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Renewable energy in eastern Asia: Renewable energy policy review and comparative SWOT analysis for promoting renewable energy in Japan, South Korea, and Taiwan

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HIGHLIGHTS

- Japan, South Korea and Taiwan need to develop renewable energy (RE).
- These countries have been too conservative to achieve a notable share of RE.
- Pro-nuclear energy policies have hindered the RE development in these countries.
- The Fukushima disaster made these countries more favorable to RE.
- Joint cooperation for R&D and deployment of RE is recommended.

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ABSTRACT

Japan, South Korea, and Taiwan are deficient of domestic fossil energy sources and depend significantly on imported fuels. Since the oil shock in the 1970s, all three countries have promoted renewable energy as an alternative energy source to improve energy security. Currently, renewable energy is being promoted to build low-carbon economies. This study reviews the development of renewable energy policies and roadmaps. It also examines and compares strengths, weaknesses, opportunities, and threats (SWOT) of these countries in the context of advancing renewable energy policies and technologies and expanding domestic renewable energy installations, as well as strategically positioning themselves in the international renewable energy market as exporters of clean energy technologies. Through the SWOT analysis, this paper identifies a capacity for additional renewable energy deployment in these countries and highlights the necessity of increased cooperation between the three countries to strengthen their domestic and regional renewable energy sectors and compete in the global renewable energy market in the post-Fukushima era.

1. Introduction

Located in Eastern Asia, Japan, South Korea, and Taiwan have historically developed similar energy systems that primarily depend on fossil fuels. Fossil fuel energy sources constitute about 75 percent of total primary energy supply (TPES) in Japan and South Korea and 90 percent in Taiwan. Also, these countries similarly lack domestic fossil energy resources and depend mostly on imported fuels. Their energy dependency rates are as high as 96 percent or more. Over the past few decades, such fossil fuel-centered energy structures have commonly resulted in causing problems such as high greenhouse gas (GHG) emissions. According to U.S. Energy Information Administration (US EIA) (2014a,2014b), Japan, South Korea, and Taiwan were the 5th, 8th and 23rd largest CO_2 emitters in the world as of 2011, respectively. Moreover, dependence on foreign fossil fuels threatens national energy security in these countries.

As an alternative energy source to fossil fuels, renewable energy sources have long attracted considerable attention among these countries. The countries have identified renewable energy development as a means not only to mitigate the negative impacts

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of their fossil fuel use, but also to strengthen their national energy security. Accordingly, renewable energy markets have been expanding in all three countries. Furthermore, the Fukushima nuclear catastrophe has renewed interest in renewable energy as an alternative to nuclear power.

The primary purpose of this paper is to investigate renewable energy policies in Japan, South Korea, and Taiwan, analyze their advantages and shortcomings for renewable energy development, and provide possible guidance for future expansion of renewable energy in these countries. To achieve this goal, this paper individually discusses the development of renewable energy policies for these countries since the 1970s and their energy roadmaps in Section 3. This section also provides a comparative analysis by utilizing the Strength, Weakness, Opportunity, and Threat (SWOT) matrix as an analysis framework. This SWOT framework is applied to detect internal and external factors that affect renewable energy development in these three countries. SWOT is also utilized to identify how to maximize the strengths and overcome the weaknesses, while taking advantage of the opportunities to overcome the threats. Lastly, the paper makes suggestions to expand renewable energy operations in these nations in Section 4.

2. Methods

This study applies a SWOT analysis framework for a comparative analysis of renewable energy policies in Japan, South Korea, and Taiwan. The framework of SWOT was originally invented for business and marketing analysis and has been broadly adopted in other research fields including energy management (Terrados et al., 2007).

In general, the SWOT framework is composed of internal and external assessments. The internal assessment is conducted to illustrate strengths and weakness of an organization or a strategic plan; the external assessment is applied to discover opportunities and threats (Matthews, 2004). Strengths stand for any available resources that can be used to advance the performance. Weaknesses are flaws, which may decrease competitive advantages, efficiency, or financial resources. Opportunities are external changes that could contribute to an additional development and threats are outside factors that may cause problems (Paliwal, 2006). In the energy management field, SWOT has typically been used to analyze energy situations of a single region or system. However, this paper attempts to expand its application by employing the SWOT analysis to examine renewable energy policies and development in multiple nations.

3. Results and discussion

3.1. Renewable energy targets and policies

The two oil crises in the 1970s led to greater interest in the development of renewable energy as alternative energy sources to oil in Japan, South Korea, and Taiwan. The history of renewable energy development over the past forty years is first reviewed in this section in order to identify unique development strategies in each country.

3.1.1. Japan

Japan depended on oil for more than 75 percent of its energy production in 1973 and the oil crises unveiled the fragility of Japan's energy structure (Ministry of Economy Trade and Industry (METI), 2012). After the first oil shock, METI[1] promptly initiated a 25-year plan called the "Sunshine Project" to develop solar energy technologies. The "Law Concerning the Promotion of the Development and Introduction of Alternative Energy" came into effect in 1980 as a means to reduce Japan's oil dependency and to promote the development of alternative energy. The early stages of renewable energy development focused on geothermal energy and small hydropower (10 MW and smaller). As a result, about 95 percent of current small hydropower plants in Japan were constructed before 1990, and about 95 percent of the current geothermal energy capacity was attained by 1996 (Japan Renewable Energy Policy Platform (JREPP), 2010).

Recent renewable energy development has been promoted under various measures, including the 1993 "New Sunshine Project," which is a successor of the 1974 "Sunshine Project," the 1997 "Basic Guidelines for New Energy Introduction," the 1997 "New Energy Act," and the 2009 "Non-Fossil Energy Act". In addition, a Renewable Portfolio Standard (RPS) has been in practice since 2003 with an annual target set for electric retailers to utilize 16 TWh of electricity derived from renewable energy (excluding large hydropower) by 2014—equivalent to about 1.6 percent of the national electricity supply. In addition, net-metering was introduced for excess solar and wind energy in 1992. These renewable energy policies have contributed to the increase of the share of renewable energy, particularly solar photovoltaic (PV), wind energy, and biomass in Japan.

Solar PV holds the largest generation capacity among Japan's renewable energy technologies. Japan has successfully increased PV installations mainly through subsidies provided by the central and local governments. The growth of domestic PV markets had stagnated since 2005 when the provision of subsidies for households ended. However, it has recovered since 2009 after financial support through subsidies were reintroduced (Ministry of Economy Trade and Industry (METI), 2012).

Moreover, the implementation of the solar Feed in Tariff (FIT) scheme that began in November 2009 has played an essential role in the recent strong growth in solar PV installations. According to the program, utilities are required to purchase surplus solar electricity for ten years at a fixed rate of JPY48 (USD 0.60)/kWh—almost twice as high as the market price of electricity—for residential PV installations below 10 kW. The FIT program has been very successful; according to Ministry of Economy Trade and Industry (METI) (2012), the annual surplus solar electricity purchased by the utilities reached 1.4 billion kWh in 2010. At the end of 2011, Japan had the third largest solar PV capacity in the world after Germany and Italy, with an installed capacity of 4.9 GW (European Photovoltaic Industry Association, 2012).

Japan has also constantly increased wind energy capacity over the last decade. The government's support through programs, such as "Field Test" and "New Energy Business Support Programs," have played an important role in the development of the wind industry in Japan, along with purchase agreements and the RPS program. Japan had a wind capacity of 2661 MW at the end of 2013 (Global Wind Energy Council, 2014).

Japan has also attained rapid growth of biomass capacity. Having increased by a factor of 7.5 since 1990, biomass now accounts for about one-fourth of total renewable energy capacity (Renewable Energy Policy Network for the 21st Century (REN21), 2012). The increase is largely because electricity generation by waste incineration is considered as renewable energy and the majority of biomass facilities are certified by the RPS in Japan. In fact, power generation from waste accounts for about 95 percent

[1] METI was established in 1945 as the revival of the Ministry of Commerce and Industry. The METI designed crucial laws and implemented important projects to promote renewable energy in Japan. In 1973, METI established the Agency for Natural Resources and Energy and began its Sunshine Project, an R&D project on new energy in the following year.

(*footnote continued*)

of all biomass power generation (Japan Renewable Energy Policy Platform (JREPP), 2010).

A new transformation of national energy policy began after the nuclear disaster in March 2011. Former Japanese Prime Minister, Naoto Kan, announced his intention to end the country's dependence on nuclear power and declared the requirement to increase renewable energy generation to meet at least 20 percent of Japan's energy supply by the 2020s. Kan also expanded the 2009 FIT program to include other forms of renewable energy. Within the expanded FIT, which launched on July 1, 2012, the Japanese government set high tariffs[2] to attract renewable energy investment and adoption. The tariffs became the highest in the world and, in fact, the rate for solar generated electricity is double the tariff offered in Germany. By the end of December 2013, the installed capacity of renewable energy increased by 34 percent compared with that before the start of the expanded FIT (Ministry of Economy Trade and Industry (METI), 2014).

Japan has set a goal to expand its renewable energy capacity from the current 39.2 GW to 85.83 GW by 2020, in which 21 GW will come from hydropower. The country aims to increase its PV capacity to 28 GW – almost six fold – and double its wind capacity to 5 GW in the next decade (Renewable Energy Policy Network for the 21st Century (REN21), 2012). Solar PV will share one-third of the total renewable energy capacity by 2020 if the goal is achieved (see Fig. 1).

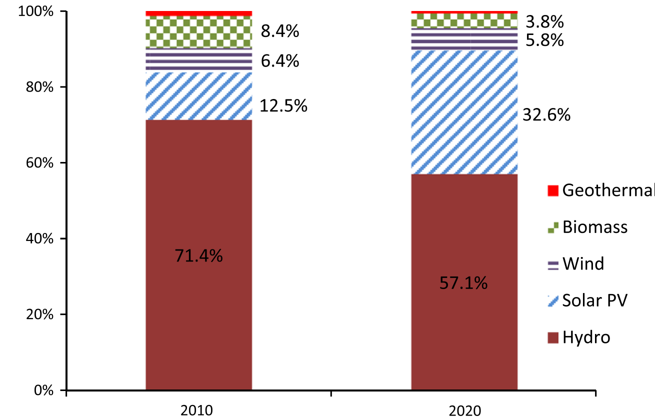

Fig. 1. Current and target components of various renewable energy sources in Japan.
Source: (Renewable Energy Policy Network for the 21st Century (REN21), 2012).

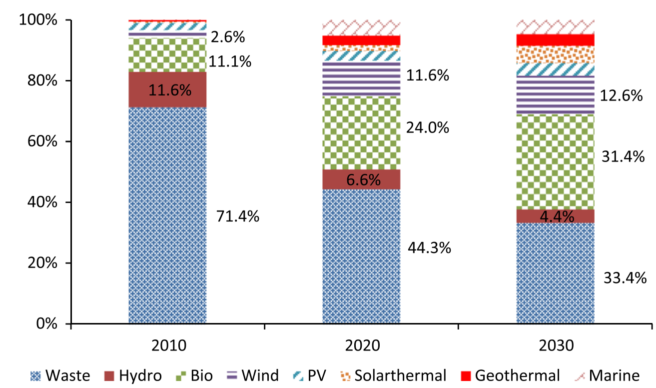

Fig. 2. Current NRE production profile and future target in South Korea.
Source: (Korea Energy Management Corporation (KEMCO), 2011; MOTIE, 2008).

3.1.2. South Korea

Similar to Japan, South Korea has also promoted renewable energy to diversify energy sources. Since the "Promotion Act for New & Renewable Energy (NRE) Development, Utilization, and Deployment" was enacted in 1972, NRE started to be deployed: (1) in the mid-1980s, it mainly focused on solar thermal heating devices and waste incineration (the most mature and cost-effective at that time) (Kim, 2009), (2) during the 1990s, the 10-year (1997–2006) national plan for NRE technology development was established, and (3) beginning in the early 2000s, NRE deployment was more aggressively and strategically promoted (e.g., NRE procurement for the public sector and the implementation of feed-in-tariffs).

By the end of 2008, the government published the "3rd Basic Plan for NRE Technology Development and Deployment," which aimed to provide more reasonable strategies for supporting the green energy industry and raised its NRE deployment target to 11 percent of TPES by 2030.[3] The previous target of the 2nd Basic Plan was only 5 percent of TPES by 2011. The Plan aims to increase renewable energy capacity including solar, wind, and biomass, while decreasing its dependence on waste energy from 71 percent in 2010 to about 33 percent by 2030 (see Fig. 2). In addition, the NRE requirements for the construction of public buildings have been strengthened. The Plan requires that new public buildings larger than 1000 m^2 employ NRE more than 5 percent of total energy usage starting in 2012, while it previously required new public buildings larger than 3000 m^2 to spend 5 percent of its construction cost for NRE.

The 3rd Plan also aims to achieve competitiveness of domestic NRE industries as a part of the "Low Carbon Green Growth (LCGG)" plan, a new national vision for the next fifty years, which was announced by former President Lee on the 60th anniversary of the foundation of the Republic of Korea in 2008. The Green Growth plan pursues sustainable economic growth without adversely impacting the environment through improving eco-efficiency, which can be achieved by significantly investing in eco-friendly technologies. Under this new economic development paradigm, green technologies are emphasized as a method to accomplish both environmental protection and economic growth (Presidential Committee on Green Growth, 2009). The government will aggressively support research and development of green energy technologies, especially solar, wind, fuel cells, integrated gasification combined cycle (IGCC) technologies, and biofuels (see Table 1) (Ministry of Trade, Industry & Energy (MOTIE), 2011).

In fact, the government aims to increase the share of domestic green energy technologies in the South Korean market and the international market from 57 percent in 2010 to 98 percent in 2030 and from 1.2 percent to 18 percent, respectively. Specifically, the government aims to develop wind turbine technology by 2020 and export wind power system through supporting the development of reliable and high performance large wind systems (2–3 MW onshore wind power, 3–5 MW offshore wind power) (Ministry of Trade, Industry & Energy (MOTIE), 2010).

As mentioned, South Korea has focused particularly on advancing wind energy capacity. The annual growth rate of wind power from 2010 to 2030 is projected to be more than 18 percent, which is higher than PV and bioenergy, which will both grow about 15 percent annually. The share of wind power in the NRE supply is projected to jump from 2.6 percent (176 ktoe) in 2010 to nearly 13 percent (4155 ktoe) by 2030 (see Fig. 2). In addition, in 2010, there is no offshore wind power in operation. However, the diffusion of offshore wind power can be expected in the future since the

[2] Utilities are now required to buy renewable electricity from providers at a rate of JPY 42 (USD 0.41)/kW h for solar electiricty, JPY 23 (USD 0.23)/kW h for wind power, and JPY 27 (USD 0.27)/kW h for geothermal, and JPY 30–35 (USD 0.32–0.34)/kW h for small hydropower, over 10–20 years.

[3] In the BAU scenario, the deployment rate of NRE is expected to increase by 5.7 percent of the TPES.

Table 1
Fifteen prioritized green energy technologies.
Source: (MOTIE, 2011).

Category	Technologies
New and renewable energy	Solar, wind, fuel cell, IGCC, biofuel
Energy efficiency/greenhouse gas emissions reduction	Carbon sequestration (CCS), clean fuel*, energy storage, light-emitting diode (LED) bulbs, green car, energy efficient building, heat pump
Electricity/nuclear	Nuclear power, clean thermal generation**, smart grid

* Clean fuel refers to clean coal/clean gas technologies such as coal-to-liquid and gas-to-liquid.
** Clean thermal generation means efficiency improvement in thermal plants.

government prioritizes offshore wind power over onshore wind power. According to the "Offshore Wind Power Promotion Roadmap (2010)," the government planed the construction of a large offshore wind farm in the Yellow Sea (Ministry of Trade, Industry & Energy (MOTIE), 2010). This project consists of three phases: a 100 MW pilot phase from 2011 to 2013; a 900 MW demonstration phase from 2014 to 2016; and a 1500 MW diffusion phase from 2017 to 2019.

Along with those efforts, South Korea has promoted NRE utilization by taking a market-oriented approach. Since 2012, the RPS program has replaced the FIT program, which entered into force in 2002. While South Korea started to achieve tangible results from FITs, the government discontinued FITs due to the financial burden on the government. Due to the rapid growth of PV installments, the actual payments for the FIT exceeded the budget allocated to the program and it accounted for a significant percentage of the total budget for NRE R&D and deployment (39 percent in 2011 and 40 percent in 2012) (Chae, 2014; Kwon, 2009). Although the national FIT program has been suspended because of difficulties in financing the program, local governments, including Seoul and Gyeonggi-do, spontaneously implement FIT programs for PV facilities less than 50 kW (Park, 2014). The RPS requires six state-run and private power utilities[4] with capacity exceeding 500 MW to generate 2 percent of energy from renewable sources in 2012, which will annually increase to 10 percent by 2022. In addition, there is a separate target for solar PV, which requires additional installments of 220 MW in 2012, which will increase by 10 MW annually by 2016. The RPS program was launched together with a Renewable Energy Certificate (REC) trading program. One unit of REC is issued to certify 1 MWh of electricity generated from renewable energy facilities, which can be traded in the REC market (Korea Energy Management Corporate (KEMCO), n.d.). In addition, a GHG cap-and-trade program will be launched in 2015 and both programs are expected to strengthen the market-oriented approach to renewable energy in South Korea. Since the legal incidence of the policy falls on fossil fuel-fired plants, renewable power generation costs will be relatively cheaper than fossil fuel power generation cost (Wang et al., 2010). At the same time, the funds raised from a program (auction revenue, trading commission, etc.) will be used to support renewable energy R&D (Sopher and Mansell, 2013).

3.1.3. Taiwan

In 1968, the Taiwanese government declared the "Principles for Taiwan Area's Energy Development" with the main purpose of providing stable and cheap energy for long-term industrial development (Taiwan Executive Yuan (TEY), 1968). In 1973, the government passed the "Taiwan Energy Policy," which stressed the importance of hydropower and geothermal power (Taiwan Executive Yuan (TEY), 1973).

Before 2000, the renewable energy promotion programs were focusing on research, education, and demonstration purposes, instead of capacity expansion of renewables. Therefore, the amount of renewable energy generation was small. In 1990, electricity generated from renewable energy accounted for about 9 percent of total electricity production, of which the majority was generated from hydropower (Taiwan Bureau of Energy (Taiwan BoE), 2011a).

The establishment of the National Energy Conference (NEC), a forum to review Taiwan's energy structure and future energy policy directions, in the late 1990s was a turning point. The NEC was held three times: in 1998, 2005, and 2009. In the first NEC that was held after the Kyoto climate change conference in 1997, the government set a target of 3 percent of TPES from renewables by 2020 and sought incentives and possible funding sources to promote renewable energy. After the Kyoto Protocol came into effect, the government held the second NEC and reconfirmed the importance of renewable energy. It also increased the renewable energy targets to 4–6 percent of total energy supply by 2020 and 10–12 percent of total electricity capacity by 2025 (Industrial Technology Research Institute (ITRI), n.d.b). The third NEC also reassured the urgent need for renewable energy. The NECs hastened the enactment of the "Renewable Energy Development Act" of 2009, which aimed to raise the share of renewables and establish fund-raising mechanisms to support renewable energy projects (Taiwan Bureau of Energy (Taiwan BoE), 2009).

Under the Act, renewable energy targets are reviewed and amended every two years for the next twenty years starting in 2009 (Taiwan Bureau of Energy (Taiwan BoE), 2009). Fig. 3 lists the renewable status in 2012 and future targets. As the Figure illustrates, Taiwan expects to grow the share of wind power and solar PV significantly by 2025. More specifically, the target for wind capacity is 2450 MW, about five times of the capacity in 2011, and that of solar PV capacity is 2000 MW, fifty-seven times greater than that of 2011. If these targets are achieved, solar and wind power will be account for 51 percent of the total renewable energy supply by 2025. The share of hydropower, biomass, and waste power are expected to decrease, but the actual capacity is projected to increase (Taiwan Bureau of Energy (Taiwan BoE), 2011a).

To achieve the targets, various measures have been implemented, including economic incentive policies, relaxing regulatory restrictions for renewable energy generation, and the installation of smart meters. In terms of economic incentive policies, subsidies have been used to incentivize renewable energy to overcome high initial costs. Examples include the "Photovoltaic Power Generator Model System Installation Subsidy Principle," and the "Green County Application Promotional Plan Subsidy Principle" (Liou, 2010; Taiwan Bureau of Energy (Taiwan BoE), 2009). The Taiwanese government also uses economic incentives

[4] In South Korea, the RPS is imposed on fourteen utility companies: six subsidiary utility companies of Korean Electric Power Corporation; Korea District Heating Corporation; Posco Energy; GS EPS; K-Power; GS Power; MPC; K-Water; SK E&S.

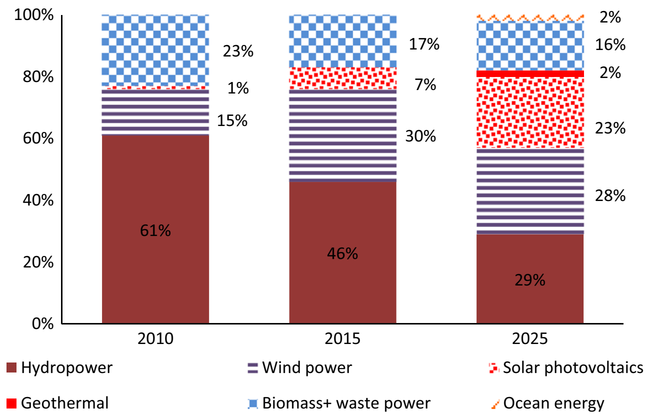

Fig. 3. Current and target components of various renewable energy sources in Taiwan. * Hydropower is conventional hydro, excluding pumped storage hydro.
Source: (Industrial Technology Research Institute (ITRI), 2012; Lee and Shih, 2011; Taiwan Bureau of Energy (Taiwan BoE), 2011b).

to encourage industries to upgrade equipment or employ renewable technology. For example, the Taiwanese government waived the import duty for construction materials of renewable energy-integrated buildings and accelerated the depreciation of qualified industrial equipment to decrease costs (Taiwan Bureau of Energy (Taiwan BoE), 2009).

The FIT has become a key mechanism to promote renewable electricity after the enactment of the Renewable Energy Development Act in 2009. The government reviews and adjusts the FIT rates twice a year based on the generation cost of renewable electricity. As of 2012, the tariff rates of solar PV are significantly higher than the rates of other technologies because of the higher generation cost of solar electricity. However, it has declined to reflect the rapid price decrease in the international PV market. For other renewable technologies, the tariff rates were kept the same or increased slightly. The government expanded the 2014 FIT to encourage the utilization of onshore wind turbines over 10 kW and renewable energy deployment on remote islands. Wind energy developers (onshore and above 10 kW) will earn 3.6 percent extra rates if they sign the contract in 2014 and the wind facilities connect to the grid by 2018. Moreover, renewable developers will enjoy 15 percent extra rates to install renewable facilities on remote islands (Taiwan Bureau of Energy (Taiwan BoE), 2013a,2013b).

The Taiwanese government has attempted to relax regulatory restrictions for the diffusion of renewable operations. In the "Renewable Energy Development Act," license acquisition processes have been simplified to encourage and stimulate the construction of renewable facilities. Moreover, renewable facilities below 500 kW are not restricted by the articles of the Electricity Act, which require that renewable electricity generators receive permission from the local authority. Because of the loosened restrictions, the facility owners need not submit reports about generation to the local authority every half year, which has simplified political procedures for operating small-scale renewable facilities (Taiwan Bureau of Energy (Taiwan BoE), 2009). These regulation adjustments have resulted in accelerating the use of renewable technologies, especially among private investors.

Lastly, the government expects to accelerate the adoption of renewable energy through smart meter systems. In September 2012, the Taiwanese government passed a budget of 130 billion TWD (US$ 4.3 billion) to construct smart meter systems in the next twenty years. The program is expected to facilitate the communication between electricity suppliers and consumers, especially between small-scale renewable electricity suppliers and the Taiwan Power Company (Taiwan Bureau of Energy (Taiwan BoE), 2012a).

3.2. The SWOT analysis of renewable energy policies

Japan, South Korea, and Taiwan have strived to expand their renewable energy capacity through various measures as previously reviewed. However, renewable energy (including large hydropower) still contributes to a relatively small portion of electricity generation in three countries (about 10 percent in Japan, about 5 percent in Taiwan, and only about 1 percent in Korea) (International Energy Agency (IEA), 2012b; Taiwan Bureau of Energy (Taiwan BoE), 2011a). This section examines the strengths, weaknesses, opportunities, and threats of promoting renewable energy for each country and then compares the key factors that affect the renewable energy diffusion in the three countries in order to explore future cooperation opportunities or possible competition in the global renewable market.

3.2.1. The results of SWOT analysis of renewable energy policies in Japan

3.2.1.1. Strengths—Japan. Historically, Japan has been a leader in advanced manufacturing industries. For example, Sharp has gained more than fifty years of experience in solar markets and Mitsubishi has considerable expertise based on forty-four years of geothermal turbine manufacturing (Sharp Electronics Europe, n.d.; Mitsubishi Heavy Industries, n.d.). At the end of 2011, Japan was home to three out of the top five geothermal turbine manufacturers and two of the top fifteen solar PV module manufacturers in the world (Renewable Energy Policy Network for the 21st Century (REN21), 2012). Recently, Japan has also started leading emerging and next generation green energy technologies, including heat pumps, power semiconductors, organic solar PV modules, fuel cells, and lithium batteries. In 2010, Japan had 55 percent of the world's renewable energy patents, followed by the United States (21 percent) (Japan for Sustainability, 2011).

Some of Japan's renewable energy programs have also shown success. The 2009 solar FIT has successfully expanded solar PV installations. Based on its success, the government expanded the program and created the most robust FIT scheme in the world in July 2012. The program could spur at least USD 9.6 billion in new installations with 3.2 GW of capacity, according to Bloomberg New Energy Finance (Watanabe, 2012). In particular, the domestic solar market is expected to experience skyrocketing growth. By September 2012, domestic shipments of solar cells and modules (627 MW) increased by 80 percent in one year (Watanabe et al., 2013). Investments in the solar industry are estimated to be 19 billion USD over the next three years; an eightfold increase from the investment in 2012 (ibid.).

In addition, the renewable energy potential in Japan is enormous. According to the Ministry of the Environment, Japan's solar energy introduction potential[5] is over 150 GW and the wind potential is as much as 1900 GW. In addition, small and medium-scale hydropower and geothermal power each have a potential of about 14 GW (Ministry of Environment, 2011).

3.2.1.2. Weaknesses—Japan. From a global perspective, Japan has lagged in the adoption of renewable energy. Renewable energy (excluding hydropower) accounted for only about 3.6 percent of total electricity generated in 2012 (U.S. Energy Information Administration (US EIA) (2014a,2014b)). Renewable energy has slowly grown partially because of the central government's historical emphasis on the development of nuclear power. Nuclear energy deployment has been a national strategic priority

[5] The energy potential refers to the amount of energy feasible, taking various limitations for energy collection and utilization into consideration.

as an alternative energy to oil since 1973. Such tendency was accelerated after the Kyoto Protocol. Japan increased its dependence on nuclear power to about one third of its electricity supply before the Fukushima disaster.

In addition, regional monopolies dominate Japan's power industry. Since electric utilities own power plants and transmission grids, advancement of renewable energy development has been hindered. Japan started deregulating its electricity market in the 1990s; however, its structure has changed little over the last two decades. There is no real competition in the market and utility firms keep resisting opening access to the grid to renewable energy partially because the development of renewable energy is thought to threaten the core profits of the power utilities (Iida, 2012). The utilities continue to charge high prices for power line use and unbalanced supply/demand loads (Japan Renewable Energy Policy Platform (JREPP), 2010). All of these costs are added to the monopoly prices and make Japan's electricity prices the world's third highest.

Against the success of the FIT program, the RPS framework has not been strong enough to create incentives. The RPS has proven ineffective because the target is quite low (as low as 1.63 percent). Furthermore, the policy allows utility companies to carry over a surplus of renewable generation from the previous year, which discourages building new renewable facilities (Japan Renewable Energy Policy Platform (JREPP), 2010). In addition, in the absence of individual targets for each renewable energy source, energy developers have focused primarily on less-expensive waste energy systems (Japan Renewable Energy Foundation (JREF), 2012).

3.2.1.3. Opportunities—Japan. The Fukushima accident is undoubtedly a significant catastrophe in human history, but this tragedy has created new opportunities for clean renewable energy. For example, in June 2012, Toshiba unveiled plans to build solar plants with a capacity of 100 MW and a month later Kyocera announced plans to construct a 70 MW solar plant. Companies that are not traditionally PV manufacturers have also begun branching into the clean technology industry. For example, the Kintetsu railway firm is building a 20 MW solar plant and Softbank telecommunications has been working on a 111 MW solar facility. Offshore wind energy is another field that could experience skyrocketing growth in the near future; the construction of a 300 MW offshore wind farm has been jointly planned by a number of big business companies (Foster, 2013).

Furthermore, local municipal governments and communities have been mobilizing to deploy renewable energy, creating new opportunities to change renewable markets from the bottom-up. For example, the Village of Sanno, a small village with a population of only 42 citizens in Hyogo Prefecture, installed 216 solar panels and on March 31, 2012 became the first municipality in Japan to generate all its own electricity from renewable solar resources. Some prefectures such as Akita also set targets for 100 percent renewables (Renewable Energy Policy Network for the 21st Century (REN21), 2012). Community-level renewable energy projects were expected to result in a total of JPY 52 billion (654 million USD) in investment by 2012 alone (Nonaka et al., 2012).

The central government has also set forward several plans to deregulate the renewable energy sector, providing another opportunity for the renewable energy market. For example, the government proposed plans that would enable geothermal energy development in certain restricted areas of national parks in 2012 to solve location constraint problems caused by the conflict between different regulations or laws. Simplifying the approval process has also been proposed to speed up solar and wind installations on abandoned agricultural land (Nonaka et al., 2012).

3.2.1.4. Threats—Japan. Despite the presence of a favorable business and political environment for renewable energy after the Fukushima crisis, several factors threaten the prospects of Japan's renewable energy market. First, there is a chance that Japan's nuclear industry will rebound, considering that Japan faced several issues after shutting down nuclear power plants, such as a reduced energy self-sufficiency rate, higher electricity prices, and the deficit of trade balance because of the importation of more fossil fuels (Ministry of Economy Trade and Industry (METI), 2014). Therefore, Japan restarted its nuclear reactors at the Ohi plants for the first time since the Fukushima crisis despite considerable public protests. The current (2014) government intends to resume using nuclear power with safety measures (Ministry of Economy Trade and Industry (METI), 2014). Many experts point out that the move may strike a blow to the development of renewable energy in Japan (Wagner, 2012).

Furthermore, Japan's dominance in some global renewable energy markets has been threatened by the emergence of foreign rival companies. A shift of leadership is particularly obvious in solar module markets and the global share of Japanese PV manufacturers has dwindled since 2008. Part of the reason for the decline is that Japanese companies have lost out to other countries in cost competitiveness although they still maintain world-leading technologies. In particular, pressure from China has been enormous. The Japan Renewable Energy Foundation (JREF) (2012) indicates that solar modules manufactured by Chinese companies are about half price of those manufactured in

Table 2
The summary of SWOT analysis results of renewable energy policies in Japan.

Strengths	Weaknesses
• Expansive renewable energy technology expertise and advanced manufacturing industries to lead renewable energy technologies • Effective incentive (FIT) • Abundant potential of renewable energy supply	• Dependence on nuclear power as alternative energy to oil as well as zero-emission energy • Limited grid access for renewables due to utilities' monopoly on Japan's electric power system, including electrical power production and distribution/transmission • Ineffective RPS
Opportunities	**Threats**
• Increased interests in renewables after Fukushima accident • Increased investments in renewables from the business sector and local governments and communities, especially in the areas of solar and offshore wind power • Enactment of revised 2012 FIT (July, 2012) • Establishment of several plans to deregulate the renewable energy sector	• Restart of nuclear reactors being driven by powerful utilities, most big business associations, and the nuclear industry • Rise of foreign rival companies

Japan. The rise of Chinese PV modules is seemingly unstoppable. Nine out of the top fifteen solar PV module manufacturers were Chinese in 2012 (Renewable Energy Policy Network for the 21st Century (REN21), 2012). Japan has experienced heavy pressure from foreign rivals not only in the global solar market, but also in the domestic market. The share of imported solar cells and modules jumped from about 22 to 32 percent of volume sold in Japan between March and September 2012 (Watanabe et al., 2013). The results of the SWOT analysis are summarized in Table 2.

3.2.2. The results of SWOT analysis of renewable energy policies in South Korea

3.2.2.1. Strengths—South Korea. South Korea has abundant renewable energy potential. According to KEMCO, theoretical renewable energy potential measured in million tonnes of oil equivalent (MTOE) is more than 2.3 million MTOE, which is significantly large compared to US renewable energy supply in 2011 (133.29 MTOE) (International Energy Agency (IEA), 2012a,2012b,2012c). More specifically, the feasible potential[6] is about 160,000 MTOE; and technical potential[7] is less than 1800 MTOE. The technical energy potential by renewable energy sources is largest for solar thermal (871 MTOE) followed by solar PV (585 MTOE), geothermal energy (234 MTOE), and wind power (43 MTOE) (Korea Energy Management Corporation (KEMCO), 2008).[8]

Furthermore, South Korea has several advanced technologies and has a robust manufacturing industry that has led the nation in unprecedented economic growth and industrialization. This nation progressed from one of the poorest countries in the 1960s to become a member of the OECD in 1996. Auto manufacturing, information technology, and shipbuilding are the leading industries in South Korea. Analysts expect a synergy effect with these industries and the renewable energy industry. For example, triple helical turbine technologies were developed for tidal current power at Uldolmok based on advanced technologies of the world's leading companies, including Hyundai C&E, Hyundai Heavy Industries, and Iljin Electric (Ishihara et al., 2010). In addition, several industries have started to produce wind power turbines. The government expects South Korea to emerge as a leader in offshore wind technology (Ministry of Trade, Industry & Energy (MOTIE), 2010).

3.2.2.2. Weaknesses—South Korea. There are several weaknesses that have led to the sluggish growth of renewable energy. First, the government has set a relatively conservative target for renewable energy deployment. While the renewable energy policy has been significantly enhanced, the target remains conservative. Although the current deployment target for NRE (including IGCC, hydrogen fuel cells, pumped storage, and industrial waste) has been increased, but the target is still low if IGCC, hydrogen fuel cells, pumped storage, and industrial waste were to be excluded from NRE, as is common in some countries like the EU countries.

Low electricity prices have led to slow development of renewable energy. In South Korea, 93 percent of the electricity – including generation, distribution, and transmission – is managed by the Korean Electric Power Corporation, which is majority owned by the government. The government has controlled the price of electricity and the rates have been kept low in order to protect low-income households and industrial consumers (International Energy Agency (IEA), 2012a). As of 2011, electricity in South Korea was sold to the industry sector for $57.8/MWh (about 58,500 Korean Won [KRW]/MWh), which was about half the average price of OECD countries and around a third of Japan's electricity price[9] (Ministry of Trade, Industry & Energy (MOTIE), 2011). To maintain the rates, the government has a tendency to support large-scale conventional energy systems including nuclear power, instead of renewable energy.

Lastly, renewable energy deployment has been hindered because it is not directly linked to the growth of the domestic economy. The NRE manufacturing industry has succeeded in increasing jobs and sales by 3.6 times and 6.5 times from 2007 to 2010, respectively. However, since NRE companies in South Korea are not competitive, and most renewable energy technologies are dependent on imports, NRE deployment has not effectively contributed to the advancement of domestic industries and technology development. For example, in 2011 two-thirds of solar PV systems were imported, and nearly 92 percent of wind technologies depended on foreign technology (Ministry of Trade, Industry & Energy (MOTIE), 2011).

3.2.2.3. Opportunities—South Korea. Several opportunities exist for South Korea to increase the share of renewable energy. First, to increase the market share of domestic technology and enhance the technology level, the government announced to provide finance for R&D for NRE technologies as mentioned in Table 1 from 2011, as part of their Green Growth strategies (Ministry of Trade, Industry & Energy (MOTIE), 2011). These efforts to bolster the domestic industry in these five NRE technologies are estimated to create about five million additional jobs, increase exports by about 26 trillion KRW (around 24 billion USD), and reduce GHG emissions about 34 Mt CO_2e by 2015 and about 210 Mt CO_2e by 2030 (Ministry of Trade, Industry & Energy (MOTIE), 2011).

Second, the Park administration emphasizes the importance of NRE and is likely to promote it. Under the next Plan, goals for NRE development are likely to be expanded compared to the current plan. At the same time, President Park is also supportive of nuclear power development and this may be a threat to the development of renewable energy sources (EnergyKorea, 2012).

Lastly, a Free Trade Agreement (FTA) with the EU is expected to bring additional opportunities. On July 1, 2011, the EU–South Korea FTA entered into force, which lowered EU-imposed tariffs on domestic goods including NRE equipment. Due to the treaty, the price competitiveness of South Korean NRE-related equipment will be enhanced and exports will increase. The tariff on solar panels is already zero, therefore, it is expected that the wind power industry will benefit the most. The domestic NRE industry is also expected to grow as joint research and technology cooperation and investments from the EU increase.

3.2.2.4. Threats—South Korea. However, it should be noted that the removal of the tariff on the imports resulting from the EU–South Korea FTA can adversely impact the domestic NRE industries as the advanced NRE goods and services are imported without tariffs from the EU (Jang, 2011).

Another threat to South Korea's renewable energy industry may come from the shale gas industry, which has recently

[6] The feasible potential is calculated according to geographical feasibility for renewable energy facilities.

[7] Theoretical potential refers to total renewable energy of the area of South Korea (e.g., the theoretical potential for solar is calculated by multiplying average daily horizontal radiation by the area of South Korea). The technical potential is estimated based on the current technology level. There is a possibility that the technical potential can expand according to technology development.

[8] For comparison with renewable energy potentials in other countries, the technical potentials are also presented in MW: (1) the technical potential for solar PV 382 GW, (2) for wind power 50 GW, (3) for small hydro 1.5 GW and (4) for ocean energy 7.1 GW (the technical potential for solar PV is calculated based on the average capacity factor of 0.7).

[9] While the price of electricity for industry is the same as it is for households, progressive electricity rates are applied to the residential sector and the share of households' electricity consumption to the total electricity consumption is much smaller than the consumption in industries. Therefore, the cheap electricity price is a real problem related to increase in green electricity.

experienced a boom in many nations, especially in the U.S. In their “reference scenario,” the Energy Information Agency (2012) projects that shale gas will constitute 49 percent of total natural gas production in the world by 2035 and the share of natural gas among the total electricity generated will increase from 24 percent in 2010 to 28 percent in 2035. The price of shale gas is around 30 to 40 percent cheaper than natural gas and it is estimated that there is enough supply to last for the next sixty years (Ho, 2012). The South Korean government focuses on the use of shale gas and in July 2012 MOTIE established the Taskforce for Shale Gas to develop strategies for its development (Yim, 2012). According to the 2nd National Energy Basic Plan (2014), the government plans to import gas products from US shale gas: LPG starting in 2014 and LNG starting in 2017 to diversify the supply chain of energy sources. In addition, the government aims to raise skilled manpower and large-scale in-situ R&D with regard to shale gas. However, possible future ramp-up and dependence on shale gas may negatively affect the diffusion of renewable energy. The results mentioned earlier are listed in Table 3.

3.2.3. The results of SWOT analysis of renewable energy policies in Taiwan

3.2.3.1. Strengths—Taiwan. Taiwan has several strong characteristics contributing to the development of renewable energy. First of all, Taiwan has rich renewable energy potential. As a subtropical island located in the monsoon area and the western edge of the Pacific volcano belt, Taiwan has wind potential of at least 3000 MW (Industrial Technology Research Institute (ITRI), n.d.d), solar radiation of more than 1000 kWh/kWp/year (Industrial Technology Research Institute (ITRI), n.d.e), theoretical geothermal potential of 1000 MW (Industrial Technology Research Institute (ITRI), n.d.a), and 11,730 MW of theoretical hydropower potential (Industrial Technology Research Institute (ITRI), n.d.c).

The second strength that fosters the development of renewable resources in Taiwan is its sound legal framework. Taiwan has enacted the “Renewable Energy Development Act” since 2009 and the “Energy Development Principles” in 2012, which require all governmental sectors to initiate energy plans in order to achieve a low carbon future and suggests renewable energy as key low-carbon resources (Taiwan Bureau of Energy (Taiwan BoE), 2012d). In addition, many laws related to renewable energy promotion, including the “Energy Tax Act,” the “Greenhouse Gas Reduction Act” and the revision of the “Energy Management Law,” are currently under development.

Taiwan’s well-established solar PV industry is evidence of the country’s growing renewable industry. With advanced semiconductor and integrated circuit (IC) manufacturing industries, Taiwan succeeded in constructing a complete PV supply chain, ranging from silicon products (upstream), solar cells, solar modules, and solar batteries (middle stream), to complete solar systems (downstream) (Taiwan Bureau of Energy (Taiwan BoE), 2012c). Taiwan’s PV manufacturing capacity has indeed built a niche in the global PV market. In 2011, Taiwan was the second largest silicon PV cell manufacturer in the world, only behind China, and had 12 percent of the global market share (Ferry, 2012).

Moreover, robust economic and trade relations with China is another strength. Taiwan has the technological know-how, while China has low-cost labor and enormous market potential. For example, the Foxconn Technology Group, a Taiwanese company and the manufacturer of Apple iPhones and iPads, operates a solar panel factory in eastern China. Moreover, Foxconn intended to set up solar-related ventures in northern China through the signing of an agreement with the Chinese solar silicon company, GCL-Poly Energy Holdings. In addition, the government of Guangxi Province in China announced its intention to cooperate with Foxconn to construct five solar equipment plants and twenty solar farms in Guangxi, although a formal contract has not yet been signed (Meza, 2013).

3.2.3.2. Weaknesses—Taiwan. Despite the strengths, several weaknesses have prevented the domestic market from reaching its full potential. The first weakness is limited suitable area for developing large-scale solar farms and inland wind farms. The land area of Taiwan is only about 36,000 km^2 (slightly larger than the U.S. state of Maryland), 59 percent of which is covered by forests (Taiwan Forestry Bureau, 2012). Moreover, some land area is categorized as ecologically sensitive area or military controlled area, which is restricted for development. Therefore, the government is currently focusing on building offshore wind turbines and rooftop PV facilities.

Second, the lack of a long-term target for an energy mix creates another weakness. Over time, the government has changed its renewable energy targets in a series of NECs and political declarations. As explained in Section 3.1.3, the three NECs set different renewable energy deployment targets. Political declarations, such as the 2008 “Sustainable Energy Policy Principles,” announced new and different targets for renewable energy development. The frequent changes in the goals serve to alienate and confuse entities looking to invest in renewable energy development as well as the governmental authorities that design and implement renewable energy policies.

The third weakness comes from the fact that Taiwanese renewable energy technology companies (especially PV) have historically focused more on the international market than on the domestic market. While Taiwan has strong solar PV technology, the domestic utilization rate is significantly low. As of 2012, merely 0.07 percent of Taiwan’s domestic electricity supply was generated from solar PV (Taiwan Bureau of Energy (Taiwan BoE),

Table 3
The summary of SWOT analysis results of renewable energy policies in South Korea.

Strengths	Weaknesses
• Considerable renewable energy potential • Historical experience with fast industrialization, allowing for mastery of high-technology • Possessing some of the world’s most advanced technology, especially in the IT and auto manufacturing industries	• Conservative target for renewable energy deployment • Low domestic electricity price • Domestic renewable energy technology has not directly contributed to the economy
Opportunities	**Threats**
• Establishment of green energy technology development strategy • The 2nd National Energy Basic Plan is being developed • Feasible increase in exports through the Korea–EU FTA	• New Park administration is pro-nuclear power development • Foreseeable increase in renewable technology imports through the Korea–EU FTA • Rise of inexpensive shale gas resources

2013a,2013b). Most PV producers have given preference to exporting their products for greater profits.

3.2.3.3. Opportunities—Taiwan. While weaknesses have prevented the development of renewables from reaching their full potential, several factors provide promising opportunities for the future growth of Taiwan's renewable industry. To begin with, continuous cooperation with China is expected to provide additional growth potential. To enhance the cooperation, the Taiwanese government has recently loosened restrictions on Chinese investment in seven sensitive high tech sectors, including solar battery manufacturing (Wu, 2012). In addition, since Taiwan and China have different political and administrative systems, some international trade barriers for Chinese manufacturers may have a positive impact on Taiwanese producers. For example, because of China's "dumping" of cheap solar cells at prices below production costs on international markets, the U.S Department of Commerce announced anti-dumping tariffs of around 31 percent on Chinese solar cells in May 2012 (Leone, 2012). High tariffs may impede Chinese PV producers to export their products to the U.S., creating more opportunities for Taiwanese PV producers to expand their export market (Ferry, 2012).

The growing anti-nuclear concerns throughout the region following the Fukushima nuclear disaster have also created an opportunity. Taiwan and Japan have similar geographical and geological characteristics and are similarly vulnerable to natural disasters, including earthquakes and tsunamis. The nuclear disaster that occurred in Japan in March 2011 clearly raised public alarm over the nuclear option in Taiwan as well.

In addition, the central government has instituted policies that will create favorable market conditions for the building of entire supply chains of several renewable energy sources, especially the solar industry. Seven "green industries" were identified as key promotional areas, including wind, biofuels, LED lighting, fuel cells, energy service companies (ESCOs), electric motors, and solar PV technologies (Taiwan Bureau of Energy (Taiwan BoE), 2012c).

3.2.3.4. Threats—Taiwan. The first threat comes from Taiwan's energy intensive industrial structure, which requires stable electricity supply. Taiwan's industrial sector consumed around 58 percent of the country's total final electricity consumption in 2013 (Taiwan Bureau of Energy (Taiwan BoE), 2014). To maintain economic growth, Taiwan needs to provide stable electricity at reasonable prices. The government has promoted the development of fossil fuels and nuclear power (although, as mentioned above, nuclear power is less favorable now) under the premise that energy produced from those fuel types is more reliable and stable. However, the overemphasis on fossil fuels and nuclear power now serves as a threat and limitation for renewable energy development in Taiwan.

The government's historical reliance on fossil fuels has created a very friendly investment environment for energy-intensive and large-scale industrial development, but an unfriendly environment for renewable energy manufacturers. Consequently, Taiwanese small and middle-sized businesses experience the difficulty of raising investment funds. For example, the FIT is an important scheme to attract renewable energy utilization in Taiwan. However, The 2013 FIT rate for solar roof systems above 100 kW and ground-mounted solar system will fall below TWD7 (USD 0.23)/kWh, which is a large enough price shift to also decrease profits and extend investment return periods. Most banks in Taiwan tend to choose to cooperate with foreign firms with good credit, and resist providing attractive financial incentives for local solar manufacturers and developers (EnergyTrend, 2012). This threat may not cause immediate impact to the renewable energy industry in Taiwan, but it will impede long-term renewable energy technology development of Taiwanese manufacturers. The results of the analysis are summarized in Table 4.

3.2.4. The comparison

Through the SWOT analysis, this paper has identified that Japan, South Korea, and Taiwan are blessed with abundant renewable energy resources. This analysis also discovered that the three countries have the capacity to build renewable energy technology expertise because they are major producers of some of the most technologically advanced products in the world, such as motor vehicles, electronics, machine tools, semiconductor, and IC products. Application of their advanced industrial capacity has enabled these countries to develop their own renewable energy technologies over the past decades, especially in Japan and Taiwan.

In addition to sharing many similar technological and economic trends, common weaknesses were also found in each country's energy policies. One example is that all three countries have historically emphasized the development of nuclear power. Nuclear energy has been promoted as an alternative to oil-fired electricity generation since the oil crises and recently as a zero-emission energy source. The pro-nuclear energy policies of these countries have simultaneously prevented the development of strong renewable energy policies. As such, the countries have not explored or utilized the full potential of their renewable energy resources.

Table 4
The summary of SWOT analysis results of renewable energy policies in Taiwan.

Strengths	Weaknesses
• Abundant renewable energy potential • Sound legal framework, incentivizing the development of renewable energy • Well-established solar PV supply chain • Robust economic and trade relations with China	• Limited suitable land area for developing large-scale renewable facilities • Inconsistent and frequently-altered renewable energy targets • The dis-linkage of renewable technology development and its actual usage rate within Taiwan
Opportunities	**Threats**
• Boosting the cooperation between Taiwan's technological know-how and China's market potential • The warning of the Fukushima nuclear disaster and growing safety concern for nuclear power • Government's support of constructing new and renewable energy supply chains in Taiwan	• Energy-intensive industrial structure which requires stable energy supply historically supported by fossil fuels and nuclear power • Investment environment favoring large-scale industry and unfriendly towards small and medium scale domestic renewable technology manufacturers

However, the SWOT analysis also identified that nascent anti-nuclear concerns after the Fukushima disaster have yielded a common opportunity. The anti-nuclear clamor in Japan triggered the expansion of investments in renewable energy, especially from business corporations and local municipal governments and communities, to reduce dependence on nuclear power. While it is less obvious, such movements that seek the renewable energy option as an alternative to nuclear power are also found in South Korea and Taiwan.

Additionally, this study discovered several unique elements in each country that could create or destroy opportunities for renewable energy. First, the analysis identified several opportunities in Japan, bolstered by recent advancements in its renewable energy policies. The 2009 solar FIT and 2012 comprehensive FIT schemes have succeeded in attracting significant investments in renewable energy. In addition, refinement of conflicting laws for renewable energy installation by the central government has provided additional expansion opportunities in Japan. The SWOT also identified that Japan has been struggling to hold its leading position in renewable energy technology due to a loss in price competitiveness, while Taiwan has succeeded in expanding its global share by establishing a strong tie with the Chinese market.

This study discovered that South Korea's renewable energy industry has gained a clear advantage over Japan and Taiwan in the EU market since the FTA with the EU entered into force in 2011. The EU–Japan FTA is still under negotiation and it does not seem likely that Taiwan will enter into negotiations with the EU for the FTA in the near future due to the diplomatically complicated situation (European Parliamentary Research Service, 2013; Ministry of Foreign Affairs of Japan, 2014). The lowered tariffs on exports have enabled the Korean renewable energy industry to improve its cost competitiveness in Europe. It has also provided opportunities for the nation to enhance overall competitiveness of its renewable energy products through joint research and cooperation with the EU.

A significant strength and opportunity for Taiwan is its price-competitive and export-oriented PV industry and its economic relationship with China. Foreign trade has been the engine of Taiwan's rapid economic growth during the past forty years. The increasing demand in the global renewable market has created a strong incentive for domestic companies in which to invest and produce renewable energy products. In particular, a long-term economic relationship with China has contributed to creating a world-leading solar PV industry through the promotion of bilateral cooperation in supply chains, joint ventures, mergers, acquisitions, and product standardization (Taiwan Bureau of Energy (Taiwan BoE), 2012b). Due to these ties, Taiwan has succeeded in producing cost-competitive renewable energy technologies by utilizing cheap Chinese labor and selling renewable technology with fewer trade barriers in Chinese markets.

4. Conclusions and policy implications

Based on the findings, joint development could have positive outcomes for the expansion of renewable energy in all three countries. Although the three countries may compete with each other for a greater global renewable market share, opportunities exist to increase collaboration among these countries.

There are precedents that demonstrate the value of multilateral cooperation and partnership amongst these and other countries. For example, Japan, South Korea, and Taiwan are all members of the Asia-Pacific Economic Cooperation, a forum of twenty-one Pacific Rim countries that seeks to promote free trade and economic cooperation throughout the Asia-Pacific region. Specifically, Japan, South Korea, and Taiwan cooperate to address energy security and environmental challenges and promote the trade of green technologies (Kurata, 2012). However, the benefits of collaboration in the field of renewable energy among these countries have been not been well recognized. As a result, these nations have developed very different renewable energy policies based on similar energy supply structures. Collaboration, including the sharing of best practices and experiences in renewable energy policy implementation, could bring considerable value to all three countries. Also, in terms of research and technological cooperation, joint development between Japan and South Korea for offshore wind power could be particularly beneficial.

Another joint development opportunity exists between Japan and Taiwan in an effort to marry Japan's advanced renewable technologies and Taiwan's ability to explore huge renewable markets in China. Cooperation between Japan and Taiwan has the potential to increase opportunities for Japan to expand market share in China, while improving renewable energy technology in Taiwan through technology transfer from Japan.

The Fukushima disaster has provided a favorable window of opportunity for renewable energy expansion. However, this window may close if all of the essential factors, including renewable energy policies, technologies, manufactures, and electricity systems and market, are not robust enough to rapidly ramp up renewable energy development. These countries are very similar in that they all have vulnerable energy systems and a pressing need to develop renewable energy sources. The establishment of a cooperative framework to foster an increase in renewable energy technology, policy, and programs in these three countries is critical to fully unlock their renewable energy potential and survive in the global renewable energy market.

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