sector interest and to ensure energy security for beneficiaries. In Thailand context, Thailand Board of Investment presents a similar approach to the act as it supports tax exemption for alternative energy utilization through Efficiency Enhancement Measure[160]. This approach can bring in benefits to relevant Thai stakeholders. Government agencies such Ministry of Energy could decrease reliance on fossil fuel as the Ministry also sets aside over millions for renewable energy and energy efficiency development funds[161]. State-owned enterprises could enjoy energy security for the economy and benefit from wheeling charge for third party access. Private enterprises would receive support from central government to permit approval for project construction. Thus, it shows a great potential to contribute to emission reduction and carbon neutrality. However, offshore wind farm construction remains difficulties to Thailand as the project would require a large capital investment from both public and private sectors and could affect fishery sector as it becomes one of important industries to export local products[162]. To manage the difficulties, central government could join hand with state-owned enterprises and private sector at domestic and global levels to co-invest in project construction where Thailand Board of Investment facilitates foreign investors for financial barriers and risks[163] and permits project approval.

159 https://www.windpowerengineering.com/132-mw-south-fork-offshore-wind-project-approved-to-start-construction/
160 https://www.boi.go.th/upload/content/No.1_2564EN_605170ba4917d.pdf
161 https://thaiembdc.org/2020/09/11/energy-ministry-ready-to-fund-1000-renewables-projects/
162 https://www4.fisheries.go.th/dof_en/view_message/232
163 https://energypedia.info/wiki/Barriers_and_Risks_to_Renewable_Energy_Financing

4.4.5. City-scale Development of New Vehicles

Policy Information ①

Policy action: incentives, regulations, and standards
Technology/approach: new electric vehicles
Implemented area: urban cities

Possibility, Contribution and Caution ③

Possibility: Rather difficult to secure sufficient budget and build sufficient charging infrastructure
Contribution: Significant contribution from EV dissemination
Caution: Large amount of budget and charging infrastructure is needed along with strong local government

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Promote energy transition and largely contribute to emission reduction in transport sector	YES
Local government	Need supporting scheme for vehicle purchase and construction of charging stations [1]	NO
Private sector	Business opportunity to introduce EV, services, and products	YES

②

Figure 36 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for City-scale Development of New Vehicles

The People's Republic of China has turned Shenzhen city into a green transport city as over 21,000 electric-powered taxi fleet was deployed[164]. The initiative is expected to reduce emissions by about 850,000t a year and 70% more energy-efficient compared to vehicles powered by fossil fuel[165]. The ambitious electric vehicle deployment is encouraged by New Energy Vehicle Industrial Development Plan 2021-2035 where incentives, regulations and standards are set to support the shift[166]. In Thailand context, central government adopts a similar approach to support the shift by providing subsidies to electric vehicle purchase according to the Thailand's Long-term Low Emission Development Strategy and the 4D1E strategy[167]. Thailand not only promotes electric vehicles purchase to drive energy sector towards carbon neutrality, but also supports electric vehicle production infrastructure. The implementation of the initiative along with central government support could promote energy transition and largely contribute to emission reduction in the transport sector. The initiative offers benefits to various relevant stakeholders in Thailand. Central government, Ministry of Energy and Ministry of Transport could fulfill the economy's effort to reduce emission in transport sector. The private sector would enjoy business opportunities to introduce electric vehicles, services, and products to the market and satisfy with increasing demand of electric vehicles. However, the bottleneck to implement the initiative is installation and distribution of charging infrastructure across the economy. Shenzhen city still has approximately 1,000 vehicles to be deployed because of a shortage of charging stations and unsatisfactory cab drivers due to supply and allocation of charging stations. In order to actualize the deployment, central government needs to support not only electric vehicle purchase, but also charging infrastructure installation and distribution. Essentially, placement of charging station installation should be incorporated appropriately by distributing to cities and sub-cities to avoid

164 https://apnews.com/article/china-technology-business-environment-mi-state-wire-62d6c9b22b7f4caaaafdf76af8521d1b
165 https://techcrunch.com/2019/01/04/shenzhen-electric-taxis-push/
166 https://theicct.org/sites/default/files/publications/China-new-vehicle-industrial-dev-plan-jun2021.pdf
167 https://www.thailand-energy-academy.org/assets/upload/coursedocument/file/E106%20Part%201%20Thailand%20Energy%20Pathway%20to%20Achieve%20Carbon%20Neutrality.pdf

the shortage of use and high demand of power in a single city. This would satisfy electric vehicle drivers and ensure energy stability in cities.

4.4.6. Hydrogen Energy Demonstration Project

Policy Information ①

Policy action: large-scale demonstration project
Technology/approach: hydrogen and fuel cell
Implemented area: innovation hubs in industrial area

Possibility, Contribution and Caution ③

Possibility: Can turn EECi into an experimental field
Contribution: Limited contribution until the investment is commercially viable
Caution: Supporting policy and regulatory framework needed

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Fulfill carbon neutrality goal and attract domestic and international investment [1]	YES
	Need to provide financial support until the projects are bankable [1]	NO
State-owned enterprise (Industrial Estate Authority)	Support fossil fuel reduction in the industries [2]	YES
Private sector	New business opportunity for hydrogen market	YES ②

Figure 37 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for Hydrogen Energy Demonstration Project

Fukushima Hydrogen Energy Research Field serves as hydrogen production plant and hydrogen fueling station in Japan. The hydrogen demonstration project is conducted with an aim to drive transport sector through use of hydrogen in vehicles to contribute to emission reduction towards carbon neutrality achievement [168]. Hydrogen advancement in the hydrogen demonstration project is supported by Japan's Green Growth Strategy where hydrogen and ammonia are expected to be produced up to 3Mt in 2030 and approximately 20Mt in 2050. In Thailand context, the hydrogen demonstration project has a similarity with the Eastern Economic Corridor of Innovation which is an innovation hub to support the economy's transformation. Thus, Thailand could adopt the hydrogen demonstration project because the Eastern Economic Corridor of Innovation has a potential to advance hydrogen research and application for vehicle use. In terms of policy support, Thailand's Long-term Low Emission Development Strategy has supported hydrogen use as fuel cell vehicles and 4D1E strategy considers hydrogen as a promising technology pillar. The adoption could drive Thailand's economy in energy and transport sectors, provide opportunity to large emission reduction, and create benefits for relevant stakeholders. Central government could fulfill long-term goals towards carbon neutrality[169], attract domestic and foreign private investment, and create green jobs and opens new markets [170]. State-owned enterprises benefit from hydrogen use for transport and logistic purposes[171], contributing fossil fuel use reduction and mission reduction in industries. Private enterprises gain new business opportunities for hydrogen market. However, only a few green hydrogen projects have been

168 https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/05_automobile.pdf
169 https://www.japan.go.jp/kizuna/2021/09/green_growth_strategy.html
170 https://blogs.worldbank.org/ppps/green-hydrogen-key-investment-energy-transition
171 https://www.bangkokpost.com/business/2489987/ieat-preparing-to-invest-in-hydrogen-projects

successfully brought into the market [172] which most green hydrogen projects are under construction and in operation at pre-commercial phase. This indicates a need for large-scale capacity construction. Thus, the hydrogen industry requires support in terms of policy and regulatory framework to incentivize from government. Blending public and private capital could make hydrogen project bankable and commercially viable [173]. Furthermore, regulations for technology enforcement and compliance should be provided in order to ensure and accelerate technology deployment at industrial scale and capacity building and technical assistance should be created for the emerging market.

4.4.7. Well-planned Electric Vehicle Subsidies

Policy Information ①

Policy action: EV subsidies
Technology/approach: well-planned incentivization
Implemented area: entire transport sector

Possibility, Contribution and Caution ③

Possibility: Doable with necessity to balance with biofuel
Contribution: Significant contribution through electrification
Caution: Consideration of ICE-based automobile supply chain and balance with biofuel use and development needed

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Increase in domestic EV demand and attract domestic and foreign investment Need to balance with biofuel use and development [2]	YES NO
Private sector	Larger EV sales and better competitiveness in global EV market [3] Shrinkage of ICE vehicle demand affects domestic automobile industry's supply chain	YES NO ②

Figure 38 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for Well-planned Electric Vehicle Subsidies

The Republic of Korea has implemented electric vehicle subsidies for transport market growth and fulfillment of long-term goals towards carbon neutrality. The Thai Cabinet also employs a similar approach to provide subsidy to increase demand for electric vehicle purchase and to accelerate market growth[174]. In the Republic of Korea, the subsidy is allocated from taxes, while a similar mechanism appears in Thailand as subsidy is from tax-based fossil fuel fund. The subsidy approach could contribute to emission reduction in the transport sector through an increase in share of electric vehicles on the road. The Republic of Korea perceives development of electric vehicles and plans to lift the subsidies when potential economic viability is presented. This approach should be taken into account in Thailand context. Subsidies would provide benefits, particularly to government and private sector. Government could increase demand for electric vehicle purchase and production and attract domestic and foreign investment, leading to emission reduction in transport sector [175]. Private enterprises would enjoy strong sales and create competitiveness in electric vehicle market[176]. With existing approach provided by Thai Cabinet and practicable actions from the Republic of Korea, the subsidy approach with strategic actions to lift

172 https://blogs.worldbank.org/ppps/green-hydrogen-key-investment-energy-transition
173 https://blogs.worldbank.org/ppps/green-hydrogen-key-investment-energy-transition
174 https://www.tilleke.com/insights/thailand-approves-incentives-to-promote-electric-vehicle-adoption-and-manufacturing/
175 https://www.tilleke.com/insights/thailand-approves-incentives-to-promote-electric-vehicle-adoption-and-manufacturing/
176 https://www.kedglobal.com/business-politics/newsView/ked202302030011

subsidies could be applicable to Thailand's context where electric vehicle demand could be increased and contribution to emission reduction in transport sector could be met. However, subsidy approach in Thailand remains a constraint which is balance between biofuel use as Thailand's strength and electric vehicle penetration into the market. Balance between biofuel use and development as Thailand's strengths should be taken into account when deploying subsidies for electric vehicle and charging infrastructure installation. Internal combustion engine vehicle with biofuel is considered a promising solution according to Thailand's Long-term Low Emissions and Development Strategies[177]. Although internal combustion engine vehicle is planned to be phased down in 2030, development of energy efficiency for internal combustion engine and biofuel blends is also on the plan and it is still reliable and compatible with Thailand's potential bioeconomy[178]. Through balancing use of the economy's strengths and promotion of electric vehicles, the subsidy approach not only paves concrete pathways to emission reduction in transport sector, but also embraces BCG actions. The balance incorporates in BCG actions in the view of adding value to energy production from farm products and local resources, improving grassroot economy, and increasing the economy's market competitive from bio-based products[179].

4.4.8. Retrofitting Building to Achieve Net-zero Carbon Emission

Policy Information ①

Policy action: retrofit code
Technology/approach: energy efficiency enhancement through better lighting, heating, etc.
Implemented area: commercial/office buildings

Possibility, Contribution and Caution ③

Possibility: Doable once implementation framework is established
Contribution: Large if private sector sees the opportunity
Caution: Standard, regulation, and technical guidance needed

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Drive building sector towards carbon neutrality No concrete framework for implementation of existing and newly constructed net-zero energy buildings [1]	YES NO
Private sector	Business and job opportunity for new, large private investment [2] Need a strong supply chain of raw materials [2]	YES NO ②

Figure 39 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for Retrofitting Building to Achieve Net-zero Carbon Emission

Canada implements retrofit code to improve energy efficiency to fight climate change and to lower emissions since building and homes in the economy contribute approximately 18% to the total emissions [180] where space heating is the largest energy contributors. The pathway to implement the retrofit code is supported by the Pan-Canadian Framework and Clean Growth Economy [181] and Canada expects to implement the retrofit code by 2025. Thailand has also perceived net-zero energy building as an important strategy to reduce emission in building sector

177 https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf
178 https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.240
179 https://www.nstda.or.th/en/images/pdf/bcg_action_plan.pdf
180 https://www.canada.ca/en/natural-resources-canada/news/2022/04/canada-invests-in-deep-energy-retrofits-for-buildings-in-toronto.html
181 https://www.canada.ca/content/dam/themes/environment/documents/weather1/20170119-en.pdf

as it is included in Building Energy Code and Energy Efficiency Development Plan[182]. In Thailand context, development of efficient lighting, refrigerators technologies, air conditioners, and use of liquefied petroleum gas stoves are promising solutions indicating in Thailand's Long-term Low Emission Development Strategy as a tropical climate economy. Thus, retrofit code for the abovementioned technologies could drive building sector in Thailand towards carbon neutrality. The retrofit code not only contributes to emission reduction in the sector, but it also provides opportunity and financial benefits to relevant sectors. Central government could lower emission derived from building sector and provide opportunity to individual building owners to be a part of creating clean future and participating climate-proofing pathway[183]. Essentially, implementation of retrofit code creates financial benefits to residents and private enterprises in the long run. This serves as a business and job opportunity for new, large private investment at domestic and global levels[184]. However, the retrofit code presents several constraints in Thailand context. The economy has no concreate framework to govern implementation of existing and newly constructed net-zero energy buildings. Thus, it needs to consider supportive mechanisms to facilitate the implementation at several scales. Central government needs to provide design, construction, renovation and verification processes, and technical guidance to building owners[185] in order to actualize the retrofit code in building sector. Standard guidance and regulations are considered essential because net-zero energy buildings are designed and constructed for high performance levels with clean power generation and least emission production on an annual basis[186]. Furthermore, the implementation should consider a strong supply chain of raw materials and volatility of costs derived from global market[187]. To address the abovementioned limitations, central government would set up retrofit code and regulations on a voluntary basis and prove benefits to the public. This would attract building owners to implement the retrofit code for long-term future profits.

182 https://so02.tci-thaijo.org/index.php/jars/article/download/81264/64665/196396
183 https://www.canada.ca/en/natural-resources-canada/news/2022/04/canada-invests-in-deep-energy-retrofits-for-buildings-in-toronto.html
184 https://delphi.ca/wp-content/uploads/2022/09/Green-Retrofit-Economy-Study-20220602.pdf
185 https://www.canada.ca/en/natural-resources-canada/news/2022/04/canada-invests-in-deep-energy-retrofits-for-buildings-in-toronto.html
186 https://www.canada.ca/en/natural-resources-canada/news/2022/04/canada-invests-in-deep-energy-retrofits-for-buildings-in-toronto.html
187 https://delphi.ca/wp-content/uploads/2022/09/Green-Retrofit-Economy-Study-20220602.pdf

4.4.9. Homes of the Future

Policy Information ①

Policy action: building code
Technology/approach: energy efficiency, local RE, and low carbon materials
Implemented area: all types of communities

Possibility, Contribution and Caution ③

Possibility: Unlikely if not implemented on a voluntary basis
Contribution: Large if private sector sees the opportunity
Caution: Requirements need to match the local context and be adopted on a voluntary basis

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Drive building sector towards carbon neutrality	YES
Private sector	business opportunity to introduce low carbon materials, devices, and services [1]	YES
	Manufacturing enterprises may face constraints in its business operation and expansion as the requirements are mandatory [2]	NO
Local community	Residents must change their buildings to meet requirements [3]	NO ②

Figure 40 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for Homes of the Future

New Zealand's Homes of the Future is presented as a sustainability-driven pilot project with an aim to reduce emission in the building sector. The project prioritizes three key factors including low carbon materials, increase in energy efficiency, and local renewable energy utilization, for emission reduction contribution[188]. Thus, the economy introduces Building Code Clause H1, with an aim to improve energy performance in buildings, to facilitate the deployment of the project. The Building Code presents a similarity to Thailand Building Energy Code on objectives to increase energy efficiency in buildings, to use energy-efficient equipment and devices to lower expenses and contribute to least emission in overall. While New Zealand aims to mandate the Building Code to new buildings and various materials and space utilization for existing building, Thailand applies its Building Code to new buildings with a plan to expand its concerned building in the future[189]. The implementation of the building codes not only offers opportunity for central government to reach long-terms goals towards carbon neutrality, but also provides business opportunity to private enterprises to introduce developing materials, tools, services, and resources to customer to meet energy efficiency standards[190][191]. However, New Zealand Building Code presents a difficulty in Thailand context. Since the Building Code Clause H1 is mandatory that new buildings work must comply with [192], private sector, particularly manufacturing enterprises face constraints in its business operation and expansion[193]. Essentially, building code standard requirements are strictly limited to particular materials, space utilization, temperature and humidity control which could create significant impacts to manufacturing sector, leading to private sector resistance. To address the difficulty, central government should adopt the New Zealand Building Code on a voluntary basis and incorporate with existing the Thailand Building

188 https://tinyurl.com/463mkbpn
189 https://www.egs-bkk.com/th/news/thailands-building-energy-code-bec-enters-into-force-as-from-13th-march-2021/
190 https://www.branz.co.nz/energy-efficiency/h1-support/
191 https://www.comfortech.co.nz/h1-hub/about-h1/
192 https://www.building.govt.nz/building-code-compliance/h-energy-efficiency/h1-energy-efficiency/
193 https://www.researchgate.net/publication/275889589_Energy_efficiency_in_the_NZ_building_code_A_new_structure

Energy Code. This would facilitate the transition to green buildings for emission reduction in the building sector.

4.4.10. First Carbon-zero House

Policy Information ①

Policy action: building certification
Technology/approach: energy efficiency and RE
Implemented area: residential buildings

Possibility, Contribution and Caution ③

Possibility: Doable on a voluntary basis
Contribution: Limited as it is applicable only for new buildings
Caution: Certification should be on a voluntary basis and RE potential of the residences should be explored beforehand

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Drive building sector towards carbon neutrality	YES
Private sector	Lower GHG emission from building construction [1]	YES
	Income from green building certification	YES
	Certification is only applicable for is applicable for new constructions and larger additions/extensions [2]	NO ②

Figure 41 Summary of Enabling Policy Contribution to Carbon Neutrality Goal for First Carbon-zero House

Sweden Green Building Council introduced Villazero as the world's first carbon neutral house through green building certification, namely NollCO_2. The certification mechanism is developed with an aim to reduce emission from building construction and to promote carbon neutral in building and urban planning sectors. To support the actions, Swedish government has put several measures, such as carbon emission taxation [194] in place to encourage the implementation and energy transformation in other sectors. NollCO_2 employs net-zero impact model[195] which keeps balance between emission in a building (embodied and operational carbon) and reduction or uptake of emission outside a building (utilization of renewable energy and carbon offset). In Thai context, green building certification is also introduced as a strategy to contribute to emission reduction. The economy presents Thai's Rating of Energy and Environment Sustainability as a green building certification which is adapted from the Leadership in Energy and Environmental Design, maintained by the United States[196]. Implementation and adoption of the green building certification maintained by Sweden presents a great potential to Thailand and would benefit several relevant stakeholders. Central government could enjoy emission reduction derived from implementation of the certification in new buildings. Private enterprises would generate additional profit by providing services to certify green buildings. Essentially, the construction industry could significantly reduce emission from building construction by following certification requirements provided by non-profit organizations. However, the certification mechanism is only applicable with new buildings which requires particular building design and construction in order to meet the certification requirements[197]. Furthermore, carbon zero house design is central to use of renewable energy such as solar power as its energy source. Areas with

194 https://www.iea.org/news/sweden-is-a-leader-in-the-energy-transition-according-to-latest-iea-country-review
195 https://www.ntnu.edu/documents/1281770977/1290530160/Session15_PiaStoll.pdf/b8379641-120e-f7fc-8eb8-7a52af6193d8?t=1574077570340
196 https://www.egs-bkk.com/en_US/green-building-certification/
197 https://www.sweco.co.uk/insights/news/world-s-first-zeroco2-certified-building-opens-on-sweden-s-island-of-gotland/

low solar radiation would face challenges to produce sufficient electricity for self-use and a long cloud weather condition would diminish the amount of sunlight reaching solar panels. Thus, abovementioned limitations to implement the certification mechanism to Thailand context should be addressed accordingly. The participation of certification should be on a voluntary basis with a minimum requirement in which reasonable benefits and financial viability should be proved to attract building owners. Furthermore, the certification requirements and preliminary criteria should be incorporated to fit with Thai context, such as certified points[198] and award levels[199] to attract building owners.

4.4.11. Smart Microgrid and Energy Trading Platform in a Rural Community

Policy Information ①

Policy action: regulatory sandbox and BCG actions
Technology/approach: Smart microgrid and energy trading platform
Implemented area: rural communities

Possibility, Contribution and Caution ③

Possibility: Potential for scaling up with enabling environment
Contribution: Contribution to greening electricity and developing grassroot economy through decentralization
Caution: Need regulatory support, initial investment, and capacity building program for local communities

Stakeholder	(Expected) Pros and Cons	Possible Response
Government agency	Energy access for rural areas and improvement of grassroot economy [1] Initial investment when the project is not economically viable	YES NO
State-owned enterprises	Reduce grid utilization through decentralized systems [2] Departing from enhanced single buyer model	YES NO
Local community	Drive grassroot economy and ensure energy security Responsibility to maintain the system in a long run	YES NO ②

Figure 42 Summary of BCG Economy Contribution to Carbon Neutrality Goal for Smart Microgrid and Energy Trading Platform in a Rural Community

Smart microgrid with an integration of energy trading platform is considered a successful model to increase share of renewable energy and to improve local economy in rural communities in Thailand. The model provides clean energy to community residents, reduces electricity expenses, and ensures energy access and security[200]. The success of implementation is derived by the Energy Regulatory Commission Sandbox, a pilot program with a permit to deploy electricity trading mechanism maintained by Energy Regulatory Commission of Thailand[201]. The model under the enabling policy offers several relevant stakeholders the chance to participate in carbon neutrality pathway and enjoy benefits. Central government could drive the economy forward to carbon neutrality achievement by integrating BCG actions into implementation. State-owned enterprises, such as Electricity Generation Authority of Thailand and Provincial Electricity Authority could reduce grid utilization through decentralized systems and gain financial benefits from wheeling charge for third party access[202] though the enhanced single buyer's role is limited. Communities of prosumers/users could access to energy, obtain benefits from surplus of self-

198 https://www.researchgate.net/figure/Comparison-between-TREES-and-LEED-criteria_tbl1_314354540
199 https://tgbi.or.th/uploads/trees/2017_03_TREES-EB-Eng.pdf
200 https://central.nstda.or.th/wiki2/cbc/คุณโข่งขอเล่า_รายสัปดาห์/177_พลังงาน
201 https://www.chandlermhm.com/content/files/pdf/Newsletter/2021/CMHM%20Newsletter%20-%20Thailand%20-%20ERC%20Sandbox%20for%20P2P%20Electricity%20Trading%204%20November%202021.pdf
202 https://www.energynewscenter.com/กกพ-เตรียมเปิดให้-6-โครงก/

generated electricity[203] and purchase electricity at optimal price[203]. The model supports and aligns with Thailand's BCG strategy[204], since it employs advanced technologies to drive grassroot economy, ensures energy security, and utilizes advanced digital technology platform to adapt to global changes. However, the model presents constraints to implement on a wider scale across the economy and in other areas under the responsibility of communities. Energy Regulatory Commission of Thailand is required to develop a regulatory framework to govern trading mechanism among communities of prosumers/users or between networked communities. Furthermore, smart microgrid with grid-connected systems may cause reverse power flow, leading to grid code issue[205]. Since the model is a demonstration initiative led by central government, the investment is made by the government. Though it presents economic feasibility, communities which adopt the model need to take responsibility to maintain the system in the long run, where maintenance cost is relatively high.

4.4.12. Innovation-driven Hub for Sustainable and Low-carbon Transformation

Figure 43 Summary of BCG Economy Contribution to Carbon Neutrality Goal for Innovation-driven Hub for Sustainable and Low-carbon Transformation

The Eastern Economic Corridor of Innovation, located in Rayong, Thailand is an innovation-driven hub to support Thailand's transformation, competitiveness, and quality of people life. It was established with a visionary goal to become a leading innovation ecosystem in Southeast Asia. The long journey of development of the innovation-driven hub is responsible by National Science and Technology Development Agency under governance of Thailand's Ministry of Higher Education, Science, Research and Innovation, and is successful thanks to PTT Public Company Limited, a close partnership, who contributes to basic infrastructure and smart township development. The presence of the innovation-driven hub supports the BCG agenda through strengthening domestic small and medium enterprises and an integration between agriculture and tourism sectors with digitalization[206]. Establishment of an innovation-driven hub could bring benefits to relevant stakeholders in several aspects. Central government such Thailand Board of Investment could contribute to Thailand's economic growth, development of technology, innovation and

203 https://www.mdpi.com/1996-1073/15/3/1229?fbclid=IwAR1lGW0pOyAgDukLNb8bK1hP35navM3rokDhT9FW7Hu7pby8t-CrjMf3mJs
204 https://www.nstda.or.th/en/images/pdf/bcg_action_plan.pdf
205 https://ieeexplore.ieee.org/document/8938887
206 https://sudsesc.nida.ac.th/main/images/books/Thailand%E2%80%99s%20BCG%20Transformation.pdf

infrastructure, and utilize BCG strategy in actual advancement of the economy[207]. Central government would also attract further domestic and foreign investment[208]. In perspective of research institutes under central government, they could support development of new S-curve industries, generating market growth for the economy[209]. Private enterprises could enjoy offers on maximum tax benefits and incentives to support their investments made for technology upgrades[210]. The concept of an innovation-driven hub not only incorporates economic growth and industrial and science and technology sectors, but also support grassroot economy according to BCG actions[211]. It could support business practices to commercialize and localize their products, utilize maximum benefits of local resources, create markets and demand for the economy's strengths, and enhance the economy's competitiveness in the region and globally on manufacturing and services. However, the implementation of an innovation-driven hub confronts challenges. Establishment of an innovation-driven hub with excellent research infrastructures requires a large capital investment. This becomes a main constraint and needs tax exemption and additional incentives offered by the government and to support investment from private sectors. Essentially, the innovation-driven hub should be located in economic/industrial areas to ensure accessibility, energy security, environmental protection, and to facilitate research and development, and logistics. The locational conditions could be one crucial factor to economic feasibility[212].

4.4.13. A Bamboo-powered Rural Community

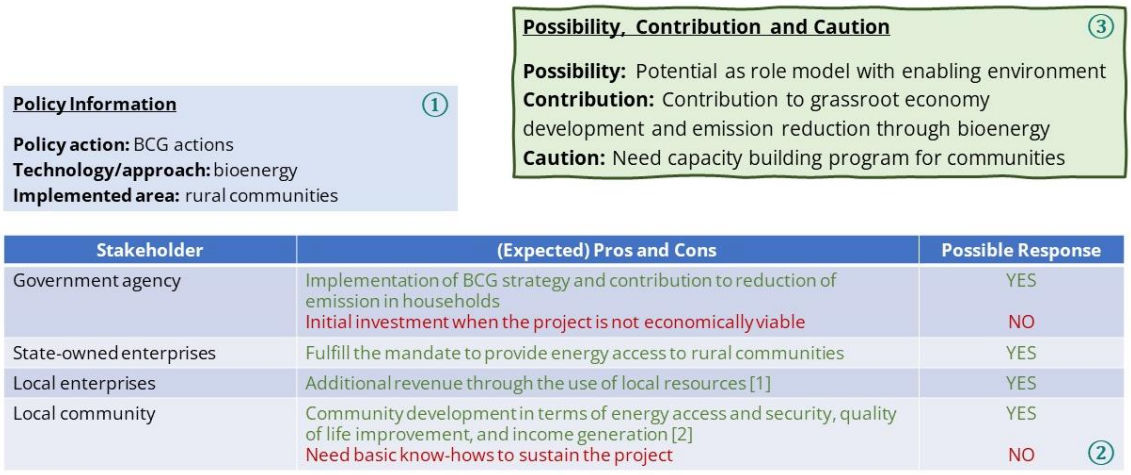


Figure 44 Summary of BCG Economy Contribution to Carbon Neutrality Goal for A Bamboo-powered Rural Community

A bamboo-powered rural community has been demonstrated as an exemplary display of Thailand's BCG strategy. The community, led by Pha Pang Community Foundation utilize abundant local resource, namely bamboo to produce clean energy and local produce, improving quality of

207 https://sdgs.nida.ac.th/home/outreach/outreach-65067
208 https://www.bangkokpost.com/thailand/pr/2500296/eeci-takes-shape
209 https://www.bangkokpost.com/thailand/pr/2500296/eeci-takes-shape
210 https://www.prnewswire.com/in/news-releases/thailand-board-of-investment-to-boost-investment-in-food-innopolis-and-eeci-689723961.html
211 https://www.bcg.in.th/eng/bcg-action-plan-english-version/
212 https://www.mdpi.com/2071-1050/14/4/2135

life[213]. Bamboo property is not only known to produce 35% more oxygen compared to other tropical plants, but also to absorb 75% more carbon dioxide. The Foundation perceives the great benefits from bamboo and starts to utilize it in a sustainable way, contributing to significant emission reduction. The bamboo-powered community model offers an opportunity to relevant stakeholders to work together, and individuals obtain benefits. Government agencies could carry out and exercise BCG strategy in actual implementation, which could largely contribute to emission reduction in household sector. State-owned enterprises would play their role to provide energy access to remote rural communities and ensure energy security. Small and medium enterprises, along with local enterprises generate additional revenue through use of abundant local resource[214]. Local residents in communities benefit from community development in terms of energy access and security, livelihood and quality of life improvement, income generation from product re-creation, while emission reduction is achieved through the cycle of activities[215]. The bamboo-powered community model aligns with BCG actions in the view of use of unique properties of abundant bamboo in the community to improve quality of life. The use of bamboo to produce synthesis gas supports the global efforts to generate clean energy from local resources, contributes to environment conservation, and increases energy efficiency and resource management. However, implementation of bamboo-powered community model in communities at wider scale presents a few constraints. Because the bamboo-powered community is led by Pha Pang Community Foundation who is taking care of community development and knowledgeable in agriculture, tourism, and energy, basic know-how on resource management, product re-creation, and power generation is essential to sustainably maintain the model. Essentially, other remote rural communities would have insufficient and inappropriate natural resources, such as bamboo to be added value and used to generate benefits to community residents. To address the constraint in the implementation, central government and local government could strengthen the community through educating essential know-how, building capacity for community residents, and creating a specific model using local resources to drive local economy. This would pave concrete pathways to reduce emissions in remote rural communities and to community development in a sustainable manner.

213 https://sudsesc.nida.ac.th/main/images/books/Thailand%E2%80%99s%20BCG%20Transformation.pdf
214 https://sdgs.nida.ac.th/home/outreach/outreach-65067
215 https://www.bangkokpost.com/business/1662248/home-is-where-the-heart-is

4.5. Quantitative Consideration of Emission Reduction Potential – Peer-to-Peer Energy Trading Platform

The GHG trajectory in the business as usual (BAU) scenario based on the past data from 2010-2020 is shown in Figure 45. Thailand's GHG emission would increase up to 661MtCO$_2$eq in 2050 at a compound annual growth rate (CAGR) of 1.7%. The figure also illustrates that the energy sector will be the largest source of GHG emissions, while the land use, land-use change, and forestry (LULUCF) sector constantly removes GHG emissions at 100MtCO$_2$eq[216].

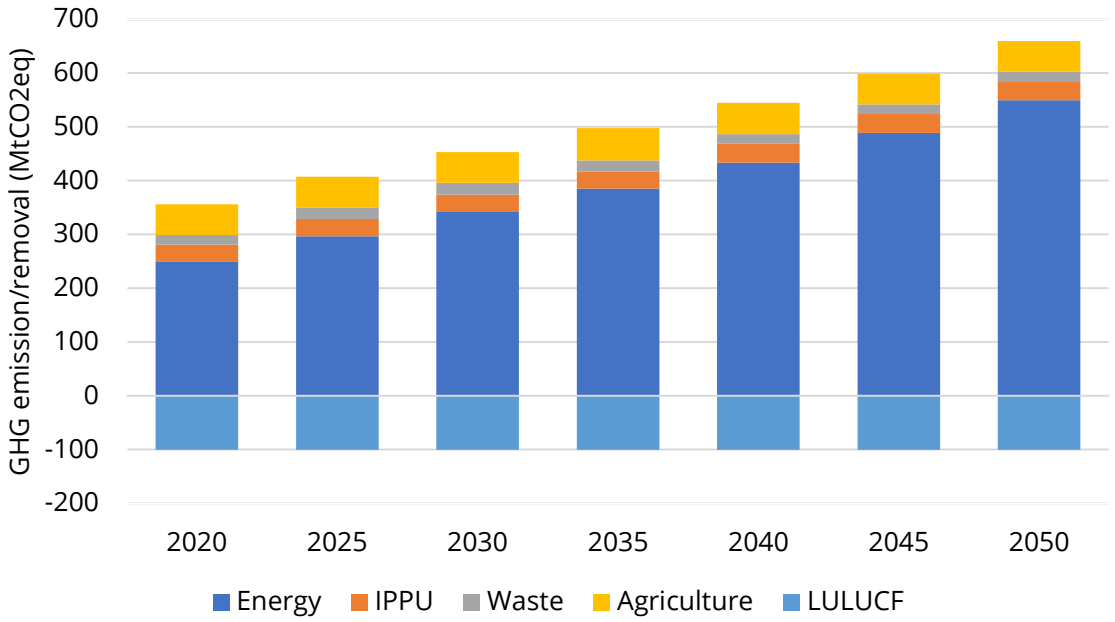


Figure 45 GHG emission/removal by sector of the BAU scenario[217]

GHG comprise various gases, for instance, methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). This quantitative consideration of emission reduction potential will focus on CO_2 emission since it makes up the majority of GHG emissions. The trend of CO_2 emission is similar to that of GHG emissions. Figure 46 shows CO_2 emission/removal of the carbon neutral scenario. The energy sector is the largest contributor to emissions among other sectors, followed by the Industrial Processes and Product Use (IPPU) sector. By 2050, the removal of the emission by the LULUCF sector should increase up to 120MtCO$_2$eq. Emissions from waste are expected to be reduced to 0.2MtCO$_2$eq by 2050, while emissions from the agricultural sector are projected to be 0.5MtCO$_2$eq in the same year.

The energy sector is generally categorized into power generation, transport, industry, and other sub-sectors. The historical data in Figure 47 shows that power generation and transport are the major sub-sectors that contribute to overall CO_2 emission in the economy.

216 https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf
217 https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf

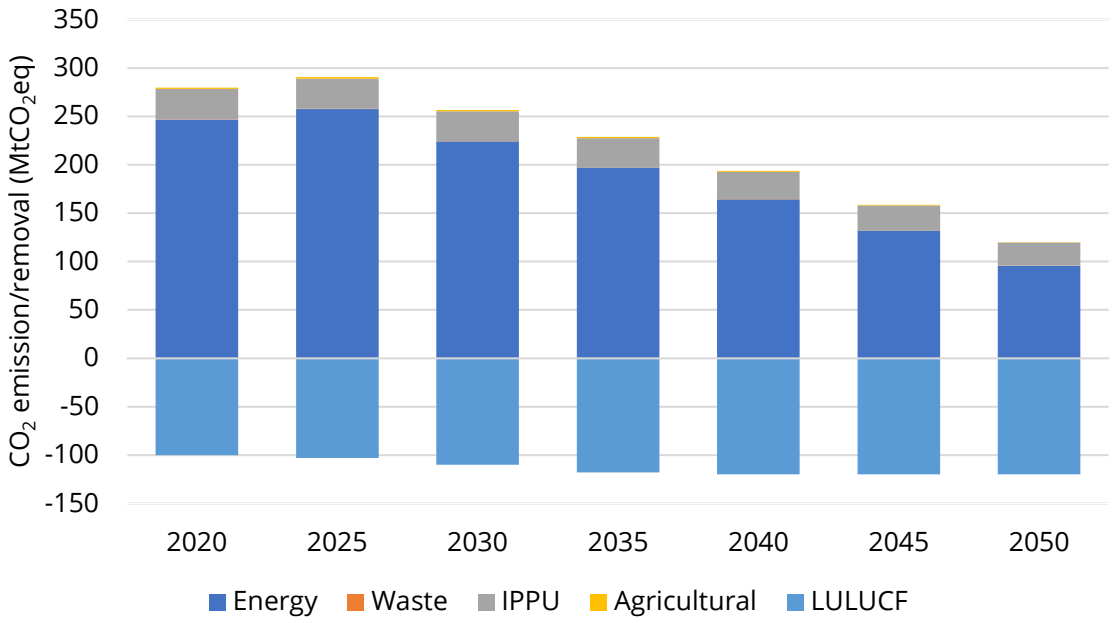


Figure 46. CO_2 emission/removal of the carbon neutral scenario[218]

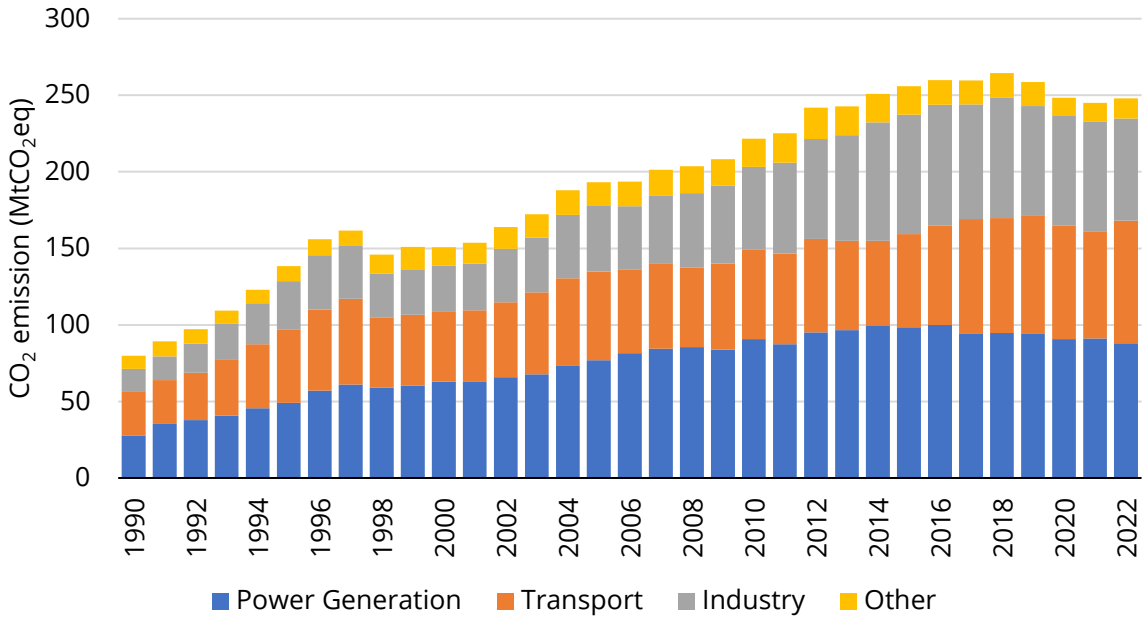


Figure 47. Historical data of CO_2 emission in the energy sector[219]

218 https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf
219 https://www.eppo.go.th/index.php/en/en-energystatistics/co2-statistic

Figure 48 shows the possible emission reduction in the power sector from the economy-wide implementation of peer-to-peer trading platform. The orange and blue lines represent the emission of the BAU and carbon neutral scenarios, respectively. The yellow dotted lines show the emission when peer-to-peer trading is implemented according to the current policy design, and the grey dotted line shows the situation when the contribution from BCG Economy Model is considered. Data for the BAU scenario was extracted from the work of Misila et al.[220]. Emission reduction in the carbon neutral scenario is established for the years 2020 to 2050, starting from 2020 when the historical data is available. It can be seen that the policy action on peer-to-peer energy trading platform alone will reduce the CO_2 emission in the energy sector by 7% while the figure can increase to over 30% when the BCG model is taken into account.

The current calculation is done with a very coarse assumption in order to make a first-order estimation of the emission reduction potential of the policy action: peer-to-peer trading platform. Emission reduction is assumed to be from renewable energy. The sites for RE installation were classified into city, industrial, and rural areas. Bangkok Metropolitan Region (including the surrounding provinces) is considered the city area. East region is identified as the industrial area. The rural area covers the rest of the land of the economy. Only solar is considered in the city area, only bio-based renewable energy is considered in the rural area, and no renewable energy technology is employed in the industrial area. With the original policy design, the peer-to-peer trading platform will only facilitate emission reduction in the city area through the introduction of solar PV by 10% in 2030, 30% in 2040, and 50% in 2050. However, if we apply the BCG Economy Model and use peer-to-peer energy trading for bio-based energy in rural communities, the policy action will contribute to emission reduction in the rural area by 5% in 2030, 20% in 2040, and 40% in 2050. This is possible through the help from the concepts of bamboo-powered rural community and smart microgrid and energy trading platform.

The study illustrates that the peer-to-peer trading policy alone facilitates solar installation in the cities, contributing to several percentages of CO_2 emission reduction in the energy sector. The emission can be further reduced when the BCG Economy Model is incorporated, as the model promotes bio-based renewable energy plus decentralized systems in rural areas which will result in more than a 30% contribution in power generation.

With the same assumptions mentioned earlier, Figure 49 shows the net GHG emissions from all sectors and the potential emission reduction when the peer-to-peer energy trading policy is applied. As the power sector covers a large portion of GHG emissions, the reduction contribution from the policy, especially when coupled with the BCG Economy Model is large. The contribution of the policy alone is 5%, and it becomes over 20% with the support from the BCG Economy Model.

[220] Misila, P., Winyuchakrit, P., & Limmeechokchai, B. (2020). Thailand's long-term GHG emission reduction in 2050: the achievement of renewable energy and energy efficiency beyond the NDC. Heliyon, 6(12), e05720

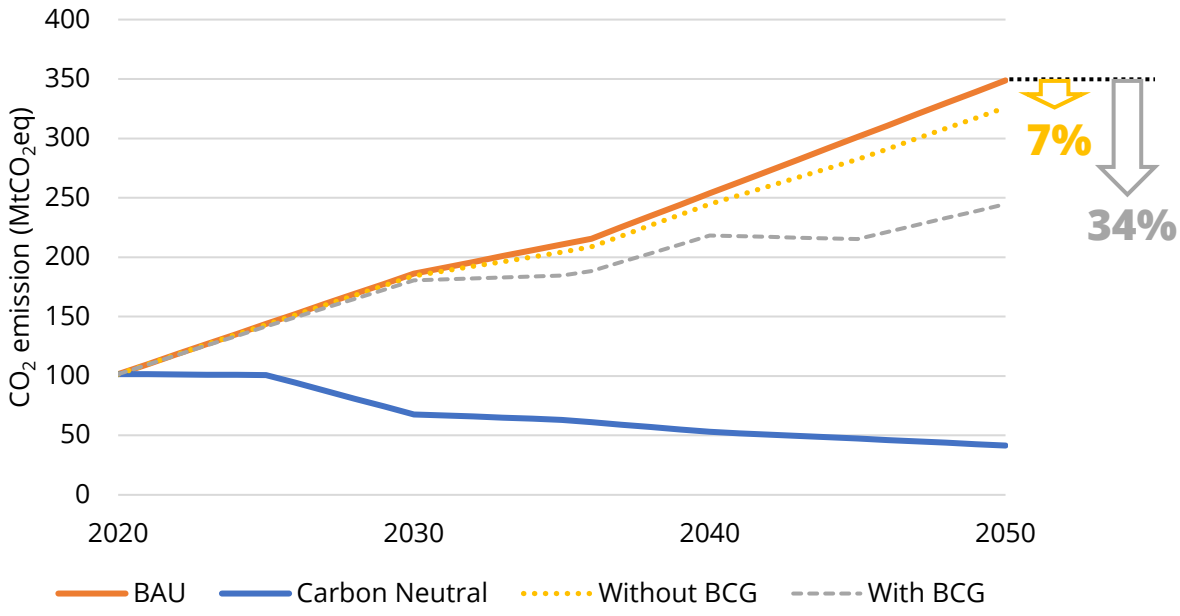


Figure 48 Possible CO_2 emission reduction in the power sector from peer-to-peer energy trading policy

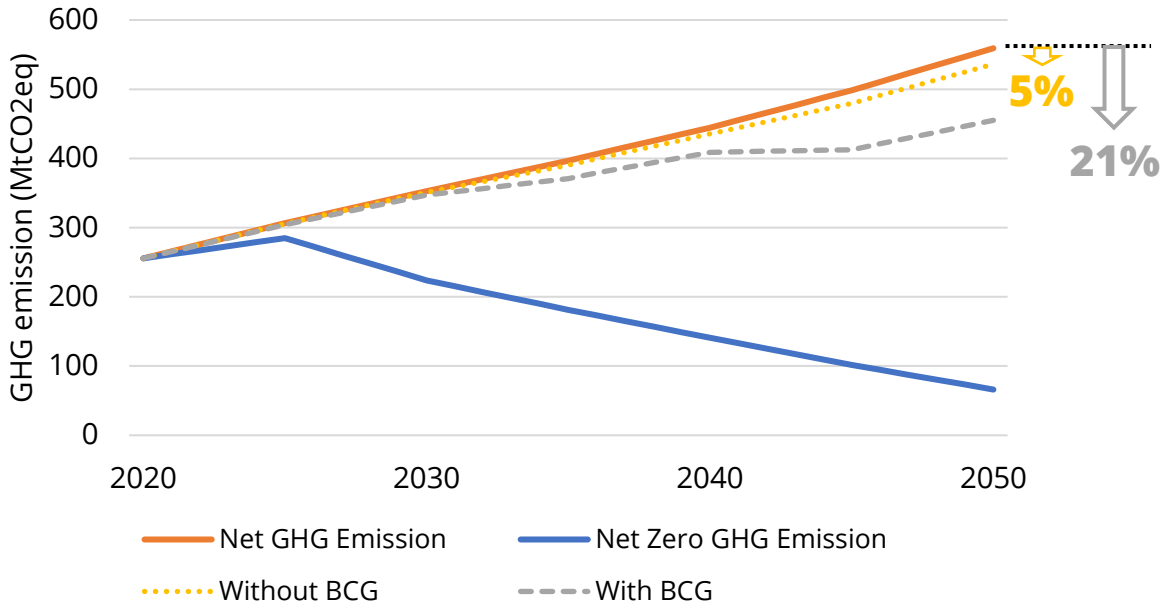


Figure 49 Possible total GHG emission reduction from peer-to-peer energy trading policy

5. Conclusions

The project successfully reviewed the carbon neutral plans from all around the world in power, transport, and building sectors. It picked up ten case studies of outstanding decarbonization technologies and corresponding policy actions from nine APEC economies and one non-APEC economy: four in power generation sector, three in transportation sector, and three in building sector. It also reviewed the Bio-Circular-Green (BCG) Economy Model and recapped three case studies on how the model can contribute to achieving carbon neutrality. The workshop acted as a platform for sharing best practices and lessons learned on carbon neutral policy formulation and implementation, discussing the role of BCG Economy Model in facilitating the achievement of carbon neutrality, and building capacity on carbon neutral policy formulation with a balanced integration of renewable energy and energy efficiency technologies and regulations. The Thailand case study qualitatively and quantitatively demonstrated how policy actions can be designed to reduce carbon dioxide emission and how BCG Economy Model can help achieve carbon neutrality.

The case studies serve as a useful reference for emerging economies to realize how low carbon technologies can be selected, how policy actions can be designed to develop, deploy, or promote those technologies, resulting in outputs and outcomes that can fulfill sectoral targets, and consequently the Nationally Determined Contribution (NDC). From the BCG Economy Model case studies, economies could see how local context can be taken into account in carbon neutral policy formulation, and how just transition towards carbon neutrality could be ensured to maintain local communities and sustain grassroots economies. From qualitative and quantitative considerations of emission reduction potential in the Thailand case study, emerging economies could also realize how stakeholders at different levels may react to the proposed policy tools, how likely the policy actions would contribute to the reduction of carbon emissions and to what extent.

6. Annex

6.1. Annex 1: Minutes of the Interviews

6.1.1. Interview with Bureau of Energy, Chinese Taipei

Venue: MTEC Pilot Plant, Thailand Science Park

About the meeting

Interview with Bureau of Energy, Chinese Taipei at MP303, MTEC Pilot plant, Thailand Science Park was scheduled from 10:00 to 12:00 on 21 November 2022. The interview was conducted with a group of Chinese Taipei delegates, aiming to exchange views on research direction and policy of renewable energy, carbon neutrality and technical resource integration, and to discuss opportunities for follow-up bilateral or multilateral cooperation. The interview started with the presentation of Bio-Circular-Green Economy Model and Development of Renewable Energy Technology towards Sustainable Development Goals (SDG) and carbon neutrality by Dr. Nuwong Chollacoop from National Energy Technology Center (ENTEC), National Science Development Agency (NSTDA). Then Dr. Chen Chung Hsien from Bureau of Energy, Chinese Taipei presented Chinese Taipei's Energy Policy and Technology towards Carbon Neutrality to give information on its energy situation and net zero transition. After the presentation ended, Dr. Chollacoop, Dr. Chen and other delegates discussed Thailand and Chinese Taipei's energy policy.

Main contribution

Chinese Taipei is following a path to achieve net zero emissions by 2050. Energy transition is at the center of net-zero transition. Zero carbon strategies will focus on the development of renewables and innovative energy technologies. Now Chinese Taipei is using solar PV, offshore wind power and plans to use hydrogen co-fired power generation to generate electricity, the new project from Taiwan Power Company (TPC) and Siemens, will starts its operation by 2025.

RE100 Islands in Penghu is another project that Chinese Taipei is doing. Penghu is a city in Chinese Taipei composed of multiple islands, with a total area of 126.86km^2. In 2021, the island has submarine cable with power capacity 200MW. The islands plan to use wind power and solar photovoltaic (PV) to generate electricity up to 400MW, which will exceed RE100.

Meeting participants

The following Table 5 shows participating members of the interview with Bureau of Energy, Chinese Taipei with a total of 12 attendees, comprised of 2 attendees from Bureau of Energy, 2 attendees from Chung-Hua Institution for Economic Research, 1 attendee from the National Penghu University of Science and Technology, 1 attendee from 3R Foundation, 1 attendee from China Productivity Center, and 5 attendees from ENTEC.

Table 5 List of participants in the interview with Bureau of Energy, Chinese Taipei

No.	Name	Position	Organization
1	Dr. Chen Chung Hsien	Director, Energy Technology Division	Bureau of Energy, Ministry of Economic Affairs
2	Ms. Yu-Shan Lin	Section Chief, Planning Division	Bureau of Energy, Ministry of Economic Affairs
3	Dr. Lih-Chyi Wen	Director	The Center for Green Economy in Chung-Hua Institution for Economic Research

No.	Name	Position	Organization
4	Dr. Chun-Hsu Lin	Deputy Director	The Center for Green Economy in Chung-Hua Institution for Economic Research
5	Dr. Neng-Yi Chu	Assistant Professor	The National Penghu University of Science and Technology
6	Ms. Apisara Boonya-atichart	Project Manager	Resources Management for Sustainability (3R) Foundation
7	Ms. Jane Tsai	Project manager, Affairs Department	China Productivity Center
8	Dr. Nuwong Chollacoop	Director, Low Carbon Energy Research Group	National Energy Technology Center (ENTEC)
9	Dr. Kampanart Silva	Researcher	National Energy Technology Center (ENTEC)
10	Mr. Pidpong Janta	Assistant Researcher	National Energy Technology Center (ENTEC)
11	Mr. Khemrath Vithean	Assistant Researcher	National Energy Technology Center (ENTEC)
12	Ms. Thitaya Pongruangrattana	Assistant Researcher	National Energy Technology Center (ENTEC)

6.1.2. Interview with BCPG Public Company Limited

Venue: M Tower and Habito Mall

About the meeting

Interview with BCPG Public Company Limited at M Tower was scheduled from 10:00 to 12:00 on 23 November 2022. It was also attended by the Chinese Taipei delegates. The interview aimed to learn about the mechanism that Thailand's government used to support green technology application, and the details of data and analysis collected from BCPG's Town Sukhumvit 77 (T77) project which was supported under ERC Sandbox. The interview started with the presentation of peer-to-peer energy trading enabled by blockchain technology. BCPG introduced their flagship, vision, footprint, and T77 project. After the presentation ended, BCPG, Chinese Taipei delegates and ENTEC discussed further details on the energy trading and T77 project. In addition, BCPG took all participants to Habito Mall to see their solar rooftop installation which is a part of T77 project.

Main contribution

BCPG introduced Town Sukhumvit 77 (T77) project, a smart green energy community, which is one of the peer-to-peer (P2P) energy trading projects under the ERC Sandbox (Energy Regulatory Commission Sandbox). Phase 1 of the project includes Habito Mall, Bangkok Prep International School, Park Court Service Apartment, and Dental hospital, all located around Sukhumvit 77. Solar panels were installed on the rooftop of the prosumers with the main aim for internal use. Since the power use may differ depending on the prosumers' demand, the excess electricity can be sold to other prosumers and consumers via the P2P energy trading platform using blockchain technology. In addition, BCPG planned to have another P2P energy trading project at Chiang Mai University.

Meeting participants

The following Table 6 shows participating members of the interview with BCPG Public Company Limited with a total of 14 attendees, comprised of 2 attendees from Bureau of Energy, 1 attendee from The National Penghu University of Science and Technology, 1 attendee from 3R Foundation, 1 attendee from China Productivity Center, 3 attendees from ENTEC, and 5 attendees from BCPG.

Table 6 List of participants in the BCPG Public Company Limited

No.	Name	Position	Organization
1	Dr. Chen Chung Hsien	Director, Energy Technology Division	Bureau of Energy, Ministry of Economic Affairs
2	Ms. Yu-Shan Lin	Section Chief, Planning Division	Bureau of Energy, Ministry of Economic Affairs
3	Dr. Neng-Yi Chu	Assistant Professor	The National Penghu University of Science and Technology
4	Ms. Apisara Boonya-atichart	Project Manager	Resources Management for Sustainability (3R) Foundation
5	Ms. Jane Tsai	Project manager	Affairs Department, China Productivity Center
6	Mr. Henry Yang	EE System Manager	Gaius Automotive Inc.
7	Mr. Chatchai Loybundit	Executive Vice President, Business Strategy and Investment	BCPG Public Company Limited
8	Mr. Waron Sanguanwongwan	Vice President, Business	BCPG Public Company Limited

No.	Name	Position	Organization
		Development Department	
9	Dr. Rujiroj Leelaruji	Vice President and Energy Innovation Specialist, Business Development Department	BCPG Public Company Limited
10	Dr. Vichshuwan Pungchareon	Senior Manager, Corporate Business Development	BCPG Public Company Limited
11	Mr. Apichai Riddiboot	Project Director, Center of Digital Energy (CODE)	BCPG Public Company Limited
12	Dr. Nuwong Chollacoop	Director, Low Carbon Energy Research Group	National Energy Technology Center (ENTEC)
13	Dr. Kampanart Silva	Researcher	National Energy Technology Center (ENTEC)
14	Ms. Thitaya Pongruangrattana	Assistant Researcher	National Energy Technology Center (ENTEC)

6.2. Annex 2: APEC Workshop on Achieving Carbon Neutrality through Bio-Circular-Green Economy Principle in APEC Region

6.2.1. Workshop Overview

The APEC Workshop on Achieving Carbon Neutrality through Bio-Circular-Green Economy Principle in APEC Region was held on 6-7 April 2023 at Outrigger Waikiki Beach Resort, Honolulu, Hawaii, the United States. The workshop was organized by Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand, in collaboration with National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA), Thailand, and Hawaii Natural Energy Institute (HNEI), the United States. The workshop aimed to be a platform for sharing of lessons learned and best practices in carbon neutral policy making for decarbonization technologies in the power generation, transport and building sectors, and the Bio-Circular-Green (BCG) Economy principle, by representatives from APEC economies; and facilitate understanding of decarbonization technologies in power generation, transport and building sectors from Japan's Green Growth Strategy to achieving Carbon Neutrality by 2050. The agenda is shown in Table 7.

Table 7 Workshop agenda

Agenda	
Thursday 6 April 2023	
08.30	**Registration**
09.00	**Opening Session and Workshop/Project Overview** **Welcoming Remark** by EGNRET Chair, Dr. Chi-Wen Liao, Industrial Technology Research Institute (ITRI), Chinese Taipei **Project Overview** by Project Overseer, Ms. Munlika Sompranon, Department of Alternative Energy Development (DEDE), Thailand **Opening Remark** by Ms. Ariadne Benaissa, EWG Lead Shepherd, Department of Energy, US **Welcoming Remark** by Dr. Richard E. Rocheleau, Director, Hawaii Natural Energy Institute (HNEI), US
09.30	**Keynote Address – Overview of Bio-Circular-Green (BCG) Economy principle** Dr. Sumittra Charojrochkul Executive Director, National Energy Technology Center (ENTEC), Thailand
10.00	**Group Photo & Coffee Break**
10.40	**Current Status of Implementation of Carbon Neutrality in APEC Region** **Indonesia**: Dr. Adhika Widyaparaga, Associate Professor, Mechanical Engineering Study Program, Universitas Gadjah Mada (UGM) **Japan**: Dr. Naoko Doi, Senior Economist, Manager, Energy Efficiency Group, The Institute of Energy Economics (IEEJ) **The Republic of the Philippines**: Ms. Ruby de Guzman, Assistant Director, Renewable Energy Management Bureau, Department of Energy **Chinese Taipei**: Mr. Yu Hsiang-Wei, Senior Specialist, Bureau of Energy
12.00	**Lunch**
13.30	**Current Status of Implementation of Carbon Neutrality in APEC Region** (cont'd)

	Thailand: Dr. Nuwong Chollacoop, Director of Low Carbon Energy Research Group, National Energy Technology Center (ENTEC) **Viet Nam**: Prof. Le Anh Tuan, Chairman of the University Council, Hanoi University of Science and Technology (HUST) **US**: Dr. Cary Bloyd, Senior Staff Scientist, Electricity Infrastructure and Buildings Division, Pacific Northwest National Lab
14.30	**Coffee Break**
14.50	**Discussion on Carbon Neutral Policy Framework and Governmental Mechanism** Moderated by Dr. Worajit Setthapun, Deputy Director, Program Management Unit for Human Resources & Institutional Development, Research and Innovation (PMU-B), Thailand
16.30	**Wrap up**
Friday 7 April 2023	
08.30	**Registration**
09.00	**Recap on Day 1 by Prof. Worajit Setthapun, PMU-B**
09.20	**Keynote Address – 8th APEC Energy Demand and Supply Outlook and Implications for BCG Program in Thailand** Mr. Glen Sweetnam, Senior Vice President, Asia Pacific Energy Research Centre (APERC) **Keynote Address – Japan Green Growth Strategy and Green Transformation** Dr. Naoko Doi, Senior Economist, Manager, Energy Efficiency Group, The Institute of Energy Economics (IEEJ), Japan
10.20	**Coffee Break**
10.40	**Current Status of Implementation of Carbon Neutrality in APEC Region** (cont'd) **Korea:** Dr. Octaeck Lim, Professor, School of Mechanical & Automotive Engineering, University of Ulsan
11.00	**Case Studies on Decarbonization Technologies in Power Generation, Transport and Building Sectors** Dr. Kampanart Silva, Researcher, ENTEC, Thailand
11.40	**Discussion on Linkages among Carbon Neutrality, BCG and Green Transformation** Moderated by Dr. Nuwong Chollacoop, Director of Low Carbon Energy Research Group, ENTEC, Thailand
12.00	**Lunch**
13.30	**Identifying Carbon Neutral Policy Framework and Governmental Mechanism for Power Generation, Transport and Building Sectors** Moderated by Dr. Worajit Setthapun, Deputy Director, PMU-B, Thailand
15.10	**Coffee Break**
15.30	**Drafting Recommendation for Carbon Neutral Policy Framework and Governmental Mechanism** Moderated by Dr. Nuwong Chollacoop, Director of Low Carbon Energy Research Group, ENTEC, Thailand
16.30	**Wrap up**

6.2.2. Workshop Participants

As shown in Figure 50 and detailed in Table 8, the 1st workshop was attended a total of 82 participants from 13 APEC member economies and 1 global organization with a female ratio of 43% (18 women and 24 men). As usual, the workshop was highly participative, with Dr. Nuwong Chollacoop, project manager from National Energy Technology Center (ENTEC), Thailand, taking on the role of the overall facilitator.

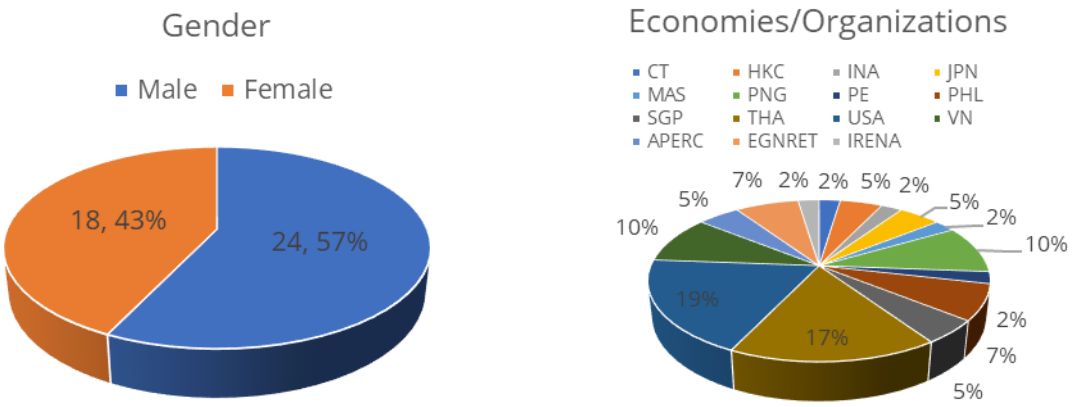


Figure 50 Breakdown statistics of workshop participants

Table 8 List of workshop participants

No.	Title	Name	Economy	Gender	Organization
1	Mr.	Yu Hsiang-Wei	Chinese Taipei	Male	Bureau of Energy
2	Ms.	Man Chit Jovian Cheung	Hong Kong, China	Female	The Government of Hong Kong Special Administrative Region
3	Ms.	Sin Man Becky Chim	Hong Kong, China	Female	The Government of Hong Kong Special Administrative Region
4	Prof.	Adhika Widyaparaga	Indonesia	Male	Universitas Gadjah Mada (UGM)
5	Mr.	Takao Ikeda	Japan	Male	The Institute of Energy Economics, Japan (IEEJ)
6	Dr.	Naoko Doi	Japan	Female	The Institute of Energy Economics, Japan (IEEJ)
7	Mr.	Muhammad Idham bin Ismail	Malaysia	Male	Ministry of Natural Resources, Environment and Climate Change
8	Mr.	Larsen Daboyan	Papua New Guinea	Male	Papau New Guinea National Energy Authority
9	Mr.	Ronald Meketa	Papua New Guinea	Male	Papau New Guinea National Energy Authority

No.	Title	Name	Economy	Gender	Organization
10	Mr.	Timothy Mais	Papua New Guinea	Male	Papau New Guinea National Energy Authority
11	Ms.	Stephanie Tulia	Papua New Guinea	Female	Papau New Guinea National Energy Authority
12	Ms.	Luciano De La Cruz	Peru	Female	Ministry of Energy and Mines Peru
13	Ms.	Celine Rose S. Jimenez	The Republic of the Philippines	Female	Biomass Energy Management Division, Renewable Energy Management Bureau, Department of Energy
14	Ms.	Ruby B. De Guzman	The Republic of the Philippines	Female	Department of Energy
15	Ms.	Rosanna Yabut Tejuco	The Republic of the Philippines	Female	Department of Energy
16	Mr.	Alvin Tan	Singapore	Male	Energy Market Authority
17	Mr.	Kang Yang Chia	Singapore	Male	Energy Market Authority
18	Dr.	Watchara Uraisakul	Thailand	Female	Thailand Science Research and Innovation
19	Dr.	Sumittra Charojrochkul	Thailand	Female	National Energy Technology Center
20	Dr.	Nuwong Chollacoop	Thailand	Male	National Energy Technology Center
21	Dr.	Kampanart Silva	Thailand	Male	National Energy Technology Center
22	Mrs.	Munlika Sompranon	Thailand	Female	Department of Alternative Energy Development and Efficiency
23	Ms.	Thitima Pikulthong	Thailand	Female	Thailand Science Research and Innovation
24	Dr.	Worajit Setthapun	Thailand	Female	Program Management Unit for Human Resources & Institutional Development, Research and Innovation
25	Ms.	Ariadne Benaissa	United States	Female	APEC Energy Working Group (Department of Energy)
26	Ms.	Kate Selley	United States	Female	APEC Energy Working Group
27	Dr.	Cary Bloyd	United States	Male	Pacific Northwest National Lab
28	Dr.	Adam Borison	United States	Male	US Support for Economic Growth in Asia (US-SEGA)
29	Mr.	Leon Roose	United States	Male	Hawaii Natural Energy Institute, University of Hawaii

No.	Title	Name	Economy	Gender	Organization
30	Mr.	Damon Schmidt	United States	Male	Hawaii Natural Energy Institute, University of Hawaii
31	Dr.	Scott Turn	United States	Male	Hawaii Natural Energy Institute, University of Hawaii
32	Mr.	Marc M. Matsuura	United States	Male	Hawaii Natural Energy Institute, University of Hawaii
33	Dr.	Le Anh Tuan	Viet Nam	Male	Hanoi University of Science and Technology
34	Mr.	Tuan Nguyen	Viet Nam	Male	Multilateral Trade Policy Department, Ministry of Industry and Trade
35	Mrs.	Hoang Thi Ngoc Thanh	Viet Nam	Female	Ministry of Industry and Trade
36	Mr.	Long Quang Nguyen	Viet Nam	Male	Electricity & Renewable Energy Authority
37	Mr.	Glen Sweetnam	APERC	Male	Asia Pacific Energy Research Centre (APERC)
38	Mr.	Ario Panggi Pramono	APERC	Male	Asia Pacific Energy Research Centre (APERC)
39	Dr.	Chi-Wen Liao	EGNRET	Male	Industrial Technology Research Institute (ITRI)
40	Dr.	Tom H.T. Lee	EGNRET	Male	Industrial Technology Research Institute (ITRI)
41	Dr.	Tarcy Sih-Ting Jhou	EGNRET	Female	Industrial Technology Research Institute (ITRI)
42	Ms.	Nazik Hassan Elhassan	IRENA	Female	International Renewable Energy Agency (IRENA)

6.2.3. Workshop Presentations and Discussions

The workshop was structured for two days. The first day of the workshop focused on sharing lessons learned and best practices in carbon neutral policy making for decarbonization technologies in the power generation, transport and building sectors; and the Bio-Circular-Green (BCG) Economy principle, by representatives from APEC economies, including Indonesia; Japan; the Republic of the Philippines; Chinese Taipei; Thailand; the United States; and Viet Nam. The invited presentations were followed by a brainstorming session to facilitate discussion on carbon neutral policy framework and governmental mechanism. The second day is a capacity building session for the understanding of future energy demand and supply of the APEC region, and learning of decarbonization technologies and strategies in power generation, transport and building sectors from Japan's Green Growth Strategy to achieving Carbon Neutrality by 2050. It was followed by a discussion session leading to recommendations for carbon neutral policy framework and governmental mechanism for APEC economies. Figure 51and Figure 52 show presentations on the 1st and 2nd days. Presentation files are available at: https://tinyurl.com/doc-ewg10

Figure 51 Presentations on the 1st day of the workshop

Figure 52 Presentations on the 2nd day of the workshop

As shown in the agenda in Table 7, the 1st day workshop started with a welcoming remark by EGNRET Chair, Dr. Chi-Wen Liao, Industrial Technology Research Institute (ITRI), Chinese Taipei, followed by the introduction of the project overview by the project overseers, Ms. Munlika Sompranon, Department of Alternative Energy Development (DEDE), Thailand, an opening remark by Ms. Ariadne Benaissa, EWG Lead Shepherd, Department of Energy, US, and finally the welcoming remark by Dr. Richard E. Rocheleau, Director, Hawaii Natural Energy Institute (HNEI), University of Hawaii, US, which also covered the introduction of the activities at HNEI to promote carbon neutrality through dissemination of renewable energy, in particular solar or wind power with energy storage systems.

The keynote address was given by Dr. Sumittra Charojrochkul, Executive Director, National Energy Technology Center (ENTEC), Thailand, on the overview of Bio-Circular-Green (BCG) Economy Principle. It is a concept that integrates bioeconomy, circular economy, and green economy, all of which are the strength of Thailand and economies in Southeast Asia. It covers four important areas, including (1) food and agriculture, (2) medical and wellness, (3) energy, material and biochemical, and (4) tourism and creative economy. It aligns very well with Sufficiency Economy Philosophy (SEP) of the late King Rama IX and the United Nations' Sustainable Development Goals (SDGs). She elaborated on the activities in the area of energy, material and biochemical where the focuses are on (1) carbon pricing/carbon credit, (2) clean and circular energy, (3) community energy, (4) smart grid and energy trading platform, and (5) biorefinery industry. APEC economies were particularly interested in Thailand's strategies on biofuel and hydrogen.

The following session was on current status of implementation of carbon neutrality in APEC region, which is the main session of the 1st day. Indonesia, by Prof. Adhika Widyaparaga, Universitas Gadjah Mada (UGM), opened the floor by introducing its goal to achieve net-zero emission by 2060. It will need to reduce 388, 1,044, 1,798MtCO_2 emissions by 2030, 2050, and 2060, respectively. In the power sector, it plans to shift the coal power plants from subcritical, to supercritical, ultra-supercritical, and finally retire all the plants, do co-firing in coal power plants, and promote solar rooftops. As for the transportation sector, it will introduce regulations on incentives and tax reduction to support vehicle electrification, disseminate charging stations and battery swapping stations, and facilitate biofuel blending mandate with palm oil fund. There was discussion on the fact that electric vehicles are increasing GHG emissions due to coal-based electricity, though they decrease the pollution in large cities. This can be used to justify electrification in the transport sector. There were also questions on the methodology to determine biomass co-firing ratio, consideration of non-land transport, and whether Indonesia will include nuclear power in its carbon neutrality plan.

Next presentation was given by Dr. Naoko Doi, Institute of Energy Economics, Japan (IEEJ). After stating Japan's goal on net-zero emission by 2050, she emphasized Japan's strategy to start from energy efficiency focusing on demand side, including efficient use of renewable energy. She then introduced Japan's roadmap on green transformation of which the sectoral roadmaps were announced in December 2022. The presentation focused on the amendment of Energy Conservation Law. The definition of energy was modified to include non-fossil fuels in order to incorporate renewable energy. Entities are required to report their energy usage to expand the use of non-fossil fuels. Finally, the law mandates optimal use of electricity which can be achieved by promoting demand response. As Japan has made tremendous efforts to improve energy efficiency, APERC asked about the plan to further improve it. The key sectors on transport, commercial, and residential sectors where more stringent standards will be introduced along with

the incentives and introduction of digital technologies. The US asked about the plan on renewable energy. Solar PV has reached its limit, and offshore wind power will be one of the solutions. Japan will also invest in R&D on hydrogen and fuel ammonia. There were great interests on fuel cell development of Japan. Japan will invest on both battery and fuel cell electric vehicles, letting the customers make the choice. Japan will have all new passenger vehicles electrified by 2035, and fuel cell buses have a significant share (up to 10%) out of new buses.

Ms. Ruby B. De Guzman, Department of Energy, the Republic of the Philippines shared the economy's progress in moving towards carbon neutrality in power and transport sectors. She introduced the target in National Renewable Energy Program 2020-2040 to add 53GW of renewable energy. The program includes Renewable Energy Act to increase the share, Green Energy Auction Program, easing foreign ownership limit in renewable energy investments, and Energy Efficiency and Conservation Act covering minimum energy performance standards and mandatory energy labeling. To decarbonize the transport sector, the Republic of the Philippines has Biofuel Act to mandate biofuel blending and Electric Vehicle Development Act to promote development of electric vehicles. There was further discussion on other power sources, namely nuclear, coal, and marine energy. The Republic of the Philippines has no plan to revive Bataan Nuclear Power Plant, and its nuclear power plan focuses on small modular reactors. It is refocusing coal power plants considering shifting from coal to biomass. Resource assessment is being done as an initial step for marine energy. The Republic of the Philippines enacted Microgrid System Act to promote electrification of small island grids, including hybridization of diesel generators with renewable energy or biofuel. There was also a question on incentives and types of electric vehicles, and the audience learned that electric 2-3-wheelers are being focused.

Mr. Yu Hsiang-Wei, Bureau of Energy, Chinese Taipei, introduced Chinese Taipei's goal to achieve net-zero emission by 2050. There are 12 key strategies to achieve the goal, many of which are for power sector. The economy will increase renewable energy share to 60-70% by 2050 through popularization of solar PV and offshore wind. It will also invest on hydrogen and promote innovative energy, including geothermal, ocean power, and biomass energy. The remaining will be filled up by hydrogen and gas-fired power plants with CCUS or carbon neutral LNG. The current policy on nuclear power is to abandon all power plants by 2025. Japan asked about the discussion on electricity price and the mitigation of impacts from high electricity price to people which will not be a problem at the moment as the electricity price is regulated. Just transition is also one of the 12 key strategies. He also stressed the necessity to communicate benefits of carbon neutral policy with the population.

Dr. Nuwong Chollacoop, ENTEC, represented the participants from Thailand and presented the overview of carbon neutral initiatives in Thailand. Thailand aims to become carbon neutral by 2050 and attain net-zero GHG emissions in 2065. It developed long-term roadmaps for GHG emission reduction in power, transport, commercial building, and residential building sectors. Dr. Chollacoop introduced important targets in energy sector, including increasing the share of renewable energy to more than 50% by 2050, increasing the share of electric vehicles to 30% of newly registered vehicles by 2030 (30@30), enhancing energy efficiency by at least 30% by 2030. He also introduced the 4D1E strategy of the power sector which includes digitalization, decarbonization, decentralization, de-regulation, and electrification. He also explained tax/import duty reduction and monetary support which has recently been put in place in Thailand.

Prof. Le Anh Tuan, Hanoi University of Science and Technology (HUST), Viet Nam started his presentation with Viet Nam's goal on net-zero emissions by 2050 which is supported by National

Climate Change Strategy 2050 and National Action Plan for Green Growth 2021-2030. The government established National Steering Committee on Green Growth that is participated by government, private sector, and local representatives, aiming to reduce emission intensity, increase energy efficiency, and increase the share of renewable energy. In transport sector, Viet Nam introduces fuel economy and emission standards, promote modal shift and fuel change. It adopted a phase-by-phase approach for electric vehicle deployment. The city government plays a leading role in the initial phase while the central government increases R&D investment. Financial support will be provided at a later stage. There was a discussion on the direction of the region on carbon market. Though some economies in Southeast Asia started carbon pricing, the rest, including Viet Nam, are still under discussion on the possibility of implementing it.

Finally, Dr. Cary Bloyd, Pacific Northwest National Lab, the United States, introduced the plan of the economy to achieve net-zero emissions by 2050. This includes a milestone of 100% carbon-free electricity by 2035. He introduced several policy directions of the United States including decarbonizing the electricity which does not necessarily cover only renewable energy, but also upscaling carbon dioxide removal. Electrification of end uses and cutting energy waste remain the two important strategies. Apart from these, the United States also plan to reduce methane and other GHG emissions. Dr. Bloyd emphasized the need to identify climate actors other than the central government, e.g., states, cities, universities, and highlighted the major role of private sector in attaining net-zero emissions. There are several questions and comments. The first point was on the strategy behind the Inflation Reduction Act to convince the parties that investment in decarbonization will bring in the money to the states and/or the economy. The discussion also touched upon the buy-back policy that gives credit of up to USD4,000 for used vehicles to encourage shift towards electric vehicles. The meeting also recognized nuclear power, especially small modular reactors (SMRs) as means for electricity decarbonization, and hydrogen as means for decarbonization without electricity.

The first day of the workshop ended with a discussion session on carbon neutral policy framework and governmental mechanism which was moderated by Dr. Worajit Setthapun, Deputy Director, Program Management Unit for Human Resources & Institutional Development, Research and Innovation (PMU-B), Thailand. Dr. Setthapun first summarized the carbon neutral goals, milestones, strategies, and policies of the APEC economies to facilitate the development or penetration of decarbonization technologies. She then introduced the steps towards carbon neutrality which is essentially the flow for dissemination of climate commitment at economy level to key sectors shown in Figure 27, followed by the guiding questions shown in Figure 53.

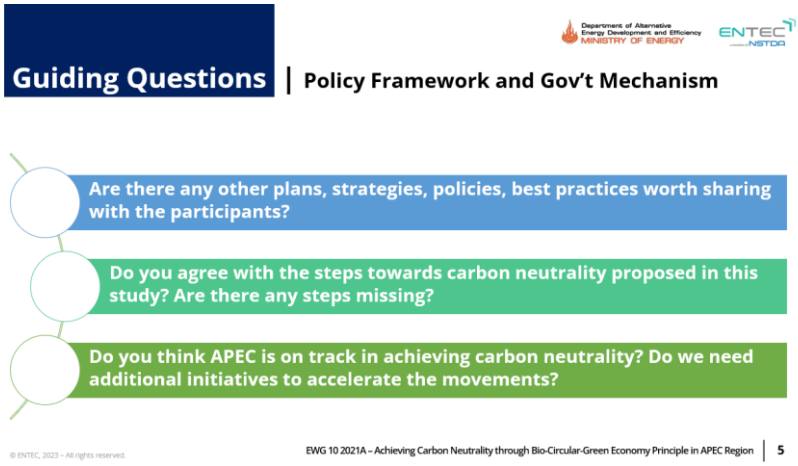


Figure 53 Guiding questions for discussion on policy framework and governmental mechanism

There were suggestions to consider synchronization with ongoing projects and initiatives under APEC Energy Working Group (EWG) and around the world. The United States recommended visiting ongoing project in APEC Expert Group Energy Efficiency and Conservation (EGEE&C) entitled APEC Retro-Commissioning (RCx) Hub: Training and Registration Scheme (EWG 07 2022A) proposed by Hong Kong, China[221]. Japan suggested studying incentives provided to housemakers and small construction companies and incentives for heat pumps in the residential sector aside from energy efficiency standards for buildings. The United States further suggest going through Australia's GreenPower program [222] which publicizes the information on energy efficiency improvement of successful buildings to encourage other entities to follow. Japan also introduced the strategy of Tokyo Metropolitan to relax the emission reduction target for buildings that meet very high energy efficiency standards. Chinese Taipei shared its strategies to integrate direct current into buildings and to have 100% of the newly registered vehicles electrified by 2040. United States also added about the importance to consider sustainable aviation fuel (SAF) that will help decarbonize aviation industry.

Viet Nam supported the idea of the project to synthesize best practices from successful economies and design pathways towards carbon net-zero emissions for economies with on clear climate goals. Japan added that Asia Energy Transition Initiative (AETI) [223] and Asia Zero Emission Community (AZEC)[224] can facilitate the sharing of knowledge and best practices on pathways towards carbon neutrality. Regarding the steps towards carbon neutrality, Japan suggested that a committee at economy level should be established to involve stakeholders to design the goals, roadmaps, and policy actions since local context differs from economy to economy. The United States touched upon an ongoing initiative under EWG to develop an APEC goal for carbon neutrality, though the consensus has not been reached. At this stage, it is fine to conclude that each economy has its own goal and the platform for best practice sharing would help accelerate the carbon neutrality movement in the region.

The 2nd day started with the keynote address entitled APEC Energy Demand and Supply Outlook: Implications for BCG in Thailand by Mr. Glen Sweetnam, Senior Vice President, Asia Pacific Energy

221 https://aimp2.apec.org/sites/PDB/Lists/Proposals/DispForm.aspx?ID=3159
222 https://aimp2.apec.org/sites/PDB/Lists/Proposals/DispForm.aspx?ID=3159
223 https://www.meti.go.jp/english/press/2021/pdf/20210528001_aetieng.pdf
224 https://www.meti.go.jp/press/2022/03/20230306005/20230306005-24.pdf

Research Centre (APERC). Picking up Thailand as an example, he explained the findings from the carbon neutral scenario. Increased electrification flattens energy demand growth. Though fuel switching from coal to electricity and natural gas increases, industry remains the largest energy consumer. The transport sector is the sector where energy demand dramatically decreases due to electrification and usage of hydrogen. Electricity demand still relies heavily on generation from gas though carbon capture and storage (CCS) will be introduced to reduce the emissions. Comparing the carbon neutral scenario to the reference scenario, he emphasized that additional efforts need to be made to achieve the NDC, especially in the transport and power sectors. He shifted the talk to the topic of energy transition, mentioning that though energy transition is not new, it is necessary to understand the complex modern energy systems. Although the costs of wind and solar energy have dropped dramatically, the solar "duck curve" creates challenges for grid operators, leading to additional expenses. On the other hand, batteries are still expensive for grid scale power storage. Additionally, low marginal production costs for renewables resulted in closure of fossil fuel plants, increasing the risks of inadequate reserve margins. This makes the integration costs higher than offset declining wind and solar prices. He finally emphasized the importance of consideration on affordability, security, and reliability during the planning for energy transition. Active discussion followed the presentation. It started with the possibility of grid interconnection in Southeast Asia, though it seems to be difficult due to current political instability. There was a question from Chinese Taipei on the reason that the energy demand of building sector does not change in the carbon neutral scenario. It seems that the slight change in the building sector is not unusual while the significant decrease in the transport sector is because electric vehicles are much more efficient than vehicles with internal combustion engines (ICE). The United States commented on the cost for integration which could be very high comparing to cost of electricity production. Therefore, it can be misleading to compare renewable electricity generating cost with other means for electricity generation. The United States added that a critical role of zero-emission vehicles in energy transition was unexpected, and it was because it is economically feasible. It is important for us to identify these kinds of technologies that can contribute to attainment of net-zero emissions and also generate savings. Mr. Sweetnam finally added that it could be better to rely on market mechanism rather than having the government set an aggressive goal.

The other keynote address on Japan's pathways towards carbon neutrality was given by Dr. Naoko Doi, Climate Change and Energy Efficiency Unit, The Institute of Energy Economics (IEEJ), Japan, focusing on demand side. Japan announced the carbon neutrality target in 2021, leading to a new energy savings target in May 2021, and amendment to Energy Conservation Law in April 2022 to include efficiency improvement of non-fossil fuels. Sectoral roadmaps for Green Transformation (Gx) were then announced in December 2022. Roadmaps for Gx is a comprehensive approach to mobilize JPY150 trillion of public-private investment for green transformation. Gx Transition Bond of JPY20 trillion will be issued over a period of 10 years to provide incentives for existing technologies and R&D, and strengthen regulations, which will consequently induce private investment. The money for the bond is expected to come from Gx Emission Trading System (ETS) and carbon surcharge which will be implemented in the future. Dr. Doi introduced the overview of Japan's Green Growth Strategy, with the information on expected investment from private sector on decarbonization. She also detailed the roadmaps for green transformation in buildings and automotive industry. She finally emphasized the crucial role of global collaboration for promoting carbon neutrality and introduced two examples: Climate Club and Asia Zero Emission Community (AZEC). The talk was followed by a lively discussion Thailand asked about the method to estimate the investment to be realized by the private sector. However, the estimation was on

the other way round. The design of the strategy started from listing the things that should be in place in 2030, followed by the investment requirement, and the estimation of the seed money that needs to be provided by the government. There was a question from APERC on the estimation of cost reduction through science and innovation, which is based on the learning curve over past years. There were questions from both APERC and Thailand on raw materials for batteries. IEEJ is working closely with Japan Organization for Metals and Energy Security (JOGMEC) to ensure the supply of raw materials at a reasonable price from its counterparts. The discussion also covered the support for energy transition for small and medium enterprises (SMEs) which is in terms of subsidies. Finally, APERC showed interest in Japan's strategy for hydrogen. Japan has a strategy for the total supply chain and market for hydrogen and ammonia, and AZEC is one of the initiatives.

Next, the case studies on decarbonization technologies in power generation, transport and building sectors synthesized by the project consultant (details on the case studies can be found in Chapters 2 and 3) were presented by Dr. Kampanart Silva, ENTEC, Thailand. The participants appreciated the efforts of the team in compiling the case studies, asked questions, and provided comments. Singapore was interested in the peer-to-peer trading platform and asked about the capacity and electricity being traded. Dr. Silva responded that it is one of the sandbox projects under the Energy Regulatory Commission of Thailand (ERC) which will pave the way for the economy towards electricity market. The United States noted the potential of the Sisaengtham model (smart microgrid and energy trading platform in rural area) and the bamboo-powered rural community, which are the two important BCG case studies, in ensuring just transition towards carbon neutral society. The United States added that it is important to identify champions in each sector or area, and have he/she as a role model for other communities. APERC emphasized the necessity for consideration of home-based electric vehicle charging which will complement fast-charging stations. The United States added that the regulation in Christchurch, New Zealand, that requires all newly built houses to possess an electric vehicle charger can be referred to. This is because it is much less expensive to equip the charger in a new house than retrofitting in an existing house. The same also applies to a solar heating shower system. As many APEC economies are using enhanced single buyer model, Indonesia posed the need to design pathways to navigate from enhanced single buyer model to peer-to-peer trading. In the case of Thailand, as Electricity Generating Authority of Thailand (EGAT) which produce the electricity are under Ministry of Energy while Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) which distribute the electricity are under Ministry of Interior, cross-ministry coordination would be the starting point of the transition. Indonesia added that finding a correct key person is inevitable to the success of any models in rural area, and it has always been a challenge to run a model when the key person is changed. The meeting agreed that identifying a successor at an early stage would be a key action, and a system needs to be developed to groom the champions. A community cooperative can be another way to sustain the activities.

The next session moderated by Dr. Setthapun, PMU-B, Thailand, was to identify carbon neutral policy framework and governmental mechanism for power generation, transport and building sectors. She started the session by recapping the case studies from APEC and non-APEC economies and invited Dr. Silva, ENTEC, Thailand to present the Thailand case study on evaluating potential contribution of selected policy tools to CO_2 emission reduction which would provide an example of the consideration of influence of local context on the contribution of policy actions in the case studies on GHG emission reduction. The information on qualitative consideration of all case studies and an example of quantitative consideration of the case on peer-to-peer trading

platform are shown in Section 4.4 and 4.5, respectively. After the presentation, Dr. Setthapun used the guiding questions shown in Figure 54 to induce discussion.

Figure 54 Guiding questions for continued discussion on policy framework and governmental mechanism

Japan recommended the consultant to conduct more detailed assessments, estimating the investment figure and identifying the key success factors of each case study, which can be considered for a future project. On the other hand, the United States commented that the examples shown by the consultant can help extract possible good practices to address concerns in other economies. Indonesia pointed out that even though electric vehicles may affect the current supply chain of automobile industry, they will provide opportunities to tiers 2 and 3 industries in respective economies. United States questioned the reason that a model of city-scale deployment seems difficult in Thailand. Since the ownership structures of public transportation fleets in Thailand are relatively complicated, involving various stakeholders in public and private sectors, a large-scale deployment is not easy. Yet the government is taking a different approach in deploying electric 2-3-wheelers in the last-mile public transport, e.g., motorcycle taxis, vans, at a smaller scale. Viet Nam also added that electric 2-3-wheelers can serve as feeders for connection between mass transit and working areas to enable smart transport. Indonesia provided information on a successful case of bamboo-powered rural community in Sumatra, Indonesia[225]. However, it was difficult to scale up and sustain the project, especially when the champion is no longer there. Close monitoring and succession of the key person are keys to the success of the project. APERC added that there is a United States Agency for International Development (USAID) project in Tamil Nadu on using bamboo to power the community[226]. However, the supply of bamboo is not sufficient and the project struggles in continuing. APERC further commented on phasing-out coal that some coal-fired power plants are relatively new, and co-firing with biomass or ammonia can be a transition solution. The Republic of the Philippines added that though the capacity of coal-fired power is capped, it is still essential in many economies to provide enough time for renewable energy to fully integrate to the central grid. The United States elaborated that jobs and funds can the important challenges during the promotion of carbon neutrality. It also commented that this workshop that aims to use BCG Economy model to ensure wellness of the communities while striving towards carbon neutrality synchronize with the APEC Workshop on

225 https://www.mdpi.com/2673-4931/3/1/47
226 https://pdf.usaid.gov/pdf_docs/PA00XWKJ.pdf

Sustainable Energy Transition: Opportunities and Challenges (EWG 08 2022A) proposed by Viet Nam. Thailand added that the economy is also looking into reskilling and upskilling to obtain essential skills for carbon neutrality. Japan proposed a study on stepwise policy for energy saving building in European Union (EU) which starts with Energy Performance Certificate, then moves forward to setting regulations and providing incentives. Japan also suggested to follow the approach of International Smart Grid Action Network (ISGAN) award that aims to promote smart grid, and establish APEC Carbon Neutral Award to motivate parties in APEC economies to take actions to lower carbon emissions. Thailand concluded that there are opportunities for economies to learn from the success of other economies. Inflation Reduction Act (IRA) helps lift financial barriers for introduction of various decarbonization technologies while Green Transformation (Gx) helps engage private sector as government budget alone is not sufficient. BCG Economy Model helps us realize the necessity of looking into local context before taking policy actions.

The final session to conclude the recommendations for carbon neutral policy framework and governmental mechanism was moderated by Dr. Chollacoop, ENTEC, Thailand. He pointed out the synergy among carbon neutrality, BCG Economy Model and Green Transformation, before presenting the draft recommendations for APEC to move towards carbon neutrality. The participants agreed upon the recommendations shown in Figure 55. The recommendations highlighted the importance of: systematic exploration of the policy framework of each economy to facilitate mutual learning of best practices among APEC economies; consideration of local context along with involvement of local stakeholders; the role of BCG Economy Model as a supporting concept for the achievement of carbon neutrality; and further studies to support economies in contributing to carbon neutrality commitment in energy sector.

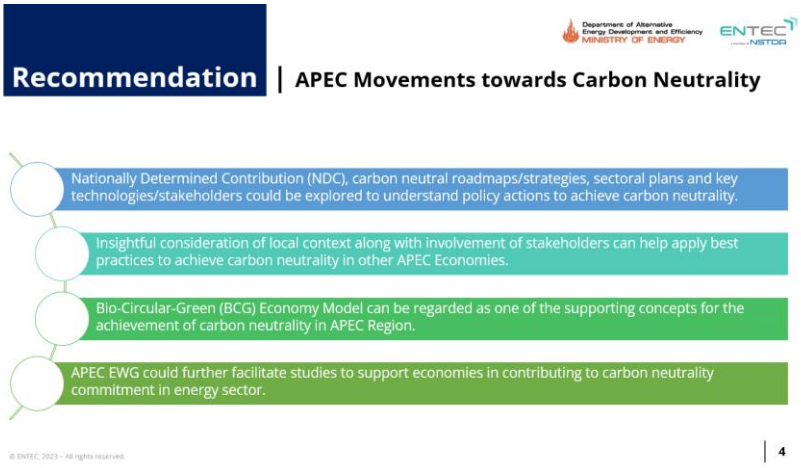


Figure 55 Recommendations for carbon neutral policy framework and governmental mechanism

At the end of discussion, Dr. Chollacoop invited Dr. Chi-Wen Liao, ITRI, Chinese Taipei and the EGNRET Chair, Dr. Sumittra Charojrochkul, the Executive Director of ENTEC, Thailand, and Ms. Munlika Sompranon, DEDE, Thailand and the project overseer to deliver closing remarks before ending the workshop.

6.2.4. Workshop Evaluation Survey

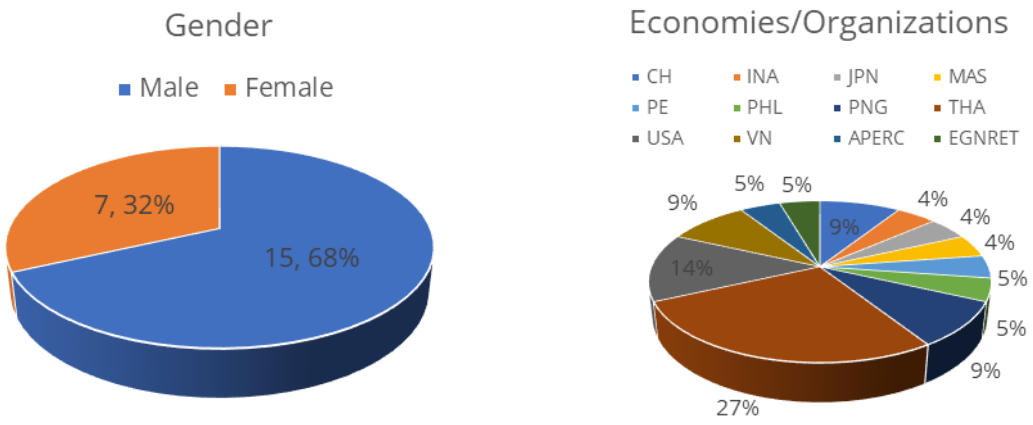


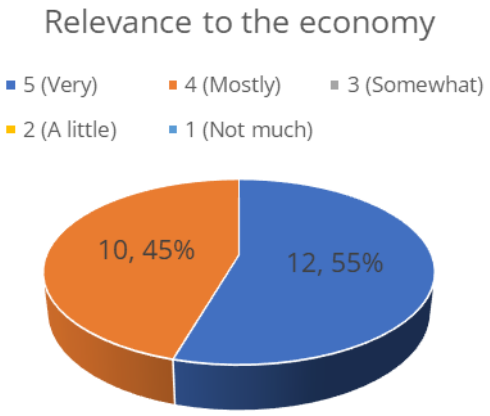
Figure 56 Breakdown statistics of survey respondents

The summary of the workshop evaluation is shown below.

Workshop evaluation questions	Strongly agree	Agree	Disagree	Comments
1. The objectives of the training were clearly defined.	91%	9%	0%	
2. The project achieved its intended objectives.	82%	18%	0%	
3. The agenda items and topics covered were relevant.	91%	9%	0%	
4. The content was well organized and easy to follow.	86%	14%	0%	
5. Gender issues were sufficiently addressed during implementation.	59%	41%	0%	
6. The trainers/experts or facilitators were well prepared and knowledge-able about the topic.	95%	5%	0%	The organizers were very well prepared and lead the workshop in an extremely professional manner.
7. The materials distributed were useful.	86%	14%	0%	- I especially appreciated how Google Drive with all the presentations was made available to us in real time. - I suggest it could be possible to share the recordings of meetings
8. The time allotted for the training was sufficient.	64%	27%	9%	- The timing was very short, and many important things were squeezed.

Workshop evaluation questions	Strongly agree	Agree	Disagree	Comments
				Participants could not adequately reflect. - I suggest it could be possible to have some meetings in different days considering the time in Peru. - The timing was very short, and I personally could not take everything at once. But generally, it was an excellent workshop and training.

9. How relevant was this project to you and your economy?



Please explain the relevance of the project to your economy.

- Important lessons for both mature and rapidly growing economies.
- Thailand uses the BCG Economy concept to drive the sustainable economy development.
- Papua New Guinea is currently developing its National Energy Transition Plan. Therefore, it was important to learn from the APEC advanced economies so that we can be guided and be better informed in the process of preparing our necessary policy and legislations.
- It can help enable Papua New Guinea to develop and implement its National Energy Transition Plan
- It is relevant for achieving net zero and carbon neutrality.

10. In your view what were the project's results/achievements?

- It highlighted the importance of strong leadership at the local/community level.
- The project has achieved the results in providing the guideline in applying the BCG concepts to the carbon neutrality projects for the APEC economy through the case studies from various sectors.
- In my simple view it refers to the milestone achievements in the energy transitions development plans, particularly the key result areas and the deliverables for a particular economy moving forward with their energy transition initiatives towards their net zero emission targets respectively.
- It shows the relevance of the energy policy of each economy.
- It provides examples of potential successes.
- I could not recall everything that was shared during the workshop. However, I would appreciate the motive of the different projects to reduce emissions of GHGs from the use of

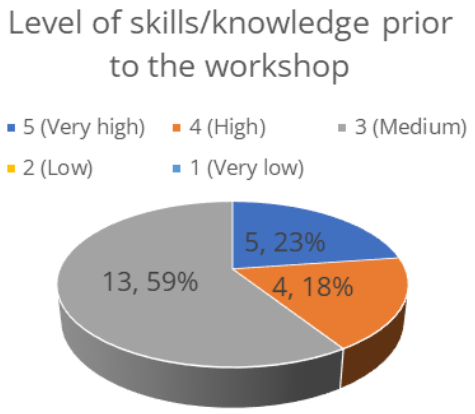
fossil fuel to attain net-zero emissions reduction target by 2050, applying the renewable energy technologies and the development and application of energy efficiency standards across APEC economies.

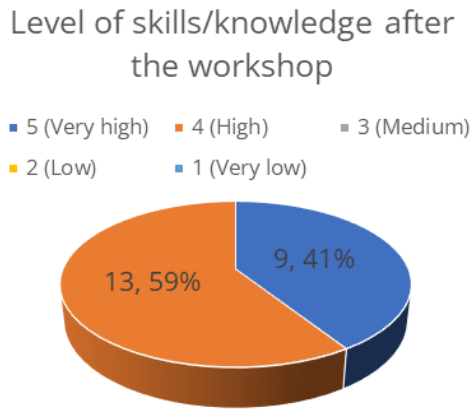
- It shows lessons learned from many economies.
- This project has summarized representative cases to reach carbon neutrality in the APEC region.

11. What new skills and knowledge did you gain from this event?

- More knowledge of key BCG projects in SE Asia region of APEC.
- Updates on the policy and updates for each economy on carbon neutrality and net-zero goals.
- Energy modelling results and wish to also receive capacity building and training on energy and economic modelling to enable proper planning.
- The engineering approach to problem solving is to first do it, then gradually adjust. But the economist's solution is to collect data to choose the best way to solve the problem. In addition, what has been learned is that the technologies to reduce the effects of GHG emissions are available, but they are costly.
- Strengthening of capacities and techniques about new technologies.
- Suggestions for overcoming barriers.
- I learnt a lot about new renewable energy technologies introduced including hydrogen and ammonia as supplementary clean fuels, carbon storage plants, energy efficiency initiatives and other interesting technologies to be replicated across all APEC economies as and when required.
- Carbon neutral policies and implementation
- Updates on efforts and activities of APEC economies to reach carbon neutrality, as well as BCG models.

12. Rate your level of knowledge of and skills in the topic prior to/after participating in the event.





Please explain how have your level of knowledge of and skills changed after participating in the event.

- More knowledge about specific projects.
- My personal understanding in terms of energy transition, energy data management and generally learning on how hydrogen is being treated as one of the important substitutes of fossil fuel.

- I learnt a lot from other economies regarding their goals and initiatives towards carbon neutrality. There are a lot of interesting projects that can be applied in my economy.
- I learnt through listening to presentations and participating in the questions and answer sessions.
- Update policy plan about net zero in various economies.
- By learning from speeches and sharing organized by the host.

13. How will you apply the project's content and knowledge gained at your workplace? Please provide examples.

- More effectively support the EWG in developing goals that incorporate BCG.
- I would bring the lesson learned from the updated policy for carbon neutrality and use as the guideline in my organization.
- Assist the team to provide advice in drafting of the National Energy Transition Plan as well as developing other sub-sectoral renewable energy policies and regulations in Papua New Guinea.
- As our agency is responsible for research, the project's content may be used to improve the research policy planning of energy issues. We can start by finding the economy's needs, and then determine the total budget that must be used to meet the needs.
- Policy initiatives and supporting training.
- Hoping to extend this work in follow on US-SEGA effort.
- These exciting experiences attained during my participation will assist me to draft sub-sector renewable energy policies on geothermal, hydro, solar, biofuel, waste to energy with others as well as to draft the Minimum Energy Performance Standards Regulations to address energy efficiency issues to reduce Papua New Guinea's GHG emissions.
- The project content gained will be used for knowledge sharing.

14. What needs to be done next by APEC? Are there plans to link the project's outcomes to subsequent collective actions by for a or individual actions by economies?

- Introduce more realism and evaluation of previous efforts.
- There should be more sharing practices and training on the cost benefit analysis for the projects as well as for the policy.
- Need to organize both economic and energy modelling training, energy data management training, and importantly provide technical and funding support to economies to kick start some initiatives through development and implementation of policies and legislations.
- Encouraging economies to follow up including with US-SEGA opportunities.
- Extend the training period to effectively cover all the important items of the agenda and provide more options where least developed economies can source funding and technical support to develop and implement some of their priorities domestically to address energy security and transition issues.

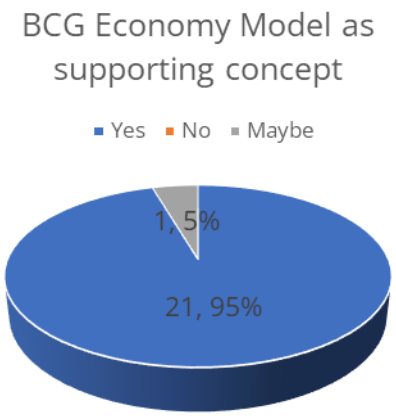
15. How could this project have been improved? Please provide comments on how to improve the project, if relevant.

- No suggestions. It was an effective and balanced discussion and examination of key issues.
- The project is great.
- It would be great if we can do the BCG principle across the economy.
- Extend project training time and show more success stories and lesson learnt from the advanced economies and link up with developing economies to have access to global

energy transition financing and for rolling out energy transition initiatives to speed up actions to reduce emissions.

- Target a few collaboratives working group to work on grant/funding application for inter-economy research/projects on EE and RE
- Setting strategy to drive the project's content to each economy faster.

16. Is it reasonable to use BCG Economy Model as one of the supporting concepts for the achievement of carbon neutrality in APEC Region?



Why do you think so?

- It highlights the importance of strong local/ community leadership.
- It increases positive impact to environment and increase value and efficiency of resources.
- Papua New Guinea is a developing economy and our acceptance to this model will be determined by the lesson learnt from other advanced economies.
- It depends on how the policies are applied to each economy.
- It is possible with appropriate funding and technical support provided to less developing economies to drive energy transition efforts.
- It is quite important to connect bio-circular-green economy to reduce carbon emission and waste, while maintaining economic growth by creating a new green business model.

17. What are the further steps to be taken by APEC EWG to regionally contribute to global carbon neutral commitment?

- Incorporate more realistic and pragmaticism in their deliberations.
- Show success cases which are expected to be examples of BCG by economy.
- Analyze Peru as a potential market in renewable energy in APEC.
- Provide support and capacity building in renewable energy technologies and provide funding and technical support to developing economies to work towards achieving their own targets.