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Japan's Energy Security: Opportunities and Challenges of Renewables in post-Fukushima Energy Scenario

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At present, more than half of the world's energy demands are fulfilled through fossil fuels. The burning of fossil fuels releases a large volume of Greenhouse Gases (hereafter GHG) and other pollutants, which are detrimental to GHG mitigation strategies. In addition, the highly fragmented nature of the global energy supply system has amplified the risk of market disruptions and unhealthy competitions for the limited energy resources. Renewable energy is a promising, heterogeneous, domestically sourced and important energy source free from GHGs. Renewable energy is an ideal choice for an energy deficient country like Japan. The article looks at the prospects and challenges of renewable resources in achieving Japan's energy and climate change strategies. The paper argues that existence of a highly advanced renewable energy industry with huge funds for R&D is quite favourable. However, Japan lags behind other nations in the adoption of renewables. The paper identifies some serious obstacles in the adoption of renewables and transition away from fossil fuel dominated energy supply system.

Keywords: Energy Security, Climate Change, Japan, Renewable Energy

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The ever-increasing global demand for scarce energy resources and the rise in GHG emissions from fossil fuels are the two critical drivers for the broader adoption of renewable energy into the global primary energy mix. Since the early 2000s, investments in renewables have expanded rapidly. The renewable energy industry has evolved into a multibillion-dollar market, generating jobs and inspiring regional development. Renewable energy development in Japan started in the mid- 1970s as a response to the oil crisis. The dearth of domestic energy resources in Japan attracted significant interest and produced a large volume of empirical and theoretical literature on the renewable energy sector. Many existing works emphasise the strategic, geopolitical and economic implications of fossil fuels and crude oil; similarly, nuclear power. Since the early 1990s, a series of policy initiatives has been introduced to expand the ratio of renewables in Japan's primary energy basket. The shutdown of nuclear power plants following the 3/11 Fukushima disaster has revitalised interest in renewable energy development. Japan unveiled plans to achieve net-zero greenhouse gas emissions by 2050, which calls for tripling renewables' share in power generation to at least 50 per cent (Nikkei Asia, 2020). In light of these developments, this paper strives to analyse the growth prospects and challenges of renewable energy in Japan. The paper presents an overview of Japan's renewable policies in the past two decades. It proceeds to discuss the structural issues and challenges hampering the growth of the sector. The concluding part outlines the potential contributions of renewable energy to diversifying Japan's energy basket. The paper does not analyse all renewable resources in detail like the ocean thermal, wave energy, algae, transition to the hydrogen society, as research is still in an embryonic state and these resources have not developed commercially in Japan. The paper entails a descriptive and analytical method based on both primary and secondary source materials available on the subject.

Considering the rising number of global environmental issues and energy consumption, the sustainable and unlimited nature of renewable energy can address these challenges effectively (Watanabe, 1995). Niazi (2013) argues that renewable energy is the best tool to reduce Japan's foreign energy dependence and achieve ambitious environmental targets. Esteban et al. (2014) supportingly posits that Japan should focus on developing various storage systems, including hydrogen cells, on making renewables more efficient and commercially successful. Nesheiwata and Cross (2013), on the other hand, argue that given the current socio-economic situation, it remains unclear whether renewables would be able to replace nuclear power effectively. Also, some scholars offer a pessimistic view about the growth of renewable energy; the cost and gestation period for various renewable energy resources are considered higher and longer. They argue that the political establishment and business class have always favoured nuclear power (Nakano, 2012; Moe, 2012; Kanako, 2015).

A Brief Review of Japan's Renewable Energy Policies

Beginnings of Intervention in the Renewable Energy Sector

For a long period, the Japanese government did not give any significance to renewable energy. Until the early 1970s, except for hydropower, Japan largely overlooked all other forms of renewables and maintained high external energy dependency. As a rapidly growing economic powerhouse, Japan remained one of the world's largest fossil fuel and uranium importers. Prior to the first Oil Crisis, the Japanese government focused mainly on developing hydroelectric power projects. Until the late 1970s, nearly 40 per cent of Japan's total electricity generated came from various hydropower projects (Nemetz et al., 1985). After the first oil crisis, the Japanese government seriously considered renewables as a viable alternative for imported oil from the Persian Gulf. In the aftermath of 1973 energy crisis, the Japanese government introduced several policy measures to significantly increase the proportion of renewable energy resources in the power generation sector, the most significant of them being the Sunshine Programme of 1974. It was one of the most aspiring and comprehensive policy documents released by the Japanese government to enhance the share of renewables in Japan's primary energy supply system (Choudhry et al., 2014). Although the Sunshine Programme aimed at promoting all renewables, in reality, the Japanese government had a keen interest only in the development and commercialisation of solar thermal technologies (Wei. et al. 2014). Other renewable energy options such as wind power and geothermal energy were wholly ignored. A significant portion of the R&D funds for renewable energy development had gone into the research of advanced solar thermal technologies. Unfortunately, the government's solar thermal energy promotion policies failed to elicit any interest from the manufacturing and power generation sector. Even the lucrative R&D funding did little to attract interest from the manufacturing sector. Both the power companies and manufacturing firms strongly believed solar thermal technologies were risky and impractical. As a result, all further research on solar thermal technologies was discontinued towards the end of the 1970s.

Interest in renewable energy technologies received a significant boost in the early 1980s. In the aftermath of the second oil crisis, the MITI introduced a law concerning the Promotion of Development and Introduction of Oil Alternative Energy or the Alternative Energy Law. On 14th May 1980, a draft bill of the Alternative Energy Act was submitted to the National Diet, and after much discussion, on 30th May 1980, it was passed (GrahamInstitute, LSC). The Alternative Energy Law is the most important and fundamental policy document on which all Japan's subsequent renewable policies are based. It also recommended the establishment of the New Energy Development Organisation (NEDO). The establishment of NEDO in October 1980 was a watershed in the development of renewable energy in Japan. Since its inception, NEDO has been assisting MITI in preparing renewable energy policies and implementing crucial renewable energy development projects. It has played an instrumental role in the research, development, and commercialisation of advanced photovoltaic (hereafter PV) technologies in Japan. NEDO's technical and financial support was crucial in establishing an advanced solar PV manufacturing industry in Japan. Japanese manufacturing giants like Sharp, Sanyo, Hitachi and Toshiba greatly benefited from the technical support and financial assistance of NEDO in the research and development of world-class PV cells in the eighties and early nineties. NEDO also unsuccessfully tried to develop a robust domestic PV market in the early 1980s. However, sales were largely constrained to specific areas such as satellites, isolated telecommunication stations, off-grid lighthouses, leading to the exit of Toshiba and Hitachi, who deviated their interests and resources to concentrate on the nuclear-related sectors (Kimura & Suzuki, 2006).

The 1980 Alternative Energy Law also gave great attention to geothermal energy development. Until the early 1980s, METI was directly involved in the R&D of geothermal technologies. In 1977, an advanced research institute was created for conducting advanced research on the development of geothermal technologies. It was also responsible for allocating budget and other financial services for entities engaged in the development of various geothermal projects. In the late 1970s and early 1980s, geothermal developers received most of the research funding allocated for renewable energy projects. It was partly due to the failure of solar thermal projects. After the establishment of NEDO in 1980, its operational activities were transferred to NEDO (Vivoda, 2014). Nearly two-thirds of the geothermal power facilities currently in operation developed in the early 1980s with the technical and financial support of NEDO. The state of wind energy remained regrettably weak throughout the eighties and nineties. The Japanese government hardly showed any interest in the development of wind energy technologies. Only a handful of projects were announced in nearly two decades until the 1990s. Since the 1980s, NEDO, with the technical support of Mechanical Engineering Laboratory (MEL), oversaw two pilot wind energy projects in Miyake Islands, Tokyo, in 1985 and 1988 (Izumi, 1999). The top brass of MITI's influential bureaucracy was indifferent to the commercial introduction of wind energy. NEDO conducted preliminary surveys for several wind power projects. However, they were abandoned due to an insufficient budget. Wind energy projects received only a tiny fraction of the R&D budget compared to PV and geothermal power development projects. The lack of government support and financial incentives deterred the big manufacturing establishments and power companies from making risky investments in the wind energy business. As a result of regressive decision-making at the top level bureaucracy, Japan lagged far behind Europe and the US in research, development, and promotion of wind energy.

1990s-2010: The Era of Diversification

Since the 1990s, the growing awareness of carbon-induced climate change has prompted world nations to reconsider their energy strategies. Japan has also played a crucial role in climate change mitigation initiatives by hosting several high-level international summits and multilateral conferences. The Japanese government also tried to promote nuclear power and eco-friendly transportation systems as a defining element of its economic diplomacy (Okano-Hejimans, 2012, pp. 340). Prior to 2011, nuclear power was at the centre of Japan's CO2 mitigation strategies. Nevertheless, the Japanese government had also launched several programmes to develop renewables (Bhattacharya et al., 2014). Initially, most of the renewable energy policies were targeted at the development of world-class PV systems. Geothermal energy development also received some support later on. MITI and NEDO had launched research funds to support renewable energy technology R&D programmes. In the 1990s, Japan held the largest R&D fund for renewable energy development among all OECD countries (IEA, 2008). However, it was only a fraction of the amount allocated for nuclear research.

The "New Sunshine Programme" was the most effective long-term renewable energy strategy announced in the 1990s. Drafted and implemented by the Energy Policy Committee of MITI, the 1993 New Sunshine Programme was the most comprehensive and meticulously formulated policy measure in nearly two decades to expand the share of renewables in Japan's primary energy supply system. An annual budget of ¥56 billion was allocated under the 1993 Sunshine Programme to research and commercialise various renewable energy technologies (Graham Institute, LSC). NEDO and New Energy Foundation (NEF) were responsible for the implementation of this programme. While the New Sunshine Programme initially aimed to enhance the ratio of all renewable energy options, when it was launched, the commercialisation of PV technologies got priority over all other renewables. More than 70 per cent of all R&D funds went into the development of highly efficient solar cell manufacturing technologies, solar cell evaluation systems, super-thin PV film, etc. The programme's launch reinvigorated the solar equipment manufacturing sector, which had been going through a slowdown since the mid-1980s. The 1993 New Sunshine Programme cemented Japan's position as a world leader in developing state-of-the-art PV technologies (Vivoda, 2014). Nonetheless, this initiative ignored all other renewable energy resources. Despite having an enormous potential of untapped heat resources and the world's most advanced technologies, the share of geothermal energy failed to register any significant growth. Despite significant growth in wind energy globally in the 1990s and 2000s, the state of wind energy deteriorated further in Japan. Though the Sunshine Programme did recommend some measures to boost the ratio of wind power generated electricity, it failed to stimulate any positive response from investors or power companies (Valentine, 2011). Since the second half of the 1990s, the ratio of the budget for wind energy development also declined sharply. Only limited research on wind energy development continued in the private sector, mainly through the research grants provided by manufacturing and corporate houses.

Despite the introduction of the Sunshine Programme, the demand for PV products remained weak. To boost the demand for solar energy systems in the domestic market, the Japanese government brought in a series of policy initiatives in the subsequent years. One such initiative was the Subsidy Program for Residential PV systems introduced in the summer of 1994. Under the scheme, subsidies were offered to individual households to purchase PV modules and auxiliary accessories. The subsidy also covered nearly 50 per cent of the cost of installations. The NEF was authorised to implement the programme. Moreover, the individual consumers had to purchase particular PV units recommended by NEF to avail themselves of the subsidies. The subsidy scheme continued for more than a decade until the programme came to an end in 2006. The 1994 Residential PV Subsidy programme played a huge role in making Japan one of the world's largest manufacturers and consumers of PV systems. At the time of the launch of the New Sunshine Programme and other PV subsidy schemes, solar energy harnessing technologies remained prohibitively expensive, despite the efforts of the Japanese government to pour in massive amounts to fund these, including the related R & D initiatives.

The ultimate goal of the Japanese government was to establish a world-class PV manufacturing industry to target the overseas market. From the latter half of the 1990s, the Japanese government launched additional policy measures to expand electricity sourced from various renewable sources. In 1996, the New Renewable Energy Policy Target was introduced with a long-term goal of renewables (excluding hydro and geothermal) to account for 3 per cent of the total primary energy system (Dent, Christopher M. 2017: 96). However, on 23rd June 1997, the Law Concerning Special Measures for Promotion of New Energy Use or the 1997 New Energy Law was adopted by the National Diet. It set a new target of renewables to account for at least 5 per cent of the total primary energy system by 2010 (Graham Institute, LSC, 2017). To achieve this ambitious target, it recommended enhancing the share of 'new renewables' in the primary energy basket. It offered financial incentives and promised tax breaks for power utilities to purchase electricity generated from solar and wind sources. However, it is essential to note that electricity generated from hydropower and geothermal sources were excluded from the scope of the 1997 Law. Similarly, in April 1998, MITI adopted Promotion for the Local Introduction of New Energy, intending to broaden the retail market for various renewables. Under this scheme, public entities and NGOs were granted a small subsidy to install new renewables such as PV, biomass and wind power. However, in reality, only the solar PV sector was the primary beneficiary of the scheme.

The adoption of the Renewables Portfolio Standard System (RPS) Law was one of the most critical policy initiatives aimed at disseminating new renewables in the last decade. Germany had successfully implemented a renewable energy purchase scheme. Various environmental groups and NPOs persuaded the Japanese government to adopt a similar electricity procurement programme, which obligated the power utilities to purchase a portion of the electricity generated from renewable sources. However, its implementation was repeatedly postponed due to high-level pressure from the influential regional power companies (Vivoda, 2014). After many delays, a watered-down version of the RPS was officially launched in 2003. It set a goal of at least 1.5 per cent of electricity generation through renewable sources by 2010. The 2003 RPS stipulated that the electric power utilities have to distribute a certain amount of electricity sourced from various renewable energy sources such as solar, wind, geothermal and biomass. Unlike previous renewable purchase schemes, electricity generated from small-hydropower projects up to 1 MW capacity were also made eligible for purchases under the 2003 RPS scheme (Maruyum et al., 2007). The power utilities had two options to meet the targets set by the RPS. They could either produce electricity from own-renewable energy generation facilities or buy electricity generated through any carbon-free sources from independent producers (Vivoda, 2014, pp. 147). The purchase volume was determined according to the cost of power generation and fluctuations in regional power demands. However, the 2003 RPS failed to achieve 1.5 per cent of electricity generation through renewables.

The 'Cool Earth 50 Project' was another ambitious initiative introduced by the Japanese government in the late 2000s. Announced by Prime Minister Shinzo Abe in May 2007, Cool Earth Project was a long-term measure to counter carbon emissions by promoting innovative renewable energy technologies in Japan and abroad (METI, 2008, pp. 13-15). The Cool Earth 50 Project identified some innovative technologies in the power generation and transportation sector for mass-production. Biofuels and plug-in hybrid/electric vehicles from the transportation sector and PV and high-performance power storage systems from the power generation sector were selected for large-scale deployment. The Cool Earth Project also emphasised the internationalisation of renewable energy technologies and strengthened international cooperation to accelerate innovative technology R&D (METI, 2008, pp. 45-51). The Cool Earth Project was a notable attempt by the Liberal Democratic Party (hereafter LDP) led government to turn Japan into a manufacturing and export hub of renewable energy technologies. It aimed to bolster Japan's credentials as a green energy pioneer in various international environmental and renewable energy forums.

The Democratic Party of Japan (hereafter DPJ) came to power in September 2009 pledged for an aggressive push for various renewables. The DPJ government promised to introduce a multi-sector Feed-in Tariff (hereafter FIT) scheme. In November 2009, the DPJ government introduced a limited FIT under the Excess Electricity Purchasing Scheme for Solar PV Electricity, replacing the existing RPS of 2003. Under the new scheme, all power utilities were directed to purchase excess electricity produced from the rooftop solar PV system at a fixed price [the purchase price for residential PV facilities was set to 48 yen/kWh and that for non-residential was limited to 24 yen/kWh] for 10 years (Dewitt, 2015). The Solar Electricity Purchase Scheme of 2009 also ensured preferential grid access to the electricity generated through PV systems. It was an ingenious plan designed to decarbonise the power generation sector. However, the power utilities actively lobbied against the introduction of the mandatory power purchase scheme. The pro-nuclear lobby within METI was also dissatisfied with the DPJ government's decision to promote costly renewables (DeWitt & Tetsunari, 2011). The sustained pressure from METI and the influential power utilities prompted a favourable outcome for the pro-nuclear clique. The DPJ government promised to make critical revisions to the 2009 Solar Purchase Scheme before its official introduction. Subsequently, when the bill was formally adopted, the power utilities were given authority to purchase electricity only from households with rooftop PV installations below 500 kWh. Furthermore, the Law also empowered the power utilities to decline power produced by commercial producers. It has severely restricted the DPJ's declared goal of decarbonising the power generation sector.

A year later, the DPJ government drafted and introduced its one and only Basic Energy Plan (BEP). "Zero-emission" from the energy sector was one of the key goals of 2010 BEP (Duffield & Woodall, 2011; Samuels, 2013). To achieve this target, it recommended doubling the ratio of renewable energy sources to 9 per cent by 2020 and a further increase to 13 per cent by 2030 (Vivoda, 2014). The 2010 BEP also highlighted the need to establish an environmentally friendly energy supply infrastructure and recommended introducing a new FIT scheme comprising all renewable energy resources for Japan's primary energy mix. The 2010 BEP urged the government to overhaul Japan's energy industries completely. However, towards the end of the 2000s, the Japanese renewable energy industry started to face intense competition from its Asian neighbours. For instance, though Japan had been a world leader in the production and sales of solar panels for more than one-and-a-half decades, towards the end of the 2000s, the low-cost Chinese and Taiwanese PV cell manufacturers captured a significant portion of the global PV market, pushing the Japanese PV makers to the margins. The 2010 BEP proposed tax cuts, subsidies and other financial incentives to boost fresh investments in the domestic renewable energy manufacturing sector. The 2010 BEP also aimed to diversify Japan's industrial base towards a multi-sector low carbon economy (Dent, 2017, pp. 98).

Post 3/11 Renewable Energy Policies

The Fukushima disaster ignited an aggressive push towards the faster adoption of renewables in Japan's primary energy system. The 2012 Innovative Strategy for Energy and the Environment (ISEE), prepared by the Energy and Environment Council (EEC), was the first major energy policy document released after the 3/11 disaster. The 2012 ISEE favoured the gradual withdrawal of nuclear power from Japan's primary energy system and looked towards eliminating it by 2040. It also recommended a far greater role for renewables in Japan's future energy scenario. Over the years, many energy-deficient countries have made significant progress in expanding renewables in their primary energy mix through various FIT programmes. Within East Asia, several countries had already adopted policies for the promotion of various renewables. The 2012 ISEE urged the government to accelerate necessary measures to formally introduce a comprehensive FIT scheme encompassing all renewable energy forms. Although Japan had a limited FIT since 2009, it was limited only to rooftop solar PVs while excluding other renewables such as geothermal, wind and biofuels. The 2012 ISEE rightly identified grid accessibility as a major obstacle for the deployment of renewables in Japan, hence proposed to establish a national distribution network called 'transmission system stabilisation system', thereby enhancing grid accessibility to renewables. The proposed system would comprise extensive power grids, interconnection points, storage solutions and other efficiency enhancement systems. Lastly, the 2012 ISEE stressed the research, development, and advancement of new renewable energy technologies such as high-efficiency photovoltaic power generation, geothermal, offshore wind power, wave, tidal and ocean thermal, and the development of high-density storage batteries (EEC, 2012). The 2012 ISEE received strong support from the general public and various environmental groups. After minor revisions, the DPJ government proceeded to incorporate the key recommendations included in ISEE into future energy policies. Nevertheless, the influential power utilities and pro-nuclear lobby yet again created unwarranted hindrances to its implementation. The METI and FEPC rebuffed all ISEE recommendations as 'unrealistic' and 'impractical' to Japan's future energy strategies. Once again, the DPJ government succumbed to the sustained high-level pressure and decided to eliminate ISEE's key proposals from prospective long-term energy strategies. It was apparent that the 2012 ISEE had a clear anti-nuclear bias. However, it was one of the most systematic policy documents released in over two decades. Unlike all previous policy papers, the 2012 ISEE precisely pinpointed the fundamental problems hampering the growth of renewables in Japan. The 3/11 incident prompted several rounds of debates and discussions regarding the future path of Japan's energy policies. The Feed-in-Tariff (FIT) scheme was the most crucial policy outcome of such deliberations.

The introduction of the Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities in the National Diet in the fall of 2011 laid down the path for introducing the FIT scheme in Japan. On 1st July 2012, the Japanese Diet passed the new FIT law, which marked a new beginning for renewables in Japan (METI, 2012). The new FIT scheme targeted to achieve 20 to 30 per cent of the energy from renewable sources by 2030 by enhancing the share of PV, wind, geothermal and other renewable energy sources (Firduas et al., 2014). It also aimed to reduce the carbon emissions by 20 to 29 million tons or 1.8 to 2.2 per cent of total domestic emissions (METI 2012; Kazuhiko et al., 2013). The 2012 FIT was a sharp departure from all renewable energy promotion programmes. It targeted the non-residential sector for the massive deployment of renewables. The earlier programmes, especially the 2003 RPS and 2009 PV Purchase Scheme were restricted only to the residential PV sector. The new FIT scheme mandated all electricity distribution companies to purchase a portion of electricity generated from all prospective renewable energy sources such as PV, wind, small hydropower, geothermal and biomass for 10-20 years at a fixed price. The higher tariff set by the FIT encouraged several investors and independent power producers to launch renewable energy development projects. As a result, 6 GW of renewable energy generation capacity was added to Japan's overall energy supply system in just 19 months starting from October 2012 (Takase, 2014). Since the official launch of the FIT in July 2012, the installed capacity of renewable energy power generation, excluding large-scale hydropower projects, grew by 34 per cent till the end of December 2013, primarily due to the wider adoption of solar energy (METI 2014, pp. 46). The construction of large-scale solar power plants soared mainly due to the relatively high tariff offered under the FIT scheme. The relatively high tariff offered for solar PV under 2012 FIT also prompted several foreign entities, including energy companies and financial institutions, to commit large-scale investments in Japan's fast-growing renewable energy market. However, the status of other renewables such as hydropower, geothermal and wind energy did not show any discernible improvements even after the induction of FIT. The concentration of fresh investments exclusively in the PV sector forced the authorities to revise the price initially set for solar. At the same time, additional funds were created for wind, geothermal, small hydropower and biomass projects (Koyama et al., 2014). Furthermore, a more stringent regulatory regime was introduced in 2014 to restrict companies from investing in unfeasible PV power development projects.

In December 2013, the initial draft for a 4th BEP was submitted by the METI before the cabinet for approval. In April 2014, the SEP was officially adopted by the Japanese government. The 2014 SEP argued for the continuation of nuclear power as an 'economic' and 'clean' energy option for future energy scenarios. At the same time, the 2014 SEP reiterated the significance of renewables in Japan's all future energy strategies. It incorporated most of the 2012 ISEE recommendations regarding renewables in achieving energy security. The 2014 Plan recommended the government take appropriate measures to reduce the lead time for the environmental assessment for new renewables (METI, 2014). It also highlighted the need to deregulate and liberalise the distribution system as well. Furthermore, the 2014 SEP provided for the research, development and large-scale deployment of high-capacity batteries and other storage options to bring down the operating cost of renewables (METI, 2014, pp. 42). It also emphasised the development and commercial introduction of innovative renewable technologies such as large floating offshore wind power generation and ocean energy technologies. The 2014 SEP also recommended the government to take necessary steps to establish the Tohoku region and Fukushima in particular, as the centre of Japan's renewable energy industries. In April 2014, the National Institute of Advanced Industrial Science and Technology had opened the Fukushima Renewable Energy Research Institute to carry out further research on geothermal and wind power generation technologies.

The latest Strategic Energy Plan approved by the cabinet on 3rd July 2018 also underscored the significance of renewable energy in Japan's long-term energy scenario. According to SEP (2018), "....it [renewable energy] is a promising, multi-characteristic and important energy source which can contribute to energy security as it can be domestically produced free of greenhouse gas emissions, is low-carbon, and is utilised with a focus on reducing the environmental load over the long term" (METI, 2018, pp. 20).

Organisational Structure

METI has complete authority over the formulation and implementation of Japan's renewable energy policies. In practice, ANRE, an influential body within METI, is responsible for the planning and execution of Japan's renewable energy strategies. NEDO, another important institution affiliated to METI, advises METI and ANRE in framing and drafting renewable energy policies. Apart from the advisory role, NEDO also plays a crucial role in the promotion and commercialisation of various renewable and green technologies. It regularly collaborates with the reputed institution to conduct advanced research on various energy technologies such as storage solutions, hydrogen fuel cells and so on. It also coordinates joint research between Japanese universities and leading international research institutions in the field of renewable energy. Furthermore, NEDO also extends financial assistance and subsidies to industry leaders for the commercialisation and export of various renewable energy technologies.

The Ministry of Environment, Ministry of Agriculture, Forestry and Fisheries are also key to the implementation of renewable energy strategies. The Ministry of Environment is entrusted with the executive authority to issue and regulate guidelines related to CO_2 and GHG emissions from the energy sector. The regulatory approval from the MoE is also mandatory for the execution of various renewable energy projects. For instance, all major geothermal heat sources are located in or close to national parks and other ecologically sensitive areas protected and directly administered by the MoE. Hence, environment assessment certification from the Environment Ministry is compulsory for any kind of research or commercial activities anywhere near the zones designated by the MoE. Similarly, the Agriculture Ministry's authorisation is required for the installation of wind power or biomass projects on pastures, agricultural land or forest area. Japan Photovoltaic Association (JPA), Japan Geothermal Association (JGA) and Japan Wind Power Association (JWPA) are the three prominent representative bodies from the private sector. JPA was constituted in the early 1990s to represent the interest of electronics and semiconductor manufacturers like SHARP, SANYO, Panasonic, Kyocera, Solar Frontier, Toshiba, and Mitsubishi. JGA was established only in 2011. Mitsubishi, Toshiba and Fuji, are the prominent members of JGA. Its main objective is to give technical advice and assistance to companies involved in geothermal energy development. JWPA is the representative body of manufacturers and equipment suppliers from the wind energy sector.

Status and Potential of Various Renewables

The Great East Japan Earthquake of March 2011 was a watershed for renewables in Japan's long-term energy security strategies. In the aftermath of the Fukushima disaster, the national, regional and local governments introduced several subsidies and support mechanisms to enhance the share of renewables in Japan's primary energy basket. As mentioned in the previous section, the adoption of FIT in July 2012 has bolstered the position of renewables. (Edahira, 2013). As a result, within two years, the share of renewables in Japan's primary energy system grew to nearly 6 per cent. Moreover, the ratio of electricity generated from various renewable sources has also risen to over 17 per cent of the total electric power supply. The following section examines the status of renewables in the post-Fukushima energy supply scenario and future growth potential in detail.

Hydropower

Japan was the first East Asian country to develop a hydroelectric project back in the late 19th century. In 1888, Bonseki Misawa Power Plant in Miyagi Prefecture went online, supplying electricity to the local community (Dent, 2017). In the 1950s and early 1960s, nearly half of electricity was provided by large-scale hydropower plants in Japan. However, since the mid-1960s, fossil fuels replaced hydropower as the largest power generation source. Even at present, a significant portion of Japan's renewable energy continues to be water-powered. Japan has roughly around 35-40 GW of hydropower capacity, providing more than 70 per cent of electricity generated from renewable sources (Vivoda, 2014). Nonetheless, no major hydroelectric power projects have been commissioned in the last two decades. All of Japan's existing major hydro projects currently in operation have been established before 1995. In the post-Fukushima scenario, the Japanese government introduced several policies to boost electricity output by effectively utilising the largely overlooked small and medium hydropower potential. The FIT was revised in 2013, and the tariff offered for small hydroelectric projects was fixed to ¥34 per kWh

(METI, 2014). Similarly, the existing River Law was revised in March 2014 to ease the application procedures for smaller and micro-hydroelectric power projects. Since then, several independent power producers (IPP) and established power utilities have submitted plans to develop several small and medium hydroelectric projects with an estimated capacity of 17 GW (Koyama et al., 2014, pp. 505).

Geothermal energy

A major advantage of geothermal energy over other renewables is its ready availability. Geothermal heat is available around the year irrespective of changes in seasons, weather or climatic conditions. Geothermal is versatile for its wide range of applications in power generation, space heating, agriculture, and aquaculture. Located close to the Pacific Ring of Fire, Japan is home to hundreds of volcanoes and hot springs, making it an ideal location for geothermal projects. According to JNIAIST, Japan's geothermal resources are estimated to be around 26 GW, making it the third-largest pool of geothermal resources globally behind the US and Indonesia (Koshiba, 2010). Electricity generation using geothermal sources started in Japan in the early 1970s. Since the late 1970s and early 1980s, the Japanese government vigorously promoted indigenous geothermal technologies. As a result, Japan currently has an excellent geothermal manufacturing industry supplying close to 70 per cent of global geothermal plants and related equipment (The Economist, 2012; Nesheiwat, 2013). Despite having immense potential and technological advantages, the share of geothermal in Japan's primary energy system remains minuscule. From the 1990s onwards, investments in geothermal projects started to decline slowly. Between 1996 and 2014, only one major geothermal power facility was commissioned in Japan. The 2,000 kW capacity Kuju Geothermal Power Plant was constructed and began its full-scale operations in 2000. At the beginning of the last decade, Japan was reasonably ranked sixth in the world for the utilisation of geothermal heat sources. However, by the end of 2009, Japan slipped to the eighth position for geothermal power generation (Koshiba, 2010).

Before the launch of FIT in 2012, the installed geothermal capacity was just 0.5 per cent, the lowest among all renewable energy resources (Koyama et al., 2014). Since then, the Japanese government has introduced various policy measures to fully utilise the potential 26 GW equivalent of the geothermal heat sources spread across the country. The FIT was the most significant policy initiative for the development of geothermal energy in over two decades. Under the 2012 FIT scheme, the government has set a rate of ¥27.3/kWh for electricity purchased from geothermal projects below 15 MW and ¥42/kWh for plants with lower capacity (Cichon, 2015). It was double the rate offered for other renewables such as wind and biomass. In addition, METI has pledged to reinstate financial support for the research and development of more advanced geothermal technologies. The Japanese government had previously offered research funding for geothermal technology R&D. However, in early 2003, all funding was abruptly ended, which resulted in a slowdown in geothermal industrial productivity (World View, 2012). Since 2012, the government has assured financial assistance and tax breaks for preliminary surveys and drilling operations. It has motivated a renewed interest in geothermal energy development (Cichon, 2015). In late 2011, Japan Geothermal Association (JGA) was also established to promote geothermal projects.

At present, JGA assists ANRE in providing support and technical advice for more than 50 companies engaged in numerous geothermal development projects. Over the past three years, several companies from diverse business backgrounds have ventured into geothermal energy development. For instance, Tokyo-based financial services company Orix announced in 2013 that it was planning to build as many as fifteen (2MW) geothermal plants in the next five years. In late 2014, Orix successfully established a 2-MW geothermal plant in Kumamoto by collaborating with Chuo Electric Power (Demetrio, 2014). It was the first major geothermal facility to go online in 15 years. Similarly, Mitsubishi, Softbank, Mitsui, Idemitsu Kosan Co., etc. have been actively engaged in exploratory operations in over 40 locations across Japan (Cichon, 2015).

Biomass/biofuel

Biomass/biofuel did not feature prominently in Japan's long-term energy strategies until the early 2000s. The first programme for the promotion of biofuels was the Biomass Nippon Strategy (BNS). The BNS was announced in December 2002 with four key goals of arresting global warming, the creation of a recycling-oriented society, the establishment of a new strategic industrial system and promotion of agriculture and forestry as rural growth and job creation strategy (Dent, 2017, pp. 283). The 2008 Cool Earth Programme and the 2010 BEP had also touched upon various measures to integrate bioenergy into the portfolio of Japan's long-term renewable energy portfolio. The use of biomass/biofuel in the power generation and transportation sector has grown exponentially since the Fukushima incident. Prior to March 2011, Japan's biomass-fuelled power generation capacity was around 1.9 GW. Japan's biomass-fired power generation capacity has witnessed an incredible 240 per cent growth in the months following the Fukushima nuclear disaster (IEA, 2016). The Japanese government also encouraged the wider application of biofuel/bioethanol in the transportation sector as part of various energy efficiency and cost reduction programmes. Even though biofuel use may appear on the rise, in reality, Japan's bioenergy programmes face far more barriers than all other renewables. Despite several attempts by the government, biofuel production in Japan remains relatively low. More than 95 per cent of bioethanol used in the transportation sector was imported from abroad [mainly from Brazil] (Dent, 2017, pp. 284). Due to Japan's unique geography, the conversion of scarce agricultural lands for growing energy crops may raise severe questions of food security. Furthermore, the highly influential farm bodies would also raise strong objections against the conversion of farmlands for energy fuel crops development. Additionally, coal and other fossil fuels are blended with biomass/biofuels to enhance thermal efficiency in the power generation process. The practice of mixing biofuels with fossil fuels would be counterproductive to Japan's ambitious GHG mitigation strategies.

Solar power

For a long time, solar power was at the centre of Japan's renewable energy strategies. The introduction of FIT has stimulated further investments in large-scale PV generated electricity projects. For instance, in 2010, the installed capacity of PV in Japan's primary energy system was 3,618 MW. However, within a gap of two years, the share of installed PV has risen 20-fold to an incredible 23,339 MW (IEA, 2016).

The rapid expansion of large-scale solar projects is the most striking development in Japan's renewables sector post-2011. Since the introduction of FIT in 2012, more than three-quarters of all electricity generated from PV sources are supplied by mega solar projects. Japan's PV market has been historically dominated by a select group of Japanese electronics and semiconductor behemoths like Sharp, Sanyo, Solar Frontier and Kyocera. These companies concentrated mainly on the manufacturing of solar panels and other hardware for residential use. However, after the introduction of FIT in 2012, several business entities have entered Japan's lucrative solar energy market (The Japan Times, 2016). Overseas investors and PV makers also have made significant investments in Japan's PV market since 2012. The high price for the solar-generated electricity offered under the FIT is the primary factor attracting overseas companies into the Japanese market. Despite tariff cuts for solar under the revised FIT, the Japanese premium for solar PV remains one of the world's highest.

Another notable development in the post-Fukushima renewable energy scenario is the entry of giant manufacturing houses and trading companies into the renewable energy business. Part of the influential nuclear energy clique, most of the big manufacturing establishments and trading firms had previously refrained from investing in the domestic renewable energy sector. However, after 2012, Japan-based multinational corporations and manufacturing giants like Mitsubishi, Toshiba, Hitachi, etc. had ventured into the manufacturing and sales of solar PV and auxiliary hardware in the domestic market. Trade houses like Itochu, Mitsui, etc. have also entered the renewable energy business (JFTC, 2016). Since the introduction of FIT in 2012, Itochu has bolstered its operations in the renewable energy sector. Likewise, in partnership with Softbank Group, Mitsui has successfully installed a 111 MW mega-solar power plant in Hokkaido (Humber, 2012).

Wind energy

Wind energy has an immense potential compared to other renewables in Japan. Japan has the potential to build enough wind power facilities to produce 280 GW of electricity annually (Mizuno, 2014). Figures from Japan Wind Power Association (JWPA) reveals that since July 2012, total wind power installations have witnessed a 30 per cent increase to 2,077 units (2015), contributing roughly around 3,038 MW of total electricity (JWPA, 2016). Nevertheless, Japan is yet to utilise the available wind power resources fully. Moreover, fresh investments in wind energy in Japan lag far behind other countries. Offshore wind farms are fast emerging as an alternative to land-based wind power projects. Steady and continuous wind conditions, the possibility of large-scale deployment without the concern for land availability and the scope for deploying larger blades of more than 100 meters in diameter are some of the factors that favour offshore wind projects (JWPA, 2016). Japan has huge potential for mass deployment of offshore wind power generation facilities. Some top-ranking research institutions and big businesses are engaged in developing economically viable offshore wind power technologies. For instance, joint consortia led by the University of Tokyo and Marubeni have completed a demonstration project off the coast of Fukushima prefecture. Mitsubishi, Nippon Steel Works, Mitsui and Mizuho Institute are also partners of this ambitious project (Marubeni, 2014). So far, the government's response has also been very encouraging.

In 2013, the cabinet announced a $68 million R&D fund to develop and commercialise cost-effective offshore wind power generation systems (The Japan Times, 2015). The latest energy strategy released in 2018 reiterated the tremendous potential of wind energy in the Japanese government's attempts to decarbonise power generation and the transportation sector.

Challenges to the Dissemination of Renewables

Japan has a well-established renewable energy manufacturing sector. Japan's geothermal and PV equipment manufacturing industry has continuously been rated among the world's best. Japan is also consistently ranked high among nations in investments in innovative energy solutions. In 2014, Japan ranked third behind the US and China in terms of R&D spending on innovative energy technologies (IEA, 2016). Japan also ranked high among countries with the highest number of patent applications in the renewable energy sector. The public opinion post-2011 strongly favours the introduction of safer and cleaner renewable energy options in the future energy scenario. The EES (2011), the FIT (2012), SEP (2014 and 2018) set ambitious targets for the expansion of renewable energy in Japan's primary energy supply system. Despite having a host of favourable factors, the ratio of renewables in Japan's energy supply basket remains extremely limited. Japan has the second-lowest share of renewables in primary energy systems among all OECD countries. As noted earlier, the Japanese government has introduced several measures to boost the ratio of renewables in the primary energy mix. Nonetheless, except for solar, all endeavours aimed at the development of renewables have been futile. Following are some of the major obstacles to the expansion of renewables in Japan's primary energy system.

Bias towards Solar Power

Majority of the renewable energy promotion programmes introduced in the last two decades or so had given paramount importance to solar power. The top-ranking bureaucrats within MITI/METI had prioritised renewable energy schemes exclusively to advance solar and PV manufacturing industries. On the other hand, the MITI/METI officials have shown little interest in promoting other cost-effective and technologically advanced renewable energy options such as wind and geothermal energy. For instance, in 2009, the average cost of wind power generated electricity was four times lower than solar energy (Vivoda, 2014). However, the limited FIT scheme introduced in 2009 focused on expanding comparatively expensive solar energy products. Geothermal, hydropower and wind power were largely overlooked in order to promote solar PV. Proponents of solar energy argue that the gestation period for geothermal and wind energy projects are far longer, and the initial capital required for the construction of hydropower projects are higher than PV. Others contend that the real intention of the top brass of the Japanese bureaucracy and political elite is to protect the commercial interest of the influential power utilities and manufacturing houses. For MITI/METI, there was no difference between energy and industrial policy (Moe, 2012; Vivoda, 2014).

When the Sunshine Programme was announced in 1974, solar and PV technologies were still in the embryonic state. The Japanese leaders were convinced that by moving early, Japanese manufacturing industries could easily establish a global monopoly in solar PV manufacturing and distribution systems (Vivoda, 2014).

Hence, MITI introduced a series of policies to support establishing a manufacturing industry to export solar and auxiliary equipment to overseas markets. Because of years of experience in the mass production of electronics and semiconductors, the establishment of the PV manufacturing industry was relatively easy. The establishment of NEDO in 1980 further accelerated the growth of a robust solar industry in Japan. Like MITI, NEDO also prioritised solar energy development as the core of Japan's future renewable energy policies. Although NEDO was established to coordinate research activities in the renewable energy sector, a substantial portion of R&D funds was allocated exclusively to develop solar and PV technologies. The nascent solar industry had received millions of yen annually as research funds from NEDO (Moe, E. 2012). The only nuclear industry received more R&D funding than the solar industry. This underscores the importance MITI has given to solar energy technologies.

The government patronage for PV industries continued into the late 1980s and early 1990s. The MITI offered research grants and subsidies for the development of the latest PV technologies. Nevertheless, the demand for PV products remained dreadfully weak despite developing a world-class solar hardware manufacturing sector. To boost local demand for PV products, the Japanese government launched a wide variety of initiatives. The launch of the New Sunshine Programme (1993), Rooftops Subsidies Programme (1994) and Subsidy Programme (1996) launched exclusively to promote solar energy at the expense of other renewables. The METI's confidence in solar PV manufacturing as a future growth industry had remained unchanged even in the last decade. For instance, the Cool Earth 50 Project, Green Innovation Plan and the BEP (both in 2010) by the DPJ government and the SEP of 2014 by the LDP government envisaged the establishment of a robust industrial sector focusing on the research and development of advanced renewable energy technologies, mainly for the overseas market (Sovacool & Matuura, 2011). Public and private entities engaged in solar energy development projects received large sums as R&D funds under such programmes. In comparison, other renewables such as wind and geothermal received only a negligible amount.

The influential power utilities also played a remarkable role in the development of solar power. Historically, the established power companies have always maintained a strong position against renewables. However, they did not oppose MITI's solar energy development programmes for several reasons. Before 2012, almost all renewable energy promotion policies were aimed at developing the small residential PV market. The households that applied for subsidies under the PV purchase schemes were already the consumers of power utilities. In addition, before the introduction of FIT, there were no large-scale PV sourced power generation projects in Japan to threaten the established power utilities. Even the 2009 Renewable Purchase Scheme was limited only to rooftop PV installations with a capacity below 500 kWh (Vivoda, 2014). On the other hand, the power utilities vehemently opposed all measures to expand wind and geothermal energy development. The power companies have suspected that wind and geothermal have technological capacity to disrupt and challenge the established market structure. NEDO had completed some pilot wind power projects in the late 1980s and early 1990s. However, the power utilities fiercely opposed the commercial introduction of such technologies into the distribution system. Moreover, the established power utilities have often denied grid access to wind and geothermal sourced electricity citing intermittency and other technical difficulties.

Rigorous Environmental Regulations

Ironically, renewables, the most environmentally friendly energy option, are subjected to rigorous and harsh environmental and other technical regulations. The status of geothermal and wind energy projects epitomise the level of bureaucratic hurdles in Japan to develop renewables. Geothermal energy is one of the most advanced and cost-effective of all renewable energy options currently in use. Unlike wind or solar, geothermal is less susceptible to the changes in weather patterns. Geothermal energy also has utilisation ratio of nearly 90 per cent, which is closer to some of the conventional coal-fired power generation facilities. A study by Japan Geothermal Energy Development Council (JGDC) estimates that electricity at a rate of ¥20/kWh can be generated from a geothermal heat source with an average temperature of 150 degree Celsius (JGDC, 2013). The generous government support received in the late 1970s and early 1980s had resulted in the establishment of a robust manufacturing sector. Japanese manufacturers hold nearly 70 per cent of the global market share in the manufacturing and distribution of geothermal plants and related equipment (Nesheiwat, 2013). Regardless of this, the share of geothermal energy in Japan's primary energy mix has remained constant in the last two decades. One of the significant constraints for the expansion of geothermal in Japan's energy system is stringent environmental regulations. Of the potential 26 GW of geothermal heat sources, more than 80 per cent is located within or close to national parks and other ecologically sensitive regions under the exclusive authority of the MoE. Since the 1970s, the MoE has passed several legislation prohibiting any activities within national parks and other protected areas. Even exploratory drilling anywhere near national parks is prohibited. After the introduction of the FIT in 2012, some of the existing regulations have been relaxed. At present, experimental surveys are permitted within the exclusive zones of national parks but with strict supervision of MoE.

The situation of wind energy development is not entirely different. The existence of rigid safety laws and environmental regulations poses a major obstacle to developing a solid wind energy market. Large wind turbines with more than 100-meter diameter are key to enhancing large-scale wind projects' operational efficiency. In 2004, the Japanese government introduced a series of new safety assessment procedures. Based on the new set of regulations, any developers planning to operate windmills of over 60 meters tall must clear more than 50 safety assessment tests, regulations, guidelines, and other related operational rules from various ministries before the project's official launch (Moe, 2012). Moreover, in October 2012, the MoE introduced a revised Environment Impact Assessment (EIA) procedure mandating all wind power projects above 10 MW to get a compulsory environment impact certificate. The lengthy regulatory process has overstretched the construction period and caused immense economic stress on investors and operators. At present, the whole process, from project planning and site selection to construction and full-scale operation, will take about four years in Japan (Mizuno, 2014). On the other hand, the same process in other countries can be finished in a ten to twelve-month gap (Vivoda, 2014).

Prior to 2012, power companies could install large wind turbines on first-grade agricultural lands and rice fields. However, in April 2012, the Ministry of Agriculture, Forestry, and Fisheries (MAFF) amended the Agricultural Land Act, prohibiting the installation of large-scale wind projects on agricultural lands and pastures (Mizuno, 2014). The JWPA and independent power producers have persuaded the Agriculture Ministry to ease some of the restrictions imposed on wind turbine installations on agricultural land. However, the attempts were mostly unsuccessful. In another move, the government has banned the installations of wind farms on mountain tops and closer to reserved forests, citing visual disturbance and avian casualties.

Fragmented Distribution System and Weak Market for Renewables

The absence of adequate distribution infrastructure is another significant barrier to the faster adoption of renewables in Japan. A well-integrated distribution network is essential for the growth of renewables. It is also fundamental to manage and limit the critical issue of supply intermittency associated with renewable energy. For instance, since 2011, the ratio of solar PV generated electricity has witnessed a significant leap in Japan. Solar panels are most effective during mid-day. With the growing number of solar panels every year, the mid-day demand for electricity is expected to fall further. It creates some serious challenges. First, the solar PV power production stops after sunset, typically when the electricity demand peaks. The coal-fired thermal power and nuclear plants have to ramp up production to compensate for the drop in solar energy. It is tough to do with the existing supply infrastructure. The second problem is purely economic. The coal and nuclear plants are economical only if they are run round the clock. It is not economically feasible for the power utilities to shut down nuclear and coal plants at mid-day. Germany, like Japan, is a highly industrialised nation with a dearth of domestic energy resources. However, Germany has made significant progress in the deployment of renewables in the last few years. Germany's power lines are connected to the European grid (Huntler et al., 2012). In the event of a drop in power density, the German power utilities have an option to easily borrow electricity directly from the European grids and fill in the void. However, in Japan there is no uniform national grid network. The existing grid system uses two different frequencies between east and west (Valentine, 2011). Without establishing additional distribution networks, the growth prospect of wind power and geothermal energy in Japan's primary energy system will be extremely difficult. Japan's best wind sources are located in remote, sparsely populated and mountainous areas far away from high demand urban and industrial regions. One of the important reasons for the impressive growth of PV is the low infrastructure and logistical cost (Dent, 2014, pp. 178). Unlike wind and geothermal energy, PV systems can be effectively operated without a major upgrade to the existing supply infrastructure. A PV system can be deployed in far-off/isolated locations without access to the regional power grid. On the other hand, for the economical operation of large-scale wind and geothermal energy power projects, massive up-gradation of the distribution system is required.

The power utility monopoly over the electricity distribution in their respective regions is also a major obstacle. Many established power companies often deny grid access to independent producers (Vivoda, 2014). The 2012 FIT set out measures to ensure grid neutrality. It recommended that the government impose penalties on power utilities for any curtailment beyond 30 days. The 2012 FIT also proposed that the manufacturing industries purchase a portion of the electricity supplied from renewable sources (METI, 2012). However, the power utilities and energy-intensive manufacturing sector vigorously protested against the proposals and persuaded the government to relax some of the power purchase rules. As a result, the manufacturing sector was given an 80 per cent discount on electricity purchased from renewable energy sources. Likewise, the regional power utilities were also empowered to deny grid access to electricity produced by the independent producers if it disrupted the demand-supply balance (Vivoda, 2014). The 2014 Strategic Energy Plan also included several recommendations to improve ease of access to the existing distribution networks. Another notable development was the establishment of the National Grid System by the LDP government in 2014 (Duffield, 2016, pp. 148-52). However, unbundling or nationalisation of power grids will not solve these issues. Additional distribution infrastructure should be developed either through public or private investments. Furthermore, the introduction of innovative grid management technologies, including IT-enabled smart grid technologies, batteries, and other storage solutions, will also greatly benefit both the producers and consumers. On the other hand, from an economic perspective, the additional cost and the capital expenditure must be kept in check; otherwise, renewable energy may render less attractive to investors.

High Cost and Weak Industrial Organisation

IEA estimates that renewable energy would be the single most significant source of electricity generation in the near future, primarily driven by the falling cost and aggressive renewables expansion spurred by the emerging economies such as China and India (IEA, 2015). In the last five years, the price of solar panels has dropped by 80 per cent. Similarly, the capital cost incurred on wind turbines and auxiliary equipment has also fallen by 30 per cent (IRENA, 2017). Some experts opine that the fall in price would essentially make renewables a more attractive energy choice. The cost of non-solar renewable energy in Japan is extremely expensive and time-consuming. For instance, the high capital cost and extended gestation period have deterred investors from venturing into geothermal projects. Surveys and exploratory drilling alone accounts for about 50 per cent of the development cost. Investing in geothermal power projects is also extremely risky because, on several occasions, the cost of exploratory drilling has far exceeded the initially estimated figures. Until March 2012, only horizontal drillings parallel to the ground surface were allowed in the areas near national parks. It had exacerbated the cost of geothermal energy development. Furthermore, additional funds need to be secured separately during plant construction and operations.

As noted above, the capital cost incurred on wind power installations has dropped substantially in the last few years. Nevertheless, the average capital cost of wind power installations in Japan during the same period was 1.5 to 2 times higher than in other major markets (IRNEA). There are hardly any globally reputed Japanese wind turbine manufacturers or equipment suppliers. The European manufacturers like Vestas and Siemens (JWPA) dominated the nascent Japanese wind energy market. In Japan, nearly 60 per cent of the capital cost is incurred on the procurement of turbines. Almost all installed wind turbines are sourced from abroad as Japan does not have any established wind turbine manufacturers. Similarly, other critical components like gearboxes, blades, bearings, etc. are sourced and imported from foreign suppliers. Furthermore, assembly and installation costs are generally high in Japan due to the lack of an organised manufacturing sector (Mizuno, 2014: 1011). This exacerbates the capital cost for wind power generation in Japan. The cost incurred on surveys, land acquisition, planning and construction put further financial stress on investors. Moreover, the operation and maintenance of wind farms is a daunting task, especially those located in far-off and remote locations (Takase, 2014).

Although offshore wind projects have a tremendous scope in Japan, it has to overcome some serious obstacles. First, Japanese coastal water has an average depth of more than 20 meters. Hence, floating variants of turbine installations are more suitable than the fixed ones. Second, the installation cost of offshore farms is much higher than land-based ones. Special vessels and cranes are required for the transportation and installation of foundation structures in the seabed. Typhoons, thunderstorms, high turbulence winds and other meteorological events pose another serious challenge. Furthermore, the maintenance cost is double that of onshore installations due to the corrosion risk caused by the continuous exposure to the saline air (Hoffman, 2014). Lastly, strong opposition from the local fisher folk is also a challenge.

One of the most important long-term goals of METI is to develop and export advanced renewable technologies to boost economic and industrial productivity. However, it would be extremely challenging to succeed in the global renewable energy market without a robust domestic market system. The European countries have become world leaders in the export of various renewable energy technologies by initially developing a robust domestic market. For instance, Denmark, the world leader in wind energy technology, initially focused on establishing a small domestic industry to cater to local demands. Through the sales of equipment in the local market, the Danish companies steadily improved their products and technologies. The Danish wind turbine manufacturers turned to the overseas market only in the early 1990s after the saturation of the domestic market (IRENA, 2013). Japan has an excellent reputation internationally for its state-of-the-art nuclear and solar PV technologies. The Japanese companies managed to achieve it through continuous improvement and many years of experience in the domestic market.

Local Opposition

The prevalence of extreme opposition to wind and geothermal energy is a crucial constraint to renewable energy development in Japan. Until the late 1990s, many local and regional governments and the general public perceived wind energy as a symbol of technological progress. Taking advantage of the prevailing favourable public sentiment towards renewables as an environmentally friendly energy option, the regional governments furnished licenses to several wind energy developers in the early 2000s. The local administration issued authorisations without conducting enough environment assessment studies. Without any consideration for the local environment, the indiscriminate installations of wind projects have later created tremendous resentment among the local people. Public protest against wind farm installations took place in many regions, forcing local officials to halt new wind power projects temporarily. The lack of a local community benefiting from any of these projects was another concern. The wind energy projects established during the late 1990s and early 2000s did not benefit local communities except visual and noise disturbances (Mizuno, 2014). Even some of the public spaces previously accessible freely to the residents were cordoned off for safety reasons. The antipathy towards wind power projects grew so strong that, in 2003, the MoE introduced a new set of environmental regulations for all wind power development projects that were announced since then. It essentially led to a sharp decline in the growth of wind power in Japan.

Several geothermal energy development projects also faced strong objections from the local communities. As mentioned earlier, more than two-thirds of Japan's geothermal heat sources are located within or close to national parks and hot springs. The national parks and hot springs attract a large number of tourists every year. For many towns and villages, tourism is the only source of stable revenue. Furthermore, there is a substantial cultural value attached to the historic hot springs. Over the years, many local conservationist groups and environmental NPOs have used litigation tactics to slow down or delay establishing geothermal power plants in sites closer to national parks (Kubota et al., 2013). Similarly, the influential onsen (hot spring) owners have also successfully prevented the establishment of new geothermal power projects closer to hot springs (Nagano, 2012). Japan Spa Association, a highly influential representative body of over 1,200 onsen operators spread across the country, has maintained that the construction of geothermal facilities could lower the temperature of the hot springs and the availability of hot water, which is indispensable for the operations of historic bathhouses. In recent times, especially after the introduction of the 2012 FIT programme, the onsen operators have intensified their protest against the establishment of new geothermal projects (The Economist, 2012).

Conclusion

The paper examined the opportunities and prospects of renewable energy in Japan. The international pressure to cut back GHG emissions from the energy sector has prompted the Japanese government to pursue renewable energy along with nuclear power as an alternative to fossil fuels. For decades, nuclear power has received the most attention from the top brass of Japanese decision-making bodies as an alternative to fossil fuels. Nevertheless, since the March 2011 Fukushima nuclear disaster, renewables have registered significant growth in Japan. The paper reveals several obstacles and constraints that impede the broader adoption of renewables in Japan's primary energy system. In the aftermath of the Fukushima nuclear disaster, solar PV sourced electricity generation has registered a substantial growth rate. However, other non-solar renewables such as geothermal energy and wind power still encounter several challenges. The lack of distribution infrastructure acts as a significant hurdle for future growth prospects of renewables. The optimal wind and solar sources lay far away from high demand industrial and population centres. Without adequate grid connectivity, much wind and solar power would go to waste. The National Grid System launched by the LDP government in 2014 is a positive step. However, further additions to the existing distribution infrastructure in the form of smart grids, high capacity batteries and other storage solutions should be instituted either through public or private investments to resolve the issue.

Intermittency is another major shortcoming of renewables. Both solar PV and wind energy are highly susceptible to fluctuations. Hydropower and geothermal heat are relatively stable and less vulnerable to intermittency. Regrettably, mega hydropower deployment is not a viable option for Japan as there is no scope for the development of large-scale hydroelectric projects. On the other hand, the paper establishes that geothermal energy has tremendous growth prospects. It has the potential to replace at least twenty ageing nuclear power plants. Moreover, a well-organised geothermal equipment manufacturing industry in Japan supplies two-thirds of geothermal plants, turbines, and auxiliary equipment globally. Thus, it eliminates the cost incurred on the import of hardware and technologies. Despite the advantages, the growth prospects of geothermal energy and other non-solar renewables have been very slow.

The paper divulges that even after the introduction of Feed-in-Tariff, the growth rate of all non-solar renewables remains very modest. There exists an institutional bias towards solar at the high levels of METI. However, it is not the only reason for the abysmal state of non-solar renewables. The existence of stringent environmental regulations and strong public opposition in some regions also impedes the further expansion of non-solar renewables. New geothermal and wind energy projects require environment assessment certifications, regulatory approvals and safety clearances from various ministries and departments. It is a very complicated and time-consuming process. The paper further revealed that opposition and resistance from local communities and environmental groups had hampered the development of geothermal projects. The biofuels development programmes and offshore wind power development projects also encountered a similar fate. The influential farmers and fisherfolks union have repeatedly expressed their strong opposition and often stall or postpone the projects by exerting political pressure and litigation tactics. Japan has ambitious plans to develop a 'hydrogen society' to decarbonise a range of sectors. Renewables have tremendous prospects in this regard. The excess renewables that cannot be used or connected to the grids can be utilised to produce hydrogen, which can, in turn, be used as a low-carbon alternative for heating offices, homes and other buildings, fuel cells in private vehicles and the urban mass transportation sector.

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