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Sectoral Innovation System in Renewable Energy: Case of Wind and Solar in Vietnam

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"Mapping sector innovation system of renewable energy in Vietnam"

FINAL REPORT

Sectoral Innovation System in Renewable Energy: Case of Wind and Solar in Vietnam

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Introduction

Energy security is strategic and crucial condition for development of any nation. Vietnam is in the process of rapid growth, fostering its competitiveness while aiming at achieving a more sustainable development pathway. Demand for energy is very high to sustain socio-economic targets. Renewable energy is part of the answers to these demands. The leadership of Vietnam considers renewable energy is one of the key directions for future country development and this culminated in a Resolution of the leading Party No. 55-NQ/TW on strategic direction for national energy development up to 2030, with vision to 2045.

Innovation plays an important role for social and economic rapid and sustainable development in general and to develop many industries in particular, including renewable energy. Recognizing the importance of innovation, for the recent years, Vietnam has promulgated many key policies to promote innovation. This framework has created a favorable legal environment for innovation, contributing to increasing productivity and competitiveness of the firms and the country development. Various important documents of the leading Party and State all required developing the National Innovation System and other formats of innovation systems such as Sector Innovation System focusing on fostering firms' performance and competitiveness. Still, the available studies on National Innovation System, and Sector Innovation System are still fragmented. This is especially true for a sector like renewable energy.

The analysis of the Sector Innovation System focusing on renewable energy is a necessary demand, towards building policy solutions supporting sector to be strong, competitive in the long term. In such a new industrial area like solar and wind energies, innovation may contribute to an early entry into the market, ensure the sustainability and competitiveness of actors involved.

With the collaboration of the Hawaii Natural Energy Institute (HNEI), the University of Hawaii, the National Institute for Science and Technology Policy and Strategy Studies (NISTPASS) under Vietnam Institute for Science, Technology and Innovation (VISTI), Ministry of Science and Technology, Vietnam has completed the study "Mapping the sector innovation system of renewable energies in Vietnam; focusing on solar and wind energies". The project team consisted of Associate Professor Dr. Tran Ngoc Ca (Team leader), Cao Thu Anh, Dang Thanh Tung, Phan Xuan Linh. In addition, it received some research and admin support of Nguyen Vo Hung, Chu Thu Ha and Nguyen Huu Xuyen. The project team also received continuous support of HNEI experts with their valuable advices and comments to the report drafting. The team is grateful to Richard Rocheleau, Mark Glick and Cung Vu for this.

The study received a generous financial support of the HNEI and the Office of Naval Research (ONR), under the "Asia-Pacific Regional Energy System Assessment (APRESA)" initiative to provide support for energy systems transitions in select locations throughout the Asia Pacific Region.

This Final Report is a product of the study comprising of four chapters identifying the concept of Sector Innovation System and then applying the concept into the

Vietnamese context. As the Conclusion specified, the study will contribute to better understanding the status of innovation in solar and wind energy industries, analyze barriers and hindrance that prevent them to grow and become more competitive, economically and technologically. Overall, this should point to certain bottlenecks shortcomings in the system to be addressed for policy considerations.

Chapter I. Theoretical framework and international practices in development of sectoral innovation system in renewable energies (focusing on wind and solar energies)

The first Chapter will provide the theoretical framework as well as international practices of developing sectoral innovation system in renewable energy.

1.1 Theoretical framework on sectoral innovation system

The theoretical framework will discuss very key concepts and definition such as innovation, innovation system, sectoral innovation system and key components of the sectoral innovation systems such as knowledge and technologies, actors and networks, institutions, demand and users, and linkages among these actors.

1.1.1 Innovation and innovation systems

Innovation is firstly mentioned by Schumpeter (1934) in which innovation is described as "new combinations" of new or existing knowledge, resources, equipment, and other factors. The main implication in Schumpeter definition of innovation is innovation as a specific social activity, or "function," carried out within the economic sphere and with a commercial purpose. For Schumpeter, innovations are novel combinations of knowledge, resources, etc. subject to attempts at commercialization - it is essentially the process through which new ideas are generated and put into commercial practice.

The Oslo Manual (2005) defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations". According to Malerba (2003), this definition of innovation takes a broad view of innovation as a phenomenon that can result in improved socioeconomic performance and can be expressed in a range of mediums (i.e., technology, governance, institutions, organizational form, household activity, etc.).

The new definition of Oslo Manual 2018 distinguishes between innovation as an outcome (an innovation) and the activities by which innovations come about (innovation activities). This edition defines an innovation as "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)". This general definition is given a more precise formulation for use with businesses that can be used to evaluate the innovation in sectoral system (OECD, 2018).

Contemporary innovation studies apply a much broader perspective on innovation (Fagerberg et al.: 2004). From this perspective, innovation is understood as the introduction of new solutions in response to problems, challenges, or opportunities that arise in the social and/or economic environment. In the innovation studies literature, such innovation, which is the result of "new combinations" of existing knowledge, capabilities, and resources, is regarded as a major source of change in all economic activities, in poor as well as rich countries (Fagerberg et al., 2010), in low-tech as well as high-tech (von Tunzelmann and Acha, 2004), in services as well as manufacturing, in the public (Osborne and Brown, 2013) as well as the private sector, and so on.

Innovation is the introduction of new technologies and practices to a given society/economy. This definition is important to understand from the outset, since it highlights the fact that innovation does not need to involve technologies or practices that are universally new. Introducing technologies or practices into any economy for the first time involves similar challenges and dynamics, even in cases when their use is widespread elsewhere. An important related point is that new knowledge or technology that is discovered or developed but not introduced into use in the economy is not innovation, but instead merely research or knowledge generation (World Bank, 2010).

The *system of innovation* approach has emerged from the field of evolutionary economics as a field of study for exploring the determinants of innovation (Edquist, 1999; Edquist, 2001; Geels, 2004). Smith (2000) describes *systems* as possessing the following basic underpinnings:

- Economic behavior rests on institutional foundations that afford individuals and organizations reduced uncertainty.
- Differences in institutional arrangements are critical in understanding differences in socioeconomic behavior and outcomes.
- Competitive advantage results from variety and specialization.
- Institutional evolutional processes are self-reinforcing allowing path dependent specialization in socio-economic structure

- Technological knowledge is distributed amongst the individuals and organizations within the system.
- The systems of innovation approach emphasize:
- Putting innovation at the center of the approach.
- Including all the elements (i.e., organizational, political, social, natural resources, etc.) that are relevant to innovation in the model.
- Exploring a historical perspective where system elements co-evolve and require historical context to understand how they have emerged.
- There is no optimal system of innovation and that learning comes from comparison between idiosyncratic systems.
- System elements (e.g., industrial firms) never innovate in isolation but that innovation occurs due to interplay with other system elements in a process that is guided by institutions (e.g., laws, regulations, habits, etc.).
- Innovation must be conceptualized beyond technological products and services in order to understand the relationship between innovation and economic growth.

Malerba (2003) showed that the systems of innovation approach suggests that innovation and economic performance are driven by the configuration of the elements of the system, how optimal these elements are relative to the demands upon the system and how effectively the system can evolve in response to demands. Knowledge is generated and applied by interactive learning between individuals and organizations within the system.

According to Botta, McCormick, and Eis (2015), to understand innovation, analysts must take a systems-level approach, given the interactive, multi-actor and non-linear process that shapes knowledge generation. Innovation is the result of a complex set of relationships among firms, universities, government, financiers, research institutes and users/consumers.

As Spielman (2005) confirmed, a comprehensive description of the innovation systems approach was first set forth by Lundvall (1985) and applied to national comparisons of innovation systems by Freeman (1987). The concept was further elucidated in Dosi et al. (1988), Lundvall (1988, 1992), Freeman (1988, 1995), Nelson (1988, 1993), and Edquist (1997), with empirical applications focusing primarily on national industrial policy in Europe, Japan, and several East Asian countries that were experiencing rapid industrialization during the 1980s. Recent work in innovation systems has added new analytical dimensions, including the study of systems at different spatial (i.e., geographically determined) levels, at different sectoral levels (Breschi and Malerba, 1997; Malerba, 2002), in different time periods, and in relation to a given technology set (Carlsson and Jacobsson, 1993). Application of the innovation systems approach has since been explored by the Organization for Economic Cooperation and Development (OECD, 1997) and its members, the United Nations Commission on Trade and Development, the European Commission, and following by the World Bank and International Monetary Fund (Lundvall et al., 2002).

1.1.2 Sectoral innovation system

Malerba (2003) in his many articles has confirmed that studies that use an innovation systems framework are recognized by their ability to analyze processes that are typically overlooked in the linear approach to R&D. Innovation systems studies often open the "black box" of innovation to analyze actors' motives and behaviors; the institutions that shape these motives and behaviors; interactive, joint, and complementary processes of innovation; and the dynamics of institutional learning and change. They also provide analyses that extend beyond narrow industries or markets to capture a wider range of *agents* (public and private), *interactions* (competition, cooperation, and learning), *institutions* (social practices and norms), and *policies* (science, technology, trade, education, and investment) that condition agents' interactions and responses to innovation opportunities. Further, they often provide analyses of policy design from the perspective of policy as a continuous process that adapts to institutional and technological opportunities presented by socioeconomic change and development (Metcalfe, 1995, 2000). This differs significantly from the neoclassical assumption that policy is the domain of fully informed social planners who reconcile social and private welfare within a system of rational maximizers.

Sectors are often a primary consideration when governments create policy instruments. Nelson and Winter (1997) posit that "policies need to be designed to influence particular economic sectors and activities.". Malerba (2002) defines a *sectoral system of innovation* as "a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. Sectoral systems of innovation have a [sector specific] knowledge base, technologies, input and demand"

Sectoral systems are composed of a set of agents carrying out market and non-market interactions for the creation, development and diffusion of new sectoral products. These agents are individuals and organizations at various levels of aggregation, with specific learning processes, competencies, organizational structure, beliefs, goals and behaviors. They interact through processes of communication, exchange, cooperation, competition and command. Their interaction is shaped by institutions. A sectoral system undergoes processes of change and transformation through the coevolution of its various elements. Thus, at first, Malerba (2005) suggested that a sectoral system could be seen as composed by three main building blocks: *knowledge and technology; actors and networks and institutions.* He was including *demand* as one block that effect to innovation sectoral system.

1.1.3. Knowledge and technologies

Any sector can be characterized by a specific knowledge base, technologies and inputs. In a dynamic way, the focus on knowledge and the technological domain also places at the center of analysis the issue of sectoral boundaries, which are usually not fixed but change over time. Sectors and technologies differ greatly in terms of the knowledge base and learning processes related to innovation, knowledge is mentioned mainly at the firm level. Knowledge differs across sectors in terms of specific scientific and technological fields at the base of *innovative activities in a sector* and *applications, users and the demand for sectoral products*.

Knowledge can be acquired/accessed either from internal or external to the sector. The accessibility of knowledge that is external to the sector may be related to scientific and technological opportunities, in terms of level and sources. The cumulativeness of knowledge can be gathered from three sources. The first source is cognitive, the second source is related to the firm and to its organizational capabilities, the third source is the feedback from the market, such as the "success breeds success" process.

A sectoral or technological approach builds on a sound understanding of the underlying technology. This includes two components. First, the policies and types of actors that support a specific technology evolve according to the stage of maturity of the technology (IRENA, 2013; IEA, 2011). As the technology matures and enters the market, the focus of policies should shift from largely basic research and development towards more demand-enabling policies. For example, in the case of renewable energy, the adoption of a demand-side policy like feed-in tariffs is unlikely to be effective (and may even be counter-productive) if the targeted technology is not yet close to market competitiveness. From this standpoint, sectoral or technological approaches have the key advantage of providing policy advice tailored to the technology under analysis. In order to properly frame the stage of technological maturity, the analysis might build on work by other organizations specialized in determining the maturity level of different technologies. The second component of this issue is the fact that an analyst must understand the basic elements of the value chain for the technology under consideration. For example, the value chain for wind power includes a set of hardware components (blades, towers, turbines, etc.) that are distinct for the purposes of research, development and demonstration (R,D&D) and manufacturing. Without a clear understanding of this value chain structure, the analyst cannot correctly frame the analysis.

a) Core technology and knowledge in *solar energy*

Some key new technology development[1]

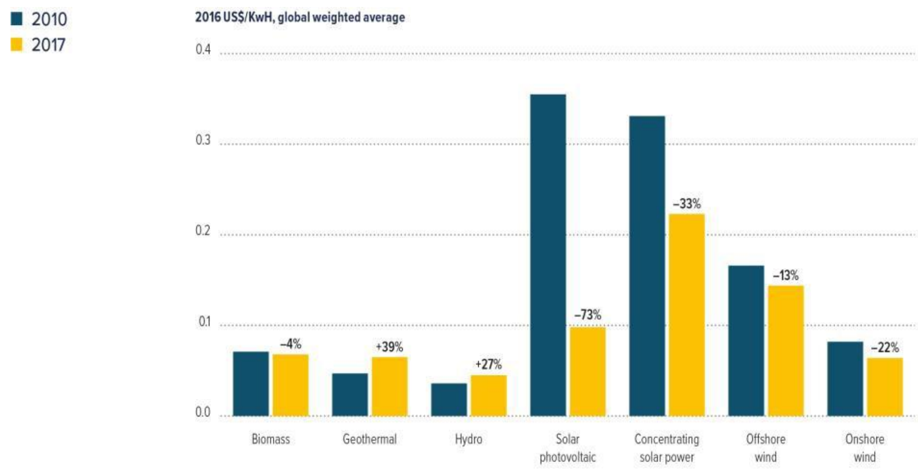
Some advancements in mainstream energy sources, such as solar, include improvements in the material science of solar photovoltaic cells. While silicon-based solar photovoltaic energy is likely to remain dominant, a promising variety of third-generation thin film cells based on earth-abundant materials (including copper zinc tin sulfide, perovskite solar cells, nanomaterials such as organic solar PVs, and quantum dot solar cells) is emerging in material science. Perovskite solar cells, for example, have excellent light-absorbing capacities and lower manufacturing costs. Photoelectric efficiencies improved from 10% to over 20% between 2012 and 2015. However, perovskites are still in the early stages of R&D, with uncertainty regarding long-term stability and feasibility for large-scale deployment. Third-generation solar photovoltaic cells are aiming for combinations of high-power conversion efficiency, lower cost and usage of materials, and lower manufacturing complexity and costs. Achieving all three objectives is not easy, but with greater efforts into R&D, solar photovoltaic technology can achieve an even larger scale of deployment. Other solar energy improvements involve concentrating solar power technologies or printable organic solar cells.

Artificial photosynthesis and cellulosic ethanol energy extraction provide opportunities for the transition to a sustainable and scalable energy system. Artificial photosynthesis has the capability of capturing and storing the energy from the sun, converting it into a usable fuel.

Of all renewables, *solar photovoltaics* (PVs) have arguably benefited the most in the past couple of years from scale and technology breakthroughs. Many of the recent improvements in this area have emerged from advances in cadmium telluride (CdTe), the semiconductor material with the smallest carbon footprint and shortest energy payback time of all solar technologies. Other so-called thin film silicon technologies, primarily copper indium gallium selenide (CIGS), as well as non-silicon approaches (chiefly perovskite) are also beginning to impact the direction that PVs will take in the future. Annual research budgets for the top 12 solar panel manufacturers increased by nearly 500% between 2006 and 2016.

[1] This section is mainly based on a study of Botta, McCormick and Eis (2015).

Figure 1: Global levelized cost of electricity from utility-scale renewable power generation technologies, 2010 – 2017



Source: IRENA, 2018

As this R&D process has been developed, the cost of solar PV electricity has fallen some 73% since 2010, according to IRENA, down to an average of roughly US$0.10 per kilowatt-hour (KwH) compared to a range of $0.05 to $0.17 per KwH for fossil fuels (Figure 1). (Swanson's Law observes that that the price of solar photovoltaic modules tends to drop 20% for every doubling of cumulative shipped volume).

In more advanced economies, consumers are being encouraged by attractive options to make the shift to solar energy. For example, solar PV wafer and cell manufacturers - such as China's JA Solar and Minnesota-based start-up SolarPod - have designed modular assembly systems that simplify the installation of solar panels and reduce maintenance costs, critical improvements needed to overcome consumer reluctance to jump off of the relatively reliable existing utility grid.

In less-developed regions, government energy departments are developing aggressive programs to expand the presence of PVs. South Africa's government has rolled out a national solar water heater program with the goal of 1 million installations in households and commercial buildings by 2019, although the campaign has been slowed a bit by financial constraints. Across Africa, the continent's market leader has installed some 400,000 PV systems. At its current rate of growth, the company may add another 200,000 to that number over the next year. These solar home systems offer cleaner, safer, and cheaper lighting over time than kerosene, the primary alternative for lighting in developing nations.

PV technologies have made even more remarkable advances. The global weighted average Levelized Cost of Electricity (LCOE) of utility-scale solar PV fell by 73% between 2010 and 2017, to US$0.10/kWh, due to the 81% decrease in solar PV module prices and increased module efficiencies, along with reductions in the balance of system costs. Increasingly this technology is competing head-to-head with conventional power sources without financial support.

Innovation in renewables of solar Photovoltaics energy

The major breakthrough in efficiency of solar PVs industry is the creation of semiconductor technology. Many improvements of solar PVs have made it becoming one of the most potential renewables sources in recent and in the near future. It does not cause air pollution, noise pollution (not use movement engines), less maintenance requirement, long life (20 – 30 years) and low operation cost. Specially, the solar PVs system can be applied in all scales from small to large.

Remote regions can easily produce their own power supply by installing a small or large solar PVs system. Solar PVs electricity generators for homes, schools, businesses... can all be applied and installed easily on roof or bare ground, operating extremely safe and quiet. The solar PVs industry is extremely potential.

Developed countries are searching solutions to promote and encourage people to install small and decentralized solar PVs electricity systems to provide demand for themselves, instead of wasting money on expensive investments of electric grid, especially in remote regions where grid connection and transmission is impossible. Currently, there are two main weaknesses in using solar PVs. Those are the amount of sunlight and the initial equipment investment cost. The amount of sunlight is a factor that varies depending on the geographical location, time of day, climate seasons and weather such as cloud, rain and storms, etc.

Solar battery or solar PVs battery is a device of energy storage from the conversion of sunlight energy into electricity by photovoltaic effect, which is a physical and chemical phenomenon. Solar PVs cell is described as being able to photovoltaic with any light source, including sunlight or artificial light (low efficiency). They are used as an image detector (such as an infrared Sounder), identifying light or other radiant near the visible range or measure light intensity.

The operation of Solar PVs cell requires three basic properties:

- Light absorption, creating the electron - hole pairs
- The separation of charged particles among material opposite each others
- The separation of charged particle waves to external circuit

Solar PVs battery can be classified into cells according to the first, second and third generation. First generation cells - also so-called as normal cells is made of single crystal or silicon polycrystal, this is the dominant solar panel technology in the market, including solar PVs battery of single crystal and mono polycrystal. The first-generation panels include silicon solar PVs battery.

Second-generation cells are thin-film solar PVs battery, including amorphous silicon cells as cadmium telluride (CdTe) and copper indium gallium selenide (CIGS); which have commercial implications for large-scale solar power manufacturers or small independent devices as pocket calculators, solar backpacks, etc. This generation battery is less expensive for manufacturing cost than the two traditional silicon crystal above because they require less manufacturing material. Thin-film solar PVs cell is a solar PVs battery technology with relatively thin physical structure. It is less efficient and requires a larger installing area, but they are much cheaper.

Third-generation cell includes a number of thin-film technology that are considered "emerging" – most of them are not yet commercially available and are still in the R&D stage. Many researchers use organic materials, normally organometallic compounds as well as inorganic compounds. Despite the fact that their efficiency and stability are relatively low compared with the above technologies but they are much potential in the future because they have low manufacturing costs.

b) Core technology and knowledge in *wind energy*

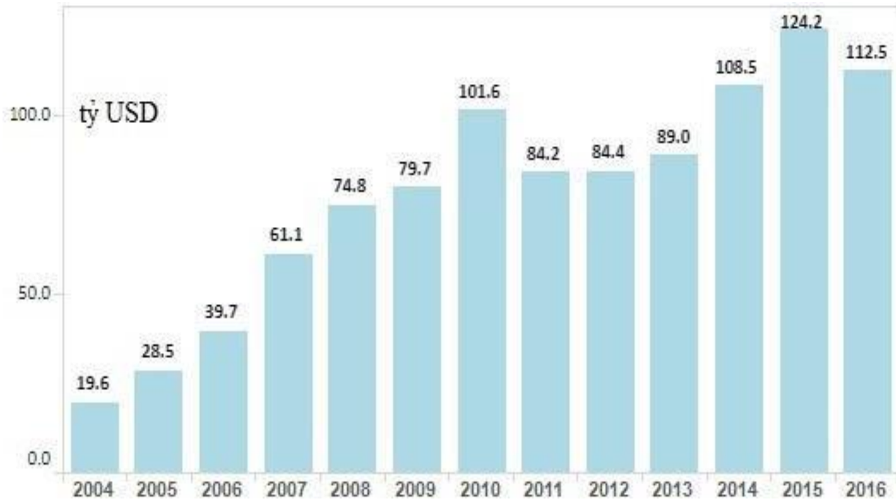
Key recent development of technologies

Wind energy is a green energy source which has a huge development in the last 10 years as wind farms with capacity from several MW to thousands MW, have appeared in countries such as China, the United States, Germany, Spain and India. According to statistics of the IREA, the total global wind energy capacity increased sharply from insignificant in 1980 to nearly 60 GW in 2005 and by 2016 reached nearly 500 GW with average rate of 20 GW/year (IRENA, 2017).

The price per unit of MWh changes rapidly in the energy sector as it is being driven by consumption demand for clean energy. In February 2017, according to the Lazard Investment Company financial report 2016 of Bloomberg about energy cost (LCOE) for different power generation technologies, renewables are the cheaper available sources in recently.

Lazard Investment Company used LCOE analysis to identify each unit of electricity (measured in megawatt per hour, or MWh) will generate how much cost during the lifetime of any power plant. The LCOE is calculated including all cost components - capital costs for construction, operation and maintenance, and different costs for operation - spread over the total number of megawatts generated during the lifetime of the plant.

Figure 2: Total Global Investment Capital for Wind Energy



Source: Lazard

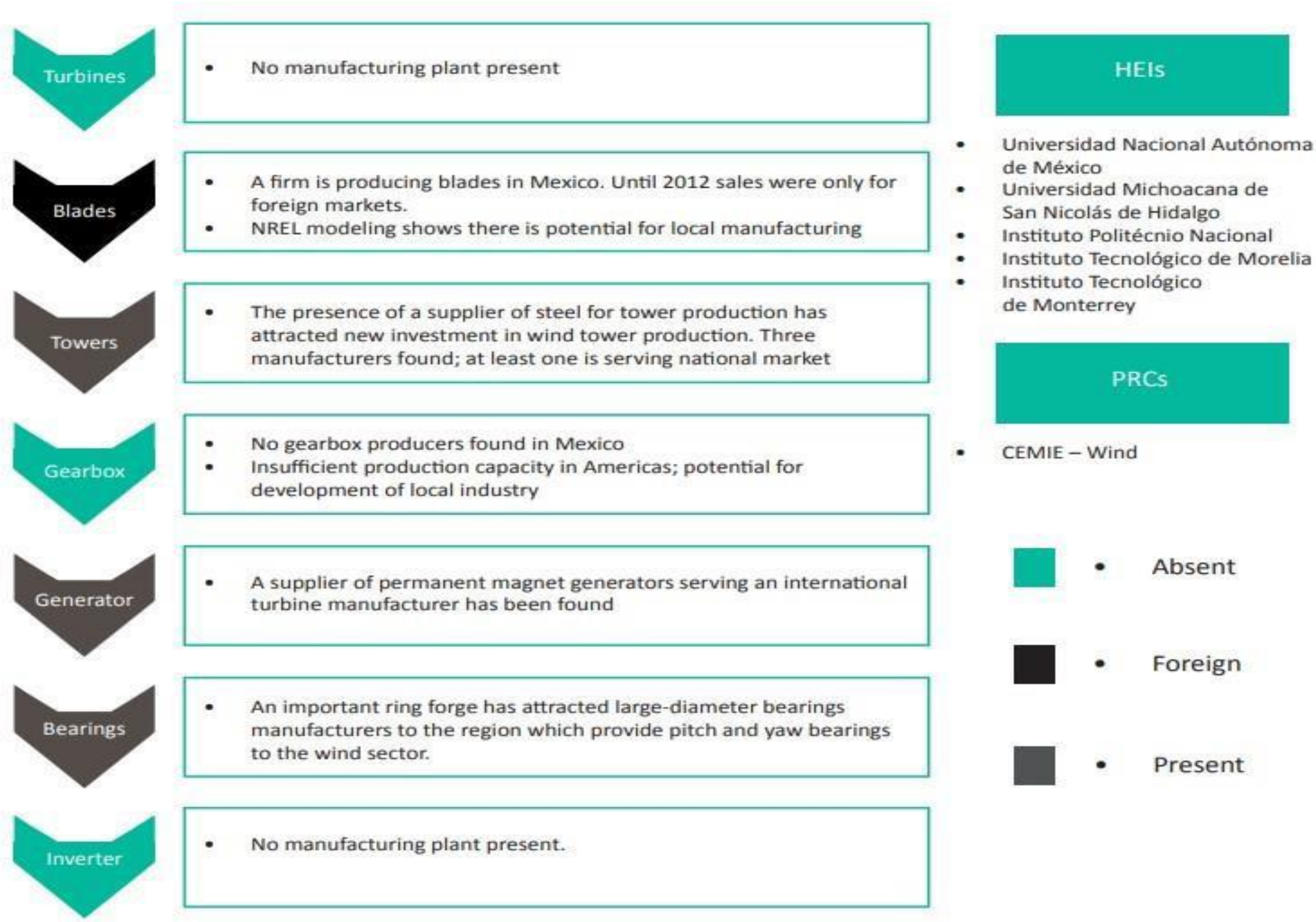
According to Lazard, wind energy cost has decreased significant by 66% since 2009, from 140 USD/MWh to 47 USD/MWh. While the lowest price of the current generation of burning fuel (coal, gas) in thermal power plants has an average LCOE of 63 USD/MWh. Total Global wind energy investment has reached more than 100 billion USD/year (Figure 2).

International and national policies that support prices and tariffs have pushed down the renewable energy cost for wind energy. The price is not only cheaper than the construction of new natural gas plants but also much cheaper than fossil fuel plants when it is accounted marginal costs (operation, maintenance, fuel costs…).

Technology innovation has also transformed the prospects for *wind energy*, making it the least expensive renewable energy source. Modern wind turbines are increasingly cost-effective and reliable, and they have scaled up in size to achieve multi-megawatt (MW) power ratings. Because of longer, lighter rotor blades, taller towers, and better drivetrains and performance optimizing control systems, an average onshore wind turbine with a capacity of 2.5 - 3 MW can produce more than 6 million kWh in a year – enough to supply 1,500 average European households with electricity, for example. Currently, at least 24 countries around the world are meeting 5% or more of their annual electricity demand with wind power.

One example of reviewing technology innovation in wind energy can be clearer seen in the wind value chain of Mexico as given in following Figure 3.

Figure 3: Illustrative map of wind value chain in Mexico



Sources: Botta et al. (2015)

Innovation in wind energy

In the past, operation of the rotor blades on the vane principle was popular in the world, but it had low efficiency, because the impact of the wind was much slippage, the force generating torque is insignificant compared to the impact force. The rotor blades were normally installed in a place where wind is not strong enough, therefore the large wind turbine (blade area of several dozen square meters, weight of few tons per blade) created inertia. That made blades could not rotate at wind speed below 8 m/s. When wind was higher, the weight of the blades made capacity decreased even at wind speed from 10 m/s to 17 m/s...

Over decades of R&D, wind turbines have been designed on the principle of the sail blocking to exploit energy with the basic advantages below.

Compared with the sail spread the wings to catch wind in all directions, whichever way the wind blows, the rotor blades also rotate, without steering wheel. Difference with horizontal axis wind turbine blade, wind impacts on the blades is much slippage, wind turbines catching wind on the principle of sail blocking with higher efficiency. This innovation supports turbines to be able to stabilize the speed of the rotor blades by increasing or decreasing the wind flow affecting the rotor. At the same time, this device has the ability to increase the pressure, increasing the rotation of the rotor, increasing the capacity several times by the subsystem.

The wind energy receiver on the principle of sail blocking is easy to design, manufacture, and install. In addition, the cost of this device is lower many times than other wind turbine devices. Wind turbines become more cost-effective, more reliable and capable of much more power production.

Today's turbines are considerably larger with a greater power generation capacity of up to 12MW. Some of the main areas of innovation are:

- Longer and lighter rotor blades with some reaching 95 meters long
- Blades with curved tips that are designed to take maximum advantage of all wind speeds
- Blades that are better able to withstand the stresses of high-altitude wind and taller towers
- Performance-optimizing control systems
- More reliable gearboxes
- Digitalization of processes

Turbines, at present, do not leverage much on digital technology. But as technology, in general, evolves to become more sophisticated, offshore wind turbines could communicate with geographically far-located asset owners much faster by adapting bandwidth upgrade from 4G to 5G.

As 'the cloud' becomes a safer space to store larger amounts of data, the wind industry can take advantage of this to allow turbines to store an increased amount of analytics than before. With more data comes further insight into the health of the turbine.

Drone use is also another technological advance the wind industry is leveraging. With drones, photos can be taken remotely and autonomously. Cloud computing can then stitch these images together, before finally passing them over to an artificial intelligence system that is programmed to identify any problems with the blade i.e., cracks, for example. This highly digitalized process means maintenance issues can be identified at an early stage, enabling technicians to be deployed before the problem becomes serious enough to warrant shutting down the turbine.

c) Core knowledge and technologies in *storage and transmission*

Fueling off-grid activities are significant breakthroughs in energy storage devices. Such devices primarily include batteries that can warehouse renewable power in people's homes or in local facilities, providing a steady stream of energy regardless of the solar or wind conditions in the area.

Since 2012, the price of lithium-ion batteries has dropped some 70%; analysts forecast that lithium-ion storage could fall down to US$100/kWh by 2025, from about US$250/kWh. At US$200/kWh, previously uneconomical applications, such as the co-location of battery storage and solar PV systems, suddenly become extremely attractive. Solar industry experts at IHS Markit believe that, by 2025, the world's base of cumulative installed battery storage capacity will reach 52 GW, and revenue from this sector is forecast to grow at a 16% compound annual growth rate (CAGR), reaching $7 billion.

The possibilities from battery storage are especially welcome in developing countries. Lithium-ion technology promises to offer emerging economic areas the alternative of quickly installing micro-grids as energy distribution sources, rather than having to wait for fully functioning national grids.

As more renewable energy is deployed, an increasing challenge is on the technical and economic aspects of integrating larger shares of renewables into electricity grids. There is now a large emphasis on infrastructure development and innovation in enabling technologies that can help to integrate variable renewables into electricity systems, including smarter electricity systems that integrate digital and so-called exponential technologies, such as artificial intelligence, and technologies to increase the flexibility of energy demand.

Energy systems are comprised not only of supply-and-demand technologies, but of infrastructures that connect them. Infrastructure is particularly significant in electricity systems, as even electricity generated close to demand requires a wire to transmit the power to the end-use device, and in cases where generators are located distantly from demand, many hundreds of kilometers of power transmission lines may be required. Such infrastructures are significant investments, and as such, once in place, have a considerable constraining and directing influence on the evolution of the supply-and-demand balance in the power system. Overall innovation and availability of technology options in RE sector are given in Table 1 below.

Table 1: **Innovation progress of technology options in the energy transition, by sector**

Pace of innovation progress	Sector: Power generation	Industry	Transport	Buildings
On track	• Hydropower • Solar PV • Onshore wind • Offshore wind • Smart grids • Battery storage • Energy efficiency in end uses	–	• EVs	–
Lagging but viable	• Biopower • Geothermal • Interconnector capacity • Ultra-high-voltage DC • Demand-side response • Solar CSP	• DRI iron-making gas + CCS • Clinker substitutes • Clinker kilns + CCS • Clinker kilns biomass • Gas ammonia production + CCS • Biomass supply at scale	• Conventional biofuels • Energy efficiency • Biomass supply at scale	• Zero-energy buildings • Energy renovation and existing stock • Clean cooking using renewables • Solar-assisted water/ space heating systems • Heat pumps
Not viable at current pace	• CCS for natural gas and biomass (BECCS)	• DRI iron-making hydrogen • Blast furnace iron-making + CCS • Blast furnace iron-making biomass • Biomass for chemicals + recycling • Hydrogen ammonia production • Material efficiency • CO_2 transportation and storage infrastructure	• Hydrogen vehicles • Advanced biofuels • Railway infrastructure for modal shift	• District heating & cooling with renewables
Not currently available	• Various negative emission technologies • New materials for advanced battery storage	• Solar thermal aluminium smelting • Direct conversion of CO_2 to fuels and materials	• Solar passenger cars • Electric aircraft	• Advanced lightweight materials for construction • New appliance technologies such as magnetic refrigerators; breakthrough materials for insulation; and advanced smart heating, cooling, and appliance use and control systems

Source: IRENA, 2017a

d) New development trends in innovation in renewable energy sector (relevant to solar and wind)

Decentralization and distributed generation

Distributed storage has also gained momentum recently with a behind-the-meter business model that allows customers to store electricity generated by their rooftop solar panels and use it when needed—for example, after the sun sets.

Decentralization of the energy sector also brings new *innovative business models* around peer-to-peer power trading, demand side responses, and power to buildings. All of this enables consumers to move out of the monopolistic markets driven by utilities and participate in a more transparent and independent manner, leading to a 'democratization of electricity'. Pay-as-you-go (PAYG) business models, which allow customers to pay directly for the electricity they require at a rate they are willing to pay, are beneficial for developing regions where customers' access to financing is limited. PAYG has been implemented in regions in Africa (e.g., M-Kopa) and India (e.g., Simpa Networks).

Electricity storage technologies are undergoing rapid development and cost reductions. Storage technologies vary significantly in terms of their output, rates of charge/discharge, and the length of time they can store energy for. Storage technology development is driven in part by the growing electric vehicle market and the increasing availability of incentives offered by some countries for larger grid-scale electricity storage. Current battery technologies are unlikely to be sufficient to deliver large-scale seasonal storage (e.g., solar electricity stored in summer to heat buildings in winter). Therefore, there is also a need for advances in other types of heat or energy storage that can operate over longer timescales.

Digitalization

Interesting opportunities exist at the crossroads of ICT and energy technology. The application of digital monitoring and control technologies in the generation and transmission domain of the electricity system has penetrated deeper into the local grids. Wider use of smart meters and sensors, along with the application of Internet of Things, has created opportunities to provide new services to consumers. Enhanced communication and control enable aggregators to bundle demand response and create 'virtual power plants'.

Smart technologies are providing data and insights on consumer behavior that enable better planning by grid operators. With improved communications, system operators gain valuable information about distributed energy sources in real time, thus enabling better production and consumption forecast models. These developments result in greater flexibility to accommodate new and variable energy sources.

As renewable energy technologies increasingly rely on *enabling digital technologies*, a key future research area is in the digitalization of energy systems that become more connected, intelligent, predictable and sustainable. Transport infrastructure and electric vehicles are being increasingly used as leverage for automated, connected, electric and shared mobility. Smart power grids can match and integrate intermittent sources of electricity such as solar and wind power with transport systems on a wide scale, owing to the cross-sectoral nature of mobility. Potential benefits include greater energy efficiency and optimized energy consumption.

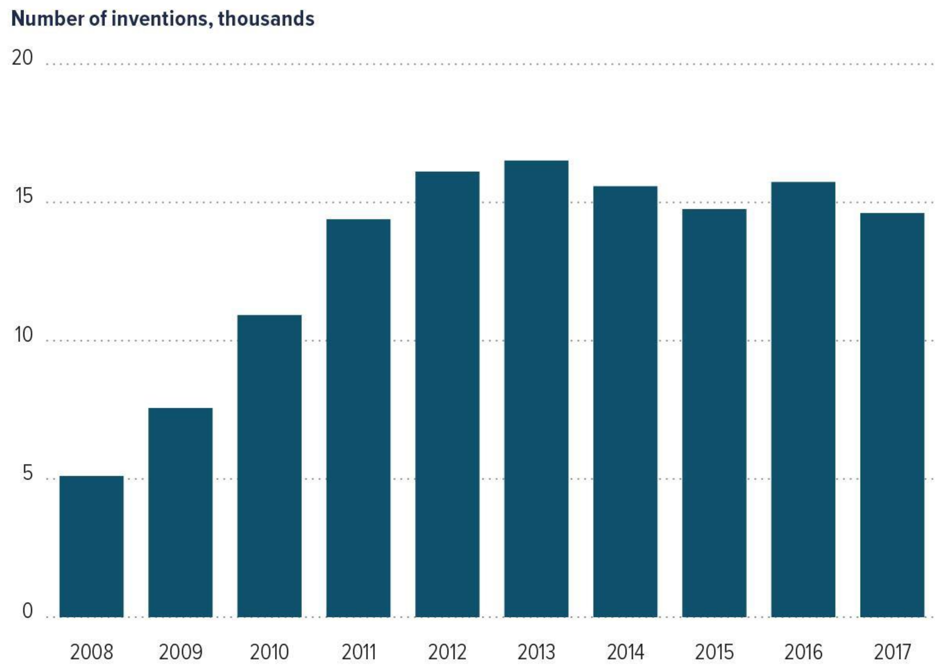
Digital technologies are also relevant to buildings, which account for more than 50% of electricity demand. Energy in buildings is generally used for heating, cooling and lighting. Digital technologies are contributing to improved energy response through real-time data by using sensors, which can be managed and monitored through smart devices. Predictive user behavior, which utilizes learning algorithms, is another emerging technology that can effectively balance energy loads between consumer demand and utility supply. However, the potential impact of greater connectivity of energy systems is still uncertain because of perceived consumer reservations on data privacy, cybersecurity and implications for employment due to automation.

Renewable energy - related patent landscape insights

The rising interest in RE as an alternative energy source asks for a deeper look at global patenting activities in this intellectual property (IP) – intensive industry. The area of PV technologies is particularly interesting because, within the next 25 years, solar power is expected to become the cheapest source of new electricity generation.

Based on worldwide PV - related inventions published from 2008 - 2017, the patent landscape analysis reported that there were indeed escalated PV-related filings globally.

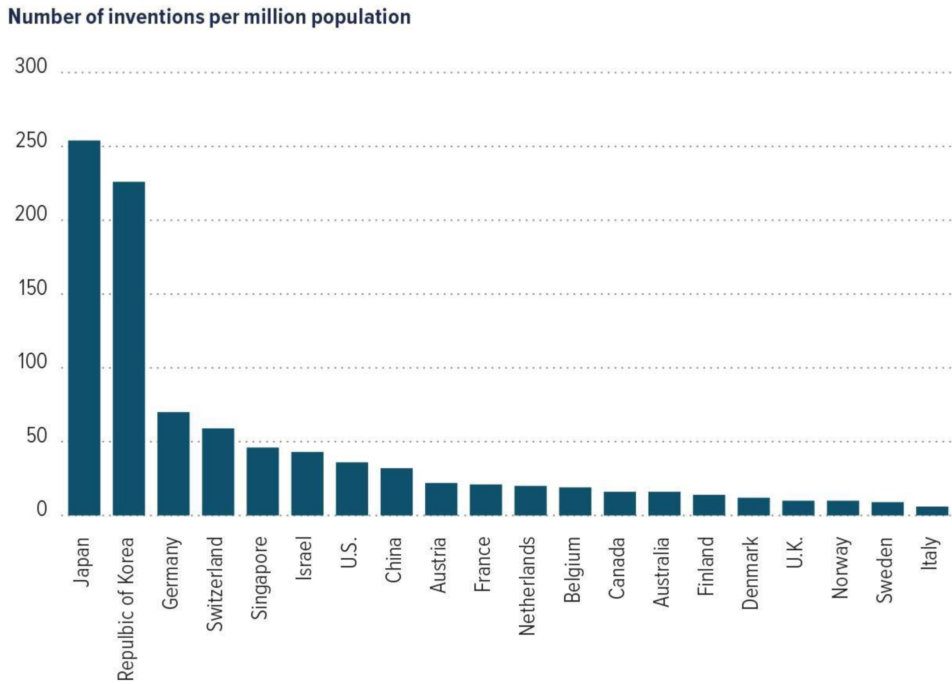
Figure 4: **Publication trend of photovoltaic-related inventions, by earliest publication year**



Source: IPOS – International, International Report

From 2008 to 2017, there were a total of 143,403 PV-related inventions (Figure 4), which were largely dominated by China and East Asia. In fact, the combined contributions from China, Japan, and the Republic of Korea accounted for about 60% of the worldwide PV-related patenting activities in the last decade.

Figure 5: Top 20 countries with the largest number of photovoltaic - related inventions, by applicant's country of origin



Source: IPOS – International, International Report

However, during the last five years – from 2013 to 2017 – a plateau in PV-related patenting activities has been observed, suggesting that PV technologies are maturing. It is noteworthy that small countries such as Switzerland, Singapore, and Israel stand out in terms of *inventions per capita*, to be ranked behind traditional major hubs for PV technology such as Japan, South Korea and Germany (Figure 5).

Figure 6: Top 10 emerging technology sub-domains in photovoltaic (PV)

2008 - 2017

	No. of inventions according to earliest publication year											% change per annum,
Emerging area	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	2012–16
PV or PV-hybrid power plants	15	26	59	45	61	40	199	277	353	267	1,342	54.5
Management & optimization of PV systems	1	0	5	9	13	25	51	56	86	105	351	45.9
Support structures for PV modules	51	116	214	202	231	249	352	679	1,030	904	4,028	39.9
Monitoring or testing of PV systems	8	20	44	108	128	129	198	363	402	406	1,806	33.2
Structural details of PV modules	10	21	20	54	61	86	121	191	200	183	947	31.7
PV module components or accessories	54	103	187	231	268	207	420	614	718	735	3,537	30.6
Solar-powered lighting	47	49	85	106	103	119	136	177	197	304	1,323	16.9
Programme-control systems	1	4	11	14	22	43	27	31	49	59	261	12.7
Circuit arrangements for AC mains	67	93	162	294	378	467	550	578	635	567	3,791	12.5
Circuit arrangements for energy storage in batteries	96	116	173	252	224	303	305	303	404	365	2,541	11.8

Key: 0–100 101–200 201–400 401–700 >700

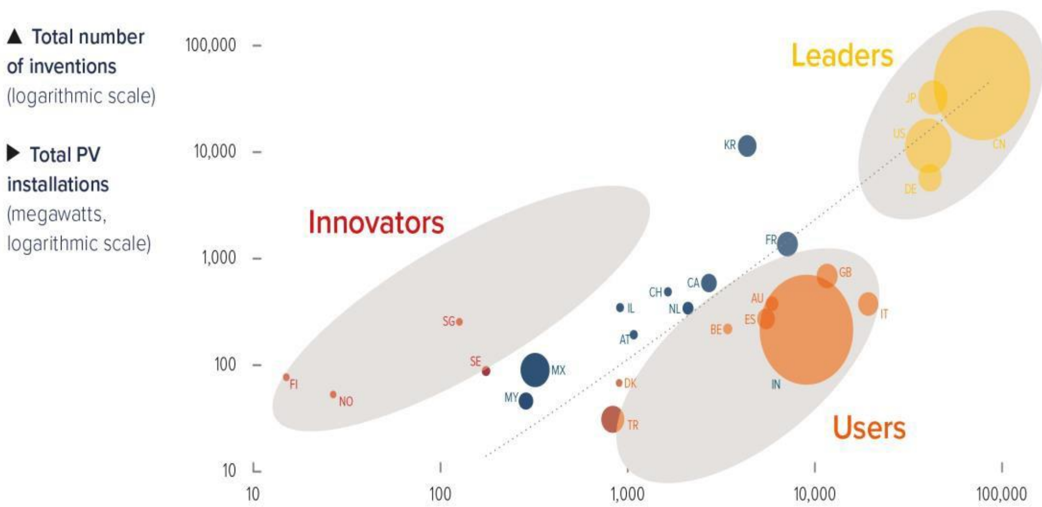
Source: IPOS - International, international Report

Another notable observation from the patent landscape analysis from 2008 to 2017 is the high growth evident in areas such as PV or PV-hybrid power plants (which has seen an increase of 54.5%), management and optimization of PV systems (up 45.9%), and support structures for PV modules (up 39.9%) (Figure 6).

Interest in such system-level integration and downstream applications is likely to continue given the strong annual growth that has been seen in these areas over the past years.

The patent landscape analysis also reported a strong correlation between countries' efforts and achievements in driving PV technologies and their use of these inventions, as can be seen in Figure 7.

Figure 7: Photovoltaic (PV) technologies: Leaders, innovators, and users



Source: UN DESA, 2017; EMA Singapore, 2016

Non technological innovation

The innovation challenge for energy goes beyond traditional R&D efforts. This challenge cannot be met by increased R&D investment alone. It requires global sectoral approaches that help to overcome a lack of cost-competitiveness while addressing carbon leakage concerns. Innovation also includes a fundamental rethinking of production processes and energy technologies required for the energy transition. A sustainable solution is one that increases productivity and enhances performance while eliminating emissions.

Efforts to increase innovation must cover the complete technology life cycle, including the demonstration, deployment (technology learning), and commercialization stages. Furthermore, the innovation ecosystem should extend across a range of activities to include creating new market designs, building innovative enabling infrastructure, forming new ways to operate energy systems, establishing standards and quality control systems, and implementing new regulatory measures.

Some tools allow both policy makers and entrepreneurs to develop market diffusion mechanisms for innovative technologies. These tools aim to enable matching innovation initiators (e.g., national institutes, private companies, and technology transfer offices) with the neediest innovation recipients (e.g., new customer groups and market niches). Examples include crowdfunding, joint ventures, patents and licenses, spin-offs, and technology incubators.

1.1.4 Actors and Networks

One important component of sector innovation system is actors and their networks. Malerba (2003) showed that a sector is composed of heterogeneous agents, which are organizations and individuals. They interact through processes of communication, exchange, cooperation, competition and command. Within sectoral systems, heterogeneous agents are connected in various ways through market and non-market relationships. Thus, in a sectoral system perspective, innovation and production are regarded as processes that involve systematic interaction among a wide variety of actors for the generation and exchange of knowledge relevant to innovation and its commercialization. Interaction includes market and non-market relations that are broader than the market for technological licensing and knowledge, inter-firm alliances, and formal networks of firms.

Industry/Firms

Firms are the key actors in a sectoral innovation system as they are involved in the innovation, production and sale of sectoral products, and in the generation, adoption and use of new technologies. Firm heterogeneity is a key feature of sectoral systems. The heterogeneity is in terms of types, beliefs, competencies, behavior and organizations that could stem from differences in a set of factors: the characteristics of the knowledge base; experience and learning processes; firm-specific interactions with demand; the working of dynamic complementarities; firms' histories; and differential rates and trajectories of innovation and growth (Nelson and Winter, 1982; Dosi, Marengo and Fagiolo, 1996; Malerba, 1992; Teece and Pisano, 1994; and Metcalfe, 1998). Firms also include users and suppliers, who have different types of relationships with the innovating, producing or selling firms. The focus on *users* puts a different emphasis on *the role of demand* while *suppliers of components and subsystems* also play a major role in affecting innovation, productivity increases and the competitiveness of downstream sectors.

Higher Education Organizations (HEI)/Universities

In emerging and developing countries, the potential contribution of public Research Organizations (PROs) and HEIs is particularly relevant since the business sector is often weak, so research capacities mostly are concentrated in universities and PROs (OECD, 2014).

The traditional roles of universities were education, basic research and science but recently a new function of universities was taken over that is creating knowledge and technology transfer to industry, commercialization of knowledge. University plays more active role in innovation systems. Tödtling (2006) has explored the four roles of universities in innovation systems and clusters of knowledge-based industries that are: (i) "Antenna" for adopting external knowledge and mediator for local knowledge circulation; (ii) Source of highly qualified labor; (iii) Knowledge provider in university-industry linkages, and (iv) Incubator for academic spin-off companies.

Universities as "antennas" for adopting external knowledge. Innovation is taking place increasingly in a division of labor of many actors in innovation system thus knowledge base becomes more "distributed" (Smith 2002), external knowledge becomes more important for generating new knowledge and innovations. University holds a key function in this respect being inserted in global knowledge communities and networks through conferences, workshops, research collaborations, co-publication, co-patenting etc. If university would like to functioning well in innovation system, they have to absorbed knowledge through various mechanisms.

University as source of highly skilled labor. The “traditional” role of universities becoming more important innovation system in the emerging knowledge economy. Graduates and highly skilled labor are one of the most powerful mechanisms for knowledge transfer to industry therefore university becomes one of the key factors for the development of high technology clusters.

University is the knowledge provider in the linkage with industry. University and industry have a clear relationship in past years. Today universities have become important knowledge sources and innovation partners for industry through many channels: R&D contracts, R&D collaborations, innovation partnerships, joint use of facilities, informal knowledge exchange. The role of university changed from simple knowledge transfer towards knowledge sharing and interaction. The linkage between university and industry is more important in knowledge-based industries and clusters.

University becomes incubators for spin-offs. The establishment of spin-offs as the commercialization of academic inventions especially in high tech industry such as ICT and biotechnology however they need a relatively new route for commercialization of academic inventions.

Tödtling (2006) concluded that universities are important actors in innovation system. They have new roles and forms of interactions with industry (U-I links, R&D collaborations, spin-offs). However, the key importance of universities for innovation system has still to be seen in the traditional roles of providing highly qualified graduates, doing excellent scientific work, providing basic science and R&D. The key challenge with university is they have to interact with industry but keep freedom and diversity of academic research. Otherwise, the role of universities in innovation systems and clusters is to bring in critical views, they have to provide new ideas/complementary knowledge not only just carrying out R&D for industry.

Botta, McCormick and Eis (2015) added that while policy attention is often concentrated on the link between HEI research and “third mission” activities (patenting, spin-offs, etc.), it is important to remember that the most significant contribution of HEIs to innovation often lies in the creation of capabilities through teaching and research-training activities.

Public Research Organizations (PROs)

The term “public research organization” is used to refer to a heterogeneous group of organizations performing research as their main activity (as opposed to HEIs, where education is equally relevant) with varying degrees of government influence on their activities and funding. PROs play a key role in bridging the divide between academia and industry and often account for a large share of direct government RD&D expenditures.

The diverse institutional arrangements of PROs also influence their roles within the innovation system; some PROs have very specific and stable missions while others perform basic and applied research in many fields.

Networks and support organizations

The number of possible support organization is very large. These organizations serve multiple purposes (knowledge sharing, lobbying, supporting facilities, etc.). Networks, both informal and formal, enable knowledge sharing and generation, and are therefore a key structural component of innovation systems. Formal networks, such as industry associations or consortia, should be included in the analysis as a first step as they are often easily recognized. The identification of informal networks -- which can include key supply-chain actors, technical experts, or individuals with common educational or professional backgrounds - is more complex, and may require discussion with industry experts, or analysis of co-patenting, co-publishing or collaboration (e.g., joint ventures, supplier groups having a common customer, joint university-industry projects).

Financial Organizations

This group of actors is composed of a spectrum of private financial entities, some with a higher appetite for risk and a desire for higher returns, and others with less risk tolerance but lower required returns. Traditional banks usually take low risk in financing firms by providing credit, while private equity like Business Angels (BAs), Venture Capital (VCs) and Private Equity Funds (PEFs) take a higher risk by buying equity in private companies not listed on the stock exchange. One of the main differences among the types of private equity is the increasing amount of capital invested and decreasing technology risk accepted. Business Angels are private persons (often successful entrepreneurs) who invest in unlisted companies and provide a key bridge between seed and venture capital for growth companies. Venture Capital funds are companies (rather than individuals) specialized in investing in young, high-potential firms after the seed stage. Private Equity Funds invest in existing firms (well beyond the early stage) with clear products and existing cash flows.

1.1.5 Institutions

Institutions include laws, regulations, social norms of behavior, habits, routines, values, and aspirations, all of which are rooted in a given society's history and culture and can directly affect the performance of an innovation system. Common examples are the attitude towards failure and the perception of the appropriate level of engagement of universities with the private sector. This is particularly true when the potential users of the outcome of the innovation process are poor or marginalized. These institutions determine the extent to which the poor can participate in the innovation process and share the potential benefits. For instance, social norms may limit women's access to higher education, or prevent innovators from realizing that there may be business opportunities provided by poor or marginalized populations (World Bank, 2010).

Policy dimension in renewable energy innovation system

In the context of rapid development of renewable energy technologies, new policies are needed. Energy intensive industries, such as cement or steel and iron production, have been largely exempt from ambitious climate policies because of international competitiveness issues and potential carbon leakage. Buildings and city designs should facilitate renewable energy integration. Regulations are needed to ensure that new buildings are of the highest efficiency, and the retrofitting and refurbishment of existing buildings needs to be accelerated.

For end-use sectors that cannot be electrified, such as freight transport, aviation, and heavy industries, innovation is needed to bring breakthrough technology solutions to market while also scaling up options lagging in deployment. These options include modern biofuels, solar thermal heat, district energy systems, and hydrogen. Four elements need to be included in a policy framework for the energy transition:

- A systemic innovation approach beyond R&D: Leveraging synergies between innovations across all sectors and components of the system, and involving all actors, is crucial. Innovations in technology should be pursued supportively as they are in enabling infrastructure and sector coupling, business models, market design, finance instruments, and policy frameworks.

- Approaches to nurture innovation: Innovation is crucial for the decarbonization of the energy sector. International cooperation on innovation for clean energy should be pursued and should take advantage of relevant existing platforms such as IRENA, Mission Innovation, and Clean Energy Ministerial.

- Advances in power-system integration: Renewable power already has a strong business case, but achieving its potential requires additional efforts in innovation for systems integration.

- Support for a portfolio of options for the end-use sectors: Effective support requires a combination of electrification, technology breakthroughs, and sector specific global agreements.

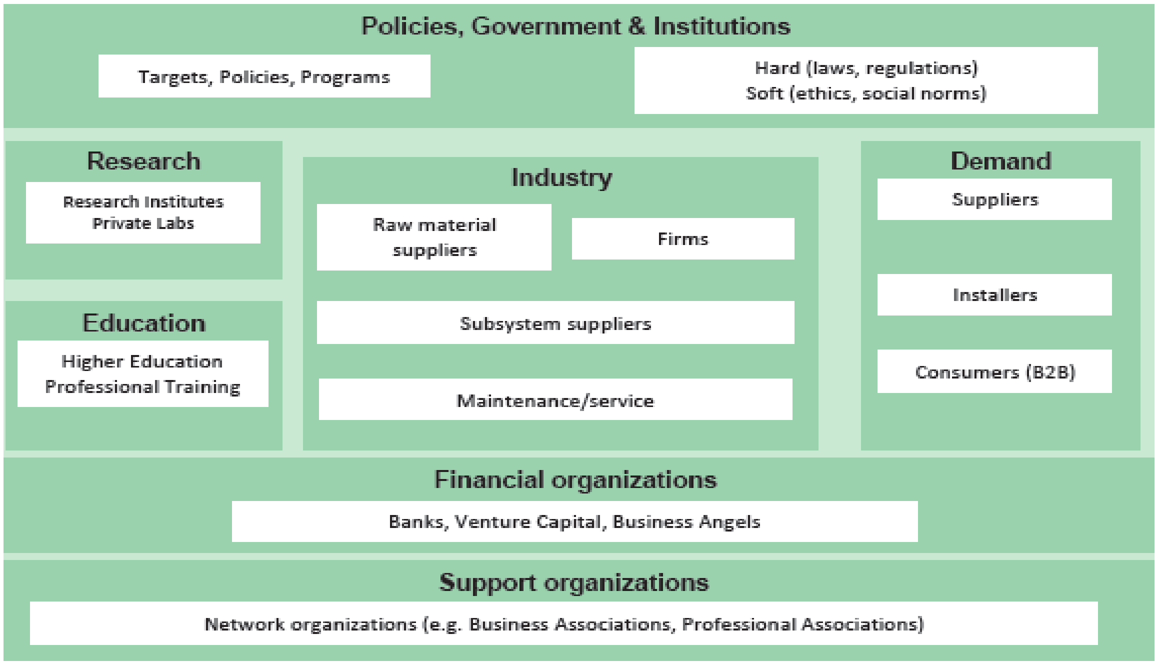
1.1.6 Demand/Users

The users of a technology are a key part of a sectoral or technological analysis. A robust knowledge exchange between users and producers of technologies is likely to increase innovation through two main mechanisms. First, users generate knowledge by giving feedback on a product's performance and failures which, together with a sound understanding of users' needs, are necessary for directing RD&D efforts towards the development of products as demanded by the market. Second, users sometimes directly innovate themselves, particularly "lead users" who face problems ahead of the majority of consumers and thus develop their own modifications to existing products, or entirely new products. User-led innovation is most common in the software industry, but it is also found in the manufacturing sectors (Von Hippel, 2005).

1.1.7 Linkages and mutual learning between stakeholders in sectoral innovation systems

Sectoral innovation systems are based on three building blocks: *knowledge and technologies*, *actors and networks*, and *institutions*. The linkage between actors is creating the structure of an innovation system. Regardless of the level of analysis chosen, innovation systems generally include the same basic elements: Higher Education Institutes (HEIs); Public Research Organizations (PROs); Government Agencies and Policies; Financial Organizations; Industry/Firms; Support Organizations (mainly network-enabling and political lobbying); and Institutions and this is also true for sectoral innovation system (see Figure 8). In addition to these elements, a sectoral or technological perspective also includes a more detailed analysis of users (Demand/Users), which can be an important source of innovation (Von Hippel, 2005), and builds on a sound understanding of the technology underlying the innovation system assessed. A key difference for RE innovation system analysis is the need to also examine policies that serve to internalize environmental externalities, and therefore contribute to creating a market for renewable energy technologies.

Figure 8: Model of sectoral innovation system



Source: Hekkart et al. (2011).

1.2 Some selected international practices in development of sectoral innovation system of renewable energies, focusing on wind and solar

In this section, the Report will discuss different international experiences of number of countries in developing renewable energies and innovation in this sector.

1.2.1. The US experiences

The United States has been at the forefront of energy innovation with the unique and extensive collaboration along the entire chain of innovation, from basic research to deployment, that engages the federal government, national labs and research institutes, universities, private sector, and state and local governments. This system has given the U.S. a global advantage for many decades.

Clean energy innovation supports multiple national goals: economic competitiveness, environmental responsibility, energy security, and national security. In serving these goals the need to address climate change is the challenge that calls most urgently for accelerating the pace of clean energy innovation.

Key features of energy systems, however, impede accelerated innovation. Energy is a highly capitalized commodity business, with complex supply chains and established customer bases, providing essential services at all levels of society. These features lead to systems with considerable inertia, focus on reliability and safety, aversion to risk, extensive regulation, and complex politics. Existing innovation processes face challenges as they work within these boundary conditions. The rapid pace of international energy investment, the commitments of most countries to Paris climate goals, and the ability of some countries such as China to rapidly increase clean energy investments challenge the preeminent position of the U.S. in clean energy innovation.

Successful clean energy innovation on a large scale in the U.S. requires alignment of key players, policies, and programs among the private sector, the federal government, and state and local governments. This report considers these alignment needs through an assessment of the roles of these various groups. It also identifies critical clean energy technologies. It further suggests the value of regional efforts to advance innovation, and discusses ways in which federal tax policy could accelerate innovation. The report offers recommendations in each of these areas.

The Role of the Private Sector

The private sector is central to clean energy innovation, providing entrepreneurial vision, channeling financial resources, and connecting innovation to the rest of the energy system and the economy. At the same time, fundamental dynamics of the energy sector present significant challenges to clean energy innovation, stemming from basic industry characteristics and from the difficulty of capturing the full value of clean energy through market transactions alone. Innovators in clean energy face significant challenges in securing financial support and in demonstrating the compatibility of new technologies with existing systems. Over the past several years, venture capital has reduced its engagement in clean energy innovation, and traditional energy companies are exploring new models and mechanisms for innovation and investment.

While the initial stages of clean energy innovation are supported by a diverse, world-class set of U.S. research institutions, the innovation support system weakens as inventions move toward commercialization. The clean energy incubators that have emerged in recent years have so far tended to support software solutions. The availability of testing facilities for product demonstration is limited by the small number of facilities suitable for sustained testing and by their specialization.

Because of the energy system’s long cycles of adoption, a broad range of approaches should be deployed to make it easier for adopters to understand, anticipate, and support the innovations that are being generated at the early stages of the innovation process. These efforts include, on the part of energy companies, open innovation, standardization of procurement requirements, encouragement of innovation testing either through dedicated evaluation staffs or through performance metrics, and active outreach to become familiar with innovations at the development stage or earlier. They include, on the part of innovators, early attention to the needs of adopters as indicated by expressed needs and by the past performance of innovation efforts.

Investments are needed from foundations and from federal, state, and local governments to expand the availability of open-access testbeds and strengthen the effectiveness of incubators in accelerating commercialization of innovative technologies. Some of these investments could fund research into best practices and performance results of incubators and testbeds and of state and local programs supporting innovation.

Because clean energy innovation incentivizes only modest financial investments at precommercial stages, and because strategic corporate investment is focused primarily on those innovations recognized as useful to business objectives, strategic philanthropic investors and coalitions of industry investors with long-term horizons could play an important role in identifying and supporting promising technology ventures that are otherwise not commercially viable in the near term.

Technologies with Breakthrough Potential

A shared agenda of primary technology objectives can help ensure that programs pursued by multiple stakeholders in the clean energy space are timely, durable, and mutually supportive. It can give entrepreneurs and creative innovators a framework for assessing the prospects of a particular area of initiative and the steps needed to sustain critical innovations over long-time spans, and it can give corporate adopters, financial investors, and policymakers visibility into the evolving future of clean energy.

A four-step methodology is suggested for identifying breakthrough technologies to address national and global challenges and help meet near, mid- and long-term clean energy needs and goals. These steps consider technical merit, potential market viability, compatibility with other elements of the energy system, and consumer value. Application of these considerations to a list of 23 potential technology candidates yields a key technology shortlist:

The Federal Government Role

The Federal government has long played a central role in supporting energy innovation. Through research grants, loan programs, tax incentives, laboratory facilities, pilot programs, and public-private partnerships, it has set the direction and pace of energy R&D, with profound impact on the national economy.

The principal agency funding clean energy innovation is the Department of Energy (DOE), which administers about 75 percent of all Federal energy R&D spending. DOE performs its role in partnership with its 17 national laboratories, academia, states, regions, other agencies, and the private sector. There are, however, several other Federal agencies with significant clean energy innovation budgets, including: the Department of Defense (DOD), the Department of Transportation (DOT), and the Department of Agriculture (USDA). Portfolios at these agencies are mission- focused, however, as opposed to being broadly based across all energy sectors.

As the primary Federal funder of energy R&D, DOE has played a critical role in changing the U.S. energy landscape over several decades. Shortly after its establishment in 1977, DOE characterized U.S. shale basins and supported the development of key drilling technologies that enabled horizontal drilling. It has had an ongoing and central role in developing supercomputing, an enabling technology for digitalization, artificial intelligence, smart systems, and subsurface characterization. Its investment in phasors and sensors support the smart grid.

The Advanced Research Projects Agency — Energy (ARPA-E) - a DOE program — has led to the creation of dozens of clean energy start-up companies which have raised more than $2.6 billion in private-sector follow-on funding.

However, DOE's performance in advancing clean energy innovation would benefit from several institutional modifications. For example, the fuels-based organizational structure of the DOE, which has been in existence since 1979, is not optimized for modern energy systems and needs. It tends to lead to budget allocations by fuel, rather than prioritization by innovation potential.

The lack of long-term stable and predictable funding is also a concern for future R&D efforts at DOE. Although the Federal clean energy RD&D portfolio is significant (approximately $6.4 billion in FY 2016 if expenditures by all Federal agencies and by DOE on basic science research are included), some prominent government and industry leaders have recommended the need for funding levels at two to three times the current levels based on the energy industry's current value to the economy (roughly $1.37 trillion). While the Bipartisan Budget Act of 2018 (BBA) set new caps for discretionary spending that are as much as 25 percent higher than the Administration's budget — providing considerable headroom for near-term increases in spending for clean energy innovation — this agreement extends through FY 2019 only. The highly uncertain budget outlook for FY 2020 makes it difficult to plan an effective energy innovation portfolio focused on technologies with high breakthrough potential.

The Role of State, Local and Tribal Governments

State and city governments have regulatory authority over most of the myriad consumer, commercial, and industrial activities that collectively shape the country's patterns of energy use. They play central roles in advancing clean energy innovation, above all by creating markets for the application of clean energy technologies and encouraging diffusion of those technologies through supportive financial mechanisms.

Cities are crucial clean energy innovation testbeds. Urbanization trends make "smart cities" especially important as technology platforms for a clean energy future. Enhanced federal-state-city, public-private, and private-private partnerships can help unleash smart city innovation for tailored urban services, mobility, and standard-of-living improvements in the 21st century. "Smart" improvements could also provide significant value to rural communities by enabling decentralized generation and manufacturing, improving energy efficiency, and supporting economic development.

The contribution of state, local, and tribal governments to clean energy innovation could be further strengthened by development of program best practices and standardization, capacity and resource enhancement, increased funding, and modernization of ratemaking and business models. Programs that support and promote clean energy and energy innovation require significant state and local administrative resources and expertise; offices and officials that run them often have limited resources. Also, traditional ratemaking policies and methodologies at the state and local level can act as barriers to deployment of innovative energy technologies due to their reliance on proven track records associated with reliability and cost savings.

The Role of Regional Clean Energy Innovation Ecosystems

Many of the innovation opportunities and risks faced by the energy sector are highly regional in nature and are appropriately managed by strategies tailored to each region's specific needs. Strong regional relationships, for example, are observable among innovation, job creation, and technology deployment in the solar and wind energy industries.

Many energy innovation clusters in the U.S. are in the process of evolving into fully integrated innovation ecosystems. While federally funded R&D historically has not been well connected to state and regional economic development, activating these regional clusters to break down the barriers among federal, state, and local resources will create new synergies. National labs could serve as anchors for these efforts. While Federal support is important, regional leadership is critical. State and local governments, the private sector, universities, and philanthropies all have important roles in developing the particular strengths and shaping the particular contributions of regional innovation ecosystems.

Mobilizing Increased Private Sector Investment in Energy Innovation

For U.S.-based entities, budget caps, reduced discretionary spending, and the Tax Cuts and Jobs Act (TCJA) will put downward pressure on Federal spending but will incentivize corporations to increase significantly business investments over the next decade (with estimates of up to $1.5 trillion in incremental new investment, some of which could be targeted to energy innovation and infrastructure. Attracting these funds into clean energy innovation will depend on success in aligning the various elements of the innovation ecosystem discussed in this report: public policies that encourage a robust pipeline of research and that create markets for clean energy applications, combined with private-sector institutions that facilitate the commercialization of innovations.

The TCJA left unchanged the existing tax credits for renewable energy (wind, solar and geothermal), but did not extend the so-called “orphan” tax credits for fuel cells, combined heat and power projects, geothermal heat pumps, and new nuclear power plants. Most of these credits had expired at the end of 2016. The Bipartisan Budget Act of 2018 (BBA), passed in February, modified and extended the nuclear power PTC; other credits were extended only through 2017 and their fate is uncertain.

In addition, the BBA included expanded provisions for carbon dioxide (CO2) capture, utilization and storage (CCUS). The new 45Q provisions have the potential to significantly enhance the development and market diffusion of CCUS technologies and processes in both industrial and power applications, creating commercial opportunities both in the U.S. and abroad. The provisions provide greater market and financing certainty to help attract additional follow-on investment from the private sector.

1.2.2 Experience of China

China, the world's second-largest economy (after the U.S.) was previously dependent on fossil fuels such as coal, oil and gas. To date, China is leading the world in clean energy production - especially solar energy.

As of 2019, China owns six of the world's 10 largest solar module manufacturing companies. According to the International Energy Agency, in 2018, China was the first country to install more than 100 gigawatts (GW) of solar capacity. The Chinese government has prioritized investment in solar energy because it allows the country to directly address issues of air pollution, climate change and energy security, and financial and environmental benefits. Moreover, in order to meet the commitments in the Paris Agreement on climate change, China was forced to increase the share of solar energy in synthetic energy from 2.3% in 2015 to 20% by 2030. This will reduce the need for the construction of new combustion power plants.

According to World Bank (2017), energy efficiency and the use of renewable sources to limit CO2 missions were minor concerns as recently as the 10th Five Year Plan (FYP) of China. However, starting with the 11th FYP and continuing through the 13th FYP, those concerns have acquired greater prominence (Hong et al. 2013). The 13th FYP (2016-20) calls for a reduction in carbon intensity and energy intensity of 18 percent and 15 percent, respectively. By the end of 2015, China had installed 146 gigawatts of wind power capacity, and its solar power capacity equaled 43 gigawatts. During 2016, China installed 23.3 gigawatts of wind turbine capacity, bringing the total to 169 gigawatts. An additional 34.54 gigawatts of photovoltaic (PV) capacity were also installed (increasing the total to 77.5 gigawatts), and employment in the renewables sector reached 3.5 million jobs. China tried to increase the share of renewables in primary energy consumption from 12 percent in 2015 to 15 percent in 2020 (Nakano and Wu, 2016). To achieve these objectives, solar capacity will rise to 110 gigawatts and wind power will reach 210 gigawatts (Spegele, 2016).

Although Chinese firms are playing increasingly significant roles in renewable energy markets around the world, many have questioned how innovative these firms are, or whether they care about contributing to the global knowledge base in these technologies, creating knowledge that is spread to other countries. Part of the challenge in answering this question stems from the fact that it is difficult to measure innovative activity in nonmarket and emerging economies.

The dominant model of innovation indicators is based on a linear model of innovation and includes such factors as R&D expenditures, human resources qualification, and patents. These indicators are not as effective at measuring what actually happens between the inputs to innovation (like R&D) and the outputs of innovation (like patents), and therefore they arguably provide only a partial view of innovation. That may be especially prejudicial for firms in emerging economies, where fewer financial resources are available for everything from patent registration and maintenance to R&D support (Marins, 2008).

As a result, taking a more comprehensive approach to measuring innovation may be more suitable for a context such as China. That approach would include looking at progress in innovation in relation to higher-performing technology or measuring cuttingedge innovations in a specific sector against a global benchmark. Examples include overall efficiency, size, or other performance metrics.

In addition, royalty payments can serve as a reflection of innovative activity versus reliance on foreign technology and capacity, complemented by information on technology licenses and other arrangements.

A deeper exploration of the dynamics of innovation in the solar, wind, and stationary storage sectors in China starts with understanding how innovation is measured in a comparative way between countries. Innovation is influenced by a variety of factors; some are more tangible and measurable (for example, basic R&D or patent filing), and others are subtle and difficult to quantify (for example, entrepreneurial support or cultural appetite for risk).

1.2.3 Practices in South Korea

Renewable energy in South Korea is focused on developing mainly solar power accounting for about 85%, the rest is wind and other renewable energy sources. South Korea began developing and developing renewable energy policies in 1987 with the enactment of a law to encourage the development of renewable energy sources. By 2002, the FIT (feed-in-tariff) electricity price mechanism for wind power was unchanged for the first time in the first five years (107.66 KRW/kWh). Then, the FIT application period for wind and solar power was extended from 5 years to 15 years. In 2010, the South Korean government decided to replace the FIT electricity price mechanism with the Renewable Portfolio Standard (RPS) mechanism and set out a roadmap to apply from the end of 2012.

In addition to the RPS mechanism, REC (REC-Renewable Energy Certificate), South Korea implements other policies/programs to promote renewable energy development such as: i) Mandatory renewable energy use program in public buildings, by 2020 the rate of electricity use from renewable energy is 30%; (ii) Preferential subsidy programs for households by region, in 2020 will support about 700,000 households to install solar power systems; (iii) The program of testing rooftop solar power systems in agricultural villages, striving to have 400,000 households installed by 2030.

1.2.4 Experiences of Japan

As early as 2008, the Japanese government has implemented a policy of supporting renewable energy home loans with a maximum repayment period of 10 years, in which, for families renovating their homes, switching to solar energy can borrow a maximum amount of up to 5 million yen. That's equivalent to nearly $5,000. In addition, the Japanese government buys electricity produced from solar energy at a higher price than the market price and reduces the price of solar panels.

In August 2011, Japan enacted a Subsidy Law (FIT) to buy renewable energy, encouraging people to produce their own solar power at home and thereby build large, centralized solar power centers. FIT law allows to support the price of electricity produced from solar energy when private businesses want to invest.

Specifically, the government buys electricity produced from solar energy at a higher price than the market price, about 40 yen /kWp (Kilowatt-peak) for projects with a capacity of 10 kW or more. For projects with a capacity of less than 10 kW, the purchase price is about 42 yen /kWp. In 2016 alone, the Japanese government spent about 2.3 trillion yen ($20.5 billion) to support the acquisition of solar power at a high price.

Japan also encourages local governments to participate in solar power projects. According to a report by the non-profit organization "Solar Power Owners Network in Japan", as of July 2013, there were 277 administrative agencies at all levels in Japan (accounting for 15% of the country's administrative agencies) performing or agreeing to "lease the roof" of public works, installation of solar cell system.

In April 2017, Japan's Ministry of Economy, Trade and Industry (METI) introduced a new FIT law (amended), which reduces taxes of renewable electricity, depending on the size of the system. This has encouraged investment from private enterprises in the renewable energy sector.

The Japanese government's incentive policy has attracted a large number of investment projects in renewable energy, the most popular of which is solar energy. Between 2011 and 2014, solar power installation capacity in Japan increased sharply from 5,000 MW to 25,000 MW. To date, about 2.4 million customers (including households, businesses...) have installed rooftop solar power in Japan.

Of the solar power projects, 80% are small-scale, mostly rooftop installations. Rooftop solar power system has many advantages such as reducing land rent, it is not necessary to sign power consumption contracts with local power companies. Customers who install rooftop solar power when they do not use up all the electricity produced can sell to power companies at preferential prices.

Solar power projects in Japan account for only 20% of total energy production because of difficulties in land clearance, agricultural land conversion, difficulties in integrating the solar power grid into the national grid, and so on.

In July 2018, Japan adopted its fifth energy development strategy plan with a vision to 2030 and to 2050. Accordingly, Japan has oriented energy development based on the principle of 3 E+S (Energy Security, Environment, Economic Efficiency, and Safety). This principle shows that Japan is aiming to establish a sustainable energy supply and demand structure, reduce its economic burden and be environmentally friendly.

According to the plan, Japan continues to maintain its goal of using a variety of energy sources. Specifically, by 2030, in the power structure, renewable energy accounts for 22-24%, fossil fuels 56%, and nuclear power from 20-22%.

1.2.5 India's experiences

India has also issued numerous policies to support the development of rooftop solar power in the country with the ambition of achieving 100 GW of solar power by 2022, including 40 GW from rooftop solar.

The Government of India has held roof tenders across all states to create a developed market for rooftop solar. About 2,032 MWp (Megawatt-peak) capacity has been allocated to localities, including 1,361 MW of real capacity that has been deployed.

The Ministry of New Energy and Renewables has provided US$254-609 per kilowatt as part of an incentive mechanism for rooftop solar projects installed on government buildings. Rooftop solar projects in India also received great support in terms of interest rates, with central investment cost support (15%) set to be replaced by a lower-interest loan (8.5%).

The Government of India has applied a tax-free period for businesses based on the profitability of projects for 10 consecutive years within the first 15 years of the project starting. The government has also set specific targets for individual states and states that have implemented clearing mechanisms to store excess electricity above consumption.

1.2.6 Some experiences in ASEAN

Not only developed countries are aware of the important role of green and clean energy development to determine global energy security, but the ASEAN region, the effective development of renewable energy sources is always an urgent issue of Southeast Asian countries. With the rapid development of the ASEAN economy over the past time, the energy demand of countries in the region is increasing. According to the International Energy Agency (IEA), ASEAN's energy consumption has increased by 60% in the past 15 years. Therefore, countries in the ASEAN region need to quickly promote the use of clean energy sources.

Singapore actively encourages the development of clean energy. In 2016, Singapore invested more than US$700 million in public sector R&D programs over the next five years to find sustainable urban solutions. This funding is expected to strengthen

Singapore's innovation capacity in areas such as clean energy, smart grid and energy reserves. Currently, the country is experimenting with building urban solar power plants and floating solar power stations on reservoirs, as well as testing a miniature storage grid system when renewable energy sources are disrupted.

In **Malaysia**, the overall policy on clean energy development has created a solid foundation for the implementation of renewable energy projects. The solar policy is marked in the Renewable Energy Act 2011 and amended in 2014 to accommodate market changes as well as the reduction in the price of energy panels. In addition, the Metering Net (NEM) mechanism was launched in 2016 with the goal of reaching 500 MW of solar power by 2020 in Peninsular Malaysia and Sabah. Accordingly, consumers can install solar cells that generate electricity for their homes and sell excess energy to the national grid. Thanks to price support policies, solar panel installation capacity in Malaysia should reach 1,356 MW by 2020.

Indonesia also passed a law on renewable energy in early 2017, which changed the tax rate on renewable energy projects. Under the new law, the level of FIT support will be based on the average electricity supply cost of the region where the new power project is built. Support under the new program is between 6.5 and 11.6 cents per kWh. FIT is also fixed throughout the term of the power purchase contract (PPA) without the influence of changes in foreign exchange rates or inflation. The new law allows solar power to compete directly with coal-fired power plants, a common form of electricity generation in Indonesia. The residential, commercial clearing mechanism for rooftop solar was also adopted in 2013, forcing Indonesia's National Electricity Corporation to pay excess energy produced by solar energy into customers' accounts. With these policies, Indonesia expects to add 870 MW of solar power by 2024.

In **the Philippines**, the FIT program has driven the development of solar energy to new heights. Regulations on clearing mechanisms and connectivity standards that came into effect in July 2013 have increased small solar power projects in the Philippines. The installed capacity of solar power was 62 MW in 2014. With FIT at 21 cents/kWh, six projects were approved, bringing solar power capacity to 108 MW in 2015. In 2016, the FIT price was revised down to 17 cents/kWh (20-year term and 0.6 percent tax reduction rate).

While **Cambodia** having preferential import tax on renewable energy production equipment, the price of solar power in Cambodia is only from 2,500-3,000 VND / kWh, while the price of grid power in the country averages about 4,000 VND / kWh. This is the reason why solar power thrives in this country. In recent years, many foreign companies have invested in the field of solar power development in Cambodia. With the support of the World Bank and the self-invested capital of the people, Cambodia now has a total of 50,000 home solar power systems installed. Due to the high price of electricity, many businesses in Cambodia invest in solar power for additional use along with grid power. There are some investors who also provide solar panel rental services, especially in industrial parks.

In 2006, **Thailand** was the first ASEAN country to adopt a FIT tariff for renewable energy, in which solar projects received the highest FIT, at 23 cents per kWh for 10 years. The program was then replaced by a 25-year FIT program that cost 17 to 20 cents per kWh depending on the type of generator. In 2014, with the cost of solar panels falling, the government lowered the price of FIT to 12 US cents/kWh on all 25-year contracts.

Vietnam, Laos, Myanmar and Brunei have also entered this bustling market with preferential policies for solar and wind projects. While still lagging behind other regions around the globe in terms of clean energy, with the new development strategy, the ASEAN region's target of producing 23% renewable energy by 2025 should certainly be within reach.

1.3 Some implications for mapping sector innovation systems in renewable energies

Following the concept of sector innovation system (SIS) in general and specific features of renewable energies in particular, one can draw up some implications for mapping exercises.

First, sector innovation system is a concept that can be used for mapping the innovation system in the renewable energy sector. This concept seems the most appropriate to deal with specific features of a sector in terms of innovation dimensions.

Second, a sector system of innovation includes ingredients such as: technologies and key knowledge as well as learning processes of the sector; actors/stakeholders operating in the sectors; institutions that regulate linkages between actors in the sectors; and demand specific to the sector.

Third, key knowledge and technologies of the sectors should span across the whole value chain of the sector such as generation/production, transmission and distribution and sale sub-systems.

Fourth, actors/stakeholders in this sector innovation system include following groups: firms of different ownership and size, both national and international operating in the market; academic organizations such as research institutes/centers, universities; intermediary organizations such as consulting, financial, information, IP and technical services organizations; and last, but not least government agencies issuing institutions which can be at both national and subnational levels (provinces, cities).

Fifth, linkages among these actors/stakeholders include cooperation, transaction, competition as well as exchange of knowledge, experiences, embodied technologies as well as other forms of knowledge via training, learning, sharing and co-working.

Last, institutional framework that regulates these linkages should include explicit official policy documents and actions, and implicit practices and regulations.

The mapping exercises should look into each group of this stakeholders, their interactions/linkages. Moreover, the whole institutional setting should be analyzed to see impact on these actors and their interactions.

Above mentioned implication should help in designing the interview and structure of the study. Preliminary questions for next steps should be following:

- What are innovation activities in the RE sector of Vietnam? What is key technology and learning process in the RE sector? In the context of rather mature markets in some RE sub-sectors, what are the niche areas for Vietnamese organization to engage in innovation?
- What is the demand in the RE sector for innovative products/processes, etc.?
- Who are the main actors/stakeholders in network of RE innovation system of Vietnam?
- How do these stakeholders interact with each other? What is the linkage between them and to what extent are they conducive for innovation activities in the sector?
- What is the institutional framework for innovation in the RE sector? What are problems and constraints? What might be the solutions to these problems?
- Other considerations?

The analysis in the following chapters will be conducted following along these questions.

Chapter II. Analysis of the renewable energy innovation system focusing on solar and wind in Vietnam

Chapter 2 will provide the overview of the energy industry in Vietnam, then go on to discuss energy structure of the country, focusing on solar and wind, and key components of the sectoral energy system like knowledge and technology, actors, demand and linkages among the actors.

2.1 Overview of the energy industry

Vietnam economy is one of the fastest growing in the world, resulting in rapid changes in the energy sector. In the period from 2005 to 2017, Vietnam's economy has achieved an impressive growth in GDP with an average rate of 6.2 %/year, with the growth rate of around 7% for 2022 despite the Covid-19 pandemic. Spurred by a growing economy and relatively low electricity tariffs, Vietnam’s power consumption grew at an average of 11.5 % per year between 2010 and 2015. To satisfy this growing demand, Vietnam relies on generating assets with an installed capacity of about 40 gigawatts (GW), and it reached 50 GW in 2018 and 69.3 GW in 2020 (Jacobs et al, 2021). From exporting country during 2005 to 2014, Vietnam has become an importing energy country since 2015 with the import value of 3 MTOE and reach to 11 MTOE in 2017. The appropriate way forward for Vietnam to secure its energy future is to focus on renewable energies.

According to the Revised National Power Development Plan No 7 (Revised PDP7, approved March 2016), Vietnam aims to increase its renewable energy share in power production substantially. In particular, it will increase the total capacity of wind power to about 2 GW and 6 GW by 2025 and 2030 respectively. The solar power sector will be developed to increase its total capacity to about 4 GW and 12 GW by 2025 and 2030 respectively. The electricity production from solar energy takes the proportion of about 1.6% and 3.3% by 2025 and 2030 respectively. The share of RE power generation by installed capacity is expected to increase to 21% by 2030. It is estimated that Vietnam can generate up to 85 GW of solar photovoltaic power and can generate more than 21 GW of onshore, near-shore and further offshore wind energy. This could deliver almost as much power as 129 GW by 2030. While coal and hydro will continue to be major sources of electricity in the short term, under the government’s Power Development Plan, it is expected that renewable energy especially solar and wind will provide an increased share of the total electricity production. Lately Vietnam has witnessed rapid growth of solar and wind energies, including more than 17,000 MW of solar and nearly 4,000 MW of wind (onshore and nearshore) are in operation by end of 2021.

Institutional and legal framework of the industry has been developed according to the Electricity Law passed in 2004, and revised in 2012. Overall, energy policy development has been enforced with National Energy Development Strategy (NEDS). In February 2020, the Politbureau issued Decree No. 55-NQ/TW on strategic directions for development of energy sector up to 2030 and vision to 2045. The Decree aimed to achieve target of RE share in total energy supply as 15 - 20% by 2030 and 25 - 30% by 2045. Also, Decision No. 2068/QĐ-TTg of PM on Strategy of renewable energy development up to 2030 and vision to 2050 expected contribution of RE is 32% of total electricity production in 2030 and 43% in 2050.

Development of rooftop solar systems

Vietnam has quite attractive policy for rooftop solar development. By using FIT model (2019), market of rooftop solar energy has been increased significantly. Rooftop solar projects have mushroomed in 2020, with more than 20 times growth from 400 MW in the end of 2019 to 9.500 MW by 2020 (Gunther 2020). This rapid growth exceeds targets of the government of 1.000 MW by 2025 with more than 100.000 rooftop solar systems installed (Decision No. 2023/QĐ-BCT of 05/07/2019 by MOIT). At the end of 2020, Vietnam has 104.282 rooftop solar systems installed with capacity of 9.580 MWp.

Localization of technology content for renewable energies

Vietnamese-owned and foreign-invested companies based in Vietnam are manufacturing and assembling different components of solar PV systems as well as wind towers. They tend to be focused on exports although some equipment has been used in Vietnam.

The towers in some of the first wind farms in Vietnam were manufactured by UBI (Vietnam) and CS Wind. CS Wind Vietnam is the main production facility of CS Wind, a South Korean group, and started operations in Ba Ria-Vung Tau province in 2003. CS Wind Vietnam currently claims a production capacity of 900 towers per year. Solar BK is a Vietnamese company headquartered in Ho Chi Minh City (HCMC). It has its roots in the research community that in 1975 it began studying and experimenting with wind, solar heating, and solar power. It started manufacturing solar PV cells and panels in 2012, and is aiming for a production capacity of 300 MW/year. It also has a manufacturing unit for solar water heaters. It supplied rooftop solar PV systems to many offices in cities and provinces. RedSun manufactures solar PV panels, with a production capacity of 12 MW/year. It was established in 2007 by New Era Technology Co. Ltd. Vietnam, and the

Energy Conservation Centre (ECC) of HCMC. Canadian Solar has production facilities in Canada, China and in Hai Phong, Vietnam, where it produces solar panels. Boviet Solar Technology Co., based in Bac Giang province, focuses on PV cell and panel manufacturing. With a manufacturing plant area of 70,000 square meters, registered capital over US$50 million, 700 employees and 200 MW annual production capacity it claims to be the largest PV manufacturer in Vietnam. The mother company is PV Powerway, a Chinese holding founded in 1987. JA Solar is a leading Chinese manufacturer of solar cells and panels that turned over US$2.5 billion in 2015. It has started construction of a large plant in Bac Giang province for assembly of solar panels. The first-phase investment capital of US$320 million is set to rise to US$1 billion and the project is estimated to generate over 3,000 jobs. In 2011 First Solar started construction of a large solar panel factory in Dong Nam Industrial Park in Cu Chi district of HCMC, with investment capital initially set to reach US$1.2 billion. After less than one year the construction was halted; but more than 100,000 square meters of factory buildings had been built for an estimated US$50 million. This investment is reported to have been taken over by another investor who wants to revive the project with its original objective of solar cell and panel production. As such, the rate of localization of equipment and technology systems for both solar and wind energies is not significant.

According to some studies by McKinsey & Co. (2018), the ranking of Vietnam in technology availability for RE is still low. Instead of manufacturing of equipment and technological parts for RE which quite depends on supporting industries, Vietnam could aim at using advanced technology and application for operation, monitoring, management activities of RE projects. An example is PECC2 that relies on digitalization such as cloud computing, robotics technology for battery cleaning or using fly Cam and I-V checker for controlling solar panels.

2.2 Energy structure

Based on the PDPR7, Vietnam’s generation mix scenarios until 2030 have been recently revised and updated by the Institute of Energy in February 2020 with various scenarios reported in the document No. 1931/BCT-DL issued by MOIT.

Table 2. Energy mix stages

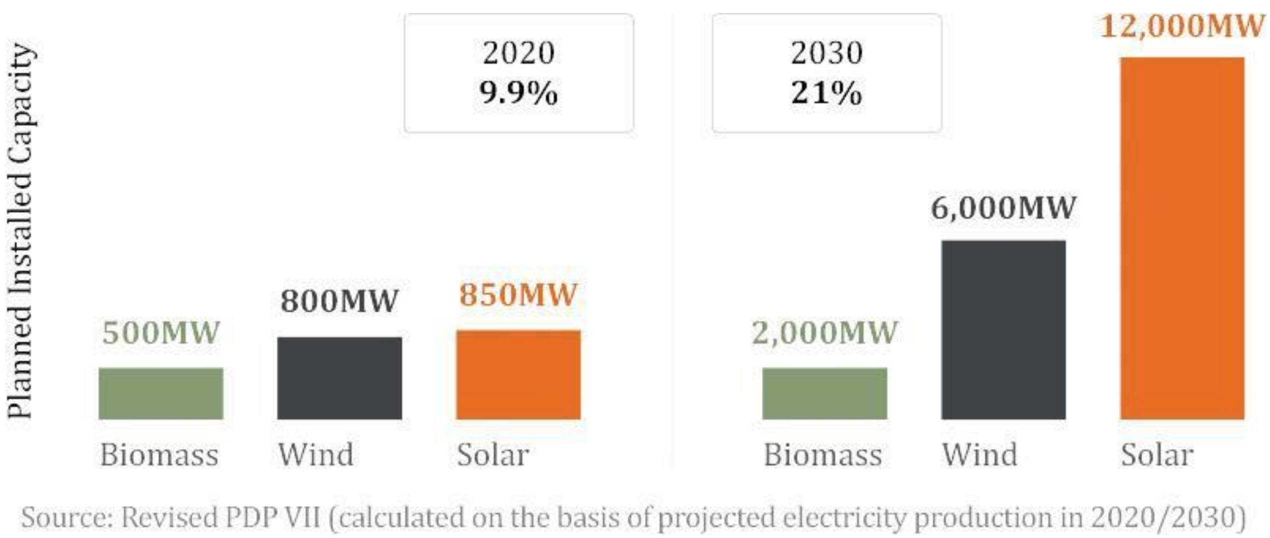
	2020	2025	2030
Total installed capacity [MW]	60,090	116,699	169,498
Share of coal and (LNG) CCGT	47.2%	46.0%	51.3%
	2020	2025	2030

Share of hydropower and pump storages	29.6%	18.4%	14.5%
Share of onshore wind	1.7%	10.0%	10.8%
Share of solar PV	12.8%	17.4%	14.9%

Source: VIET, 2018

According to revised PDP7 for period 2011 – 2020, Vietnam aimed at 800 MW of wind energy in 2020 and 6,000 MW in 2030, solar energy of 850MW and 12,000 MW in 2020 and 2030 respectively.

Figure 9. Projected electricity production



2.2.1. Solar PV energy generation

While the solar technology has been progressed strongly, solar energy sector in Vietnam is deemed as having strong development perspective in the future. The exploitation and use of this energy source have been improved significantly due to application of many advanced technologies, and gradually became very competitive sector. Institutional framework that encourages use of solar energy and awareness of society have also been enhanced.

Following the decision No. 2068/QD-TTg in 2015, the development of grid-connected renewable generation has become more attractive with new feed-in-tariffs (FITs). Especially, the high FIT for solar PV projects (9.35 $ cents/kWh) has boosted significantly the renewable installed capacity before this tariff scheme gets expired in 2019. According to the updated information from the recent MOIT's document No. 724/BCT-DL (2020), the total PV installed capacity has reached above 8.3 GW by 2020. This improvement is further undertaken with the recent document No. 1968/TTr-BCT (2020), adding up to 2.7 GW installed capacity of solar PV from the existing projects after 2020. With the new FIT for solar PV released in 2020, the installed capacity of solar PV is expected a steady increase with more contribution from floating PV and rooftop installations.

2.2.2. Wind energy generation

Vietnam has large potential for wind energy. Estimation shows that potential for wind energy in the country is ranging around 1.785 MW - 8.700 MW, there is even estimation by a source of more than 100.000 MW (WB). Wind energy is available not only in the coastal area but also in the mountainous areas with valley along rivers and streams.

According to the Decision No. 39/2018/QĐ-TTg, wind projects are also beneficial from the high FITs with 8.5 and 9.8 $cents/kWh for onshore and offshore wind generation, respectively. A large number of wind projects with the total capacity of 4.8 GW have been approved to add to the PDPR7 to be eligible for these FITs before October 2021. However, according to the document No. 2491/BCT-DL (2020) from MOIT, there are currently only 11 projects in operation with the total installed capacity of 377 MW. It is expected an additional capacity of 1.6 GW to be in operation before end of 2021. This is however still quite low comparing with the approved 4.8 GW wind capacity for the PDP period 2020 – 2025.

MOIT is proposing in the document No. 2491/BCT-DL (2020) to extend the application of FIT mechanism till the end of 2023. The FIT price is going to be reconsidered to maximize the possibility for the total wind capacity installed in the high case scenario by 2025 which is expected to be 11.6 GW. This also creates an opportunity for offshore wind projects to have a considerable proportion in the national generation mix.

The estimation of wind potential, sometimes is not complete and accurate due to lack of data. Many wind projects have produced electricity below the expectation. The biggest challenge now is purchasing price for wind energy and incentive support for wind energy purchase. Purchasing price of wind energy in Vietnam is comparatively low (Table 3).

Appropriate prices are given in the Decision No 39/2018/QĐ-TTg of 10/9/2018 on mechanisms to develop wind energy projects in Vietnam.

Table 3: Wind energy prices in some countries (US cent/kWh)

Country	**Onshore**	**Offshore**
Vietnam	7.8 then 8.5 (1/11/2018)	9.8 (since 1/11/2018)
China	5.8 (zone 1) - 8.3 (zone 4)	12-14.0 (near shore)
The Philippines	19.0	Not available
Thailand	18.22 (very small projects); 15 (less than 0.05MW); 11.7 (more than 0.05 MW)	Not available
Japan	19 (2017); 17 (2019); 50 (small projects)	36.0

Source: Dinh Văn Nguyen, Nguyen Xuan Hoa, Nguyen Thi Thu Huong, 2019

There are two challenges for development of offshore wind projects. These are the creation of Marine Spatial Planning including survey, building and management of database on wind resources, conservation areas, marine flows, defense needs and construction of transmission system leading energy onshore.

2.2.3. Transmission system

The existing 500kV substations and their associated 500kV transmission lines create a backbone for Vietnam's power system, interconnecting the North, Central, and South regions. By commissioning the second North-South 500kV interconnection line and the third one, the transmission capacity has been doubled to be capable to supply power for the peak load in the South, overcoming several operation issues[2]. The current bottleneck is in the North – Central interconnection which is limited to 1,700 MW.

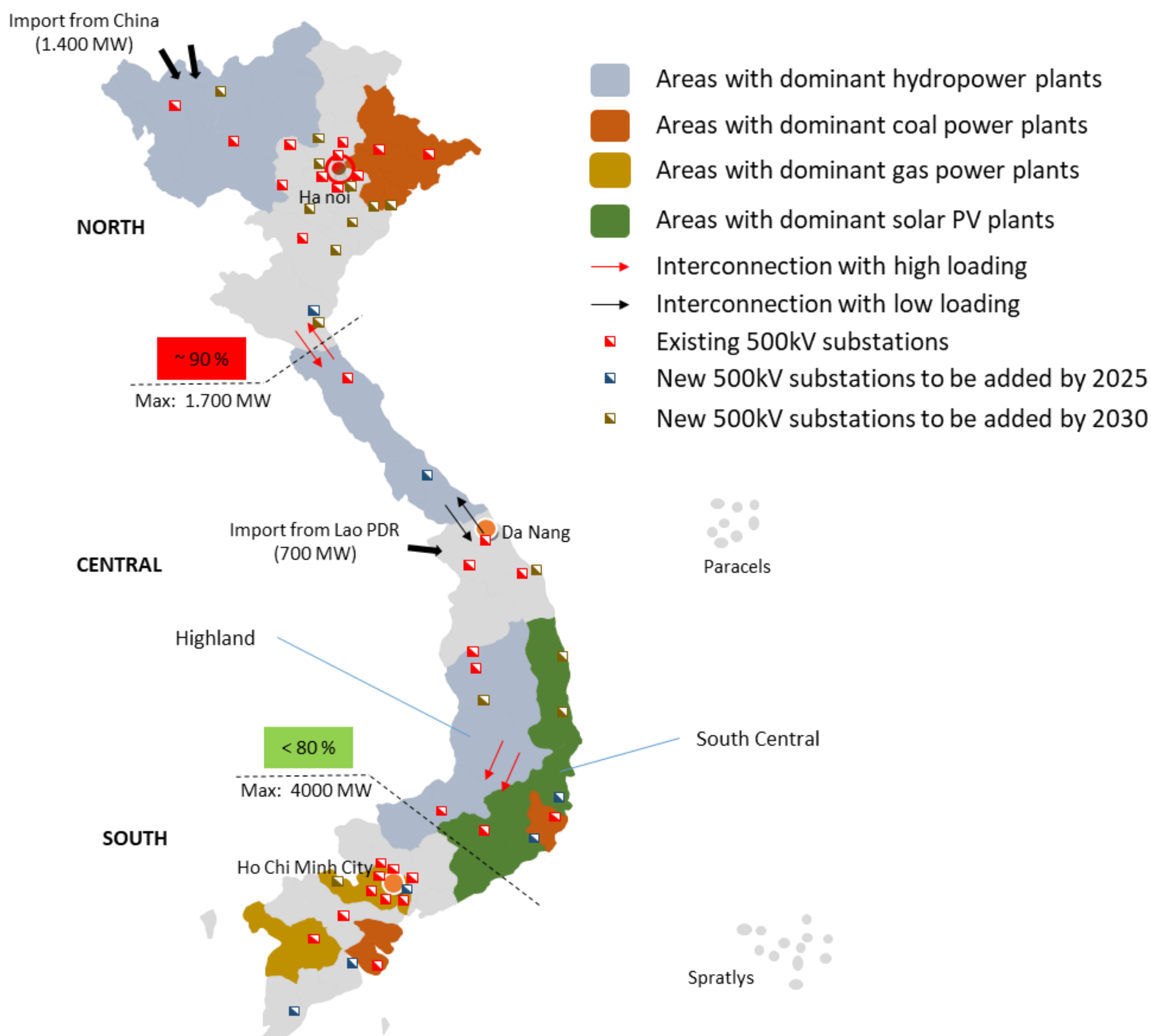
[2] S. H. Ngo and T. H. Nguyen, "Operational problems and challenges in power system of Vietnam," in 2011 EPU-CRIS International Conference on Science and Technology, 2011, pp. 1–5.

Due to the rapid growth of renewable capacity in the South Central area (Phu Yen, Binh Dinh, Ninh Thuan, and Binh Thuan provinces), several grid congestions are occurring. To improve the transmission capacity to release this high amount of renewable capacity, several transmission projects are requested to be in operation soon according to the document No. 724/BCT-DL from MOIT, including upgrading some critical substations of 500kV; upgrading 220kV and 110kV transmission lines; building new 500kV.

In the short and medium-term planning till 2025, the transmission grid will be expanded to ensure the transmission capacity be able to provide the peak load in South areas. Besides reinforcing the North-South 500kV interconnection with the third line, several 500kV and 220kV transmission lines and substations projects are requested to start as earlier as before 2025 to ensure the transmission capacity to release high amounts of solar PV and wind capacity from the South Central and Highland areas. In the long-term planning till 2030, a significant investment is needed to enhance the transmission capability for the North – Central and Central – South interconnections.

Due to incompleteness of the transmission systems infrastructure to meet demand of the growing renewable energy supply, the production capacity of several RE projects have been cut down. According to EVN, it has ensured that the majority of RE projects can run on full capacity (81 out of 100 RE projects with total capacity of 4,400 MW, or equivalent to 86% total capacity of all solar and wind projects in operation). There are only 19 projects in Ninh Thuan and Binh Thuan provinces with total capacity of 670 MW (13% of operating capacity) which have to follow the cut of production due to local congestion of 110kV line. GIZ also identified that in Ninh Thuan province, 10 solar and wind projects will have to reduce capacity for around 38% - 65% while in Binh Thuan province, RE projects reduce production capacity for 30% on average. This situation of capacity reduction happens quite often, mostly in the South-Central provinces.

Figure 10. Overview of Vietnam's Power System in the period 2020 - 2030.



Source: VIET, 2018.

2.3 Knowledge and technologies

According to MOIT, there are 99 solar power plants in the national electricity system with total of production capacity of more than 5,000 MWp, and to serve this, by August 2019, Vietnam has 8 plants to produce solar panel. Theoretically, solar panel can be used for 25-30 years. While they are containing lead (Pb), cadmium (Cd) and many other toxic chemicals that cannot be eliminated once the panel is broken. In that sense, solar panels can be harmful for environment if are not collected and processed properly and Vietnam should deal with this kind of technological potential problem (Phan Dinh Tuan, 2021). On average, production of every one MWp would produce around 70 tons of waste after 20-25 years since the start of production. By the forecast of Strategy for renewable energy development, the waste volume of solar panel in 2030 and 2050 would be 2 and 12 million tons respectively that could create a huge environment problem and waste of resources. So far, in Vietnam there has not done any research in processing technology as well as suitable policies on solar panel waste. The application of waste processing technologies for solar panel is still quite limited.

Another issue is related to technology of transmission systems which required rapid upgrading in the context of fast-growing energy supply of both solar and wind projects.

Concerning technologies for wind energy production, most of technologies used in wind project were imported from very advanced technology suppliers, including turbine, generators, blade, control system and other automation equipment. Also, the need to cut cost for offshore wind projects depends on the development and support of new technologies. So far turbines used for offshore projects in Vietnam were designed for areas with wind speed higher than that of average speed offshore Vietnam. Therefore, there is a need to develop new type of rotors suitable for average wind speed in Vietnam. Besides, there are also required technological solutions to deal with problems of extreme climate condition such as tropical typhoon or lack of wind. In addition, Vietnam needs to innovate technologies in production, installation and operation suitable to specific conditions, to increase reliability of supply and reduce production cost of energy.

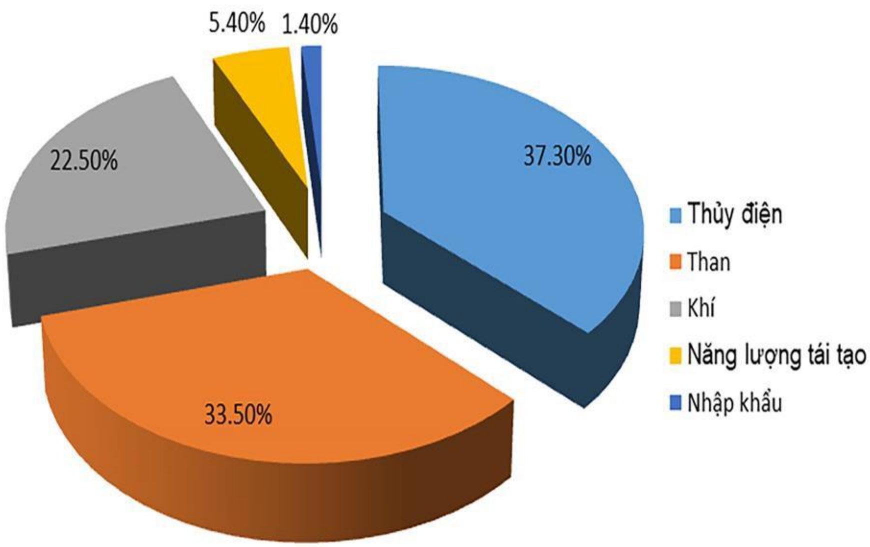
Battery technologies have got a strong push for development in the last few years, with reduced cost and increased volume. Large scale battery system to support grid is in operation widely (IRENA, 2017b). The accumulative system of batteries provides the flexibility and therefore increase the stability of the whole system by peak shifting or peak shaving practices. With this availability, Vietnam should concentrate on improvement of flexibility of current energy sources. Among technology solutions, one being considered is hydrogen technologies and Vietnam should follow closely the development of hydrogen technology and commercial feasibility of this technology. Overall, analyses point to the possibilities of Vietnamese stakeholders to take part more actively in the whole value chain of RE sector. For instance, in anticipated strong growth of offshore wind projects, WB study (2021) suggested that there are many organizations already or will be active players to provide products and services.

2.4 Demand

Industrial production sector in Vietnam consumers nearly 55% of electricity in the country, while consumer consumption is about 35% and 10% is for trading services (https://tiasang.com.vn/dien-dan/tai-sao-gia-dien-can-phai-tang-16375).
The World Bank also calculated that Vietnam is consuming highest ratio of electricity per

capita in comparison with other countries in the same income group like India, Cambodia, Indonesia or the Philippines**.** The accelerated growth of the economy and industrialization, together with increased population forecasted higher demand of the electricity consumption. Following the revised PDP7, the demand for electricity in Vietnam will be increased 11.15% annually during 2016-2020 and then 7.4%-8.4% annually during 2021-2030.

Figure 11: Electricity production and capacity in Vietnam

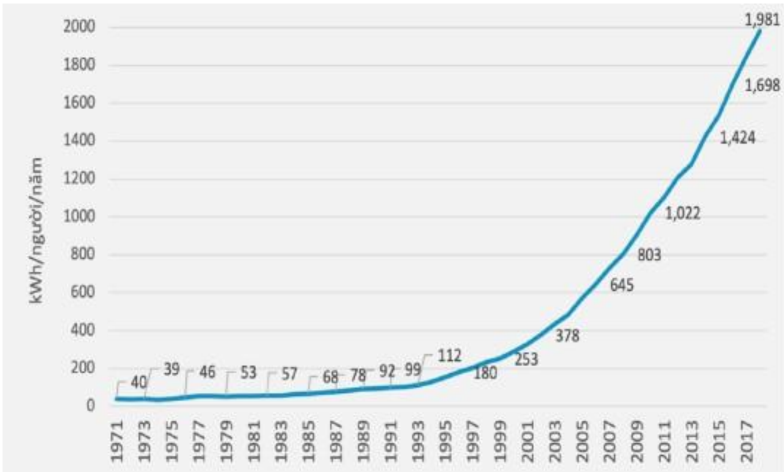


Source: IoE (2016)

Remarks: Light blue: Hydro; Orange: Coal; Grey: Gas; *Yellow: RE*; Dark blue: Import.

In order to increase electricity supply, the industry tried to introduce better policy environment to encourage investors to develop the sector, including rooftop solar, in accordance with Decision 13/2020/QĐ-TTg of PM on incentive mechanisms to develop solar energy in Vietnam. Renewable energy projects are being developed strongly, especially grid linked large solar farms and wind farms. Still, there is lack of national database of all installed projects. Vietnam needs to build up overall framework supporting electricity system for renewable energy as well as a smart grid. The increased contribution of RE projects in the market should help to stabilize the overall system by integrating them into a market of supporting services (Jacobs et al., …)**.**

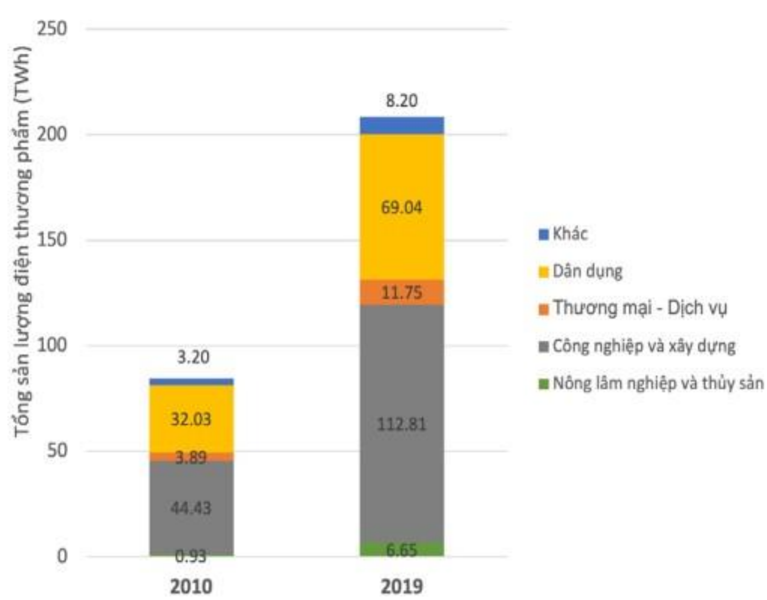
Figure 12. Electricity consumption in Vietnam during 1971 – 2018 (kWh/per/year)



Source: WB and GSO

The rate of electricity consumption per capita of Vietnam has been increased from 253 kWh/person/year in 1999 up to 1,981 kWh/person/year in 2018, up for 8 times in 20 years-span (Figure 12). Industry, construction, manufacturing and civil consumption used most of the electricity as in Figure 13. Demand for electricity also distributed not evenly among provinces and cities. The North and the South (including Hanoi and HCMC) has demand much higher than the Central. Figure 14 reveals the electricity supply by five regional electricity companies for consumption in various regions of Vietnam (North, South, Central, Hanoi and HoChiMinh City).

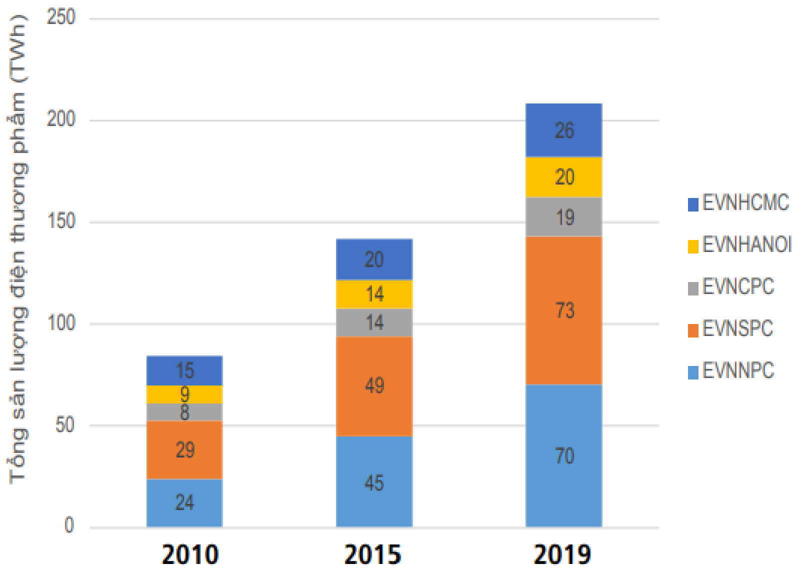
Figure 13. Electricity consumption by sectors for 2010 - 2019



Source: IOE 2021

Remarks: Grey: Industry and construction; Orange: Trade and services; Yellow: Civil consumption.

Figure 14. Consumption demand by regions for 2010, 2015, and 2019



Source: IOE 2021

Supply and demand of electricity depend also on the reform process of the industry toward more competition among wholesale and retail markets. Vietnam Wholesale Electricity Market (VWEM) began to operate since 2019. During the first six months of 2020, there were 100 power plants participated directly in the VWEM with total installed capacity of 27 GW. RE power projects as to relying on FIT mechanism for 20 years, did not participate in this whole sale market.

Vietnam built the PDP8 for period 2021-2030 with vision to 2045, relying on the demand for electricity which is the decisive factor for developing scope of production and expansion of transmission grid in the future. IOE has created a forecast for electricity demand growth as given in the Table 4. The results reveal that demand for electricity will be increased up to 491.3 TWh in 2030 and 877.1 TWh in 2045, up 2 and 4 times from 2020. Demand will rise faster in the North and the South (45% each of total demand in 2030) while the Center has only 10%. However, as most of solar and wind projects concentrated in the Central part, this creates a challenge for balancing national electricity grid and ask for more investment in the transmission lines.

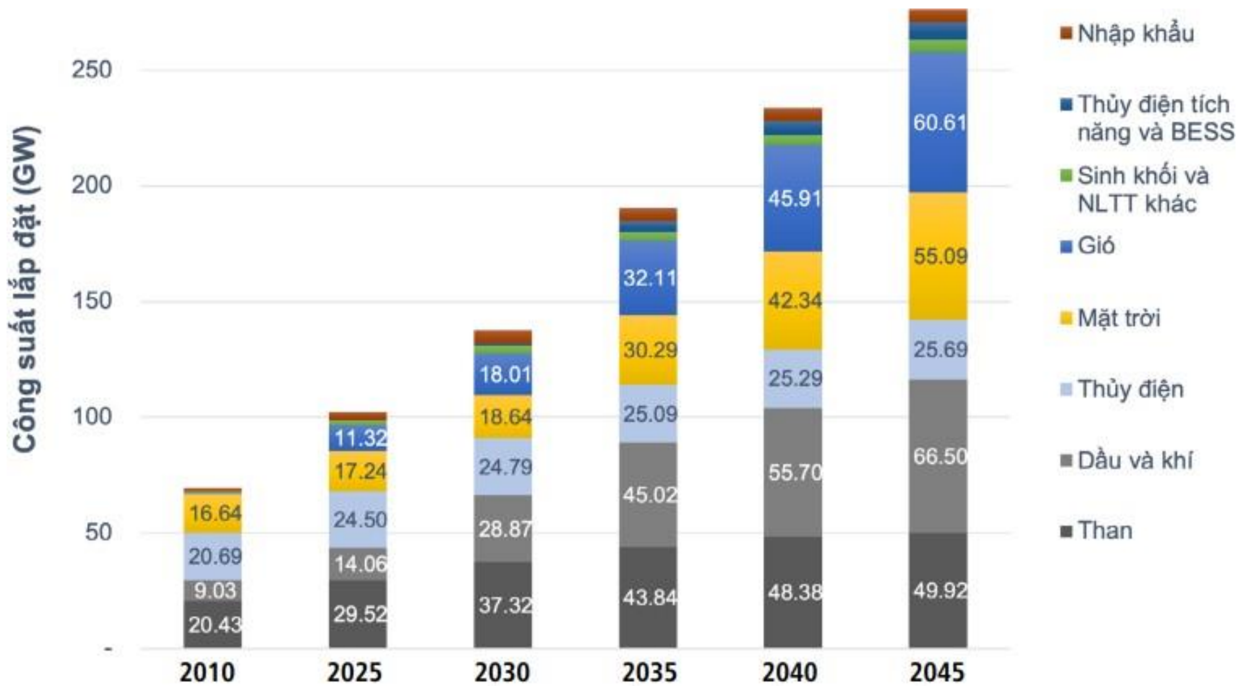
Table 4. Forecast of electricity demand by 2045

Key indexes	Unit	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045
GDP as 2010 prices	Thousand bln. VND	3,836	5,322	7,266	9,722	12,747	16,652
Population	Mln.	96.7	101.8	107.1		118.2	
Income/capita	USD/capita	3,490	5,580	8,177	11,758	16,582	23,323
Electricity/GDP	kWh/mln. VND	56.5	63.0	67.6	66.8	60.8	52.7
Electricity consumption per capita	kWh/person	2,243	3,294	4,588	5,770	6,554	7,076
GDP growth for 5 years	%/year	5.9	6.8	6.4	6	5.6	5
Electricity consumption growth for 5 years	%/year	9.9	9.1	7.9	5.7	3.6	2.5
Demand for electricity	TWh	216.8	335.3	491.3	649.4	774.6	877.1
Installed capacity	GW	69.9	102.2	137.7	190.4	233.8	276.6

Source: IOE

PDP8 also proposed structure of the electricity up to 2045 to have significant increase of renewable sources (non-hydro), from 26% of total capacity in 2020 up to 29% in 2030 and 44% in 2045 (Figure 15).

Figure 15. Structure of electricity sources up to 2045 (PDP8 draft)



Source: IoE 2021

2.5 Actors and Networks

Mapping the energy innovation sector in renewable energy of Vietnam is not an easy task. The sector is new to Vietnam's economy and society. The scope of key knowledge and technologies are wide ranging and the issues and problems are complex. As such, the mapping of the innovation sector with a focus on wind and solar energy is likely to stimulate a deeper analysis of these issues and the relevant stakeholders.

According to the methodology devised for this study, the mapping of the system should is focused on number of groups of stakeholders: (i) Government agencies that provide oversight, regulatory authority, and energy policy framework on renewable energy; (ii) Research and educational organizations like research institutes and universities that provide knowledge and human resources via research and training for the renewable energy sector; (iii) Companies working in the energy sector that are using, adopting and implementing innovative energy technologies; and (iv) Intermediary organizations that support and facilitate the process of technology and other types of innovation of the sector. Financial organizations maybe included into this group or be analyzed separately.

With this overview of the four groups of stakeholders in the sector, the Report will provide basic data and analysis of many of the key stakeholders in the wind and solar energy subsector of the renewable energy sector. This should serve as the background for next step of the study as further in-depth interview with relevant organizations and persons. Depending on the available data, the brief description and analytical overview could be different from case to case.

2.5.1 Industry/Firms

Firms are the most important players in the sector innovation system in any industry. There are many companies participated in the renewable energy production. Most of them are joint stock companies and many are former SOEs. In addition to Vietnamese companies, there are also many players coming as foreign investors to tap into the RE market in Vietnam. Companies took part in the RE business in various capacities: investors, suppliers of equipment, technology, services, operators, etc. There are numbers of companies (most are foreign invested) which have begun to manufacture parts and supplies in Vietnam for RE industry.

The booming of solar and wind energy sector during 2019 and 2020 witnessed the involvement of many large and medium sized companies in Vietnam, foreign companies, financial organizations both domestic and international, and to a lesser extent SME. Technical companies used to belong to EVN take part in large projects in the design and feasibility studies phases. Other companies doing designing, purchasing and EPC have emerged as new players in the sector.

According to some security companies, many companies invested huge amount of resources into renewable energy, including on the stock market (https://www.tinnhanhchungkhoan.vn/hang-loat-doanh-nghiep-niem-yet-rot-von-nuoi-dien-mat-troi-post220525.html). Many well-known and quite prestigious companies in the stock market have been doing new business in RE of solar and wind such as FECON (index FCN), PECC2 – (TV2), Sao Mai Group (ASM), GENCO 3 (PGV).

Following the boom of solar energy companies (both solar farms and rooftop solar), more wind energy companies are also beginning their activities. Overall, there are large number of companies focusing in solar and wind (onshore) farms, rooftop solar and more recently offshore wind projects for last two years.

2.5.2 Higher Education and Research Institutes

Universities, research organizations of both public and private ownership play key role in providing knowledge and high-quality human resources for innovation. Still, research and training activities of Vietnamese organizations in relation to RE are just limited efforts. The scope and scale of these activities are small, having experimenting nature and there is lack of overall national programs for research and training specializing on RE.

Corporate group, as the real market for RE is not strong yet, and companies tend to rely on outsourcing activities in relation to technical change and improvement, not to say about R&D. Many companies do not have an urgent need to conduct R&D themselves. The need for training of staff is beginning to emerge. Few universities and training organizations began to conduct related activities. University of Science and Technology in Hanoi (USTH) is among the first universities to have degree programs on renewable energies (from Bachelor to PhD). In 2010, Faculty of Energy of the university began to recruit first cohort of students with two specializations of green electricity and bioenergy. Now the university recruits 10-15 students for each year. Electrical Power University (under MOIT) is the second one having training on RE. In 2015, Faculty of Energy Economics started to recruit the first cohort of 30 students. By 2020, the first group of undergraduates on RE came out.

There are, however, some issues related to training human resources in RE. There existed a perception that RE technologies in solar and wind already existed elsewhere for quite some time. As a result, for quick benefit, most companies tend to bring in them without much of changes into the market, be they Vietnamese or foreign companies. These are practices seen in many companies producing solar panels like VinaSolar, JASolar, BoViet, producing wind equipment like GE or operating wind farms. Vietnamese universities aiming to serve these companies tend to focus mainly on supply of human resources working on operation, maintenance, repairs, monitoring of installation, and technology consulting activities. Only in the long run, training organizations can aim higher at producing staff who can handle and master technologies to cope with localization needs of equipment and technical parts like blade, turbine, control devices for wind or solar projects. There is another fact that many staff of solar and wind projects are not graduated with RE specialization but other energy related subjects like electrical, electronics, energy economics, construction background. They now work in operation and maintenance after short training for 6 months. Staff with other background like precision mechanics, material science also can participate in wind projects. As such, there is a need to train specifically graduates with RE specialization as it should bring more efficiency and productivity to the production.

Most of Vietnamese researchers working on RE are graduated from Europe, but they tend to work on what they know and are strong in. The solutions they work on tend to be narrow in their own specialization, without linked to overall larger need of the industry. Vietnam has some national research programs related to energy sector, but the content and focus on RE are insignificant. For example, for KC-05, a state national research program on energy, there are only 7 out of 34 projects during 2011-2015 related to RE. There is a short-term mentality of companies operating without long-term R&D and training for quick return. In this context, some research organizations turn to research on perovskite, a new material with many advantages for solar. Other organizations like Nano and Energy Center (NEC) under HUST pay attention to exploitation of energy micro equipment such as cooling and thin film for energy conservation usage; or to hydrogen research direction.

2.5.3 Intermediate Organizations

In a market economy, linkages between different actors, especially R&D and training organizations and firms are key to innovation process. But in Vietnam, they tend to be weak and loosen. The intermediary organizations have a key role to promote and support this kind of relationship. These include domestic organizations working in provision of information, consulting services, technical services and other like standard, quality control, management, IP and others. Apart from that, foreign organizations (companies, NGO, branches of international organizations) also provide different kinds of support for firms and government agencies in promoting RE development in the country. Association and societies of workers, farmers, youth, women so far did not take part much in the process of promoting energy transition to renewable, but did pay attention to related matters such as job creation and investment opportunities, or environment impact, etc. But overall, their influences are limited. At the same time, international organizations based in Vietnam such as GIZ, USAID, Embassies, World Bank, etc. are quite active in helping, supporting and advocating for renewable energy development. They even funded or sponsored various projects to study issues of RE development.

2.5.4 Government Agencies

There are key organizations in the Party and State system involved in the development of renewable energies. The Party's Politbureau is the highest body of the leading Party in Vietnam (Communist Party of Vietnam). The Politbureau issued numbers of policy documents and the most well-known is the Resolution 55 for development of energy sector up to 2045 and the key foundation for developing differences between the revised PDP7 and drafted PDP8. The Central Economic Commission (CEC) under the Central Committee of the Party is in charge for economic affairs in the Party leadership. CEC pushed for the issuance of Resolution 55 and working with many research organizations, NGO and international organizations to promote renewable energy development.

Government agencies as the providers of institutions, legal framework. On behalf of the Government, the Electricity and Renewable Energy Authority (EREA) under MOIT is responsible for renewable energy development.

Department for Energy Efficiency and Sustainable Development under MOIT has important role in introducing policies for climate change in industry, trade and energy. The Department is also in charge for Vietnam National Energy Efficiency Program (VNEEP).

Overall, MOIT is the organization that advices and consult the government many necessary policies to balance demand and supply in energy, including that of RE, encouraging private sector to invest in the development of the energy supply and transmission system.

MOIT is also speeding up the process of preparation and submission of the PDP8 to the Prime Minister (PM). To promote especially the development of RE, MOIT is proposing to government and PM policies and incentive mechanisms for this purpose such as electricity pricing, bidding mechanisms, to ensure transparency in the planning and implementation of projects. Apart from MOIT and other government agencies at the central level, authorities at provincial levels also have crucial role at different stages of RE development that include People Committee of provinces and cities, Department of Industry and Trade (DOIT), Department of Natural Resources and Environment (DONRE), DOST, etc. Sometimes, this hierarchy of decision making is slowing the whole process and increase complexity of the project implementation and cost (Neefjes & Ngo, 2021)

Although companies working in RE business are mostly non-state such as joint stock companies, some government companies like National Power Transmission Corporation (NPT) under EVN is also a key player in ensuring safe and reliable transmission in the whole electricity system. NPT provides technical assistance to RE projects in linking to the grid and support companies and households to connect to the national grid.

2.5.5 Financial organizations

As providers of financial support for innovation, financial organizations such as bank, credit organizations, etc. have a very influential role in promoting and nurturing innovation activities. In general, banks and credit organizations (domestic and foreign) are the one should be involved in support RE projects. Still, the funding for solar and wind projects so far come mainly from companies own resources, with few investments coming from foreign development bank and international funding organizations. Despite some existing difficulties in pricing mechanism for RE, many financial international organizations such as WB, ADB, JBIC, German KfW, Dragon Capital fund and many other banks are interested in investing in RE project, both solar and wind. For example, the WB provided a credit for a RE Development Project during 2009-2014. KfW provided 35 million USD loan for a wind farm at Phu Lac 1. Dragon Capital created Clean Development Fund Mekong Bhahmaputra for investing in clean energy, energy efficiency with initial investment of 45 million USD (with around 100 million USD for the following phase). Vietnam Development Bank has many programs to fund RE projects, with mid-term and long-term loans, etc. Still, the role of financial organizations in promoting innovation in RE sector is not yet visible, especially of those domestic organizations. In the context of Vietnam aiming at Net Zero as committed at COP26, the whole structure of green finance is still being built, with Law on Environment Protection, Decision 1658 of PM on Green Development Strategy to 2030, Decision 13 of PM on incentives for importing technologies of RE, policies of banking and financial sectors, activities of green investment fund and green bond scheme are considered. The participation of international partners like UNDP, GIZ, WB began to bring benefits. But more needs to be done. If this green financial vehicle is not in place, the new forthcoming PDP8 will not be viable.

As discussed above, the stakeholder analysis is a review of stakeholders coming from various groups, but can be divided mainly into government agencies; companies; research institutes and universities; and intermediary organizations. According to a study by Neefjes & Ngo (2021), the extent of impact that these organizations had on the development of energy transition in general and in RE in particular are quite visible. Among the most influential, Politbureau of the CPV, MOIT, MOIT EREA, and some government corporations like those under EVN have the top level of impact and provide the most efficient and effective support. Second tier of impact belongs to organizations like National Assembly (Parliament), CEC, Government Office, Ministry of Finance, MPI, MOIT Agency for Electricity Regulation, Department for EE and SD. Third tier of impact includes organizations such as some other Ministries like Transport, Construction, MONRE, MARD, provincial governments, business associations like VCCI, and international organizations like donors, funders, investors, independent academic organizations, and middle-income consumers. The rest had little impact on promoting RE development. This synopsis may have a useful suggestion for deeper analysis.

2.6 Institutions

The Government of Vietnam recognized that renewable energy development will reduce the dependence on imported energy sources and ensure national energy security, has issued many policies to encourage the development of renewable energy, set the targets of using and developing renewable energy.

The Prime Minister's Decision No. 1855/QD-TTg of 27 Dec 2007 approved the 'National Energy Development Strategy 2020 with an Outlook to 2050,' the target of increasing the renewable energy rate is set at about 3% of total primary energy consumption by 2010, 5% by 2020, and 11% by 2050. Other regulations include:

- Law on Electricity dated 14 December 2004
- Decision 1855/QD-TTg Development Strategy of Energy's National Renewable Vietnam 2020 Vision in 2050 dated 27 December 2007
- Decision No. 37/2011/QD-TTg dated 29/6/2011 on support mechanism for wind power projects
- Decision No. 1208/QD-TTg The National Power Development Plan 2011-2020 with a Vision to 2030 (Master Plan 7), dated 21 July 2011
- Circular No.32/2012/TT-BCT dated 12/11/2012 on development wind power projects and power purchase agreement for wind power projects

On May 10, 2017, the Prime Minister issued a decree (No. 622/QD-TTg of May 10, 2017) to set "The Sustainable Development Targets for Vietnam to 2030" which are VSDG. Among 17 goals, Goal 7 specifically addresses sustainable, reliable and affordable energy with specific goals and organizations to implement them, to ensure access to sustainable, reliable and affordable energy sources for all.

The Prime Minister also approved The National Power Development Plan for the 2011-2020 Period with the Vision to 2030 (the Power Development Plan PDP 7) on 21 July 2011 under the Decision No. 1208/QD-TTg. The Power Development Plan 7 puts strong emphasis on energy security, energy efficiency, renewable energy development and power market liberalization. On 18 March 2016 and by Decision No. 428/QD- TTg, the Prime Minister approved the adjustment of National Power Development Plan 7 (referred to as PDP 7 REV) for the Period of 2016-2030 with the Vision to 2030.

On 25 November 2015, the PM issued Decision 2068/ QĐ-TTg on the Strategy of RE development of the country up to 2030, with vision to 2050. The Decision regulated many issues regarding EVN role in developing RE sector, incentive system for RE. On the 11 April 2017, the Prime Minister issued Decision No. 11/2017/QD-TTg commonly referred to as Decision 11. This was a huge milestone in the country's goal to create a regulatory environment that facilitates the adoption of solar power.

In its ongoing efforts to bolster renewable energy, the Vietnamese government has passed a new circular prescribing the power purchase agreement form between generators and Electricity of Vietnam (EVN) for grid-connected and rooftop solar projects in Vietnam. With a clear regulatory framework now in place, the solar energy sector in Vietnam is set to grow, provided that the challenges in financing solar energy projects can be overcome.

The Circular No. 16/2017/TT-BCT of the Ministry of Industry and Trade (MOIT) on the Development of Solar Power Projects and the Power Purchase Agreement Form Applicable to Solar Power Projects, dated 12 September 2017 ("Circular 16") setting the regulatory stage for solar power investments in Vietnam.

Among incentives, the most popular is the FIT system for solar and wind energy. FIT for solar is 9,35 US cents/kWh; for onshore wind is 8,5 US cents/kWh and offshore wind is 9,8 US cents/kWh. These FIT are valid for 20 years. So far, the purchasing price of RE is higher than average price for electricity in Vietnam. Apart from FIT, the government introduced other incentives such as tax exemption and reduction, land allocation, business procedures, credit, and so on. In 2020, the PM issued new Decision No.13/2020/QĐ-TTg to change FIT for solar energy to a lower level for various types of solar projects. Even though, there are some considerations that FIT for rooftop solar projects should be lowered even further to 5.2-5.8 US cent/KWh (Nguyen Anh Tuan, 2021). This may cause an unpredictability of business and confusion for investors.

Table 5. Incentive FIT for types of RE

Energy sources	**FIT 1 (US cent/kWh)**	**Supporting policies**	**FIT 2 (US cent/kWh)**	**Supporting policies**
Solar farm	9.35	*Decision No.11/2017*	7.09	*Decision No.13/2020*

		of PM		of PM
Solar rooftop	9.35	As above	8.38	As above
Solar floating	9.35	As above	7.69	As above
Wind onshore	7.8	*Decision No.37/2011* of PM	8.5	*Decision No. 39/2018* of PM
Wind offshore	7.8	As above	9.8	As above

Source: aggregation of available material

To promote *smart grid*, MOIT also issued number of documents such as Circular 40/2014/TT-BCT on 05/11/2014, Circular 44/2014/TT-BCT on 28/11/2014 and Circular 28/2014/TT-BCT on 15/9/2014 to regulate procedures to deal with accident in the grid, many others on transmission in the grid system; requirement for technical standards and processes and others for solar and wind projects to be connected to national grid.

During 2017 - 2018, many incentives and new regulations on promoting development of solar and wind energies were issued (Decision 11/2017/ QĐ-TTg on 11/4/2017 of PM; Decision 39/2018/QĐ-TTg on 10/9/2018). Still, due to slow implementation, lack of stability, the regulations and policies are not catching up sufficiently with the rapid growth of the industry, and creating some risks for investors.

Resolution 18-NQ/TW of the Party on National strategy for development of energy up to 2020 vision to 2050 is one of key documents guiding the future. The most important document is the Resolution 55-NQ/TW of the Politbureau issued in 2020 on direction for Strategy of energy development up to 2030 vision 2045, which emphasized strongly the development of RE. To implement this Resolution, MOIT created an action plan to draft the Renewable Energy Law and revised Electricity Law. Still, the PDP8 will be a key policy guideline for the future. Among specific policy tools, there are new FIT system, bidding mechanism, pilot mechanism of direct electricity purchase (DPPA), new investment and operation mechanism for transmission, development of national information database for energy, and others.

Regarding issue of increasing *localization and domestic manufacturing of technology and equipment of solar and wind energy industries*, Decision 39/2018/QĐ-TTg also regulated that MOIT is responsible for preparing and submitting to PM supporting incentives for domestic manufacturing of wind energy equipment and increasing local content of wind projects.

Overall observation pointed to the lack of transparency, still, of policy making process, such as list of additional projects in revised PDP (a precondition for granting new licenses), or environment impact assessment. This lack of transparency can cause the increase of project cost.

Among institutions, incentive policies for developing offshore wind is a new area of growth. According to some estimation, potential for offshore wind in Vietnam could reach160 GW (Ngo & Dinh, 2020) and Vietnam could accumulate around 10GW offshore wind during 2023-2030. Recently, there are more advocacies for specific institutional framework to promote development of offshore wind energy projects.

Among the actors or stakeholder groups within the innovation system, linkages are the key factor to decide the dynamism and efficiency of this system. This will be analyzed in more details in the following chapter.

Chapter III. In-depth study of key actors and institutions in the innovation system of the wind and solar in Vietnam

This Chapter will analyze deeply the cases of four groups of actors in the sectoral innovation system that would provide overall trends and key findings.

3.1 General background of the study

Following the work plan, after the overview of stakeholders in the RE innovation system, this project has conducted two rounds of in-depth interviews with stakeholders in the renewable energy sector in Vietnam, focusing on solar and wind energies. The stakeholders to be interviewed are divided into four groups, as presented in Table 6 below: (i) companies; (ii) academic organizations such as R&D organization and universities; (iii) government agencies and (iv) intermediary organizations. For both rounds of interviews, ***40 cases*** have been chosen and interviewed, and categorized under the headings of Cases I, II, III, and IV as follow:

- Group I: companies (19 firms, under Cases I)
- Group II: academic organizations (9 institutes and universities, under Cases II)
- Group III: government agencies (7 organizations, under Cases III)
- Group IV: intermediary organizations (5 organizations, under Cases IV)

Interviews' results will be presented for each of the previously described 4 groups. The findings of all the 40 stakeholders are detailed in the next section. Instead of paying attention to all issues related to overall RE development, this analysis will focus mainly on aspects relevant for learning and upgrading technological capabilities of stakeholders for the purpose of fostering localization and indigenous capabilities, and promoting the innovation system.

Table 6. Stakeholder for analysis

Case Number	Organization name and types	Main location	Notes
Group I	***Companies***		
I-1	Bitexco Power Joint Stock Company	South	
I-2	PetroVietnam Power Corporation (PV Power)	South	
I-3	Gia Lai Electricity Joint Stock Company – Thanh Thanh Cong Group	South Central	
I-4	Renewable Energy Investment Joint Stock Company/Licogi 16 JSC	Central	
I-5	Vu Phong Solar	South	
I-6	Pacifico Energy Company - Mui Ne Solar Power Plant	South Central	
I-7	Dan Khue Solar rooftop solar power	South	
I-8	Thuan Binh Joint Stock Company/Phu Lac Wind Power Plant	South Central	
I-9	Gulf Mekong Wind Power Joint Stock Company (Ben Tre)	South	
I-10	Cong Ly 1 Super Wind Energy Joint Stock Company, Bac Lieu Wind Power project	South	
I-11	VietsoPetro (Services for offshore wind power)	South	
I-12	PVC-MS - Petroleum Equipment Assembly & Metal Structure J.S.C (services for offshore wind power)	South	
I-13	Asia Petroleum Energy Corporation	South	

	(AsiaPetro)	Central	
I-14	Hoanh Son Group Joint Stock Company (Cam Hoa Solar Power Plant in Cam Khe, Ha Tinh province)	Central	
I-15	Licogi 13 Joint Stock Company (LIG Quang Tri Solar Power Plant)	Central	
I-16	Gelex Group Joint Stock Company (GEX) (Huong Phung 2 & 3 and Gelex 1, 2 & 3 Wind Power Plants Cluster).	Central	
I-17	PECC1/EVN	North	
I-18	Wind power projects of Gia Lai Electricity Company (GEC) - Thanh Thanh Cong Group (TTC)	South	
I-19	Wind power at Licogi 16 Power Joint Stock Company	South	
Group II	***Research institutes /universities***		
II-1	Center for Scientific Research and Application - Lac Hong University (LHU)	South	
II-2	Electricity Power University (EPU)	North	
II-3	Institute of Materials Sciences, Vietnam Academy of Science and Technology (VAST)	North	
II-4	Ho Chi Minh City University of Technology and Education (HCMUTE)		
II-5	Institute of Energy Science (Vietnam Academy of Science and Technology, VAST)	North	
II-6	Ho Chi Minh City University of Technology - Ho Chi Minh City National University	South	
II-7	Ho Chi Minh City University of Technology (HUTECH)	South	
II-8	Institute of Energy - Ministry of Industry and Trade	North	
II-9	Laboratory “100% Renewable Energies” - Hanoi University of Science and	North	

	Technology		
Group III	***Government agencies***		
III-1	Electricity and Renewable Energy Authority, (EREA), Ministry of Industry and Trade	North	
III-2	Department of Science and Technology for economic technical branches, Ministry of Science and Technology	North	
III-3	Department of Science, Technology and Environment, Ministry of Education and Training (MOET)	North	
III-4	Department of Science and Technology and Department of Industry and Trade of Ben Tre province	South	
III-5	Saigon Innovation Hub (SIHUB), Department of Science and Technology of Ho Chi Minh City	South	
III-6	Department of Science and Technology and Department of Education and Training of Bac Lieu province	South	
III-7	State-level Key Science and Technology Program on Energy (KC-05), Ministry of Science and Technology	North	
Group IV	***Intermediary organizations***		
IV-1	Vietnam Clean Energy Association, HCMC	South	
IV-2	Vietnam Energy Transformation Initiative (VIET)	North	
IV-3	Green Innovation and Development (Green ID)	North	
IV-4	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ - Organization for International Cooperation of the Federal Republic of Germany)	North	
IV-5	Vietnam Union of Science and Technology Association (VUSTA)	North	

Source: results of the study.

3.2 Industry/Firms

There will be 19 cases to be analyzed from the perspective of innovation activities and issues.

3.2.1 : Case I-1.

As a subsidiary of Bitexco Group, Bitexco Energy Joint Stock Company (Bitexco Power) was established in 2000. Over 20 years of development, Bitexco Power Joint Stock Company currently manages and operates 21 hydropower plants. Up to now, Bitexco Power Company is investing and operating only one solar power plant, Nhi Ha Solar Power Plant Phase 1, in Ninh Thuan province, with a design capacity of 50MWp.

Regarding project development activities, Bitexco Power only performs licensing, design, verification, approval, operation and maintenance activities for projects without participating in manufacturing and construction. The equipment of the projects is mainly imported from China, India and Europe through contractors.

In the bidding packages of the Nhi Ha Solar Power Plant Project Phase 1, Vietnamese contractors participate in about 30% of the total investment items of the projects, but mainly the infrastructure construction components such as building premises, providing equipment for transformers and electrical panels. Even for electrical cabinets, Vietnamese contractors only process mechanical parts and install components imported from abroad. The EPC general contractor for this project is a Spanish company.

The electricity selling price of the Nhi Ha Solar Power Plant Project (Phase 1) is 9.35 cents/kWh according to Decision No. 11/2017/QD-TTg for completed solar projects and signed power purchase agreements with the EVN before June 30, 2019 (FIT 1). Electricity produced from Nhi Ha Solar Power Plant is sold through Nhi Ha 220kV substation invested by Bitexco Power itself, not through Trung Nam - Thuan Nam 500kV substation.

For Nhi Ha Solar Phase 2 (design capacity is 150MW), the company has just completed the project survey and is suspending the project implementation. This is because businesses are waiting for a new policy from the Government and the Ministry of Industry and Trade in the near future. However, if the project were to continue, at this stage, Bitexco Power could have assumed the role of EPC general contractor for its project. This is because many of the company's personnel were involved in the construction and supervision at the first phase of the company's solar power project and they learned a lot from the experience of the Spanish general contractor.

In addition to solar power projects being surveyed and evaluated for feasibility, Bitexco Power is also researching and developing more in wind power projects. In Bitexco Power's wind and solar power development strategy, the wind power segment is expected to be the mainstay of the company's energy strategy in the future with about 1,000 MW of wind power to be generated by 2030 and will then be further developed up to 3,000 MW with the addition of offshore wind projects. In the immediate future, Bitexco Power is planning to invest in an onshore wind power plant with a capacity of 45 MW in Ninh Thuan province. In addition, Bitexco Power also plans to deploy floating solar power plants on surface of hydroelectric reservoirs and lakes that the company is operating and exploiting, as well as rooftop solar power models on some buildings in Hanoi and HCMC.

Training activities

For Bitexco, people are the most valuable asset of an enterprise. Bitexco Power always focuses on training and developing personal skills to the highest standards through annual training programs for operational engineers at the company's hydro and solar power plants. Similarly, after completing the Nhi Ha Solar Power Plant, the Spanish EPC general contractor has handed over and coordinated operation and technology training for the permanent staff of the company within one year so that the company can operate the factory on its own in the future.

Research activities

Due to the company's positioning of merely applying technology to production and business, the Company currently does not have an R&D department. For its renewable energy projects, company leaders employ the strategy of setting up technology scanning groups to find the latest and most suitable technologies when Bitexco Power is aiming to do RE projects by themselves from design, procurement, construction and operation of own solar plants in the future.

Cooperation and association

Bitexco Power currently does not have close links with universities and research institutes in both R&D and human resource recruitment. The company participates in the Vietnam Renewable Energy Association but only participates to the extent of listening and exchanging some views related to Renewable Energy policies such as the Energy Master Plan No. 8.

While Bitexco Power soon started to invest in the renewable energy sector and used a foreign EPC general contractor, Bitexco's first solar project took nearly 3 years to complete (2017 - 2019). The execution time of this project is significantly longer than that of other projects, which normally take only 6 months to 1 year to complete. Therefore, there may have been difficulties in the actual implementation of this project.

Regarding the technology used for Nhi Ha Solar Power Plant, most of the equipment used is imported from abroad such as China, India and Germany. Only a very small part of the total equipment used is from domestic suppliers such as transformers from Dong Anh Electrical Equipment Corporation. The Vietnamese contractor only acts as a sub-contractor and is mainly responsible for the construction of infrastructure items. This shows the current reality that domestic equipment suppliers have not really made a commensurate contribution in the value chain of the solar energy sector when the core technologies of solar power such as photovoltaic cells and inverters are in the hands of foreign suppliers.

As the interviewee mentioned, for Nhi Ha Solar, Bitexco Power was fortunate to have not encountered many difficulties during the project implementation period from 2017-2019 with the active support of local authorities as well as local governments and other support policies. However, the company encountered difficulties in recruiting qualified personnel in the area to operate the plant. Bitexco Power also tried to refer to the option of transferring experienced personnel from hydroelectric power plants to operate Nhi Ha Solar Power Plant. However, these employees do not want to change their existing working positions, while the local human resources in the locality where the solar power plant is located do not meet the requirements for professional knowledge. To solve the problem, Bitexco Energy recruited new graduates of the electricity industry and conducted both training and practice in the field when the Spanish EPC general contractor handed over the operation process of Nhi Ha Solar Power Plant. Thanks to this solution, Bitexco Power was able to learn a lot from its Spanish partner in a year of working together, improving its technology capacity and actively does EPC for other projects in the future for themselves or customers.

Regarding the issue of cooperation and association with other organizations, Bitexco Power still does not have any linkage with institutes and organizations or with other businesses in the industry, although the business still has demand for personnel with expertise in renewable energy. The role of institutes in the relationship with businesses in the energy industry such as Bitexco is still too vague and does not seem to have an official link. The only relationship at the moment that Bitexco Power is maintaining is with the Vietnam Renewable Energy Association. However, the role of this business in the association has just remained at the level of participation in a rather passive way, mainly to update information about related policies that are about to be issued as a draft on the Energy Master Plan No. 8.

Institutional issues

One of the proposals that Bitexco is interested in regarding policy is to encourage and promote the recycling of solar panels after they have reached their end of life and encouraging the use of energy storage devices. To do this, Bitexco Power proposes that the Government should have a policy of binding environmental responsibility for solar power equipment's manufacturers in the form of commitments to recall and recycle products after the expiry date. However, this policy may push up the price of solar panels because the manufacturer will seek to raise the selling price of solar panels to offset the cost of recalling and recycling later.

On the plus side, although solar power can have some kind of waste like solar panels, more than 90% of solar panels are recyclable materials such as aluminum frame, glass, silver coating. ... This means it's still much cleaner than coal-fired electricity. Therefore, the State needs to have policies to strongly promote and support RE development.

Another proposal that the company proposes is the State is going to need policies to force RE projects to achieve a certain level of domestic content in the entire RE value chain. Again, this proposal may also face some technological barriers when domestic businesses themselves are still unable to research, produce and master core technologies in the field of solar energy, while for the wind power sector, these core technologies are almost too difficult for domestic enterprises to grasp and master, let alone the activities that generate them.

3.2.2. Case I-2

PetroVietnam Power Corporation is a one-member limited liability company with 100% charter capital invested by Vietnam Oil and Gas Group. PV Power Corporation is the investor and developer of the Phu Quy Wind Power Plant project with a total capacity of 6MW in Phu Quy island district, Binh Thuan province in 2010. This project is constructed by PV Power Renewable Energy Co., Ltd, a subsidiary of PV Power, with an estimated output of electricity of about 25.4 million kWh annually. The turbine engines used in this project are from Vestas (Denmark), with a capacity of 2 MW each and 3 turbines have been installed for this project. The height of each turbine is 60 meters and the wingspan is 37 meters wide. The main contractor is Amec Technology Joint Stock Company, while Marine Engineering Services Joint Stock Company (PTSC M&C) is the main installation contractor.

Phu Quy Wind Power Plant is a very special project, as it was integrated into the island's 22kV grid with a previously existing 3 MW diesel power plant. The combined operation of two wind-diesel systems with a wind/diesel capacity ratio of 6MW/3MW is very unique, since normally if a combined wind and diesel power system exists, the electric capacity from diesel is usually higher than the total wind power capacity. In the case of Phu Quy Wind Power Plant, the situation has reversed. The operation of this dual system requires the system operator to be extremely focused and to follow an approved coordination process.

As for the development direction in the field of renewable energy, PV Power is planning to develop about 55 MW of renewable energy by 2021 (rooftop solar power and floating solar power on hydroelectric reservoirs). With the rooftop solar power model, PVP RE is expected to install small-scale rooftop solar power systems (1MW - 2MW) on a number of buildings and power plants of PV Power Corporation with an expected total capacity of 5MW - 6MW. With the project of a floating solar power plant on a hydro-electric lake, PV Power is expected to carry out the project at the surface of Dak Ring hydropower reservoir in Quang Ngai with an expected capacity of 50 MW. Currently, the project is hiring consultants to survey and prepare documents to assess feasibility before implementation. In addition, the company is also researching waste electricity (generating electricity from burning garbage).

Training

With the goal of learning and mastering the process and technology, which is a long tradition of PV Power, the company always wants to learn from the experience of the contractors and suppliers of electrical equipment in the power industry to target increasing the localization rate of PV Power's engineering services. Therefore, the company always sends engineers to learn from contractors and organize training in the field when completing the project. However, this activity is still difficult due to the negotiation with some subcontractors on the conversion of contract form, and the intensive training is also difficult because the original equipment manufacturer only organize training for their staff, not for customers, and moreover, the equipment has a high technology content, which is not easy to manufacture in Vietnam.

For internal training activities, PV Power regularly organizes annual human resource training at PV Power's own factories. Each employee will be guided to understand more than one job in the factory, in order to better support colleagues in case of force majeure. In addition, PV Power often organizes training courses and invites industry experts on professional training for the company's human resources. Employees who participate in training courses with these experts will be bound by their time of dedication to the company. This is to reduce or slow down brain drain and avoid unfair competition from competitors in recruiting trained professionals.

Research

Although PV Power is a very large company, they have not yet established a dedicated R&D department for a variety of reasons.

Firstly, because the most modern technologies in the energy industry are mostly in the hands of foreign companies, one concern of PV Power is whether the technology developed and produced by the company itself can compete with the products of the factories that outsource products to foreign patent holders or not.

Secondly, the idea of forming a research department of PV Power existed when the company's board of directors had intended to apply the "Scientific and technological regulations of the enterprise" according to Circular No. 12/2016/TTLT-BKHCN-BTC dated June 28th, 2016 of the Ministry of Science and Technology and the Ministry of Finance to develop scientific research. However, the application of this mechanism in practice faced many difficulties for businesses.

Although there is no dedicated team for scientific research, PV Power still has some technological improvements in the operation of plants by the company's engineers.

Cooperation and linkages

For the issue of connecting with institutes and intermediary organizations, currently, PV Power has cooperated with Hanoi University of Science and Technology, University of Mining and Geology and Vietnam University of Petroleum in many fields of research topics, not just focusing on the field of RE. The cooperation model is mainly based on the form of professional contracting to find answers to the problems that the Corporation is facing.

In the case of PV Power, it is easy to see that this business currently does not have too much interest in the field of renewable energy. It can be said that although PV Power has many advantages to take the lead in this field (having a subsidiary specializing in renewable energy and experience in investing and operating Phu Quy wind power plant - the first wind power plant in Vietnam), the company still chooses to focus on developing mainly in the traditional energy sectors such as hydropower and coal-fired thermal power.

Regarding multi-party cooperation, the linkage between PV Power and research institutes and universities, although established, is still not strong enough to meet the expectations of both sides. These relationships are mainly to solve a number of issues related to the energy sector in general and the training of specialized human resources, not just the field of RE. Similarly, PV Power's relationship with other intermediaries in this field is also relatively weak and lacks depth.

The fact that the mechanisms to encourage the development of research in businesses are too rigid and unreasonable has led to businesses having to abandon the plan to develop their own internal S&T departments. Outsourcing research to find technological solutions for the company seems to be easier and much lower cost than deducting funds for research by itself.

As a major player in hydroelectricity and thermal power with many plants in all parts of Vietnam, PV Power is currently facing the situation of reducing the generating capacity of traditional power plants of the company. This is because the power transmission system currently cannot handle the demand for capacity release of power plants in the provinces. Along with that, the Government's priority policy for renewable energy development leads to the fact that solar power plants are given priority to generate electricity on the grid at daytime. This has forced PV Power's thermal and hydroelectric power plants to switch to work at night, when solar power plants no longer generate electricity. As a result, PV Power's plants have lost up to 50% of their design capacity. Even according to a representative of PV Power, there even are factories that are allowed to operate for only one day since the beginning of 2021 until the end of March 2021.

Concerning coal-fired thermal power plants, it is going to take around 8 hours to produce electricity from the moment when these factories start their production line. If during the transmission of power from the solar power plants have problems and causes a power shortage, the entire power transmission system will not be able to promptly replenish the shortage with electricity from the traditional coal-fired power plants, because the long start-up time of these plants. If not calculated correctly, the power transmission system may face difficulties in matching the power supply with power demand. Therefore, one of PV Power's recommendations is that the Electricity Regulatory Authority should rebalance the supply ratio between renewable and traditional energy sources while waiting for the electricity transmission line network to be upgraded and expanded.

In addition, PV Power is also very concerned on standards and regulations for imported equipment in the field of renewable energy. As observed by the company, currently, there is no regulation on uniform standards and regulations on imported equipment in this field. As a result, project investors (especially solar projects), tend to import poor quality equipment from China to use in their solar factories and farms. This has generally created instability on the transmission grid when these solar power plants and farms connected to the national grid. A representative of PV Power's Technical Department said that for poor quality equipment, after only a period of use, the device's performance will be poorer and no longer generate electricity to the same performance level as the original commissioned equipment. Instead, these devices will generate power with incorrect transmission frequency (harmonics). When this amount of power enters the grid, it will cause harmonic interference and generate heat as well as loss of electrical energy transmitted on the grid. Similarly, another consequence is that this equipment of poor quality can cause short-circuits and fires for solar factories and farms themselves. According to the business, currently, the State does not have any regulations on fire prevention and fighting for renewable energy plants. Therefore, the most urgent issue today in the State's management that PV Power is proposing is to have a set of standard assessment tools and regulations on equipment in the field of renewable energy as well as regulations and sanctions on fire prevention for RE plants.

Another aspect is the recovery and recycling of solar panels after the end of their use life. PV Power proposes to attach the responsibility of the manufacturer to the recalling and recycling of solar power equipment through the selling price of the product.

Regarding the difficulty in applying Circular 12/2016/TTLT-BKHCN-BTC of the Ministries of Finance and Science and Technology to the actual situation of businesses, the representative of PV Power also proposed to adjust the regulations on the deduction for the Science and Technology development fund (from 3% - 10% of the taxable income of the enterprise) so that it can be applied to the business by adding the following term: "For businesses not operating in the field of research, if businesses can research and develop technologies themselves or hire technology R&D, the use of Science and Technology development funds should comply with internal regulations of the enterprise itself". This change will create more flexibility for businesses in deciding the rate of deduction for the development of R&D within the company based on the actual needs of the business.

3.2.3. Case I-3

Gia Lai Electricity Joint Stock Company as established on June 1st, 1989 with 100% state capital. In 2013, Gia Lai Electricity Joint Stock Company officially became a member of Thanh Thanh Cong (TTC) Group and is the core unit of the Group in the field of Energy. Currently GEC has successfully energized 7 plants with a total capacity of over 300 MWp. The solar panel technology used mainly in GEC's solar power projects is a monocrystalline silicon solar panel with capacities from 330 Wp, 345 Wp, 395 Wp and 440 Wp provided by the SHARP corporation from Japan. The reason GEC chooses SHARP as the equipment supplier for its solar power plants is because the quality of SHARP's solar panels has been proven to produce high efficiency and maintain stable generating capacity over the lifespan of the battery. In addition, the power transmission cable system installed in GEC's solar power projects is the LS Prysmian cable of Prysmian Group from Italy. For inverter equipment, GEC chooses global suppliers such as SUNGROW, TMEIC (a joint venture between Toshiba and Mitsubishi) and ABB. The only components in GEC's solar power plant with domestic elements are transformers and electrical cabinets provided by Dong Anh Electrical Equipment Corporation and Cam Pha Electrical Equipment Company – the two leading manufacturers of electrical equipment in Vietnam.

For the first 6 solar power projects, GEC selected SHARP as the general contractor EPC to ensure the quality and completion schedule of the plants built. However, to control the contractor, GEC still hired independent consulting units (owner engineering) to advise the investor. After 6 projects, GEC's engineers have self-learned, gained experience and mastered the technology to become the EPC general contractor cum investor for the Chuc Son Solar Power project in Dak Nong province.

In addition to the role of investment and construction of solar power projects, GEC also provides operation and maintenance (O&M) services and technical consulting and testing services for equipment used in solar power plants for other companies.

Training

During the design evaluation and comment phase through implementation and acceptance after construction, GEC's engineers closely follow foreign consultants to learn from experience in construction and operation of the system. For the project handover phase after construction, the contractor only provides operational training when handing over the plant in a short on-site training course of about 4-5 days and accompanied by the signing of a warranty contract package for 2 years. After this, some equipment suppliers can still extend the operation and maintenance contract if the investor wishes to continue using their services.

In addition to the activities of receiving and transferring knowledge on system's operation and maintenance, every year, GEC organizes recruitment and training for new and existing personnel at the company's factories to adjust additionally qualified human resources for their next renewable energy projects.

Research

Engineers from the Electrical Engineering Department of GEC have successfully tested and fabricated a self-adjusting rack system for the company's solar power plants. At the same time, GEC has also successfully manufactured, applied and commercialized solar panel cleaning robots. Currently, the product is being used at GEC's solar power plants and some other factories outside the company.

Cooperation and linkage

According to the representative of Gia Lai Electricity, all projects must compete with the deadline for FIT prices forcing the company to hire foreign experts and consultants to ensure progress. If GEC hires domestic institutes to do it, it will take a lot of time because current institutes are all entangled with a number of problems related to the process and procedures of financial autonomy when operating in the field of consulting services for projects. However, for universities, colleges and vocational schools, GEC still has a need to recruit personnel with specialized training in electricity to operate its projects in the future.

For research cooperation, although GEC has not had a relationship in the field of R&D with universities, the company supplied number of solar panels to some universities (i.e., Ho Chi Minh City University of Technology and Education) in order to create favorable conditions for its students to access and learn about solar power technologies.

In addition, GEC also actively participates in the annual seminars on Renewable Energy to share information about renewable energy projects for foreign investors and demonstrate technologies of solar panel and wind turbine manufacturers. These seminars are also a place to discuss project transfer issues for investors who have approved projects but do not want to implement them.

Supply of some technologies such as solar panels and inverters depends on sourcing by a number of foreign suppliers. In the case of GEC, these devices are all supplied by Sharp, Chinese Sungrow and TMEIC. However, there are still a number of Vietnamese enterprises that have been able to participate in the value chain of the solar power with products such as transformers, electrical cabinets, cables and bracket systems for solar panels.

Compared to other businesses, the process of self-learning from experience in construction and operation of solar power plants at GEC is significantly slower. GEC/TTC Group had to gradually learn experience through 6 solar power projects with foreign general contractors. It can be said that at present, the main role of GEC in the field of Solar Power is still the investor of the projects.

With most of the projects using foreign general contractors, GEC still has not had a close relationship with institutes in both scientific research activities and training of qualified human resources.

Financial problems such as unreasonable collection of import tax on equipment and components used in renewable energy projects have caused many difficulties and troubles for project investors.

Regarding capacity release of solar power plants, GEC does not face any difficulty in releasing capacity for its plants unlike some of its competitors. This is because, right from the project survey stage, Gia Lai Electricity has experience in power transmission system, so the release of power generation capacity for future plants has been taken into account. Because the current local power transmission system is overloaded in the peak season, instead of focusing on building large capacity solar power plants with a capacity of more than 100 MWp, GEC only implement plants with small capacity to match the regional power grid. In addition, GEC also tries to implement projects outside the concentration spots of power transmission grid to avoid problems in capacity release and reduce investment costs of building large capacity substations and transmission lines.

However, GEC is facing major difficulties in terms of import tax on components and equipment. The state tax authority is asking for import tax on the racking system for the solar power plant when GEC imports frames for solar panels from China for the first 2 solar plants of the company. At the time of the construction of these two factories, there was not a single domestic enterprise that could produce these frames by themselves. Now, when the renewable energy industry develops too quickly, some domestic enterprises have been able to produce this product and the tax authority also believes that technologically these frames are also considered like other galvanized steel products that Vietnam can produce, thus they require GEC to pay import tax for the imported frames used at the two plants above. This kind of backward taxing is very ridiculous and created extra difficulties for the company.

Another factor is the impact of the Covid-19 pandemic, many of GEC's foreign consultants are unable to supervise projects in Vietnam. Some experts, when coming to Vietnam, had to be quarantined for 14 days upon entry according to the requirements of pandemic prevention and control policy, leading to the project's progress being interrupted while the project still had to rush to race against the deadline of the FIT price.

The company has also accelerated its learning process through working with foreign partners. After hiring and working with the consultant, along with short-term training activities, the company was able to master the operation capacity and EPC, without having to hire experts again. So far, improving the learning capacity of businesses does not rely much on the academic institution sector (supply side).

As for the institutional system, the tendency of banks wanting to preserve capital due to fears that the project will fail, compel investors to sign a long-term consulting contract with a foreign company on maintenance. This puts businesses in a position of long-term dependence on foreign consultants, hindering efforts to learn and become self-sufficient.

Concerning other policies, the need for human resource support, FIT price stabilization, and technology import tax are the issues of concern. For example, in terms of taxes, it would be difficult to levy taxes on small components that are supposed to be manufactured in Vietnam (such as screws, bolts, etc.) as these parts are component of whole package technology supply. To separate them from the core package and to source them from domestic suppliers (just for the sake of domestic production) cannot guarantee the quality required by technology supplier.

3.2.4. Case I-4

Licogi 16 Joint Stock Company was established on the basis of reorganizing the branch in Ho Chi Minh City of Licogi Construction and Infrastructure Development Corporation. Currently, Renewable Energy Investment (REI) Company, Licogi 16 is operating 2 Solar Power Plants with a total capacity of 75 MWp. In particular, the solar power project in Gia Lai uses solar panels provided by Canadian Solar - a Canadian energy company manufacturing in China. Inverters imported from TMEIC (a joint venture between two leading Japanese electronics enterprises Toshiba and Mitsubishi). This is also the first and only project where Renewable Energy Company, Licogi 16 had to hire an EPC general contractor to implement the project because of schedule pressure and lack of experience in the field of renewable energy. For the remaining projects, the company has been able to both assume the role of an investor and also a general contractor through the experiences learned from supervising the construction of the first project and through the process of technology exchange cooperation with equipment suppliers and consulting units.

In the first stage, the project investors had to contact foreign contractors to execute their first projects to ensure that they keep up with the FIT 1 price schedule and the quality of the technical items. At that time, the cost of hiring foreign contractors was very high, up to 750,000 – 800,000 USD per MWp of solar power. Now with the participation of REI Licogi 16 and domestic construction contractors, the cost of hiring contractors to construct solar power projects has decreased to about 500,000 USD per MWp. Along with that, with the fact that some equipment used in solar power plants can be localized (solar panel brackets, transmission cables and transformers) making the construction cost of solar power projects less expensive than before.

During the learning process, REI Licogi 16 believes that the technology used in the solar power plant is actually not too complicated, except for solar panels and inverters, which are owned by leading companies in the sector. As for solar panels, although the manufacturers of these products have opened a number of factories in Vietnam, they only stop at the level of installation and completion of products, but cannot manufacture photovoltaic cells and solar wafers in Vietnam. Meanwhile, for inverter, REI Licogi 16 believes that the technology used is not too difficult to understand and the license production can be easily purchased or leased from other firms for domestic production. However, the next problem is the cost of domestic inverter products to compete with those imported from China.

The construction and installation part of solar plants are quite simple because equipment suppliers have provided technical manuals to install equipment for construction for the contractor.

In addition to the Nhon Hai Solar Power Project in Ninh Thuan province invested (with a total investment of 700 billion VND) and built by REI Licogi 16 itself, the company is also the EPC general contractor of 5 other solar projects. Only a few projects still use Chinese general contractors because the investors of those projects or shareholders holding voting rights in joint ventures between Vietnam and China belong to Chinese companies, they have the right to appoint EPC contractors to Chinese construction companies for their own solar projects.

Training

Like other companies operating in the field of construction, REI Licogi 16 regularly organizes training sessions for the company's employees every year at the factories.

Research

With the diversified development orientation, REI Licogi 16 position itself as a technology search and application firm instead of a technology research and development company. Therefore, the company has no plans to organize an R&D department yet.

Cooperation and linkage

Currently, although REI Licogi 16 has links with a number of universities such as University of Hydrology, University of Transport, University of Transport Technology, Tra Vinh University, these linkages are only to serve the purpose of recruiting professional personnel in related industries.

For research institutes, REI Licogi 16 cooperates with a number of state agencies such as the Institute of Energy (MOIT) through consulting contracts, evaluating, supporting and proposing connection plans of projects to the national power transmission grid and the Electricity Consulting Joint Stock Company 4 (PECC4) to advise, propose and evaluate the potential of projects before submitting the license application.

According to REI, the problem of the transmission system and the safety of the operation of the national grid is the most important. One of the solutions that REI Licogi 16 believes that the Government should issue preferential policies for new solar power projects.

Licogi 16 is also proposing to solve the grid overload by developing an energy storage system (BESS - Battery Energy Storage System). The inclusion of the BESS storage technology requirement would increase the investment cost by approximately US$200,000 per MWp, but the efficiencies this storage system offers in storage and playback increase. This system provides electricity to the grid at night or at times when the load on the line is much lower. Moreover, the system will also contribute to stabilizing the power grid by avoiding overcapacity on the line.

REI Licogi 16 said that investors, as partners of the company, are wishing to invest in renewable energy projects with a total capacity of up to about 10,000 MWp - 20,000 MWp. However, with the current development status of the power transmission infrastructure (only increasing by 6%/year), it will not be possible to meet the demand for releasing the additional annual capacity of new RE projects (average growth rate of more than 20%/year). This leads to the possibility of additional planning of these new projects is not high. Therefore, REI Licogi 16 also recommends that the energy sector may have to think about additional planning in many stages and should not prioritize additional projects before and after in the order of time of planning submission, because in the Master Energy Plan No.7, there was a situation where many businesses did not have the capacity to deploy, only applying for the project planning slot and waiting to resell these projects at high prices to earn the difference. To change this situation, the capacity mobilization mechanism for the Master Energy Plan No.8 must be equal between the backlog projects that have not been implemented from the Master Energy Plan No.7 and the new projects.

A phenomenon often mentioned is the unstable FIT price with a deadline that is too fast, causing investors to fall into a passive state, having to race against time to complete the schedule and affect the sustainable development of the renewable energy industry. In this situation, enterprises do not have long-term stability to be able to accumulate technology, build technological capacity and learn on the basis of advantages of economies of scale to help the process localization can take place when purchasing technology equipment and services in Vietnam.

3.2.5. Case I-5

Vu Phong Solar Power Company was established in February 2009 in Binh Duong. To date, it has implemented more than 1,000 projects, installed more than 500 MW of solar power, and had 9 branches and representative offices nationwide.

Vu Phong has been constructing 8 solar power farms nationwide with the main purpose of approaching the investors of these farms to convince the investors to use Vu Phong's operation and maintenance services. The company is applying for land in the high-tech park of Ho Chi Minh City to open a factory to produce auxiliary equipment for solar and wind power such as automatic solar panel cleaning robots and solar farm monitoring drones. For the BIM 2 project with a total power of 246 MW, Vu Phong is directly operating and maintaining the project after convincing the French general contractor Bouygues Energies & Services to allow them to participate in the operation and maintenance process (after only 2 months Vu Phong running the trial operation, Bouygues Energies & Services withdrew all manpower and handed over the entire operation and maintenance process to Vu Phong). The reason is that Vu Phong is able to recruit domestic O&M human resources more easily than Bouygues and the second reason is by letting Vu Phong directly operate and maintain the project, Bouygues Energies & Services can reduce the O&M costs of the project. Vu Phong is also testing a robot that automatically maps and cleans solar panels, designed and manufactured by Vu Phong in an ongoing project. The company is testing tracking technology (adjusting the orientation of solar panels in the direction of the sun) for solar farms with a capacity of less than 30 MW. The Tracker device has been patented by Vu Phong with the National Office of Intellectual Property since September 2020.
Vu Phong was once interested in solar panel manufacturing technology - it acquired a 48MW solar panel production line from a Taiwan company. However, to import auxiliary materials from China for solar panels with a preferential tax rate of 0% is seemingly impossible and Vu Phong decided to stop the plan to produce solar panels after that.

Vu Phong has an association with Taiwan's AEC company to produce inverter equipment in the form of modules to easily replace accessories. The AEC company will take on the role of manufacturing inverters for Vu Phong's projects while Vu Phong will take on the role of manufacturing monitoring circuits/modules and sending them through AEC for installation in those inverters. For Vu Phong, the production of inverters is not too difficult, because the core technology licenses of inverter equipment are held by Texas Instrument and they can buy or rent this technology. If there is a large enough customer size/ market and localization support policy, many Vietnamese companies can also produce these inverter devices.

Some key complains by VP include that imported spare parts and accessories are not eligible for tax incentives. Due to the small scale of production, even if the domestic company can produce complete set of products, it will have to face the quality of imported parts and accessories for these products. It is difficult to guarantee the quality of parts if the order is not big enough, and local manufacturers cannot work directly with suppliers (due to the requirement of minimum order quantity from suppliers) but can only work with agents/intermediaries who cannot guarantee the quality of component sources. In addition, Vietnamese firms are usually quite small and not attractive enough for suppliers. In this disadvantageous position, if local companies buy bad quality products, they will not be in a position to hold the supplier responsible for these defective products. Currently, Vu Phong is planning a product segment of Solar Home projects for millions of households (the market is big enough). The company can completely start to produce and market the first international standard inverter product in 2022 if it follows the usual commercial method (importing equipment and assembling into complete set of products). However, by doing this Vu Phong will not be able to learn anything from the imported system. Apart from solar panels, Vietnam can completely localize the technology of solar power equipment.

Technical manpower and learning

Vu Phong staff are former students of Ho Chi Minh City University of Technology. In addition, the company technology department has more employees who are alumni of Hanoi University of Science and Technology specializing in automation, robotics and mold making. As such, they were well trained and prepared for the job. The company supplied their engineers to work for First Solar's factory (producing solar panel) in HCMC and Blacksun's solar panel factory in Germany for quality inspection training. This is an opportunity for Vu Phong to approach, discover and learn the "Thin-Film Silicon solar cell" technology from those solar panel manufacturers.

Linkages

Vu Phong still does not have many connections with universities and research institutes in Vietnam. It is very difficult for institutes and universities to link up with businesses in the renewable energy industry because most of the businesses investing in generating and selling electricity today are doing it in the commercial form (importing equipment and hiring experienced contractors) and they have to race against the FIT price deadline. No one dares to risk hiring a technology research institute because it would be very time consuming to develop and can be very risky too. The company is actively participating in learning, through working with foreign partners such as Boygues, who have transferred the entire O&M process to Vu Phong through the BIM 2 project. There has also been a patent registration by Vu Phong for trackers at NOIP to replace imported products.

Policy recommendations

There should be small tariff barriers for imported inverters and batteries to protect domestic products or encourage foreign inverter and battery manufacturers to open factories in Vietnam. However, tax should not be imposed on solar panels as they are unlikely to be localized anytime soon in the near future. Another option is to support import tax on components for small domestic enterprises to cut costs and increase the competitiveness of domestic products. Vu Phong commits to invest in production lines but will need to access preferential loans for science and technology activities.

3.2.6. Case I-6

The plant has average daily electricity output of about 200,000 kWh (about 70 million KW/year). Financial partners are Dragon Capital (50% capital), Pacifico (50%) for a total investment of 400 million USD.

Technology

The project uses the technologies, mainly imported from China including m*odules, strings and junction box, inverter*. The factory uses 2 transformers of 25 MVA and two *meteorological measuring stations.*

Construction process and capacity

The project encountered small problems during construction such as site clearance. The project acquired land from another company, so it did not face many compensation problems. Still, there were some people who had small disputes over land, which were later settled amicably.

Operation and maintenance

To operate the plant, it needs 10 operators, 10 guards and 7 people doing cleaning jobs like mowing the lawn and cleaning the solar panels. Plant operators need to have specialized training and must have a college or university degree in electricity. Particularly, the station head must have A0 and A2 certificates. Upon receiving the project, the project's employees were trained by the technology supplier. Typical maintenance tasks included inspecting the combine boxes, power lines and panels

In general, the Mui Ne project shows that Vietnam's human resources can master the normal operation of the plant. Learning process has taken place to a certain extent. The company also does not have much need to link up with training institutions in Vietnam because they receive technology directly from foreign suppliers in a turnkey manner. The technology is mainly imported from China with high stability. Vietnamese companies hardly participate in providing any core equipment or technology (battery panels, inverters, combine boxes), except for a few small accessories that can be provided at a moderate level such as steel frames for solar panels, etc.

3.2.7. Case I-7

Designing and installing solar panel systems is one of the specific and basic service activities of Dan Khue Solar. When the solar power source is exhausted, the consumed loads will switch to grid power. The installation of a solar panel system needs a team of experienced and skilled technicians. Currently, Dan Khue Solar Company is conducting research on the process to improve the design, improve the installation/construction process of a grid-tied solar power system with storage.

The rooftop solar power service of Dan Khue Solar is in the process of being completed and has a strong development plan from 2021. The rooftop solar power system is to take advantage of the spaces of the terrace and houses’ rooftop and high ground with lots of sunlight. Dan Khue Solar Company is also researching to reduce the cost of services related to rooftop solar power for households and businesses. Dan Khue Solar can advise on choosing a rooftop solar power system for businesses with an appropriate capacity.

Dan Khue Company is currently providing, researching and perfecting cleaning services for solar panels, including solar panel cleaning service for villas; service of cleaning solar panels on the roof (rooftop) of the building for the office; service of cleaning solar panels on the roof of the factory; solar panel cleaning service for solar power plants with high-efficiency automatic technology.

In addition to cleaning solar panels in the traditional way and with specialized vehicles, Dan Khue Company is researching to apply a water pressure cleaning robot, using a robot with a nozzle that uses strong water pressure to clean dirt on the surface of the panels. In addition, the company is researching solutions to use a robot to clean the panel without using water.

Technology value chain: Dan Khue Solar mainly procures, designs and assembles equipment, provides equipment for households and projects supplying electricity to the grid. The remaining activities of solar panel production, or current conversion inverter are only at the stage of learning and researching to master and improve the technologies in the future.

Technology capacity: Dan Khue Solar has relatively good capability on market research, operation, adaptation and small improvement in technologies, especially solar power technologies from China. In order to improve the technological capacity of business, Dan Khue Solar has participated in training activities organized by ministries, agencies and localities every year. The company has especially close links with a number of highly qualified experts in the field of solar power, currently researching and teaching at a number of research institutes and universities in Vietnam.

Problems

First, it is difficult for the company to understand and apply some government policies. In fact, some guidelines for determining rooftop solar power projects are not clear, so it is difficult for the company to advise its customers.

Second, Dan Khue Solar is a small business, so its technological and financial capacity is limited. Therefore, the company is facing many difficulties in the process of learning technology, improving and renovating technology, perfecting the organizational structure and developing links with prestigious domestic and foreign scientific and technological organizations in the field of solar power.

Third, Dan Khue Solar has not yet enjoyed the State's incentives in upgrading, improving, learning and improving technological capacity and technological innovation of enterprises. Part of the reason is that Dan Khue is a new enterprise with a relatively small scale and capital; partly because the company is not really active in accessing and using preferential policies of the state, especially preferential policies in the field of solar power.

Some proposals

First, the State should continue to support, encourage and create conditions for small and medium-sized enterprises, such as Dan Khue Solar, to participate in the rooftop solar power market in stages from research, production, to electricity distribution. Since the support policy is still in short-term, it is not really motivating businesses to taken part in the market. Therefore, the policies need to be in longer-term, so it can boost business and investors' confidence and motivate them to join in the renewable energy sector. The method of paying for electricity sales is still slow, there are no detailed instructions on safety standards and techniques. In addition, financial incentives are not really suitable with the actual context, making businesses operating in the field of solar power not assured of investment and development.

Second, the State should continue to support and provide tax incentives in a more open and favorable way and create more favorable conditions for businesses, especially small businesses like Dan Khue Solar to develop. The regulations related to the application for a construction permit, the roof structure load when installed are not really clear, so businesses and project developers only focus on one area, leading to the ability to connect to the grid is limited. Along with that, the State needs to support businesses in researching and decoding to gradually increase the localization rate of components and equipment in the solar power system to introduce new products, services and technologies which are more competitive in the solar power market.

In general, the company mainly provides rooftop solar power services for households and businesses. The company does not manufacture anything by itself, but mainly imports all equipment, machinery and components from China, assembles it and provides its services. However, the company has purchased some small components, such as steel rods and screws from local suppliers and more recently purchased solar panels from V-Energy, a local supplier from Vinh Phuc province. In company's view, because the State does not have a general policy on supporting the development of domestic capacity in solar power (unlike China) despite the sufficient capability of Vietnamese technical engineers to do so, it has not yet turned the solar power industry into a competitive industry.

3.2.8. Case I-8

The Phu Lac Wind Power Plant is located on Lac Tri, Phu Lac commune, Tuy Phong district, Binh Thuan province with a surveyed area of 400 hectares and a total power capacity of 50 MW. 12 wind turbines installed in this project was V100-2.0 MW type brought from Vestas, with a rotor diameter of 100 meters and a power capacity of 2 MW for each turbine. Fichtner, a German engineer and consulting firm, was in charge of consultancy and technical support for the project. The project provides around 200,000 kWh per day. During the preparation of construction of the factory, two German experts were hired to assess the environmental impact of the project.

Operation and maintenance process

The solar farm signs an operation, management and maintenance contract with Vestas. Maintenance requires 3 Vestas experts in charge. Maintenance and repair process for 12 columns costs about 14 billion Vietnamese Dong/ year. The factory currently has 26 operators; capacity is only 30% because around the farm there are about 21 solar power plants. Therefore, the wind power plant has to reduce its capacity due to transmission grid congestion. By doing this, the factory has lost of about 32 billion Vietnamese Dong since those solar power projects connect to the grid. It is expected that by the time EVN completes the transmission line, it is possible to release the plant's full capacity. Power output: 79 GWh/year in 2018 and then the output decreased to 65 GWh/year due to the grid congestion problem. Number of employees in charge of maintenance: 1 leader from abroad, 2 Vietnamese officers of Vestas at the factory. Vestas has a maintenance service team in Vietnam. The equipment purchase contract includes a 5-year warranty. Vestas' warranty and maintenance costs are very high. There are 5 packages with prices ranging from 1,000 – 5,000$. Phu Lac wind power bought the $4,000 package. Operation & management cost for the factory is about 14 billion VND/year. This is almost a mandatory condition of the Danish turbine supplier when signing a technology purchase and sale contract.

The process of training human resources for operation and maintenance: Vestas does not transfer technology on operation and management and the general contractor failed to sign a training contract with Vestas.

On June 27th, 2019 the Southern Load Dispatch Center (A2) sent to relevant businesses after calculating the normal operation mode at peak hours, informing that when solar and wind power plants in Ninh Thuan, Binh Thuan and An Giang provinces generate high capacity, that may cause overload in the relevant area grid. According to the notice, 22 renewable power projects in operation are required to cut their power generation capacity by 61% - 65% from June 28th, 2019 to July 1st, 2019. This example showed a serious problem happening in the Vietnam's electricity transmission system. This mismatch causes a bottleneck phenomenon between the supply and demand of renewable energy.

Although the Southern Power Corporation had a plan to upgrade the transmission capacity of the Thap Cham - Ninh Phuoc - Tuy Phong - Phan Ri transmission line from 110 kV to 130 kV and build a second 110 kV line, the construction is still very slow and the total power transmission capacity on this route still cannot catch up with the mushrooming development of wind and solar power projects in Binh Thuan and Ninh Thuan provinces. This situation explains for the decision on power cut requirement from the Southern Load Dispatch Center (A2). This unsolved situation, thus, still exist currently. Also, by 2020, many solar and wind power plants in Binh Thuan and Ninh Thuan will still be required to cut power generation by about 61% and this may affect the payback progress of these projects and the survival of the whole projects.

Apart from the cut requirement of power production due to low capacity of transmission line, another problem is the strict condition for having maintenance contract with supplier Vestas. Due to this, it is very difficult for Vietnamese company to be able to learn and handle technology, upgrading learning efforts.

3.2.9. Case I-9

Mekong Wind Power, a subsidiary of Gulf Energy Development Group, started the installation of monopile foundations of the Binh Dai offshore wind power project with a total capacity of 310MW. This is the offshore wind power project applying monopile technology in Ben Tre province.

Technology

The wind turbine engine uses Siemens Gamesa technology with a capacity of 2.5 MW - 3.3 MW for each wind turbine. The project is using the wind turbine of the 5.0 series of Siemens Gamesa turbine manufacturer (Siemens Gamesa Renewable Energy, SGRE) to generate electricity which only needs a single foundation pillar for each turbine. The project uses piles based on Monopile metal pipe technology to resist corrosion in sea water conditions instead of the traditional concrete foundation method to save construction time (normally it will take a few days to complete the construction of a Monopile pillar). The most difficult part of monopile technology is the design part, while the construction is simpler. Monopile foundations are made by a Chinese factory. The upper body of the Monopile pillar (to the bottom of the turbine) is built by CS Wind, a 100% Korean foreign invested company located in Vietnam.

Project lender - World Bank - appointed a multinational independent design evaluation and consultancy which is the ULVS (Australia and the Netherlands) but the experts were unable to travel to Vietnam due to the Covid-19 pandemic situation. Therefore, the project design was slow (reached only 56% total process at the time of interview) and resulted in delayed construction, despite attempts to order equipment as soon as each design step was completed.

Training activities

Equipment supplier (Siemens) provides training and certification program when entering the operation stage. In addition, operators will have to attend and must have a certificate issued by EVN to be allowed to operate. The factory operation team is led by experts from Gulf Group and directly participated by Vietnamese engineers. Through this training process, Vietnamese staff have learned a lot from the experience and knowledge on construction, management and operation of wind power projects.

Maintenance and repair

The project will have to sign a long-term maintenance contract with the wind turbine manufacturer Siemens Gamesa due to the lack of technological knowledge in diagnosing future wind turbine failures. As such, the project will continue to depend on the supplier for a near future.

EPC General Contractor

- The EPC general contractor of the project is Power China HDEC-INTL. However, in the opinion of project managers, over time, Vietnamese companies are fully capable of being EPC general contractors for construction and installation and fabrication of Monopile pipes and the upper body to the turbine and even construction and installation of the whole project, except for the manufacturing of turbines, gearboxes.

Linkages

Currently, the company has no relationship with R&D institutes and universities because for all of the 3 stages of the project (design, procurement and construction), the investor already has a contractor to perform them. Thus, R&D organizations and universities almost have no role in the process of building a wind power project.

- Environmental and Social Impact Assessment (ESIA) is carried out by the lender via hiring a number of foreign professional assessment firms, but these companies still need to hire a number of individual consultants in research institutes in Vietnam.
- Due to the Covid-19 pandemic, the project design and appraisal faced many difficulties. It is very difficult for design experts of contractors from abroad to enter Vietnam.

Recommended policy

Government should extend the time of FIT price support for 1-2 years, to create stability for renewable energy projects. Government should also create specific and appropriate policies to improve the content and localization rate of wind power equipment. These policies could be similar to the Prime Minister's Decision 1791/QD-TTg approving the pilot implementation mechanism of domestic design and equipment manufacture for thermal power plants in the period 2012 - 2025. So far, most of the stages in the technological chain of wind power are undertaken by foreign companies: EPC, core technology supply, supervision consultancy, fabrication of main equipment components, etc. However, over time, Vietnamese firms can gradually participate in simpler stages such as construction and progress to become EPC general contractors or manufacture some simpler parts (the pillar). The design and manufacture of complex technologies (turbines, gearboxes, propellers/ wings) are still beyond the reach of Vietnamese companies.

3.2.10. Case I-10

Cong Ly company is one of the first wind energy projects in Vietnam. Total capacity of the project is 99.2 MW (each turbine has a capacity of 1.6 MW). The foundation in the first stage (for the first 10 turbines) is done according to the traditional design. In stage 2 (for the following 52 turbines), the foundation is built according to the heart-pile design (build a large pillar instead of circling a small pillar as before and pour concrete around the base of the pillar to create the foundation) to save time. Core technology is from General Electrics (GE) which provides the turbine and the cylinder pillar (except for the foundation which is designed and built by the Vietnamese contractor). EPC contractor: Cong Ly made the EPC by themselves, then Vietnamese subcontractors were selected by Cong Ly to construct and install all parts of the wind turbine under supervision of experts from GE. For the construction work, Vietnamese contractors are only involved in the construction of the foundation and the building of the substation from 690V/22kV at the base of the turbine pillar.

- For the project design part, Cong Ly must conduct wind and geological surveys on its own to decide the location of the initial turbines and GE experts will advise on adjusting the location of the turbines if necessary.

Operation and maintenance

GE supports operation and maintenance within 2-3 years after the project comes into operation under the contract. After 2 years, Cong Ly can hire additional services or operate and maintain it, GE will provide email and support contacts if needed. GE also initially offered a maintenance package with the equipment price. However, the maintenance cost was too high (94 billion Vietnamese Dong for 62 turbines within 1 year), so Cong Ly decided to operate and maintain the system by itself. Cong Ly also built a warehouse and procured equipment and supplies for maintenance from GE. One maintenance team of 10 technicians, of which 5 are trained by GE, then they will pass on the learned knowledge to their successors (training of trainers - TOT model). The current technical team can only maintain the hardware and transmission, the central circuit board and software embedded in the processing chips on those circuit boards must be sent to

GE to repair and then sent back to Vietnam. Or if the company need to buy a new one right away, GE can provide it for 120 million Vietnamese Dong/set because the time it takes to send it back to GE for repairing and returning will take about 2 months, greatly disrupting the operation of the project.

Training activities

GE provided a basic paid training course for 5 technicians of Cong Ly - sent to the US for training even before project construction started. When returning home, these 5 technicians will directly follow GE's electrical supervisor at the construction site (on-site training) for about 1 year to understand the structure and operation of the system. After 2 years of operation, Cong Ly hired 2 more GE experts to come to Vietnam to support the operation and maintenance within 1 year.

- 5 staff members who were sent to study at GE only committed to work for Cong Ly for a few years. At the end of the commitment period, they are free to choose to continue their dedication or move to other companies or other projects.

Linkages

- There is no help from institutions or universities because the sophistication level of wind power technology is far beyond the level of research of these institutions. Cooperation between Cong Ly and the university is only one-way relationship when Cong Ly allows some students from universities to practice at the company as internships and one of students after graduation has returned to work for Cong Ly for a few years before moving to VESTAS. This can be a problem of training high-quality human resources that not only Cong Ly but also other companies in this field are facing.

Other issues

- R&D institutes and universities should conduct research on the operation of turbines and the software controlling these turbines. In addition, these organizations also need to develop software capabilities for their scientists to help businesses understand operational process of the wind power system and thereby reducing dependence on foreign suppliers.
- There should be a policy to source wind power equipment locally to encourage suppliers of wind power equipment to manufacture in Vietnam.
- There should be also activities to promote appropriate human resource training, or retain trained human resources.

3.2.11. Case I-11

VietsoPetro is a joint venture between Petro Vietnam (PVN) (with 51% shareholders) and Russian's Zarubezneft (with 49% shareholders). The company has many assets that can be utilized for offshore wind project such as 14 Fixed platforms; 25 WHPs/satellite platforms; 02 Central processing platforms; 02 Water injection platforms; 03 Gas compression platforms; 03 FSOs; over 770km Infield Pipeline; 200km Submarine Power Cable. There are nearly 6,000 officials and employees, in which, the percentage of employees working in onshore projects is 53% and for offshore projects is 47%.
- Not only exploiting but also providing oil and gas services, managing 50 marine works, 14 fixed platforms and 3 oil tankers.
- Having a Board of Management and shares in many oil and gas zones.
- Onshore property has a manufacturing yard with a total area of 32 hectares, an assembly yard of 144,000 m^2; factory 20,000 m^3, office 5000 m^3, 3 slides bring the structure to the sea, 2 roads have a load capacity of 170t/$m^{3.}$
- A fleet of 22 ships for transportation and installation works.

VSP believes that they can completely have a strong role and position if they switch to serving the emerging industry of offshore wind power. Based on the capacity to design, manufacture and construct offshore structures for the oil and gas industry, these capabilities are fully applicable to the offshore wind power industry.

Research
The joint venture has an especially strong Design Research Institute in its structure (VNIIPI Institute). This research institute has had many research works applied directly to the operation and bringing many economic benefits to the joint venture. VSP's Design Research Institute is one of the strongest R&D institutes in Vietnam in terms of design capabilities for large-scale marine structures. Currently, the company can:
- Plan on casting onshore: concrete block 500 - 1,000 tons and move it out offshore, but the investor wants the offshore casting option.
- Research on the installation of turbines and transporting turbines to the sea.
- Fabricate wharfs to handle the capacity of 22 tons/m^2 despite a 4-5 tons/m2 wharf load is difficult to handle 90 tons turbine.
- Potentially lift from shore to the barge through a floating crane, although this solution still requires a calculation of the load that could be technically feasible to lift. However, there is a possibility that in the business relationship, VSP will not be able to purchase insurance for the entire process.

3.2.12. Case I-12

Established on October 20, 1983 with the name of Steel Structure Facility, the company was turned in 2009 into PetroVietnam Metal Structures and Machinery Erection Joint Stock Company, directly under the Vietnam Oil and Gas Construction Joint Stock Corporation. The company specializes in design, procurement, installation, construction and manufacturing offshore equipment.

Cooperation and association:

- Vietsovpetro and PVC-MS have cooperated together since the early days of establishment with the start of manufacturing rig equipment on the port's storage yard and then the construction of a wharf system to transport equipment. However, the storage area of this port is only 30 hectares, so if the PVC-MS and Vietsovpetro alliance participate in the installation of offshore wind power projects, this alliance will likely encounter some difficulties when implementing offshore wind power projects with a total capacity of about 600 MW/year or more.
- On the other hand, the fleet of ships carrying out offshore equipment installation of PVC-MS and Vietsovpetro alliance can only handle offshore wind power projects with a total installed capacity of about 400 MW in a year. If the total installed capacity of one year is 600 MW, this fleet will not be able to meet this demand because the time to install each offshore wind tower will need at least 3 days to be completed. Therefore, if this alliance wants to undertake offshore wind power projects with a total capacity of 600 MW/year or more, they will have to consider the option of equipping a second fleet and upgrading the port's storage yard to be able to serve the installation and construction of offshore wind power projects with a total optimal capacity of 800 MW/year.

The current status of PVC-MS company and the alliance between the company and Vietsovpetro show that this company has quite good capacity to assemble and execute many projects in different industries, especially in the oil and gas industry. The construction of a number of offshore oil and gas projects has allowed the company to accumulate a lot of experience in construction and logistics handling for offshore operations. All of these experiences can be transferred to construction and installation activities for offshore wind power projects.

However, for this to happen, both companies as well as industry and the government agencies need to have a strategy to transition from oil and gas projects to offshore wind power projects. In addition, the company should also organize training activities and skills transfer to update and disseminate new technologies in the transportation and installation of equipment of current offshore wind power projects to employees and staff.

3.2.13. Case I-13

Asia Petroleum Energy Corporation (AsiaPetro) was established in February, 2008 by experienced and senior experts, especially in large projects of oil and gas industry and renewable energy.

Activities

The company is operating and building a number of renewable energy projects such as Duyen Hai Wind Power Plant, La Gan Offshore Wind Power in Binh Thuan province. Copenhagen Infrastructure Partners (CIP) and AsiaPetro and Novasia Energy have signed a Memorandum of Understanding (MOU) with Binh Thuan People's Committee for the development of a 3.5 GW offshore wind project off the coast of the Binh Thuan province in Vietnam.

In terms of technology, AsiaPetro has a series of foreign partners such as Vestas and Siemens Gamesa Renewable Energies providing wind turbine technology, CS Wind providing turbine pillars and others. Since AsiaPetro's new projects are in operation or are still being implemented, the real technology problems have not appeared much. Mainly Duyen Hai 1 Wind Power project in Tra Vinh province is developed nearshore and follows the same procedures and processes for many other nearshore wind power projects. The sources of wind turbine technology are from Vestas. Meanwhile, the La Gan project is offshore wind power, with a much greater degree of technological complexity. The choice of mainstream technology can be between Vestas or Siemens Gamesa, depending on wind survey test results.

From the business point of view, the business sector cannot work alone. They desperately need the support from the Government with the role of creating, directing, orienting and creating initial conditions.

One of the important purposes of offshore wind power development, emphasized by businesses, is related to the protection of sovereignty over sea and islands, protection and development of the continental shelf and exclusive economic zone of Vietnam. Attracting foreign investors in offshore wind power projects will not only bring economic benefits, but also help create internationalization and diversification of maritime development and marine economy in Vietnam, against the powerful hegemony of a certain foreign force.

3.2.14. Case I-14

The Renewable Energy segment of Hoanh Son Group Joint Stock Company was established in 2018 with the birth of Ha Tinh Solar Power Joint Stock Company and Cam Hoa solar power plant. Cam Hoa solar power plant, with a design capacity of 50 MW, was designed by experts from Germany and the project's consulting contractor is a Spanish company. When the project completed the design phase, Hoanh Son searched and hired foreign general contractors to implement the project, but there was no EPC general contractor accepting the construction contract. Therefore, Hoanh Son Company made a bold decision to carry out the project by itself with its own human resources, although the company's experience in the construction field at that time was not much. However, the Company was able to use the experience of constructing electrical works from newly recruited employees.

In the process of self-implementation, because the terrain of the project is located on sandy coastal land, it is difficult to transport equipment by truck while the project implementation schedule is urgent. Realizing that front-loaders can run on coastal sandy terrain, Hoanh Son engineers replaced the excavator part of this fleet of vehicles with homemade specialized forks to transport equipment to the construction site. At the same time, in order to speed up the implementation of the project, instead of renting concrete pile driving machines to build the pillar system for the solar panel racks from other companies, Hoanh Son voluntarily converted its excavators into concrete pile presses by replacing the bucket section with a split pile hammer system sold by a supplier in Ho Chi Minh City. As a result, the construction speed of the project has been significantly improved.

Cam Hoa Solar Plant also uses 2 semi-automatic solar panel cleaning robots imported from China. However, the efficiency of these robots is not high. Therefore, Hoanh Son wants scientists to be able to research and manufacture a fully automatic glass cleaning robot and use the dried cleaning method instead of using water as today.

In addition, Hoanh Son has just completed a 20 MW rooftop solar power project combined with an agricultural farm model. The height of the corrugated iron roof to install the solar battery system is 2.7m using Trina Solar's TSM-540DE19 monocrystalline silicon panel (China) with a maximum capacity of 540Wp and the peak photovoltaic conversion efficiency reached 21.2%, while the inverter was provided by Huawei.

Because of the difficulties in transmission and capacity release that the electricity industry is facing in the central provinces, in Hoanh Son's opinion, the next solar power projects in the future will need to have a solar power system integrated with energy storages to store peak-hour capacity and release grid off-peak capacity for these projects.

In addition, if the system is large enough, it can not only store electricity from renewable power plants, but also store electricity from traditional power projects such as hydropower and coal.

Hoanh Son also proposed building a large energy storage plant of several thousand MW using wet battery technology instead of dry battery technology as the world is currently using to reduce the investment cost per MW of electricity stored. Thus, at peak hours, electricity from projects with excess generating capacity will be purchased by Hoanh Son at low prices and sold at off-peak hours to parties with electricity demand. Hoanh Son is ready to invest to pilot the construction of an energy storage plant if there is a storage technology developed from the results of research projects from domestic scientists.

Learning

For the field of renewable energy, Hoanh Son established Ha Tinh Solar Power Joint Stock Company with a team of engineers with basic expertise in the electricity industry and personnel from the provincial electricity company. The only training activity that Hoanh Son conducts with equipment suppliers is the handover ceremony of the factory combined with short-term operation training for Hoanh Son's personnel. Through the construction of the factory under the supervision of experts from a foreign consulting company, Hoanh Son's workers and construction engineers have taken the learning-by-doing method, combined with the improvement of machinery and technology to be able to complete Cam Hoa Solar Power Plant in a record time of 3 months.

Research

Similarly, Hoanh Son's orientation is that the company seeks and applies technologies to actual production and business, therefore, the company has not yet invested in its own research and development activities. Academic institutions tend to organize their research and training programs according to their strengths without a clear general orientation on the output of research results and quality of trained human resources compared to the requirements of businesses.

Cooperation and linkages

Hoanh Son has not had any connection with these academic institutions. The technology that Hoanh Son uses in its factories and solar power farms comes from foreign equipment suppliers.

3.2.15. Case I-15

LIG Quang Tri Solar Power Plant is installed with about 126,400 Sungrow’s solar panels with a capacity of 365 Wp/ panel with a frequency of about 1,000 Hz - 1,332 Hz and a voltage of 40V. The whole plant is operated 100% automatically except for the maintenance of solar panels. The control system of the plant is connected and controlled by the National Load Dispatch Center (A0). Most of the equipment in the factory is provided by China's Sungrow such as solar panels, circuit breakers, and inverters. However, the components inside these Sungrow’s devices are all imported from Europe. The communication system connects equipment with voltage 22kV or less using Sungrow equipment and software, while information about the activities of 110kV devices is controlled by Inaccess’s system imported from Greece. Sungrow does not share the source code of the control software or information collected by Sungrow's devices at the LIG solar power plant with the investor. All software maintenance and repair work are controlled remotely and through Licogi 13 technicians at the factory. The fixed panel mounting system imported from Thailand allows the factory to withstand storms up to level 14 with wind speeds of about 160m/s. The transformer station used by the plant is a 22kV/110kV transformer of Dong Anh Electrical Equipment Company. In addition, Quang Tri LIG Solar Power Plant also uses some equipment provided by domestic companies such as concrete pillars to fix the frame brackets to the ground or electric cables.

The plant's information system is designed, implemented and operated by EVN's telecommunications division. However, by April 2021, EVN had to transfer the right to operate this system to the Vietnam Posts and Telecommunications Group (VNPT) and this has caused inadequacies in the management of the plant's communication channels because VNPT's IT department could not understand all the parameters and how the power plant operates. Currently, the progress of changing the information channels of the solar power plant to the new management agency (VNPT Quang Tri) has only completed 2/5 of the channels connecting to: National Load Dispatch Center A0 and The Central Region Load System Dispatch Center A3.

In terms of personnel, because the operation of LIG Quang Tri Solar Power Plant is mostly automated, there are only 11 technicians who take turns to manage, operate and repair the plant every day.

Research

The company does not have a specific department in charge of technology research, improvement and development.

Training activities

To operate the LIG Quang Tri Solar Power Plant, Licogi 13 engineers must attend training courses to receive certificates from EVN and then continue to be trained in both hardware and software used at the plant when the equipment suppliers organize trial operation and hand over the factory. However, the supplier will not hand over the source code of the management software of the plant.

Cooperation and linkages

Currently Licogi 13 does not have any links with academic institutions in terms of research or training. The company chose to adopt technologies available from suppliers and markets rather than trying to develop them on their own with high risk. Similarly, the human resources to operate LIG Quang Tri solar power plant are also recruited based on the criteria of practical work experience in this field through previous projects, rather than recruiting fresh graduates who have only learned theoretical knowledge, which may be far from the reality of working at a solar power plant.

Regarding localization, Licogi 13 have been able to master the assembly and operation of solar power plants, equipment with domestic production factors is very limited used in this project. Despite the fact that LIG Quang Tri Solar Power Plant has used 22/110kV transformers provided by Dong Anh Electrical Equipment Company, transformers with smaller capacity (22kV or less) again are supplied by foreign partners, especially from Chinese companies. Explaining the asynchronous phenomenon in the transformer equipment set up, the representative of Licogi 13 said that: for the requirements of small capacity transformers, the response speed of Dong Anh Electrical Equipment Company to capacity customization requirements is very slow because some of the power level requests from customers may not be available in the capacity list of transformers that had been tested and certified according to Vietnamese metrological standards. Meanwhile, for Chinese companies, the power level of transformers provided is very diverse with many different power levels and can completely meet the needs of all customers. Therefore, the need to customize small series of products according to the needs of customers is a problem that needs to be raised with Vietnamese equipment manufacturers.

The electricity consumption in Quang Tri province is mainly powered by rooftop solar power systems, which have grown very rapidly and out of control in recent times. This leads to a concern for Licogi 13 in terms of initial return on investment. The expected payback period of the project is 10 years, LIG Quang Tri Solar Power Plant will have to continue to reduce its generating capacity and recalculate the payback period of the project.

3.2.16. Case I-16

Gelex Group Joint Stock Company (GELEX) is currently investing in building 5 projects in Quang Tri province. The capacity of the turbine used in Gelex's projects in Quang Tri is 4.2 MW provided by Enercon of Germany, with *gearless technology*, so the minimum wind speed required is only 2 m/s to be able to start generating electricity. This type of turbine will reach the rated generating capacity when the wind speed reaches 15 m/s and when the wind speed reaches 22 m/s, the turbines will automatically adjust the angle of inclination of the blades to avoid power capacity overload. In case the wind speed reaches 28 m/s or above, the blades and turbine will be angled parallel to the wind direction and locked in motion to avoid damage to the blades and turbine. However, due to topographical characteristics, in the months of March, April and May every year, the wind speed of this area can hardly meet the minimum requirements for wind turbines to operate. Wind power projects in this area are built to be able to operate during the remaining 9 months of the year, especially in the summer time when this area has strong southwest wind. The turbine pillar has a height of 110 meters and is the only component imported from China.

Technology transfer

At the project construction stage, there are no activities related to technology transfer because the technology used has been embedded in the 4 main modules of the wind turbines. However, the equipment supplier commits to organize a basic operation training course in a short time once the general contractor has completed the construction of the project. For its wind power projects in Quang Tri province, Gelex hires SCI Joint Stock Company (a Vietnamese company) as the EPC general contractor for all 5 projects.

In addition to difficulties in transportation, another common problem faced by wind power projects in Huong Hoa districts is site clearance for the project. Currently, in Huong Hoa district alone, there are about 37 wind power projects under construction (quite densely), so in order to save investment costs as well as land use, the investor of a number of wind power projects has negotiated for investment, jointly using the transformer station and the connection line. In order to quickly clear the construction site for the project, Gelex as well as other private investors had to directly negotiate land compensation prices with local people (often at a higher price) rather than waiting for local authorities to assist under the compensation and clearance process.

At present, the whole Huong Hoa district has only one 110/220kV Lao Bao substation to take care of electricity transmission tasks for projects in the region to the national 220kV grid. This substation was calculated and built from a time when only a few wind power projects were planned. However, with the continuous granting of additional permits, at present, in Huong Hoa district alone, there are 37 wind power projects being built next to each other. This phenomenon of planning with too much density of wind power projects in the area in future may lead to overloading of the 110/220kV Lao Bao substation and 220kV transmission line when all 37 projects come into operation, along with a significant amount of capacity coming from local spontaneous rooftop solar power projects.

Regarding supplier relationships, Enercon is not bound for O&M services like other wind turbine suppliers like Vestas, however Gelex still chooses to sign a 20-year operation and maintenance contract with Enercon to ensure the long-term stable operation of the project. The maintenance cost of the turbine is about 55,000 Euros/turbine/year. This operation and maintenance service will be performed by personnel of Enercon Vietnam Company.

Learning

The operation personnel for the project have been prepared in advance. Right from February 2021, Gelex has organized a personnel recruitment exam and organized training and certification exam for shift leader at the National Load Dispatch Center (A0). After completing the course, Gelex has acquired more than 20 engineers to meet the operating requirements of Gelex's wind power plants in the near future. In addition, Gelex also signed a training contract with a professional training institute in the country to continue to add knowledge to this newly added human resource. Besides, these personnel are also assigned to follow the experts from Enercon in the field to learn the experience of installing and operating wind turbines under the technology transfer contract between Gelex and Enercon.

For the installation work, Enercon will guide and support the EPC general contractor on how to install the first 4 wind turbines for the 4 installation groups. The initial installation time of a wind turbine according to Enercon's instructions was about 12-14 days, but after a period of construction, the installation speed of 4 construction groups was accelerated and shortened the installation time down to about 7-10 days.

Research

Gelex has a solid foundation in the research and development of civil and industrial electrical equipment. However, in the field of renewable energy, the technologies used are mostly proprietary technologies and have been researched and developed for a long time, so not only Gelex but also other Vietnamese companies will also have difficulty in researching and developing their own technology in this field because of the risks involved. Instead, buying and adopting technology has become more relevant for businesses like Gelex.

Linkages

Currently, Gelex does not have any connections with research institutions and universities. The company is still focusing on its production strengths in the segment of civil and industrial electrical equipment along with the ability to self-innovate and diversify its products in business. The selection of Enercon wind turbine supplier from Germany using *"gearless"* technology has been carefully calculated by Gelex. Accordingly, Gelex can reduce maintenance costs for each turbine to $US 50,000/turbine/year compared to using Vestas turbines with the same generating capacity - which has an annual maintenance cost of $US 70,000/turbine/year. Moreover, Enercon does not require the project investor to sign an operation and maintenance contract with the company, however, to ensure the optimization of turbines' power generating efficiency and maintenance, Gelex still signs an operation and maintenance contract with Enercon for 20 years.

3.2.17. Case I-17

Power Engineering Consulting Joint Stock Company 1 is the leading power engineering consulting firm in Vietnam Power Sector. PECC1 is a subsidiary of EVN, with 54% of shares are of EVN's.

For the renewable energy section, PECC1 has an advantage, which is consultancy for connection and transmission technology projects because renewable energy projects have a clearly strong need for transmission.

Concerning wind power and solar power floating on hydropower reservoirs, PECC1 has submitted to EVN a plan for creating floating solar power stations in hydropower areas.

In RE development, due to a relatively easiness of business development from the beginning, the sector expands too quickly and widely, leading to uneven quality. This phenomenon is completely different from the development of hydropower and thermal power before. In RE, all parties design and builds projects, but the quality is managed by poorly. In the process of rapid development, the Ministry of Industry and Trade and EVN themselves did not have time to react, when issuing policies to encourage electricity prices, they both accelerated spontaneous development. Thus, it can be seen that there is a lack of responsibility from the state management agency because the state management agency must have a plan to keep the development under monitoring. Many solar power projects have been completed in large quantities, and only then just began to work on standards, while wind power and other types of renewable energy have no standards yet. At present, it is not clear who will be the inspector, who will ensure the quality of those RE projects, not to mention other factors such as the environment and wastes of RE. Solar energy projects are easy to build, easy to buy technology equipment such as solar panels imported mainly from China. The risk of environmental pollution has not been clarified for issues such as who is responsible and handling the consequences. Usually, the legal clauses in the contracts are not firm, because the Contract also stipulates that the technology supplier companies will recover the wastes. When the Contract ends approximately after 20 years, those companies may no longer exist. The Ministry of Industry and Trade is also developing regulations to handle this issue quite actively. Obviously, this passiveness has to be learned from solar power for offshore wind power.

R&D

In PECC1, there is the Engineering and International Cooperation Department (formerly Department of Science, Technology and Environment) in charge of scientific research. Previously, the leaders of PECC1 had many connections with the Ministry of Industry and Trade, and the scientific research projects were assigned as the projects of EVN and the Ministry of Industry and Trade such as research consultancy and then application in the practice. Recently, PECC1 began to have more projects like consultancy for thermal power plant model of 600 mKW capacity (with tens billion VND fund), research activities related to software and slope expansion components, calculation related to harmonics of the power line.

On linkages and learning

For PECC1, the main linkages are with the other businesses in RE sector such as project investors. In these relationships, PECC1 plays diverse roles like design consultant, survey, EPC, etc. While researching these issues, PECC1 is connected with several university and institutes. The Engineering and International Cooperation Department has several connections with scientists at universities such as Hanoi University of Science and Technology.

Regarding learning from experts, when PECC1 signs a project contract, it must be followed the policy on to what extents domestic capacity will be used; which section must select the foreign partners due to their strengths; and which sector the company will implement by itself. When the project finished, the capability of the partner improved and PECC1's capability in knowledge also increased, and to enhance the endogenous capability to localize the design and operation capability of project.

On related policies

For PECC1, the financial problem is serious due to a debt package caused by inefficient investment decision. Therefore, investment in scientific research is affected strongly. Previously, the company’s budget spent 5% of sales on scientific research, but now that 5% is devoted for debt repayment, and the company has no more budget for scientific research. To find sources of budget for scientific research the company needs to combine with policy solutions to support staff retraining or learning in the research process. A good policy practice could be to encourage experts in production departments to combine research – training – consulting activities, and researchers will become as consultants as well.

Recently, renewable energy development is under a situation that companies with large potential financial can all take part in investment and State agencies have little idea what they do with investment projects. When they start to produce electricity, then agencies like EVN find a way to connect the power line in for transmission. That way of doing business is not appropriate and sustainable. The main problem is that State agencies do not have a long-term plan yet. Back to the offshore wind power, Vietnam needs to quickly assign agencies such as the Ministry of Natural Resources and Environment to make marine spatial planning, while electricity or renewable energy planning will be implemented by the electricity sector to ensure that all framework structures relatively followed standard, and not be deflected. It is necessary to have researches to concretize the existing major orientations and findings of international organizations about specific project level, wind intensity, energy consumption and purchase rate on the grid, etc. It is urgent to overcome the current status of development with no general long-term planning, lacks of strategies and arguments of scientific research. The electricity sector should be more active to report these difficulties to the Ministry of Industry and Trade or to the Prime Minister.

3.2.18. Case I-18

Gia Lai Electricity Joint Stock Company (GEC) was established in 1989 with 100% state capital. In 2013, Gia Lai Electricity Joint Stock Company officially became a member of Thanh Thanh Cong (TTC) Group and is the core unit of the Group in the field of Energy.[3] For the wind power field, GEC is currently implementing 3 projects with a total capacity of 260 MWp, including, V.P.L Wind Power Plant in Ben Tre Province (capacity of 60 MWp); Tan Phu Dong Wind Power Plant in Tien Giang Province (capacity of 150 MWp), La Bang 1 Wind Power Plant in Gia Lai province (capacity of 50 MWp).

In terms of technology, most of the technology and equipment used in the field of wind power must be imported from abroad. In its wind power projects, GEC uses wind turbines from Danish company Vestas with a mandatory provision to use turbine steel pillar provided by CS WIND. In addition, Vestas also obliges the investor to sign an operation and maintenance contract with the Danish turbine supplier. At the same time, the operation and maintenance contract (AOM 1,000-5,000) is also a condition to enjoy the warranty of Vestas’s wind turbines for the first 2 years and the purchase of spare parts, if a failure occurs, from Vestas. In its projects, GEC negotiates to only use the operation and maintenance contract for 10 years because Vestas' maintenance costs are quite high (about $US 70,000/turbine/year).

In addition to Vestas’ turbines, there are turbines from other manufacturers on the market such as Enercon and Siemens Gamesa of Germany, General Electric of the US and Goldwind of China. However, the wind turbine products of the Chinese manufacturer are not appreciated by many banks and credit institutions for their quality and performance because wind power projects have huge investment capital, so the use of turbines from new and untested brands can be very risky. For that reason, GEC decided to use Vestas' wind turbines.

For the foundation of wind turbine projects, there are currently 3 main types of foundation designs that are commonly used: Gravity Base form for onshore wind power

[3] Although GEC has been analyzed as case I-3 for solar part of business, for grouping of sub-sector, GEC is again presented as Case I-18 for its wind business.

projects; Multipiles and Monopile for nearshore wind power projects. In Vietnam, most of the projects are using Gravity and Multipiles foundation designs and the construction of this pillar foundation is mostly undertaken by domestic companies. GEC's wind power projects are also using these 2 foundation designs. Among GEC's 3 current wind power projects, one project is using China's EPC general contractor while the other two projects are assigned by GEC to Power Construction JSC No.1 (PCC1) as the EPC general contractor.

In Ben Tre province, Thanh Cong Group has also been approved for another project, the Mekong Wind Power Project, but has now been transferred to Gulf Energy Corporation of Thailand (now known as Gulf Mekong Wind Project). The fact that the Vietnamese companies after designing, applying for an investment license and even operating projects for a while, then transfer parts or the entire project to foreign companies is a clear trend nowadays. The reasons for this phenomenon are many, but one of the main reasons is that Vietnamese businesses do not have enough resources to maintain too many projects that they have applied for and approved. The transfer of ownership helps them make a sizable short-term profit but sometimes shows the uncontrollable explosion of too many renewable energy projects today.

The current part of domestic consulting services on wind power projects in the country is underdeveloped, especially reputable and experienced consulting organizations, because the field of wind power is still too new in Vietnam. When working with banks and financial institutions to prove the project's wind output assessment records, documents from foreign consultants such as DNV GL, TRACTEBEL, FICHTNER, K2M or AFRY with extensive experience in wind power projects is always more convincing.

While Vietnamese businesses can only participate in infrastructure construction and installation items, the technological aspect of the wind power sector is much more specific. The technologies used in this field are proprietary, embedded in devices and protected by intellectual property rights. By using technological exclusivity, turbine suppliers have bound project investors to operation and maintenance service contracts and with other strategic foreign partners of the turbine suppliers. Therefore, although some Vietnamese businesses have been able to master some stages in the operation process or produce some components in wind power equipment themselves, there is little possibility for Vietnamese companies to break into the wind power value chain because of the constraints of this technology monopoly.

Similar to solar power, the tax authority is also asking GEC to pay import tax for imported components (i.e., bolts and screws used in turbines) because Vietnamese manufacturers can now produce these components themselves. However, when the investor signs a contract for the purchase of wind turbines from Vestas, these components are a package of spare parts attached to the turbine purchase contract and are supplied by Vestas for 0 VND and cannot be taxed. Therefore, this is another problem that business like GEC and other investors are facing.

There is a fact that the bank forces GEC to sign a contract for operation and maintenance of wind power turbines within at least 13-14 years and not 10 years as GEC negotiated with Vestas. The reason is because business loans between GEC with banks for wind power projects have a maturity period of 13-14 years. Therefore, from the point of lenders, the bank wants to ensure the smooth operation of the project, avoid risks and ensure the return of capital to avoid unexpected problems. This will incur additional costs for businesses for extending this service. Finally, due to the impact of the Covid-19 pandemic, many foreign consultants of GEC were unable to supervise projects in Vietnam.

3.2.19. Case I-19

Along with solar power projects, Licogi 16 is also proposing to invest in the construction of 4 onshore wind power projects in Gia Lai with a design capacity of 100 MWp each and in Quang Tri has a capacity of 48 MWp each. However, these projects are currently facing some difficulties.

Licogi 16 is only engaged in the construction of projects as subcontractors - mainly in charge of construction of infrastructure items for the project and the foundation of wind turbine pillars. Explaining this, Licogi 16 said that the 3 most difficult items for contractors and consultants when implementing wind power projects are: *assessing wind power potential, designing the most optimal layout for the plant* and *selecting the right type of turbine for the project.*

For these categories, the capacity of Licogi 16 is not enough to perform. Although some of Vietnam's domestic consulting teams can meet the technical requirements of investors, they do not meet the requirements of international financial arrangements. Therefore, these items are usually only performed by international consultants while domestic companies are only acting as subcontractors for wind power projects.

Regarding the Vietnam's contribution in the value chain of wind energy, the steel pillar for wind turbines can be produced domestically by a Vietnamese company itself - UBI Tower Company. However, there are not many wind power projects in Vietnam using UBI Tower's steel pillars, which are mainly exported to European and American markets. Licogi 16 said that wind turbine manufacturing companies such as Vestas or Enercon all require designating suppliers of steel pillars (CS WIND) for their projects. Therefore, the investor has absolutely no opportunity to choose another supplier of steel pillars because of the binding requirements on the supplier of equipment components from the company supplying the wind turbines.

Licogi 16 even arranged financial loans from abroad to ensure the highest feasibility for these projects. The reason for Licogi 16 to choose loans from foreign financial institutions is because their loan interest rate is much lower than that of domestic banks. For example, the average lending interest rate of domestic joint-stock commercial banks is around 10.5% - 11.5%/year, while the lending interest rate from Japanese commercial banks is only about 4%. However, with the current FIT price policy for wind power, which is only applied for 2 years, international financial arrangements for projects will have to be done before the project is approved for planning because the time to arrange finance from abroad will take about 1 year on average.

In order to attract and encourage new investors in the wind power sector, the application period of the policy such as FIT must be long enough for businesses to have sufficient time to prepare the necessary steps. In addition, a long enough incentive policy will not only encourage new wind power projects but also expand the market for wind power equipment such as turbines and steel pillars. Once the consumer market is large enough, manufacturers of wind energy devices may consider the option of opening a production or assembly plant in Vietnam and thereby creating opportunities to learn technology for domestic businesses.

The technology used in wind power equipment is still mainly imported from foreign companies because there are not many domestic companies that can produce these devices, especially wind turbines which only have a few suppliers from Germany, Denmark, the US and China. Although these technologies may have appeared somewhere in the basic research on operating principles at some research institutes and universities in Vietnam, the level of technology readiness (Technology Readiness Level) of these research results only stops at the level of creating prototypes or simulation models, but cannot go into the process of mass industrial production. Therefore, businesses have become uninterested in research and technology application cooperation with institutes and universities in Vietnam.

In addition, the binding policies from turbine manufacturers in the wind power sector are based on monopoly power and it has contributed to preventing the participation of Vietnamese companies such as UBI Tower in the value chain of wind power. To create opportunities for Vietnamese businesses to participate in the value chain, policies issued for the wind power sector will also need to take into account factors to create a healthy competition, anti-monopoly on equipment supply between domestic and foreign companies.

Regarding policy problems, the representative of Licogi 16 said that the time limit for applying the FIT price for wind power is too short. The formulation of preferential policies in such a short time will not be able to promote or encourage new investors to enter this field.

Licogi 16 has 2 wind power projects in Quang Tri province. Although these two projects have not yet been approved for official planning, Licogi 16 is having to coordinate planning with a group of other wind power investors in the province to jointly invest in building a 500 kV substation and a new 500 kV transmission line in order to release capacity for renewable energy projects in Quang Tri province in the near future. The reason for this situation is the current local 110 kV and 220 kV transmission grids are becoming overloaded and will not be able to meet the demand for power transmission if there are other renewable energy projects.

Licogi 16 also has a policy proposal on preferential discounts for selling grid-connected wind power. Specifically, instead of ending the time limit for the preferential wind power price on October 31th, 2021, the Government can reduce this incentive step by step and in several stages, but it is not recommended to immediately apply the competitive electricity price. The recommended reduction rate is 25% for each period. This is because the characteristics of the wind power sector are very different from solar power in terms of investment costs and implementation time. Licogi 16 also proposed the Government to continue to extend the preferential electricity price for the wind power sector until 2023 and after that adjust the preferential electricity price down step by step according to the norm of 25% for each period.

3.3 Higher Education and Research Institutes

For academic organizations, there will be 9 cases to be analyzed.

3.3.1. Case II-1

Lac Hong University was established in 1997 with 9 campuses, 11 faculties, 21 training disciplines, 12,000 students and 600 post-graduate students, 6 majors of master's training and 2 majors of doctoral training.

Currently, the university does not have an official training program on renewable energy, but Renewable Energy subject is integrated in the bachelor and master training

program of the Faculty of Electrical and Electronic Engineering. The main reason for this situation is that social demand and employment in this industry are not high at present.

The Center also manufactures a robot to clean solar panels and is being tested and evaluated at a solar power plant. For the technology transfer activities, the lecturers and students directly receive and perform many small technology improvement orders from enterprises in industrial zones in the province. There are even lecturers from the school who have set up their own companies to produce technologically improved products and sell them to the market. The university is implementing a rooftop solar power project with the People's Committee of Dong Nai Province.

There is no mechanism to accept failure for projects using state budget expenditure. Venture capital sources for scientific research are too few and difficult to access. This reduces the motivation of scientists to do research.

The university has a fairly good human resource capacity for scientific research activities with a number of patents and technological product prototypes, but it is difficult to commercialize these products. The robot for cleaning solar cells is an example. Many products are technologically viable but not marketable.

Linkages

As a non-public university, Lac Hong University has a good relationship with the business sector. Business enterprises accept students for internships, scholarships, and request solutions from the university. The university receives and fulfills technology improvement orders to develop appropriate technologies and deliver them to businesses. The university has provided a lot of technical services to many Japanese companies operating in industrial zones around the locality (Dong Nai, Binh Duong, etc.). The university's alumni network is relatively strong, so the connection development is quite favorable.

3.3.2. Case II-2

Electricity Power University (under the Ministry of Industry and Trade) is the second university in Vietnam offer a training code for renewable energy. In 2015, the Department of Renewable Energy (Faculty of Energy Technology) enrolled the first course with 30 students. Faculty of Energy Technology is training 01 master class in Energy Engineering, 14 regular university classes and 6 college classes.

The Faculty of Energy Technology, under the Department of Energy Engineering Technology of the Electricity Power University, has introduced subjects related to the field of renewable energy.

Students enrolled in the School of Energy Engineering Technology will be trained in a combination of theory and practice through the practice of construction, installation and practice at solar power projects, waste electricity, etc. biogas and wind power according to their wishes and at the same time can participate in seminars on renewable energy with lecturers who are founders of the Vietnam Renewable Energy Community.

By 2020, the students majoring in Renewable Energy of the 1st course of the Electricity Power University have graduated. With the knowledge provided in the school, graduates can not only work at renewable energy facilities but also join other power generation plants as well as trading and consulting companies.

Research

The Electricity Power University always performs S&T tasks in order to meet the needs of customers and practice.

Over the years, the university has researched hundreds of research topics at various levels such as the university, EVN, Ministry of Industry and Trade, provincial Department of Science and Technology, and National level. The research results have created many products with high scientific development value and practical application.

Currently, the Electricity Power University is also experimenting with self-development of photovoltaic glass technology to take advantage of the window structure of urban buildings to produce electricity to initially supply some lighting equipment in the building. Experimental photovoltaic glass panels researched by the university staff are being installed at several locations in several buildings on campus to measure the effectiveness of this product. This is a product that promises high commercialization.

In addition, the school is also proposing to the Ministry of Industry and Trade on a national research task on the Smart Grid System to solve the dilemma that Vietnam's electricity industry is facing.

Currently most of the staff in charge of operation and control positions in some wind power and solar power plants in Vietnam have not graduated with a major in renewable energy, but in other energy sectors after having attended a short training course of about six months. From the university's point of view, the mechanism for generating electricity in different forms of energy may be different, but the transmission mechanism is generally the same, so if students have a good background in electrical engineering they will be able to do the jobs. There are also other engineering disciplines such as precision mechanics, materials science, etc. that can also participate in different areas of wind power.

3.3.3. Case II-3

Currently in the field of renewable energy, the basic research of scientists at the Vietnam Academy of Science and Technology (VAST) is mainly working on new materials, nanomaterials and technological processes for the manufacturing of test equipment, operating principles and electric system moderation in the fields of solar power, wind power and gas power. As the largest specialized institute of the Vietnam Academy of Science and Technology (300 staff members: 11 Senior Researchers, 15 Professors/Associate Professors, and another 75 staff with PhD degree and Major Researcher or higher); the Institute of Materials Science plays a key role in forming ideas about advanced materials, organizing research and realizing these ideas.

Training

Currently, the two main units in charge of the education of the VAST are the *Training Institute of Science and Technology (the Institute)* and the *University of Science and Technology of Hanoi* (USTH). The Department of Materials Science and Energy (which is specialized by the Institute of Materials Science, Institute of Energy Science, Institute of Tropical Technology) is the only one that has an education program related to the field of renewable energy with 5 majors including Electronics materials; Optical, optoelectronic and photonic materials; Polymeric and composite materials; Metallography; Energy engineering.

Research

For the aspect of technology research used in solar power systems, currently the main research direction of the Energy Components and Materials Department is to focus on basic research on new generation solar cell technologies (nanostructured) bypassing silicon solar cell technology.

The Energy Components and Materials Department has also successfully researched the current most advanced perovskite solar cell technology using titanium oxide - TiO_2 - and grid printing technology. The advantage of this technology is that the manufacturing cost is quite cheap and this material used can be synthesized from other materials in nature. However, the biggest disadvantages of perovskite solar panels are in their longevity, durability, and their current energy conversion rate.

The second research direction of the Energy Components and Materials Department is the energy storage using ion battery technology. With the current research equipment of the Institute of Materials Science, scientists can only manufacture small capacity ion batteries for the need of testing technology. To be able to deploy the application of these technologies on a large scale in practice, much larger investment resources will be required.

For the current research orientation of the renewable energy field of the Institute of Materials Science, the scientists of the Institute are also researching and developing more about hydrogen energy technology.

Collaboration

The cooperation and collaboration between the Institute of Materials Science and business enterprises is not really strong at present. In the past, the Institute of Materials Science cooperated with the Rang Dong Light Source and Vacuum Flask Joint Stock Company to develop new generations of light bulbs for this business. However, this partnership has now been interrupted.

It can be said that VAST in general and the Institute of Materials Science in particular are still operating as an academic organization that favors basic or theoretical research rather than applied research for commercial applications. The Academy's lackluster relationship with the business community is a testament to this issue. Furthermore, the Institute's internal relationship within VAST is also fundamental to academic exchange activities or education and training programs, without cooperation in the implementation of projects or actual research. This philosophy is seen as one of barriers to promote more innovation in academic domain.

Policies to support scientific research are still binding scientists with administrative procedures and criteria that are not suitable for scientific research. Because science always requires novelty and unpredictability of research results, hence in the process of implementation, there will always be adjustments and changes to suit the conditions and intermediate results. However, these adjustments and changes require scientists to carry out complicated administrative procedures to explain and apply for permission to adjust the budget for the scientific research projects. Therefore, to untie scientists, a flexible financial mechanism specific to scientific research is needed, such as a form of leasing finance for scientific research combined with research purposes and legal payment documents.

3.3.4. Case II-4

Established on October 5th, 1962, Ho Chi Minh City University of Technology and Education (HCMUTE), has gone through many stages of development with different names.

Training

HCMUTE officially initiated a training major in Renewable Energy Engineers in 2018. This is the result of a project on opening a training major in Renewable Energy Engineers since 2017. The project was built on the results of surveys from the university's annual business seminars on the issue of human resource needs of some renewable energy business enterprises and professional comments about the university's curriculum in the field of renewable energy.

Up to now, the school has recruited 3 courses, each course has about 60 students. Students of the "Renewable Energy Engineer" major are trained in a number of specialized subjects such as aerodynamics, fluid mechanics, heat transfer, radiation, and power transmission.

The Department of Renewable Energy also has links with a number of corporations and companies such as UBC Renewable Energy. Besides, the school also organizes high-quality human resource training according to the orders from business enterprises.

Thanks to the outstanding quality of training, businesses have considered HCMUTE as a leading resource for providing high-quality human capacity.

Research activities

HCMUTE has established key research groups in the fields of science and technology that are of interest to society, including a key research group on new energy sources. At the same time, the university also established a Renewable Energy Research Center with a core of faculty members who share the same passion for research on the university's Renewable Energy industry. The Renewable Energy Research Center is orienting its research on t*he problem of reducing and regulating the generating capacity of the solar power system*; t*he problem of grid instability due to frequency interference of the current (filtering harmonics on the grid)*; t*he issue of energy storage for renewable energy projects, especially solar power projects*.

The university's lecturers also have conducted research on solar and wind power, but the results are only at the simulation level because the current equipment conditions of the university have not yet permitted proceeding to the application stage.

For national scientific and technological research programs such as the Program KC-05 in the field of renewable energy, the University has not yet participated in the chairing of research projects in the fields of renewable energy program but only at the level of participation with other universities. The KC program that the university is participating in is mostly Program KC-03, in the field of mechanical engineering. In addition, the university has also successfully manufactured and transferred technology on automatic solar panel cleaning robots to businesses. Together with researching new technologies, the university also organizes a Technology Transfer Center to support technology transfer between businesses that are looking for technology and technology solution providers globally.

Cooperation and linkages

International cooperation is a strength of HCMUTE. In recent years, the school has participated in many cooperation projects in both education and research. In addition, the school also regularly maintains relationships with other domestic business enterprises and organizations.

The University's Renewable Energy Research Center also participates in training cooperation with various universities such as HCM University of Agriculture or Lac Hong University.

Issues

In general, the university has quite close and strong linkages in the system with different types of partners, effectively supporting training and research activities. It can be said that although HCMUTE has opened the training program for Renewable Energy Engineers and is about to finish the first course, the university has not really had enough facilities for more in-depth training in this area. Currently, investment in infrastructure and laboratories for this training course of the university is rather limited. The university wants the Government to have a specific strategy in the medium and long term in the field of Renewable Energy and from there to train human resources specialized in technology research in the field of RE as well as the way to operate these technologies.

Although there are many studies by lecturers in the university on renewable energy, these studies are only at the stage of simulation or prototype, but cannot be applied to the actual production scale. Therefore, the Ministry of Science and Technology should have a policy to support promoting research specifically in the field of renewable energy such as information, resources, and application of results obtained from fundamental research published by the university to gradually commercialize these research results.

The Government needs to set requirements on the policy of recovery and recycling of solar panels to avoid damaging the environment. Ministry of Science and Technology also need to quickly issue standards and technical regulations for equipment imported and used in solar power projects to reduce the generation of harmonics on the grid, jamming the national power transmission system - a situation that is causing headaches for transmission system managers today. There should be stability and consistency of macro policies for renewable energy development, creating a stable premise for related training and research activities.

3.3.5. Case II-5

The Institute of Energy Sciences has the following functions directly related to solar and wind energy: four (4) main research directions: Energy systems, New and renewable energy, Energy saving, Energy and Environment. The Institute has carried out activities such as designing and constructing grid-connected solar power stations to supply electricity to office buildings and households; Mixed source technology (solar, wind, biogas) provides electricity to remote areas and islands.

Training activities

The Institute has participated in some training in the field of energy science and other related fields. It has involved in training for Bachelor of Energy, in collaborating network of USTH.

The Bachelor of Energy program allowed students to enroll in the "Master of Energy" program or any other master's course in the field of energy. The master program provided students with in-depth knowledge in energy majors. In addition, students could have the opportunity to do internships or graduate studies at more than 40 universities and research institutes in France.

Research activities

The Institute has a number of research project in solar and wind energy such as "The cost of electricity generation based on renewable energy in Vietnam". The Institute believes that research on microgrid is more necessary for Vietnam than research on smart grid, although the cost of research on microgrid will be quite high.

Cooperation and linkages

The Institute has activities in consulting for businesses and other organizations in the field of renewable energy, especially for private and joint-stock businesses on solar power. The need to support the provision of technology experts for these businesses is very large and the Institute has actively participated in this process. In design consulting activities, businesses need to hire chief engineers and technical experts. The Institute can assist by transferring old competencies from design skills of hydropower projects to solar power projects.

Regarding the environment for research cooperation activities, currently the linkage is very weak between the different partners in the system, one reason is the lack of trust and distrust in cooperation.

3.3.6. Case II-6

HCMCUT is a multidisciplinary university in engineering majors in Vietnam, a member of the National University system.

Training activities

HCMCUT is basically a multidisciplinary university, strong in technology, with a number of training activities related to the renewable energy industry chaired by the Department of Materials and Energy such as material technologies.

Research activities

The rate of research results through international publications of HCMCUT is also quite strong, with more than 400 articles annually, of which Q1 accounts for 50%, Q2 accounts for 30%. In research activities, the university has a number of research projects on turbine design, through calculation of wind speed and turbine rotation, the degree of influence on wind power poles, and research on electricity storage technology, research on solar panel maintenance and cleaning systems and manufacture automatic cleaning robots for solar panels. In general, these research projects are small-scale, experimental in nature, mastering scientific principles, and have not yet produced prototypes.

Cooperation and linkages

HCMCUT has a number of activities providing technical services when businesses hire lecturers and technical staff of the university to help them with problem solving and technical assistance. Some businesses in the field of solar power originate from the university such as BK (Bach Khoa) Solar, named after the university, or the company that produces solar panels and accessories – RedSun - founded by a former lecturer of the university. In the research on manufacturing solar panel cleaning robots, the school has also sold a number of products to solar farms in Binh Thuan and Ninh Thuan. However, in general, in the field of renewable energy, the commercialization capacity of school staff is still limited. Among businesses, BK Solar, originated from the university, founded by a former lecturer, has had a good relationship with the university through a number of sponsorships and student connections. Ho Chi Minh City University of Technology also participates in consulting activities for businesses in terms of project design, construction and installation and also some consulting contracts for EPC projects.

Other issues

Many businesses jump into investment and project development in the field of renewable energy mainly due to the attractiveness of securing agreements to sell electricity to EVN at favorable prices, although these companies have almost no background or experience in the electricity sector, are ill-prepared and lack capacity and resources to perform. When faced with a policy environment in Vietnam that lacks stability and a long-term vision, many businesses enter a state of confusion that reveals a variety of internal weaknesses. Developing the technology market, changing the perception and assessment of the scientific community by businesses are necessary to create demand for innovation and attract scientists to join in solving problems for businesses' needs.

To build technological capacity, Vietnam can locally invest in methodologies and technologies to improve the core elements of wind turbines, provided that the supporting industry players in Vietnam also strongly develops the capacity to help the product manufacturing process. Vietnam has good human resources and should develop advanced solar cell technologies. It is necessary to develop the entire ecosystem for the renewable energy industry. However, to do so, Vietnam needs to have appropriate policies that better manage and govern supply and demand of renewable resources and a system of intermediaries capable of supporting Vietnam's renewable energy industry. Existing policies to support the renewable energy industry are still mainly procured under FIT pricing, a short term, fixed-price mechanism in a very dynamic market that has temporary effects on the pace and duration of growth in solar and wind power. Uncertainty in the structure and pricing of the renewable energy market in Vietnam greatly complicates efforts to further develop research, training, science, technology and innovation activities in the emerging RE sector.

3.3.7. Case II-7

Ho Chi Minh City University of Technology - HUTECH was established on April 26th, 1995 as a private university.

Training activities

HUTECH does not have a specialized training organization in renewable energy, much less specialized training fields for solar and wind power. There are only a few that have relevant and useful basic knowledge for the renewable energy sector, such as electromechanical and electronic engineering.

Research activities

HUTECH has an Institute of Applied Science, an Interdisciplinary Research Center and a number of other units more or less related to research activities in the RE field such as the Faculty of Electricity and Information Technology. Especially, the Technical Institute has a certain degree of research on solar power. The university established a number of strong research groups specializing in renewable energy led by a number of professors. The university has also decided to establish a High Technology Institute located in the Hi-Tech Park of Ho Chi Minh City, focusing on research activities in a number of technology fields, including the renewable energy sector.

Cooperation and linkages

The university has cooperation activities associated with businesses through the form of contract for consulting and technology services. In general, HUTECH has a number of affiliated activities based on its strengths in several fields such as information technology and electronics. However, there are not many activities related to solar and wind power, because this is not necessarily the strength of the university.

The university has many strengths in training and technology, but it is not necessarily strong in a relatively new field where the university has no tradition such as renewable energy technology.

The field of renewable energy has initially been an area of interest in development by HUTECH in some of its training and research activities, but the level is still quite primitive compared to many other technology fields. This is a fairly common situation with many Vietnamese private universities as renewable energy and more specifically wind and solar power have only recently become areas of concern. The efforts of institutions to organize research and training in this field are relatively new and are still in the first steps of providing human resources and research results to renewable energy businesses.

3.3.8. Case II-8

Institute of Energy operates in the fields of research on strategy, policy and national energy/ electricity development planning; research on energy/ electricity science and technology, environment and energy development; science and technology consulting and services; training to human resources and cooperation in science and technology with domestic organizations, foreign organizations and other business industries.

Scientific and technological services and design consultancy

The Institute of Energy conducts design consultancy service for wind and solar power projects for private companies investing in this field. Customers using this service are domestic and foreign businesses that are intending to invest in RE plants in Vietnam. Specifically, the Institute of Energy will be in charge of building the pre-feasibility profile of the project for investors to apply for investment policy. After the project has obtained the policy, the Institute of Energy continues to advise and design project items for the investor to calculate and hire contractors, as well as to advise on building the transmission line system, substations, etc. and connecting the grid plans for projects.

On the issue of localization, different fields of renewable energy will have different localization rates, depending on the complexity of the applied technology and the responsiveness of domestic production. For example, solar power projects often have a higher localization rate than wind power projects. This is because in addition to solar panels and inverter equipment, all the remaining equipment of a solar power project can now be produced domestically. Meanwhile, the core technology of the wind power project is embedded in equipment such as turbines, propellers, cabinets and control boards, sensor systems, etc., all belong to the category of technology secrets and Vietnam is not able to research and produce on its own by this moment.

While the research and production capacity of domestic technological equipment for Vietnam's renewable energy projects is still weak, the areas of system design consultancy, construction and installation and services are domestic companies' advantages. The transportation and installation of equipment for RE projects of domestic companies is gradually improving and becoming more professional.

When considering localization support policies for RE projects, legislators should consider focusing support policies on the stage with the highest proportion of added value in the life cycle of a project instead of just providing a generic support policy. High-tech equipment does not necessarily bring high added value. If the research and production capacity of domestic companies cannot keep up with those high-tech products, we should shift our focus to products and services that Vietnam has strengths and still bring to customers high added value.

In addition, regarding the quality of imported equipment in renewable energy projects, Vietnam does not have a set of evaluation criteria and standards for equipment in this field. Currently, investors mainly still rely on the reputation and specifications published by foreign manufacturers to calculate profit margins and payback periods.

In order to attract businesses to invest in renewable energy, especially offshore wind power projects with large capital, Vietnam needs to create a stability in policy planning. The promulgated policy must have a long-term roadmap for example to 2030 - 2035 - 2040 and 2050 in order to create confidence for businesses when deciding to invest in renewable energy projects in Vietnam. The current policies to encourage investment through the current preferential electricity purchase price (FIT) should only be maintained for a certain initial period, later on, the supportive policies will need to remove the FIT price in order to reduce the burden of buying electricity at high prices of market operators such as EVN.

R&D activities

The current research of the Institute of Energy is mainly focused on strategic and policy aspects in the field of energy such as National Electricity Development Master Plan and the National Master Plan for Energy Development.

The Institute has also established a research group to develop roadmaps, mechanisms and policies for the development of Hydrogen energy sources. Regarding smart grid technology, the Institute of Energy is implementing a project approved by the Prime Minister with the Electricity Regulatory Authority and EVN under the Ministry of Industry and Trade to develop this technology.

Cooperation and linkages

Since operating with self-financing mechanism, the Institute of Energy has rapidly developed the field of science and technology services and design consultancy to generate revenue to cover operating costs of the Institute and these activities are also bridges to connect with the actual needs of businesses.

For the aspect of cooperation and linkage with other research institutions in the country, the Institute of Energy has actively participated in projects as a bridge between other organizations in the government such as the Electricity Regulatory Authority of Vietnam, the Institute of Energy Science… with a number of technical universities such as Hanoi University of Science and Technology and Ho Chi Minh City University of Technology … and some other intermediary organizations. Besides, the Institute of Energy is also cooperating with a number of other foreign organizations such as GIZ, USAID to implement a number of capacity building activities for Vietnam's energy sector.

Other issues

Acting as a think-tank of the State in the field of energy, the Institute of Energy is in charge for the National Electricity Development Master Plan, the National Master Plan for Energy Development. With the role of a bridge between its domestic and foreign organizations, the Institute of Energy is an important link in the Innovation Ecosystem in the field of energy and especially the renewable energy industry.

3.3.9. Case II-9

The Lab 100% RE is a research organization under the Hanoi University of Science and Technology (HUST), with following key research areas: V Irradiance; Load Forecasting; Wind Power; Smart Converter / Inverter; High Voltage Direct Current (HVDC); Electric Vehicles and Battery System; Demand Response; Smart Grid.

R&D activities

One of the specific features of the Lab is that although it is under the umbrella of Hanoi University of Science and Technology, the lab indeed operates as a center of excellence of multi-university background, with partners and members coming from various academic organizations, comprising the research portfolio of renewable energies.

With this complex team, the Lab can conduct several different research projects related to many aspects of renewable energies development. However, so far this Lab did not have a chance to take part in the state research program KC-05 specializing on energy issues due to complicated procedures and difficulties tended to happen to young researchers.

Training activities

In general, training for RE as a special subject is not very clear yet. To train 50 new students on RE in an advanced English program, HUST will have to discuss and clarify clearly the subject and knowledge relevant. But due to unstable market needs, the program had experienced many difficulties. The same situation occurred in other universities. Vietnam-France University had a program to train students on RE, but after sometime, it cannot recruit new students (only 7 students per year). Then it had to change the name of training subject to include electrical systems, to give graduates more flexibility in finding jobs. Due to this difficulty, its department was not able to focus only on RE, but to combine RE with electrical systems and training student on both subjects. Industrial University or Water Resources University began to combine their own subjects of hydro power with training on renewable energies. The best training for students in this area is to combine specialization on electrical systems and renewable energies, like they would get double majors and ready for more choices of job offers. The more diversification of knowledge is more suitable in current situation for works in companies with short terms and rapid need. Too specific and deep dive knowledge of RE are only needed for large research organizations specialized on RE.

Linkages

The University and its department have close linkages with many companies especially those working in electricity domain. Most staff and leaders of these companies were trained and graduated with degrees on electrical systems and thermal electricity subjects which were strong traditional subjects of HUST. EVN as well as other private companies had many leaders and senior staff graduated from HUST. With the new development of RE project, there should be more attempts to send students to be interns at companies, but right now, there is little such a cooperation. Linkages tend to be more on a personal basis where department worked closely with several associations like RE Association of Binh Thuan province. On the linkage with intermediary organizations, it seems that foreign organizations are more active and they are more professional as well. So, University prefers to work more with them than with local organizations. Meanwhile government agencies tend to have quite strong inertia in working culture, unreadiness to change and made working relationship with them tough. As such, the University also had little cooperation with various government agencies like MOET or MOST. Most of the Lab research results have been produced as publications and teaching material for courses related to this area. Few projects have contributed directly to activities of businesses. One can say that this Lab acts as a center of excellence with multi-organization involvement and focused more on basic research rather than producing patents or innovation for firms.

In comparison with nuclear energy development, this sector got strong support from the government for training due to the fact that EVN is the only investor for nuclear energy projects. It is understandable that government provided lot of support to prepare human resources for nuclear energy sector (which was terminated in 2014 for many reasons, see also case of KC-05 program). The RE sector, on the other hand, is not government led investment but most investment coming from private sector (domestic and foreign). As such, little support coming from the government with its own resources for training and preparing human resources in this area. Overall, there is a strong need for having a comprehensive strategy and policy framework for preparing human resources for RE sector.

3.4 Government agencies

Seven organizations under the government structure will be discussed in this section.

3.4.1. Case III-1

Electricity and Renewable Energy Authority, (EREA), Ministry of Industry and Trade. The Authority has functions and tasks directly related to solar energy and wind energy: (i) Develops and submits to the Minister of Industry and Trade for approval the master plan on potential development of new and renewable energy in the provinces; mechanisms and policies to encourage the development of new and renewable energy sources, and national programs on new and renewable energy; (ii) Organizes the management and inspection of the implementation of national programs, and new energy and renewable energy development projects according to the approved planning; (iii) Evaluates and submits for approval investment policies, investment projects, design documents - cost estimates of construction works of renewable energy projects and organize inspection of quality control and acceptance renewable energy construction works under the management of the Ministry of Industry and Trade.

The Authority (i) has formulated FIT prices since 2011; (ii) coordinates international collaborations: i.e., participating in ODA projects. The Department also participates in consulting for training on rooftop solar power and creating requirements to integrate into training activities; (iii) Regarding the RE promotion segment: The Department does not have a promotion function nor does the activities on RE sector because of lacking of investment portfolio. Private enterprises are actively working and self-deploying project with localities where are calling for investment.

The Authority has no direct relationship with business enterprises in the private sector. For project implementation activities, business enterprises automatically use circulars and decrees on renewable energy to apply for agreements on projects and land. The issue of technology localization in the RE field is mainly related to the Industry Department of the Ministry of Industry and Trade, within the framework of the guidelines to promote localization in general for industries, there is no in-depth policy and orientation for renewable energy.

In terms of the system, the linkages of the Authority with others are still quite loose, except for those related to some programs in which the Department participates directly with connections to the business sector. The Authority also has almost no association with academic institutions, as well as intermediaries. The role of these organizations has not been seen as prominent. The efforts of the State to provide support policies are quite simple, mainly focused on offering attractive enough FIT prices for businesses to boldly focus on this field.

Regarding demand/market, the demand for energy is high and the market is quite large. However, in the field of wind and solar power, the structure of the industry and the market are still subject to many uncertainties. Therefore, the participation of enterprises in the wind and solar power markets still depends a lot on factors of low stability, even seasonality, high volatility such as FIT prices, etc.

In the near future, it is anticipated that the price of solar power will drop to about 6 cents (VND 1,386), so solar power will be more and more popular. This will cause difficulties in the operation and management of the power grid, as the transmission capacity will increase; the grid must run in parallel.

Policies issues

Smart grid should be used for power grid management and forecasting. In addition, it is necessary to have inspection activities to check provinces and localities on the deployment and connection of rooftop solar power projects.

The existing regulation that considers photovoltaic panels "as hazardous waste" should be changed to "general industrial waste". This will make it easier to handle photovoltaic panels because according to regulations, ordinary industrial waste will be allowed to be buried or recovered for recycling and reuse.

Clarifying content of regulations on electricity transmission is needed for the State in Resolution 55-NQ/TW including contents on operation, management and investment in power transmission activities.

There should be clear policies and mechanisms for waste electricity and support from the State. In addition, a long-term plan is needed to develop waste-to-energy electricity.

3.4.2. Case III-2

The Department of Science and Technology for economic - technical branches is a unit under the Ministry of Science and Technology. Specific activities of the organization related to renewable energy include:

- Program “Research on application and development of energy technologies”, coded KC.05 managed by Ministry of Science and Technology

- National program on high technology development up to 2030 (Decision No. 130/QĐ-TTg of PM), with purposes: research and master high technology, effective application of high technology into socio-economic development, ensuring the needs of security and defense, environment protection; fostering production, provision of goods and services; to create some high-tech industries, agricultural high-tech application and firms working in this area.
- Business association activities with the higher education sector and other intermediaries are integrated into the national science and technology programs such as the program "Research, application and development of energy technology", code KC.05; the National High-technology Development Program to 2030; the National Innovation Program.

Over the past time, S&T has actively supported and has been a very good companion in the development of the energy sector in general and the RE sector in particular. However, there still exist some limitations as follows:

+ Energy technology innovation life cycle is very fast, especially with wind power and solar power. At the same time, due to the practical demand for electricity as well as attractive financial policy support from the Government in a short period of time, it has prompted domestic enterprises to mainly buy products from abroad to develop their projects. Therefore, the research and decoding technologies for the domestic renewable energy field in the recent period is very limited. The research mainly stops at laboratory test products (prototypes), difficult to commercialize due to lack of interest of enterprises.
+ The policy of mobilizing financial investment for S&T research in the energy industry is limited, mainly from the state budget. The mobilization and exploitation of the potentials of Groups, Corporations, Research Institutes, Universities, and S&T enterprises are not commensurate with their capabilities.
+ The orientation and concentration of research potentials, solving major and urgent problems for the sustainable energy industry, and responding to climate change is limited and unfocused; Specific policies and strong solutions to make a breakthrough in energy fields where Vietnam has advantages such as wind power, solar power ... are not clear.
+ The financial support mechanism in using funding from non-business sources is unreliable, inconsistent, overly burdened with administrative procedures, and slow, i.e., costs are not effectively linked with end results, making for a much too lengthy process for completing disbursements.

+ The contingent of leading researchers in some energy fields is still limited, and there is no mechanism to encourage a pool of highly qualified overseas researchers to actively participate in S&T research.
+ The link between research activities and development strategies and plans for fields and disciplines with research mission is limited.
+ There are no supporting mechanisms and policies to offset risks in research and application of research results, which partly limits the application response of enterprises.

3.4.3. Case III-3

The Ministry of Education and Training has a number of main activities which involve training and conducting research (the object of operation is universities). The most related organization under MOET is the Department of Science, Technology and Environment, responsible for promoting research and innovation within university system.

Vietnamese universities have not had an overall support from the State in training human resources for renewable energy development, including wind and solar power. Most universities operate on a spontaneous basis, with training plans for their own market according to the capacity of each university.

Vietnam does not have a formal training strategy for human resource development for the renewable energy sector. Most of these activities are just spontaneous initiatives of training organizations or the self-training of business sector.

The support and promotion (if available) of the State in R&D is mainly aimed at a number of training institutions in the public sector, the private sector is almost excluded from these support activities.

Resources to support the higher education sector in general in terms of scientific research and technological development are very limited, and they are becoming increasingly meager and too new in the field of renewable energy. The research topic and results depend on the initiative of the university, the faculty and staff on the basis of their own capacity accumulation without depending on the needs of the market and business enterprises in many fields, including renewable energy field.

3.4.4. Case III-4

The Department of Industry and Trade of Ben Tre Province is a state management agency for industry and commerce in the province under the professional direction of the Ministry of Industry and Trade. The Department works on supporting projects in the field of wind power. For wind turbine technology, most of the current wind power projects in Ben Tre use European technology provided by Enercon and Siemen Gamesa. There are few projects use Chinese technologies, but these brands are still in the top 10 wind turbine manufacturers (Gold Wind and Envision). Regarding the activities and policies to support human resources for businesses, the Department of Industry and Trade has not seen investors report the need for training, so it has not conducted much research on this need.

Regarding other policies, the province mainly supports investors to access land and works with EVN to support the investors. The policies are mainly based on the general mechanisms and policies of the nation (under supervision of the Ministry of Industry and Trade), while the locality does not have a specific support mechanism for wind power/renewable energy projects.

According to the province's observation, the difficulties that investors often face are:

- Connecting to EVN's power grid system and freeing up power capacity for factories - capacity reduction plans.
- The problem of site clearance is quite difficult due to the high population density (other southwestern provinces have a population density of about 10 people/ha, especially in Ben Tre province, this density is about 100 people/ha). Therefore, investors have encountered difficulties in site clearance and relocation because the reserve land fund is too meager; even if the investor can clear the ground, they will have to pay a rather high cost.

It can be seen that the role of the Department of Industry and Trade is quite active in relation to renewable energy projects in the province, including the following types of work:

- The Department has coordinated with sectors to appraise, approve and supplement wind power projects.
- Arrange transmission lines through residential areas and terrain.
- Coordinate with Department of Natural Resources and Environment, Department of Planning and Investment and Border Guard to clear ground for projects.

In the field of wind power and solar power, because the appraisal capacity of the staff of the Department of Science and Technology has not really been updated, it is difficult to participate in the appraisal of these projects.

3.4.5. Case III-5

Saigon Innovation Center (SIHUB) is an organization under the Department of Science and Technology of Ho Chi Minh City and was established on the basis of merging 3 units of the Department: Energy Center, Application Center and Technical Design Center. The starting point of the SIHUB is mostly associated with the Energy Center.

SIHUB mainly focuses on activities to support innovation and start-ups, in four categories: building organizations, promoting activities, connecting the entire ecosystem and developing human resources. SIHUB is also quite active in issues such as technology leasing, preparing assessment reports and technology audit for businesses. In general, SIHUB believes that the development orientation of technology extension activities is necessary, including creating demand, training, consulting and supporting investment in technology projects.

With the results of SIHUB's activities, this model and its experiences have been replicated in 45 provinces and cities nationwide, demonstrating the role of the State participating in startup and innovation activities.

SIHUB has a mission to become a bridge connecting Vietnamese businesses with foreign suppliers such as Singapore and Korea for technology projects, etc.

Regarding activities related to renewable energy, SIHUB was formerly under the Energy Center of the City’s Department of Science and Technology. This Center has spawned several companies specializing in the production and assembly of solar panels since 2009. However, due to various factors, these activities ceased and only three companies still around which were established from the Department’s activities in energy sector. One that has invested in rooftop solar power projects in the early stages and then was later sold to Red Sun Company. In the recent period, the Department of Science and Technology in general (through the Center for Advanced Application of Science and Technology) and SIHUB in particular are not directly involved in investment activities in renewable energy, but mainly turn to technical support for technology projects in general in various fields, including renewable energy such as rooftop solar, solar-based drying and hot water, etc.

In promoting the operation of the SIHUB model, a number of policy issues have been raised. There is a need to facilitate connectivity because networking is the core operating foundation of this type of model. Then there should be preferential policies on facilities and infrastructure for the organization, followed by policies to facilitate the transformation of operating models from Centers of Science and Technology

Departments to technology extension activities, with emphasis on innovation through promotion of intellectual property, information, and transfer, etc.

The thinking of de-centralization (State) is clearly shown through the operation model of SIHUB and this may be a new trend in the operation of these types of Centers, which are both created by the State agency but towards de-centralization (State). Regarding renewable energy, it can be seen that this is not a priority area and has not received any special attention and support from the city Department of Science and Technology and SIHUB. One of the reasons was that SIHUB had dealt with RE before and faced many difficulties and tended not to engage in RE anymore as a difficult area comparably to other sectors.

3.4.6. Case III-6

Bac Lieu Department of Science and Technology is a state management agency at the local level of Bac Lieu province. In 2019, according to the decision of the leadership of Bac Lieu province, the Department was dissolved and merged into the Department of Education and Training as part of a trend of reducing administrative focal points in the province. Currently, the Department does not have any relationship or mechanism for cooperation and support for businesses in the field of renewable energy. The province has a number of outstanding and early wind power projects such as (Cong Ly wind power), but the state management agency in science and technology at the local level has almost stood aside and considers this as just the domain of the Department of Industry and Trade. The sudden change and lack of careful organizational preparation have created many difficulties for science, technology and innovation activities in Bac Lieu province. Thus, Bac Lieu province is the only province that has abolished the Department of Science and Technology to merge into another unit. Because the new Department is Education and Training, under the professional management of the Ministry of Education and Training, interactive activities, links and professional support in Science, Technology and Innovation with the Ministry of Science and Technology has been significantly affected.

3.4.7. Case III-7

The most relevant to research on energy content is the State-level Key Science and Technology Program on Energy (coded as KC-05), managed by Ministry of Science and Technology. The Program has two main foci: Nuclear energy and Traditional energy (which includes renewable energy). In the program's research spectrum, there are almost no (or very few) topics related to renewable energy. In the process of developing the program, there have been a number of proposals to include in a topic related to renewable energy, such as the study of building a map of solar and wind power in Vietnam, but these were not supported by the leadership. Meanwhile, in the content of the program, there are still research topics related to the use of coal in power generation because the demand for mixed coal to fuel thermal power plants is still very large due to coal shortages, and the need to maintain the large power production capacity of these plants.

In KC-05, most of the organizations and individual researchers participating in the program have very little interest in the field of renewable energy. One of the implicit reasons often cited is that the solar power industry has been saturated and dominated by Chinese organizations and businesses, and consequently the market demand and potential for research emanating from Vietnam is low. Research related to solar power when it does occur, such as research on perovskite technology, are typically early exploratory studies about new technologies at a small scale at just a few research organizations and universities. Therefore, it is difficult for such research to have any great impact on the economy and business development in Vietnam. As long as Vietnam does not have a major strategic policy to officially master the field of solar power technology and given that the market dominated by Chinese interests, it will be difficult for Vietnamese research institutions to make meaningful inroads that result in strong efforts to propose and organize research in this area.

Wind power, an area with more complex and high technology, has not been saturated by foreign interests yet, but it is also dependent almost completely on foreign suppliers (Europe and USA) and it was beyond the reach of the Vietnamese scientific and manufacturing sector. Therefore, the topics of wind power and solar power are not visibly supported in KC-05 programs.

Following program evaluation criteria, it can be said that the program mainly has research purposes for publishing, publication and training. Even the publication is mainly at the level of domestic journals. The percentage of targets that can be commercialized technology products and specific innovations with intellectual property is not high. In summary, the reality of the KC-05 program shows that even with a national program on energy, the position and role of research on renewable energy is still quite blurred and does not contribute much to innovation activities in this field in Vietnam.

3.5 Intermediary Organizations

Among intermediary organizations that work on related issues of renewable energies, five organizations were identified and analyzed.

3.5.1. Case IV-1

Vietnam Clean Energy Association (VCEA), HoChiMinh City is one of the active players to promote renewable energy development. According to VCEA, the Ministry of Science and Technology should advise the Government to have a strategy to promote the local content in equipment of renewable energy projects, especially with components that can be manufactured in Vietnam.

So far, the generated energy is sold exclusively to one buyer, EVN. Power purchase agreements cannot be used for international loans. Only a few wind power projects can access the export credit capital of European countries, the rest have to borrow capital from domestic banks, which have very high interest rates. This greatly reduces the efficiency of projects.

Government support is too short (the FIT price should be applied for at least 3 years) while the volume of electricity production is too large. Domestic business enterprises are too small compared to Chinese and cannot be ready in time for enjoying FIT. Due to monopoly of supplies, the investor also cannot negotiate the price with the Chinese supplier for equipment supply which is the only possible option. Therefore, policies must be stable in the long run so that domestic enterprises can be fully prepared and able to participate in the value chain. In future, the electricity price can be adjusted according to the market price. In general, solar power technology still relies on Chinese imports. Although many Vietnamese manufacturers have enough technical capacity to master some stages of the solar power industry, such as they can manufacture some parts of equipment (racks and inverters), but they still have to import them. Regarding wind power, there are even more difficulties. In order to promote Vietnam to be able to master the renewable energy industry, the government urgently needs to have appropriate supporting policies, with certain incentives and stability, similar to the way China did. The context of Covid even more needs these supportive policies.

3.5.2. Case IV-2

VIET is an organization operating under the social business model (similar to an NGO). One of VIET's operational functions is researching and advocating for energy transition to sustainable and renewable energy. One focus of VIET is to try to bring international standards and experiences into practice in Vietnam's RE activities.

According to VIET, this organization does not focus on solar energy because this market is quite saturated, and is already in the hands of foreign businesses, which are dependent on Chinese technology. Meanwhile, the wind power market, especially offshore wind power, still has a lot of room for development and needs a lot of support.

With the role of an intermediary, brokerage and consulting organization in the system, VIET has had quite a positive impact on the activities of all other elements, supporting businesses in facilitating the business environment.

VIET has recently launched a series of quality research products related to offshore wind power development planning. As an intermediary and promotion organization for renewable energy development, VIET has played a prominent role in the renewable energy innovation system in Vietnam. One feature of VIET is that this organization promotes linkages but is not aimed at consulting in specialized technology areas. Instead, it focuses on promoting in-depth linkages in institutional and policy systems. With this feature, the impact of VIET's activities will have a much deeper and more pervasive level.

3.5.3. Case IV-3

The Green Innovation and Development center (Green ID) is a non-profit organization working to promote sustainable development in Vietnam and the larger Mekong region.

According to the Project on Adjusting the National Electricity Development Planning for the period 2011 - 2020 with a vision to 2030 (referred to as Power Master Plan No.7) approved by the Prime Minister, with the view that the development of renewable energy is a breakthrough to help ensure national energy security and minimize negative impacts on the environment. However, the investment in renewable energy development is not commensurate with the potential and available strengths. Vietnam does not have appropriate mechanisms and policies to attract domestic and foreign investors for renewable energy development.

Efforts should be prioritized in policy and in implementation in *financial investment*. That is the solution to promote efficient energy development, even there must be adjustments in policy directions, so as to ensure the promotion of the low-energy economy but create higher economic value. In order to do that, it is necessary to have a policy on electricity prices according to the market, to calculate correctly and sufficiently, to separate them so that the power producing units can be financially secure, do business without being attached to social responsibility. Separate the issue of cross-compensation or social responsibility from the firms for production and business.

According to GreenID, it is necessary to issue development policies to increase the competitiveness of developing transport systems with vehicles using renewable energy. The state needs to have flexible policies that can be adjusted to the market and have capacity limits. Policies on solar power need to pay attention to distributed development along with synchronous development to avoid the situation that in some places, the project is large but the scale is not responsive, having problems with transmission system, has not been deployed in parallel with other economic development policies and need to take advantage of the resources of bare land and hills to develop solar power.

3.5.4. Case IV-4

GIZ is a German organization strongly advocates for just energy transition in Vietnam.

Functions

GIZ assists the Government of Vietnam in building a Renewable Energy and Energy Efficiency market by addressing barriers to large private sector investments in renewable energy and energy efficiency infrastructure. The main commissioning party of the GIZ Energy Support Program is the German Ministry for Economic Cooperation and Development (BMZ).

Type and mode of operation

In general, the Energy Assistance Program projects cover the following three areas of activity: Supporting Legal Framework Development, Capacity Development, and Promoting Technology Cooperation. The simultaneous implementation of these three areas of activity in projects and technologies is expected to contribute to the comprehensive development of Vietnam's energy sector.

Issues on policies:

Power Purchase Agreement (PPA) is the most important factor determining the cost of capital. Standardized, transparent and accepted PPA by financial institutions is necessary to reduce risk and cost of capital. Therefore, the PPA needs to be further refined in order to be approved by international financial institutions and for the power generation capacity using renewable energy in Vietnam to meet the increasing demand for electricity.

In general, GIZ is one of the most active foreign organizations (similar to USAID, Embassy of Denmark, UK, EU, WB, GWEC) in supporting, encouraging and promoting Vietnam to follow suit direction of energy shifts from carbon-based to clean and sustainable energy. The biggest impact of this activity is supporting capacity building through training and technology transfer, technical cooperation and policy advocacy. GIZ has relations with most of Vietnam's policy organizations, even at high levels such as the National Assembly, the Economic Committee of the Party, the Ministry of Industry and Trade, so the impact is quite large. One of GIZ's policy advocacy orientations is the policy of localizing and enhancing the indigenous capacity of Vietnam's renewable energy sector, and believes that the government needs to have appropriate policies and roadmaps for this direction. This is a long-term direction and goal, and there is also a need for cross-sectoral coordination activities, promoting technology transfer and learning with the business sector, as well as R&D and training in the sector of universities and institutes. Due to the lack of coordination and inter-sectoral linkage, GIZ also faced many difficulties in operation. According to GIZ, the renewable energy industry is developing too hot and too fast, but it mainly follows the number of projects and does not really care about the quality of the projects. This phenomenon creates a number of problems such as the weak capacity of some local managers to cope with the development of projects. Many management actions are ad-hoc in nature. Therefore, the government should have long-term policies and stability (consistency) and a long-term vision to ensure sustainable development of the industry.

3.5.5. Case IV-5

The Vietnam Union of Science and Technology Associations (VUSTA) was established under Decision No. 121 BT dated July 29th, 1983 of the Council of Ministers (now the Government) of the Socialist Republic of Vietnam. In general, VUSTA has as its members 90 national scientific associations in different fields along with about 600 different S&T organizations. Particularly in the field of Energy and Renewable Energy, there is no separate group, but these organizations belong to the general group of environment and climate change (resource conservation, etc.). There are about 115 organizations, of which 12 have strengths in the field of energy. In the period 2015-2018, there were about 35 organizations in consultancy and design related to renewable energy. Some strong organizations operating regularly such as Green ID, Institute of Automation and Clean Energy, Center for Sustainable Development CCS, Institute of Energy Environment are related to RE. However, in general, VUSTA does not have many organizations specializing in renewable energy, compared to other fields such as sustainable development, environment, ecology, etc. VUSTA supports the establishment of the organization, facilitating the participation of alliances such as the Vietnam Sustainable Energy Alliance (VSEA). In the *Vietnam Sustainable Energy Alliance*: organizations actively work together, to jointly apply for projects, take turns chairing the Alliance. This alliance has 10 members, including some international organizations such as SNV, WWF, etc. There are many VUSTA organizations also joining this Alliance (6/10 member are from VUSTA) such as Green ID, RTCCD, Live and Learn, CEWAREC, C&E. In the composition of VUSTA, there are not many intermediary organizations operating in the field of RE in general and related to solar power and wind power in particular. However, there are some strong organizations that are quite active. For the most part, these organizations are mainly engaged in research and policy advocacy, but are moving towards specific projects. These S&T organizations have many links with the business sector, but not so close with state agencies and universities. These relationships are mainly based on personal contacts. For the operation of this type of organization, there is currently no suitable policy for a type of non-public S&T intermediaries in the innovation system of the RE sector.

3.6 Some general observation and conclusion

As we can see from the results of interviews in the previous section, there are number of overall tendencies and findings could be drawn as below.

First observation is related to *supply side* of the innovation system: research organizations and universities that provide new human resources and R&D for the sector. Most of cases confirmed that the *human resources* for renewable energies in Vietnam are seriously in shortage. Other areas of energies like nuclear energy which has special policy and strategy to develop appropriate human resources. Hundreds of people have been sent to Japan or Russia for training on nuclear energy. Meanwhile, RE sector did not have such policy and strategy. Companies tend to use existing human resources trained in related areas like electrical and electronics, construction, transport, for purposes of RE projects. Only few universities began to offer training courses or degrees in RE. HCMUTE is the place to open specialized degree program of Renewable Energy engineering. In several universities such as HUTECH, there were no specialized training courses on renewable energies as this area was still new to them. Some universities like Hanoi University of Science and Technology (HUST) adopted the approach to combine training for renewable energies in the complex of electricity training. With that, the offering to students will be more attractive in electricity training (with solar and wind as sub-subjects) rather than just to focus on RE expertise. According to this university, the market is not ripe enough for offering RE degrees training only. Moreover, for RE sector like solar and wind energies, the government did not have funding for organizing specialized training programs similar to that of nuclear energies in the past. Most of some limited funding for training RE came from enterprises, majority of them were of non-state sector. Some companies like LIG argued that human resources supply from the university sector was not adequate for the need of firms. Part of the reasons is that there are universities thinking that the technological issues in operation of a wind or solar power plant are not very different from that of a thermal power plant. And so, many projects can completely use people who have been trained in common areas of expertise such as electrical, electronics, energy, thermal, and mechanical engineering for the operation of renewable energy plants. However, there are certain characteristics of solar and wind power that require deep knowledge of technology and specialized training in renewable energy. Thus, the training activities of universities are still spontaneous. Support for state-run training institutions is mainly available to state-owned companies, while private organizations are often left outside. Many RE training activities of universities have not been supported under an organized program, or long-term orientation.

Another observation is that human resources for RE sector was also lacked for management activities in the sector. For instance, many provincial departments for S&T and Industry and Trade (such as of Ben Tre province) did not have sufficient knowledge, skills and experiences for dealing with projects in solar and wind energies (monitoring, appraisal, evaluation). In particular, intermediary organization like Green ID commented that there is always a shortage of good enough staff for wind energy projects in many provinces. There is certainly a large need for this kind of expertise to be supplied.

Second, regarding *R&D activities*, Vietnamese research institutes as well as universities in the renewable energy industry also face the same difficulties as the entire science, technology and R&D system of Vietnam. These organizations often stay out of the market demand for renewable energy, especially wind and solar power. Although these organizations also carry out a number of research projects related to renewable energy, they are all at the level of testing, exploration, understanding and mastery of principles and theories, and they are usually conducted on a small scale. Some research institutes have actively approached new research directions, which are basic research such as perovskite or hydrogen technology, but they are mainly for exploration and investigation, without significant results. In applied research, these organizations often carry out research in which they have strengths (such as the robot cleaning solar cells of Lac Hong University or the photovoltaic glasses of the University of Electricity) but these researches are not necessarily intended to solve the particular problems posed by the needs of many businesses. A few institutions such as Ho Chi Minh City University of Technology and Education or Lac Hong University have good business relationships and have conducted practical research that directly serving businesses. Hanoi University of Science and Technology (HUST) or Institute of Energy (IE) under MOIT, had some activities related to renewable energies. While HUST had quite diversified portfolio in R&D projects on technologies, IE did more on R&D for soft solutions in planning and designing, project management and implementation. University like HUTECH also had number of research groups working in the RE subject. The lecturers of Lac Hong University also have to spend their own money on research first, then compensate the amount later. Meanwhile, some other strong universities like HCMCUT had been less so active in research on renewable energies. There were some noticeable patterns seen. Despite different universities and research institutes had different context and efforts of involvement in RE R&D, most had one thing in common as rather inactive and weak capability in commercialization of research results. Not many organizations can come up with a patent or a specific technology that can be commercialized, and turned into innovation for the market and firms. This group of organization is still a bit far behind the innovation need of the renewable energy industries. To some extents, there are opinions that if looking at research potential and efforts by universities and research community, it is not visible intentional strategy of Vietnam to catch up and to master key technologies in renewable energies. Technologies like "perovskite" are just minor experimenting of individual researchers for solar energy, without back up of government large programs. Even in the content of a national research program like KC-05, the share of RE projects is minimal.

The *research system (R&D system) and research management (R&D management)* network still have many shortcomings, causing many difficulties for organizations performing the function of providing research results for innovation activities in the business sector, including: reviewing and approving research agenda, conducting and funding research, and evaluating the results. Some state-level research programs specializing in energy (such as the KC-05 program) often include quite general topics, not really addressing business needs. The promotion of the commercialization of R&D results and innovation implementation by businesses is weak. There is almost no concept of venture capital investment in an area as uncertain as R&D with a lot of risk. Funding for research is still not much, especially for procurement of research equipment.

One another observation is that some R&D efforts of universities (like HUST) tend to be for publication and record for an academic career rather than for industrial uses. One solution to this constraint was put forward by IE. The Institute considers that Vietnamese R&D organizations may not have to be necessarily excellent in all kind of research and technology domains, but do what they are best at. For example, IE can be a strong research group as one of the best think tanks of the country in energy sector in general, and then in RE in particular. Soft issues like solutions, system design are the subjects of research they should focus on and utilize.

In enterprise sector, companies like Licogi 16, LIG (Licogi 13) did little on R&D. Some companies (Gelex) had good accumulated experiences in electrical R&D in general, but difficult to turn them into research skills for renewable energy. Others like Hoanh Son group or Green ID indicated clearly the need for more research on energy storage and hydrogen technology and need support from R&D institutes.

Third, in the field of renewable energy, it can be seen that *core technologies* are embedded in the following aspects. For *solar power*, there are technologies to manufacture solar cells, inverters, and combo boxes, and some other accessories such as racks, wires, etc. In this field, almost main suppliers are Chinese companies such as SunGrow, Trina Solar, Longi Solar, Jinko while to a lesser extent are companies from Germany, USA, Japan (TMEIC, Sharp), etc. Company like LIG acquired almost all its technologies from abroad, especially from China. For *wind power*, these are turbine technology (wind blades, gearbox, generator), inverter, transmission system inside the pile, etc. In this field, Vietnam does not manufacture any products and these are completely imported from abroad, mainly from Europe (Vestas from Denmark, Siemens Gamesa and Enercon from Germany), the United States (GE) and a small part is coming from China (Gold Wind, and Envision). There are few foreign invested companies operating in Vietnam can produce certain parts of equipment and system like CS Wind. Thus, it can be seen that currently in the technological components of wind and solar power, Vietnamese organizations participate very little, almost insignificantly, in the creation of these technologies. Even learning to master these technologies in operation is already a big effort and takes time. A common phenomenon through surveying investors of wind power projects in Vietnam is that technology providers often want customers to rely more on them to continue exploiting profits from customers. For example, the two wind turbine manufacturers, Vestas and Siemens Gamesa, while negotiation for providing wind power technology with project investors, often require the investors to sign long-term operation and maintenance contracts at very high costs for a relatively long time which up to 15 years. Moreover, Vestas does not carry out technology transfer, operation and maintenance instructions for the investor's personnel to ensure the profitability and security of their core technologies. This makes the learning process of Vietnamese firms become much more difficult, especially in the field of wind power. The option to buy an operation and maintenance package with technology is also implemented by GE at a quite high price, but for the American wind turbine manufacturer, this is not a mandatory condition included in the equipment and ancillary service combo package like Vestas's.

Fourth, from the above point, it is necessary to discuss the issue of *Vietnamese enterprises mastering technology and localizing the technologies and equipment* of Vietnam's wind and solar power. So far, the current situation shows that the localization rate of Vietnam in the technologies and equipment of solar and wind power is quite low. In solar power, there are only a few components such as racks, wires, metal shelf, carton boxes, etc., that are involved by Vietnamese suppliers. The remaining core technologies such as solar cells or inverters are mainly imported from China. Although among research organizations there is a view that the localization in solar technology is easier than in wind technology, rate of localization in solar is still low like the case of LIG, as technology supply is dominated by China. In wind power, this ratio is even lower when Vietnam almost stays out from all types of wind power technologies, from complex technologies such as turbines, blades, gearboxes, etc. to simpler technologies such as inverters, steel piles, combine boxes. In wind power companies like Gelex or GEC/TTC, there was no localization and companies all depend on foreign imported technologies. For businesses providing rooftop solar power services such as Dan Khue Solar, most of the technology is imported from China due to the simple and mass production technology, so the cost is relatively low.

There are many barriers to the localization. Licogi 16 even received request of foreign contractors to use foreign supplied technologies only. This prevented the company to take part in a value chain. According to organizations like GIZ or Green ID, localization process asks for a carefully designed roadmap and planning with necessary preparation. However, the practice of some businesses shows that a few businesses have started to pioneer the trend of trying to localize RE technology devices. For example, in the field of solar power, businesses like Vu Phong Solar have started manufacturing inverters, or in wind power, some businesses have started to manufacture steel piles, simple solutions of power systems such as sun tracking racks, electrical cables, electrical cabinets. Most of the components of the substations have been localized due to the capacity of supplying quality products of Dong Anh Transformer Factory, Hanoi. BK Solar Company manufactures some parts of the photovoltaic panels themselves and optimal observation technology or Vu Phong Solar Company produces an automatic robot to clean the solar panel itself.

One of the basic reasons cited by businesses when discussing the limitation of localization is that the design and manufacturing capacity of Vietnam's supporting industries is still very weak, making it difficult to participate in the supply chains of the manufacturing and supplying of these types of equipment and technologies. In order to encourage and promote the localization process, an appropriate policy environment is needed, which will be further discussed below.

Fifth, unlike mastery of designing and manufacturing wind and solar power technology equipment, which is still at a very limited level, *Vietnamese businesses have developed and mastered the capability to construct and operate* solar and wind power projects. As for solar power, quite a few businesses after a period of working and implementing a few projects with EPC general contractors, were able to implement the next projects themselves or for other businesses. In the solar and wind power value chains, quite a number of Vietnamese businesses have been able to do as an EPC general contractor on their own, or preside over the construction, construction and assembly of some projects. Companies like AsiaPetro, TTC, Hoanh Son group, Licogi 16 or LIG all have rather good capabilities in construction, handling equipment, installation of facilities and operation of projects. Some companies explained this strong capability to the cooperation with other R&D organizations like Institute of Energy which by itself has quite a strong design capability and provision of soft solution for the system. The difficulty level of these works also increases gradually from the construction of solar farms to the construction of the foundations of wind power piles and the installation of super-long and super-weight wind power components and parts.

Sixth, many businesses have had *learning activities* organized either proactively or based on the plans of foreign partners who also are technology suppliers. The main learning mechanism of Vietnamese businesses in solar and wind power is via a number of *short-term training courses by technology suppliers* for a limited number of core staff only. On that basis, this core human resource will continue to train the business's staff members on a larger scale (*training-of-trainers*, TOT, method). Besides, there is the process of *learning-by-doing*, constructing and operating together. Most businesses have organized short-term training programs and classes at their facilities (*on-the-job training*) to improve the capacity of their employees. This gradual learning process has helped many Vietnamese companies, after one or a few initial projects, obtain a capability in projects construction, assembly and operation management. Some construction and installation service providers of Vietnam such as Vinaconex, Lilama, Fecon, etc. also had experiences in energy, construction and transportation projects that have also provided the necessary services for wind and solar power sector. For example, Fecon was able to master the construction of concrete foundations for the wind power piles. The exception is wind power investors such as Trung Nam Group who have invested in buying a large number of construction and installation equipment to be able to independently build and install wind power piles for their own projects as well as others. Hoanh Son group learned from foreign suppliers of its equipment via some training courses which helped the company to completed project construction in record 3-month time. LIG, Gelex all learn from working with foreign partners or organization of short training courses. PECC1 learned by doing projects, and after each of completed project, its capability was upgraded.

Seventh, regarding the *interactive linkages between components of the innovation system* in the field of renewable energy, a mixed picture can be seen. Overall, linkages between different actors in the system are not strong. Licogi 16 has very weak linkage, while companies like Gelex, Hoanh Son or LIG has almost none of it. Only a small number of companies like PECC1 has strong linkages with partners. The links among businesses (both domestic and foreign) such as suppliers, customers, service providers, etc. is more active. Especially, the connection between Vietnamese companies with foreign technology suppliers, investors, and some consulting organizations. Meanwhile, linkage between academic organization with others are varied. The cooperation between businesses and the academic sector such as research institutes and universities are almost negligible. This is a fairly common phenomenon in most industries in Vietnam and renewable energy is no exception. Most businesses in wind and solar power sector have only a few connections with R&D institutes or universities. The main source of knowledge that businesses have is from foreign suppliers, service providers and consultants of international organizations. However, it can still be seen that there are a few businesses and institutes that have developed effective linkages, especially those with a strong tradition of serving the business sector such as the Ho Chi Minh City University of Technology and Education or Lac Hong University. Small numbers such as the Institute of Energy have quite diversified linkages with partners, while HUST strong linkages relied much on personal relationship. HUTECH has some linkages but little related to renewable energies, and HCMCUT emphasized on the need for policy conducive to linkage development. Links between state management organizations and the business sector and academic institutions are also quite limited, mainly through a few specific support programs (if any). Discussing the linkages, intermediary organizations like GIZ, Green ID or VUSTA have quite extensive network of linkages with various types of actors in the system. But they also complained about lack of appropriate policy environment that encourages stakeholders in the system to link with each other, to cooperate and coordinate their actions. Most importantly, these actors need to have "trust" in each other. One of the reasons explaining the weak link between businesses, universities and research institutes is because the capacity of the institutes - universities often cannot keep up or bring efficiency to business production activities. Another reason is that trust between different types of organizations is not well developed.

Eighth, the *market* of the renewable energy industry is quite nascent and still has many instability problems with many changes. The developed market size is not large enough, thus has not created large-scale effects of the economy (economies of scale), and because of that it is difficult to create conditions for long-term development investments while discourages learning and investment into technology research and development. Intermediary organizations (GIZ, Green ID), companies (Gelex, PECC1, TTC) or research institute like IE confirmed that the market of renewable energies in general developed too fast and too hot, without proper planning and preparation in advance. This kind of nearly "chaotic" development affected strongly all aspects of the industry, including that of management structure and process. One issue is that quality of projects tends to be neglected and care of by little. The two most important management bodies for the sector as MOIT and EVN seem to be confused, and passive in dealing with this hot phenomenon of solar and wind power development. There is still a *lack of strong, long-term and stable RE supporting mechanisms and policies* (like China's) to promote the strong development of this industry. In this context, businesses are mainly interested in lobbying and getting projects to put them into operation on time to enjoy preferential FIT prices, rather than paying attention to long-term issues such as promoting R&D, innovation or learning to improve capacity. The role of *organizations that provide institutions and policies* to support the development of solar and wind power is not really clear, except for focusing on offering FIT prices to attract investment.

Ninth, the market and investment for renewable energy projects (wind and solar power) also show the phenomenon that many Vietnamese investors, after applying for a project license (or after a short period of operation) have sold these projects to foreign investors. Among cases, TTC is the one that sold its interest in the Mekong project for Gulf from Thailand to take over the project and become Gulf Mekong. This phenomenon shows that the *policy of attracting investment* in wind and solar power through *short-term benefits* such as attractive FIT prices with term has encouraged opportunistic and unsustainable investment projects. Moving forward with the renewable energy wholesale and retail market reforms which are greatly lagging should be a long term and more sustainable policy solution.

Tenth, in general, the *institutional system for RE development is quite primitive, lacking many options and different forms of support (poor policy mix)* and it is mostly based on using attractive FIT price policy to quickly attract investment into this field. Most of cases have views that FIT-based policies for RE development so far are very unstable, inconsistent and not so conducive to business and sector development. Although FIT provide quick incentive for firms to rush into the industry, this policy has low stability, because the attractive FIT price will have to end at a certain time (usually 1-2 years) and in the future, no one can be sure how the support policy will be determined. Many businesses have to race against time to put their projects into operation before the end of the FIT price deadline to be able to enjoy attractive prices. This hasty race leads to the phenomenon that a number of projects are not good at quality, built in a hurry to cope with progress, so it does not guarantee quality and sustainability. On the other hand, some investment preparation plans of businesses have to be suspended to wait for and see if the new FIT price is economically viable. This reduces the desire of businesses for stable, long-term investment, which is not favorable for the accumulation of technological capabilities and learning experiences that require long-term and stable efforts. Besides, there are many inadequate policies and unreasonable regulations that cause difficulties for businesses, especially taxes on components in imported technology packages. Companies like Licogi 16, LIG, Hoanh Son all mentioned the hastiness of policy making as spontaneous reaction to demand. According to Licogi 16, it is necessary to have a long term and stable policy for learning to take place. TTC argued on tax levied on imported equipment as inappropriate. To support research, PECC1 also asked for supportive policy environment, Institute of Energy needs stable policies to plan for its research activities and strategy, trying to focus on what it does best as provision of system solutions or software development. The short-term vision of policymaking as called it by Green ID or a poor policy mix in general are not favorable for longer perspective of renewable energy development. Among policies, the FIT is just one measures that HCMCUT complained as jeopardy to cause rushing into investment projects. Gelex mentioned land policy could also have negative impact of the project. GIZ suggest that the policy environment must be consistent.

Problems of policy framework are related not only to policies themselves, but also to management system, structure and capability for policy implementation of bodies like EVN as seen in the views of LIG and PECC1. Interestingly, there is a company (Hoanh Son group) mentioned rushing impact of policy even can have positive influences on its actions to completed project in a record time.

Eleventh, a group of elements of the innovation system are *intermediaries and brokers.* However, in the field of wind and solar power, the role of these organizations is not really prominent. Most of the sources of knowledge, technology and experience come from enterprises that are technology suppliers mainly from abroad, and a smaller part from the academic sector. Vietnamese consulting organizations such as PECC 1, 2, 3 and 4 can mainly assist businesses on issues in power generation in general. The strong consulting companies that support a lot of wind and solar power are mainly foreign companies having branches operating in Vietnam. In addition, it must be seen that the role of individual consultants and intermediaries sometimes is more important than that of organizations. VUSTA is an umbrella for many Vietnamese intermediary organizations in science and technology areas. In its structure, there are hundreds of different organizations working on consulting, supporting services for companies or operate like companies themselves, under various names. However, activities portfolio of VUSTA organization tend to concentrate on other areas more than on renewable energies. Compared to other sectors like environment technologies, or agriculture, etc., RE share in works of intermediary organizations is quite modest. Also, lack of specific policy incentives to encourage intermediary organizations to provide their services hinder their activities. Company like Licogi 16 has quite low view on services of domestic consulting companies as compared to that of international ones.

At the same time, for those intermediary organization having strong links and partnership with foreign actors, the situation is much better. They have more proactive approaches in dealing with intermediary and broker actions. Organizations like VIET, Green ID or GIZ (a foreign organization itself) actively approach many high-level bodies in management system of Party, government, National Assembly for policy advocacy and advisory services on renewable energy. Organization as SIHUB with both local government mandate but acting like a consulting organization is quite an interesting model for intermediary organization. This way of doing business need more attention and special policy incentives to support.

Twelfth, *a*n emerging issue that strongly affects the accumulation of technological capacity and knowledge learning process in the solar and wind power sectors is the *mismatch between the power generating capacity of the projects and the power capacity of the transmission system*. The problem of cutting capacity is complained by most businesses. The productivity and efficiency of the RE plants are not guaranteed, because they are not operating at full capacity due to the weak transmission system, representing the imbalance between electricity production and the capacity of the transmission system, as well as the correlation on ratio distribution between power generation sources such as solar power, wind power, coal and gas thermal power. Companies like Gelex or Licogi 16 all faced this bad experience when they have to cut down their production volume due to poor transmission capacity. Gelex, for example complained that overconcentration of nearly 40 wind power projects in one small province of Quang Tri in central part of Vietnam certainly did cause the congestion of power generation capacity and led to request of cutting down energy generation. PECC1 confirms this due to very inefficient transmission system with lines are overloaded and cannot cope with power production, especially at the peak time.

Thirteenth, technical regulations and standards for the solar and wind power field is another issue that is raised by businesses as a factor that still hinders innovation activities in this field. Many comments suggested that there should be a more uniform system of standards, including regulations on storage of renewable energy data in Vietnam. The lack of a technical barrier and certain technical standards and regulations can cause potential breeches in safety and reliability to the national power grid when poor quality power generation equipment is connected and operated in an unstable manner. According to Institute of Energy, the complete set of technical standards and other standard specifications for renewable energies are lacked. PECC1 even emphasized this shortage of standard for renewable energy projects is a very serious problem and caused downgrading quality of the project design, construction, installation and implementation. For many projects, even when their construction already completed, standards are still prepared and to be applied.

Fourteenth, environmental factors are also cited as a barrier to wind and solar power project development, but with different perspectives. Although the transition to renewable energy helps to solve the problem of climate change, it also causes some concerns such as environmental pollution due to waste from end of life of solar panels or turbine blades, etc. Opinions are also quite different on this matter. There is a view that this is the biggest problem when many projects and homes are massively switching to rooftop solar installations in a disorganized manner, so when solar panels expire, it would cause environmental pollution at a large scale and it is necessary to have binding policies and sanctions to deal with this problem. Other opinions from technicians at solar power factories suppose that the problem of solar battery waste or the impact on the ecology of the environment around the wind columns is not as big as the concern raised in the media because most of components in solar panels are recyclable and all wind power projects have been analyzed/ assessed for environmental impacts and carefully selected by foreign consulting organizations to avoid damaging the environment surrounding the project. There is some opinion that almost 70% components from solar panels are made of non-toxic materials such as glass, steel, and glue, which do not pose environmental concerns as they can be recycled and reused. Besides, there are points of view suggesting that there should be a policy to treat the waste of the renewable energy industry (such as solar panels and wind turbine blades) as ordinary industrial waste, not as hazardous waste. While PECC1 expressed some concerns on waste management of renewable energy projects like solar panels and consequences of unclear responsibility of management bodies in long run, Hoanh Son company is more optimistic and suggests measures to deal with environment potential problems. Look at the overall power generation, Institute of Energy admits that in Vietnam coal use is still important part of energy structure and national energy system cannot get rid of coal immediately. Instead, it suggests to have research on technologies dealing with how to use coal in a better and more environment friendly mode, with less pollution.

Fifteenth, The *Covid pandemic* has had certain effects on the development and implementation of solar and wind power projects in Vietnam. These influences cause difficulties such as delayed delivery of equipment and machinery for RE projects. TTC company did face lot of problems and the pandemic set in and cause lot delays in project implementation. Shortage of experts/specialists due to the new quarantine policy of the Government is another concern. This slows down the progress of many projects that are racing against deadlines to enjoy good prices FIT.

Sixteenth, among types of innovation that emerged in Vietnamese companies, in addition to type of technological hardware, *innovation in transmission systems* as in the case of Gelex is observed. This enforces the direction of IE to do more research on *soft part of renewable energy* such as solutions, system design rather than on hard part of equipment which beyond the capability of Vietnamese producers and manufacturers. This would be a promising direction for Vietnamese organizations in their pathways for innovation.

Seventeenth, one type of stakeholders in the innovation system is the *local government* of provinces and cities and their professional agencies like Department of Science and Technology (DoST) or Department of Industry and Trade (DoIT). In this regard interviews with these departments in provinces like Ben Tre, Bac Lieu or HoChiMinh City show different situation. DoST tend not to engage very much in supporting renewable energy projects in their location. Their technology appraisal function of investment project is not carried out due to lack of appraisal capability. Meanwhile, DoIT tend to be more supportive of RE projects, but type of support usually in terms of procedures under their mandate, rather than on technological learning. GIZ and Ben Tre DoST also commented on this weakness of local government in this system and stressed that there are no specific customized policies for RE in local context implemented.

Eighteenth, looking at operation of local government specialized agencies, one another observation is that sometime *political decisions and considerations take over technical and professional factors* and change the course of development. This is the case of Bac Lieu province when Department of S&T was disbanded just by some decision of political leader of the province, to be merged with another department. This decision affected strongly the technology development of the province and its projects, including that of renewable energy. Changing organization certainly led to appearance or disappearance of various actors in the innovation system and its effectiveness.

Nineteenth, one of the new areas of RE development is *offshore wind development*. Most of companies have expressed interest in this new development and even have plan and projects to go offshore. To offer services to offshore wind projects many companies having strong capability in offshore project for oil and gas like PVC-MS or VietsovPetro are ready to transform themselves for new business area. Still, as this new business area is vast and much more complicated economically, technologically or environmentally, than onshore wind or solar energy, company like PetroAsia asked for a special strong policy to specifically support offshore wind projects.

Twentieth, discussing new business area, *rooftop solar power and floating solar power* on hydro-reservoirs are other two types of business that many companies are rushing into. In rooftop solar, incentive policy supposed to encourage homes and companies using their roof tops as the place to generate energy to be commercialized over the grid system. The same is applied to agriculture companies using their roofs of poultry or cattle farms for base for solar panels. The incentive provided to this kind of business is quite attractive. However, according to many companies as Hoanh Son Group, LIG or Green ID, this policy is abused by creating quasi-farms for solar energy generation without anything related to agriculture production.

Twenty first, background of companies before entering renewable energy business is another interesting observation. Looking at all cases in enterprises sector for both solar and wind, one can say that they used to work in the areas that have little to do with energy in general or renewable energy in particular. Many companies worked in areas such as transport (like Hoanh Son Group), construction, manufacturing, services, even some are merely trading or financial services companies without any technology background. Due to very attractive FIT policy, they just simply jump into renewable energy business with little preparation, with their own capital or loans from banks and financial organizations. This kind of business mentality and preparation, lack of suitable capability made many projects short-lived, and vulnerable to many difficulties in the cycle of design, construction and operation later on.

As presented in above analysis, components of sector innovation system in renewable energy of Vietnam as well as their interactive linkages have been analyzed. With observed trends and identified patterns, combined findings of two rounds in-depth interviews can provide a general picture of actors, their linkages as well as institutional framework in the innovation system of renewable energy sector in Vietnam.

Chapter IV. Key emerging issues of the sectoral innovation system in Vietnam renewable energies focusing on wind and solar

The last Chapter will discuss some key emerging issues of the sectoral innovation system in renewable energies, and policy framework.

4.1 Some key emerging issues

The status of sector innovation system in RE in Vietnam, with focus on solar and wind energy is briefly summarized as follows.

Firms are very active players in developing RE sectors and they are coming from various background, including both national and international. They are the central component in the sector innovation system for RE (solar and wind) in Vietnam. The firms began strong push for developing this new solar and wind energy sector in the country and have helped to increase the share of RE in electricity production rapidly. The firms mainly are involved in different capacities of investors, operators, service providers and producers. Despite this active participation, the technology and management capabilities are remained to be improved. Firms' linkages tend to be closer among themselves rather than with other groups of stakeholders in the system. Some firms have rushed into the industry with interesting behaviors such as hastiness and inadequate readiness, in responses to unique business opportunities provided by very favorable FIT policies under pressure of tight deadline. The innovation activities tend to linked more to action of foreign actors like technology suppliers and partners.

R&D and training organizations are less active in RE areas and tend to be weak and left unprepared for solar and wind technologies. Many research and training activities are too new to this group of organizations and the domestic R&D and training organizations are not ready to take on more RE activities. Moreover, issues and problems of overall innovation system in the country are influencing their behaviors for RE as well. The linkages between this group of organizations and the rest in the system seemed quite loosen and not much learning for R&D institutes and universities happening from the interactions with foreign technology providers.

Government agencies have quite influential impact on the innovation activities, for introducing incentive policies (mainly FIT). Many key policy documents were introduced, creating foundation for RE development. But specific institutions for supporting innovation in RE are not yet available. The issue of localization and technology learning by domestic stakeholders is just began to draw attention of policy makers with few incentives available.

Intermediary organizations in general play little role in supporting RE development in general, and leaning and innovation in particular. This is true for most domestic organizations, while few selected international organizations are more effective and vigorous in promoting RE development. Still, the intermediary organizations both domestic and international could be more proactive in pursuing pro-innovation activities and tendencies.

Financial organizations are the least active in promoting innovation of the system. What they do most is to fund some profitable projects that can ensure the return. For this sake, sometime banks or credit organizations requested the firms to sacrifice certain elements of learning. The wider and more substantial financial support is still needed for not only RE development in general but for innovation activities in particular. Recently, one can observe more direct cooperation between firms and banks such as partnership of SolarBK, BIDV, and its insurance company BIC to provide financial insurance and services for solar solution BigK. The whole question of how to fund the RE system, including solar and wind is still a big debate (Duong, 2022). Following several recommendations of international organizations, to build up a comprehensive green financial system, facilitating green credit and green banks, etc., increasingly to rely and attract financial resources of private sector are the answers.

Linkages and learning reveal a mix picture with inter-firms' linkages look strong, while the other types of linkages are not so. As academic circles seem to stay out of the latest development in RE, their interactions with corporate sector are quite limited. The dominant mode of interactive linkages currently is for firms with their international partners: technology suppliers, funders, service providers. The connection between firms and the rest of the domestic economy and system seems a missing link that needs to be enhanced.

Technology, localization and domestic content is another important issue. The practices of stakeholders show that the rate of localization in technology, both hardware and software, is negligible in solar and wind energy industries. Majority of technology were supplied by foreign companies, if there are some domestic supplies, they are also by international companies. There is little possibility for Vietnamese organization to get into this business. However, there are still niches areas that Vietnamese organization, be the companies or R&D institutes, to work on. These are soft skills and subjects of construction, installation, operation, management of projects. To pursue this strategy, there is required some specific framework to develop supporting industries as well as suitable policy incentives.

Customer, demand and market are a broader picture of the sector development. The issues like overheating development of the whole RE sector, lack of appropriate mechanism to support, short-term orientation and instability of some key policies sometimes create big problems for investment, energy production, and transmission. Certainly, this has important impact on the learning behavior and attitudes for innovation for many stakeholders in the innovation system. To deal with this situation, in addition for improvement of overall policy framework for industry development, there are also needed specific incentives for whole science, technology and innovation system.

Overall, the sector innovation system for solar and wind areas in Vietnam has already included all necessary components. But their actions, interlinkages and extent of activities are varied. The system is still in its nascent stage with many incomplete pieces and having an involving nature. The innovation system will be developed gradually along the development and rapid changes of the sector itself.

4.2 Towards a policy and institutional setting for Vietnam innovation system in RE

A policy and institutional setting for renewable energy development and some suggestions to promote innovation will be discussed in this section.

4.2.1 Overall policy framework for RE development

Although there are many key documents for policy in place, this system requires numbers of aspects to be dealt with. First is the systematic stability and predictability of the whole legal framework. Right now, content related to development of RE are spread out and fragmented in many policy documents, with different levels of regulations and influences. While overall in energy, electricity and oil and gas have their own laws, the highest level of a legal document, RE area did not have such kind of document, but only PM Decision or Circulars at a lower level of MOIT and related agencies. Some regulations in energy sector are still overlapping with each other's and lack of cohesion and consistency within RE subsector, energy sector and the whole legal structure. Another point of concern is the timing and completeness of the policies. There is still slowness in issuance of new regulations or revised one for RE. Many documents are still outstanding debt in the list of necessary documents pending for promulgation. Many examples can be given for RE such as Circular 58/2008/ TTLT-BTC-BTN&MT having unsuitable regulations.

There are some potential proposals. One is to consider moving from feed-in-tariff to reverse bidding process coming from buyers. Power purchasing contracts with EVN need to be revised and adjusted so that the credit from banks and financial organizations can be easier to proceed for RE. The FIT mechanism needs more stability for firms already invested or are planning longer term perspective of business. Without these stability and predictability, it is impossible for firm to invest seriously into subjects of long-term nature like innovation and learning.

To attract international investors, it is crucial to reform the bidding procedures, especially for large scale projects (more than 10 MW) in RE. The call for investment may need to pay more attention to combination of RE projects and the BESS technology at the level of the whole grid to ensure its stability. More appropriate policy framework for roof top solar projects is also needed, to encourage small scale module of roof top projects to be diffused widely.

Among measures to be considered is the compatibility of electricity grid to production. Creation of the complete standard configuration of all production projects and their compatible transmission grid are essential to make the system operate in a balanced mode, without need for capacity shutdown. This can be ensured by a thorough design and calculation of all involved technical factors at the outset. The stability of the system should also be enhanced by reducing changes in capacity. In wind sector, for instance, high-wind-ride-through regime could be an option to be considered when a wind project can reduce its capacity when wind speed is high, hence avoiding abrupt changes of the marginal output.

To make many RE projects viable, the supply of cheaper finance via development of so-called green banks. Access to cheap finance is one of the barriers for many RE projects and caused the price of RE power as unnecessary expensive, especially for domestic producers. According to IRENA (2020), national development green banks, or other credit and funding programs of national banks could help with credit access. This support could also be attached to incentives for localization, with lower credit interest applied to investors and developers involved in the localization of value chain.

4.2.2. Some suggestions on localization, local content and fostering innovation

To promote science, technology and innovation and provision of quality human resources in RE, the linkages mechanism between stakeholders in the system should be enforced vigorously. Different type of programs of science, technology and innovation should be designed and implemented, and integration of STI activities right into various planning, strategies for development of RE. Just like other industries, there are needs for more incentives to encourage RE companies to invest into R&D, to create innovation centers and units for the RE, solar and wind energies. National research program on energy like KC-05 should include and pay more attention to RE subject and technologies, to increase the share of projects focusing on solar and wind energies in the portfolio of the program.

In relation to policy framework for fostering localization and learning of technology in RE (solar and wind) sector, there are numbers of policy directions. There should be a policy to increase investment for R&D, financial support for production of solar and wind sectors. There could also be organized various programs on capacity building and training, link requirements for localization to the credit support provided by green development banks. In general, the requirement for localization has a form of percentage of total project value and to be increased over time. After the industry becoming strong, the requirement for localization may be reduced gradually. So far Vietnam used FIT to encourage domestic companies to take part easier in the market and attachment of localization issues to FIT could be a useful option. But then while organizing bidding, Vietnamese companies may have difficulties to compete with larger foreign firms due their small scale and limited resources. Hence, the requirements of localization should be part of bidding design, for instance to assess the bid based not only on prices offered, but other factors as well.

One area that this orientation seems most visible in is wind energy. A long-term solution for deciding electricity purchasing price is to reduce the electricity production unit cost by increasing local content of wind technology equipment, such as turbine. The industry can also reduce the energy subsidies to encourage more equal competition of investors, customers, and distributors. Government can proceed with supporting programs to increase our awareness of RE in general and solar and wind in particular. Technology exchange activities and capacity building programs via scientific workshops, seminars, long-term and short-term courses for firms, R&D institutes and universities should be supported.

Regarding training and education, to develop staff skills appropriate for future demand in RE, Vietnam should consider to have a generic strategy to integrate RE content into overall higher education and vocational training programs. To do this, it is required to have coordination among government agencies such as MOIT, MOET, MOLISA and MOST. Training curriculum need to be updated with more practical skills for rapid changes in the industry, with more focus paid to digital skills and advance material. In the long run, Vietnam should create closer and more integrated interactions among policies for sector development and for skills development. Requirement for human resources in different segments of value chain of solar and wind energies both onshore and offshore can be identified and promoted. According to a study by IRENA (2020), a solar farm focused most of its efforts on O&M with 56% of total human resources, then production of 22% and construction and installation of 17%. For an onshore wind project, O&M has 43% of total job, construction and installation 30% and 17% for production and manufacturing. In the same vein, for an offshore wind farm, production and procurement has 59%, 24% for operation and maintenance and 11% for installation and connecting to the grid. This kind of clarification will help to focus necessary resources and efforts only on those suitable segments that are closer to capabilities of Vietnamese organizations.

In terms of technologies, MOIT and other relevant ministries can introduce incentive policies to develop some specific technologies of utmost importance for RE such as BESS and grid technology to deal with the imbalance problems between production and load of transmission and helping regulation of accumulating energy more flexibly. In addition, they can explore technology of cloud computing, and other Industry 4.0 technology background like Internet of Things that helps to make whole system of management, operation, monitoring more effective. For future of the sector, exploration of new technologies like hydrogen should be included in the attention circles of stakeholders.

The energy sector in general and renewable energy in particular is among the most important sectors of any economy. Renewable energies for the last several decades have changed profoundly thank to many new technologies and innovation. Solar and wind energies are not exception. In Vietnam, for the last 5-10 years, solar and wind energies witnessed significant increase in their share of total energy output, growing market with many new comers, domestic and international included, and very promising perspective for further development. In this context, innovation and innovation system have more room for growth. As the sector is changing so fast, the stakeholders in the system seem to face many challenges. Some can be adjusted rapidly, and other may require longer term solution. As the situation in the whole national innovation system, and innovation systems in other sectors, innovation activities and the development of innovation system in renewable energy sector, via examples of solar and wind energies, are at the junction of rapid changes. The overall institutional framework needs to be more adaptive and flexible, at the same time maintaining its stability and predictability to provide the sector a conducive development environment. This is not an easy task and all related stakeholders in the system do need to have more coordinated linkages to play their role accordingly in the most synergetic pattern for innovation.

Conclusion

The renewable energy in Vietnam is a high growth industry in the last decades. Net to the initial success, there many shortcomings needed to be addressed if the industry wants to be a source for ensuring energy security, meeting the demand of rapid socio-economic development of the country. Science, technology and innovation should be a key ingredient and backbone for development of the country in general, and of the industry in particular. In the landscape of national innovation systems, sector innovation system approach is a useful concept for developing an industrial area. For a relatively new industry like renewable energy, issues and problems of the sector innovation system seem to be more diversified and many faceted. As such, to have a concise mapping of the sector innovation system is crucial exercise for identifying problems and suggesting adjustment, especially in the policy framework.

This study, conducted by the team at the National Institute for Science and Technology Policy and Strategy Studies (NISTPASS) with support of the Hawaii Natural Energy Institute, has provided a mapping of renewable energy sector in Vietnam, while focusing on solar and wind energy. The study used the methodology and framework of a sector innovation system approach. It has identified number of trends and issues emerged from the practice of the sector development. The framework itself can be used for similar sectors or subsectors of the energy industry.

The issue of localization and self-mastering technology capability of Vietnamese actors within industry is one of particular interest. It demands that overall policy framework and incentive system in Vietnam need to be more proactive in various aspects to promote the development of the independent industrial sector for the country in the years to come. Academically, this study could be a useful source for further analysis of status of innovation and innovation systems in other industries. For energy sector, this study contributes to a better understanding and exploring new pathways of the sector development in Vietnam.

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