Asia-Pacific Economic Cooperation

Advancing Free Trade for Asia-Pacific Prosperity

Filling the Gap to Reach the Goal of Doubling Renewable Energy in the APEC Region - Phase 2

APEC Energy Working Group

May 2022

Filling the Gap to Reach the Goal of Doubling Renewable Energy in the APEC Region - Phase 2

APEC Energy Working Group

Expert Group on New and Renewable Energy Technologies

May 2022

APEC Project No.: EWG 02 2019A

Produced by:
Industrial Technology Research Institute, Chinese Taipei
195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Chinese Taipei 31040
Tel: +886-2-8772-0089803
Email: tarcy@itri.org.tw
Website: https://www.itri.org.tw/

Prepared 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#222-RE-01.6

Acknowledgment

We express our deepest gratitude to the APEC Secretariat and Bureau of Energy, Chinese Taipei, for providing guidance and financial support in the implementation of this APEC project. We are particularly grateful to Dr Chung-Hsien Chen, the APEC Project Overseer, and Dr Tom Hom-Ti Lee, the Chair of Expert Group on New and Renewable Energy Technologies (EGNRET), for their supervision.

We would also like to express our appreciation for the assistance rendered by the APEC Energy Working Group Expert Group on Energy Data and Analysis (EGEDA) and the Asia Pacific Energy Research Centre (APERC) in collecting data and conducting quantitative analysis.

Moreover, we would like to thank all the representatives from the APEC member economies, APEC Energy Working Group, EGNRET, Asia Pacific Energy Research Center, ASEAN Centre for Energy, Monash Energy Institute, and International Renewable Energy Agency for attending the workshop held on September 23, 2021, and providing invaluable comments and substantive information.

Authors

Bing-Shun Huang, Sih-Ting Jhou, Han-Yun Lee, An-Ling Lee, Shao-I Wu
(Alphabetical Order by Author's Last Name)

Table of Contents

1. Introduction

1.1 Research Background and Objectives

The 2012 Leaders' Declaration of the APEC suggested for energy security to be strengthened in the APEC region to develop clean energy sources for sustainable development. In 2014, energy ministers at the APEC Energy Ministerial Meeting (EMM11) reaffirmed the United Nations (UN) "Sustainable Energy for All" (SE4All) initiative and instructed the APEC Energy Working Group (EWG) through the Expert Group on New and Renewable Energy Technologies (EGNRET) to develop a roadmap for the goal of doubling the share of renewable energy in the APEC energy mix. Moreover, at the APEC Leaders' Meeting in 2014 and the APEC Energy Ministers' Meeting in 2015, two APEC aspirational goals for achieving sustainable and resilient energy development within the APEC region were set, namely reducing aggregate energy intensity by 45% by 2035 and doubling the share of renewables in the APEC energy mix, including in power generation, from 2010 levels by 2030. To attain this target, APEC economies should enhance cooperation and promote innovation in renewable energy technologies to make renewable energy more inexpensive, sustainable, and competitive in the energy market.

This project was therefore launched to assess APEC's progress with respect to the target of doubling renewable energy use and what can be done to overcome hurdles impeding realization of this target. This work extended the results of the phase 1 project and aimed to further develop a strategic roadmap with recommendations provided, including in the power generation and nonpower sectors (transportation and heating). The findings of this report can serve as a reference for APEC economies when reviewing and adjusting their targets and supporting policies to double the share of renewable energy use in their energy mix.

The objectives of this report were to (1) collect data and assess the level of renewable energy development required to close this gap; (2) develop a strategic roadmap for doubling the proportion of renewable energy use in various sectors, such as the power, transportation, and heating sectors, and prioritize the policy recommendations formulated in phase 1 of this project; (3) create a final report on the research findings for renewable energy development in the APEC region; and (4) achieve gender equality in the doubling of the proportion of renewable energy use. The aforementioned objectives are detailed as follows.

(1) Data collection and gap assessment: First, we collected data and reviewed literature on current renewable development in the APEC region. We reviewed external resources to obtain data, policy-related information, and recommendations related to global renewable energy that are applicable to this study. Subsequently, the gap between the status quo and the goal of doubling renewable energy use in the APEC region was assessed.

(2) Development of a strategic roadmap: On the basis of the collected data and gap assessment, a strategic roadmap was developed to recommend action plans and create a cooperative framework among APEC economies for doubling the use of renewable energy in the APEC region.

(3) Creation of a final report: A final project report was produced to provide policy recommendations and a strategic roadmap for the development of renewable energy and the achievement of the doubling goal. This report covers the research outcomes, policy recommendations, challenges, barriers, and strategies related to doubling the use of renewable energy in the APEC region.

(4) Achievement of gender equality: In line with the APEC Gender Inclusion Guidelines, the proposed project focused on equal rights, responsibilities, and opportunities for men and women. Gender considerations were included in the research process.

1.2 Process and Research Framework

First, defining renewable energy in the context of the roadmap of this report is critical. The definition of renewable energy in this report is consistent with that of the APEC Energy Working Group Expert Group on Energy Data and Analysis (EGEDA) and includes large hydro projects (but not traditional biomass) in the category of renewable energy sources. Second, the development of a roadmap for renewable energy development is divided into two phases: (1) roadmap baseline analysis and (2) comprehensive roadmap development. The work leading to this report was mainly focused on collecting information on renewable energy, evaluating the gap between the current renewable energy use scenario and the goal of doubling renewable energy use, and establishing a strategic roadmap for achieving this goal.

The framework of research and activity culminating in this report (Figure 1) comprised planning a roadmap for achieving the doubling goal, conducting workshops, establishing a roadmap network, and promoting cooperation. Through the application of the management method, a political, economic, social, and technological (PEST) analysis was conducted to assess major external factors influencing the operation of different sectors. The policy recommendations made in this report have the aim of ensuring market access, policy development (including the development of incentive mechanisms), capacity building, and economic and financial engagement related to renewable energy. Therefore, these recommendations can serve as a reference for all the APEC economies to increase their renewable energy deployment and achieve the goal of doubling the share of renewable energy in their overall energy mix.

On the basis of the roadmap establishment methods proposed by the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA), a framework was developed in this project for filling the gap between the current use and doubling goal of renewable energy in the APEC region. The developed framework includes goal setting based on the Leaders' Declaration of the APEC, gap analysis according to the method proposed by the Asia Pacific Energy Research Centre (APERC), and policy analysis. Furthermore, this report identified challenges that must be overcome for achieving the doubling goal in the power, transportation, and heating sectors as well as the APEC economies that can inspire regional development in the use of renewable resources. Finally, recommendations are provided for overcoming the challenges for the aforementioned sectors in the APEC economies.

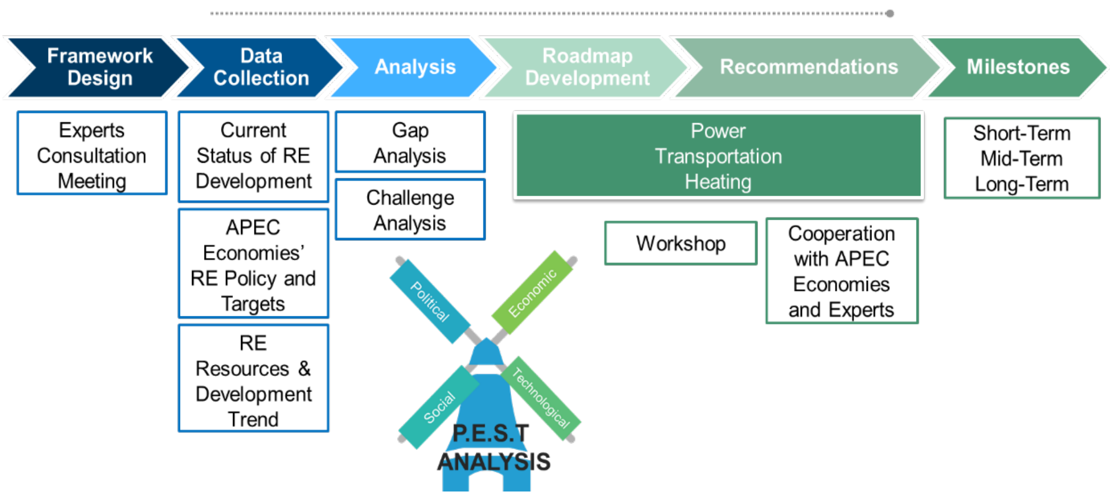


Figure 1. Research Process and Framework

2. Renewable Energy Development in the APEC Region

2.1 Status of and Development Policies for Renewable Energy

2.1.1 Power Sector

From an environmental perspective, 2020 was a watershed year for the energy sector because the COVID-19 pandemic restricted in-person contact; the overall energy demand declined due to the lockdowns enforced to control the spread of COVID-19. Many APEC members are developing numerous projects for the generation of renewable energy to adhere to the requirements of commitments such as the Green Deal, net-zero-emission (NZE)/carbon neutrality pledges, and the UN's 2°C temperature rise agreements. Table 1 presents the current renewable power policies in the APEC region, including targets, regulatory policies, and financial and fiscal supports.

Renewable energy targets must be revised to reflect the status or achievement of renewable energy deployment. The targets adopted by APEC members vary in focus and metrics, with economy-wide targets being less common than sector-specific targets. A total of 19, 5, and 4 APEC members have set targets for the power, transport, and heating and cooling sectors, respectively. 11 APEC members have revised their renewable power targets since 2020. Of these members, Brunei Darussalam and Japan have made ambitious changes, with Brunei Darussalam (for 2035) and Japan (for 2030) increasing their targets for the proportion of renewable energy use from 10% to 30% and from 23% to 37%, respectively.

Table 1. Renewable energy power targets of different APEC members

Economy	Descriptions
Australia	Annual large-scale renewable energy (RE) target of 33,000 GWh; expires in 2030 (2015).
Brunei Darussalam	30% RE capacity by 2035 (July 2020).
Canada	100% nonemitting sources by 2025 (applicable for federal assets). Five provinces (Alberta, Nova Scotia, Quebec, Saskatchewan, and Yukon) have RE generation targets.
Chile	70% RE generation by 2030, 40% nonconventional renewable energy sources by 2030 (2019).
China	25% nonfossil share in total primary energy supply (TPES) by 2030. More than 50% RE capacity by 2030; 1,200 GW accumulated solar and wind capacity by 2030 (Dec. 2020).
"Hong Kong, China	10% RE generation by 2035 (Oct. 2021).
Indonesia	17% RES in total final energy consumption (TFEC) by 2030 (2017). 23% modern RES (excludes traditional biomass) in TPES by 2025, 31% by 2050 (2017). 51.6% additional RE capacity for 2021–2030, total RE capacity of 19,899 MW (June 2021).
Japan	13%-14% RES in TPES by 2030 (2015). 36%–38% RE generation by 2030 (July 2021).
Republic of Korea	14.3% RES in TPES by 2030 (2014). 12.4% RES in TFEC by 2034; 22.2% RE generation by 2034, total 80.8 GW (Dec. 2020).
Malaysia	31% RES capacity by 2025, 40% by 2035; 18 GW RE capacity by 2035 (June 2021).
Mexico	28.3% RE generation obligation by 2020, 30% by 2021, 31.7% by 2022, 33% by 2023, and 35% by 2024. 35% clean energy share by 2024 (2014). 43.1% clean energy share by 2035 (2021).
New Zealand	100% RE generation by 2030 (Sep. 2020).
Papua New Guinea	100% RE generation by 2030, 100% RES in TPEC by 2050.
Peru	15% RE generation by 2030 (2018).
The Philippines	100% RES in TFEC by 2050. 30% RE generation by 2030, 50% by 2040 (Oct. 2021).
Russia	20% RE generation (4.5% excluding large hydro) by 2024, 5% in TPES by 2020 (2009).

Singapore	Solar capacity of 1.5 GW by 2025, 2.0 GW by 2030 (2019).
Chinese Taipei	20% RE generation by 2025 (2019). Total RE capacity of 27 GW by 2025.
Thailand	30% RES in TFEC by 2037, solar capacity of 15,574 MW by 2037 (2019), 100% RES in TFEC by 2050.
United States	Carbon-free power sector by 2035, 30-GW offshore wind by 2030 (Apr. 2021). 30 states and DC have a renewable portfolio standard (updated Sept. 2020).
Viet Nam	15%–20% RES in TFES by 2030, 25%–30% by 2045 (Feb. 2020). Power Development Plan VIII (draft): 15.4%–16.8% hydro, 11.9%–13.4% other RE generation by 2030.

In Table 2, the policy measures for promoting renewable energy use are divided into the two categories of financial incentives and obligation enforcement. Financial incentives include feed-in tariffs, premiums, net metering, and tradable certificates. These measures were the most effective strategy for scaling the use of renewable energy; however, the frequency of providing financial incentives for renewable energy use has decreased over time, because these incentives are become less effective. Currently, policymakers in APEC economies prefer to enforce obligations and utilize support mechanisms without financial incentives and with limited administrative interference, thus shifting to nonmonetary mandates. These measures include more competitive business models, such as auctions and corporate power purchase agreements, and even revisions to existing financial applications, feed-in tariffs viable only for communities that are small or off the grid, and auctions with a volume that is far lower than the market supply. The aforementioned trends have been initiated because grid parity has been achieved in APEC economies, and the popularity of postsubsidy policy measures is expected to increase throughout the APEC region.

Table 2. Measures adopted in APEC economies for promoting the use of renewable power

Economy	Feed in Tariff (FiT)	Feed in Premium (FiP)	Renewable Portfolio Standard (RPS)	Renewable Energy Certificates (RECs)	Auction	Net Metering
Australia	Y^S	Y^S	Y	Y	Y^S	Y^S
Brunei Darussalam						
Canada	Y^S			Y^S		Y^S
Chile						Y
China	Y		Y	Y		
Hong Kong, China	Y			Y		
Indonesia	Y					
Japan	Y			Y	Y	Y
Republic of Korea	Y		Y	Y	Y	Y
Malaysia	Y				Y	Y
Mexico	Y		Y	Y	Y	Y
New Zealand						
Papua New Guinea						
Peru					Y	Y
The Philippines	Y	Y	Y	Y		Y
Russia		Y			Y	
Singapore						
Chinese Taipei	Y			Y		
Thailand	Y					
United States	Y^S		Y^S	Y^S	Y^S	Y^S
Viet Nam	Y		Y			Y

Note: S: subnational

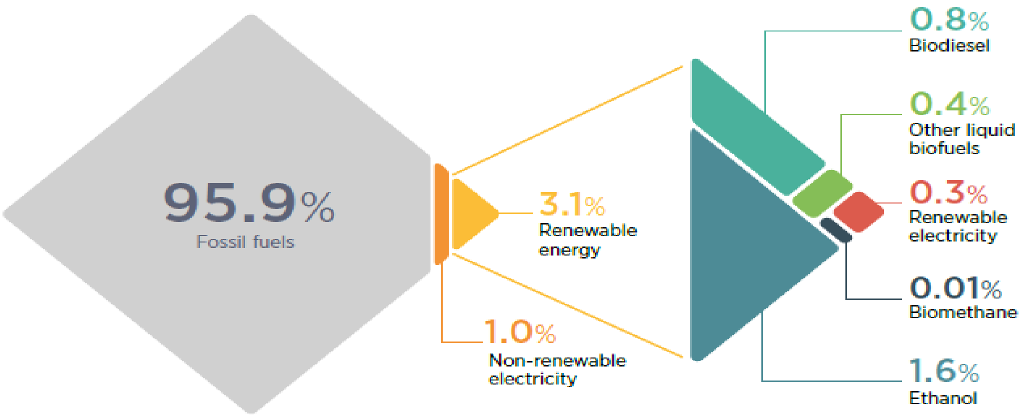
Source: REN21 (2021), IEA policy database

2.1.2 Transportation Sector

The main renewable energy source used in the transportation sector is liquid biofuels, with bioethanol and biodiesel being the most commonly used biofuels. In 2016, liquid biofuels powered approximately 4% of all road transportation worldwide (ITF, 2017). In 2015, the transportation sector accounted for 75% of global total final energy consumption (TFEC). Of the contribution of the transportation sector to the global TFEC, 95.9% was attributable to fossil fuels and 3.1% was attributable to biofuels. Specifically, 1.6%, 0.8%, 0.4%, 0.01%, and 0.3% of the TFEC in the transportation sector were attributable to bioethanol, biodiesel, other liquid biofuels, biomethane, and renewable electricity, respectively (IRENA, 2018).

The aviation sector consumes biofuels primarily by blending them with aviation fuels, with more than 100,000 commercial jets worldwide currently using biofuels (IATA, 2018). Another example of vehicles running on renewable energy is solar-powered jets, which are still in the early research and design (R&D) stage. Although marine transport can also be powered by biofuels, wind, and solar-powered engines, blending biofuels in conventional fuels is still the main method of using renewable energy in marine transport vessels. For example, ships powered by biodiesel blends are present in the waters of the United States.

In recent years, electric vehicles (EVs) have become an emerging means of transport. Nevertheless, EVs do not necessarily run on electricity generated from renewable energy. An increase in EVs on the road would result in an increased power demand; however, power consumption estimates do not include the consumption from EVs that may be added to the road in the future. Therefore, the roadmap of renewable energy use in the transportation sector discussed in this report focuses on the use of biofuels.

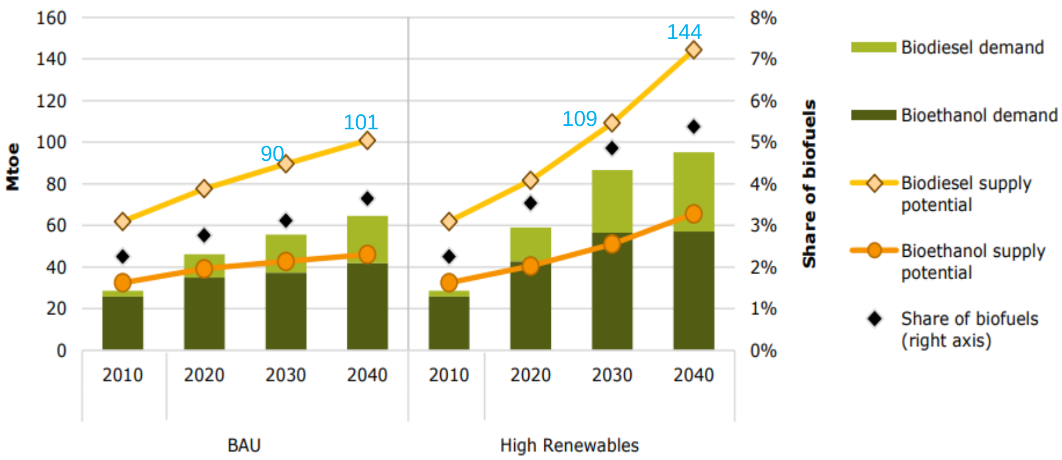


Source：IRENA (2018)

Figure 2. Energy Consumption of Global Transportation Sector by Fuel Type in 2015

2.1.2.1 Overview of Biofuel Development in APEC Region

According to an estimate of the APERC (2016), the biofuel supply in the APEC region is expected to increase by an average annual growth rate (AAGR) of 1.4% in the Business-as-Usual (BAU) Scenario, from 70 Mtoe in 2013 to 90 Mtoe in 2030. In the High Renewables Scenario, the biofuel supply in the APEC region is projected to grow by an AAGR of 2.7% to 109 Mtoe in 2030. The biofuel feedstock supply in the APEC region was calculated by subtracting food consumption from total food production in the region and adding the difference to the feedstock produced from unutilized agricultural land under the assumption that this land is used to grow biofuel crops. The biofuel supply potential in the APEC region is illustrated in Figure 3.



Source: APERC (2016)

Figure 3. Biofuel Demand and Supply Outlook in APEC Economies

The United States, China, and Southeast Asia account for 63%, 8%, and 9%, respectively, of the projected bioethanol supply potential in the APEC region by 2040. In particular, Indonesia and Thailand have the potential to increase their bioethanol production by using unutilized land to grow energy crops, and China has the potential to produce more energy crops by enhancing productivity. Southeast Asia accounts for 75% of the biodiesel supply potential in the APEC region. Indonesia and Malaysia are the most promising suppliers of biodiesel because they have large areas of unutilized arable land to grow additional palm fruits. Moreover, the United States, which has large areas of land and a high potential to increase biofuel crop productivity, accounts for 20% of the biodiesel supply potential in the APEC region. Other North and South American economies, which have the potential to increase soybean productivity, account for 4.9% of the biofuel supply potential in the APEC region.

In the BAU Scenario, the biofuel consumption potential in the APEC region is projected to have an AAGR of 3.7%, and biofuel consumption is expected to increase from 29 Mtoe in 2010 to 87 Mtoe in 2030. The expected increase in biofuel consumption in the APEC region is driven by government blend rate mandates, blend rate targets, and incentives for boosting biofuel usage. Biofuel usage for transportation is projected to increase from 2.3% in 2010 to 4.9%.

Biodiesel consumption is projected to grow at an AAGR of 6.6% and outpace the growth in bioethanol consumption by 2.6%; however, two-thirds of biofuels consumed worldwide are varieties of bioethanol. By 2030, the biodiesel and bioethanol consumptions are expected to reach 30 and 57 Mtoe, respectively. Bioethanol consumption is higher than biodiesel consumption in the APEC region primarily because of greater demand for gasoline than for diesel. With regard to biodiesel consumption by region, Southeast Asia is projected to account for 22% of the bioethanol consumption in the APEC region by 2030. Nevertheless, because the demand for bioethanol is increasing, a shortage in the biofuel feedstock supply would cause bioethanol consumption to outpace bioethanol production in the APEC region between 2019 to 2034. To meet the biofuel consumption targets set by their governments, APEC member economies should increase the production of first-generation biofuels by growing additional feedstock, producing second- and third-generation bioethanol, or importing bioethanol from other economics.

2.1.2.2 Policies and Measures for Biofuel Development in APEC Region

APEC economies define biofuel targets by using different metrics (Table 3), with some setting blend rates and others setting annual production targets to boost the supply and usage of biofuels; however, most APEC economies base their targets according to their available pool of resources to boost biofuel development. For example, China has set a blend rate target of 10% for bioethanol and biodiesel; VietNam has set a blend rate target of 5% for bioethanol since 2015; Korea has set a blend rate of 2.5% for biodiesel; and Indonesia has set a blend rate target of 3% for bioethanol and 2.5% for biodiesel. Malaysia currently uses a blend rate target of 5% for biodiesel but has planned to increase this target to 7% in the future. Thailand has adopted a blend rate target of 7% for biodiesel, E10–E20 bioethanol blends, and the E85 bioethanol blend. Finally, the Philippines has adopted a blend rate target of 2% for biodiesel and 10% for bioethanol (Gumera, 2014). Table 3 presents the biofuel targets in various APEC economies.

Table 1. Measures and targets adopted by APEC economies to promote biofuel use

Economy	**Regulation**	**Blend rate mandate**		**Blend rate target**		**Incentives, subsidies, and taxation**
		Bioethanol	**Biodiesel**	**Bioethanol**	**Biodiesel**	
Australia	√	√*	√*	E4/E5	B2	√
Brunei Darussalam	-	-	-	-	-	-
Canada	√	E8.5	B4	E5	B2	√
Chile	-	-	-	E5	B5	-
China	-	E10	-	10 Million Tonnes （2020）	2 Million Tonnes （2020）	√
“Hong Kong, China	√	-	-	-	-	√
Indonesia	√	E3	B2.5	E20 （2025）	B30 （2025）	√
Japan	√	√	-	0.5 Million Loe		√
Korea	√	-	B2.5	-	B5 （2020）	√
Malaysia	√	-	B7	-	B10	√
Mexico	√	E5.8	-	√	-	√
New Zealand	-	-	-	-	-	-
Papua New Guinea	-	-	-	-	-	-
Peru	√	E7.8	B2	E7.8	B5	√

Economy	Regulation	Blend rate mandate		Blend rate target		Incentives, subsidies, and taxation
		Bioethanol	Biodiesel	Bioethanol	Biodiesel	
The Philippines	√	E10	B2	E20 (2020)	B20 (2025)	√
Russia	√	-	-	-	-	-
Singapore	-	-	-	-	-	-
Chinese Taipei	√	-	-	-	-	√
Thailand	-	E10-20、E85	B7	2.6 Billion L/yr	5.1 Billion L/yr	√
The United States	√	E15	B10	136 billion L/yr (2022)		√
Viet Nam	√	E5	-	E10	-	√

2.1.3 Heating Sector

Renewable heating is the generation of energy from renewable technologies and resources for end-use applications (e.g., space and water heating in buildings, heating water for pools, cooking, industrial heating processes, and heating processes in agriculture [primarily for greenhouse heating]). According to the Renewables 2021 Global Status Report (REN21, 2021), global energy use in the heating and cooling sector (including space and water heating, space cooling, and industrial heating processes) accounts for 51% of TFEC, significantly outweighing other sectors; however, renewables account for only around 10% of the aforementioned energy use. Heat demand continues to constitute the vast majority of energy use, although energy demand for cooling is increasing rapidly. Moreover, industry uses account for approximately half of this heat (e.g., production of steam for industrial processes), and the remainder is for heating buildings and water, cooking, and agricultural uses.

In 2020, the reduced economic activity due to the COVID-19 pandemic had a limited direct influence on renewable heat demand in the short term. The decrease in global heat demand was more pronounced in the industrial sector than in the building sector mainly because of lockdown measures and teleworking practices. The IEA (2020) projected renewable heat demand to grow slightly between 2020 and 2022, owing primarily to an increase in residential heat consumption (primarily for cooking). In summary, the energy used for heating and cooling (e.g., processing heat and building heating and cooling) continues to be a significant contributor to global energy demand

and climate change.

In the APEC region, space heating (34%), water heating (22%), and cooking (19%) represent most of residential energy demand with respect to end use, collectively accounting for three-quarters of total demand (APERC, 2019). APEC economies have abundant renewable resources and have developed considerable renewable energy capacity across several technological fields (e.g., solar PV, wind power, hydropower, bioenergy, and geothermal). For example, the APEC region is roughly coterminous with a large extent of the Pacific Ring of Fire, where most of the world's geothermal energy potential is concentrated; however, the geothermal energy sector is currently underdeveloped in this region. Bioenergy and solar heating technologies that can supply direct heating needs are also being actively developed. In the APEC region, renewable energy usage in the heating sector includes the use of geothermal heating and solar water heating, which are primarily used in buildings and by the agricultural and industrial sectors. However, because heating accounts for a small proportion of overall energy consumption and the promotion of renewable energy usage in the heating sector is a more complex task relative to that in the power sector, APEC economies face considerable challenges in formulating policies to promote renewable energy in heating. At present, more than half of the APEC economies have yet to formulate policies to regulate renewable energy usage in the heating sector.

2.1.3.1 Promoting Renewable Heating in APEC Region

To promote renewable energy use in heating, several APEC economies have developed policies and regulations (e.g., solar heat obligations, technology-neutral renewable heat obligations, and renewable heat FiT) on the basis of their resources. For example, China made numerous high-profile commitments to replace coal as a primary source for heating, including the imposition of a coal ban in 28 cities, the promotion of an enhanced role for renewables, and the establishment of several renewable heating-related targets in their 13th Five-Year Plan. By subsidizing measures to enhance energy efficiency and reduce energy consumption, including installing solar water heaters and heat insulation projects, governments seek to improve residential energy efficiency. Table 4 presents the policies that APEC economies have implemented to promote renewable energy usage in heating, where approximately half of the APEC economies have taken steps to encourage the use of renewable energy in heating.

Because fossil-fuel-powered heating results in massive greenhouse gas emissions, an increasing number of economies have begun to recognize the importance of using renewable energy in the heating sector to reduce carbon emissions and achieve their emissions targets. Despite the aforementioned facts, the growth of renewable energy use in the heating sector remains slow, and policy attention in this sector is still lacking. China and the United States, which are two economies with the highest heat consumption, together accounted for 37% of the world's total heat consumption in 2015; however, the renewable energy usage in the heating sector was only 3% and 10% in China and the United States, respectively (IEA, 2018). Increasing the shares of renewable energy usage in the heating sector in these economies would considerably help the APEC region to achieve its goal of doubling the proportion of renewable energy use in the heating sector.

Table 2. Policies and measures adopted by APEC economies to promote renewables in heating and cooling sector

Economy	Policies/Measures	Year
Australia	Solar Communities Program	2016
United States	29 US states have incorporated renewable heat technologies into their renewable portfolio standards	-
Canada	Manitoba Geothermal Program	2016
	ecoENERGY for Renewable Heat Program	2007
Chile	Regulatory Framework for Solar Water Thermal	2009
China	13th Five-Year Plan (2016 to 2020)	2016
	Notice on planning the exploitation and utilization of geothermal energy for power and heating	-
Korea	Home Subsidy Program	2004
	New and Renewable Energy Equipment Certification	2003
Mexico	Solar Water Heating Mandate of Mexico City	2006
Peru	Implementation and application of the alternative heating technology "passive solar energy collection system	2008
Chinese Taipei	Regulations for Subsidizing the Utilization of Renewable Heat	2015

Economy	Policies/Measures	Year
Thailand	Solar hot water hybrid system promotion project	2008
	AEDP2015 Plan	2015

2.1.3.2 Potential for Renewable Heating in APEC Region

Modern sources of renewable energy include direct renewables (e.g., modern bioenergy, geothermal energy, and solar thermal energy) and renewable electricity used for heating and cooling (e.g., through air-source heat pumps). In addition, the rapid development of heat pumps in the previous decade has made ambient heat an essential renewable heat source, but its global role is difficult to estimate because of a lack of data for several markets (IEA, 2020).

1. Heat From Modern Renewables

Bioenergy can technically provide process heat for all sectors; however, it is predominantly used in the industrial and building sectors. In the industrial sector, bioenergy accounts for the majority of renewable heat consumption, and it is predominantly used to produce biomass waste and residues. Bioenergy has also long been used to deliver large amounts of renewable heat to buildings. Most economies in the APEC region have large volumes of underutilized bioenergy feedstock. In the APEC region, biomass residues (including agricultural residues, forestry residues, animal residues, and municipal solid waste) reached an estimated 1,132 Mtoe in 2016, with the largest volumes being reported by China, the United States, and Indonesia (APERC, 2019). However, most of these residues were not used, indicating the potential for APEC members to increase bioenergy use.

Solar thermal heating includes applications such as rooftop solar water heating and solar heating for industrial processes. China continues to play a leading role in the global and regional markets, with its operating capacity reaching 364 GWth—67% of the global capacity in operation by the end of 2020 (REN21, 2021). If implemented, APERC (2019) projects in the APEC region represent the potential to install more than 2,200 GW of solar panels by 2050; in this manner, the hot water heating demand in residential buildings can be met.

The direct use of geothermal energy for heating on the global scale continues to grow; however, the geothermal energy market remains small because it is highly concentrated geographically. The geothermal energy used in the building sector has multiple direct applications (e.g., bathing and swimming), but its growth is mainly driven by space heating. In the industrial sector, geothermal heat is mainly used in the food and beverage, pulp and paper processing, and chemical extraction industries. Within the APEC region, the main economies employing direct geothermal heating continue to be China, Japan, New Zealand, and the United States. Recent years have seen increasing growth in geothermal heating in both industrial and building sectors. However, the main barriers to promoting geothermal heat continue to be those pertaining to cost and technological innovation (e.g., new resource recovery techniques and seismic risk mitigation).

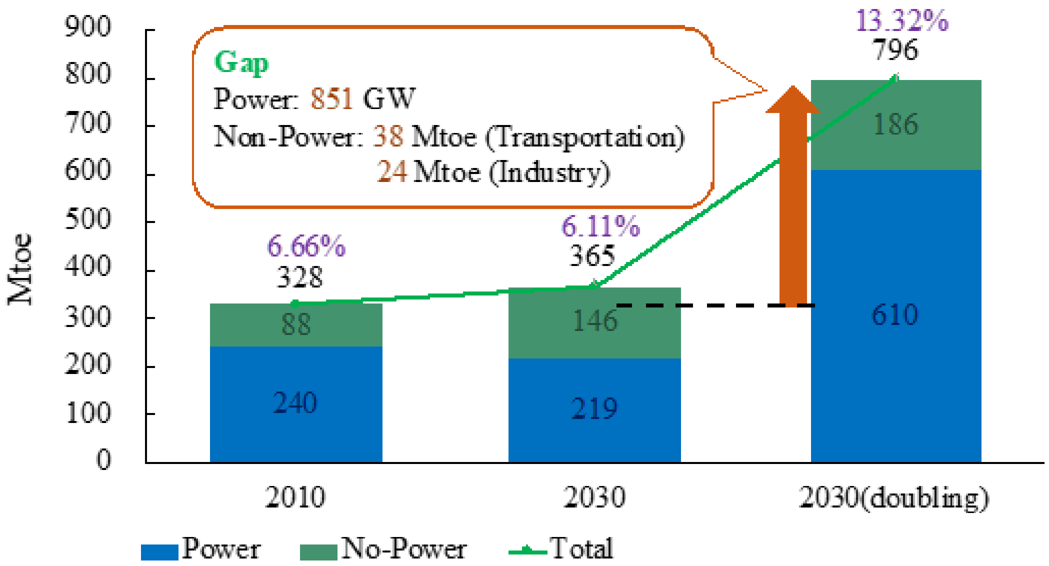
2. Renewable Electricity for Heat

With the increasing attention on the use of biomass, solar thermal, and geothermal heating, heating electrification is also proposed as an alternative strategy and a substitute fuel for space and process heating in the industrial and building sectors in many economies. Renewable electricity can be used to heat buildings through various methods, notably through electric radiators or electric heat pumps. For example, electric heat pumps can provide heating in buildings and low-temperature heating in several industries (e.g., food and beverage), and they are attracting increasing policy attention from governments interested in implementing policies related to heat pumps. At present, the major global markets for electric heat pumps are China, Japan, and the United States.

2.2 From Present to 2030

APEC aims to double the share of renewable energy in its energy mix from 2010 to 2030. According to statistics from the APERC (APERC, 2019), the renewable energy power demand in the APEC was 328 Mtoe in 2010 and is expected to be 365 Mtoe in 2030 (APERC, 2019). These values account for 6.66% and 6.11% of the corresponding total final energy demand (TFED), respectively. To achieve the aforementioned goal of the APEC, collecting data on the current statuses of the renewable energy capacity, generation, and policies in each APEC economy and identifying the gap between the status quo and the goal are crucial steps.

According to the 7th Edition of APEC Energy Demand and Supply Outlook, to achieve the aforementioned goal, the share of renewable energy should reach 13.32% of the TFED, namely 796 Mtoe (APERC, 2019). The APEC region must increase its renewable power capacity by 851 GW to double the share of renewable electricity in its overall electricity mix. A total of 38 and 24 Mtoe of additional renewable energy must be generated from biofuels for the transport and industrial sectors, respectively (Figure 4).



*BAU: Business-as-Usual Scenario; HiRen: High Renewables Scenario

Source: APERC (2019)

Figure 4. Target and Gap for Reaching the Goal of Doubling the Share of Renewable Energy in the TFED

2.3 Future Trend

Major disastrous weather events are reported across the APEC region. In 2020, China experienced record-breaking rainstorms and flooding; wildfires raged across a record-breaking area in the United States; and Typhoon Goni caused strong winds, torrential rains, landslides and deaths in Luzon, the Philippines. Some contend that climate change contributed to these natural disasters, and the APEC economies around the Pacific Rim have been identified as being most at risk from such natural disasters. Climate change is therefore considered a greater threat to the region than even the COVID-19 pandemic; thus, the production of renewable energy grew at its fastest ever pace during the COVID-19 pandemic. Renewable energy accounted for 80% of new energy capacity additions worldwide in 2020, with APEC economies collectively accounting for 77% of additions to renewable energy capacity.

APEC region has made considerable efforts to stem the effects of climate change, such as attempting to double the share of renewable energy in the TFED, increasing energy efficiency, ensuring sustainable land use, and reducing emissions through the development of clean fossil fuels. The aforementioned efforts form the core of APEC's policies to limit warming to 2°C by 2100 and achieve net-zero emissions (NZE) /carbon neutrality Adopting NZE/ carbon neutrality pledges to indicate a decisive commitment to the environment has become a trend worldwide. According to the IEA, 44 countries have adopted NZE pledges to date (May 2021). Nine APEC economies, namely Canada, Chile, China, Japan, Korea, Malaysia, New Zealand, the United States, and Viet Nam, have adopted NZE pledges/carbon neutrality, and three APEC economies are planning to adopt NZE pledges, namely the Philippines, Chinese Taipei, and Thailand.

The NZE/carbon neutrality pledges adopted by the APEC economies vary considerably even though all of them are based on the Paris Agreement of the UN and stipulate renewable energy capacity, energy efficiency, and carbon offset as key measures, but with their NZEs/carbon neutrality not bound that all loose in compositions, different in mapping path. Each APEC economy has adopted renewable energy policies that are suitable to its energy requirements and goals; therefore, it is likely to unfold in the future that away from the energy transition intended. The future increase in the production of renewable energy might be insufficient for surpassing the production of fossil fuels because renewable energy accounts for a large share of the power sector's energy production but only a small fraction of the overall energy mix. In the World Energy Outlook, the IEA predicted that although the production of renewable energy would increase considerably in the future, fossil fuels would continue to be dominant in 2050.

The use of renewable energy in the power sector can be increased; however, it is impracticable to expand the use of renewable energy in the heating and cooling sector and transportation sector. Moreover, renewable energy cannot be consumed under full-load conditions because of intermittency. Nevertheless, the trend of electrification might enable the use of renewable energy electricity across various sectors. The World Economic Forum foresaw this possibility many years ago and stated that the three major trends of electrification, decentralization, and digitalization would transform the energy system. Electrification is critical for the achievement of long-term carbon reduction goals and will account for an increasing share of renewable energy use in the future.

EV, hydrogen, and fuel-cell technologies have begun to attract broad support from relevant stakeholders and are increasingly being deployed in the APEC region The former outperformed the transport sector from its fast expansion, and the later pipelined hard-to-low-carbon industrial sector from its flexibility and potential; however, EVs and hydrogen fuel are not yet affordable or inherently green. Without sufficient policy enforcement and financial support, synergy would not be achieved in sector-wide electrification. Moreover, without carbon monitoring and verification, synergy would not be achieved in the enhancement of renewable energy production and consumption.

3. Challenges

3.1 Power Sector

3.1.1 Political Challenges

3.1.1.1 Policy Consistency

Policy consistency is crucial because promoting renewable energy requires substantial capital investment and, therefore, access to credit. In general, unstable policy is worse than the absence of policy (Wüstenhagen and Bilharz, 2006). If government policies are uncertain and inconsistent, loans would be difficult and costly to obtain.

The mitigation of climate change is the main driving force behind the increasing demand for renewable energy. However, the results of this project indicate inconsistencies between the climate and renewable energy policies of some APEC economies. Such inconsistencies result in an unstable renewable energy supply, dramatic interruptions of the renewable electricity supply, and a sudden increase in the demand for fossil fuels. Furthermore, although some economies have set renewable energy targets, their renewable energy target schemes do not require state or local governments to develop suitable renewable energy development projects. This phenomenon results in an unclear and uncertain direction of renewable energy development and a lack of investor confidence.

Fossil fuel subsidies are often introduced as as a protectionist economic–political tool, and they inhibit the deployment and development of renewable energy. However, fossil fuel subsidies are not being phased out because the fossil fuel industry provides the largest employment and highest capital accumulation in some economies. The sudden removal of fossil fuel subsidies may harm not only household incomes but also domestic industries (Schmidt et al., 2017).

Furthermore, due to the increased maturity of renewable energy technology and the unanticipated high extent of rooftop solar panel installation, the costs of renewable energy infrastructure (especially photovoltaic [PV] modules) have decreased considerably. The unanticipated high extent of the installation of residential-scale renewable energy infrastructure has increased the load on subsidy systems (e.g., FiT) of governments. In some cases, governments have reduced tariffs and ended schemes abruptly, which has introduced uncertainties into the policy landscape and affected small solar panel businesses. The aforementioned arguments do not imply that policies should not be changed. The consensus is that policies must be sufficiently flexible to adapt to new technologies and changing markets. However, they must not be changed frequently and unpredictably because such changes interrupt and discourage investments in R&D.

3.1.1.2 Capability of Infrastructure

Electrical infrastructure plays a crucial role in the power grid system and domestic economic development. The demand for electricity is increasing because of rapid population growth. Because the power generated from renewable energy sources is unreliable and intermittent, the power grid requires adequate energy storage systems to stabilize power systems, handle partial voltage control issues, and increase the reliability of electricity utilization. Moreover, a large-scale introduction of distributed energy into the grid system might restrict the capability of the central dispatch center.

Because several APEC economies face the effects of natural events every year, if the capability of infrastructure and the stability of the power supply are insufficient, the electricity supply might be seriously affected in these economies. Therefore, the power grid systems of many economies must be reinforced for the introduction of electricity generated from renewable energy sources. The challenges caused by a lack of electrical infrastructure are discussed in the following section.

3.1.1.3 Grid Capacity

In addition to natural events, insufficient grid capacity might greatly affect the power grid. For example, China faces high rates of wind power and solar PV power interruptions. In China, the northwest (Xibei) and southwest (Xinan) regions, including Xinjiang, Gansu, Ningxia, and Qinghai, have high renewable energy potential. Wind and solar PV power interruptions in China occur because the transmission capacity is insufficient to process the power generated by renewable energy power plants. Therefore, most of the newly developed renewable energy power plants in China are not functional.

Interruptions in wind and solar PV power stem from two causes: the local demand for electricity is low, and the capacity of the power grid infrastructure is insufficient. Specifically, the economy of the western region of China is stagnant, and its electricity demand is lower than that of other densely populated regions in China. Although China has been developing renewable energy at a high rate, transferring the electricity generated from renewable energy sources to the grid is difficult in western China; therefore, wind and solar PV power interruptions frequently occur in this region.

The economic growth of China has recently slowed down. The demand for electricity by manufacturers has been below expectations, which has created an imbalance between supply and demand. Moreover, most areas with high renewable energy potential in China are sparsely populated and not easily accessible because of the harsh terrain. Therefore, constructing transmission lines in such areas is challenging. Economies might face difficulties in constructing long-distance electrical power transmission lines, which require high capital investment, high administrative costs, and a complicated assessment and review process. Therefore, the construction speed of power plants might not catch up with the high construction speed of power grids.

3.1.1.4 Lack of Regulations

To increase the utilization and development of renewable energy, economies should abide by a common set of international regulations. For example, the offshore wind power industry is rapidly growing worldwide, and many APEC economies have undertaken major wind power development projects. Developers might face several issues related to environmental impact assessment during the development of offshore wind power. For instance, developing piles for offshore wind turbines or installing submarine power cables for offshore wind farms might disrupt the habitats of marine mammals. Therefore, governments should implement relevant regulations to ensure the protection of workers and the marine environment during marine construction, and developers should follow standard operating procedures for constructing electrical infrastructure.

3.1.2 Economic Challenges

Investments in renewable energy are generally expensive, and the payoff is distant. The renewable energy sector relies more heavily on government policies than do other technology sectors (World Bank, 2014). The large capital cost of renewable energy installations is usually one of the major obstacles for renewable energy investments. The construction costs of renewable energy installations are higher than their operations and maintenance (O&M) costs. In addition, delays in a project increase the installation cost because of increases in labor costs and interest amounts, which increases the capital requirements of investors.

Small and medium enterprises (SMEs) play a crucial role in renewable energy development in the APEC region because they can utilize domestic resources to invest in renewable energy. However, SMEs are facing greater challenges in renewable energy development than large firms because of their lack of capital and a smaller capacity to stomach risk. The main challenges and risks of renewable energy investment that have been identified by the World Bank are explained in the following subsection:

1. Lack of Long-Term Financing

Although short-term debt and funds can be used to finance the operation of projects, the payoff for renewable energy projects is usually distant. This increases the risk of investment. Different renewable energy technologies have different payback periods. Obtaining long-term financing is difficult because of regulations or other restrictions on long-term bank lending, which also constrain investment opportunities in the short term.

2. Lack of Project Financing

Obtaining loans to finance renewable energy projects is more difficult than obtaining loans to finance conventional energy technologies because renewable energy projects are riskier and depend on technological development, government support, and the weather. Furthermore, activities that must be conducted before starting the development of renewable energy projects, such as site identification and resource assessment, usually require considerable time. Therefore, such projects require high capital investment.

3. Project Development

The project development phase for renewable energy development is time-consuming, expensive, and unpredictable. Moreover, the purchase of land for such development is usually a challenge. For instance, some renewable energy resources are located in areas where the installation of renewable energy equipment is difficult because of geological, security, and pollution concerns. Therefore, the process of land acquisition is long in renewable energy projects.

4. Small Scale of Projects

International commercial banks are generally uninterested in projects with a budget of less than US$10 million, and attracting investments for projects valued at up to US$20 million is difficult (Hamilton, 2010). For example, the financing barriers in the solar energy industry are the small scale of projects and difficulties in obtaining loans. For such projects, financing should be sought from domestic financial resources and banks because large-scale loans are difficult to obtain.

5. High Financial Cost

The cost of renewable energy investment is higher than that of conventional energy investment. Compared with the development of conventional energy, the development of renewable energy requires more capital and is subject to higher interest rates, especially in some developing economies. For example, geothermal energy projects usually incur high costs in relation to resource assessments and project development.

6. Regulatory Risk

Renewable energy development relies on government support and the establishment of a stable financial and legal framework. Therefore, fluctuations in laws, renewable energy policy, FiT rate, and taxation or legislative priorities make renewable energy projects riskier and more uncertain.

3.1.3 Social Challenges

3.1.3.1 Capacity Building

Advanced technologies, sufficient funds, and an adequate number of qualified workers are cornerstones for increasing the share of electricity generated from renewable energy sources in the electricity market. The promotion of renewable energy is difficult without a well-trained and skilled workforce from various sectors or sufficient public awareness. Therefore, establishing a capacity building system is important. The process for establishing a capacity building system includes developing and training a capable workforce, enhancing public awareness, and maintaining gender equality.

3.1.3.2 Market Reform

To promote the development of renewable energy, the entire market mechanism in an economy must be reformed. Economies must create a more suitable environment for accelerating the growth of renewable energy and accommodating a large volume of renewable energy. First, the price of electricity plays a crucial role in the competition between renewable energy sources and traditional fossil fuels. The distorted market price caused by high fossil fuel subsidies weakens the competitiveness of renewable power and reduces the funds available to provide financial support for renewable energy technologies.

Second, because of certain properties of renewable energy resources, such as high capital intensity requirements, limited predictability, and variability, the electricity market must be redesigned to cope with the challenges of handling a high volume of renewable energy. The market demand for multinational companies with renewable energy certification is another issue that governments must consider.

3.1.4 Technological Challenges

The efficiency and cost of renewable energy technology are the main factors influencing the deployment and development of renewable energy. Most APEC economies are implementing projects related to renewable energy technology development. However, the number, scale, and intensity of projects focused on improving the efficiency of individual renewable energy technologies are insufficient. Moreover, although some economies have set energy efficiency targets, most economies, particularly developing economies, still lack policies to achieve these targets. Furthermore, policies that support energy efficiency and renewable energy are insufficiently integrated.

Renewable energy is theoretically unlimited and thus sufficient for humankind; however, the availability of this energy across space and time is limited, which affects the cost of renewable energy technologies in different economies. The former brings up the high variable renewable energy (VRE) issue, technological solutions such as Industry 4.0 technologies, energy storage, weather forecasting advancement are served for the better grid and sectoral integration; the latter concerns cost reduction and energy efficiency, on this aspect, a rapid and substantial progress with 56%–85% cost reduction has achieved in renewable energy technologies over 2010–2020, and foreseeable future in 2030 reaching grid parity across the 21 APEC economies. The theoretical efficiency of solar energy is between 15% and 22%; that of wind energy is up to 59%; and that of hydropower and biomass energy is 90%, the highest among renewables.

Table 6. Technological solutions for APEC's goal of doubling the share of renewable energy in the TFED

Barriers	Technological solutions
VRE	● Using Industry 4.0 technologies to support smart grids, VPPs, new business models, and new paradigms of balancing supply with demand ● Conducting advanced weather forecasting by using sensors, IoT technology, big data, and AI

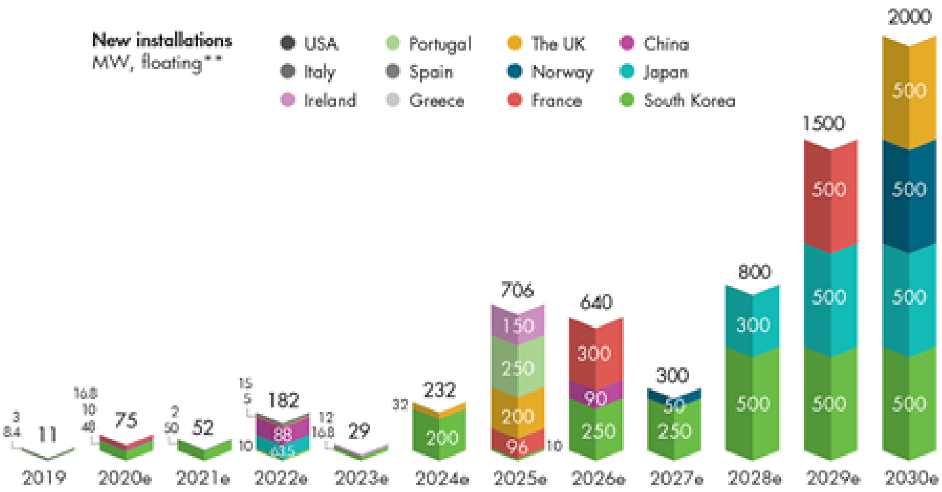
	● Cross-border interconnectors and technologies support synchronous operation ● Grid modernization and reinforcement ● Energy storage (e.g., in batteries and in the form of TES, hydrogen, biogas, and biomethane)
Cost reduction/energy efficiency	● Going offshore: offshore wind power (with a fixed or floating foundation), floating PVs, and ocean energy technologies (wave, tidal, OTEC, and salinity gradient energy) ● Wind energy: double-digit wind turbine capacity ● Solar energy: popularity of mono PERC modules and HJT cells ● Hydropower: eco-friendly hydropower ● Advancements in O&M techniques: predictive maintenance with drone technology ● Technologies to improve conversion efficiency and loss reduction ● Electrification and sector coupling: hydrogen, synfuels and EV/FCEV fleets ● EMS and microgrid: optimal operation through aggregated ESS and load management

VPPs: virtual power plants; IoT: Internet of Things; AI: artificial intelligence; TES: thermal energy storage; PERC: Passivated Emitter and Rear Contact; HJT: heterojunction technology; O&M: operation and maintenance; BEV: battery electric vehicle; FCEV: fuel-cell electric vehicle; EMS: energy management system; ESS: energy storage system

3.1.4.1 Cost Reduction and Energy Efficiency

Renewable energy resources are abundant in the APEC region, which has a large landmass and long coastline; however, these resources are insufficient for meeting the energy requirements of the 2.9 billion people that reside in APEC economies. Because of a lack of space on land in most APEC economies, organizations in these economies have begun to engage in major projects offshore related to floating offshore wind, floating PV, and ocean energy technologies for expanding the facilities for renewable energy. Some of these technologies are at an early stage of development and have a high potential for commercialization.

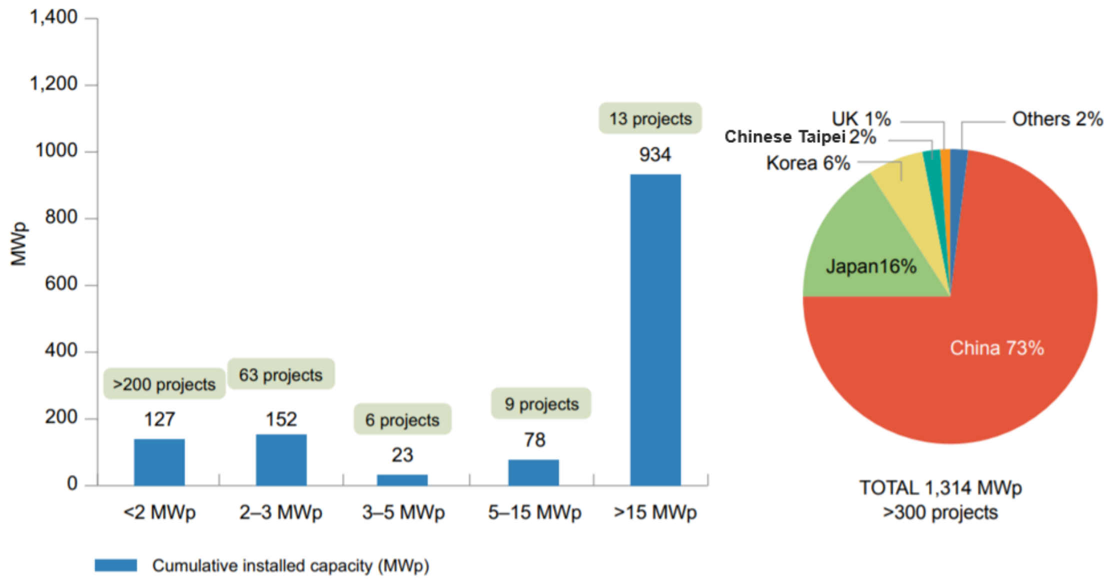
Offshore wind: The Global Wind Energy Council (GWEC) forecasts that the worldwide offshore wind energy capacity would reach 234 GW by 2030, with fixedbottom and movable-bottom wind energy technologies accounting for 97% and less than 3% (6.2 GW) of this capacity, respectively (GWEC, 2020). However, floating offshore wind technology is expected to reach full commercialization by 2030, which would result in levelized cost of electricity (LCOE) reduction and increased wind energy deployment in APEC economies. Other innovations, such as predictive maintenance using drone technology, can reduce offshore operation costs for wind energy, thereby opening new market opportunities for it to become more economically viable.



Source: GWEC (2020)

Figure 5. GWEC's Prediction Regarding the Capacity for Floating Offshore Wind Energy

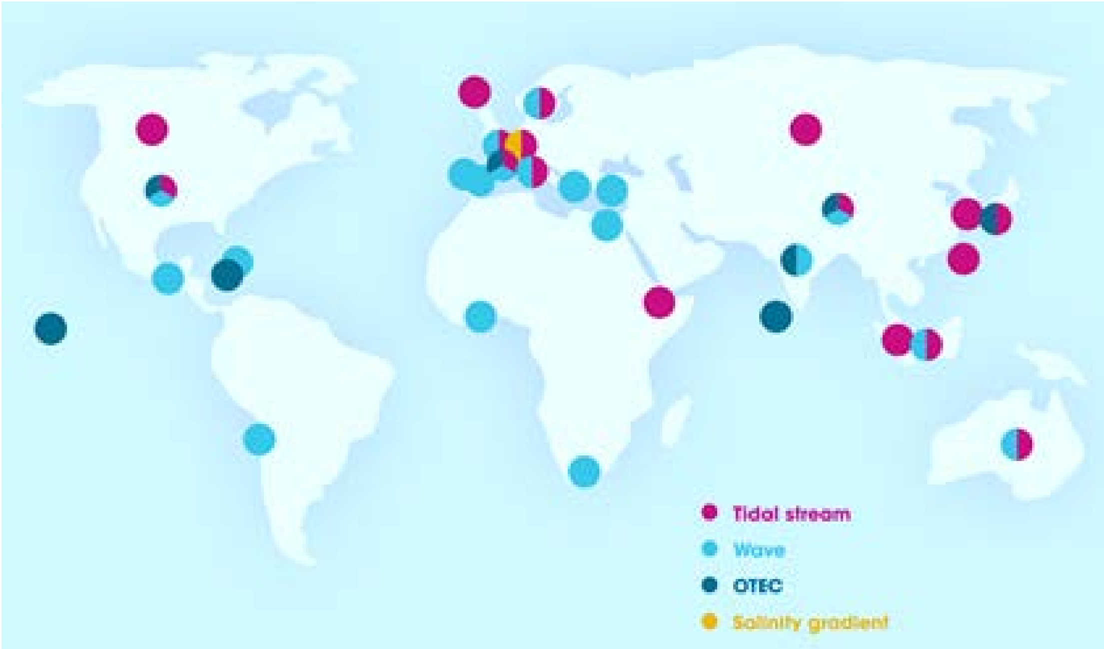
Floating PVs: Solar energy levels vary widely across the globe; however, almost all solar energy technologies are based on conventional land-based solar tracking or the use of stationary panels. A floating PV was first demonstrated in Japan in 2007. Since then, floating PVs have attracted considerable interest among economies with high population density or land scarcity. Floating PVs on different water bodies, such as reservoirs, irrigation ponds, and nearshore salt water bodies, are being increasingly implemented in the APEC region because the future development potential of land-based PVs is low due to limited land availability. Floating PVs have a higher energy yield (by approximately 10% to 20%) than do land-based PVs because of the cooling effects of water and the decreased presence of dust on floating PVs, which eventually balances the initial higher capital expenditures for floating PVs (by approximately 10% to 15% higher) over the system's lifetime.



Source: World Bank Group, ESMAP and SERIS (2019)

Figure 6. Status of Floating PVs as of 2018, Including the Power Plant Size and Market Share for these PVs

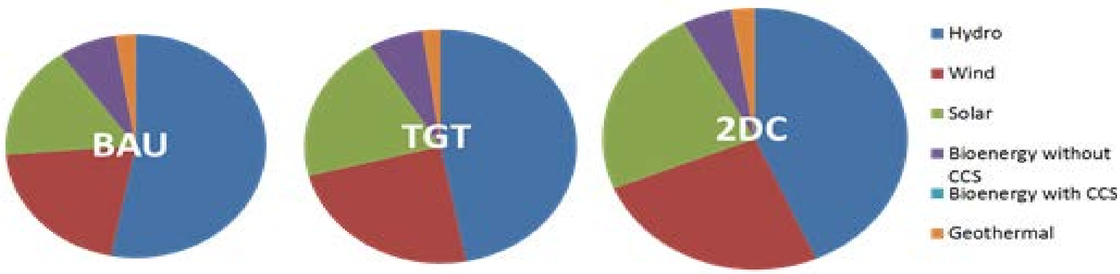
Ocean energy technologies: Ocean energy has many benefits, such as the achievements of water desalination with power generation, synergies for wider VRE deployment, and stable and predictable energy capacities. Therefore, ocean energy technologies are prescribed for island economies with remote coastal areas, including the 21 APEC economies and economies with a high VRE share or potential (which comprise more than three-fourths of the APEC economies). The main drawback of ocean energy is its relatively high LCOE, which has been reduced considerably but is expected to remain high beyond 2030. Therefore, the use of ocean energy should be promoted and its risks should be reduced holistically, through international cooperation, and with advances in R&D.



Source: IRENA (2021)

Figure 7. Geographic Distribution of Ocean Energy Projects in the APEC Region

According to the 7th Edition of APEC Energy Demand and Supply Outlook, the difference in renewable energy production between the BAU Scenario and the Target Scenario is 979 GW and that between the BAU Scenario and the 2-Degrees Celsius (2DC) Scenario is 1,760 GW (APERC, 2019). To ensure that the doubling goal is met, the wind and solar energy production would need to be increased to cover 83% of the gaps to the doubling goal and the production of hydro energy would need to be increased to cover for 15% of these gaps.



Source: APERC (2019)

Figure 8. APEC's Renewable Energy Power Mix in Three Scenarios by 2030

According to the IRENA, the share of wind energy in the energy mix is expected to reach 21% and 35% globally by 2030 and 2050, respectively. Moreover, the share of solar energy in the energy mix is expected to reach 13% and 23% globally by 2030 and 2050, respectively. Among individual APEC economies, China is expected to have the highest wind energy share in the energy mix (29% and 51% by 2030 and 2050, respectively), followed by the United States (28% and 46% by 2030 and 2050, respectively). Economies with a large land mass and long coastline are suitable locations for the establishment of wind farms. Among individual APEC economies, Japan is expected to have the highest solar energy share in the energy mix (26%) by 2030, followed by the United States (18%), and China (15%); however, by 2050, Australia is expected to have the highest solar energy share in the energy mix (40%), followed by the United States (33%), Japan (30%), and China (23%). The coast of southeastern China is rich in solar energy; however, the dense population in this area is expected to prevent China from achieving a higher share of solar energy in the energy mix. The main barrier to the development of solar energy projects is the limited availability of land. The high LCOE and isolated grids associated with solar energy use are barriers that can be overcome through technological solutions.

The LCOE values of different types of renewable energy are mainly influenced by geographical location. Geographical location influence the resource-related, economic, and institutional advantages and disadvantages that affect the LCOE. The resource can be interpreted as a form of exploitable technology or technologies. Some exploitable technologies are more crucial than are others, these technologies influence the scale and efficiency of a renewable energy project. The trends in wind power development include increasing the heights of wind turbines and increasing the project scale. By comparison, the trends in hydropower development include decreasing the size and increasing the efficiency, which is capable of using limited height difference and avoiding large reservoirs that are the main limitative factors of existing technologies, and develops eco-friendly small to medium hydropower.

3.2 Transportation Sector

3.2.1 Political Challenges

Political and regulatory challenges related to the use of renewable energy in the transportation sector are described in the following subsection. First, certain economies do not set targets and formulate supporting policies to promote the use of renewable energy. Most regulatory barriers originate from the absence of a unified and well-defined regulation for renewable energy use. Second, the lack of regulatory mechanisms for the inspection of project quality results in incompatible renewable energy equipment and quality inconsistencies. Moreover, the absence of relevant land resource regulations leads to inefficient land use. For example, although unutilized land is still available in certain parts of Southeast Asia for growing biomass feedstock, no land resource regulation or policy exists to guide planning for growing such feedstock. Third, the fossil fuel subsidy affects the adoption of renewable energy in the transportation sector. APEC has announced its goal to reduce the fossil fuel subsidy because this policy is inefficient and to set up a peer review mechanism for the fossil fuel subsidy; however, the fossil fuel subsidy still accounts for an unneglectable share of government spending in certain economies. The aforementioned subsidy undermines the competitiveness of biofuels with respect to price, and the massive amount of this subsidy could have otherwise been used to subsidize renewable energy deployment and development.

3.2.2 Economic Challenges

Economic issues are crucial challenges impeding the development of renewable energy use in the transportation sector because investors face difficulties in obtaining financial support up front in the investigation or exploration stage, which requires a large amount of capital and entails a high investment risk.

3.2.2.1 Market Building

Economic considerations are the main obstacles hindering the adoption of renewable energy in the market. Because of market size and cost limitations, unsubsidized renewable energy stands at a disadvantage vis-à-vis fossil fuels. The obstacles in the early demonstration stage of the new-generation renewable technology include undeveloped supply chains, high production costs, and market size uncertainty. Consequently, reliance on the government for R&D subsidies and market building is high. For example, the promotion of high-level biofuel blends must be accompanied by car market transformation because high-level biofuel blends can only be used in certain types of vehicles, such as flexible-fuel vehicles (FFVs). Producing and manufacturing vehicles that run on biofuels is also vital for the long-term development of the biofuel market. However, FFVs have a small market size and low price competitiveness. Therefore, car manufacturers are reluctant to manufacture or import FFVs because of economic and technical concerns in the absence of integrated policy support from government. Moreover, encouraging consumers to purchase FFVs powered by high-level biofuel blends is a crucial step in promoting the use of renewable energy.

3.2.2.2 Price of Commodities

Commodity prices in the biofuel market depend on market conditions, including global oil prices, goods prices (e.g., sugar and palm oil), and exchange rates. Global oil price slips have implications for the development of the biodiesel market, and price decreases in biodiesel and ethanol gasoline have resulted in their reduced production because biofuels are more expensive than is crude oil. Thus, macroeconomic trends can directly affect local biofuel prices directly without changing local market conditions first.

3.2.3 Social Challenges

3.2.3.1 Market Reform

Subsidies for fossil fuel have distorted the energy market and have resulted in renewable energy being unable to compete with fossil fuel energy through market mechanisms in various sectors, including the power, transportation, and heating sectors. Moreover, the environmental and social cost of fossil fuels should be reflected in the market; otherwise, the competitive advantages of renewable energy would decrease.

3.2.3.2 Capacity Building

A lack of expertise and public awareness are obstacles when promoting the use of renewable energy. Lack of public awareness could cause public opposition to the use of biofuel or ethanol and hinder the implementation of renewable energy policies. Insufficient expertise in an economy makes renewable energy targets difficult to reach and greatly hinders the implementation of projects.

3.2.4 Technological Challenges

Technological challenges for promoting the use of biofuels in the transportation sector originate from the fact that the technologically permissible maximum ratio of bioethanol to gasoline is 10%–15%. High-level biofuel blends are unsuitable for old engines and might cause operational problems. A few international reports have indicated that the effect of mid-level bioethanol blends (less than 10%) on vehicle wear is determined to a large extent by the technologies involved and the domain where such blends are applied. For example, biofuels may cause oxidative degradation, crystallization, and increased nitrogen oxide discharge, which result in air pollution and high particulate matter concentrations. Other technology-related challenges originate from difficulties in storage and quality control. Biofuels are produced from vegetable oil, and different raw materials may have different long-term storage requirements and low-temperature attributes. For example, biodiesels produced using water cress oil from Europe are of high quality, whereas those produced using palm oil from Southeast Asia might easily freeze in the winter, which causes problems in fuel supply. Biodiesels produced using recycled cooking oil can oxidize when their thermal properties change. Korea, Thailand, Malaysia, and Indonesia have adopted the European EN 14214 standard for biodiesel to solve this problem (Soon, 2015).

3.3 Heating Sector

3.3.1 Political Challenges

Policy and regulatory barriers to promoting renewable use in heating include poor policy design, discontinuity of policies, perverse or split incentives, unfavorable or unsupportive policies, unclear agreements (e.g., power purchase agreements, feed-in tariffs, and self-consumption), and a lack of transparency. Uncertainty and inconsistency regarding targets and policies (including retroactive changes) substantially hamper renewable energy expansion; this is because unclear support schemes or procedures reduce the confidence of investors and developers (IRENA, 2012). The IEA (2018) indicated that targets are essential for providing a sense of direction, and the achievement of such targets is dependent on the implementation of effective policy measures. Target setting for renewable heating and cooling is poor in the APEC region. Even though some APEC economies such as China and Thailand have set clear goals for using renewables for heating and cooling, the development of a tracking system, long-term targets, and clear policies is necessary.

In addition, permitting procedures related to land use (solar heating and cooling) and drilling rights (geothermal heat) can be inefficient and may require streamlining. Tapping into renewable heat sources may involve the use of public land and resources. The benefits of renewable heat are not sufficiently acknowledged, but related problems have often been overcome through the implementation of building labels or holistic city emission reduction targets. Therefore, streamlining application and permitting procedures at a high level can considerably increase public awareness of these projects and reduce the risk associated with lengthy bureaucratic procedures. Numerous barriers to expanding renewable heat are also present in the building sector. For example, certain renewable heating and cooling options may not be suitable for certain buildings (e.g., apartments). The building owner usually is required to invest in a renewable heating system, but the occupier/tenant receives the benefit of operating cost reductions. Therefore, to overcome building-related barriers, implementing measures such as building codes for renewable heating and cooling is encouraged.

3.3.2 Economic Challenges

Economic barriers may include insufficient funding, high upfront investment cost, and risks perceived by potential customers and investors. Although short-term debt and funding can be used to finance the operation of projects, renewable energy projects usually have longer payback periods relative to other types of projects. This barrier increases the risk of investment; different renewable energy technologies have different payback periods. The aforementioned challenges are exacerbated in renewable projects; for such projects, investment costs account for a greater share of total expenses over the lifetime of a project than investments in conventional generation technologies. Although financing is a major obstacle because of the large upfront investment cost of renewable heating projects, this obstacle can be reduced mainly by reducing risk, stabilizing demand at an early stage, and identifying appropriate complementary financing sources. The implementation of existing energy infrastructure and other infrastructure projects can also reduce upfront investment costs.

In addition, prospective investors perceive many of these strategies as being riskier because they are unconventional. For example, solar cooling is a relatively new and underutilized technology. The perception of risks relating to solar cooling and lack of awareness regarding its economic benefits are considerable barriers to its development. Therefore, demonstration projects play a crucial role in increasing investor and customer confidence and facilitating the widespread implementation of specific strategies for renewable heating and cooling. Starting with a low capacity allows for the demonstration of a scheme’s viability, the reduction of risk, and the securing of new customers prior to an expansion.

3.3.3 Social Challenges

Capacity building relates to a lack of sufficient information and knowledge concerning renewables and their performance and a lack of skilled personnel and training programs. Developing economies often struggle with capacity and training limitations, which lead to a lack of a qualified and skilled workforce and an insufficient local value chain. Capacity barriers (e.g., inability to properly conduct operation and maintenance activities) can cause renewable systems to fail after their implementation. Lack of awareness of and confidence in renewable heating and cooling technologies can apply to households and heating system specifiers and lenders. The perception of renewable systems as being inferior to other systems in terms of user comfort is exacerbated by previous failures of poorly designed or installed systems.

The competitiveness of renewable heat options is determined by their capital and operating costs relative to fossil fuel alternatives. In some cases, renewable heat options can easily compete with fossil fuels and may even be the preferred option. For example, in the food and beverage or paper and pulp industries, biomass residues are often available at zero cost, which compensates for the generally higher capital costs of biomass boilers. However, even when a renewable heat option remains competitive over its lifetime following its installation, consumers can still be deterred by problems such as much higher capital costs and lack of economies of scale, which result in higher system costs.

3.3.4 Technological Challenges

Technology-based constraints to promoting renewable energy use in heating vary widely among economies, sectors, and specific renewable heat applications; however, they are centered on cost, availability, inflexibility, and the need for heat demand mapping and resource assessment. Some constraints are of a technical nature, whereas others pertain to a lack of understanding regarding specific heat requirements at a policy level and a lack of renewable heat options at the consumer end. For example, industrial heat requirements (specifically the temperature, pressure, and quantity of heat required by some industrial users) can be challenging for some renewable technologies to meet. The use of biomass may also be limited by stringent emission requirements.

A lack of awareness of and confidence in renewable heating technologies is another barrier that can affect households and heating system specifiers and lenders.

The perception of renewable systems as being inferior to other systems in terms of user comfort is exacerbated by previous failures of poorly designed or installed systems. Furthermore, heat demand is dispersed over many individual sites, and the infrastructure for transporting thermal energy is often lacking or uneconomical to construct, particularly for long distances. When modern direct renewables (e.g., bioheat, solar thermal energy, and geothermal heat) are used, their implementation usually involves a mix of technologies that are specific to local resource potential, unique heat demand/supply, and available infrastructure (e.g., district heating and cooling networks).

4. Recommendations for Policies to Achieve APEC's Aspirational Goal of Doubling the Share of Renewable Energy by 2030

Although hurdles remain to achieving the goal of doubling the share of renewable energy in the energy mix by 2030 and the identified barriers must be overcome, the goal can still be achieved if more effort and actions are taken by APEC economies. Governments play a key role in leading the transition, and they must provide credible step-by-step plans to achieve the doubling goal and build confidence among industry members, investors, and citizens. This chapter discusses the overall recommendations that are suitable for all sectors, and we provide recommendations for each sector and for power, heating, and transportation. Several methods and measures that have been adopted on a global and regional scale for achieving the goal are analyzed and further discussed in the following.

4.1 Implementing More Ambitious and Dedicated Renewable Energy Targets

Almost all the APEC members have already set renewable energy targets and implemented supporting mechanisms or policies to promote the development of renewable energy; however, the aforementioned targets, mechanisms, and policies are neither long term nor sector specific. In some cases, such targets are general targets relating to renewable energy as a share of total power generation, whereas others are technology specific. Some members have no targets, whereas others have multiple targets for multiple sectors. However, if APEC members intend to achieve the goal of doubling their respective renewable energy use as a share of their energy mix by 2030, they must adopt higher and more ambitious renewable energy targets.

Moreover, given the global transition to NZE/carbon neutrality and the development of emerging technologies, APEC economies should regularly review their renewable energy targets and look beyond 2030. Notably, we must remember that we are approaching a crucial and decisive moment for international efforts to tackle the climate crisis.

4.2 Long-Term Support for Renewable Energy Development

Renewable energy policies should be sufficiently flexible to adapt to technological changes, climate change, and market shifts. They should be tailored to the different phases of renewable energy development to avoid any sudden cuts in subsidies and uncertainty for investors. A particularly urgent problem is the lack of strategies that support the planning phase of renewable energy projects. Such strategies would assist in the planning of renewable energy projects by increasing the provisions of early-stage risk mitigation mechanisms, risk capital, and risk mitigation facilities. Therefore, relevant and flexible support mechanisms and regulations must be developed according to global trends, the state of the climate crisis, and technological changes. The utilization of risk mitigation instruments must also be enhanced to accelerate the uptake of renewable energy in developing areas. Risk mitigation instruments are recommended to be prioritized and set up by using climate finance and traditional development finance channels.

4.3 Enhancing Supporting Policies and Policy Enforcement

Renewable energy targets must be backed by specific policies tailored to the local conditions of each economy. Policies and regulatory frameworks enabled by the government ensure predictable revenue for renewable energy development projects, which creates a stable and predictable investment environment. Measures based on the conditions of each economy, such as leveling the playing field by pricing externalities and reducing fossil fuel subsidies, should be adopted. However, complementary measures, such as developing a job transfer counseling plan for laborers and a plan that provides low-income households access to affordable electricity, are required to avoid the negative social impacts of renewable energy development.

The global discussion on mechanisms or policies such as NZE/carbon neutrality pledges and carbon pricing is underway, and APEC economies should consider implementing such mechanisms and policies. Although those mechanisms or policies have yet to be fully implemented worldwide, they are expected to increase investment in the renewable energy sector and help accelerate the use of renewable energy.

4.4 Increasing Positive Cross-Cutting Effects of Renewable Energy on Sustainable Development

Access to cost-effective, reliable, and environmentally sustainable modern energy services has positive effects on public health, individual livelihoods, poverty alleviation, and job creation. Standalone and minigrid systems are currently the most economical options for expanding access to off-grid renewable energy systems in many rural areas. For instance, solar-powered irrigation technology is an off-grid solution that can increase yield and incomes and reduce vulnerability to erratic rainfall and the hardships of farmers, especially women farmers. The aforementioned systems provide societies with access to modern and sustainable energy and climate-resilient infrastructure, which protects and restores rural ecosystems.

4.5 Enhancing the Integration of Renewables Used in Different Sectors

Relative to the power sector, the current share of renewables used in transportation and heating systems remains low; specifically, the uptake of modern renewables for heating and cooling has increased at a substantially slower pace. Notably, more renewable energy targets are set and achieved in the power sector than in the transportation and heating sectors. Renewable energy investments are also more concentrated in the power sector.

Policies that incorporate renewable energy use in the power, heating and cooling, and transportation sectors must be integrated into the larger energy and economic system and consumers' daily lives. Such policies include infrastructure enhancements (e.g., transmission and distribution networks, charging stations for EVs, and district heating and cooling infrastructure) and improvements to system flexibility. For example, the integration of renewable energy into road-based transportation can be advanced primarily through vehicle electrification, and heat pumps provide untapped potential for enabling the use of renewables in the heating and cooling sector. In addition to energy storage, the enabling technologies of heat pumps and EVs support the integration of renewables and help increase the flexibility of power systems. With the further integration of the power, heating and cooling, and transportation sectors, comprehensive decision-making and policy design are crucial for leveraging synergies and accelerating the shift toward a more sustainable energy system.

4.6 Increasing Economic Incentives

Financial incentives must be implemented to attract more businesses to invest in renewable energy facilities and enhance the development of renewable energy. Basic financial incentives for driving start-ups toward renewable energy investment include government-guaranteed loans or government-issued bonds, favorable loan terms or a project loan from financial service providers, or seed funding by governments to provide the initial capital required for entering the market. Issuing bonds to raise funds, which is a direct source of funding, can decrease capital costs for businesses. Moreover, government-guaranteed loans make it easier for businesses to obtain capital from the financial sector. On the other hand, to relieve businesses of financial burdens and increase the incentives to invest, governments can decrease tariffs, provide favorable investment loans or financial incentives, or offer tax credits to investors in renewable energy projects. For example, governments can offer goods or business tax credits to attract business investment, decrease or waive tariffs for imported renewable energy equipment, or decrease or waive land rent for businesses investing in renewable energy. By offering favorable loan terms, such as low interest rates and long repayment periods, or lowering the threshold for loan application, governments can make it easier for businesses to receive funding.

4.7 Urgency of Market Reform

Subsidies for fossil fuels are still a persistent challenge for renewable energy development, and they have impeded its development in all sectors. Governments must balance the subsidies for fossil fuel and renewable energy and create a market mechanism that is fair and robust. To reflect the environmental and social cost of fossil fuel use, governments can implement carbon pricing policies (e.g., emission trading systems and carbon taxes or other stronger measures) to increase the competitiveness of renewable energy.

4.8 Increasing Regional Engagement and Cooperation

Regional engagement and cooperation can stimulate cross-border trade, reduce costs, attract investments, and boost financial capacity, thereby accelerating the global deployment of renewable energy. The experiences of various APEC members or regions in setting renewable energy targets and implementing policies (to ensure that these targets are met) provide crucial opportunities for learning and sharing best practices.

Economies that are still in the early stage of developing or deploying specific renewable energy options can learn from the experiences of economies that have already acquired such technologies or are conducting relevant assessments. Governments can also benefit from each other's experiences in addressing some of the barriers that impede renewable energy deployment. The potential benefits of regional engagement and overseas cooperation are as follows.

1. Aggregation of overseas investment helps renewable energy projects reach the required scale to attract large-scale private investment.

2. A regional market can help decrease the cost of renewable energy products, facilitate the trading of renewable energy, and overcome limitations caused by the climatic conditions in each economy.

3. Combining the human and technical resources of different states or regions creates hubs of knowledge, excellence, and innovation.

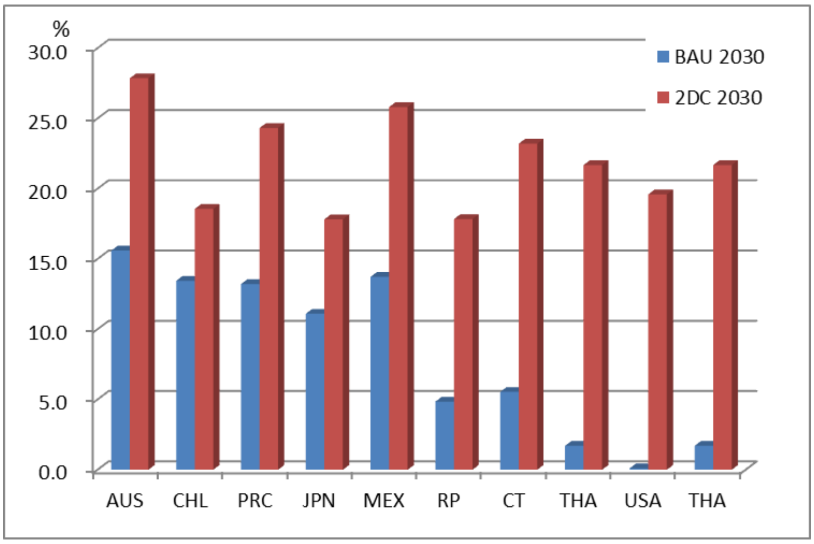
4.9 Recommendations for Power Sector

The direction of policies and strategies for accelerating the transformation of existing energy systems are discussed as follows.

4.9.1 VRE solutions

A high VRE share and electricity curtailment are not problems at the regional or economy levels in the APEC region. Even in the BAU Scenario, the VRE shares of individual APEC economies are expected to be less than 15% by 2030. The IEA split them into phase 1 and phase 2 of the IEA's system integration. The VRE has no substantive influence on phase 1. In phase 2, the VRE becomes noticeable in the energy mix but is manageable without significant grid reconfiguration. However, under the 2DC scenario, favorable policy efforts would increase VRE deployment in 6–10 APEC economies over next 10 years to meet the criteria of phase 3 or phase 4 system integration. The IEA outlines recommendations on best practices. Among the recommendations of the IEA, the most effective recommendation is to determine solutions in a collaborative manner. For example, interconnected grids with various loadings that cover a large landmass stretching across borders can be constructed to achieve superior supply–demand balance. Examples of such grids include the North American power transmission grid, Association of South East Asian Nations (ASEAN)

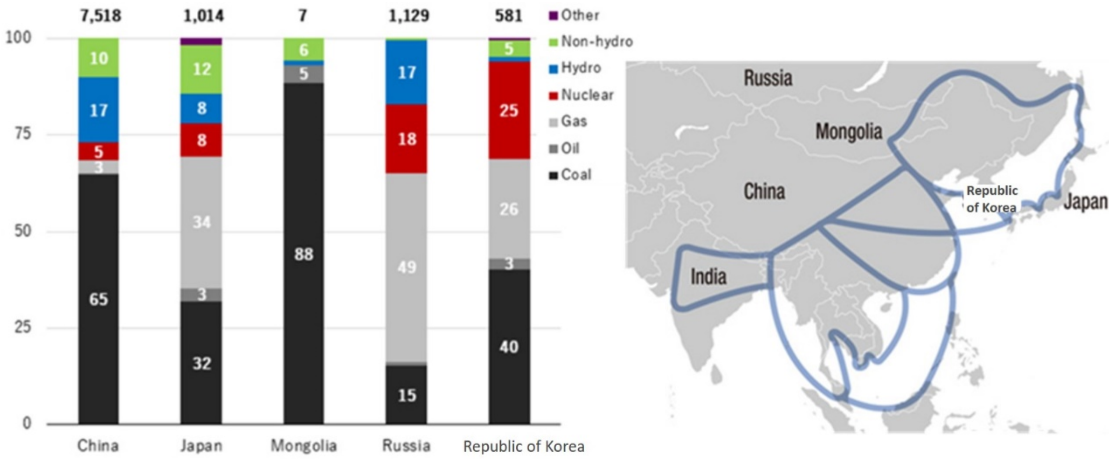
Power Grid, and Asia Super Grid (ASG).



Source: APERC (2019)

Figure 9. VRE Share by 2030 in Selected APEC Economies in Business-as-Usual (BAU) and 2DC Scenarios

The aim of developing the ASG was to interconnect the grids of five Northeast Asian economies. The ASG project was initiated in 2011 but executed in a worse manner than were the North American power transmission grid and ASEAN Power Grid projects. The ASG aims to achieve the cross-border exchange of rich natural renewable energy resources and the transmission of electricity in a reliable, efficient, and economical manner; however, this project is not cost-effective. First, the ASG is highly costly because it covers a large landmass and offshore area with a few existing cross-border transmission lines. Second, it has not increased renewable energy access and VRE integration over the project area. As of 2019, the cumulative VRE capacity of the five Northeast Asian economies covered by the ASG was 500 GW, which accounted for less than 8% of the cumulative electricity capacity in these economies in the same year.



Source: Renewable Energy Institute

Figure 10. Energy Mix in the five Northeast Asian Economies Covered by the ASG

In contrast to the ASG, the ASEAN grid is expected to provide area-wide electricity accessibility by 2030 and integrate the VRE with a large conventional hydropower capacity. The North American power grid connects multiple wide-area synchronous grids, some of which, such as the Eastern Interconnection and Western Interconnection, have achieved close interactive dispatching and system flexibility. Other grids, such as the Texas Interconnection, Quebec Interconnection, and Mexican grid, still have some room for improvement. The Mexico grid is poorly resilient, does not comprise interconnections, and urgently requires an interconnection to achieve its rich solar and wind potential.

Although the VRE share currently has no effect on individual economies, some subregional areas have achieved a considerably high VRE share, and their system operators (such as the National Electricity Market from South Australia, CAISO and ERCOT from the United States, Kyushu Power and Hokkaido Power from Japan, and State Grid and Gansu Power from China) have reported frequent load shifting and negative prices caused by daily and seasonal VRE intermittency. These phenomena are a part of phase 3 of the IEA's system integration. With the predicted sharp VRE growth by 2030, a high number of TSOs (state grids or RTOs) and DSOs from the areas harnessing the highest quantities of renewable power, such as Australia, Mexico, China, Chinese Taipei, Thailand, the United States, Chile, Japan, and the Philippines, are expected to encounter difficulties associated with variability. Therefore, to achieve system flexibility, the IEA suggests additional investments in various projects, such as bilateral or multilateral interconnections and system-wide transformation by using some of the technological solutions presented in Table 7.

Table 7. Recommendations and best practices for VRE integration

	Technological solutions
Transmission	● Grid reinforcement: FACTS devices, HTLS conductors, and grid code design ● Grid modernization: SCADA real-time monitoring and smart grid deployment ● Modernization of the dispatch center and enhancement of the system-wide granularity
Distribution	● Peak load and network congestion management: IoT, AI, blockchain, and big data ● Optimization of local production and consumption: smart meters, minigrids, supergrids, peer-to-peer electricity trading, VPPs, behind-the-meter battery, and aggregators
Energy market	● Enhancement of monitoring and management capabilities (e.g., AGC and real-time transactions) ● SCADA evaluation and EMS design ● Digitalization and bidirectional energy and data flow ● System costs of the VRE are considered in the LCOE
Power plants	● VRE fleets: storage (electrical or thermal) ● Other power plants: Rapidly reacting conventional system
Sectoral coupling	● DER prosumers: new business model ● Demand shaping ● New paradigm: EV fleets, PtX (H_2 and synfuels), and heat pumps

FACTS: flexible AC transmission system; HTLS: high temperature, low sag; SCADA: Supervisory Control and Data Acquisition; DER: distributed energy network; LCOE: levelized cost of electricity
Source: IEA, System integration of renewables, 2018

4.10 Recommendations for Transportation Sector

Achieving fundamental shifts to renewable-based transportation systems requires not only technology development but also behavioral change and greater policy support.

The integration of policies that address the three renewable transport dimensions—the availability of energy carriers and renewable fuels, the deployment of vehicles capable of running on renewable energy fuels, and the enhancement of infrastructure—is crucial for achieving the aforementioned shift. Appropriate standards and certification mechanisms should be established for renewable fuels to enhance public confidence in renewable energy. Developing a certification mechanism for renewable energy is an effective method for monitoring biofuel development. Such a mechanism makes it more attractive for biofuel producers to invest in the biofuel market and ensures a reliable standard of biofuel quality. Land resources and ownership should be evaluated and inventoried to enable potential corporate investors who are interested in a specific area to acquire the relevant information relating to land ownership and government contacts. When challenges related to land acquisition emerge, governments can coordinate the construction of renewable energy facilities to ensure that investment projects proceed smoothly.

Specifically, to promote biofuels, which are primarily used in road transportation, supportive policy measures include blending mandates, fiscal incentives, and public financing should be implemented. In addition, emerging technologies and less mature renewable fuels (e.g., advanced biofuels) are expected to play an increasingly essential role in certain transportation subsectors (e.g., long-haul transport, aviation, and shipping) where fewer alternatives are available. Therefore, financial incentives and mechanisms for encouraging research and development and pilot projects for promoting crucial technologies and renewable fuels in the aforementioned transportation subsectors should be implemented.

4.11 Recommendations for Heating Sector

A key obstacle to promoting renewable heating is that policy attention and support for the uptake of renewables in the heating and cooling sector remain limited despite the large share of renewables in final energy consumption. Renewables play a key role in the low carbon development of the heating sector; however, this can only be achieved by establishing dedicated targets and supporting policies that are required at higher levels and reflect local conditions (e.g., building stock, industrial heat demand, resource potentials) and context-specific barriers. Mandates and obligations (e.g., those relating to solar water heaters, technology-neutral renewable heat obligations, and renewable heat FiTs) can increase the likelihood of deployment. For example, mandatory building codes that set energy performance requirements can play a key role in the uptake of renewable heating and cooling, particularly for new construction and retrofits.

To ease the burden on developers for investing in renewable energy use in the heating sector, governments can provide subsidies, extensive financing options, loan guarantees, or guaranteed income in the initial stage of projects for reducing risk and attracting investors. Fiscal and financial incentives, particularly heat generation–based incentives, reduce the capital and upfront costs of renewable-based heat technologies, and they also provide long-term support that can help such technologies to compete on level terms with conventional energy technologies.

5. Milestones and Roadmap

The roadmap and milestones analysis in this report was designed on the basis of the current development of renewable energy in the APEC region and the global initiatives and future trends for renewable energy technologies. The milestones presented in this roadmap are regional in scope, but each economy is strongly encouraged to design its own pathways and strategies in accordance with specific and local circumstances.

On the basis of an overview of the renewable energy policies, measures, and plans adopted by APEC members, the roadmap and milestones for 2030 were developed, and they are presented in Table 8. The timeframe of this roadmap is from 2020 to 2030, and it is divided into three phases, namely the short-term (2020–2023), midterm (2024–2026), and long-term (2027–2030) phases.

Table 8. Roadmap and milestones for doubling renewable energy share by 2030

	Short-Term (2020-2023)	Mid-Term (2024-2026)	Long-Term (2027-2030).
Target	Set a long-term target	Regularly review renewable energy targets	Achieve long-term target
Policy	Develop relevant support mechanisms and regulations	Establish target-specific supporting projects and develop specific regulations	Integrate policies
Mechanism	Remove subsidies for fossil fuel	Provide favorable investment loans or financial incentives	Develop risk mitigation instruments
Cooperation	Experience sharing	Technology transfer involving strategic/cooperative	Adopt advanced and renewable energy technology

	Short-Term (2020-2023)	Mid-Term (2024-2026)	Long-Term (2027-2030).
		alliance	and policies

Setting long-term and sector-specific targets is the first priority for developing renewable energy. Therefore, it serves as the starting point and short-term milestone for achieving the target of doubling renewable energy use. The development of relevant support mechanisms and regulations is the short-term milestone for policy implementation. Establishing a legal regulatory framework is also necessary to attract investors, which will promote the development of renewable energy. Moreover, the phasing out of all fossil fuel subsidies is the first step for developing a market for renewable energy development, and this can ensure that the appropriate price signals are given. Policies should limit or disincentivize the use of certain fuels and technologies in the short term.

After a target is set, renewable energy development goals must also be reviewed periodically; then, midterm milestones can be established. In the midterm, more renewable energy projects can be implemented, which will attract more investors. Therefore, decisions must be made in the midterm regarding the optimal market creation strategies for renewable energy development, and favorable investment loans or financial incentives must be provided in the midterm.

The relevant polices will be developed in the long term; therefore, policies that incorporate renewables used in the power, heating and cooling, and transportation sectors should be integrated in the long term. Concurrently, the utilization of risk mitigation instruments is also a long-term milestone for accelerating the uptake of renewable energy in developing areas.

6. Conclusion

The year 2020 was a key milestone for climate change policy commitments and renewable energy development both globally and in the APEC region. Despite the COVID-19 crisis, renewable energy deployment has increased, and policy support for renewables has generally remained robust throughout 2020. Furthermore, the application of emerging and innovative technologies (e.g., hydrogen, carbon capture and storage, battery storage, and advanced biofuels) has attracted increasing attention.

The findings of this report indicate that the APEC region continues to play a leading role in the ongoing push for renewable energy at the global scale and the region has demonstrated considerable progress and strong potential for future development. However, when APEC economies engage in renewable energy development, they face numerous challenges, such as policy inconsistencies, inadequate power infrastructure, the large capital costs of renewable energy, insufficiently extensive projects for improving the efficiency of renewable technologies, a lack of qualified and skilled workers, insufficient public awareness, and various challenges related to power systems and market design. Specifically, barriers to developing renewable use in multiple sectors (power, transportation, and heating) were also identified.

This report proposes several policy recommendations for overcoming the aforementioned challenges. More ambitious and dedicated targets, stronger supporting policies, and legal and regulatory frameworks should be implemented to guide investment in the renewable energy sector. Policy attention is also required for nonpower sectors. Amending renewable energy laws and strengthening renewable energy policy commitments are methods for improving policy consistency. To solve the problem of insufficient power infrastructure, micro-grids and smart grids can be used for renewable energy development in rural regions. Such grids can enable a more efficient transformation of grid functions. Moreover, refundable and nonrefundable investment tax credits, grants, and venture capital equity can be provided to investors to overcome the problem of the large capital costs of renewable energy development.

Increasing innovations related to each renewable energy technology and expanding technology cooperation would accelerate renewable energy development in the APEC region and solve the problem of insufficient projects for improving the efficiency of renewable energy technologies. Furthermore, developing training programs based on existing programs for specific sectors and conveying the advantages of renewable energy may solve problems such as a lack of skilled workers and insufficient public awareness. Market reform, such as managing the risk transfer mechanism for capital intensity and enhancing short-term markets for achieving limited market unpredictability and variability, and RECs would be beneficial for increasing the volume of renewable energy in the energy market.

In general, almost every APEC member has set renewable energy targets and implemented supporting policies and mechanisms. Numerous economies have also established energy mix projections and roadmaps, but they are not necessarily enforced. On the positive side, some have even exceeded their targets. The APEC region has entered a new era of renewable energy. On the basis of the findings of this report, we conclude that APEC economies should propose more ambitious and renewable energy development plans to achieve the goal of doubling the share of renewable energy in their energy mix.

Moreover, they should review their renewable energy development goals periodically. The aforementioned strategies are strongly expected to stimulate the diversification of renewable energy sources, increase energy autonomy, and demonstrate the determination of the APEC region to promote renewable energy development. Thus, by using these strategies, the APEC region is more likely to achieve the goal of doubling the share of renewable energy in its energy mix by 2030, thereby enabling it to establish a sustainable future.

Because of time and resource constraints, this project could not examine all the data and details that reflect the conditions of every APEC economy. However, doubling the share of renewable energy in the energy mix by 2030 must not be the end point. Therefore, further research on overall development, case studies, as well as the establishment of a follow-up mechanism for monitoring progress are required.

Reference

Ahmed, S.F., Khalid, M., Rashmi, W., Chan, A., Shahbaz, K., 2017. Recent progress in solar thermal energy storage using nanomaterials. Renewable and Sustainable Energy Reviews 67(Supplement C), 450-460.

APERC (Asia Pacific Energy Research Centre), 2019. APEC Energy demand and supply outlook 7th edition-Volume I.

Canada's Premiers, 2015. Premiers-Canadian energy strategy.

Chan, D., Cameron, M., Yoon, Y., 2017. Key success factors for global application of micro energy grid model. Sustainable Cities and Society 28(Complete), 209-224.

Chellaswamy, C., Ramesh, R., 2017. Future renewable energy option for recharging full electric vehicles. Renewable and Sustainable Energy Reviews 76(Supplement C), 824-838.

Choi, J., Do, D.-P.N., 2016. Process and features of smart grid, micro grid and super grid in South Korea. IFAC-PapersOnLine 49(27), 218-223.

Coady, D., Parry, I., Sears, L., & Shang, B., 2017. How large are global fossil fuel subsidies?. *World development*, *91*, 11-27.

Cobierno de Mexico, 2021. Programa para el Desarrollo del Sistema Eléctrico Nacional 2021 a 2035. Accessible at <https://www.gob.mx/cenace/documentos/programa-para-el-desarrollo-del-sistema-electrico-nacional-276178>

Cohen, M.G., 2017. Climate change and gender in rich countries-Work, public policy and action.

Department of Alternative Energy Development and Efficiency, 2015. Alternative Energy Development Plan 2015, DEDE, Ministry of Energy of Thailand, Bangkok.

Department of Energy Philippine, 2021. Philippine Energy Plan 2020-2040. Accessible at <https://www.doe.gov.ph/pep/philippine-energy-plan-2020-2040>

Ellabban, O., Abu-Rub, H., 2016. Smart grid customers' acceptance and engagement: An overview. Renewable and Sustainable Energy Reviews 65(Supplement C), 1285-1298.

EWG, 2010. Peer review on energy efficiency in Chinese Taipei.

EWG, 2017. APEC Energy statistics prepared by energy statistics and training office.

Gao, Z., Zhang, Y., Song, N., Li, X., 2017. Biomass-derived renewable carbon materials for electrochemical energy storage. Materials Research Letters 5(2), 69-88.

Gonzalez-Salazar, M. A., Venturini, M., Poganietz, W. R., Finkenrath, M., Kirsten, T., Acevedo, H., & Spina, P. R, 2016. Development of a technology roadmap for bioenergy exploitation including biofuels, waste-to-energy and power generation & CHP. Applied Energy, 180, 338-352.

GWEC (Global Wind Energy Council), 2020. Global Offshore Wind Report 2020.

Hamilton, K., 2010. Scaling up renewable energy in developing countries: Finance and investment perspectives. Chatham House.

Hirose, K.H., Shimakage, T., Reilly, J.T., Irie, H., 2013. The Sendai Microgrid Operational Experience in the Aftermath of the Tohoku Earthquake: A Case Study. New Energy and Industrial Technology Development Organization.

HK RE Net, Accessible at <https://re.emsd.gov.hk/english/gen/overview/over_re.html>

IATA (International Air Transport Association), 2018. Annual Review 2018 .

IEA (International Energy Agency). IEA policy database. Accessed on 10 Oct. 2021. Accessible at < https://www.iea.org/policies>

IEA (International Energy Agency), 2016a. Electricity market design and RE deployment.

IEA (International Energy Agency), 2016b. Repowering market.

IEA (International Energy Agency), 2018. Renewable Heat Policies.

IEA (International Energy Agency), 2020. Renewables 2020

IEA (International Energy Agency), 2021. Net Zero by 2050 A Roadmap for the Global Energy Sector

IEEE(Institute of Electrical and Electronics Engineers), 2004. IEEE guide for electric power distribution reliability indices.

IISD (International Institute for Sustinable Development), 2014. The impact of fossil-fuel subsidies on renewable electricity generation.

IRENA (International Renewable Energy Agency), 2017. Adapting market design to high share of variable renewable energy.

IRENA (International Renewable Energy Agency), 2016. REmap: Roadmap for a Renewable Energy Future, 2016 Edition.

IRENA (International Renewable Energy Agency), 2017a. Renewable Energy Outlook.

IRENA (International Renewable Energy Agency), 2017b. Renewable Energy in District Heating and Cooling: A Sector Roadmap for REmap.

ISES (International Solar Energy Society), 2017. Guideline to introducing quality renewable energy technician training programs.

KAPSARC (The King Abdullah Petroleum Studies and Research Center), 2016. Designing electricity markets to integrete renewable energy.

Kim, S.T., Lim, B.I., Park, W.K., Kim, M.K., Son, S.-Y., 2016. An analysis on the effectiveness of a smart grid test-bed project: The Korean case. Renewable and Sustainable Energy Reviews 59(Supplement C), 868-875.

KMPG international, 2015, 2015. Taxes and incentives for renewable energy.

Labour Party New Zealand, 2020. 100% renewable electricity generation by 2030. Accessible at < https://www.labour.org.nz/release-renewable-electricity-generation-2030 >

Lefebvre, D., Tezel, F.H., 2017. A review of energy storage technologies with a focus on adsorption thermal energy storage processes for heating applications. Renewable and Sustainable Energy Reviews 67(Supplement C), 116-125.

Li, Y., Yang, J., Song, J., 2017a. Design structure model and renewable energy technology for rechargeable battery towards greener and more sustainable electric vehicle. Renewable and Sustainable Energy Reviews 74(Supplement C), 19-25.

Li, Y., Yang, J., Song, J., 2017b. Nano energy system model and nanoscale effect of graphene battery in renewable energy electric vehicle. Renewable and Sustainable Energy Reviews 69(Supplement C), 652-663.

Malaysia's Ministry of Energy and Natural Resources, 2021. Press Release ASEAN Energy Meeting. Accessible at< https://www.ketsa.gov.my/ms-my/pustakamedia/KenyataanMedia/Press%20Release%20ASEAN%20Energy%20Meeting%2021%20June%202021.pdf>

Ministry of Economic Affairs (MOEA) of Chinese Taipei, 2012. Master plan of smart grids in Chinese Taipei.

Ministry of Economic Affairs (MOEA) of Chinese Taipei, 2017. Smart grid master plan.

Ministry of Energy Brunei Darussalam, 2020. 1. Brunei Darussalam National Change Climate Change policy. Accessible at < https://me.gov.bn/>

Ministry of Energy and Mineral Resource Indonesia, 2021. Bigger Share Given to Renewables in 2021-2030 Electricity Procurement Plan, Accessible at < https://www.esdm.go.id/en/berita-unit/directorate-general-of-electricity/ruptl-2021-2030-diterbitkan-porsi-ebt-diperbesar>

Nizami, A.S., Shahzad, K., Rehan, M., Ouda, O.K.M., Khan, M.Z., Ismail, I.M.I., Almeelbi, T., Basahi, J.M., Demirbas, A., 2017. Developing waste biorefinery in Makkah: A way forward to convert urban waste into renewable energy. Applied Energy 186(Part 2), 189-196.

REN21, 2017a. Advancing the global renewable energy transition.

REN21, 2021. Global Status Report 2021.

Schmidt, T.S., Matsuo, T., Michaelowa, A., 2017. Renewable energy policy as an enabler of fossil fuel subsidy reform? Applying a socio-technical perspective to the cases of South Africa and Tunisia. Global Environmental Change 45(Supplement C), 99-110.

Standards Council of Canada, 2014. The canadian smart grid standards roadmap: A strategic planning document.

Stevens, C., 2009. Green jobs and women workers - Employment, equity, equality.

The White House, 2021. Fact Sheet on 29 Mar. 2021 and 22 Apr. 2021. Accessible at <https://www.whitehouse.gov/briefing-room>

Tuballa, M.L., Abundo, M.L., 2016. A review of the development of Smart Grid technologies. Renewable and Sustainable Energy Reviews 59(Supplement C), 710-725.

UNU, 2016. World risk report.

Uyar, T.S., Beşikci, D., 2017. Integration of hydrogen energy systems into renewable energy systems for better design of 100% renewable energy communities. International Journal of Hydrogen Energy 42(4), 2453-2456.

Viet Nam Energy Partnership Group, 2020. Politburo's Resolution 55-NQ/TW on the Orientation of the Viet Nam's National Energy Development Strategy to 2030 and outlook to 2045. Accessible at < https://vepg.vn/legal_doc/cpv-resolution-on-the-orientation-of-the-viet-nams-national-energy-development-strategy-to-2030-and-outlook-to-2045/>

Wilson Rickerson, Tina Halfpenny & Sander Cohan, 2009. The emergence of renewable heating and cooling policy in the United States, Policy and Society, 27:4, 365-377, DOI: 10.1016/j.polsoc.2009.01.004

World Bank, 2012. Financing renewable energy options for developing financing instruments using public funds.

World Bank, 2014. Building competitive industries.

World Bank, 2017. World development indicator.

World Bank Group, ESMAP and SERIS, 2019. Where Sun Meets Water: Floating Solar Market Report. Washington, DC: World Bank.

World Economic Forum, 2021. Fostering Effective Energy Transition 2021 edition

Wüstenhagen, R., Bilharz, M., 2006. Green energy market development in Germany: effective public policy and emerging customer demand. Energy Policy 34(13), 1681-1696.

Xu, Z., Xue, Y., Wong, K.P., 2014. Recent Advancements on Smart Grids in China. Electric Power Components and Systems 42(3-4), 251-261.

Yan, J., Zhai, Y., Wijayatunga, P., Mohamed, A.M., Campana, P.E., 2017. Renewable energy integration with mini/micro-grids. Applied Energy 201(Supplement C), 241-244.

Zhang, Y., Chen, W., Gao, W., 2017. A survey on the development status and challenges of smart grids in main driver countries. Renewable and Sustainable Energy Reviews 79(Supplement C), 137-147.

Zhao, Y., Noori, M., Tatari, O., 2017. Boosting the adoption and the reliability of renewable energy sources: Mitigating the large-scale wind power intermittency through vehicle to grid technology. Energy 120(Supplement C), 608-618.

Zhu, X., Han, X.-q., Qin, W.-p., Wang, P., 2015. Past, today and future development of micro-grids in China. Renewable and Sustainable Energy Reviews 42(Supplement C), 1453-14

日本經濟新聞，2021。“30 年度に再生エネ 36～38%　電源構成案、政府が最終調整” Accessed on 16 July 2021. Accessible at <https://www.nikkei.com/article/DGXZQOUA16C200W1A710C2000000/>

新华通讯，2020。 “习近平在气候雄心峰会上的讲话” Accessed on 12 Dec. 2020. Accessible at <http://www.xinhuanet.com/politics/leaders/2020-12/12/c_1126853600.htm>

“제 5 차 신・재생에너지기술개발 및 이용·보급기본계획”. Accessible at <https://www.knrec.or.kr/download/file_download.aspx?key=1682&gubun=notice&div=FILE_NM2>