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Accommodating Disruptive Technology into RE&EE Policies for Energy Security

APEC Energy Working Group

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Contents

Table of Figures

Executive Summary

Disruptive technologies have emerged in the renewable energy and energy efficiency sectors which have rapidly change the global energy landscape. Disruptive technology is defined as a technology, which create a new business model that could disrupts a traditional business model. These disruptions generate a revolution in technology capability, digital transformation, cost, new business model, and change of policy. A number of energy-related technologies has become the game changers of energy demand and supply in APEC region and the world. APEC economies had agreed upon two energy-related goals: 1) 45% energy intensity reduction by 2035 and 2) doubling the share of renewable energy by 2030. Therefore, the new disruptive energy developments could aid to achieve the APEC goals as well as securing the profits of reliable, affordable, and sustainable energy.

This report aims to systematically illustrate the landscape of different disruptive technologies in the energy arena in three sectors, including power, building and transportation with the focus on enabling policy and driving mechanism, the analysis of impact and market, and the forecast of future trends. Twelve key disruptive technologies were identified and classified according to relevant sectors namely Smart Grid, Microgrid, Blockchain, AI, IoT, W2E, Energy Storage and 2nd Generation Power, Green Hydrogen, Green Building, V2G, and CASE. There are several technologies with important roles at the interface between two sectors (e.g., microgrid linking power supply to households and buildings, hydrogen linking power production to transportation). There are also technologies that may disrupt all sectors: smart grid and blockchain. This report also include summary of the "APEC Workshop on Accommodating Disruptive Technology into RE&EE Policies for Energy Security" which was organized virtually on April 29-30, 2021. The objective of the workshop was to share the best practices on the current disruptive technologies on power generation/distribution, transport, and buildings sectors as well as brainstorm necessary RE&EE policies to ease integration of disruptive technologies for energy security.

Understanding the impact of disruptive technologies on different sectors of energy, including power generation and distribution sector, transportation sector, and building sector, is crucial and necessary, as it will allow disruptors to move further over time. Some technologies affect across the three sectors, bringing greater effects to the society. Smart grid, microgrid and blockchain are among those technologies that enable the exploration of coming digital nexus across multiple areas which allow the stakeholders to make full use of the energy. They contribute to increase in renewable energy, and also enhancement of energy efficiency. They facilitate generation, delivery, distribution, and integration of various energy sources, most importantly renewable energy. To accommodate the disruptive technologies, it is necessary to call for a strong policy support. To promote the technologies in appropriate markets, it requires customer support and empowerment as well as incentives and subsidies from government to make up economic viability gap for renewable energy and energy efficiency projects. Regulatory sandboxes or demonstration projects are also good approaches to introduce new technologies to the market. Reduced taxation for investors who invest in these technologies should also be introduced to facilitate technology penetration. On the other hand, it is also important to ensure that the technologies are beneficial and not harmful to human being and society.

1. Introduction

Currently, global energy sector is being disrupted by the rapid change of technologies. The disruption creates a change in cost, technology capability, new business model, digital transformation, and change of policy. The challenge in new energy development focuses on securing the profits of reliable, affordable, and sustainable energy[1]. To manage and cope with the disruption, understanding situation to accommodate level of disruption could reduce future risk and create sustainability in all businesses. For the identification of disruption level, Disruptability Index was developed by Accenture, which could be used to assess current disruption as well as forecast future disruption susceptibility. Figure 1 shows that when breaking out the scores, based on high or low susceptibility and current disruption, into quadrants, each sector thus could be classified in one of four distinct periods, namely *durability, vulnerability, volatility or viability*. It was found that energy sector presents high in the volatility quadrant[2].

An outstanding example of energy disruption could be seen in energy generation industry using coal as a main resource. In the past ten years, coal demand has remained broadly flat while demand of other type of energy resource has increased, as well as the change of policy and society. The increasing of new energies utilization especially renewable energies such as PV and wind turbine creates a prosumer model by changing energy user to be able to produce their own power and consume power. The combination of smart grid and prosumer could transform to new type of disruption in the free trade energy market.

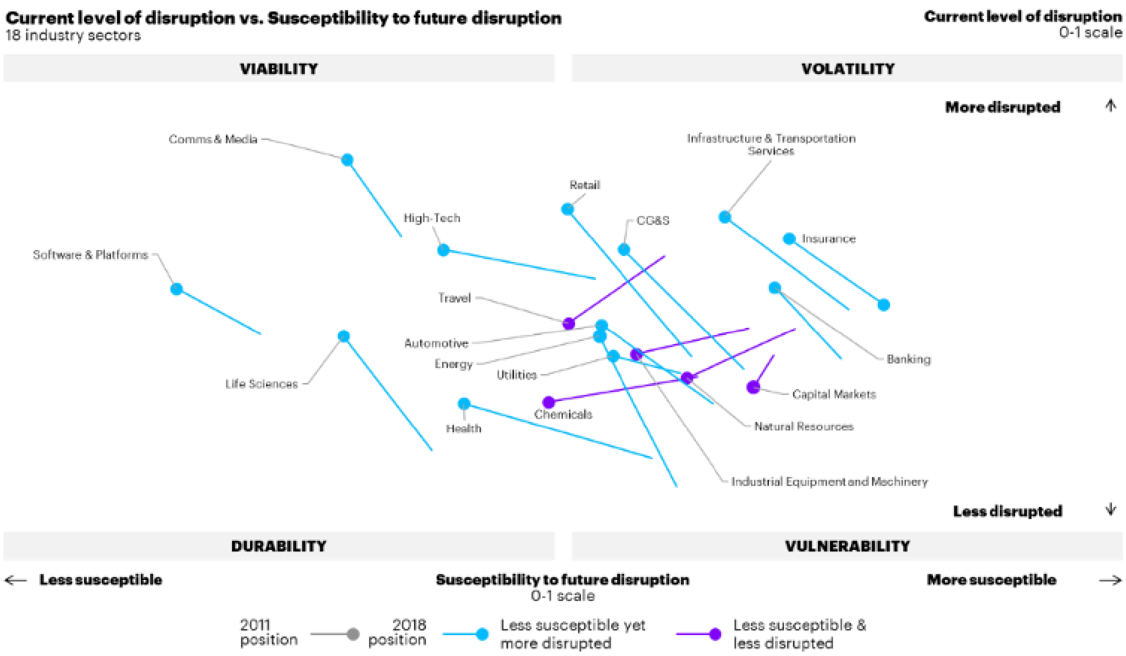

Figure 1 Level of disruption

[1] World Energy Council. (2019). *Designing for Disruptions*. London: World Energy Council, https://www.worldenergy.org/assets/downloads/Designing_for_Disruption_FINAL_for_website.pdf

[2] https://www.accenture.com/us-en/blogs/blogs-good-things-come-those-who-dont-wait

Disruptive technology is defined as a technology, which create a new business model that could finally disrupts a traditional business model[3]. Disruptive technologies could emerge from the improvement, integration of current technologies or formation of entirely new challenge ones[4]. This report aims to systematically illustrate the landscape of different disruptive technologies in the energy arena and their contributions to increase share of renewable energy and level of energy efficiency in three sectors, including power, building and transportation. In power sector, disruption will occur in both supply and demand sides. Starting from the supply side, new renewable sources (so-called second-generation power sources) will increase the significance of renewable energy in the energy market. Increasing awareness on importance of sustainable development has also led to more environmental-friendly energy production, for example, turning household and agricultural wastes to energy. Energy storage systems (e.g., batteries) help store excessive power produced by variable renewable energy (VRE) and discharge them for use when electricity demand exceeds electricity supply. Virtual power plant (VPP) is also a new concept of power production, which aggregates various small power production from renewable energy sources into a larger virtual power production system that can supply to a large number of customers. As for the demand side, key technologies that will significantly increase the efficiency in the management of electricity demand are internet of things (IoT), artificial intelligence (AI) and blockchain. IoT and AI will help monitor and control the usage of electricity in households and industries. On the other hand, blockchain eases the purchase and sale of individual customers, prosumers, and small power producers. Buying and selling of the electricity can be done through smart grids (including mini grids and micro grids), which has become significant energy infrastructures playing a crucial role along with conventional electrical grids. Other than electricity, hydrogen will also become another cost-effective energy-storing medium to enable effective use of energy, especially renewable energy.

Shifting to the building sector, the main technological driver is green building. Having in mind the goal to achieve environmental sustainability and carbon emission reduction, green building concept introduces new features to a number of functions in houses and buildings, e.g., more energy-efficient lighting, smart heating and cooling, and solar panels or other renewable energy systems as the building power generation system. To enable efficient power supply from these renewable energy systems, smart grids and microgrids, along with IoT and blockchain, help connect different power producers and power consumers to ensure sound power distribution and smooth power transaction. Finally, for the transportation sector, the key disruptive technologies can be summarized using the terminology CASE (Connected, Autonomous, Shared, and Electric). Thanks to the digital evolution, future vehicles will be connected to the driver, to each other and to the regulating agencies via digital platform. However, drivers may not be essential anymore since future vehicles will be able to move autonomously. The number of vehicles may also decrease as the shared mobility platform will allow people traveling to nearby destinations to travel in shared vehicle. Lastly, shifting from internal combustion engine to electric vehicles will considerably change energy usage in the transportation sector. Changing from fossil fuel-based vehicles to electricity-based vehicles will increase the efficiency in the energy usage, and reduce the carbon dioxide emission.

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[3] Hajebrahimi, A., Kamwa, I., & Huneault, M. (2018). A novel approach for plug-in electric vehicle planning and electricity load management in presence of a clean disruptive technology. Energy, 158, 975-985.

[4] Kostoff, R. N., Boylan, R., & Simons, G. R. (2004). Disruptive technology roadmaps. Technological Forecasting and Social Change, 71(1-2), 141-159.

Electric vehicles could become a power storage system, which can supply the electricity back to the main grid when needed (for example, during power failure or disaster).

Figure 2 shows the landscape of disruptive technologies in building, transportation, and power sectors. Out of many technologies mentioned above, key technologies were identified and classified according to relevant sectors. There are several technologies with important roles at the interface between two sectors (e.g., microgrid linking power supply to households and buildings, hydrogen linking power production to transportation). There are also technologies that may disrupt all sectors: smart grid and blockchain. The following section will describe the nature of these technologies, followed by the summary of enabling policy and driving mechanism, the analysis of impact and market, and the forecast of future trends.

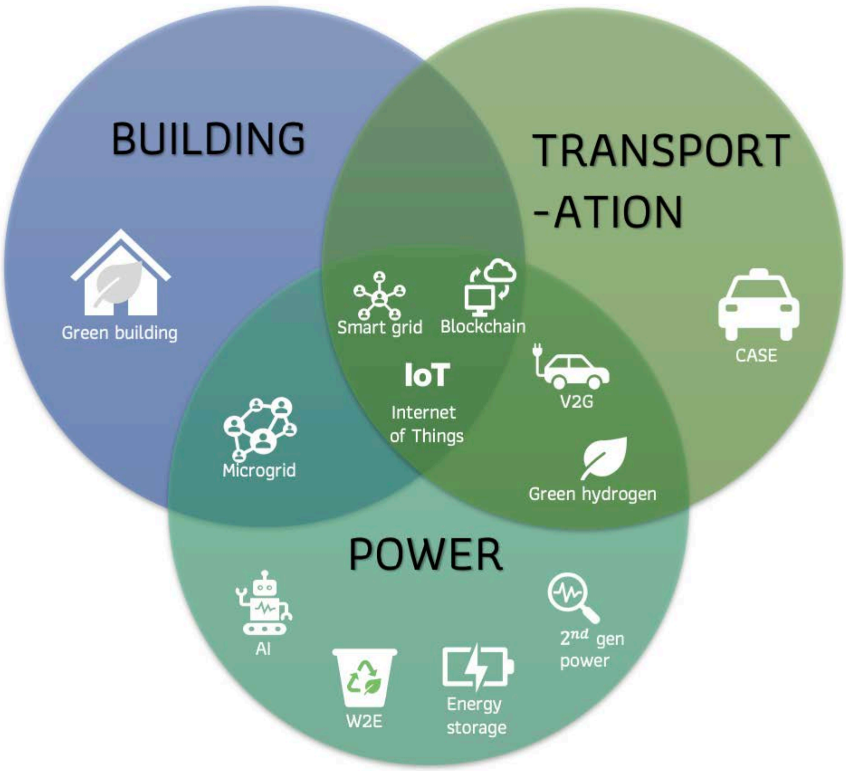

Figure 2 Disruptive technologies in building, transportation, and power sector

2. Review of Disruptive Technologies for Renewable Energy and Energy Efficiency

2.1. Power – Transportation – Building Sector

Smart Grid/Microgrid

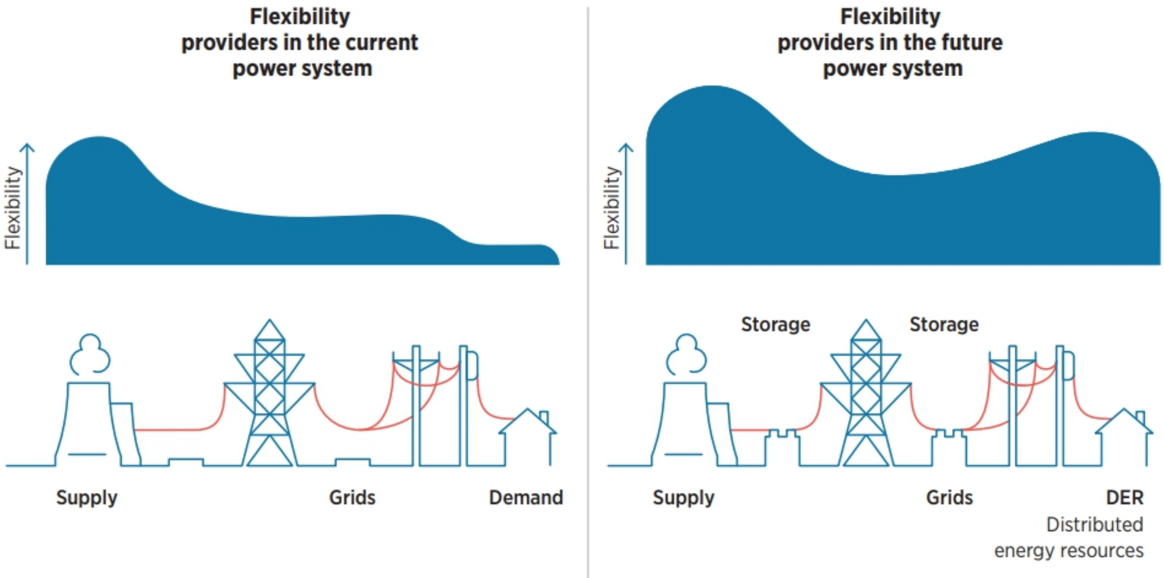

Figure 3 Flexibility Options across Power Sector provided by Innovations[5]

Technology Description

Smart grid is an intelligent technology that modernizes electricity grid by the combination of various innovations together to obtain self-healing, adaptive, resilient, and sustainable power system with foresight for prediction under different uncertainties. Smart grid employs innovative products and services along with smart control, communication, monitoring, as well as power forecasting system to provides flexibility to power system and manage power exchange including of delivering, managing, and integrating green and renewable energy technologies (Figure 3)[6,7,8].

The microgrid is a small distribution grid which is physically appeared at the load centers. It could be fueled by several resources such as solar, wind, biomass, hydro, diesel, and natural gas. Microgrid also comprises few additional micro sources like diesel engine

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[5] IRENA (2019). Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables. International Renewable Energy Agency, Abu Dhabi.

[6] IRENA. (2020). Renewable Energy and Jobs-Annual Review 2020, International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Sep/IRENA_RE_Jobs_2020.pdf

[7] International Energy Agency. (n.d.). Smart Grids. Retrieved January 8, 2021, from https://www.iea.org/fuels-and-technologies/smart-grids

[8] Mollah, M. B., Zhao, J., Niyato, D., Lam, K. Y., Zhang, X., Ghias, A. M., Koh, L.H., & Yang, L. (2020). Blockchain for future smart grid: A comprehensive survey. IEEE Internet of Things Journal.

generator, microturbine to improve capacity and reliability of the system. Besides this, few energy storage systems like battery storage system, ultra-capacitor and flywheel energy storage are utilized to manage grid energy efficiently. Microgrid systems are popular in the grid-independent application in several communities in developing economies due to the challenge of poor and inefficient power grid infrastructure[9,10].

Policy & Driving Mechanism

Smart Grid

Smart Grid Projects are capital intensive so the regulatory approval for capital investment is an important step in the project development. Smart grid technologies are still developing and hence many, smart grid projects were taken up as pilot demonstration projects by various utilities in the world. Regulators must put in place financial incentives structures that appropriately reward smart grid investments by the utilities or private sector. However, regulators all over the world have basically given importance to the impact of investments on consumer tariffs, improvement in quality and reliability of consumer supply/services due to smart grid projects and cost benefit analysis, to ensure that alternative better ways of investments are not available to render the similar benefits. Therefore, the smart grid policy, regulations and incentives were launched in series for renewable energy, smart meters, net metering policies, interconnection standards & rules, dynamic pricing policies, EVs, energy storage, V2G, grid modernization, telecommunication, etc.[11].

Microgrid/Minigrid

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

- Enabling policies and regulatory structures for interconnected minigrid
- Legal and licensing provision for private sector to generate, distribute and sell electricity to consumers.
- Standardization of renewable minigrid
- Tailored approach to tariff regulations to catalyze private sector minigrid development
- Access to funding and long-term investment

Impact & Market

- High cost of smart grid is considered a primary barrier to its adoption.
- Between 2008 to 2017, annual average investment in smart grid is approximately $3.61 billion. If this level of investment continues, this would put

[9] Sahu, P. C., Prusty, R. C., & Panda, S. (2020). Improved-GWO designed FO based type-II fuzzy controller for frequency awareness of an AC microgrid under plug in electric vehicle. Journal of Ambient Intelligence and Humanized Computing, 1-18.
[10] Akinyele, D., Olabode, E., & Amole, A. (2020). Review of Fuel Cell Technologies and Applications for Sustainable Microgrid Systems. Inventions, 5(3), 42.
[11] Smart Grid Handbook for Regulators and Policy Makers (2017), India Smart Grid Forum, Shakti Sustainable Energy Foundation

spending well below estimates made by EPRI and Bratte to build smart grid by 2030.

- According to a market intelligence report, smart grid in ASEAN is expected to reach approximately $2.9 billion by 2024, rising a CAGR of 18.76% from 2019 to 2024.
- The drivers of market are rising share of renewable energy in the energy mix, increasing focus on smart economies, growing market penetration of advance technologies such as EV charging infrastructure and V2G, and rising demand for efficient energy consumption and billing.

Future Trend

The demand for low carbon emission technologies and power supply-demand gap will drive the economies toward decentralized solutions. Energy Transition will use smart grid to drive the distributed generation, storage, and free market[12].

Blockchain: Transactions

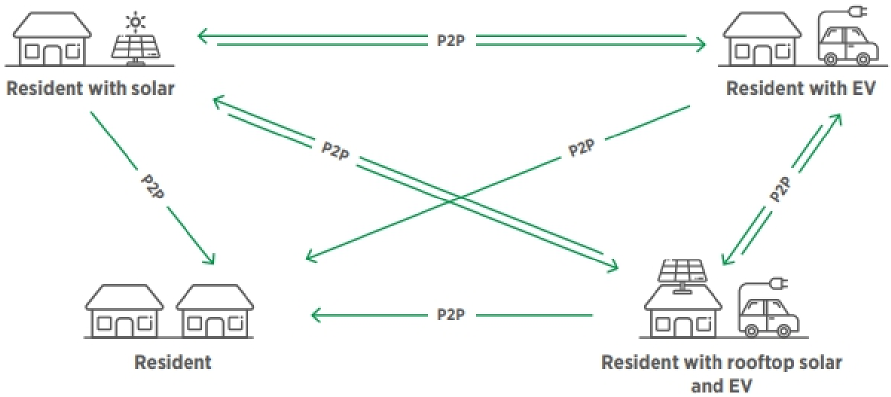

Figure 4 Structure of Electricity Trading Model[13]

Technology Description

Blockchain is the trusted system for all types of transactions both monetary and non-monetary units. Blockchain is a continuous account database, which is complete, distributed, and unalterable. Most excellent value of blockchain is a decentralized system, whose security chain is very long (Figure 4). In general, distributed power system and blockchain is more

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[12] Institute for Energy Economics and Financial Analysis (2018), The Seven Technology Disruptions Driving the Global Energy Transition: A Primer, https://ieefa.org/wp-content/uploads/2018/10/Seven-Technology-Disruptions_October-2018.pdf

[13] IRENA (2020). Innovation landscape brief: Peer-to-peer electricity trading, International Renewable
Energy Agency, Abu Dhabi.

suitable when there are more than one administrative authority and there is a lack of trust between these parties. Therefore, the essential advancement is the distributed trust offered by blockchain technology comprising of removing the trusted third party to facilitate transactions, decreasing the cost of trading, and reducing the time. Thus, blockchain is expected to set off the power industrial and commercial revolution and promote economic reform worldwide[14,15].

Policy & Driving Mechanism

Policy Needs: Communication protocols

- Regulation and supervisory role for promoting safe, efficient and cost-effective electricity transmission and exchange
- Regulation for the interaction of new blockchain-based trading and evolution of existing electricity trading regulations
- Promotion of decentralized generation

Regulatory Requirements

Retail market

- Market regulations that enable electricity exchange between consumers and prosumers (for P2P trading applications), and between prosumers and system operators (for grid transactions)
- Customer and producer support and empowerment
- Understanding of the need for open market dynamics
- Certainty in the ability of prosumers to freely sell power generated from residential distributed energy resources to other grid-connected consumers

Distribution

- Incentivize DSOs to modify their business models and take up the role of a facilitator and supervisor
- Organize payment rules for use of the DSO electricity grid and potentially also the use of the TSO grid if exchange over multiple DSOs is needed

Impact & Market

Key Insights

- Over 46% of blockchain energy start-ups are concentrated in Europe which top 3 are the United States, Germany, and Netherlands.
- The most common use is peer-to-peer (P2P) energy trading.
- Around 50% of the existing projects use the Ethereum blockchain16.
- Close to 74% of the companies were started/founded between 2016 and 2018, which reflects the early stage of the technology.

[14] Chang, V., Baudier, P., Zhang, H., Xu, Q., Zhang, J., & Arami, M. (2020). How Blockchain can impact financial services–The overview, challenges and recommendations from expert interviewees. Technological Forecasting and Social Change, 158, 120166.
[15] Di Silvestre, M. L., Gallo, P., Guerrero, J. M., Musca, R., Sanseverino, E. R., Sciumè, G., Vasquez, J.C., & Zizzo, G. (2020). Blockchain for power systems: Current trends and future applications. Renewable and Sustainable Energy Reviews, 119, 109585.
[16] https://ethereum.org/en/

- It is believed that blockchain is integral to the feasibility of the platform through enabling all parties to minimize transaction costs, improving the economics for all involved.

Future Trend

- The free market will increasingly propel demand for distributed renewables, with wind and solar expected to make up the largest global proportion. Blockchain is needed to manage the transaction between distributed generations in the economy level, regional level and international level.

2.2. Power – Transportation Sector

V2G: Vehicle to Grid

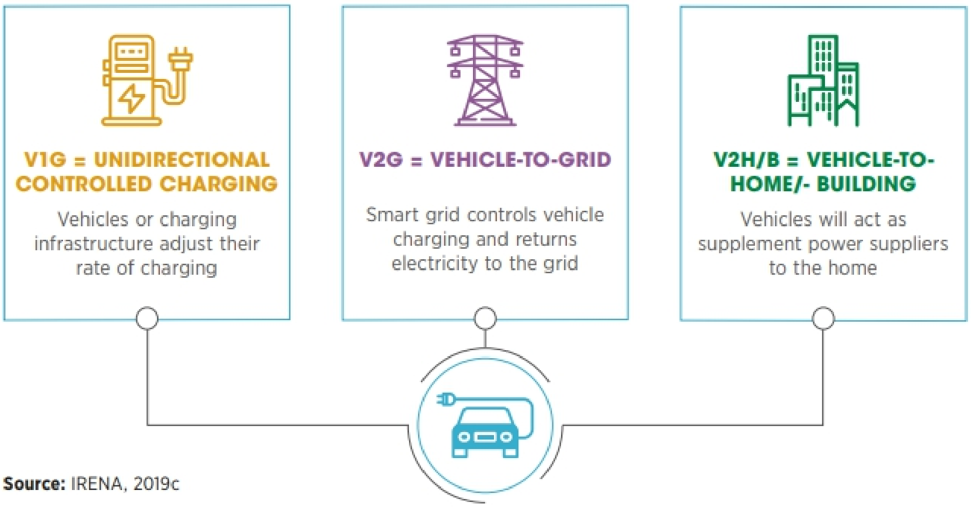

Figure 5 Forms of Emergency Power Source offered by V2G[17]

Technology Description

Vehicle to grid (V2G) uses electric-drive vehicles to provide power to particular electric markets. It presents the potential for the grid system operator to call on the vehicle as a distributed energy source. V2G technology can be employed, turning each vehicle with its energy storage (such as fuel cells, battery, or hybrid of these two) into a distributed load balancing device or emergency power source (Figure 5). Electricity flows all over the utility grid from generators to consumers whereas unused energy flows back and forth from the electric vehicles[18].

[17] IRENA (2019). Innovation landscape brief: Electric-vehicle smart charging, International Renewable
Energy Agency, Abu Dhabi.
[18] Dileep, G. (2020). A survey on smart grid technologies and applications. Renewable Energy, 146, 2589-2625.

Policy & Driving Mechanism

Regulations for V2G Integration

- Adjustment of market thresholds and access conditions for different wholesale segments.
- Avoiding double charging of storage for the grid that penalizes V2G as well as second-life batteries.
- Updating outdated regulations prohibiting the resale of electricity from the grid without a supplier, to account for EVs.
    - Ex. US: San Diego Gas & Electric (SDG&E) Vehicle-Grid Integration project (2016) - dynamic pricing and, through an app, incentivizes charging activities
    - Ex. US: Nuvve V2G experience (2018) - optimisation software choose to supply electricity back to the grid, or provide other services.
    - Ex. Hamburg, Germany: V2G project (2019) - V2G technology and load-dependent tariffs (EVs are controllable consumption).
    - Ex. Denmark: Parker project (2019) – EVs to support and balance power systems based on RE; frequency and voltage control; provide grid flexibility

Impact & Market

- In early 2019, 5.6 million EVs were on the roads. China and the United States are the largest markets with 3.7 million EVs together.
- EV sale grew rapidly during the period 2012 to 2017, with a CARG of 57% which indicating early stage of the technology.
- Policy support schemes and international/economy/private commitments on EV deployment are the main drivers for the market uptake.
- Apart from China and United States as currently being the largest market, the considerable growth (during 2012 to 2017) of the following is expected to be the next largest market: Germany (75%), Norway (70%) and UK (68%).
- The number of EV sales is not only the indicator, but also number of EVs integrated into overall vehicle fleets.

Future Trend

The incorporation of electric vehicles (EV) and Plug-in hybrid electric vehicle (PHEV) is an additional part of the Smart Grid system. V2G power employs electric-drive vehicles to provide power to particular electric markets.

Green Hydrogen

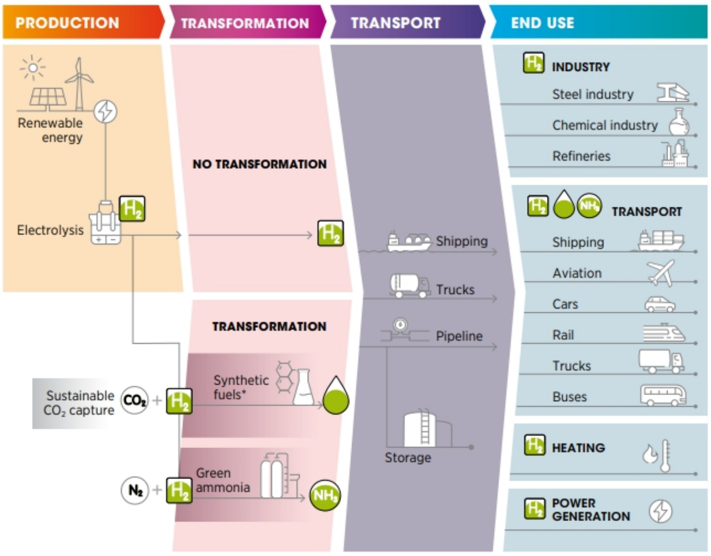

Figure 6 Green Hydrogen Production and End Uses across Energy System[19]

Technology Description

One common method of green hydrogen production is by splitting water. The energy required for this process can be provided from renewable or clean energy sources such as wind, hydroelectric, geothermal, ocean thermal energy conversion, anaerobic digestion of biomass and bio waste (Figure 6). Energy from renewable sources is often intermittent and needs to be stored before it is used in industry, transport, heating process or further power generation. Hydrogen could be stored for a period of time, and then oxidized or otherwise chemically reacted to recover the input energy[20].

Policy & Driving Mechanism[21]

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

Generation

- Stable and supportive policy framework to encourage private investment
- Facilitate access to low-cost renewable electricity
- Partial Exemptions of grid charges, taxes and levies for electrolyzers

[19] IRENA (2020). Green Hydrogen: A guide to policy making, International Renewable Energy Agency, Abu Dhabi.
[20] Koohi-Fayegh, S., & Rosen, M. A. (2020). A review of energy storage types, applications and recent developments. Journal of Energy Storage, 27, 10104.
[21] IRENA (2018), Hydrogen from renewable power: Technology outlook for the energy transition, International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Sep/IRENA_Hydrogen_from_renewable_power_2018.pdf

- Technology-neutral instruments, including carbon pricing, emissions restrictions, specific mandates for RE content

Scale Up

- Specific instrument to de-risk infrastructure investment and improve economics of supply chain (related to carbon market)
- Increasing electrolyzer stack production with automation in GW scale manufacturing facilities can achieve a step-change cost reduction[22]

Market/End use

- Transport
    - Measures to cover initial cost difference (in case of vehicle application)
    - Market pull regulations (zero-emission zone, emission standard)
    - Market push instrument (subsidy, tax rebate)
    - Infrastructure policy
- Industry
    - Carbon pricing
    - Sectorial mandates (emission, RE content)
- Natural gas grid
    - Feed-in Tariff
    - Carbon pricing
    - Harmonized blending limits

Impact & Market

- Hydrogen feedstock market has a total estimated value of $115 billion and is expected to grow rapidly in coming years, reaching $155 billion by 2022.
- The largest share of hydrogen demand is from the chemicals sector. Other industry sectors also use hydrogen, such as producers of iron and steel, glass, electronics, specialty chemicals and bulk chemicals, but their combined share of total global demand is still small.

Future Trend

- Various hydrogen storage technologies will be used to minimize hydrogen storage size such as high-pressure and cryogenic-liquid storage, adsorptive storage on high-surface-area adsorbents, chemical storage in metal hydrides and complex hydrides and intermetallic compounds, and storage in boranes.
- Hydrogen and electricity, as energy carriers, are complementary in the energy transition. Hydrogen from renewables has the technical potential to channel large amounts of renewable electricity to sectors for which decarbonization is otherwise difficult.

[22] IRENA (2020), Green hydrogen cost reduction: Scaling up electrolysers, https://irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf

2.3. Power Sector

AI: Decision Making

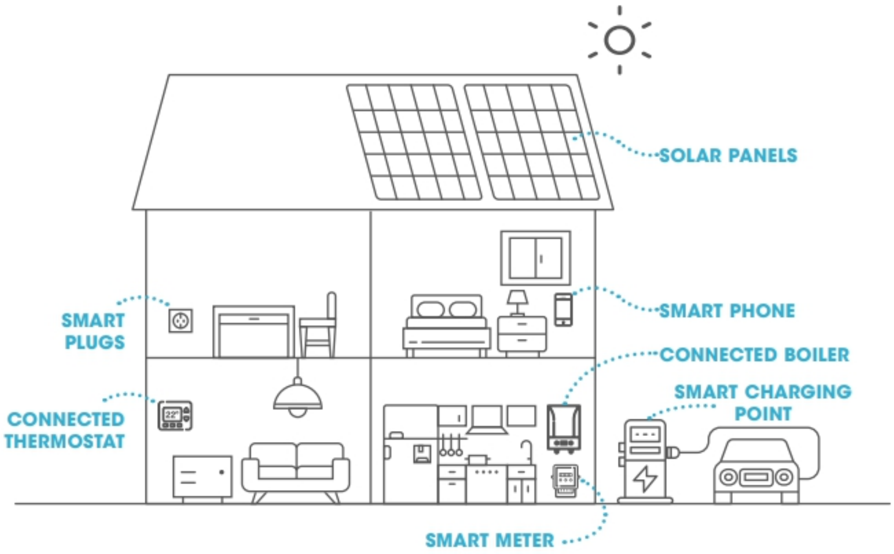

Figure 7 AI Role in Smart Home[23]

Technology Description

AI is referred to an area of computer science that focuses on the creation of intelligent machines that work and react more like humans. It could response to data observed, collected, and analyzed as well as change behavior without being explicitly programmed. Combined with the explosion of processing power and the generation and availability of large amounts of useful data, AI models are increasingly able to manage connected appliances and equipment smartly as presented in Figure 7 and perform specific tasks without instructions, especially in the decision making for power management[24].

Policy & Driving Mechanism

Policy Needs

- Assess the impact of AI on jobs, promote re-skilling to prevent job loss, and create new job opportunities
- Allow public access to data so that anyone can use or develop digital technologies
- Inform and empower consumers, including prosumers, to participate in demand-side management programs
- Enable funding of research and development of AI applications

[23] IRENA (2019). Innovation landscape brief: Internet of Things, International Renewable Energy Agency, Abu Dhabi.
[24] IRENA. (2019). Innovation landscape brief: Artificial intelligence and big data, International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

Regulatory Requirements

- Define data privacy regulation for consumers, and create incentives to participate in pilot projects as data providers
- Define cybersecurity protocols
- Define protocols for the interoperability of big data
- Ensure algorithms comply with existing power sector regulation, or adapt, where necessary

Enabling Factors

- Availability and quality of data
    - Ex. EU: "Regulation (EU) No. 543/2013 of 14 June 2013 on submission and publication of data in electricity markets" established the rules online data platform for European electricity system data. The Transparency Platform is operated by the European Network of Transmission System Operators for Electricity and contains, among other information, data items on load, generation, transmission, balancing and outages, which could be used by private sector companies to develop new business models and offer new services to consumers.
    - Ex. EU: "Regulation (EU) 2016/679 of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data" for end consumer data such as loads from household consumers and electric vehicle charging patterns.
- Importance of cyber security:
    - Policy makers must balance between supporting the development of AI technologies and managing any risks.
- Training and re-skilling of energy sector professionals
    - Tools to help policy makers include public investments in research and development as well as support for a variety of training programs, which can help nurture AI talent.

Impact & Market

- Ongoing initiatives of AI projects had increased as cybersecurity is growing its importance. AI and service provided in market vary based on where technology is applied. Several projects (companies) included EWeLiNe and Gridcast (Germany), DeepMind (United States), and EUPHEMIA (Europe) are the successful approaches in RE generation and demand forecast, maintaining gird stability, demand management, energy storage operation.
- Other approaches also appeared in France, Singapore, India, United Kingdom, Spain, Brazil, and Denmark.
- In East Africa market, there is growing number of new market entrants. Existing AI African company such PAYGo may take advantages over new-comers in which the company demonstrated its concentrating 85% of all sale in Kenya and Tanzania alone.

Future Trend

Digital transformation and smart technology will enable energy infrastructure to be more flexible, intelligent, connected & responsive energy systems.

IoT: Internet of Things

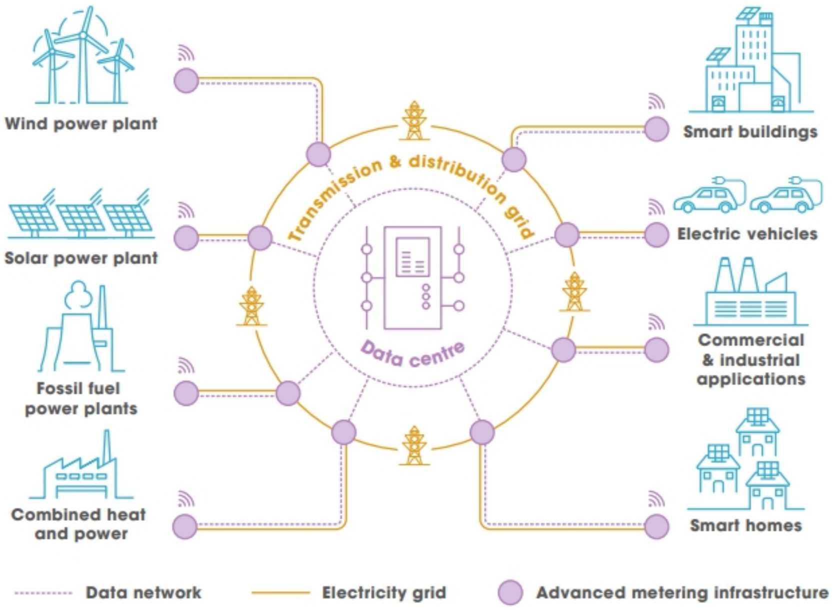

Figure 8 IoT Functions in Demand and Supply side in Energy Sector[25]

Technology Description[26]

Internet of things, widely known as IoT, is the inter-networking of physical devices embedded with electronics, software, sensors and exchange data, sometimes referred to connected or smart devices. The primary goal of IoT is to automate devices that facilitate our lives and increase the efficiency of associated processes ranging from demand to supply side (Figure 8). IoT functions transform physical objects into smart devices to collect, communicate, monitor and interpret information from their surroundings in real time. IoT requires internet connection to devices, where each device has a unique IP address, enabling remote monitoring and control through cloud-based control systems.

Policy & Driving Mechanism

Policy Needs

- Inform and empower consumer, including prosumers to participate in demand-side management programs
- Encourage data exchange and improved communications on a transparent basis
- Develop data privacy and regulation for consumers and define cybersecurity protocols

Regulatory Requirements

Retail Market

- o Customer support and empowerment, through efficient price signals

[25] IRENA (2019). Innovation landscape brief: Internet of Things, International Renewable Energy Agency, Abu Dhabi.
[26] IRENA (2019). Innovation landscape brief: Internet of Things, International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Internet_of_Things_2019.pdf

- o A free retail market that enables innovative business model for consumers

Distribution

- o Incentivize distribution system operator to invest in power generation sector

Wholesale Market

- o Promote appropriate markets and product-service definitions to value flexibility in operation of generation fleet

Impact & Market

IoT technologies developed in recent years underpin a historic transformation that will lead to cleaner (environment sector), and more distributed and increasingly intelligent grids (power generation sector). With the rise of artificial intelligence and improved availability of information worldwide, IoT will play a crucial role in highly developed decision support tools, enabling remote control and automated execution of decisions. In power generation sector, IoT can lead to better management of assets and operations through the application of digital monitoring and control technologies, resulting in a greater reliability and enhanced security.

Future Trend

IoT will power new technologies and unlock new industry in the coming years. By 2025, 75 billion devices worldwide will be able to connect to the Internet, providing accessibility to information to consumers, manufacturers, and utility providers. Along with the rise of artificial intelligence (AI) and big data, the rise of IoT will also feed necessary information to machine learning algorithms which will further enhance the automation of the entire power system.

W2E: Waste to Energy

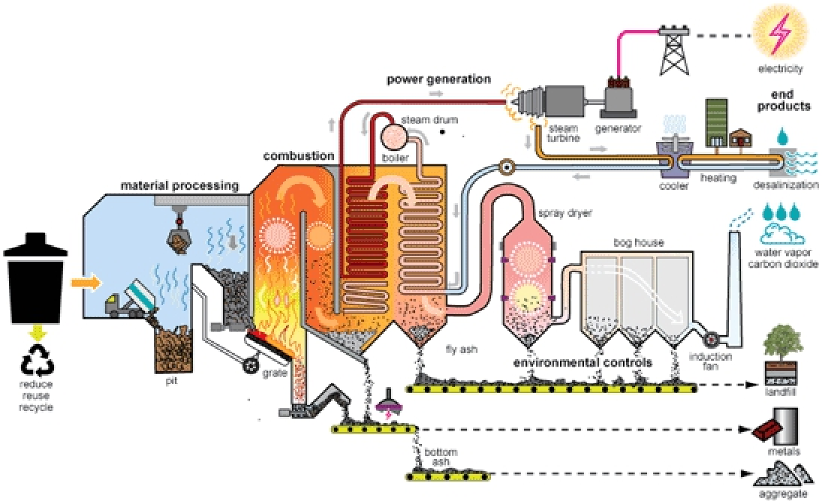

Figure 9 Waste-to-Energy Plant connected to Main Grid[27]

[27] EIA. (n.d.). How waste-to-energy plants work. U.S. Energy Information Administration. Retrieved March 16, 2021, from https://www.eia.gov/energyexplained/biomass/waste-to-energy-in-depth.php

Technology Description

Waste-to-energy (W2E) technologies are promising technologies, especially for developing economies, to turn waste into a useable form of energy. W2E will play an essential role in sustainable waste management and the relief of environmental matters where it also helps increase share of RE through connecting to the main grid (Figure 9). These technologies are generally classified as biological treatment technologies (or biochemical processes, such as anaerobic digestion technologies or as thermal treatment technologies (or thermochemical processes, such as pyrolysis, gasification, and incineration technologies[28].

Policy & Driving Mechanism

Many economy and international aspects could negatively affect W2E including but are not limited to unplanned management, cultural and socio-economic aspects, industrialization, and low standard of living. Strong governmental supports in various angles could drive success of W2E. Appropriate economy policies on fossil fuel dependency, low-carbon society, and environmental protection could accelerate sustainability of W2E. The special governmental financial supports such as funding grants, financial subsidizing, tax reduction, and feed-in tariff on energy converted from waste could significantly facilitate W2E[29].

Impact & Market[30]

- Global Municipal Solid Waste (MSW) will be increased to 9.5 billion tons/year by the year 2050
- It is expected the produced MSW of 261 million ton/year could be converted 283 TWh of electricity and heat by 2022.
- Electricity produced from MSW could be served as bioenergy to the economy electricity grid to enhance economy energy security.
- Biomethane from bioconversion processes could also replace natural gas in a transportation sector.

Future Trend

The future trend of W2E will be the integration of multiple conventional technologies (i.e. biological, and thermochemical waste conversion processes) namely biorefinery. The main purpose of this concept is to simultaneously, optimize the benefit of W2E process and minimize the waste production. In addition, biorefinery could facilitate waste conversion processes and equipment to produce fuels, power, and chemicals. Thus, such approach aims

[28] Hoang, N. H., & Fogarassy, C. (2020). Sustainability Evaluation of Municipal Solid Waste Management System for Hanoi (Viet Nam)—Why to Choose the 'Waste-to-Energy'Concept. Sustainability, 12(3), 1085.
[29] Zhang, D., Huang, G., Xu, Y., & Gong, Q. (2015). Waste-to-energy in China: Key challenges and opportunities. Energies, 8(12), 14182-14196.
[30] Awasthi, M. K., Sarsaiya, S., Chen, H., Wang, Q., Wang, M., Awasthi, S. K. & Zhang, Z. (2019). Global Status of Waste-to-Energy Technology. In Current Developments in Biotechnology and Bioengineering (pp. 31-52). Elsevier.

at maximizing the profit by producing low volume high-value products while meeting the energy needs by producing low-value high volume fuels. Thus, the targeted market could be significantly extended and the economic viability of W2E systems could be enhanced.

Energy Storage: Utility Scale Batteries/Behind-the-meter batteries

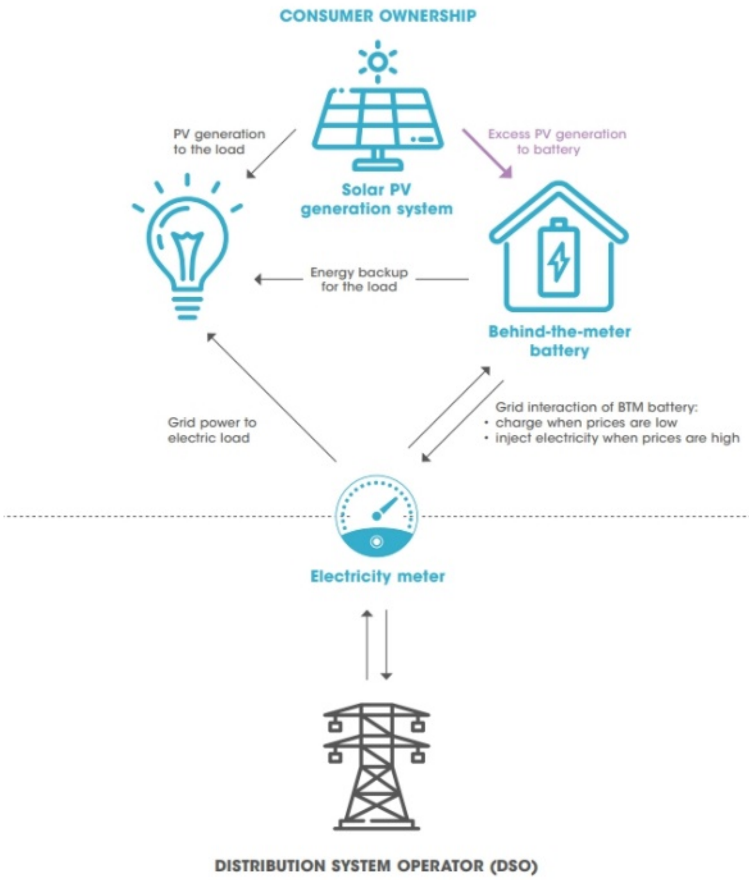

Figure 10 Behind-the-Meter Battery Energy Storage Configuration[31]

Technology Description

Energy storage can provide several advantages for energy systems, such as permitting increased penetration of renewable energy and better economic performance (Figure 10). Also, energy storage is important to electrical systems, allowing for load leveling and peak shaving, frequency regulation, damping energy oscillations, and improving power quality and reliability[32]. Energy storage is currently an economic solution off-grid in solar home systems and mini-grids where it can also increase the fraction of renewable energy by

[31] IRENA (2019). Innovation landscape brief: Behind-the-meter batteries, International Renewable Energy Agency, Abu Dhabi.
[32] Koohi-Fayegh, S., & Rosen, M. A. (2020). A review of energy storage types, applications and recent developments. Journal of Energy Storage, 27, 10104.

providing excess energy to power system to as high as 100%[33]. The various types of energy storage can be divided into many categories such as electrochemical and battery energy storage, thermal energy storage, thermochemical energy storage, flywheel energy storage, compressed air energy storage, pumped energy storage, magnetic energy storage, chemical and hydrogen energy storage.

Policy & Driving Mechanism

Strategic policies

- Incentive to make up economic viability gap of electricity storage projects
- Inclusion of energy storage solution in long-term capacity expansion plans
- Funding for pilot or demonstration projects and dissemination of learning from case studies

Regulatory Requirements

Wholesale market

- Allow large-scale battery storage systems to participate in ancillary services markets and be remunerated accordingly for all the services they can provide to support the system
- Develop accounting, billing and metering methods for large-scale grid-connected battery storage systems
- Incentivize long-term contracts to have a clearly defined revenue stream over the amortization period of the project

Transmission and distribution system

- Allow large-scale battery storage systems to participate in ancillary services markets and be remunerated accordingly for all the services they can provide to support the system
- Deploy large-scale battery storage systems as a solution to reduce overall investments in generating capacity and network reinforcement

Enabling Factors for Large Scale Battery Storage Market[34]

- Reduce upfront costs:
    - Stimulate demand by provide subsidies to battery storage owners
    - Policy similar to support VRE deployment in early stages of development such as capacity payment, grants, feed-in-tariffs, peak reduction incentive, investment tax credit or accelerated depreciation.
    - Ex. USA – American Recovery and Reinvestment Act of 2009: financing for large-scale battery storage owners (2009-2014)
- Conducive Regulatory Framework:
    - Must consider market players and services
    - Clear regulations defining ownership and operating models can enable wide range of revenue streams for storage providers i.e. Participation in wholesale

[33] IRENA (2017). Electricity Storage and Renewables: Costs and Markets to 2030. International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf

[34] IRENA (2019), Innovation landscape brief: Utility-scale batteries, International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Utility-scale-batteries_2019.pdf

electricity market or sale of frequency response or ramping services to frequency operators.
    - Ex. European Commission: Clean energy for all Europeans package 2018: new regulatory framework that allows energy storage to compete with other flexible solutions such as demand response, interconnections, grid upgrade and flexible generations.
    - Ex. UK: Smart systems and flexibility plan, 2017: remove barriers for energy storage such as define energy storage as a subset of generation asset class; modify license charges to exempt storage system from final consumption levies; bringing clarity to the co-location of storage with renewable energy generation plants without impacting existing agreements such as "Contracts for difference and feed-in-tariffs" (Ofgem, 2017).
    - Ex. US: FERC Order 841 (2018) – require wholesale market operators allow storage to provide every market product such as capacity, energy and ancillary services, generating facility; revise interconnection rules and protocols for storage; provisions enable energy storage to utilize spare capacity on transmission system.

Impact & Market

- The market for storage technologies has been expanding. In 2016, the domestic market for storage grew by 284%, and is expected to reach an installed capacity of 40 gigawatts by 2022. Combined with failing cost and battery advancements, the co-location of storage systems is quickly becoming an essential add-on for households installing small-scale renewables.
- Utility-scale battery storage systems are mostly being deployed in Australia, Germany, Japan, United Kingdom, United States, other Europe members and several Islands and off-grid communities. Energy storage deployments in emerging markets are expected to increase by over 40% year on year until 2025.
    - Li-ion batteries represent over 90% of total installed capacity for large-scale battery storage. However, li-ion battery cost has fallen by 80% from 2010 to 2017.

Future Trend

- Lithium batteries are playing an increasingly important role in portable electrochemical energy storage technologies.
- Among the various energy storage system categories, hydrogen energy storage systems appear to be the one that can result in large changes to the current energy system. Several technological, economic, social and political barriers need to be overcome before hydrogen technologies can be used in large scale applications.

2nd Generation Power

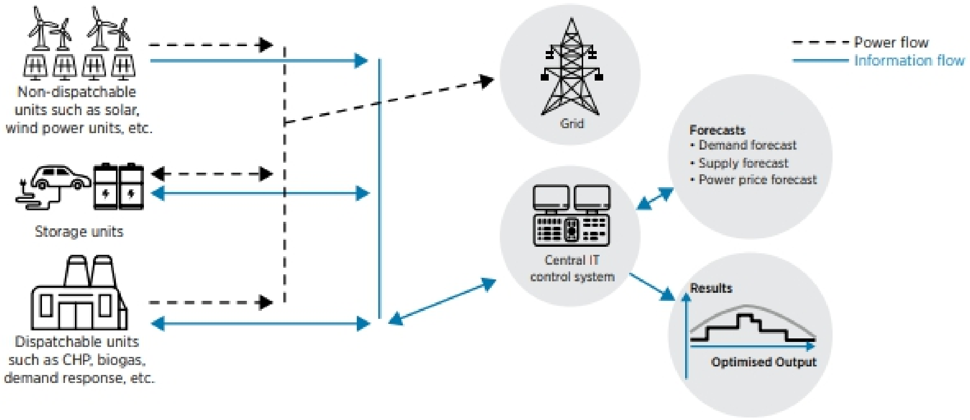

Figure 11 2nd Generation Power to Supply Smart Grid[35]

Technology Description

The change from the 1st generation power system, where fossil fuels such as coal and natural gas are mainly used to produce power, to the 2nd generation power system, where renewable energies become increasingly important and widely used, could create a disruption. The importance of large power plants will decrease because there are small power plants that use renewable energy derived from several green technologies spread out everywhere (decentralization) (Figure 11), while large transmission lines will be replaced by micro grid and smart grid[36].

Current Policy

Most economies around the world, including APEC economies, generally set policies and target to support renewable energy[37]. Due to the worldwide support in renewable R&D, the costs for renewable technologies fall, economic and financial measures continue to evolve, resulting in higher shares of variable renewable energy in electrical grids. International Renewable Energy Agency (IRENA) promotes a collective transition toward renewable energy by fostering synergies between energy and socio-economic systems[38]. Energy transition will then contribute not only to environment protection, by also to socio-economic aspects, including GDP, employment and welfare.

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[35] IRENA (2020). Electricity Storage Valuation Framework: Assessing system value and ensuring project viability, International Renewable Energy Agency, Abu Dhabi.
[36] https://www.egat.co.th/en/index.php?option=com_content&view=article&id=546:moe-egat-discuss-thai-energy-in-the-disruptive-era&catid=11
[37] REN21 (2019) Renewable 2019 Global Status Report, https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf
[38] IRENA, Overview of Global and Regional Renewable Energy Policy Landscape, Retrieved from: https://www.irena.org/-/media/Files/IRENA/Agency/Events/2019/May/Session-1a-Overview-of-Global-and-Regional-RE-Policy-by-IRENA.pdf (5 March 2021)

Impact & Market

Power Generation Market Coverage

- Turbines (Gas, and Steam)
- Generator Sets (Diesel, and Gas)
- Power Rentals
- Solar (CSP, PV and so on)
- Wind Turbines
- Biofuels market (bioethanol, biodiesel and biomass)
- Waste to Energy
- Power Plant Services Market (Steam turbines, gas turbines, wind turbines, & boilers)
- Fuel Cells
- Heat Recovery Steam Generator

Market Drivers[39]

- Government regulations and domestic project plans
- Growing power demand
- Adoption of power purchase agreements (PPAs) influencing power producers to choose renewable energy
- Price drop

Market Restraints

- Low affordability and lack of strong supply chain slowing down market adoption
- Slow adoption of clean energy resources in developing economies
- COVID-19 causing project installation delays

Future Trend[40]

Renewable energy will rise to the forefront. BNEF estimates that USD 13.3 trillion will be invested in new power generation assets to fund 15,145 GW of new plants between 2019 and 2050 of which 80% is expected to be carbon-free. BNEF estimates that by 2050, wind and solar will make up 50% of the world's electricity generation. Europe is expected to decarbonize the fastest and furthest, while China and the US will play catch-up.

System-level flexibility with energy storage solutions, flexible thermal power generation, and interconnectors are essential to enable the penetration of cheap renewables and balance their intermittent nature.

According to IRENA, there will be a need to look more closely at controlling demand worldwide by reducing, increasing or shifting it to a specific period of time.

[39] Innovation in Turbine Capacity and Regulations to Impel the APAC Offshore Wind Turbine Market Until 2025

[40] Wartsila (2020), 5 trends that will shape the energy sector in 2020, https://www.wartsila.com/insights/article/5-trends-that-will-shape-the-energy-sector-in-2020

2.4. Transport Sector

CASE: connected, autonomous, shared, electric

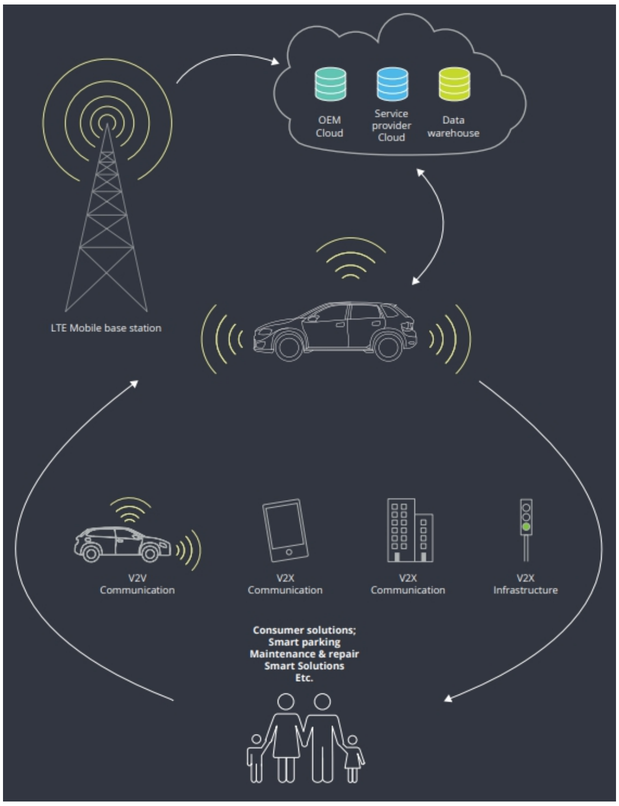

Figure 12 Innovative Automobile connected to Infrastructure[41]

Technology Description

The Mobility of tomorrow will be fundamentally different. CASE refers to new areas of "Connected" cars, "Autonomous / Automated" driving, "Shared", and "Electric". Through interconnection between automobile and infrastructure, technological advances in these areas are greatly changing the concept of the automobile (Figure 12). The mobility companies should find out how they can ease the lives of their customers and make products and mobility services as comfortable, as efficient and as intuitive as possible. CASE is not a matter of passenger cars alone; it is also pursued for vans, trucks, buses and financial services[42,43]

Current Policy[44]

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[41] Deloitte, (2018) Disruption in the automotive industry: Enhancing the customer experience through connectivity. Deloitte North West Europe. Deloitte.

[42] https://global.toyota/en/mobility/case/

[43] https://www.avl.com/documents/10138/8682805/16+Ehlers.pdf

[44] Adler, Martin & Peer, Stefanie & Sinozic, Tanja. (2019). Autonomous, connected, electric shared vehicles (ACES) and public finance: An explorative analysis. Transportation Research Interdisciplinary Perspectives. 2. 100038. 10.1016/j.trip.2019.100038.

It is suggested that additional policies related to new technological context and tax revenue requirements should be introduced. The reason behind is that OECD (organization for Economic Co-operation and Development) economies have 5-12% federal and up to 30% of local tax revenue which is currently attributed to fuel and vehicle taxation. The diffusion of CASE will significantly affect transport-related government expenditure by reducing sources of government revenues.

Impact & Market[45]

China is the dominant region in terms of sales of electric vehicle for several reasons: Europe and the U.S. Government subsidiaries, leniency for exemption of number plates in select major cities, and stringent regulations for electric vehicles industry and government subsidies which help reduce the cost of buying vehicles in China.

However, Germany and Norway have the highest rate of acceptance for electric vehicles in European Union. Norway promoted electricity vehicle as a second car by 2019. This indicates the high rate of adoption of electric vehicle in Norway. Other driving factor is new policy of electric vehicle, implemented in 2019. The policy mandates automaker to comply with electric vehicle target. This causes several original equipment manufacturers (OEMs) to partner with domestic economies for electric vehicle development.

Future Trend

It is indicated CASE trend will take off somewhat earlier, grow faster than expected, and finally reach an almost complete saturation level by 2040. CASE diffusion will increase gradually and expect to operate in transport system with substantial share of conventional vehicle for multiple decades.

However, in initial stage of diffusion, CASE will be more expensive than cars with combustion with engines. It is expected that CASE will first penetrate the transport sector in the luxury private car market.

[45] https://www.transparencymarketresearch.com/connected-autonomous-shared-and-electric-case-market.html

2.5. Building Sector

Green Building

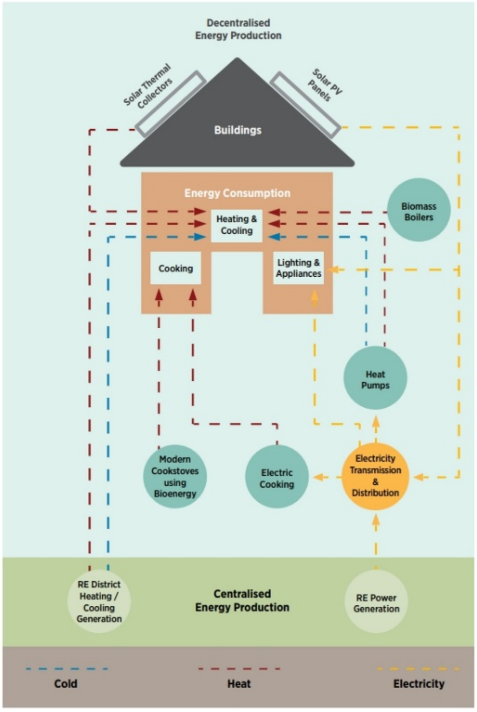

Figure 13 Renewable Energy Options in Residential Building[46]

Technology Description

A green building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on climate and natural environment. Green buildings preserve precious natural resources and improve quality of life. There are a number of features which can make a building green including key criteria such as efficient use of resources, renewable energy utilization, nice air quality, waste and pollution reduction, environmentally friendly design and materials etc. (Figure 13)[47].

Current Policy

APEC economies exercise various types of policies to support the introduction of green buildings, including but not limited to:

- New and more stringent building codes and standards, or legal and regulatory requirements
- Funding for research, development, and demonstration projects
- Other fiscal incentives, including subsidization
- Green building certifications and awards[48]

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[46] IRENA (2016). Renewable Energy in Cities, International Renewable Energy Agency (IRENA) Abu Dhabi.
[47] https://www.worldgbc.org/what-green-building
[48] Wei, X., & Zhang, S. (2017). APEC 100 Best Practice Analysis of Nearly/Net Zero Energy Building, https://www.apec.org/-/media/APEC/Publications/2017/5/APEC-100-Best-Practice-

Impact & Market

The global green buildings market is projected to enjoy a 10.26% CAGR through 2018 to 2023. The emphasis on sustainability and the pressing need of the economy to reduce their carbon footprint are factors expected to drive the market growth during the forecast period. Supportive government policies encouraging the construction of these buildings coupled with sustainable certifications such as the Leadership in Energy and Environmental Design (LEED) are anticipated to fuel market demand. The high resale value of these properties is another factor expected to kickstart the construction of these buildings in developing economies such as India. However, the time required to acquire LEED certifications can restrain market growth[49].

The global Green Building Market has also been assessed on the basis of product and application. In terms of product, the global green buildings market is segmented into interior and exterior products. The exterior products segment has been further segmented into smart lighting, HVAC systems, solar products, building systems, and others. The interior products segment has been further segmented into roofing and flooring. The exterior products segment is dominating the market and accounts for the majority share of 79.6% of the global market. The segment is expected to reach a market valuation of USD 268,573.8 Mn at a CAGR of 10.76% by the end of 2023. By application, the market includes residential and non-residential. The residential segment is dominating the market. The segment stood at USD 123,401.5 Mn in 2018 and accounted for almost 60.9% share of the global market. It is anticipated to reach USD 206,855.7 Mn by the end of 2023 at a CAGR of 10.88%; The non-residential segment is likely to reach USD 121,270 Mn at a CAGR of 9.25% over the forecast period[50].

Future Trend

In the World Green Building Trends report, almost half (47%) of industry respondents expected to transform the majority of their projects to green in the near future. As green building projects expand their penetration in the industry, stakeholders like the government and legislature, contractors, design firms, consultancy agencies, developers/owners, and material suppliers have received benefits of reductions in energy consumption, financial profits, improved user experiences, and sustainability in this trend of green building development. The green building market is a complex business ecosystem comprising the previously mentioned standards, legislation, products (projects), and various stakeholders in the field of green buildings[51].

Analysis-of-NearlyNet-Zero-Energy-Building/217_EWG_APEC-100-BEST-PRACTICE-ANALYSIS-OF-NET-V11_20-Apr.pdf

[49] Global Green Buildings Market: Information by Product (Interiors, Exteriors), Application (Residential, Non-residential), and Region - Forecast Till 2023

[50] Green Building Market 2019: Global Industry Overview By Historical Analysis, Comprehensive Research Study, Opportunities, Competitive Landscape and Regional Trends by Forecast to 2023

[51] Development trend and segmentation of the US green building market: Corporate perspective on green contractors and design firms. DOI: 10.1061/(ASCE)CO.1943-7862.0001924.

3. Recommendation for Accommodating RE&EE Policies

From the review in the previous section, several energy-related technologies have become the game changers of energy demand and supply in APEC region and the world. Understanding the impact of disruptive technologies on different sectors of energy would facilitate in reaching the APEC economies two energy-related goals: 1) 45% energy intensity reduction by 2035 and 2) doubling the share of renewable energy by 2030. The energy landscape encompasses over several sectors including power generation and distribution sector, transportation sector, and building sector. Some disruptive technologies affect across the three sectors, bringing greater effects to the society. Smart grid, microgrid and blockchain are among those technologies that enable the exploration of coming digital nexus across multiple areas which allow the stakeholders to make full use of the energy. They contribute to increase in renewable energy, and also enhancement of energy efficiency. They facilitate generation, delivery, distribution, and integration of various energy sources, most importantly renewable energy. Vehicle to grid (V2G) and green hydrogen are at the interface of the power sector and the transportation sector. These technologies offer a variety of benefits to renewable energy and energy efficiency. V2G technologies act as a source to store up energy, while green hydrogen enable generation of large amount of energy in a shorter time and the energy is in the form that can be used to power the vehicles. Other technologies primarily benefit one particular sector. As for the power sector, Artificial intelligence (AI), Internet of Thing (IoT), waste to energy (W2E), energy storage are technologies that assist the management of power generation, supply, and consumption. They enable flexibility, intelligence, and responsiveness of energy infrastructure. On the downside, the rises of AI and IoT increase threat in cybersecurity which may become a serious future issue. CASE: connected, autonomous, shared and electric vehicles are the major technologies in the transportation sector. The advancement of vehicles eases users' lives, and at the same time, increase the efficiency of the energy usage. The electric vehicles will also expedite the usage of renewable energy as they are powered not by fossil fuels but electricity. Finally, for building sector, green building in the main concept that people use to introduce various types of energy-related technologies.

To accommodate the disruptive technologies, it is necessary to call for a strong policy support. To promote the technologies in appropriate markets, it requires customer support and empowerment as well as incentives and subsidies from government to make up economic viability gap for renewable energy and energy efficiency projects. Regulatory sandboxes or demonstration projects are also good approaches to introduce new technologies to the market. Reduced taxation for investors who invest in these technologies should also be introduced to facilitate technology penetration and scaling up. On the other hand, it is also important to ensure that the technologies are beneficial and not harmful to human being and society. In this report, the recommended RE&EE policies to accommodate the disruptive technologies in the energy sectors were reviewed as follows:

Smart Grid – Smart grid can be considered as platform for the efficient integration of renewable energy sources to the main grid and management of power distributed targeted to the load demand. Therefore, the smart grid policies will be launched in series starting with the policies to promote the usage of renewable energy to increase the installed capacity. Then, the policies to set up the infrastructure for the smart meters will be launched which would provide information from the load profiles. In addition, the regulations and standards regarding to the interconnection of renewables and load and security of data transfer and telecommunications must be placed. The main benefit of smart grid for the consumers are the quality, reliability and flexibility of power supply and services. So, the policy and regulations regarding to new business application such as EVs and vehicle to grid should be defined to support the private sector investment and push market demand. Smart grid as the support for new business application is considered new to most of the APEC economies. Therefore, there are still the need for demonstration sites or sandbox projects to prove the viability of the new energy business models. Policies and regulations are necessary to provide dynamic pricing and electricity exchange between consumers and prosumers in addition to prosumers and system operators. Lastly, policies and incentives must also target grid modernization which should be invested by the utilities and the private sectors.

Microgrid – Microgrid can contribute the potential of energy management for the main grid as well as be the independent grid application in the developing economies. Microgrid application is different between developing and developed economies policies and regulations are needed for interconnected microgrid or mini grid to the main grid. There are also need for regulations and standards for renewables connecting to the microgrid or mini grid as well. In the implementation stage, incentives should be tailored specifically toward the application of microgrid with tariff regulations. Legal and licensing provisions should be made for private sectors in their generation, distribution, and selling of electricity to consumers.

Blockchain – In the energy sector, Blockchain is an upcoming disruptive technology to regulate and supervise the safe, efficient, and cost-effective ways for electricity transmission and exchange. Blockchain is used to promote the decentralized generations and facilitate the open market dynamics. Blockchain is still in its earlier stage. Therefore, there is a need for technical, data security standard, and compatibility standards in the blockchain protocol. There are vast potentials in the use of blockchain and the policy should support new businesses regarding the introduction of new blockchain based trading for currency and electricity. Regulations should be set up regarding to the prosumer in selling power and the payment rules. In addition, market enabling policy should focus on the exchange between consumers and prosumers as well as electricity exchange between prosumers and the utility system operators.

IOT – IoT or the Internet of Things can be considered as the platform for linking and communicating the information for the energy sector supply and demand side for the energy management. Data and information are the key and there is a need for transparency in the transaction. Therefore, the regulations and standard of data privacy and cyber security protocols are needed. In the implementation stage, incentives should be targeted to the distribution system operators and private sector in the investment of IoT platform in the power generation sectors and load demand sectors, respectively. Data driven policy is needed for the market to support and empower the customer through fair and efficient pricing mechanism. The IoT platform can enable innovative business models for the retail energy market. Incentives are needed to promote the flexible and appropriate market, products and services in the energy businesses.

AI – AI or artificial intelligence is all about the usage of data algorithms to make decisions. AI is still in the earlier stage with the application to the existing power sector. The policy and incentives should be focused on research and development of AI applications for the energy sector and data provider. Policy research should be promoted to develop regulations and standardization for the interoperability of big data and cyber security protocol. The standards should be made to ensure the AI algorithms comply with the existing power sector regulations or adapt where necessary to ensure the safety and security of consumers.

Green Building – The green building policy trajectory is quite mature already. New and more stringent building codes and standards as well as regulatory requirements should be the focused. The policy to adopt renewable energy as co-benefit with the energy efficiency measures for the green buildings should be given priority. Fiscal incentive with subsidies should still be continued for the green buildings in addition to certifications and awards. Mandatory training programs should be placed to enable renewable energy adoptions and energy efficiency to the buildings. To push the market, incentive should be provided to the tenants of the eco-friendly property to support the positive response to the green building implementation.

V2G – Vehicle to grid is quite a new disruptive technology in the APEC economies. The main benefit of V2G is the use of electric vehicles as distributed load balancing device. Since V2G is still in the early stage, policy should promote research and demonstration of V2G with case studies of renewable energies and microgrids/buildings in load balancing. There is also a need for regulations to support EVs and balancing power system based on renewable energy. The APEC economy should also harmonize the charger standards for electric vehicles as well as the interoperability for EVs connection to home, building, and grid to provide bidirectional charge and discharge. In addition, regulation for battery waste should be set up to ensure the sustainability of V2G. For the future implementation stage, regulation should be provided with dynamic pricing and incentive for charging activities. Load dependent tariff should also be considered. The regulations should be aware of charging from storage and avoid double charging to penalize the V2G as well as reselling electricity from the grid without supplier.

W2E – Waste-to-energy could reduce global environmental footprint. It requires strong governmental supports in various angles to drive success of W2E including funding grants on energy converted from waste, financial subsidizing, tax reduction, and feed-in tariff on energy converted from waste. For the business promotion, there is a need to develop new lines of business funding the factory owners to build W2E facilities themselves and secure sufficient technical and commercial undertaking from the technologists and developers. The implementation of W2E should be also carried out with well-developed set of safeguards standards to reach environmentally friendly development purpose.

Green Hydrogen – Green hydrogen policies trajectory should focus on scaling up through private investment. Commercial scale implementation is feasible and need supportive and stable policy framework to encourage private investment such as carbon pricing, sectoral mandate on emissions and renewable energy. Regulations such as partial exemption of grid charges, taxes and levies for electrolyzers could reduce the investment cost for the private sectors. Policy should support and facilitate access to the low-cost renewable electricity. For the market pull regulations, zero emission zone and emission standards should be implemented. The market push instrument for the usage of green hydrogen could be subsidy and tax rebate.

2nd Gen Power – The policy trajectory for the 2nd generation power would focus on the increase of the installed capacity for renewable energy to achieve the renewable energy target and a carbon neutral target for each economy. The policies aim to promote decentralize generation as small power plants using renewable energy. Power purchase agreements (PPA) should still be adopted to support the small-scale power producer to choose the renewable energy. For more sustainable implementation, dedicated policies are needed to encourage investment to the end user sector including mandates, building codes, financial incentives, and tax exemption. Supporting mechanisms should be in placed such as financial schemes for new RE power plants, permitting, licensed and technical standards to facilitate grid connection.

Energy Storage – Due to the high penetration of VRE, energy storage system could be one of the best options to provide energy security and stability. To support the energy storage system, policy and regulation should be revised to remove barriers for energy storage, especially the investment cost issue. At the early stage of the plan, funding for pilot or demonstration projects and dissemination of learning from case studies should be offered. Deployment of large-scale battery storage systems could be carried out as a solution to reduce overall investments in generating capacity and network reinforcement. Also, new regulatory framework could allow energy storage to compete with other flexible solutions such as demand response, interconnections, grid upgrade and flexible generations. As of infrastructure preparation, interconnection rules and protocol for storage should be revised. From the need to utilize energy storage system in widespread sectors, developing of accounting, billing and metering methods for large-scale grid-connected battery storage systems can enable standardization. To endorse the real implementation of energy storage, government sector is required to provide incentive to make up economic viability gap of electricity storage projects, incentivize long-term contracts to have a clearly defined revenue stream over the amortization period of the project, modify license charges to exempt storage system from final consumption levies, and allow large-scale battery storage systems to participate in ancillary services markets and be remunerated accordingly for all the services they can provide to support the system.

CASE – Connected, autonomous, shared and electric (CASE) vehicles depend on various infrastructure to support the real implementation. Providing this infrastructure will depend on both commercial and security challenges. Therefore, rolling out new CASE infrastructure needs collaboration across a diverse supply chain that includes traditional infrastructure providers, and technology providers and data analytic specialists. At the beginning stage, government could support the expansion of charging station and create the policy to reduce EV tax in order to increase number of EV customers. At the next stage, the policy to support the creation of CASE infrastructure should be concerned, including of reliable, fast and secure wireless data networks, edge computing to power V2X connectivity, physical infrastructure such as deployment of existing street furniture, road signs, traffic lights, and markings to regulate the flow of traffic and convey messages of upcoming incidents to vehicles. For the standardization, policy to cover a host of issues should be created including insurance, product liability, international vehicle standards, criminal liability for driving offences, civil penalties for driving infractions, roadworthiness standards and procedures, consumer information and marketing standards, driving licenses, accident investigation procedures, data protection regulations, regulation of the taxi and private hire markets. At the implementation stage, public buy-in is needed to drive business confidence to invest as well as public policy interventions to provide a key lever to bridging gap of return on investment. Moreover, fleets and battery leasing could be considered as new business models for CASE.

Table 1: Recommended RE&EE Policies for Accommodating Disruptive Technologies

Disruptive Technology	Policy Trajectory	Early Stage		Middle Stage		Implementation Stage		
		Research & Demonstration	Promotion & Awareness	Infrastructure Regulations	Standardization	Incentives	New Business Regulations	Market Regulations
Smart Grid	- Policy launched in series - Investment & implement by utilities and private sectors	- Demonstration projects by utilities around the world	- Quality and reliability of consumer supply/ services due to smart grid projects	- Renewable Energy - Smart Meter - EVs - Energy Storage - V2G - Grid Modernization	- Interconnection standards - Security on data transfer/connection between devices to grid - Tele communications	- Incentives for smart grid investment by utilities and private sector	- Dynamic pricing policies	
Microgrid	- Contribution and potential to main grid for energy management	- Grid-independent application in developing economy communities	-	- Interconnected microgrid	- Standardization of renewable microgrid	- Tailored approach to tariff regulations	- Legal and licensing provision for private sector to generate, distribute and sell electricity to consumers	
Blockchain	- Regulation and supervisory role for promoting safe, efficient, and cost-effective electricity transmission and exchange		- Promotion of decentralized generation - Open market dynamics		- Technical standard, data security standard, and compatibility of security should be concerned.	- Incentivize DSOs to modify their business models and take up the role of a facilitator and supervisor	- Regulation for the interaction of new blockchain-based trading and evolution of existing electricity trading regulations - Prosumers to freely sell power generated from residential distributed energy resources to other grid-connected consumers - Organize payment rules for use of the DSO electricity grid and the use of the TSO grid	- Enable electricity exchange between consumers and prosumers (for P2P trading applications) - Enable electricity exchange between prosumers and system operators (for grid transactions) -

Disruptive Technology	Policy Trajectory	Early Stage		Middle Stage		Implementation Stage		
		Research & Demonstration	Promotion & Awareness	Infrastructure Regulations	Standardization	Incentives	New Business Regulations	Market Regulations
IOT	- Encourage data exchange and improved communications on a transparent basis		- Inform and empower consumer, including prosumers to participate in demand-side management programs		- Develop data privacy and regulation for consumers and define cybersecurity protocols	- Incentivize distribution system operator to invest in IoT power generation sector		- Customer support and empowerment, through efficient price signals - A free retail market that enables innovative business model for consumers - Promote appropriate markets and product-service definitions to value flexibility in operation of generation fleet
AI	- Data regulations	- Incentives to participate in pilot projects as data providers	- Enable funding of research and development of AI applications	- Ensure algorithms comply with existing power sector regulation, or adapt, where necessary	- Define cybersecurity protocols - Define protocols for the interoperability of big data			
Green Building	- Regulations for new building and retrofit old buildings. - Energy efficient policies of cost savings for consumers	- Funding for research, development, and demonstration projects			- New and more stringent building codes and standards, or legal and regulatory requirements	- Fiscal incentives, subsidization - Green building certification and awards	- RE certificates' training program that enable RE adoption in different types of companies	- Support tenants for eco-friendly properties help create market responding positive to green building implementation

Disruptive Technology	Policy Trajectory	Early Stage		Middle Stage		Implementation Stage		
		Research & Demonstration	Promotion & Awareness	Infrastructure Regulations	Standardization	Incentives	New Business Regulations	Market Regulations
V2G	- Vehicles as distributed load balancing device	- Demonstration on V2G with RE & Buildings		- EVs to support and balance power systems based on RE; frequency and voltage control; provide grid flexibility - Battery waste is required policy for management system	- The V2X Charger, Vehicle to Home/Building/ Grid and provides bi-directional charge and discharge power conversion for EVs	- Dynamic pricing and, through an app, incentivizes charging activities - V2G technology and load dependent tariffs	- Optimization software chooses to supply electricity back to the grid or provide other services. - Avoid double charging of storage for grid that penalized V2G and second life batteries - Update regulations prohibiting of resale electricity from grid without supplier	- Market thresholds and access conditions for different wholesale segments
W2E	- Strong governmental supports in various angles to drive success of W2E		- Funding grants on energy converted from waste		well-developed set of safeguards standards	- Financial subsidizing, tax reduction, and feed-in tariff on energy converted from waste	- Develop new lines of business funding the factory owners to build W2E facilities themselves and secure sufficient technical and commercial undertaking from the technologists and developers	
Green Hydrogen	- Scaling up via private investment	- Hydrogen development and application as fuel are on-going as project implementation and research development		- Stable and supportive policy framework to encourage private investment - Industry: Carbon pricing & Sectorial mandates (emission, RE content)		- Partial Exemptions of grid charges, taxes and levies for electrolyzers - Facilitate access to low-cost renewable electricity	- Carbon pricing, emissions restrictions, specific mandates for RE content	- Transport Measures to cover initial cost difference (in case of vehicle application) - Market pull regulations (zero-emission zone, emission standard) - Market push instrument (subsidy, tax rebate)

Disruptive Technology	Policy Trajectory	Early Stage		Middle Stage		Implementation Stage		
		Research & Demonstration	Promotion & Awareness	Infrastructure Regulations	Standardization	Incentives	New Business Regulations	Market Regulations
				- Natural gas grid with Feed-in Tariff, - Carbon pricing, - Harmonized blending limits				
2nd Gen Power	- Increase installed capacity toward RE target and carbon neutral target	- Small power plants using renewable energy derived from several green technologies spreading to serve decentralization policy	- Most of government support the using renewable energy in energy generation plan	- Adoption of power purchase agreements (PPAs) influencing power producers to choose renewable energy		- Dedicated policies are needed to encourage investments in end-use sectors, including measures such as mandates, building codes, financial incentives, tax exemptions	- Provided financing schemes to support projects - Developed permitting and licensing mechanisms and technical standards to facilitate grid Interconnection	
Energy Storage	- Remove barriers for energy storage	- Funding for pilot or demonstration projects and dissemination of learning from case studies	- Deploy large-scale battery storage systems as a solution to reduce overall investments in generating capacity and network reinforcement - New regulatory framework that allows energy storage to compete with other flexible solutions such as demand	- Revise interconnection rules and protocols for storage	- Develop accounting, billing and metering methods for large-scale grid-connected battery storage systems	- Incentive to make up economic viability gap of electricity storage projects - Incentivize long-term contracts to have a clearly defined revenue stream over the amortization period of the project - Modify license charges to exempt storage system from final consumption levies	- Require wholesale market operators allow storage to provide every market product such as capacity, energy and ancillary services, generating facility	- Allow large-scale battery storage systems to participate in ancillary services markets and be remunerated accordingly for all the services they can provide to support the system

Disruptive Technology	Policy Trajectory	Early Stage		Middle Stage		Implementation Stage		
		Research & Demonstration	Promotion & Awareness	Infrastructure Regulations	Standardization	Incentives	New Business Regulations	Market Regulations
			response, interconnections, grid upgrade and flexible generations.					
CASE	- Rolling out new CASE infrastructure will require collaboration across a diverse supply chain that includes traditional infrastructure providers, and technology providers and data analytic specialists	- Develop a model for end-to-end security testing of components from multiple suppliers	- Support the expansion of charging stations -	- Reliable, fast and secure wireless data networks - Edge computing to power V2X connectivity - Physical infrastructure such as deployment of existing street furniture, road signs, traffic lights, and markings to regulate the flow of traffic and convey messages of upcoming incidents to vehicles - Charging infrastructure	- Policy to cover a host of issues including insurance, product liability, international vehicle standards, criminal liability for driving offences, civil penalties for driving infractions, roadworthiness standards and procedures, consumer information and marketing standards, driving licenses, accident investigation procedures, data protection regulations, regulation of the taxi and private hire markets	-Reduce EV tax	- Public buy-in is needed to drive business confidence to invest	- Public policy interventions to provide a key lever to bridging gap of return on investment

Appendix A: Best Practices shared from Developed to Developing Economies

Summary APEC Workshop on Accommodating Disruptive Technology into RE&EE Policies for Energy Security

The APEC Workshop on Accommodating Disruptive Technology into RE&EE Policies for Energy Security was held virtually during 29-30 April 2021 through Zoom video conferencing service. The objective of the workshop is to share the current disruptive technologies on power generation/distribution, transport and buildings sectors, such as smart grid, micro grid, energy storage, peer-to-peer power trading, prosumer, electric vehicle (EV), mobility as a service and smart building, with highlights on how RE&EE policies play important roles in unlocking potential of disruptive technologies to achieve two main energy goals of APEC (45% energy intensity reduction by 2035 and doubling the share of renewable energy by 2030) by experts from APEC economies. The 1st day workshop started with a welcome speech and a short introduction to the event by Assoc Prof Dr Chatree Maneekosol, President, Chiang Mai Rajabhat University, Thailand. He stated that disruptive technologies could be the accelerating key to reach the renewable energy and energy efficiency goals. Then, opening speech was delivered by Dr Prasert Sinsukprasert, Director General, Department of Alternative Energy and Efficiency (DEDE), Ministry of Energy, Thailand, emphasizing on APEC energy goals to reduce energy intensity by 45% by 2035 and to double the proportion of renewable energy by 2030. The agenda for The APEC Workshop on Accommodating Disruptive Technology into RE&EE Policies for Energy Security is shown in Table A1.

Table A1 Workshop Agenda

29 April (Thursday) – Virtual-Workshop – Presentation	
08:00–08:30	Registration and Reception (Online)
08:30–08:40	**Introduction-Workshop overview and goals** 1. Instructions for online workshop 2. A short introduction to the event: workshop objective, expectation, and agenda ***Dr Worajit Setthapun****, Project Manager, Chiang Mai Rajabhat University (CMRU) [Thailand]*
08:40–08:45	**Welcome Remark** ***Assoc Prof Dr Chatree Maneekosol,*** *President, Chiang Mai Rajabhat University [Thailand]*
08:45–08:55	**Opening Ceremony** Opening Speech by ***Dr Prasert Sinsukprasert,*** *Director General, Department of Alternative Energy and Efficiency (DEDE), Ministry of Energy [Thailand]*
8:55–9:00	Virtual Group Photo

29 April (Thursday) – Virtual-Workshop – Presentation	
	Sharing current disruptive technologies on power generation/distribution, transport and buildings sectors **Moderator: *Dr Chayanon Sawatdeenarunat***, *Chiang Mai Rajabhat University (CMRU) [Thailand]*
09:00–09:20	**Power Generation/Distribution Sector** **Democratization of Energy - Power to the People through Innovation**
09:20–09:40	***Mr Bundit Sapianchai***, *President of BCPG Public Company Limited [Thailand]*
09:40–10:00	**Smart grid: Smart Power Distribution** ***Dr Yu Nagatomi,*** *Senior Researcher, The Institute of Energy Economics [Japan]*
10:00–10:20	**Energy Storage Technologies for Supporting Renewable Energy Development in China** ***Prof Dr Xiangping Chen,*** Department of Instrument, Measurement and Control Engineering, Guizhou University *[China]* ***Q&A***
10:20–10:40	Break
	Moderator: *Dr Nuwong Chollacoop*, *National Energy Technology Center (ENTEC) [Thailand]*
10:40–11:00	**Transportation Sector** **Vehicle to Grid** ***Mr Phusit Hinhad***, *Product Manager, Energy Infrastructure & Industrial*
11:00–11:20	*Solution Business Group, Delta Electronics (Thailand) PCL. [Thailand]* **Green Hydrogen: BioHydrogen as a Member of Renewable Energy System** ***Associate Professor Dr Chen-Yeon Chu (Andrew)***, *Executive Secretary, APEC Research Center for Advanced Biohydrogen Technology & Director, Institute of Green Products, Feng Chia University [Chinese Taipei]*
	Building Sector
11:20–11:40	**Blockchain platform for Peer-to-Peer Energy Trading with Net Billing/Metering in Sisaengtham Sandbox Project** ***Dr Somchai Chokmaviroj,*** *Director, Research and Innovation Division, Electricity Generating Authority of Thailand (EGAT) [Thailand]*
11:40–12:00	**Building Green: Praces, Technologies and Policies** ***Mr A. James Maskrey***, *Associate Specialist, Building Energy Management, Hawaii Natural Energy Institute, University of Hawaii [USA]*
12:00–12:20	***Q&A***
12:20–12:30	**Summary of Day 1 and Brief of Day 2 Activities** ***Dr Worajit Setthapun***, *Project Manager, CMRU [Thailand]*

30 April (Friday) – Virtual Workshop – Presentation & Discussion	
08:00–08:30	Registration and Reception (Online)
08:30–08:40	**Introduction: Day 2 Workshop overview and goals** ***Dr Worajit Setthapun**, Project Manager, CMRU [Thailand]*
08:40–09:00	**Virtual Site Visit of EGAT & Sansiri** Video presentation on Energy Disruptive Technologies by Electricity Generating Authority of Thailand (EGAT) and Sansiri
9:00–10:00 10:00–10:30	**Group Discussion -RE&EE policies to ease integration of disruptive technologies for energy security** **Facilitators:** ***Dr Worajit Setthapun**, CMRU [Thailand]* ***Dr Hathaithip Sintuya,** CMRU [Thailand]* **Economy Sharing** Each Economy is invited to share for 5 min of their status and the impact of RE&EE disruptive technology on power generation/distribution, transport and buildings sectors in their economy. The representatives are encouraged to share their best practices and challenges in technology implementation, market impact and policy, if possible. *Participating Economies:* Australia/ People's Republic of China/ Hong Kong, China/ Indonesia/ Japan/ Malaysia/ Mexico/ The Philippines/ Chinese Taipei/ Thailand/ The United States/ Viet Nam ***Discussion***
10:30–10:50	**Break**
10:50-11:10	**Presentation on the Review of RE&EE Disruptive Technology & Policy** ***Dr Worajit Setthapun**, Project Manager, CMRU [Thailand]*
11:10–11:40	**Group Discussion –** **Facilitators:** ***Dr Nuwong Chollacoop**, National Energy Technology Center (ENTEC) [Thailand]* ***Dr Kampanart Silva**, National Energy Technology Center (ENTEC) [Thailand]* **1. Discussion of issues/obstacles of RE&EE: Current Policy that hinders the deployment of disruptive technology** a) Power and Distribution Sector vs Virtual Power Plant, Energy Trading Platform, Smart Grid, Waste to Energy b) Transport Sector – EV, V2G, Green Hydrogen c) Building Sector – Green Building, Energy Management via Blockchain 2. **Identify area of policy to accommodate disruptive technologies** a) Perspective of policy maker

30 April (Friday) – Virtual Workshop – Presentation & Discussion	
	b) Perspective of technology provider
11:40–11:50	**Wrap up – possible way forward and collaborations**
11:50–12:00	**<u>Closing Remarks</u>** **Mrs Munlika Sompranon,** *Director of Energy Cooperation Section, Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy [Thailand]*

Workshop Participants

Figure A1 and Table A2 present the attendee of the workshop with a total of 105 participants from 13 APEC member economies with the percentage of female 32% and male 68% (33 women and 72 men). The virtual workshop was highly participative, with Dr Worajit Setthapun, project manager from Thailand, taking on the role of overall facilitator. All participants were gathered to review and share the impact of disruptive technologies on the energy security especially for power generation and distribution, transport, and buildings sector.

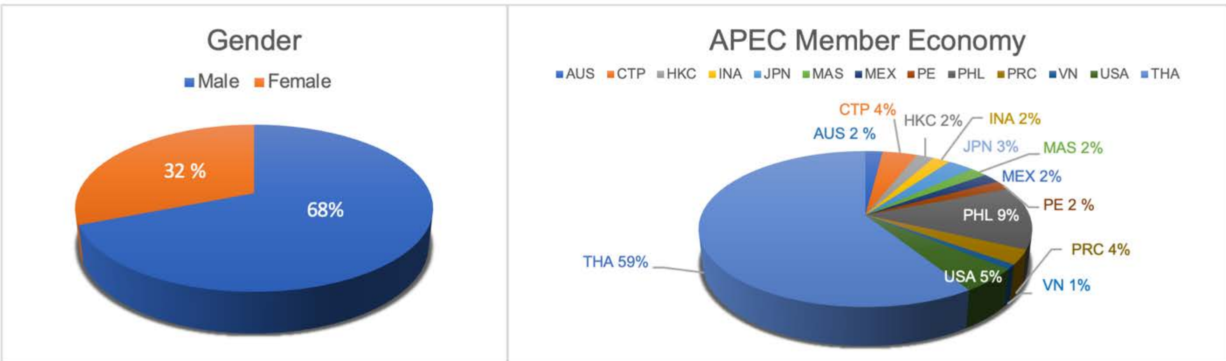

Figure A1 Breakdown Statistics of Workshop Participants

Table A1 List of Workshop Participants

No	Economy	Title	Name	Gender	Organization	Email
1	Australia	Ms	Cathy MCGOWAN	Female	Department of Industry, Science, Energy and Resources	Cathy.McGowan@industry.gov.au
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5	Chinese Taipei	Assoc Prof Dr	Chen-Yeon CHU	Male	APEC Research Center for Advanced Biohydrogen Technology	cychu@fcu.edu.tw
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Note: We have recorded the screen name of all the participants in this table. However, some of the participants did not change their screen name so we have recorded the shorten name.

Workshop Presentation and Discussion

The 2-day virtual workshop was organized on April 29-30, 2021. On the first day, the invited speakers shared the current disruptive technologies on power generation/distribution, transport and buildings sectors such as BCPG's Sansiri Blockchain Project, Smart grid and Smart Power in Japan, Peer-to-Peer Energy Trading with Net Billing/Metering in Sisaengtham Sandbox Project of the Electricity Generating Authority of Thailand, Pumped Hydro Energy Storage (PHES) technology, Battery electric storage system (BESS) technology in China, Delta's V2G Project, Green Hydrogen technology in Chinese Taipei, and Green Building in USA. The second day of the meeting was a discussion on RE&EE policies to ease the integration of disruptive technologies for energy security. Each Economy was invited to share for 5 min of their status and the impact of RE&EE disruptive technology on power generation/distribution, transport and buildings sectors in their economy. The representatives were encouraged to share their best practices and challenges in technology implementation, market impact and policy. Then, Dr Worajit Setthapun, Project Manager, CMRU presented the review of RE&EE disruptive technology & policy which was divided into 3 sectors including of power generation/distribution, transport and buildings sectors. The review focused on technology, policy driving mechanism, impact, market and future trend of each disruptive technology. The next session was a group discussion on issues/obstacles of RE&EE and current policy that hinders the deployment of disruptive technology. Participating APEC Member Economies shared their experience in obstacle and best practices on RE&EE policies to accommodate the disruptive technologies that could be useful for capacity building on integration of the disruptive technologies for energy security. Table A3 shows the summary of presentation on the first day. Presentation materials used in the workshop are shared at "https://drive.google.com/drive/u/1/folders/14VEf4-kx1AFJqly55yLjPI5J-zIbmvoY".

Table A3 Summary of presentation on the first day of workshop

Sector	Power Generation/Distribution			Transportation		Building	
Organization / Economy	BCPG Thailand	IEEJ Japan	Guizhou University China	Delta Electronics Thailand	Feng Chia University Chinese Taipei	EGAT, Thailand	University of Hawaii USA
Disruptive technologies	- P2P Energy Trading at T77 Precinct - IOT - Blockchain - Advanced analytics	- Edge tech: DER, IoT - Management tech: Blockchain, VPP - Analysis tech: Data analysis	Energy Storage	- V2G - V2H - V2X	- Green hydrogen - $BioH_2$ from dark fermentation of biowaste	- Blockchain platform - P2P - Net Metering & Billing - EV, Energy Storage - Microgrid - VPP, Load aggregator	- Green building - Building shell with low emissivity glass - Glass walls: Overhangs and shade fins - Smart Lighting: - Lighting controls, programmable - Adaptive Lighting - Outside LED fixtures
Future trend/ Plan/ Market	- EDDD - Electrification - Decarbonization - Decentralization - Digitalization - Rooftop PV - Behind the meter	- Resilient network, HVDC, Storage, Hydrogen, Ammonia, etc. - Smart grid - 4Ds - Digitalization - Deregulation - Decentralization - Decarbonization	- China focuses the deployment of energy storage systems on - hydrogen - electrochemical batteries (Lithium-ion batteries) - compressed air energy storage - flywheels	- V2H -Smart EV charging -Load shifting -Peak shaving -Emergency power bach up -PV self-consumption - V2G -Frequency regulation -Ancillary services -Smart EV charging -VPP	- Solar power installations: the government's goal of 20 GW by 2025. - Offshore wind sector: Chinese Taipei aims to add 5.7 GW by 2025 and a further 10 GW by 2035. - Green hydrogen and other RE trend to increase due to the cost reduction.	- P2P RE trading platform - Blockchain will be applied to obtain consensus, provenance, immutability, and finality energy business.	- Gaining acceptance / approaching mainstream - Economic advantages - Improves productivity - Attractive to users, managers, owners - Technology adapting and evolving rapidly - Governments worldwide are responding with codes, standards and programs
Challenge/ Key success factors	- Early engagements with relevant stakeholders. - Right partners. - "There is no disruption without value creation."	- Regulation - Market - Needs and Consumer protection	- Capabilities of power and energy - Reliability and safety in large-scale energy storage systems - Hydrogen holds much promise - Cost efficiency	- System integration - Infrastructure - Communication	- Green hydrogen expensive than conventional hydrogen. However, it is cheaper compared to equipment used for electrolysis. - Green hydrogen is getting cheper	- ERC Sandbox - Market players - Collaboration/ MOU - Experience of team and organization	- Cost and long payback -Not factoring in non-energy costs - Non-energy values -Operation and Maintenance Savings - Occupancy turnover - Tax
Policy need/ Driving Mechanism	- It can identify the regulatory challenge into 4 perspectives by type of stakeholders: utility, energy, financial, taxation. - Government that is committed to the energy transition agenda.	- Technical standard for safety and efficiency - Cyber Security of Electric Network	- Government support and promotion for real implementation	- Infrastructure and communication development	- Policy and financial support for project implementation and research development	- ERC Sandbox could allow test bed deployment for smooth and effective policy change.	- Green Policies and Standards are needed. - DI policies - Building beyond code - Building certificate and rating - Net zero energy goals - RE goals - Sustainable materials requirements - Third party bldg. management

On the first day of the workshop, current disruptive technologies on power generation/distribution, transport and buildings sectors were presented. The first presentation was "Power AI: Virtual Power Plant & Trading AI in SANSIRI Blockchain Project" given by Mr Bundit Sapianchai, President of BCPG Public Company Limited, Thailand. He mentioned that E-DDD (Electrification, Decarbonization, Decentralization, Digitalization) was set to transform energy landscape. Blockchain, Internet of things, are core technology in the business canvas. P2P energy trading at T77 sukumvit is a demonstration project which is the future of energy utilization. The project is recognized by World Economy Forum. The system is commercialized to CMU smart city in order to fulfill peak demand by using blockchain technology for transactions among facilities and feeders. Vehicle is used to store energy. In addition, he has stated that there are regulatory challenges that can be divided into 4 perspectives by type of stakeholders, namely utility, energy, financial, and taxation. In the process of writing new regulation to serve new technologies, key success factors are early engagement with relevant stakeholders and right partners. He also indicated that "*There is no disruption without value creation".*

Next presentation for the power generation and distribution sector was given by Dr Yu Nagatomi, Senior Researcher, The Institute of Energy Economics, Japan. Smart grid and smart power distribution were presented with the idea of resilient network that includes various kinds of technologies such as HVDC, energy storage, hydrogen, ammonia, etc. Japan focuses on the 4Ds: decarbonization, decentralization, digitalization, and deregulation. These are megatrends that are structurally transforming the electricity sector. Management with IOT is important for future energy system. Additionally, cyber security of electric network is the important issue that should be strongly concerned if there are several devices connected to the grid. Network DER, IoT may have risk of security hole. A tiny security hole may have great impact on the whole power system. Therefore, technical standard, security standard, monitoring, update of security, compatibility of security should be concerned.

Last presentation for the power generation and distribution sector was "Energy Storage Technologies for Supporting Renewable Energy Development in China" given by Prof Dr Xiangping Chen, Department of Instrument, Measurement and Control Engineering, Guizhou University, China. She stated that China has installed a 32.4GW capacity, 1.6% of electrical power systems (2019), while the world average 2.7% in electrical systems. By 2050, China will have 200 GW energy storage systems to support the grid. In March 2021, China launched "The 14th Five-year Economic, Social Development Plan and 2035 Target". It focuses the deployment of energy storage systems on hydrogen, electrochemical batteries (Lithium-ion batteries), compressed air energy storage, and flywheels. Current innovative technology is more expensive than conventional technology. Therefore, there is a need to explore inexpensive technology by research development. She mentioned that the challenges in energy storage development are capabilities of power and energy, reliability and safe in large-scale energy storage system, hydrogen holds much promise, and cost efficiency (RE costs more than conventional energy, its efficiency needs to be improved).

The first presentation of transportation sector was given by Mr Phusit Hinhad, Product Manager, Energy Infrastructure & Industrial Solution Business Group, Delta Electronics (Thailand) PCL., Thailand. He explained E-mobility, especially V2G, that is the technology for the future. Delta Electronics's components are an integral support for electric vehicles. Delta is empowering e-Mobility with Delta EV Charging solutions, automotive electronics, automotive fans and telecom power. The V2X Charger brings Vehicle to Home/Building/Grid and provides bi-directional charge and discharge power conversion for EVs. Combined with Home Energy Management System (HEMS), the core of home charging infrastructure used to manage energy from the supply to consumption, enabling smart charging to both allocate electricity more efficiently as well as to supply grid services. V2X application also could be used for the load shifting, peak shaving, emergency power backup.

The second presentation of transportation sector was given by Associate Professor Dr Chen-Yeon Chu (Andrew), Executive Secretary, APEC Research Center for Advanced Biohydrogen Technology & Director, Institute of Green Products, Feng Chia University, Chinese Taipei. He presented the current development of biohydrogen from dark fermentation of organic waste and cellulosic materials. In 2006-2015, the research groups of Canada, Britain, Singapore, Republic of Korea, Malaysia, Russia and other economies have pointed out that Feng Chia University is the first record in biohydrogen production rate in the world. Biohydrogen gas-fuel station and mini-fuel cell car were demonstrated at Feng Chia University. They have established a cost-effective large-scale pilot plant including key technology of design and SOP instructions. Green hydrogen is more expensive than the conventional hydrogen. However, it is cheaper when compared to equipment used for electrolysis. An Australian National University report last year estimated Australia could currently produce green hydrogen at about $3.18-3.80 per kg and at $2 per kg by the end of the decade.

The first presentation of building sector was given by Dr Somchai Chokmaviroj, Director, Research and Innovation Division, Electricity Generating Authority of Thailand (EGAT), Thailand. Blockchain platform for peer-to-peer energy trading with net billing/metering in Sisaengtham Sandbox Project was shared. EGAT has a concept to innovate in each behavior of type customers namely residential type, commercial type and rural area type to provide the 5 services e.g. Peer-to-Peer Energy Trading Net Metering Net Billing BESS CES Microgrid Load Aggregrator for support the electricity services in the ESI of Thailand. Market players were selected for activities: battery energy storage system, microgrid, P2P energy trading platform, and EV load aggregator. ERC sandbox focuses on 5 projects in 3 areas: ENERGY: energy is yours (focuses on residential perspective), EGAT-TU (for commercial), Sisaengtham (support rural area). RE integration with energy management system (EMS) provides functions of cost optimization, customized dashboard, resilience function, RE forecast function, demand forecast function, and reduce GHG emissions. The platform offers the prosumers to schedule the capacity needed a day ahead. Blockchain changes the business in several ways. Traditional platform of energy transaction is inefficient, expensive, and vulnerable. However, with blockchain applied, the transaction is consensus, provenance, immutability, finality.

The last presentation sharing of practices, technologies and policies of green building was given by Mr A. James Maskrey, Associate Specialist, Building Energy Management, Hawaii Natural Energy Institute, University of Hawaii, USA. He stated that green building could led to carbon reduction, energy use reduction, healthy and productivity. The green building related policy in the U.S. could be divided into 3 level as follows: 1) Federal level (appliance standards, federal efficiency program, EPA energy star program, EE resource standard, financial incentive programs), 2) State level (state-specific energy standards, lead by example), and 3) Local level (energy codes, zoning and permitting). In addition, disruptive policies are initiated such as building beyond codes, building certification and rating, net zero energy goal, RE goals, sustainable materials requirements, third party building management, verification and enforcement, distributed power, power distribution (e.g. DC), cost model that include non-energy benefits etc. He also revealed that barriers to green policies and standards were financial constraint, difficulty of the technology complementation, and need to lower cost and achieve payback. Key success for disruptive policies was found to be an economic value of healthy building. The example of current disruptive green technologies implemented in the U.S. are heating ventilation and air conditioning (HVAC), building shell with low emissivity glass, overhangs and shade fins glass walls, smart lighting (with lighting controls, programmable, and adaptive Lighting), air cleaning paint, electrochromic windows, smart lighting, new BMS algorithms, radical disruption, and 3d printing. For the market of green building, the key driver was tenants seek out eco-friendly properties to reduce their expenses. Therefore, market responding becomes positive to green building implementation.

On the second day, the workshop overview and goals were presented by Dr Worajit Setthapun, Project Manager, CMRU, Thailand. Disruptive technologies in three sectors were focused, namely building, transportation, and power sectors. Key technologies were identified and classified according to relevant sectors. There are several technologies with important roles at the interface between two sectors (e.g., microgrid linking power supply to households and buildings, hydrogen linking power production to transportation). There are also technologies that may disrupt all sectors: smart grid and blockchain. The nature of these technologies, followed by the summary of enabling policy and driving mechanism, the analysis of impact and market, and the forecast of future trends.

The next session was “Virtual Site Visit of EGAT & Sansiri”. Video presentation on energy disruptive technologies by Electricity Generating Authority of Thailand (EGAT) and Sansiri were presented. Firstly, EGAT’s presentation introduced the Solar Power Plant and Hydropower Plant Project, also known as the Hydro-Floating Solar Hybrid Project. The pilot project is at Sirindhorn Dam in Ubon Ratchathani Province and has a capacity of 45 MW. Moreover, the project is included in the Power Development Plan B.E. 2561-2580 (PDP2018) and is considered the largest Hydro-Floating Solar Hybrid in the world. The highlights of the project are 1) Low cost due to the use of EGAT’s original power system, such as the transmission system and the use of space for maximum benefit 2) Increasing power system security, reducing unstableness of renewable energy with Integrated Renewable Firm Power System and Energy Storage, and using Energy Management System (EMS) to control the power distribution 3) No impact on society, community, and environment by installing an HDPE (High Density Polyethylene) floating device made from the same material as water pipes, which is not dangerous to the environment and aquatic animals, and is installed on the water surface of EGAT’s dams; therefore, it does not affect the agriculture area and the community’s boat route.

The next video presentation from BCPG presented the project that Sansiri and Power Ledger join force to pioneer the world’s largest realt-ime blockchain-based, peer-to-peer (P2P) electricity trading pilot project at Town Sukhumvit 77 (T77), Southeast Asia’s first public-private-people partnership model for self-sustained energy management. Solar power was traded amongst four participating entities at Bangkok’s T77 precinct – a shopping centre, international school, serviced apartments, and a dental hospital. Rooftop solar systems with a capacity of 635 kW and a co-located battery storage system is expected to provide 20 percent of the community’s overall electricity needs. End-users won’t notice anything different about their power supply but the benefits to them will be cheaper and more reliable electricity. The benefit to the environment is that the power generated will be 100% carbon free. The aim of the trial is to provide a base case for future prospective projects in the region.

After the virtual site visit, a discussion on RE&EE policies to ease integration of disruptive technologies for energy security was facilitated by Dr Worajit Setthapun, CMRU, Thailand. Each Economy was invited to share their status and the impact of RE&EE disruptive technology on power generation/distribution, transport and buildings sectors in their economy. The representatives are encouraged to share their best practices and challenges in technology implementation, market impact and policy. Table A4 shows summary of the discussion.

Table A4 Discussion on RE&EE policies to ease integration of disruptive technologies for energy security on the second day of workshop

	Power Generation/Distribution	Transportation	Building
Disruptive technologies	- P2P, Blockchain, Net Metering & Billing - Energy Storage - Smart grid - Waste to energy	- Green hydrogen - EV - ESS	- Green building - Carbon nuetral technology
Best Practices/ Challenges policy & Regulations	- **Philippines** -Philippines has several plan to promote RE, smart grid, ESS, EE -The policy support DI but there is few RE generation units to test for P2P, blockchain. -90% of island served with conventional power generation. - **Indonesia** -Government set plan to increase RE -Focust to support remote area -Energy mix policy - **Vietnam** -FIT for RE promotion -Reduction of tax for RE equipments -Limitation of RE sources, especially bioresource -Grid penetration challenge by the increasing of RE connected to grid -Government seek for smart grid to manage the grid - **Thailand** -4D1E -Energy storage / EV / Carbon neutral -BCG -Community power plant project that community can own their power plant -Cooperation between several ministries to reach Thailand BCG goal -Bio process to generate green power	- **Indonesia** -Biodiesel mix, biomas, methanol are on going projects to convert available sources from community.	- **The United States** -Policy support net zero emission and climate change -USA has plan and set goal for each RE such as solar, wind, hydrogen. -Carbon capture **Hong Kong, China** -Green Tech Fund to support carbon neutrality goal -Create a platform to match services improvement needs with innovative solutions -Provide incentives to promote RE connection to the grid
Experience in Disruptive Technology Adoption/ new energy business	- **China** -R&D for new energy -Government create Green Finance to support RE innovation -Pilot project and demonstration site for showcase of new DI such as smart grid, VPP, power trading platform. Best practice, lesson learn and standard could be obtained.	- **China** -Government support SME by R&D for small scale production. -Green vehicle, battery businesses are supported by government. **Chinese Taipei** -Green hydrogen has been stydied by using differnce kinds of biowaste. -Application of green hydrogen with fuel cell car has been tested.	- **The United States** -Large companies in USA pay attention to carbon neutral goal (including RE, clean transportation etc.) such as Google, Apple, Amazon etc.

The first experience sharing was given by Ms Mylene Capongcol, Renewable Energy Management Bureau, Department of Energy, the Philippines. She stated that policy of the Philippines supports smart grid, energy storage, EE, and RE. In the electric power industry reform, consumer can sell power produced by themselves (prosumer concept) but the cap is just only 100 kW. At present, blockchain and P2P is developed. The difficult part is the harmonization of the policy, government and regulator that takes time. There are over 7,000 islands in the Philippines which are good opportunity for RE utilization.

Dr Cary Bloyd, Pacific Northwest National Laboratory, the United States, shared that one of the disruptions in the U.S. is the election that results in the situation change of climate. President Joe Biden announced at the Climate Summit on April 22-23 a goal to reduce CO2 by 50-52% by 2030 to be committed at COP26 in Glasgow and is working toward net zero carbon in 2050. The U.S. aims to reduce the price of solar energy by 60%, install 30 GW of offshore wind by 2030, make hydrogen competitive to natural gas, slash the price of batteries, and develop EV to be cheaper than gas vehicles. Private sectors in the U.S. such as Google, Apple, and Amazon pay attention to carbon neutral goal (including RE, clean transportation etc). For example, Google reached its goal of becoming carbon neutral for 2007 and aimed to be carbon free by 2030. Amazon also started climate pledge to be net zero carbon by 2040 with over 100 trillion dollars in revenue and to buy 20,000 EV delivery vans by 2022 and 100,000 by 2030. To reach out to private sector, including smaller companies, the U.S. Environmental Protection Agency (EPA) provides RE certificates' training program (at the federal level) that enable RE adoption in different types of companies. They do it through the infrastructure created by US EPA.

Dr Nuwong Chollacoop, National Energy Technology Center (ENTEC), Thailand, pointed that Thailand aims for Carbon neutral by 2080. The International REC (I-REC) Standard by EGAT stems from an initiative to track the origin of electricity beyond the borders of established renewable energy certificate markets. PTT has been accredited by the I-REC Standard since early October 2020 as a representative to provide services in renewable energy equipment registration, renewable energy certificate issuing request and trading.

Mr LAI Hon Chung, Harry, EMSD, Hong Kong, China advised that Hong Kong, China had set the goal to achieve carbon neutrality by 2050. Green Tech Fund had been established to support projects in achieving the said goal. An online platform called E&M InnoPortal was launched in 2018 to encourage the application of innovative solutions including EE, RE, IoT, AI, etc. Incentive schemes such as FiT and RE certificate were introduced. Waste-to-energy projects including T-Park (sludge waste) and O-Park (food waste) were put into operation by phases while the first phase of integrated waste management facility was planned to be completed by 2025.

Mr Muhammad Reza HUSEINI, University of Muhammadiyah, Indonesia, revealed that the target of RE in India was set to increase 23% by 2025. This indicates that Indonesia is ready to introduce disruptive technology in energy. The priority is to support electricity in remote area and increase the electrification rate. There is a political push for biodiesel aiming for B100. By the regulation, biodiesel is intended for large capacity vehicles, such as transport trucks, factory trucks and diesel engines in several factories. In other hand, for electric vehicles were used as motorbikes, cars and buses so there will be no friction in both.

Mrs Pham Thuy Dzung, Electricity and Renewable Energy Authority, Ministry of Industry and Trade, Viet Nam, mentioned that RE accounts for 25% of the power capacity in Viet Nam. The driving mechanism is incentives in reduction of income and import tax for RE equipment. Difficulties are solar and wind introduction focused on specific areas that could result in the curtailment issue, limitation of RE sources, especially bioresource, and grid penetration challenge by the increasing of RE connected to the grid. Therefore, smart grid & forecasting is in the planning phase.

Dr Yaowateera Achawangkul, DEDE, Thailand also introduced 4D1E concept for Thailand energy goal. There is an increasing of EV as well as RE. Therefore, energy storage is needed. Thailand aims for carbon neutral in the future. Thailand have a new model called "BCG" which aims to streamline economic development. "B" stands for bioeconomy. "C" stands for circular economy. And "G" stands for green economy. The BCG model helps the economy to achieve the sustainable development goals of the United Nations whose desire is to lift the wellbeing of people around the world in all respects. The concept focuses on the balance between the economy, society, and environment with the cooperation between several ministries. Dr Nuwong Chollacoop, National Energy Technology Center (ENTEC), Thailand, also emphasized that BCG concept will be proposed in the Asia Pacific Economic Cooperation (APEC) in November 2022 that will be held in Bangkok, Thailand.

Dr Vivia Luo, YASTI, China, stated that there is a large number of products related to disruptive technologies have been developed in China. The combination of technologies, e.g., blockchain, 5G, will enable more efficient and accurate RE utilization. Currently, government create Green Finance to support RE and green innovation. Pilot project and demonstration site were built as showcase of new DI such as smart grid, VPP, blockchain, and power trading platform. Best practice, lesson learn, and standard could be obtained. Green vehicle and battery businesses are supported by government.

Associate Professor Dr Chen-Yeon Chu (Andrew), Executive Secretary, APEC Research Center for Advanced Biohydrogen Technology & Director, Institute of Green Products, Feng Chia University, Chinese Taipei, mentioned that research activities in the hydrogen development and their application as fuel are on-going. A video of Bio-hydrogen car developed by Feng Chia University was presented. By the way, green hydrogen market in Chinese Taipei is still limited. Currently, grey hydrogen produced by fossil fuels was mainly used.

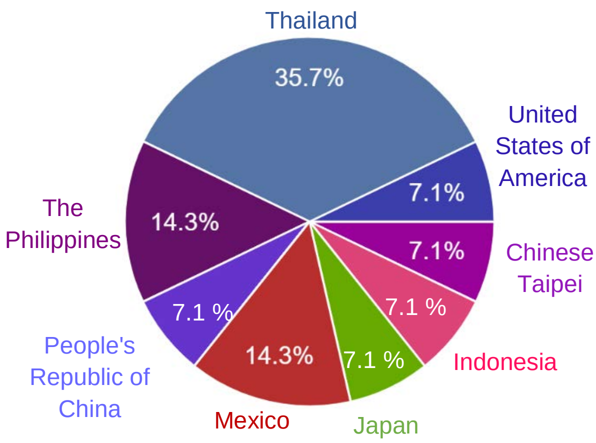
Next, discussion of issues/obstacles of RE&EE including current policy that hinders the deployment of disruptive technology. It is found that, to create new business model to overcome disruption, the preparation of community especially people in rural area which are lacked of knowledge, opportunity to accepted the disruptive technologies was found to be an important issue. Good preparation of facilities & policies should be in place. The Philippines encourages private sector to invest power plant under subsidy program from government. Lessons learned and best practices were revealed with community involvement. Implementation of smart grid and other RE also one of the future goals. In Thailand, Local Energy Planning (LEP) was set by government to increase the RE & EE implementation. Key success for community development is community involvement, education, and government policy. Furthermore, demonstration site showing real implementation in community could create people acceptance. Another important issue is the solution to deal with battery waste. At present, the utilization of green vehicle in China has been increased. Therefore, Chinese government includes the waste battery management in the policy. Most of large companies such as Toyota manage waste battery by themselves, some companies send waste battery back to the producer.

At the end of discussion, closing speech was given by Mrs Munlika Sompranon, Department of Alternative Energy Development and Efficiency (DEDE). She said thank you to all participants for contribution to the workshop. She expected that the presentation and discussion on the disruptive technologies in RE&EE will give the best practice for the policymakers in the APEC Economies.

Workshop Evaluation Survey

"APEC Project Evaluation Survey: APEC Workshop on Accommodating Disruptive Technology into RE&EE Policies for Energy Security."
Workshop date: 29-30 April 2021

APEC ECONOMY



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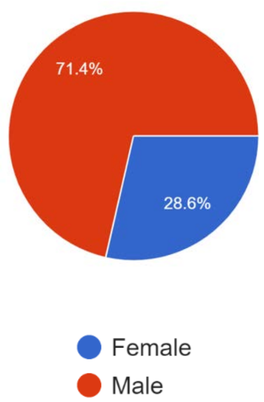
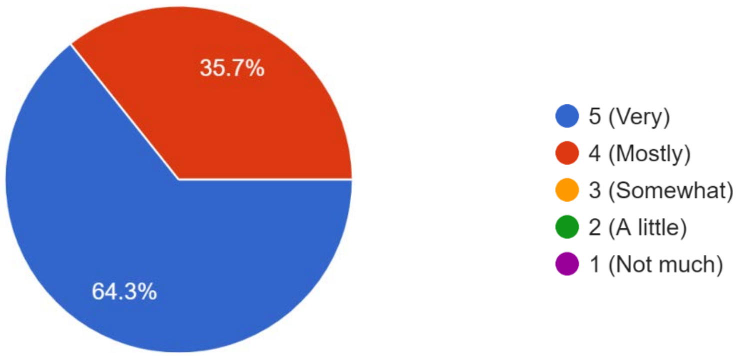


Workshop Evaluation Questions	Strongly Agree	Agree	Disagree	Comments
1. The objectives of the training were clearly defined.	60.8%	39.2%	0%	- We already know from BEST PRACTICES regarding DISRUPTIVE INNOVATIONS - Well, structure. - One of the questions that we need to know is the policies considered in each economy, not only from the market point of view, - The workshop was clear enough in order to explain the different disruptive

				technologies and the way other economies are implementing them. - I think the workshops have provided a platform on knowledge/experience exchange and sharing than training.
2. The project achieved its intended objectives	60.8%	39.2%	0%	- The moderators have provided great support for this event. The moderators may take a little bit more time for giving background introduction for the projects next time.
3. The agenda items and topics covered were relevant.	64.3%	35.7%	0%	- I agree that the main talks have covered the most relevant topics in the projects.
4. The content was well organized and easy to follow	71.4%	28.6 %	-	- Unfortunately, there are always set backs due to the technology of communications in each economy. - The event have been well organized.
5. Gender issues were sufficiently addressed during implementation.	60.9%	31.2%	7.9%	- Up to know still male speaker.
6. The invited speakers were well prepared and knowledgeable about the topic.	50%	42.9%	7.1%	- The topic/issue of speaker is so COOL.
7. The materials distributed were useful.	78.6%	21.4%	0%	- Materials were not provided before the workshop.
8. The time allotted for the training was sufficient.	28.6%	71.4%	0%	- But each speaker should keep their allotted time.

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



Please explain the relevance of the project to your economy

1. We already know government support.
2. We should think about the whole life cycle of the disruptive technology and participate with local people.
3. Around the world, there is an urgency for decarbonizing the energy sector. We need to combine disruptive technologies in order to achieve a sovereign energy transition in our technical and economic capacities, so it is essential to know more about different technologies.
4. The project's purposes can be deployed to the RE&EE development in Thailand under the disruptive circumstance. The attendances can gain more ideas and experiences to apply with work corresponding to energy policies, for example, new innovation on green and clean energy. Our economy is moving forward to new trend of the world direction and technology.
5. Micro grid application
6. Renewable energy and highly efficient utilization is a great concern across the world. The talks in the events have covered mostly attracted topics related to this concern. China has launched many relevant policies and pilot projects to support the development of renewable energy. Some experiences and successful practices may provide the demos for other economic bodies to share and discuss.

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

Answers:

1. APEC economies' participations
2. This project resulted to the awareness of all participants in different innovation and emerging technologies in different economy which will give ideas, samples, guide, procedures. It also made the participants to think what the best thing would be to do on the waste of this emerging and disruptive technology such as old batteries.
3. Success cases and sharing ideas in other economies would be benefit for this project.

4. Yes
5. To open minds to new green smart technology
6. The principal outcome was sharing experiences and knowledge from different economies that have successful policies. Moreover, to have the opportunity to share with other colleagues from around the world opinions and examples of innovative projects.
7. Each economy can learn for the situation on energy development done by APEC, as well as experiences from the speakers.
8. AIoT for Energy Management
9. Great results
10. The experience sharing and knowledge exchange

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

Answers:

1. Advanced disruptive technologies
2. I gained the awareness on the updated projects of other economy.
3. The advance of the energy technology
4. I learned more on how Blockchain Technology and the P2P Trading operates
5. The need to exchange knowledge between members of OPEC
6. the importance of the disruptive technologies in the energy transition.
7. I learned about new disruptive technologies in RE and EE that are being implemented within APEC economies.
8. Acknowledging of new innovation development concerning to energy.
9. Blockchain
10. Technology is important but how to get people to participate is important too. Should develop more tools and mechanisms to get people enjoying our issues.
11. government policies, successful practices and industrial development in the economies and regions.

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

13. Rate your level of knowledge of and skills in the topic after participating in the event:

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

1. Deep understanding in disruptive Technology from best practices
2. I have learned the idea and model presented. The ideas in video presentations are also interesting specially on the EV topics.
3. To know more about peer to peer, blockchain etc.
4. I now have a clear idea as to formulating the necessary policies.
5. we already have a program to include new technologies in the domestic energy policy.
6. I had the opportunity to learn from the experts that presented information in this workshop.
7. I obtain more knowledges, as well as energy development situation among APEC, from the speakers, especially, some technology and innovation can be applied in Thailand (e.g. green hydrogen, ESS, virtual power plant, etc).
8. Blockchain application in AIoT domain
9. Get more data and information from many speakers around the world
10. As a senior researcher and shake holder in renewable energy and relevant research field, I have provided a view of government policies, successful practices of energy storage system in China. Meanwhile, I have gained more first-hand knowledge and experiences from the speakers and participants through their speech and discussion.

14. How will you apply the project's content and knowledge gained at your workplace? Please provide examples (e.g. develop new policy initiatives, organize training, develop work plans/strategies, draft regulations, develop new innovation/technology etc.)

Answers:

1. Cooperation with economies
2. Will support and organize some training courses on challenging disruptive technologies.
3. The topics are related to emerging technology which is related also to my job. Development of policy frameworks on EV charging stations

4. Develop the policies about the green hydrogen.
5. Policy Development
6. Organize debates over each technology and design our path for green energy transition.
7. To share the knowledge and to provide training.
8. Knowledges can be applied for energy policy establishment, in order to achieve domestic RE target, including the pathway to be a carbon neutral in future.
9. Could adopt the blockchain for P2P energy trading application
10. Apply for my project, Local Energy planning.
11. I may setup joint projects with the participants in the events and expand my research field after this event.

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

Comments:

1. APEC economies should cooperate in deeper advanced disruptive technologies.
2. Yes. Pursue the initiatives.
3. Maybe would be a good idea to organize these workshops in more detail per economy or subregion.
4. Recommendations and guidelines to be carbon neutral.
5. No
6. It depends on how the organizers' plan.

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

Answers:

1. Up to know already joke in 1st day.
2. I appreciate well organized summary provided by Worajit-san (Dr Worajit Setthapun).
3. This project should be strengthened in governmental sectors among APEC economies.
4. Seems okay.
5. If these events could be organized on regular bases to foster specific cooperation projects and to evaluate improvements in each economy
6. If these events could be organized on regular bases to foster specific cooperation projects and to evaluate improvements in each economy
7. No
8. Keep going on
9. I may provide more opinions if the organizers could provide more details information on this project. I am happy to communicate more with the organizers in the near future. Thank you.