Promotion of Energy Resilience for Renewable Energy Infrastructure in the Asia-Pacific Region

Kampanart Silva*, Pidpong Janta, Nuwong Chollacoop

National Energy Technology Center (ENTEC), 114 Thailand Science Park
Phaholyothin Road, Klong Nueng, Klong Luang, Pathum Thani 12120, Thailand

*Corresponding author
Email: kampanart.sil@entec.or.th

Abstract

Energy resilience is a concept to build the capacity of energy infrastructures against disasters and climate change. There are several energy resilience initiatives in the Asia-Pacific region at both policy and grassroots levels. APEC Energy Working Group issued APEC Energy Resiliency Principle which is a policy document that identifies factors, initiatives, and stakeholders that will improve energy resilience against disasters. ASEAN started its efforts at the grassroots level with the ASEAN Energy Resilience Assessment Guideline that can be used as a guide for an assessment of a solar power system. ASEAN brought energy resilience up to the policy level when it issued the 7th ASEAN Energy Outlook in which a chapter has been dedicated to the discussion on measures to enhance the resilience of the energy sector. Inclusion of energy resilience in the Philippine Energy Plan and the actual energy resilience assessment of a solar power plant in Thailand serve as practical examples of energy resilience initiatives in the region. Both of the examples have been discussed in this paper.

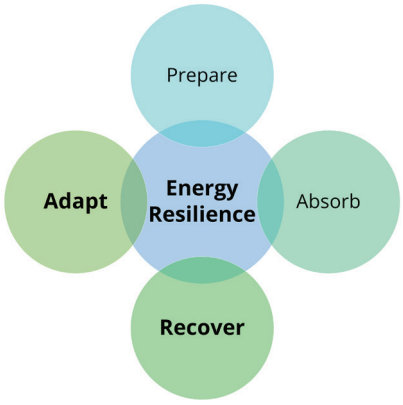
Introduction

Resilience has gained increasing interest among countries and international organizations as it is believed to strengthen the adaptive capacity of critical infrastructure. The term "resilience" appeared in at least two important Sustainable Development Goals (SDGs) by United Nations (2015), Goal 11: Sustainable Cities and Communities which suggests cities and human settlements to adopt integrated policies and plans toward resilience against disaster and create financial scheme and technical support for building resilient infrastructures, and Goal 13: Climate Action which recommends nations to cultivate resilience and adaptive capacity against climate-related hazards and natural disasters. Glasgow Climate Pact which is the result of the 2021 United Nations Climate Change Conference (COP26) (UNFCCC, 2022) also acknowledged the importance of resilience as it ensures global recovery after calamities and emphasized the urgency of creating actionable supporting scheme in terms of finance, capacity building, and technology transfer to enhance and strengthen resilience against climate change. Priority 3: Investing in disaster risk reduction for resilience under Sendai Framework (United Nations, 2015) introduces a similar idea. It emphasizes the role of public and private sectors in investment in disaster risk reduction to enhance resilience of individuals in economic, social, health, and cultural aspects.

Above-mentioned global commitments have proved that climate change and disasters can bring about great impacts to individuals and critical infrastructures. Particularly for the energy systems, the concept of resilience plays an important role in coping with the impacts. It is a key concept that contributes to the enhancement of climate adaptability of energy infrastructure and facilities. A number of global initiatives show strong interest and willingness to adopt the concept of energy resilience to strengthen and prepare energy infrastructures. This approach is helping these energy infrastructures to withstand impacts from climate change that are increasing in severity. The rise of energy resilience has led to several initiatives in the Asia-Pacific region at both policy and grassroots levels, and this article provides a glimpse of these initiatives along with the ways to promote the concept at different levels.

Energy resilience

The concept of energy resilience (also known as energy resiliency) is a strand of the resilience concept that was originally introduced by Holling (1973). Energy resilience is vague in definition, and the way it has been defined and interpreted varies from one discipline to another. Introduced and originated in ecology, resilience emphasized a system's ability to withstand disturbance by absorbing the impacts that occurred and can still restore to pre-disturbance conditions (Sharifi, 2016). One of the widely adopted definitions of energy resilience is *the ability to prepare for and adapt to changing conditions, and withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents* (Presidential Policy Directive 21, 2013). This ideal concept has further developed to four basic elements of energy resilience: *plan/prepare*, *absorb*, *recover,* and *adapt*, as shown in Figure 1.



Source: Roege et. al., 2014.

Figure 1. Basic elements of energy resilience concept

Though a common understanding about energy resilience has somehow been agreed upon, many of the studies or initiatives are still at the stage of a conceptual framework and the development of metrics or criteria for resilience assessment. Thus, several countries in the Asia-Pacific region realized the necessity of raising awareness of the concept in a larger pool of audience and putting it into practice in energy systems in their own countries. The study of the concept of energy resilience has emerged and received even more attention as the concept can be integrated not only at the policy level where resilience policy can be enforced to build adaptive capabilities of critical energy infrastructure against disruptive events, but also at the operational level where energy resilience assessment can be performed for energy infrastructures, in particular renewable energy systems, to understand the gaps to be fulfilled in order to maintain the functionality of the system during undesired disruptions. The initiatives to promote energy resilience in the Asia-Pacific region at policy and grassroots levels have been discussed further.

APEC Energy Resiliency Principle

Asia-Pacific Economic Cooperation (APEC) first introduced the concept of energy resilience in 2015 in the Cebu Declaration (Asia Pacific Energy Portal, 2015), where APEC Economies affirmed the importance of energy resilience to promote energy security and achieve sustainable development in 2015 APEC Energy Ministerial Meeting with the theme of "Towards an Energy Resilient APEC Community." Energy resilience was believed to help secure stable energy supply by effectively dealing with natural and man-made disasters which have been recognized as a continuous challenge of the region. Later, the APEC Energy Working Group (EWG) established Energy Resiliency Task Force (ERTF) to enable focused discussion on the concept. ERTF is co-chaired by the Philippines and the United States (DOE, n.d.). ERTF Secretariat launched APEC Energy Resiliency Principle (ERTF Secretariat, 2020) in the 59th APEC EWG Meeting in August 2020 in Malaysia. APEC Energy Resiliency Principle defines energy resiliency as the ability and quality that enables for energy systems to withstand extreme natural and manmade disasters and to recover and return to normal conditions in a timely and efficient manner and to build back better. The Principle focuses on identifying the framework and a comprehensive set of factors, initiatives, and stakeholders that will improve energy resiliency against disasters. It recommends that governments establish regulations, standards, and guidelines for energy resiliency plans, and encourages the energy supply industries, other industries, and general energy consumers to formulate and implement energy resiliency plans. It also suggests financial institutions to evaluate, invest, and finance public and private projects that help enhance energy resiliency. Finally, the Principle advocates APEC Economies to balance cost, risk and performance of energy resilient infrastructure with asset management systems (ISO, 2014), adopt emerging technologies, and take voluntary measures to share best practices on energy resiliency enhancement among stakeholders.

APEC EWG has taken several follow-up actions, under ERTF, based on the APEC Energy Resiliency Principle. Japan, another active member of the ERTF, proposed two projects to put the Principle into practice. One was the Workshop on Energy Resilience Principle (APEC, 2020) to promote the dissemination of the Principle, build the capacity of the energy sector, and draft a Guideline based on experience and views of APEC Economies to match the Guideline with the local context of each APEC Economies. The other was the APEC Energy Resiliency Enhancement Project (APEC, 2021) which aimed to develop an energy resiliency evaluation model, create Energy Resiliency Sectoral Guidelines for energy infrastructure companies, and raise awareness of energy resiliency in the region. Apart from these activities that are directly linked to the APEC Energy Resiliency Principle, there was also a Workshop on Improving Energy Resiliency in Off-grid Areas in APEC Member Economies, led by the Philippines, that resulted in Guidelines to Develop Energy Resiliency in APEC Off-Grid Areas (APEC Energy Working Group, 2017) which will contribute to the enhancement of energy resiliency of marginalized and off-grid communities. The United States held an APEC Workshop on Promoting Resilience in the Energy Sector, which led to the solutions to promote resilience in the energy sector against climate change (APEC Energy Working Group, 2018).

The issuance of the APEC Energy Resiliency Principle along with the establishment of ERTF and other supporting initiatives show the eagerness in the APEC energy sector to work at the policy level to enhance the resilience of energy infrastructure in the Asia-Pacific region. APEC EWG also tries to engage all relevant stakeholders and suggest the mechanisms to make the Principle practical by developing an evaluation model, creating guidelines, and holding training sessions.

ASEAN Energy Resilience Assessment Guideline

On the other hand, efforts to promote energy resilience in the Association of Southeast Asian Nations (ASEAN) start at the grassroots level. National Energy Technology Center (ENTEC), Thailand, tailored the Self-Guided Reference for Practitioners of National Renewable Energy Laboratory (NREL) (Stout et al., 2019), by introducing

the change over time of the risk and modifying some assessment items to match ASEAN local context (see Figure 2), and used it to conduct four energy resilience assessments of four different renewable energy systems, including a state-owned on-grid solar power plant, a rural solar microgrid, a commercial biomass power plant, and a community biogas plant. Based on the assessments and the findings from a bibliometric study (Janta et al., 2022), it was concluded that the assessment would better fit a solar power plant compared to other renewable energy systems. The assessment framework was further adjusted to suit the assessment of solar power plants in ASEAN.

ENTEC, with the support of the Office of the Permanent Secretary of the Ministry of Higher Education, Science, Research and Innovation (MHESI), made energy resilience a 2021 annual priority of the ASEAN Committee on Science, Technology and Innovation (COSTI) to address the United Nations' Sustainable Development Goals (UN SDGs) (COSTI, 2021). ENTEC then developed the ASEAN Energy Resilience Assessment Guideline (ENTEC, 2022) and had it endorsed by the ASEAN Sub-Committee on Sustainable Energy Research (SCSER) at the 50th SCSER Meeting, and consequently by COSTI at the 82nd COSTI Meeting, both in October 2022 (COSTI, 2022). The Guideline is recommended to be used for energy resilience assessment of a solar farm in ASEAN, though it can also be applied to a large-scale solar rooftop or a large-scale solar carpark. The Guideline has been used to assess the 50 MW_{AC} Gambang Solar Power Plant of Universiti Teknologi MARA (UiTM) (ENTEC, 2022) and the 2.8 MW_{AC} UiTM Penang Solar Rooftop and Solar Integrated Carpark (ENTEC, 2022).

As the ASEAN Energy Resilience Assessment Guideline is positioned to promote the assessment at the grassroots level, it includes the standard operation procedure (SOP) for energy resilience assessment which is accompanied by a detailed description of each step to help the assessment team go through the assessment from the beginning to the end. As shown in Figure 2, the assessment starts from the identification and scoring of threats, followed by the assessment of impacts from those threats, identification, and scoring of the vulnerability of the system and its surroundings. The risk pairings and their scores are then obtained by multiplying the threat and vulnerability scores; these scores will be evaluated for changes over time. Finally, energy resilience solutions are proposed, and the feasible ones are selected for implementation at the site by the owner. Another emphasis of the Guideline is the active participation of the stakeholders. The assessment team (usually composed of technical experts) will basically facilitate the assessment while the operators, the owners, and other direct stakeholders will perform the assessment. The Guideline contains sample worksheets to be used during the assessment as well as instructions for performing it with stakeholders. This ASEAN Guideline can complement the effort of APEC EWG to promote the concept of energy resilience at the policy level by encouraging actual energy resilience assessment in ASEAN Member States (AMS) which will result in various energy resilience solutions to be implemented in solar power plants in ASEAN.

Energy Resilience in the 7th ASEAN Energy Outlook

Lately, ASEAN has also started to incorporate the concept of energy resilience at the policy level. The 7th ASEAN Energy Outlook (AEO7) issued by ASEAN Centre for Energy (ACE) (ACE, 2022) in October 2022 includes a dedicated chapter to discuss the measures for energy resilience. AEO7 explores the scenarios to fulfill the targets set forth in the ASEAN Plan of Action for Energy Cooperation (APAEC) (APAEC Drafting Committee, 2020) to increase the renewable energy share in the total primary energy supply and in the installed power capacity to 23% and 35%, respectively, and reduce the energy intensity by 32% based on 2005 level, by 2025. AEO7 also incorporates the facts that several AMS made challenging commitments at the 2021 United Nations Climate Change Conference of Parties (COP26) (Safrina, 2021) and that AMS have to build back stronger and more sustainable from the COVID-19 pandemic.

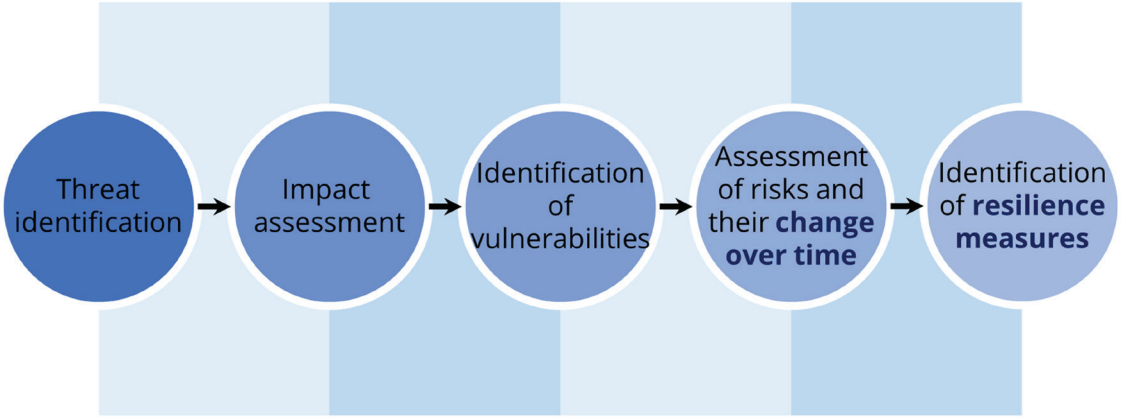


Figure 2. Energy resilience assessment flow

To enhance the energy resilience of the region, AEO7 explores the technologies for grid integration and the strategies to enhance the ability of dispatch of renewable energy in order to deal with a larger share of variable renewable energy (VRE). It suggests the utilization of fossil fuels during energy transition as they can be a strategic reserve for AMS to ensure energy resilience and an emergency supply against unexpected events. It also covers important topics to ensure resilient energy transition, including necessary transformation to improve industrial efficiency, consideration of financing clean energy to achieve carbon neutrality, and management of safety and social acceptance of nuclear power.

Practical Examples of Energy Resilience Initiatives in the Asia-Pacific Region

This section discusses the practical examples of energy resilience enhancement activities being conducted in the Asia-Pacific region. The subsection on energy resilience in the Philippine Energy Plan shows the realization of the APEC Energy Resiliency Principle at the national level while the subsection on energy resilience assessment of an actual solar farm in Thailand demonstrates the practicality of the ASEAN Energy Resilience Assessment Guideline. Note that though both examples happened before the establishment of the Principle and the Guideline, they can serve as good showcases on how the Principle and the Guideline can be put into practice to support future usage of the two new documents.

Energy Resilience in Philippine Energy Plan

The Philippines is one of the top-runner countries in the application of energy resilience concept in its policy making. Philippine Department of Energy (DOE) issued a Department Circular in 2018 on Adoption of Energy Resiliency in the Planning and Programming of the Energy Sector to Mitigate Potential Impacts of Disasters, the so-called Energy Resiliency Policy (DOE, 2018). It aims to build the capacity of energy infrastructure to adapt and withstand disruptive events, to be able to reconstruct and rehabilitate after being damaged by the events, to have standards and practices to ensure rapid restoration, and to develop resiliency standards for future energy facilities. It requires energy supply industries to submit the Resiliency Compliance Plans (RCPs) which include structural and nonstructural measures to ensure an appropriate response to and recovery after disasters and strengthen the preparedness of the energy infrastructure. Apart from the self-funding by the energy supply entities, the Energy Resiliency Policy also encourages the government to help finance the implementation of RCPs. It also documents the creation of the Task Force on Energy Resiliency to facilitate the policy and requires DOE to issue appropriate guidelines to support the implementation of the Circular.

Thanks to the issuance of the Energy Resiliency Policy, the latest 2020-2040 Philippine Energy Plan (DOE, 2022) includes resiliency and security of energy infrastructures as one of the strategic focus areas. The document includes policies, strategies, and measures formulated and/or implemented by DOE to improve the energy resiliency of energy infrastructure and facilities. It starts with the assessment of RCPs submission with a plan to join hands with the United States Agency for International Development (USAID) to evaluate the submitted RCPs to determine common and smart practices and identify gaps and challenges. It then summarizes the preparedness and response of the energy sector against emergencies, large disasters, compound disasters, and COVID-19 which can act as a list of best practices for energy supply industries. The document also indicates the ways to rehabilitate damaged energy facilities through the Build Back Better Principle and the plan of DOE to find pragmatic financing solutions for energy resiliency development, for example, an insurance mechanism.

The integration of the concept of energy resilience into the policy making of the Philippine energy sector is apparently in line with the APEC Energy Resilience Principle. The government plays a role to establish an energy resiliency policy which starts with the requirement for the development of RCPs by energy supply industries and includes guidance on how to enhance the resiliency of energy infrastructure and facilities in the updated national energy plan. The energy supply industries also gradually submit the RCPs which will be reviewed to extract good practices and recommend relevant changes. A study team is also being established to consider financing schemes for public and private investment in energy resiliency enhancement.

Energy Resilience Assessment of Solar Power Plant in Thailand

A state-owned 700 kW_{AC} solar farm at Asian Development College for Community Economy and Technology (adiCET), Mae Rim Campus, Chiang Mai Rajabhat University (CMRU), to demonstrate the feasibility of solar power plants in a governmental entity was chosen for the case study of energy resilience assessment (adiCET and ENTEC, 2021). Various stakeholders joined the assessment, including the operating team, the Dean and the Vice Dean of the College, the faculties and the students of adiCET, and the representatives from respective faculties in Mae Rim Campus who are the users of the electricity from the solar farm. The top five threats identified by the stakeholders based on the information on historical events gathered by the operating team appear in the left column of the risk matrix shown in Figure 3. Surprisingly, most threats are man-made, except for the invasion by animals which can increase due to climate change and bushfire, which is a compound disaster (drought and arson). Stakeholders were asked to use the framework shown in Figure 4 to assess the impacts of respective threats. Based on the threats and the associated impacts, stakeholders identified the top five vulnerabilities that appear on the top row of the risk matrix shown in Figure 3. Risk pairs were considered one by one, and the irrelevant pairs were omitted (those appear in black). The risk score was calculated by multiplying the threat score to vulnerability score. Darker pink color

of the risk cell shows a higher risk score. Note that all the scores were intentionally omitted. Top eight risk pairs were selected based on the risk scores. Table 1 shows the extensive list of resilience solutions that the stakeholders proposed to address the risks of the 700 kW_{AC} CMRU Solar Power Plant. As most resilience solutions can address multiple risks, they were sorted by the most highly associated threat for simplicity. Then, the assessment team evaluate the changes over time in the loss of opportunity to sell electricity due to the top risk pairs and the changes over time when the resilience solutions were applied to alleviate the risks. The reduction of opportunity loss was compared with the investment required for the solutions to determine their feasibility. Resilience solutions in orange characters which are economically viable were selected. Most of them were associated with the improvement of operation and maintenance schemes and procedures which can be done relatively easily by the operating team. The rest were the installation or storage of inexpensive equipment which made them feasible. The entire results were shown to the CMRU Executives for their consideration. It led to the approval of the installation of fire belts which is among the costliest resilience solutions that cannot be covered by adiCET.

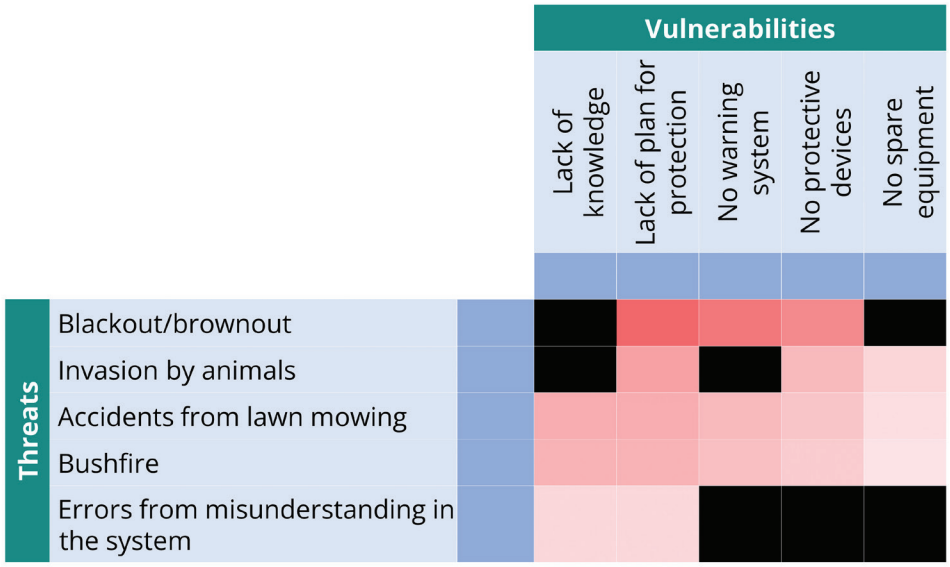


Figure 3. Risk matrix for 700 kW_{AC} CMRU Solar Power Plant

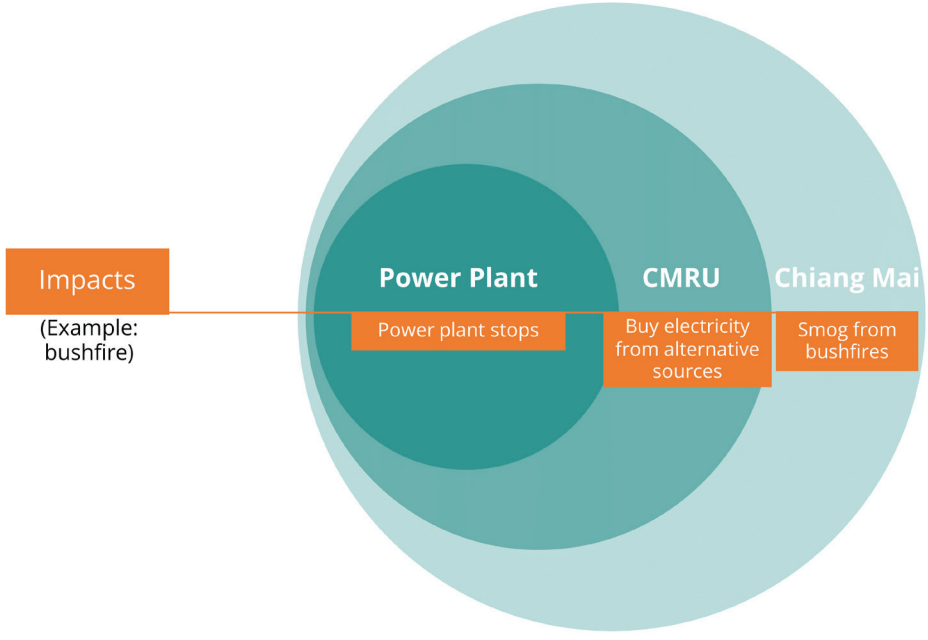


Figure 4. Impact assessment framework for 700 kW_{AC} CMRU Solar Power Plant

Threat	Resilience solutions	
Blackout/brownout	**Without equipment failure** • Installation of energy storage system • Installation of islanding system • Installation of warning system • Collaboration with PEA • Installation of diesel generator	**With equipment damage** • Planning for preventive maintenance • Emergency planning • Maintenance & repair training, and storing spare parts & devices
Invasion by animals	• Installation of animal protection equipment • Periodic lawn mowing / branch cutting	• Maintenance & repair training, and storing spare parts & devices
Lawn mowing accidents	• Installation of sign for lawn mowers	• Storing spare parts & devices
Bushfires	• Fire belts	• Installation of fire monitoring system

Table 1 List of selected resilience solutions for 700 kW_{AC} CMRU Solar Power Plant

By following the procedure indicated in the ASEAN Energy Resilience Assessment Guideline, the assessment team could facilitate an assessment that was done by the direct stakeholders. The evaluation of changes of risks over time helped the assessment team identify the feasible resilience solutions. The assessment also led to the implementation of several solutions that can significantly contribute to the resilience enhancement of the 700 kW_{AC} CMRU Solar Power Plant. This case study demonstrates the capability of the Guideline to promote energy resilience enhancement activities at the grassroots level.

Way forward

The Asia-Pacific region has been promoting the concept of energy resilience at the policy level to equip the energy infrastructure and facilities with an ability to withstand, respond to, recover from, and adapt to disruptive events, including rapid onset events such as disasters and slow onset events like climate change. As both APEC and ASEAN have energy resilience included in their energy-related documents: APEC Energy Resilience Principle and a chapter to discuss measures to ensure energy resilience in the 7th ASEAN Energy Outlook, the next step would be to propagate the concept to national energy plans of that Asia-Pacific countries. In this sense, the government has a very important role in putting energy resilience into practice as the energy supply industries will be opted to start including the concept in their operation when the government put it as a requirement. In addition, government would also need to create a supporting mechanism to finance the investment for energy resilience enhancement in order to accelerate the process.

On the other hand, promotion of energy resilience enhancement at the grassroots level is also inevitable. ASEAN Energy Resilience Assessment Guideline will serve as a good guidance for solar farm owners who want to build their capacity against disruptive events. As the APEC Energy Working Group is also developing guidelines for energy resilience enhancement that take into account local context and conditions in respective sectors, energy enterprises would start initiatives to enhance the resilience of their infrastructure and facilities accordingly when the guidelines are available. Workshops or training to facilitate the practical usage of these guidelines would be beneficial for energy enterprises in the Asia-Pacific region. Apart from capacity-building programs for the transfer of clean energy technology, the Asian and Pacific Centre for Transfer of Technology (APCTT) may consider expanding its scope to cover the capacity-building programs to facilitate resilient and sustainable usage of such technology.

With the promotion of energy resilience at both policy and grassroots levels, the Asia-Pacific region will be able to enhance the resilience and the adaptability of energy infrastructures against disruptive events, especially renewable energy systems which are relatively vulnerable to disasters and climate change. Therefore, it will also contribute to the increase in the regional share of renewable energy. The concept of energy resilience will perfectly synchronize the efforts to address Goal 7: Affordable and Clean Energy and Goal 13: Climate Actions of the United Nations' Sustainable Development Goals.

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