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SOLAR ENERGY IN JAPAN: INNOVATIONS AND POLICY OUTLOOK

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SOLAR ENERGY IN JAPAN

INNOVATIONS AND POLICY OUTLOOK

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Summary

The effects of climate change have led governments around the world to increase the share of renewable energy sources in their national energy mix. For Japan, the 2011 Fukushima nuclear disaster had a vast impact on the country's renewable energy policy and energy self-sufficiency. Solar power has become a major renewable source of electricity, yet the policy landscape since 2011 has become a stumbling block for the growth of solar-related businesses. At present, Japan is seeking to adjust its renewable energy policies to balance out the needs of companies and consumers alike. At the same time, Japan must compete with growing foreign solar power markets such as China and India. This Risk Report provides insight into what innovations Japan has been investing in and how government policies shape the market.

List of Abbreviations

CO2	Carbon dioxide
FIT	Feed-in-Tariffs
GHG	Greenhouse gases
GW	Gigawatt
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
JAXA	Japanese Aerospace Exploration Agency
kWh	Kilowatt hour
METI	Ministry of Economy, Trade and Industry
Mtoe	Million tons of oil equivalent
MW	Megawatt
OCCTO	Cross-Regional Coordination of Transmission Operators
OPEC	Organization of the Petroleum Exporting Countries
RES-E	Electricity from renewable energy sources
RPS	Renewable Portfolio Standards
SBSP	Space-based solar power
Solar PV	Solar photovoltaics
SSPS	Space-based solar power systems

TAGS: SOLAR ENERGY, RENEWABLE ENERGY, JAPAN, EAST ASIA, ASIA, GOVERNMENT REGULATIONS, GOVERNMENT POLICIES, FEED-IN-TARIFFS, SOLAR ENERGY MARKET, MARKET COMPETITIVENESS, ELECTRICITY PRICES, FLOATING SOLAR PANELS, SOLAR PANELS IN SPACE, INNOVATION, CO2 EMISSIONS, FUKUSHIMA NUCLEAR DISASTER.

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Introduction: An Overview of Energy in Japan

With a population of almost 127 million inhabitants as of 2019[1], Japan's energy demand is among the highest in the world, ranking as the world's fifth-largest consumer of energy measured by Mtoe (million tons of oil equivalent) after China, the United States, India, and Russia.[2] What is critical about Japan's energy profile is that the country is relatively poor in natural resources, making it highly dependent on imports of natural oil and gas from OPEC (Organization of the Petroleum Exporting Countries) nations including the United Arab Emirates, Saudi Arabia, Kuwait, and Iran. Japan also imports coal from Australia and the US to satisfy its energy demands. In 2014, Japan's energy self-sufficiency ratio was particularly low at only 7%, which was below that of other developed countries.[3]

The use of fossil fuels for energy emits CO2 (carbon dioxide), contributing to the urgent issue of climate change, and Japan ranks as the world's fifth-largest emitter of CO2.[4] Observing the various negative effects of climate change, governments around the world have made efforts to increase their share of clean renewable energy to create sustainable energy production and consumption behaviors and to reduce GHG (greenhouse gas) emissions, as recommended in the 2016 *Paris Climate Agreement*. Renewable energy met approximately 26% of global electricity demands in 2019, and forecasts predict a further increase of about 4% by 2023.[5]

In order to reduce its CO2 emission levels, Japan's government aims to increase the use of renewable energy such as hydro, solar, wind, biomass, and geothermal power in the longer-term future. 15% of Japan's energy mix was covered by these renewables in 2016, and the government

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[1] Worldometers (2019): *Japan population*. Available at: https://www.worldometers.info/world-population/japan-population/ (Accessed September 17, 2019).

[2] Enerdata (2019): *Global Energy Statistical Yearbook 2019*. Available at: https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html (Accessed September 17, 2019).

[3] Komiyama, R. & Fuji, Y. (2017): Assessment of post-Fukushima renewable energy policy in Japan's nation-wide power grid, *Energy Policy* 101, pp. 594-611.

[4] Obayashi, Y. & Jacob-Phillips, S. (2019): Japan's 2017/2018 CO2 emissions drop to 8-year low, *Reuters*. Available at: https://www.reuters.com/article/us-carbon-japan/japans-2017-18-co2-emissions-drop-to-8-year-low-idUSKCN1RS05Q (Accessed September 17, 2019).

[5] International Energy Agency [IEA] (2019): *Renewables 2018: market analysis and forecast from 2018 to 2023*. Available at: https://www.iea.org/renewables2018/ (Accessed September 17, 2019).

plans to further raise this ratio.[6] In the financial year 2017-2018 ending on March 31, 2018, Japan was able to reduce its GHG emissions to an eight-year low as emissions levels fell by 1.2%.[7]

As the technology for solar panels is advancing and market prices for solar energy are falling globally, solar power is becoming an attractive alternative to fossil fuels. While Japan has driven innovation in solar technology forward with the development of floating solar panels, Japan's solar energy market is struggling because of price regulations by the Japanese government, which has pushed solar energy businesses into bankruptcy. A closer look at technological innovations in solar energy production, the significance of the Fukushima Daiichi nuclear disaster on March 11, 2011, and subsequent governmental energy policies will provide insight into risks and opportunities in the solar power sector in Japan.

Technological Innovations

Japan is a heavily populated, mountainous country, stretching over 3,000 km (1,900 mi) along the Pacific Coast of East Asia and covering a broad range of climate zones, from the frostier north near Russia to the humid, subtropical south close to Taiwan. Available land is a valuable resource in Japan because of its scarcity. The country is divided into approximately 6,800 islands, and vast areas are covered by mountainous zones, making much of the land unsuitable for agricultural farming and housing. This prompts the question of where to place solar farms. Since land use must be approached thoughtfully in Japan, innovators have sought resourceful and space-saving ways to install solar panels despite these challenges. Solar panels floating on water or in outer space are one way to approach this issue. Another option is to restructure solar power supply from utility-based production to home-based production.

[6] The Japan Times (2019): Japan's post-3/11 energy policy, *The Japan Times*. Available at: https://www.japantimes.co.jp/opinion/2019/03/13/editorials/japans-post-3-11-energy-policy/#.XX9O7X_gqM9 (Accessed: September 13, 2019).

[7] Obayashi, Y. & Jacob-Phillips, S. (2019): Japan's 2017/2018 CO2 emissions drop to 8-year low, *Reuters*. Available at: https://www.reuters.com/article/us-carbon-japan/japans-2017-18-co2-emissions-drop-to-8-year-low-idUSKCN1RS05Q (Accessed September 17, 2019).

Floating Solar Panels

Asia is a developing global hub for floating solar power plants, with most of the world's largest plants located in China, Japan, and South Korea. In mid-2018, the total installed capacity of floating solar panels was roughly 1.1 GWp (gigawatt-peak). Ground-based solar panels reached the same capacity in the year 2000, indicating that floating solar power may develop similarly rapidly. [8] China accounts for the largest portion and also hosts the largest floating power plant in the world near Anhui, which reaches a capacity of 78,000 MW (megawatt) and can supply approximately 21,000 households with electricity.[9] South Korea plans to exceed these levels in the future, aiming for a floating solar plant with a capacity of 102.5 MW to power even more homes. Singapore and India are also expanding their floating solar power assets. Singapore has invested in the world's largest offshore floating solar power plant in the Strait of Johor to circumvent space shortages, while India targets an installed capacity of 10 GW.[10]

Japan is home to the world's first floating solar power plant, which was built in Aichi Prefecture in Central Honshu in 2008. Numerous lakes and water reservoirs can be utilized to generate electricity through floating solar panels. Hence, Japan has become a top producer of floating solar power, generating almost 50% of the capacity of the 100 biggest floating solar plants in the world, which adds up to a cumulative capacity of 246 MW.[11] Additionally, 73 of the world's 100 largest floating solar plants are located in Japan.[12] The country's biggest floating solar power plant is at Yamakura

[8] World Bank Group (2018): *Where sun meets water: floating solar market report*. Available at: http://documents.worldbank.org/curated/en/579941540407455831/Floating-Solar-Market-Report-Executive-Summary (Accessed: September 30, 2019).

[9] Broom, D. (2019): How Japan become the world leader in floating solar power, *World Economic Forum*. Available at: https://www.weforum.org/agenda/2019/03/japan-is-the-world-leader-in-floating-solar-power/ (Accessed: September 13, 2019).

[10] Chandran, R. (2019): In land-scarce Southeast Asia, solar panels float on water, *Thomson Reuters Foundation News*. Available at: https://news.trust.org/item/20190208102615-bye4f/ (Accessed: September 13, 2019).

[11] Broom, D. (2019): How Japan become the world leader in floating solar power, *World Economic Forum*. Available at: https://www.weforum.org/agenda/2019/03/japan-is-the-world-leader-in-floating-solar-power/ (Accessed: September 13, 2019).

[12] Ibid.

Dam in Chiba Prefecture, which is close to Tokyo. The plant is 18 hectares large and can supply almost 5,000 households with electricity.[13]

Risks associated with floating solar panels include their vulnerability to bad weather conditions such as typhoons. An environmental risk pertaining to floating panels is the negative impact they could have on ecosystems in lakes and oceans as they block the sunlight. Yet floating panels reportedly have the benefit of increasing energy efficiency by up to 16% as compared to land-based solar panels.[14] Moreover, floating panels can potentially reduce water evaporation levels in reservoirs, since they block the sun and provide shade for the water beneath.

Solar Panels in Space

Recent discussions about how to advance solar technology and expand its capacity have introduced the topic of solar panels in space. Japan's *Basic Plan on Space Policy* by the Strategic Headquarters for Space Policy has determined development-oriented utilizations of space for industrial, scientific, and technological purposes.[15] The Japan Aerospace Exploration Agency (JAXA) began research on space solar power systems (SSPS) – also known as space-based solar power (SBSP) – as early as the 1980s.[16]

SSPS provide a number of advantages; they can supplement shortfalls of earth-based solar systems such as comparatively low energy output, which renders the possibility of relying solely on solar power and achieving zero emissions relatively unlikely. The benefit of orbital SSPS is that they always face the sun, day and night, and are not influenced by atmospheric interferences such as weather conditions, including clouds and rain. This also makes SSPS invulnerable to terrestrial

[13] Broom, D. (2019): How Japan become the world leader in floating solar power, *World Economic Forum*. Available at: https://www.weforum.org/agenda/2019/03/japan-is-the-world-leader-in-floating-solar-power/ (Accessed: September 13, 2019).

[14] Ibid.

[15] Japanese Cabinet Office (n.d.): *Basic plan on space policy*. Available at: https://www8.cao.go.jp/space/plan/keikaku.html (Accessed: September 17, 2019).

[16] Japan Aerospace Exploration Agency [JAXA] (2013): *About the SSPS*. Available at: http://www.kenkai.jaxa.jp/eng/research/ssps/ssps-ssps.html (Accessed: September 25, 2019).

natural disasters like earthquakes, floods, or storms. Additionally, solar irradiance is 40% stronger in space because of increased proximity to the sun, yielding a greater energy potential.[17]

The difficulty of realizing SSPS projects is that there are two major challenges that must be overcome. Launching bulky materials for solar power stations into space is expensive. Furthermore, materials would have to be assembled in space, requiring well-trained staff. US-based company Made In Space, Inc. is exploring the option of manufacturing solar stations in space with the aid of robotics, solving the personnel issue. Yet another factor that makes SSPS unprofitable at present is energy loss resulting from energy conversion. Electricity harvested in space must be transformed into microwaves that are transmitted to receivers on earth, where they are converted back into electricity. These multiple conversions reduce energy efficiency, which means that energy is lost during the process.[18] Therefore, technology is not advanced enough yet to make SSPS efficient and lucrative.

Two risks that must be taken into account are the issue of space hazards and space debris. Solar panels in space must be robust in order to withstand the harsh conditions and hazards of outer space. Therefore, the safety and maintenance of SSPS must be secured in order to avoid damage and financial loss. Moreover, when large-scale constructions such as space stations or satellites are decommissioned, they remain in outer space as space debris, cluttering the environment and creating impediments to future space travel and exploration as journeys become increasingly dangerous to vehicles and personnel. Such space debris would also become a risk to the safety of SSPS. At the same time, obsolete SSPS would themselves clutter up the outer space environment, further compounding the problem.

Possessing high-level expertise in technology and robotics, Japan may be able to develop space-based solar panels in the long-term future. Skeptics, however, argue that SSPS are unlikely to become a viable energy option in the future if the cost of transportation cannot be drastically reduced and electricity conversion does not become more efficient.

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[17] Japan Aerospace Exploration Agency [JAXA] (2013): *About the SSPS*. Available at: http://www.kenkai.jaxa.jp/eng/research/ssps/ssps-ssps.html (Accessed: September 25, 2019).

[18] Doyle, K. (2012): Elon Musk on SpaceX, Tesla, and why space solar power must die, *Popular Mechanics*. Available at: https://www.popularmechanics.com/technology/a8101/elon-musk-on-spacex-tesla-and-why-space-solar-power-must-die-13386162/ (Accessed: September 25, 2019).

Residential Solar Power Production

Residential, or home-based, solar power panels supply individual homes with electricity. They are commonly installed on the roof or in the vicinity of a building. This way, the issue of a lack of space for large solar power plants can be circumvented, since customers can attach residential solar photovoltaic (solar PV) panels on their rooftops. While trends in the years 2012 to 2014 had suggested that the Japanese solar market was moving towards large commercial and utility-scale solar power production,[19] solar energy researchers forecasted in 2016 that solar power generation will shift away from large solar farms towards smaller residential solar panel solutions.[20] A reason for this development can be found in the government's intervention. Since 2016, the Japanese government has become more proactive in approving new utility-scale solar power projects.[21] While commercial, large-scale solar PV is likely to continue dominating the market, new opportunities for residential PV have opened up.

What may be important to consider when entering the Japanese solar market is that Japanese housing behavior is relatively fast-paced, particularly in cities. In contrast to European houses, for instance, Japanese apartment blocks tend to have shorter lifespans.[22] For this reason, a crucial requirement for Japanese solar panels is capacity rather than durability, and designing panels that last more than 20 years is not necessarily profitable in Japanese cities.

[19] Hahn, E. (2014): The Japanese solar PV market and industry: Business opportunities for European companies, *EU-Japan Centre for Industrial Cooperation*. Available at: https://www.eu-japan.eu/sites/default/files/publications/docs/pvinjapan.pdf (Accessed: September 26, 2019).

[20] Watanabe, C. (2016): Rooftop solar booms in Japan as market moves beyond utilities, *The Japan Times*. Available at: https://www.japantimes.co.jp/news/2016/03/23/business/rooftop-solar-booms-japan-market-moves-beyond-utilities/#.XZW7VWZCQ2w (Accessed: September 26, 2019).

[21] Bermudez, V. (2018): Japan, the new 'El Dorado' of solar PV?, *Journal of Renewable and Sustainable Energy* 10, 020401. Available at: https://aip.scitation.org/doi/full/10.1063/1.5024431 (Accessed: October 1, 2019).

[22] Crossley-Baxter, L. (2019): Too good to ignore: the new solar panel scheme for the masses, *Rethink Tokyo*. Available at: https://www.rethinktokyo.com/trende-solar-panels-japan (Accessed: September 13, 2019).

The Implications of the Fukushima Nuclear Disaster for Japan's Energy Policy

The Tohoku earthquake, the tsunami crashing on Japan's eastern shores and the subsequent Fukushima Daiichi nuclear power plant disaster in March 2011 was a shocking experience for Japan that had a great impact on its energy policy. Before the catastrophe, also referred to as 3/11, Japan had derived approximately 30% of its electricity from nuclear power and had planned to increase this ratio to 40% by 2017.[23] Building on this increase, the Japanese government had hoped to eventually generate 53% of its total energy production from nuclear power by 2030.[24] In the immediate aftermath of the Fukushima disaster, however, nuclear power plants were shut down across the entire country, leaving Japan with a serious energy supply gap. Updating safety measures at power plants after the disaster demanded increased investment and rendered nuclear power more expensive and less competitive than other energy options. As a consequence, renewable energy sources gained momentum in Japan.

The Government's Renewable Energy Targets

While incumbent Prime Minister Shinzo Abe's administration had approved the reactivation of 17 nuclear power reactors since 2015 and plans to raise the ratio of nuclear energy to 20% by 2030,[25] renewable energy is an increasingly important factor in Japan's energy policy. As governments around the world seek to reduce CO2 emissions and decelerate climate change, Japan aims to contribute to this effort by raising the share of renewables in its energy mix from 15% in 2016 to

[23] World Nuclear Association (2019): *Nuclear power in Japan*. Available at: https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx (Accessed: September 26, 2019).

[24] Takeuchi, S. (2019): Japan's energy policies at a critical juncture, *The Japan Times*. Available at: https://www.japantimes.co.jp/news/2019/07/01/business/japans-energy-policies-critical-juncture/#.XX-EHn_gqM8 (Accessed: September 16, 2019).

[25] World Nuclear Association (2019): *Nuclear power in Japan*. Available at: https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx (Accessed: September 26, 2019).

22-24% by 2030.[26] Most of the renewable energy in Japan will be sourced from hydropower, solar power, and biomass. Hydroelectricity will account for 8.8-8.2%, solar power for 7.0%, and biomass for 3.7-4.6%.[27] Solar power will, therefore, become a pillar of Japan's renewable energy target.

Government Policies and Domestic Market Strategy

Energy supply and self-sufficiency became two major goals in the Japanese policy strategy after the Fukushima catastrophe. This is reflected in Japan's *Basic Act on Energy Policy*, which was last updated in its fifth installment in 2018. The 2016 *Basic Act on Energy Policy* included the government's 2030 goal for its energy mix, addressing the need to raise Japan's energy self-sufficiency to approximately 25% after it had plunged to 6% in 2013 following the shutdown of nuclear power plants across the country.[28]

In order to foster market competition after the Fukushima disaster, Japan reformed its energy market strategy, shifting away from a regionally segmented market that divided the country into 10 regions. These regions each had their own regional electric power company controlling and managing local demand and supply. This split the country into relatively isolated energy markets, which had low levels of cross-regional coordination.[29] Implementing its market reform plans, Japan established the Organization for Cross-Regional Coordination of Transmission Operators (OCCTO)

[26] Nikkei (2018): Japan's solar panel makers suffer as power plant demand fades, *Nikkei Asian Review*. Available at: https://asia.nikkei.com/Business/Business-trends/Japan-s-solar-panel-makers-suffer-as-power-plant-demand-fades (Accessed: September 13, 2019).

[27] Yamazaki, T. (n.d.): Japan's renewable energy policy, *Ministry of Economy, Trade and Industry* [METI]. Available at: https://www.ieabioenergy.com/wp-content/uploads/2018/09/0.2-Takuya-Yamazaki.pdf (Accessed: September 13, 2019).

[28] Takeuchi, S. (2019): Japan's energy policies at a critical juncture, *The Japan Times*. Available at: https://www.japantimes.co.jp/news/2019/07/01/business/japans-energy-policies-critical-juncture/#.XX-EHn_gqM8 (Accessed: September 16, 2019).

[29] Yamazaki, T. (n.d.): Japan's renewable energy policy, *Ministry of Economy, Trade and Industry* [METI]. Available at: https://www.ieabioenergy.com/wp-content/uploads/2018/09/0.2-Takuya-Yamazaki.pdf (Accessed: September 13, 2019).

in 2015 and deregulated the energy retail market, raising competition among companies. This reform affected not only sales but also power generation, transmission, and distribution.[30]

Accordingly, Japan's newly liberalized market grew independent of a supply chain dominated by energy monopolies. This carries significant implications for the rise of renewables. Companies that plan to set up their businesses close to a customer base can tap into off-grid energy options like solar or wind power. This can advance market decentralization while also facilitating decarbonization.[31] Businesses may also utilize modern technology, including social media, big data, and market analyses, to determine what energy options customers prefer and how consumer behavior and trends are changing over time.

Government Policies and Their Impact on Businesses: From the RPS Scheme to Feed-In-Tariffs

Japan had started to include electricity from renewable energy sources (RES-E) in its government schemes early on. Between 2003 and 2012 the Japanese government aimed to increase the use of renewable energy with the Renewable Portfolio Standards (RPS) system. The RPS obliged electricity retailers to source a certain amount of electricity from 'new energy'. The following renewable power sources fall under the umbrella term 'new energy': solar photovoltaics, wind energy, biomass, geothermal power, and medium to small-sized hydroelectricity installations with a capacity of up to 1 MW.[32] The scheme was based on the 1997 *Special Measures Law Concerning the Use of New Energy by Electric Utilities*, and the specific amount generated by new energy depended on how much electricity retailers sold.[33] Retailers could meet the requirements established by the RPS by

[30] Yamazaki, T. (n.d.): Japan's renewable energy policy, *Ministry of Economy, Trade and Industry* [METI]. Available at: https://www.ieabioenergy.com/wp-content/uploads/2018/09/0.2-Takuya-Yamazaki.pdf (Accessed: September 13, 2019).

[31] See Takeuchi, S. (2019): The future of Japan's energy and environmental politics, *The Japan Times*. Available at: https://www.japantimes.co.jp/news/2019/07/29/business/future-japans-energy-environmental-policies/#.XX9O73_gqM9 (Accessed: September 16, 2019).

[32] Ibid.

[33] International Energy Agency [IEA] (2016): *Green power: Renewable Portfolio Standards (RPS)*. Available at: https://www.iea.org/policiesandmeasures/pams/japan/name-23884-en.php (Accessed: September 26, 2019).

either producing electricity from renewables, procuring renewable energy from another retailer, or by buying *New Energy Certificates* from another party.[34]

After the 2011 Fukushima disaster and the subsequent energy shortage in Japan, the country replaced the RPS with Feed-In-Tariffs (FIT) system, which was enacted in July 2012. The FIT provided RES-E producers with long-term contracts and a fixed purchase price.[35] In order to promote the utilization of renewable energy in the country, the Japanese government created incentives for energy businesses to focus on renewables by setting the purchase prices for RES-E relatively high. This also allowed Japan to increase its domestic energy generation and fill the energy deficiency gap after the nuclear disaster in 2011. The purchase price is annually revised according to the type, form, and size of the electricity utility and published by the Ministry of Economy, Trade and Industry (METI).[36] The electricity supply and production cost factors determine the annual FIT.[37] A positive development after the FIT was introduced was that installed RES-E capacity rose by about 32% between 2011 and 2013.[38] In concrete terms, Japan's solar PV capacity increased almost tenfold from 4.9 GW in 2011 to 55.5 GW in 2018, ranking among the highest in the world.[39]

While the FIT is meant to spur growth in the Japanese renewable energy sector, recent years have shown that the high price levels for RES-E are a burden to consumers. Surcharges to cover the purchase cost are passed on to customers and have totaled approximately 10 trillion yen ($93

[34] International Energy Agency [IEA] (2016): *Green power: Renewable Portfolio Standards (RPS).* Available at: https://www.iea.org/policiesandmeasures/pams/japan/name-23884-en.php (Accessed: September 26, 2019).

[35] International Energy Agency [IEA] (2018): Feed-in Tariff for renewable electricity and solar PV auction. Available at: https://www.iea.org/policiesandmeasures/pams/japan/name-30660-en.php?s=dHlwZT1yZSZzdGF0dXM9T2s (Accessed: September 26, 2019).

[36] Ibid.

[37] Dong, Y. & Shimada, K. (2017): Evolution from the renewable portfolio standards to feed-in tariff for the deployment of renewable energy in Japan, *Renewable Energy* 107, pp. 590-596.

[38] Dong, Y. & Shimada, K. (2017): Evolution from the renewable portfolio standards to feed-in tariff for the deployment of renewable energy in Japan, *Renewable Energy* 107, pp. 590-596.

[39] International Renewable Energy Agency [IRENA] (2019): Renewable capacity statistics 2019. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Mar/IRENA_RE_Capacity_Statistics_2019.pdf (Accessed: September 30, 2019).

billion) since the FIT was introduced in 2012.[40] In fiscal year 2019, the FIT surcharge was estimated to reach as much as 2.4 trillion yen ($22 billion). According to an assessment by the METI, surcharges will increase to approximately 4 trillion yen in 2030 ($ 37 billion).[41]

The longer-term risk is that such high prices curb the demand for RES-E among consumers. While customers worldwide benefitted from a global trend of falling prices for electricity from solar PV, Japanese consumers did not experience the same due to the FIT scheme. While the prices for solar energy in Japan have decreased over time, they still exceed those of other countries. Japan's prices are roughly twice as high as Germany's, for instance.[42] Meanwhile, Japan's Asian competitor India is now generating the most affordable solar power in the world.[43] Cost reduction is a crucial determinant in paving the way for renewables in Japan. Aware of this factor, Japan's government is gradually lowering costs for consumers. In fiscal 2019, the purchase price was 14 yen ($ 0.13) per kWh (kilowatt hour), roughly a third of the 40-yen price when the FIT was first implemented in 2012.[44]

Gradually falling prices had created difficulties for solar energy businesses, however. Banking on initially high revenues from the FIT scheme, solar energy businesses have struggled to turn a profit in recent years. Eighty-eight Japanese solar energy-related companies went bankrupt in 2017, most of which were smaller businesses. During the first half of 2018, another 44 enterprises became insolvent. Even large companies such as Kyocera, Panasonic, or Solar Frontier took losses in fiscal

[40] Dong, Y. & Shimada, K. (2017): Evolution from the renewable portfolio standards to feed-in tariff for the deployment of renewable energy in Japan, *Renewable Energy* 107, pp. 590-596; Takeuchi, S. (2019)b: Building toward large-scale use of renewable energy in Japan, *The Japan Times*. Available at: https://www.japantimes.co.jp/news/2019/07/08/business/building-toward-large-scale-use-renewable-energy-japan/#.XX-EM3_gqM8 (Accessed: September 16, 2019).

[41] Komiyama, R. & Fuji, Y. (2017): Assessment of post-Fukushima renewable energy policy in Japan's nation-wide power grid, *Energy Policy* 101, pp. 594-611.

[42] Takeuchi, S. (2019): Building toward large-scale use of renewable energy in Japan, *The Japan Times*. Available at: https://www.japantimes.co.jp/news/2019/07/08/business/building-toward-large-scale-use-renewable-energy-japan/#.XX-EM3_gqM8 (Accessed: September 16, 2019).

[43] Wood, J. (2019): India is now producing the world's cheapest solar power, *World Economic Forum*. Available at: https://www.weforum.org/agenda/2019/06/india-is-now-producing-the-world-s-cheapest-solar-power/ (Accessed: September 17, 2019).

[44] Nippon.com (2019): Cloudy outlook for solar-energy companies in Japan, *Nippon.com*. Available at: https://www.nippon.com/en/japan-data/h00377/cloudy-outlook-for-solar-energy-companies-in-japan.html (Accessed: September 13, 2019).

year 2017 because of government policies and limited space for large solar power plants in the country.[45]

Japan plans to further reduce prices in the course of the coming years.[46] In order to achieve this goal, the government has been transitioning towards a new auction system for nonresidential solar power since 2017. This new mechanism has the potential to reduce the price of solar-based electricity. During the auction in summer 2018, the government set the upper limit at 15.5 yen ($0.14) per kWh; however, the lowest tender was 16.47 yen ($0.15). The participating bidders had anticipated a higher limit, and eventually no contracts were awarded in the course of that bidding round.[47] In the summer of 2019, the METI set the upper price limit at 14 yen ($0.13) per kWh. The lowest bid was 10.5 yen ($0.098). The lowered prices can be considered a success, but the energy generation capacity did not reach the expectations of the government,[48] requiring further improvement.

In sum, Japan's major challenge in advancing solar energy domestically is to lower prices for consumers in order to increase demand and be on par with global prices. At the same time, Japan must also further seek to create an attractive market environment for domestic businesses.

[45] Arias, J. (2018): Solar energy, energy storage and virtual power plants in Japan, *EU-Japan Centre for Industrial Cooperation*. Available at: https://www.eu japan.eu/sites/default/files/publications/docs/min18_1_arias_solarenergy-energystorageandvirtualpowerplantsinjapan.pdf (Accessed: September 26, 2019); Nikkei (2018): Japan's solar panel makers suffer as power plant demand fades, *Nikkei Asian Review*. Available at: https://asia.nikkei.com/Business/Business-trends/Japan-s-solar-panel-makers-suffer-as-power-plant-demand-fades (Accessed: September 13, 2019).

[46] Nippon.com (2019): Cloudy outlook for solar-energy companies in Japan, *Nippon.com*. Available at: https://www.nippon.com/en/japan-data/h00377/cloudy-outlook-for-solar-energy-companies-in-japan.html (Accessed: September 13, 2019).

[47] Takeuchi, Y. (2018): Japan struggles to cut its high solar power costs, *Nikkei Asian Review*. Available at: https://asia.nikkei.com/Spotlight/Environment/Japan-struggles-to-cut-its-high-solar-power-costs (Accessed: September 13, 2019).

[48] Bellini, E. (2019): Japan's fourth solar auction concludes with lowest bid of $0.098/kWh, *PV Magazine*. Available at: https://www.pv-magazine.com/2019/09/03/japans-fourth-solar-auction-concludes-with-lowest-bid-of-0-098-kwh/ (Accessed: September 26, 2019).

Challenges and Opportunities

There are two areas that Japan must further develop in order to close the gap with overseas competition. First, Japan must create an inviting domestic market environment to boost the growth of solar-related companies. Second, Japan trails behind foreign competition like India or China, which offers cheaper solar energy technology. For instance, Japanese electronics company Sharp owned the highest market share in solar PV panels in 2006. Eleven years later, Chinese companies have vastly outpaced Japanese competitors; as a result, the accumulated global share of all Japanese market leaders accounted for only 1% in 2017.[49]

Another challenge Japan inherently faces is a lack of land due to its geography and diverse climate conditions along the long string of Japanese islands. While some regions enjoy a greater amount of average solar irradiance, other regions must rely on less sunshine and therefore less electricity output. Hence, strengthening a cross-regional share of energy can aid in supplying the entire country with renewable energy.

Furthermore, energy storage capacities require further improvement. While hydroelectricity facilities can be utilized as energy batteries, solar power is an intermittent source of electricity. Therefore, Japan must create a balanced ratio in its future renewable energy mix to allow for greater storage capacities. This is where hydropower can supplement lacking storage capabilities of current solar power technology.

After the introduction of the FIT scheme in 2012, solar-related companies proliferated, yet wind, biomass, and geothermal energy options have remained largely unexplored.[50] While other renewable energy options like wind farms can provide an opportunity to expand the renewable energy sector, the implementation of such a plan must be approached with caution. Like solar energy businesses, wind-related companies will also struggle with the issue of limited space in

[49] Hanada, Y. (2018): Foreign solar panel makers take command of Japanese market, *Nikkei Asian Review*. Available at: https://asia.nikkei.com/Business/Business-trends/Foreign-solar-panel-makers-take-command-of-Japanese-market (Accessed: September 26, 2019).

[50] Yamazaki, T. (n.d. 2018?): Japan's renewable energy policy, *Ministry of Economy, Trade and Industry* [METI]. Available at: https://www.ieabioenergy.com/wp-content/uploads/2018/09/0.2-Takuya-Yamazaki.pdf (Accessed: September 13, 2019).

Japan. Therefore, investing in renewable energy innovation with the largest energy output and storage capacity can be worthwhile.

Finally, a comparison between floating solar power plants and residential solar PV shows that both have the potential to expand the solar energy market in Japan and integrate greater quantities of renewable energy into Japan's energy mix. It is important to consider, though, that falling prices for utility-scale solar power can negatively affect the growth of residential solar PV, since customers resort to utility-based electricity. In 2016, demand for residential solar PV decreased by 10% as FIT for commercial and utility-scale solar energy fell.[51] The new auction system, by contrast, is projected to impact residential PV to a lesser extent, as growth in the residential PV market will remain flat. Increasing retail electricity prices, however, will foster the lucrativeness of local PV self-consumption.[52] While utility-scale solar energy supply may still dominate the market, off-grid solutions can supplement RES-E supply.

Strategic Summary

Opportunities

- Solar PV capacity is improving not only in Japan but globally. As one of the world's leaders in solar energy, Japan has the potential to further bank on solar PV development and increase the share of renewables in its national energy mix.
- Due to Japan's geographical location and climate conditions, the solar PV market may provide opportunities for innovations and alternative solutions. Since space for large land-based solar farms is limited, floating and residential solar panels can be a viable option for businesses.
- After the 2011 Fukushima disaster, the Japanese government struggled with an energy deficiency as nuclear power plants were shut down. Subsequently, greater energy self-

[51] **Bermudez, V. (2018): Japan, the new 'El Dorado' of solar PV?, *Journal of Renewable and Sustainable Energy* 10, 020401. Available at: https://aip.scitation.org/doi/full/10.1063/1.5024431 (Accessed: October 1, 2019).**
[52] **Ibid.**

sufficiency and increased use of renewable energy sources became a policy target. Hence, the METI is adjusting regulative policies to support the growth of solar energy.

Risks

- Japan's costs and prices for solar energy are relatively high and therefore cannot compete with many other countries, such as India, where solar PVs are becoming cheaper.
- Due to the relatively high prices of solar energy, Japan should anticipate foreign competition in the domestic market.
- Japan has been struggling to accommodate both businesses and customers with RES-E government policies.
- What is critical in the Japanese market is that solutions are space-saving and affordable to customers to raise the attractiveness of solar energy.

Tactical Breakdown

Operational

- Businesses operating in Japan's solar PV market must take housing behavior, the scarcity of land for solar panels, and potentially adverse government policies such as the FIT scheme into consideration.
- Market reforms such as deregulation and improved cross-regional coordination among transmission operators facilitated market competition and growth in Japan.

Financial

- Consumers have benefitted from falling FIT surcharges, yet businesses have suffered from the government's efforts to reduce prices in order to accommodate consumers and be on par with global trends.
- While building solar panels in space to fully harness the power of the sun appears to be an innovative and worthwhile investment, various hurdles must be overcome before solar panels in space become lucrative. Unprofitable energy conversion, the enormous cost of

transporting bulky materials into space, the harsh outer space environment, maintenance requirements, and the effects of space debris are discouraging factors.

Compliance

- After the 2011 Fukushima disaster, the Japanese government sought to foster the growth of RES-E in the domestic market. The FIT scheme initially facilitated the expansion of the solar energy market in Japan through high purchase prices, yet long-term effects have forced the METI to re-evaluate policies. At present, the government is implementing an auction system to unburden solar-related businesses while still lowering prices.
- Shortly after the Fukushima catastrophe, the government had aimed to radically decrease the ratio of nuclear energy in the national energy mix. Yet energy self-sufficiency is critical for the island state. The current government under Prime Minister Abe plans to raise the use of nuclear energy again to 20% by 2030. At the same time, however, the government aims to also increase the share of renewables to 22-24% by 2030. Solar power will account for 7%, ranking as the second most utilized renewable energy source after hydroelectricity.

Conclusion

Opinions in the debate around the share of renewable sources and nuclear energy in Japan's energy mix diverge. While Shinjiro Koizumi, Japan's new Minister of the Environment, holds the view that all nuclear power plants should be shut down after the 2011 Fukushima nuclear catastrophe,[53] the government's energy goal for 2030 provides for the reactivation of nuclear plants across the country in order to raise the ratio of nuclear energy to 20%. Two critical determinants in Japan's discourse on energy policy are energy self-sufficiency and the growth of the renewable energy sector in the future. Solar is estimated to be the second most important renewable energy source by 2030 after hydropower. In recent years, the Japanese government has adopted new regulations in order to support competitiveness in the energy market. Yet Japan's solar panel

[53] **McCurry, J. (2019): Japan should scrap nuclear reactors after Fukushima, says new environment minister, *The Guardian*. Available at: https://www.theguardian.com/world/2019/sep/12/japan-should-scrap-nuclear-reactors-after-fukushima-says-new-environment-minister (Accessed: October 2, 2019).**

makers are losing ground in the face of foreign competition and are instead building expertise in alternative areas, including home energy management systems and energy-saving mechanisms for lighting, air conditioning, and other equipment.[54] Major challenges that businesses and policymakers must meet are 1) remaining a frontrunner in floating solar panel technology and other solar-related technology, 2) balancing out costs for businesses and consumers, 3) integrating modern technologies into the domestic market to explore consumer demands, and 4) reducing GHG emissions.

[54] **Hanada, Y. (2018): Foreign solar panel makers take command of Japanese market, *Nikkei Asian Review*. Available at: https://asia.nikkei.com/Business/Business-trends/Foreign-solar-panel-makers-take-command-of-Japanese-market (Accessed: September 26, 2019).**

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