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GREEN TRANSFORMATION (GX) IN JAPAN'S ENERGY POLICY AND CARBON NEUTRALITY STRATEGY

Okiliddin Isamutdinovich Alimov
PhD in Political Science, Associate Professor
Tashkent State University of Oriental Studies
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Abstract: This article examines Japan's Green Transformation (GX) policy as a comprehensive national strategy aimed at achieving carbon neutrality by 2050. It analyzes the strategic directions of Japan's energy policy in the context of global climate change, energy security challenges, and technological innovation. The study is based on qualitative analysis of governmental policy documents, international energy reports, and academic literature.

The findings show that Japan's energy transition is characterized by a multi-layered approach combining renewable energy expansion, nuclear energy utilization, hydrogen and ammonia technologies, and carbon capture, utilization, and storage (CCUS) systems. A key role is played by the Green Transformation (GX) framework, which integrates industrial restructuring with environmental sustainability and economic growth.

Despite strong policy commitments, Japan continues to face structural challenges such as high dependence on imported fossil fuels, technological and financial constraints, and public concerns regarding nuclear energy. Nevertheless, through initiatives such as the GX League and large-scale public-private investment programs, Japan is positioning itself as a global leader in green innovation and sustainable energy development.

Keywords: Japan; Green Transformation (GX); carbon neutrality; energy policy; renewable energy; hydrogen energy; nuclear energy; decarbonization; GX League; energy transition.

Introduction

In the contemporary stage, Japan's energy policy is increasingly shaped by global climate change mitigation efforts, the pursuit of carbon neutrality, and the need to ensure long-term energy security. Since energy consumption accounts for more than 80% of greenhouse gas emissions in the country, decarbonization has become a central pillar of national strategy.

The Sixth Strategic Energy Plan (2021) outlines Japan's strategic direction for 2030–2050, emphasizing structural transformation of the energy system, expansion of renewable energy sources, modernization of nuclear energy, and development of hydrogen, ammonia, and carbon capture technologies. In parallel, the Green Transformation (GX) agenda aims to restructure Japan's industrial and socio-economic systems based on clean energy and innovation-driven growth.

Methods

This study is based on a qualitative policy and document analysis of Japan's energy and climate strategies, as well as relevant international and academic sources. The analytical framework includes:

- Statistical and energy balance data from the International Energy Agency;
- Policy documents and strategic frameworks issued by the Ministry of Economy, Trade and Industry (Japan);
- National strategies such as the Sixth Strategic Energy Plan and the Green Growth Strategy;
- Institutional analysis of the GX League as a multi-stakeholder governance mechanism;

- Case studies of major corporations, including Tokyo Electric Power Company Holdings and Nissan Motor, to illustrate industrial decarbonization trends.

Results

The analysis identifies several key findings:

1. Japan remains highly dependent on imported energy, with fossil fuels accounting for a dominant share of the energy mix.
2. The country targets carbon neutrality by 2050 through a diversified energy strategy combining renewables, nuclear energy, hydrogen, ammonia, and CCS technologies.
3. The GX policy framework promotes strong collaboration between government, industry, and academia, supported by large-scale investment initiatives.
4. Rapid development is observed in offshore wind energy, electric vehicles, hydrogen technologies, and carbon capture systems.
5. Despite decarbonization goals, fossil fuels—particularly coal—continue to play a significant role in the energy system due to technological and economic constraints.

Discussion

The **Sixth Strategic Energy Plan**, announced by the Government of Japan in 2021, established the principal strategic directions for the country's energy demand and supply for the period 2030–2050. Since the energy sector accounts for more than 80% of Japan's greenhouse gas (GHG) emissions, the Plan provides a comprehensive framework of measures aimed at reducing emissions generated by energy production and consumption. In addition to expanding the utilization of renewable and nuclear energy sources, the Plan emphasizes the necessity of promoting technological innovation to facilitate the deployment of hydrogen- and ammonia-fired power generation systems, as well as initiating the practical implementation of carbon capture, utilization, and storage (CCUS) technologies.

Japan's robust innovation ecosystem and advanced technological capabilities constitute a decisive factor in developing the technologies required to achieve the country's energy and climate objectives. Cutting-edge technologies and scientific advancements play a pivotal role in fostering the development of a green industrial economy by enabling environmentally sustainable production methods, diversifying energy sources, and integrating resource-efficient solutions. At the same time, the corporate sector increasingly recognizes that the adoption of green technologies is attractive not only from the standpoint of environmental sustainability but also because of its potential to generate economic benefits and create new business opportunities.

The Japanese government expects that expanding cooperation among industrial enterprises, academic institutions, technology providers, public administration, engineering and financial service sectors, and civil society will accelerate the country's economic development. Such collaborative efforts are expected to reinforce Japan's position as one of the world's leading economic and scientific-technological centers while enabling the country to strengthen its global leadership in the development, deployment, and commercialization of green technologies.

In this context, alongside Japan's Digital Transformation (DX) policy, which has been implemented since 2016, the government announced the launch of the national environmental initiative known as Green Transformation (GX). The GX initiative is intended to facilitate the transition toward a carbon-neutral economy by promoting sustainable industrial transformation, accelerating technological innovation, and integrating environmental objectives into the country's long-term economic development strategy.

Accordingly, the Japanese government is exploring various policy options to strengthen the country's Green Transformation (GX) agenda while enhancing the prospects of achieving carbon

neutrality by 2050. The successful implementation of this policy will depend on a range of interrelated factors. Among the most critical are the pace of introducing advanced technological innovations, the efficiency and competitiveness of energy generated from alternative sources, market demand for emerging energy technologies, and the economic viability of these energy resources.

A more comprehensive account of the evolution of Japan's energy policy is presented by **K. Hirose** and **T. Matsumura**, researchers at **The Institute of Energy Economics, Japan (IEEJ)**. In discussing the country's Green Transformation (GX) policy, the authors argue that the successful implementation of the government's strategic objectives requires firm commitments from both public authorities and private-sector companies that have embraced green development strategies and are pursuing the environmental modernization of industrial production.

At the same time, the authors critically observe that, although large corporations are expected to serve as the principal drivers of industrial decarbonization, not all of them are capable of transitioning—even partially—to environmentally sustainable production systems. This limitation is primarily attributable to the substantial financial costs and technical complexity associated with retrofitting industrial facilities and electrifying production processes. Consequently, the authors conclude that energy-intensive industries, including steel manufacturing, cement production, aviation, and the chemical industry, are likely to remain dependent on conventional fossil fuels for the foreseeable future[1].

Hugh Whittaker, Professor at the University of Oxford, argues that achieving the objectives of both Digital Transformation (DX) and Green Transformation (GX) is possible only through highly coordinated and effective collaboration between the government and the corporate sector. However, he notes that Japan's large-scale digitalization process, officially launched in 2017, has experienced significant delays. According to the author, these setbacks are primarily attributable to the slow pace at which companies have modernized their aging production facilities and technological infrastructure.

Indeed, the emergence of this challenge had been anticipated. Japan's Ministry of Economy, Trade and Industry (METI) had previously warned of such risks in its report entitled *The 2025 Digital Cliff*, which highlighted the economic consequences of failing to accelerate digital transformation. Against this backdrop, Whittaker emphasizes that Green Transformation is intrinsically linked to Digital Transformation, implying that the successful greening of the Japanese economy will require substantial efforts from all stakeholders.

In particular, corporations must prioritize the rapid modernization of obsolete equipment while simultaneously developing comprehensive management strategies that enable them to respond effectively to the opportunities and risks arising from an increasingly competitive digital environment. Only through such coordinated technological and organizational transformation can Japanese firms successfully adapt to the evolving requirements of a low-carbon and digitally integrated economy[2].

According to the **International Energy Agency (IEA)**, fossil fuels accounted for **88% of Japan's total primary energy supply in 2024**, ranking the country sixth among IEA member states in terms of dependence on fossil fuel-based energy. Moreover, Japan satisfies **more than 95% of its current energy demand through imports**, highlighting the country's high degree of external energy dependence.

[1] Hirose K., Matsumura T. Green Transformation in Oligopoly Markets under Common Ownership. – 2022.
[2] Whittaker H. New Capitalism. Japan SPOTLIGHT. September / October 2022 стр. 30-33.

To remain on track toward reducing greenhouse gas emissions by **26% or more by 2030** and achieving **carbon neutrality by 2050**, Japan intends to substantially increase the share of renewable energy sources in its national energy mix.

In support of accelerating the green transition, the **Japan Climate Leaders' Partnership (JCLP)** called on the government in 2020 to raise its 2030 renewable energy target to **50%**. Furthermore, a coalition comprising more than **170 leading Japanese companies** urged the government to prioritize environmental sustainability over short-term economic considerations. The coalition also advocated the gradual phase-out of inefficient coal-fired power plants and the suspension of new coal power plant construction.

In December 2020, the Japanese government, in cooperation with the business community, introduced the **Green Growth Strategy** under the framework of the **Carbon Neutrality Strategy 2050**. The strategy seeks to integrate environmental protection with economic growth by promoting close collaboration between the public and private sectors, thereby transforming decarbonization into a driver of sustainable economic development.

According to the strategy, by 2050 approximately **50–60%** of Japan's electricity demand is expected to be supplied by renewable energy sources, while **30–40%** will be generated by nuclear and thermal power plants equipped with **carbon capture and storage (CCS)** technologies. The remaining **10%** is projected to be met through electricity generated from **hydrogen and ammonia**.

The energy sector occupies a central position within Japan's national development agenda. The **Sixth Science, Technology and Innovation Basic Plan (2021–2026)** defines the country's principal priorities in science, technology, and innovation policy for the current stage of development. The Plan identifies Japan's ambition to become the world's most innovation-friendly nation and introduces the national **Society 5.0** concept, which envisions comprehensive integration of digital technologies across all sectors of society to stimulate economic growth while addressing major social challenges. Within this framework, the energy sector has been designated as one of the five strategic priority areas for national development and modernization.

In addition to the objectives of developing energy-efficient and environmentally safe technologies, the Plan also emphasizes the need to strengthen cooperation among universities, public research institutes, and private companies, expand international collaboration, and promote the adoption of advanced energy innovations among small and medium-sized enterprises (SMEs).

Japan's energy development concept for the period up to 2030 is reflected in the **"Innovative Energy Strategy"**, published in 2016 by the Ministry of Economy, Trade and Industry (METI). This strategy is aimed at ensuring a balanced energy mix in line with long-term supply and demand projections for the period 2015–2030. Particular emphasis is placed on improving energy efficiency, expanding renewable energy sources, and introducing new energy systems, including measures such as supporting new entrants in the electricity market and promoting distributed generation and consumption systems.

Japan's long-term energy vision is also reflected in the **"National Energy and Environmental Innovation Strategy toward 2050"**, released in 2016 by the Council for Science, Technology and Innovation. This strategy establishes the technological and innovation foundations necessary for achieving Japan's target of reducing greenhouse gas emissions by 80% by 2050.

The strategy identifies nine priority technological domains for development:

1. Innovative manufacturing processes;
2. Development of lightweight and high heat-resistant materials;
3. Next-generation battery technologies;
4. Carbon-free hydrogen;

5. Next-generation photovoltaic systems;
6. Advanced geothermal sensing technologies;
7. Innovative carbon capture, utilization, and storage technologies;
8. Energy system integration and optimization technologies;
9. Next-generation electronics.

Among these technologies, the Japanese government places particular emphasis on those with significant potential to reduce CO_2 emissions, those requiring coordinated efforts between industry, academia, and government, and those in which Japan could potentially achieve global technological leadership.

In 2020, Japan also introduced the **"Environmental Innovation Strategy"**, designed as a roadmap to achieve the technological development goals outlined in the National Energy and Environmental Innovation Strategy. This roadmap was subsequently expanded to include the agricultural sector, reflecting the expectation that advanced energy technologies could play a significant role in reducing greenhouse gas emissions in this field.

The **Environmental Innovation Strategy** consists of three main components.

The first component encompasses a range of priority directions, including the transition toward renewable energy as a primary energy source, the establishment of a low-cost hydrogen supply chain, the development and deployment of efficient carbon capture and utilization technologies, as well as the promotion of a smart society based on artificial intelligence (AI) and decentralized energy management systems.

The second component, entitled **"Acceleration Plans for Innovation,"** provides a detailed framework for the implementation of innovation-related action plans, including the research frameworks and investment promotion policies required to support technological development and commercialization.

The third component, **"Zero-Emission Initiatives,"** is aimed at promoting international cooperation in the field of zero-emission research and development. Within this framework, Japan organizes annual meetings with leading representatives from industry, finance, and the scientific community in order to disseminate Japanese initiatives and promote their global outreach.

Within the framework of the Environmental Innovation Strategy, the Japanese government and major corporate stakeholders plan to allocate substantial financial resources to public and private research and development activities in the fields of environment and energy over the coming decade. Owing to such long-term strategic initiatives, Japan has achieved a series of significant technological breakthroughs in the energy sector, ranging from large-scale utilization of solar energy to the development of electric vehicles.

In recent years, Japan has made considerable progress in the development of renewable energy technologies, next-generation electronics, and innovative fuel combustion systems. These achievements are fully consistent with the objectives and priorities outlined in the Environmental Innovation Strategy. At the same time, particular attention has increasingly been directed toward advancing carbon capture, utilization, and storage (CCUS) technologies, as well as hydrogen-based energy systems.

Green Transformation (GX) Initiatives

According to the analysis presented in the **Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)**, continued increases in greenhouse gas concentrations may result in a global mean surface temperature rise of approximately **3.3–5.7°C by**

the end of the century[3]. In response to these projections, Japan has initiated the **Green Transformation (GX)** agenda as a comprehensive reform strategy aimed at fundamentally restructuring its national socio-economic system.

The GX initiative is designed to transform Japan's industrial structure and social system through the deployment of environmentally sustainable energy systems. In October 2020, the **Ministry of Economy, Trade and Industry (METI)** advanced the concept of carbon neutrality, setting the objective of achieving **net-zero greenhouse gas emissions by 2050**[4]. Subsequently, the government announced the **Green Growth Strategy**, which outlines an action plan based on 14 priority policy areas to support the transition toward carbon neutrality by 2050. In addition, in April 2021, the government approved a climate change mitigation plan targeting a **46% reduction in greenhouse gas emissions by 2030 compared to 2013 levels**.

Alongside environmental objectives, the Japanese government has identified the GX initiative as a strategic and high-potential area for investment. In 2022, the government adopted the **"Grand Design and Action Plan for a New Form of Capitalism,"** in which Green Transformation was designated as one of the priority investment domains. Under this framework, approximately **USD 1.2 trillion** in public–private investment is expected to be mobilized over the next decade to support GX-related initiatives. To stimulate investment, the government also plans to issue **GX Economic Transition Bonds**[5].

In the context of ongoing geopolitical tensions, energy security concerns, and the need to reduce dependence on imported energy resources, the government has also set policy directions aimed at restarting more than ten nuclear power plants and developing and constructing next-generation innovative nuclear reactors[6].

Within the framework of GX policy, the Japanese government has introduced two key initiatives: the establishment of a **GX Promotion Council** and the formulation of a **GX Strategy/Growth Strategy**, as well as the creation of a dedicated platform known as the **GX League**, which serves as a structured framework for collaboration among government, industry, and academia in advancing green transformation.

The **GX Society (GX League)** serves as a platform for stakeholders from industry, government, and academia to formulate rules for the GX market and to discuss future visions of a carbon-neutral society. Through the GX League, participants aim to simultaneously achieve corporate growth and contribute to global environmental sustainability.

The key requirements for GX League participants include:

1. Reduction of emissions by corporations;
2. Implementation of emission reduction measures across value chains;
3. Expansion of the GX market.

The main advantages for participating companies in the GX/GX League framework include tax incentives provided by the government and improvements in corporate reputation. In addition,

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[3] IPCC Sixth Assessment Report https://www.ipcc.ch/assessment-report
[4] 2050 年カーボンニュートラルに伴うグリーン成長戦略を策定しました
https://www.meti.go.jp/press/2021/06/20210618005/20210618005.html
[5]新しい資本主義のク゛ラント゛テ゛サ゛イン及ひ゛実行計画
https://www.cas.go.jp/jp/seisaku/atarashii_sihonsyugi/pdf/ap2022.pdf
[6]第二百十回国会における岸田内閣総理大臣所信表明演説
https://www.kantei.go.jp/jp/101_kishida/statement/2022/1003shoshinhyomei.html

small and medium-sized enterprises (SMEs) are expected to receive additional budgetary support under this policy framework.

Tokyo Electric Power Company Holdings (TEPCO) is one of Japan's largest national electricity generation and supply companies. In March 2022, the company announced its support for the GX League initiative. Within the GX framework, TEPCO has adopted a policy of accelerating the development of zero-emission energy sources that generate no CO_2 emissions in electricity production[7].

Nissan Motor Corporation has also emphasized that the automotive industry should contribute to the development of environmentally friendly transport solutions, including electric vehicles. The company has set a target of achieving carbon neutrality across the entire vehicle lifecycle—covering raw material extraction, production, vehicle use, and end-of-life recycling—by 2050. It also plans to ensure that all new vehicles introduced in major markets from 2030 onwards will be electric vehicles. Furthermore, Nissan has announced investments of approximately **USD 34 billion** over the next five years in technological innovation in electrification[8].

Within the framework of GX policy promotion, local municipalities are also advancing their own initiatives. The city of Hamamatsu has allocated **USD 6.5 million** to support SMEs engaged in green transformation under an additional budget framework. Of this amount, more than **USD 3.4 million** is provided through a special government grant for regional modernization, while the remaining funds are allocated from the city's general revenue sources[9].

Nuclear Power Plants and Green Transformation

Japan's current energy policy is based on the utilization of peaceful nuclear energy. However, the Fukushima Daiichi Nuclear Power Plant accident and associated safety concerns have prompted the search for alternative solutions in nuclear energy governance. At the same time, the **Sixth Strategic Energy Plan** states that Japan intends to restart existing nuclear power plants following the implementation of the strictest safety standards for equipment modernization and plant operation.

The strategy recognizes several advantages of nuclear energy, including:

- High energy efficiency relative to fuel input;
- A high level of energy independence for Japan;
- Significant potential for achieving decarbonization goals.

Although nuclear energy remains a controversial issue due to limited public acceptance, the government does not intend to abandon its policy of restarting nuclear facilities, given their importance for energy security and decarbonization. The strategy places strong emphasis on technical and policy measures related to nuclear waste management, fuel recycling (including plutonium), and the decommissioning of nuclear power infrastructure.

In October 2021, the **Sixth Strategic Energy Plan** was published, in which the Japanese government reviewed the outcomes of its post-Fukushima energy policy and formulated a long-term strategy for achieving a **carbon-neutral society by 2050**. The government also plans to further support the development of renewable energy sources.

In 2018, Japan adopted the **Act on Promotion of Utilization of Marine Renewable Energy in Marine Areas for Power Generation Facilities Development**, which came into force in April

[7] GX リーグ基本構想」への賛同について. https://www.tepco.co.jp/press/release/2022/1694228_8712.html
[8] 経済産業省「GX リーグ基本構想」への賛同について. https://global.nissannews.com/ja-JP/releases/220331-01-j
[9] 令和 4 年度 5 月補正予算編成（第 3 号）の基本方針. https://www.city.hamamatsu.shizuoka.jp/zaisek/budget/02budget11hosei/5hosei3.html

2019. The law enables the allocation of designated maritime zones for energy projects through a registration and licensing system, while ensuring coordination with local communities. According to some official estimates, Japan could become the world's third-largest offshore wind energy producer, with potential installed capacity reaching **up to 45 GW**.

However, one of the main barriers to offshore wind development in Japan is the transmission of electricity from offshore facilities to major consumption centers such as Tokyo. Insufficient transmission capacity represents a major constraint for project implementation. To address this issue, the government has allocated **USD 44 million** to support research into the development of submarine cable technologies, which would enable electricity transmission from Hokkaido and other regions to Tokyo and other major urban centers.

Japan possesses the world's sixth-largest exclusive economic zone and therefore has substantial offshore wind energy potential. The total potential electricity generation from offshore wind energy is estimated at approximately **3,460 TWh per year**, which is roughly three times Japan's annual electricity consumption.

Offshore wind energy is expected to play a key role in ensuring Japan's energy stability and may become a decisive factor in achieving a carbon-free and nuclear-reduced energy balance in the near future.

Japan's new energy strategy also places significant emphasis on hydrogen and ammonia-based power generation, particularly in meeting small-scale utility demand. By 2030, electricity generated from these sources is expected to account for approximately **1% of total electricity production**.

Hydrogen and ammonia have high potential from a decarbonization perspective and can be applied across various sectors, including transport, industrial production, and extractive industries. Accordingly, Japan's energy strategy includes discussions on the development of an international hydrogen and ammonia supply chain. Electricity consumers are expected to play a central role in shaping market demand for these energy carriers. Hydrogen can be utilized in gas-fired power plants, while ammonia can be used in coal-fired plants as a co-firing fuel. However, the government has postponed this project indefinitely due to geopolitical factors, as initial plans envisaged cooperation with Russia, which was suspended following diplomatic tensions. Overall, such projects are long-term in nature and require substantial time for the development and commercialization of hydrogen- and ammonia-based energy technologies.

Conclusion

In conclusion, the ongoing measures are expected to enable Japan to achieve carbon neutrality in the medium and long term, enhance energy security by reducing import dependency, and significantly transform its production system toward a green energy-based structure. If successfully implemented, these policies will ensure substantial economic development and position Japan among the global leaders in renewable energy production and utilization.

Based on the analysis, it can be concluded that a cross-sectoral approach may facilitate the integration of innovation with broader energy, environmental, and climate policy objectives. However, achieving these goals depends not only on the financing of projects and programs but also on multiple other factors, including the successful development of a green technology market, the entry of both large corporations and SMEs into this market, and the continuous monitoring and evaluation of technological performance and business models.

Japan's experience in transforming and developing its fuel and energy system is of significant interest and relevance, particularly for developing countries. This can be explained by several factors. First, Japan is a global leader in high technology, making its technological and innovative

solutions in the energy sector highly valuable for study and potential adaptation. Second, Japan is one of the key long-term strategic partners of Central Asian countries, and familiarity with its practical energy policies is crucial for developing both bilateral and multilateral cooperation strategies.

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