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# Energy Strategy and Transition to Green Energy in Japan

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***Abstract.*** The paper presents an analysis of the current state of green energy in Japan. The study showcases that Japan's energy strategy focuses primarily on eliminating energy deficit and, secondly, on greening the sector. After the Fukushima accident, Japan recognized renewable energy as a solution to the energy security problem and intensified government policies to stimulate investment in renewable energy. Policy incentives, primarily the introduction of feed-in tariffs, and massive investments have led to an increase in the share of renewable energy sources, especially solar PV, in the structure of electricity generation, and contributed to $CO_2$ emissions decline after 2013, as well as the improvement in the energy efficiency of the economy. By the end of the second decade of the 21st century, Japan was among the top-five countries based on installed renewable power capacity (excluding hydropower). However, the costs of electricity have been rising and the costs associated with installing renewables in Japan are very high comparing with other countries. Meanwhile, Japan is among the top-five economies with the highest $CO_2$ emissions, 90 percent of which are energy-related, and has been criticized by the international community for its ongoing support for fossil fuels.

In 2020, Japan announced an ambitious plan to achieve carbon neutrality by 2050 by speeding up the development of key technologies such as next generation solar batteries and carbon recycling. The promotion of *hydrogen society* is called one of the most important steps towards a low-carbon economy in Japan. Achieving the goal will require a significant revision of the current

energy plan, according to which, by 2030, more than half of the country's energy will continue to be produced by fossil fuel plants.

Japan has made some progress in its green energy policy, but whether it is sustainable remains to be seen. In addition, in light of low oil prices and the COVID-19 recession, the future of renewable energy sources remains uncertain.

***Keywords:*** Japan, green energy, renewable energy, greenhouse gases emissions, energy efficiency.

## Introduction

The choice of a way for the further development of the world economy is becoming increasingly urgent in the modern conditions of global instability. Although the economic system that prevailed earlier provided certain results in raising the people's living standards, the negative consequences of this system referred to as *brown economy* are significant. To survive and develop, mankind will need to adopt a new paradigm of development, which will not subject future generations to substantial environmental risks.

The concept of green economy evolving in recent decades is aimed at a more harmonious coordination of economic and environmental issues. The global interest in green economy has grown dramatically since this term was first mentioned in 1989. [Pearce, Markandya & Barbier 1989, p. 192]. After the UN had started implementing its ecological program "Green Economy Initiative", the concept became generally accepted. UNEP defines green economy as one that "improves human well-being and builds social equity, while significantly reducing environmental risks and environmental scarcities", as "low carbon, resource efficient and socially inclusive".[1]

[1] UNEP, 2011, Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication – A Synthesis for Policy Makers, www.unep.org/greeneconomy

It is the energy sector that is regarded as one of the key ones on the way to forming a new model of economy as it is the largest source of carbon dioxide emissions. The importance of this area is proven by the fact that two of 17 Goals in the field of sustainable development for the period until 2030 are associated with the development of green energy (7. Affordable and Clean Energy and 13. Climate action).

Although there is no single universally accepted definition of green energy, most experts understand it as a shift toward greater reliance on renewable resources (RES), regarded as more sustainable than relying on depletable energy and fossil fuels [Reilly 2012, p. S85]. Yet features and contradictions of the current global energy development testify that the green aspect in this sector of the economy is much more comprehensive. This viewpoint is presented in OECD publications [OECD 2011, p. 106] where it is noted that green energy implies not only the growth of investments in RES and the increase of their share in the structure of energy production and consumption, but also requires large-scale greenhouse gases (GHG) emission reductions and includes rationalizing and phasing-out inefficient fossil fuel subsidies that encourage wasteful consumption. Moreover most important indicators for the green energy development incorporate energy efficiency improvement, the number of projects and clean technology patent applications, and government support measures.

The development of low carbon energy is of particular importance to Japan as the country facing the challenge of addressing energy security, having a high degree of dependence on fossil fuels and being one of the largest producers of greenhouse gases, 90 percent of which are originated by the energy sector.

Issues associated with the evolution of Japan's energy policy were most fully reflected in the materials compiled by the researchers of the Institute of Energy Economics, Japan, as well as in topical studies by a number of Russian authors ([Pipiya & Dorogokupets 2017, p. 38; Korneev & Popov 2019, pp. 44–53] and others). There are a number of publications both in Russian and English devoted to the development of green economy in Japan ([Streltsov 2012; Capozza 2011] and others).

However, transition to green energy in Japan has not yet received full coverage.

This paper analyses the current state of green energy in Japan based on the OECD definition and provides conclusions of its prospects and economic energy efficiency.

## Evolution of Japan's Energy Policy and RES Role

There are many definitions of renewable energy in literature. One way or another, they all underline that this is energy obtained through natural processes capable of replenishing themselves naturally without being depleted. There exist several forms of renewable energy including the one generated by such sources as the solar, wind, and biomass as well as geothermal, water power resources, biogas and liquid biofuels. Nuclear energy – like the solar and wind energy – is a low-carbon energy source. However, threats to safety and problems of radioactive waste disposal prevent it from getting into one line with renewables. Attributing nuclear energy to the rank of green one is still a disputable issue.

Getting down to the analysis of Japan's energy policy evolution, it should be noted that geographical and climatic factors brought about a very conservative approach to any meaningful innovations in the country. The energy strategy in Japan changed predominantly through various contingencies: economic (the oil crisis in the 1970s and the prolonged recession in the 1990s), natural and climatic (natural disasters and consequent destruction of the energy infrastructure), as well as technological (the Fukushima nuclear disaster).

Soon after World War II, the country entered the period of high economic growth rates referred to as the Japanese economic miracle. Its implementation would have hardly been possible if not for the lucrative oil deposits in the Middle East discovered in the 1960s. Oil – as an energy resource convenient to produce and, especially, transport – made it possible to rapidly increase energy production and replace coal as the

most important type of fuel in the country's energy balance. The feasibility of this strategy was in many respects ensured by low prices for this type of fuel (the nominal cost of oil remained virtually unchanged for a long period of time in the mid-20th century since it was artificially restrained by the cartel of vertically integrated international oil companies, called the "Seven Sisters"). The share of the "black gold" in the structure of primary energy resources consumption in Japan exceeded 75 percent (Figure 1). The bulk of oil was delivered from the Persian Gulf countries. The level of energy self-sufficiency in Japan at that time amounted to a mere 15 percent.[2]

The oil shocks of the 1970s demonstrated a high degree of energy vulnerability of Japan's economy and conditioned the need for drastic changes in the country's energy strategy [Lebedeva & Kravtsevich (eds.) 1990, p. 3]. It was then that Japan began developing policies aimed at ensuring energy security. Energy saving, oil import reduction, and encouragement of alternative energy sources use were designated as long-term priorities. Yet the focus was made on the use of nuclear energy as well as coal and liquefied natural gas (LNG) rather than renewables.

These policies helped reduce the dependence on oil, and by 2003 Japan had reached the landmark limit: the share of this type of fuel reduced to 50 percent in the total primary energy consumption. By the beginning of the second decade of the 21st century, nearly 40 percent of Japan's energy needs were satisfied by oil; as Japanese economists estimate, this ratio is not likely to change significantly in the following years (Figure 1).

The Fukushima Daiichi nuclear disaster in 2011 compelled not only Japan, but also many other countries of the world to reconsider their attitude to nuclear energy as an environmentally friendly, cheap, and safe energy resource. Japan had had 54 working nuclear reactors prior to the disaster (third place in the world after the USA and France),

[2] Japan's Agency for Natural resources and Energy. URL: http://www.enecho.meti.go.jp/en/

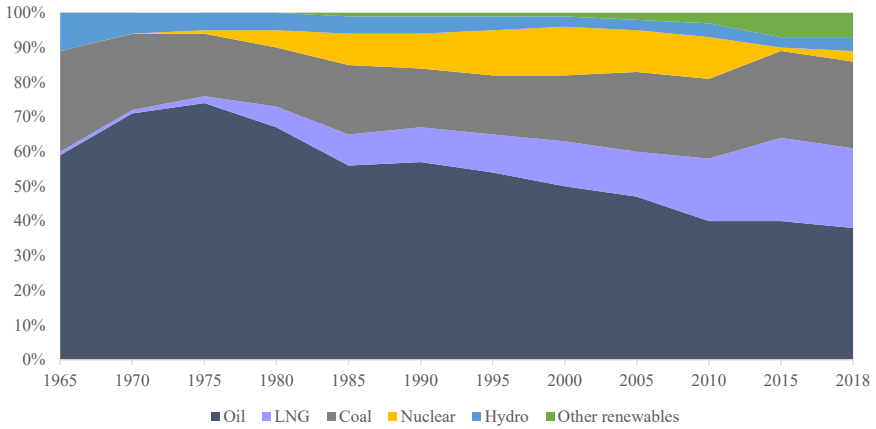


*Figure 1.* Structure of primary energy supply in Japan[3]

that provided over 25 percent of national electricity supply (Figure 2).[4] The disaster's consequences made Japan modify its strategy of energy and environmental security as well as temporary halt nuclear power production. It is after the 2011 that the importance of RES in the country's energy balance began to increase markedly. Yet, along with that, the use of coal and natural gas was growing even more considerably. The dependence of Japan's economy on mineral fuels increased from 81 percent in 2010 to 87 percent by 2017.[5]

Unlike Germany, which made a decision to abandon the nuclear power by the end of 2022 and the one of coal by 2038 in favor of RES, the Japanese government started to restore nuclear power production several years after the shutdown of reactors despite the

3 Compiled by the data of Japan's Agency for Natural Resources and Energy.

4 Japan is the fourth country in the world by electric power consumption after China, USA, and India. Yet, the bulk of the electric power is generated with the use of mineral fuels.

5 Agency for Natural Resources and Energy, Japan. http://www.enecho.meti.go.jp/en/

lack of support from the population. As of May 2020, nine reactors had been recognized as fitting the new standards of safety and had resumed operation.[6]

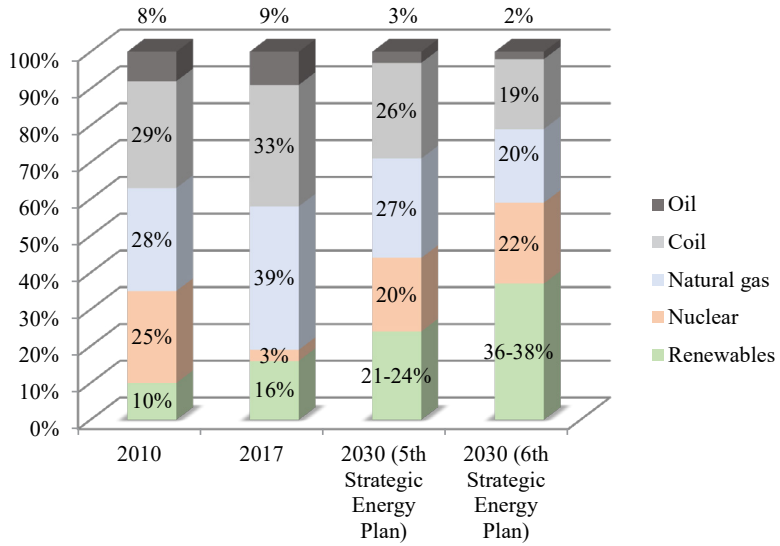


*Figure 2*. Electric Power Generation in Japan[7]

Japan's current energy policy is based on four basic principles called 3E + S: Energy Security, Economic Efficiency, Environmental protection, and Safety.[8]

Changes in Japan's energy strategy are reflected in the government's middle-term energy programs. They were made mandatory by the 2002

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6 IEA. Japan 2021. Energy policy review. https://iea.blob.core.windows.net/assets/3470b395-cfdd-44a9-9184-0537cf069c3d/Japan2021_EnergyPolicyReview.pdf

7 Agency for Natural Resources and Energy, Japan. http://www.enecho.meti.go.jp/en/

8 Japan's Strategic Energy Plan. https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf

Fundamental Law on Energy Policy, which decreed to compile long-run basic energy plans for five years. The year of 2018 saw the approval of the Fifth Energy Plan indicating for the first time that RES were to become a major source of electric power by 2050. The document did not, however, contain any specific measures of achieving this goal. In addition, although the share of renewable energy in the total electric power supply, as stated in the projected energy structure for the interim year of 2030, is supposed to increase to 21-24 percent, it will be lower than the share of thermal power plants using coal, gas, and oil (54–56 percent). The nuclear energy will account for 15–20 percent, slightly less than prior to the Fukushima-1 disaster (Figure 2).

On October, 2021, the Ministry of Economy, Trade and Industry (METI) released the Sixth Strategic Energy Plan, which proposes to reduce the total primary energy generation and includes the following key changes in 2030 targets from the previous version of plan: increase in the use of renewables to 36%–38%; reduction in reliance on oil and coal; and addition of hydrogen and ammonia to the list of energy sources.

The largest share of power generated with the use of RES in Japan at the end of the second decade of the 21st century was that of hydro energy (7.9 percent), the second place was occupied by solar energy (5.2 percent), the third – by biomass (2.1 percent); followed by wind (0.6 percent) and geothermal (0.2 percent) energy. According to the Sixth Strategic Energy plan, the share of each of the above RES will have increased by 2030, and the structure of electric power generation with the use of renewables will look as follows: solar energy – 14–16 per cent, hydro energy – 11 percent, wind energy – 5 percent, biomass – 5 percent, geothermal energy – 1 percent.[9]

Japan was among the top five countries possessing the largest renewable power capacity (not including hydropower) by the end of 2020. Japan also occupied the third place by installed solar PV capacities, the tenth – by geothermal power capacities, the ninth – by hydro power ones. These areas gained the most significant impetus in Japan [REN21 Renewables 2020, 2021].

[9] Ibid.

It should be noted that the Japanese renewable energy is not characterized by high level of economic efficiency. Japan's installed costs for new utility-scale solar PV projects, utility-scale solar PV and offshore wind weighted-average LCOE are the highest in the world. Thus, weighted-average total installed cost of utility-scale solar PV projects commissioned in 2018 in Japan was USD 2 101/kW. For reference: these costs do not exceed 1 500 USD/kW in the United States and Australia and are below 1 000 USD/kW in China, India, and Italy. Russia (2 302 USD/kW) and Canada (2 427 USD/kW) had highest costs among the G20 countries [IRENA 2019]. Japan's high expenses are conditioned by high standards of safety measures observance and a higher level of salaries (Japan was the 18th in the world by the average wages level in 2020; the average wages in Japan are 1.6 times higher than in Italy, 2.7 times higher than in China, 5.7 times higher than in Russia, and 6 times higher than in India).[10]

## Japan's Investments in Renewable Energy Sources and Fossil Fuels

One of the most important indicators for the green energy development is the volume of investments channeled to create and maintain relevant facilities, introduce green technologies and develop projects in these fields. Global investments in renewables capacity (excluding large hydro) reached $282.2 bln in 2019 (Figure 3). Capital expenditures on new renewables capacity exceeded the volume of investments in setting up new coal, natural gas, and nuclear energy using facilities, which testifies the shift of priorities in the global energy development [REN21 Renewables 2020].

As to the types of sources, wind energy has become the most attractive for capital inputs since 2010, taking up 49 percent of investments, which was promoted by the further reduction of capital costs and the slowdown

[10] https://www.picodi.com/ph/bargain-hunting/average-wages

in China's PV market. The solar energy accounted for 46.5 percent of all investments. The other RES showed less striking results [Frankfurt School-UNEP Centre/BNEF 2020].

Japan is one of the largest investors in RES – it took the third place in the world after China and the USA over the period 2010-2019. Japanese investments grew from $7 bln in 2010 to $16.6 billion in 2019 reaching the peak of 36.2 bln in 2015. (Figure 3).

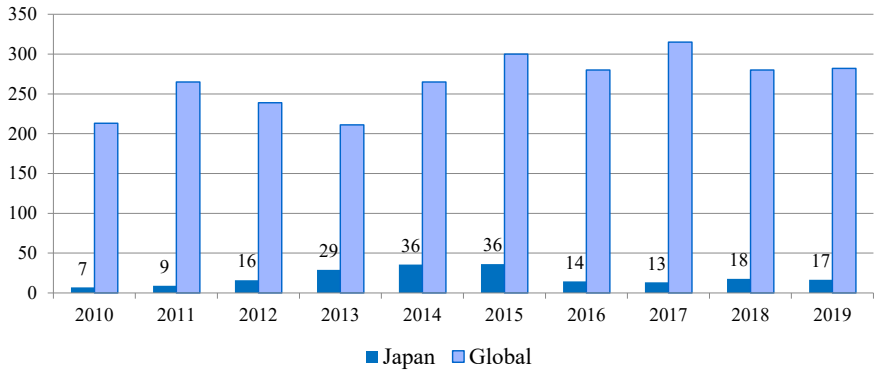


*Figure 3.* Investments in RES, USD bln[11]

As a promotion measure for the accelerating investments for RES, Japan, like many other countries, introduced the system of feed-in tariffs (FIT). Under the feed-in tariff scheme, the electric utility is obligated to purchase electricity from a renewable energy producer at a fixed price for a long-term period guaranteed by the government. The year of 2020, however, witnessed the beginning of gradual transformation of the renewable energy support provided by the Japanese government. The key change was to gradually develop a feed-in-premium (FIP) scheme, stimulating electric power producers through the market price markup. The markup can be determined in two ways: a) on the recommendation of the Purchase Price Computation Committee as in the case with feed-in tariffs, and b) using the tender

[11] *Source:* [Frankfurt School-UNEP Centre/BNEF 2020]

system. Meanwhile the reference price will vary depending on the supply and demand balance on the market. This transition is in line with the global practice as feed-in tariffs are subjected to criticism for placing an excessive burden on consumers and taxpayers because the fixed price thwarts competition.

It is noteworthy, that introduction of feed-in tariffs made a significant impact on RES development in Japan. Solar energy production facilities grew over 150-fold – from 370 MW in 2010 to 63 GW in 2019, while the share of solar energy in power generation reached 6.6 percent.

Meanwhile Japan faces the following challenges on the way to green energy:

High costs. The increase in the use of renewable energy directly depends on its production costs reduction. The costs are to be brought to the level comparable with the costs of energy production from other sources to make RES attractive.

The negative attitude to RES from local inhabitants. People frequently do not perceive them as a stable and reliable source of energy and express concerns about the safety and the disposal of installations after their service life is over.

Difficulties of renewable energy integration into the national power system. On the one hand, the energy supply system in Japan (generation and energy transmission lines) does not always cover areas suitable for renewable energy production (for example, areas with good conditions for wind energy development). On the other hand, the mass adoption of renewable energy is challenged by power grid limitations.

Unstable production of electric power from renewable sources. The volumes of electricity generated from RES such as solar energy and wind are difficult to control as they are affected by seasonal and weather conditions. That may result in the abundance or shortage of electricity, which are to be compensated for by the use of fossil fuels.

The need for new investments including foreign capital. According to the Renewable Energy Country Attractiveness Index calculated by

Ernst&Young,[12] Japan ranked No. 8 among 40 countries in October 2021 [EY RECAI 2021].

It should be pointed out that investments in fossil fuels in Japan still considerably exceed capital investments involved in RES. Japan continues supporting the development of oil, gas, and coal projects – both inside the country and abroad – by means of its fiscal policy and government funding mechanisms. Although Japan undertook the commitments to lower subsidies, such as the G7 declaration to phase out fossil fuel subsidies by 2025, the country's government is not transparent in presenting information on the progress achieved in this field. Some studies conclude that it would be more profitable for Japanese operators to invest in renewable energy sources such as wind or solar than to operate coal power plants after 2025 [Gray, Takamura, et al. 2019]. However, Japan's government encourages investments in fossil fuels to maintain diversification of energy sources.

Japan plans to build 22 new coal-burning facilities in the next five years. Although they will be electric power plants of a new type with high energy efficiency indices, they will emit almost as much carbon dioxide annually as all passenger cars sold annually in the United States of America, and more than the overall emissions in Norway or Sweden.

Japan's policy in this field differs from that in other developed countries. Thus, for example, Great Britain intends to give up coal energy by 2025, and France announced that it would close down coal power plants much earlier, by 2022 [Tabuchi 2020]. Japan remains the only country of the G7 that continues building coal power plants inside the country; it is also the largest investor in similar projects abroad.

Three largest banks of Japan – Mitsubishi UFJ (MUFG), Mizuho, and Sumitomo Mitsui (SMBC) – channeled $281 bln to the projects focused on fossil fuel development throughout the world in 2016-2019.

[12] This index accounts for changes in national energy policy priorities, reforms aimed at improving the investment climate, environmental policies, the private sector's participation in renewable energy projects, etc.

Moreover, the volume of these investments is only increasing from year to year [Banking on Climate Change 2019]. Japan is the third among the G20 countries by the amounts of coal industry subsidies after China and India. It is followed by South Africa, South Korea, Indonesia, and the USA. Japan also holds the second place among the G20 countries (after China) by the amounts of government investments in foreign coal projects. The main beneficiaries of Japanese investments are Vietnam, Indonesia, and Bangladesh.[13]

Despite the fact that, in 2019, a number of Japan's trading houses, including Itochu, Marubeni, Mitsui and Sojitz – the biggest investors of coal-fired TPSs, – announced their plans to give up or limit investing in coal projects, these statements are to be treated with caution. They are not related to the implementation of the running projects and those adopted earlier and being now under consideration. Moreover, these plans do not apply to coal-fired power stations with ultra-supercritical technologies (cutting-edge technologies of coal-fired power stations that have the lowest intensity of emissions at less than 750 g $CO_2$/kWh).[14]

## Emission of Greenhouse Gases in Japan

One of the most important issues related to green energy is the reduction of carbon dioxide ($CO_2$) emission as its concentration in the atmosphere has notably increased over the last century and now exceeds the mid-1800s level by 4 percent. The energy sector is the largest GHG emitter among all the spheres of human activity accounting for over 70 percent of total emissions [Ritchie & Roser 2020]. China, the USA, India, the EU, Russia, and Japan are the largest global $CO_2$ producers. These countries account for 2/3 of the global fossil fuels emissions (according

[13] G20 coal subsidies. Tracking government support to a fading industry. https://www.odi.org/sites/odi.org.uk/files/resource-documents/12744.pdf

[14] Ibid.

to the 2019 data). The share of Japan amounts to 3 percent of global emissions (Figure 4). 85 percent of the emissions in Japan come from energy generation.

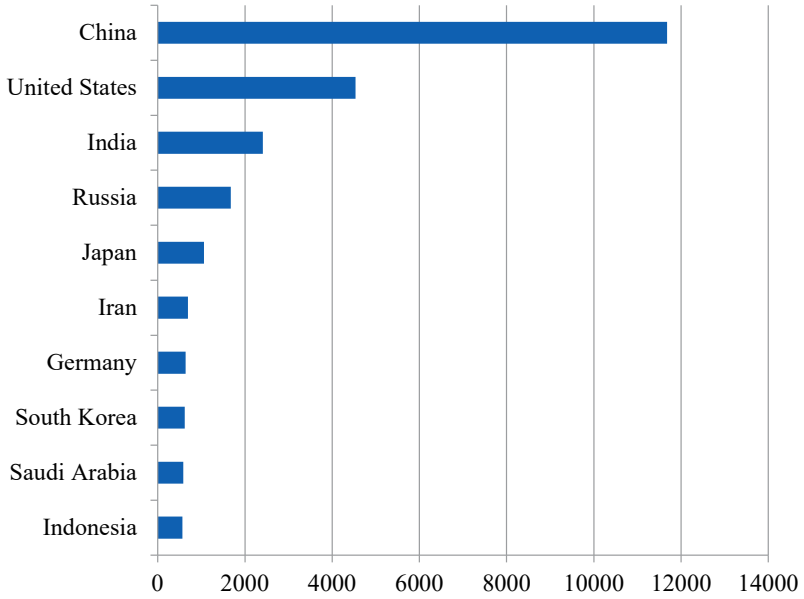


*Figure 4*. Top 10 countries – largest $CO_2$ emitters in 2020, ml tons[15]

GHG emissions in Japan had been increasing until 2013, when the historical high was recorded, followed by a gradual reduction. The most considerable emission reduction was observed in 2018-2019 and associated with the resumption of nuclear power operations as well as the expansion of renewable energy (Figure 5).

Combining efforts of all countries is of great importance in combating climate change. International negotiations on climate change are held within the UN Framework Convention on Climate Change (UNFCCC) aimed at coordinating measures undertaken to

[15] *Source:* EDGAR

address human-induced global warming. The UNFCCC was adopted in 1992 and ratified in 1994. Most countries of the world, including Japan, acceded to the Convention.

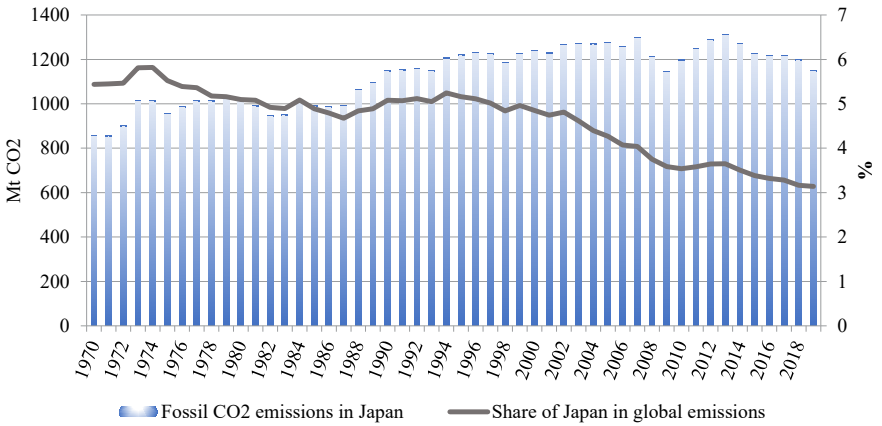


*Figure 5.* Fossil $CO_2$ emissions in Japan[16].

The UNFCCC provides for the principle of common but differentiated responsibility considering different levels of countries' socio-economic development. It is recognized that the leading role in combatting climate change and its negative consequences is to be played by industrially developed and emerging countries which made the biggest contribution to the overall amount of anthropogenic GHG emissions in the process of their development (the principle of historical responsibility).

Realizing the urgence of more stringent measures to solve the climate change problem, in addition to the UNFCCC, the international community adopted the Kyoto Protocol (KP) in 1997. Japan was the initiator of this major international treaty on combatting global warming. The Kyoto Protocol assigned quantitative reduction and limitation commitments for anthropogenic greenhouse gases emissions to each of the countries listed in Annex I of the

[16] *Source:* EDGAR, IEA

UNFCCC. These countries were to ensure reduction of GHG emissions at least by 5 percent in the period of 2008-2012 as compared with the 1990 level.

For the purpose of minimizing economic costs of the emissions limitation and reduction commitments, the Kyoto Protocol stipulated the system of "flexible mechanisms": Clean Development Mechanism, Joint Implementation, and Emissions Trading[17]. Other schemes began to appear simultaneously with the development of these mechanisms. Notably, the last mechanism became the most popular, even among the countries that had not undertaken any quantitative reduction commitments. In fact, it laid the basis for the development of a new segment of world trade – carbon market. The main driver on this market is the European emissions trading scheme (EU ETS). China is also actively developing the national system of emissions trading. There are currently several systems for trading emission quotas on various levels – international, national, and regional [Podoba & Kryshneva 2018].

Japan launched the so-called Joint Crediting Mechanism (JCM). It is a system of agreements between Japan and developing countries on measures to reduce greenhouse gases emissions, with the result of this reduction being assessed as the contribution of both partner countries and Japan. Promoting the dissemination of advanced low carbon technologies through the JCM, Japan attempts to help solving the climate change problem on the global scale. This mechanism was suggested by Prime Minister Shinzo Abe at the Climate Change Conference in Paris (COP21) in 2015. Japan signed the JCM partnership documents with 17 countries of Asia, Africa, Latin America, Middle East, and small island developing economies.[18]

In 2012, the Kyoto Protocol effective period was prolonged until 2020. Yet, like Russia and Canada, Japan considered its further participation in

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[17] For more detail about KP mechanisms and "green energy' development in BRICS countries see [Z. Podoba, D. Kryshneva, 2018].

[18] The Joint Crediting Mechanism (JCM). https://www.jcm.go.jp/

the project pointless. It should be recalled that the USA never ratified the KP, while China did not undertake any commitments having the developing economy status. Despite the wide acceptance of the Kyoto Protocol mechanisms, it turned into an ineffective instrument. The Paris Climate Agreement was concluded within the UNFCCC framework in December 2015; it entered into force in November 2016 and was supposed to replace the Kyoto Protocol after 2020. The Agreement is aimed at intensifying global response to the climate change threat, including such measures as restraining the global average temperature growth below 2°C (and preferably limit the increase to 1.5 °C) compared to the pre-industrial level.[19] Japan ratified the Agreement in 2016, and Russia – in 2019.

The document stipulates that all countries will present national plans to overcome global climate change consequences that are to be renewed every 5 years (Nationally Determined Contribution, *NDC*). In accordance with the preliminary version presented in 2015, Japan undertook commitments to reduce GHG emissions by 26 percent by 2030 against the 2013 level (25.4 percent against 2005).[20] The achievement of the above goals presupposes, among other things, the use of the JCM mechanism. According to the requirements of the Paris Agreement, in 2020, Japan confirmed its commitment to the plans declared earlier.[21]

Interestingly, the emissions reduction benchmarks in Japan are presented against the 2013 level, while the USA makes comparisons with 2005, and EU – with 1990. If the above countries' benchmarks are compared with the 2013 level, it may be noted that Japan's benchmark is higher than in other leading developed countries (Table 1).

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19 Paris Climate Agreement. 2015, p. 3. https://unfccc.int/files/essential_background/convention/application/pdf/russian_paris_agreement.pdf

20 Submission of Japan's Intended Nationally Determined Contribution (INDC). 2015. P. 1. https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Japan/1/20150717_Japa n's%20INDC.pdf

21 Ibid. P. 4.

*Table 1*

Greenhouse gases remissions benchmarks by 2030[22]

| Country | Compared with 1990 | Compared with 2005 | Compared with 2013 |
|---|---|---|---|
| Japan | ▲18.0 % | ▲25.4 % | ▲26.0 % (by 2030)* |
| USA | ▲14.0–16.0 % | ▲26.0–28.0 % (by 2030)* | ▲18.0–21.0 % |
| EU | ▲40.0 % (by 2030)* | ▲35.0 % | ▲24.0 % |

* Benchmark indicated in the national contribution.

In addition, in 2019, Japan's government drafted a new document titled "Long-Term-Strategy under the Paris Agreement" that proclaimed building the "de-carbonized society" in the second half of the current century and taking measures to reduce GHG emissions by 80 percent by the middle of the current century to be the major goal of the Japanese society. Achievement of sustainable development goals, joint creation of innovations, formation of 5.0 Society, a circular economy and an environmentally responsible economy are to become the main elements of the strategy's implementation. All possible means will be used for de-carbonization in the energy sector: increased use of renewables, reduction of fossil fuels dependence, development of hydrogen energy, carbon capture and storage technologies (CCS), as well as carbon capture and utilization (CCU), energy storage systems using accumulator batteries, etc.[23]

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[22] Japan's Agency for Natural Resources and Energy. Japan's Energy 2019.

[23] The Government of Japan. The Long-term Strategy under the Paris Agreement. Cabinet decision, June 11, 2019. https://unfccc.int/sites/default/files/resource/The%20Long-term%20Strategy%20under%20the%20Paris%20Agreement.pdf

Growing attention in Japan is focused on the efforts for creating a hydrogen-based society. The development of hydrogen energy is not only regarded as a way towards low-carbon economy, but also as a key to enhancing energy security. The country plans to put up 320 hydrogen filling stations and increase the number of hydrogen-driven vehicles by 2025. Thereafter Japan expects to become the world leader in the field of hydrogen energy. Japanese corporations have already started building a global hydrogen supply chains. In the autumn of 2020, Prime Minister Yoshihide Suga announced that Japan must become a carbon-neutral country by 2050 at the latest.

In 2021, METI published the "Green Growth Strategy Through Achieving Carbon Neutrality in 2050". It is based on the decarbonization of the electric power sector through more active use of hydrogen and ammonia, as well as nuclear energy and renewable energy sources. At the same time, it promotes electrification in all areas, including transport, industry, and households, as well as technologies for the accumulation and storage of electricity.

However, experts recognize that significant technological innovations are required for this strategy to be successful. For these purposes, an action plan has been developed in 14 important areas, such as offshore wind energy, fuel ammonia, hydrogen, cars and batteries, semiconductors and ICTs, ships, buildings, next generation solar energy, etc. The Strategy formulates the tasks and ways to solve them at each of the four stages: the research and development phase, the practical testing phase, extended implementation, and independent commercial use. To support innovation, the government will create a 2 trillion yen ($ 18.3 billion) fund to help active companies develop and test technologies. In addition, tax incentives will be introduced for them, and reforms will be carried out to ease restrictions.

## Energy Efficiency of Japan's Economy

Measures to raise energy efficiency are usually the most rational method of "greening" the energy sector. However, many countries attach much less importance to this area than, for example, to the use of RES. As most widely interpreted, efficiency is a ratio of some economic result (GDP, a company's production, etc.) to the costs in energy units (energy resources consumption, electric power generation, power costs at an enterprise, etc.). However, the reverse indicator – the energy intensity of the economy is much more often used in the global practice.

Japan started to develop and implement the policy of energy conservation and reduction of fossil fuel consumption after the oil shocks of the 1970s and made significant achievements in this area. Thus, the energy efficiency of its economy grew 35 percent in 1970-1990, and Japan reached the highest levels of energy efficiency indicators in virtually all industries. The process, however, slowed down in 1990-2010. Environmental protection and global warming were prevailing issues in that period. The shift in priorities of the government was associated, firstly, with the fact that the traditional policy of energy conservation, based on a decrease in specific indicators of energy consumption, has largely exhausted itself, and secondly, with the fact that measures on reducing GHG emissions became a key issue on the agenda. The latter directly depended on the country's achievements in energy saving as well as on efforts to restructure the energy balance. As a result, the political goals in the energy and environmental spheres began to merge in the second half of the 1990s [Streltsov 2011, pp. 19–20].

The energy intensity of Japan's economy is one of the lowest in the world. In 2019, Japan's indicator was 2.7 times lower than that in Russia, 2.2 times lower compared to the USA, and 1.6 times lower than that in China. The steps undertaken by the Japanese government to increase the RES share and raise energy efficiency resulted in a situation where the total amount of energy necessary to generate one unit of GDP showed

a downward trend in the second decade of the 21st century. Yet, Japan's results proved to be more moderate than similar indicators of some European countries, Germany in particular (Figure 6).

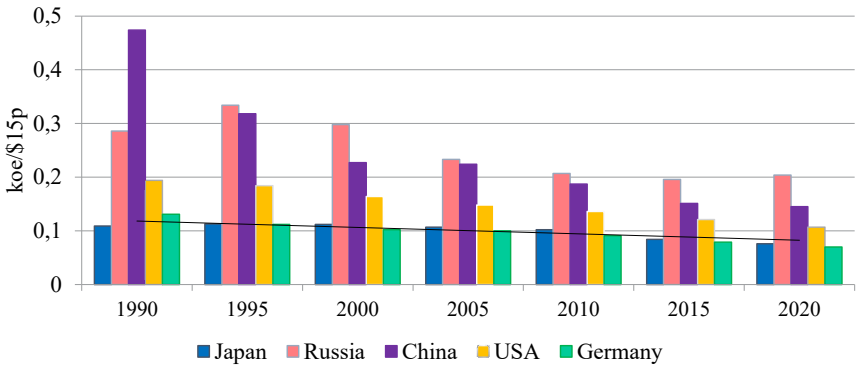


*Figure 6.* Energy intensity[24]

Japan's policy of energy conservation is implemented through encouragement of research and development in this field as well as the system of tax incentives and preferential subsidies. For example, from one-third to a half of an enterprise's investment costs on introduction of energy saving equipment and technologies may be subsidized. Companies with foreign capital also enjoy the right to these subsidies (Japan's Ministry of Economy and Trade appropriated some 700 mln yens for this purpose in 2017).[25]

There are no minimal energy efficiency standards in Japan, but the country has "Top Runner", a program of standards aimed at promoting energy efficient products. The program sets target indices for energy efficiency of product units for the subsequent years based on the analysis of average-weighted indicators for the current

[24] *Source*: Enerdata

[25] METI. 2020. Energy Efficiency and Conservation. https://www.meti.go.jp/english/policy/energy_environment/energy_efficiency/index.html

period. Products which meet the energy efficiency standard receive a Top Runner label and get support (promotion in mass media, special marking, etc.). The program includes the following goods: automobiles, air conditioners, TV-sets, computers, refrigerators, and others (over 30 item names in total).

A set of measures has been designed to raise energy efficiency in the construction industry and buildings operation as the bulk of houses consume energy inefficiently. Thus, Japan's government promotes an initiative of building Zero Energy Houses (ZEH). Energy saving without sacrificing the comfortable habitat may be achieved through better thermal insulation, highly efficient equipment, and RES.

Finally, for purposes of raising the economy's energy efficiency and energy system sustainability it is projected to set up a new type of the decentralized electric power system with the intellectual distributed management achieved through energy transactions between its users. This system is called "Internet of Energy" and includes three components: 1) distributed energy sources, most of which will be based on RES use; 2) final consumers who own distributed small and microgeneration, as well as energy storage units, and who are ready to regulate the consumption of facilities they manage; 3) "smart networks" combining more advanced ways of power transmission with more effective distribution mechanisms.

## Conclusion

Japan's current energy policy and energy funding are aimed, first of all, at elimination of energy supply deficit, and, secondarily, at providing comprehensive development of green energy. After the Fukushima-1 accident Japan began to regard renewable energy as a means of addressing the challenge of energy instability and vigorized its state policy of stimulating investments in RES. Political incentives, such as introduction of feed-in tariffs, and significant investments led to an increase of renewable energy sources share, especially solar PV, in the

structure of electricity generation, and contributed to the reduction of $CO_2$ emissions after 2013, as well as to the improvement of energy efficiency. Yet, average total installed costs of renewable energy in Japan are very high compared to other countries, and electric power rates have risen considerably. All this puts a burden on consumers, reducing the potential for economic growth.

Japan's policy has been increasingly aligned with international rules in recent decades. On the whole, Japan is trying to implement its commitments under international treaties and has announced its ambitious plans to reduce greenhouse gases emissions within the framework of the Paris Agreement that exceed the intentions of other leading global economies. The goal to achieve carbon neutrality by 2050 was set in 2020. According to the Sixth Strategic Energy Plan released in 2021, Japan aims to achieve the GHG reduction target by 2030 by reducing the total primary energy consumption and increasing the share of renewables to 36%–38%, along with adding of hydrogen and ammonia to the list of main energy sources.

Although Japan has definitely made achievements in advancing green energy, it is still unclear whether this trend is sustainable. According to the latest version of the national energy plan, the share of fossil fuels will still be higher than that of renewable energy and the share of nuclear power generation will grow significantly by 2030. In addition, Japan continues to invest intensively in fossil fuels, and given low oil prices and the COVID-19 pandemic-caused recession, the future of renewable energy sources remains uncertain.

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