Asia-Pacific
Economic Cooperation

Filling the Gap to Double Renewable Energy in the APEC Region

(EWG 11 /2016A)

APEC Energy Working Group/
Expert Group on New and Renewable Energy Technologies

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APEC Project No.: EWG11 2016A

Produced by:
Industrial Technology Research Institute, Chinese Taipei
195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Chinese Taipei 31040
Tel:(886)87720089*813
Email: sjli@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#217-RE-01.27 ISBN: 978-981-11-6325-8

Acknowledgement

We wish to express our deepest gratitude to the APEC Secretariat and Bureau of Energy, Chinese Taipei for the proper guidance and financial support in implementing this APEC project. We are particularly grateful to Mr Jin-Sheng Su, the APEC Project Overseer and Chung-Hsien Chen, the Chair of Expert Group on New and Renewable Energy Technologies (EGNRET) for their proper supervision.

We also appreciate Asia Pacific Energy Research Center (APERC) for their assistance on quantitative research, and Clean Energy Solutions Center (CESC) for offering valuable advices.

The great appreciation send to all workshop participants and members of APEC Energy Working Group (EWG) and EGNRET, and experts from International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) to contribute their valuable comments and information. We would have been unable to complete this report and project without all of assistance.

Authors

Shin-Je Li, Cheng-Nan Chu, Sih-Ting Jhou, Kung-Wen Chiang, En-Chin Su, Nianwey Wang, An-Ling Lee

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1. Introduction

1.1 Project Background and Objectives

The effects of climate change on humans and the global environment are inevitable. Renewable energy can minimize carbon emissions and has a lower impact on the environment compared to non-renewable energy. The role of renewable energy in meeting our future energy needs is becoming increasingly important.

The United Nations Environment Programme (UNEP, 2007) defined renewable energy sources as energy sources that are sustainable, unlimited, and not subject to depletion. Renewable energy sources include solar, wind, geothermal, tidal, and wave power. These renewable energy sources are considered as zero fuel costs energy. Moreover, the cost of renewable energy sources has reduced steadily over the past few decades. Wind and solar energy have become competitive with energy from conventional sources in many regions Therefore, with the growth of commercialization and increase in the demand of renewable energy sources, the avenues of mass production of renewable energy have improved. Therefore, it is estimated that the price of renewable energy installations will decrease.

In 2012, the APEC Leaders' Declaration announced that energy security in the APEC region should be strengthened to develop cleaner energy sources for sustainable development. Moreover, in the APEC Leaders' Meeting in 2014 and the APEC Energy Ministers' Meeting in 2015, the goals to reduce aggregate energy intensity by 45% by 2035 and double the share of renewable energy in the overall energy mix by 2030 to achieve sustainable and resilient energy development within the Asia-Pacific were set. To attain these goals, the APEC economies should enhance cooperation and promote innovations in renewable energy technologies to reduce costs and improve the competitiveness and sustainability of renewable energy in the energy market.

1.1.1 Project Objectives

Aligned with the goal of doubling the share of renewable energy in the energy mix of the APEC region, this project aims to assess the gaps in the development of renewable energy technologies and provide a strategic roadmap to address these gaps.

Therefore, the main objective of this project is to develop a strategic roadmap that outlines a set of policy recommendations to accelerate renewable energy development in the APEC region. This paper introduces the current renewable energy status, evaluates the development challenges, and identifies the gaps in and key factors of renewable energy development. Furthermore, this project identifies different dimensions and strategies to foster renewable energy development in the APEC region.

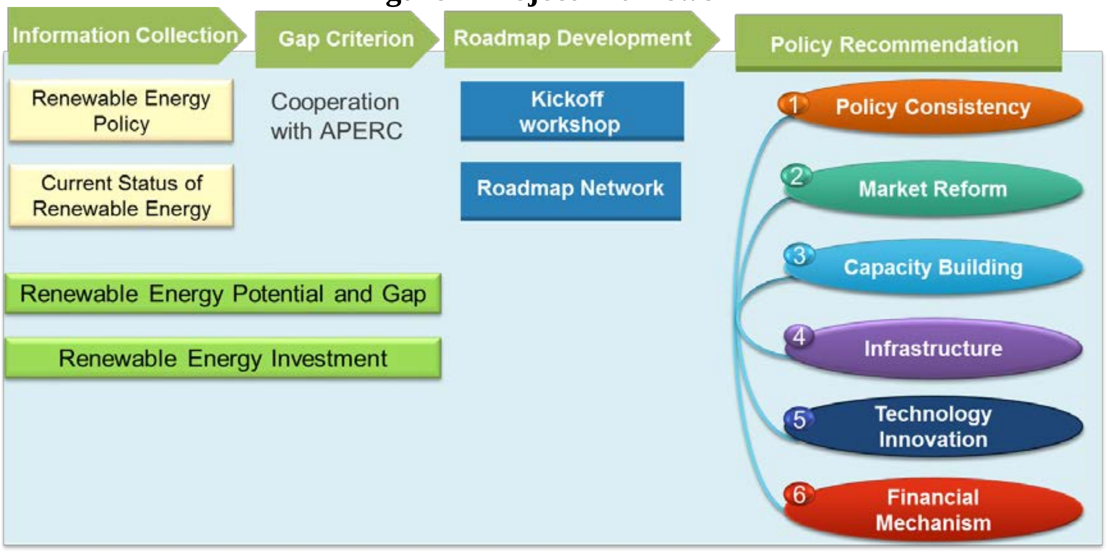
1.1.2 Process and Framework of the Project

First, it is necessary to define what renewable energy means in the context of the roadmap developed in this project. The definition of renewable energy in this project is consistent with the EGEDA definition, which does not include traditional biomass in the renewable energy source category; however, large-hydro projects are included. Second, the development of a roadmap for renewable energy development is divided into two phases: (1) roadmap baseline analysis and (2) comprehensive roadmap development. This project is in phase 1, which focuses on collecting information on renewable energy, evaluating the gaps between the current scenario and the goal to double the share renewable energy in the energy mix, and outlining the strategic roadmap. Moreover, the strategic roadmap for renewable energy development developed in this project is limited to the electricity sector.

The framework of this project includes roadmap planning, conducting workshops, establishing a roadmap network, and promoting cooperation.

Figure 1 shows the framework of this project. Additionally, six strategies for establishing the energy market namely, policy consistency, market reform, capacity building, infrastructure, technology innovation, and financial mechanism were developed in this project. The policy recommendations are aimed to ensure market access, policy and incentive development, building capacity, and economics and finance engagement. Therefore, these recommendations as a can serve as a reference for all the APEC economies to foster their renewable energy deployment and achieve the goal of doubling the share of renewable energy in the overall energy mix.

Figure 1 Project Framework



1.1.3 Cooperation and Network

A cooperative network to promote discussions about the renewable energy roadmap among the APEC economies was developed in this project. This enhances contributions towards attaining the goal of doubling the share of renewable energy. This project was conducted in collaboration with the Asia Pacific Energy Research Center (APERC), which assisted in quantitative analysis including the detailed assessment of renewable energy development potential and the gap criterion to attain the goal of doubling renewable energy share in the APEC region. The Expert Group on Energy Data and Analysis (EGEDA) provided renewable energy data of the APEC region to promote renewable energy development in this region.

The Clean Energy Solutions Center (CESC) also assisted in this project by providing research recommendations for developing policies and identifying priorities for the development of the roadmap to achieve the goal of doubling the share of renewables in the APEC energy mix by 2030. Furthermore, the International Renewable Energy Agency (IRENA) shared their experiences in developing a renewable energy roadmap. Additionally, a renewable energy expert network for discussions and planning of renewable energy strategies by the APEC economies is being built to strengthen the renewable energy roadmap for the APEC region.

1.2 Background

The Industrial Revolution, which began in the late 1700s, lasted for over hundred years. It is considered as the major momentum of economic growth. Owing to industrialization, energy-related sectors burn fossil fuels for generating electricity. This results in significant greenhouse gas emissions and climate change.

According to the World Bank (2017), the combined gross domestic product (GDP) of the APEC region in 2016 was about USD 43.7 trillion. Additionally, these data show that the total population of the APEC region in 2016 was about 2.8 billion, which denotes an increase of 19.6 million compared to the population in 2015. This global population growth will lead to an increase in the demand for electricity and energy.

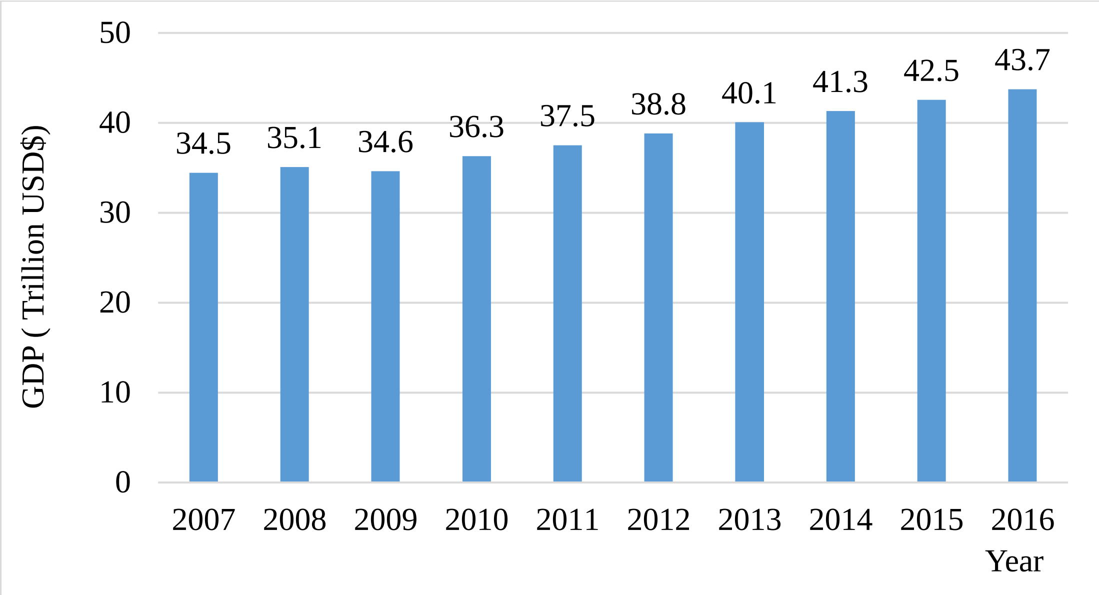
The APEC has 21 member economies (**Figure 2**). The APEC economies are distributed over a wide geographical area and have an assortment of natural conditions and energy resources. Although many of the member economies are developed countries, several others are less developed.

Figure 2 Map Showing the 21 Member Economies of the APEC

Source: APEC, 2017

According to the World Bank (2017), the combined gross domestic product (GDP) of the APEC region in 2016 was about USD 43.7 trillion (**Figure 3**) (World Bank, 2017). Additionally, the World Bank data (2017) also show that the total population of the APEC region was about 2.8 billion in 2016, which is an increase of 19.6 million compared to the total population in 2015 (World Bank, 2017). This growth of population will lead to an increase in the demand for electricity and energy

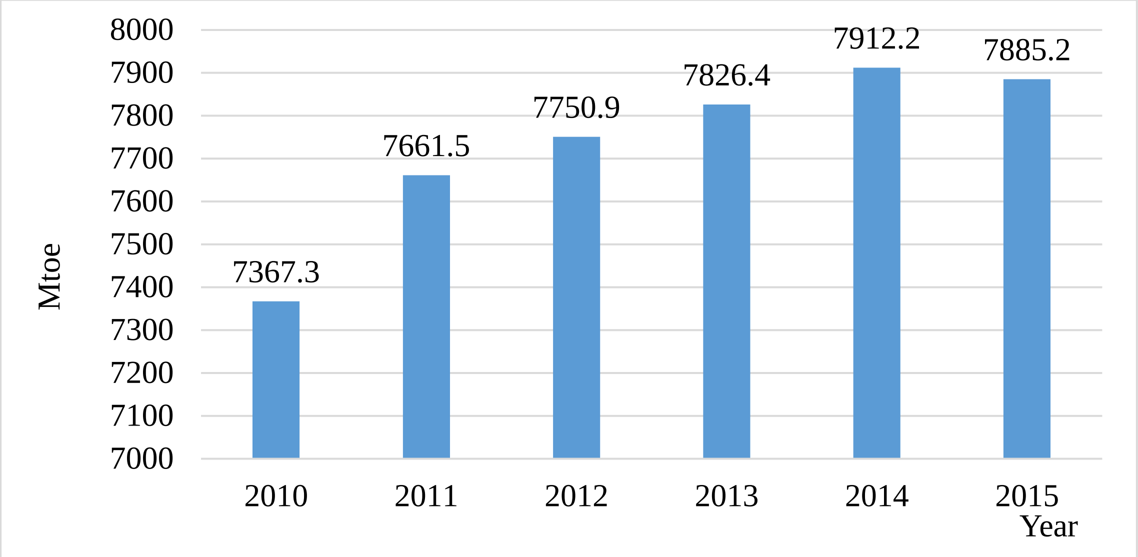
Figure 3 Total GDP of the APEC region



Source: World Bank, 2017

Furthermore, regarding energy supply and demand, the APEC Energy Working Group (2017) calculated the total primary energy supply (TPES) and total final energy consumption (TFEC) of each APEC member economy since early years (EWG, 2017). In 2015, the combined TPES of the APEC region amounted to about 7,885.2 Mtoe (Figure 4) and the combined TFEC amounted to about 4,728.2 Mtoe.

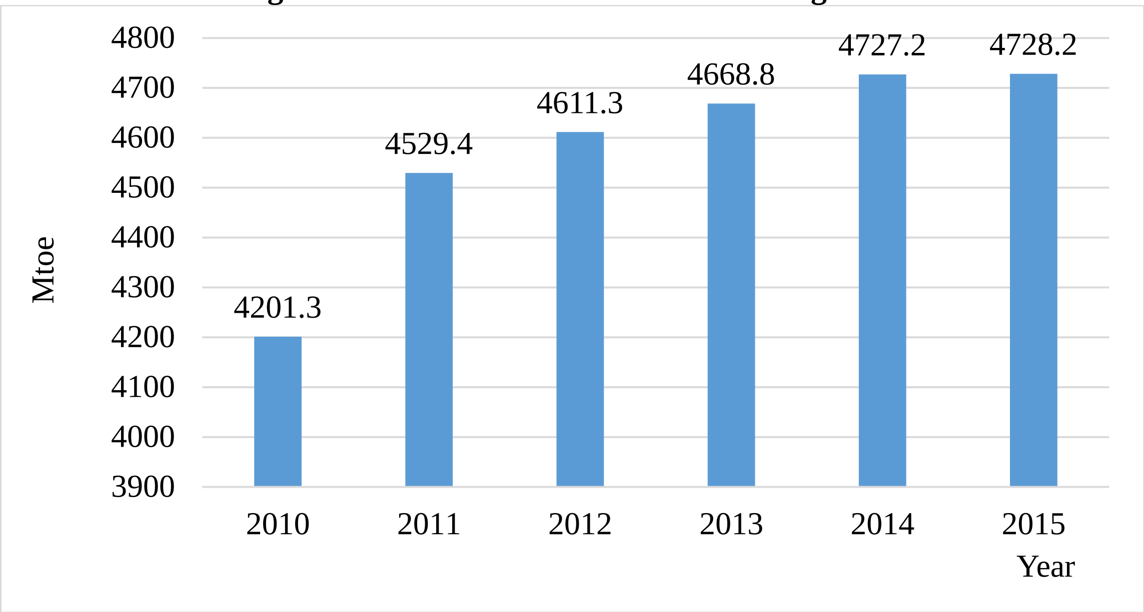
Figure 4 Combined TPES of the APEC region



*TPES: Total Primary Energy Supply

Source: EWG, 2017

Figure 5 Combined TFEC of the APEC region



*TFEC: Total Final Energy Consumption

Source: EWG, 2017

The findings of this project showed that many of the APEC economies have proposed renewable energy development goals to expand the utilization of renewable energy sources. However, several member economies still rely highly on fossil fuels to meet energy demand. Therefore, this paper discusses various ways to double the share of renewables in the APEC energy mix by 2030, such as incentives, laws and regulations, and measures for developing resources.

2. Renewable Energy Development and Trend

2.1 Renewable Energy Development in the APEC Region

Aligned with the United Nations SE4ALL initiative and to meet the demand for electricity and energy, the goal to double the total renewable energy generation, from 2010 levels, in the APEC region was set. According to the findings of this project, the total installed renewable energy capacity and power generation of the APEC region in 2010 were about 612.3 GW and 2,092.4 TWh, respectively. According to latest statistics, the total installed renewable energy capacity and power generation of the APEC region as of 2015 are about 998.2 GW and 2,996.8 TWh, respectively.

Most newly added renewable energy capacity has been installed in developing countries, particularly in China. Hence, China has the largest installed renewable energy capacity of 502.8 GW in 2015, which accounts for 53.8% of the total installed renewable energy capacity. It is followed by the United States and Japan with installed capacities of 182.5 GW (19.5%) and 62.6 GW (6.7%), respectively. The APEC region added 94.1 GW of installed renewable energy capacity in 2015. The results of this project revealed that the total renewable energy power generation of the APEC region in 2015 was about 2,608.6 TWh. China has the largest power generation of 1,390.6 TWh, which accounts for 53.3% of the total power generation of the APEC region. It is followed by the United States and Russia with power generation of 544.2 TWh (20.9%) and 168.6 TWh (6.5%), respectively. Furthermore, the APEC region increased renewable energy power generation by 103.8 TWh in 2015.

Regarding the development of solar energy, the results of this project showed that the total installed solar energy capacity was about 107.2 GW in 2015. China has an installed capacity of 42.2 GW, which accounts for 39.3% of the total installed capacity. It is followed by Japan and the United States with installed capacities of 33.3 GW (31.1%) and 13.7 GW (12.7%), respectively. Regarding wind power development, the total installed wind power capacity was about 228.7 GW in 2015. China's installed capacity was 130.8 GW, which accounted for 57.2% of the total installed capacity. It is followed by the United States and Canada with installed capacities of 72.6 GW (31.7%) and 11.5 GW (5.0%), respectively. Regarding biomass energy, the total installed biomass energy capacity was about 41.8 GW in 2015. The United States has an installed capacity of 14.09 TWh, which accounted for 33.7% of the total installed capacity. It is followed by China and Japan with installed capacities of 10.32 TWh (24.7%) and 4.08 TWh (9.7%), respectively.

Regarding hydropower development, the results of this project showed that in the APEC region, the share of hydropower capacity in the total renewable energy installed capacity decreased from 88.9% in 2006 to 60.1% in 2015 due to the rapid development of solar energy and wind power. Furthermore, the share of hydropower generation in the total renewable energy power generation decreased from 87.4% in 2006 to 71.8% in 2015. Regarding geothermal energy development, the total installed geothermal energy capacity in the APEC region was 8.5 GW in 2015. The United States had an installed capacity of 2.5 GW, which accounted for 30.0% of the total installed capacity. It is followed by the Philippines and Indonesia with installed capacities of 1.9 GW (22.4%) and 1.4 GW (17.0%), respectively. With respect to ocean power, the total installed ocean energy capacity in the APEC region was 0.258 GW in 2015. The Republic of Korea has an installed capacity of 0.255 GW, which accounted for 98.8% of the total installed capacity. It is followed by China and Russia with installed capacities of 0.004 GW (1.5%) and 0.002 GW (0.8%), respectively.

Therefore, the results of this project revealed that many of the economies are making every effort to attain the goal of doubling the share of power generation from renewable energy in the APEC region. Additionally, many of the economies have proposed various renewable energy policies in response to the renewable energy development goal.

Table 1 Overview of the Renewable Energy Policies and Measures Adopted in the APEC Region.

Economy	Target renewable energy generation share	Renewable energy policies	Development of renewable energy technology	Renewable energy storage	Renewable hybrid system	Renewable electricity transmission/ distribution
Australia	23.5% in 2020	Y	Y			
Brunei Darussalam	10% in 2035	Y				
Canada	*	Y	Y			
Chile	60% in 2035; 70% in 2050	Y	Y	Y		Y
China	27% by 2020	Y	Y	Y	Y	Y
Hong Kong, China	-					
Indonesia	25% in 2025	Y	Y		Y	
Japan	22-24% in 2030	Y	Y	Y		
Republic of Korea	13.4% in 2035	Y	Y	Y		Y
Malaysia	11% in 2020	Y	Y			
Mexico	35% in 2024; 50% in 2050	Y			Y	Y
New Zealand	90% in 2025	Y				
Papua New Guinea	100% in 2050	Y	Y			
Peru	60% by 2025	Y				
The Philippines	15,304 MW by 2030	Y				
Russia	18-27 TWh in 2035		Y			Y
Singapore	-	Y	Y			
Chinese Taipei	20% in 2025	Y	Y	Y	Y	Y
Thailand	30% in 2036	Y	Y			Y
United States	*		Y	Y		
Viet Nam	38% in 2020; 32% in 2030; 43% in 2050	Y	Y			Y

Note: *: No national target for renewable energy share. Targets were established at the provincial level; Y stands for yes

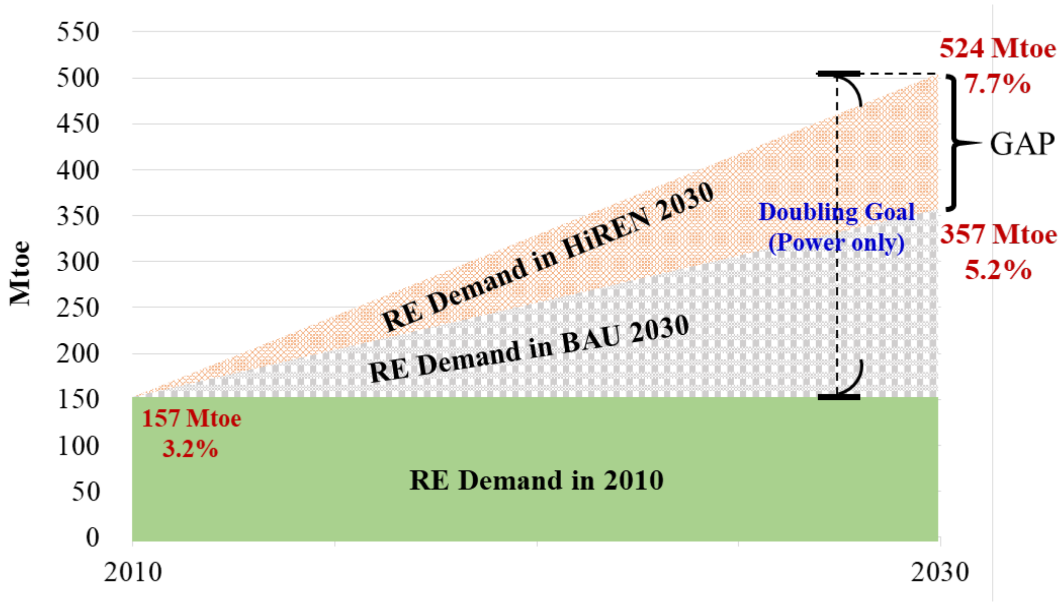
(Continued)

Economy	Renewable energy incentives							Renewable energy fund	Carbon reduction	Fossil fuel subsidy reform
	Feed-in tariff (FiT)	Feed-in premium (FiP)	Renewable portfolio standard (RPS)	Auction	Net metering	Renewable energy certificates (RECs)	Others			
Australia	Y		Y			Y	Y	Y	Y	
Brunei Darussalam										
Canada	Y				Y	Y	Y	Y	Y	
Chile					Y		Y		Y	
China	Y		Y				Y	Y	Y	
Hong Kong, China										
Indonesia	Y						Y		Y	Y
Japan	Y				Y		Y	Y	Y	
Republic of Korea			Y	Y	Y	Y		Y	Y	
Malaysia	Y							Y		
Mexico	Y		Y	Y	Y	Y	Y	Y		
New Zealand							Y		Y	
Papua New Guinea										
Peru				Y			Y			Y
The Philippines	Y		Y		Y	Y	Y		Y	
Russia		Y		Y			Y			
Singapore							Y		Y	
Chinese Taipei	Y					Y		Y	Y	
Thailand	Y						Y	Y		Y
The United States	Y		Y	Y	Y	Y	Y		Y	
Viet Nam	Y		Y		Y		Y		Y	Y

2.2 Doubling Goal and Renewable Energy Gap

The APEC goal of doubling renewable energy aims to double the share of renewable energy demand in the total final energy demand (TFED) by 2030, from 2010 levels. According to statistics from the APERC, the renewable energy power demand was 157 Mtoe in 2010, which accounts for 3.2% of the TFED. Under the high renewables scenario (HiRen) 2030, which is the scenario for doubling the share of renewable energy, the share of renewable energy power demand would reach 524 Mtoe (7.7%) by 2030.

Figure 6 Target and Gap for Reaching the Goal of Doubling Renewable Energy

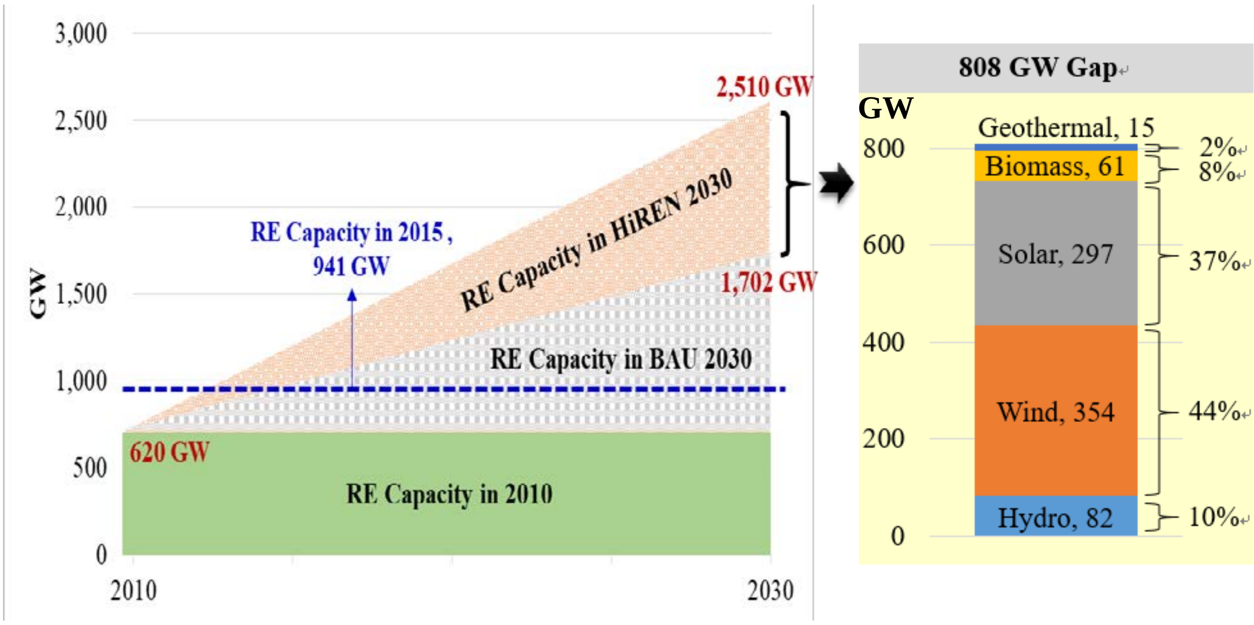


*BAU: business as usual scenario; HiRen: High Renewables Scenario
Source: APERC, 2016

In order to achieve APEC's goal of doubling renewable energy, collecting data on the current status of renewable energy capacity, generation, and policies in each economy and identifying the gap between the current status and the goal are crucial steps. According to statistics from the APERC, in order to achieve the goal of doubling the share of renewable energy, the cumulated renewable energy capacity in the APEC region should reach 2,510 GW in 2030. This value is calculated under HiRen 2030. The gap between BAU (business as usual scenario) 2030, which is estimated under current policies and target, and the HiRen target for 2030 is 808 GW (APERC, 2016).

The gap of 808 GW is comprised of five technologies: hydro (excluding pumped storage), wind, solar, biomass, and geothermal. The share of wind and solar in the gap is the most, accounting for 44% (354 GW) and 37% (297 GW), respectively, of the total gap. They are followed by hydro (10%, 82 GW), biomass (8%, 61 GW), and geothermal (2%, 15 GW). The breakdown of the gap could assist in the development of the strategic roadmap for the APEC economies in this project.

Figure 7 Target and Gap for Reaching the Goal of Doubling Renewable Energy



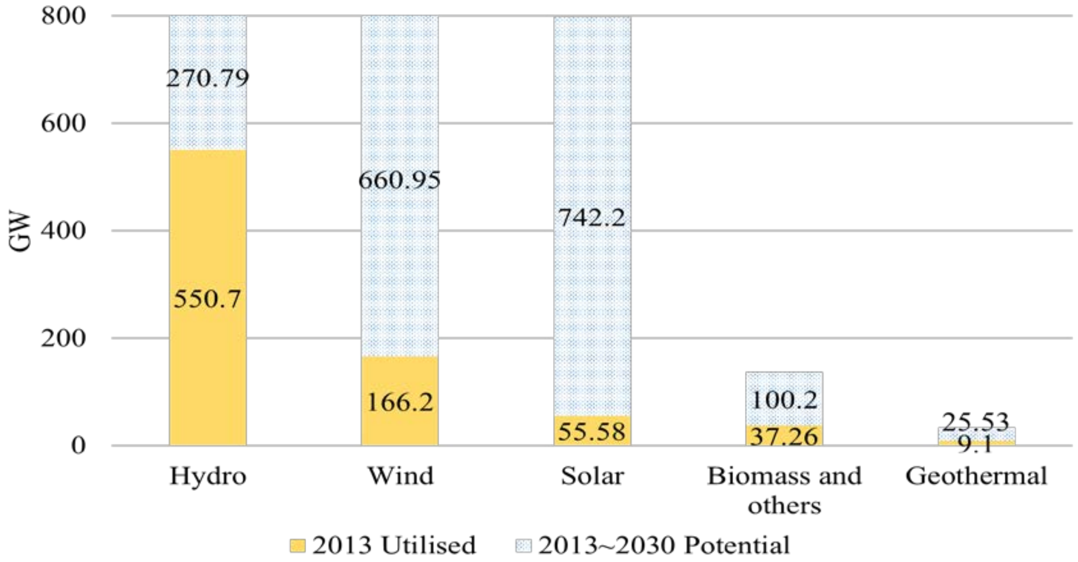
*BAU: Business as Usual Scenario; HREN: High Renewables Scenario
*Hydro data shown here is excluding pumped storage
Source: APERC, 2016

2.3 Potential of Renewable Energy

In order to fill the gap of 808 GW to the double the goal in the APEC region, it is important for each economy to maximize the utilization of renewable energy potential of each area. According to the sixth edition of the APEC Energy Demand and Supply Outlook published by the APERC, in the APEC region, the total renewable energy potential is estimated to increase to 1,800 GW from 2013 to 2030. This includes hydro, wind, solar, geothermal, and biomass and others. Solar accounts for 41.2% of the total renewable energy potential. It is followed by wind (36.7%), hydro (15.1%), biomass and others (5.6%), and geothermal (1.4%) (Figure 8). About half of the total renewable energy potential is located in China, and almost a quarter is located in the United States. These data show the uneven distribution of renewable energy potential in the APEC region.

In 2013, the utilization of renewable energy was 819 GW. Hydropower was utilized the most; about 67% of hydro potential was explored. The utilization rates of solar and wind power were relative low with unexplored potential being 742 GW and 660 GW, respectively. This indicates that solar and wind power would play crucial roles in achieving the renewable energy doubling goal in the future. Although renewable energy resources in China and the United States are abundant, their utilization rates in these two economies are merely about 30%.

Figure 8 Potential and Utilization of Renewable Energy in the APEC Region

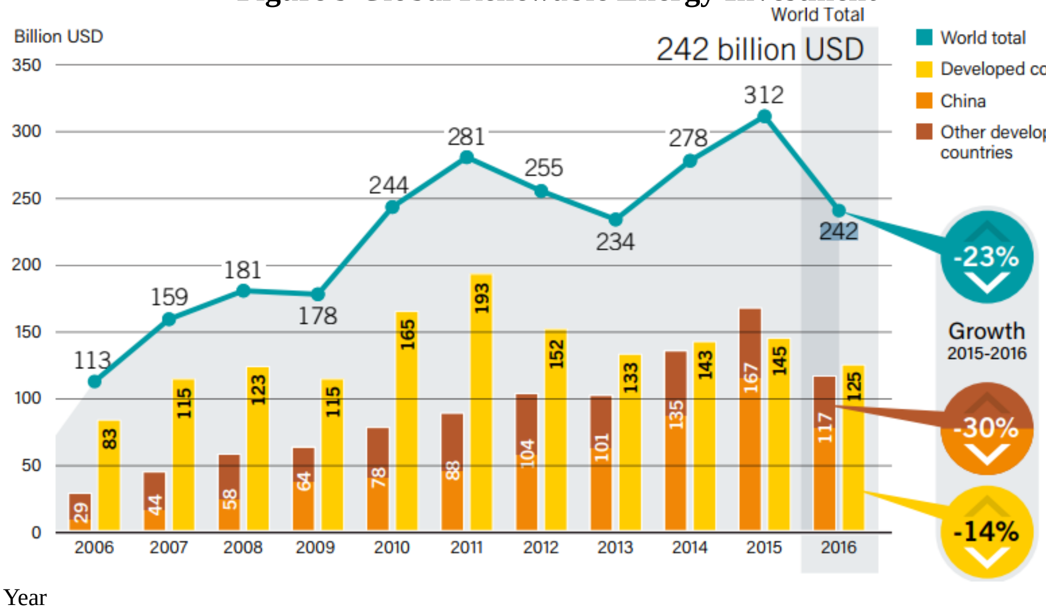


Source: APERC, 2016

2.4 Renewable Energy Investment and Cost

According to the REN21 report and estimations of the Bloomberg New Energy Finance (BNEF) in 2017, global renewable energy investment (excluding large hydropower projects) was USD 241.6 billion in 2016, which is 23% lower than that in 2015. This is because the cost of renewable energy technology dropped rapidly thereby reducing the cost of investment. The global investment trend is shown in Figure 9. Therefore, the installed capacity of renewable energy is continuously increasing. Renewable energy investments mainly focus on solar power and wind energy, which accounts for about 47% of the total investment.

Figure 9 Global Renewable Energy Investment

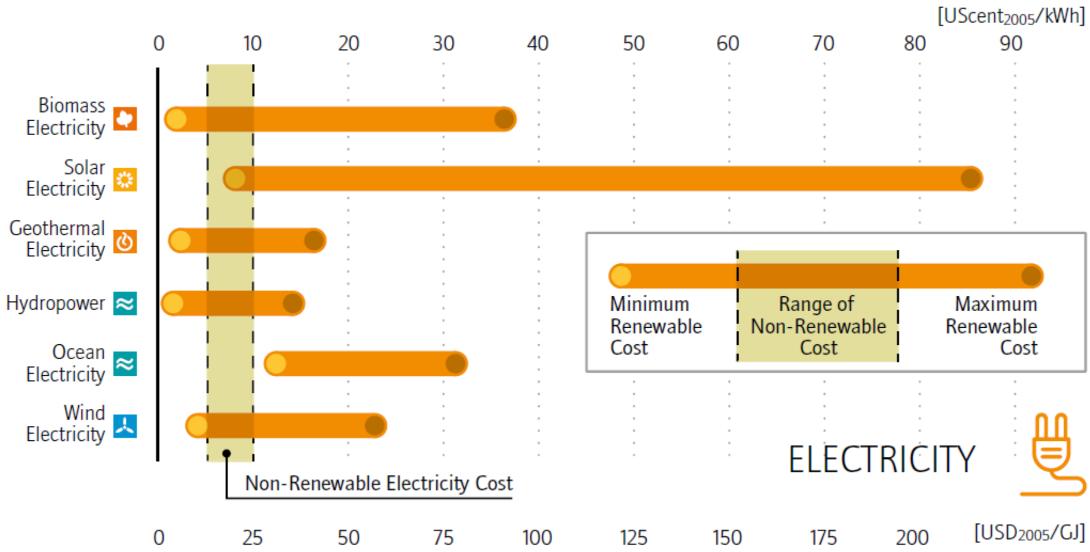


Source: REN21, 2017b

Costs of renewable energy technology are declining due to advancements in technology and manufacturing. Cost of solar photovoltaic (PV) generators declined by about 58% between 2010 and 2015. This decreasing trend is likely to continue (REN21, 2017b). The IRENA estimates that cost of PV generators will decline by another 57% by 2025. This means that grid parity can be achieved soon.

The cost of wind energy technology has also become competitive because wind turbine prices have remained relative low for the past 10 years and the average capacity factor is continually increasing, which means that more electricity can be generated per turbine. The change in the costs renewable energy technologies over the last decade is shown in Figure 10. The declining costs of onshore wind energy and solar PV technology make renewable energy more cost-competitive and provide an opportunity for renewable energy development.

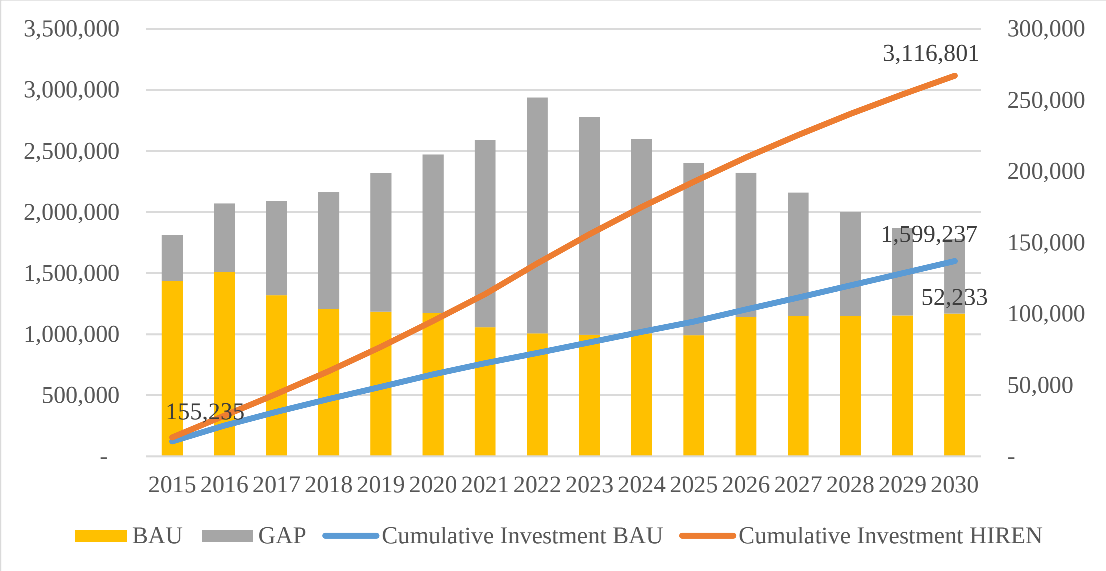
Figure 10 Range of LCOE of Renewable Energy Technologies



Source: REN21, 2017b

According to the APERC's estimation, renewable energy investment in the APEC region was USD 155,235 million in 2015. In order to achieve the APEC economies' targets (BAU), the cumulative investment in renewable energy should increase to USD 1,599,237 million by 2030. However, there is still a gap to reach the target of doubling renewable energy. An increase of USD 52,233 million in the renewable energy investment is required.

Figure 11 Renewable Energy Investment in the APEC Region



Source: APERC, 2016

3. Challenges

3.1 Policy Inconsistencies

Policy consistency is important because projects that promote renewable energy require large capital investments and thereby require access to credit. It has been observed that an unstable policy is more detrimental than having no policy (Wüstenhagen and Bilharz, 2006). If government policies are uncertain and inconsistent, loans will be difficult to obtain and costly.

Mitigation of climate change is the main driving force behind the growing demand for renewable energy. However, the results of this study show inconsistencies between the climatic policy and renewable energy policy of some economies. This results in unstable renewable energy supply, dramatic interruptions of renewable electricity supply, and sudden increase in the demand for fossil fuels. Additionally, although some of the economies have set renewable energy targets, the renewable energy target scheme does not require the state or local governments to develop suitable renewable energy development projects. This results in an unclear and uncertain direction of renewable energy development and a lack of investor confidence.

Moreover, fossil fuel subsidies, which were introduced as a political tool for social protection, 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. Sudden removal of fossil fuel subsidies may have harmful effects not only on household incomes directly, but also on domestic industries and jobs (Schmidt et al., 2017).

Furthermore, due to the increased maturity of renewable energy technology and unanticipated high installation of rooftop solar panels, the costs of renewable energy infrastructure (especially PV modules) have declined significantly. The unanticipated high installation of residential-scale renewable energy infrastructure increases the load on systems of subsidies (e.g., FiT) paid by the government. Governments have reduced tariffs and ended schemes abruptly. This has introduced uncertainties into the policy landscape and affected small solar panel businesses. These arguments do not imply that policies should not be changed. The consensus on this issue is that policies have to be flexible enough to adapt to new technologies and changing markets However, they must not be changed frequently and unpredictably, since this interrupts and discourages investments in R&D activities.

3.2 Infrastructure

Electrical infrastructure plays an important role in the power grid system and national economic development. Due to rapid growth of population, the demand for electricity is increasing. Since power generated from renewable energy sources is unreliable and intermittent, the power grid requires adequate energy storage systems to stabilize the power systems, deal with partial voltage control issues, and increase the reliability of electricity utilization. Additionally, large-scale introduction of distributed energy into the grid system might restrict the capability of the central dispatch center.

Furthermore, since several APEC economies face the impact of natural events every year, if the capability of infrastructure and stability of power supply are not powerful enough, electricity supply might be seriously impacted. Therefore, the power grid systems of many economies need to be reinforced for the introduction of electricity generated from renewable energy sources. The challenges due to lack of electrical infrastructure are discussed below.

- **Impacts of Natural Events**

Several economies might face significant restrictions related land acquisition and environmental policies during the process of expansion and development of renewable energy. The "World Risk Report 2016" published by the United Nations University (UNU, 2016) reports the impacts of extreme natural events on the infrastructure of the economies. The results of the research conducted by the UNU (UNU, 2016) illustrates that the Philippines (ranked 3rd), Brunei Darussalam (ranked 7th), Papua New Guinea (ranked 10th), and Japan (ranked 17th) are ranked among the top most vulnerable economies to natural events. Owing to its geographical conditions, there are a number of islands in Southeast Asia. The Philippines for instance has 7,107 islands; however, it does not have a uniform domestic grid infrastructure. Most of the islands are highly dependent on coal, oil, thermal, and natural gas energy and have high primary energy consumption. Thus, the capability of the power grid has an important role in renewable energy development.

Table 2 World Risk Index of the APEC Region

Unit: %

Rank	Economy	World Risk Index	Exposure	Vulnerability	Susceptibility	Lack of Coping Capacity	Lack of Adaptive Capacity
3	The Philippines	26.70	52.46	50.90	31.83	80.92	39.96
7	Brunei Darussalam	17.00	41.10	41.36	17.40	63.17	43.53
10	Papua New Guinea	16.43	24.94	65.90	54.81	83.94	58.95
17	Japan	12.99	45.91	28.29	17.82	38.04	29.00
18	Viet Nam	12.53	25.35	49.43	24.95	76.67	46.67
22	Chile	11.65	30.95	37.66	19.67	58.61	34.70
36	Indonesia	10.24	19.36	52.87	30.09	79.49	49.04
78	Peru	6.59	14.40	45.74	27.34	73.65	36.23
85	China	6.39	14.43	44.29	22.81	69.86	40.18
86	Malaysia	6.39	14.60	43.76	19.02	67.52	44.73
89	Thailand	6.19	13.70	45.22	19.34	75.53	40.79
95	Mexico	5.97	13.84	43.10	23.36	71.69	34.27
113	Republic of Korea	4.59	14.89	30.82	14.31	46.55	31.59
116	New Zealand	4.55	15.44	29.48	16.55	44.45	27.45
121	Australia	4.22	15.05	28.01	15.67	42.53	25.84
127	The United States	3.76	12.25	30.68	16.35	48.24	27.46
128	Russia	3.58	9.38	38.15	21.53	59.12	33.81
145	Canada	3.01	10.25	29.42	15.20	45.95	27.10
159	Singapore	2.27	7.82	28.99	14.24	49.44	23.28

Source: UNU, 2016

- **Insufficient Grid Capacity**

In addition to natural events, insufficient grid capacity might also affect the power grid system significantly. For example, China is facing high rates of wind power and solar photovoltaics power curtailment. In China, the Northwest (Xibei) and Southwest (Xinan) regions, including Xinjiang, Gansu, Ningxia, and Qinghai have high renewable energy potential. The curtailment of wind and solar photovoltaics power occurred because the transmission capacity was insufficient to process the power generated by renewable energy power plants Therefore, most of these newly developed renewable energy power plants are not functional.

There are two major reasons for the curtailment of wind and solar photovoltaics power: the local demand for electricity is low and the capacity of power grid infrastructure is insufficient. On the one hand, the economy of the western region of China is stagnant and the demand for electricity is low compared to that of densely populated regions. Although China has been developing renewable energy at a high rate recently, it was difficult for the local region to process the electricity generated from renewable energy sources, thereby resulting in the curtailment of wind and solar photovoltaics power.

On the other hand, the economic growth of China has recently slowed down.The demand for electricity by manufacturers has been below expectation, thus creating an imbalance between supply and demand.. Moreover, most of the areas with high renewable energy potential are sparsely populated and not easily accessible due to natural conditions. Therefore, building transmission lines in such areas is challenging. The economies might face difficulties in constructing long-distance electrical power transmission lines. Moreover, it requires high capital investment, administrative costs, and a complicated assessment and review process. Therefore, the construction of power plants might be unable to catch up with the rapid construction speed of power grids.

- **Incomplete Installation Regulation**

In order to increase the utilization and development of renewable energy, economies should follow a common international regulation. Therefore, for the construction of renewable energy facilities, developers should follow the standard operating procedure for electrical infrastructure construction.

Offshore wind power has become a rapidly growing industry and major development projects of many economies are based on it. Developers might face several issues related to environmental impact assessment during the development of offshore wind power. Developing piles for offshore wind turbines or installing submarine power cables for offshore wind farms, for instance, might disrupt the habitats of marine mammals. Therefore, the economies should propose regulations that ensure the safety during construction and protection of the marine environment.

3.3 Financing Mechanism

Investments in renewable energy generally have higher upfront capital requirements and longer payback periods for investors; the renewable energy sector relies more heavily on government policies than other technology sectors (World Bank, 2014). Large capital cost of renewable energy installations is usually one of the major obstacles for renewable energy investments. The costs of renewable energy installations are higher than operations and maintenance costs (O&M costs). In addition, delays in the project increase installation cost due to increase in labor costs and amount paid as interest, which increases capital requirements of investors.

Small and medium enterprises (SMEs) play an important role in renewable energy development in the APEC region since they can utilize domestic resources to invest in renewable energy. However, SMEs are facing more challenges due to lack of capital than larger firms. This is because unlike larger firms, SMEs do not have large amounts of capital, loan guarantee, and the ability to afford risks. The main challenges and risks of renewable energy investment, which have been identified by the World Bank, are explained below.

3.3.1 Challenge of Financial Mechanism

1. Lack of Long-term Financing

Although short-term debt and funds can be used for to finance the operation of projects, renewable energy projects usually have longer payback periods. This obstacle increases the risk of investment; different renewable energy technologies have different payback periods. Some renewable energy technologies can return the investment costs faster than other technologies.

Obtaining long-term financing is difficult due to regulations or other restrictions on long-term bank lending. This will 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 for conventional energy technologies because renewable energy projects are riskier and depends on technology development, weather, and government support. Furthermore, activities that must be carried out, before starting project development, such as site identification and resource assessment usually requires significant time. Therefore, such projects require higher capital investments.

3. Project development

The project development phase is time consuming, expensive, and unpredictable. Additionally, purchase of land for renewable energy development is usually a challenge; for instance, some renewable energy resources are located in areas where installation of renewable energy equipment is not easy because of geological, security, and pollution concerns. Therefore, the process of land acquisition is long.

4. Small Scale of Projects

International commercial banks are generally not interested in projects with a budget below USD10 million and attracting investments for projects up to $20 million is difficult (Hamilton, 2010). For such projects, financing should be sought from domestic financial resources and banks since 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. Development of renewable energy requires more capital and is subject to higher interest rates, especially in some developing countries.

6. Regulatory Risk

Renewable energy development relies on government support and the establishment of a stable financial and legal framework. Therefore, changes in law, renewable energy policy, FiT rate, and taxation or legislative priorities will cause uncertainties and risks for renewable energy projects.

Table 3 Financing Barriers and Risks

	Wind	Solar	Small Hydro	Biomass	Geothermal	Solar/Micro Hydro
Lack of long-term financing	▲	▲	▲	▲	■	■
Lack of project financing	■	■	■	■	■	●
Project development	●	●	■	●	▲	■
Small scale of project	●	■	■	■	●	▲
High financial cost	■	▲	●	■	●	■
Regulatory risk	■	■	■	■	■	●
High costs of resource assessments	●	●	■	●	▲	●
Uncertainty over resource adequacy	■	■	▲	▲	■	■

Note: ▲: High; ■: Medium; ●: Low

Source: World Bank, 2012

3.4 Innovations in Renewable Energy Technology

The efficiency and cost of renewable energy technology are the main factors that influence the deployment and development of renewable energy. Most of the APEC economies are conducting projects related to renewable energy technology development (Table 1). However, projects focused on improving the efficiency of individual renewable energy technology are not sufficient. Moreover, although some of economies have set energy efficiency targets, most of the economies, particularly developing economies, still lack policies to achieve these targets. Furthermore, policies that support energy efficiency and renewable energy are not sufficiently integrated.

Additionally, the intermittent nature of power generated from solar and wind energy is a big issue that needs to be addressed to ensure reliable electricity supply in real time. It implies that the integration of intermittent energy system has become a pressing challenge. Strategies for integrating large shares of intermittent energy into power grids and developing storage system for the dispatch of renewable electricity are urgent requirements (APERC, 2016).

In addition to increasing the efficiency of renewable energy technology, integrating intermittent renewable energy system and developing storage system for dispatching renewable electricity, the problem of unequal regional distribution of renewable energy supply and demand needs to be solved. This can be done by developing a transition and distribution network.

3.5 Capacity Building

Advanced technologies, sufficient funds, and an adequate number of qualified workers are cornerstones to increase the share of electricity generated from renewable energy sources in the electricity market. Without well-trained and skilled workforce from various sectors, the promotion of renewable energy will be difficult. In some economies, the development of renewable energy is impeded due to the lack of qualified and skilled personnel and insufficient public awareness. Therefore, it is essential to establish a capacity building system, which includes developing and training a capable workforce, public awareness building, and gender equality issue.

3.6 Market Reform

In order to promote the development of renewable energy, the whole market mechanism needs to be reformed. Economies need to 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 significant role in the competition between renewable energy sources and traditional fossil fuels. The distorted market price caused by huge fossil fuel subsidies weakens the competitiveness of renewable power and reduces the funds available to provide financial support for renewable energy technologies.

Furthermore, due to the properties of renewable energy resources such as high capital intensity requirements, limited predictability, and variability, the electricity market needs to be redesigned to cope with the challenges of handling a high volume of renewables. Additionally, the market demand for multinational companies with renewable energy certification is another issue that economies need to consider.

4. Recommendations

4.1 Policy Recommendation

The direction of policies and strategies for accelerating the transformation of the existing energy system are discussed below.

4.1.1 Amend renewable energy laws to increase the renewable energy target

According to the current renewable energy policies and strategies of each economy, if the government of each economy wants to contribute towards the goal of doubling the share of renewable energy in the APEC region by 2030, a higher and more ambitious renewable energy target should be set to fill the gap. An economy with a high share of electricity generated from renewable energy sources may further increase their contribution to renewable energy development by overseas investments or sharing their state-of-the-art renewable energy technologies.

4.1.2 Develop a policy for long-term renewable energy development

Policies should be flexible enough to adapt to new technologies, changing markets, and climate change. They should be tailored to the different phases of renewable energy development to avoid the sudden cutting of subsidies and uncertainties in investments. An urgent issue that requires special attention is the development of strategies to support the planning phase. Such policies will assist in the planning of renewable energy projects by increasing the provisions of early-stage risk mitigation mechanisms, risk capital, and risk mitigation facilities. Enhancing the utilization of risk mitigation instruments accelerates the uptake of renewable energy in developing countries. It is recommended that risk mitigation instruments be prioritized and set up by using climate finance and/or traditional development finance channels.

4.1.3 Strengthen renewable energy policy commitment

Renewable energy targets need to be backed by specific policies that are tailored to the local conditions of each economy. Policies and regulatory frameworks enabled by the government ensure predictable revenue for renewable energy development projects, thus creating a stable and predictable investment environment.

Measures that are based on the conditions of each economy, such as leveling the playing field by pricing externalities and reducing fossil fuel subsidies, can 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 negative social impacts.

Although a global carbon price has not been implemented successfully, it is believed that the effective implementation of such a global price will trigger greater investments in the renewable energy sector. Furthermore, it is strongly believed that emission of greenhouse gases will decrease with the implementation of an appropriate carbon pricing mechanism. Such mechanisms will help identify the real economic advantages of renewable energy development in the market.

4.1.4 Increase the positive cross-cutting impact of renewable energy on sustainable development

Access to cost-effective, reliable, and environmentally sustainable modern energy services have positive impacts on health, livelihoods, poverty alleviation, and job creation. Standalone and mini-grid systems are currently the most economical options for expanding access to off-grid renewable energy systems in many rural areas. Solar-powered irrigation technology, for instance, is an off-grid solution that can increase yield and incomes and reduce vulnerability to erratic rainfall and hardship of farmers, especially women farmers. Such systems will provide societies with access to modern and sustainable energy and build climate resilient infrastructure, which protects and restores rural ecosystems.

4.1.5 Increase regional engagement and overseas cooperation

Regional engagement and overseas cooperation can stimulate cross-border trade, reduce costs, attract investments, and boost financial capacity thereby accelerating the global deployment of renewable energy. The potential benefits of regional engagement and overseas cooperation are discussed below.

1. Aggregation of overseas investment helps renewable energy projects reach the scale necessary to attract larger scale private investments.

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

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

4.1.6 Strategies for the development of renewable energy storage, hybrid, and transition and distribution systems

Although the APEC region has a vast renewable energy potential, there are many significant hurdles in the transition to a renewable energy system. First, there is an unequal regional distribution of energy supply and energy demand. An area with a high renewable energy potential is not necessarily an area with a high energy demand The energy needs in Ontario and Alberta in Canada, for instance, cannot be satisfied entirely through renewable energy; however, the renewable energy supply potential of this area is 15 times higher than the energy needs in Newfoundland and Labrador. Additionally, renewable energy sources are not necessarily located near large population centers.

This energy supply and demand imbalance means that policy makers should consider practical needs when developing policies for renewable energy promotion. Additionally, policy makers need to set strategies to develop renewable energy storage, hybrid systems, which mitigate the problems due to intermittent and variable renewable energy supply (e.g., solar and wind energy), and transition and distribution systems for the dispatch of renewable electricity.

4.2 Infrastructure

In order to increase the power generation to meet the demand for electricity, the APEC economies should ensure that renewable energy facilities comply with installation regulations. Distributed generation systems can benefit small-scale technologies that generate electricity for end-users by increasing the rural electrification rate, reducing incidents of large-scale power outages, and improving the curtailment rates of solar and wind power. Distributed generation systems can provide high power generation and improve the reliability of the grid. Micro-grids, smart grids, and energy storage systems are applications of distributed generation systems. A micro-grid is an independent generation system and can be used to increase the rural electrification rate, provide high power supply efficiency and steady power quality, and decrease carbon emissions (Chan et al., 2017).

Infrastructure for the generation, transmission, and distribution of renewable power are equally important for power grid systems. The farther major power grids are from the power plants, the more difficult it is to construct transmission lines. Therefore, investment in power grids requires vast capital. The power grid construction might be unable to catch up with the installation of power generation facilities. Furthermore, high time and cost requirements have become prodigious burdens for renewable energy developers. Consequently, the use of renewable energy sources necessitates smart grid systems to implement a power dispatch model.

4.2.1 Application of Micro-grid for Preventing Power Supply Interruptions due to Natural Events

Many economies are making every effort to expand their renewable energy capacities to decrease their reliance on fossil fuels and reduce greenhouse gas (GHG) emissions. Since the supply of renewable energy is intermittent, stability, reliability, and power quality issues, such as voltage and frequency fluctuation, imbalance between power supply and demand when the distributed generation system is connected to the utility power grid, may occur (Zhu et al., 2015). Moreover, natural events, such as typhoons and earthquakes, might seriously affect the power grid system. Therefore, micro-grids can provide efficacious solutions for renewable energy integration and preventing interruptions due to natural events.

Micro-grids consist of micro-sources and loads and provide both electricity and thermal energy (Zhu et al., 2015). Additionally, Yan et al. reported that micro-grid is an electrical infrastructure that can provide electricity to a wide number of customers, from a single building to an entire island (Yan et al., 2017). Micro-grid can be interconnected and interact with the primary utility grid or operate independently based on the distributed energy generation. Moreover, micro-grid is an independent and intelligent system that enhances the electricity consumption efficiency through the applications of big data, internet of things (IoT), and energy storage system (ESS)

(Choi and Do, 2016).

Energy storage systems make renewable energy storable, dispatchable, and controllable. Distributed energy storage systems can help solve issues such as storing electricity, stabilizing electricity voltage, improving power generation from intermittent renewable energy sources.

Zhu et al. described two primary methods to integrate renewable energy resources into the utility power grid (Zhu et al., 2015). One method involves building large-scale solar and wind farms, in an appropriable area, with high solar energy and wind power potential. Therefore, these renewable resources are connected to the utility power grid through the transmission network. The other method integrates small-scale solar and wind energy conversion systems to low voltage distribution systems. Micro-grid are operated in many economies (Chan et al., 2017). The new energy and Industrial Technology Development Organization (NEDO) of Japan has funded a number of micro-grid demonstration projects since 2003. One such micro-grid demonstration project in Sendai provided electricity and heat to a local hospital, nursing care facilities, and other campus buildings located within the coverage area (Hirose et al., 2013).

4.2.2 Application of Smart Grid for Monitoring Electricity Consumption

Use of smart grids is an indispensable avenue to decrease GHG emissions and realize de-carbonization in the energy sectors (Zhang et al., 2017). Traditional grids can only transmit or distribute electric power. However, modern grids can store, communicate and make decisions while smart grids can transform the conventional grid to function more cooperatively, responsively, and organically (Tuballa and Abundo, 2016). Additionally, to realize the goal of de-carbonization with smart energy management algorithms, automated control, and modern communications technologies, the use of smart grids will improve efficiency, dependability, and security of grid (Ellabban and Abu-Rub, 2016).

The State Grid Corporation of China (SGCC) proposed the “Strong & Smart Grid” concept and China has incorporated smart grids into the 12^{th} Five-Year Plan (2011-2015) for promoting pivotal infrastructure and green-growth of strategic emerging industries. Xu et al. reported that the SGCC has divided smart grid development into three phases (Xu et al., 2014). Additionally, the SGCC has certified six primary areas, covering generation, transmission, substation, distribution, electricity utilization, and dispatching, for essential smart grid investments. About RMB 4 trillion and RMB 1.7 trillion has been allocated for Phase II and Phase III of development, respectively.

Table 4 The SGCC's Smart Grid Development Schedules and Goals

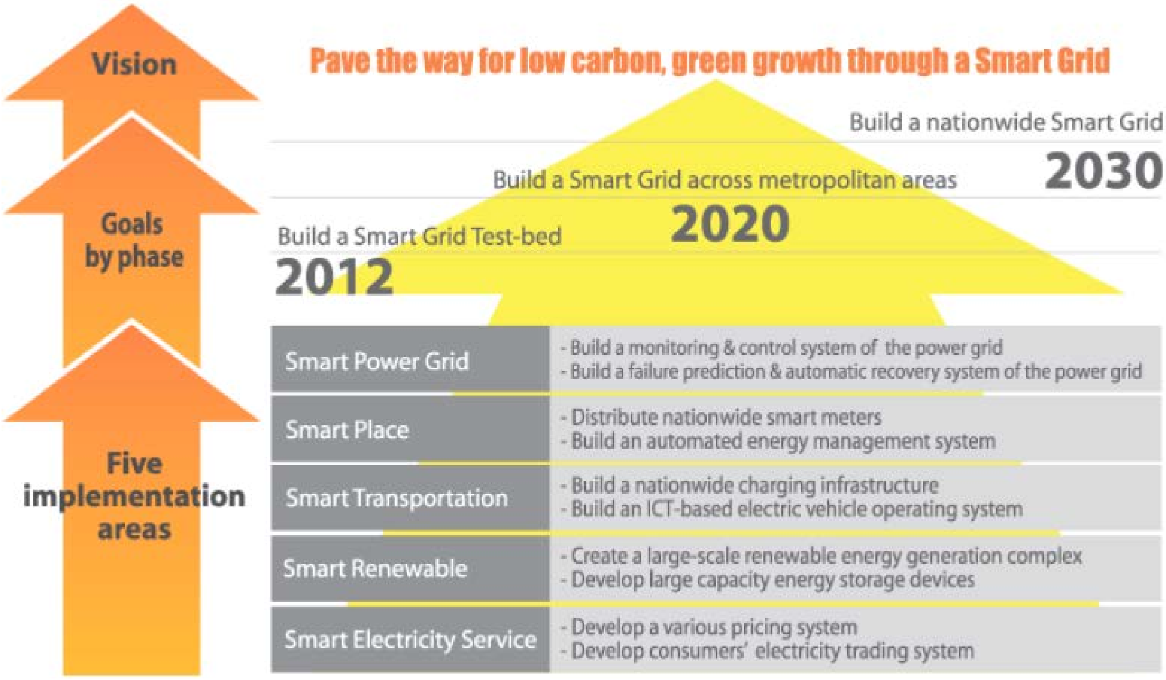
Phase	Schedule	Goal
Phase I	2009-2010	Initial Planning and Pilot Phase
Phase II	2011-2015	Comprehensive Construction Phase
Phase III	2016-2020	Upgrading and Enhancing Phase

Source: Xu et al., 2014

Kim et al. stated that imbalance in electricity supply and demand still exists in the Republic of Korea, particularly due to the increase in renewable energy integration (Kim et al., 2016). Due to a temporary shortage of power supply compared with its demand, the first blackout in the Republic of Korea's history has occurred. Hence, the government of the Republic of Korea initiated the Jeju Smart Grid Demonstration Project in 2010 to promote the smart grid industry and educate citizens about smart grids (Choi and Do, 2016).

Aligned with this demonstration project, the government of the Republic of Korea passed the "Smart Grid Construction and Utilization Promotion Act" (Act No. 10714) to offer legislative support for the development of the smart grid industry. Additionally, the government of the Republic of Korea drafted the smart grid roadmap, which targets to create a low-carbon and green-growth economy by 2030. The government of the Republic of Korea disclosed three developing objectives (build a smart grid test-bed, build a smart grid across metropolitan areas, and build a nationwide smart grid), three-phase promotion schedule (2012, 2020, 2030), and five areas of implementation(smart power grid, smart place, smart transportation, smart renewables, and smart electricity service).

Figure 12 Vision and Goals of the Republic of Korea's Smart Grid



Source: Choi and Do, 2016

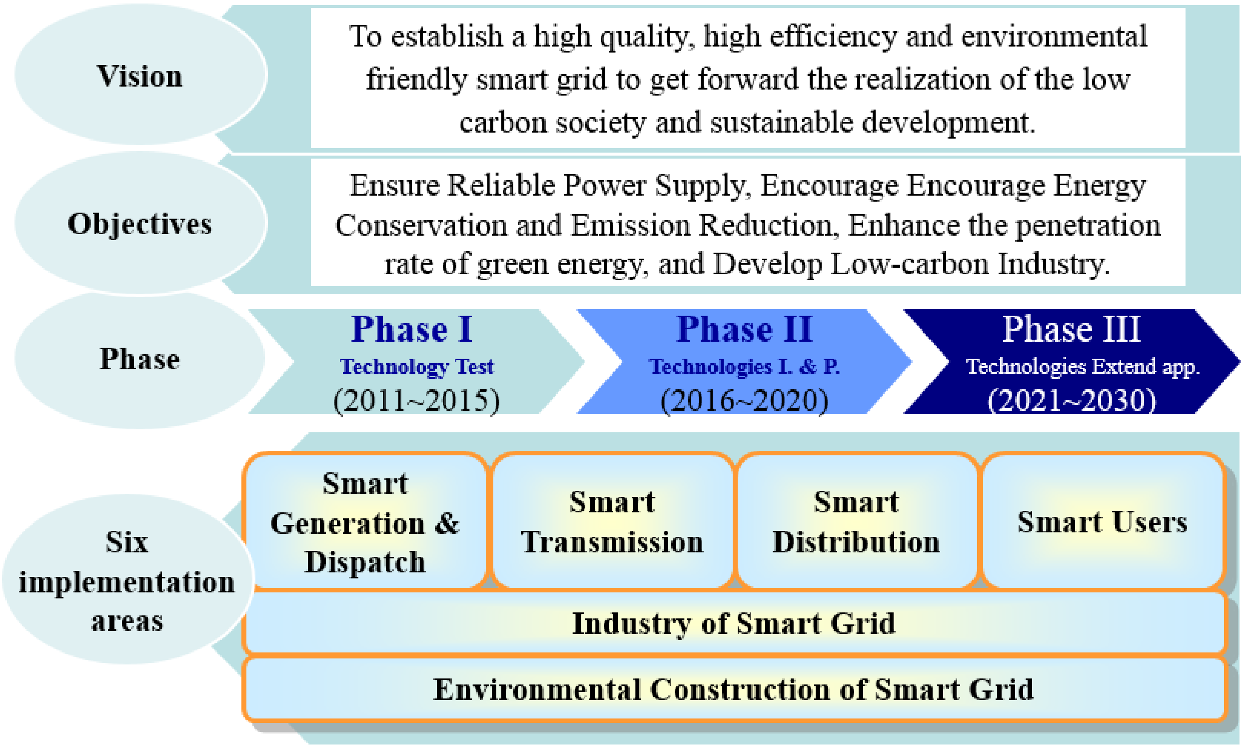
The third national energy conference (NEC) of Chinese Taipei was held in 2009 and four primary conclusions[1] were drawn. "Energy Technology and Industry Development," outlines that Chinese Taipei would focus on the research related to new energy, renewables, and energy-saving technology. The promotion of smart grids and advanced metering infrastructure (AMI) were prioritized (EWG, 2010).

The Ministry of Economy Affairs (MOEA, 2017) declared that the vision of smart grids of Chinese Taipei is to establish high quality, high efficiency, and environmentally friendly smart grids towards the realization of a low-carbon and sustainable society. Furthermore, Chinese Taipei revealed four developing goals (ensure reliable power supply, encourage energy conservation and carbon emission reduction, enhance the market penetration rate of renewable energy, and develop low-carbon industrial strategy), three-phase promotion schedules (2011-2015, 2016-2020, 2021-2030), and six developing perspectives (smart generation and dispatch, smart transmission, smart distribution, smart users, industry of smart grid, and

[1] Sustainable Development and Energy Security; Energy Management and Increased Efficiency; Price Signals and Market Liberalization; Energy Technology and Industry Development.

environmental construction of smart grid).

Figure 13 Master Plan of Smart Grid in Chinese Taipei



Source: MOEA, 2012

According to the MOEA (2017), the system average interruption duration index[2] (SAIDI) of Chinese Taipei was 21 minute/customer.year in 2011 (MOEA, 2017). In 2015, after the smart grid promotion, the SAIDI was 16.27 minute/customer-year. Hence, the promotion of smart grid could improve the reliability of power supply.

[2] IEEE (2004) shows the average frequency of momentary interruption events. The SAIDI is calculated by month or year IEEE, 2004 (IEEE, 2004).

Table 5 Anticipated Benefits of Smart Grid

Goals		Unit	2015 [Initial 2011]	Phase I 2012-2015	Phase II 2016-2020	Phase III 2021-2030
Ensure Reliable Power Supply	Reduce National Blackout Time (SAIDI)	Minute/ Customer.year	16.27 [21]	17.5	16	15.5
Facilitate Energy Conservation & Energy Reduction	Reduce CO_2 Emission	Million tonnes/Year	14.98 [-]	11.78	35.99	114.71
Reinforce Renewable Energy Penetration Rate	Increase Parallel Renewable Energy Capacity	Cumulative Percentage	10.5% ↑ [10% ↓]	15%	20%	30%
Develop Low-Carbon Industry	Develop Smart Grid Industry	USD/Year	44.10 [8.26]	32.26	96.77	225.81

Source: MOEA, 2017
Note: USD:NTD = 1:31

The Standards Council of Canada revealed that the Canadian government's approach toward the future for Smart Grid focuses on three core policy targets: ensuring reliability (which includes security), adequacy, and environmental performance (Standards Council of Canada, 2014). First, the notorious Northeastern blackout of 2003 caused economic losses amounting to approximately USD 10 billion in the United States and Canada. Therefore, it is important to complete the smart grid system and ensure reliability, particularly concerning security of the grid. Second, in order to meet customer loads, it is crucial to have sufficient grid infrastructure to support electrical system across all aspects. Third, environmental performance of smart grids can be ensured by allowing customers to purchase cleaner, low-carbon emitting generation and manage their own energy consumption. The integration of renewable energy sources at customer sites is the most important step to achieve this objective.

According to the findings of this project, to increase the electrification rate, reduce incidences of large-scale power outages, and improve the solar and wind power curtailment rates, application of micro-grid and smart grid can benefit the addition of renewable energy power generation. These technologies have recently become popular in the international development of renewable energy. Micro-grid and smart grid can contribute to increasing the penetration rate of renewable energy sources in the regional grid. During the peak time, power generated from renewable energy sources and stored in energy storage systems is consumed in meeting electrical load demands. The integration of power grid technology and the introduction of smart grid techniques allow the use of big data to analyze electricity consumption of power plants, transmission lines, and distribution systems, thereby increasing the reliability and security of power grids. This will ultimately achieve the goal of increasing the share of renewable energy power generation and decreasing carbon emissions in the APEC region.

4.2.3 Formulating Legislations for Related Techniques

In order to ensure the quality of electrical infrastructure of renewable energy facilities, it is crucial to formulate legislations related to the construction of such infrastructure With regard to standards for the installation fuel cells, the international electrotechnical commission (IEC) has formulated international standards, such as IEC/TS 62282 standard for battery, energy efficiency, and energy storage.

Additionally, several APEC economies have proposed their own fuel cell technology standards to ensure the safety of electrical equipment and components, to protect public security, and to address other safety issues. The Japan Electric Association (JEA), for instance, has developed the Japan Electric Association Code (JEAC) based on Japan’s electrical appliance and material safety law. The JEA also proposed the JEAC 5002-1992 fuel cell power generation regulation to ensure safety of the fuel cell.

The 2009 national electrical code (NEC) of the United States, which is provided in the NEC - Article 692, specifies safety regulations of energy storage systems with respect to fuel cell systems. Similarly, Chinese Taipei has developed the Chinese National Standard (CNS) and regulations for fuel cell standards. The CNS 15468 - fuel cell technologies regulates the safety and performance of fuel cell modules.

Therefore, the development of renewable energy in each APEC economy should consider the intermittent nature of renewable energy power generation since it might affect grid voltage and regional power grid stabilization. However, the combination of micro-grids and energy storage systems could effectively increase the stability of power grids and renewable energy power generation. Moreover, when using fuel cells and other energy storage systems, it is crucial to be aware of whether the energy storage systems comply with international standards and the regulations of the relevant economy to ensure that end-users are able to acquire safe electricity.

In a nutshell, since energy storage systems increases the stability of energy supply, many sectors of the community are making every effort to utilize solar energy, wind power, and other renewable energy as primary sources for power generation. Micro-grid, energy storage systems, and smart grids can be used to monitor the electricity consumption of regional power grids. In the near future, APEC economies could this information to develop renewable energy in areas with relative electricity shortage.

4.3 Financing Mechanism

Although renewable energy investment is the leading trend in the energy market, financing environment and related mechanisms are important factors that attract financing and investors. A clear and stable financing mechanism is required to provide affordable credit and a suitable payback period for investors. This will accelerate renewable energy development since it can attract investments in renewable energy. The implementation of renewable energy projects such as rooftop solar, micro-grids, thermal projects, rural development and technology development, and educational programs related to renewable energy requires financial support.

4.3.1 Supply Chain and Cost

Construction costs include renewable energy installations and construction costs, technology costs, and operation and maintenance (O&M) costs for the expected lifetime of equipment, and customization and interest costs. These costs can be broken down into costs for different renewable energy technologies and industrial segments. The value chain of renewable energy installations includes different technological elements, such as wind turbines, solar PV modules, solar thermal collectors, and landfills.

The middle segment of this value chain is the balance of system (BoS) or engineering, procurement, and construction (EPC), which includes project development, civil construction works, planning and design, retailing and sales, and delivery. The final segment of the value chain is operations and maintenance (O&M). The costs incurred in this segment include O&M costs for the average expected lifetime of the technology, routine maintenance and inspection costs, ongoing labor costs, warranty enforcement costs, and insurance costs. The value chains of different technologies are shown in Table 6.

Table 6 Activities in the value chain of 15 technology areas

Technology	Major Equipment	EPC/BoS	O&M
Onshore wind	Turbine: 57%	22% civil construction works: 44% BoS :31% Other costs: 25%	21% Insurance Routine component
Solar thermal	Solar collector: 45%	37% civil construction works BoS Other costs	
Solar PV	PV module: 54% (> 1 MW), 45%(< 1 MW)	36% (> 1 MW) 46% (< 1 MW) civil construction works BoS Other costs	10% (> 1 MW) 9% (< 1 MW) Routine inspection Preventative maintenance
Solar CSP	36% Solar field: 80% Thermal storage system: 20%	55% civil construction works: 35% BoS: 30% Other costs: 35%	9% Routine inspection Preventative maintenance Corrective maintenance
Small hydro	Electro-mechanical equipment: 23%	57% civil construction works: 65% BoS: 25% Other costs: 10%	20% Fixed costs Variable costs
Geothermal	Power Plant: 32%	45% civil construction works BoS Other costs	23% Fixed costs Variable costs
Bioenergy	42%	27%	32%

Technology	Major Equipment	EPC/BoS	O&M
	Feedstock conversion: 80% Prime mover: 20%	civil construction works BoS Other Costs	Fixed costs Variable costs

Source: World Bank, 2014

4.3.2 Financing Instruments and Options

Many APEC economies already have financial mechanism and measures in place to promote the development of renewable energy. These incentives include grants, loans, and tax credits. Financial incentives that have been implemented in the APEC economies are shown in Table 7.

Table 7 Financial Mechanism in the APEC Region

Economy	Grants	Investment or Tax Credits	Public Investment Loan or Financing	Reductions in VAT, or other taxes
Australia	Y		Y	
Brunei Darussalam				
Canada	Y	Y	Y	Y
Chile	Y	Y	Y	
China	Y	Y	Y	Y
Hong Kong, China				
Indonesia			Y	
Japan	Y		Y	
Korea				Y
Malaysia	Y	Y	Y	
Mexico	Y			
New Zealand	Y			Y
PNG				
Peru	Y	Y	Y	Y
The Philippines	Y	Y	Y	Y
Russia				
Singapore				
Chinese Taipei			Y	
Thailand	Y	Y		Y
United States	Y	Y	Y	Y

Economy	Grants	Investment or Tax Credits	Public Investment Loan or Financing	Reductions in VAT, or other taxes
Viet Nam		Y	Y	Y

Investment, financing, and policy support mechanisms are necessary to overcome the challenges of renewable energy development. The financial instruments and measures for overcoming challenges and some case studies are discussed below.

- Tax Credit

Governments provide tax credit as incentives allowing taxpayers to deduct a certain amount of tax by investing in renewable energy projects. Many APEC economies, such as the US and Japan, have applied this financial mechanism to attract financing for renewable energy projects.

Canada provides refundable and/or non-refundable investment tax credits (ITC) worth between 10% and 15% of the annual eligible expenditure (depending on the particular province) for all corporations that conduct business through a permanent establishment located in that province. Eligible expenditures are generally those that qualify for federal ITC purposes and are generally capped at a maximum annual credit (KMPG International).

Similarly, Japan provides a green investment tax incentive for taxpayers who have obtained approval for the feed-in tariff and acquired solar or wind power generation equipment and land within one year from the date of acquisition. The taxpayer can choose one incentive from the following: 30% special depreciation in addition to ordinary depreciation, 100% depreciation for wind power generation equipment, and tax credit amounting to 7% of the acquisition costs; the last option is only available for SMEs (KMPG international, 2015).

Governments provide capital grants for long-term finance to investors or banks. This reduces project costs and allows investors to obtain loans from banks more easily. Furthermore, grants are not only limited to capital grants; project preparation grants are also available for resource assessments and preparation for the project. This will make obtaining loans when the project is in the preparation stage easier. However, the risk of this mechanism is that public sectors may gain control of projects if grants are the major fund for investments.

The case study discussed below shows that the U.S. government used grants effectively to attract renewable energy investments. The U.S. government enacted the American Recovery and Reinvestment Act (ARRA) in 2009 and spent USD 60 billion in community investments (smart meters, weatherization projects, and green buildings), USD 11 billion on smart grids and extension of investment tax credit (ITC) for solar uptake. In the section 1705, Temporary Program for Rapid Deployment of Renewable Energy and Electric Power Transmission Projects, the U.S. government spent USD 16 billion on wind and solar energy investments and stimulated investments amounting to USD 10 billion from the private sector. This program has increased the installed renewable energy capacity of the U.S. by 6.1 GW and will generate 14.5 TWh annually.

- Venture Capital Equity

Equity funding from public sources to support renewable energy projects can comprise of long-term investments. Venture capital financing is usually for new technologies and companies. Such funds are incubated, thus allowing more investors to join and develop markets for advanced renewable energy technologies.

- Soft Loan and Project Financing

Different loans provided by the public sector such as soft loans, loan guarantees, and project financing reduce project costs by providing long-term finance.

Providing lower interest rates or project financing can help initiate project implementation and attract investors. The government of the Republic of Korea proposed eco-friendly energy towns in 2014 with three demo-sites, using new eco-friendly technology in landfills and incinerator plants. Determining the location and technology of each site was under the town's autonomy and the government provided low interest financing and capital grants for investments.

- Bond

Since this financing mechanism depends on bonds and not on loans, the costs may be lower than the interest rate from banks. The funding of different projects can be combined into one bond. This is a good tool for expanding the capital market and lowering the risk for public sectors.

- Resource Insurance

There are different types of insurances that reduce different risk for investors such as resource insurance and political insurance. The resource insurance guarantees return to investors if renewable energy generation is not sufficient, for instance, the investors of hydro power plants can obtain insurance during dry years. Political insurance guarantees protection against political or regulatory risks. This guarantees protection against risks from changes in policy and regulatory commitments by the host economy. The table shows financing options for overcoming financing barriers and obstacles.

Table 8 Financing Options for Overcoming Financing Barriers and Obstacles.

	Grants	Venture Capital Equity	Loan	Bond	Resource /Political Insurance	Tax Credit
Lack of long-term financing	Y		Y	Y	Y	
Lack of project financing	Y	Y	Y	Y	Y	
Project development		Y				Y
Small scale of project	Y		Y			
High financial cost	Y		Y	Y	Y	Y
Regulatory risk					Y	
High costs of resource assessments	Y				Y	
Uncertainty over resource adequacy					Y	

Source: World Bank, 2012

4.4 Innovations in Renewable Energy Technology

4.4.1 Research

Reduction in greenhouse gas emissions is the main driving force behind the increase in innovations related to renewable energy technology. Advancements in renewable energy technology will improve energy efficiency and security, resulting in the expansion of renewable energy use. Moreover, new and emerging renewable energy technologies act as catalyst for economic prosperity and provide jobs to highly skilled workers. Some recommendations for renewable technology development and innovation are discussed below.

4.4.1.1 Increase innovations in each renewable technology

- Concentrating solar thermal power (CSP)

Recently, three CSP facilities have been coupled with thermal energy storage, which stabilizes power supply. Besides, CSP facilities are on a significant growth trajectory with as much as 900 MW expected to enter operation in 2017. Additionally, CSP is receiving increased policy support in economies with a need for energy storage (REN21, 2017a).

- Wind energy

The efficiency of integrating wind energy into the electricity sector and the adoption of electric vehicles in the transportation sector has been studied. The result obtained indicates that the introduction of wind power through vehicle-to-grid technologies could mitigate the intermittency of wind energy and reduce greenhouse gas emissions. Fluctuations in newly integrated wind power could be balanced by using electric vehicles and vehicle-to-grid technologies (Zhao et al., 2017).

- Bioenergy

A study has shown that waste-based biorefinery technologies is promising for the conversion of municipal solid waste (MSW) to energy. The waste-to-energy technologies include anaerobic digestion (AD), transesterification, pyrolysis, and refuse derived fuel (RDF). In Makkah city, waste-based biorefinery technologies are used to produce energy, generating savings of about Saudi Arabian Riyal (SAR) 87.6 million from carbon credits. Additionally, net revenue of SAR 758 million can be generated from landfill diversion and electricity generation. Moreover, 1.95 million barrels of oil and 11.2 million MCF of natural gas could be saved by using waste-to-energy processes (Nizami et al., 2017).

- Hydrogen energy

The transportation sector is focused on finding ways to utilize renewable energy. Hydrogen from renewable resources is regarded as one of the most suitable candidates for transitioning to 100% renewable energy. Overall planning of the energy system at the local, national, and global levels is required to integrate renewable hydrogen and electricity into the existing system. Hydrogen, one of the most abundant elements in nature and efficient energy carriers, can solve the energy crisis, particularly with respect to transportation and storage (Uyar and Beşikci, 2017).

- Electric vehicles

Use of electric vehicles has become a promising way to reduce greenhouse gas emission. Additionally, the economic attractiveness of electric vehicles can be enhanced as the cost of conventional fuels increases due to fuel taxes such as carbon pricing, which needs to be implemented in parallel with grid de-carbonization efforts. The prerequisites for promoting the use of electric vehicles are convenient battery charging stations, cheaper electric vehicles and batteries, and financial support from the government for the manufacture of electric vehicles and construction of charging stations (Chellaswamy and Ramesh, 2017; Li et al., 2017a).

- Energy storage

Various energy storage technologies are available including mechanical, chemical, electrostatic, magnetic, biological, and thermal. Furthermore, energy storage can be divided into two categories: short-term storage and long-term storage. Energy storage technologies benefit the environment by reducing greenhouse gas emissions and provide remarkable monetary savings. Water is the most conventional and traditional heat storage element. However, due to the low thermal conductivity of water in the vapor state, the applications of water as a heat storage medium are limited. The use of thermal energy storage (TES) materials in solar collectors for storing solar thermal energy has been widely studied (Ahmed et al., 2017). The use of nanomaterials (e.g., Zeolite 13X, silica gel, and activated alumina) for solar thermal storage has also been evaluated (Lefebvre and Tezel, 2017).

Additionally, the use of biomass-derived renewable carbon materials for storing electrochemical energy has been studied. Materials that are widely used for constructing supercapacitors and lithium-sulfur batteries are activated carbon, porous carbon, carbon fibers, graphene, and fullerene. Especially, graphene is regarded as a good charge carrier for batteries due to its large surface area. Graphene batteries have higher energy density, which is beneficial for renewable energy storage for vehicles. Due to the increased demand for large capacity batteries in electric vehicles, graphene batteries have become a key element in the development of electric vehicles. Common carbon materials are costly and often derived from nonrenewable resources under harsh environments. Currently, various types of porous carbon materials can be produced from natural and renewable biomass materials (e.g., activated carbon fibers are produced from cotton). Carbon materials derived from biomass are effective in improving the energy density of supercapacitors and in inhibiting the dissolution of reaction intermediates in lithium-sulfur batteries (Gao et al., 2017; Li et al., 2017b).

4.4.1.2 Goals and actions of technology cooperation

First, the APEC economies can work together to identify research strengths and gaps in renewable energy technologies. Subsequently, the APEC economies can evaluate targeted funding sources, coordinate research efforts, and collaborate on demonstration projects. Finally, economies can explore ways to commercialize the results of renewable energy research and innovation, including technological products, internationally. This will create opportunities for innovation and accelerate the growth of energy sectors including micro-grids, clean technologies, and renewable energy (Canada’s Premiers, 2015). The recommended goals and actions of the different phases are described in Table 9.

Table 9 Goals and Actions for the Different Phases of Advancing Renewable Energy Technologies.

Phase	Goal	Action
I.	Enhance the efficiency of renewable energy technology in terms of safety and sustainability of energy production, storage, transmission, and distribution of energy, and resilience to climate change and its impacts.	Identify existing gaps in renewable energy technology and barriers against the development of novel technology. Support the development of novel and efficient renewable technology to overcome limitations due to climatic condition and expand the use of renewable energy resources in the existing renewable energy systems.
II.	Encourage cooperation between key stakeholders across economies to enhance knowledge sharing concerning innovation, demonstration, production, and use of renewable energy technologies.	Share best practices related to the demonstration and implementation of technologies through multilateral agreements. Facilitate collaborative research projects between governments, industries, and academic institutions.
III.	Adopt optimal approaches to enhance innovations in the processes, products, and services of renewable energy development.	Create a new financing mode for renewable energy innovations to expand markets and attract investors.

4.5 Capacity Building

Advanced technologies, sufficient funds, and an adequate and qualified workforce are cornerstones to increase the share of electricity generation from renewable sources. Promotion of renewable energy will be difficult without well-trained and skilled workers from various sectors. This project provides some strategies and identifies target groups to be considered when implementing training programs for building a capable workforce.

4.5.1 Strategies for Developing Training Programs

- Conduct Assessment to Identify Gaps Between Current and Future Market Prospects

If stakeholders in the renewable energy industry believe that there is a need for quality training in a particular region, the first step should be undertaking a needs and gap analysis (ISES, 2017). The gap analysis should identify the current and future market prospects of various technologies It is important to evaluate the demand of trained workers for developing renewable energy in the coming years based on the information on the market situation.

The evaluation trained workforce requirement should include two aspects: how many trained workers are required and what are the vocational skills they should possess. To determine the number of trained workers required, an analysis of the approximate number of workers required per MW of installation for each RE technology being deployed within that economy or region and the time taken per MW installed (IEA, 2017) should be undertaken. Detailed information on the specific vocational skills required, which is related to the design of training programs, can be acquired through discussions with project developers, planners, and installers.

- Develop Training Programs Based on the Existing Programs

The renewable energy sector engages workers from a wide range of fields, including electricians, engineers, plumbers, and mechanics. Therefore, diverse categories of training programs exist. Collecting information on the current training programs would be the first step in developing new training programs. Further planning of training programs should be based on an analysis of the status of existing training programs.

It is beneficial to build training courses on the basis of existing technical and vocational programs. Training courses for electricians or plumbers, for instance, can be combined with existing training courses for electricians and plumbers instead of creating an entirely separate course for the renewable energy sector. The advantages of integrating renewable energy-focused curriculum and activities with the existing vocational training and apprenticeship are more efficient training performance due to the existing foundation, benefits from the existing network connection, and more cost-effective than creating entirely separate programs.

It is important for government policymakers to work in conjunction with industries and educational institutions for establishing guidelines and criteria for clean energy training. With practical experiences, industry partnerships can create effective standards for certification and are often well suited to provide training on key topics.

Therefore, communication and consultations between government, industries, and educational institutions are important for developing an appropriate renewable energy training program that can cultivate a professional workforce to satisfy the need in the market.

- Design the Quality Framework of the Renewable Energy Training Program

One of the key activities in designing a quality framework is the formation of an entity comprising of key government departments or ministries, major industry players, industry associations, donor communities, training centers, universities, and interested individuals or bodies. This entity is responsible for overseeing the development of training programs and conducting regular reviews of the training framework. Additionally, requirements and standards for the training centers should be established to ensure quality. The standards for registered training organizations of the Australian skills quality authority has been applied to the training programs for workers in the renewable energy sector for over 10 years and is a suitable establishing related requirements.

- Create a Regional Training Approach

Since the APEC is an international organization, whose members share a common goal of developing renewable energy and have a tight cooperation and connection, building a regional training approach for clean energy is important. Regional coordination for certification and training requirements can enable economies to share the burden of developing programs, which is especially beneficial for smaller economies, and allow job portability of skilled workers to meet market needs in a broader area.

A standardized regional training program can create job opportunities in the domestic market and encourage community engagement. Mutual recognition of certificates will ensure uniform requirements from the workforce and standards for developing renewable energy projects. It will also enhance cooperation and knowledge exchange among the economies, which makes the implementation of new projects and technologies more efficient and scalable.

4.5.2 Targets Groups for Workforce Development

In addition to the strategies for developing training programs, which have been discussed above, the promotion of renewable energy requires cross-sector collaboration between governmental policy makers, private institutions, utilities, and financial institutions. The contribution of each sector is indispensable for the performance and efficiency of renewable energy development. Therefore, it is essential to develop specific training programs for each sector.

- Governmental Policy Makers

Government officials play a vital role in the development of renewable energy. These include inspectors, regulators, and policy makers of local and central governments. Every decision of government officials could significantly affect the viability of the renewable energy technology. Therefore, training of governmental policy makers is essential. This training program should focus on improving the capacity of decision-making, execution, supervision, and risk management.

The quality of decision-making could directly affect the performance of renewable energy development. Therefore, it is important to train the policy makers establish policies that ensure the feasibility of each renewable energy technology. The capacity of execution could influence the practical efficiency of renewable energy deployment. If, for example, a local or central government official is unable to publish a transparent tender with clear requirements and follow an efficient tendering procedure, then the confidence of developers might be lowered. Supervision and risk management abilities are also necessary for government officials to implement policies and cope with emergencies.

- Private Institutions

Private institutions include private companies, technicians, planners, engineers, associations, chambers, business incubators, and small and medium entrepreneurs. Programs that support enterprises in the development of new businesses can increase its likelihood of success. Both financial support and advisory services, which can build business knowledge and skills of companies, are equally important.

A comprehensive training program provided by government can strengthen confidence of private institutions thereby attracting investments in renewable energy. Such training programs should focus on government policy promotion and supporting resource acquisition. A detailed assessment of renewable energy resources, market analysis including identifying market needs and opportunities and addressing supply chain need and gaps, technical assistance, and supportive financing programs are required. Business programs that are designed to support research, development, and deployment of renewable energy technologies can also support the development of new markets.

- Utilities

Utilities play an important role in renewable energy generation since they are responsible for ensuring energy supply and protecting grid security and their existing infrastructure. Integrating a high volume of renewable energy, for example, would seriously affect the operation of the existing grid. In a number of economies, utilities are responsible for grid upgrading and maintenance. Therefore, it is essential for governments to train utilities to enhance their knowledge of new technologies and risk reduction.

Governments can educate electric and thermal utilities and businesses that supply fuel to increase their understanding of new technology, encourage joint efforts to resolve technical concerns, and bring them in as valuable future stakeholders of this market. Education and engagement of existing energy utilities and infrastructure can help identify issues and requirements and formulate standards for the integration of new renewable energy sources into the energy market. This can build confidence and lower the risks associated with new technologies.

- Financial Institutions

Financial problem is a key challenge for promoting renewable energy since the development of renewable energy requires large capital and strong financial support. Educating financial institutions, such as commercial banks, development banks, micro finance institutions, and savings associations, about the high risk associated with renewable energy exploitation and high cost of installation can helps establish a robust and supportive mechanism in the economies. This would effectively accelerate investments in the renewable energy industry.

The training program for financial institutions should focus on providing technical knowledge of renewable energy technologies, analysis of market potential, and financial instruments. Peer-to-peer training provides perspectives of experienced members of the financial community. Demonstration projects that actively engage the local financial community can build their understanding of renewable energy. Sharing of experiences and successful case studies between economies is a great way for training financial institutions, especially for financial institutions in developing economies. Educating financial institutions could be a cornerstone for developing renewable energy and helps ensure financing and greater market acceptance of new renewable energy projects.

4.5.3 Public Awareness Building

Public acceptance of clean technologies deeply influences the promotion of renewable energy in the economies since energy supply directly affects the daily life of the public. Compared to nuclear energy, renewable energy is positively perceived by the public and has a higher acceptance level. This is because renewable energy is environmentally friendly and is less dangerous than nuclear energy.

However, on-site implementation of renewable energy projects commonly faces strong opposition from local communities. The resistance of local communities, related interest groups, and non-governmental organizations can sometimes seriously impede the progress of projects thereby resulting in considerable delays. Therefore, it is essential for governments to enhance public awareness for facilitating smooth renewable energy installations. Concepts and issues related to renewable energy projects should be identified and discussed with the public to enhance public awareness. Additionally, the tools to be used for renewable energy promotion and target groups should be considered.

4.5.4 Information for Building Public Awareness

- Motivation for Developing Renewable Energy

The first step for enhancing public awareness is to illustrate the reasons for developing renewable energy. The threat of climate change and the risks associated with nuclear power have forced economies to pursue a sustainable energy system. It is important for governments to analyze and compare the advantages and disadvantages of using renewable energy, fossil fuels, and nuclear energy. A transparent and fair discourse would help to build trust between the government and the public, which is crucial for forming public consensus.

Governments could focus on the global initiatives in renewable energy to emphasize the importance of developing renewable energy. Examples of such global initiatives include the intended nationally determined contributions (INDC), which was proposed by countries in the UNFCCC COP 21 and the commitment of companies around the world, such as Walmart, Costco, Google, and ASDA, to reduce their carbon footprint and adopt renewable energy. All these examples can be used to educate the public, enhance awareness of using renewable energy, and obtain a public consensus.

- Introduction of Renewable Energy Technologies

After a public consensus on the development of renewable energy is established, enhancing public knowledge of renewable energy technologies, which are unfamiliar for the public, is important. A basic introduction to renewable energy technologies might be necessary for building public knowledge, which can in turn enhance the efficiency of communication between governments and the public.

Each type of renewable energy has diverse characteristics. Governments should link these characteristics to its advantages for the economies and emphasize on the characteristic that are most likely to be developed to enhance public understanding of renewable energy projects. Some economies, for example, have great geothermal potential, while some have abundant solar resources. In this way, the public can identify the most suitable technology for their economy. This will help governments in the promotion and implementation of related policies.

- Illustration of Government Policy and Supporting Measures

Policy promotion is one of the most significant issues for developing renewable energy in economies. Based on the enhanced public knowledge and public consensus, which were discussed in above, a transparent policy illustration could help accelerate public acceptance for deploying renewable energy installation. A transparent and clear policy declaration shows the determination of the government and builds public confidence, which is important for building public awareness

In the policy illustration, governments need to clearly declare their goals and the policies and methods to be adopted to attain these goals. Additionally, related supporting measures, which are implemented to mitigate the impacts of developing renewable energy, are equally important. Moreover, communication with the public is necessary in each stage. Governments will achieve better results in public awareness building if they establish a bilateral communication mechanism instead of a one-way communication mechanism.

4.5.6 Target Groups

The campaigns for public awareness building should be designed depending on the target group. Generally, target groups can be divided into students, general public, local communities, and relevant organizations. Each group can further be divided into different sub-groups. The content of campaigns designed for students, for example, would be different for junior, senior, and college students and the campaigns designed for the public would be different depending on the social economic level and consumption habit. Additionally, the geographical area might be another factor that should be considered when designing the campaign content.

Local communities and relevant organizations, such as environmental groups, animal protection groups, and fishermen's associations play a crucial role in protests against renewable energy deployment. This is because the drawbacks of renewable energy installation might directly affect their interest and affect their daily life or because it is against the mission of certain organizations. According to the findings of this project, when communicating and negotiating with local communities and relevant organizations, it is important to focus on supporting measures and compensating measures. Moreover, it is necessary to collect comprehensive information on international case studies and global creditable research in the specific field. This information can be used as evidence to support government policies and convince the local communities and relevant organizations to allow renewable energy deployment.

4.5.7 Tools

A number of tools are available for enhancing public awareness; it is important to select appropriate tools for different target groups and different purposes. Educational displays or events might be suitable for students while for the public with professional knowledge, workshops, conferences, or seminars on specific topic might be considered. To promote awareness in younger generations, social media platforms like Facebook, Twitter or Instagram might be an effective approach. Moreover, tools for collecting feedbacks and public opinions are as important tools for delivering information. Different characteristics of different tools can be used to establish connection with different groups. Therefore, it is essential for governments to analyze and group the public into different target groups to select the most suitable approach for strengthening public awareness.

4.5.8 Gender Equality and Renewable Energy Development

- Public Policies

A legal framework to support the employment of women in the renewable energy sector should be established. First, we need to identify the potential sectors where women can be employed, so that we can allocate budgets and establish policies for the right sector.

Off-grid, micro-grid, and standalone renewable energy initiatives often employ a large number of women. These initiatives are deployed at the local level where women are more likely to be involved in the procurement, design, installation, operation, maintenance, and consumption of energy. These women also participate in decision making because larger energy utility systems require high-level professional staff (Cohen, 2017).

Policies that support gender equality requires contractors in public sectors to adopt affirmation action goals to correct the underrepresentation of women in their workforce. These sectors, for instance, need to employ the required number or percentage of women. Women would have more opportunities to join renewable energy industries and participate in decision making and planning through such pro-women policies, which give women more opportunities to be trained and employed.

- Government Funds

Government spending through stimulus packages and public procurement can address gender inequality (Stevens, 2009). Establishing a designated fund to promote gender equality in the renewable energy sector would have demonstration effects. It will ensure availability of adequate financing for renewable energy projects and designing different renewable energy training courses for women and men to incubate human resource development in the renewable energy field to be employed as researchers, policymakers, engineers, procurement officers, and operators.

The U.S. government has earmarked significant stimulus funding in the after math of the 2008 financial crisis for a green initiative and funds were allocated for the integration of women into green occupations; these are good examples of initiatives that promote gender equality (Cohen, 2017). Under the American Recovery and Investment Act of 2009, the U.S. government allocated USD 27 billion for training women to be employed in renewable energy and energy efficient industries and investments. These pilot initiatives for promoting gender equality have influenced women to participate in renewable energy fields.

- Training Program

Training programs are designed to build the capacity of both men and women to work in the renewable energy field. Therefore, the APEC economies need to design renewable energy courses for different target audience such as policymakers, designers, managers, and suppliers to establish their knowledge on renewable energy and related tools.

Furthermore, it is necessary to design different courses and programs for different target groups since different target groups have different objectives, interests, and abilities. Therefore, it would be better to design different programs for men and women and for cities and rural areas. It is important to increase the capacity of women in rural areas so that they can participate in renewable energy sectors. The training programs designed for local women can focus on teaching them how to maintain renewable energy facilities and training them to develop skills and access to capital and markets in the energy sector.

- Building Network for Women

Networks of women researchers and policymakers and women from local organizations to share knowledge and information should be supported and established. Websites can be built to serve as a platform to centralize and share related information and for outstanding women to share their experiences.

- Scholarship

Women could have more opportunities to enter universities, research institutes, or laboratories and gain knowledge related to renewable energy if they have financial support. Consequently, women will have more opportunities to enter the fields of renewable energy technology, engineering, and mathematics at a professional level. Another organization that provides scholarships for women in the field of renewable energy is the clean energy council, which offers scholarships to women to improve gender balance in leadership and board positions of the renewable energy sector. This scholarship aims to support a female employee from a clean energy council member company to undertake the Australian institute of company directors (AICD) foundations of directorship course.

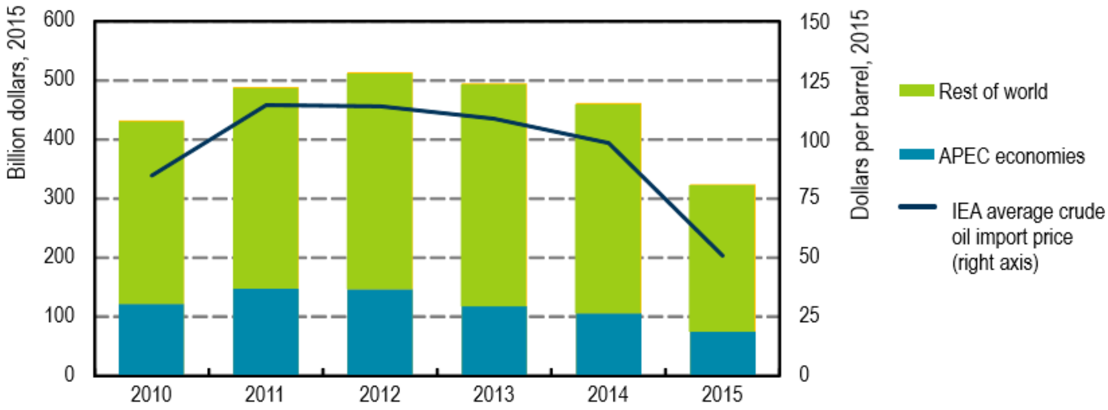
4.6 Market Reform

4.6.1 Reduce Fossil Fuel Subsidy and Maintain Reasonable Electricity Price

Electricity price is one of the factors that directly affect the development of renewable energy. Providing subsidies is the most common method used by governments to control electricity price. In the APEC region, governments of some economies provide significant fossil fuel subsidies to maintain low energy costs. In the long term, this has resulted in a serious market distortion, which hinders the development of renewable energy. According to a research conducted by the Global Subsidies Initiative (GSI), the impacts of fossil fuel subsides on renewable energy development include weakening the cost-competitiveness and reducing fiscal space of renewable energy and distorting investment decisions of public and private sectors (IISD, 2014).

With the awareness of the impact which caused by fossil fuel subsidies, APEC has reaffirmed their landmark 2009 commitment to “rationalize and phase out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption while recognizing the importance of providing those in need with essential energy services" in 2015. According to IEA's report, Tracking fossil fuel subsidies in APEC economies, the fossil fuel subsidies in APEC region have declined since 2011, and the share of APEC economies in the global estimate for fossil fuel subsidies fell from 30% in 2010 to around 20% in 2015 Figure 14), reflecting the region's progress with pricing reforms (IEA, 2017).

Figure 14 Trend in Fossil Fuel Consumption Subsidies in APEC Economies



Source: IEA, 2017

Although the trend in fossil fuel consumption subsidies in APEC region has declined, in some economies the expenditure of fossil fuel subsidies still accounts a certain proportion in government budget. The findings of this project suggest that reducing fossil fuel subsidies and maintaining a reasonable electricity price is critical for developing renewable energy in the APEC region. It is necessary to continue to reform fossil fuel subsidies, especially for economies with subsidies that account for a higher percent of GDP. Recently, based on the recommendations of the APEC fossil fuels subsidy reforms peer review, six economies have conducted fossil fuels subsidy reforms. These economies are New Zealand, Peru, the Philippines, Chines Taipei, and Viet Nam. Furthermore, other economies including China, Indonesia, Malaysia, Mexico, Thailand, and Viet Nam are also devoted to conducting fossil fuel subsidy reforms. Conducting subsidies reform may follow three approaches: reduce fossil fuel subsidy gradually, enhance the subsidy for renewable energy, and impose external costs on electricity generated from fossil fuels.

Removing and reducing fossil fuel subsidies is the most direct approach, which would help to reflect the generation cost for each energy type, for correcting distortions in the electricity market. This will reflect the cost advantage of renewable energy. According to a report of the IEA, in areas with abundant resources, hydro, geothermal, on-shore wind, and solar photovoltaic technologies are currently more cost-competitive than new fossil fuel based plants, even without generation-based subsidies (IISD, 2014). Therefore, removing fossil fuel subsidies gradually will benefit the development of renewable energy in the market by increasing cost competitiveness.

However, cutting fossil fuel subsidies is not an easy process for economies since it is tightly linked with society welfare, economic aspects, interests of numerous groups, and political aspects. Considering the challenges of removing fossil fuel subsidies mentioned above, providing incentives to renewable energy is another method for correcting the imbalance between the costs of renewable energy and fossil fuels. The incentives for renewable energy such as FiT and tax exemption are widely implemented by many economies with significant results. However, there are some risks involved if incentives are provided incorrectly. As in the case of removing subsidies for fossil fuels, doing away with incentives after they have been implemented over the long term is likely to be difficult. Therefore, the governments should consider all potential effects during the policy design stage to avoid market distortion.

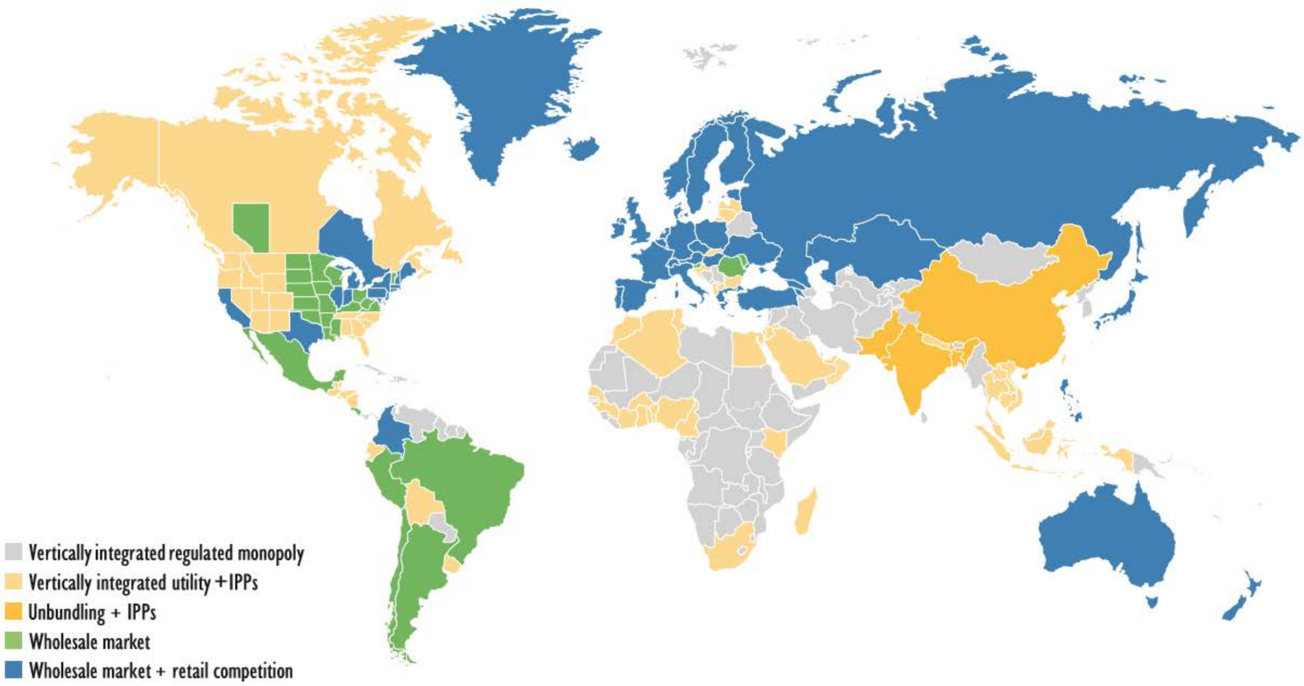
In addition to providing subsides for fossil fuels and renewable energy, a reasonable electricity price may be maintained by considering the environmental and social costs of using fossil fuels. Some examples of such a mechanism are the introduction of carbon tax and the payment of fees to discharge water used in cooling processes (IISD, 2014). In conclusion, it is important for economies to mitigate the market distortion caused by subsidies and regulate electricity price structure to maintain a more reasonable electricity price. This will attract investments and is significant motive to develop new power sources to serve the increasing demand for energy in the future.

4.6.2 Electricity Market Design for Integrating Renewable Energy

The electricity market plays a crucial role in the development of renewable energy. Since the characteristics of renewable energy generation and fossil fuel generation are not similar, their degrees of competitiveness in the electricity market of each APEC economy will be different. In this project, APEC economies have been classified based on the status of its electricity market and the challenges of integrating renewable energy generation to provide suitable recommendations for economies with different status of electricity market liberalization.

4.6.2.1 Electricity Market in the APEC Region

Figure 15 Map showing the Status of Electricity Market Liberalization



Source: IEA, 2016b

The IEA has divided power market into four types based on the degree of competition: vertically integrated regulated monopoly, vertically integrated utility with independent power producers (IPPs), unbundling IPPs, wholesale market, and wholesale market with retail competition. Figure 15 shows the status of power markets around the world. Most APEC economies including Canada; Indonesia; Malaysia; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam have adopted vertically integrated utility with IPPs. Australia; Brunei Darussalam; Japan; New Zealand; the Philippines; and Russia have power markets with the highest degree of liberalization. Power markets in Korea and Papua New Guinea are monopolized governmental enterprises. China; Hong Kong, China; Chile; Mexico; and Peru have adopted unbundling IPPs and wholesale market (Table 10).

Table 10 Electricity Market Design of the APEC Economies

Electricity Market Design	Description	APEC Economy
Vertically integrated regulated monopoly	Pure monopoly	Republic of Korea; Papua New Guinea
Vertically integrated utility + IPPs	Most basic level of competition; existence of (IPPs)	Canada; Indonesia, Malaysia; Singapore, Chinese Taipei; Thailand; the United States; Viet Nam
Unbundling IPPs	Represents a further step in market reform; vertically integrated utilities are divided into distinct companies, which either own or operate generation assets or the transmission grid and distribution network with related services	China, Hong Kong; China
Wholesale market	Allows power producers to compete for the sale of electricity to utilities	Chile; Mexico; Peru; parts of Canada; the United States
Wholesale market + retail competition	Represents the ultimate degree of market liberalization	Australia; Brunei Darussalam; Japan; New Zealand; the Philippines; Russia

Source: IEA, 2016b

4.6.2.2 Challenges of Accommodating Renewable Energy in the Electricity Market

Electricity market reforms are required because of the difference in the characteristics of renewable energy and fossil fuels. There are some challenges that power markets with a high share of renewable energy will inevitably encounter. These include capital intensity and low-run marginal cost, limited predictability, and variability, and decentralized and scattered generation (IEA, 2016).

Table 11 presents the challenges for power systems and power markets caused by the properties of renewable energy. The first challenge is caused by the capital intensity of renewable energy. High capital intensity, low-run marginal cost, and the changing cost structure of renewable energy generation affects the “marginalist market” and alters the optimal power generation mix. Furthermore, the increased power price volatility driven by high shares of renewables will magnify the impact of current power market imperfections and make fixed cost recovery even more challenging (IEA, 2016).

The second challenge is caused by the most obvious characteristic of renewable energy sources i.e., limited predictability and variability. The capability of short-term dispatch coordination and stability of power systems need to be enhanced due to this property of renewable energy. Additionally, spot market and ancillary service designs that can cope with the variations caused by the use of renewable energy are required.

The last challenge is caused by the decentralized and scattered generation of renewable energy. Since most sites of renewable energy generation are located away from densely populated load centers, the geographic coordination between power generation and power grids is a challenge for power market design. Therefore, planning the operation and expansion of transmission and distribution grids is crucial. Moreover, for prosumers who generate and consume electricity at a single site, the charging the retail price rather than the wholesale price might be considered as an incentive for investment and dispatch (IEA, 2016).

Table 11 Challenges for Power System and Market Design

RE Property	Power System Challenges	Market Design Challenges
Capital intensity	➢ Changing cost structure ➢ Optimal generation mix shift	➢ Fixed cost recovery and cost of capital ➢ Credible investment incentives
Limited predictability and variability	➢ Short-term dispatch coordination ➢ Time horizon of power system operation shortens ➢ Assurance of system stability	➢ Price volatility and uncertainty ➢ Spot market design ➢ Design of ancillary services
Decentralized and scattered generation	➢ Transmission and distribution grid planning and operation	➢ Geographic coordination between generation and grid ➢ Prosumers: retail pricing and metering rules

Source: IEA, 2016a

4.6.2.3 Suggestions for Electricity Market to Accommodate Renewable Energy

- **Risk Transfer Mechanism for Capital Intensity**

To address the issues of capital intensity, fixed cost recovery, and high-risk exposure, policy makers can consider a mechanism of risk transfer and risk hedging that ensures financeability and bankability of capital-intensive technologies (IEA, 2016a). Furthermore, considering the low-run marginal cost of renewable energy, the current structure of liberalized electricity market might be no longer suitable for the promotion of renewable energy (KAPSARC, 2016). Economies that are in the process of market liberalization should pay attention to this key issue.

- **Enhancement of Short-Term Markets for Limited Predictability and Variability**

Power systems with a large share of renewable energy will need to maintain power balance closer to real time. This requires a market design that appropriately reflects the short-term system operation costs (IEA, 2016a). Therefore, the design of short-term markets should be enhanced and refined at all levels, including timelines, bidding formats, clearing and pricing rules, and their integration with reserves and regulation markets (IRENA, 2017).

Furthermore, the characteristic of decentralized generation from renewable energy would affect the operation of transmission and distribution systems. Governments should consider adopting policies that support innovation and smart and unconventional solutions, such as smart grids. Smart grids could significantly enhance the controllability and responsiveness of highly distributed resources within electric power systems.

- **Coordination between Transmission and Distribution**

Suitable sites for renewable energy generation tend to be far from densely populated load centers. This circumstance means more plants are connected to a distribution grid and results in scattered market participation. Therefore, coordination between transmission and distribution networks and establishing new rules to accommodate a large number of small players becomes important (IEA, 2016a).

4.6.3 Renewable Energy Certificates

There are diverse measures to promote renewable energy, such as feed-in Tariff (FiT), feed-in Premium (FiP), bidding, net metering, renewable portfolio standard (RPS), and renewable energy certificates (REC). **Table 12** presents the measures adopted by each economy. The table shows that FiT is the conventional incentive for promoting renewable energy in the APEC region. This is because the public can understand FiT better than other incentives and it ensures the purchase price for developers. However, since the FiT supports emerging technologies in their prime stage, with the gradual decrease in the cost of the technologies and the increase in the fiscal burden of governments, the use of FiT as an incentive might not be feasible in the long-term.

Table 12 Measures for Promoting Renewable Energy in the APEC Economies

Economies	FiT	FiP	RPS	Bidding	Net Metering	REC
Australia	Y		Y			Y
Brunei Darussalam						
Canada	Y				Y	Y
Chile					Y	
China	Y		Y			Y
Hong Kong, China						
Indonesia	Y					
Japan	Y				Y	Y
Korea			Y	Y	Y	Y
Malaysia	Y					
Mexico						
New Zealand						
Papua New Guinea						
Peru				Y		
The Philippines	Y		Y		Y	Y
Russia		Y		Y		
Singapore						
Chinese Taipei	Y					Y
Thailand	Y					
United States	Y		Y	Y	Y	Y
Viet Nam	Y		Y		Y	

REC is a pathway for renewable energy generation to return to the market mechanism. The price of the certificates is determined by the supply and demand in the green energy market and the tradable characteristic of the certificates. Aligned with the current global trend of carbon reduction, numerous multinational companies have declared a voluntary commitment to adopt 100% renewable energy. An example is the global renewable energy initiative RE100 taken by more than 80 of the most influential companies in the world. Such actions by large-scale multinational enterprises will stimulate the demand of REC in different regions of the world including the APEC region since multinational corporations have several overseas branches.

Since multinational enterprises should use a certain proportion of green energy to comply with the standards set by the parent company REC can be a significant mechanism for economies to attract investments from such enterprises. Identifying and analyzing the demand of renewable energy in the market would be the first and the most important step for establishing an REC mechanism. Findings answers to questions such as the potential target groups for REC, their motivation for purchasing REC, volume of REC needed by the market, and standard of REC likely to be accepted by the market, is essential for building a successful REC system.

It is important to ensure that the standard of REC issued by the economy is recognized by the government of foreign investors for markets where RECs are mainly sold to multinational enterprises; otherwise the REC would be worthless to the investors. Hence, the communication and discussions with foreign investors is necessary. Another way for ensuring that the standard of REC is acceptable is to apply the existing international REC standards, such as the renewable energy certificate, which is promoted by Google in the Asian region, the guarantee of origin of the European Union, and the international renewable energy certificate (I-REC), instead of creating a new one. Economies should conduct a comprehensive market investigation before making decisions related to such standards.

5. Conclusion

The findings of this project indicate that when APEC economies develop renewable energy, they are faced with a number of arduous challenges. These challenges include policy inconsistencies, insufficient power infrastructure, large capital costs of renewable energy, insufficient projects for improving the efficiency of renewable technologies, lack of qualified and skilled workers, insufficient public awareness, and the challenges related to power system and market design.

The policy recommendations of this project propose various strategies to deal with such challenges. Amending renewable energy laws and strengthening renewable energy policy commitments are avenues to improve policy consistency. To solve the problem of insufficient power infrastructure, introducing micro-grids and smart grids could provide decent advantages for renewable energy development in rural regions and a more efficient transformation of grid functions. Additionally, providing refundable and/or non-refundable investment tax credits, grants, and venture capital equity would help overcome the issue of large capital cost of renewable energy development.

To solve the issue of insufficient projects for improving the efficiency of renewable energy technologies, increasing innovations related to each renewable energy technology and expanding technology cooperation would accelerate renewable energy development in the APEC region. Furthermore, developing training programs based on existing programs, developing training programs for specific sectors, and conveying the advantages of renewable energy could solve the problems such as lack of qualified and skilled workers and insufficient public awareness. Market reforms such as managing risk transferring mechanism for capital intensity and enhancement of short-term markets for limited predictability and variability, and RECs would beneficial to introduce a higher volume of renewable energy into the market.

The APEC region has entered a new era of renewable energy. Based on the findings of this project, we can conclude that the APEC economies should propose various renewable energy development plans to support the goal of doubling the share of renewable energy. Additionally, the APEC economies should review their renewable energy development goals periodically. It is strongly believed that these strategies would stimulate diversification of renewable energy sources, increase energy autonomy, and demonstrate the determination of the APEC region to promote renewable energy development. In this way, the APEC region could achieve the goal of doubling the share of renewable energy generation by 2030 and move towards a sustainable future.

Since the findings of this project are limited by time and resource, we suggest establishing a comprehensive roadmap in the future that includes biofuel and thermal energy development in the APEC region. Moreover, it is important to establish a follow up mechanism to track renewable energy development in the APEC region.

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Industrial Technology Research Institute, Chinese Taipei
195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Chinese Taipei 31040
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
www.apec.org

APEC#217-RE-01.27
ISBN: 978-981-11-6325-8