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Abstract:
Japan is actively promoting the development of renewable energy, particularly in the fields of solar and wind power, with the aim of achieving carbon neutrality and transforming its energy structure. However, despite abundant natural resources and supportive policies, the actual progress of renewable energy deployment remains slow and exhibits significant regional disparities. To derive policy insights on how regional policies can better facilitate renewable energy adoption, this paper systematically reviews recent leading studies on renewable energy, the current status of renewable energy in Japan, policy evolution, and spatial distribution characteristics. The investigation reveals a certain degree of correlation between regional renewable energy development and local policies, manifesting as spatial disparities. By analyzing both first nature and second nature, the study finds that areas with abundant natural resources and densely populated urban regions are more likely to become priority zones for distributed renewable energy development. This suggests that the spatial alignment between electricity demand and resource supply plays a crucial role in energy deployment. Furthermore, differences in local policies among municipalities with similar natural resources and population sizes may also be key factors contributing to the variation in actual renewable energy adoption. This aspect will be explored through systematic quantitative analysis in future research.

Keywords: Renewable energy, Regional policy, Spatial Disparities, Japan

1 Introduction

In response to global climate change and the pursuit of a sustainable society, countries around the world are accelerating the adoption of renewable energy. In recent years, with continuous technological advancements in solar and wind power and a significant reduction in generation costs, renewable energy has gradually established itself as a primary source of electricity worldwide. Internationally, the annual newly installed capacity of renewable energy continues to reach record highs, and its economic competitiveness has surpassed that of traditional fossil fuels. In Japan, the government is also actively promoting the spread of renewable energy to achieve a "decarbonized society." Since the Great East Japan Earthquake in 2011, Japan has re-evaluated its reliance on nuclear power and accelerated its transition toward decarbonization, leading to significant changes in renewable energy-related policies and systems. The Japanese government has set a target to increase the share of renewable energy to 36–38% by 2030, and is vigorously developing diverse energy sources such as solar and wind power. At the same time, efforts are being made to advance technological development, improve electricity transmission infrastructure, and promote coexistence policies with local communities, positioning renewable energy as a central pillar of Japan's energy policy. In terms of development potential, Japan possesses solar and offshore wind resources equivalent to 14 times the amount needed to achieve 100% renewable electricity supply, along with substantial potential for large-scale off-river pumped hydro energy storage (Cheng et al., 2022). From a technical perspective, Esteban & Portugal-Pereira (2014) simulated Japan's hourly electricity demand in 2030 and analyzed meteorological data for wind and solar energy. Their results indicate that Japan's power system is technically capable of increasing the share of renewable energy to 100%, with stable and reliable electricity supply achievable through the use of pumped hydro and battery storage to balance daily supply-demand fluctuations. Even in the Kanto region, which has the highest electricity demand, the offshore wind power potential along the coast is estimated at 287 terawatt-hours (TWh) annually—slightly exceeding the annual supply capacity of Tokyo Electric Power Company (Yamaguchi & Ishihara, 2014)—when economic and social factors are excluded. This demonstrates that Japan has sufficient and abundant natural resource potential for renewable energy development. However, at the current stage, Japan still faces challenges in terms of renewable energy adoption rates, cost competitiveness, and stable power supply, and lags behind leading countries in these areas.

EU member states are global leaders in expanding the adoption of renewable energy. For example, Germany, under its "Energiewende" policy, has increased the share of renewables in electricity generation to over 55% (Ember, 2025), while actively promoting distributed energy systems and citizen-participation projects. In Northern Europe, the development of wind and hydro power has progressed rapidly. Denmark, for instance, generates more than 50% of its electricity from wind power (2023). EU countries benefit from long-term policy stability and have set clear targets for renewable energy adoption, such as those outlined in the Renewable Energy Directive. Legal and institutional frameworks, including green finance and electricity market reforms, are also being continuously improved. In the United States, although federal renewable energy policies are relatively limited, individual states have established their own targets and implemented Renewable Portfolio Standards (RPS). California stands out as a leading state in renewable energy promotion, with rapid progress in large-scale solar and wind power deployment, as well as grid-scale energy storage technologies. By 2024, renewable energy accounted for 57% of California's electricity generation. China is the world's largest adopter of renewable energy, with large-scale development of solar, wind, and hydro power, alongside a strengthened supply chain. By the end of 2024, China's cumulative installed capacity reached 887 GW for solar, 521 GW for wind, and 436 GW for hydro power (IRENA, 2025). Through feed-in tariff systems, subsidy policies, and clearly defined adoption targets, China has achieved rapid expansion in equipment capacity and significant cost reductions. In comparison, Japan lags behind major countries in terms of renewable energy adoption rates. Motivated by this issue, the present study revisits Japan's renewable energy policies and development trends, with the goal of identifying policy implications to enhance adoption.

The remainder of this paper is structured as follows. Section 2 reviews recent leading studies on renewable energy, covering its development prospects, current challenges, and potential promotion strategies. Section 3 outlines the evolution and characteristics of Japan's renewable energy-related policies. Section 4 analyzes the current status of renewable energy adoption in Japan, with a focus on spatial disparities. Finally, Section 5 presents the conclusion of the paper.

2 Previous studies

2.1 Current status and challenges of solar and wind power generation

As a clean and renewable energy source, solar power has seen remarkable global development in recent years. In 2024, solar energy accounted for 6.9% of global electricity generation, a significant increase from approximately 3.6% in 2022, and represented about 21.5% of global renewable electricity generation (Ember, 2025). In the coming years, solar power is expected to play an increasingly critical role in the global energy mix. Solar energy is particularly notable for its potential applications at both commercial and residential levels (Shakeel et al., 2023). In agriculture, solar technologies can provide thermal energy and electricity for various industrial processes such as water pumping, cooling, distillation, desalination, and drying (Kumar et al., 2023). Solar systems used for these applications have proven to be more efficient than traditional energy sources. In residential settings, rooftop

GIS-based analysis estimates that detached houses can meet up to 26% of their electricity consumption through polycrystalline photovoltaic systems, while apartment buildings can meet around 7% (Vecchi & Berardi, 2024). Local solar resources can reduce dependence on the grid and enhance the feasibility of energy communities. Among renewable energy sources, solar power is also the least affected by climate change, with relatively stable annual generation (Osman et al., 2023). In terms of environmental impact, solar energy consumption contributes to reductions in CO_2 emissions (Kuşkaya et al., 2023). This has also been demonstrated in ecological footprint studies—a quantitative method for assessing the relationship between human demand for natural resources and the ecosystem's capacity. According to Hussain et al. (2023), a 1% increase in solar energy usage corresponds to a 2.9% reduction in ecological footprint. However, the development of solar energy also faces several challenges. The variability and intermittency of solar power make large-scale deployment and commercialization difficult, limiting the advancement of solar power technologies (Wang et al., 2024). These characteristics also pose challenges to the operation of power grids and electricity markets (Ekoue et al., 2025). Energy storage technologies, multi-energy complementary systems, electricity trading mechanisms, and surplus generation capacity can help mitigate some of these issues. In addition, the recycling of solar panels at the end of their life cycle is a major concern. It is estimated that by the middle of this century, the volume of discarded panels will reach several million tons, posing potential threats to both society and the environment. Life cycle environmental analyses have shown that recycling photovoltaic panels can significantly reduce these impacts, particularly in terms of human toxicity and freshwater ecotoxicity, with reductions of approximately 78% (Daniela-Abigail et al., 2022). Faircloth et al. (2019) evaluated the environmental benefits of material recovery by comparing recycling methods with the production processes they replace, and found that recycling solar panels imposes a lower environmental burden than landfill disposal. However, further research is needed to determine how solar panel recycling can be made economically viable.

Secondly, wind power generation has also experienced rapid growth in recent years, particularly offshore wind energy. However, it faces several challenges. In addition to the common issues associated with intermittent renewable energy, offshore wind development is often hindered by conflicts with fishermen and difficulties in gaining consensus among local residents. This is mainly because wind farms may affect fishery production and restrict access to traditional fishing grounds (Willis-Norton et al., 2024). On the other hand, prior research has suggested that floating wind turbines can function as fish aggregating devices (FADs), potentially increasing catch rates for certain species (Fayram & De Risi, 2007). Shimada et al. (2022) also noted that small-scale wind power projects may not pose significant threats to local fisheries. Most studies on the impact of offshore wind farms on fishery species provide only indirect evidence (Gill et al., 2025), and there is a lack of research offering direct evidence. As a result, many uncertainties remain regarding the actual impact of offshore wind on fisheries. This issue was also highlighted in recent research by Chaji & Werner (2023), which pointed out that prior studies lack economic data or data collection efforts focused on economic aspects. Quantitative assessments of economic impacts in key areas of concern are extremely limited, and there is a shortage of peer-reviewed models and methodologies for evaluating economic effects, as well as comprehensive summaries of best practices or lessons learned regarding the economic impact of offshore wind farms on fisheries. These gaps make it difficult to assess the impact of offshore wind using direct data. Some studies have proposed indirect evaluation methods. For example, Hélène et al. (2022) used vulnerability analysis to assess the impact of offshore wind farms. Regarding the impact on local residents, survey-based studies have found that the closer residents live to the coast, the more they prefer offshore wind farms to be located farther from shore (Ladenburg et al., 2024). However, other surveys have shown that most respondents do not perceive significant disturbances from wind farm-related issues such as noise, shadow flicker, rotating blades, or obstruction lights (Motosu & Maruyama, 2016). Additionally, wind power also faces challenges related to recycling. The wind power industry is a major global consumer of glass fiber-reinforced plastic (GFRP) composites, and given current and future development trends, the amount of GFRP waste generated by the industry is expected to continue increasing (Jensen & Skelton, 2018). This also suggests that circular economy business models in the wind power sector have the potential to deliver significant economic and social benefits, enhance resource security, and improve environmental performance (Mendoza et al., 2022).

2.2 Policy implications for the development of solar and wind power

In terms of adoption challenges, prior research has highlighted the importance of neutral organizations and financial support. Smythe (2024) pointed out that conflicts between wind energy development and fisheries have been exacerbated by the absence of neutral bridging organizations, and that introducing such entities, such as trusted government agencies can help mitigate these conflicts. Kumar et al. (2024) noted that the promotion of non-rooftop solar energy faces obstacles due to a lack of financial incentives and high upfront costs. Government subsidies and tax incentives can encourage investment in renewable energy, especially by supporting the growth of small and medium-sized renewable energy enterprises, where subsidies play a central role (Yang et al., 2019). Green bonds, within the framework of green finance, also have the potential to scale up renewable energy development by properly managing and distributing key risks, thereby channeling large amounts of capital into renewable energy projects (Fu & Ng, 2021). Moreover, policy support can stimulate technological innovation (Zhang et al., 2025). Payne et al. (2024) further discussed the spillover effects of policy, noting that the positive impact of renewable energy policies is not limited to the regions where they are implemented, but can also promote renewable energy development in neighboring areas.

Prior research has also emphasized the importance of collaboration. First, regarding stakeholder cooperation, Lebo (2019) analyzed the case of North America's first freshwater offshore wind farm and highlighted the significance of collaborative governance regimes (CGR) led by committed project advocates in advancing renewable energy projects. Second, interregional collaboration is crucial, as cooperation across multiple regions can help overcome barriers to large-scale projects, including cost, price suppression, and reduced developer risk (Bradley et al., 2014). Third, technological collaboration, both between companies and across regions is another key aspect. For example, innovation partnerships between large corporations and small and medium-sized enterprises (SMEs) can enhance the offshore wind sector's innovation capacity and competitiveness (Brink, 2017). Although SMEs may face a "glass ceiling" in demand-driven roles if they lack rare and specific valuable knowledge, they often find opportunities in supplier-driven roles when they collaborate with large firms and develop innovative solutions. Regarding interregional collaboration, Tang (2018) identified knowledge spillover effects at the state level in wind farm operations, which supports the rationale for cooperation among local governments. Technological advancement has also been shown to stimulate domestic demand for renewable energy (Choi, 2024), suggesting that investment in technology is vital for promoting renewable energy adoption.

Finally, the integration of solar and wind power generation can help alleviate the supply stability issues caused by the intermittency of renewable energy sources. For example, solar power is affected by weather conditions and the day-night cycle, making it unavailable at night and less efficient during cloudy mornings and evenings. Wind power, on the other hand, depends on wind speed, which varies by time and location, and cannot generate electricity during calm weather. These characteristics make intermittent renewable energy highly dependent on energy storage systems and backup power sources. In addition to solutions such as storage systems and the development of interregional power grids, combining multiple energy sources is an effective approach. One such method is the complementary use of solar and wind energy. Song et al. (2022) noted that both solar and wind power exhibit high volatility and a negative correlation, with strong time-varying spillover effects. By integrating solar and wind power generation, it is possible to reduce the overall generation risk and better match electricity demand.

2.3 Decentralized power systems

Decentralized power systems refer to energy production, storage, and consumption that are no longer concentrated in large-scale power plants, but instead distributed across multiple small, geographically dispersed energy units. These systems are particularly compatible with renewable energy, as their wide geographic distribution allows for local production and consumption, reducing energy losses from long-distance transmission and enabling the development of energy sources tailored to local natural resources. In addition, decentralized power systems contribute to enhanced energy security by reducing dependence on single large power plants and increasing system resilience. Overall, the characteristics of decentralized power systems align well with Japan's current energy development trends. First, the development of decentralized energy sources can help reduce regional income disparities (Deng et al., 2024), which aligns with Japan's regional revitalization policies, especially those integrating energy policy with local community development. Second, decentralized systems also support Japan's emphasis on energy security by improving regional energy self-sufficiency, reducing reliance on imports, and enhancing energy diversity (Du et al., 2024).

To address the intermittency of renewable energy, the development of energy storage systems is essential. A combination of short-term and seasonal storage not only provides the flexibility required by renewable energy sources (Zozmann et al., 2021), but also helps reduce curtailment during supply-demand peaks and alleviate grid congestion (Simshauser, 2025). However, relying solely on energy reserves is insufficient to ensure system reliability. While long-duration storage can enhance reliability, it may pose challenges to market performance and the profitability of all participants (Zhang et al., 2024). This suggests that, in addition to energy reserves, power reserves are also critically important. These include spinning reserves (provided by running but underloaded generation units), non-spinning reserves (standby units that can be quickly activated), and frequency regulation reserves (used to maintain grid frequency stability).

3 Renewable energy policies in Japan

3.1 Evolution of Japan's renewable energy policies and institutional overview

Japan began formally promoting the adoption of renewable energy in the 1990s. The enactment of the Act on Special Measures Concerning the Use of New Energy in 1997 marked a significant turning point in accelerating the spread of renewables. This law supported the introduction of new energy sources such as wind, solar, biomass, and small-scale hydro, gradually positioning renewable energy as a key component of national energy policy. In 2003, the Renewable Portfolio Standard (RPS) Law—officially the Act on Special Measures Concerning the Use of New Energy by Electric Utilities—was implemented, requiring power companies to supply a certain proportion of electricity from renewable sources. While this system contributed to the spread of renewables to some extent, its low target settings and complex certification procedures became obstacles to further expansion. In 2012, the RPS system was replaced by the Feed-in Tariff (FIT) scheme. Under the FIT system, electric utilities were obligated to purchase renewable electricity at fixed prices for a designated period, which led to a rapid expansion of solar power generation. Following the implementation of FIT, Japan saw a significant increase in renewable energy capacity. However, the FIT system also faced several challenges. First, the cost burden and rising electricity prices became major concerns. The purchase costs under FIT were passed on to consumers through a “renewable energy surcharge,” and the initially high tariff rates were maintained for an extended period, increasing the financial burden on the public and sparking widespread debate over electricity price hikes. Second, grid constraints and output curtailment emerged as critical issues. The rapid growth of renewable energy generation led to insufficient transmission capacity and uneven geographic distribution. In areas with high solar concentration, grid congestion made it difficult to accommodate additional electricity, resulting in frequent forced curtailments of solar power generation.

Following this, three major Basic Energy Plans were introduced. First, the Fifth Basic Energy Plan in 2018 marked a turning point by stating for the first time that renewable energy should become a “main power source.” The plan set a target to increase the share of renewables to 22–24% by 2030, with a long-term outlook of reaching 80% by 2050. Second, the Sixth Basic Energy Plan in 2021 raised the 2030 target for renewable energy to 36–38%, aligning with Japan’s policy goals of achieving carbon neutrality by 2050 and reducing greenhouse gas emissions by 46–50% by 2030. This plan explicitly stated the need to “thoroughly position renewable energy as a main power source, and maximize its adoption while minimizing the public burden and promoting coexistence with local communities.” To achieve this, the government designated “Renewable Energy Promotion Zones” to accelerate the deployment of solar, onshore wind, and offshore wind power. Additionally, to foster harmony with local communities, the government supported the development of relevant ordinances and strengthened technical standards to ensure safety and environmental compatibility. To reduce the financial burden on the public, the plan also introduced the Feed-in Premium (FIP) system and promoted the use of auction schemes. The FIP system was officially implemented the following year. Unlike the FIT system, where utilities purchase electricity at fixed prices, the FIP system allows power producers to sell electricity on the market and receive a premium on top of the market price to ensure profitability. This mechanism not only helps reduce the public burden but also incentivizes power producers to supply electricity during peak demand periods. Finally, with the continued development of renewable energy, the Seventh Basic Energy Plan in 2025 raised the 2040 renewable energy target to 40–50%, positioning renewables as the largest power source. For the first time, the plan specified the breakdown of renewable energy sources, with solar accounting for 23–29% and wind for 4–8%. It also clearly stated the intention to reduce the share of thermal power generation to 30–40%.

In addition, Japan has introduced carbon pricing mechanisms. These include the existing carbon tax (¥289 per ton of CO_2) and regionally limited emissions trading systems (ETS), implemented in Tokyo in 2010 and Saitama Prefecture in 2011. Subsequently, GX-ETS was implemented starting in 2023, with the GX (Green Transformation) Promotion Act serving as the foundational legislation for Japan's GX goals. This law systematically promotes carbon pricing mechanisms and the GX-ETS as core policies, which are structured into three phases. The first phase (2023–2026) is primarily based on voluntary participation, allowing companies to set their own emission reduction targets. The system emphasizes information disclosure and attracting investors, but lacks overall emission caps and mandatory compliance mechanisms, resulting in limited incentives for emission reductions and making it difficult to ensure effective overall reductions. The second phase (from 2026 onward) significantly strengthens regulatory requirements, mandating participation for companies above a certain scale. The government allocates reduction targets based on industry benchmarks, introduces third-party certification, compliance verification, and penalties for unmet targets, thereby enhancing fairness and effectiveness. This phase will be compulsory and cover approximately 50–60% of national emissions. Initial allocation of emission allowances is mainly based on the benchmarking method, with the grandfathering method applied to certain industries. The system also includes price stabilization measures to prevent excessive market volatility and ensure predictability for corporate decarbonization investments. To address carbon leakage risks, additional allowances are provided to affected companies, encouraging ongoing emission reductions and technological innovation. The third phase is expected to be implemented from 2031 onwards, marking Japan's emissions trading system's further alignment with international mainstream models. In this phase, a paid auction mechanism will be introduced for the power generation sector, requiring companies to obtain emission allowances through market bidding, thereby enhancing the market-based pricing of emission rights and strengthening incentives for emission reductions. Since electricity is not subject to international trade, the cost increases resulting from auctions will not affect international competitiveness; however, power companies with a high proportion of thermal generation will face greater pressure to decarbonize. The system design must also consider the impact of rising electricity prices on export industries and low-income groups to ensure fairness and sustainable development. Overall, the third phase will achieve stricter total emission control and market-based operations, driving Japan toward its carbon neutrality goals and further refining the GX-ETS policy framework.

3.2 Regional approaches to renewable energy policy

One of the distinctive features of Japan's renewable energy policy is that many initiatives are led by local governments, with diverse policy models developed independently based on regional conditions. Since 2008, the Japanese government has launched the "Eco-Model Cities" initiative, selecting a group of cities to serve as pioneers in building a low-carbon society. These cities set greenhouse gas reduction targets tailored to their size and regional characteristics, and implemented comprehensive measures including energy conservation, renewable energy adoption, public transportation development, promotion of eco-friendly buildings, and urban greening. Selection criteria included the potential for greenhouse gas reduction, demonstrability, regional adaptability, feasibility, and sustainability. The first 13 cities were selected in 2008, followed by 7 more in 2012 and 3 in 2013 (see Table 1). Policy measures covered a wide range of areas, with renewable energy-related initiatives focusing on the utilization, integration, and management of energy. For example, 12 municipalities in northeastern Yokohama collaborated on renewable energy integration; Kitakyushu City promoted the development of regional energy hubs; and in Niigata City, citizens invested in solar power projects. Many of these initiatives emphasized interregional cooperation. Some, like Yokohama and Kitakyushu, implemented inter-municipal collaboration policies, while others, such as Minamata, established research and information dissemination hubs to foster regional linkages. These examples suggest that regional policies are not only effective within individual areas but also have spillover effects across regions.

Table 1 Eco-Model Cities

Year	Municipality
2008	Hokkaido: Obihiro City, Shimokawa Town; Kanagawa: Yokohama City; Toyama: Toyama City; Fukuoka: Kitakyushu City; Kumamoto: Minamata City; Tokyo Metropolis: Chiyoda Ward; Nagano: Iida City; Aichi: Toyota City; Kyoto: Kyoto City; Osaka: Sakai City; Kochi: Yusuhara Town; Okinawa: Miyakojima City
2012	Ibaraki: Tsukuba City; Niigata: Niigata City; Gifu: Mitake Town; Hyogo: Kobe City, Amagasaki City; Okayama: Nishiawakura Village; Ehime: Matsuyama City
2013	Hokkaido: Niseko Town; Nara: Ikoma City; Kumamoto: Oguni Town

In 2011, the Japanese government introduced the “FutureCity” initiative as an upgraded version of the Eco-Model Cities program, emphasizing integrated development across environmental, social, and economic dimensions. This policy not only addressed environmental issues but also incorporated solutions to societal challenges such as declining birthrates, aging populations, and industrial revitalization. Launched in the aftermath of the Great East Japan Earthquake, the initiative placed particular emphasis on energy security and urban resilience. From the pool of Eco-Model Cities, 11 cities and regions were selected as FutureCities (see Table 2). The policy also established an evaluation mechanism to assess annual progress across three dimensions: environmental, social, and economic. In the environmental evaluation, indicators related to renewable energy adoption were included, such as the newly installed capacity of solar power and the deployment of wind power systems.

Table 2 FutureCity

Municipality
Shimokawa Town, Hokkaido; Kashiwa City (and others), Chiba; Yokohama City, Kanagawa; Toyama City, Toyama; Kitakyushu City, Fukuoka; Ofunato City, Rikuzentakata City, Sumita Town (and others), Iwate; Kamaishi City, Iwate; Iwanuma City, Miyagi; Higashimatsushima City, Miyagi; Minamisoma City, Fukushima; Shinchi Town, Fukushima

In 2018, the Japanese government launched the "SDGs FutureCity" initiative as a continuation and development of the previous two programs, aiming to realize the United Nations Sustainable Development Goals (SDGs) at the local level. This initiative integrates the global SDGs framework with Japan's regional revitalization and local development policies, supporting local governments in achieving comprehensive sustainability across environmental, economic, and social dimensions. The actual implementation covers a wide range of areas. In addition to renewable energy, many municipalities focus on promoting awareness and information dissemination. Furthermore, interregional collaboration is one of the key themes of the policy. Approximately 30 cities are selected each year, and the program includes the "SDGs Model Projects for Local Governments," which provides financial support to particularly advanced municipalities (see Figure 1). Starting in 2025, all SDGs FutureCities will be eligible for subsidies. Looking at the geographic distribution of selected areas, the cities are spread across the country. However, at the municipal level, a clear adjacency correlation can be observed, suggesting that areas near already selected regions are more likely to be chosen in the future. This may be related to the spillover effects of renewable energy development foundations, such as infrastructure development, local energy systems, information dissemination, and public acceptance, which can extend across municipal boundaries. Moreover, the selection of SDGs FutureCities shows a strong correlation with previous initiatives, as many cities designated as Eco-Model Cities were also selected for the SDGs FutureCity program. This reflects the continuity between the two policies, which share many common selection criteria. Additionally, regions influenced by these policies may have developed stronger foundations for renewable energy, suggesting that policy factors may contribute to spatial disparities in renewable energy development. Through spillover effects, this can lead to concentrated energy adoption within certain areas.

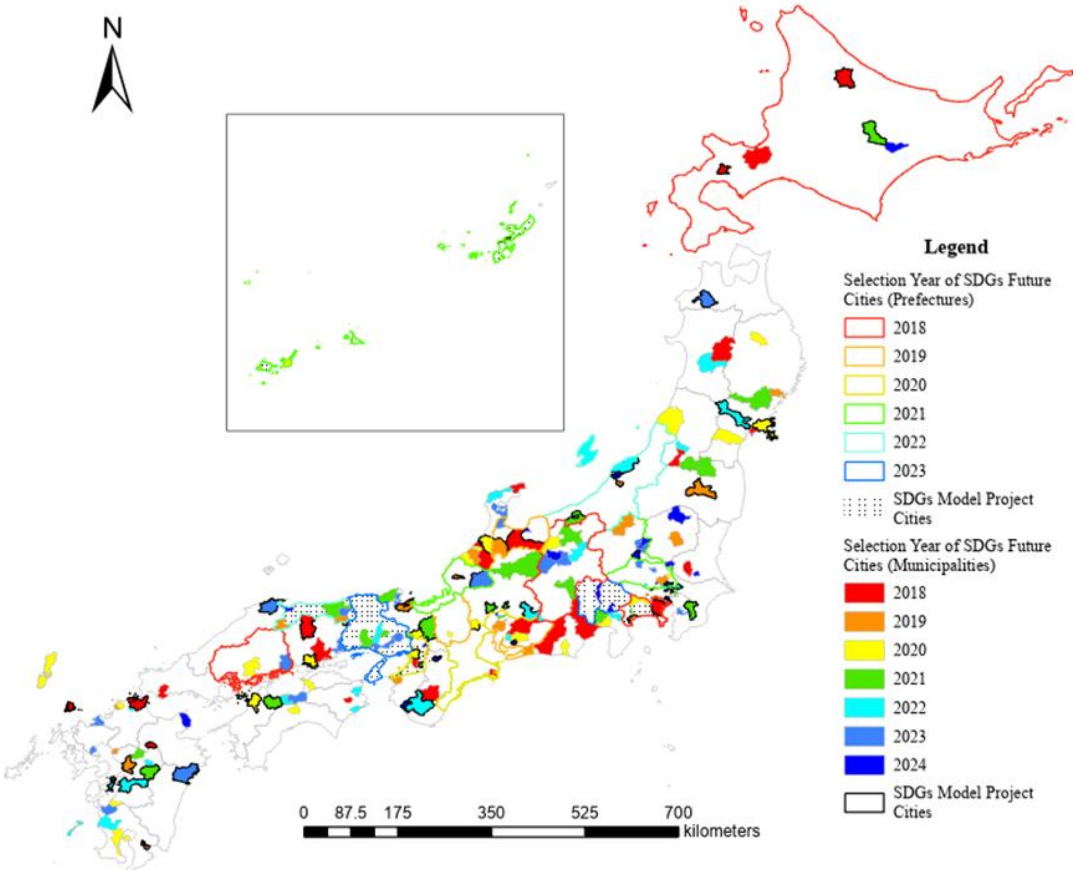


Figure 1 SDGs FutureCities

Notes: For ease of viewing, the figure shows only the main areas of Hokkaido, Honshu, Shikoku, Kyushu and zooms in on Okinawa section.

Since 2021, the Japanese government has promoted the “Decarbonization Leading Areas” initiative as a key measure to achieve carbon neutrality by 2050. This policy aims to designate local governments with unique regional characteristics and resource advantages to take the lead in achieving net-zero CO_2 emissions from electricity consumption in the residential sector by 2030. These areas serve as models not only in energy transition but also in reducing greenhouse gas emissions in transportation, heat utilization, and other sectors, aligning with national decarbonization goals. Selected regions must demonstrate the ability to effectively utilize local resources and show high levels of sustainability and scalability in renewable energy adoption, addressing social challenges, and revitalizing the local economy. To support these transitions, the government developed the “Regional Decarbonization Roadmap,” which sets a goal of establishing at least 100 Decarbonization Leading Areas nationwide by 2030, with the expectation that horizontal expansion will drive nationwide carbon neutrality. Financially, the initiative is backed by mechanisms such as the “Regional Decarbonization Transition and Renewable Energy Promotion Grant,” which encourages collaboration between local governments and private enterprises to promote renewable energy adoption and infrastructure development. As of 2024, a total of 116 prefectures and municipalities have joined the initiative (see Figure 2).

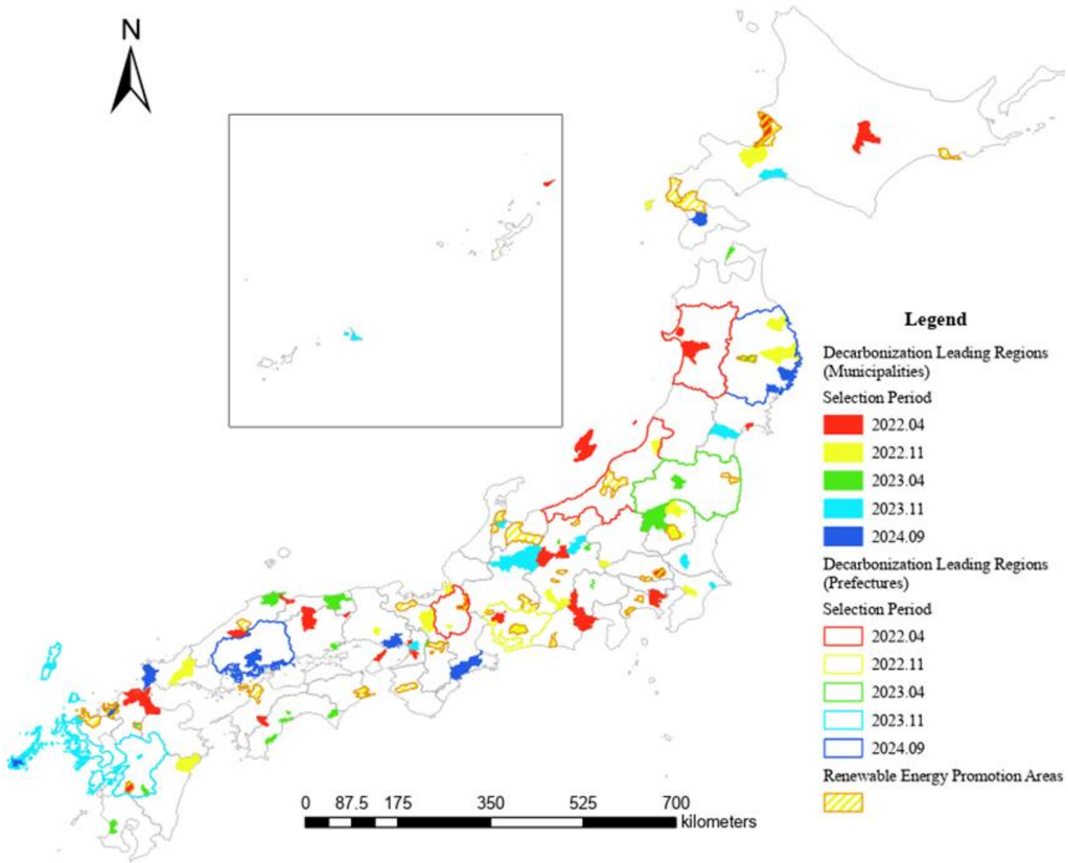


Figure 2 Decarbonization Leading Areas and Renewable Energy Promotion Zones

Notes: For ease of viewing, the figure shows only the main areas of Hokkaido, Honshu, Shikoku, Kyushu and zooms in on Okinawa section.

Since 2022, the Japanese government has introduced the “Renewable Energy Promotion Zones” system to encourage locally led renewable energy development. Under this system, local governments can designate specific areas as priority zones for renewable energy deployment, based on environmental criteria set by the national or prefectural governments. These zones are incorporated into local implementation plans, which must clearly outline requirements for environmental protection and regional contribution. Projects that meet these criteria can be officially recognized by the municipality and are eligible for policy support such as tax incentives and priority access to subsidies. The system emphasizes coexistence between projects and local communities, requiring developers to reach consensus with residents and stakeholders before implementation, ensuring a balance between environmental considerations and regional benefits. Projects must comply with standards related to ecological conservation, landscape harmony, and noise control, while also contributing to local economic development—for example, by creating jobs, improving energy self-sufficiency, and enhancing disaster resilience. As of May 2024, 36 cities, towns, and villages have been designated as promotion zones (see Figure 2). The geographic distribution of these two policies also shares similarities with previous initiatives, showing a tendency toward adjacency correlation. Many of the designated areas overlap with those selected under earlier policies, further suggesting the possibility of spatial concentration driven by policy factors.

4 Spatial disparities in renewable energy adoption in Japan

In 2023, Japan's electric power companies generated a total of 149,337 GWh from renewable energy sources, out of a total electricity generation of 826,481 GWh (only includes electricity generation by electric power companies). This means that renewables accounted for 18.1% of the total. Solar power and wind generation have shown steady annual growth, reaching a combined total of 32,234 GWh in 2023. As shown in Figure 3, although the share of renewable energy in Japan's overall electricity mix has been gradually increasing, the pace of growth remains slow, and traditional thermal power generation continues to dominate. Despite policy declarations positioning renewable energy as a central pillar of Japan's energy strategy, actual progress in deployment remains limited.

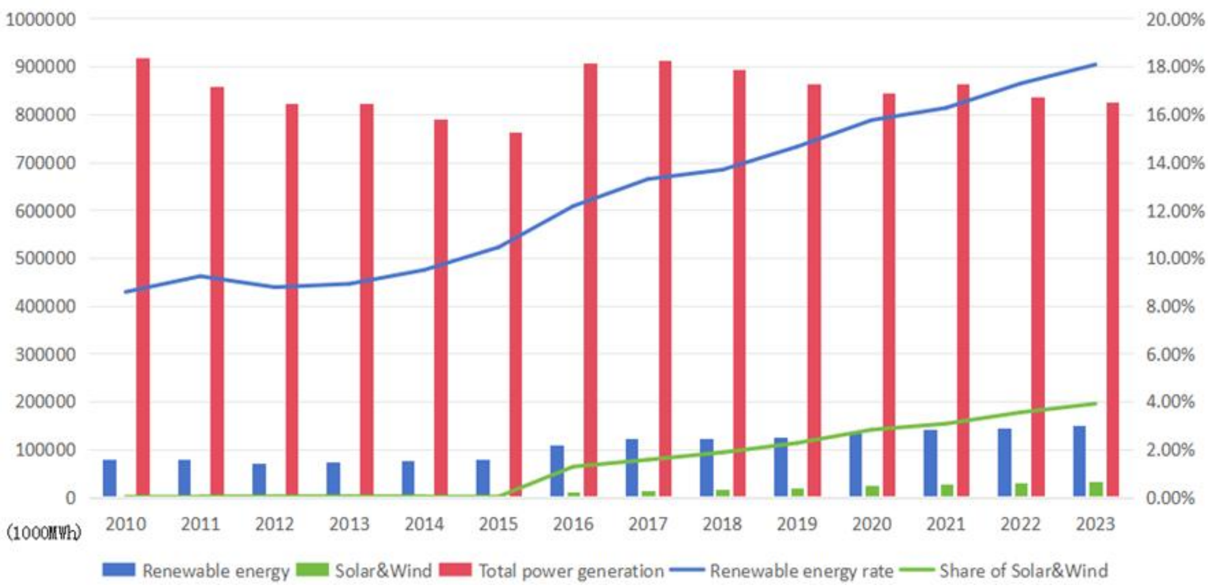
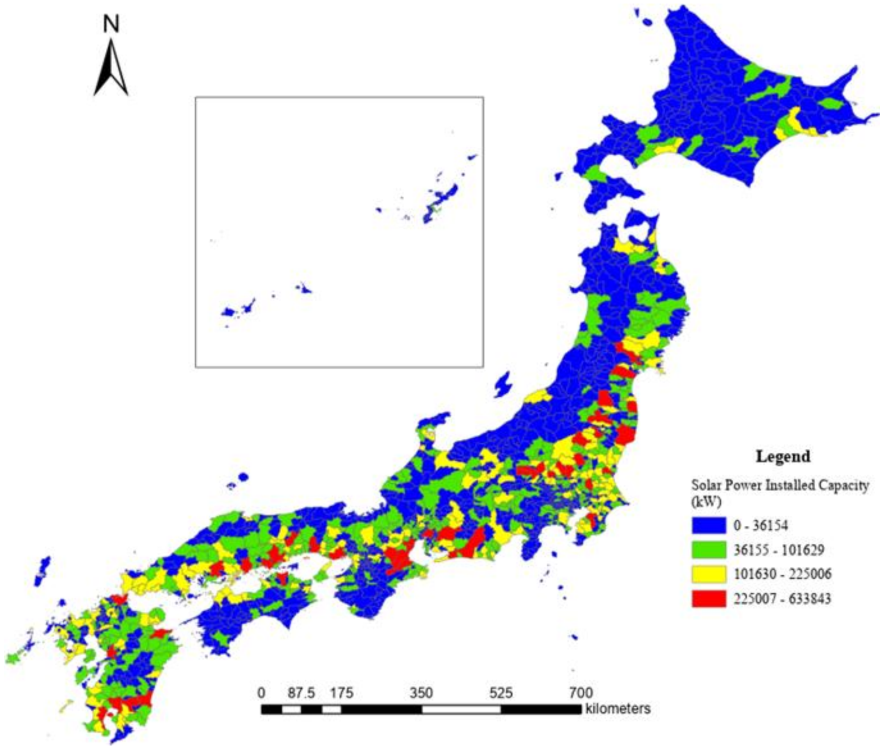


Figure 3 Trends in renewable energy generation

Notes: 1) The data only includes electricity generation by electric power companies; 2) source: based on the electricity generation data published by the Agency for Natural Resources and Energy

Figure 4 illustrates the distribution of installed capacity for solar and wind power in Japan. The map shows that solar energy deployment is primarily concentrated along Japan’s eastern coast. Specifically, notable regions include Miyagi and Fukushima in the Tohoku region; the entire Kanto region; Shizuoka and Aichi in the Chubu region; Mie and Hyogo in the Kansai region; Okayama and Hiroshima in the Chugoku region; Takamatsu and Matsuyama Cities in Shikoku region; and Kitakyushu City, Miyazaki, and Kagoshima in Kyushu region. In contrast, wind power deployment is more geographically limited, with major installations concentrated in Wakkanai City, Toyotomi Town, and Ishikari City in Hokkaido, as well as parts of Aomori and Akita. Overall, the spatial concentration of renewable energy adoption in Japan is clearly evident. To explain these spatial disparities, spatial economics and geography often refer to the concepts of “first nature” and “second nature.” First nature refers to physical and natural conditions such as topography, climate, and resource distribution—characteristics of the natural environment that are not shaped by human intervention and represent innate locational advantages. Second nature refers to human-made or institutional environments formed through accumulated development, including population and business agglomeration, infrastructure development, and the implementation of regional policies—locational characteristics shaped by human activity.

Taking solar power as an example, Figure 5 shows the distribution of annual average solar radiation and total annual sunshine hours. Solar radiation directly affects the amount of electricity generated, while sunshine hours determine the potential time available for solar power generation. Overall, regions with abundant solar resources tend to align with areas that have high installed capacity. For instance, Japan’s eastern coastal regions have richer solar resources, and these areas also show relatively higher levels of solar power deployment. However, when narrowing the geographic scope, discrepancies emerge. For example, although the Chubu region has richer solar resources than the Kanto region, the actual installed capacity is higher in Kanto. Similarly, Shikoku and Kyushu have comparable solar resource levels, yet Kyushu has significantly more solar installations. These differences cannot be explained by first nature factors alone.



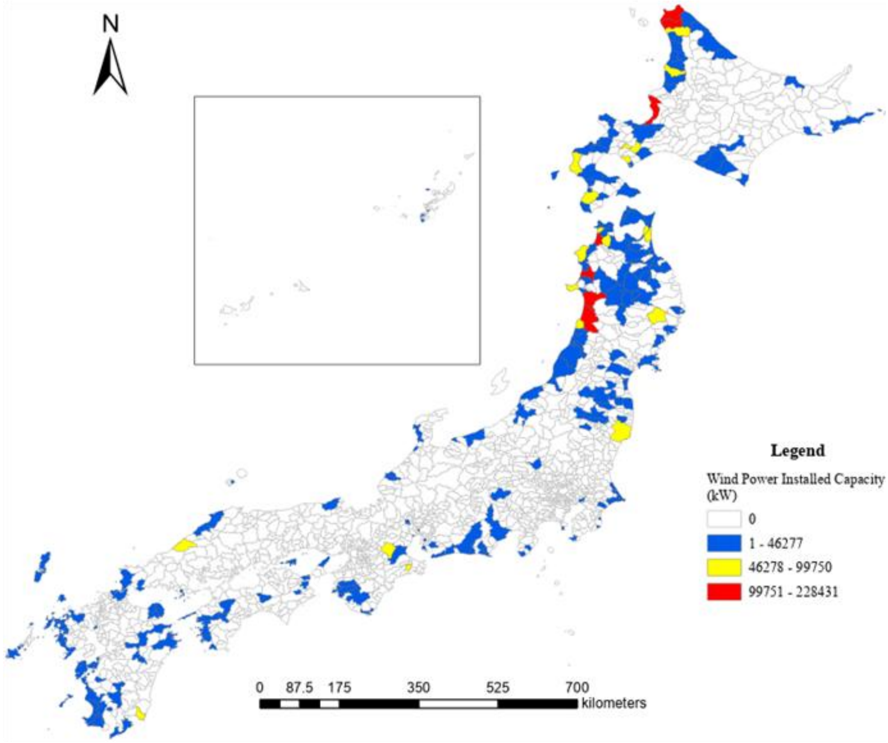


Figure 4 Installed capacity of solar and wind power

Notes: 1) Source: created based on data from the Agency for Natural Resources and Energy, “Renewable Energy Power Generation Facilities under the Act on Special Measures Concerning the Promotion of Utilization of Renewable Energy Electricity”; 2) for ease of viewing, the figure shows only the main areas of Hokkaido, Honshu, Shikoku, Kyushu and zooms in on Okinawa section.

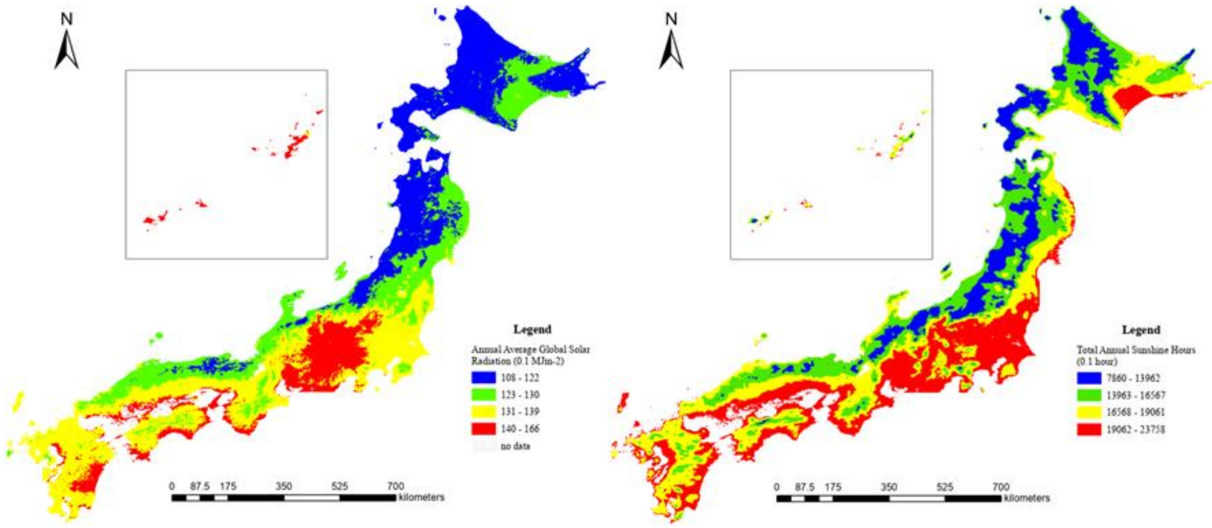


Figure 5 Solar radiation and sunshine duration

Notes: 1) Source: created based on the "Climatological Norm Mesh Data" published by the Ministry of Land, Infrastructure, Transport and Tourism; 2) the data represents climatological normals for each 1 km mesh (third-order mesh), based on observations from 1991 to 2020; 3) for ease of viewing, the figure shows only the main areas of Hokkaido, Honshu, Shikoku, Kyushu and zooms in on Okinawa section.

Regarding second nature factors that may influence renewable energy adoption, Figure 6 presents one example: urban population size. Regions with larger urban populations tend to have higher electricity demand. Developing distributed renewable energy sources near densely populated areas allows for local supply, reducing transmission losses across the grid. In fact, a comparison with Figure 4 reveals a strong correlation between population concentration and regions with high renewable energy capacity. Furthermore, other second nature factors—such as urban functions, land use, land prices, and regional policies—may also contribute to spatial disparities in renewable energy deployment. In particular, regional policies appear to be a significant factor. By examining Figures 1 and 2, it becomes evident that differences in renewable energy adoption among municipalities with similar natural resources and urban characteristics may be explained by policy interventions.

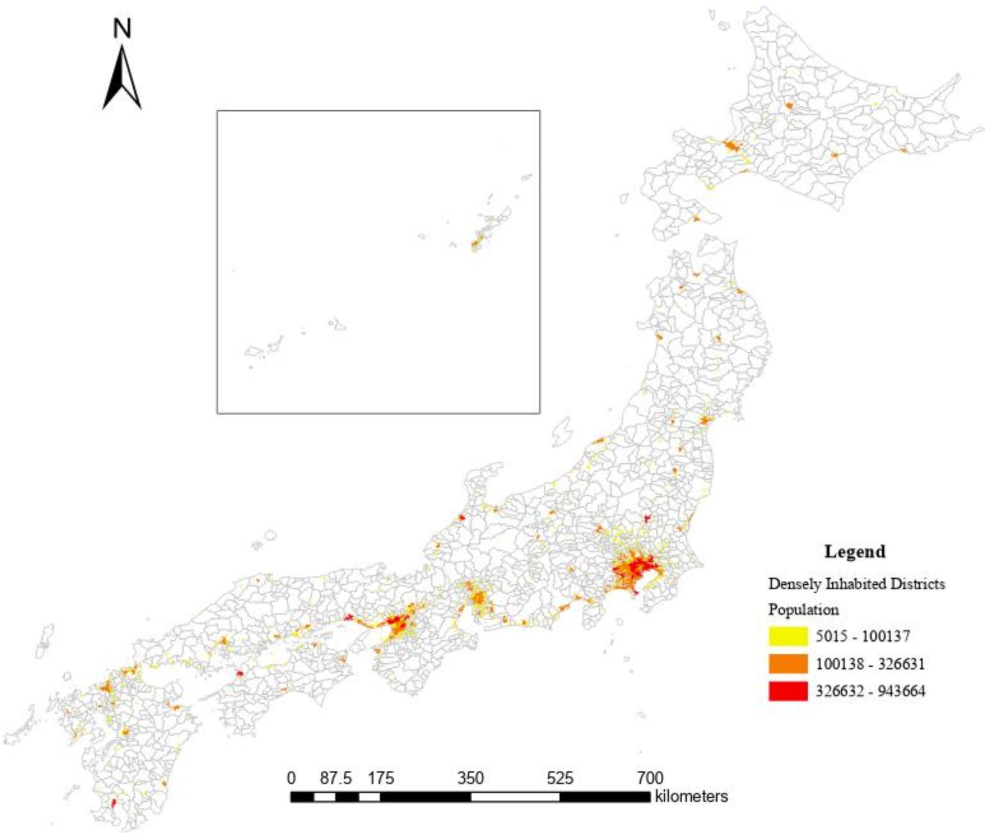


Figure 6 Densely Inhabited Districts

Notes: 1) Source: created based on the “DID (2020)” published by the Ministry of Land, Infrastructure, Transport and Tourism; 2) in principle, a "Densely Inhabited District" refers to a region where basic statistical units with a population density of 4,000 or more people per square kilometer are adjacent to each other within municipal boundaries, and the total population of these contiguous units is 5,000 or more at the time of the national census; 3) for ease of viewing, the figure shows only the main areas of Hokkaido, Honshu, Shikoku, Kyushu and zooms in on Okinawa section.

5 Conclusion

This paper first reviewed recent leading studies on renewable energy. These studies show that solar and wind power, as clean and renewable energy sources, have rapidly developed worldwide, demonstrating broad application potential and environmental benefits. However, they also face technical and social challenges such as intermittency, storage requirements, and recycling issues. Offshore wind power, in particular, involves conflicts with fisheries and challenges in gaining public acceptance. On the policy level, the involvement of neutral organizations, financial incentives, green finance, technological innovation, and regional cooperation are identified as key factors in promoting renewable energy development.

Additionally, the complementarity between solar and wind power helps mitigate intermittency issues and improve system stability. Decentralized power systems, through localized generation and storage, enhance energy security and resilience, aligning with Japan's regional revitalization and energy self-sufficiency policies, and offering a promising pathway for future energy transition. Next, this paper examined Japan's renewable energy policies, including both national and regional approaches. It was found that Japan's renewable energy policy exhibits strong regional characteristics and interregional correlations. Furthermore, by analyzing the current status of renewable energy adoption in Japan, this study identified significant spatial disparities. Through data analysis on solar irradiance, sunshine duration, and urban population concentration, it was found that areas with abundant natural resources and densely populated urban centers are more likely to become priority zones for distributed renewable energy development. This indicates that spatial matching between electricity demand and resource availability plays a crucial role in energy deployment. In addition, regional policy orientation also influences the spatial distribution and development pace of renewable energy. Especially when comparing municipalities with similar natural resource conditions and population sizes, differences in regional policies may be a key factor behind the variation in actual renewable energy adoption.

In future research, we will employ the Difference-in-Differences model to quantitatively analyze the effectiveness of Japan's regional policies in promoting renewable energy development. Specifically, we will examine how these policies influence the spatial distribution of renewable energy and attempt to explain the underlying mechanisms behind regional disparities. Furthermore, our study will pay attention to the spatial spillover effects of regional policies—that is, whether the impact of a policy extends to neighboring areas—and investigate how the interconnections between policies with inherited characteristics lead to differences in their promotional effects. Through these analyses, we aim to reveal the mechanisms and pathways through which regional policies facilitate the introduction of renewable energy, providing a scientific basis for future policy design. Ultimately, the goal of this research is to propose more targeted and effective policy recommendations, so as to fully leverage the role of regional policies in promoting renewable energy development, optimizing the energy structure, and achieving carbon neutrality objectives.

References

Bradley, D., Peterson, J., & Koujak, D. D. (2014). Regional Collaboration Opportunities as Catalyst to Unleash U.S. Offshore Wind Industry. *The Electricity Journal*, *27*(3), 28–34. https://doi.org/10.1016/j.tej.2014.03.007

Brink, T. (2017). Innovation collaboration in the renewable offshore wind energy sector. *International Journal of Energy Sector Management*, *11*(4), 664–680. https://doi.org/10.1108/IJESM-04-2016-0005

Chaji, M., & Werner, S. (2023). Economic Impacts of Offshore Wind Farms on Fishing Industries: Perspectives, Methods, and Knowledge Gaps. *Marine and Coastal Fisheries*, *15*(3), e210237. https://doi.org/10.1002/mcf2.10237

Cheng, C., Blakers, A., Stocks, M., & Lu, B. (2022). 100% renewable energy in Japan. *Energy Conversion and Management*, *255*, 115299. https://doi.org/10.1016/j.enconman.2022.115299

Choi, H. (2024). Technology-push, demand-pull and spillover from the major market demand: The case of the United States wind power market. *Technology in Society*, *79*, 102684. https://doi.org/10.1016/j.techsoc.2024.102684

Daniela-Abigail, H.-L., Tariq, R., Mekaoui, A. E., Bassam, A., Vega De Lille, M., J Ricalde, L., & Riech, I. (2022). Does recycling solar panels make this renewable resource sustainable? Evidence supported by environmental, economic, and social dimensions. *Sustainable Cities and Society*, *77*, 103539. https://doi.org/10.1016/j.scs.2021.103539

Du, J., Gu, H., Shen, Z., Song, M., & Vardanyan, M. (2024). Assessing regional energy security characteristics: Evidence from Chinese province-level data. *Energy Economics*, *140*, 107964. https://doi.org/10.1016/j.eneco.2024.107964

Ekoue, M. K., Woerman, M., & Clastres, C. (2025). Intermittency and uncertainty in wind and solar energy: Impacts on the French electricity market. *Energy Economics*, *142*, 108176. https://doi.org/10.1016/j.eneco.2024.108176

Esteban, M., & Portugal-Pereira, J. (2014). Post-disaster resilience of a 100% renewable energy system in Japan. *Energy*, *68*, 756–764. https://doi.org/10.1016/j.energy.2014.02.045

Faircloth, C. C., Wagner, K. H., Woodward, K. E., Rakkwamsuk, P., & Gheewala, S. H. (2019). The environmental and economic impacts of photovoltaic waste management in Thailand. *Resources, Conservation and Recycling*, *143*, 260–272. https://doi.org/10.1016/j.resconrec.2019.01.008

Fayram, A. H., & De Risi, A. (2007). The potential compatibility of offshore wind power and fisheries: An example using bluefin tuna in the Adriatic Sea. *Ocean & Coastal Management*, *50*(8), 597–605. https://doi.org/10.1016/j.ocecoaman.2007.05.004

Fu, J., & Ng, A. W. (2021). Scaling up Renewable Energy Assets: Issuing Green Bond via Structured Public-Private Collaboration for Managing Risk in an Emerging Economy. *Energies*, *14*(11), 3076. https://doi.org/10.3390/en14113076

Gill, A. B., Bremner, J., Vanstaen, K., Blake, S., Mynott, F., & Lincoln, S. (2025). Limited Evidence Base for Determining Impacts (Or Not) of Offshore Wind Energy Developments on Commercial Fisheries Species. *Fish and Fisheries*, *26*(1), 155–170. https://doi.org/10.1111/faf.12871

Hélène, B., Marjolaine, F., Christelle, L. G., & Le Floc'h, P. (2022). Vulnerability and spatial competition: The case of fisheries and offshore wind projects. *Ecological Economics*, *197*, 107454. https://doi.org/10.1016/j.ecolecon.2022.107454

Hussain, B., Asif Ali Naqvi, S., Anwar, S., & Usman, M. (2023). Effect of wind and solar energy production, and economic development on the environmental quality: Is this the solution to climate change? *Gondwana Research*, *119*, 27–44. https://doi.org/10.1016/j.gr.2023.01.012

Jensen, J. P., & Skelton, K. (2018). Wind turbine blade recycling: Experiences, challenges and possibilities in a circular economy. *Renewable and Sustainable Energy Reviews*, *97*, 165–176. https://doi.org/10.1016/j.rser.2018.08.041

Kumar, Ch. M. S., Singh, S., Gupta, M. K., Nimdeo, Y. M., Raushan, R., Deorankar, A. V., Kumar, T. M. A., Rout, P. K., Chanotiya, C. S., Pakhale, V. D., & Nannaware, A. D. (2023). Solar energy: A promising renewable source for meeting energy demand in Indian agriculture applications. *Sustainable Energy Technologies and Assessments*, *55*, 102905. https://doi.org/10.1016/j.seta.2022.102905

Kumar, P., Gupta, S., & Dagar, V. (2024). Sustainable energy development through non-residential rooftop solar photovoltaic adoption: Empirical evidence from India. *Sustainable Development*, *32*(1), 795–814. https://doi.org/10.1002/sd.2644

Kuşkaya, S., Bilgili, F., Muğaloğlu, E., Khan, K., Hoque, M. E., & Toguç, N. (2023). The role of solar energy usage in environmental sustainability: Fresh evidence through time-frequency analyses. *Renewable Energy*, *206*, 858–871. https://doi.org/10.1016/j.renene.2023.02.063

Ladenburg, J., Knapp, L. A., & Petrovic, S. (2024). Distance to offshore wind farms, onshore wind power spillover relationships, and the willingness to pay for farshore, large-scale wind power development. *Applied Economics*, 1–17. https://doi.org/10.1080/00036846.2024.2392051

Lebo, F. B. (2019). Evaluating a collaborative governance regime in renewable energy: Wind power and the Lake Erie Energy Development Corporation (LEEDCo). *Environmental Development*, *32*, 100449. https://doi.org/10.1016/j.envdev.2019.06.004

Mendoza, J. M. F., Gallego-Schmid, A., Velenturf, A. P. M., Jensen, P. D., & Ibarra, D. (2022). Circular economy business models and technology management strategies in the wind industry: Sustainability potential, industrial challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *163*, 112523. https://doi.org/10.1016/j.rser.2022.112523

Motosu, M., & Maruyama, Y. (2016). Local acceptance by people with unvoiced opinions living close to a wind farm: A case study from Japan. *Energy Policy*, *91*, 362–370. https://doi.org/10.1016/j.enpol.2016.01.018

Osman, A. I., Chen, L., Yang, M., Msigwa, G., Farghali, M., Fawzy, S., Rooney, D. W., & Yap, P.-S. (2023). Cost, environmental impact, and resilience of renewable energy under a changing climate: A review. *Environmental Chemistry Letters*, *21*(2), 741–764.

https://doi.org/10.1007/s10311-022-01532-8

Payne, J. E., Saunoris, J. W., Nazlioglu, S., & Smyth, R. (2024). Renewable energy production across U.S. states: Convergence or divergence? *Energy Economics*, *140*, 108015. https://doi.org/10.1016/j.eneco.2024.108015

Shakeel, S. R., Yousaf, H., Irfan, M., & Rajala, A. (2023). Solar PV adoption at household level: Insights based on a systematic literature review. *Energy Strategy Reviews*, *50*, 101178. https://doi.org/10.1016/j.esr.2023.101178

Shimada, H., Asano, K., Nagai, Y., & Ozawa, A. (2022). Assessing the Impact of Offshore Wind Power Deployment on Fishery: A Synthetic Control Approach. *Environmental and Resource Economics*, *83*(3), 791–829. https://doi.org/10.1007/s10640-022-00710-0

Simshauser, P. (2025). Competition vs. coordination: Optimising wind, solar and batteries in renewable energy zones. *Energy Economics*, *143*, 108279. https://doi.org/10.1016/j.eneco.2025.108279

Smythe, T. C. (2024). Conflict or coordination? An analysis of the Southern New England offshore wind - fisheries policy network. *Marine Policy*, *163*, 106106. https://doi.org/10.1016/j.marpol.2024.106106

Song, F., Cui, J., & Yu, Y. (2022). Dynamic volatility spillover effects between wind and solar power generations: Implications for hedging strategies and a sustainable power sector. *Economic Modelling*, *116*, 106036. https://doi.org/10.1016/j.econmod.2022.106036

Tang, T. (2018). Explaining technological change in the US wind industry: Energy policies, technological learning, and collaboration. *Energy Policy*, *120*, 197–212. https://doi.org/10.1016/j.enpol.2018.05.016

Vecchi, F., & Berardi, U. (2024). Solar analysis for an urban context from GIS to block-scale evaluations. *Energy Policy*, *184*, 113884. https://doi.org/10.1016/j.enpol.2023.113884

Wang, G., Zhang, Z., & Lin, J. (2024). Multi-energy complementary power systems based on solar energy: A review. *Renewable and Sustainable Energy Reviews*, *199*, 114464. https://doi.org/10.1016/j.rser.2024.114464

Willis-Norton, E., Mangin, T., Schroeder, D. M., Cabral, R. B., & Gaines, S. D. (2024). A synthesis of socioeconomic and sociocultural indicators for assessing the impacts of offshore renewable energy on fishery participants and fishing communities. *Marine Policy*, *161*, 106013. https://doi.org/10.1016/j.marpol.2024.106013

Yamaguchi, A., & Ishihara, T. (2014). Assessment of offshore wind energy potential using mesoscale model and geographic information system. *Renewable Energy*, *69*, 506–515. https://doi.org/10.1016/j.renene.2014.02.024

Yang, X., He, L., Xia, Y., & Chen, Y. (2019). Effect of government subsidies on renewable energy investments: The threshold effect. *Energy Policy*, *132*, 156–166. https://doi.org/10.1016/j.enpol.2019.05.039

Yasmeen, R., Wang, B., Shah, W. U. H., Khan, A., & Hussain, A. (2023). Adequacy of photovoltaic power on provincial and regional levels of income inequality in China.

Solar Energy, *262*, 111906. https://doi.org/10.1016/j.solener.2023.111906

Zhang, J., Yu, S., Zhang, Y.-J., Su, B., & Sun, Y.-F. (2025). How do renewable energy policies affect energy green development? Evidence from Chinese listed energy firms. *Energy Economics*, *142*, 108154. https://doi.org/10.1016/j.eneco.2024.108154

Zhang, Y., Davis, D., Brear, M. J., & Vecchi, A. (2024). The performance of renewable-rich wholesale electricity markets with significant energy storage and flexibility. *Energy Economics*, *140*, 108026. https://doi.org/10.1016/j.eneco.2024.108026

Zozmann, E., Göke, L., Kendziorski, M., Rodriguez Del Angel, C., Von Hirschhausen, C., & Winkler, J. (2021). 100% Renewable Energy Scenarios for North America—Spatial Distribution and Network Constraints. *Energies*, *14*(3), 658. https://doi.org/10.3390/en14030658