Japan 2021

Energy Policy Review

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Foreword

The International Energy Agency (IEA) has conducted in-depth peer reviews of its member countries' energy policies since 1976. This process supports energy policy development and encourages the exchange of and learning from international best practices. By seeing what has worked – or not – in the "real world", these reviews help identify policies that deliver concrete results.

Japan was a founding member of the IEA back in 1974 and has remained an important and active member ever since. I am particularly grateful to Mr Hiroshi Kajiyama, Minister of Economy, Trade and Industry, and his colleagues for the strong collaboration the IEA enjoys with Japan today and believe this will be instrumental in building a secure and sustainable global energy future.

Since the IEA last review of Japan's energy policies in 2016, Japan has diversified its energy mix through the gradual expansion of renewable energy and the restart of nuclear power plants. This has benefitted both Japan's energy security and the climate globally – Japan's greenhouse gas emissions have now fallen for five consecutive years. But the challenge ahead is considerable. While Japan is well on track to meet its 2030 climate goals, its dependence on fossil fuels remains high. A very significant reduction of greenhouse gas emissions post-2030 will be necessary if Japan is to realise its ambition of achieving carbon-neutrality by 2050.

Japan's strong innovation and technology base will play a vital role in developing the technologies needed to achieve its energy and climate ambitions. I applaud Japan for its leadership in advancing low-carbon hydrogen and carbon-recycling technologies, which will be crucial in decarbonising so called "hard-to-abate sectors". But at the same time as these emerging technologies are scaled up, I encourage Japan to also accelerate its energy transition in sectors where low-carbon alternatives are already available, notably in the power sector. Wind and geothermal power have large potential in Japan and can complement the emissions reductions being achieved through the expansion of nuclear and solar energy. The IEA welcomes Japan's decision to phase out inefficient coal power plants by 2030, which marks a turning point in Japan's clean energy transition.

Japan has made important strides in reforming its domestic electricity and natural gas markets. The increasing competition in these sectors is encouraging, but further reform is needed to achieve a true level playing field for all market participants. Additional regulatory reforms will also be important to encourage investments in zero-emission electricity and to improve power system flexibility. It will also be necessary to ensure that the market regulator has sufficient powers and independence. Energy security remains a focus area for the IEA and a priority for the Japanese government. The continued diversification of energy sources is an important development in this regard. I congratulate Japan for its recent steps to strengthen the resilience of its electricity system.

I strongly believe that the policy and regulatory reforms proposed in this report can help Japan advance its energy and climate goals while supporting its economic growth. As it has done since 1974, the IEA will continue to stand side-by-side with Japan as it moves ahead with the process of implementing the next round of its domestic energy and climate policies as well as on the important work it is leading on global clean energy transitions.

Dr. Fatih Birol

Executive Director

International Energy Agency

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ANNEXES

LIST OF FIGURES, TABLES AND BOXES

Figures

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Tables

Boxes

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1. Executive summary

Overview

In October 2020, the new Prime Minister of Japan declared that by 2050 Japan will aim to reduce greenhouse gas emissions to net-zero and to realise a carbon-neutral, decarbonised society. This declaration is a defining moment for Japan's future energy and climate policies, and the government is developing additional policies and measures to achieve this target. In November 2020, a bipartisan group of lawmakers declared a climate emergency in a symbolic vote to support the earlier announcement by the Prime Minster. This IEA in-depth review comes timely, as it makes numerous recommendations that can be helpful in developing policies and measures to support achieving the new goal.

Over the last decade, Japan made substantial progress in implementing its vision of an efficient, resilient and sustainable energy system. The gradual restart of nuclear power generation, expansion of renewable energy and energy efficiency gains have reduced the need for imported fossil fuels, and contributed to a continuous decline in greenhouse gas (GHG) emissions. These reached an historic peak in 2013, as fossil fuels filled the gap caused by the temporary shutdown of all nuclear power plants after the Fukushima accident. In 2018, GHG emissions had decreased by 12% compared to 2013, back to same level they had in 2009.

Despite all efforts, Japan remains heavily reliant on imported fossil fuels. In 2019, fossil fuels accounted for 88% of total primary energy supply (TPES), the sixth highest share among IEA countries. Japan's carbon intensity of energy supply increased rapidly after 2011 and is only gradually reducing since; the carbon intensity of power generation is among the highest in IEA member countries.

Achieving the aim of carbon-neutrality by 2050 will require Japan to substantially accelerate the deployment of low-carbon technologies, address regulatory and institutional barriers, and further enhance competition in its energy markets. It will also be important to develop different decarbonisation scenarios, to prepare for the possibility that certain low-carbon technologies, such as nuclear, do not expand as quickly as hoped.

Japan's vision of a decarbonised society

Japan presented its new "Green Growth Strategy in line with Carbon Neutrality in 2050" in December 2020. The strategy is specifically designated as an industrial policy and promotes the creation of a virtuous cycle of economic growth and environmental protection, together with the business community. The strategy builds on the speech of the Prime Minister that recognised that pro-active climate policy will transform not only industrial structures but also the economy and the society and will lead to dynamic

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economic growth. The Prime Minister also specifically pointed to benefits of regulatory reforms and digitalisation to advance the green transformation and to ensure green investments.

The Green Growth Strategy identifies 14 sectors with high growth potential towards the 2050 ambition. The government counts on an ambitious expansion of renewables, a recovery of nuclear power and on the deployment of new technologies, including low-carbon hydrogen, safer advanced nuclear reactors and carbon recycling to decarbonise the electricity sector. As a reference for discussion, the strategy sees renewables accounting for between 50% - 60% of electricity demand in 2050 with the reminder supplied by nuclear and thermal plants with carbon capture utilisation and storage (CCUS) (30-40%) and 10% of hydrogen and ammonia generation.

Japan launched an ambitious long-term innovation strategy in early 2020, with innovation paths and cost targets for technologies that are considered necessary to achieve the 2050 vision. The strategy is driven by a strong sense of urgency, recognising that innovation needs to be accelerated.

Hydrogen is expected to play a central role in Japan's clean energy transition. Japan was among the first countries to launch a national hydrogen strategy, which aims to make hydrogen cost-competitive with natural gas. By 2030, Japan aims to have 800 000 fuel cell vehicles, more than 5 million residential fuel cells and to establish an international hydrogen supply chain. It is also experimenting with large-scale power generation based on hydrogen. All this will provide valuable lessons to the international energy community. Japan is well positioned to push for an internationally shared vision on making hydrogen a truly clean energy source.

CCUS is another focus area, due to Japan's large reliance on fossil fuels. Requiring new gas- and coal-fired power plants to be constructed "capture ready", so that CCUS can be more easily deployed later on, can help avoid that new plants become stranded assets. Due to limited storage sites, Japan has a strong focus on carbon recycling. However, given the uncertainty about the technology's true mitigation potential, the promotion of low-carbon technologies should remain a focus, so as to reduce Japan's dependence on carbon-intensive assets. The IEA welcomes the recent announcement to phase out inefficient coal-fired plants by 2030. A pledge that was underlined in the Prime Minister's speech when he talked about drastically changing Japan's policies regarding coal- fired power generation.

Until now, Japan mainly relies on regulatory measures and voluntary agreements to reach its climate goals. Stronger reliance on market-based instruments could be one policy option for Japan to reduce emission costs-effectively, foster innovation for CCUS and other low-carbon technologies, and further increase Japan's high level of energy efficiency. Japan imposes lower prices on CO_2 emissions from energy use than many other IEA member countries and the IEA sees scope for Japan to make better use of price signals to enhance low carbon technologies to reduce CO_2 emissions by steering behaviour, both of end consumers and of the industrial sector, and to re-direct industrial investments to innovative technologies. However, such price signals would need to be designed carefully, so as to limit negative impacts on end user electricity prices, which are already high in Japan. The Green Growth Strategy of December 2020 calls for a discussion about a carbon border adjustment mechanism to ensure a level playing field for Japanese companies vis-a-vis their foreign competitors. The strategy seems to be alluding to

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introduce more robust economic mechanisms by calling for regulatory reform, including market-based tools that could include credit trading, carbon tax and carbon border adjustments. This marks a major development in Japan's climate policy and a reversal of its earlier position regarding carbon pricing.

Main energy goals to 2030

Reaching carbon neutrality by 2050 requires steep emission reductions as early as possible and latest from 2030 onwards, and the quick implementation of a wide set of policies and measures. The Green Growth Strategy will have implications for the next Strategic Energy Plan that is currently under discussion, and which may include a revised 2030 energy mix.

Japan's energy policy is guided by the principles of energy security, economic efficiency, environmental sustainability and safety (the "three E plus S"). The 5^{th} Strategic Energy Plan, adopted in 2018, aims to achieve a more diversified energy mix by 2030, with larger shares for renewable energy and restart of nuclear power. It also aims to enhance the efficiency of fossil fuel use and to reduce energy demand.

In the 5th SEP, the share of renewable energy in TPES is expected to reach 13% in 2030, up from 8% in 2019. Renewable power generation is expected to reach 24% in 2030, up from 19% in 2019. Japan has seen rapid expansion of solar photovoltaic in recent years, driven by generous feed-in-tariffs. More efforts are needed to develop other renewable technologies, including wind and geothermal, for which Japan's energy potential is large. In the power sector, the main challenge is to address grid constraints, including through better connectivity between Japan's regional grids. Regulatory reform can help improve electricity system operation, thereby allowing for integration of larger shares of variable renewable energy. Expansion of renewables in the heat and transport sectors remains slow due to limited policy support.

Nuclear energy is expected to increase to at least 11% of TPES by 2030, up from 4% in 2019. Prior to 2011, nuclear energy accounted for some 15% of TPES. This 2030 target is achievable if the number of operational reactors increases from 9 to at least 30. That will require concerted efforts by the electricity utilities, government and regulators to satisfy enhanced safety standards, as well as extensive work with local communities to regain social acceptance.

While fossil fuel use is expected to decline, it remains high, at 76% of TPES and more than half of power generation in 2030. The envisioned energy mix for 2030 is coherent with the goal to reduce GHG emissions by 26% by 2030 compared to 2013 levels, and assumes that nuclear energy restarts as planned. However, in light of the newly announced ambition to become carbon-neutral by 2050, there is a need to raise the zero-emission power source ratio already by 2030. The upcoming revision of the SEP in 2021 is a logical starting point for this. The government should develop scenarios how to close an eventual gap in electricity generation if restarts of nuclear plants are delayed. Uncertainty regarding these dimensions risks supressing the necessary investments in energy infrastructure.

Japan is among the most energy-efficient economies in the world and aims to improve efficiency even further to curtail future energy demand growth. The challenge will be to identify where savings potential is largest, and how this potential can be realised cost-effectively. It will also be important to monitor progress, in particular in areas where efficiency goals are aspirational or voluntary.

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Electricity and gas market reform

The 2011 accident prompted the government to accelerate reform of the electricity market. In parallel, it also advanced reforms in its domestic gas market. The reforms followed the same three objectives: to enhance security of supply, to increase competition, and to reduce end-user prices.

In the electricity market, key steps included the full liberalisation of the retail market in 2016 and the legal unbundling of ten vertically integrated electricity companies in April 2020. Competition in the electricity retail market is increasing, although the incumbents' retail businesses still account for some 85% of total retail sales. Liquidity in the wholesale market is also increasing, with some 30% of electricity now being traded at the Japanese Electric Power Exchange. New markets (including a balancing, baseload, capacity and non-fossil certificate market) have been established to address market barriers and further foster competition. It will be important to monitor the interaction of these new markets and their effect on wholesale power trade. It may also be worthwhile to consider making wholesale trading mandatory to remove the incumbents' advantage of internalised wholesale trading.

The IEA welcomes the electricity bill passed in June 2020, which initiated a new phase of market reform. The bill introduced changes to transmission charges to spur investments in the transmission and distributed network. It also strengthened the role of the Organization for Cross-regional Coordination of Transmission Operators (OCCTO), which was established in 2015 with the task to balance electricity supply and demand on a nationwide level and to improve power exchanges across Japan's regional grids. A well-integrated national grid will both facilitate the integration of variable renewable electricity and enhance energy security. Advancing regulatory reform to improve the operational efficiency of the electricity system will also be important. Japan has ambitious goals to promote distributed energy sources, connect mobility infrastructure to the power grid, and to use digital technologies for efficient electricity demand management and demand response.

In the natural gas market, the retail sector was fully liberalised in 2017 and the vertically integrated gas companies will need to unbundle their businesses by April 2022. Competition in the gas market remains modest and there are three regions that have seen no new retail entrant to date. Non-discriminatory open access to gas infrastructure and better interconnectivity of the regional gas networks will be paramount to foster competition. The introduction of third-party-access to liquefied natural gas (LNG) terminals in 2017 is an important step in the right direction, although only one competitor was granted access to date.

Security of gas supply is a particular concern, as demonstrated by the shortages in gas supply for the power sector in January 2021, resulting in purchases of spot cargos at record high prices - even higher than after the Fukushima accident in 2011. Electricity market prices jumped by a factor of 10 as the electricity reserve ratio declined to close to 3%. The gas shortage came as a surprise to many market participants, as there is little transparency on gas stocks in the country. Also there is no obligation for electricity companies to store LNG ahead of winter to overcome cold weather periods. The gas shortage in this winter highlights the importance of ensuring electricity security in Japan where the grid is isolated and the country relies on imports of LNG. This calls for a holistic approach beyond gas supply and storage, and to also consider other energy sources and market frameworks to mitigate the effects of gas shortages on the electricity and gas markets including their better integration. The Japanese government is discussing how to improve electricity security while aiming for the carbon neutrality target.

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Enhancing competition by early and complete implementation of the electricity and gas market reforms is needed for Japan to reach its goals of increasing security of supply and reducing costs for end users. To facilitate this early and complete implementation, Japan may wish to consider making the Electricity and Gas Market Surveillance Commission a more independent regulator with its own executive and enforcement powers.

Strengthening the resilience of the energy sector

As an island country with limited natural resource endowments and no international gas pipelines and electricity connections, Japan faces fundamental energy security challenges. Dependency of imported fossil fuels sparked to 94% of energy supply in 2014, but the restart of nuclear, expansion of renewables and lower energy demand helped reduce this share to 88% in 2019.

Japan has successfully diversified its import sources for liquefied natural gas (LNG), while oil imports remain heavily concentrated in a small number of Middle Eastern suppliers. At the same time, Japan has one of the largest oil stockholdings globally, which acts as insurance against geopolitical risks and large global shocks. Japan continues to play an important role in international energy markets by bringing together energy producers and consumers to ensure stable supply at reasonable prices. Japan's efforts to promote a more liquid and transparent global LNG market are particularly commendable.

Traditionally, Japan has a very high level of electricity security by international comparison. However, in recent years a series of natural disasters caused long and large-scale blackouts that highlighted the vulnerabilities of the current system. The challenge to maintain electricity security of supply will become even larger as the share of variable renewable energy sources in the power mix increases. Japan's electricity network is fragmented into many regional areas with limited interconnections, which makes it difficult to efficiently balance supply and demand across the country. The legislative changes of June 2020 enhance the disaster response preparedness of electric utilities with important roles for distributed power systems, and the IEA encourages Japan to also swiftly move forward with the planned strengthening of interconnections.

Key recommendations

The government of Japan should:

- ☐ Map out energy scenarios, including road maps, for achieving the 2050 decarbonisation aim that take into account various futures for the development of energy sources.
- ☐ Establish price signals to encourage investments across the economy in efficient and low-carbon technologies.
- ☐ Encourage investments in the electricity network and improve electricity system operations to facilitate the cost-effective integration of larger shares of variable renewable electricity sources, achieve a diverse mix of low-carbon electricity generation sources and enhance security of supply.
- ☐ Advance the electricity and gas market reform and consider making the Electricity and Gas Market Surveillance Commission a more independent regulator.

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2. General energy policy

Key data

(2019 estimated)*

Total primary energy supply (TPES): 419.1 Mtoe (oil 37.9%, coal 27.2%, natural gas 23.1%, nuclear 4.0%, bioenergy and waste 3.8%, hydro 1.6%, solar 1.6%, geothermal 0.6%, wind 0.2%), -11.9% since 2009

TPES per capita: 3.3 toe/cap (IEA average (2018): 4.2 toe/cap)

TPES per unit of GDP*: 93 toe/USD million (IEA average (2018): 95 toe/USD million)

Energy production: 51.1 Mtoe (nuclear 32.6%, bioenergy and waste 28.0%, hydro 13.6%, solar 12.9%, natural gas 5.0%, geothermal 5.0%, wind 1.3%, coal 0.8%, oil 0.8%), -47.4% since 2009

Total final consumption (TFC) (2018): 283.0 Mtoe (oil 51.0%, electricity 28.7%, natural gas 10.3%, coal 7.5%, bioenergy and waste 2.2%, district heat 0.2%, solar 0.1%, geothermal 0.05%), -10.0% since 2008

* Data for Japan are reported based on Japan's fiscal year (e.g. April 2018 to March 2019 for 2018).

**GDP data are in billion USD 2015 prices and PPPs (purchasing power parity).

Country overview

An island nation off the eastern coast of the Russian Federation (hereafter "Russia"), the People's Republic of China (hereafter "China") and Korea, Japan has an area of approximately 378 000 square kilometres (km^2). It consists of several thousands of islands, among which Honshu, Hokkaido, Kyushu and Shikoku are the four largest ones (Figure 2.1). Mountains cover around 70% of the country and arable land just under 13%. The climate is largely temperate, with four distinct seasons.

Japan has a population of approximately 126.5 million and its population density is the fourth-highest among IEA countries after Korea, the Netherlands and Belgium. Japan's population is ageing rapidly, in part driven by long life expectancy, which is the highest in the IEA. The total population of Japan is projected to decline by almost 25% between 2015 and 2050, falling below 100 million people (OECD, 2019).

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Figure 2.1 Map of Japan

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Japan has the third-largest economy in the world, after the United States and China. In 2019, its nominal gross domestic product (GDP) was USD 5.1 trillion. After tipping into recession after the 2011 Great East Japan Earthquake and the subsequent nuclear accident at the Fukushima Daiichi Power Plant (hereafter called "the 2011 events"), GDP growth has fluctuated between 0.3% and 2.2% since 2012 (World Bank, 2020). Due to the confinement measures and lower foreign demand caused by the COVID-19 pandemic, Japan is expected to experience its deepest recession of the post-war era in 2020, with GDP declining by 6-7%. A modest recovery is expected for 2021 (OECD, 2020a).

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ENERGY INSIGHTS

As in most developed economies, the service sector dominates with 69% of total GDP, followed by the industry sector with 29% (World Bank, 2020). Japan's industries are globally recognised for their high-quality products and technological advances. Japan is the world's fourth-largest trading nation after China, the United States and Germany, with particularly strong export performance in vehicles, machines and electronic equipment (WTO, 2019).

The current Prime Minister, Yoshihide Suga from the Liberal Democratic Party, assumed office in September 2020. The fiscal year runs from 1 April to 31 March.

Supply and demand

The 2011 events have had a significant impact on Japan's energy system. The accident led to a total suspension of the nuclear power fleet, which has only partially restarted. This has made Japan more dependent on fossil fuels to close the gap in electricity generation.

In 2019, total primary energy supply (TPES)[1] in Japan totalled 419 million tonnes of oil equivalent (Mtoe), the second highest in the IEA after the United States and the fifth largest in the world. Relative to its GDP, however, Japan's energy consumption is moderate, ranking the 11th lowest in the IEA in 2018. Japan's energy sector is dominated by fossil fuels, which accounted for 88% of TPES in 2019 (Figure 2.2). Japan hardly has any domestic production of fossil fuels and therefore relies mostly on imports for coal, crude oil and natural gas.

Oil is the largest energy source in Japan, representing 38% of TPES in 2019 and 51% of total final consumption (TFC)[2] in 2018. Coal was the second-largest energy source, with 27% of TPES, followed by natural gas with 23%. Coal and natural gas are also the largest sources of power generation and their importance increased after the 2011 events. In 2019, coal and natural gas together accounted for two-thirds of electricity generation. Japan has a large energy-intensive industry sector, which accounts for 41% of TFC.

[1] TPES is comprised of: production + imports – exports – international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. power generation and refining) or in final use. Nuclear energy supply in TPES includes losses. The primary energy equivalent of nuclear electricity is calculated from the gross electricity generation by assuming a 33% conversion efficiency.
[2] TFC is the final consumption of energy (electricity, heat and fuels, such as natural gas and oil products) by end users, not including the transformation sector (e.g. power generation and refining).

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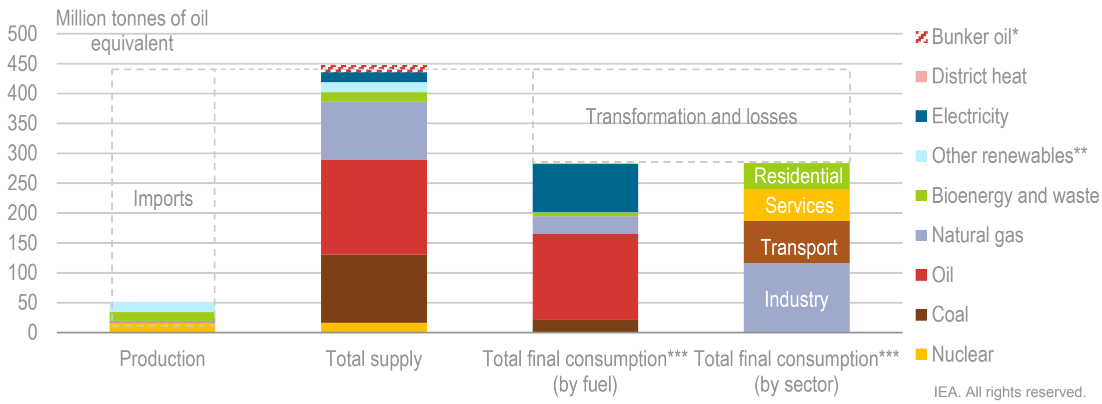
Figure 2.2 Overview of Japan's energy system by fuel and sector, 2019



Energy supply and demand in Japan are highly dependent on fossil fuels, in particular oil, while domestic energy production covered only 12% of total energy supply in 2019.

* *Bunker oil* includes international aviation and marine bunker fuel (not included in TPES).

** *Other renewables* includes hydro, solar, geothermal and wind energy.

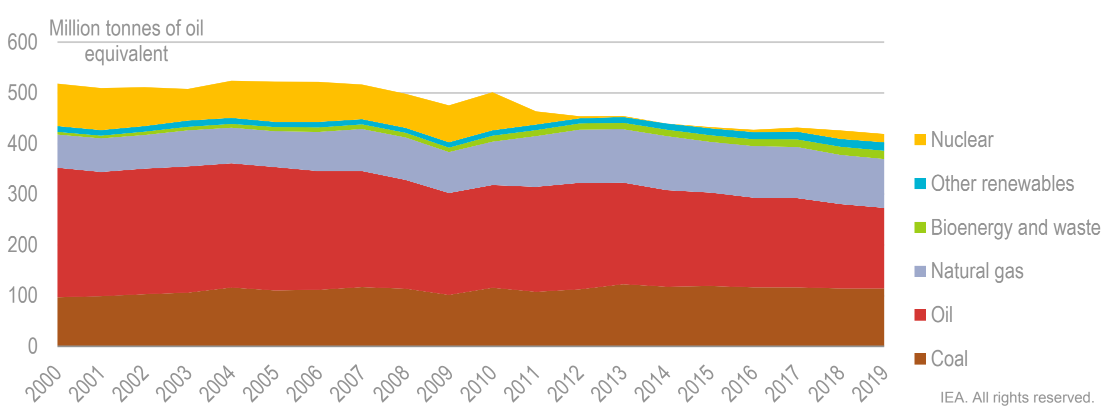
*** *Total final consumption* data are from 2018.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Primary energy supply

Japan's TPES has gradually declined since the Fukushima accident, with a 16% drop in TPES between 2010 and 2019 (Figure 2.3). One reason for this are energy efficiency improvements that have led to reduced energy demand across several sectors. Another reason is that nuclear energy with large thermal losses has been replaced by energy sources with lower conversion losses, which reduces the primary energy demand. The share of nuclear energy in TPES fell from 15% in 2010 to 0% in 2014 and picked up slightly to 4% in 2019.

Figure 2.3 Total primary energy supply by source, Japan, 2000-19



TPES in Japan has steadily decreased since 2010, while the share of fossil fuel increased up to 94% until 2014 to fill the gap of lost nuclear power supply.

* *Other renewables* includes hydro, geothermal, solar and wind.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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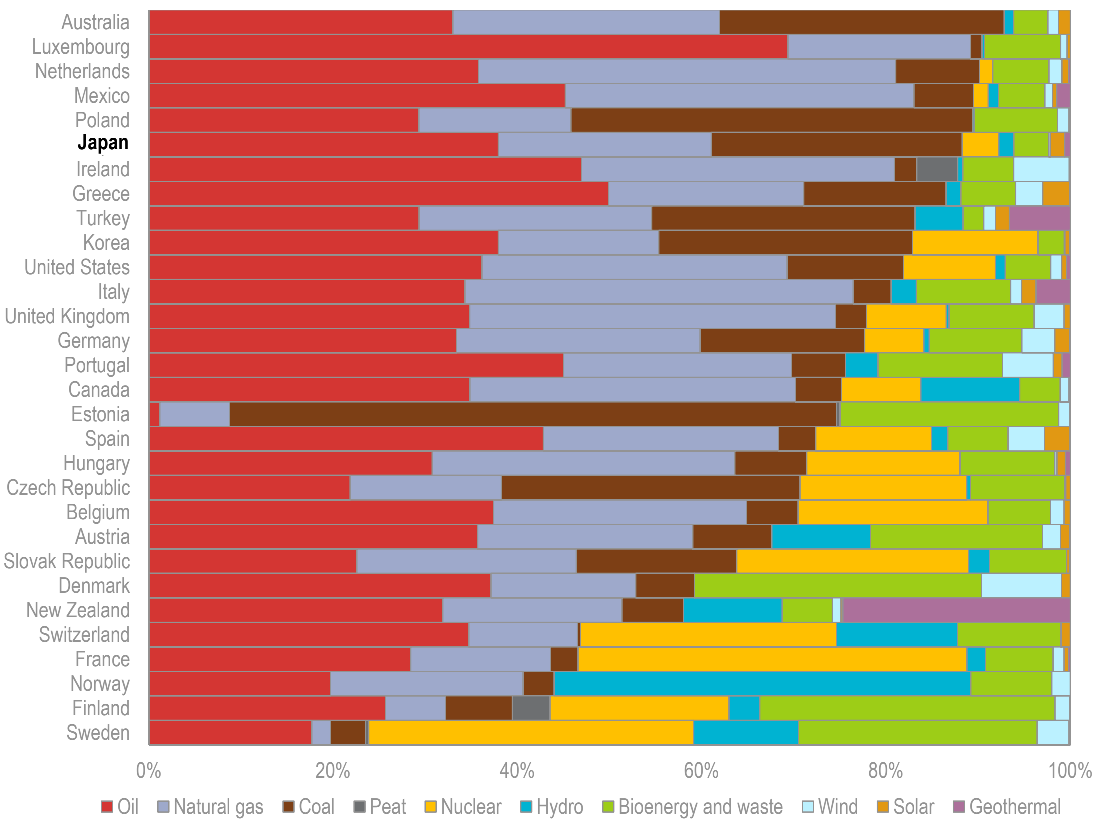
The reduction in nuclear has been largely replaced by natural gas, but energy savings and additional renewable energy capacity have also helped to close the gap. Over the 2010-19 time frame, natural gas supply increased by 13%, while coal supply remained stable and oil supply decreased by 22%. The share of renewable energy in TPES increased from 4.4% in 2010 to 7.8% in 2019, mainly driven by solar energy, which grew from near zero in 2010 to supplying 1.6% of TPES in 2019.

Fossil fuels (coal, oil and natural gas) accounted for a total of 88% of TPES in Japan in 2019, the sixth-highest share among IEA member countries (after Australia, the Netherlands, Poland, Luxemburg and Mexico) (Figure 2.4).

Figure 2.4 Breakdown of total primary energy supply in IEA member countries, 2019



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Fossil fuels accounted for 88% of TPES in 2019, the sixth-highest in an IEA comparison.

* Estonia's coal is represented by oil shale.

** *Solar* includes solar PV, solar thermal, wave and ocean power, and other power generation (e.g. from fuel cells).

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Energy production and import dependency

Japan produced 51 Mtoe of energy domestically in 2019, or 12% of TPES that year. Before 2011, nuclear energy[3] accounted for 70-80% of domestic energy production, but dropped

[3] Nuclear power is included under domestic production, although uranium, which is used as a fuel in nuclear power plants, is imported. Nuclear energy production is measured in primary energy terms and includes thermal losses. The

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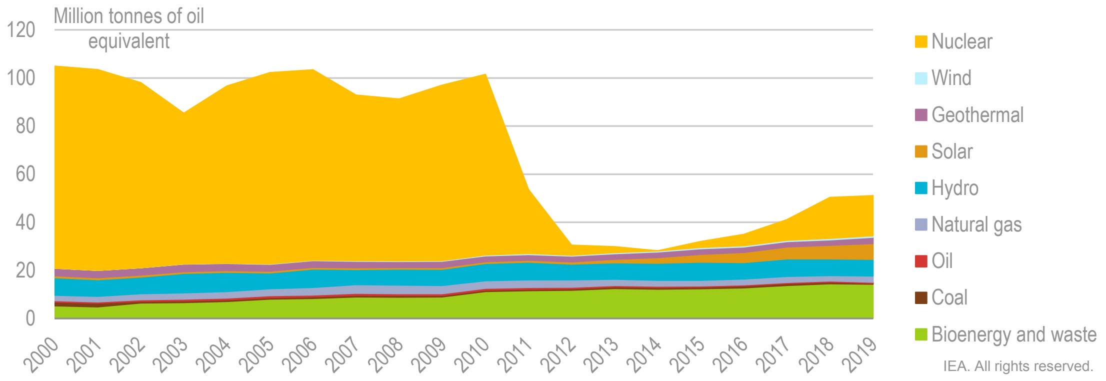
to zero in 2014. Growth in renewables and the restarting of some nuclear power plants has led to a rebound in domestic energy production to about half of the level in the 2000s (Figure 2.5).

Figure 2.5 Energy production by source, Japan, 2000-19



The 2011 events led to a dramatic drop in Japan's energy production, which has partly picked up in recent years thanks to growing renewables and the restart of some nuclear plants.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Japan was already highly dependent on energy imports, and the drop in energy production since 2011 led to even higher import dependency. Japan's self-sufficiency ratio[4] fell from around 20% during the 2000s to around 7% right after the 2011 events. By 2019, Japan's self-sufficiency rate had increased to 12%, which was the second-lowest among IEA member countries after Luxembourg and far below the median value of around 50%.

Energy consumption

Energy consumption in Japan totalled 283 Mtoe in 2018, representing 66% of TPES. Consumption has declined by 10% since 2008 (Figure 2.6). Energy demand saw a slight rebound in 2017, but declined again in 2018.

Industry was the largest energy-consuming sector, with 41% of TFC in 2018, followed by transport with 25%, services with 19% and the residential sector with 15%. All sectors have seen their energy consumption gradually decline since 2008.

primary energy equivalent of nuclear electricity is calculated from the gross electricity generation by assuming a 33% conversion efficiency.

[4] Defined as domestic energy production divided by total energy supply (TPES + oil fuels used in international aviation and navigation bunkers).

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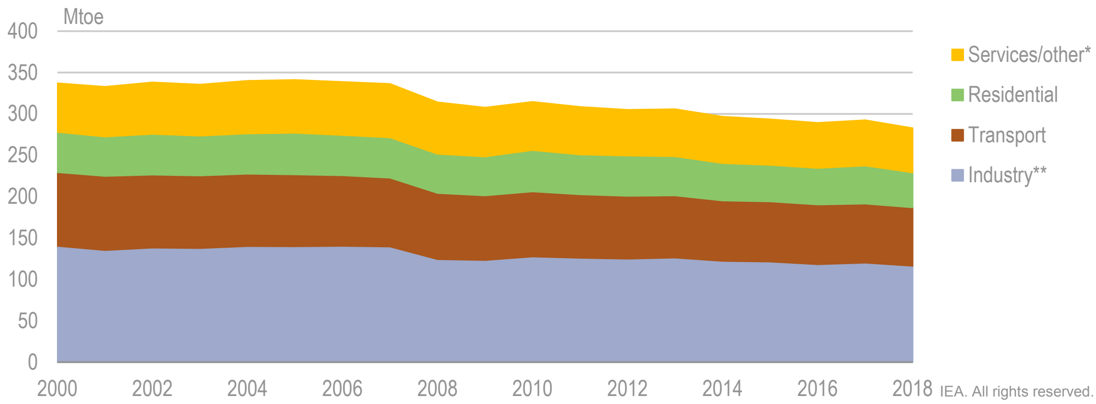
Figure 2.6 Total final consumption by sector, Japan, 2000-18



Japan's energy consumption has decreased in all sectors in the last decade, mainly driven by the industry sector, which is the largest energy consumer at 43% of TFC in 2018.

* *Services/other* includes commercial and public services, agriculture, forestry, and fishing.

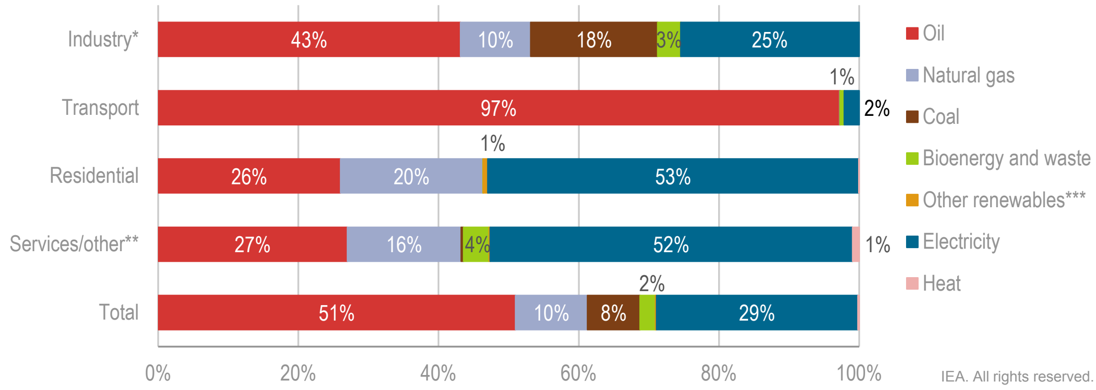
** *Industry* includes non-energy consumption.

Note: Mtoe = million tonnes of oil equivalent.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Oil accounted for over half of TFC in 2018 and dominates in particular energy demand in transport at 97%. Oil is also the largest energy source in industry at 43% of total demand and accounts for 26% and 27% in the residential and service sectors respectively. Electricity is the second-largest source of TFC, covering more than half of the energy demand in buildings, including both the residential and service sectors (Figure 2.7).

Figure 2.7 Total final consumption by source and sector, Japan, 2018



Oil accounted for 51% of TFC in Japan, dominating the transport and industry sectors, while electricity accounted for half of energy consumption in buildings.

* *Industry* includes non-energy consumption.

** *Services/others* includes commercial and public services, agriculture, forestry, and fishing.

*** *Other renewables* includes solar and a minor share of geothermal.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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Japan's general energy policy strategy

Japan's general energy policy is outlined in strategic energy plans (SEPs), which are adopted under the 2002 Basic Act on Energy Policy. The latest one is the 5th SEP, adopted in July 2018 (METI, 2018). Previous plans are from 2014, 2010, 2007 and 2003. The basic principle underlying these plans is to achieve energy security, economic efficiency and environmental sustainability (commonly referred to as the "3Es").

The 2011 events have drastically changed Japan's energy policy. The 4th SEP, adopted in April 2014, introduced safety as a key priority of energy policy, alongside the three traditional principles ("3Es plus S"). It envisaged to lower dependency on nuclear power to the extent possible, while promoting energy efficiency, expanding renewable energy and improving the efficiency of thermal power plants (METI, 2014). This contrasts with the 3rd SEP of 2010, which aimed to increase the share of nuclear energy in power generation.

The 5th SEP continues the vision and broad policy direction of the 4th SEP. It maintains the "3Es plus S" principle and updates the 4th SEP by "learning from and reflecting on the experience of the 2011 accident" (METI, 2018). It describes the policies and measures needed to achieve the envisioned energy mix to 2030 (see below), as well as a broad outline of how to reach Japan's aspirational goal to reduce greenhouse gas (GHG) emissions by 80% by 2050, taking into account the climate change mitigation targets set under the 2015 Paris Agreement. The 5th SEP's overall premises are to: pursue the adoption of renewable energy resources and minimise dependence on nuclear power; and work constantly to develop and secure new energy technologies, in view of the lack of domestic fossil fuel resources (METI, 2018).

The 5th SEP aims to establish a well-diversified portfolio of energy sources in which the strengths and weaknesses of various fuels are combined to achieve maximum efficiency and low costs. Other strategic goals include making the energy supply structure more resilient against disasters; advancing the reform of the electricity and gas markets; and improving energy efficiency across sectors through standards, investment and innovation. Looking to the longer term, the 5th SEP promotes distributed power systems and the use of artificial intelligence, the Internet of Things and big data, with a view to making the energy system more flexible and resilient.

The 5th SEP's long-term view is to work towards an energy transition and to decarbonise the economy. For this, all options regarding decarbonisation technologies will be considered and their development will be promoted through public-private co-operation. Hydrogen and carbon capture, utilisation and storage (CCUS) technologies are expected to play a key role in Japan's long-term energy transition and Japan leads several international initiatives to foster these technologies (see Chapter 6).

Japan's envisioned energy mix to 2030

The 5th SEP aims to fully realise the *Long-term Energy Supply and Demand Outlook to 2030*, which the Ministry of Economy, Trade and Industry (METI) published in 2015 (METI, 2015). The outlook is both a forecast and a vision of the desired energy supply-demand structure as outlined in the 4th SEP. The SEP is to be reviewed at least every three years, and the next review will be undertaken in 2021. According to the outlook, TPES is expected to reach approximately 489 million kilolitres in crude oil equivalent by 2030, 6% below the 2017 level (Figure 2.8). Achieving this will require a 13% reduction in energy demand

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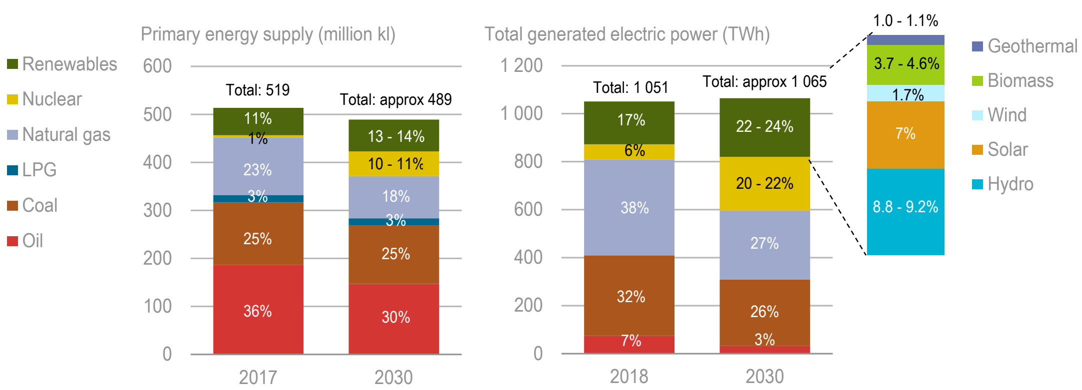
by 2030 compared to a business-as-usual baseline. The reduction is expected to be achieved through a number of measures, including energy efficiency standards set under the model Top Runner Program, voluntary agreements with major industrial consumers and financial support (see Chapter 4).

The share of fossil fuels in TPES is expected to decline to 76% in 2030 (compared to 89% in 2018), driven mostly by a reduced oil and natural gas use. The share of nuclear in TPES is envisaged to increase from 1% to 10-11%, while that of renewable energy would increase from 11% to 13-14%. The 5th SEP recognises renewables as a promising, low-carbon domestic energy source, but the plan notes that relatively high costs and grid constraints complicate rapid large-scale deployment. Nuclear is considered “a task for the future”, as it has only partially gained the trust of society (METI, 2018). Nuclear, coal and natural gas are all considered important baseload power sources. Oil is considered an important energy source in the transport sector, as well as a peaking power source.

Electricity generation (Figure 2.8) is projected to remain stable over the period to 2030, as lower demand from a declining population and energy efficiency improvements outweigh increasing electricity demand from economic growth and electrification of the economy. Renewables are projected to rise to 22-24% and nuclear to 20-22% of power supply, while the shares in electricity generation of natural gas supply would decline to 27%, coal to 26% and oil to 3%. The 5th SEP further set the targets of raising the “zero-emission power source ratio” (renewables plus nuclear) to at least 44% (up from 19% in 2017) and of maintaining the cost of electricity generation below 2013 levels. However, in light of the newly announced desire for Japan to become carbon-neutral society by 2050, there is a need to raise the zero-emission power source ratio already by 2030. The upcoming revision of the SEP in 2021 is a logical starting point for this.

Figure 2.8 Primary energy supply (2017) and power generation (2018) in Japan by fuel and outlook for 2030



Notes: LPG = liquefied petroleum gas. Kl = kilolitre. TWh = terawatt hour.
Source: METI (2020a), *Japan’s Energy 2019,* www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2019.pdf.

Japan’s transition to a carbon-neutral society by 2050

On 26 October 2020, the new Prime Minister of Japan declared that by 2050 Japan will aim to reduce GHG emissions to net-zero and to realise a carbon-neutral, decarbonised society (Prime Minister of Japan and His Cabinet, 2020). The Prime Minister further set out that “addressing climate change is no longer a constraint on economic growth” and

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that Japan needs to adjust "to a paradigm shift that proactive climate change measures bring transformation of industrial structures as well as our economy and society, leading to dynamic economic growth" (Prime Minister of Japan and His Cabinet, 2020).

The focus of the new vision will be on promoting innovation and new technologies such as next-generation solar cells and carbon recycling while ensuring stable supply of energy by further enhancing energy efficiency, maximising the introduction of renewable energies, as well as further advancing nuclear energy with the highest priority on safety while drastically changing Japan's polices regarding coal-fired power generation (Prime Minister of Japan and His Cabinet, 2020). In addition, the Prime Minister also addressed the need for regulatory reforms to support green investments, with a view towards Japan leading the global green industry. Another key aspect of the Prime Minister's vision for a decarbonised society by 2050 is the digital transformation of the economy and the society.

On 25 December 2020, METI[5] briefed a meeting of the "Committee on the Growth Strategy" on the "Green Growth Strategy towards 2050 Carbon Neutrality" that has been developed in collaboration with related ministries and agencies. The strategy sets out challenges and actions, formulates action plans and policies covering, among others, taxes, regulatory reforms and standardisation, and international collaboration (METI, 2020b).

Aiming for carbon neutrality by 2050 is a formidable task for Japan. Japan's Nationally Determined Contribution under the Paris Agreement, submitted in November 2016 and confirmed in March 2020, aims to reduce GHG emissions by 26% in 2030 compared to 2013, when emissions reached the highest level ever recorded (GoJ, 2020). Given that the energy sector accounts for most GHG emissions (88% in 2018), it plays a central role in achieving the new vision.

Meeting the Nationally Determined Contribution target relies on achieving the envisioned energy mix for 2030. Reaching the 44% share of non-fossil based power generation will be particularly important. While the share of renewables in TPES has increased markedly over the past decade (from 4% to 8% between 2009 and 2019), grid constraints will need to be resolved to allow more renewable power facilities to connect to the grid. Efforts are also needed to raise the share of renewables in heat and transport (see Chapter 5).

The envisioned share of nuclear energy (10-11% of TPES in 2030) is achievable if the number of operating reactors increases from 9 in 2020 to approximately 30 (out of a total of 36 operable reactors). To return to service after the 2011 events and subsequent nuclear shutdown, reactors must complete the Nuclear Energy Agency's safety review. There is uncertainty, however, whether this can be done for all 30 reactors by 2030 (see Chapter 11).

Nearly a decade after the 2011 events, and despite stricter safety requirements, public trust in administrative agencies and operators involved in nuclear energy generation remains low (METI, 2018). The government is actively trying to re-establish public trust, for example by conveying information about energy policy through symposiums and the official website.

[5] Annex A provides detailed information about institutions and organisations with responsibilities related to the energy sector.

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In order to accelerate the clean energy transition, in July 2020 the government announced its intention to phase out its inefficient coal-fired power plants by 2030. This could mean that some 100 out of the 140 operating coal-fired power plants that are currently operating would need to close (Reuters, 2020; The Economist, 2020). Details on how the phase out will be achieved have yet to be developed.

To achieve its 2050 decarbonisation vision, Japan counts on radical innovation. The Long-term Strategy Under the Paris Agreement, adopted in 2019, aims to realise "a virtuous cycle of environment and growth" towards the 2050 vision with business-led disruptive innovation (GoJ, 2019). The Prime Minister's statement in October 2020 reinforced this commitment to a virtuous cycle (Prime Minister of Japan and His Cabinet, 2020). The Environment Innovation Strategy, launched in January 2020, provides the innovation paths and cost targets of the core technologies needed to achieve this. Hydrogen and CCUS technologies are expected to play a key role in Japan's long-term energy transition.

The accelerated phase out of inefficient coal-fired power plants provides a good opportunity to revise and update the Long-term Supply and Demand Outlook to 2030 published in 2015. The government may also consider developing scenarios of how the 2030 mix would appear if nuclear falls short of its 10-11% target, and articulating the role of different energy sources post-2030. Uncertainty regarding these dimensions is supressing investment in electricity infrastructure, according to Japan's largest business association (Keidanren, 2019).

Liberalising electricity and gas markets

Achieving the government's long-term targets for the energy sector requires open and competitive markets. Recognising this, the 5th SEP aims to advance the ongoing electricity and gas market reforms. Cabinet approved these policy reforms in 2013 and 2015 respectively, with the aim to enhance security of supply, foster competition and reduce end-user prices. In the electricity sector, major steps of the reform included:

- the establishment of the Organization for Cross-regional Coordination of Transmission Operators in 2015 to balance electricity supply and demand on a nationwide level and to improve power interchange across regions
- the creation of the Electricity and Gas Market Surveillance Commission (EGC) in 2016 to monitor the market and promote competition
- the full liberalisation of the retail market in 2016
- the legal unbundling of ten [6] vertically integrated electricity utilities into generation, transmission and distribution, and retail companies as of 1 April 2020.

In June 2020, the government passed legislation to initiate another round of reform. The bill aims to pave the way for a more resilient electricity system that can accommodate a larger share of variable renewable energy in a cost-effective way. Among other things, it transforms Japan's feed-in tariff system (in place since 2012) into a feed-in premium in a bid to integrate renewable energy into the electricity market (see Chapter 5). It further requires electricity businesses to collaborate in disaster responses, and amends the charging system for wheeling services with the aim to promote investment in the transmission network (see Chapter 7). The need for regulatory reform to support green

[6] The Okinawa electric power company is excluded from the unbundling requirement for geographical reasons.

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investments was explicitly recognised in the Prime Minister's speech in October 2020 (Prime Minister of Japan and His Cabinet, 2020).

Competition in the retail market is increasing, although the former vertically integrated incumbents continue to serve more than 80% of the market and end-user prices have not yet fallen to a level comparable to other countries that have liberalised their electricity market (Keidanren, 2019). Wholesale market trading, which is not compulsory in Japan, is increasing and the government plans to introduce new markets (e.g. a capacity and balancing market) to further improve liquidity and address market failures (see Chapter 7).

In the gas sector, the retail market was fully liberalised on 1 April 2017. On that date, Japan also introduced third-party access to gas infrastructure, i.e. to terminals to store and regasify liquefied natural gas (LNG).[7] The three largest integrated gas businesses (so-called city gas companies) are required to legally unbundle on 1 April 2022.

Competition in the retail gas market is developing a little slower than in the electricity market. Similar to the electricity network, the gas pipeline network is fragmented, as pipelines have developed around LNG terminals. By early 2020, four out of eight regions had seen no new retail entrant to date. Non-discriminatory open access to gas infrastructure will be an important factor to foster competition, but to date third-party access to LNG terminals has only been granted once (see Chapter 8).

The EGC will play an important role in monitoring markets, promoting competition and protecting consumers as the liberalisation advances. In contrast to other jurisdictions, the EGC's decisions are not enforceable and it is not fully independent from METI. At this early stage of market liberalisation, this set-up may be appropriate. However, it would be worthwhile to consider making the EGC more independent once the market is more fully developed. Almost all IEA countries have already opted for a model in which the electricity and gas sector is regulated by a body that is fully independent from industry and the government.

Energy security

Another broad policy goal of the SEP is to foster energy security. In order to achieve this, the government aims to continue its resource diplomacy strategy with energy-exporting countries as well as public financial support to overseas energy supply projects with the involvement of Japanese companies. The stated goal is to increase the "independent development ratio" (that is, the share of imports developed by Japanese companies) to 40% for oil and natural gas, and to 60% for coal by 2030 (METI, 2018).

Japan has successfully diversified its supply of LNG. Just over one-third of LNG supply comes from Australia, with the remainder coming from a large pool of countries, including Malaysia and the United States. In addition, Japan actively promotes the development of a flexible and transparent international LNG market to enhance security of supply. Crude oil imports are less diversified, with 88% coming from the Middle East in 2018. Without power transmission lines to other countries, Japan does not import electricity.

Japan's geographical location makes it vulnerable to external natural disasters and extreme events such as earthquakes, tsunamis and typhoons. In 2018 and 2019,

[7] Having marginal domestic production and no pipeline connections to other countries, Japan imports virtually all of its gas in the form of LNG.

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earthquakes and typhoons caused large and long-lasting power outages in various parts of the country and prompted a renewed focus on electricity security and resilience. One of the main considerations of the latest phase of electricity market reform (in June 2020) was to strengthen the resilience of the electricity transmission and distribution grids. Japan also aims to achieve a more flexible system with a greater focus on demand-side led distributed energy systems in order to make the electricity sector more efficient and resilient.

Taxation and subsidies

All fuels and energy services are subject to a general consumption tax at a flat rate of 10% and to excise and other taxes at varying rates according to the type of fuel (Table 2.1). A petroleum and coal tax applies to crude oil, coal, oil products and hydrocarbon-based gases (including those used for power generation). Gasoline, diesel and liquefied petroleum gas used in road transport are subject to additional excise taxes. Japan is one of the few countries taxing aviation fuels used domestically. It also applies an electricity output tax, making it one of the few countries to tax both inputs and outputs of electricity. Most of the tax revenue is earmarked for specific purposes. For example, the climate tax is directed to climate mitigation measures while the tax on gasoline is directed towards road construction and maintenance.

Table 2.1 Standard energy excise taxes in Japan

Energy excise tax	Applies to:	Rate in JPY	Rate in USD
Petroleum and coal tax	Crude oil, coal, oil products; hydrocarbon-based gases	2 040/kl*1; 1 080/tonne*2	18.55/kl; 9.82/tonne
Diesel oil delivery tax	Diesel used in road transport	15 000/kl*3	136/kl
Gasoline tax	Gasoline used in road transport	28 700/kl*4	261/kl
Oil gas tax	Liquefied petroleum gas used in road transport	17.5/kg	0.16/kg
Aircraft fuel tax	Aviation fuels used domestically	26 000/kl*5	236/kl
Power development promotion tax	Electricity sold	0.375/kWh	0.003/kWh

* The following are exceptional measures (current tax rate):
*1 has been increased to JPY 2 800 per kilolitre since April 2016.
*2 has been increased to JPY 1 860 per kilolitre since April 2016.
*3 has been increased to JPY 32 100 per kilolitre since April 2010.
*4 has been increased to JPY 53 800 per kilolitre since April 2010.
*5 has been reduced to JPY 18 000 per kilolitre since April 2011.
Source: Based on information provided by the Ministry of Economy, Trade and Industry during the review process.

Several exemptions apply for non-road transport (e.g. for shipping and railway transport) as well as the agricultural sector (e.g. heavy oil is untaxed). In the industrial sector, fossil fuels are tax-exempt when used in petrochemical production; and coal, coke and related gases are tax-exempt when used for the production of iron and steel or coke and cement. In 2012, Japan introduced the climate change mitigation tax, an explicit carbon tax imposed additionally to the petroleum and coal tax. The tax is JPY 289 (EUR 2.35 or USD 2.65)[8] per tonne of CO_2, one of the lowest levels among countries with explicit carbon-pricing mechanisms in place (World Bank, 2019).

[8] 1 EUR = 123 JPY; 1 USD = 109 JPY.

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The overall tax burden resulting from these taxes is low by international comparison. Energy taxes account for only 12-30% of road fuel prices, which is small compared to most other IEA countries (see Chapter 9). Retail oil prices are among the lowest of all IEA countries due to low taxes. Electricity and gas prices are high by international standards, but this is linked to high production costs (i.e. high import fuel prices) rather than tax levels. Taxes accounted for merely 9% of household electricity prices in 2019, the second-lowest level among IEA countries (see Chapter 7).

The effective tax rate on CO_2 emissions from energy use (that is, the price imposed on each tonne of CO_2 emitted from energy use, considering all energy excise taxes and the climate change mitigation tax) is low compared to most other IEA member countries (OECD, 2018).

As in other countries, the effective tax rate varies considerably across users and fuels. The transport sector faces high effective CO_2 prices relative to the industrial, residential or power generation sector. As regards the fuels, effective CO_2 prices are the lowest for coal (see Chapter 3). In addition, two CO_2 emissions trading systems (ETS) operate at the subnational level (in Tokyo and Saitama), but they cover a small share of national emissions (see Chapter 3).

Based on an international comparison, the IEA sees scope for Japan to make better use of price signals to reduce CO_2 emissions by steering behaviour, both of end consumers and of the industrial sector, and to redirect industrial investments to innovative technologies.

Fossil fuel subsidies

As a member of the G7, Japan committed in May 2016 to “the elimination of inefficient fossil fuel subsidies” by 2025. Subsidies to fossil fuel production and consumption are modest in an international comparison. According to the OECD Inventory of Support Measures for Fossil Fuels, fossil fuel subsidies equalled 0.2% of total tax revenue in 2018, compared to an OECD average of 0.7% (OECD, 2020b). A large share of these subsidies support business activities related to the exploration of overseas oil and natural gas exploration and development projects conducted by Japanese companies. In 2018, such subsidies amounted to JPY 44.8 billion (USD 411 million) (OECD, 2020c).

Japan also supports the exploration and development of coal resources overseas, although with much smaller budgets. Support for domestic coal production ended in the early 2000s. In July 2020, Japan announced a tightening of its export policy for support to newly planned overseas coal-fired power generation projects.

Based on this new policy, Japan will not, in principle, support the overseas installation of coal-fired power generation. However, it will support the installation of coal-fired power generation at or above ultra-supercritical with top-class environmental performance using Japan’s cutting-edge technology in countries where coal-fired power is currently an indispensable option due to energy security or economic reasons during the transition to decarbonisation. Countries asking for support from Japan must make efforts for behavioural changes in accordance with their development stage.

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Assessment

In October 2020, Japan entered a new area in its energy and climate policies with the Prime Minister's announcement to reduce GHG emissions to net-zero and to realise a carbon-neutral, decarbonised society by 2050. The IEA congratulates Japan for this vision that aligns it with other countries at the forefront of global climate engagement.

Japan is the world's third-largest economy (by nominal GDP) and fifth-largest energy consumer (in absolute terms). As an island country without international gas pipelines or electricity connections and with limited natural resource endowments and large energy needs for its advanced industrial sector, Japan faces fundamental energy security challenges, relying on imports to satisfy 88% of its energy supply in 2019. In the same year, fossil fuels accounted for 88% of TPES, down slightly from a peak of 94% in 2014, which in turn reflected the closure of the entire nuclear fleet after the 2011 Great East Japan earthquake and subsequent accident at the Fukushima nuclear power plant.

Japan's overall energy policy is outlined in its strategic energy plans. The 5th SEP is based on the principles of energy security, economic growth and environmental sustainability, along with safety (the "three E plus S"). It includes plans to achieve the 2030 energy target mix, as outlined in the *Long-term Energy Supply and Demand Outlook to 2030*. According to this outlook, renewables and nuclear energy together are expected to account for 24% of TPES, double the share in 2019. The share of renewables in the power sector is expected to reach 22-24%, compared to 19% in 2019. Meanwhile, the share of nuclear in power generation is expected to recover to 20-22%, compared to 6% in 2019.

The 5th SEP also includes a general outline of an aspirational goal to reduce GHG emissions by 80% in 2050. According to the 5th SEP, Japan aims to: maximise the role of renewable energy resources while reducing the dependence on nuclear power as much as possible; develop and implement new energy technologies, with a view toward enhancing energy self-sufficiency; and improve energy efficiency and resource use in the economy.

Energy security remains a high priority for Japan. The 5th SEP anticipates Japan's energy self-sufficiency rate to increase from 20% prior to the 2011 events to 24% in 2030. This should be achieved by a combination of a rapid expansion of renewable energy, more efficient use of fossil fuels generation assets, substantial recovery of nuclear production and improving energy efficiency. Innovation and development of new energy sources, such as hydrogen, are also expected to contribute to energy security. With regards to fuel supply, Japan has successfully diversified its LNG import sources, while oil imports remain heavily concentrated in a small number of Middle Eastern suppliers.

Japan continues to play an important role internationally in energy markets by bringing together energy producers and consumers to ensure stable supply at reasonable prices. It is actively promoting a more liquid and transparent global LNG market, both in international fora and through bilateral collaboration with exporting and other major importing countries. Japan's efforts to create an international hydrogen supply chain are also noteworthy.

Due to the lack cross-border electricity connections, insufficient interconnection capacities and co-ordination among regions, Japan's electricity sector has shown higher signs of vulnerability to natural disasters in recent years. The IEA welcomes the new legislation

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passed in June 2020 to strengthen the resilience of the electricity sector through a number of new measures, such as the requirement for transmission and distribution operators to develop partnership plans to facilitate a quick initial response to disasters, and promotion of distributed grids, which are more resilient to disasters.

Liberalising electricity and gas markets

Japan has made progress towards the liberalisation of its energy markets. However, more needs to be done to improve competition and accelerate the transition of the energy sector. In the electricity sector, key steps already undertaken include the establishment of the Organization for Cross-regional Coordination of Transmission Operators to oversee transmission operations in 2015 and the EGC to promote competition in 2016. Japan opened the retail market to full competition in April 2016 and required the incumbents to legally unbundle their network operations from the power generation and retail activities in April 2020. In June 2020, Japan passed another round of reforms to strengthen the electricity sector's resilience and efficiency as the share of variable renewable energy increases.

The EGC can investigate and make recommendations, but has no formal powers to regulate the markets, and is not yet fully independent from the government. Meanwhile, the legal unbundling of the vertically integrated incumbents is less comprehensive than what is seen in some other jurisdictions, where transmission and distribution assets have been fully separated from generation and retail.

Looking ahead, the rapid decentralisation and digitalisation of Japan's energy system will allow consumers not only to consume, but also to produce, store and sell energy and become so-called "prosumers". Such a process will require intense co-operation between the central and local governments, municipalities, and local utilities in order to deliver benefits for consumers. The aim for a carbon-neutral society by 2050 can also build on the benefits of further regulatory reforms and of digitalisation to advance the green transformation and ensure necessary investment in green technologies.

In the natural gas market, existing legislation requires the largest gas providers to legally unbundle their business by 1 April 2022. Japan's efforts to develop more flexible international LNG markets and establish itself as an eventual LNG trading hub are positive developments. Additional gas market liberalisation could help reduce prices for consumers.

Transition to a zero-carbon, resilient energy sector

The Prime Minister's announcement in October 2020 to reduce emissions to net-zero by 2050 and to realise a carbon-neutral, decarbonised society implies a major step-change in Japan's energy and climate policies. The country will need to be open-minded towards exploring all possible energy and climate measures, including those that are not currently part of the policy mix.

While the *Long-term Energy Supply and Demand Outlook to 2030* aims to achieve a more balanced energy mix, with greater shares for nuclear and renewables, fossil fuels are still expected to contribute some 75% of TPES and more than half of power generation in 2030. There is a need to enhance the ambition for 2030 already with a view to prepare the transition to 2050 and to avoid a lock-in of technologies that may result in stranded assets. Measures for this could include repurposing existing installations, switching to

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low-carbon fuels or adding CCUS capacities to existing energy assets that burn fossil fuels. The upcoming revision of the SEP in 2021 and the subsequent update of the long-term outlook should reflect the new 2050 target.

Decarbonising Japan's power sector remains a significant challenge. The country has sufficient renewable resources to reach the 2030 target; indeed, renewable energy has already expanded notably thanks to the remarkable (but costly) growth in solar photovoltaics since 2012. However, grid constraints are limiting the dispatch of renewable power generation and discouraging investment in additional renewable projects, whose best potential lies in areas located far from demand centres. Moving forward, the provision of enabling legal, regulatory and market frameworks, along with investments in the necessary grid and storage infrastructures and optimisation of grid operations, will be critical to facilitate the desired penetration of renewable energies. In this regard, the Prime Minister's announcement to use regulatory reform and digitalisation to advance the green transformation is welcome.

The recovery of Japan's remaining temporarily shut-down nuclear power plants remains critical to meeting its decarbonisation goals. Progress to date has been slow, with only 9 out of a total of 36 nuclear plants back in operation. To achieve the target for nuclear to supply 10% of TPES by 2030, approximately 30 reactors would need to operate. The full recovery of Japan's nuclear plants will require a concerted effort by the utilities, government and regulators to satisfy enhanced safety standards, followed by extensive work with local communities to regain social acceptance. Relying on fossil fuels to make up for any gap in ramping up nuclear power would complicate Japan's ability to meet its climate goals, as the shares of coal and natural gas in the 2030 electricity generation mix are already expected to remain large, at 26% and 27% respectively.

The IEA welcomes the announcement made in July 2020 to phase out inefficient coal-fired power plants by 2030. Japan's coal power generation fleet already ranks among the most efficient in the world, and the closure of inefficient plants will increase its efficiency even further. Nevertheless, even an efficient coal plant emits more CO_2 than any alternative power source. Japan is a global leader in the deployment of more efficient coal plants, as well as in the development of CCUS and carbon recycling technologies. To date, however, CCUS deployment has been limited due to prohibitive costs and a lack of incentives and business models. Meanwhile, Japan ranks among the few advanced economies to anticipate new coal generation capacity, which, if unabated by CCUS, would place additional pressure on meeting its 2030 and 2050 climate goals.

While Japan's electricity sector has experienced substantial capacity growth in renewables over the past five years, they currently account for only small shares in transport and heating, which have not been prioritised by the government. The government may consider providing additional targeted support to accelerate the development of renewables outside the power sector.

Japan enjoys a credible record for energy efficiency innovation and implementation, based on regulation such as its model Top Runner Program, numerous voluntary agreements with major industrial consumers and financial support. The 5th SEP supports this trend, rightly assigning high priority on demand reduction. Final energy consumption in 2030 is expected to be 13% lower compared to the business-as-usual scenario (a 1% reduction per year on average), but even more ambitious efforts could be undertaken, like many other countries have committed to. While Japan already has quite low energy intensity per

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unit of GDP by international comparison, reaching or exceeding the 2030 target will be important for energy security, and will require mobilising new technologies like digitalisation, financial innovation and regulatory reform.

Under the Paris Agreement, Japan committed to reduce GHG emissions by 26% in 2030 compared to 2013 levels. The government has stressed the need to develop and deliver “disruptive technologies” and significantly lower costs for hydrogen and CCUS. Climate policy in Japan is characterised by strong and successful collaboration with industry, notably through voluntary action plans.

However, the fact that several of the industries participating in the voluntary agreements had already achieved their self-imposed targets for 2030 in 2019, questions whether the self-set targets are indeed ambitious enough to deliver on Japan’s climate targets. This is especially so in light of the new vision for carbon neutrality by 2050. The IEA recommends that the government introduce regulations, such as mandatory performance benchmarks, to provide stronger incentives to industry to innovate and reduce energy consumption and emissions.

The IEA is of the view that increased pricing signals to enhance low-carbon technologies are a good policy option for Japan to reduce emissions cost-effectively. Explicit carbon-pricing instruments comprise carbon taxes and emissions trading systems. In cap-and-trade systems, like in the two regional ETS in Japan, the quantity of the emissions is fixed, but not the price of the emissions. When applying carbon taxes, the price of emissions is fixed, but not their quantity. IEA analysis has shown that if a country has set an emission reductions target, as Japan has done, the use of a cap-and-trade system is more target-oriented.

Japan introduced a climate mitigation tax in 2012 on top of liquid fuel excise taxes. The climate mitigation tax is JPY 289 (USD 2.65) per tonne of CO_2 and has not increased since 2016. The IEA commends Japan for using the revenues from the climate tax exclusively to finance reduction of CO_2 emissions from energy use, by supporting for example renewable energy and energy efficiency. An ETS already exists in two regions of Japan, but they cover only a small amount of the country’s total emissions. A study on the option of a national ETS has been ongoing since 2016. The IEA urges the government to swiftly finalise its ongoing deliberations.

However, not all sectors lend themselves for the introduction of a cap-and-trade system. Small quantities of emissions from non-stationary sources, like transport, are hard to capture under such a system. Similarly small commercial and industrial units are not ideal candidates for inclusion in an ETS. In those cases, a price signal like a carbon tax is a more appropriate solution.

Maintaining the economic competitiveness of the industrial sector is a key concern in all IEA countries and additional taxes are frequently seen as contradicting these concerns. However, governments should take a holistic view of taxation, either for a specific sector or in general. Governments can, for example, consider lowering other taxes imposed in the transport sector, such as registration taxes, while increasing the fuel tax. Achieving steering behaviour through carbon taxation is indeed possible without increasing the overall tax bill.

Japan is an innovative global leader in the development of a wide range of low-carbon technologies. CCUS and CO_2-free hydrogen are assigned particular importance. Japan is

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among the few countries to produce hydrogen-fuelled cars and seeks to commercialise hydrogen power generation, around 2030. Home to one of the largest automotive industries in the world, Japan is also a global leader in the production and sales of electric vehicles.

Recommendations

The government of Japan should:

- Continue Japan's leadership role in enhancing global energy security, and in innovative technology development in key sectors such as energy efficiency and hydrogen.
- Deepen Japan's electricity market reform, ensuring that the wholesale electricity market encourages the participation of all generation sources, and stimulates investments in zero-emission electricity while ensuring electricity security and affordability. Provide additional regulatory powers and independence to the EGC, the electricity and gas regulator.
- Encourage investments in zero-emission electricity generation, transmission and distribution infrastructure, and improve electricity system operations, thereby reducing grid constraints across the country that, in turn, should enable larger penetration of variable renewable electricity sources.
- Accelerate the Nuclear Regulatory Agency (NRA) safety reviews to facilitate prompt return to operation of Japan's nuclear reactors, thereby ensuring that the 2030 climate goals are achieved, while meeting high safety standards and public acceptance.
- Evaluate the need for future coal-fired power generation capacity in Japan, taking into account both GHG emission goals and the decreasing costs of alternatives such as renewables and LNG.
- Assign higher priority to the deployment of CCUS on coal- and gas-fired power stations, and create a requirement that any new coal and gas plants are built "CCUS-ready".
- Map out energy scenarios, including road maps that are compatible with the vision for a decarbonised society by 2050. Consider strengthening price signals to encourage investments across the economy in low- and zero-emission technologies.
- Deepen engagement with civil society in energy policy making to gain greater social acceptance for infrastructure developments needed to meet Japan's energy and climate policy goals.

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3. Energy and climate change

Key data

(2018/19 estimated)

Greenhouse gas (GHG) emissions with LULUCF:* 1 180.9 Mt CO_2-eq, -8.3% since 2005, -12.0% since 2013

GHG emissions without LULUCF: 1 238.3 Mt CO_2-eq, -10.2% since 2005, -12.0% since 2013

Energy related CO_2 emissions:

CO_2 emissions from fuel combustion (2019): 1 066.2 Mt CO_2, -9.8% since 2005, -13.6% since 2013

CO_2 emissions by fuel (2019): coal 40.6%, oil 34.5%, natural gas 21.5%, other 3.4%

CO_2 emissions by sector: power and heat generation 48.7%, transport 18.9%, industry 17.7%, services 6.6%, residential 4.8%, other energy 3.3%

CO_2 intensity per GDP (2019):** 0.20 kg CO_2/USD (IEA average 0.20 kg CO_2/USD)

* Land use, land-use change and forestry (Source: UNFCCC).

** Gross domestic product in 2015 prices and purchasing power parity (PPP).

Overview

In October 2020, the new Prime Minister of Japan declared that by 2050 Japan will aim to reduce greenhouse gas (GHG) emissions to net-zero; that is, to realise a carbon-neutral, decarbonised society (Prime Minister of Japan and His Cabinet, 2020). This is a considerable increase in ambition compared to Japan's earlier vision to reduce emissions by 80% by 2050 and to become a decarbonised society soon after. In his speech to the Diet, the Japanese parliament, the Prime Minister stated that "we need to adjust our mindset to a paradigm shift that proactive climate change measures bring transformation of industrial structures as well as our economy and society, leading to dynamic economic growth" (Prime Minister of Japan and His Cabinet, 2020). This statement is an important new mark on the horizon for Japan's energy and climate policies and in the coming period the government will develop additional policies and measures to achieve this new aim. This IEA in-depth review is timely, as it makes numerous recommendations that can be helpful in developing such policies and measures.

Japan is one of the world's ten-largest emitters of GHG, both in absolute terms and per capita or unit of gross domestic product (GDP) (WRI, 2020). Its GHG emissions have fluctuated between 1 200 million tonnes of carbon dioxide equivalents (Mt CO_2-eq) and

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1 400 Mt CO_2-eq over the past three decades. Emissions fell after the global financial crisis in 2008 but increased after the 2011 Great East Japan Earthquake and the subsequent nuclear accident at the Fukushima Daiichi Power Plant (hereafter called "the 2011 events"), which led to higher dependence on fossil fuels in the energy mix. Emissions reached 1 408 Mt CO_2-eq (excluding LULUCF) in 2013, the highest level ever recorded, but have been declining since. In 2018, they reached 1 238 Mt CO_2-eq, 12% below the 2013 peak, thanks to lower emissions from the energy sector (Figure 3.1). This is the second-largest reduction among G7 countries (in absolute terms) over the period 2013-18.

The energy sector is the largest emitter of GHG emissions, accounting for 88% of total emissions in 2018 (excluding LULUCF). The remainder stemmed from industrial processes (8.1%), agriculture (2.7%) and the waste sector (1.6%). The LULUCF sector has been a small net carbon sink in the past three decades (absorbing about 5% of national gross emissions) (UNFCCC, 2020).

Thanks to the recent decline in GHG emissions, Japan met its 2020 climate change mitigation target ahead of time. It is it also on track to meet its target for 2030 of cutting emissions by 26% from 2013 levels, if nuclear power generation expands as planned.

However, reaching carbon neutrality by 2050 requires efforts for steep emission reductions starting as early as possible and at the latest from 2030 onwards, and a substantial rethinking the country's energy and climate policy for achieving a "decarbonised society" by 2050 and the implementation of a wider set of policies and measures than currently contemplated.

Until the recent announcement by the Prime Minister, the government aimed to achieve carbon neutrality by 2050 mostly through disruptive technological innovation, notably through large-scale use of hydrogen and carbon capture, utilisation and storage (CCUS) and carbon recycling technologies. Reducing the high carbon intensity of the power sector will be a challenge. Making stronger use of market-based solutions, including price signals to enhance low-carbon technologies, could be a cost-effective complement to current efforts to achieve net-zero growth by 2050. This would require a balanced approach however, to avoid carbon leakage and paying attention to the effects on households and small and medium-sized enterprises, which already face high electricity prices in Japan.

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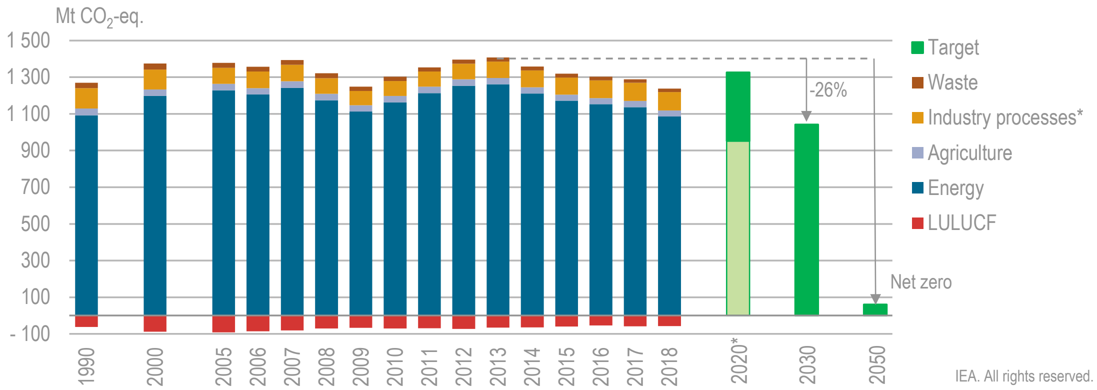
Figure 3.1 Japan's greenhouse gas emissions by sector, 2005-18, and mitigation targets



In 2018, GHG emissions had decreased by 12% compared to the 2013 peak level. The government committed to reduce emissions further, by a total of 26% by 2030.

* The 2020 bar shows the two targets: the initial target to reduce GHG emissions by 25% from 1990 set in 2009 (light green); and the revised target of 2013 to reduce emissions by 3.8% from 2005 (dark green).

Notes: Mt CO_2-eq = million tonnes of carbon dioxide equivalents. LULUCF = Land use, land-use change and forestry.

Sources: UNFCCC (2020), *Summary of GHG Emissions for Japan*, https://di.unfccc.int/ghg_profile_annex1.

Japan's energy-related CO_2 emissions

The energy sector emitted 1 066 million tonnes carbon dioxide (Mt CO_2) in 2019, slightly below the level in the year 2000. Almost all are from fuel combustion, with a small amount (less than 1%) stemming from fugitive emissions (UNFCCC, 2019). The power sector is the largest CO_2 emitter, representing 49% of total emissions from fuel combustion in 2018, followed by transport (19%), industry (18%), services (7%), residential (5%) and other energy (3%) (IEA, 2020a). Energy-related emissions have decreased in all sub-sectors since 2000, but this was offset by increasing emissions from power generation, which grew by 24%.

Energy-related emissions fell considerably following the 2007/08 global financial crisis, noticeably in power generation and industry (Figure 3.2). However, they picked up again quickly in the following years, reflecting both economic recovery and increased consumption of fossil fuels after the Fukushima accident and subsequent nuclear shutdown. The shift from nuclear to natural gas, coal and oil for power generation made energy-related emissions peak at 1 234 Mt CO_2 in 2013. Emissions have since decreased (by 14% between 2013 and 2019) thanks to the gradual expansion of renewable power generation, energy efficiency improvements and the restart of some nuclear power plants.

By fuel, most energy-related CO_2 emissions came from the combustion of coal (41% of total emissions) and oil (35%), followed by natural gas (22%) in 2019. Emissions increased from all fossil fuels between 2010 and 2012, when consumption increased to replace nuclear power following the 2011 events, but the long-term trend has differed by fuel. Oil-related emissions have decreased for decades, with a 42% drop since 2000

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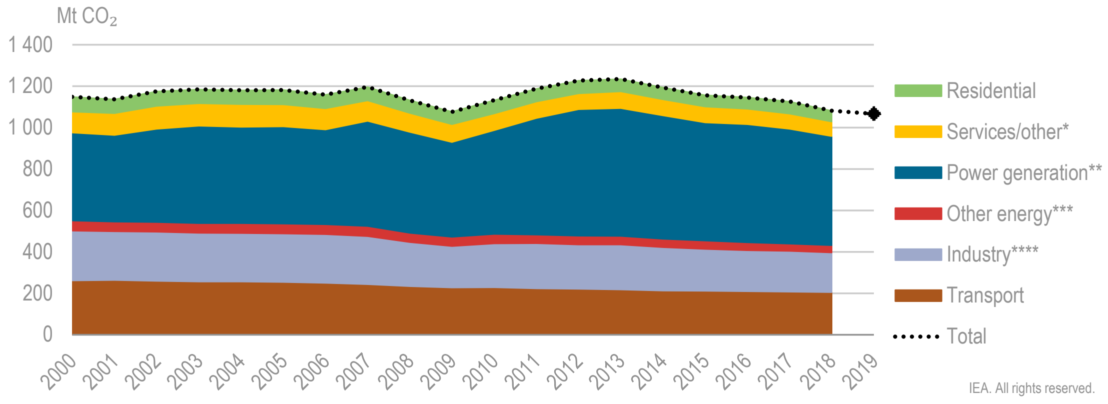
(Figure 3.3). Coal and natural gas emissions, on the other hand, have increased from the 2000 level, but have been stable in recent years.

Figure 3.2 Japan's energy-related CO_2 emissions by sector, 2000-19



Since peaking in 2013, energy-related CO_2 emissions have been declining across all sectors, with the biggest change in power generation, which has fallen by 15% in the last four years.

* *Services/other* includes commercial and public services, agriculture, forestry, and fishing.

** *Power generation* includes a minor share of district heat generation.

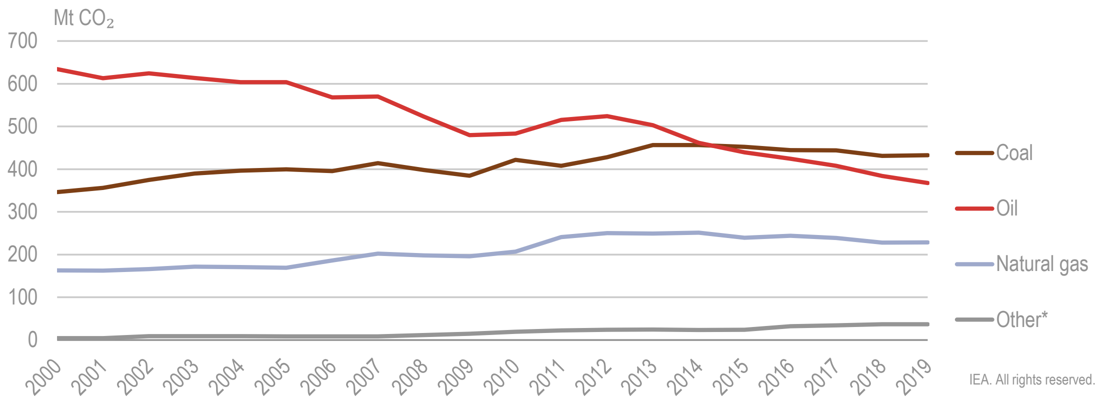
*** *Other energy* includes emissions from coke ovens, oil refineries and liquefied natural gas plants.

**** *Industry* includes CO_2 emissions from combustion at construction and manufacturing industries.

Note: Mt CO_2 = million tonnes carbon dioxide.

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

Figure 3.3 Japan's energy-related CO_2 emissions by energy source, 2000-19



Oil-related emissions have declined by 42% since 2000, while emissions from coal and natural gas have remained stable in recent years after a previous increase.

* *Other* includes emissions from non-renewable waste.

Note: Mt CO_2 = million tonnes carbon dioxide.

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

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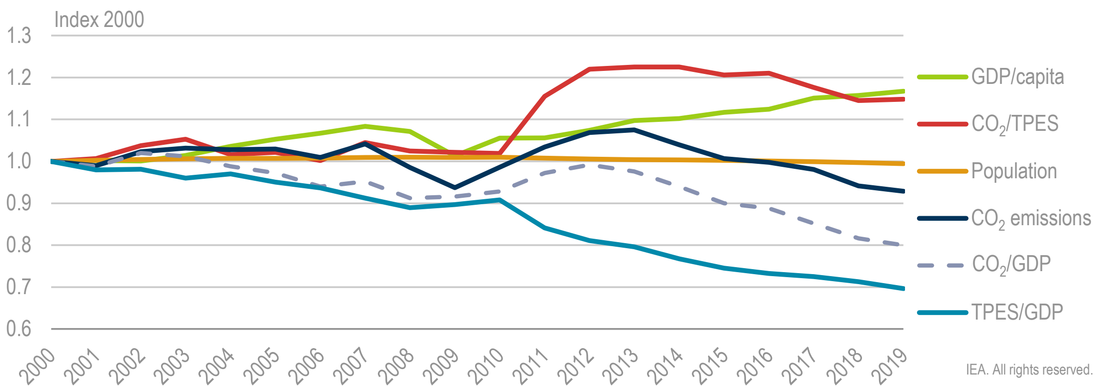
Carbon intensity of the Japanese economy

The carbon intensity of the Japanese economy, measured as energy-related CO_2 emissions per unit of GDP, amounted to 200 grammes of carbon dioxide (g CO_2) in 2019, the ninth-highest among IEA member countries and above the IEA median of 159 g CO_2. Carbon emissions per capita are also above the IEA median. Since 2000, the carbon intensity of the economy has improved by 20%, which, however, constitutes a small improvement compared to that in most other IEA member countries.

The improvement in Japan's carbon intensity has largely been driven by energy efficiency improvements. The energy intensity of the economy (measured as total primary energy supply/gross domestic product [TPES/GDP]) has improved by 30% since 2000. However, the benefits of higher energy efficiency (in terms of CO_2 emissions) were largely offset by an increase in the carbon intensity of energy supply (+20% in 2010-12) (Figure 3.4), which resulted from the shift from nuclear to fossil fuels in power generation. Due to this shift, Japan is among the few IEA countries that has seen the carbon intensity of power and heat generation increase over the past decade (Figure 3.5).

Figure 3.4 Energy-related CO_2 emissions and driving factors, Japan, 2000-19



Japan's carbon intensity of energy supply rapidly increased after 2011, while the energy intensity of the economy has shown a significant drop thanks to improving energy efficiency.

Notes: GDP = gross domestic product. TPES = total primary energy supply. CO_2 refers to energy-related CO_2 emissions from combustion processes. Real GDP in USD 2015 prices and purchasing power parity (PPP).

Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

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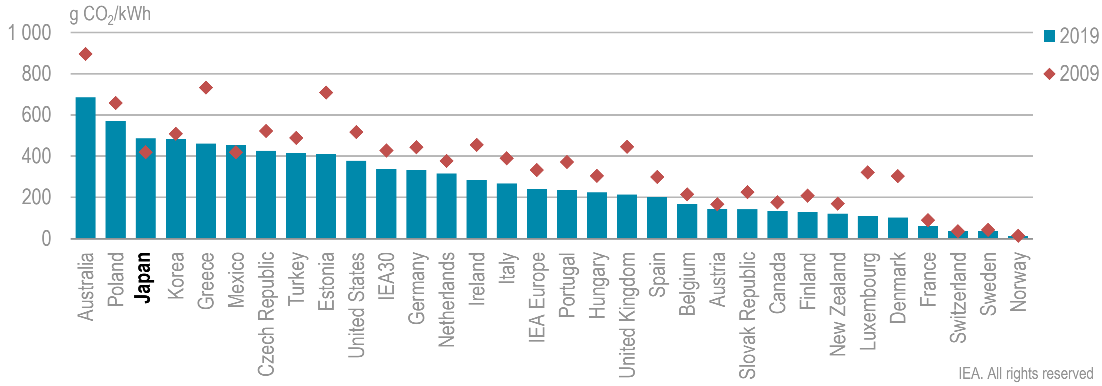
Figure 3.5 CO_2 intensity of power and heat generation in IEA countries, 2008-19



Japan's CO_2 intensity of power and heat generation has increased over the past decade, and is high in an international comparison, reflecting the increased use of fossil fuel after the closure of nuclear power plants.

Note: g CO_2/kWh = grammes of carbon dioxide per kilowatt hour.
Source: IEA (2020a), *CO_2 Emissions from Fuel Combustion 2020*, www.iea.org/statistics.

Climate change governance

Responsibilities for climate change policy are split among several ministries. The Ministry of the Environment[1] is responsible for the development of the national GHG inventory and reporting to the United Nations Framework Convention on Climate Change (UNFCCC), while line ministries are in charge for implementing climate action in their respective fields. The Ministry of Economy, Trade and Industry (METI), which is responsible for climate change mitigation policy in the energy sector, plays an important role in national climate policy, given the sector's share in overall emissions.

The Cabinet co-ordinates climate policy making through the "Global Warming Headquarters", first established in 1997 with the aim of implementing the Kyoto Protocol. Chaired by the Prime Minister and made up of all ministers, the Headquarters monitors the implementation of Japan's climate change mitigation plan (the Global Warming Countermeasure Plan, see below) and tracks progress towards specific targets and individual measures on an annual basis. It also discusses budget and tax reform proposals and proposed laws concerning climate change. An executive committee gathers directors of government ministries. At the subnational level, "regional energy and global warming mitigation councils" have been established to co-ordinate regional climate action, including with local governments.

Subnational and non-state actors are becoming increasingly active in designing and implementing climate policy, with many large cities having developed their own emission reductions plans. The Tokyo municipality and Saitama Province have been running local emissions trading schemes since 2010 (see the section on carbon pricing). As of February 2020, 20 cities had signed the Covenant of Mayors for Climate and Energy; and a total of 56 local governments, including the megacities of Tokyo, Kyoto and Yokohama,

[1] Annex A provides detailed information about institutions and organisations with responsibilities related to the energy sector.

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announced targets to reach net-zero carbon emissions by 2050 (MoE, 2020). In October 2018, the Japan Climate Initiative was launched as a network of non-state actors committed to accelerate the low-carbon transition. By April 2020, the network had more than 450 members, including 330 businesses, as well as local governments and civil society organisations.

Japan's emissions reduction targets and policies

Targets to 2020

Japan's target under the Kyoto Protocol's first commitment period (2008-12) was to reduce GHG emissions (excluding LULUCF) by 6% compared to the base year (1990). Even though emissions stood 1.4% above 1990 levels in 2008-12, Japan met its commitment thanks to carbon sinks and international flexibility mechanisms (IEA, 2016). The economic recession following the global financial crisis, which led to a significant decline in emissions in 2008-10, has also helped Japan to meet its Kyoto target.

While Japan did not make a commitment for Kyoto's second commitment period (2013-20), it pledged at COP15 in Copenhagen in 2009 to reduce emissions by 25% from 1990 to 2020. This target was one of the most ambitious pledges among the participating countries and particularly challenging for Japan, which had seen its emissions rising for most of the 2000s. The target largely relied on plans to increase the share of nuclear power in electricity supply from 30% to 50%. The 2011 events then fundamentally changed the conditions for nuclear power and thus climate policy. Following the shutdown of all nuclear reactors, GHG emissions spiked to 1 408 Mt CO_2-eq in 2013, the highest value ever recorded in Japan. The same year, Japan revised its 2020 target from a 25% reduction from 1990 to a 3.8% reduction from 2005 (which effectively translates into a 5% *increase* from 1990 levels). The revised target means that Japan aimed to maintain emissions at the level prior to 2011.

While the revised target was based on the assumption that no nuclear reactors would restart, lower electricity demand, an increase in renewables and the restarting of some nuclear power plants resulted in a drop in GHG emissions earlier than anticipated. Japan did not revise its target again, but added a "or more" to the -3.8% goal in 2016, so as to capture additional emissions reductions resulting from the reintegration of some nuclear reactors into the power mix. In 2017, GHG emissions had declined to 4.3% below 2005 levels, which means that the country met its revised 2020 target three years ahead of time.

Target to 2030

Japan's Nationally Determined Contribution (NDC) under the Paris Agreement, submitted to the UNFCCC in November 2016 and reconfirmed in March 2020, aims to reduce GHG emissions by 26% in 2030 compared to 2013 (or by 25.4% compared to 2005). According to the NDC, this establishes a maximum emissions level of 1 042 Mt CO_2-eq for 2030 (translating into a 15% reduction from 1990). Japan adopted an unusual accounting method, in which the LULUCF sector is excluded from the base year (2013) but included in the target year (2030), making the target larger than it otherwise would be.[2] The revised NDC of March 2020 states that Japan will pursue efforts to reduce emissions beyond the

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[2] If calculated on a net-net basis (i.e. including LULUCF for both the base year and the target year) or on a gross-gross basis (i.e. excluding LULUCF for both the base year and the target year), the NDC's GHG emissions reduction target would be smaller, around 23% rather than the stated 26%.

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26% in the medium and long term, and to review the target with the revision of the energy mix, ahead of the next deadline for NDC revisions in 2025.

Japan aims to achieve its 2030 target through domestic emissions reductions and removals from LULUCF activities. The target was set following bottom-up estimates by sector that could be achieved with existing domestic policies and measures, taking into account technological and cost considerations, and assuming that the envisioned energy mix for 2030 would be achieved (UNFCCC, 2019). Most emissions reductions are expected to be delivered by the energy sector, whose emissions are anticipated to decline by 25% by 2030 compared to 2013 levels. Within the sector, most reductions would occur in the residential and commercial sectors, followed by transport (Table 3.1). The government also plans to use the Joint Crediting Mechanism with developing countries to reduce Japanese emissions (50-100 Mt CO_2-eq by 2030) (GoJ, 2015a). The policies and measures to reach this target are listed in the 2016 Plan for Global Warming Countermeasures (see the section below on main policies and regulations).

Table 3.1 Japan's 2030 greenhouse gas emissions reduction targets by sector

Sector	2030	2013	Reduction 2013-30
Energy originated CO_2 (in Mt CO_2)	927	1 235	-25%
Industry	401	429	-7%
Commercial	168	279	-40%
Residential	122	201	-39%
Transport	163	225	-28%
Energy conversion	73	101	-30%
Non-energy originated greenhouse gases (in Mt CO_2-eq)	152	173	-12%
LULUCF (in Mt CO_2-eq)	-37	–	–

Note: LULUCF = land use, land-use change and forestry.

Source: GoJ (2015a), Submission of Japan's Intended Nationally Determined Contribution (INDC), www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Japan%20First/20150717_Japan%27s%20INDC.pdf.

The continuous decline in emissions since the peak in 2013 has put Japan in a good position to achieve its 2030 target using existing policies (UNEP, 2019). However, meeting the NDC target relies on the assumption that the envisioned energy mix for 2030, as outlined in METI's *2015 Long-term Energy Supply and Demand Outlook* (METI, 2015), would be achieved. This means that the share of nuclear energy in total energy supply would increase to 10-11% (up from 1% in 2017) and renewables would increase to 13-14% (up from 11%), while the shares of oil and natural gas would decline and that of coal would remain constant (at 25% of TPES). According to the government, the 10-11% share of nuclear energy is achievable if approximately 30 nuclear reactors (out of the 36 that are currently offline) return to service.[3] However, it is still unpredictable whether this can really be achieved by 2030 (see Chapter 11).

Should nuclear fall short of its 10-11% targets, the gap in power generation will need to be filled with additional renewable energy generation, or additional efforts to reduce electricity demand in order to reach the 2030 target. Using fossil fuels to fill the gap may jeopardise reaching the 2030 climate goals, except if CCUS technologies can be deployed at a large

[3] The 20-22% share in electricity mix is available if at least 30 reactors complete the Nuclear Energy Agency's safety review, acquire local approval, return to service and operate with an average capacity factor of 80% (see Chapter 11).

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scale by then. This may, however, prove challenging. Reliance on fossil fuels will also make it more difficult and costly to achieve further emissions reductions after 2030.

The government regularly reviews progress towards its energy and climate targets through comprehensive energy and GHG emissions statistics. This will help identify whether corrective measures are needed to reach the 2030 targets. At the same time, to prepare for all possible outcomes, the government may consider mapping out the different pathways for reaching the 2030 target, including for a scenario in which nuclear falls short of its target. In addition to minimising the risks of not reaching the NDC, this would also help identify additional mitigation potential in all sectors (going beyond the potential identified in the NDC), paving the way for additional mitigation.

In contrast to other countries, Japan does not have “with additional measures” projections to 2030 that would model GHG emissions reductions through measures not yet implemented (UNFCCC, 2019). However, in its NDC, Japan commits to review the reduction targets in line with changes in the energy mix more frequently than the five-year period set under the Paris Agreement. Those reviews take into account all policies and measures for all categories of GHG and set aspirational targets to encourage the implementation of more ambitious measures.

According to the International Panel on Climate Change, current pledges under the Paris Agreement are insufficient to limit global warming to well below 2°C above pre-industrial levels, even with an increase in scale and ambition of mitigation after 2030 (IPCC, 2018). In this context, Japan may consider joining international efforts to strengthen commitments and action for climate change mitigation even further, going beyond the current target of -26% by 2030. A more ambitious short-term target would also provide greater guidance on the transition to the goal of a decarbonised society by 2050 (see below), while sending strong signals to businesses and investors. The Japan Climate Initiative, with its 350 member companies, has committed to accelerate their efforts to decarbonise and called on the government to raise Japan’s NDC in line with the Paris Agreement (JCI, 2020).

Carbon neutrality by 2050

The new aim to realise a carbon-neutral, decarbonised society by 2050 reflects a radically new vision by the government about how climate policy can support the long-term economic and social development of Japan and ensure the country’s position as a global industrial power. In his speech on 26 October, the Prime Minister stated that his administration is committed to the extent possible to “bring about a green society, while focusing on a virtuous cycle of the economy and the environment as a pillar of our growth strategy’ (Prime Minister of Japan and His Cabinet, 2020).

The policy focus will be on next-generation solar cells, carbon recycling and the transformation of industrial structures, while ensuring stable supply of energy by further enhancing energy efficiency, maximising the introduction of renewable energies and further advancing nuclear energy with the highest priority on safety, while drastically changing Japan’s polices on coal-fired power generation (Prime Minister of Japan and His Cabinet, 2020). In December 2020, METI issued a press release informing that it has formulated a Green Growth Strategy towards 2050 Carbon Neutrality setting out challenges and actions, and framing action plans and policies covering, among others, taxes, regulatory reforms and standardisation, and international collaboration (METI, 2020a).

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In ensuring public support for its new climate policy, the national government could draw on the 160 local governments that have already pledged the same decarbonisation goal for 2050 and that represent 62% of the population (The Economist, 2020).

Aiming for carbon neutrality by 2050 means that the pace and scale of mitigation will need to significantly increase in the next decades and Japan will need to substantially reassess and widen its current set of policy measures and concrete action plans for each sector.

Japan's Long-term Strategy Under the Paris Agreement (GoJ, 2019) sets basic principles for implementation as well as broad policy directions for each sector. The government recognises that the leap from 2030 to 2050 will require radically more efficient, low-carbon technology. It aims to realise "a virtuous cycle of environment and growth" towards the 2050 vision with business-led disruptive innovation. The 2019 strategy also calls for swift implementation of actions from now on and for international collaboration. For the energy sector, the vision is to make renewables the main power source; reduce dependency on nuclear as much as possible while ensuring its safety; reduce CO_2 emissions from thermal power generation; make use of hydrogen, storage batteries and CCUS; and improve energy efficiency (GoJ, 2019).

The government had already started to develop possible pathways towards achieving the previous ambition of an 80% reduction by 2050. Those pathways are now being revised to reflect the new aim to realise carbon neutrality by 2050. In September 2020, the interim "Climate Innovation Finance Strategy 2020" was published (METI, 2020b). It aims to promote finance for the energy transitions, green technologies and innovation, which includes the formulation of "industry-specific road maps". Such pathways will help Japan outline options of how to achieve the 2050 carbon neutrality goal, e.g. in different scenarios of technological innovation or socio-economic development. Regular updates and reiterations can help ensure flexibility of policies and approaches to changing conditions. International experience has shown that long-term pathways can be a useful means to engage all parts of government, business and civil society around the practicalities of achieving the long-term goals, help identify trade-offs and promote societal buy-in for the needed changes (OECD, 2019a).

Main mitigation policies

The main framework for climate change policy is prescribed in the Act on Promotion of Global Warming Countermeasures (Ministry of Justice, 1998), first adopted 1998 and last revised in 2016. Among other things, the act requires the national and local governments to develop plans with concrete targets and measures to achieve the national mitigation goals.

The Plan for Global Warming Countermeasures

The Plan for Global Warming Countermeasures (MoE, 2016), Japan's overall climate change mitigation plan adopted in May 2016, introduces key measures to be implemented by the national and local governments, businesses, and citizens to achieve the 2020 and 2030 targets. In line with the NDC, it provides mitigation targets for each sector and outlines policies to achieve them. The plan is based on the envisaged energy mix to 2030 and relies on a combination of regulation, governmental spending, voluntary measures and economic incentives.

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In line with the NDC, the commercial and residential sectors are expected to deliver nearly two-thirds of the total emissions reductions needed, with smaller reductions expected in transport, industry and energy conversion (see the section on emissions reduction targets above). Most reductions are expected to be delivered through energy efficiency improvements, the expansion of renewable energy, improved efficiency of thermal power generation, use of nuclear power generation and diversification of fuels in industry. Japan has estimated the mitigation potential of some key policies and measures (Table 3.2). Key measures are presented in the following sections. In its revised NDC of March 2020, Japan announced it will update its Plan for Global Warming Countermeasures.

Table 3.2 Estimated mitigation potential of selected measures

Sector	Measure	Estimated impact by 2020 (Mt CO_2-eq)*	Estimated impact by 2030 (Mt CO_2-eq)
Renewable energy	Expanded use of electricity generated by renewable energy	–	~ 160 000
	Expanded use of heat generated by renewable energy	–	~ 36 000
Energy efficiency (i.e. use of highly efficient equipment and devices)	In industry	~ 42 000	~ 71 000
	In the commercial sector	~ 9 000	~ 11 500
	In the residential sector	~ 9 000	~ 15 000
	In thermal power generation	~ 7 000	~ 11 000
Transport	Diffusion of next-generation vehicles and improvement of fuel efficiency	~ 7 000	~ 24 000
Cross sectoral	Tax for climate change mitigation		~ 6 000**

* Million tonnes of carbon dioxide equivalent.

** Estimated by the expert review team of the United Nations Framework Convention on Climate Change.

Note: The estimated mitigation impacts are estimates of CO_2 emissions avoided in a given year as a result of the implementation of mitigation actions.

Source: UNFCCC (2019), *Report of the Technical Review of the Seventh National Communication of Japan*, https://unfccc.int/sites/default/files/resource/idr.7_JPN.pdf.

Mitigation in industry

The NDC's target is to reduce GHG emissions in industry by 7% by 2030 compared to 2013 levels. Climate action in the industrial sector is mainly promoted through voluntary action plans, organised by the Japan Business Federation Keidanren since 1997. Building on the voluntary efforts, the 2016 Plan for Global Warming Countermeasures lists two policies for the sector: 1) promoting and verifying industries' voluntary action plans; and 2) introducing highly energy-efficient equipment, using factory energy management systems and promoting collaboration among businesses. The long-term vision for the sector is to reduce emissions using CCUS as well as CO_2-free hydrogen as a substitute for chemical reactions.

Keidanren's Commitment to a Low-Carbon Society, announced in 2013, stipulates industry-specific reduction targets to 2020 and 2030 (see Table 3.3 for examples), along with a pledge to contribute to reductions in other sectors and countries through development, diffusion and transfer of innovative technologies (Keidanren, 2013). As voluntary efforts like Keidanren's spread, the private sector's commitment in Japan covers

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85% of emissions from the industrial and energy conversion sectors, 27% of emissions from the commercial sector, and 67% from the transportation sector in Japan as a whole (slightly lower than the respective shares in the previous voluntary action plans to 2012) (METI, 2020c). A government council reviews industries' performance and progress against the target on an annual basis.

Table 3.3. Emissions reduction targets pledged by nine major industries under Keidanren's Commitment to a Low-Carbon Society

Sector	Baseline year	Target indicator	2020 reduction target	2030 reduction target
Iron and Steel Federation	BAU	CO_2 reduction	-5 Mt CO_2	-9 Mt CO_2
Chemical Industry Association	BAU	CO_2 reduction	-1.5 Mt CO_2	-2 Mt CO_2
Paper Association	BAU	CO_2 reduction	-1.39 Mt CO_2	-2.86 Mt CO_2
Four electrical and electronics associations	2012	Energy intensity	> -7.73% (*)	> -16.55%
Cement Association	2010	Energy savings	-39 MJ/t-cem	-125 MJ/t-cem
Automobile Manufacturers Association	1990	CO_2 emissions	-28%	-33%
Petroleum Association	2010 (2020)	Energy savings (2020)	-0.53 million kL	
	BAU (2030)	Energy consumption (2030)		-1 million kL
Gas Association	1990	CO_2 intensity Energy intensity	-89% -85%	-89% -84%
Electric power industries	–	CO_2 intensity		Maximum of 0.37 kg CO_2/kWh

* Average annual energy intensity improvement rate of 1% until 2020.

Notes: BAU = business as usual. Mt CO_2 = million tonnes carbon dioxide. MJ/t-cem = megajoules per tonne of cement. kL = thousand litres. kg CO_2/kWh = kilogrammes of carbon dioxide per kilowatt hour.

Source: METI (2014), *Voluntary Approaches on the Environment: The Voluntary Action Plan on the Environment/Commitment to a Low-Carbon Society*, www.meti.go.jp/english/policy/energy_environment/global_warming/voluntary_approach/pdf/summary_documents_01.pdf.

According to Keidanren, the action plans helped reduce the CO_2 emissions of participating industries by approximately 10.5% from 2013 to 2018 (Keidanren, 2020). Emissions decreased in the industrial, energy conversion and commercial sectors since 2013, but not in the transportation sector. According to the latest progress report, 41 out of 62 participating industries had achieved their 2020 targets by March 2019, while 21 had already achieved their 2030 targets (Keidanren, 2019). This suggests that there is room to review and strengthen some of the targets. Recognising this, Keidanren called on its member companies and organisations to formulate a long-term vision to 2050. As of December 2019, 97 companies had formulated their vision and another 105 were in the process of doing so.

The voluntary plans have a long tradition in Japan and were successful in delivering emissions reductions. The government should continue to monitor whether the voluntary approach provides sufficient incentives to industries to make the investments in new

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technologies and production processes that are needed to achieve carbon neutrality by 2050 and discuss enhanced efforts with industry if the target is not within reach.

Mitigation in the power sector

Policy measures to reduce emissions in the power sector focus on expanding renewable energy, further improvements in the efficiency of thermal power plants, facilitating the restarts of nuclear power plants that have received safety approval from the Nuclear Regulation Authority, and the introduction of CCUS. In addition, in 2015, the electricity industry voluntarily agreed to achieve a CO_2 emission factor of approximately 0.37 kg CO_2/kWh for power generation. This is equivalent to a reduction of 35% from 2013 levels, and compares to a factor of 0.496 kg CO_2/kWh in 2017 (JEPIC, 2019). The electricity industry also pledged to target a non-fossil-fuel ratio of 44%, and to achieve a thermal-efficiency ratio of 44% by 2030. Japan's Long-term Strategy Under the Paris Agreement envisions making renewables economically self-sustained and the main power source by 2050 while reducing reliance on nuclear as well as emissions from thermal power generation.

Japan's carbon intensity of power generation is one of the highest in the IEA (see Figure 3.5 above), which largely reflects the high reliance on coal. Japan currently has coal-fired plants with a capacity of 46 gigawatt (GW) in operation, and is among the few advanced economies to anticipate construction of new coal generation capacity of about 11 GW by 2026 (see Chapter 10). Although Japan's coal fleet is one of the most efficient in the world, coal remains a high-carbon source of electricity. Even a highly efficient coal plant emits more than 700 g CO_2/kWh, compared to roughly 300-500 g CO_2/kWh from a natural gas-fired plant. If unabated, the additional coal capacity will offset gains from renewables and efficiency improvements and lead to a substantial increase in emissions and the risk that Japan would not meet its NDC. It also risks locking in carbon-intensive infrastructure, which could increase both the potential financial and commercial risk associated with high-carbon assets and the overall cost of transitioning to a net-zero carbon economy.

In the 5th Strategic Energy Plan (SEP) of 2018, Japan announced it would make efforts to demonstrate the viability of CCUS and to study the introduction of "CCUS-ready" facilities as early as possible (METI, 2018a). Making new coal plants CCUS-ready had already been proposed in the 3rd SEP in 2010. The 2019 Long-term Strategy states that the introduction of CCUS in coal-fired power generation by 2030 will be considered, with a view to commercialisation. Japan is a global leader in the development of CCUS technologies, but prohibitive costs and a lack of incentives and business models have limited the technology's deployment thus far.

A gradual increase of the price signals to enhance low-carbon technologies would help accelerate the take up of the technology. Alternatively, Japan should consider further reducing the permissible limit of CO_2 emissions per kWh, and requiring new coal and gas plants to be built CCUS-ready as soon as possible (see Chapter 10).

Renewable power generation has been promoted through feed-in tariffs, which led to a boom in solar PV. However, the relatively high cost of renewable power generation and constraints related to grid access and capacity remain major challenges. The government is working to address these issues, including through a new support system based on feed-in premiums and auctions (see Chapter 5).

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Mitigation in the commercial and residential sectors

The commercial and residential sectors are expected to reduce their GHG emissions by 40% and 39% respectively by 2030, compared to 2013. This will be achieved primarily through energy efficiency measures (see Chapter 4). In the commercial sector, climate actions will be pursued through the voluntary action plans of industry, along with more energy-efficient buildings through the promotion of mandatory energy conservation standards for new constructions, energy management systems for buildings and energy-efficient devices.

In the residential sector, the Top Runner Program for household appliances, equipment and building materials remains central, along the public campaign "cool choice", which aims to encourage citizens to consume low-carbon products and services and to adopt an energy-efficient and low-carbon lifestyle. In addition, Japan aims to install 5.3 million small-scale fuel cells by 2030 to generate electricity and heat for residential buildings. These cells require combustion (typically natural gas) for heat generation; however, the system emits less CO_2 (as well as local air pollutants) than conventional combustion for electricity and heat production (see Chapter 6).

Mitigation in transport

Japan's NDC set a 28% reduction target in GHG emissions from transport for the period 2013-30. It has a comprehensive approach to reducing emissions in the transport sector, with measures targeting improved fuel efficiency of cars; the promotion of low-emission vehicles; as well as traffic flow improvements and eco-driving; the use of public transport and modal shift; and energy efficiency improvements in rail, shipping and aviation. The 2016 Plan for Global Warming Countermeasures also stipulates the goal of achieving a 50-70% market share for new sales of "next-generation low-carbon vehicles" by 2030 (MoE, 2016).

In 2018, METI launched the Strategic Commission for the New Era of Automobiles and tasked it to develop a long-term goal and strategy for the Japanese automotive industry to tackle climate change. The commission's interim report, published in August 2018, recommended a target to reduce GHG emissions from domestic automakers by 80% by 2050, compared to 2010. For passenger cars, a more ambitious target of 90% was suggested, along the goal to reach a 100% market share of electrified vehicles (defined as consisting of hybrid electric vehicles that cannot plug-in [HEVs], plug-in hybrid electric vehicles [PHEVs] and battery electric vehicles [BEVs]) by 2050 (METI, 2018b). The goal is to realise "well-to-wheel zero emissions", thereby linking the 2050 vision to global efforts for realising zero emission of the energy supply.[4] The report also states the ambition to stimulate innovation in terms of "how vehicles are used", e.g. looking into concepts such as mobility as a service, and connected and autonomous driving.

[4] The term "tank-to-wheel" refers to energy use and emissions caused by a vehicle from the point at which energy is absorbed (e.g. charging point, fuel pump) to discharge (being on the move). The term "well-to-wheel" refers to a life-cycle approach which additionally considers energy resource use and emissions involved in the production, transportation and distribution of the fuel.

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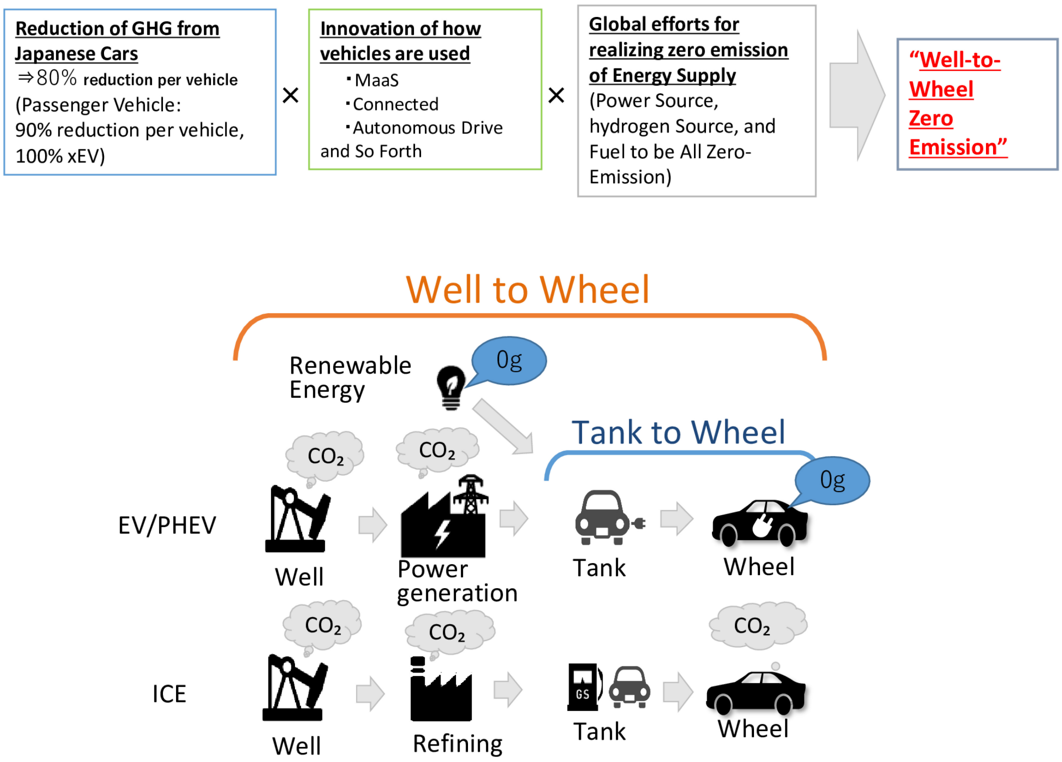
Figure 3.6 Japan's Well-to-Wheel Strategy



Source: METI (2018c), *Long-Term Goal and Strategy of Japan's Automotive Industry for Tackling Global Climate Change*, www.meti.go.jp/english/press/2018/pdf/0831_003a.pdf and other material provided by METI. Reproduced with the permission of METI.

Promotion of energy-efficient next-generation vehicles

"Next-generation vehicles" – which include HEVs, BEVs, PHEVs, fuel cell electric vehicles (FCEVs) and "clean" diesel vehices[5] – are expected to play a key role in achieving Japan's climate targets. The market share of BEVs and PHEVs is expected to grow from just 1% to at least 20% by 2030. FCEVs are also expected to increase, although their market share will likely remain small, at about less than 3%. HEVs and clean diesel vehicles would account for nearly half the market share in 2030 (see also Chapter 4).

Home to one of the world's largest automotive industries, Japan's approach to future mobility will be key for driving emissions reductions both domestically and globally. Some Japanese companies have been pioneers in developing electrified vehicles (such as Toyota, Nissan and Mitsubishi), helping the Japanese electric vehicles (EV) market to start to grow as early as 2010 (Figure 3.7). In 2019, the Japanese passenger car fleet contained 294 000 EVs (excluding hybrid EVs)[6] and was the world's fourth-largest market after the People's Republic of China (hereafter "China") (3.4 million), the United States (1.5 million) and Norway (328 600). About half of EVs are BEVs, the other half are PEVs. Japan is the only major electric car market where sales fell for a second year in a row: down by 14% between 2018 and 2019 and by 8% between 2018 and 2017 (IEA, 2020b).

[5] Japan defines "clean diesel vehicles" as those diesel vehicles that conform to exhaust emission standards of 2009 and thereafter.
[6] Only vehicles that can be charged by an external power source count as EVs, thus not regular hybrid cars.

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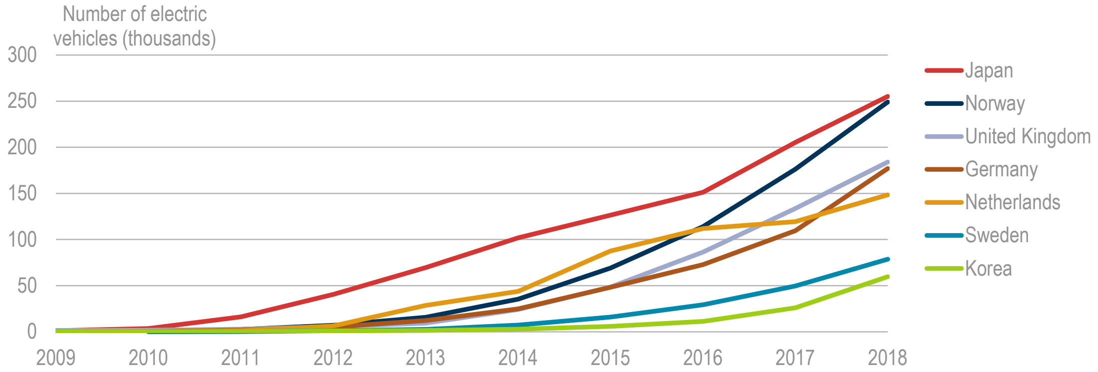
Decarbonisation of power generation will be important in Japan as mobility becomes electric. The lower the carbon intensity of its electricity mix, the larger the environmental gain from growing EV use will be in terms of GHG and air emissions. However, even if an EV is produced and driven in a country with a carbon-intense energy mix like in Japan, it emits 20-30% less CO_2 than a conventional diesel or petrol vehicle over its lifetime (Dornier, 2020). Direct support to charging infrastructure has been decreasing in recent years. While Japan allocated about JPY 100 billion (USD 1 billion) [7] to charging infrastructure in the first half of the 2010s, budget allocation fell to JPY 1.4 billion (USD 13 million) between 2016 and 2019 (IEA, 2019a). Accordingly, the installation of new charging stations somewhat stagnated in 2017 (NeV, 2018). Japan's New Era of Automobiles Strategy includes plans to harmonise future charging standards, which is fostering collaboration with China (METI, 2018b). The strategy provides support to various research, development and demonstration (RD&D) projects for 2018-23 that assess the feasibility of wireless charging and vehicle-to-grid applications. Japan may also consider developing measures to promote the installation of charging infrastructure in multi-apartment buildings. The European Union, for example, passed legislation requiring the installation of charging infrastructure in new and renovated buildings.

Figure 3.7 Electric vehicle fleets in Japan and a selection of IEA member countries, 2009-18



Note: Excludes hybrid electric vehicles.

Source: IEA (2019a), *Global EV Outlook 2019. Scaling-up the Transition to Electric Mobility*, www.iea.org/reports/global-ev-outlook-2019.

In addition to EVs, Japan is a frontrunner in the development of hydrogen-based transport. In 2019, Japan had almost 3 700 FCEVs and about 130 charging stations in place (NeV, 2020). Installations of hydrogen charging stations for commercial use are currently underway in the four major cities in Japan, supported by METI's Creation of New Demand for Fuel Cell Vehicles subsidy programme (in place since 2014). *The Basic Strategy of Hydrogen*, a government paper, states the ambitious goal to have 200 000 fuel cell EVs on the streets by 2025 and 800 000 by 2030. It further aims to attain 320 stations by 2025 (MCRE, 2017). Achieving these targets will require significant investment by Japan's automakers, as the current production capacity is limited to a few thousand fuel cell EVs per year.

Japanese automakers Toyota and Honda are among the few companies that make hydrogen fuel cell vehicles commercially available. Toyota is also developing a

[7] USD 1 = JPY 109.

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hydrogen-powered fuel cell truck. In December 2019, Mitsubishi launched the world's first liquid hydrogen carrier ship. As for electric vehicles, it will be important for Japan to source hydrogen from carbon-free energy sources to make fuel cell vehicles a real low-carbon solution. At present, almost all of the globally produced hydrogen is generated from fossil fuels (mostly natural gas and coal) (IEA, 2019b).

Vehicle taxation

Japan has provided tax breaks to favour more environmentally friendly vehicles since 2009. This mostly included exemptions or reductions for "new generation vehicles" (i.e. EVs, hybrids, FCEVs and clean diesel vehicles) and fuel-efficient vehicles, but also increased tax rates for older vehicles. In 2019, Japan updated and modified its vehicle tax regime. It extended tax reductions for new generation vehicles until March or April 2021, abandoned the acquisition tax (as of October 2019), and introduced an automotive environmental performance-based tax (also as of October 2019) (Table 3.4). The environmental performance-based tax is a purchase tax that is based on a vehicle's fuel efficiency and exhaust emissions.

Tax breaks to incentivise the purchase of environmentally friendly vehicles are generally less efficient than directly taxing the polluting dimension of road transport. They also represent fiscal revenue foregone for the government and can contribute to increased vehicle use (van Dender, 2019). The introduction of the automotive environmental performance-based tax is therefore a welcome step.

Table 3.4 Taxes on passenger vehicles in Japan

Tax	Tax base	Tax rate	Reductions and exemptions
Vehicle tonnage tax	Vehicle weight	JPY 4 100/0.5 t/ year	- Exemption for new generation vehicles - Reduction for vehicles exceeding 2020 fuel efficiency standards - Higher rates for vehicles more than 13 years old
Automobile tax	Engine size	JPY 25 0000 to JPY 110 000/year	- 75% reduction for new generation vehicles - Reductions for vehicles exceeding 2020 fuel efficiency standards
Mini-vehicle tax	–	JPY 10 800/year	- 75% reduction for new generation vehicles - Reductions for vehicles exceeding fuel efficiency standards
Automotive environmental performance-based tax	Purchase price (for new and used vehicles)	0-3% (mini vehicle: 0-2%)	- Exemption for new generation vehicles - Exemption for vehicles exceeding 2020 fuel efficiency standard by 20% (mini-vehicle: 10%) - 1% for vehicles exceeding 2020 standard by 10% (mini-vehicle: complying with the 2020 standard) - 2% for vehicles complying with the 2020 standard (mini-vehicle: not complying with the 2020 standard)

Source: JAMA (2019), *The Motor Industry of Japan 2019*, www.jama.or.jp/industry/ebook/bookdata_e/book.pdf.

Carbon pricing

Japan introduced the tax for climate change mitigation as a direct carbon tax in October 2012 and increased its level in 2014 and 2016 to reach a rate of JPY 289 (USD 2.65) per tonne of CO_2. The tax is applied as an add-on to the petroleum and coal tax and is thus levied on crude oil and oil products, natural gas, and coal. Tax revenue is recycled for the reduction of CO_2 emissions from energy use, e.g. for renewable energy and energy efficiency projects. The tax yields revenues in the order of JPY 260 billion (USD 2.4 billion) per year (UNFCCC, 2019).

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Japan does not have a national emissions trading system (ETS), but there are two local ETS schemes in operation: one in the Tokyo municipality (since 2010) and the other in Saitama Province (since 2011), which is part of the Greater Tokyo area. Together, these two areas are home to roughly 20 million people. The two systems are linked, meaning that credits can be traded between the two jurisdictions. They jointly cover CO_2 emissions from fuels, heat and electricity consumption of about 1 550 commercial and public buildings and 600 industrial facilities, or roughly 20% of each jurisdiction's total emissions. Their carbon price was around JPY 600 (USD 5.50) per tonne of CO_2 in 2019 (ICAP, 2021). Overall emissions from these two areas are, however, small compared to the country's total emissions.

Japan's 2016 Plan for Global Warming Countermeasures announced that Japan would carefully study the option of a national ETS. The study is still ongoing. In addition, the 2019 Long-term Strategy Under the Paris Agreement states that professional and technical discussions are required to consider the perspective of international trends, conditions in Japan and international competitiveness related to carbon pricing (GoJ, 2019). The IEA advises the government to swiftly finalise its ongoing deliberations.

Due to the relatively low levels of the carbon tax and the small coverage of the ETS, carbon pricing in Japan mainly results from energy excise taxes on fossil fuels. Japan imposes excise taxes on all fossil fuels, although at lower levels than many other IEA countries. Yet, despite low tax levels, overall energy prices are high in Japan by international comparison (see Chapter 2). Considering both excise taxes and the specific carbon tax (but excluding the ETS), Japan priced the majority of CO_2 emissions (86%) from energy use in 2015. However, only 21% were priced above EUR 30, which is a conservative estimate of the climate damage from 1 t CO_2 (OECD, 2018). As a consequence, Japan has the eighth-highest "carbon pricing gap" among OECD countries, which measures how much countries fall short of pricing CO_2 emissions in line with a EUR 30 benchmark value (Figure 3.8).

The effective tax rate varies considerably across users and fuels. As in most countries, transport fuels are taxed at the highest effective rate and diesel is taxed significantly less than petrol, although it contributes more to air pollution and CO_2 emissions. The residential and commercial sectors face higher effective rates than the industrial sector and benefit from fewer reductions and exemptions. Effective rates are the lowest in the electricity sector (Figure 3.9). The majority of unpriced emissions were emitted by the industry and electricity sectors.[8] As in many countries outside of the EU-ETS, effective carbon prices are particularly low for coal, despite its harmful climate and air pollution impacts, as it is considered a critical resource for energy security.

[8] In industry, fossil fuels are subject to the petroleum and coal tax. Exceptions exist for fuels used in petrochemical production and coal; coke and related gases are untaxed when used for the production of iron and steel or coke and cement (OECD, 2018).

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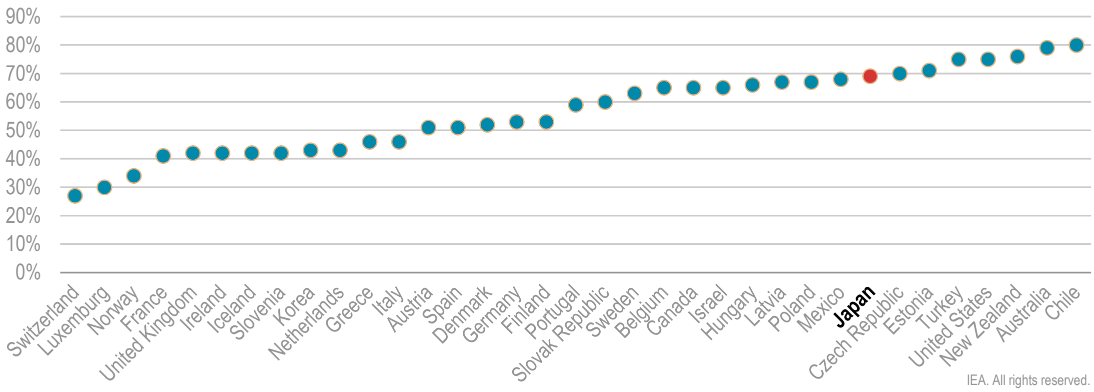
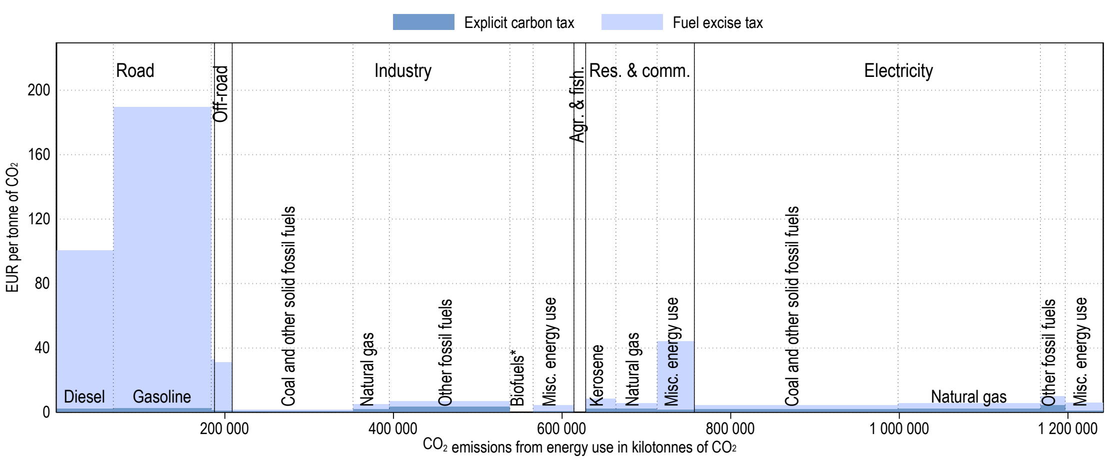
Figure 3.8 Carbon pricing gap in OECD countries, 2015



Note: The carbon pricing gap measures how much countries fall short of pricing CO_2 emissions in line with a EUR 30 benchmark value.

Source: OECD (2018), *Effective Carbon Rates 2018: Pricing Carbon Emissions through Taxes and Emissions Trading*, https://doi.org/10.1787/9789264305304-en.

Figure 3.9 Average effective carbon rate in Japan by sector and fuel, 2018



Notes: The effective carbon rate is the sum of taxes and tradeable permits that put a price on carbon emissions. This figure includes energy excise taxes applied in Japan, as well as the tax for climate change mitigation. It excludes two emissions trading systems that operate at the subnational level. Tax rates are shown as of 1 July 2018. CO_2 emissions are calculated based on energy use data for 2016 from IEA (2018). Energy categories that represent less than 2% of the horizontal axis are grouped into “miscellaneous energy use”. “Agr & fish” refers to agriculture and fisheries. “Res. & comm.” Refers to residential and commercial sector.

Source: OECD (2019b), *Taxing Energy Use 2019: Using Taxes for Climate Action*, https://doi.org/10.1787/058ca239-en.

Other cross-cutting measures

Innovation

The Japanese government sees a critical role for energy RD&D in helping Japan meet its climate targets. It has adopted several strategies and programmes to this end. The New Low-Carbon Technology Plan, adopted in 2013, focuses on technologies expected to be in practical use in around 2030. The National Energy and Environment Strategy for Technological Innovation towards 2050 (NESTI 2050), adopted in 2016, provides the framework for fostering innovation necessary to reach Japan’s GHG emissions reduction

ENERGY SYSTEM TRANSFORMATION

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goal of 80% by 2050. Based on this, the government launched the Environment Innovation Strategy in January 2020. It updates the innovation paths for technologies already identified in NESTI 2050, sets concrete targets for cost reductions and expands the scope of innovation to non-energy sectors (e.g. agriculture). Japan actively engages in international co-operation on innovative technologies, including through the annual Innovation for Cool Earth Forum, which Japan has been hosting since 2014. A particular focus is placed on CO_2-free hydrogen and CCUS (see Chapter 6). As a major exporter of energy and transport technology, the development and commercialisation of low-carbon technology in Japan could have a positive impact on emissions reductions globally.

Green finance

The Low Carbon Society Establishment Finance Initiative, launched by the government in 2013, aims to mobilise additional private finance for domestic climate action. The initiative has three components: 1) an investment fund for promoting local low-carbon investments (JPY 4.8 billion); 2) an interest subsidy for expanding environmental finance (JPY 1.6 billion); and 3) an eco-lease promotion programme (JPY 1.9 billion) (UNFCCC, 2019). Japan has also promoted the issuance of green bonds. In 2017, there were more than JPY 160 billion in such bonds, five times the amount in 2014 when the bonds were first issued (UNFCCC, 2019).

The J-Credit Scheme

The J-Credit Scheme is a mechanism administered by the government that aims to promote voluntary emissions reductions efforts and carbon offsetting among companies. Participating companies receive credits for their emissions reduction and removal efforts (e.g. from renewable energy projects or forest management for increasing carbon absorption), which are certified by a certification committee made up of experts appointed by the government. The credits can be used for various purposes, including for achieving the target commitments under the companies' voluntary action plans. As of March 2020, 317 projects had been registered, with a joint certified emissions reduction of 5.9 Mt CO_2. The government expects 12 Mt CO_2 in potential certified emissions reductions for 2030. Credits are traded both over the counter and via auctions held by the J-Credit Scheme Secretariat, which are held several times a year. The auctions held in January 2020 had average trading prices of around JPY 1 400-1 900 (USD 13-17) per tonne of CO_2-eq. METI; the Ministry of the Environment; and the Ministry of Agriculture, Forestry and Fisheries oversee the management of this scheme.

International collaboration

In November 2015, at COP21 in Paris, Japan announced the "Actions for Cool Earth (ACE) 2.0", in which it committed to provide about JPY 1.3 trillion (USD 11.9 billion) of public and private climate finance to developing countries in 2020.[9] This is an important contribution towards the global goal of mobilising USD 100 billion of collective climate finance annually by 2020 and confirms Japan's leadership in providing international climate finance. Japan is also the largest donor to the Global Climate Fund, with a contribution of USD 1.5 billion.

[9] ACE 2.0 succeeded ACE, a JPY 1.6 trillion (USD 14.6 billion) climate finance goal covering the period 2013-15.

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Japan promotes the global diffusion of low-carbon technologies, including through its Joint Crediting Mechanism (JCM). The JCM is a bilateral mechanism proposed by the government of Japan in 2011 to support mitigation actions in developing countries. As of early 2019, there were 17 JCM partner countries with 29 registered projects; another 120 projects were in the pipeline, with an estimated GHG emissions reduction potential of 7 Mt CO_2 in 2030 (UNFCCC, 2019).

Adapting to climate change

Japan has already started to feel the effects of climate change in the form of rising mean temperatures and extreme weather events. Average annual temperatures have increased by more than 1°C since 1900 while rainfall has become more variable since 1970. Mean sea surface temperatures around Japan have risen by more than 1°C since 1900, roughly twice the corresponding value for the North Pacific overall (GoJ, 2017). Heat waves, heavy rains and strong typhoons have become more frequent. In the summer of 2018, Japan registered the highest temperatures ever recorded, in addition to heavy rains that led to economic damage in the order of USD 27.5 billion (GoJ, 2019). The city of Iki in south-western Japan became the country's first municipality to declare a "climate emergency".

Climate projections suggest that mean temperatures will continue to rise over the course of this century. While annual rainfall will be characterised by large-range inter-annual variability, the frequency of heavy rainfall and short-term intense rainfall and the occurrence of typhoons will increase across the country. Sea temperatures around Japan are expected to continue to rise faster than those of the seas south of Japan. Overall, Japan ranks among the countries the most exposed to the impacts of climate change (ND-GAIN, 2020).

In order to address current and future climate impacts in a more systematic and co-ordinated way, Japan approved its first Climate Change Adaptation Plan in November 2015 (GoJ, 2015b). The plan establishes basic principles and key measures for adaptation in seven sectors (agriculture, forestry and fisheries; water; natural ecosystems; natural disasters and coastal areas; human health; industrial and economic activities; and urban life). In June 2018, Japan passed the Climate Change Adaptation Act, which obliges the government to formulate an adaptation plan and to develop methodologies to monitor and evaluate progress of adaptation efforts. It also requires the government to develop climate change impact assessments every five years and to update the national adaptation plan as necessary. Local governments are encouraged to draw up their own adaptation plans and to set up local adaptation centres that would act as a hub for the collection, analysis and provision of local climate risk data and information on adaptation measures.

The National Adaptation Plan is surprisingly silent on risks and adaptation options for the energy sector. It attributes "not very high significance" and low urgency to climate risks on energy supply and demand due to the limited number of cases (GoJ, 2015b). It does, however, mention concerns about changes in energy import prices and suggests measures to strengthen energy efficiency in housing, buildings and transport to reduce artificial exhaust heat from human activities. As recent events have shown, there is a need to strengthen the energy sector's resilience against geological and climate-related risks. Japan has experienced large-scale and relatively long power outages in various parts of the country caused by extreme weather events. This includes the 2018 electricity outage

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that followed Typhoon Jebi in western Japan, which left more than 1 million homes without electricity, and the 2019 outage following Typhoon Faxai, which left nearly 1 million households without electricity in the Tokyo area.

These events, and the relatively long time span needed to restore power, caused the government to consider new legislation to strengthen the resilience of the electricity sector. In February 2020, Cabinet approved a bill proposing amendments to three energy-related laws with a view to enhance the robustness and resilience of the electricity supply system. The bill, which was brought to parliament in March 2020, requires electricity transmission and distribution operators to develop partnership plans to facilitate a quick initial response to disasters. It furthermore asks the government to establish a system to support the costs of inter-regional transmission lines and requires JOGMEC (the administrative institution responsible for securing a stable supply of non-ferrous metals and mineral resources)[10] to procure LNG and other fuels for power generation at the request of METI in the event of an emergency.

Assessment

In October 2020, the new Prime Minister of Japan declared that by 2050 Japan will aim to reduce GHG emissions to net-zero; that is, to realise a carbon-neutral, decarbonised society. The IEA congratulates Japan for this commitment that aligns the country with other countries at the forefront of global climate engagement.

In 2018, Japan's GHG emissions were 1 238 Mt CO_2-eq, excluding emissions from LULUCF, and GHG emissions intensities (both per capita and per unit of GDP) are currently above the IEA median. Energy-related emissions accounted for 88% of total GHG emissions in 2018, with nearly 50% of total emissions coming from power generation.

Japan met its pledge under the Kyoto protocol's first commitment period (2008-12) and although it did not take a commitment for the second period, with a reduction of GHG emissions of 4.3% in 2017 compared to 2005 levels, it met its national 2020 target (-3.8%) ahead of time.

In its NDC under the Paris Agreement, Japan has committed to reduce its GHG emissions by 26% in 2030 compared to 2013 levels. To achieve this, it has implemented the Global Warming Countermeasure Plan and had already reduced its GHG emissions by 11.8% in 2018 relative to 2013. While Japan is very much focused on energy policy, for energy security and affordability reasons, it is also dedicated to address climate change and is on track to fulfil its international commitments for 2030. An essential part of fulfilling these commitments will be achieving a power mix in 2030 in line with Japan's energy strategy.

The Paris Agreement commits countries to limit global warming in this century to well below 2°C and to pursue efforts to limit it to 1.5°C. According to the International Panel on Climate Change, current pledges are insufficient to limit global warming to well below 2°C above pre-industrial levels, even if pledges are supplemented with significant increases in scale and ambition of mitigation after 2030. Japan submitted its revised NDC in March 2020, confirming the 26% reduction target set in 2015, while announcing efforts to reduce

[10] Annex A provides more information about organisations and agencies with relevance to the energy sector.

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emissions beyond the 26% in the medium and long term. The revised NDC further announced to review the target with the revision of the energy mix, ahead of the next deadline for NDC revisions in 2025.

All countries are expected to update their pledges before COP26 in Glasgow in 2021. Given the successful reduction of GHG emissions since 2013, Japan may consider joining international efforts to strengthen commitments and action for climate change mitigation. A more ambitious target to 2030 would support the transition to carbon neutrality by 2050, while sending strong signals to businesses and investors.

Japan aims to realise "a virtuous cycle of environment and growth" towards reaching carbon neutrality by 2050 with business-led disruptive innovation. To achieve this, Japan aspires for an ambitious expansion of renewables, recovery of nuclear power, as well as the development and deployment of new technologies, including CCUS and low-carbon hydrogen. Japan also committed to change its policies on coal-fired power generation. These new commitments will have a strong impact on Japan's society and economy. To prepare and implement these changes, Japan, like other countries, will need to develop comprehensive long-term pathways and impact analyses, in consultation with stakeholders.

Energy efficiency improvements have been the key driver in lowering GHG emissions in the past decade. With a combination of mandatory policies such as the Top Runner Program and voluntary measures through the Keidanren business organisation, Japan has achieved efficiency improvements in industry, business and households. The government intends to continue this approach for reaching its energy efficiency targets. However, in light of the significant increase in climate ambition, the IEA believes that the government should also consider introducing regulations, mandatory performance benchmarks or market-based instruments, which would provide stronger incentives to industry to innovate and reduce energy consumption and emissions.

Japan adopted several policies to reduce GHG emissions from energy supply. Even though its island nature limits the variety of options to decarbonise power generation, the share of renewable energy in TPES increased to almost 8% in 2019. In combination with nuclear power (4%), this amounts to about 12% of non-fossil energy in 2019 TPES, mostly concentrated in the electricity sector. In the non-power sectors, the uptake of renewable energy remains very low (1.5% in buildings and only 1% in transport in 2018). If non-fossil energy sources are to play an important role in Japan's GHG mitigation efforts, all sectors will have to significantly increase non-fossil energy use in the short, medium and long term.

In the electricity sector, meeting the 2030 climate targets relies strongly on an increase in the share of nuclear from 6% in 2019 to 20-22% and for renewables from 19% in 2019 to 22-24%, as laid out in the 5th Strategic Energy Plan. In particular with regard to its target to restart nuclear power plants, it remains unpredictable whether this can really be done in time for 2030. If this does not materialise, Japan would have to significantly increase its efforts to reduce its overall emission intensity, either by a significant addition of renewable energy across the board or by pushing very aggressively for more energy efficiency in all sectors.

To succeed in achieving its goals for climate mitigation, Japan needs solid incentives to mitigate GHG emissions. For this, all policy options should be taken into account. Japan introduced an explicit carbon tax, the Climate Change Mitigation tax, in 2012 and gradually increased it in three stages to 2016. The tax level is low compared to explicit carbon taxes

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in many other IEA countries, at JPY 289 (USD 2.65) per tonne of CO_2. Carbon pricing in Japan therefore results primarily from excise taxes on energy use. These are high for some sectors (such as transport), but significantly lower for energy use in the industrial sector, or for energy generation. Effective carbon prices are particularly low for coal, as coal is considered a critical resource for energy security. The IEA considers it important for Japan to expand on market-based incentives to reduce CO_2 emissions, including price signals to enhance low-carbon technologies, acknowledging that Japan faces specific circumstances such as a large industrial base and high end-user prices for electricity and natural gas. Nevertheless, the IEA reiterates its view that Japan should consider price signals to enhance low-carbon technologies, which can be implemented in a way that mitigates the acknowledged risks.

As an island state and being located in a region with increasing intensity of typhoon activity, adaptation to climate change needs to be a crucial element of Japan's climate policy. The Japanese government has conducted a series of assessments of how Japan will be affected by climate change. In addition, Japan is strongly committed to constantly increase the resilience of its population, energy infrastructure and economy in general, to natural disasters including earthquakes, tsunamis and extreme weather events. The country has therefore a long history of taking specific measures for disaster prevention and control. These activities can also prove very useful for long-term adaptation to a changing climate and increasing anomalies in climate patterns. Going forward, it will be important to incorporate policies and measures for climate resilience into long-term energy and climate plans to make the energy sector more resilient to climate hazards. The update of the 2015 National Adaptation Plan provides another opportunity to identify and address climate-related risks to the energy sector.

Recommendations

The government of Japan should:

- ☐ Develop long-term pathways to guide Japan's transition to a decarbonised society through business-led disruptive innovation. Revise pathways as technology and framework conditions change and continue to regularly assess whether existing strategies, policies and instruments need to be revised.
- ☐ To support achievement of medium- and long-term decarbonisation goals, further enhance cost-efficient and effective instruments, by providing gradually increasing long-term price signals to enhance low-carbon technologies, covering all emission-intensive energy sources and industrial processes. While doing so, assess options for recycling the additional revenue to address potentially adverse effects on end-user prices and the risk of carbon leakage.
- ☐ Expand the scope of the well-established policies and measures that prepare for natural disasters to include climate change adaptation measures and to make the energy sector more resilient.

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4. Energy efficiency

Key data

(2018)

Total final consumption (TFC): 283.0 Mtoe (oil 51.0%, electricity 28.7%, natural gas 10.3%, coal 7.5%, bioenergy and waste 2.2%, district heat 0.2%, solar 0.1%), -10.0% since 2008

TFC by sector: industry 41.1%, transport 24.9%, services 19.0%, residential 15.0%

TFC per capita: 2.2 toe/capita (IEA average 2.8 toe/capita, IEA median 2.4 toe/capita), -8.8% since 2008

TFC per GDP:* 53 toe/USD million (IEA average: 62 toe/USD million, IEA median 62 toe/USD million), -15.9% since 2008

* Gross domestic product in million USD 2015 prices and purchasing power parity (PPP).

Overview

Japan is among the most energy-efficient countries in the world and has succeeded to improve its efficiency further in recent years. Nationwide energy savings efforts played a major part in coping with the sudden drop in nuclear power generation after the 2011 Fukushima accident, and many of these savings translated into efficiencies in later years, illustrating the large potential for efficiency improvements even in countries with an already low energy intensity. Between 2011 and 2018, total final energy consumption (TFC) decreased by 8%, while gross domestic product (GDP)[1] increased by 8%, resulting in a 15% reduction in the energy intensity[2] of the economy (Figure 4.1).

Energy efficiency improvements have been driven by successful policy, including efficiency standards for products and vehicles, as well as energy management and performance requirements for industry, based on benchmarking. Japan has also set ambitious targets to improve the energy performance of new buildings. The country continues to attribute high priority to efficiency improvements to achieve its energy security and climate goals. The challenge will be to identify where savings potential is the greatest and how this potential can be realised cost-effectively. It will also be important to monitor and evaluate progress towards national targets, in particular in areas where efficiency goals are aspirational or voluntary.

[1] Measured in million USD 2015 prices and purchasing power parity (PPP).

[2] Measured as TFC divided by GDP in million USD 2015 prices and PPP.

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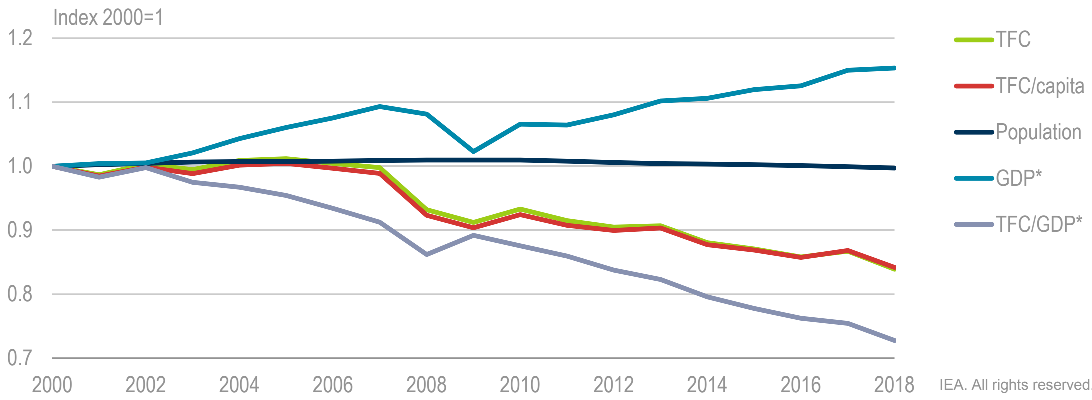
Figure 4.1 Energy consumption and drivers in Japan, 2000-18



While Japan's economy recovered from the 2008/09 financial crisis, energy consumption continued to decrease, lowering the economy's energy intensity.

* GDP data are in million USD 2015 prices and purchasing power parity (PPP).

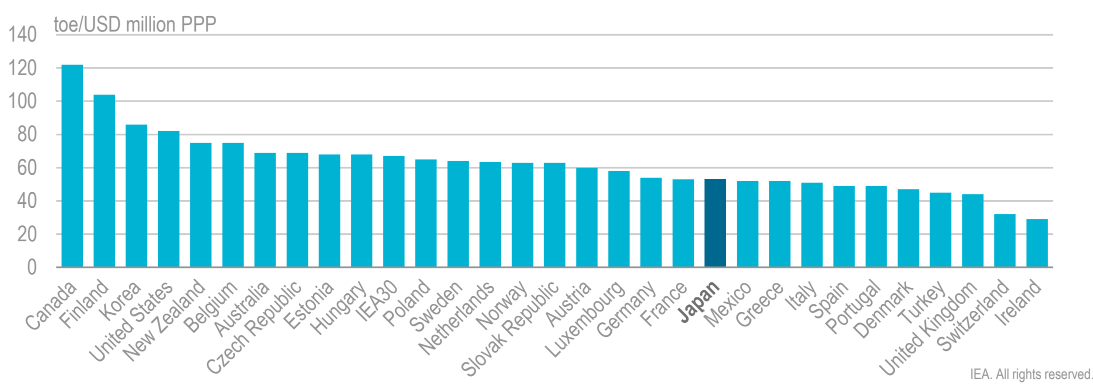
Notes: TFC = total final consumption. GDP = gross domestic product.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Energy intensities

Japan has relatively low energy intensities. In 2018, it consumed 53 tonnes of oil equivalents (toe) per USD million PPP of GDP, which was the 11th-lowest value among IEA member countries (Figure 4.2). Japan's energy intensity per GDP fell by 28% from 2000 to 2018, following a trend comparable to other large IEA economies. As regards per capita consumption, Japan ranks in the middle range among IEA countries. TFC per capita declined by 16% from 2000 to 2018 (IEA, 2020a).

Figure 4.2 Energy intensity in IEA member countries, 2018



Japan's energy intensity, as measured by TFC per GDP, is the eleventh lowest in the IEA.

Notes: toe = tonnes of oil equivalents. Energy intensity in total final consumption, not including the energy transformation sector. GDP data are in million USD 2015 prices and PPP.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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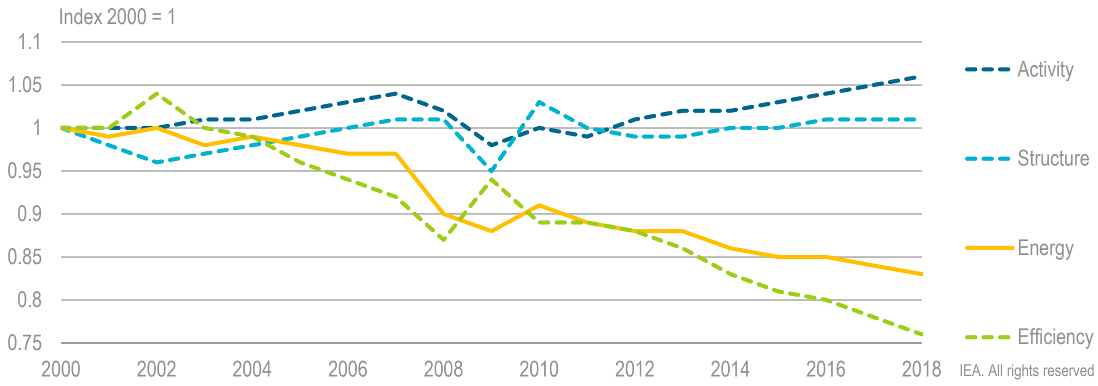
Drivers of Japan's declining energy consumption

Three main factors determine a country's energy consumption level: 1) the level of activity; 2) the structure of activity; and 3) the level of energy efficiency. In the case of Japan, both the level and the structure of activity have increased final energy consumption (Figure 4.3). The level of activity reflects, among other things, rising levels of economic activity, while the structure of activity reflects a shift towards more energy-intensive activities (e.g. increasing floor areas per dwelling in the residential sector). Despite the rise in these two factors, energy consumption has decreased over the past decade, thanks to efficiency improvements. Without efficiency improvements, energy consumption would have been 25% higher in 2017 (IEA, 2020b).

Figure 4.3 Decomposition analysis of Japan's energy consumption, 2000-18



The decline in energy consumption was solely driven by energy efficiency gains.

Source: IEA (2020b), *Energy Efficiency Indicators*, https://www.iea.org/reports/energy-efficiency-indicators.

Energy improvements have been achieved in all consumer categories. The largest energy efficiency gains occurred in the services and industry sectors, resulting in accumulated energy savings of 12 410 petajoule (PJ) in 2000-18 (Figure 4.4). Efficiency gains in the residential and transport sectors were also substantial, with savings amounting to about 5 000 PJ in each category in the same period. Within transport, most savings have been achieved in freight transport.

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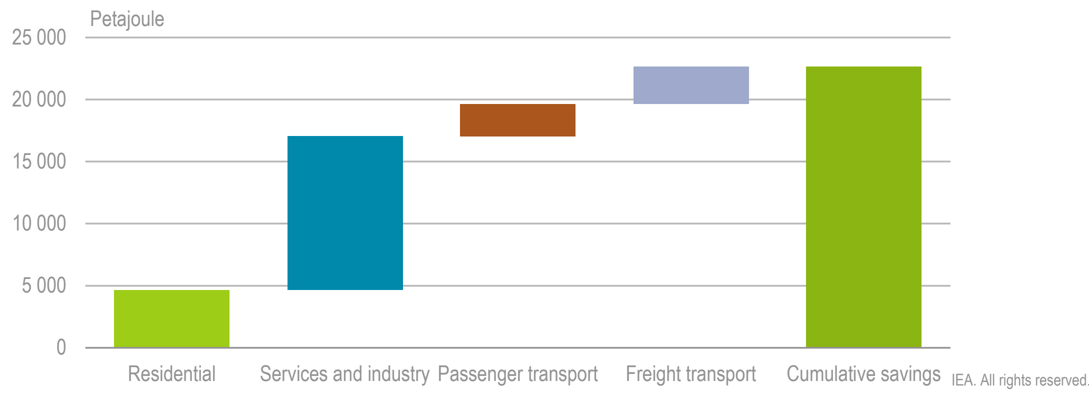
Figure 4.4 Estimated cumulative energy savings by sector in Japan, 2000-18



The largest energy savings since 2000 have resulted from efficiency improvements in the services and industrial sectors.

Source: IEA (2020b), *Energy Efficiency Indicators*, https://www.iea.org/reports/energy-efficiency-indicators.

Energy consumption by sector

Japan's TFC was 283 million tonnes of oil equivalent (Mtoe) in 2018, most of which was consumed in industry (41.1%), followed by transport (24.9%), services (19.0%) and the residential sector (15.0%). Following a drop in energy consumption during the 2007/08 global financial crisis, TFC picked up again in 2010 with the economic recovery. The overall trend, however, has been a steady decline, with a 5% drop in the period of 2009-16. In 2017, TFC increased again (+1.2%), driven by higher consumption in industry and the residential sector, but then dropped again in 2018 to the lowest value since 1990.

Following the 2011 Great East Japan Earthquake and the subsequent nuclear accident at the Fukushima Daiichi Power Plant (hereafter called "the 2011 events"), the government launched a nationwide energy savings movement called *Setsuden* to cope with the sudden drop in nuclear power generation. Households and companies were asked to make extensive efforts to save electricity, for example by shifting industry's operational hours and days, switching off lights, or limiting the use of air conditioners or electric heating in peak hours. There has been no visible rebound effect after the programme ran out in 2015, indicating that consumers have maintained efforts to reduce demand and manage peak loads.

Energy consumption in industry

Japan's industry sector consumed 116 Mtoe in 2018, including non-energy use (34 Mtoe), 6% below the level in 2008 (Figure 4.5). The sector's energy demand dropped by 11% during the 2007/08 global financial crisis, mainly driven by a reduction in oil consumption in chemical industries, and continued to decline over the period 2010-16. In 2017, consumption picked up again, driven by higher demand in some manufacturing sectors as well as the chemical sector, but then fell again in 2018. Oil accounted for 43% of total energy consumption in industry, with the remainder being electricity (25%), coal (18%), natural gas (10%) and biofuels (3%).

Over half of total fuel demand in industry (including non-energy use) is from two industrial sectors, namely the chemical and petrochemical industry, and iron and steel (Figure 4.6).

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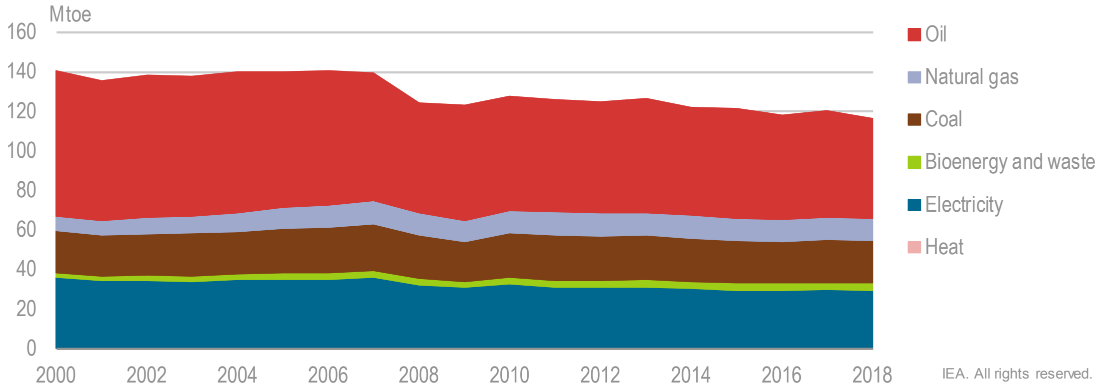
The chemical and petrochemical industry consumes mostly oil products for non-energy purposes, while the iron and steel industry consumes mainly coal, coal products and electricity.

Figure 4.5 Total final consumption in Japanese industry by source, 2000-18

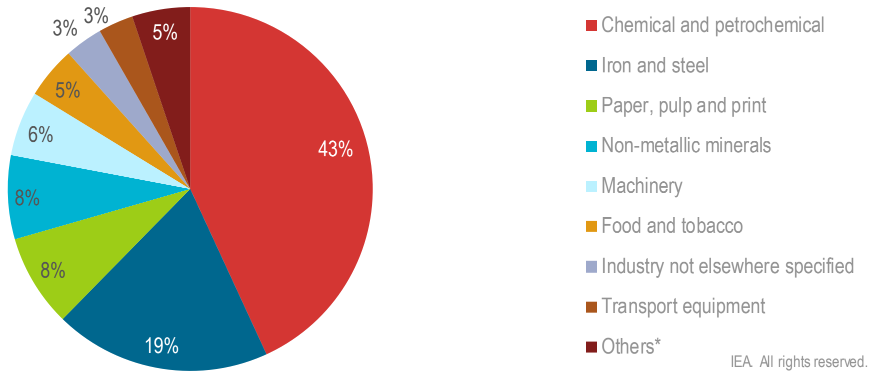


Energy demand in industry has decreased by 6% since 2008, mainly driven by a reduction in oil and electricity consumption.

Notes: Mtoe = million tonnes of oil equivalent. Includes non-energy consumption.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Figure 4.6 Fuel consumption in Japanese industry sectors, 2018



Chemical and petrochemical industries accounted for 43% of total industrial fuel consumption in 2018, over half of which was non-energy consumption of oil products.

* *Others* include non-ferrous metals, mining and quarrying, wood, construction, and textile and leather.

Note: Includes fuel consumption for non-energy use.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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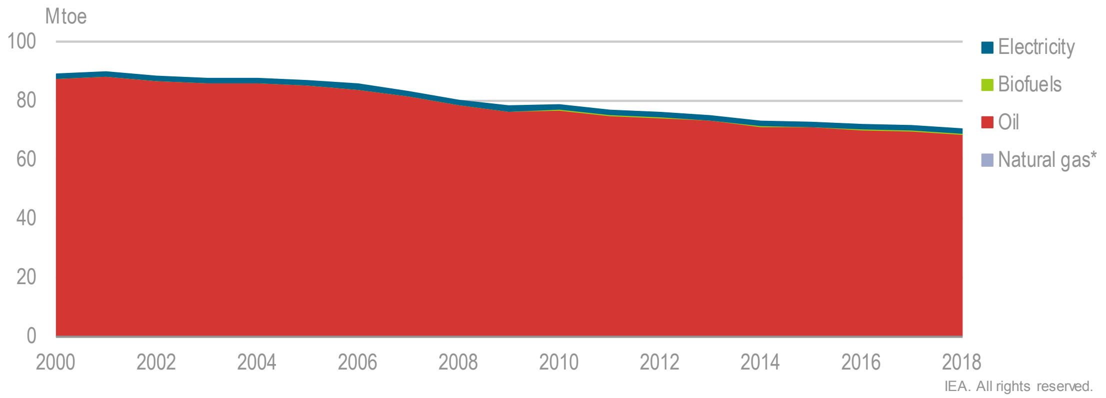
Energy consumption in transport

Energy consumption in transport totalled 70.6 Mtoe in 2018, 12% below the level a decade earlier (Figure 4.7). Transport energy demand has fallen continuously since 2000 with a few exceptions (2002 and 2010), driven partly by stricter efficiency standards for cars. Similar to other countries, the transport sector in Japan highly relies on oil fuels, which accounted for 97% of the sector's total energy demand in 2018, followed by electricity (2%) and biofuels (1%).

Figure 4.7 Total final consumption in transport by source, Japan, 2000-18



Fuel consumption in transport has declined continuously over the last decade.

* Not visible on this scale.

Notes: Mtoe = million tonnes of oil equivalent. The transport sector demand excludes international aviation and navigation.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Road transport accounted for 88% of total domestic transport energy demand in 2018, largely stemming from cars or light trucks (65%) and freight trucks (20%) (Figure 4.8). The remainder is consumed in domestic aviation, navigation and rail, each with small shares. Motor gasoline accounted for 55% of total transport energy demand and diesel for 33%. The remaining oil fuels used in domestic transport were mainly kerosene-type jet fuel for domestic aviation and fuel oil used in domestic navigation. Electricity accounted for 2% of total transport-related energy consumption and is mainly used in Japan's large rail network, plus a minor share in the small but growing fleet of electric vehicles (EVs).

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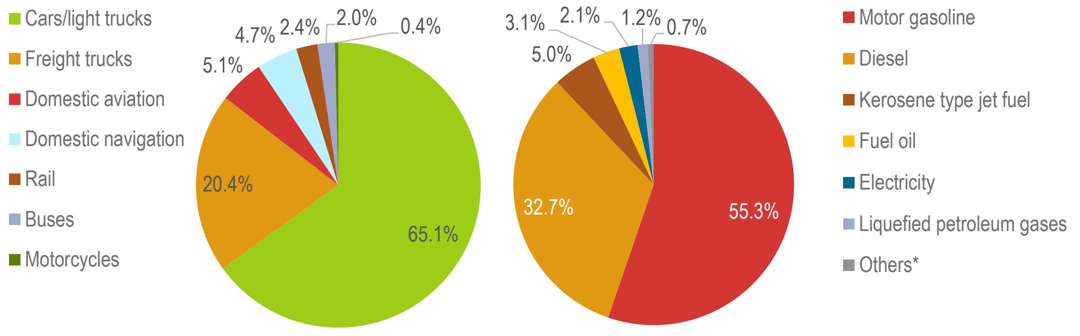
Figure 4.8 Breakdown of energy consumption in domestic transport by mode and fuel, Japan, 2018



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Road transport consumed 88% domestic transport energy demand in 2018. Gasoline is the dominant fuel, accounting for 55% of total energy used in transport, followed by diesel at 33%.

* *Others* include liquefied petroleum gas, natural gas, and coal and coal products.

Note: Not including fuels for international aviation and navigation.

Sources: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics; IEA (2020b), *Energy Efficiency Indicators*, https://www.iea.org/reports/energy-efficiency-indicators.

Energy in the residential and services sector

Energy consumption in the residential and services sector[3] was 96 Mtoe in 2018; the residential sector accounted for 44% and services for 56%. Electricity accounted for half of energy used in these sectors, followed by oil (27%) and natural gas (18%), with only small shares coming from biofuels (2%) and district heat (1%) (Figure 4.9). Despite annual fluctuations due to differences in heating demand, energy consumption in the two sectors declined by 12% from 2008 to 2018.

In the residential sector, most energy demand is consumed for electric appliances (including lighting) (35%) as well as water and space heating (27% and 26%, respectively), with cooking and cooling accounting for the remainder (Figure 4.10). Electricity is the primary source for residential appliances, while space and water heating mainly use oil and gas. In the services sector, space heating accounted for 12% of the sector's total energy demand (in 2018) and space cooling for 14%, with the remainder mostly being electricity use in buildings.

[3] The services sector mainly refers to commercial and public service buildings, but also includes energy demand in agriculture, forestry and fisheries (the three subsectors accounted for 9% of total energy demand in services in 2017).

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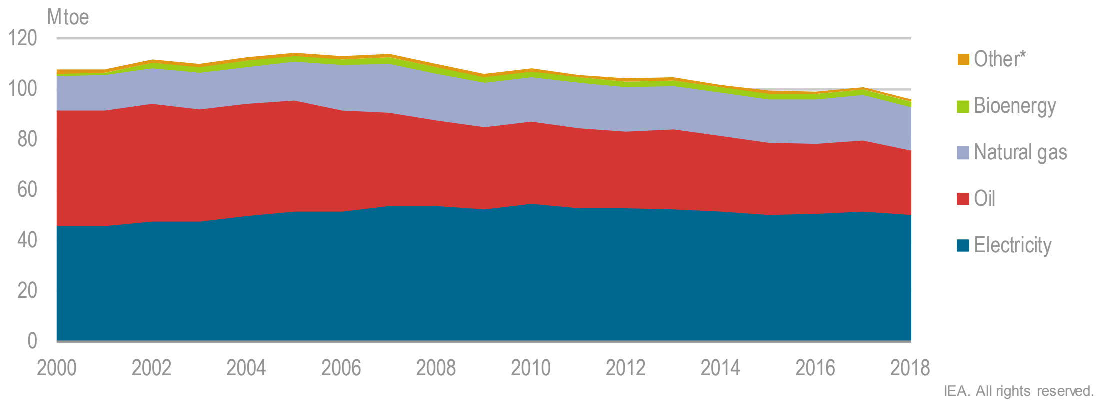
Figure 4.9 Total final consumption in the residential and services sector by source, Japan, 2000-18



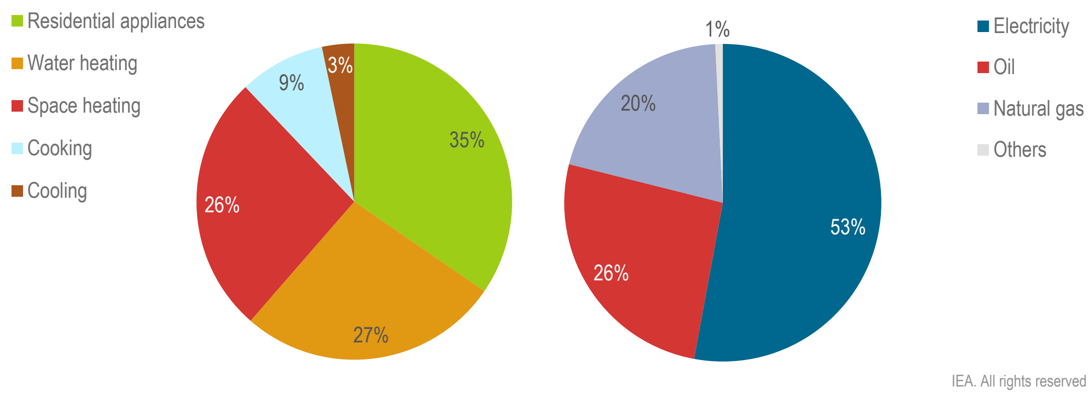
Energy consumption in the residential and service sectors declined by 13% between 2008 and 2018.

**Other* includes coal, geothermal, solar and heat, not visible on the scale.

Notes: Mtoe = million tonnes of oil equivalent. The service sector includes commercial and public services, agriculture, forestry, and fishing.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Figure 4.10 Breakdown of residential energy consumption in Japan by use and fuel, 2018



Residential appliances and water and space heating together accounted for 88% of energy demand in the residential sector in 2018, most of which is covered by electricity and oil.

* *Others* includes coal and district heating.

Sources: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics; IEA (2020b), *Energy Efficiency Indicators*, https://www.iea.org/reports/energy-efficiency-indicators.

Japan's regulatory framework for energy efficiency

The Act on the Rational Use of Energy (Energy Efficiency Act), established in 1979 and last updated in 2018, is the pillar of Japan's energy efficiency policies. It sets energy performance standards as well as energy reporting and management requirements for all sectors. The revision in 2018 aimed at encouraging joint energy efficiency improvements

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among companies and revised the definition of transporters (primarily to better cover e-commerce retailers) to further promote energy savings in freight transport. Buildings' energy efficiency is regulated through the Building Energy Efficiency Act since 2015.

Japan's 5th Strategic Energy Plan (SEP) of 2018 continues to put a strong emphasis on energy efficiency as one of the means to achieve the goals of energy security, economic efficiency and environmental protection. It envisions reducing energy demand by 13% by 2030, compared to a business-as-usual scenario, which equals energy savings of about 50.3 million litres of oil equivalent (43 Mtoe).[4] If the target is achieved, energy demand would decline by 10% compared to 2013 levels. As regards electricity, the 5th SEP expects to reduce demand by 17% compared to the baseline, meaning that electricity demand would remain at 2013 levels, despite economic growth and increasing electrification of the economy (METI, 2018a). The government expects nearly half of energy savings to be delivered by the commercial and residential sectors, with the remainder coming from transport and industry (Table 4.1).

Table 4.1 Japan's expected energy savings to 2030 by sector

	Main measures	2030 target in Mtoe*
Industry	• Commitment to a low-carbon society of four major industries (steel, chemical, cement, pulp and paper) • Strengthened energy management in factories • Development and introduction of innovative technology (e.g. environment-conscious iron manufacturing process and use of CO_2 as raw material) • Introduction of highly efficient facilities (e.g. low-carbon furnaces, high-performance boilers, co-generation)	8.86 (21%)
Transport	• Diffusion of next-generation automobiles and improvement of fuel efficiency • Traffic flow control	13.66 (32%)
Commercial sector	• Energy efficiency in buildings (mandatory standards for new buildings; promotion of net zero-energy buildings) • Introduction of high-efficiency equipment (promotion of efficient lighting) • Building energy management systems (introduction to about half of the buildings) • Promotion of national movement *Setsuden*	10.42 (24%)
Residential sector	• Energy efficiency in houses (mandatory standards for new houses, promotion of net zero-energy buildings) • Introduction of high-efficiency equipment (promotion of efficient lighting) • Home energy management systems (introduction to all houses) • Promotion of national movement *Setsuden*	9.86 (23%)
Total savings		42.76

* Japan's officially stated goal is to achieve energy savings of 50.3 million kilolitres of oil equivalent. One kilolitre of oil equivalent equals 0.85 metric tonnes of oil equivalent.
Source: METI (2018b), *Japanese Industrial Energy Efficiency Best Practices*, www.aceee.org/sites/default/files/pdf/conferences/intl/2018/ito.pdf.

To achieve the 2030 goals, Japan will need to improve the energy intensity of its economy by about 2.5% per year, a rate similar to what had been achieved in the two decades following the oil crisis (1970-90) and well above the improvement made in the past two decades (which averaged about 1.5% per year). The government reports that energy savings of about 10 million litres of oil equivalent (8.5 Mtoe) had already been achieved by 2017. Still, given Japan's already high level of energy efficiency, concerted efforts will

[4] One kilolitre of oil equivalent equals 0.85 metric tonnes of oil equivalent (Mtoe).

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be needed to achieve the ambitious goals for 2030. It will also be important that Japan monitor efficiency improvements in each sector and adjust policies where sectors fall short of their savings potential.

Industry

Energy efficiency measures in the industrial sector have concentrated on two main pillars: the Energy Efficiency Act and voluntary initiatives of Japan's major industry associations. The Energy Efficiency Act obliges businesses with an annual energy consumption of at least 1 500 thousand litres (kL) (in oil equivalent) to establish energy management systems, report yearly energy consumption, and submit mid- and long-term energy efficiency plans. The obligation applies to manufacturing industries as well as offices and franchise companies (such as convenience stores and restaurants) with a consumption of more than 1 500 kL. An estimated 90% of industry and 40% of the commercial sector are covered by the regulation. The Energy Efficiency Act further sets a non-binding target for companies to reduce their average energy consumption by at least 1% per year.

The 2018 revision of the Energy Efficiency Act changed the provisions on reporting requirements, allowing companies and businesses to include efficiency improvements made in other companies if the improvement was gained by their joint effort. This allows, for example, savings from the integration of production processes to be shared. The change aimed at fostering joint investment and consolidation of equipment among energy-intensive companies. Individual companies report a share of the total savings achieved depending on their contribution to the total savings.

Furthermore, the government continued to expand the industry benchmarking under the Energy Efficiency Act. The non-binding benchmarking system sets performance indicators and targets based on the energy efficiency levels of the best-performing companies within the same sub-sector (the top 10-20%). Companies covered by the system are recommended to meet performance targets based on these benchmarks. They are also obliged to submit yearly reports on progress towards the benchmarking indicators as well as the non-binding 1% target. The benchmarking system was originally limited to energy-intensive industries (e.g. iron, steel, power generation, cement, public and paper, oil refining, chemicals), but has been expanded to also include distribution and service industries (e.g. convenience stores, hotels) in 2016, and universities, national government buildings and Pachinko parlors in 2019.[5] As of April 2019, the system covered about 70% of energy consumption in all industries. The government may consider expanding coverage further.

In May 2018, Japan introduced a new tax system for promoting energy efficiency. Businesses that have been ranked as energy-efficient for two consecutive years under the Energy Efficiency Act classification and evaluation scheme can benefit from accelerated depreciation of their energy efficiency investments (30% of the purchase price). The system also foresees a tax credit for small and medium-sized enterprises (7% of the purchase price) (METI, 2020).

In addition to the Energy Efficiency Act's provisions, several industries voluntarily committed themselves to reduce greenhouse gas (GHG) emissions and, as part of that, improve energy efficiency performance under the voluntary Commitment to a Low-Carbon

[5] Pachinko is a Japanese pinball game.

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Society initiative organised by the Japan Business Federation Keidanren.[6] Participating companies set GHG emissions reduction targets for 2020 and 2030, many of which are linked to efficiency improvements. Progress towards the voluntary targets is reviewed both by Keidanren and the government on an annual basis (see Chapter 3).

The combination of energy management requirements, efficiency targets under the benchmarking system and voluntary commitments has led to energy efficiency improvements of more than 1% for some industrial sub-sectors. However, further improvements are needed to achieve the ambitious goal of reducing industrial energy consumption by 10 million litres of oil equivalent by 2030. The government should continue to regularly review progress of industries' energy savings performance and ensure that both the benchmarking system and industries' voluntary commitments are ambitious enough to deliver substantial energy savings. In 2018, only one-quarter of industrial companies complied with the benchmarks set in 2009 or 2010 (METI, 2019a).

Japan may also consider strengthening compliance promotion and enforcement of its performance targets. Enforcement in Japan is designed to guide operators to comply with the requirements, but not to impose penalties. For example, when the government sees sizable lack of efforts with respect to the 1% target or the benchmarks, it usually takes action in the form of recommendations and public disclosures. It can also issue orders and, if these are not followed, fines, but they are limited to JYP 1 million (USD 9 500), which is likely too low to act as an effective deterrent.

Residential and commercial sector

In the residential and commercial sector, energy efficiency measures are largely concentrated on improving the energy performance of buildings. In July 2015, Japan passed the Act on the Improvement of Energy Consumption Performance of Buildings (Building Energy Efficiency Act), which obliges new large buildings to meet energy efficiency standards and incentivises efficiency improvements through labelling. Japan also promotes the construction of zero-energy buildings. Energy improvements in appliances and equipment have mainly been driven by the long-standing and successful Top Runner Program (see below). In addition, Japan has set targets to reach 100% efficient LED lights, install 5.3 million residential fuel cells and equip 90% of households with efficient water heating systems by 2030 (METI, 2019b).

Thanks to these measures, the residential and commercial sectors have seen considerable improvements in energy efficiency over the past decade. In the residential sector, per capita energy demand declined by 8% over 2007-17. This was partly driven by efficiency improvements in heating and residential appliances. Energy use for space heating per dwelling, for example, declined by 20% from 2007 to 2017, while demand for water heating and residential appliances per dwelling decreased by 22% and 19%, respectively. In the services sector, space heating and cooling (per square metre) improved by 32% and 18%, respectively (IEA, 2020b).

Structure of the housing and buildings stock

The number of occupied dwellings (apartments and houses) increased from 49.6 million to 53.7 million between 2008 and 2018, even though the population declined by 1% over

[6] Annex A provides detailed information about organisations and agencies with responsibilities related to the energy sector.

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the same period. The average floor space is 93 squaremetre (m^2) per dwelling, resulting in a total residential floor area of nearly 5 billion m^2 (Statistics Bureau of Japan, 2018). In addition, Japan has around 750 000 commercial buildings with a total floor area of 1.1 billion m^2 (IEA, 2016).

The number of new dwellings constructed each year has been increasing, and reached 926 000 new dwelling units in 2019 (Statistics Japan, 2018). The relatively high level of building destruction and construction means that the building stock is relatively new and opens opportunities for efficiency improvements. Almost two-thirds of occupied dwellings (61%) are owner occupied, which minimises the risk of principal-agent challenges that often discourage energy efficiency investment and behaviour in rented dwellings. At the same time, a relatively large number of dwellings are unoccupied (8.6 million, or 14% of the total). This reflects the dynamic construction of new units, combined with a declining population as well as migration from rural to urban areas.

Building standards and labelling

The 2015 Building Energy Efficiency Act introduced energy efficiency standards for new buildings, which are being implemented gradually. Mandatory standards were first implemented for new large-scale commercial buildings (with a floor space greater than 2 000 m^2) in 2017 and will be expanded to medium-sized commercial buildings (with a floor space above 300 m^2) as of April 2021. Medium-scale residential buildings are exempt from the requirement, but constructors need to report on their energy-saving performance. Small-scale buildings (with a surface less than 300 m^2) will need to report on conformity starting in April 2021.

The introduction of mandatory standards for large- and medium-sized commercial buildings is a major improvement, as the standards were previously not mandatory, resulting in less than half of new buildings complying with them (with compliance rates reaching 36%, 44% and 51%, respectively, for large-, medium- and small-sized buildings) (MLIT, 2017). The government expects full compliance with the standards to bring about energy savings in the order of 2.8 Mtoe by 2030 (equalling 7% of the total energy savings aimed for by 2030) (METI, 2019c). Depending on the improvement of compliance rates, the government could make the standards mandatory for all buildings and houses. There may also be potential to strengthen the standards for residential buildings, given they are the same as the previous 1999 standards and less stringent than standards in other IEA countries such as France, Germany and the United States (CAT, 2020).

The Buildings Energy Efficiency Act also regulates that all new constructions and retrofits may receive certification if they conform with certain efficiency standards. Certified buildings may then receive certain benefits, such as eased restrictions on building size (allowing developers to construct buildings with more floor space). As of late 2019, nearly 93 000 buildings had been certified.

To promote energy efficiency of existing buildings, Japan provides subsidies for renovations and refurbishments (e.g. for insulation retrofits). However, it lacks a comprehensive strategy to promote efficiency improvements in the existing building stock. The labelling and incentives system introduced by the Building Energy Efficiency Act is welcome, as it will help strengthen information and transparency on the energy-saving performance of buildings. Making the display of a building's energy performance mandatory, for example when it is rented or sold, could be a next step to incentivise retrofitting and renovation further.

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Zero-energy buildings

Japan's 4th SEP (2014) set the ambitious goal that all new constructions should, on average, be net zero-energy houses (ZEHs) or net zero-energy buildings (ZEBs) by 2030. The goal was confirmed in the 5th SEP in 2018. Newly constructed public buildings and half of newly constructed detached houses should already be net-zero energy by 2020, a target which, however, will be difficult to meet. ZEBs are defined as buildings that generate energy and reduce net energy consumption by at least 50% compared to an ordinary building through improved heat insulation, high-efficiency equipment (for air conditioning, hot water supply, lighting and elevators) as well as natural ventilation, solar shading and daylight use. ZEHs are defined as residential buildings that have an annual net energy consumption of more or less zero while maintaining a comfortable living environment.[7]

The buildings standards applied to ZEHs and ZEBs are more stringent than what is required under the Building Energy Efficiency Act. Insulation standards for ZEHs, for example, are 15-45% more stringent than those stipulated in the act.[8]

To promote ZEBs, METI has developed guidelines that explain, define and provide model cases of such buildings for certain sectors (such as schools and hospitals). It also provides subsidies both for ZEHs and ZEBs. In 2019, more than 9 000 houses (nearly 20% of all ZEHs constructed that year) benefited from these subsidies. By the end of 2018, the number of ZEBs and ZEHs reached 70 and 56 000, respectively, or 0.1% and 13% of total buildings/houses constructed.

The Top Runner Program

The Top Runner Program has been Japan's main tool to stimulate efficiency improvements in appliances. It also covers vehicles (see the section on transport below) and, since 2013, building materials. The programme sets mandatory energy efficiency targets based on the most energy-efficient technology available on the market. Companies (both manufacturers and importers) then need to meet these targets within three to ten years, depending on the nature of the product. The programme has been highly successful in delivering energy savings. Efficiency of air conditioners, for example, improved by 28% between 2001 and 2016, while that of TV sets and electric refrigerators improved by 71% and 52%, respectively (METI, 2018a). Looking forward, the government expects that the widespread adoption of efficient water heating systems will result in energy savings of 2.3 Mtoe by 2030, equivalent to 5% of the overall savings aimed for by then (METI, 2019c).

The programme's coverage has been expanded over time. As the IEA recommended in its 2016 in-depth review, Japan included new commercial products in the programme, such as multi-function devices and printers. As of February 2020, the programme had covered 32 product categories (Table 4.2), or 70% of total energy consumption of appliances in the residential sector.

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[7] The regulation recognises that high-rise and large-scale buildings have limited rooftop areas and thus limited energy generation potential. Buildings that achieve energy savings of at least 50% but cannot generate energy are considered "ZEB ready". Buildings that achieve net energy savings of at least 75% (i.e. including generated energy) are considered "nearly ZEB", while those achieving net energy savings of 100% or more are granted "ZEB" status.

[8] Insulation standard refers to the average heat transmission coefficient of the building envelope. Like in the Building Energy Efficiency Act, these standards are differentiated by region to account for climatic differences.

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Table 4.2 Equipment and material covered under the Top Runner Program

Passenger vehicles	Space heaters	Switching units
Air conditioners	Gas cooking appliances	Multifunction devices
Lighting equipment	Gas water heaters	Printers
TV sets	Oil water heaters	Electric water heaters
Copying machines	Electric toilet seats	AC motors
Computers	Vending machines	Lamps
Magnetic disk units	Transformers	Showcase
Freight vehicles	Electric rice cookers	Insulation materials
Video cassette recorders	Microwave ovens	Sashes
Electrical refrigerators	DVD recorders	Multi-paned glazing
Electrical freezers	Routers	

Source: Information provided by the Ministry of Economy, Trade and Industry during the review visit in February 2020.

Energy management systems

The government continues to promote the use of home energy management systems and business energy management systems for offices. These systems provide real-time information on energy consumption and costs and allow for controlling connected devices automatically (including, for example, major electrical appliances, lighting, and heating and air conditioning systems). Deployment of these systems has been supported as early as the early 2000s, both through subsidies and large-scale demonstration projects. As of early 2020, home energy management systems had been installed in more than 500 000 homes (or 1% of dwellings) and about 16% of all buildings were equipped with business energy management systems.

Japan envisions to connect home energy management systems and business energy management systems with smart meters, local energy generation equipment (e.g. from solar photovoltaic panels) and storage batteries (e.g. in the form of electric vehicles). The ultimate goal is to develop “smart houses and buildings”, in which all devices are connected with one another and in which energy consumption is optimised through the application of artificial intelligence. The expansion of smart meters (see Chapter 7), electric vehicles and advancement of Internet of Things technology[9] are expected to increase the market for smart energy management systems.

Transport

Fuel economy standards

Energy efficiency in transport has mainly been encouraged through performance standards under the Top Runner Program. For each vehicle type and weight class, the model with the best fuel efficiency is designated as the “top runner”, and all other vehicles in the same class are required to surpass that model’s level within three to ten years. If a company fails to meet the fuel efficiency standards, METI can make recommendations, publish the company name, make orders and, in the case of non-compliance, issue fines

[9] The Internet of Things refers to the interconnection of computing devices embedded in everyday objects via the Internet, enabling them to send and receive data.

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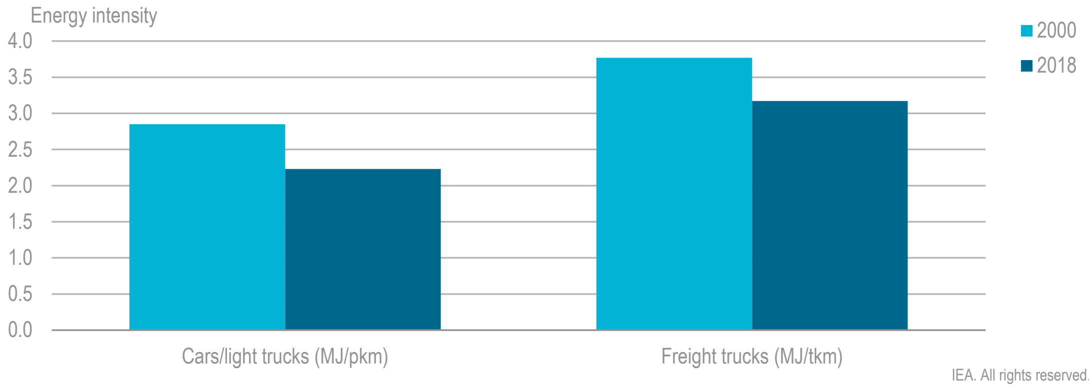
of up to JPY 1 million (USD 9 174)[10]. Vehicles that exceed fuel efficiency standards benefit from reduced vehicle purchase and ownership taxes (JAMA, 2019).

Thanks to the standards, the energy intensity of passenger cars and light trucks has decreased by 22% since 2000, from 2.85 MJ/pkm (megajoule per passenger-kilometre) to 2.23 MJ/pkm in 2018. Freight trucks' fuel intensity (in energy use per tonne kilometre) was reduced by 16% over the same period (Figure 4.11).

In 2019, Japan introduced new fuel economy standards both for light-duty vehicles and for heavy-duty vehicles running on diesel. As regards light-duty vehicles, the new standard is set at an average of 25.4 kilometres per litre for 2030 (METI, 2019d), which implies an improvement of 51% compared to the 2015 standard (16.8 km/L), or of 25% compared to the 2020 standard (20.3 km/L). The new standards are welcome, in particular because the 2020 standards for light-duty vehicles (defined in 2009) had already been reached in 2013 and the average fuel economy of new passenger cars of internal combustion engine vehicles has hardly improved since (JAMA, 2019). Fuel economy standards are also gaining importance as consumer preferences shift towards larger vehicles (as in many countries, the number of SUV sales has been increasing in recent years) (IEA, 2017). The new standard is less stringent than the 2030 standards in the European Union, but it is ahead of other major vehicle markets such as the People's Republic of China (hereafter "China") and the United States (ICCT, 2019a).[11]

Figure 4.11 Energy intensity in road transport by mode, Japan, 2000 and 2018



Energy intensity for cars and light trucks decreased by 22% from 2000 to 2018, while that of freight trucks decreased by 16%.

Notes: Energy intensity of passenger vehicles is in megajoule per passenger-kilometre (MJ/pkm), while that of freight trucks in megajoule per tonne-kilometre (MJ/tkm).

Source: IEA (2020b), *Energy Efficiency Indicators*, https://www.iea.org/reports/energy-efficiency-indicators.

[10] USD 1 = JPY 109.

[11] The comparison is based on analysis that translates the standard value (i.e. the fuel efficiency mandates or emissions limits in the case of the European Union) into comparable values and accounts for the impacts of differences in test cycles.

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In addition to being more stringent, the new standard for light-duty vehicles also improves and expands the scope of the previous regulation. While the 2020 standard covers gasoline, diesel, hybrid electric vehicles that cannot plug-in (HEVs) and liquefied petroleum gas vehicles only, the 2030 standard also includes plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).

Accordingly, the new standard in Japan is based on a “well-to-wheel” rather than a “tank-to-wheel” approach, meaning that it not only considers the vehicle’s efficiency when running, but also the efficiency in the production of electricity (see Chapter 3). Electric vehicles are required to show the driving range in kilometres and energy consumption in watt-hours per kilometre in charge-depleting mode, while plug-in electric vehicles are required to display the driving range in kilometre in charge-depleting mode and the fuel economy in watthours per kilometre in charge-sustaining mode and charge-depleting mode. Moreover, the new regulation changes the test cycle to the Worldwide Harmonized Light Vehicle Test Procedure, and replaces the bin-based targets for different vehicle weights by a linear curve with a minimum fuel economy floor for the heaviest vehicles (ICCT, 2019a).

As regards heavy-duty vehicles, the 2019 regulation requires new trucks and buses with a total weight of more than 3.5 tonnes to have a fuel economy of 7.63 km/L by 2025. This implies an efficiency improvement of 13% relative to the 2015 standard (METI, 2019c). While Japan was a pioneer in adopting fuel efficiency standards for heavy-duty vehicles back in 2005, the stringency of its regulations started to fall behind those in countries that have adopted standards since (i.e. Canada, China, the European Union, India and the United States). For tractor trucks, for example, Japan’s requirements in 2015 and 2025 – starting from a 2002 baseline – translate to annual improvements of around 1%, well below the annual efficiency gains in the United States, China and the EU (which range from 3% to 5% per year) (ICCT, 2019b).

Energy-efficient next-generation vehicles

Japan set the ambitious target to increase the market share of “next-generation vehicles” among new passenger car sales to between 50% and 70% by 2030 (METI, 2018c). Japan defines next-generation vehicles to include HEVs, BEVs, PHEVs, fuel cell electric vehicles (FCEVs) and “clean” diesel vehicles. The market share of BEVs and PHEVs is still small (around 1% of new car registrations in 2018), but is expected to increase to more than 20% of car sales in 2030 (Table 4.3). Japan expects the increased sales of next-generation vehicles to bring about savings of about 8 Mtoe by 2030, which is equivalent to 20% of Japan’s overall savings target to 2030 (METI, 2019c).

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Table 4.3 Long-term goal and strategy of Japan's automotive industry for tackling global climate change

Sector	Market share in 2018	2030 target	2050 goal
Hybrid electric vehicles	32.6%	30-40%	• 100% xEVs* • 80% reduction of greenhouse gas emissions from domestic vehicle manufactures • Innovation of vehicle use
Battery electric vehicles and plug-in hybrid electric vehicles	0.5% 0.6%	20-30%	
Fuel cell electric vehicles	0.01%	3%	
Clean diesel vehicles	4.0%	5-10%	
Total	**37.8%**	**50-70%**	

* The term xEVs is used in Japan and includes hybried electric vehicles, battery electric vehicles, plug-in hybrid electric vehicles and fuel cell electric vehicles.

Notes: Market share refers to the share in new passenger car registrations (total in 2018: 4.4 million). Clean diesel vehicles refer to vehicles conforming to exhaust emission standards of 2009 and thereafter. 2030 targets per sub-category are indicative and do not add up to the total.

Sources: METI (2018c), *Long-Term Goal and Strategy of Japan's Automotive Industry for Tackling Global Climate Change*, www.meti.go.jp/english/press/2018/pdf/0831_003a.pdf; JAMA (2019), *The Motor Industry of Japan*, www.jama.or.jp/industry/ebook/bookdata_e/book.pdf.

The roll-out of new generation vehicles has been supported through tax incentives, purchase subsidies and subsidies for the installation of charging infrastructure for a number of years. Japan also envisions to develop next-generation vehicles and associated infrastructure for the commercial vehicle segment (see Chapter 3). Japanese companies have also started developing boats powered by two hydrogen fuel cells. Energy efficiency in the conventional shipping sector is promoted through tax reductions and soft credits as well as demonstration of innovative energy-saving shipping technology.

District heating and co-generation[12]

District heating and cooling (DHC) is operated in 132 districts, mostly in densely populated ones; another 4 systems are planned to be developed. The overall role of district heating is, however, still limited. In 2017, district heating accounted for less than 0.2% of TFC (around 0.5 Mtoe). The widespread use of air conditioning in Japan's urban centres makes DHC a possibly attractive option to increase overall system efficiency and facilitate the large-scale uptake of variable renewable energy via thermal energy storage. To date, however, natural gas dominates the DHC networks. The switch to biomass is limited due to space constraints in relatively small systems, high costs and an underdeveloped local fuel supply chain (see Chapter 5). Some DHC developments feature co-generation.

The 2018 SEP recognises co-generation as a means to enhance efficiency in heat utilisation while also facilitating the deployment of renewable energy, managing peak demand, diversifying the power mix and enhancing resilience to disasters. Co-generation is increasing, in part due to the rise in electricity prices after the 2011 Fukushima events, but further efforts are needed to move from small installations in individual buildings and factories to large-scale installations (METI, 2018a). The IEA 2016 in-depth review noted

[12] Co-generation refers to the combined production of heat and power.

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that a possible barrier to enhanced uptake of co-generation in DHC networks is the lack of an appropriate remuneration framework for the sale of excess electricity, such as a liquid wholesale spot market (IEA, 2016).

Assessment

Japan continues to do well regarding energy efficiency. It improved its energy intensity in terms of TFC per unit of GDP by 27% between 2000 and 2018. This ranks Japan with the 11th-lowest energy intensity among IEA countries, and 14% below the IEA median in 2018. In terms of TFC per capita, Japan ranks around the IEA median.

The 5th SEP continues to assign a high priority to energy efficiency and advances have been made since the last in-depth review in 2016. The 5th SEP aims to reduce energy demand by 50.3 million litres of oil equivalent by 2030; if this saving is realised, energy demand will decline by 10% compared to 2013. Between 2013 and 2017, energy demand had already declined by about 10 million litres of oil equivalent, which shows that the measures being taken are effective. Nearly half of the energy savings to 2030 are expected to be obtained in the commercial and residential sector, followed by transport and industry.

The industry sector is the largest user of energy in Japan and has made continuous improvement in energy use. This is a result of requirements under the Energy Efficiency Act for companies to establish energy management systems and to report yearly on energy consumption, and to meet energy efficiency targets based on benchmarking. The act also has a non-binding target for industry to improve its energy efficiency by 1% per year. Energy efficiency improvements are also a result of a range of subsidies and fiscal incentives for investment as well as voluntary commitments made by industries under the Keidanren voluntary action plans.

The fact that companies continuously conduct energy mapping of their operations is an important and long-lasting way of enabling energy efficiency improvements. However, to improve energy efficiency by 1% a year is not an ambitious target for companies that regularly renew their equipment and can even act as a brake to achieve further improvements. In addition, nearly three-quarters of industrial companies do not yet comply with the benchmarks set in 2009 and 2010. It is therefore important that the effectiveness of the system is regularly evaluated. Making targets mandatory and enhancing enforcement action (for example through higher fines) could be considered to increase the level of compliance. The government could also consider extending the coverage of its reporting requirements and benchmarks to other sectors.

The Top Runner Program is successfully and continuously leading toward more energy-efficient products and materials, affecting energy consumption in sectors beyond industry. The programme covers 32 products, stretching from improved fuel economy for vehicles to energy-using products. Products in the programme cover about 70% of household total energy consumption for appliances. As recommended in the 2016 in-depth review, product coverage has been extended and now also includes electric refrigerators and freezers, multi-function devices, printers, electric water heaters (heat pump water heaters) and LEDs.

The Top Runner Program is an important tool in the continuous development of energy-efficient products that will result in energy savings in all sectors. Japan is encouraged to continue to develop and expand it.

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Energy consumption has declined in the commercial and residential sectors over the past decade. In recent years, the decline is mainly due to the use of energy-efficient products within the Top Runner Program, the implementation of energy management, and the promotion of energy-efficient houses and buildings.

The last in-depth review highlighted the buildings sector's considerable potential for additional energy savings. Mandatory energy efficiency standards for new large-scale buildings were implemented in 2017, and will be expanded to medium-scale buildings in 2021. Smaller and residential buildings only have an obligation to take note of the standard, and to try to comply with energy efficiency standards. This is a step toward more energy-efficient buildings, and at the same time provides opportunities for the government to enhance efficiency by introducing mandatory elements. The government should closely monitor the degree of voluntary adoption of small buildings and consider making measures mandatory, if needed.

The 5th SEP sets goals to promote net zero-energy houses and net zero-energy buildings. By 2030, all new constructions should be either ZEH or ZEB. This will have a large impact on the housing and building stock for decades to come. As Japan will likely miss its intermediate target of having half of newly constructed residential buildings net zero energy by 2020, continued efforts are needed to accelerate their deployment. Building regulations and standards, labelling, and goals for ZEHs and ZEBs together will make all new buildings more efficient. Compliance with these regulations will need to be monitored closely. The energy efficiency of the existing building stock is affected when renovating and more energy-efficient equipment and building materials are used through the Top Runner Program.

Energy consumption in the transport sector has declined substantially since the beginning of the 2000s. Under the Top Runner Program, the fuel efficiency of vehicles has improved significantly, and new standards are even tougher. For example, a specific type of passenger car should have increased fuel efficiency from 13.6 km/L in 2004 to 16.8 km/L in 2015. The target for 2030 is 25.4 km/L. As one of the first countries globally, Japan also introduced efficiency targets for plug-in hybrid and battery electric passenger cars, which are expected to reach a market share of 20-30% by 2030. Japan has also implemented actions to practice eco-driving, improve logistics and traffic flow, develop electric and hydrogen-based solutions for heavy goods transport, and improve efficiency for ships, which shows an integrated approach to further reduce energy consumption.

The government provides subsidies and tax incentives for next-generation vehicles (HEVs, PHEVs, BEVs, FECV and clean diesel vehicles), which had a 38% market share in the new car market in Japan in 2018. The ambitious policy target set for 2030 is to increase this share to 50-70%.

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Recommendations

The government of Japan should:

- ☐ Consider expanding the successful benchmarking system to more industry and commercial sectors.
- ☐ Evaluate the effectiveness of the non-binding target in industry to improve energy efficiency by 1% per year and consider enhancing the target.
- ☐ Investigate what effect the increased share of pure electric and plug-in hybrid vehicles will have on electricity demand and grid integration, considering the target of having these vehicles cover 20-30% of new sales in 2030.
- ☐ Strengthen and expand the highly successful Top Runner Program to cover more products.
- ☐ Design a policy to accelerate the renovation rate of existing buildings.

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ENERGY SYSTEM TRANSFORMATION

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5. Renewable energy

Key data

(2018/19 estimated)

Renewables in total final energy consumption (TFEC) (2018): 18.4 Mtoe/7.4% of TFEC (hydro 2.5%, bioenergy 2.5%, solar 2.1%, wind 0.2%, geothermal 0.1%)

IEA median (2018): 15.5% of TFEC

Renewables in electricity generation (2019): 184.4 TWh/18.6% of electricity generation (hydro 80.6 TWh, solar 74.1 TWh, bioenergy* 19.4 TWh, wind 7.5 TWh, geothermal 2.8 TWh)

IEA median (2019): 37.7% of electricity generation

* Includes bioenergy: primary solid biofuels, renewable municipal waste, liquid biofuels and biogas; excludes non-renewable municipal waste and industrial waste.

Overview

In 2014, Japan set a target of achieving 13-14% of renewable energy in its total primary energy supply (TPES) by 2030. In order to achieve this target, it also introduced technology-specific targets for electricity generation from solar photovoltaics (PV), wind, bioenergy, hydropower and geothermal to reach a goal of 22-24% of renewables in the electricity mix by 2030.

Since the introduction of Japan's 2030 target, the share of renewables in TPES has increased, from around 5% in 2014 to 8% in 2019. This growth was primarily driven by the expansion of renewables – mainly solar – in the electricity sector, thanks to a feed-in tariff (FIT) system introduced in 2012. From 2012 to 2018, renewable electricity capacity almost doubled, with solar PV representing 94% of this expansion. In 2019, renewable energy accounted for 19% of total electricity generation, compared to 10% in 2012.

Supply and demand

Renewable energy in Japan is mostly consumed in the form of electricity, with smaller amounts being used directly for heating purposes or in the transport sector (Figure 5.1). Three-quarters of renewable energy in total final energy consumption (TFEC) is consumed as renewable electricity, 60% of which in buildings and 35% in industry. Over 2008-18, the share of renewables in electricity more than doubled, while it remained stable in the heat sector and experienced a slight increase in the transport sector. Electricity, however, only accounted for 25% of Japan's energy demand in 2018, while the heat and transport sectors covered the rest.

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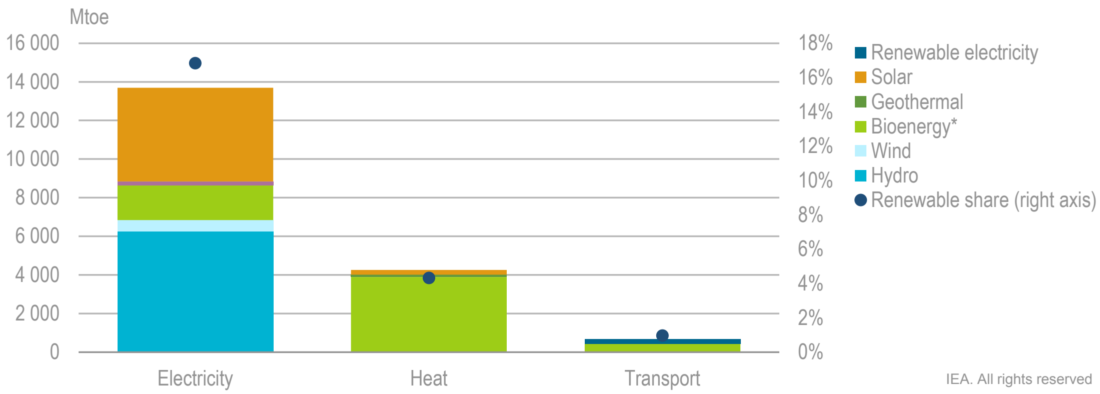
Figure 5.1 Renewable energy in total final energy consumption by source and energy carrier, Japan, 2018



Most of Japan's renewable energy comes from the electricity sector, while the share of renewable energy remains low in heat and transport.

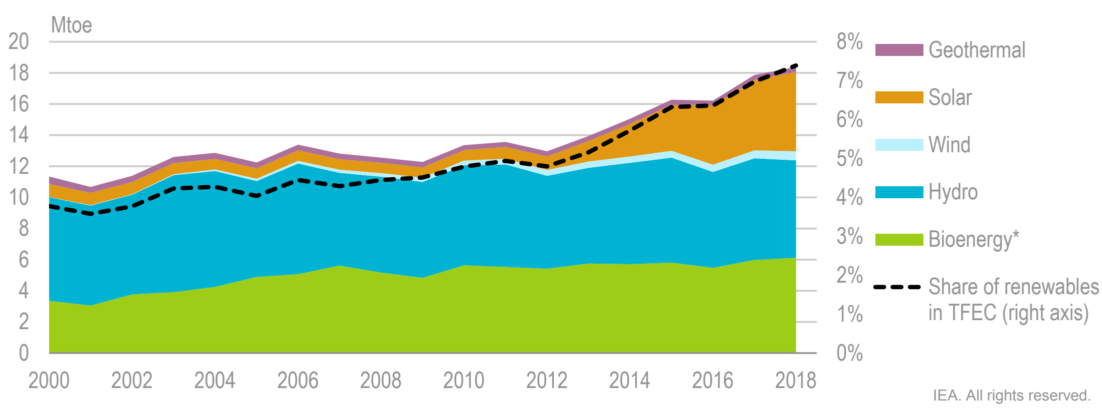
* *Bioenergy* does not include energy from non-renewable waste.

Notes: Mtoe = million tonnes of oil equivalent. Heat includes direct use of renewable energy and renewable district heating in industry, residential total final energy consumption (TFEC), service buildings and agriculture, forestry, and fishing. Electricity refers to final electricity consumption in TFEC, with the breakdown by fuel based on domestic electricity generation. Electricity used for heating is included under electricity due to limitations in statistical data collection.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Hydropower and bioenergy are the two largest sources of renewable energy in Japan, together accounting for 67% of total renewable energy in TFEC in 2018 (Figure 5.2). Hydropower accounts for almost half of Japan's overall renewable electricity generation; however, its output has been stable over the last decade, as the country has already developed most of the feasible sites.

Figure 5.2 Renewable energy in total final energy consumption by source, Japan, 2000-18



Renewable energy accounted for 7% of TFEC in 2018, up from 4% in 2008, after a rapid increase in solar PV and stable supply of hydro and bioenergy.

* *Bioenergy* does not include energy from non-renewable waste.

Notes: Mtoe = million tonnes of oil equivalent. TFEC = total final energy consumption.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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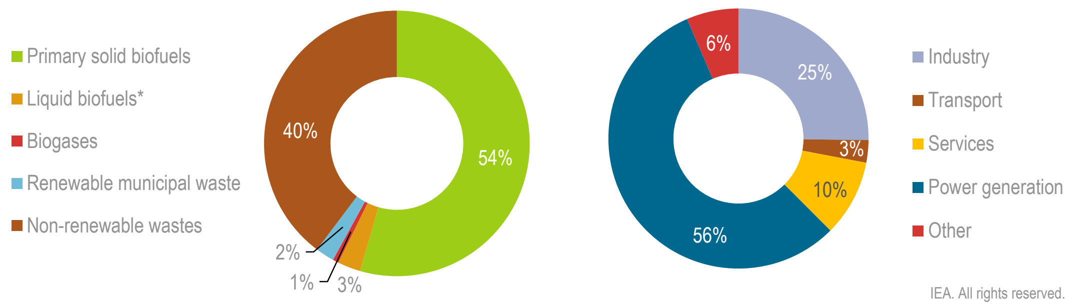
More than half of the bioenergy consumed in Japan is primary solid biofuels (Figure 5.3). Roughly half of those are used in power generation via co-firing with coal and in dedicated biomass plants. The other half is used as a direct energy source, mainly in the pulp and paper industry. Only 3% of biofuels are used in transport, in the form of ethanol.

Figure 5.3 Biofuels and waste supply and consumption, Japan, 2018



Primary solid biofuels used in industry and power generation account for most of Japan's bioenergy.

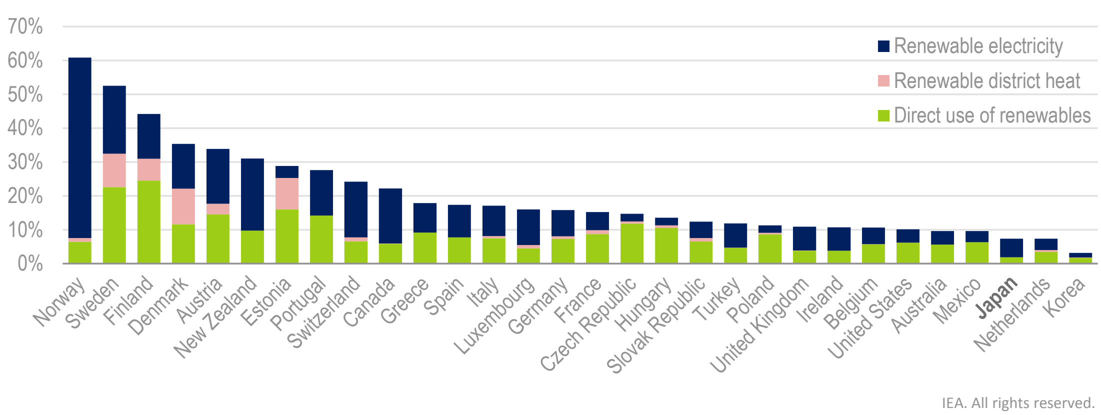
* Includes bio-gasoline and biodiesel.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Since 2008, solar PV output has increased rapidly and produced a quarter of all renewable energy consumed in 2018. The rest was smaller shares of wind power, geothermal power, and direct use of solar and geothermal heat. In total, renewable energy accounted for around 7% of TFEC in 2018, up from around 4% a decade earlier.

In an international comparison, Japan still consumes small amounts of renewable energy. In 2018, it had the third-lowest share of renewable energy in TFEC among IEA member countries and the second-lowest for bioenergy (Figure 5.4).

Figure 5.4 Renewable energy as share of total final energy consumption in IEA member countries, 2018



Japan's share of renewables in TFEC ranked the third-lowest among IEA countries in 2017.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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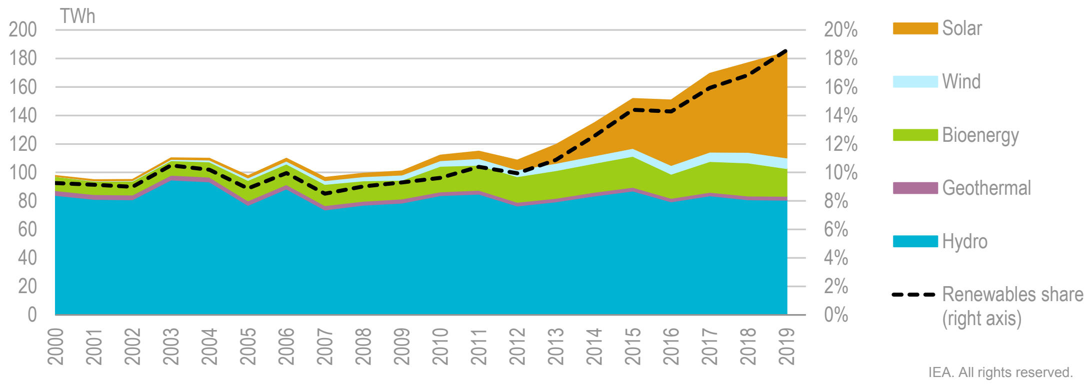
Electricity from renewable energy

Between 2012 and 2019, renewable electricity generation grew by 70% and solar power accounted for almost 90% of this growth (IEA, 2020a), while a modest contribution came from wind power (Figure 5.5). The share of renewable energy in total power generation increased from 10% in 2012 to almost 19% in 2019. The growth has helped to compensate for the drop in nuclear power after the 2011 Great East Japan Earthquake and the subsequent nuclear accident at the Fukushima Daiichi Power Plant (hereafter called "the 2011 events").

Despite its growing share of renewables in electricity generation, when compared to the other IEA countries, Japan remains in the bottom half (Figure 5.6). However, this is significantly higher than the ranking for renewables in TFEC, which shows the relative importance of electricity in Japan's renewable energy supply.

Figure 5.5 Renewable energy in electricity generation, Japan, 2000-19



Solar power has increased tenfold in the last seven years and contributed to a rapid growth in renewable electricity, which accounted for 19% of total electricity generation in 2019.

* *Bioenergy* includes solid primary biofuels, liquid biofuels and biogases.

Note: TWh = terawatt hour.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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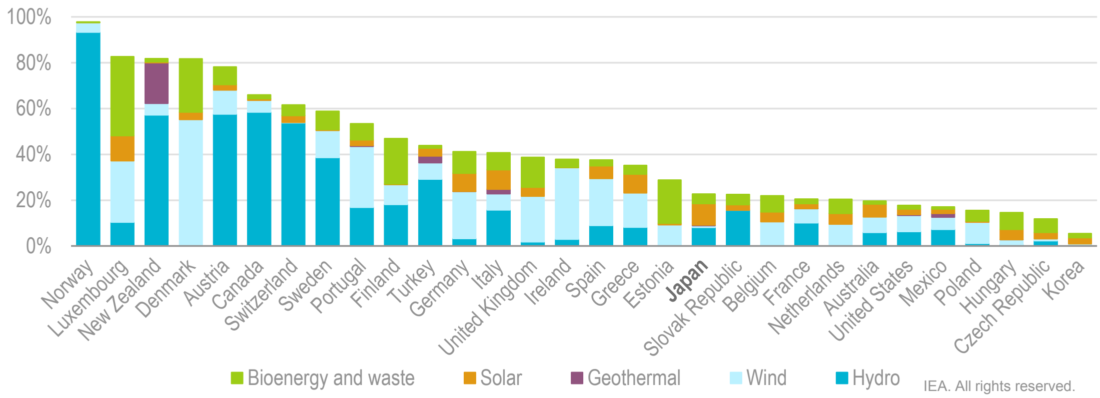
Figure 5.6 Renewable energy as share of total electricity generation in IEA countries, 2019

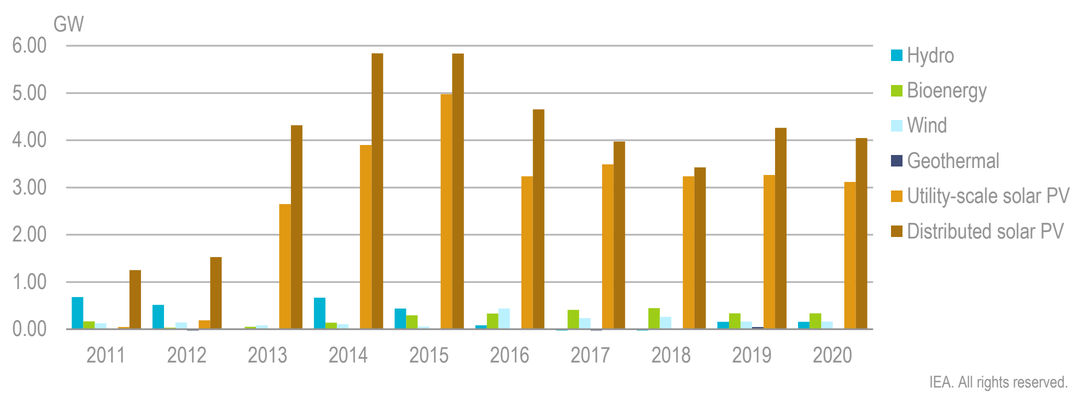


Despite the recent growth in solar power, Japan had the 12th-lowest share of renewables in electricity generation among IEA countries in 2019, a similar ranking as in 2009.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Historically, renewable electricity in Japan stemmed primarily from hydropower. Since 2012, however, solar PV capacity installations have started to expand rapidly driven by the generous FIT (Figure 5.7). Since the introduction of the FIT in 2012, solar PV has accounted for 94% of all renewable electricity capacity installations. Between 2011 and 2019, total PV capacity grew almost thirteen-fold and by 2018 it had overtaken hydropower. Residential systems accounted for most of the PV installations. However, since 2013, larger projects have started to take off. Nevertheless, the distributed segment, which includes residential, commercial and industrial applications, remains the strongest driver, with commercial installations making up over 50% of yearly growth. Despite existing support from the FIT, all other renewable technologies have only shown modest growth over time.

Figure 5.7 Yearly renewable electricity capacity additions, Japan, 2011-20



After a record year in 2015 (11 GW), annual solar PV additions now remain below 8 GW.

Notes: GW = gigawatt. Solar PV additions are GW peak or direct current (DC) calculated by the IEA.
Source: IEA (2020b), *Renewable Energy Market Update: Outlook for 2020 and 2021*, www.iea.org/reports/renewable-energy-market-update.

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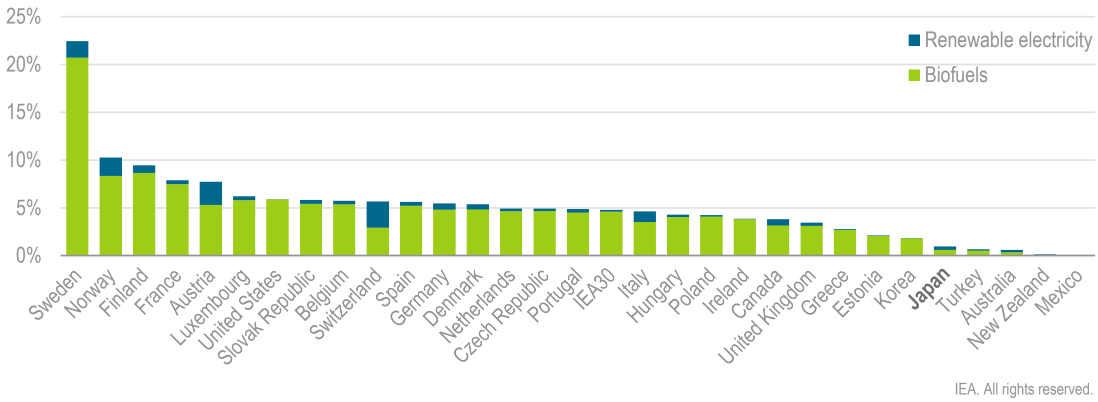
Renewable transport

Japan's transport sector relies heavily on fossil fuels. In 2018, renewable energy accounted for only 1% of total energy consumption in domestic transport, the fifth-lowest value among IEA countries (Figure 5.8). Biofuels account for 0.6% of energy consumption in transport and renewable electricity for 0.4%. Japan's large electrified rail network consumed almost 4 TWh of renewable electricity in 2017, that is, 98% of all renewable electricity consumed in transport (IEA, 2020a). As power generation is dominated by fossil fuels, the renewable share of electrified transport remains suppressed (16% in 2017).

Figure 5.8 Renewable energy in transport in IEA member countries, 2018



With less than 1% of renewable energy in domestic transport in 2018, Japan had the fifth-lowest share in the IEA.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Renewable heat

The share of renewables in overall heat consumption was 4.3% in 2018, lower than the global average of 13% (IEA, 2019). Biomass accounts for the majority of renewable heat use, but geothermal and solar thermal remain notable sources of renewable heat generation in buildings. Japan lacks an extensive district heating infrastructure, limiting the opportunities for integrating renewables into the heat sector.

Policies and measures

The 2011 events drastically changed Japan's energy policy and its vision for the power mix. While the 3rd SEP (2010) aimed to increase the share of nuclear energy in power generation, in reaction to the 2011 events, the government shifted the focus in the 4th SEP, adopted in April 2014, envisioning to lower dependency on nuclear power to the extent possible, while improving energy efficiency, expanding renewables, improving the efficiency of fossil fuel-based power generation and lowering dependency on imported fossil fuels (METI, 2014). The 5th SEP maintains the broad vision and policy direction of the 4th SEP and its premise to foster renewables.

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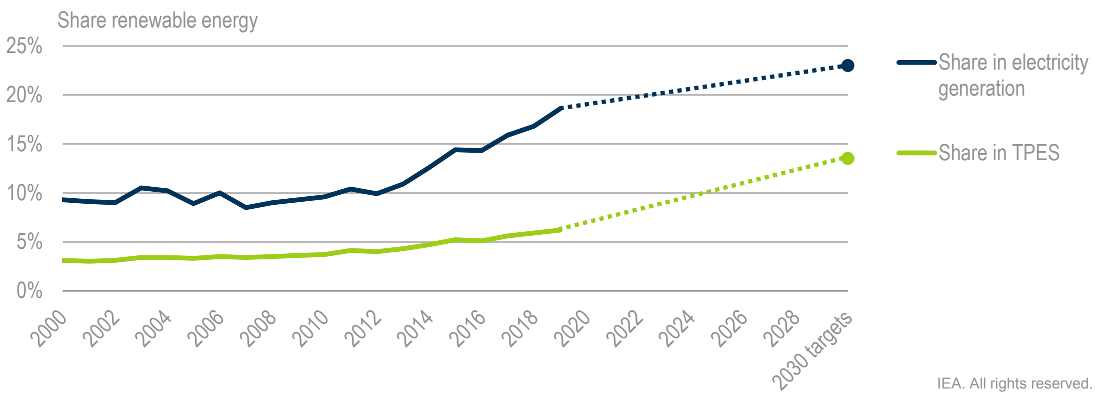
Renewable energy targets

In 2014, Japan set a target of achieving 13-14% of renewable energy in its primary energy supply by 2030, excluding non-renewable waste. In order to achieve this target, the country introduced technology-specific targets for a total of 22-24% of renewable electricity generation by 2030. The share of solar PV in electricity generation is expected to increase from 1% in 2013 to 7% in 2030, wind from less than 1% to 2%, bioenergy from 2% to 4%, hydropower from 7% to 9%, and geothermal to rise to 1%.

From 4.7% in 2014, the share of renewables in TPES has expanded to reach 6.2% in 2019, leaving the country currently off track to reach its 2030 target (Figure 5.9). As for renewables in electricity, however, growth since 2014 has been much faster (from a share of 12% to 18% over the same period) thanks to the FIT. Japan is on track to reach or even overshoot its generation target for 2030.

Figure 5.9 Renewable energy share in total primary energy supply and electricity generation, Japan, 2000-19 and 2030 targets



Since the introduction of the feed-in tarif in 2012, the share of renewable electricity generation increased from 10% to 19%, and is on track towards the 2030 target; the share of renewables in TPES is not.

Note: TPES = total primary energy supply.
Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

To meet the 2030 electricity generation targets, the government also introduced targets for installed power generation capacity for each renewable source. In total, installed renewable capacity would need to increase to between 92 GW and 94 GW to meet the target (METI, 2020a). This compares to 24 GW installed in 2019 (Figure 5.10). Over half of this growth is expected to come from solar PV (alternate current, AC), requiring a 27% increase in capacity relative to 2019. With current low levels of deployment, wind capacity will need to almost triple, while for hydropower an increase of 12-20% is targeted. Bioenergy capacity will need to expand by 50-82%, and current geothermal capacity will need to more than double by 2030 (METI, 2020b).

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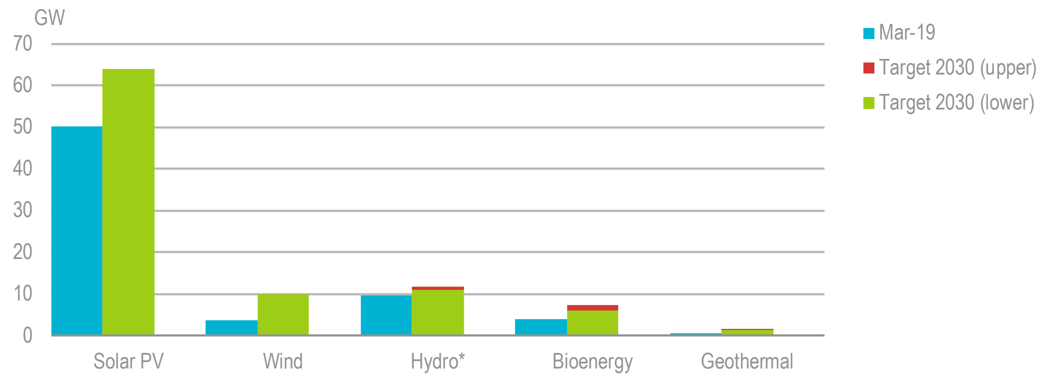
Figure 5.10 Total renewable electricity capacity in Japan, March 2019 and 2030 targets



Solar PV is the main driver for achieving Japan's 2030 renewable electricity targets while wind capacity growth is lagging behind.

* *Hydro* includes small and medium-sized projects.

Note: GW = gigawatt.

Source: Based on information provided by the Ministry of Economy, Trade and Industry of Japan in February 2020.

As part of Japan's Long-term Strategy Under the Paris Agreement, the government expects renewable energy to become the major power source in order to achieve the ambitious goal of an 80% reduction in greenhouse gases by 2050.

Electricity

The principal instrument for promoting renewables in Japan's electricity sector has been the FIT. In recent years, auction schemes for several technologies have been implemented, although their success to date remains limited. The government is considering switching to a feed-in premium scheme starting from 2022.

Feed-in tariff

After an initial phase of solar PV FIT starting in 2009, Japan introduced an FIT policy for solar PV, wind, bioenergy, hydropower and geothermal in 2012. Solar PV has benefited the most from the FIT. Its share in power generation grew from less than 1% in 2012 to 6.5% in 2018, which is almost the level that is required by 2030 (7%).

In 2012, the FIT for solar PV was at a generous level of around JPY 40/kWh (USD 0.4/kWh)[1] (OECD, 2020a), but after yearly and quarterly (after 2015) adjustments, it decreased to JPY12-13/kWh (USD 0.11-0.12//kWh) in 2020. The FIT for other renewable technologies, such as onshore wind and small hydropower, was also revised down, but to a lesser extent, considering the lack of deployment. Offshore wind and small hydropower tariffs have remained unchanged since their introduction (Figure 5.11).

FIT schemes also exist for bioenergy and geothermal. However, deployment of geothermal is relatively limited. Remuneration for bioenergy within the FIT scheme ranges from JPY 13 to 40/kWh (USD 0.12/kWh to USD 0.47/kWh) depending on fuel type and origin. Given the generous support levels for bioenergy, the government has received a high level of FIT

[1] USD 1 = JPY 109.

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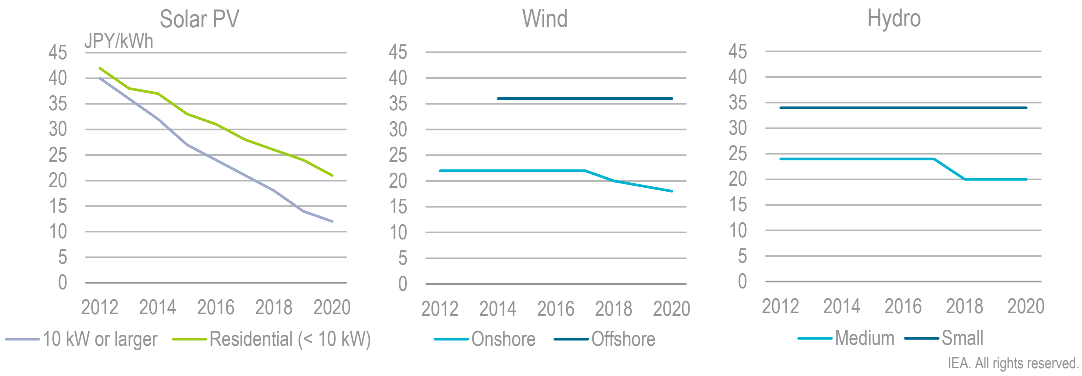
applications since 2012, which led an increase in installed bioenergy capacity of almost 2 GW between 2014 and 2019 (a 77% increase). Since 2019, co-firing biomass with coal is no longer eligible for FIT support.

In 2019, the government set a target of reducing the cost for utility-scale solar PV from an average of JPY 15.2/kWh in 2018 to JPY 7/kWh of power generation cost by 2025. Wind power generation costs are expected to decline to JPY 8-9/kWh y 2030 (METI, 2019a).

Figure 5.11 Japan's feed-in tariff rates by technology, 2012-20



Since 2012, solar PV FITs have declined 50-70% along with cost reductions, but they remain significantly higher than in many other countries. For wind and hydro, FIT levels have remained stable.

Notes: PV = photovoltaic. JPY = Japanese yen. kWh = kilowatt hour.

Sources: METI (2020b), *Fixed Price Purchase System*, www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/kakaku.html#h30; METI (2019a), *Opinions Regarding Procurement Prices after 2019*, www.meti.go.jp/shingikai/santeii/20190109_report.html.

Japan's remuneration levels for solar PV and onshore wind are significantly higher than the OECD average (OECD, 2020b). Auctions held since 2018 in many OECD countries have shown contract prices for solar PV and onshore wind ranging from JPY 21/kWh to JPY 64/kWh for both technologies, which is 2 to 5 times lower than the Japanese FIT for solar PV and onshore wind (IEA, 2020b). The difference can partly be explained by higher investment costs in Japan compared to other countries. In 2019, the average investment cost in Japan was one-third higher than the global average for onshore wind and twice the level for utility-scale PV projects (IRENA, 2020). For solar PV, costs associated with mechanical and electricity installation and inspection are significantly higher in Japan compared to other G20 countries (IRENA, 2020).

The costs of the FIT are paid by end users through renewable energy surcharges. Since the introduction of the FIT, the surcharge has steadily increased, from JPY 0.22/kWh in 2011 to JPY 2.98/kWh in fiscal year (FY) 2020 (Figure 5.12). For industrial consumers, the surcharge represents a higher share of their total electricity bill than for residential end users. However, there are exemptions for very large consumers who are granted surcharge reductions between 20% and 80%.

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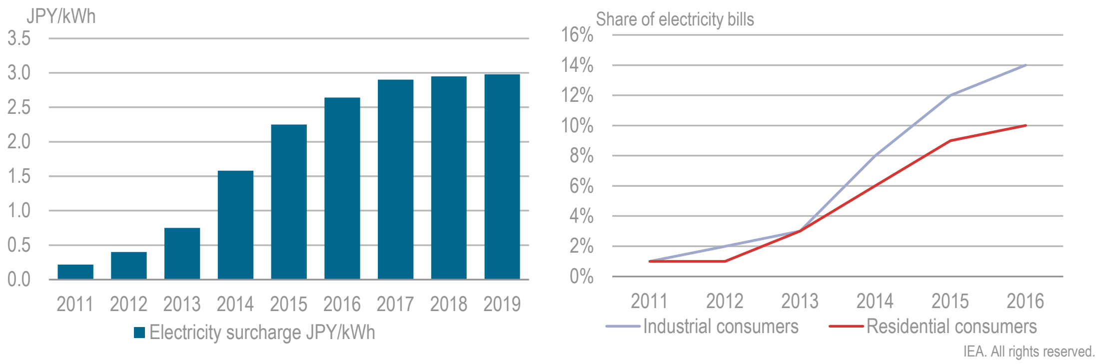
Figure 5.12 Renewable energy surcharge for end users in Japan



The electricity surcharge has continuously increased since the introduction of the FIT in 2012, but at a lower speed in recent years thanks to lower remuneration levels.

Notes: JPY = Japanese yen. kW = kilowatt hour.
Source: METI (2020c), *Japan's Energy 2019*,
www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2019.pdf.

The Ministry of Economy, Trade and Industry (METI)[2] originally did not apply strict commissioning deadlines for FIT applications. Consequently, in March 2015, around 80% of the projects with FIT awards were not yet operational. In May 2016, the government passed a new regulation requiring FIT-approved projects that had not yet been commissioned to submit their grid connection contracts by April 2017 at the latest. Moreover, the reform established strict approval requirements for a grid connection contract applying to both previously approved projects and new projects. Some projects were cancelled as a result, but the number of non-operational FIT-eligible projects remained high. Accordingly, METI introduced another FIT revision in 2019, giving another commissioning deadline (March 2020) for solar PV that received FIT approval before March 2015. If these projects do not meet the deadline, their FIT rate will be cut by almost half.

The government is now in the process of designing a new renewable support programme based on market-based feed-in premiums, to improve the integration of renewables into the Japanese power market and further reduce the costs of renewable energy subsidies in partial combination with competitive auctions. In June 2020, the Japanese parliament passed the law on the "Proposal to Amend the Renewable Energy Act". Under the proposal, new renewable energy projects with a competitive outlook such as large-scale solar PV and wind would be eligible for receiving a feed-in premium on top of the market price from April 2022 onward. The details on the implementation of the feed-in premium mechanism are under discussion at the time of writing of this report.

Auctions

In addition to the FIT, the government held competitive auctions with 20-year power purchase contacts for utility-scale solar PV and bioenergy projects. In November 2017, Japan held a solar PV auction for 500 megawatts (MW) of capacity with contract prices ranging 0-18% below the FIT at the time of the auction (between around JPY 17.20/kWh

[2] Annex A provides detailed information about institutions and organisations with responsibilities related to the energy sector.

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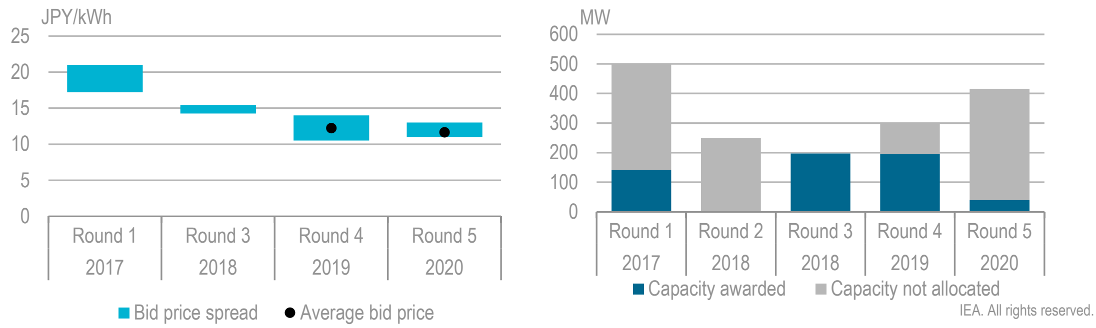
[USD 0.12/kWh] and JPY 21.00/kWh [USD 0.18/kWh]). The second solar PV auction held in September 2018 ended with no winners, as all bids were above the ceiling price of JPY 15.5/kWh. In the third and fourth solar PV auctions held in 2019, auction prices decreased and average bid prices were JPY 12.98/kWh and JPY 12.27/kWh respectively (USD 0.118/kWh and USD 0.122 /kWh) (Figure 5.13, left panel). In addition, in all but one auction, there was an issue of the sum of winning bids not covering the capacity originally on offer (Figure 5.13, right panel).

Figure 5.13 Solar PV auction results, Japan, 2017-20



Bid prices for utility-scale solar PV saw a steep decline. With the eligibility threshold being lowered to 500 kW (2019) and 250 kW (2020), the bid spread became wider.

Notes: JPY = Japanese yen. kWh = kilowatt hour. MW = megawatt. Bid prices are based on awarded projects. No capacity was awarded in round 2. Average bid prices are only disclosed for rounds 3 and 4.

Source: GIO (2020), *Low Carbon Investment Promotion Organisation Japan*, www.teitanso.or.jp.

Act for the Promotion of Marine Renewable Energy

Japan's offshore wind resource potential has remained untapped despite generous FIT levels. This is mainly due to high perceived technology risk and administrative challenges concerning the permitting. However, in 2013, a first offshore floating wind farm demonstration project (at most 14 MW) started operation in Fukushima; the wind farm still operates as an empirical research project with a view to further expanding offshore wind power.

In November 2018, the Japanese parliament approved the Act for the Promotion of Use of Marine Areas for Development of Marine Renewable Energy Generation Facilities, to introduce a new national framework for offshore wind projects (METI, 2019). The act designates sea areas for the construction and development of offshore wind farms and introduces a competitive auction scheme that will provide a seabed lease for 30 years. By entering into effect in April 2019, the procurement price and period are decided by the auction guidelines. In June 2020, METI and the Ministry of Land, Infrastructure, Transport and Tourism issued a call for developers to participate in the auctioning of a 16.8 MW (or larger) floating wind farm off Goto City (METI, 2020d). The project will receive remuneration at the current offshore FIT (floating) level of JPY 36/kWh. The call for tender closed in December 2020 and disclosure of the winning project is expected around June 2021. From 2021 onwards, Japan aims to develop 1 GW from three to four wind power projects annually (reNEWS, 2020).

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Grid integration of renewables and the Japanese version of Connect and Manage

The Japanese transmission network is fragmented into ten regional grids and divided into two frequency levels: eastern Japan operates at 50 Hz and western Japan at 60 Hz (see Chapter 7). Transmission capacity between the two regions remains limited and available wind (in the north-west) and solar resources (in the south-east) are far from major demand centres. Grid congestion already exists in the Kyushu and Hokkaido regions, which experienced rapid deployment of solar PV. So far, only the Kyushu region has faced renewables curtailment. Curtailment rates of wind and solar PV plants are announced to generators one day ahead of delivery based on day-ahead weather forecasts, because curtailment requires physical presence at the plant site in many cases.

Eliminating these power grid constraints is important to maximise generation from existing renewable capacity and to add new capacity in line with the 2030 target. In order to achieve this, the government has introduced a strategy within its electricity market reform programme: maximise the use of existing flexibility sources from both conventional technologies (e.g. interconnection, pumped hydro storage and thermal power plants) and new flexibility technologies (virtual power plants, vehicle-to-grid technology and demand-side response); and grid reinforcement based on cost-benefit considerations.

The market reform has introduced various tools to achieve a cost-effective and secure integration of renewables into the Japanese electricity market. These new tools include a balancing market (in 2017), a non-fossil market in which certificates for FIT electricity are traded (2018), a baseload power market (in 2019) and a capacity market (in 2020) (all discussed in Chapter 7). It is too early to assess the impact of these markets on the investment in renewable energy sources. Enhancing liquidity on the wholesale market will be important to establish the necessary price signals to optimise the use of flexible resources, attract investment in new flexible power capacity, and ensure cost-optimal integration of renewables in both wholesale and retail markets.

In addition, the government decided to introduce a wheeling charge to be paid by all power generators (a so-called G-charge) from 2023 onward (with the exception of residential solar PV less than 10 kW), to finance investments in network facilities necessary for expanding renewable electricity. The G-charge would also promote the efficient utilisation of network facilities, as generators will be offered a reduction on the charge if they are located in specifically designated areas (discounted areas) (see Chapter 7). In anticipation of the introduction of the G-charge, the connection charge for new capacity was already reduced in June 2018, lowering the barriers to entry for renewables such as solar and wind power plants.

The G-charge that is under consideration will be non-discriminatory, technology-neutral and fairly distribute the network costs.

The Electricity and Gas Market Surveillance Commission was tasked in December 2019 to design guidelines that will allow renewable energy generators that benefit from the FIT scheme to pass on additional costs caused by the G-charge to their customers. Additional adjustments in the design of support policies for renewables are also under discussion. In order for the G-charge to be non-discriminatory, technology-neutral and fairly distribute the network costs, it is important that its final design does not create any unintended bias for or against any generation type, and takes into consideration the contracted capacity and actual use of the grid.

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To accommodate greater amounts of electricity generation from wind and solar, the "Japanese version of Connect and Manage" policy provides several measures to enhance current grid operation and allow for maximum use of existing transmission and distribution capacity. It includes:

- estimating available grid capacity based on actual power flows from previous years, rather than the theoretical maximum nameplate capacity
- revaluating the transmission reliability capacity such as in an inter-trip scheme[3]
- establishing the non-firm access, which allows new entrants to connect to a grid with insufficient available capacity under the condition that output is limited/curtailed in case of grid contingency.

The first two measures are expected to increase the net transfer capacity by 46 GW, according to the Organization for Cross-regional Coordination of Transmission Operators.

Transport

Japan is one of the few G20 countries to have no mandatory biofuel blending target. In 2009, the government set a voluntary target of using 500 million litres of crude oil equivalent (around 830 million litres of ethanol) of biofuels annually by 2017, leaving it up to industry on how to meet this target. This goal was met on time, mainly through imported ethanol. In April 2018, the government extended the target until 2022. The national average blend rate of ethanol in gasoline has risen to 1.6% (as of FY2019) under the programme, which, however, is one of the lowest rates among countries with a biofuels programme in place. Due to concerns of potential damages to vehicle engines, bioethanol blending rates are capped at 3%, with exceptions for some vehicles specifically designed for a 10% blend rate (USDA, 2018).

Since 2008, Japan has had tax incentives to promote the use of biofuels that contain 3% bioethanol, which are effective until 2023. There are no incentives for biodiesel production or consumption. Outside of R&D incentives, the advanced biofuels development remains limited. However, the 5th SEP of 2018 announced that preferential measures for the introduction of the domestically produced next-generation bioethanol will be considered, as will the introduction of biodiesel (METI, 2018).

Japan's main strategy to decarbonise road transport is based on improving the energy efficiency of the existing vehicle fleet and increasing the share of next-generation vehicles in all car sales from 38% in 2018 to 50-70% in 2030. Next-generation vehicles include hybrid, plug-in hybrid, battery electric, fuel cell, and clean diesel cars and buses (see Chapter 4).

In 2017, Japan developed its first national strategy on hydrogen, the Basic Hydrogen Strategy. Its goal is to strengthen technological development and supply of hydrogen, including for final use in transport (see Chapter 6). Hydrogen (both fossil- and renewable-energy generated) is expected to have an increasingly important role in the transport sector through fuel cell vehicles, enhancing the potential for green hydrogen from renewable energy sources.

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[3] The automatic operation of an inter-trip generally requires the monitoring of all transmission circuits in a zone, which are linked with system protection arrangements. If a selected circuit trips, the logic process will then trigger the activation of the scheme to disconnect (trip) generation. Inter-trip schemes typically operate in less than 100 milliseconds, allowing them to be used to resolve both thermal and stability issues.

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Heat

Japan does not have a financial incentive programme, nor specific regulation for renewable heat generation. The consumption of renewable heat is concentrated in industry where bioenergy is used for heating purposes. The use of solid biomass in the residential sector remains limited. Reasons for this are limited domestic resource availability and underdeveloped supply chains, a particularly high level of urbanisation, and high population density, giving preference to gas or electric solutions, as, for example, combined air conditioning and heating devices. Reversible heat pumps in particular are a common option, due to their ability to also provide air conditioning in the summer. About 500 000 heat pumps were installed in Japan in 2017. Moreover, as electricity accounts for almost 54% of final energy consumption in buildings, low shares of renewables in electricity generation relative to the world average lead to a low renewable energy content in TFEC.

Assessment

In 2014, Japan set a target of achieving 13-14% of renewable energy in its primary energy supply by 2030. In order to achieve this target, it also introduced technology-specific targets for electricity generation from solar PV, wind, bioenergy, hydropower and geothermal to reach a goal of 22-24% of renewables in the electricity mix by 2030.

Since the introduction of the 2030 target, Japan's share of renewables in TPES increased from around 5% in 2014 to 8% in 2019. This growth was primarily driven by the expansion of renewables – mainly solar – in the electricity sector, thanks to government's support through FITs introduced in 2012. Renewable capacity almost doubled from 2012 to 2018, with solar PV representing almost 95% of this expansion. However, electricity only accounted for 25% of Japan's energy demand in 2018, while the heat and transport sectors covered the rest. The progress of renewables in heat and transport remains low due to limited policy support.

The rapid expansion of renewable electricity has also brought several challenges, which were identified in the Long-Term Energy Supply and Demand Outlook of 2015: unbalanced deployment between renewable technologies; increasing cost burden of the FIT to society; and grid integration of variable renewable energy technologies. Despite many policy changes and improvements, these challenges remain and were highlighted again in the 5th SEP.

Renewables support schemes

Since 2012, the FIT rates for solar PV projects have decreased by 40-65%; however, they remain among the highest in the world. The installation costs of renewables are relatively high in Japan because of the limited availability of cheap land, high labour costs and special safety requirements for equipment against natural disasters. However, there is potential for reducing costs, especially through increased competition. International policy lessons have shown that relatively high FIT rates or other incentives result in higher costs, as equipment suppliers and service providers will factor in those elevated remunerations when pricing their products in order to increase their profits.

In 2016, the government initiated an FIT reform targeting mainly solar PV, because many projects had received FIT approvals at very high prices over 2012-13 but never became operational. The reform has established strict approval requirements for financial support

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for both previously approved and new FIT projects. A close monitoring of this reform is necessary in order to draw lessons that could be valuable in designing upcoming remuneration policies that are cost-effective, and ensure timely project delivery.

In parallel, Japan launched a policy transition from FIT to competitive auctions for utility-scale PV and bioenergy projects. This is a welcome change. However, auctions thus far for both solar PV and bioenergy were undersubscribed and therefore did not attract enough competitors. The government subsequently modified the auction rules and there was greater participation in the financial year 2019 PV auction, which enhanced competition. However, there is still ample room for increasing competition to achieve the PV cost reductions target set by the government. The disclosure of the ceiling price could increase participation.

As a next step in the reform process, the government recently proposed to introduce a feed-in premium scheme in order to increase the exposure of renewables to electricity markets. Details of this new scheme are still to be established.

The progress of wind towards meeting 2030 targets has been slow to date, despite relatively high FITs, due to lengthy environmental permitting processes and limited grid capacity in resource-rich areas, especially for onshore wind in Hokkaido. To remedy this, Japan implemented a new act for promoting offshore wind energy in 2019, and introduced measures for enhancing grid capacity, including the "Japanese version of Connect and Manage". These measures are expected to increase onshore and offshore wind capacity significantly. In 2019, the government increased the licensing period of seabed lease from 2-3 years to 30 years for offshore projects under the new act, announced the first promotion in December and launched a competitive auction in 2020. Although the long environmental impact assessment process remains a key challenge for wind (onshore and offshore), the government's involvement in defining development areas is expected to facilitate the process.

Offshore wind is currently a nascent industry in Japan, with relatively high costs and elevated investment risks, as developers are responsible for the entire project development, including offshore wind transmission lines. Within this set-up, a successful auction, timely project development and cost reduction will depend on leveraging international experience through close co-operation between Japanese and experienced international companies.

Geothermal deployment has also been slow since the introduction of the FIT because of high project risks associated with the exploration phase of the development. Long environmental assessment processes and local acceptance remain key challenges as well.

Electricity market reforms

Electricity market reforms will bring both opportunities and challenges for deployment and the system integration of renewables, especially for solar PV and wind. Japan has made progress since the IEA 2016 in-depth review, especially in improving the use of the existing transmission network system. First, the use of interconnectors between regions has been managed centrally by the Organization for Cross-regional Coordination of Transmission Operators since 2016, and the allocation of interconnection capacity is included in the day-ahead market, in order to increase economic efficiency. Second, the government introduced the "Japanese version of Connect and Manage" policy, which changed the

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calculation of available grid capacity for variable renewables from maximum nameplate capacity to an estimated future power flow of electricity based on previous performance. This will make more grid connection capacity available for variable renewables without additional grid enhancements. Third, Japan launched several demonstration projects on smart use of decentralised energy systems by aggregating demand and using vehicle-to-grid potential. The government introduced a non-fossil fuel certificate market in the power exchange, which includes renewables and nuclear, enabling retailers to procure non-fossil electricity.

However, several challenges remain for renewables despite the abovementioned improvements. First, the distribution of installed solar PV capacity among regions is uneven, leading to increasing levels of curtailment, notably in the Kyushu region. The majority of solar PV installations in Japan are commercial systems ranging from 10 kW to 500 kW with low self-consumption rates, as selling electricity to the grid has been more profitable because of high FITs. Promoting self-consumption could facilitate grid integration and reduce curtailment.

Second, limited transmission capacity within and between regions continues to create bottlenecks in transferring power from supply to demand centres. In addition, the curtailment rates of wind and solar PV plants are announced one day ahead of delivery based on day-ahead weather forecasts, because curtailment requires physical presence at the plant site in many cases. It is important to improve remote energy management systems to enable faster grid response of renewable energy plants.

Third, there are multiple new products in the electricity market (e.g. baseload, balancing, non-fossil certificate market). Currently, it is difficult to assess interactions between these products because of limited liquidity. It will be important to improve liquidity to provide necessary price signals to optimise the use of existing flexibility resources, attract investment in new flexible capacity, and ensure cost-optimal integration of renewables in both wholesale and retail markets. The co-existence of the FIT and the non-fossil fuel certificates market may not be fully compatible because renewables and nuclear are lumped together while being under different policy schemes.

Transport

The transport sector accounts for almost 23% of Japan's final energy consumption and one-fifth of the country's CO_2 emissions. Renewable electricity consumption in the rail sector accounts for 40% of renewables in transport.

Next-generation vehicles, which include hybrid, full electric, fuel cell and "clean" diesel vehicles with lower emissions, are expected to play a role in achieving CO_2 reduction targets. Full electric vehicles only represented around 1% of new passenger car sales in 2018, despite support of a purchase subsidy and tax incentives. By 2030, Japan targets to increase this share to 20-30% assuming that the cost of BEVs continues to decline. Full electric vehicles and fuel cell vehicles could make a key contribution to the targeted emissions reduction for transport. However, their contribution will highly depend on the successful decarbonisation of electricity generation, which will require not only rapid uptake of renewables, but also the restart of existing nuclear plants. In addition, the expansion of electric vehicle charging and hydrogen fuelling infrastructure will be necessary to reach the ambitious goals.

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The role of biofuels in reducing GHG emissions in transport remains limited. Japan is not a producer of crop-based conventional biofuels due to limited land availability. The government has a voluntary biofuels blending target of 500 million litres of crude oil equivalent, or 1.6% (as of FY2019) of Japan's gasoline consumption. The target is set from FY2018 to FY2022. Increasing the use of sustainable biofuels in both existing and newly purchased internal combustion engine vehicles will contribute to CO_2 emissions reductions of the transport sector. Beyond road transport, the government provides funds for the research and development of advanced biofuels (e.g. microalgae) focusing mostly on the hard-to-abate aviation sector.

Heating and industry

A scale-up of renewable energy for heat will be needed to achieve the 2030 renewables target in Japan. Heating in buildings and industrial processes is the largest energy end-use category in Japan, yet the share of renewables in the heat sector has held stable at around 4% since 2011, less than half of the global average. Bioenergy from imported biomass remains the largest source of renewable heat. According to the government, domestic biomass production can entail high costs and reliance on biomass imports raises energy security concerns. To date, natural gas dominates district heating network supply and opportunities to switch to biomass are limited due to space constraints in many buildings, capital costs and underdeveloped fuel supply chains. Future developments for heat decarbonisation may principally consist of: improving building insulation and efficiency; substituting gas with heat pumps in well-insulated buildings in areas of lower building density; deploying low-carbon district heating and cooling networks, using municipal waste and/or large-scale electric heat pumps in higher building density areas; and decarbonising electricity further. Moreover, there is untapped potential for greater use of solar thermal water heaters.

Recommendations

The government of Japan should:

- ☐ Improve the current renewable electricity auction system in order to increase competition and accelerate cost reductions.
- ☐ Ensure a smooth transition to the envisaged feed-in premium scheme that should strike a balance between providing long-term revenue stability to developers and exposing variable renewables to electricity market price signals, while reducing the cost of subsidies.
- ☐ Explore the use of potentially abandoned farmland for utility-scale solar PV projects, given the limited land availability in Japan.
- ☐ Design appropriate regulatory measures to improve electricity system operations and ensure that various products in the electricity market complement each other and provide efficient price signals that incentivise cost-effective use of flexibility options and system integration of variable renewables.

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- ☐ Set a new biofuel target from FY2023 in the transport sector on sustainable conventional and advanced biofuels.
- ☐ Set a target for decarbonisation of the heating and cooling sector for 2050, and develop a technology road map that would integrate energy efficiency policies with renewables.

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6. Energy technology research, development and demonstration

Key data

(2019 estimated)

Government energy RD&D spending: JPY 314 billion (USD 2.88 billion)*

Energy RD&D spending per GDP (2018): 0.058% of GDP (IEA* median: 0.032%)

Energy RD&D spending per capita (2018): USD 23.2 (IEA** median: 15.0)

* USD 1 = JPY 109.

** Median of 27 IEA member countries for which 2018 data are available.

*** Median of 20 IEA member countries for which 2018 data are available.

Overview

Japan continues to be a world leader in research, development and demonstration (RD&D), being among the few countries to dedicate more than 3% of its gross domestic product (GDP) to RD&D. Energy technology receives a large share of this budget, reflecting the importance Japan attaches to energy technology and innovation as a means to enhance energy security, foster industrial competitiveness and combat climate change without sacrificing economic growth. Public investment in energy R&D has decreased in recent years, but it remains high by international standards. Japan announced plans to mobilise JPY 30 trillion (USD 275 billion) of public and private investment for RD&D on the environment and energy in the next decade.

Japan continues to be actively engaged in international energy RD&D fora, and has taken a leading role in advancing international collaboration in the fields of hydrogen and carbon capture, utilisation and storage (CCUS). These two technology areas are considered critical to reaching net-zero emissions in the second half of the century. Japan is a global frontrunner in the field of hydrogen and fuel cell technology, declaring its commitment to pioneer the world's first "hydrogen society" in its 5th Strategic Energy Plan (SEP) in 2018.

RD&D funding

In 2019, public spending on energy-related RD&D was JPY 314 billion (USD 2.88 billion). Spending decreased after the 2011 Fukushima nuclear accident, in particular for nuclear energy (Figure 6.1). It grew again in 2018 (by JPY 53 billion compared to 2017), although most of the increase is explained by the inclusion of spending data from the Ministry of the Environment (JPY 45 billion), which was not covered in previous years. In 2019, energy RD&D spending decreased by JPY 7 billion compared to 2018.

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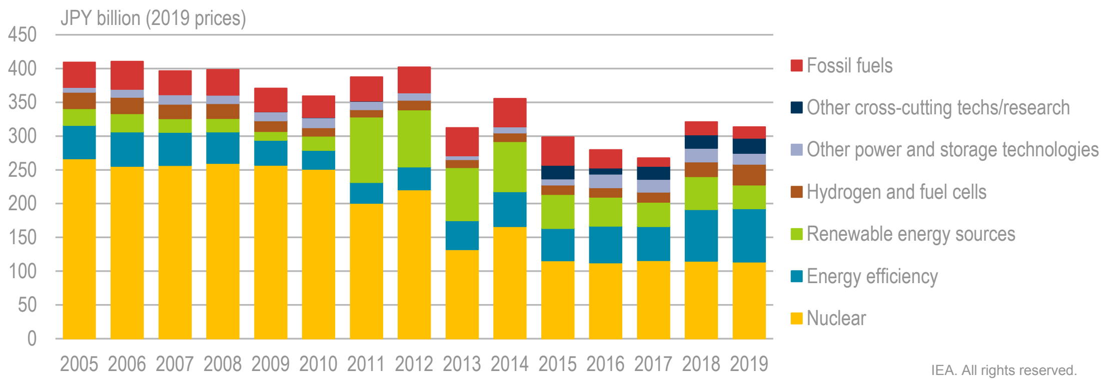
The focus of public spending has moved from nuclear energy towards a more balanced mix targeting energy efficiency, renewables, hydrogen and energy infrastructure. Spending on nuclear nearly halved between 2012 and 2019 (in real terms), while that on energy efficiency, hydrogen, and power and other storage technologies increased by 132%, 112% and 52%, respectively. Despite the decline, nuclear still is the largest funded sector at 36% of the total in 2019, with three-fourths of funding targeting nuclear fission. Energy efficiency was the second-largest sector in 2019, with 25% of the total and a focus on industrial techniques and processes. Renewable energy sources accounted for 11% of the 2019 budget, with almost half of the budget targeting wind. Hydrogen and fuel cells accounted for 10%, while other power and storage technologies, cross-cutting research and fossil fuels received the rest with around 6% each.

Figure 6.1 Government energy RD&D spending in Japan by category, 2005-19



In 2019, the government spent JPY 314 billion on energy-related RD&D, of which 60% targeted nuclear and energy efficiency.

Notes: JPY = Japanese yen. Data for 2018 include for the first time the additional spending of the Ministry of the Environment (JPY 45 billion), which was not covered for previous years. It explains most of the 2017-18 growth (JPY 53 billion).

Source: IEA (2020a), Energy Technology RD&D Budgets 2020: Overview (database), www.iea.org/statistics.

Despite the decline in recent years, Japan remains one of the largest investors in energy-related RD&D among IEA members. In 2018, it was the second-largest investor in the IEA in absolute terms, following the United States, and the third-largest investor relative to its GDP (Figure 6.2). Japan spent 12% of its total national RD&D budget on energy, which is the second-highest share in the IEA, after Mexico, and it is the country with the largest share on RD&D spending on low-carbon energy (OECD, 2020; IEA, 2020a). With regard to individual technologies, in 2018, Japan had the largest RD&D budget for nuclear (USD 1.1 billion in 2018 in purchasing power parity [PPP]), hydrogen and fuel cells (USD 216 million), and other power and storage (USD 201 million) in the IEA.

Business investment in R&D in particular is also high by international standards (OECD, 2020). However, it is largely concentrated among big enterprises. The Japanese government does not systematically collect data on private RD&D investment in the energy sector. The IEA estimates that global listed companies headquartered in Japan spent about USD 14.1 billion on energy RD&D in 2019, growing by over 4% relative to 2018 and reaching 2015 peak levels (Figure 6.3). This is equal to about 15% of the total spending by global listed companies active in the energy space.

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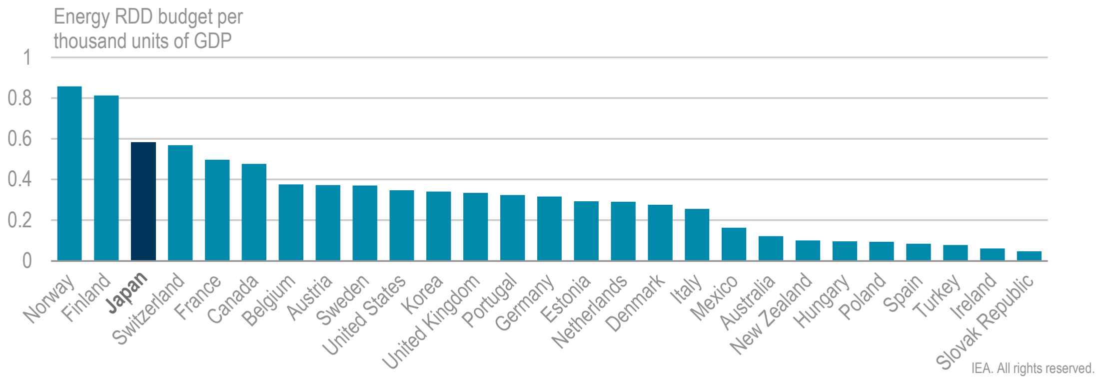
Figure 6.2 Government energy RD&D spending per GDP in IEA countries, 2018

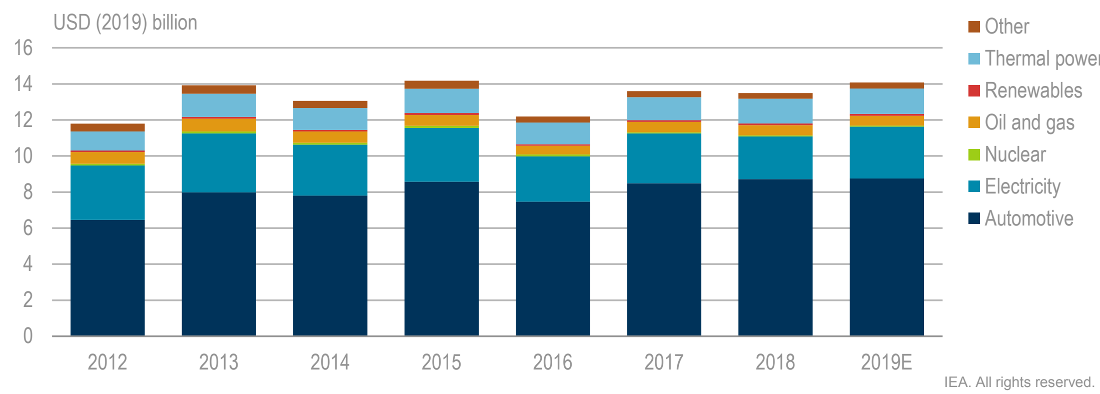


With 0.058% of GDP spent on energy RD&D, Japan ranked the third-highest among IEA member countries in 2018.

Note: No data available for the Czech Republic, Greece and Luxembourg.

Source: IEA (2020a), *Energy Technology RD&D Budgets 2020*: *Overview* (database), www.iea.org/statistics.

Figure 6.3 Estimated corporate energy RD&D spending by global listed companies headquartered in Japan, 2012-19



Notes: "Other" comprises carbon capture, utilisation and storage; electricity storage; insulation; lighting; other fossil fuels; and smart energy systems. Corporate energy R&D spending includes reported R&D expenditure by companies in sectors that are dependent on energy technologies, including energy efficiency technologies where possible. Classifications are based on the Bloomberg Industry Classification System.Data for 2019 are estimates.

Source: IEA (2020b*), Word Energy Invesment 2020*, https://www.iea.org/reports/world-energy-investment-2020.

In 2019, over 60% of corporate energy RD&D budgets came from automotive companies, about 20% from electricity generation and networks, and 10% from thermal power and combustion equipment. Overall, about 80% are estimated to have been spent in low-carbon energy technology areas. It should be noted that companies do not necessarily report in which country innovation activities take place. Similar to other economies in the region, Japan makes little use of public funds to finance clean-tech start-ups. Only a handful of venture capital deals for clean energy start-ups take place each year in Japan, according to the latest available data.

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Japan's RD&D institutional and policy framework

The institutional framework

The Council for Science, Technology and Innovation is the top decision-making body in Japan's RD&D policy. It is one of four policy councils of the Cabinet Office and comprises the Prime Minister, relevant ministers and experts. The council is responsible for formulating science, technology and innovation policy; setting the budget; co-ordinating government institutions involved in RD&D policy; and undertaking evaluations of RD&D activities.

The Agency of Natural Resources and Energy (ANRE) of the Ministry of Economy, Trade and Industry (METI) [1] is responsible for articulating and implementing energy innovation policy. Its remit covers renewable energy, energy efficiency, the rational use of fossil fuels and power generation (including nuclear power). Research on climate change mitigation is under the remit of the Ministry of the Environment (Skea et al., 2019). The ANRE's budget is strongly oriented towards RD&D. It works with or through a range of affiliate agencies, including the National Institute of Advanced Industrial Science and Technology, one of the largest public research institutions in Japan, as well as the New Energy and Industrial Technology Development Organization (NEDO), which channels a significant part of the ANRE's RD&D budget.

NEDO plays an important role in fostering collaboration between the private sector, academia and government institutions. It supports projects along the innovation chain, from basic research to pre-commercial demonstration and deployment. For projects with potential commercial value, NEDO forms consortia with private companies, research institutes and universities for technologies and provides funding, depending on the technology's stage in the innovation chain.[2]

Monitoring and evaluation

Monitoring and evaluation of nationally important RD&D projects with public expenditure above JPY 30 billion (USD 275 million) are conducted by the Council for Science, Technology and Innovation. For other projects, central government agencies evaluate projects in accordance with the National Guideline for R&D Evaluation, the latest version of which dates to December 2016. METI conducts evaluations at four stages: *ex ante*, interim (long-term R&D), close to completion of the R&D and *ex post* evaluations of R&D projects in fields such as energy savings and CO_2 emissions reductions, based on the guidelines and evaluation methods developed by METI in accordance with the National Guideline. Key criteria for evaluation include necessity, efficiency and effectiveness.

The policy framework

The 5th Science and Technology Basic Plan (2016-20) is Japan's overarching RD&D policy framework. It states Japan's ambition to become the most innovation-friendly country in the world and sets a vision towards becoming a world-leading "Society 5.0", where systematic integration of digital technologies and the physical world spurs economic

[1] Annex A provides more information about organisations and agencies with relevance to the energy sector.

[2] In early-stage research, NEDO funds consortia in full; in applied research, it fully funds universities and other research institutions, while private companies have to cover two-thirds of the costs; in demonstration projects, NEDO meets 50% of the costs.

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growth and provides solutions to societal challenges (GoJ, 2016). Energy is one of the five identified societal challenges. The plan aims to address some of the main challenges related to RD&D in Japan, i.e. to strengthen collaboration between universities, public research institutes and private companies; to foster international collaboration; and to boost innovation among small and medium-sized businesses.

Japan has a tradition of establishing a long-term vision for energy-related innovation that is accompanied by road maps outlining clear targets for technology development, cost reductions and deployment. Its current vision is much driven by the desire to reduce greenhouse gas (GHG) emissions without harming economic growth. Japan's Long-term Strategy Under the Paris Agreement, submitted to the United Nations Framework Convention on Climate Change in 2019, aims to realise "a virtuous cycle of environment and growth… with business-led disruptive innovation" (GoJ, 2019). Innovation is at the heart of Japan's strategy to become a decarbonised society (see Chapter 3).

Japan's vision to 2030 is laid out in the Innovative Energy Strategy, issued by METI in April 2016. The strategy aims to achieve the 2030 energy mix set out in the 2015 *Long-Term Energy Supply and Demand Outlook to 2030* (METI, 2015). It has a focus on energy efficiency and renewable energy sources, while also promoting new energy systems (e.g. by encouraging new entrants to the electricity market or promoting local systems for energy production and consumption) (METI, 2016).

The long-term vision is laid out in the National Energy and Environment Strategy for Technological Innovation towards 2050 (NESTI 2050), issued by the Council for Science, Technology and Innovation in April 2016. NESTI 2050 provides the framework for fostering the technologies and innovation necessary to reach Japan's goal of reducing GHG emissions by 80% by 2050. It has nine priorities:

- innovative production processes (e.g. separation membranes, catalysts)
- ultralight and super heat-resistant materials
- next-generation storage batteries (e.g. post-lithium)
- CO_2-free hydrogen
- next-generation solar photovoltaic (e.g. perovskite structure, quantum dot)
- next-generation geothermal (e.g. supercritical, extreme environment-compatible sensors)
- innovative carbon separation and recovery technologies
- energy systems integration and optimisation technologies (e.g. using big data and artificial intelligence)
- core system technologies (e.g. next-generation power electronics, superconductivity).

Among them, the government will prioritise technologies that are high-impact; have the potential for widespread adoption and large CO_2 emissions reductions; require combined forces by industry, academia and government; and technologies in which Japan can become a global leader. NESTI 50 updated the previous long-term strategy for environmental and energy technology, the 2013 Innovation Plan for Environmental Energy Technology.

Based on NESTI 2050, the government issued the Environment Innovation Strategy (EIS) in January 2020 as a road map to achieve the visions and technologies identified in NESTI 2050. The EIS also aims to update NESTI 2050 to take into account Japan's Long-term Strategy Under the Paris Agreement. Its stated goal is to develop innovative

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technologies that enable the reduction of GHG emissions towards carbon neutrality by 2050. It even goes further, aiming to reduce CO_2 accumulated in the atmosphere (going "beyond zero") by 2050. The EIS also broadened the scope of NESTI 2050 to the agricultural sector, in recognition that energy technologies can play a role in reducing the sector's GHG emissions.

The EIS is based on three pillars. The first pillar consists of "innovation action plans" for 16 technological challenges in 5 fields (energy transformation; transport; industry; businesses, households and cross-cutting measures; and agriculture). These challenges include, for example: making renewable energy the main power source; constructing low-cost hydrogen supply chains; developing low-cost CCUS; green mobility; and developing smart communities using big data, artificial intelligence and decentralised energy management. The action plans set concrete targets for technology development, cost reductions and GHG emissions reductions for the technologies identified in NESTI 2050, and present scenarios and actions needed to move from basic R&D to practical application and demonstration.

The second pillar consists of "innovation acceleration plans", which detail research frameworks and investment promotion policies needed to implement the innovation action plans. As part of this, Japan aims to establish a committee that will oversee the progress of the innovation plans. It also announced a number of initiatives to attract new talent, including the "Zero Emission Creators 500" initiative that aims to support young researchers and the "Global Zero Emission Research Center" that would engage researchers from other G20 countries. Dedicated support has been announced for support for zero-emission start-ups and demonstration sites. Overall, the acceleration plans aim to increase public and private investment in energy-related RD&D to JPY 30 trillion (USD 290 billion) for the decade 2020-30.

The EIS's third pillar consists of "zero-emission initiatives" that aim to foster international collaboration on zero emissions RD&D. Japan aims to gather global leaders of industry, finance and academia to share Japan's initiatives with the world on an annual basis. This will happen through conferences such as the Green Innovation Summit, which was launched under the umbrella of Japan's G20 presidency in 2019 (see the section on international collaboration below).

As part of the EIS, Japan has indicated that it aims to mobilise about JPY 30 trillion (USD 290 billion) in public and private RD&D in fields related to the environment and energy over the next decade. This compares to about JPY 3 trilling of public funding in the previous decade (2009-18). Achieving the JPY 30 trillion target will therefore require considerable investment by the private sector. However, data on private sector investment in energy RD&D are currently not available. Systematically collecting these data would help follow progress towards the JPY 30 trillion target, while facilitating the evaluation of public spending and support programmes.

Selected energy programmes

Thanks to national strategies based on long-term perspectives and strong public support, Japan has achieved breakthrough innovations in a number of energy fields ranging from widespread diffusion of solar energy to the commercialisation of electric vehicles. Japan continues to be active in a large range of technology fields. Notable initiatives include the Fukushima Renewable Energy Institute, established in 2014 to promote R&D in renewable

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energy, and specific initiatives on next-generation power electronics and innovative combustion technology under Japan's Strategic Innovation Program, which entered into its second phase in 2018 (JST, 2020). Another notable initiative is the joint meeting of the first meeting of the green innovation strategy and the first meeting of the working group for the green innovation strategy on 7 July 2020.

In recent years, and in line with other strategic priorities, the technology focus is firmly shifting to CCUS and hydrogen technologies. The following discussion will therefore be limited to these two areas that offer the newest insights.

Carbon capture, utilisation and storage

Given its relatively large reliance on fossil fuels (which accounted for 89% of energy supply and 72% of electricity generation in 2018), Japan considers CCUS a key technology for meeting its energy and climate goals, along with energy savings and renewable energy. With more than 16 gigawatts (GW) of new coal- and gas-fired power plants under construction, successful application of CCUS will be vital for Japan to meet its GHG emissions reduction target and to avoid large-scale stranded assets. CCUS, together with hydrogen (see below), is recognised as an important technology for reducing emissions, particularly from energy-intensive industrial processes for which direct electrification is technically less advanced and would not avoid process emissions from the carbon contained in the raw materials used.

Japan has established itself as a leader in the development of CCUS technology, hosting a number of demonstration projects involving both public organisations such as NEDO and the Advanced Industrial Science and Technology and private companies. While early efforts focused on improving CO_2 capture and storage technologies, the policy focus is increasingly turning to the use of CO_2 as a resource to produce valuable products (referred to as "carbon recycling" in Japan).

Carbon capture technologies

Japan runs a number of pilot and demonstration projects to test various carbon capture technologies (e.g. chemical solvents, solid absorbents and CO_2 separation membranes). Most of these technologies are still in the development or demonstration phase; some technologies based on chemical absorption have been used in industry for decades and are commercially available, but the process remains costly and highly energy-intensive for some applications. Support for innovation therefore remains critical to overcome these barriers to competitiveness (see Chapter 10).

In the industrial sector, a major carbon capture demonstration project takes places within the COURSE 50 initiative.[3] COURSE 50 is a major RD&D project with two components: reducing CO_2 emissions from blast furnaces and separating and capturing CO_2 from blast furnace gases. As for carbon capture, COURSE 50 aims at developing and testing new absorbent solutions (chemical and physical) to reduce the energy needed for carbon capture. It also aims to recover waste heat from steelmaking processes to optimise energy needs for carbon capture. As for the CO_2 reduction component, COURSE 50 aims to replace some of the coking coal needed in the blast furnace with a gas stream containing carbon monoxide and hydrogen, which results in the reduction of the CO_2 from the blast

[3] COURSE 50 stands for CO_2 Ultimate Reduction System for Cool Earth 50. It was started in response to the Cool Earth 50 programme, which was developed by Japan in 2008.

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furnace gas. The programme also explores the possibility to reuse coke oven gas by reforming part of its carbon content (e.g. tar) into hydrogen and diverting the resulting gas into the blast furnace too, as a complementary reducing agent. With these measures, COURSE 50 aims to reduce CO_2 emissions from steelmaking by approximately 30% (if the captured CO_2 gets stored). The project is run by NEDO and involves four private companies. It is fully financed by NEDO. The aim is to commercialise these technologies by 2030 (JISF, 2011).

In the power sector, a major carbon capture demonstration project began operations in November 2020 at the biomass-powered Mikawa plant in Fukuoka (Kyushu). The project is expected to capture up to 500 tonnes of CO_2 (t CO_2) per day, corresponding to about half of the plant's daily emissions. On a smaller scale, carbon capture is already being deployed at the Saga incineration plant in Kyushu since 2016. The plant captures 10 t CO_2 per day (and uses the captured CO_2 to stimulate the growth of crops and algae cultures). Both projects use a post-combustion carbon capture process based on chemical absorption.

In addition, tests have started to capture carbon at an integrated coal gasification combined cycle power plant in Hiroshima (Chugoku) under the Osaki CoolGen Project. It is hoped that the system will be able to collect more than 90% of the CO_2 emitted in the coal gasification power generation process, using a physical absorption technology. The project also seeks to demonstrate the potential for recycling captured CO_2 and, eventually, for incorporating coal-sourced synthesis (comprised of H_2 and CO) gas into fuel cells.

CO_2 storage

A 2009 survey identified a technical CO_2 storage potential of 146 billion tonnes in Japan, mostly located in deep geological formations offshore. This compares to about 1 billion tonnes of CO_2 from fuel combustion emitted per year in Japan. Given Japan's geographic location and seismic activity in the region, there is uncertainty about how much of this potential can actually be used. In 2014, METI and the Ministry of the Environment commenced a detailed geological survey and assessment project with the aim to identify at least three offshore sites that can be used for CO_2 storage by 2021. Japan is also looking at shipping as a way to transport captured CO_2, which could be relevant for both offshore domestic storage and for international storage and recycling options.

The first pilot-scale CO_2 storage project in Japan dates back to the beginning of the 2000s, when 10 000 t CO_2 were injected into a saline aquifer between 2003 and 2005 in Nagaoka (Chubu). More recently, in late 2019, a demonstration project in Tomakomai (Hokkaido) has reached its initial target of injecting 300 000 t CO_2 underground. The Tomakomai project has been the first Japanese project demonstrating the entire CCS value chain, covering capture, transport and permanent storage. It is a landmark demonstration project in Japan, even if relatively small scale compared to industry-driven CO_2 storage projects operating throughout the world. The CO_2 was captured at a hydrogen production unit at a refinery complex in Tomakomai City over a period of three years.[4] The captured CO_2 was then transported by pipeline for injection into two nearby offshore saline aquifers for storage and monitoring. As a next step, in addition to monitoring the CO_2 injected, METI plans to start carbon recycling at the Tomakomai facility.

[4] The process removes hydrogen sulfide (H_2S) and CO_2 from refinery gas.

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Carbon recycling

The Japanese government has increased efforts to use CO_2 as a raw material to produce valuable products, in particular fuels, chemicals and building materials. It established a Carbon Recycling Promotion Office within METI in February 2019 and launched the long-term Roadmap for Carbon Recycling Technologies at the G20 Energy Ministers' Meeting in June 2019. The road map highlights carbon recycling as "one of the key technologies for society to achieve climate targets, together with energy savings, renewable energy and CCS" (METI, 2019a). This was accompanied with a carbon recycling budget of JPY 35 billion (USD 318 million) for fiscal year (FY) 2019. In addition, CO_2 use and recycling are part of the Moonshot R&D programme, launched in 2019, and which aims to support high-risk, high-impact R&D that would help solve some of the country's biggest challenges (NEDO, 2020).

The Roadmap for Carbon Recycling Technologies outlines the current technological status of materials and products in which recycled CO_2 can be used, describes steps for technology advancement, and sets goals for cost reductions to be achieved by 2030 and 2050 (see Table 6.1 for examples). From 2030, it aims for commercialisation of established and high value-added commodities, such as bio-jet fuel produced from algae, polycarbonates and some products made from concrete (e.g. road curb blocks). From 2050, it aims to promote the commercialisation of products that create high demand for CO_2, such as olefins (building blocks of the petrochemical industry), gaseous fuels (mainly methane) and general-purpose concrete products. Production of many of these products will be dependent on the availability of cheap CO_2-free hydrogen, as well as the competitiveness of CO_2 capture technologies and the roll out of CO_2 transport infrastructure.

Efforts to reduce the costs of capturing carbon will continue, with the aim to cut costs by 75% from today's level by 2050. Such a drastic reduction in cost would increase the economic case for carbon recycling. Increasing the costs of unabated CO_2 emissions (e.g. through a higher carbon tax) would strengthen the case for CCUS even further. As the transformation of CO_2 into other products requires a large amount of energy for most applications, decarbonisation of energy supply will be critical. The government of Japan recognises this and announced it ould adopt a life-cycle approach to assessing carbon recycling technologies. Such an approach should cover both the energy used to capture the carbon and the process of carbon use (with the latter becoming particularly important for short-lived products such as fuels).

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Table 6.1 Technologies identified in Japan's 2019 Roadmap for Carbon Recycling

Category	Substance after CO_2 conversion	Current status	Challenges	Domestic price of existing equivalent product*	In 2030	From 2050 onwards
Basic substance	Syngas/methanol, etc.	Partially commercialised; innovative process (e.g. light, electricity use) at R&D stage	Improvement of conversion efficiency and reaction rate, improvement in durability of catalyst	–	Reduction in process costs	Further reduction in process costs
Chemicals	Oxygenated compounds	Partially commercialised (e.g. polycarbonates); others at R&D stage	Reduction of CO_2 emissions (for polycarbonates), improvement in conversion rate/ selectivity (for other substances)	~ JPY 300-500/kg (polycarbonate)	Reducing costs to those of existing energy/products	Further cost reduction
	Biomass-derived chemicals	Technical development stage (non-edible biomass)	Cost reduction, effective pre-treatment technique, improvement of conversion technologies	–	Reducing costs to those of existing energy/products	Further cost reduction
	Commodity chemicals (e.g. olefin, BTX**)	Partially commercialised (e.g. syngas produced from coal)	Improvement in conversion rate/ selectivity	~ JPY 100/kg (ethylene)	–	Reducing costs to those of existing energy/products
Fuels	Liquid fuels (microalgae biofuel)	Demonstration stage (current price: JPY 1 600/L)	Improvement in productivity, cost reduction, effective pre-treatment technique	~ JPY 100/L (bio jet fuel)	Reducing costs to those of existing energy/products	Further reduction in costs
	Other liquid fuels (CO_2-derived fuels or biofuels)	Demonstration stage (e.g. E-fuel), edible biomass-derived bioethanol partially commercialised	Improvement in current processes, system optimisation	JPY 50-80/L (alcohol as raw material) ~ JPY 130/L (industrial alcohol)	–	Reducing costs to those of existing energy/products
	Gas fuel (methane)	Demonstration stage	System optimisation, scale-up	JPY 40-50/Nm^3 (imported natural gas)	Reduction in costs for CO_2-derived CH_4	Reducing costs to those of existing energy/products
Minerals	Carbonates/concrete products, concrete structures	Partially commercialised; R&D for various technologies are underway to reduce costs (current price for road curb blocks: ~ JPY 100/t)	Separation of CO_2-reactive and CO_2-unreactive compounds, comminution	JPY 30/kg (road curb block)	Road curb blocks: similar costs to those of existing energy/products	Other products: similar costs to those of existing energy/products
Common technology	CO_2 capture	Partially **commercialised** (chemical absorption); **other techniques are at RD&D stage** (current price for chemical absorption: ~ JPY 4 000/t CO_2)	Reduction of required energy	–	~JPY 1 000-2 000/t CO_2 (chemical absorption, solid absorption, physical absorption, membrane separation)	JPY 1 000/t CO_2 or lower
Basic substance	Hydrogen	Technologies roughly established (e.g. water electrolysis); R&D for other techniques underway to reduce costs	Cost reduction	–	JPY 30/Nm^3	JPY 20/Nm^3 (cost at delivery site)

* Prices researched by the Secretariat for the Roadmap

** BTX refers to mixtures of benzene, toluene and the three xylene isomers, all of which are aromatic hydrocarbons.

Notes: Basic substances, chemicals (excluding some oxygenated compounds) and many technologies for fuels require large amounts of inexpensive CO_2-free hydrogen. Biomass-derived fuels may require hydrogen for hydrogenation treatment.

Source: METI (2019a), *Roadmap for Carbon Recycling Technologies*, www.meti.go.jp/press/2019/06/20190607002/20190607002-2.pdf.

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Strategic vision for hydrogen

Japan's 5th SEP views hydrogen as an important energy carrier in the county's future energy structure (METI, 2018). Hydrogen can be produced from a wide variety of energy sources, including fossil and renewable energy, can be stored and transported and, when used, does not emit CO_2 or local air pollutants. As such, it can offer a clean solution for not only power generation and transport, but also industrial processes and heat applications – areas that are difficult or costly to electrify. Hydrogen is therefore considered a key energy carrier to diversify and enhance the security of Japan's energy supply while bearing significant potential to help decarbonise the economy.

Japan was the world's first country to develop a national hydrogen strategy. Its Basic Hydrogen Strategy, launched in December 2017, reiterates Japan's ambition to become a "hydrogen society" in which hydrogen is used in everyday life and industrial activities.[5] It outlines visions and milestones to be achieved by 2050, while also serving as an action plan to 2030. Key milestones include making hydrogen cost-competitive with conventional energy sources, establishing robust international supply chains and massively scaling-up its use in all end-use sectors (METI, 2017).

The 2021 Olympic Games and Paralympic Games in Tokyo are considered a key opportunity to both showcase achievements and further advance progress on the deployment of hydrogen (Box 6.1). Japan's pioneering initiatives in this area could have a positive global impact on bringing down the costs, helping markets develop and positioning Japan as a future supplier of hydrogen technologies to the world.

[5] The vision of a "hydrogen society" was first established in the 4th SEP in 2016.

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Box 6.1 Hydrogen at the 2021 Tokyo Olympic and Paralympic Games

The Japanese government intends to leverage the 2021 Summer Olympic and Paralympic Games in Tokyo to showcase its world-leading hydrogen and fuel cell technologies, as well as to advance their large-scale deployment. As part of this effort, Japan plans to make the athletes' village the world's first hydrogen-powered town, using hydrogen to provide electricity and hot water in the buildings that will accommodate approximately 10 000 athletes. The energy will be partly sourced from the Fukushima Hydrogen Energy Research Field (FH2R) project, a solar powered hydrogen production unit whose opening ceremony was held on 7 March 2020 (see below).

It is intended that about 100 fuel cell buses and 500 fuel cell vehicles will ferry athletes to and from venues around the city. A new filling station opened in January 2020 near Tokyo's fish market to serve the fuel cell buses (some of which are already operating in Tokyo). The new station is the 113th filling station in Japan and to date the country's largest, with a supply capacity of 300 normal cubic metres (Nm^3) of hydrogen per hour. Hydrogen will also be used for the first time to fuel the Olympic torch.

The roll out of hydrogen infrastructure is part of Japan's efforts to hold environmentally friendly Games. In addition to promoting hydrogen, the organisers announced to offset all CO_2 emissions generated during the games, to use recycled materials for a number of products (including beds in the athletic villages) and more generally to use the Olympics to enhance environmental awareness in Japan.

Sources: Japan Times (2020), "Hydrogen to fuel 2020 Olympic flame", www.japantimes.co.jp/sports/2020/01/10/olympics/hydrogen-fuel-2020-olympic-flame/#.XqhUiWgzZnI; Tarrant, J. (2020), "Tokyo 2020 to power Olympic torch with hydrogen for first time", www.reuters.com/article/us-olympics-2020-torch/tokyo-2020-to-power-olympic-torch-with-hydrogen-for-first-time-idUSKBN1ZQ0D5.

National targets for hydrogen

The Hydrogen and Fuel Cell Strategy Roadmap, first developed in 2014 and revised in 2016 and 2019, sets numerical targets for technology development, cost reductions and practical application of hydrogen. The Basic Hydrogen Strategy of 2017, which provides a long-term vision and policy details, set additional targets to 2020, 2030 and 2050.

The Basic Hydrogen Strategy set the overall goal to make hydrogen cost-competitive with competing fuels like gasoline in transport and liquefied natural gas (LNG) in power generation, reducing its plant delivery cost from USD 1 Nm^3 to USD 0.30/Nm^3 by 2030 and to USD 0.20/Nm^3 by 2050. The 2019 road map specified that hydrogen would need to be priced at USD 0.12/Nm^3 (JPY 13/Nm^3) to match the current price of LNG on an energy-equivalent basis (disregarding the environmental benefit or value of hydrogen) (METI, 2019b).

On the supply side, the Basic Hydrogen Strategy aims to build commercial hydrogen supply chains to procure about 300 000 tonnes of hydrogen by 2030. Liquid hydrogen supply chains should be technically developed by mid-2020 and commercialised by 2030. The road map set additional targets related to transport capacity and energy use in hydrogen liquefaction (Figure 6.4). It also set a near-term goal to limit CO_2 emissions to 60% of the level when hydrogen is produced from natural gas; the long-term goal is to reduce CO_2 emissions to virtually zero (METI, 2019b).

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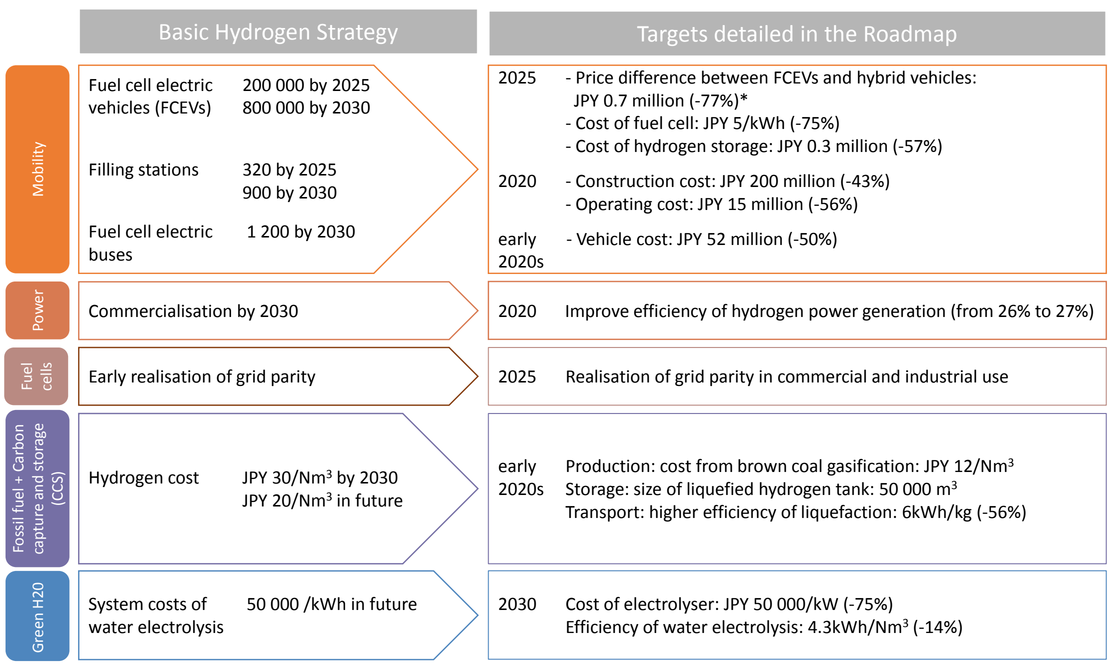
Japan is among the very few countries in the world to have an explicit goal for the use of hydrogen in the power sector, aiming to reach 1 GW of power capacity based on hydrogen by 2030 (and 15-30 GW in the longer term).[6] The costs of power generated by hydrogen are envisaged to decline to JPY 17 (USD 0.16) per kilowatt hour, and generation efficiency should increase to 57%.[7] In addition, Japan aims to identify requirements for introducing co-combustion power generation, using hydrogen in existing thermal power plants in the early 2020s.

On the demand side, the strategy set ambitious goals for hydrogen-powered fuel cell vehicles and fuel cell co-generation units, both of which are already relatively widespread in Japan (see below). In the longer term, it also aims to replace fossil fuels in industrial and other processes that are difficult to decarbonise through electrification. The 2019 road map announced the establishment of an expert commission to evaluate progress for each field.

Figure 6.4 Targets set in Japan's Strategic Roadmap for Hydrogen and Fuel Cells



* Figures in brackets indicate cost reduction from current levels.

Source: METI (2019b), *Strategic Roadmap for Hydrogen and Fuel Cells*, www.meti.go.jp/english/press/2019/pdf/0312_002a.pdf.

Hydrogen supply

Japan aims to source low-cost, zero-emission hydrogen from overseas fossil fuels combined with CCUS or, alternatively, from renewable energy electrolysis. In March 2020, a consortium including Toshiba Energy Systems & Solutions and NEDO finalised the construction of a renewable energy-powered hydrogen plant in Fukushima. The Fukushima Hydrogen Energy Research Field project uses 20 megawatts (MW) of solar

[6] The 1 GW in hydrogen-based power generation is an indicative goal resulting from hydrogen demand of 300 000 tonnes.

[7] This target refers to large-scale gas turbines (100 MW class). The efficiency target for small-scale gas turbines (1 MW class) is 27%.

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power generation facilities, together with some electricity from the grid, to conduct electrolysis of water in a 10 MW-class hydrogen production unit. The plant has the capacity to produce up to 1 200 Nm^3 of hydrogen per hour. The hydrogen produced will mainly be transported in tubes and bundles to supply the Fukushima Prefecture as well as the Tokyo Metropolitan Area and other regions. The plant is now in a test phase that seeks to optimise the production and storage of hydrogen and power grid supply and demand balancing adjustments without the use of storage batteries. Hydrogen production began in March 2020 and fully fledged operation is scheduled to begin in mid-2020 (FuelCellsWorks, 2020; Toshiba, 2020).

To secure hydrogen supply from overseas, Japan has entered into a number of international collaborations. The Hydrogen Energy Supply Chain project is the first initiative globally to establish an integrated commercial-scale supply chain that encompasses the production, storage and transportation of mass quantities of hydrogen over a long distance by 2030. In the project's demonstration component that is already underway, hydrogen is produced through brown coal gasification in Latrobe Valley in Australia, transported by truck to the port of Hastings, liquefied, then shipped to Japan using a ship that was purposefully built for carrying liquid hydrogen. Kawasaki Heavy Industries launched the first small-scale liquefied hydrogen ship, built for demonstration purposes in December 2019, and plans to have two large-scale carriers available for commercial operations in 2030. Simultaneously, a consortium including Mitsubishi and Mitsui has started a pilot project to ship hydrogen produced from natural gas at an LNG plant in Brunei to Japan, whose operations started in 2020. It will be transported, using technology from Chiyoda, mixing the hydrogen with toluene to convert it to methylcyclohexane (MCH), which is then reconverted into hydrogen at destination.

Ensuring that these projects operate CCUS will be critical to ensure the hydrogen is carbon-free and sustainable. Currently, almost all globally produced hydrogen is generated from fossil fuels (mostly natural gas and coal) (IEA, 2019a). The establishment of an internationally shared vision on a pathway for decarbonising the production of hydrogen should therefore be part of Japan's efforts to establish international supply chains.

Hydrogen consumption

Japan places a strong emphasis on pushing the market for hydrogen-powered vehicles. It set the ambitious goal to have 800 000 fuel cell electric vehicles (FCEVs), 1 200 fuel cell buses and at least 900 refuelling stations installed by 2030 (see Table 6.1 above). In 2019, Japan had 3 600 FCEVs, which represents about one-fifth of the global fleet of passenger FCEVs (IEA, 2020b). Japanese automakers Toyota and Honda are among the few companies that have made FCEVs commercially available. Japan is also developing fuel cell electric buses, with government support.

Efforts are also increasing to develop hydrogen-powered commercial vehicles. Honda and Isuzu Motors recently announced the joint development of hydrogen-powered trucks. Toyota has been expanding the use of fuel cell forklifts at its car plant in Toyota City and plans to collaborate with Seven-Eleven Japan to deploy small fuel cell delivery trucks. The company also announced collaboration with the East Japan Railway Company to develop a rail vehicle powered by a hydrogen system that combines fuel cell and lithium-ion batteries. The first test runs in the greater Tokyo area are planned for 2021, with possible commercialisation in 2024. The first prototypes for fuel cell-powered boats were expected for 2020 (E4tech, 2020).

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The goal regarding refuelling infrastructure is to install 160 hydrogen filling stations by 2020, 320 in 2025 and to make hydrogen stations commercially independent in the second half of the 2020s. As of late 2019, there were about 133 stations installed (IPHE, 2020). In 2018, a number of companies, infrastructure developers and investment companies founded the joint venture “Japan H_2 Mobility (JHyM)” with a goal to build 80 new hydrogen filling stations by 2022 (for a total of 160), in co-operation with the government and with the help of government subsidies. The government revised regulation to accelerate the roll-out of infrastructure, including by modifying fire safety provisions to allow gas station operators to integrate hydrogen stations into existing conventional filling stations. The government may also consider revising regulatory provisions to ensure that filling station components (e.g. control panel, safety equipment, dispensers, etc.) be offered under uniform standards. This would allow components from different manufactures to be combined, which in turn can help reduce costs.

In the power generation sector, Japan continues to be a global leader in the application of small-scale stationary fuel cells. It was among the first countries to introduce fuel cell co-generation units in single family houses, and by late-2019 more than 300 000 units had been installed (METI, 2019b). Most of these units, referred to as energy farms (or “Ene-farms”), benefited from government subsidies. However, Japan reached its goal of a self-sustaining market by 2020: the cost of an Ene-farm unit has decreased by about 70% over the past decade; Ene-farms no longer benefit from public subsidies and some companies have initiated exports to foreign markets. Yet, the country is still far from its goal to have 5.3 million units installed by 2030. Fuel cells for larger buildings are slowly gaining ground, with the first hotels, stadiums and a brewery being supplied with power through a fuel cell.

There are also examples for power generation based on hydrogen-based fuels such as ammonia and synthetic natural gas. In 2017, the Japanese Chugoku Electric Power Corporation successfully demonstrated the co-firing of ammonia and coal, with a 1% share of ammonia (in terms of total energy content) at one of their commercial coal power stations (IEA, 2020b). In addition, a NEDO project involving Obayashi Corporation and Kawasaki Heavy Industries generates electricity and heat using a gas turbine fuelled entirely by hydrogen (NEDO, 2018).

International collaboration

Japan attaches great importance to international collaboration on energy technology RD&D. It leads or actively engages in numerous international initiatives and has a strong bilateral co-operation programme.

Japan is a very active contributor to the IEA Technology Collaboration Programme (TCP), engaging in 30 of the 38 collaborations (Table 6.2). Since the last IEA in-depth review in 2016, Japan has joined the Wind TCP in 2017. In addition, the Central Research Institute of Electric Power Industry became the first Japanese entity to join the Industrial Energy-Related Technologies and Systems TCP in 2018.

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Table 6.2 Japan's participation in IEA technology collaboration programmes, as of April 2020

End-use technologies	**Nuclear energy**
Buildings	Tokamak Programmes
Buildings and Communities	Environmental, Safety, Economic Aspects
Energy Efficient End-use Equipment	Fusion Materials
Energy Storage	Nuclear Technology Fusion Reactor
Heat Pumping Technologies	Plasma Wall Interaction
Electricity	Reversed Field Pinches
High-Temperature Superconductivity	Stellarators and Heliotrons
Smart Grids	Spherical Tori
Transport	
Advanced Fuel Cells	**Renewable energy and hydrogen**
Advanced Motor Fuels	Bioenergy
Clean and Efficient Combustion	Geothermal Energy
Industry	Hydrogen
Industrial Technologies and Systems	Photovoltaic Power Systems
	Solar Heating and Cooling
Fossil energy	Wind Energy
Clean Coal Centre	Ocean Energy Systems
Enhanced Oil Recovery	
Fluidised Bed Conversion	**Cross-cutting**
Greenhouse Gas R&D Programme	Energy Technology Systems Analysis

Japan also participates in Mission Innovation and three of its "Innovation Challenges": IC3 on carbon capture, IC5 on converting sunlight, and IC8 on renewable and clean hydrogen.

It is also a member of the Clean Energy Ministerial and seven of its initiatives: 1) the Hydrogen Initiative; 2) the Nuclear Innovation: Clear Energy Future Initiative; 3) the International Smart Grid Action Network; 4) the Multilateral Solar and Wind Working Group; 5) the Electric Vehicle Initiative; 6) the Energy Management Working Group; and 7) the CCUS Initiative.

Japan has taken a leading role in promoting and advancing international collaboration on hydrogen and CCUS. It hosted the world's first Hydrogen Energy Ministerial Meeting in 2018 (and its successor in 2019) as well as the world's first International Conference on Carbon Recycling in September 2019, in the context of its G20 presidency in 2019. Japan furthermore held a Green Innovation Summit in October 2019, which brought together leaders from three clean energy meetings convening the same week in Japan: the RD20 Forum (which gathered leading clean-energy research institutes from G20 countries); the Summit of the Task Force on Climate-Related Financial Disclosures; and the Innovation for Cool Earth Forum (which Japan has been hosting since 2014).

In the context of its G20 presidency, Japan collaborated closely with the IEA. Major outcomes of this collaboration include the reports *The Future of Hydrogen* (IEA, 2019a), *Securing Investments in Low-Carbon Power Generation Sources* (IEA, 2019c) and *Innovation Gaps: Key Long-term Technology Challenges for Research, Development and Demonstration* (IEA, 2019d), as well as other activities and analyses to encourage greater international collaboration on data gathering.

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Japan also aims to foster international collaboration among researchers and engineers. In the context of the International Conference on Carbon Recycling in 2019, Japan launched the "Carbon Recycling 3C Initiative", which aims to foster knowledge exchange, establish research centres and demonstration sites, and strengthen international joint research on carbon recycling technologies. Japan also founded the Global Zero Emissions Research Center in January 2020, which connects 120 000 international scientists from G20 member countries to work on seven thematic areas: 1) artificial photosynthesis; 2) energy carriers (enabling synthesis of hydrogen carriers); 3) efficient thermoelectric devices; 4) organic PV devices; 5) electrochemical reaction control (to produce hydrocarbons using water electrolysis); 6) CO_2 separation and utilisation; and 7) energy evaluation (improving life-cycle analyses). The centre will be set up under the National Institute of Advanced Industrial Science and Technology and incorporate existing laboratories in Fukushima, Ibaraki and Osaka Prefectures.

Assessment

Japan is a leading global energy technology developer and provider. It has an impressive track record in research on photovoltaic and battery technology and is a frontrunner in fuel cell and hydrogen technology and CCUS. Technology and innovation have always been critical with a view towards ensuring Japan's long-term energy security, as it lacks domestic energy resources. Domestic ambitions to reduce GHG emissions have become an additional driver behind Japan's commitment to developing innovative energy technologies. Innovation is at the heart of Japan's strategy to reach its ambition of becoming carbon-neutral by 2050.

Japan maintains a commendable high level of funding for energy RD&D. Public spending on energy RD&D is the second-largest in the IEA in absolute terms, and the third-highest relative to GDP. Nuclear is the single largest sector receiving funding, with energy efficiency and renewable energy receiving most of the remainder. Increasing attention is being paid to hydrogen and fuel cells, as well as to technologies that facilitate the grid integration of renewables. The IEA welcomes the inclusion of spending data for energy-related RD&D by the Ministry of the Environment, which makes overall spending data more complete. Looking ahead, Japan has indicated that it aims to mobilise about JPY 30 trillion in public and private RD&D in fields related to the environment and energy in the next decade.

In 2016, NESTI 2050 set ambitious targets for technologies considered necessary to reach Japan's long-term climate change mitigation goals. It strengthened the focus on technology areas required to integrate more renewable energy sources in the energy system and included a broad range of topics that are at different stages of market introduction, including established technologies like batteries and PV.

The Japanese government wants to take its RD&D efforts even further. In January 2020, it launched the Environment Innovation Strategy, which detailed the innovation paths, cost targets and estimated mitigation potential of the core technologies identified in NESTI 2050. The EIS approach is comprehensive and ambitious, including innovation action plans for key technologies, acceleration plans aimed at strengthening the involvement of the private sector, promoting green finance, supporting young researchers and stimulating start-ups, as well as initiatives to foster international co-operation.

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Japan is continuously increasing its engagement in and support for international RD&D collaboration. Beyond its engagement in 30 out of 38 IEA Technology Collaboration Programmes, Japan is an active member of the Clean Energy Ministerial and Mission Innovation. Increasingly Japan is taking a leading role in advancing and promoting international collaboration, in particular for hydrogen and CCUS. The Hydrogen Energy Ministerial Meeting and the International Conference on Carbon Recycling, which Japan launched during its G20 presidency in 2019, are important contributions to a growing international understanding of the potential of these technologies. Japan's strong international engagement reflects a growing awareness that sharing costs and risks at an early stage in the innovation process is essential for accelerating the development of the new technologies that are needed to reach climate goals.

Carbon capture, utilisation and storage

Japan is among the global leaders in the development of CCUS technologies. It runs a number of pilot-scale demonstration projects to separate and capture CO_2 at different facilities (e.g. power plants, refineries, steel mills). The completion of the Tomakomai project in 2019 constitutes Japan's first project demonstrating the entire value chain, covering CO_2 capture, transport and permanent storage. Japan aims to identify at least three CO_2 storage sites by 2021.

Carbon recycling

While early efforts focused on improving CO_2 capture technologies, the policy focus is increasingly turning to the use of CO_2 as a resource to produce valuable products (referred to as "carbon recycling" in Japan). The Roadmap for Carbon Recycling Technologies, launched at the G20 Energy Ministers' Meeting in June 2019, focuses on reducing costs and increasing the demand for captured CO_2. Concretely, it aims to cut the costs of carbon capture by 75% from today's level, and to commercialise products that create high demand for captured CO_2 (such as gaseous fuels and general-purpose concrete products) by 2050. Whether these commercialisation targets can be achieved will, to a large extent, depend on the cost and nature of the CO_2 sources used, as well as on the availability of cheap CO_2-free hydrogen.

Hydrogen

Building on its strong knowledge on hydrogen and fuel cell technology, Japan has the ambition to become the world's first "hydrogen society", in which hydrogen is widely used in all end-use sectors. Since 2014, its Strategic Roadmap for Hydrogen and Fuel Cells (last version from 2019) defines clear targets for costs and technologies, and gives a straightforward analysis of issues to tackle. In 2017, Japan launched its Basic Hydrogen Strategy to co-ordinate public and private initiatives related to hydrogen, define a common vision and milestones for 2030 and 2050, and provide policy details. Targets include having 800 000 fuel cell vehicles, 900 refilling stations, 5.3 million residential fuel cells and 1 GW hydrogen power generation by 2030. Achieving strong cost reductions by 2030 will be crucial. Japan aspires hydrogen to be competitive with natural gas.

The IEA report *The Future of Hydrogen*, launched during the G20 in Japan, indicated that the coming decade will be critical for keeping hydrogen in the energy toolbox, with governments playing a crucial role. Due to its pioneering efforts, Japan is addressing the critical challenges of adapting regulations, getting the infrastructure in place and stimulating markets through support schemes. Household fuel cells and fuel cell vehicles

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have already entered the market, but continuous efforts will be needed to reach the ambitious goals for 2030. In line with developments in other countries, more emphasis on the use of hydrogen for heavy and long-distance transport will help to demonstrate the benefits of hydrogen, in particular for air quality.

Keeping the momentum will require continuous efforts, with sufficient attention to regulatory aspects and support measures, along with technology innovation. The various demonstration projects that are currently being implemented throughout Japan with different applications of hydrogen and fuel cells can serve as valuable testing grounds for innovative policies and regulations that will accelerate market development. Involving local communities will help create public acceptance, in particular if the focus is on using hydrogen and fuel cells for integrating local renewable sources, like solar and wind. The 2021 Tokyo Olympic Games, where hydrogen will be used for vehicles, electricity and even for the Olympic torch, will offer an excellent platform to showcase the impressive achievements to date with hydrogen.

Japan stands out for its efforts in exploring the potential of using hydrogen for flexible power generation (e.g. in gas turbines or co-firing in existing plants). Strong government support, however, will be needed this decade to make this a viable option by 2030 to compete with existing fossil options. Next to the technical challenges, availability of low-cost and low-carbon hydrogen will be key. Japan's efforts to develop an international hydrogen supply chain could become a game-changer in the energy world. The private sector is actively engaged, with the hope to start commercial operations around 2030. An internationally shared vision on a path for decarbonising the production of hydrogen should be part of the strategy.

Disruptive innovations

Japan's new RD&D strategy is driven by a strong sense of urgency. Innovations have to be accelerated, in particular for those technologies that are considered indispensable to reach the carbon neutrality goal by 2050. Japan puts strong hopes on "disruptive" innovations that may drastically change the existing energy system and the structure of the economy more broadly. Allowing such drastic changes to happen will require new approaches to innovation policy that go beyond programmes aimed at specific technologies.

A cross-sectoral approach can help to link innovation with broader energy, environment and climate policy goals. The EIS does address these issues, but further implementation will have to show to what extent current RD&D structures can achieve the desired acceleration. In addition, as new technologies such as hydrogen and CCUS enter the first stages of market introduction, factors other than funding become important. This includes policy measures related to regulations, intellectual property, market entry and market creation (demand-pull measures). Japan should adopt such an integrated approach. Creating regulatory sandboxes that allow for live testing of innovations could be a useful tool. Considering its leading role, it is vital that Japan continue to actively put hydrogen and CCUS on the international political agenda. The Japanese market cannot develop in isolation; cost reductions and innovations resulting from market developments in other countries are needed. Harmonising standards for the technologies and associated regulations will be important for the development of international markets.

Evaluation and monitoring are key to assess whether strategies, budgets and structures are delivering the desired outcomes or require adjustment. Japan has a well-functioning

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system to evaluate national RD&D projects. With the announced increase in spending on energy-related RD&D, close monitoring of results against pre-set evaluation criteria will become even more important. As a substantial part of the RD&D is carried out by the private sector, it is essential to also collect more data on private funding. This is in line with a growing need felt by a number of IEA member countries to improve the analyses of private RD&D. For example, Austria has recently published its first report on private sector energy RD&D funding outside of public-private partnership efforts.

Recommendations

The government of Japan should:

- Swiftly implement the Environment Innovation Strategy and integrate its approach and ambition into the overall energy policy, by preparing policies and measures, including regulatory sandboxes and demand-pull measures, which will accelerate the actual introduction of "disruptive innovations" in the energy system.
- Conduct systematic evaluations and analyses of existing RD&D programmes and schemes, including data on RD&D carried out by the private sector, in order to monitor whether results are in line with the policy objective of accelerating innovation, and make timely adjustments when necessary.
- Continue to play a leading role in advancing and promoting international energy RD&D collaboration, both in Asia and globally, by sharing costs and risks.
- Continue its leading role in international collaboration and push for measures that help the development of a global hydrogen market, including harmonisation of standards across regions and safety protocols.
- Showcase decentralised applications and their benefits for reducing local air pollution, energy security and integrating local renewable sources from wind and solar, to demonstrate the advantages of the Hydrogen Society concept.
- Accelerate the role of hydrogen in fleets, freight and corridors and in particular for long-distance and heavy weight applications (trucks and ships).

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7. Electricity

Key data

(2018/19 estimated)

Electricity generation (2019): 992.5 TWh (natural gas 34.2%, coal 31.9%, solar 9.4%, hydro 8.1%, nuclear 6.4%, oil 4.8%, non-renewable waste* 2.2%, bioenergy** 2.0%, wind 0.7%, geothermal 0.3%), -8.5% since 2009

Installed capacity (2018): 344.9 GW

Electricity consumption (2018): 959.9 TWh (industry 35.4%, services/other 33.4%, residential 27.9%, transport 1.8%, energy 1.5%), -7.4% since 2008

* Includes non-renewable municipal and industrial waste.

** Includes bioenergy: primary solid biofuels, renewable municipal waste, liquid biofuels and biogas; excludes non-renewable municipal waste and industrial waste.

Overview

Since the 2011 Great East Japan earthquake and subsequent Fukushima Daiichi nuclear accident (hereafter called "the 2011 events"), that prompted the closure of all nuclear power plants, fossil fuels have been the dominant energy source in Japan's electricity mix, representing nearly three-quarters of total power generation in 2019. However, renewable energy has grown substantially, reaching 19% of total generated power in 2019. Nuclear power generation is also on the rise again, accounting for 6% in 2019. By 2030, the government aims to achieve a more balanced electricity mix, in which coal, gas, nuclear and renewables account for about a quarter of power generation each. By 2050, renewables are envisioned to become the main power source.

Japan's electricity system is facing security of supply challenges. Natural disasters such as earthquakes and typhoons have led to long and large-scale power outages in various parts of the country. Japan's electricity grid is fragmented and there is limited capacity between regions. In addition, its grid is isolated, without the possibility for international electricity trade. The growth in variable renewable energy poses additional challenges to maintaining efficient and resilient electricity supply.

To address these challenges, the government started a reform of the electricity market in 2013. Major components included the establishment of a regulatory authority and full liberalisation of the retail market in 2016, and the legal unbundling of the vertically integrated incumbents in 2020. Further steps are being taken to spur investment in transmission and distribution grids, with the aim to facilitate the integration of variable renewable energy and to enhance the overall resilience of the electricity system.

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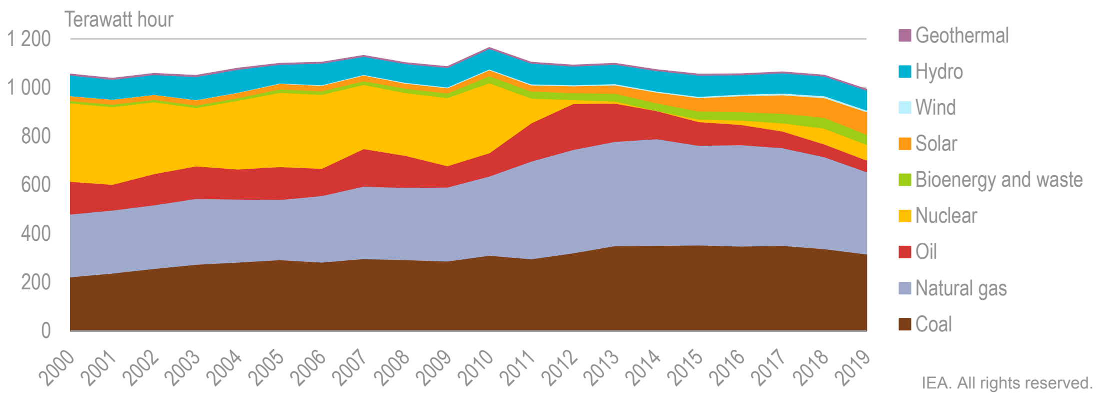
Electricity supply and demand

Electricity generation

The 2011 events had a significant impact on Japan's power mix, as the share of nuclear in electricity generation fell from 25% in 2010 to zero in 2014. The gap of nearly 300 terawatt hours (TWh) was initially filled by fossil fuels, notably oil and natural gas, but as of 2013, growing renewable electricity output and lower electricity demand also played a role (Figure 7.1). In 2019, total electricity generation stood at 993 TWh, 15% below the level in 2010.

Figure 7.1 Electricity generation by source in Japan, 2000-19



Fossil fuels filled the gap from reduced nuclear generation since 2011, although the share of solar power increased noticeably since then.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

The use of natural gas in power generation spiked after the 2011 events, but peaked in 2014 and has declined since (by 23%), to reach 339 TWh in 2019. Oil power generation also decreased rapidly (by 75%) since peaking in 2012. Coal power, on the other hand, has been stable at around 350 TWh since 2012, although it declined in 2018 and 2019 to reach 316 TWh. Nuclear power restarted operating from 2015, and produced 64 TWh in 2019, though still far from levels a decade earlier (258 TWh in 2008). Electricity generation from renewables has nearly doubled in a decade, from 101 TWh in 2009 to 184 TWh in 2019. This was driven by a rapid increase of solar power, which grew more than tenfold since 2012, following the introduction of a generous feed-in tariff (FIT) system (see Chapter 5).

Even though the reliance on fossil fuels for power generation has declined since 2014, it still represented 71% of electricity generation in 2019, the sixth-highest share among IEA countries (Figure 7.2). Natural gas accounted for 34% of total power generation, which was the sixth-highest in the IEA, and coal with 32% ranked the seventh-highest. The rest was solar (9%), hydro (8%), nuclear (6%), oil (5%), bioenergy and waste (4%), and small shares of wind and geothermal. Although the share of renewable electricity is low at 19%, compared to the IEA median of 33%, Japan had the second-highest share of solar power in the IEA in 2019, and the second-highest solar power generation in absolute terms.

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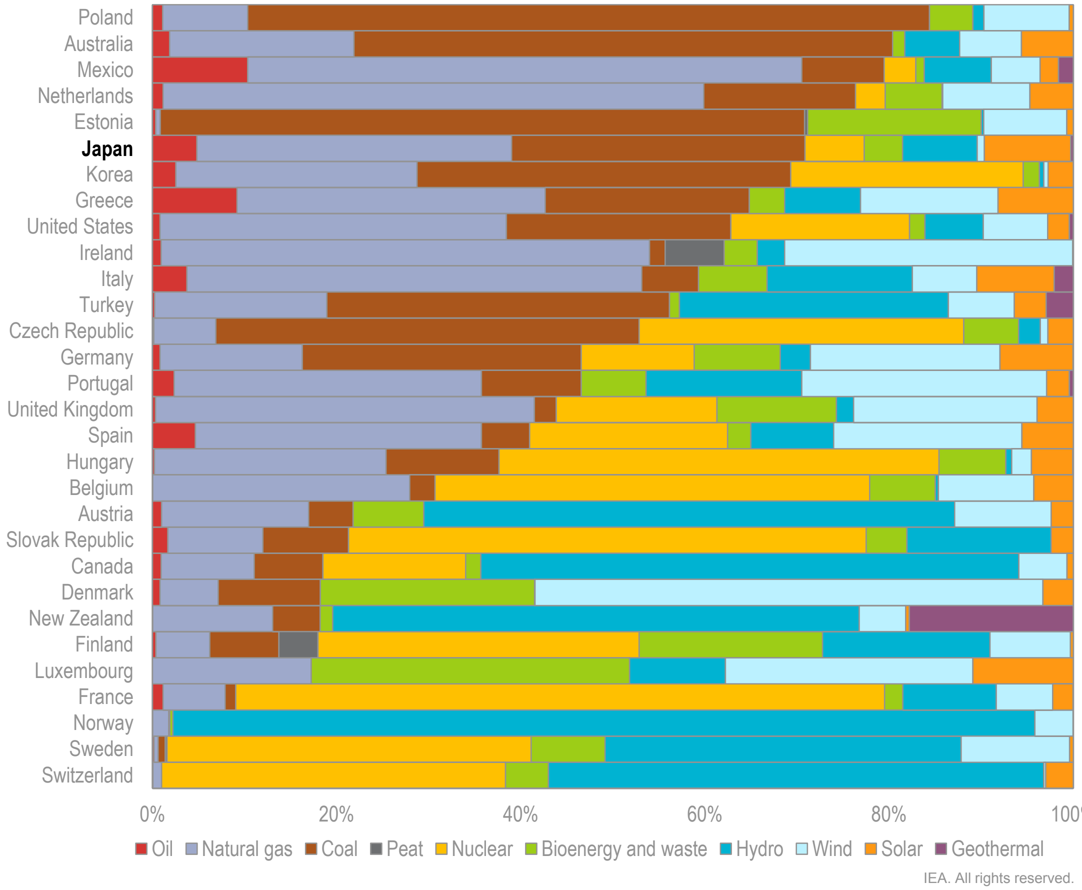
Figure 7.2 Electricity generation by source in IEA member countries, 2019



Japan has the sixth-highest share of fossil fuels in electricity generation in an IEA comparison, while the share of solar energy ranks the second-highest.

* Estonia's coal represents oil shale.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Total installed generation capacity increased by 22% between 2008 and 2018, to reach 344.9 gigwatts (GW). This was largely due to solar capacity, which increased from 2.1 GW in 2008 to 56.2 GW in 2018, replacing hydro as the largest renewable power source by capacity. Wind capacity doubled, but remains relatively small at 1.7 GW in 2018. The installed capacity in power plants using combustible fuels increased by 8% over this period, from 181.9 GW in 2008 to 196.7 GW in 2018. Meanwhile, nuclear power generation capacity decreased by nearly 21%. Capacity of hydro and geothermal energy remained relatively stable, at around 50 GW and 500 megawatt (MW), respectively.

Electricity consumption

In 2018, Japan consumed 960 TWh of electricity, 7% less than a decade earlier (Figure 7.3). The consumption is equally split between the industrial, service and residential sectors, with around one-third of total electricity demand each, plus minor shares consumed in the transport and energy sectors. The residential sector saw the largest drop in demand, at 13% over the period 2010-18. The industrial and services sectors declined by 9% and 4.8%, respectively.

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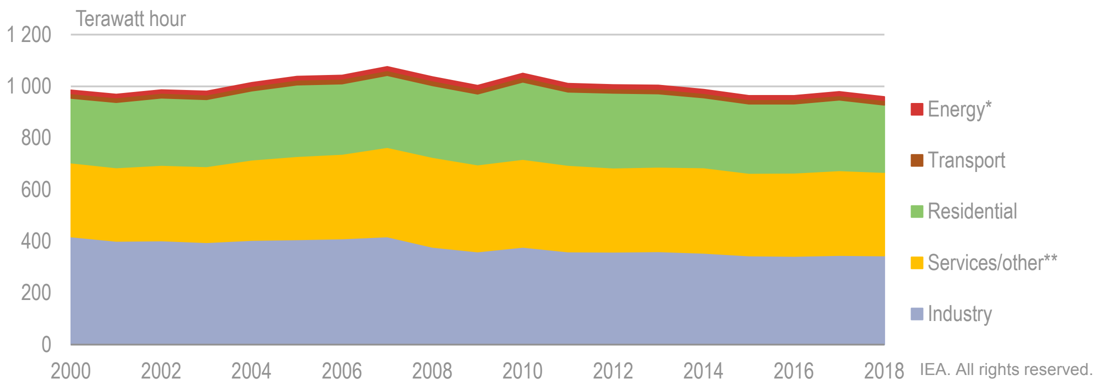
Figure 7.3 Electricity consumption by consuming sector in Japan, 2000-18



Japan's total electricity consumption has gradually decreased over the last decade, and its reduction was mainly driven by industry.

* *Energy* includes coke ovens, petroleum refineries and liquefied natural gas liquefaction.

** *Services/other* includes commercial and public services, agriculture and forestry, and fishing.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Japan's electricity outlook

Power demand is expected to remain relatively stable, thanks to energy conservation measures that are expected to offset the effects of economic growth and the electrification of the economy. The government projects power demand to reach 980 TWh in 2030, 2% above the 2018 consumption level. Energy savings are expected to materialise through a number of measures, including more energy-efficient electric devices, improved demand management through new technologies (e.g. large-scale roll out of smart meters and use of artificial intelligence) and more dynamic electricity pricing (METI, 2018a). The electrification of the economy is expected to continue, in part driven by Japan's goal to electrify mobility (see Chapter 4).

Power supply is expected to become more balanced, with nuclear, renewable energy, natural gas and coal envisioned to supply roughly a quarter each by 2030. Based on the philosophy of energy security, economic efficiency, environmental sustainability and safety (the "3E+S"), the 5th Strategic Energy Plan (SEP) of 2018 aims to reduce dependence on nuclear power as much as possible by reducing energy demand, expanding renewable energy and improving the efficiency of thermal power plants (METI, 2018b). By 2030, renewables are projected to account for 22-24% of power supply, nuclear for 20-22%, natural gas for 27% and coal for 26%; oil would account for only 3% (Figure 7.4). This means that power generation from renewables would need to increase by 37% compared to 2018 according to data provided by the Ministry of Economy, Trade and Industry (METI). It is important to note that by 2030, the category of renewables will not include non-renewable waste. Nuclear power generation would need to increase sevenfold, while fossil fuel-based generation would decline by about 30%.

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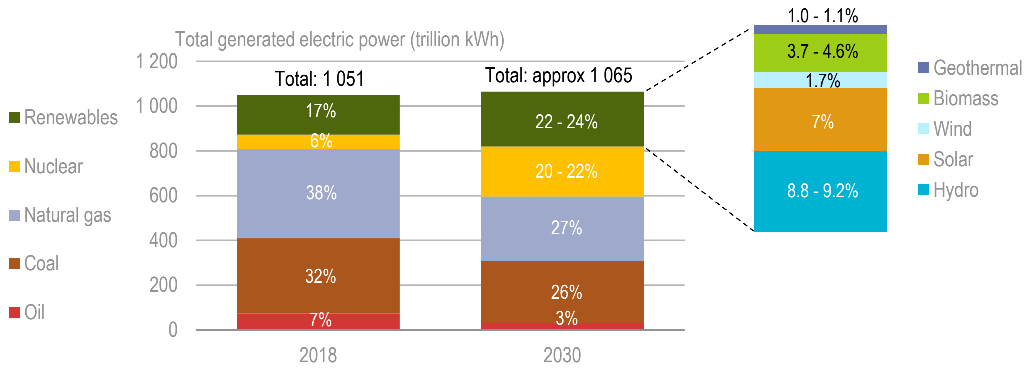
Figure 7.4 Actual and projected power generation by source in Japan, 2018 and 2030



Note: kWh = kilowatt hour.

Sources: METI (2020a), *Japan's Energy 2019*, www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2018.pdf; https://www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2019.pdf; information provided by the Ministry of Economy, Trade and Industry.

The 2018 SEP sets two additional targets for the electricity sector, namely to generate at least 44% of power from zero-emissions sources by 2030, and to lower electricity costs. The first target follows from legislation passed in 2016 that makes it mandatory for electricity retail companies to reach a non-fossil power supply share (nuclear plus renewable power) of at least 44% by 2030. In 2018, the ratio stood at 25%. Achieving the target will require an increase in non-fossil power generation of about 5% per year on average. Compared to an average growth of 14% per year over 2014-18, this target seems within reach, if nuclear power comes back on line as scheduled.

With regards to electricity costs, Japan set the goal to keep the total of power sector fuel import costs and the cost of the FIT system[1] below JPY 9.5 trillion (USD 871 billion[2]) in 2030. Following the 2011 events, fuel import costs nearly doubled to reach JPY 9.2 trillion in 2013; and the cost of the FIT (implemented in 2012) reached JPY 0.5 trillion that same year. By 2018, fuel costs levelled off to pre-2011 levels (JPY 5.7 trillion), but the FIT costs grew to JPY 2.8 trillion, bringing total costs to JPY 8.5 trillion.

Japan's long-term strategy for reducing greenhouse gas (GHG) emissions, adopted in June 2019, sets the ambition to reduce emissions by 80% by 2050 (GoJ, 2019). The strategy envisions turning renewables into Japan's major power source, under the condition that drastic cost reductions can be achieved and grid constraints overcome. The long-term strategy further envisages to reduce the carbon footprint of thermal power plants, which will remain a core element of the power mix during the transitional period, and to use nuclear power plants that have been confirmed to be safe. The 2019 strategy does not provide quantified targets for power generation sources in 2050.

Installed power generation capacity is set to increase by 12% in the decade to 2028, according to utilities' supply plans announced in 2019 (Figure 7.5). This is significantly higher than the expected increase in power demand (2%), but will help accommodate

[1] Japan introduced a Feed-in Tariff scheme in 2012. See Chapter 5.
[2] USD 1 = JPY 109.

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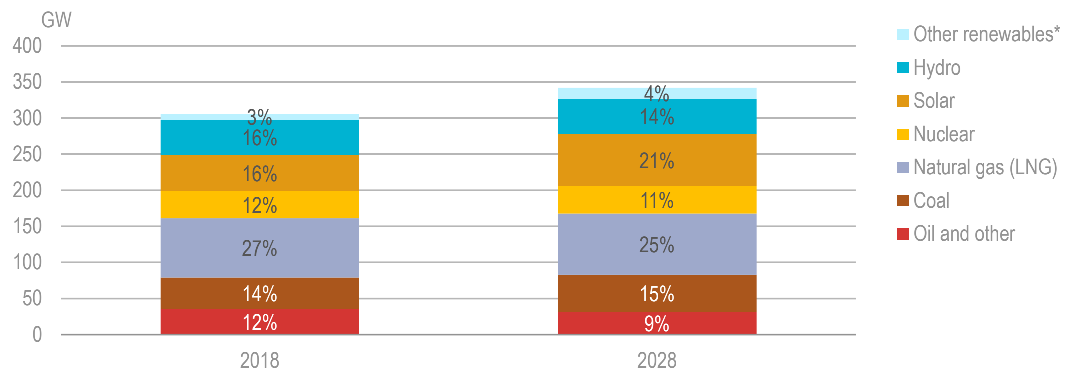
larger shares of variable renewable generation. According to these plans, the installed capacity of coal- and gas-fired power generation will trend upward, as construction of new capacity will outweigh ongoing decommissioning (OCCTO, 2020a). Generation capacity of oil-fired power plants will decline. Renewable capacity will increase, driven by the construction of new solar power plants and wind farms. There are no plans to increase the installed capacity of other renewable sources (e.g. hydro, geothermal or renewable waste).

However, in July 2020, the government announced a plan to close or mothball inefficient coal-fired power plants by 2030. Details on how this phase out will be implemented, and how it will affect the installed capacity and envisioned power generation mix for 2030, have yet to be announced. Assuming that Japan would close all plants with subcritical or supercritical technology and that the construction of new coal capacity would proceed as planned, the total installed capacity of coal-fired power generation could decrease by about one-third by 2030 (see Chapter 10).

In parallel, the government announced it would study options for further promoting renewable energy, including by reforming rules on using the power grid. Japan's electricity grid is fragmented into many regional grids and not connected to other countries, which makes it challenging to accommodate large amounts of variable renewable electricity. Adding to this, a large share of renewable energy potential (e.g. from solar and wind) is located far from the demand centres (see Chapter 5). Recognising these challenges, the 2018 SEP announced the government would invest in network infrastructure and efficient grid management, electricity storage, demand response, and use of digital control technologies. It also aims to promote distributed energy sources as a means to enhance the resilience of power supply (METI, 2018b).

Figure 7.5 Installed power generation capacity in Japan, 2018 and 2028



* *Other renewables* includes energy from wind, geothermal, biomass and waste.

Notes: GW = gigwatt. LNG = liquefied natural gas. The figure is based on electricity utilities' development plans up to FY2028. The planned capacity for 2030 does not consider the announced phase out of inefficient coal plants by 2030.

Source: OCCTO (2020a), *Annual Report: Fiscal Year 2019*, www.occto.or.jp/en/information_disclosure/annual_report/files/annual_report_FY2019.pdf.

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Network infrastructure

As an island country with no cross-border interconnections, Japan needs to balance all of its electricity production and consumption itself. A particular feature of Japan's electricity system is that the transmission network is divided into two regions running at different frequencies: eastern Japan (including Tokyo, Kawasaki, Sapporo, Yokohama and Sendai) operates at 50 Hz and western Japan (including Okinawa, Osaka, Kyoto, Kobe, Nagoya and Hiroshima) at 60 Hz (Figure 7.6). There are three frequency converters with a total transmission capacity of 1.2 GW: Sakuma in Shizuoka Prefecture with a converting capacity of 0.3 GW, Shin-Shinano in Nagano Prefecture with 0.6 GW and Higashi Shimizu in Shizuoka Prefecture with 0.3 GW.

As mentioned above, Japan's electricity grid is fragmented into ten regional grids which were developed by the former electric power companies (EPCOs). This brings specific challenges balancing demand and supply and increases Japan's vulnerability to supply disruptions (see below). The government aims to increase transmission capacity to enhance resilience. Interconnection capacity between the two frequency regions is planned to increase from the current 1.2 GW to 2.1 GW by March 2021, and to 3 GW by March 2028. Interconnection projects are also in progress within the frequency regions. A second interconnection route (of 300 MW) between the Tohoku and Hokkaido regions entered into service in March 2019, bringing the route's total provision to 900 MW, and there are plans to increase the capacity of the Tokyo-Tohoku interconnection by 4.6 GW by 2027, bringing total capacity to 10.3 GW (JEPIC, 2020).

The total length of the transmission network was around 179 000 kilometre (km) (in March 2018), of which about 15% were underground lines. The total length of distribution lines was approximately 4.1 million km, of which only 1.8% were underground (JEPIC, 2020; 2019). The high share of overhead lines reduces recovery time in case of a disruption, but also increases the risk of it happening. To enhance the reliability of the power supply to the central districts of large cities, extra-high voltage underground transmission cables are being installed (JEPIC, 2020).

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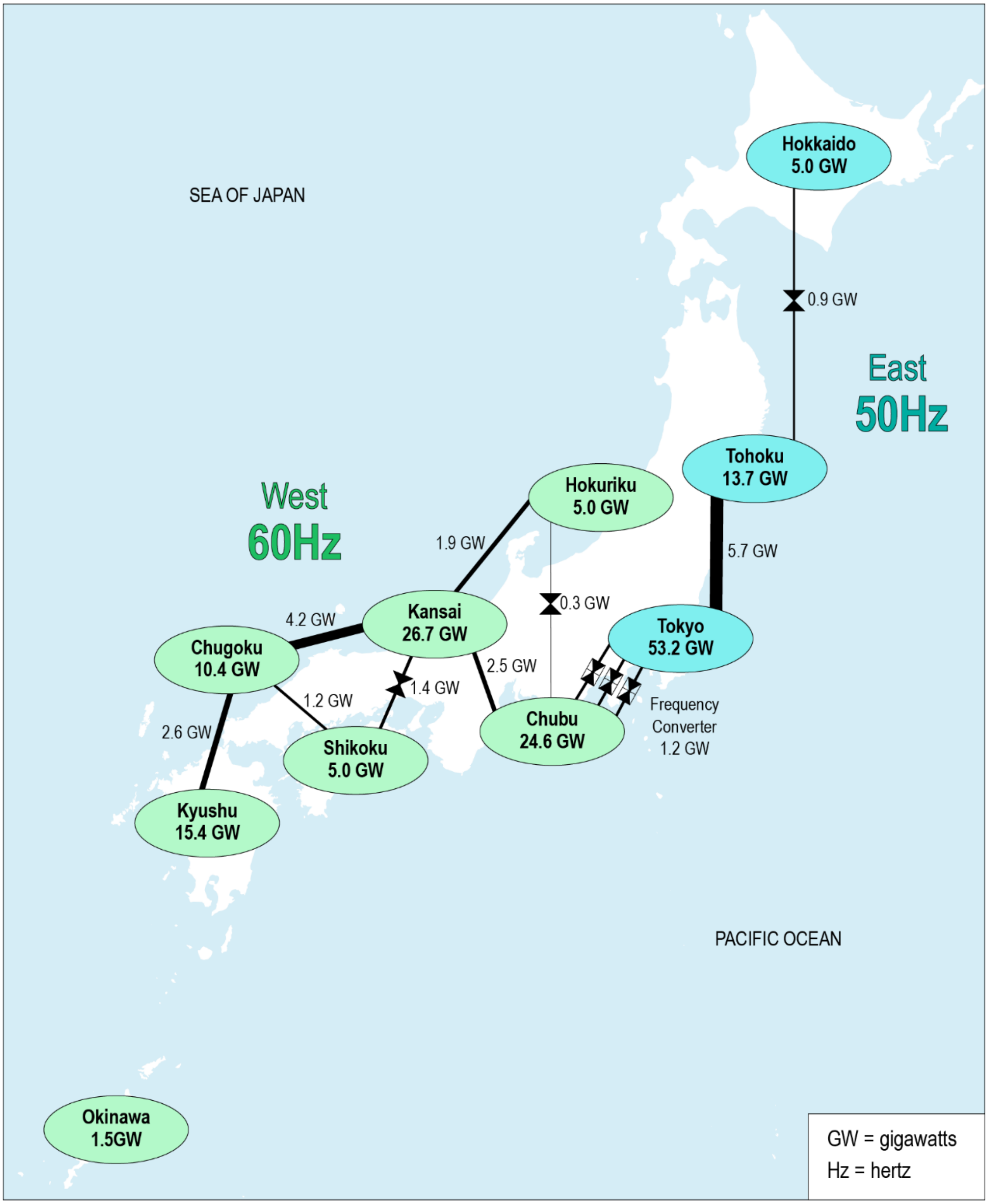
Figure 7.6 National grid connections, early 2020



Source: Ministry for Economy, Trade and Industry.

Japan's regulatory framework and market structure

In 2013, Japan initiated a major electricity market reform aimed at addressing the weaknesses in Japan's electricity system that became apparent following the 2011 events. These included the lack of transmission capacity (exacerbated by a difference in frequency between east and west Japan), dominance of the vertically integrated regional monopolies and the absence of competition, and the limited flexibility of the power system to increase

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the share of renewables. The reform substantially restructured the regulatory framework governing electricity businesses, and the market structure is changing accordingly. Major steps of the reform, which was implemented in three phases, include the establishment of the Organization for Cross-regional Coordination of Transmission Operators (OCCTO)[3] and the Electricity Market Surveillance Commission, both in 2015; the full liberalisation of the retail market in 2016; and the unbundling of the vertically integrated electricity utilities in 2020. Further steps are considered to enhance investment in transmission and distribution grids, with the aim to facilitate the integration of variable renewable energy and enhance the overall resilience of the electricity system.

Key elements of Japan's electricity market reform

Historically, Japan's electricity system was fragmented into ten areas, operated by vertically integrated EPCOs. These had a monopoly in their respective service area and were relatively isolated from each other, limiting competition in the wholesale and retail markets. In 1995, Japan liberalised the generation sector, allowing independent power producers to participate in the wholesale electricity market. This was followed by a partial liberalisation of the retail sector in 2000-05, when power producers and suppliers were granted the right to sell electricity to larger consumers using the EPCOs' transmission networks.[4] The Japanese Electric Power Exchange (JEPX) was established in 2003 to encourage more active power exchange. However, despite these reforms, effective competition remained limited, especially across regional boundaries, and the generation and delivery of electricity generally remained bundled together by the same EPCO (IEA, 2016).

The 2013 reform had three main objectives: 1) secure stable electricity supply; 2) reduce electricity prices; and 3) expand consumer choice and business opportunities. Three measures were identified to reach these goals: 1) expansion of cross-regional grid operation; 2) full liberalisation of retail market entry; and 3) the legal separation of transmission and distribution from the vertically integrated general EPCOs.

These measures were implemented through three phases of legislative reform. The first phase, initiated by amendments to the Electricity Business Act in 2013 and implemented from April 2015 onwards, aimed at enhancing cross-regional co-ordination. OCCTO was created with the primary task to balance electricity supply and demand on a nationwide level and to improve power interchange across regions, also between the two frequency regions. Its main functions include prescribing utilities to increase power generation and to interchange when the supply-demand balance tightens; co-ordinating and reviewing utilities' supply and demand plans; managing cross-regional interconnecting lines; and planning transmission network development. All electricity companies are required to become a member of OCCTO.

The second phase of the reform, implemented as of April 2016, liberalised the retail market for low-voltage customers (consuming less than 50 kW). Since then, the whole consumer base can chose their electricity supplier. The Electricity Market Surveillance Commission had been established shortly before (in September 2015) as a regulatory authority under

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[3] Annex A provides detailed information about institutions and organisations with responsibilities related to the energy sector.

[4] In 2000, power producers and suppliers were granted the right to sell electricity to extra-high voltage users (consuming more than 2 MW); in 2004, this was expanded to users requiring more than 500 kW, and in 2005 to users requiring more than 50 kW.

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METI to strengthen oversight and foster competition in the power market. In 2016, its remit was expanded to also cover the gas market, and its name changed to the Electricity and Gas Market Surveillance Commission (EGC).

The establishment of the EGC as regulatory authority is consistent with common practice in liberalised electricity markets. However, in contrast to many other IEA countries, the EGC is not fully independent. While it has the authority to audit and inspect utilities, undertake arbitration, and make recommendations for business improvements, it cannot enforce these recommendations itself. It can also make recommendations to METI for regulatory changes related to enhancing competition and consumer protection, but the decision whether enforcement action or regulatory changes are taken rests with METI and its minister. The commission is composed of a chairman and four commissioners, who are appointed by the Minister of Economy, Trade and Industry. It is supported by a secretariat, which has regular staff exchanges with METI.

The third step of the reform was the requirement for the vertically integrated EPCOs to legally unbundle their businesses. Earlier, businesses operating in the electricity market had been vertically integrated and categorised according to type and historical origin into five categories:

- general electricity utilities (the EPCOs)
- wholesale electricity utilities
- wholesale suppliers
- specified electricity utilities (which supply electricity to certain defined areas using their own power generation and distribution facilities)
- specified-scale electricity suppliers (also known as power producers and suppliers).

Since 1 April 2016, electricity businesses are horizontally categorised according to their functions, i.e. generation, transmission and distribution operators, and retailing. METI's Agency for Natural Resources and Energy imposes regulations for each sector. Companies conducting multiple categories of electricity business were required to legally unbundle their power generation and retail business from the transmission and distribution business by 1 April 2020. All EPCOs have legally unbundled, except for Okinawa, which for geographical reasons is not required to do so, choosing either a holding company approach and/or a format of affiliated companies.

In June 2020, the government passed legislation to initiate another round of reform with the view to further enhance competition, strengthen the resilience of the electricity sector and promote the expansion of renewable power sources in a cost-effective manner (METI, 2020b). Major components of the act include a requirement for electricity businesses to collaborate in case of a disaster, and for transmission and distribution businesses to systematically renew their existing facilities. The act strengthens the role of OCCTO, giving it the mandate to develop a master plan on the development of cross-regional grids. It also proposes changes to network transmission charges so as to encourage investment in the transmission grid and initiates a reform of the FIT scheme for renewable energy into a feed-in premium system. The details of these changes are explained in the following sections. Changes to the FIT system are detailed in Chapter 5.

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Electricity market structure

Wholesale market

Unlike in many jurisdictions, Japan has no mandatory wholesale market. The only electricity trading market is the JEPX, which was created in 2003 as a private and voluntary wholesale power exchange. It was designated a wholesale electricity market under the provisions of the Electricity Business Act in 2016.

Participation in the JEPX was very limited (roughly 1% of electricity sold for the decade following its establishment) and most electricity trading was conducted through bilateral transactions between generators and retailers. Since 2016, however, liquidity has increased considerably: in December 2019, transactions at the JEPX accounted for more than 30% of all retail sales, compared to merely 2% in April 2016. The principle market participants are electricity generation and retail businesses, although general electricity transmission and distribution utilities that accept electricity generated by FIT plans and demand-response aggregators are also permitted to participate in order to facilitate trading of non-fossil and negawatt trading contracts (see below). In July 2019, the JEPX had 167 companies as trading members, compared to 130 members prior to the liberalisation of the retail sector (JEPIC, 2020).

Trades available in the JEPX as wholesale of electricity are spot market, forward market, intra-day market and over-the-counter trading. The **spot market** is the largest one in terms of trading volume. It trades 30-minute increments of electricity for next-day delivery. Trading is done through a blind single-price auction system (i.e. the intersections between the sell and buy bid curves is defined as the system price and trade volume). High buy bids and low sell bids are executed at the system price. When market fragmentation occurs (for example due to capacity constraints of connections between services areas), system prices and trade volumes are calculated at the level of each of the fragmented markets.

Furthermore, the JEPX runs an **intra-day market** which allows for correcting unexpected misalignments between supply and demand occurring between a spot market transaction and delivery (a minimum of one hour later), as well as a **forward market**, where electricity is traded for delivery over the course of a specified future period. Currently, five products are available in the forward market: yearly 24-hour, monthly 24-hour, monthly daytime, weekly 24-hour and weekday-daytime products.

In 2018, the JEPX established a **non-fossil fuel value market** in which certificates for FIT electricity are traded. The purpose of this market was to address concerns that new market entrants faced difficulties in purchasing electricity from non-fossil fuel sources, as they lacked sufficient trading experience compared with the former EPCOs. It is also hoped that the market will help retailers meet their obligation to source 44% of their supply from non-fossil resources by 2030. Another consideration was that the cost of the environmental value of electricity derived from renewables purchased through the FIT scheme should not have to be borne by all customers, but instead should be borne primarily by those customers who desire that value.

The first auction, held in May 2018, brought to the market 53 TWh of non-fossil certificates from power generated under the FIT programme from April to December 2017, but only 0.01% (5.2 GWh) was contracted (Arias, 2018). Another nine rounds have followed since. In each round, most of the traded certificates were contracted at the lowest bid price, at JPY 1.30/kWh (JEPIC, 2020). The traded volume has gradually increased, and reached

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151 GW in the tenth auction held in August 2020. Trading of non-fossil power sources other than those covered by the FIT scheme was scheduled to commence in November 2020 with the first auction.

In July 2019, the JEPX launched a **baseload power market**. This market aims to address the perceived difficulty new market entrants face to own or buy electricity from affordable baseload power plants (such as coal, large-scale hydro, nuclear power and geothermal plants). As the former EPCOs mostly own these power plants, new entrants mostly rely on higher cost generation from plants such as gas-fired facilities. The baseload power market that gives the former EPCOs and new entrants equal access to electricity from baseload plants is expected to increase competition in the retail market, by lowering new retailers' purchase costs. The market works similarly to the mechanism for regulated access to historic nuclear power (ARENH), the baseload market introduced in France in 2011.

Approximately 30% of installed capacity (109 GW) is considered baseload capacity, which could be sold to this market. Participation in the baseload market is not mandatory, but the government expects incumbents to sell around 30% of their generation into this market, at a price lower than the expected wholesale price. Contracts are sold in 12-monthly blocks a year ahead. The first round of contracts was for April 2020 to March 2021 and contracted 1.6 TWh (equalling 1.3% of the volume purchased by retailers in 2019). The initial auctions achieved a 12-15% savings in the settlement price compared to the average wholesale spot price. In comparison, prices in the French capacity market were 23% lower than the French 2018 wholesale spot average (Genscape, 2019).

Balancing market

The tasks of controlling frequency and balancing supply and demand are performed by the regional electricity transmission and distribution companies, which spun out from the former EPCOs. However, the reform moved some of the grid management responsibilities to OCCTO. Since April 2016, retailers and electricity generators need to submit demand/supply plans to OCCTO, which then verifies these plans, checks the balance of electricity demand and supply, and requires retailers and power generators to make amendments where necessary to balance demand and supply as of the time of "gate close" (one hour before real time). It may also require utilities to interchange when the supply-demand balance tightens. In 2018, OCCTO ordered such interchanges 25 times. In addition, it implemented long-cycle frequency control 56 times to send surplus electricity from solar PV in the Kyushu region to the Chugoku region using cross-regional interconnection lines (OCCTO, 2020a).

If the actual amount of demand/sales or generation/supply diverts from the respective plan, the retailer or power generator pays an imbalance charge to the transmitters that have accepted the surplus or supplemented the shortage, based on the spot price of the JEPX. Since 2017, the capacity needed to balance supply and demand has been procured by tenders conducted by the network operators (prior to this, procurement of balancing services was not based on a competitive bidding process). Most transmission and distribution companies procure balancing capacity from sources within their supply area.

The government has plans to set up a real-time **balancing market** to procure and operate balancing capacity more efficiently on a cross-regional basis. It is planned that generators (as well as demand-response providers) can offer their capability to balance between demand and supply after the gate closure for the network operators. The intent is to offer timespans from a week ahead down to a day ahead and to launch the market in 2021.

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Shorting the gate closure times, to for example 15 minutes, will enhance the operation of a system with high shares of variable renewable energy, as it increases the use of the flexibility available from generators.

For mid- and long-term balancing, the government launched a **capacity auction market** in July 2020. The rational for this market is to promote investment in flexible supply capacity in order to accommodate the growing share of variable renewable energy in the power mix. There are concerns that the electricity market liberalisation and the growing wholesale market would deprive investment predictability and hence investment in flexible supply capacity. Under capacity auctions, generators (and demand-response providers) can bid for capacity payments based on their capacity to provide electricity. Capacity payments are sourced from electricity retailers according to sales volume.

Access to the transmission and distribution network

Under the Electricity Business Act, network operators may not refuse requests by power generators to connect their facilities to the transmission grid without a justifiable reason (such as the risk of impeding stable electricity supply). Similarly, they may not refuse requests to provide wheeling services without a justifiable reason. Under the Electricity Business Act, the general transmission and distribution operators set the conditions of transmission services, including their costs, which are approved by METI. METI and OCCTO are also responsible for monitoring and arbitrating access to the transmission and distribution network.

The transmission network is fragmented, with limited interconnections, as it was developed by the ten former EPCOs for their regional service areas (see the section on network infrastructure below). Interconnection lines that span the service areas of different transmission system operators (TSOs) are administered by OCCTO. Since October 2018, access to interconnections is granted through an implicit auction approach, under which usage rights are assigned to contracts concluded in the day-ahead market. Previously, access was granted on a first-come first-served basis. It was hoped that the new approach would expand the use of interconnections by new market participants (other than the former EPCOs). In the 2019 fiscal year (FY), six power exchanges were conducted, mainly during unexpectedly hot or cold periods (OCCTO, 2020b).

The limited interconnection capacity and difference in frequencies is exacerbating grid congestion and curtailment issues, which appeared as renewable electricity generating facilities have expanded. Access to high-voltage transmission has also been based on first-come first-served rules, under which power-generating facilities that are already connected to the grid are guaranteed transmission capacity equivalent to their maximum generating output. This rule triggered concern that new renewable energy-generating facilities face difficulties to connect to the grid, as many grids lacked sufficient capacity and new facilities would need to bear part of the costs of reinforcing the grid (REI, 2018).

To address these issues, the government introduced the so-called “Connect and Manage” policy, under which new entrants can connect to a grid running short of available capacity before work to reinforce grid capacity is completed. In addition, the new policy changed the calculation of available grid capacity for variable renewables from maximum nameplate capacity to an estimated future power flow of electricity based on previous performance. This will make more grid connection capacity available for variable renewables without additional grid enhancements (see Chapter 5).

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The first curtailment of solar energy occurred in October 2018 in Kyushu and another 22 days of curtailment followed in the succeeding months. On 3 May 2019, 1.9 GW of solar power was curtailed in Kyushu. In Japan, the curtailment rates of wind and solar PV plants are announced one day ahead of delivery based on weather forecasts, because curtailment often requires physical presence at the plant site. The use of remote energy management systems could alleviate this to some extent by enabling faster grid response of renewables plants (see Chapter 5).

In order to finance grid expansion, as well as operation and maintenance, the government is planning to impose network transmission charges – which are currently only imposed on retailers – to generators. This new wheeling charge (the so-called G-charge) will be imposed on all generators (existing and new) from 2023 onwards, with the exception of residential solar PV less than 10 kW. The original concept to base the G-charge on the contracted kW to the grid is under review to ensure consistency with the new congestion management rules of transmission lines that are also under consideration. The new rules aim to reduce existing inefficient thermal generation and to accelerate the introduction of renewable power generation. The G-charge is expected to incentivise power producers to use the grid more efficiently.

In addition, a reduction of the G-charge for generators located in specifically designated areas is under consideration with the aim to promote the efficient utilisation of network facilities by generators. Power plants are able to choose these locations and solar power plants would be eligible for the reduction.

In December 2019, the Electricity and Gas Market Surveillance Commission was tasked to design guidelines that will allow renewable energy generators that benefit from the FIT scheme to pass on the additional cost caused by G-charge to their customers as is already possible for other power generators. Additional adjustments in the design of support policies for renewables are also under discussion.

Furthermore, in anticipation of the introduction of the G-charge, the connection charge for new capacity was reduced in June 2018, which has significantly reduced the barriers to entry for renewables like solar and wind power plants.

Industry structure

Electricity generation

As of January 2020, there were 834 registered electricity providers in Japan. Most entrants to the generation business are autonomous distributed generators, including firms from the paper manufacturing, steel manufacturing, and the gas and petroleum industries. Some local governments have also entered, albeit on a small scale. The former EPCOs and the two largest former wholesale electric utilities (J-POWER and the Japan Atomic Power Company) still dominate the sector, jointly accounting for around 55% of capacity and approximately 80% of peak output (JEPIC, 2020). To enter the market, businesses only need to notify METI.

Transmission and distribution

The power transmission and distribution sector consists of regional monopolies. Since April 2020, when the legal separation of the transmission and distribution segment from the generation and retail segments took effect, the new electricity transmission and distribution companies act as the TSOs and are responsible for grid management and

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system security in their respective areas. They are also responsible for providing "last resort" service to those who have no other means of obtaining electricity, as well as universal service to isolated islands. General transmission and distribution operators and transmitters must have a licence to conduct their business.

There are two further categories of transmission operators: 1) so-called "transmitters", which operate inter-grid transmission lines and offer frequency conversion facilities between the 50Hz and 60 Hz regions for the TSOs; 2) so-called "specified transmission and distribution operators", which operate their grids in certain defined areas.[5]

Retail

The retail market counted 637 companies in January 2020 (including the retail arms of former EPCOs). The full liberalisation of the retail market in 2016 attracted a large number of new operators to the market, including telecommunication carriers, trading companies, gas and petroleum companies, steel manufacturers, and subsidiaries of former EPCOs. These enriched options for consumers, including packages with gas and telecommunications services, loyalty schemes, and supply of CO_2-free electricity. To enter the market, companies must apply for registration with METI, which is accepted unless the business is found to fall under certain negative requirements, such as lack of ability to procure electricity to match its demand (an obligation put on retailers by the Electricity Business Act).

By early 2020, nearly four years after liberalisation, some 12 million low-voltage consumers (e.g. households) had switched supplier, equal to about 12.9% of contracts in effect prior to liberalisation. There is significant regional variation, however. Competition is intensifying in Tokyo and Kansai, where more than 16% of low-voltage consumers had switched suppliers by September 2019. In Hokuriku and Chugoku, the switching rate was below 5% and in Okinawa it was 1.4%.

Even though the former EPCOs still dominate the retail market, the share of new entrants is increasing, from about 5% of all electricity retail sales in April 2016 to nearly 16% in September 2019. At that point in time, new entrant retailers supplied 16.7% of low-voltage demand (up from 0% before the liberalisation in April 2016), 22.3% of high-voltage demand (compared to 10% in April 2016) and 5.4% of extra high-voltage demand (a similar level to that in April 2016).

The Electricity Business Act imposes certain obligations on retailers to protect consumers, such as explaining the price and other conditions of the retail supply and promptly handling consumer complaints. In addition, METI has set out guidelines for electricity retail businesses, which cover a wide range of retailer conduct, from advertisement to the termination of contracts (METI, 2018a). The more transparent information on generation portfolios, pricing and switching options, the easier it will be for consumers to benefit from the more competitive retail market.

Electricity prices

Japan has high electricity prices in an international comparison, despite having relatively low tax rates. In 2019, Japan's industry paid the second-highest prices among IEA member countries (164 USD/MWh), even though only 2% of the price came from taxes (Figure 7.7).

[5] The specified transmission and distribution operators correspond to the transmission and distribution activities conducted by the former specified electricity utilities.

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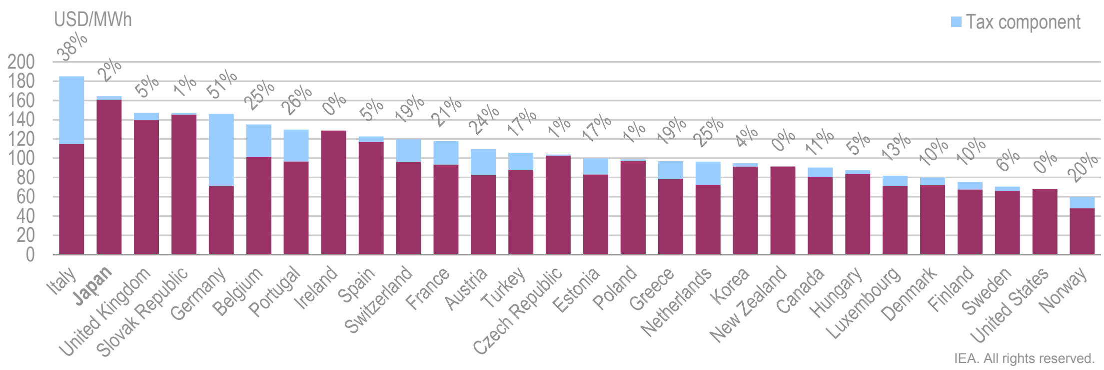
Household prices in Japan were the seventh-highest in the comparison (USD 253/MWh), again despite one of the lowest tax shares, at 9%.

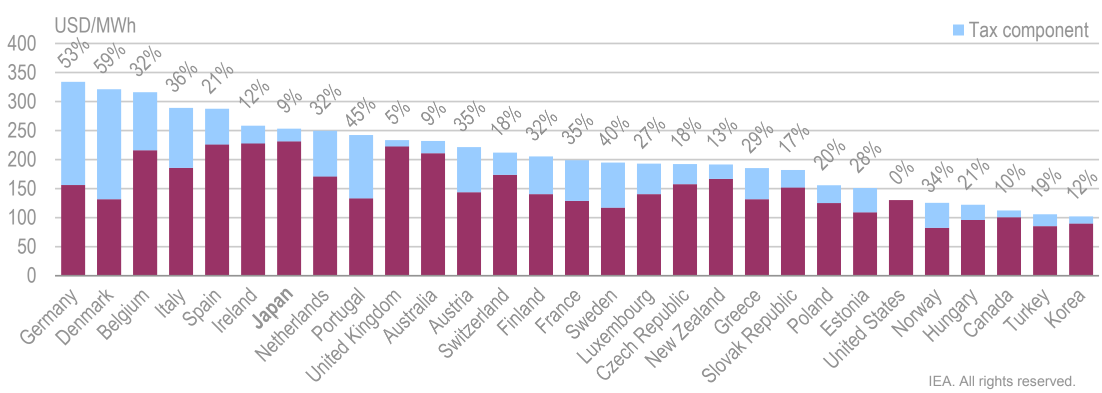
Electricity prices surged in 2012, due to the increased use of imported fossil fuels following the 2011 events, but have been on a declining trend since. Between 2012 and 2017, retail prices for industry and households decreased by 22% and 23% respectively, to reach levels roughly similar to those prior to the 2011 events. Prices picked up again in 2018, however, reflecting increasing fuel import prices.

Figure 7.7 Electricity prices in IEA member countries, 2019

Industry



Households



Japan has high electricity prices in an international comparison, in particular for industries, despite having one of the lowest tax rates.

Notes: MWh = megawatt hour. Industry data are not available for Australia. Tax information in industry and households is not available for the United States.

Source: IEA (2020b), *Energy Prices and Taxes 2020* (database), www.iea.org/statistics.

Despite full market liberalisation in 2016, retail prices for the low-voltage sector (e.g. households) are still regulated, as a transitional measure to protect consumers. Regulated prices were originally foreseen to end in March 2020. However, as competition had not developed sufficiently, METI decided in July 2019 to maintain regulated rates, and there is no foreseen date for when regulated tariffs should end. Consumers can chose to remain with the regulated tariffs provided by their EPCO or opt for an unregulated rate

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either by their EPCO or by a power producer or supplier. In April 2019, about 60 million low-voltage customers (78% of the total) were still paying regulated prices (JEPIC, 2020).

Future power system

The 5th SEP recognises that Japan's electricity supply and demand structures will change in the mid- to long term with the expansion of renewable energy; electrification of mobility and other parts of the economy; and alterations in the overall demand structures due to a decreasing population, digitalisation and artificial intelligence. To cope with these changes, Japan aims to develop a more flexible and resilient power system in distributed energy systems and demand-side management plays a central role (METI, 2018b).

The deployment of smart meters is advancing rapidly. By March 2019, the installed rate of smart meters at the low-voltage level was 64% nationwide and the government expects to reach 100% by the early 2020s. Since April 2016, smart metering is a pre-requisite for customers who switch retail supplier.

Demand response and virtual power plants

Demand response has gained interest in Japan as a way to balance supply and demand in a more cost-effective way. In 2018, demand response was used for several consecutive days to cope with critical supply-demand imbalances in the Tokyo area, saving capacity equivalent to a mid-sized thermal power plant. Demand-response electricity is traded through balancing auctions conducted by the TSOs and in the wholesale market (as negawatts)[6] since 2017. The government plans to include demand response in the balancing and capacity market in the future.

In 2020, Japan's TSOs procured a total of 1.3 GW of demand response as reserve power for severe peak hours in their balancing actions, equal to 30% of contracted capacity. The average contract price for a negawatt in these auctions was nearly 20% cheaper than that of a power plant, but remained high by international standards, at JPY 5 100 (USD 47) per kW.[7] Most of the demand response came from large-scale industrial consumers, but households can participate as well.

To develop the market for demand response, the government subsidises the establishment of "virtual power plants" (VPPs) that remotely control and aggregate distributed energy resources at factories and households (e.g. distributed solar PV, storage batteries, electric vehicles). In 2020, these subsidies amounted to JPY 5 billion. In 2019, Japan launched one of the world's largest "behind the meter" VPPs, which will aggregate some 10 000 distributed energy assets. The VPP initially focuses on only batteries, but can later incorporate assets such as solar PV, electric vehicle chargers and smart home thermostats (SEI, 2019).

Integrating mobility infrastructure in the power system

Among flexible demand-response resources, electric vehicles (EVs) are expected to make the greatest contribution. Japan envisions the gradual electrification of mobility, with the

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[6] A negawatt is a negative megawatt, which is a hypothetical unit of power measuring the amount of power saved compared to a baseline. METI has stipulated standard methods to calculate the baseline.

[7] The average price is calculated as the weighted average of the total contract amount of power sources sold, divided by the total contract volume of capacity.

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target to reach an EV market share of at least 50% by 2030, and 100% by 2050 (see Chapter 4)[8]. The vision is to integrate mobility infrastructure into the overall power system by using electricity from EV batteries to supply electricity to the grid (vehicle-to-grid), or to directly use the energy in homes (vehicle-to-home) and buildings (vehicle-to-buildings). These technologies, all of which are already being piloted in Japan, can help realise cost savings by reducing peak electricity demand, while also allowing for emergency supply in the case of power outages. The expansion of VPPs will support business models for using power storage and generation capacity in EVs, creating a further push for these technologies.

In anticipation of a growing EV market, Japan aims to promote the reuse of EV batteries for power storage as a means to strengthen their end-of-life management. After eight to ten years, the capacity of a lithium battery may be too low to power an EV, but it is usually still performant enough to store power. This is being tested, for example, in a joint project run by Toyota and the convenience store chain 7-Eleven, where retired EV batteries are used to store power from solar panels on 7-Eleven stores. In Yokohama City, former EV batteries are used as backup when the nearby wind power plant cannot run due to insufficient wind. Developing a common methodology and standards on how to evaluate the “state-of-health” of used batteries will be important to promote the development of markets for second-life applications.

Security of supply

Japan has a generally high level of power supply reliability. In 2017, it counted 14 power interruptions per 100 customers, and 16 minutes per customer on average (JEPIC, 2020), which is substantially lower than in most other IEA countries. However, maintaining reliable electricity supply has been a challenge in recent years, notably in 2018 and 2019 when earthquakes and typhoons caused long and large-scale power outages (Box 7.1). In 2018, the average power interruption per customer rose to 225 minutes, the second-highest level in 30 years after the 2011 Great East Japan Earthquake (METI, 2019).

The fact that Japan has no cross-border interconnections, ten areas with ten TSOs and two distinct frequency areas (50 hz and 60 hz) brings specific challenges to security of supply and a need for sufficient interconnections capacity and proper co-ordination. In addition, the surge of variable renewable energy in recent years has led to concerns for power supply reliability and created a need for more flexible balancing of supply and demand. The planned strengthening of interconnections will help further enhance the resilience of the electricity system. The establishment of the planned capacity market may also help.

[8] This includes hybrid electric vehicles, plug-in electric vehicles, full battery electric vehicles and fuel cell electric vehicles.

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Box 7.1 Earthquakes and weather conditions affecting power supply in 2018 and 2019

On 6 September 2018, a 6.7 magnitude earthquake caused a large-scale power outage in Japan's northern Island Hokkaido that affected more than 5 million people. The earthquake caused severe damage to a coal-fired power plant in Atsuma, which led to an imbalance in the electricity supply and demand and ultimately a blackout throughout Hokkaido. It took about 48 hours to restore power to most customers. The Atsuma power plant restarted one of its three units almost two weeks after the earthquake. The Organization for Cross-regional Coordination of Transmission Operators (OCCTO) issued 16 power exchange instructions to regulate the supply and demand balance following the earthquake.

In September 2019, Typhoon Faxai caused extensive and continued power outages in Chiba Prefecture, east of Tokyo. The typhoon toppled electric poles and many power lines were damaged by falling trees and flying objects. More than 930 000 households in Chiba and 6 other prefectures were without power. One week later, more than 70 000 households were still without electricity, as sustained heavy rain hampered recovery efforts.

Earlier in 2018, the Tokyo region experienced an electricity supply shortage due to heavy snowfall, which led to lower than expected solar PV output as snow accumulated on PV panels, unusually high electricity demand and an unplanned shut down of thermal power plants. Tokyo Electric Power Company (TEPCO) activated balancing measures (drawing on pumped-storage hydroelectricity and demand-response measures). As hydro storage declined, OCCTO intervened by requiring Chubu Electric Power to send power to TEPCO. The example highlights the elements of security of electricity supply in the 21st century: unpredictable electricity output (e.g. from variable renewable energy), storage (and its limits), and interconnection and efficient use of power across regions.

Sources: Japan Times (2019), "Japan may give Typhoon Faxai 'severe' designation to release more state funds for storm-hit areas", www.japantimes.co.jp/news/2019/09/16/national/one-week-typhoon-faxai-80000-households-still-without-power-heavy-rains-hit-chiba/#.XxmZXZ4zaMp; Japan Times (2018), "Preventive glitch led to Hokkaido blackout: Paper", www.japantimes.co.jp/news/2018/09/22/national/blackout-hit-bigger-assumed-power-loss-quake-hit-hokkaido-document/#.Xv8lkSgzaHs; Tsukimori, O. (2018), "Power restored in most of Japan's quake-hit Hokkaido; Toyota plants to shut", https://www.reuters.com/article/us-japan-quake/power-restored-in-most-of-japans-quake-hit-hokkaido-toyota-plants-to-shut-idUSKCN1LN2S9; OCCTO ((2020b), *Power Supply and Demand and Power System*, www.occto.or.jp/houkokusho/2020/files/denryokujyukyuu_2019_200805.pdf.

Emergency preparedness and response

Following the lessons learnt from the 2011 events, OCCTO was created in 2015 as a co-ordinating entity above the ten TSOs. It ensures emergency preparedness such as a minimum generation reserve margin in each area (of at least 3%) and identifies priority customers jointly with the TSOs. It also monitors the need for new capacity and can raise funds for this purpose.

In case of a power supply shortage or instability in a certain area, OCCTO can impose power exchanges between the different regions and can order electric utilities to supply more electricity in order to maintain stable supply. It also shares vital information with

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METI, such as blackout areas and capacity of inactive power plants. OCCTO uses a cross-regional operation system that monitors the supply/demand balance and generator outputs in real time.

In case the supply-side measures are not sufficient, the government has the authority to instruct large-scale customers to cut electric power consumption for a certain period of time. In contrast to some other IEA member countries, Japan has no mechanism for obligated fuel reserves in critical infrastructure and the TSOs do not have any mandate to verify these.

Based on the lessons learnt from the 2018 and 2019 events, the Diet (the Japanese parliament) passed a legislative proposal in July 2020 that includes a requirement for the TSOs to develop joint partnership plans to facilitate a quick initial response to disasters. This would follow the existing requirement for oil refineries and suppliers to submit a plan for joint operations of oil supply in disasters under the Oil Stockpiling Act. These plans would include, for example, provisions of fuel for power supply vehicles, information sharing among utilities and co-ordination with other relevant bodies (e.g. local governments, telecommunications and the construction industry).

The government furthermore plans to increase the efficiency of patrols as an immediate response to a power outage (e.g. by using drones) to quickly determine damage status and to develop technologies that enable recovery even where comprehensive collection of information is difficult (using big data, artificial intelligence, etc.). It further plans to revise the technical standards for steel towers and utility poles to consider local conditions (e.g. such as wind speed) and to accelerate efforts to eliminate utility poles by using underground power cables.

The creation of a mutual aid system to cover disaster recovery costs is also under consideration. Under this system, affected transmission and distribution companies may apply to the mutual aid system to cover eligible costs of support from other electric business and provisional recovery operations for early power failure resolution compared to full recovery, incurred in the event of a disaster.

Cybersecurity

In 2016, Japan introduced cybersecurity legislation into its Electricity Business Act and issued security guidelines for smart meters and for power control systems which must be followed by the operators. This was followed by the issuance of cybersecurity guidelines for energy resource aggregation businesses in 2017. Compliance with the guidelines, which cover aspects such as vulnerability assessments, service continuity and countermeasure requirements, is assessed as part of the licensing process for aggregation businesses that want to participate in ancillary service markets. In addition, in 2017, the Japanese electricity industry established Japan's "E-ISAC" (Electricity – Information Sharing and Analysis Center) with the aim of sharing best practices, exchanging information related to vulnerabilities and cyberattacks, and extending co-operation with other centres overseas. In 2018, Japan released a cybersecurity policy for critical infrastructure protection, which includes guidelines for establishing safety principles for ensuring information security as well as a risk assessment guide.

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Assessment

Historically, Japan's electricity system was fragmented into ten areas, operated by vertically integrated monopolies (general electric power companies). These EPCOs were poorly interconnected and there was limited competition in the wholesale and retail markets. Several natural disasters, including the 2011 events, after which all nuclear reactors were subsequently closed, as well as more recent large-scale and long-term power outages in various parts of the country caused by earthquakes and typhoons, highlighted shortcomings of the current electricity system.

In June 2020, the government passed legislation to strengthen the resilience of the electricity sector. The act includes a requirement for transmission and distribution operators to develop partnership plans to facilitate a quick initial response to disasters, changes to transmission charges to spur investments in transmission and distribution, and promotion of distributed grids which are more resilient to disasters.

The 2020 act is the next phase of the electricity market reform, which started in 2013. The reform had the three main objectives – secure a stable electricity supply, reduce electricity prices and expand consumer choice and business opportunities – and was implemented in three stages. In 2015, in the first stage, OCCTO was created and tasked with assessing generation adequacy and ensuring that adequate transmission capacity is available. In the second stage, also in 2015, the EGC was created as the regulatory authority for electricity (and later also gas) under METI. The third stage, implemented in April 2020, consisted of the legal unbundling of the transmission and distribution segments of the EPCOs from the generation and retail segments.

The establishment of regulators and operational agents such as EGC and OCCTO is consistent with normal practice in liberalised electricity markets in other jurisdictions. Where jurisdictions differ, however, is how functions are apportioned between regulator(s) and the degree of independence granted to such organisations. That is, whether they can take their own independent decisions or whether they simply advise ministerial decision makers.

The EGC can investigate improper behaviour by market participants, undertake arbitration and recommend a remedy to business. However, it cannot enforce its orders. In extreme cases, it can provide advice to the Minister of Economy, Trade and Industry regarding a breach of law for further action. The EGC secretariat has regular staff exchanges with METI and is only semi-independent. At this stage of the market's development, such a set-up may be appropriate; however, it would be worthwhile considering making the EGC more independent once the market is more fully developed. For example, a more independent agency could direct enforcement actions through an appropriate court rather than recommend action through the ministry.

OCCTO has exercised its power to instruct electricity exchanges when TSOs faced difficulties to balance supply and demand in their region. The new legislation of June 2020 granted additional powers to OCCTO facilitate the development of interconnection capacity across regions. Looking forward, Japan should monitor the efficiency of electricity generation and trade of electricity among regions and consider granting additional powers to OCCTO if these dimensions do not develop as hoped. A welcome initiative is the preparation of a master plan by OCCTO to enforce the construction and extension of the electric power grid.

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Japan's power exchange JEPX commenced operations as a wholesale electricity market in 2016. As of mid-2019, 167 companies were trading members. Unlike in many jurisdictions, trading in this market is not compulsory, although liquidity is increasing. Power traded through the spot market increased from about 3% of electricity sold in 2014 to 30% in early 2020. A compulsory pool where all generation must be traded would be an alternative design to consider. If enacted, it would expose all retailers to the same wholesale price, removing the incumbent advantage of internalised wholesale trading.

Approximately 30% of generators' volume is sold to a so-called baseload market, with the remainder being either internally traded or sold through bilateral contracts (around 40-45%). The baseload market was introduced in 2019 to meet a perceived market failure whereby new retailers could not access low-cost power available to larger incumbents. The baseload market is not compulsory, but incumbents are expected to sell around 30% of their generation in this market, at a price lower than the expected wholesale price. The expectation is that the creation of the baseload market will lead to increased competition in the retail market by lowering new retailers purchase costs.

There are yet insufficient data available to fully assess the effectiveness of this new baseload market. Accordingly, it will need reviewed in the future. Such a review should consider not only measures to improve it, but also whether the baseload market should be replaced by a compulsory wholesale spot market.

The growth in renewable generation and recent natural disasters have highlighted the shortcomings of existing systems of regional markets. The government is now moving to adopt a market-based system where a congestion management system will be introduced to address unfair competition among companies, and to bring about wide-area merit order use of interconnection facilities.

The most favourable sites for renewable generation are not always the best locations for transmission access or close to centres of demand. Japan's northern island of Hokkaido is particularly suitable for wind generation while the southern island of Kyushu has good solar resources. It is important to ensure that regulatory and market systems are capable of facilitating and encouraging investments in sufficient transmission and distribution infrastructure to reduce grid constraints so as to remove barriers to renewable investments. Reducing interregional transmission constraints is necessary to enhance electricity security and improve market competition, and the proposals for a balancing market and the powers granted to OCCTO are a good development to achieve this objective.

The electricity market reform proposes new wheeling charges (a so-called "G-charge") to finance necessary investments in the network facilities for the expansion of renewable energy, and to promote the efficient utilisation of network facilities by generators. The charge will be imposed on all generators as of 2023. The final design of the G-charge is under review, with a view to maintaining consistency with the new congestion management rules of transmission lines that are also under consideration.

Internationally, there is no universal agreement on how to apportion transmission costs in wheeling charges, but cost-reflective and non-discriminatory tariff design is very important for efficient electricity tariff design. A move for the wheeling charge to be levied on both generators and load is consistent with international practise. It is Japan's intention for wheeling charges to cover infrastructure costs (fixed costs) and Japan introduced a lower connection charge (shallow) and intends to introduce cost-reflective transmission charges.

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Given the importance of investment in the expansion of network facilities, it will be key to ensure that the wheeling charge that is under consideration is technology-neutral, non-discriminatory and fairly distributes the network costs. At the same time, it will also be important that the final design of the G-charge does not create any unintended bias for or against any generation type.

Ideally, power generation investments should be recoverable through market transactions. However, as variable resources such as wind and solar are introduced to meet the 2030 energy mix targets, the need for flexible resources will increase. At the same time, revenue is expected to become less predictable, making investments in both new generation facilities and financing of maintenance of existing facilities more difficult. To address these concerns, the government plans to introduce a capacity mechanism to provide generators that maintain generation capacity with a revenue stream even during periods when they are not producing electricity.

A decision on the final design is outstanding. Internationally, capacity mechanisms are recognised as one of the tools for meeting short- or long-term resource adequacy needs. They should be technology-neutral, accounting for both supply and demand response, and they should be forward-looking. That is, ideally, they should include a locational component, so that investments are targeted where they are needed the most. Capacity markets also need to be carefully designed to prevent market distortions. They are not a replacement for getting wholesale market price signals right in the first place, so care is needed to ensure that capacity revenues do not dominate market revenues.

The tasks of controlling frequency and balancing supply and demand are performed by the regional TSOs. A balancing market will be introduced in 2021 for procuring and operating balancing supply and demand on a cross-regional basis. Such a mechanism will mean TSOs can more efficiently procure power supply and demand response in order to achieve a more efficient supply-and-demand balance.

Electricity retailers must procure 44% of their supply from non-fossil resources (renewables and nuclear) by 2030. However, new retailers' means of procuring these resources is limited, making it difficult to accomplish this goal. The non-fossil fuel value market, which started operating in 2018, addresses this problem by allowing new entrants to secure electricity from non-fossil fuel sources. The costs of the environmental value of electricity derived from renewables will be borne primarily by those customers who buy in this market.

Liberalisation of the retail electricity market took effect in April 2016. Even though the market share of new electricity retailers had increased to 15.8% by September 2019, incumbent retailers continue to dominate the market. Household electricity prices are still subject to regulation as a transitional measure to protect consumers. To date, new entrant retailers have mainly focused on profitable customer segments, for example supermarket chains, mid-sized factories and large households. Many large factories remain with incumbents, as do smaller households. This parallels early retail market development trends in other jurisdictions.

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Recommendations

The government of Japan should:

- In the context of the ongoing liberalisation of the electricity market, review the market design, once fully implemented, to ensure that the market delivers on energy security, sustainability and affordability goals. Such a review should at a minimum:
  - Evaluate the operation of the baseload market, by considering its continuation or enhancement against the adoption of a compulsory wholesale pool. Such evaluation should ensure that market participation provides sufficient liquidity to make the market function in a viable way.
  - Evaluate the operation of the non-fossil fuel value market.
  - Ensure that the capacity market design is market-based, technology-neutral, includes supply- and demand-side sources, and is forward-looking.
- Evaluate the operations of the EGC and consider legislative changes to increase its independence as part of the next phase of market liberalisation.
- Encourage investments in transmission and distribution infrastructure, thereby increasing electricity security, reducing grid constraints across the country to facilitate smart grid developments and cost-effective penetration of larger shares of variable renewable electricity.
- Ensure that the wheeling charge that is under consideration to finance the expansion of the electricity network necessary to accommodate larger shares of renewables will be non-discriminatory and technology-neutral, and promotes efficient utilisation of network facilities by generators.
- Adjust the operational technology to reduce the amount of supply that is curtailed with 24 hours' notice to minimal levels.
- Support providing transparent information to consumers on generation portfolios, pricing and switching options.

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8. Natural gas

Key data

(2019 estimated)

Domestic production: 2.6 bcm (2.6 Mtoe), -32% since 2009

Net imports: 105.0 bcm (105.0 bcm imports, 0 bcm exports)

Share of gas: 5.0% of domestic energy production, 23.1% of TPES, 34.2% of electricity generation, 10.3% of TFC*

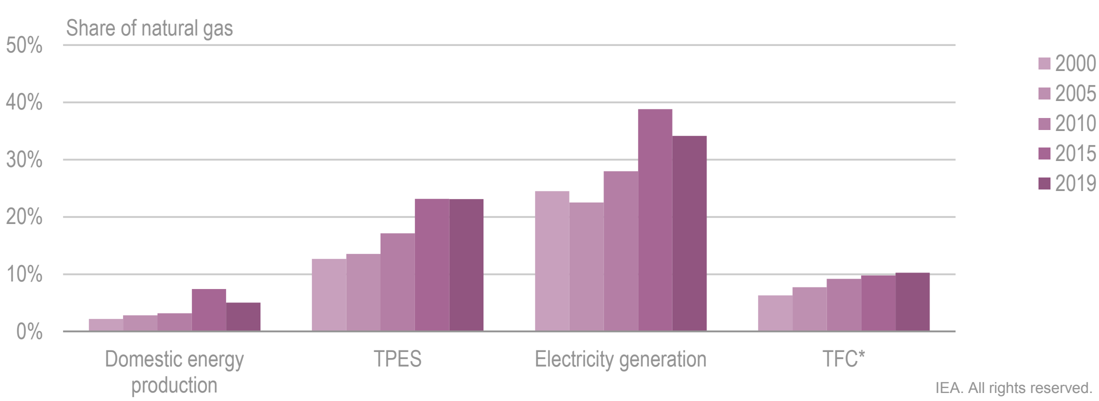
Gas consumption (2018): Total consumption 108.2 bcm (power and heat 68.9%, industry 12.0%, residential 8.8%, services 9.0%, other energy 1.3%, transport 0.04%)

* TFC data refer to 2018.

Overview

Natural gas plays a critical role in energy supply in Japan, representing the third-largest energy source in total primary energy supply (TPES) (after oil and coal), and the largest energy source in electricity generation. In 2019, natural gas accounted for 23% of TPES and 34% of electricity generation (Figure 8.1). With domestic production being limited, Japan imports nearly all its gas, and since Japan has no cross-border pipeline connections, all gas is imported in the form of liquefied natural gas (LNG).

Figure 8.1 Share of natural gas in Japan's energy system, 2000-19



Natural gas demand has been increasing for decades, with a recent large growth in electricity generation to compensate for the drop in nuclear power after the 2011 Fukushima accident.

* Latest TFC data refer to 2018.

Notes: TPES = total primary energy supply. TFC = total final consumption.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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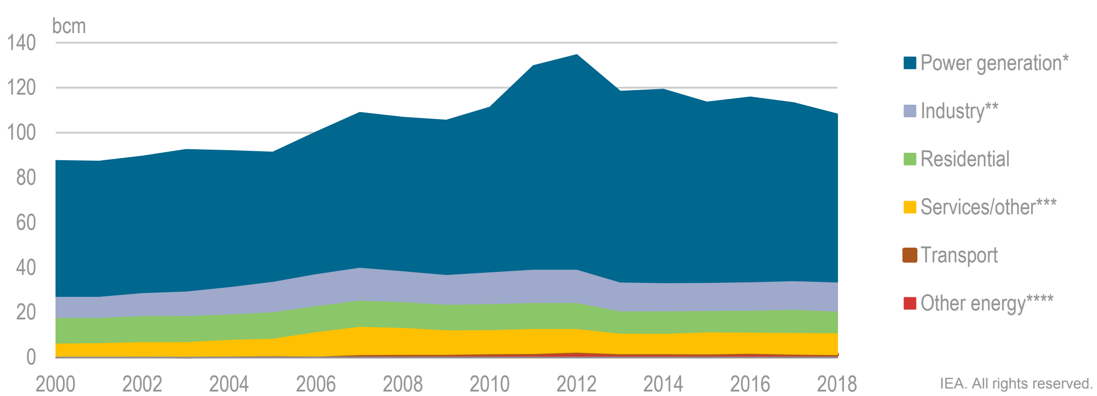
The 2011 Great East Japan earthquake and subsequent Fukushima Daiichi nuclear accident (hereafter called "the 2011 events") that resulted in the closure of all nucler plants and the subsequent increase in the demand for natural gas has led to major changes in Japan's LNG procurement strategy. More emphasis is being placed on flexibility in Japan's long-term procurement contracts, while new pricing formulas are introduced on top of the traditional link to crude oil prices. Domestically, Japan has embarked on a comprehensive gas market reform with a view to enhance security of supply, increase downstream competition for end users and reduce end-user prices. Major components of this reform include the full liberalisation of the retail market in 2017 and a requirement for vertically integrated gas companies to unbundle their businesses by April 2022.

Supply and demand

The importance of natural gas in Japan's energy mix has steadily increased over the past two decades, driven by increasing demand for electricity generation. This demand was even more inflated by the 2011 events. Total natural gas consumption increased by 21% between 2010 and 2012, entirely driven by demand growth of natural gas in the power sector (Figure 8.2).

Since 2012 however, natural gas consumption has levelled off again, due to the rebound of nuclear power, expansion of renewable electricity and flat electricity demand. Gas consumption in the industrial, residential and services sectors has also decreased since the 2012 peak (by 12%, 17% and 8%, respectively). This resulted in an overall drop of 20% in Japan's gas consumption between the peak in 2012 and 2018.

Figure 8.2 Natural gas consumption in Japan by sector, 2000-18



Natural gas consumption rapidly increased from 2010 to 2012, due to growth in demand from power generation, but has decreased since.

* *Power generation* includes a minor share of district heat generation.

** *Industry* includes non-energy use.

*** *Services/other* includes commercial and public services, agriculture, forestry, and fishing.

**** *Other energy* includes petroleum refineries, coke ovens, own use in power and heat generation, and liquefaction.

Note: bcm = billion cubic metre.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

In 2018, Japan's gas consumption totalled 108.2 billion cubic meters (bcm). Two-thirds of this (66%) was consumed by power generation, with the remainder being distributed to

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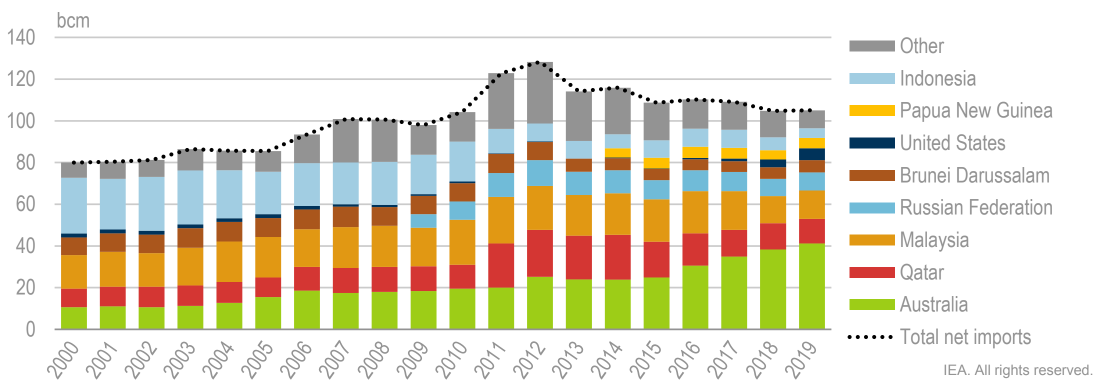
industrial, commercial and residential consumers as city gas. Industry is the second-largest gas consumer, accounting for 12% of total consumption in 2018. Nearly two-thirds of this is used in the iron and steel; chemicals; and food, beverage and tobacco industries. The residential and service sectors each accounted for 9% of gas demand in 2018, while transport and other energy sectors accounted for about 1%. Natural gas demand has a seasonal pattern, with the highest demand occurring during the winter, due to higher demand for heating.

Imports

With domestic production being limited, Japan imports nearly all of its natural gas. As an island nation with no pipeline connections to other countries, Japan relies entirely on LNG supply. In 2019, it imported 105 bcm of natural gas, equivalent to 97% of gas demand that year. Japan is the world's largest LNG importer, accounting for 22% of global trade in 2019 (IGU, 2020).

Japan's LNG imports are well diversified. In 2019, over one-third (39%) of imports came from Australia, followed by Malaysia (13%), Qatar (11%), the Russian Federation (8%) and Brunei (6%) (Figure 8.3). Imports from Australia have substantially increased since 2014, while those from Japan's other major trading partners have decreased. In 2017, Japan began purchasing shale gas-originated LNG from the United States, and import volumes from the country tripled in 2017-18. While Japan has no history of exporting LNG, it is noteworthy that there is increasing investment in reloading capacity at some Japanese LNG terminals, which allows for the diversion of received LNG cargoes to other destinations in and outside Japan. The first LNG cargo was re-exported in 2017 via the Sodeshi terminal (IGU, 2019).

Figure 8.3 Natural gas imports to Japan by country, 2000-19



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Japan imported 105 bcm of LNG in 2019, over a third of which came from Australia, followed by Malaysia, Qatar and the Russian Federation, and recently increasingly also from the United States.

Note: bcm = billion cubic metre.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Domestic production

Japan has very limited natural gas resources and hence limited domestic production. In 2019, domestic production reached 2.6 bcm, equivalent to 2% domestic demand.

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According to the Ministry of Economy, Trade and Industry (METI),[1] proven natural gas reserves stood at 38.8 bcm in March 2018. The two largest upstream development companies are INPEX and JAPEX.

The Japanese government supports domestic resource exploration, including through government-led explorations using three-dimensional seismic scanning vessels. Between 2013 and 2018, METI conducted explorations of about 6 000 square kilometre ($km^{2)}$ per year in Japan's seas. From 2019 onwards, it will conduct explorations flexibly, with the aim to cover approximately 50 000 km^2 over a period of ten years (METI, 2018).

The government also continues to invest in technologies to produce natural gas from frozen methane hydrate, which is present in Japan's seas. Following the world's first offshore tests for natural gas production in deep methane hydrates in 2013, Japan conducted another test involving two wells from April to June 2017. These tests delivered 200 000 cubic metre (m^3) and 35 000 m^3 of gas over a period of 24 days and 12 days, respectively. The research associated with methane hydrate has been conducted under an industry-government-academia collaboration research group established back in 2001. It is hoped that commercial projects exploring methane hydrate will begin between 2023 and 2027.

Japan's outlook for natural gas demand

Japan's *Long-term Energy Supply and Demand Outlook to 2030* (METI, 2015a) projects natural gas demand in 2030 to decline back to levels comparable to those prior to the 2011 events. Nevertheless, at a projected 18% of TPES and 27% of electricity generation in 2030 (compared to 23% and 40% in fiscal year (FY) 2017), natural gas will remain a strategically important energy resource in Japan.

The 5th Strategic Energy Plan (SEP) of 2018 confirms a central role of natural gas in Japan's future energy mix, aiming to make it the single largest power source and the third-largest source in TPES in 2030 (after oil and coal) (METI, 2018). Natural gas is considered a critical "intermediate power source" that can accommodate demand and supply fluctuations. The use of natural gas in the industrial, commercial and residential sectors is expected to increase, driven by competitive LNG prices thanks to the shale gas revolution in the United States, as well as the desire to reduce greenhouse gas (GHG) emissions.

Natural gas is expected to play a key role in helping Japan meet its goal to reduce GHG emissions by 26% from 2013 levels by 2030, and by 80% by 2050 (see Chapter 3). To encourage the shift from coal to natural gas, the government subsidises fuel cells for commercial and industrial uses (with a budget of JPY 52 billion (USD 447 million)[2] in FY2019) as well as the installation of natural gas co-generation[3] facilities (JPY 40 billion) and high-efficiency boilers, industrial furnaces, or other gas appliances that save energy and CO_2 emissions (JPY 8 billion). The Japan Gas Association estimates that the shift to natural gas technologies could mitigate up to 62 million tonnes of CO_2 by 2030 (equivalent

[1] Annex A provides detailed information about institutions and organisations with responsibilities in the energy sector.
[2] 1 USD = 109 JPY
[3] Co-generation refers to the combined production of heat and power.

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to 6% of Japan's energy-related CO_2 emissions in 2018). The 5th SEP also announced efforts to reduce natural gas purchase prices to encourage natural gas use.

Japan's Long-term Strategy Under the Paris Agreement, which sets the vision to 2050, confirmed the central role of natural gas in the country's clean energy transition and announced to maintain efforts to promote natural gas use in all sectors (GoJ, 2019). This includes promotion in areas in which electrification and hydrogenation is difficult, such as industrial high-temperature heat and shipping. It also notes the role of natural gas in advancing the "hydrogen society", which is expected to play a major role in Japan's long-term energy transition (see Chapter 6). Clearly defining the role of natural gas for climate change mitigation and in the hydrogen society would provide clarity to gas companies as they decide on their long-term LNG procurement strategies and infrastructure investments.

In the near term, LNG demand will be much driven by the demand for power generation, which in turn will depend on the pace of nuclear restarts, as well as the cost and availability of alternative energy sources. The IEA projects natural gas imports to decline by about 10% over 2019-25 with nuclear restarts and steady growth in renewables (IEA, 2020b). This is in line with Japan's *Long-term Energy Supply and Demand Outlook to 2030*, which projects power generation from LNG to decline by 32% over 2015-30. However, installed gas-fired power plant capacity is growing, with a total of 7.8 gigawatt (GW) currently under construction. This compares to 5.3 GW that will retire by 2028, and an overall installed capacity of 82 GW in 2018 (OCCTO, 2020). Demand for city gas[4] is expected to be stable. Nationally, around 27 million consumers use city gas, 96% of which are residential consumers. In terms of volume, the majority of city gas is distributed to industry (59% in 2018) (JGA, 2019).

Gas market strategy and regulation

The rapid increase in natural gas demand following the 2011 events has brought challenges to Japan's gas market, including energy security issues associated with an increased dependence on imported LNG and rising gas and electricity costs associated with international oil-linked LNG prices. To address these challenges, Japan began to fundamentally reform its domestic city gas market, liberalising the retail market in 2017 and requiring its vertically integrated city gas companies to unbundle their businesses by 2022.

Japan has also been actively promoting a more liquid, flexible and transparent global LNG market, driven by the belief that a well-functioning global LNG market would greatly contribute to its security of natural gas supply. The Strategy for LNG Market Development, published in 2016, defined three fundamentals that are needed to achieve this goal: 1) better tradability of LNG and natural gas (e.g. by resolving trade barriers, fostering demand and promoting international collaboration); 2) robust LNG pricing mechanisms; and 3) enhanced gas infrastructure and improved access to it (METI, 2016). This strategy is in line with the general development among LNG importing countries to diversify from long-term contracts that are indexed to the price of crude oil, towards increased use of

[4] City gas refers to natural gas that is distributed to residential, commercial and industrial consumers via city gas companies, i.e. that is not used by electricity companies for power generation. In Japan, about two-thirds of natural gas supply is used by electricity companies for power generation and one-third is distributed as city gas.

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spot markets and shorter term contracts, as well as flexible long-term contracts and new pricing formulas.

Reform of the domestic city gas market

In 2017, the government embarked on a comprehensive reform of the domestic city gas market, in parallel to the electricity market reform (see Chapter 7) and in line with the recommendations made in the IEA 2016 in-depth review (IEA, 2016a). The reform has the same three objectives as the electricity market reform: enhancing security of supply, decreasing prices, and expanding consumer choice and business opportunities.

Japan's city gas market was historically fragmented into many vertically integrated regional companies. These companies were monopolistic suppliers within their districts until the government liberalised the retail market for large consumers (which consume more than 2 million cubic metres [mcm] per year) in 1995. Three additional phases of market reform followed in 1999, 2004 and 2007, liberalising gas sales to consumers with 1 mcm, 0.5 mcm and 0.1 mcm, respectively. Effective competition was, however, slow to develop.

In 2015, Japan amended its Gas Business Act to initiate a major phase of market reform. A key component of this reform was the full liberalisation of the retail sector. Since April 2017, the entire natural gas consumer base (including small-scale consumers) can select its own gas supplier. Regulated tariffs were abolished, except for the nine largest vertically integrated gas companies (Tokyo Gas, Osaka Gas, Toho Gas, Keiyo Gas, Keiwa Gas, Nippon Gas, Atami Gas, Kawauchinagano Gas and Nankai Gas), which will continue to supply gas under regulated tariffs until regulated tariffs are abolished. This exemption, which is intended as a transitional measure, applies to about 18.7% of total city gas sales.

Secondly, Japan radically restructured the regulatory framework of the city gas market. While gas businesses were previously vertically categorised according to their type, they are now horizontally categorised according to their function (Figure 8.4):

- The "gas manufacturing business", or LNG terminal business, which procures LNG for its own regasification terminals.
- The "pipeline service business", which operates a pipeline network. The sector is further divided into "general gas pipeline service business", which operates high-pressure to low-pressure networks and supplies small amounts of gas, and the "specific gas pipeline business", which operates only high- and medium-pressure pipeline networks and supplies gas to a specific point. The two businesses are regulated differently.
- The "gas retail business", where gas companies supply and sell gas.

Prior to the reform, there were 206 general gas businesses, most them privately owned. Three vertically integrated companies – Tokyo Gas, Osaka Gas, Toho Gas – dominated the market, accounting for about three-quarters of city gas sales. In addition, there were 15 large-volume businesses (which supplied to users exceeding 0.1 mcm per year) and 23 pipeline service businesses (which supplied to the wholesale market, using their own pipelines), both of which emerged with the gradual liberalisation of the retail sector to large consumers. There were also numerous small, community gas utilities. Most pipelines were owned by the vertically integrated general gas utilities.

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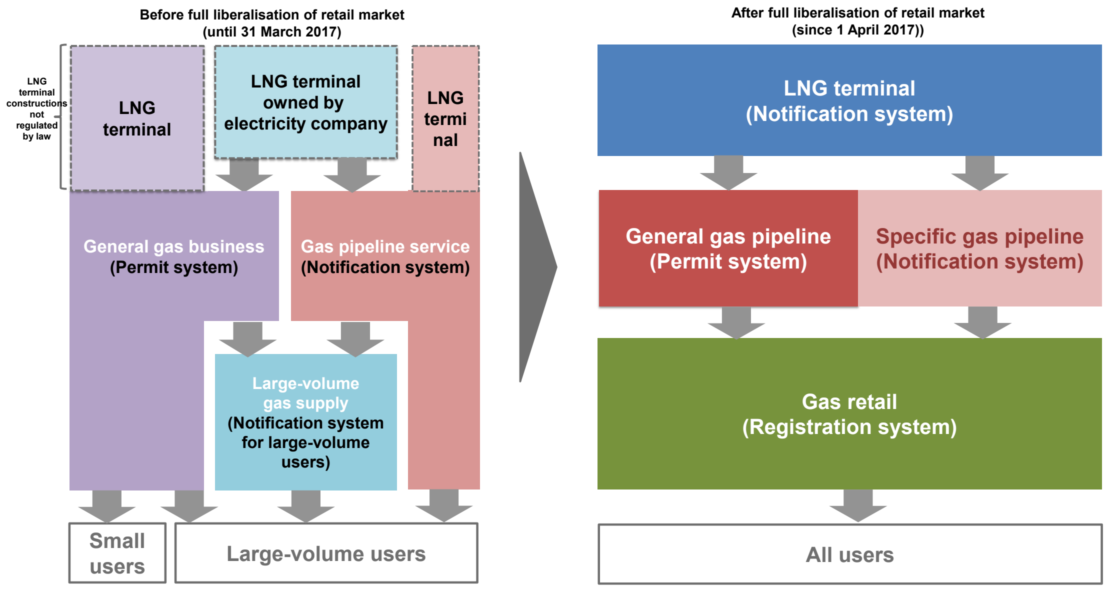
Figure 8.4 Japan's gas market structure before and after the 2017 reform



Source: METI (2015b), *22nd Gas System Reform Subcommittee Documents Submitted by the Secretariat*, www.meti.go.jp/shingikai/enecho/kihon_seisaku/gas_system/pdf/022_03_00.pdf.

As of June 2020, there were 27 manufacturing businesses; 195 general piping service businesses and 29 specific gas pipeline businesses; and 79 gas retailers. The three major gas providers (Tokyo Gas, Osaka Gas and Toho Gas) continue to dominate all market segments: they own 12 LNG import and regasification terminals belonging to the gas industry, hold half of pipeline infrastructure and account for about two-thirds of city gas retail sales in Japan.

A third component of the reform is the promotion of third-party access (TPA) to gas production infrastructure (TPA to pipelines had already been introduced in 2004). Since April 2017, owners of 31 LNG terminals with tank capacity of 200 000 kilolitres or more are prohibited from rejecting third-party use without justifiable reasons. Such reasons can include the occurrence of natural disasters and other events that threaten gas security, exceeding the contracted amount over facilities' available capacities, or unacceptable gas quality. The regulation requires terminal owners to submit and publish their annual estimated available spare storage and regasification capacity, as well as the terms and conditions for TPA use, including access fees. METI and the Electricity and Gas Market Surveillance Commission[5] have responsibility to monitor access and the government can order changes in the conditions where it deems necessary.

The idea behind the new regime was to promote competition in the gas market by utilising unused storage and regasification capacity of the existing terminals. However, only one applicant has acquired access to LNG terminals to date; other applications were either refused as per the relevant rules or are waiting for the result. The government should

[5] The Electricity and Gas Market Surveillance Commission was established in 2015 under METI to monitor and foster appropriate competition in the electricity retail markets. In 2016, its remit was expanded to also cover the gas market. See details in Annex A.

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closely monitor the situation and adjust TPA conditions and the regulatory framework if necessary.

Progress of liberalisation in the retail gas market has been slow compared to that in the retail electricity market, but it is picking up. By April 2018, one year after liberalisation, merely 3.7% of residential consumers had switched their gas suppliers (IEA, 2018). By November 2019, this share had increased to 12% of all users (equal to about 3 million individual contracts). There is wide regional variation however: in the Kinki region, for example, the switching rate rose to 17%, while three regions (Tohoku, Chugoku and Shikoku) have seen no new retail entrant to date. Nationwide, new entrants accounted for 14.3% of total retail sales volume in September 2019, up from 8.2% in April 2017. The market share is the highest among industrial consumers (18%) and reached 9% and 4% for households and commercial consumers, respectively.

The limited number of new entrants can partly be explained by the nature of Japan's wholesale market. There is no well-defined wholesale market where retailers could procure LNG conveniently. Most entrants therefore need to import LNG by using LNG terminals under TPA conditions, or purchase regasified natural gas from existing importers that are willing to enter into contracts with them. However, there is a limited number of importers in any given region, given that gas pipeline networks are not interconnected. Better pipeline connectivity and a well-functioning TPA regime are therefore important for the development of a competitive wholesale market and, eventually, to introduce greater competition in the retail market.

Towards a more flexible and transparent LNG import market

Since its first importation of LNG from Alaska in 1969, Japan has been a leader of the global LNG market, not only as the biggest buyer of the fuel, but also as an innovative force of the market. Several new ideas such as price indexing to Japan customs-cleared crude oil (JCC) and S-curve pricing[6] came out from its negotiation with sellers, some of which became established references in Asian LNG trade.

Traditionally, Japanese companies have imported LNG through long-term contracts that are indexed to the price of crude oil. However, when long-term contracts were not able to meet the sudden increase in demand following the 2011 events (with nearly 25% of demand being uncontracted in 2012), Japan's importing companies were forced to turn to spot markets and shorter term contracts. Asian spot trade expanded rapidly in this period and, until 2014, Japan accounted for almost all short-term and spot LNG trade in Asia. Long-term contracts accounted for less than 80% of Japan's total contracted volume in 2014, compared to 95% in 2005 (IEA, 2019a; 2019b).

The sudden increase in Japanese LNG demand, tighter supply and high oil prices led to a significant increase in Asian spot LNG import prices, causing Japanese (as well as other Asian) buyers to sign contracts that are based on US domestic market prices, rather than based on crude oil, which were substantially lower than oil prices at that time. More recently, Japanese contracts have also been linked to European traded gas and Japanese/Korean imported gas prices, or hybrid pricing models involving multiple

[6] S-curve pricing refers to a pricing formula where the relationship between the LNG price and the oil price varies over different oil price ranges.

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commodities. In 2019, for example, Tokyo Gas signed a ten-year LNG contract with Shell that has a pricing formula partially indexed to coal.

Japan's importing companies also started to introduce more flexibility in their procurement contracts, both in terms of volume and with respect to the possibility to resell LNG cargoes to other countries. In part, this emerged as a tool to manage excess capacity in the market, which emerged in 2016 when gas demand decreased and started to lag behind contracted supply volumes. A recent example is the agreement signed by Tokyo Gas and Centrica (United Kingdom) with the Mozambique LNG project in 2019, under which the two companies aim to share the contracted volume and adjust it to meet their demand fluctuations. In addition, the cargoes have no destination restrictions, which would prohibit importers from redirecting or reselling the volumes to other destinations and which have been observed in previous Delivered Ex Ship contracts. Several Japanese terminal owners are showing interest in becoming "portfolio players", as evidenced by their interest in flexible contracts and investment in reloading capacity. Shizuoka Gas, for example, converted its Shimizu LNG Sodeshi Terminal into a reloading facility in 2016. Similarly, Saibu Gas announced it will use its Hibiki LNG terminal for reloading LNG from Russia to the growing Asian market.

The Japanese government is actively promoting the trend towards a more flexible and liquid LNG market, which it considers to be a way to enhance its security of gas supply. In 2017, it announced it would relax or eliminate reselling restrictions (such as destination clauses), following a review of the Japanese Fair Trade Commission, which concluded that destination clauses and other competition-restraining clauses or business practices are likely to violate Japan's Antimonopoly Act (JFTC, 2017). The commission's review also concluded that such clauses should be eliminated from new or revised LNG contracts, and LNG sellers should review existing contracts. Since the ruling, Japanese LNG importers have made an effort to sign new term contracts without destination clauses and some have started to renegotiate existing contracts to eliminate these clauses (Obayashi, 2019).

Internationally, Japan has been promoting a well-functioning LNG market through the LNG Producer-Consumer Conference held in Tokyo annually since 2012. In 2017, Japan signed memoranda of co-operation with India and the European Union on promoting a liquid, flexible and transparent global LNG market. Under these memoranda, the countries committed to exchange experiences and best practices to improve the functioning of the global LNG market. This includes more flexibility in LNG sales contracts, price transparency and reporting, and enhanced co-ordination regarding responses to unexpected gas market disruptions. The government is also actively promoting price transparency and hopes to create a proper price discovery mechanism that reflects LNG supply and demand fundamentals. The LNG spot market launched by the Japan OTC Exchange in April 2017 is hoped to provide valuable price information for both the domestic and the global LNG market.

The government also supports LNG infrastructure projects that it considers conducive for a more flexible Asian LNG market. In 2017, METI announced a plan to finance new LNG infrastructure projects in Asia with a value of up to USD 10 billion over a period of 5 years, and training was provided for 500 skilled workers and government officials. In 2019, an additional USD 10 billion was announced, as well as plans to train another 500 experts in areas such as LNG reception technology and environmental regulations (Reuters, 2019). Japan has long provided financial support for overseas oil and gas exploration and development projects through the Japanese Oil, Gas and Metals National Corporation

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(JOGMEC). Over the past decade, such support averaged about JPY 29.2 billion (USD 273 million) per year (OECD, 2020). While such support was limited to upstream projects, Japan passed legislation in June 2020 allowing JOGMEC to also support investment in projects further downstream, such as LNG terminals. The government expects the expanding receiving capacity in Asia to help Japanese companies to trade with other consuming countries.

Infrastructure

LNG terminals and storage capacity

Having no pipeline connections to other countries, Japan imports all its natural gas in the form of LNG. Japan counts 37 operational LNG terminals with a total regasification capacity of 210 million tonnes per year (286 bcm/y), equivalent to 25% of the world's total (IGU, 2020). Most LNG terminals are located in the main population centres of Tokyo, Osaka and Nagoya, near major urban and manufacturing hubs. Additional terminal capacity expansion and construction projects are underway, including an expansion of the Hitachi Terminal (commercial operation is expected in 2021) and the construction of the Niihama Terminal (for which operations are expected to start in 2022). The capacity utilisation rate has been declining in recent years and stood at 36% in late 2019 (down from 39% in 2018) (IGU, 2020).

Most LNG import terminals are owned by electricity utilities, some are owned by vertically integrated general gas companies, and some are joint ventures (including with the participation of regional governments) or are owned by other big industries (e.g. a steel company). Electricity companies and gas companies largely import their gas independently from each other, although there are instances where they jointly procure LNG.

Japan has five underground gas storage facilities situated at depleted gas fields with a total capacity of around 1.4 bcm. These storage sites mostly serve peak-shaving purposes and to balance seasonal fluctuations. All facilities are owned and operated by domestic gas exploration companies, which own mineral rights, using their storage facilities as part of their operation. In addition, Japan's 37 LNG receiving terminals have a total LNG storage capacity of around 18 mcm (equivalent to around 12 bcm of natural gas storage capacity) (IGU, 2020). Plans to build a new LNG terminal and to expand the storage capacity of existing facilities will give the country another 1 mcm by 2022. Japan's total storage capacity meets around 36 days of domestic natural gas consumption. However, given the poor suitability of LNG for long-term storage, Japan typically has a two-week stockpile. There is no obligation for mandatory reporting of actual stock levels imposed on the industry, which may act as an impediment to gas market development and gas security in the case of a supply disruption.

Pipelines

According to Japan Gas Association, total domestic gas pipeline length in 2017 was 261 167 km, of which 86% is low-pressure networks for local distribution, 13% medium-pressure networks and 0.9% high-pressure transmission lines (JGA, 2019).

Japan's gas pipeline network is very fragmented, as pipeline networks have developed separately to connect LNG-receiving terminals with demand centres. There are some interconnection points between areas, but the trunk-line networks are not necessarily

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connected to each other (Figure 8.5). In rural areas, gas demand is mostly met by liquefied petroleum gas.

Figure 8.5 Japan's main LNG terminals and pipeline network, April 2019

As the trunk-line networks are fragmented, there is no single operator of the national transmission system in the country. Natural gas-related businesses (mainly electricity utilities and city gas companies) own and operate their gas pipelines separately. TPA to trunk pipelines and distribution networks was introduced in 2004, and is to be individually negotiated by parties proposing to supply customers. However, the lack of interconnections between regions limits the ability to increase competition through TPA.

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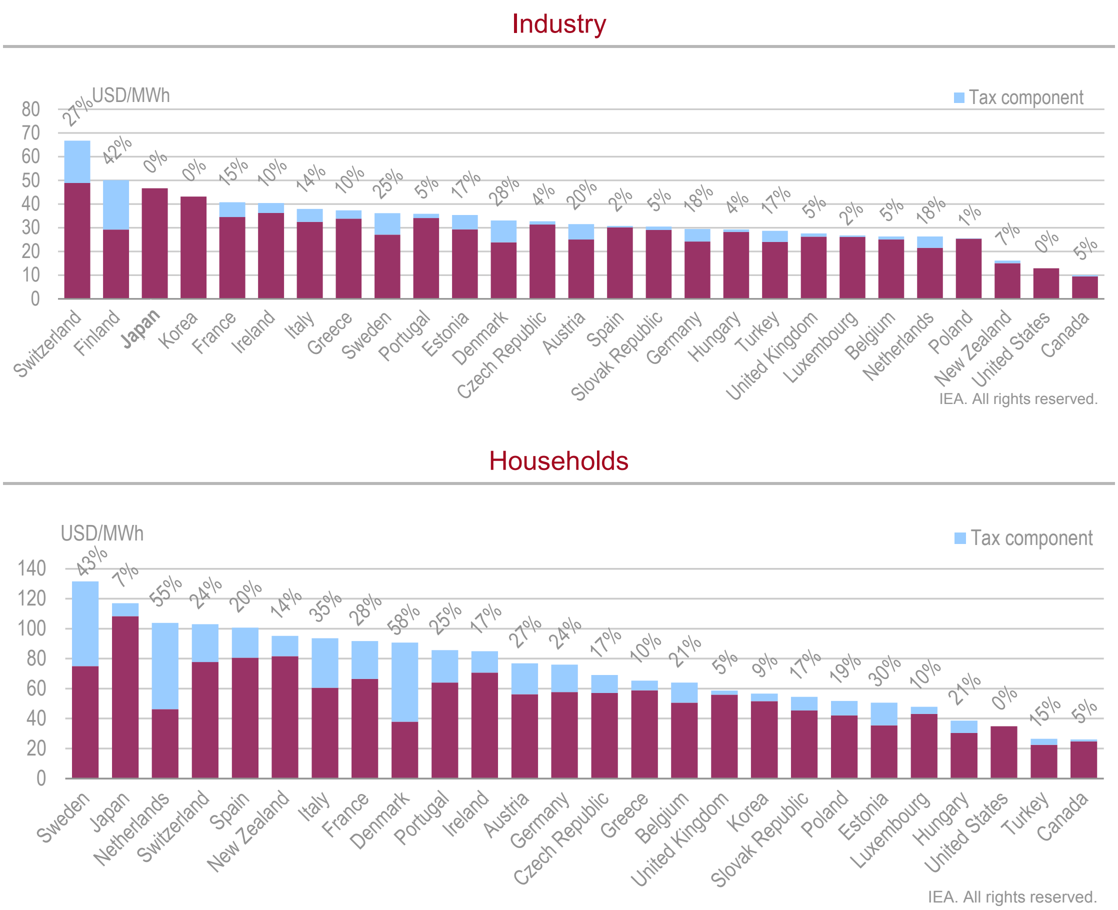
The government is trying to promote more interconnections via the revised Gas Business Act, which allows the government to order business operators to conduct consultations among themselves and to arbitrate between them on pipeline development. The gas pipeline development policy was finalised in June 2016. It establishes clear rules on how decisions on interconnections are to be taken and how these projects would be financed, in order to accelerate the realisation of interconnection projects.

Retail prices and taxes

Retail gas prices for both industry and households in Japan are high by international comparison (Figure 8.6). The average gas prices in industry was USD 46.7 per megawatt hour (MWh) in 2019, representing the third-highest price among IEA countries, despite imposing no taxes on industrial natural gas consumption. Residential gas prices ranked the second-highest in an IEA comparison after Sweden. Japanese households paid USD 117.1/MWh in 2019, of which 7% was taxes (compared to a tax level of 43% in Sweden).

Figure 8.6 Natural gas retail prices in IEA member countries, 2019



In 2019, Japan had the third- and second-highest gas retail prices for industries and households, respectively, in the IEA, despite no and low tax rates.

Notes: MWh = megawatt hour. Missing data for Australia, Mexico and Norway. No data for tax components in the United States, or for household prices and taxes in Finland.

Source: IEA (2020c), *Energy Prices and Taxes 2020* (database), www.iea.org/statistics.

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Japan's high reliance on LNG leads to fluctuating prices, given that the vast majority of LNG imports are based on long-term contracts that are indexed to oil. During the period after the Fukushima accident, oil prices were high, and the increased gas demand in Japan led to spot price spikes. Between 2007 and 2012, gas prices in Japan increased by 97% for industry and by 59% for households. In 2015, prices fell with the rapid drop in global oil prices, but started to recover soon after. The average import price has not reached the pre-Fukushima level (USD 10/ Million British thermal units) however, in part thanks to the diversification of pricing formulas used in Japanese LNG procurement contracts.

Natural gas emergency response

Emergency preparedness and response measures

Japan's overall gas security policy focuses on diversifying its long-term supply contract portfolio, ensuring that long-term contracts include flexibility to increase imports during an emergency, diversifying suppliers, supporting LNG production in other countries with the involvement of Japanese companies, establishing international co-operation frameworks and using voluntary commercial LNG stocks in industry.

There is no formal national emergency organisation for oil and gas supply disruptions. However, METI is supposed to take the lead in co-ordinating the necessary action and liaising with industry. In the case of an interruption of city gas supply caused by an earthquake or a flood, METI and the city gas industry have established a system of sharing information and co-operate with each other to establish a timely recovery. A similar system also exists for the electricity companies.

There is no legal obligation for industry to hold emergency stocks in the form of natural gas, LNG or alternative fuels. However, electric power companies and city gas companies normally hold a commercial stock equivalent to about two weeks of natural gas consumption. There is no mandatory reporting of stock levels imposed on the industry. Better information on stock levels would both enhance the transparency of the market and strengthen awareness in the case of a supply disruption.

Japan has no legislation that allows the government to oblige electricity utilities to switch fuels from natural gas to alternative sources during a gas supply disruption. During such a disruption, system operators will reduce gas supplies according to interruptible contracts. Tokyo Gas, for example, which accounts for about one-third of city gas sales, can reduce its supply to customers using over 0.5 million m^3 per year, except for priority customers such as hospitals, welfare institutions and government offices. Tokyo Gas also has over 200 portable air-mixed propane gas generators to temporarily supply gas for priority consumers.

Network resilience

In order to strengthen resilience to such disasters, the Japanese gas industry has replaced aged low-pressure gas pipes with polyethylene pipes and high seismic-resistant pipes. For prevention of secondary disasters, it has developed a shutting-off system, which uses block formations and devices for automatic remote shutdown. The 5th SEP announced that further measures will be taken to enhance the resilience of city gas-related facilities against earthquakes.

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In 2016, the IEA conducted a *Gas Resiliency Assessment of Japan* (IEA, 2016b), which offered a range of recommendations for the country. This included, among others, a recommendation to monitor how the market liberalisation – and the associated increase of market participants – affects emergency preparedness and to consider creating a national emergency strategy organisation to effectively co-ordinate relevant parties in case of natural gas supply disruptions. Following up on this recommendation, the Japan Gas Association established guidelines for large-scale natural gas supply disruptions. After the Kumamoto earthquake in 2016, the Japan Gas Association established an “emergency headquarters” in the affected regional city gas company, and co-ordinated repair and restoration in the affected area, making use of staff from 22 different city gas companies. Also in response to the 2016 IEA assessment, the government intends to conduct regular natural gas disruption exercises on a national level.

Assessment

The consequences of the 2011 events shed light on the role of natural gas as a flexible energy source. Natural gas largely filled the electricity supply gap caused by the temporary shutdown of all nuclear power plants. The new LNG spot trading market played an important role in meeting the new demand, which soared by 25% from 2010 to 2012.

However, the blessing of sufficient natural gas supply was accompanied by tremendous costs. Price indexing to oil was, and still is, very common in LNG contracts held by Japanese electricity and gas companies. High oil prices of more than USD 100 per barrel pushed Japan’s LNG expenditure high for a few years after the 2011 events.

The 4th and 5th SEPs and the natural gas market policies derived from them are firmly based on lessons learnt during that period. Domestically, gas market liberalisation was accelerated in tandem with liberalisation of the electricity market. At the same time, Japan became committed to realise a well-functioning liquid global LNG market, driven by the belief that it would greatly contribute to its energy security.

Japan is the first major economy in Asia to liberalise its natural gas market. The liberalisation can serve as a model to other countries in the region that hesitate to follow suit for various reasons. The present liberalisation process is proceeding as scheduled and will be completed with legal unbundling of the three biggest city gas companies in 2022.

The gas market liberalisation has commonalities with the earlier liberalisation of the electricity market, but competition in domestic city gas markets may be more modest judging from the progress made since the introduction of full retail competition in 2017. For instance, three regions (Chugoku, Shikoku and Tohoku) have seen no new retail entrant to date, and city gas consumers in these regions are yet to enjoy the full benefits of a competitive market.

Non-discriminatory open access to gas infrastructure and better interconnectivity of the regional gas networks will be important factors to foster competition. As Japan imports 97% of its gas consumption in the form of LNG, and LNG terminals hold most of the gas storage capacity as well as regasification facilities, any restriction on third-party access to LNG terminals might prevent new competitors from entering retail markets. While Japan introduced TPA to LNG terminals in 2017, it is noteworthy that thus far only one applicant

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has acquired access. The insufficient interconnections among regional gas grids are another hurdle for competition, reducing the potential benefits of legal unbundling.

Looking beyond the domestic market, Japan has been actively promoting a more liquid, transparent and flexible global LNG trade. In 2017, the Japan Fair Trade Commission ruled that so-called destination clauses, which restrict buyers from reselling their cargoes, were not aligned with the Japanese Fair Trade Law. Japan is now engaging with the European Union and other major LNG trading countries to lay the groundwork for enhancing tradability by, for example, drafting model clauses on destination and cargo diversion of LNG contracts. Japan's assistance towards and co-operation with developing countries to invite them to the LNG market are notable, too.

Japan intends to establish an LNG hub, which should improve the liquidity and flexibility of the Asian LNG market. Various attempts have been made, such as starting an over-the-counter LNG trading market. Ongoing market liberalisation can be a powerful driving force for the development of a reliable price index backed by considerable demand once natural gas begins to be traded freely. At the same time, Japan will need to address the structural hurdles in its domestic market – i.e. promote open access to LNG terminals and enhance interconnection of the regional gas grids – to ensure that the benefits of well-functioning global LNG markets will trickle down to consumers.

Japan has been successful in maintaining stable supply of gas to end users. Gas infrastructure has been resilient to large-scale natural disasters and no serious LNG supply disruption has taken place thanks to the robust design of LNG receiving terminals and co-operation in the city gas industry. Still, emergency preparedness is likely to vary significantly among retailers. This issue deserves more attention from the government, with a particular focus on small-sized retailers in isolated grids.

Japan's *Long-term Energy Supply and Demand Outlook to 2030* projects natural gas demand in 2030 to decline back to levels comparable to those prior to the 2011 events. At the same time, natural gas is expected to play a key role in helping Japan meet its 2030 and 2050 GHG emissions reduction targets. The natural gas infrastructure can also facilitate the advancement of Japan's hydrogen strategy. As a consequence of these developments, the long-term outlook for natural gas demand in Japan is unclear. Clearly defining the role of natural gas for climate change mitigation and in the hydrogen society would provide clarity to gas companies as they decide on their long-term LNG procurement strategies and infrastructure investments.

Recommendations

The government of Japan should:

- ☐ Take necessary measures to promote and enhance the benefits of gas market liberalisation, such as removing barriers for effective third-party access and enhancing grid interconnection while considering the economic feasibility for enhancing grid interconnection.
- ☐ Evaluate the operations of the Electricity and Gas Market Surveillance Commission, and consider legislative changes to increase its independence as part of the next phase of market liberalisation.

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- Clearly define the role of natural gas in achieving GHG emissions reduction goals, the Basic Hydrogen Strategy and the policy goals laid out in the Strategic Energy Plan to provide clarity to gas companies that have to take decisions on long-term LNG procurement strategies and investments in infrastructure.

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9. Oil

Key data

(2019 estimated)

Domestic crude oil production: 8.8 thousand barrels per day (kb/d), -48% since 2008

Net imports of crude oil: 3 035 kb/d, -17% since 2009

Domestic oil products production: 3 277 kb/d, -14% since 2009

Net imports of oil products: 593 kb/d, -5% since 2009

Share of oil: 38% of TPES,* and 5% of power generation, 51% of TFC (2018)

Oil consumption by sector: 3743 kb/d (domestic transport 41.2%, international bunkers 6.6%, industry including non-energy consumption 29.7%, services and agriculture 8.4%, residential 7.2%, power generation 5.4%, other energy 1.5%)

* TPES does not include oil used for international bunkering.

Overview

Oil is the most significant energy source in Japan, accounting for 40% of the country's total supply in 2019 and 51% of total final consumption (TFC) in 2018. Domestic oil demand is on a downward trend due to increased fuel efficiency of vehicles as well as a switch from oil to natural gas and electricity in the industrial and household sectors (Figure 9.1). The share of oil in total primary energy supply (TPES)[1] is expected to decline from 38% in 2019 to 33% in 2030, with further reductions in demand foreseen to 2050, as Japan works towards its target of reducing carbon emissions by 80% (METI, 2018).

Japan, as an island country without significant oil production, is dependent on seaborne imports for 99.7% of its supply. Therefore, despite a decline in consumption and imports, the Japanese government still considers oil security to be one of the pillars of its economic security. Japan has one of the highest levels of oil emergency stocks among IEA countries, as well as a well-developed crisis management structure, based both on the IEA emergency response system and regional co-operation. The government remains strongly committed to ensuring security of oil supply, which should go hand in hand with the country's plans to become a decarbonised economy (METI, 2019a).

[1] TPES excludes international bunker fuels.

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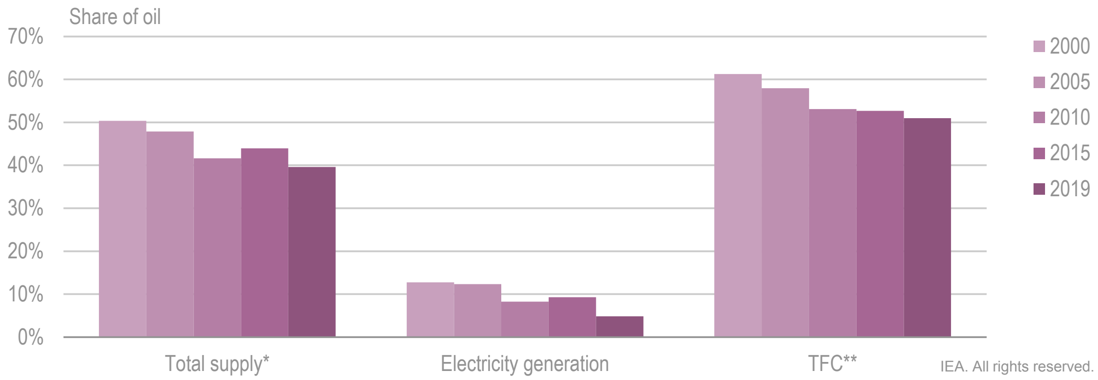
Figure 9.1 Share of oil in total supply, electricity generation and total final consumption in Japan, 2000-19



Oil is the largest fuel in Japan's energy mix, with 40% of total supply and over 51% of TFC, but the shares have decreased by around 10 percentage points since 2000.

* Share of oil in TPES plus international bunker fuels.

** Latest TFC data refer to 2018.

Note: TFC = total final consumption.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Supply and demand

Japan is the world's fourth-largest crude oil importer, after the United States, the People's Republic of China (hereafter "China") and India. Oil demand has steadily decreased over the past decade, from 4.33 million barrels per day (mb/d) in 2009 to 3.66 mb/d in 2019, representing a drop of 16%. The only exception to a steadily declining trend was after the the 2011 Great East Japan earthquake and subsequent Fukushima Daiichi nuclear accident (hereafter called "the 2011 events") that resulted in the closure of all nuclear capacity, when old oil-fired power generation facilities were quickly brought back online to compensate for the missing nuclear power generation (Figure 9.2).

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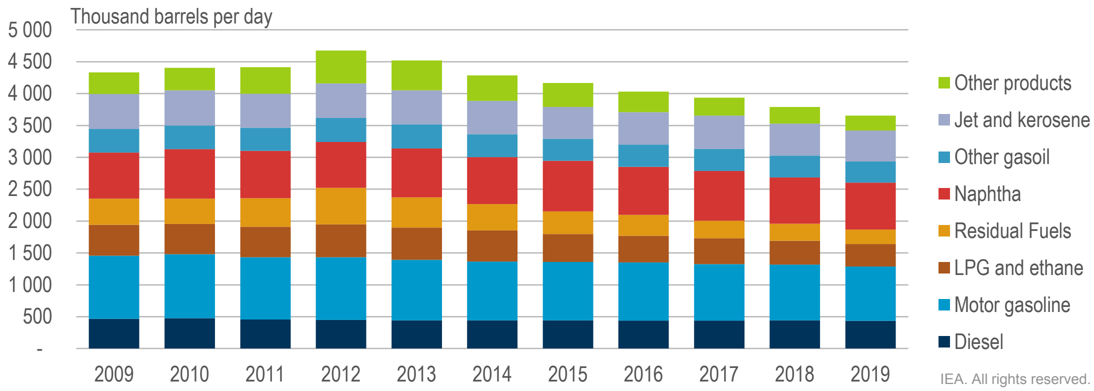
Figure 9.2 Oil consumption by refined oil product, Japan, 2009-19

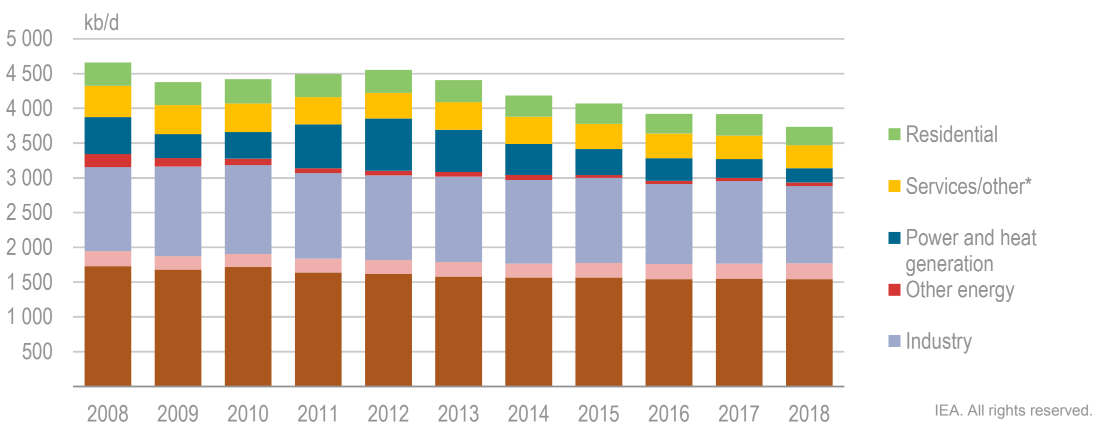


Japan's oil consumption declined by 16% between 2009 and 2019, mainly due to a decline in the use of residual fuel oil.

Notes: kb/d = thousand barrels per day. LPG = liquefied petroleum gas.
Source: IEA (2020b), *Monthly Oil Data Service* (database), www.iea.org/statistics.

The transport sector represented 41.2% of total consumption in 2018, while the industry sector accounted for 29.7%, of which over half was non-energy consumption in chemical and petrochemical industries. Remaining oil consumption was in services and agriculture (8.4%), international bunkering (6.6%), residential use (7.2%), power generation (5.4%), and other energy (1.5%) that includes other transformation, own use and losses (Figure 9.3).

Figure 9.3 Oil consumption in Japan by sector, 2008-18



Oil consumption decreased in all sectors, with the largest declines observed in the power sector and transport, at 62% and 11% respectively between 2008 and 2018.

* Includes commercial and public services, agriculture, forestry and fishing, and non-energy use.
Note: kb/d = thousand barrels per day.
Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

The domestic transport sector saw the largest volumetric decrease in oil consumption, falling by 11% since 2008 (to reach 1.54 mb/d in 2018). Industrial oil consumption dropped by 8% (to reach 1.1 mb/d in 2018). In percentage terms, the biggest drop occurred in the

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power and heat generation sector. In 2008, the sector represented 11.4% of Japan's total oil consumption and equalled 0.54 mb/d. In 2012, in the aftermath of the Fukushima accident, it had increased to 0.75 mb/d and represented 16.4% of country's oil consumption. Since then, oil demand for power and heat generation has been declining, and returned to pre-Fukushima level in 2015. In 2018, it averaged 0.2 mb/d, the lowest level on record.

Trade and production

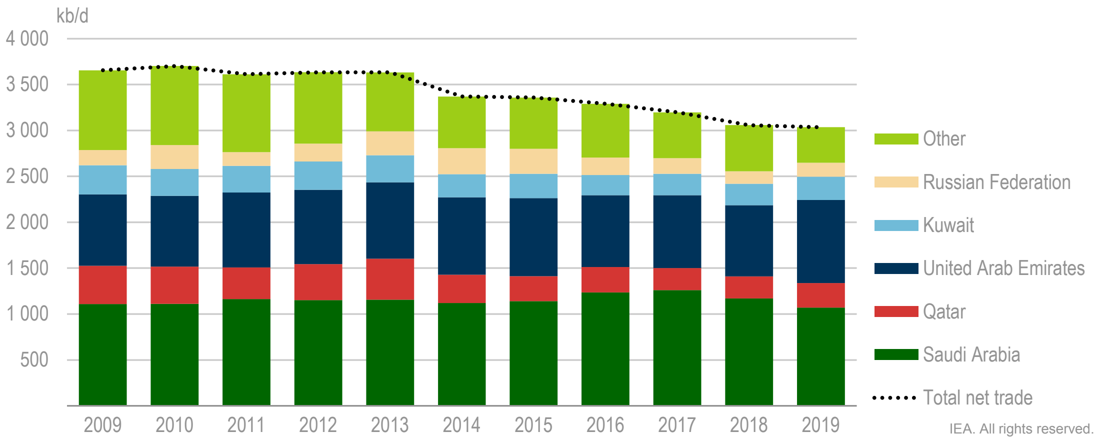
Crude oil

Japan imported close to 3.04 mb/d of crude oil in 2019, 82% of which originated from the Middle East (mainly Saudi Arabia, the United Arab Emirates, Qatar and Kuwait). The Russian Federation is also an important supplier with 5% of Japan's overall purchases (Figure 9.4). Japan established oil trade relations with the Middle East in the aftermath of the first oil shock in 1974 and Japanese refineries are set to process heavier and sourer crude grades, which may limit the potential appetite for the diversification of suppliers. Crude oil import sources have not changed since the 1970s.

Since 2008, Japan's crude oil imports have decreased by 25% and deliveries from major suppliers have reduced proportionally. The exception is Saudi Arabia, whose volumetric share has remained almost unchanged over the past decade. In consequence, in 2019 Saudi Arabia supplied 35% of Japan's crude oil, compared to 30% in 2009.

Japan's domestic crude oil production is on a downward trend and amounted to 10 kb/d in 2019. This represents less than 0.3% of the oil demand that year and a 48% decline compared to 2008. The volume of recoverable reserves for crude oil in the country was estimated to be 37.7 mb at the end of 2018.

Figure 9.4 Japan's crude oil net imports by country, 2009-19



Crude oil imports have dropped by 25% since 2008, following the consumption trend. Japan imported 82% of its crude oil from the Middle East in 2019.

Notes: kb/d = thousand barrels per day. Crude oil trade includes crude oil, natural gas liquids and feedstocks. 2019 oil trade data are extracted from the monthly oil database, whereas 2000-18 data are extracted from the annual oil database.

Sources: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics; IEA (2020b), *Monthly Oil Data Service* (database), www.iea.org/statistics.

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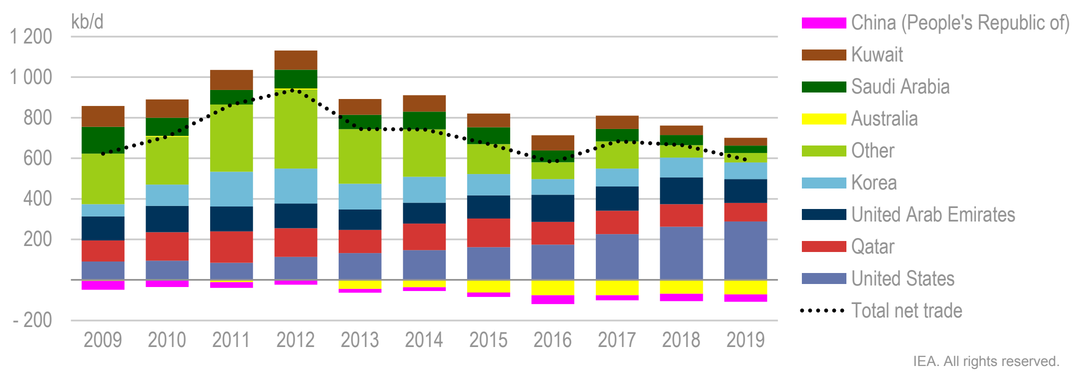
Refined products

Japan also relies on imports of oil products. In 2019, it imported 979 kb/d of refined products. The top three countries from which Japan imported oil products that year were the United States (34%), Korea (14%) and the United Arab Emirates (12%). Japan imported mainly LPG, as well as naphtha and lubricants (JLPGA, 2019).

Japan is an exporter of oil products as well. In 2019, it exported 386 kb/d of refined products, mainly to countries in the region (Australia, Korea, China and Singapore). Half of the exported volumes was diesel oil and the rest was gasoline, jet fuel and fuel oil. The level of Japan's exports has remained stable since 2008, with the exception of 2011-12 after the 2011 events, when exports dropped by a 26% due to higher domestic demand. But exports returned to previous levels in 2013 and have been stable since.

Net imports of refined oil products stood at 593 kb/d in 2019. Since 2008, Japan's net imports of refined products have fluctuated between 614.1 kb/d in 2008 and 939.1 kb/d in 2013 in the aftermath of the 2011 events, when a 70% increase of imports from Korea covered the demand gap. Product imports decreased to 580.2 kb/d in 2016, the lowest level since the 1970s, and slightly increased in the following years. Between 2008 and 2019, product imports increased from the United States, which covers 75% of Japan's LPG imports; at the same time, they decreased from the Middle East (Figure 9.5).

Figure 9.5 Japan's oil products trade, 2009-19



Japan is a net importer of oil products, trading with a large number of countries. The United States supplies the most; Australia and Korea are the largest export destinations of Japanese refined products.

Note: kb/d = thousand barrels per day.

Source: IEA (2020a), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Downstream

Japan had 22 operating refineries with a total crude distillation capacity of 3.52 mb/d in 2018. Its refining capacity has decreased by 20% since 2013, when it stood at 4.3 mb/d. Japan produced 3.28 mb/d of oil products in 2019, representing an average refinery utilisation rate of 92%. Japan is the fourth-largest country by refining capacity in the Asia-Pacific region. All refineries in Japan are located on the coasts and near the demand centres.

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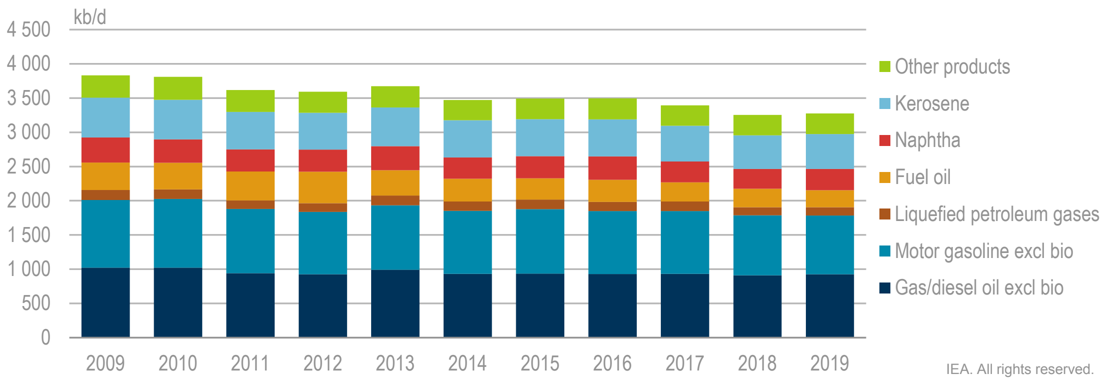
Japanese oil product production has fallen by 14% since 2009, with the biggest drop (38%) seen for fuel oil. Japan's refineries are mostly designed to process heavier and sour crude oil grades, which affects potential diversification of crude oil imports and refinery yields. In 2019, Japan's crude oil processing output was 28% for diesel oil, 26% for gasoline, 16% for kerosene, 9% for naphta, 8% for fuel oil and 4% for LPG (Figure 9.6).

Figure 9.6 Japan's refinery production, 2009-19



Japan's refinery output has fallen by 20% since 2008, following decreasing oil consumption in the country.

Note: kb/d = thousand barrels per day.

Source: IEA (2020b), *Monthly Oil Data Service* (database), www.iea.org/statistics.

Japan's refineries are capable of meeting domestic demand for most of the oil products, with the exemption of LPG and naphtha (Figure 9.7). Responding to the strengthened regulations on sulphur oxides (SO_x) emissions by the International Maritime Organization, Japan implemented relevant regulations in 2019 to prohibit the sale of high-sulphur fuel oil from January 2020 onwards.

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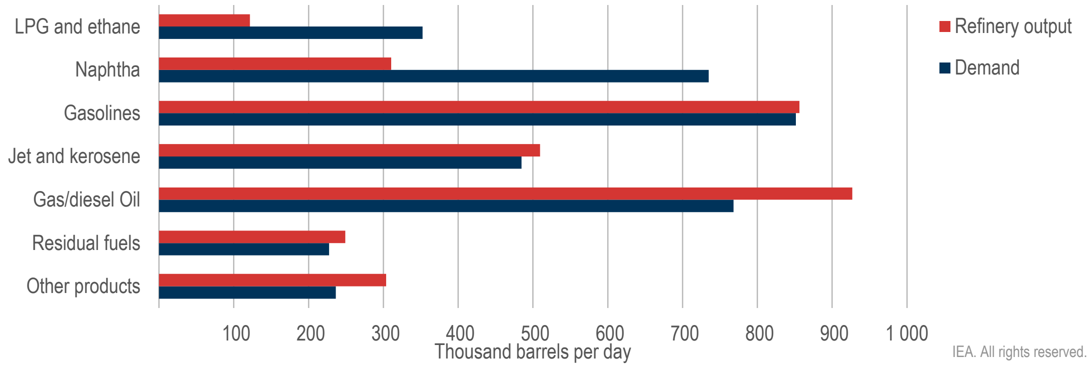
Figure 9.7 Japan's refinery outputs and domestic demand, 2019



Japan is self-sufficient in most oil products, with domestic refinery output well matched with demand, except for LPG and naphtha.

Notes: LPG = liquefied petroleum gas.
Source: IEA (2020b), *Monthly Oil Data Service* (database), www.iea.org/statistics.

Japan's oil supply and demand outlook

Oil consumption in Japan has been gradually falling since the mid-1990s and the government expects this trend to continue over the next decade. This is due to a continued emphasis on energy conservation, increased fuel efficiency of vehicles, a gradual shift to electric vehicles, reduction of oil consumption in electricity and heat generation, a declining population, and the ambition to reduce greenhouse gas (GHG) emissions.

In the near term, the government expects domestic demand for petroleum products to decline by 1.3% per year on average (from 3.74 mb/d in 2018 to 3.5 mb/d in 2023). In particular, demand for gasoline is expected to decline from 860 kb/d in 2018 to 779 kb/d in 2023. The Japanese government does not foresee further reductions in fuel oil consumption for electricity generation, as it has plateaued at 0.2 mb/d in 2018, the lowest level on record, and is anticipated to remain at this level for emergency and disaster response purposes.

Despite declining oil consumption, the 5th Strategic Energy Plan (SEP), Japan's overarching energy policy document adopted in July 2018, states that oil will remain a crucial part of Japan's energy mix, given its importance in the transport sector as well as for manufacturing industries (METI, 2018). Given the well-developed nationwide supply network and abundant stockpiles, oil can also serve as an alternative when other energy sources have been lost, as was the case in the aftermath of the 2011 events.

The 5th SEP also emphasises that among fossil fuels, oil has the highest geopolitical risk related to supply. Maintaining undisrupted oil deliveries therefore remains fundamental for the government. The policy direction set out in the 5th SEP for the oil sector entails diversification of oil supply sources, co-operation with oil-producing countries, enhancement of crisis management including stockpiling, efficient use of crude oil and diversification of fuels for transportation. In addition, since oil will be an energy source of "last resort" in the event of a disaster, the government finds it necessary to further strengthen the resilience of oil supply networks and to enhance the efficiency of the oil industry in order to maintain oil security.

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The government continues to support Japanese companies to explore and develop oil and gas resources overseas. By 2030, it aims to increase the ratio of combined domestic and foreign oil and gas production to cover at least 40% of the country's consumption. In 2018, this ratio stood at 29.4% – up from 22.5% in 2008 (METI, 2019a).

In addition, Japan aims to increase the efficiency of processing crude oil. In October 2017, the government issued the third ordinance to the Act on Sophisticated Methods of Energy Supply Structures with the aims to enhance efficiency and strengthen the international competitiveness of Japanese refineries (METI, 2019b). The ordinance required oil refiners to set improvement targets regarding the vacuum distillation residual oil throughput to reduce heavy distillate products and increase light and middle distillate products.

Oil industry structure

Japan has no single national oil champion company. The Japanese oil market is open and competitive, without any particular entry and exit barriers.

The relationship between energy sector companies and the Japanese state has historically been co-operative, and the government has been proactive in providing forecasting trends and adapting regulations to allow for efficient market functioning. The Ministry of Economy, Trade and Industry (METI) oversees the oil industry through the Agency for Natural Resources and Energy (ANRE) and its Natural Resources and Fuels Department.[2]

The continuous decline in demand for oil has consequences for the domestic market structure, pushing consolidations and adaption of operators to make them better prepared for market competition under declining demand. Following a series of mergers, acquisitions and market restructuration, the number of major refining companies has dropped over the last four decades, from 17 to 5 in 2019.

Recent examples of corporate consolidations include JX Energy Corporation acquiring TonenGeneral Sekiyu K.K. in 2017 and renaming it JXTG Nippon Oil & Energy Corporation (rebranded to Eneos as of June 2020); and Showa Shell Sekiyu K.K. and Idemitsu Kosan integrating their businesses and operations through the exchange of shares in April 2019 (Idemitsu Kosan, 2019). It is hoped that the deal will allow both Idemitsu and Showa Shell Sikiyu to accelerate expansion in the domestic market and to raise the competitiveness of the Japanese refining industry in the international arena.

The major players in the refining and retailing sector are as of 2020 Eneos Corporation, Idemitsu Kosan Co., Cosmo Oil Co. and Taiyo Co. The largest of these companies, Eneos Corporation, controls nine refineries with a combined processing capacity of 1.62 mb/d (46% of the country's total) and accounts for 50% of the fuel sales market. Idemitsu Kosan operates five refineries with 0.83 mb/d total capacity and is active in the petrochemical and minerals sectors. Cosmo Oil Co. operates three refineries with 0.36 mb/d total capacity and Taiyo Co runs a refinery with 0.14 mb/d of total capacity.

In addition, the various oil refining and distributing companies pursued collaboration or decided to move parts of their business operations to other activities. For example, in July 2019, then JXTG announced that the refinery in Osaka – which the company runs through

[2] Annex A provides detailed information about agencies and organisations with responsibilities in the energy sector.

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a joint-venture with PetroChina – would stop refining oil and convert the site into an asphalt-fuelled power plant as of October 2020.

Upstream

Private sector companies, with financial and technical support of the Japan Oil, Gas and Metals National Corporation (JOGMEC), conduct exploration and development of oil within and outside of Japan (JOGMEC, 2020a).

The Japanese government supports domestic resource exploration, including through government-led explorations, conducted with three-dimensional seismic scanning vessels. Between 2013 and 2018, METI conducted explorations of about 6 000 square kilometre (km^{2}) per year in Japan's seas. From 2019 onwards, it started conducting explorations flexibly, with the aim to cover approximately 50 000 km^2 over a period of ten years (METI, 2018).

JOGMEC is a key organisation in supporting upstream endeavours of Japanese companies both in Japan and overseas. Its main role in the case of oil is to provide financial and technical support for oil research and development. An amendment of the "Act on the Japan Oil, Gas and Metals National Corporation, Independent Administrative Agency" in November 2016 increased JOGMEC's role in supporting Japanese companies in their domestic and foreign operations and enlarged the area where JOGMEC can invest – including oil upstream activities and the downstream sector beyond country's borders (JOGMEC, 2020b).

Major players amongst the upstream operators in Japan are INPEX Corporation (INPEX) and the Japan Petroleum Exploration Company Limited (JAPEX). Trading companies such as Itochu, Marubeni, Mitsubishi, Mitsui and Sumitomo remain active in the oil upstream sector through their exploration and production branches, but new private investors do not engage in upstream activities. INPEX is Japan's largest oil and gas exploration and production company. It is engaged in approximately 70 projects spread across more than 20 countries worldwide, with operational offices in Brazil, the United States and the Bolivarian Republic of Venzuela. In 2019, INPEX produced 586 kb/d of crude oil (INPEX, 2020). JAPEX is also engaged in oil and gas exploration and production activities in Japan and overseas (including Iraq and the United Kingdom), and produced 60 kb/d in 2019 (JAPEX, 2020).

Retail

Relaxation of regulation and diversification of consumer needs have resulted in new business models, increased price competition and diversification of service station models. At the end of 2018, there were 30 070 service stations (half the number from the peak in 1994 and 3 500 stations less than in 2014). Despite the decline, the number of service stations remains high in comparison with other large industrialised countries (FuelsEurope, 2019).

Small and medium-sized companies constitute the majority of the wholesale and retail sector in Japan. According to a survey conducted by the National Petroleum Association in 2018, more than 70% of all service stations are businesses which operate in just a single location, servicing a local market and competing strongly with other operators (information provided during the review visit in February 2020).

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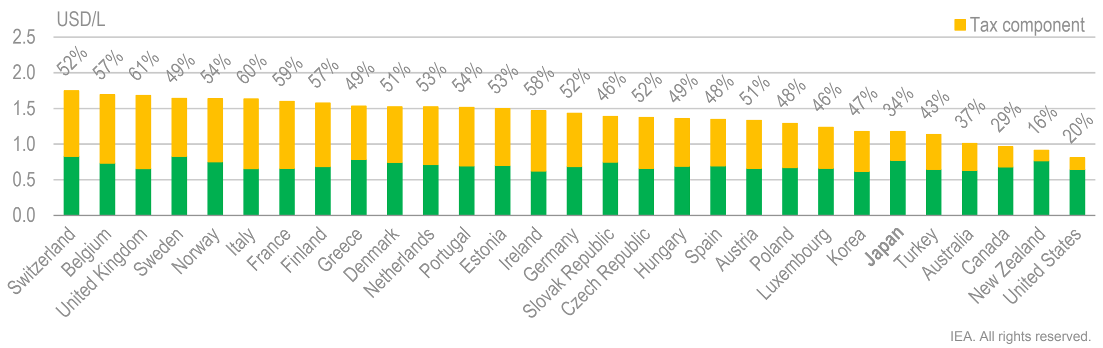
Prices and taxation

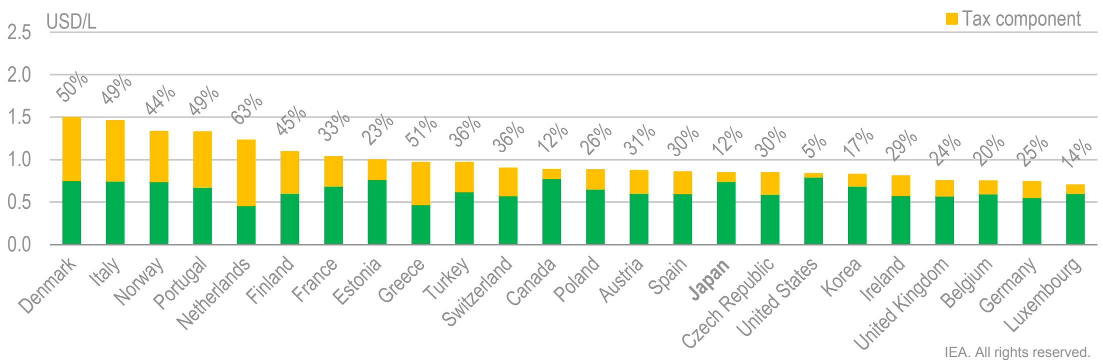
Fuel prices in Japan are low compared with other IEA countries, mostly due to lower taxes. Japan's diesel and light fuel oil prices were respectively the sixth-lowest and the ninth-lowest in the IEA at USD 1.18 per litre (L) and 0.85 USD/L in the fourth quarter of 2019, with a tax component of 34% and 12% respectively (Figure 9.8).

Figure 9.8 Price comparison for oil fuels in the IEA, 4Q 2019

Automotive diesel



Light fuel oil



Japan has low fuel prices compared with other IEA countries, with the second-lowest taxation rate for light fuel oil amongst IEA countries.

Note: USD = United States dollar. L = litre.
Source: IEA (2020c), *Energy Prices and Taxes First Quarter 2020* (database), www.iea.org/statistics.

In normal times, the Japanese government has no authority for fuel price setting; prices are determined by the market. For emergencies, however, the Act on Emergency Measures for Stabilization of National Life, enacted in 1973, has a provision which states that "In cases where the price of commodities rises rapidly […] or there is concern over such a rise, then it shall be possible under Cabinet Order to designate the relevant products related to daily life as being goods for which particular effort should be made to stabilize the price."

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Oil supply infrastructure

As Japan is an island country, all imports of crude oil and oil products arrive by tankers. The country is served by five main oil ports, which are located in Yokohama, Kawasaki, Kagoshima, Tomakomai and Chiba. The Chiba port serves supplies to four refineries. The Yokohama port supplies imported crude oil to two refineries in Kawasaki, while the Yokkaichi port also delivers crude oil to two refineries in the city. The oil ports in Shibushi and Okinawa mainly supply crude oil to closely located national stockholding bases.

Figure 9.9 Japan's oil infrastructure

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Coastal tankers, tank trucks and railroad tankers transport both crude oil and oil products to fuel depots and filling stations across the country. Japan only has one oil pipeline, which transports jet fuel from the Chiba refinery to Narita International Airport.

Storage

The Japanese government estimated total storage capacity in Japan at over 850 mb in September 2019. Of this, there are ten bases for government stocks with a total capacity of 252 mb and private companies have a capacity of over 600 mb. Industry maintains 233 mb of crude oil storage capacity, mainly at refineries, and 285 mb of refined product storage capacity in their storage facilities and distribution networks. Private companies also hold 86 mb capacity leased by the government for public stocks. The ten national stockholding bases are spread out around coastal areas in the country in different forms: 111 mb of stock are held in 193 above-ground tanks at 4 national stockholding bases; 30 mb are held in 9 underground caverns at 3 bases; 53 mb are held in 13 floating barges at 2 bases in the south of the country; 23 mb are held in 12 in-ground tanks. Currently, there is no plan to expand storage capacity for public stocks.

There are additionally five storage sites for strategic LPG stocks in the country – both in water-sealed rock caverns (Namikata and Kurashiki) and above-ground, low-temperature, tanks (Nanano, Fukushima and Kamisu). The combined capacity of these LPG storages is 1.5 million tonnes.

Oil emergency policies and organisation

Emergency response policy

The Petroleum Refining and Reserve Division of the Natural Resources and Fuel Department of METI acts as a secretariat and forms the core of the Japanese National Emergency Strategy Organisation during oil supply disruptions, in co-operation with other relevant ministries and industry.

The Oil Stockpiling Act allows the Minister of Economy, Trade and Industry to take decisions to release government stocks and/or lower the industry obligation. If such a decision is taken, the Petroleum Refining and Reserve Division co-ordinates government stock releases with JOGMEC, which is responsible for managing the government stocks. When lowering the industry obligation, the division co-operates closely with the National Petroleum Association. In the aftermath of the 2011 crisis, the government additionally obliged oil companies to jointly prepare emergency oil supply co-operation plans in order to ensure co-operation among companies in supplying oil products to end users in the event of a disaster.

The Oil Stockpiling Act requires METI to set five-year targets for oil stocks; the target for 2017-21 is 90 days of imports for government stocks and 70 days of domestic demand for industry stocks. According to relevant laws and regulations of the act, refineries, specified distributors and importers are obliged to hold 70 days of their average daily imports, sales or production in the previous 12 months. Since February 2018, METI has also reduced mandatory industry LPG stocks from 50 days to 40 days, while public LPG stockpile remained unchanged at 50 days of net imports (JLPGA, 2019).

The industry covers the costs of holding emergency stocks and passes them on to consumers. There is, however, a supporting mechanism of JOGMEC which provides loans

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to private companies with stockpiling obligations to finance the purchase of oil and LPG for stockpiling.

METI has the power to conduct on-site inspections when necessary, and can order companies that are non-compliant to comply. Penalties for non-compliance can reach millions of yen or even imprisonment.

In a crisis, METI would determine which stocks should be released according to the nature and expected duration of the crisis and the needs of the markets. To date, all emergency releases, including the IEA co-ordinated actions, were conducted with industry stocks. The government stocks are regarded as a “last resort”. They function as a back up to the private stocks to keep supplying oil to domestic refineries in the case of an emergency. According to the government, there could also be a negative perception by the public if these “last resort” stocks were used prematurely. This is in contrast to other IEA countries holding public stocks, where the general public would expect these stocks to be used first during an emergency, as significant public resources are spent on their acquisition and maintenance. Most IEA countries have policies to use public stocks as a first choice in an IEA collective action or to take ad hoc decisions on a case-by-case basis.

METI has the authority to instruct the oil industry to provide priority supply to critical customers in the case of a supply shortage. Following the Great East Japan earthquake in 2011, for example, METI instructed the industry to provide priority fuel supply to emergency vehicles. Following the Kumamoto earthquake in 2016, METI has increased emergency response measures by introducing a subsidy for certain stations to set up emergency back-up power to provide fuel supply to general customers. The list of fuel stations designated to act in an emergency is regularly updated in co-operation with the industry.

Stockholding arrangements with Middle East countries

Another initiative to ensure the availability of crude oil supplies during an emergency are arrangements with the country’s top two oil suppliers: Saudi Aramco of Saudi Arabia and the Abu Dhabi National Oil Company (ADNOC) of the United Arab Emirates. These agreements allow both companies to use Japanese crude storage tanks for their own commercial activities in the Asian market (while the government supports part of the rental costs for these storage facilities), in exchange for prioritising the supply of crude to Japanese companies in an emergency. The first agreements of this kind were concluded between Japan and the two countries in the 2000s and have been renewed every few years since then. The latest renewals took place in October 2019 with Saudi Aramco and in January 2020 with ADNOC – both extensions were signed for three years (ENA, 2020). The total maximum capacity for these arrangements is 16.4 mb.

Emergency oil stocks

METI is responsible for overseeing the Japanese stockholding system. In practice, under the Oil Stockpiling Act, JOGMEC has the responsibility to manage 90 days of public stocks. The public stocks mostly consist of crude oil, but the government has expanded its emergency inventory to also include oil products – gasoline, kerosene, fuel oil, diesel oil and LPG. METI has a total management contract signed with JOGMEC, which has concluded operation and management contracts with five companies for managing ten national oil stockpiles sites and similar contracts with five LPG operators to manage the national LPG sites (five-year contracts, the current ones are due until the end of 2022).

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Based on the operation and management contracts, JOGMEC receives reports from the operator of each national stockpiling base. Based on the total management contract, JOGMEC reports these data to METI once a month. METI reports public and industry stock data to the IEA. Industry holds its obligated stocks through private arrangements – in own or rented capacities.

Japan has consistently met its IEA stockholding obligation. The level of oil stocks in Japan as of April 2020 was as follows:

- Government stockpiles stood at 288.3 mb, of which 97% was crude oil (294.0), and 3% refined oil products (8.9 mb). According to the IEA methodology, it covered 118 days of net imports. LPG stocks stood at 1.4 million tonnes. Crude was held in 10 national bases and 13 leased locations; LPG was stored in 5 dedicated national depots.
- The private stockpiles amounted to 200.3 mb, of which 48% crude oil. It added 82 days of coverage per the IEA methodology. LPG stocks stood at 1.4 million tonnes and covered over 50 days of net imports.
- Joint storage programmes with oil-producing countries added another 11.8 mb in crude oil stocks of Japan.

Oil demand restraint

Japan considers demand restraint as a secondary emergency response measure that could complement an oil stock release. Due to sufficient levels of emergency oil stocks, Japan would only deploy demand restraint measures in the event of a severe oil supply crisis.

Japan's demand restraint measures range from light-handed measures (e.g. accurate information sharing and energy-saving campaigns) to heavy-handed measures (e.g. limitations in oil use in specific industrial sectors, instruction of oil products limitation for end users and allocation of oil). Allocation of oil measures can be taken under the Petroleum Supply and Demand Optimization Act. According to the act, the Prime Minister can announce necessary demand restraint measures based on a Cabinet council decision.

Assessment

Oil is the largest primary energy source in Japan, representing 38% of TPES in 2019. Demand has decreased by a third over the last two decades, despite a rebound in 2011-12 following an increase in demand for power generation after the 2011 events. The transport sector is the largest consumer with 41.2% of total oil demand, followed by industry with 29%, of which over half was non-energy consumption in chemical and petrochemical industries.

The share of oil in TPES is expected to decline to 33% in 2030, with further reductions in demand expected to 2050 as Japan works towards its ambition to become carbon-neutral. The ongoing decline in demand for oil has significant consequences for the domestic market participants.

Japan has limited domestic oil production, covering only 0.3% of domestic needs. This means it will never have any meaningful level of self-sufficiency in oil supply. Japan has a large nameplate refining capacity that covered product demand in 2018 for most fuels;

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however, it lacks sufficient production capacity for LPG and naphtha. Japan imported 3 035 kb/d of crude oil in 2019, mostly from the Middle East. In addition, Japan's import of

refined products amounted 979 kb/d and mostly consisted of LPG (over 50% of country's consumption), naphtha, lubricants and petroleum coke. Japan exported 386 kb/d of refined oil products in 2018, mostly diesel oil.

The 5th Strategic Energy Plan of 2018 considers that "among fossil fuels, oil has the highest geopolitical risk". Therefore, Japan's energy policy aims for the oil sector to focus on:

- securing interests in upstream projects, aiming to raise the oil (and natural gas) independent development ratio from 27% in 2016 to 40% in 2030
- increasing the number and geographical diversity of countries that supply oil to Japan
- improving security of supply through resource diplomacy, including deepening relationships with major supply countries and sharing emergency oil stocks with other countries in the region
- increasing the competitiveness of the domestic refining industry
- ensuring oil products are available as the energy of last resort in the event of an emergency or disaster.

Japan has made good progress since the last IEA in-depth review in a number of areas. The independent development ratio had increased to 29.4% in 2018. Government-guided rationalisation of the refining industry has continued, with a series of mergers reducing the number of oil refining companies over the past four decades from 17 to 5 in 2019. Emergency preparedness and resilience continues to be a focus, with oil companies developing joint plans for "co-operation in oil supply at times of disaster", which were a new requirement following fuel shortages during the 2011 events. These efforts appear to have been successful in reinforcing existing supply chains.

Japan's reliance on Middle East sources for crude oil increased from 80% in 2015 to 85% in 2018. Further, joint stockholding arrangements with national oil companies from the Middle East support preferential access to crude oil in the case of an emergency, but also limit supply from other sources during normal times.

Diversification of crude oil suppliers is difficult given the current operation of the domestic market. Refinery configurations are geared to heavy sour crudes, which limits potential oil sources. In addition, the smaller number of companies now operating may have contributed to a consolidation around Middle East oil suppliers as companies have sought stable arrangements with existing business partners. Nonetheless, the ongoing reliance on the Middle East is surprising given recent changes in the global market that have seen a larger proportion of supply coming from other countries, including Brazil and the United States, and the stated government policy seeking to diversify supply.

Maintaining a competitive domestic oil market in the face of declining demand is becoming a key issue for Japan to manage. This challenge is likely to increase over time, particularly with the reduction in demand that will accompany Japan's target of reducing carbon emissions from domestic-made cars by 80% by 2050.

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Although declining domestic demand remains a challenge, if the industry can become more competitive, there are product markets in the region with increasing demand that Japan could target. This will be challenging, however, given increases in refining capacity in China, India and elsewhere in Asia.

Nonetheless, there may be steps that Japan could take to improve both competitiveness and supply security. Retooling refineries to accept a wider range of crude grades could lower the dependence on oil from the Middle East and the geopolitical risks to supply. This means there may be value in investments that reinvigorate Japan's refining industry.

Further, exporting a greater proportion of Japan's refined products may support better market access for imported oil products and potentially contribute to supply diversity. In addition, recent experience in Australia has shown that a reduction in refining capacity can improve supply diversity. After Australia lost over 40% of its refining capacity between 2011 and 2014, there was a large increase in the number of countries that oil products were sourced from, benefiting both competition and supply security.

Japan has one of the largest global stockholdings relative to demand, which acts as insurance against geopolitical risks and large global shocks. These arrangements could be enhanced through further co-operation in the region, including by reinvigorating progress on the ASEAN Petroleum Security Agreement (ASEAN, 2012).

Recommendations

The government of Japan should:

- Encourage Japanese oil companies to diversify their crude oil and product supply sources.
- Continue to guide rationalisation of the refining industry while maintaining competition on the domestic oil products market.
- Continue working towards joint stock and emergency oil-sharing arrangements with countries in the Asia-Pacific region.

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10. Coal

Key data

(2019 provisional)

Production: 0.7 Mt (0.41 Mtoe), -38% since 2009

Imports: 185.0 Mt (114.8 Mtoe), +13% since 2009

Consumption: 185.7 Mt (114.1 Mtoe), +13% since 2009 (breakdown by sector in Mtoe in 2018: power and heat generation 61.7%, industry [includes coke ovens and blast furnaces in steel industry] 38.1%, services 0.2%)

Share of coal: 27.2% of TPES and 31.9% of electricity generation

Overview

Coal is the second-largest primary energy source in Japan after oil, representing 27% of total primary energy supply (TPES) and 32% of electricity generation in 2019. The shares have been increasing steadily since the turn of the century (Figure 10.1), driven primarily by growing coal demand for power generation. Power generation accounts for more than 60% of Japan's coal consumption, and iron and steel production for most of the remainder.

Coal consumption surged after the 2011 Great East Japan earthquake and subsequent Fukushima Daiichi nuclear accident (hereafter called "the 2011 events") that resulted in the closure of all nucler plants, but slowly started to decline again in 2014. As domestic coal production is marginal, coal supply depends almost entirely on imports.

Japan aims to maintain the role of coal in the energy mix to 2030. A total of 10 gigawatts (GW) of new coal-fired power generation capacity will be built in the coming years, which equals 22% of existing capacity. This will have implications for greenhouse gas emissions (GHG) and air pollution, despite the fact that Japanese coal-fired plants are among the most efficient and clean globally. Coal-based power generation accounts for 29% of Japan's annual CO_2 emissions from energy use and the CO_2-intensity of its power generation is high compared to other IEA countries. Other coal use (e.g. in industry) accounts for an additional 12% of CO_2 emissions.

To mitigate the environmental impacts from coal use, Japan is investing heavily in the development of high-efficiency new generation coal technology as well as carbon capture, utilisation and storage (CCUS) and carbon recycling. Rapid deployment of CCUS and carbon recycling will be critical to ensure the sustainability of coal use in the future. New plans to phase out most of Japan's inefficient coal plants by 2030 will also help reduce the environmental load from coal use.

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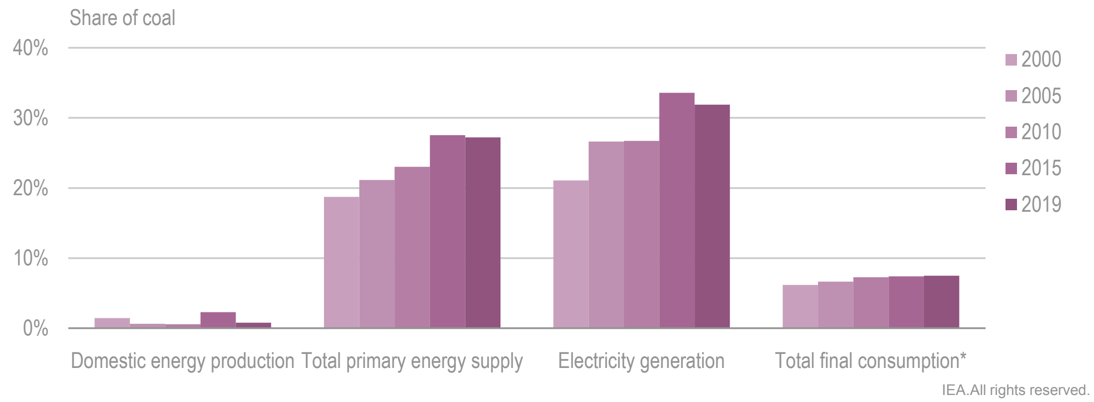
Figure 10.1 Share of coal in total primary energy supply and electricity generation, Japan, 2000-19



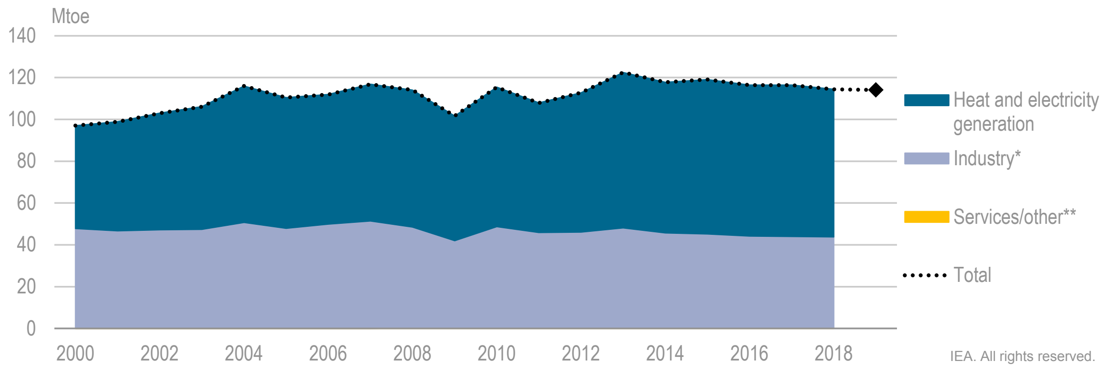
The share of coal in TPES and electricity generation has increased over recent decades, to reach 27% of TPES and 32% of electricity generation in 2019.

* The most recent data for TFC refer to 2018.Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Supply and demand

In 2019, total coal consumption in Japan was 114 million tonnes of oil equivalent (Mtoe), comparable to the level before the 2007/08 global financial and economic crisis (Figure 10.2). Coal use surged by 14% in 2011-13 due to increased coal use for power generation after the 2011 events. It has been declining slightly since, owing to the reintroduction of some nuclear power plants, expansion of renewable energy resources and lower demand from the steel industry.

Figure 10.2 Coal consumption in Japan by sector, 2000-18



Japan's coal consumption was 114 Mtoe in 2019. The power sector accounted for over 60% in 2018 and the rest was used mainly in steel industries.

* *Industry* includes direct energy use and transformation in coke ovens and blast furnaces.
** Not visible on this scale.
Note: Mtoe = million tonnes of oil equivalent.
Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

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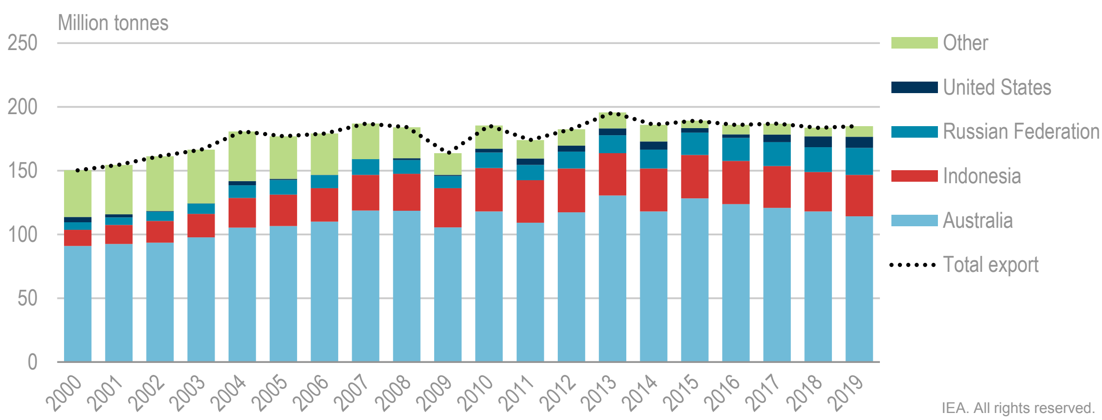
In 2018, 62% of coal was used in power generation. Coal is the second-largest source in power generation (after natural gas), accounting for 32% of total electricity generation. The remaining 38% of coal demand is used in industry, directly and indirectly (in coke ovens and blast furnaces). This is mostly for iron and steel production, with smaller volumes being used in the cement, chemicals, and pulp and paper industries. Other sectors accounted for 0.2%. Of all coal consumed, 75% was steam coal (3% anthracite with the remainder other bituminous coal), used for the electricity generation. The remaining 25% was coking coal, used in coke ovens and blast furnaces.

Domestic coal production reached 0.7 Mt in 2019, or 0.4% of domestic coal use. This means that Japan relies almost entirely on coal imports. Japan imported 185 Mt of hard coal in 2019, making it the world's third-largest importer. Imports increased by 23% compared to 2000, reflecting the combination of increasing demand and almost negligible domestic production. Australia is the main coal supplier, delivering 62% (114 Mt) of Japan's total coal imports in 2019, followed by Indonesia (18%), the Russian Federation (11%) and the United States (5%) (Figure 10.3). The rest came from a number of smaller suppliers like Canada, the People's Republic of China (hereafter "China") and Colombia.

Figure 10.3 Japan's coal imports by country, 2000-19



Japan imports nearly all of the coal it consumes. Australia is its main supplier, with 62% of total coal imports in 2019, followed by Indonesia, Russia and the United States.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Domestic coal production and industry structure

Japan has seven coal mines in operation, which produce approximately 1 Mt of coal annually. Domestic coal production reached over 50 Mt per year in the mid-20th century, but the industry has been constantly declining since due to degrading quality, increasing mining costs and declining import costs. All seven mines are located in Hokkaido, and are all privately owned. Domestically produced coal is mainly used for power generation.

The latest survey on coal reserves conducted in Japan, which dates to 2009, estimated Japan's coal reserves at about 20 billion tonnes. This includes 4.9 billion tonnes in proven reserves, 3.4 billion tonnes in probable reserves and 11.8 billion tonnes in possible reserves. The majority of coal deposits are in the Hokkaido and Kyushu islands.

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Japan abolished support for domestic coal exploration and production in 2001. However, a number of measures support the exploration and development of coal resources in foreign countries, as well the construction of coal thermal power stations abroad, with involvement of Japanese companies (see below).

The future of coal

The 5th Strategic Energy Plan (SEP) of 2018 recognises coal as an important fuel to achieve Japan's energy security and economic efficiency objectives, given that coal is globally abundant and relatively cheap (METI, 2018). In line with the *Long-term Energy Supply and Demand Outlook to 2030* (METI, 2015) issued in 2015, the 5th SEP aims to maintain the role of coal in the energy mix at around 25% of TPES in 2030 (it stood at 27% in 2019). Before the 2011 events, Japan had planned to reduce the share of coal in TPES to 17% by 2030.

The 5th SEP aims to reduce the environmental impact of coal use through the phase out of inefficient coal use, the development and deployment of high-efficiency and new generation coal technology, and, in the medium and long term, CCUS. Other priorities identified in the SEP are to ensure a stable and low-cost coal supply, deploy Japanese low-carbon technologies abroad, and promote efficient use of coal in the iron and steel industry in the context of the sector's voluntary action plans (METI, 2018).

Outlook for coal-fired power generation

The *Long-term Energy Supply and Demand Outlook to 2030* foresees that the share of coal in electricity generation would reach 26% in 2030, down from 33% in 2017. As electricity demand is expected to remain stable, the absolute amount of coal-fired power generation would decline by about 20% (from 350 kilowatt hours [kWh] to 277 kWh), or by 1.8% per year on average (METI, 2020).

Despite the projected decline in coal-fired power generation, the installed capacity for coal-fired power generation has been growing. As of April 2020, Japan had 150 coal-fired power plants, with a total installed capacity of 47.9 GW. Of this, 3 GW was built in the past four years (2016-19), while 0.4 GW was retired. Another 14 stations with a cumulative capacity of 8.4 GW are currently under construction (Table 10.1), and another 2.6 GW are planned. According to electric utilities' supply plans, installed coal-generation capacity will increase by about 15% over 2019-29, to reach almost 53 GW in 2028 (OCCTO, 2020). This positions Japan as the only G7 country to anticipate growing coal power generation capacity.

However, in July 2020, the government announced it will phase out inefficient plants by 2030 (Reuters, 2020a). This announcement will likely effect older power plants running on subcritical or supercritical technology. Details on which plants will be effected by this, and how the phase out will be implemented, have yet to be announced, but options under consideration include changes to the electricity transmission charges as well as the energy taxation (IEA YouTube channel, 2020). Excise taxes levied on coal use are low, leading to a weak effective carbon price for this fuel. Japan introduced an explicit carbon tax in 2012 as an add-on to its energy excise taxes, but the tax level is low by international comparison (see Chapter 3).

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Table 10.1 Coal-fired power plants under construction in Japan, March 2020

Company	Technology	Capacity	Commercial operation date
Takehara	USC	600 MW	2020
Kashima	USC	645 MW	2020
Nakoso	IGCC	540 MW	2020
Kushiro*	n.a.	112 MW	2020
Kaita	n.a.	112 MW	2021
Hitachinaka	USC	650 MW	2021
Hirono	IGCC	540 MW	2021
Taketoyo	USC	1 070 MW	2022
Kobe #1	USC	650 MW	2022
Misumi #2	USC	1 000 MW	2022
Kobe #2	USC	650 MW	2023
Saijo New N1	USC	500 MW	2023
Yokosuka #1	USC	650 MW	2023
Yokosuka #1	USC	650 MW	2024
Total	**–**	**8 369 MW**	**–**

* Co-fired with biomass.

Notes: MW = megawatt. USC = ultra-supercritical. IGCC = integrated coal gasification combined cycle. n.a. = not available.

Sources: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics; Kiko Network (2020), *Japan Coal Plant Tracker*, https://sekitan.jp/plant-map/en.

Of the currently operating 150 coal-fired power generation plants, 94 are equipped with subcritical technology, 24 with supercritical technology, 28 with ultra-supercritical (USC) technology and 2 with most advanced integrated coal gasification combined cycle (IGCC) technology. The less efficient subcritical and supercritical plants account for about 60% of installed capacity (Figure 10.4). About half of installed capacity has been built within the past 20 years; 40% is 20-40 years old; and 10% has been operating for more than 40 years. It is not yet clear which plants will be affected by the phase out, and whether they will be closed or merely mothballed, to maintain generation capacity for emergency situations (Nikkei, 2020). If Japan were to decide to close all plants running on subcritical or supercritical technology, the installed capacity for coal-fired power generation would decrease by about one-third by 2030, assuming that new coal capacity will go ahead as planned.

The phase out of inefficient plants will improve the environmental performance of Japan's fleet of coal-fired power plants, which is already one of the most efficient in the world. In 2016, the fleet had an average efficiency of 41.6% (based on the lower heat value), which was at that point in time the highest in the world (Wiatros-Motyka, 2016). The CO_2-intensity of coal-fired power generation measured 898 grammes of CO_2 per kWh (g CO_2/kWh) in 2018, compared to the IEA average of 942 g CO_2/kWh.[1] Most plants are equipped with high-performance air pollution control facilities, resulting in low emissions of nitrogen oxides (NO_x), sulphur oxides (SO_x), particulate matter (PM) and mercury, compared to coal-fired power plants in many other countries.

[1] CO_2 emissions per kilowatt hour of electricity, including co-generation. Co-generation refers to the combined production of heat and power.

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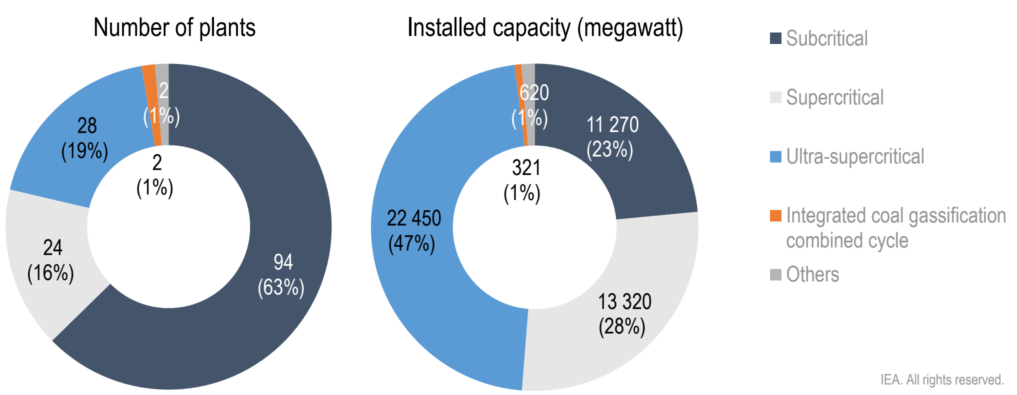
There is currently no specific schedule to phase out efficient (e.g. USC or more advanced) coal-fired power plants.

Figure 10.4 Technologies used in Japan's coal-fired power plants



Most coal-fired power plants are based on subcritical coal technology. However, in terms of installed capacity, ultra-supercritical coal technology has the largest share.

As of April 2020. Excludes co-generation plants (4.5 MW).
Source: IEA (2020) *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Promoting high-efficiency and new generation coal technology

In 2016, Japan amended the Energy Efficiency Act to require new coal-fired power plants to have a generation efficiency of at least 42%, or USC-level efficiency. Since 2010, most new plants were already USC, although some smaller plants used less efficient subcritical and supercritical technology. Japan furthermore passed legislation to require electric power companies to achieve an average power generation efficiency of at least 44.3% for all thermal power generation plants, and retailers to source 44% of their supply from non-fossil fuel energy sources by 2030.

In addition, the government plans to shorten the time needed for environmental impact assessments from an average of three years to two years or less, in order to facilitate the replacement of older, inefficient coal plants. Smaller coal plants (with outputs at or below 112.5 MW) are exempt from environmental assessments.

However, the government amended the "Ordinance of the Act on the Rational Use of Energy" in 2017 to require that smaller coal plants newly planned after 2017 must also satisfy the generation efficiency standard of 42%. The amended ordinance is not applicable to those small coal plants that were planned and approved before 2017, nor to those small plants that co-fire with biomass and meet the 42% generation efficiency standard.

The ordinance was further reinforced in 2019. Since then, the efficiency of small coal-fired plants is assessed based on their design efficiency and without considering the intention to co-fire biomass. Moreover, the amended ordinance is applicable to all new small coal-fired plants, except those that were already under construction at the time the 2019 amended ordinance became effective.

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As a result, it is now practically impossible to build a small coal plant in Japan, as current available technologies are unlikely to meet the efficiency standard of 42%.

Japan continues to invest in research, development and demonstration (RD&D) in new generation coal technologies to further enhance the economic and environmental performance of coal technologies. In the early 2020s, the government aims to achieve the practical use of advanced ultra-supercritical and IGCC plants, which are capable of achieving efficiencies above 46%. Practical use of integrated coal gasification fuel cell combined cycle (IGFC) technologies, which can achieve efficiencies above 55%, is hoped to be achieved in the 2030s. Two IGCC plants are already in operation (the oxygen-blown 166 MW IGCC Osaki plant for demonstration and the 250 MW IGCC Nakoso plant) and another two are currently under construction (the 540 MW Hirono and 540 MW Nakoso plants). At the Osaki plant, the addition of a fuel cell is planned to create the first large-scale pilot for an IGFC plant (see Chapter 6).

The new, high-efficiency coal power plants will improve the CO_2 footprint of Japan's coal-fired power generation even further. The USC plants under construction will emit around 750 g CO_2/kWh, which is some 15% below the average amount of CO_2 emitted by Japan's coal-fired power plant fleet in 2018. The IGCC plants under construction are designed to emit around 650 g CO_2/kWh, and the IGFC merely 590 g CO_2/kWh.[2] However, while these technologies are significantly less carbon-intense than conventional coal-fired power plants, they still emit more than natural gas-fired plants, which typically emit 300-500 g CO_2/kWh.

Given that the design lifetime of a coal plant is typically 40-50 years, adding new coal capacity therefore risks locking in carbon-intensive infrastructure, even if the most advanced technology is used. This makes it more challenging and costly to meet Japan's climate mitigation goals, while also creating stranded assets (see Chapter 3). The falling prices of renewable electricity, the restart of nuclear power and weakening electricity demand may constrain coal capacity to work at full load, reducing the profitability of coal-fired power plants. Since the 2011 events, a number of planned coal-fired power plants (with a cumulative capacity of 7 GW) have already been cancelled due to changing market conditions and declining profitability (REI, 2019).

Promoting efficient coal use in the steel industry

Japan is also a global leader in the development of efficient coal technology in steel production. It is the world's third-largest steel producer, after China and India, accounting for nearly 6% of global crude steel production in 2019 (WSA, 2020). Iron and steel production accounts for the majority of coal used in industry (which accounts for about 40% of national coal use, directly or indirectly). Unlike electricity generation, coal cannot be fully substituted in iron and steel production without increasing costs and losing efficiency, making the sector more difficult to decarbonise.

The Japanese iron and steel sector has established voluntary targets to enhance energy efficiency and reduce CO_2 emissions to 2020 and 2030, as part of the Commitment to a Low Carbon Society initiative organised by the Japan Business Federation Keidanren (see Chapter 3). Given the already high energy efficiency in Japanese steel mills, most mitigation potential is identified in technology dissemination to other steel-producing

[2] Information provided by the government of Japan.

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countries as well as development of next-generation steelmaking processes. The main project in this respect is COURSE 50, which aims to develop less CO_2-intensive technologies by evaluating technologies that incorporate hydrogen and biomass, direct electrolysis of iron ore, and CCUS. These technologies are expected to be introduced by 2030 and to increase in market share thereafter (see Chapter 6).

Carbon capture, utilisation and storage

Unabated coal-fired power generation is increasingly incompatible with the CO_2 emissions reduction goals to limit the global temperate rise to 2°C below pre-industrial levels. This makes the environmental sustainability of future coal use conditional on the feasibility of CCUS for new and existing plants (IEA, 2018). Recognising this, CCUS is a major pillar of Japan's strategy to reach its longer term climate targets. The 5th SEP of 2018 set the goal to make practical use of CCUS around 2020. Japan's Long-term Strategy Under the Paris Agreement (2019) specified that the introduction of CCUS and carbon recycling for coal-fired power generation by 2030 will be considered (GoJ, 2019).

Japan is a global leader in the development of CCUS technologies and runs a number of smaller scale demonstrations for carbon capture and storage. It also has ambitious goals to use captured CO_2 as a resource to produce valuable products (see Chapter 6). The practical application of CCUS technologies is, however, still limited by relatively high costs and a lack of incentives and business models. Some carbon capture technologies based on chemical absorption have entered the commercial stage, but the process remains more energy-intensive and costly than hoped. For example, carbon capture based on chemical absorption costs approximately JPY 4 000 (USD 37) per tonne of CO_2 (METI, 2019). In 2008, these costs were hoped to decline to JPY 1 000/t CO_2 in the 2020s (GoJ, 2008). The 2019 Roadmap for Carbon Recycling Technologies to 2050 sets new cost reduction targets for carbon capture and recycling technologies, with a vision to reduce carbon capture costs to JPY 1 000 to JPY 2 000/t CO_2 by 2050 (METI, 2019).

According to the road map, application of carbon recycling technology will begin with RD&D projects to use CO_2 as raw materials in 2020 (e.g. by using captured CO_2 to produce concrete, artificial photosynthesis and microalgae bio-jet fuel) and eventually expand the application of carbon recycling technologies into other application areas as cost effectiveness improves. The experience gained through these projects will provide valuable lessons for the international RD&D community. Japan actively promotes international collaboration on carbon recycling and hosted the world's first International Conference on Carbon Recycling in September 2019 (see Chapter 6).

In addition to reducing costs, it will be important to establish economic incentives as well as a stable and transparent regulatory environment to attract commercial investment in CCUS technologies (IEA, 2019). Some components of this regulatory framework are yet to be developed, for example on public participation and long-term liabilities (e.g. attribution of responsibilities following the closure of a storage site, or for long-term storage of CO_2) (GCCSI, 2016).

Until the economic and regulatory preconditions are in place, new coal-fired power plants could be required to be "CCUS-ready" (IEA GHG, 2007).[3] This would facilitate CO_2

[3] Making facilities CCS-ready means that they could be retrofitted with CCUS technology when the necessary regulatory and economic drivers are in place. The concept implies that developers eliminate factors that would prevent

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mitigation in the future and reduce the risk of stranded assets and carbon lock-in. Such a requirement had already been proposed in the 3rd SEP of 2010. The 5th SEP of 2018 announced that Japan would study options to make facilities CCS-ready as early as possible.

Overseas investment in coal mining and coal-fired power plants

Japan imports almost all of the coal it consumes, and 80% of imports are from Australia and Indonesia. Australia remains by far the largest coal supplier, as Japan's high-efficiency coal power plant fleet is better adapted to Australia's high-quality and quality-consistent coal. To help ensure stable coal supply, the government aims to diversify its imports, however. It also provides public finance for the exploration and development of coal resources overseas. The 5th SEP aims to maintain the coal independent development ratio (the ratio of coal imports produced by Japanese corporations) at about 60% until 2030. Japan also intends to develop technology to expand the use of low-quality coal, which will allow for a diversification of supplier countries (METI, 2018).

Japan's public finance institutions (including the Japan International Cooperation Agency, Japan Bank for International Cooperation, and Nippon Export and Investment Insurance) are among the world's largest providers of international public finance for the development of coal-fired power generation capacity. In 2017, Japan provided an estimated USD 5.2 billion of public finance for coal overseas, which mostly benefited the development of coal power plants in Bangladesh, Indonesia and Viet Nam. This includes support for supercritical boilers, coal mining and grid development in connection with coal-fired power (Doukas and Roberts, 2019; REI, 2019).

The 5th SEP stipulates that Japan will continue to support the export of its coal technology, in accordance with partner countries' energy and climate mitigation policies, and in line with OECD rules.[4] It states that coal-related investments and exports would be limited to countries "forced to choose coal as an energy source from the perspectives of energy security and economic viability" and that equipment should in principle be at or above USC efficiency level (METI, 2018). In July 2020, the government announced a new policy related to the export of coal technology, which limits financial support to plants using USC technology and to countries that have a decarbonisation strategy in place (Financial Times, 2020). The new policy applies to new projects, but not to those already in the planning stage.

Japan's commercial banks also rank among the largest financiers of new coal plants globally. The three biggest banks – Mizuho Financial Group, Mitsubishi UFJ Financial Group (MUFG) and Sumitomo Mitsui Financial Group (SMFG) – together accounted for 32% of direct lending to coal power plant developers between January 2017 and September 2019 (Takahashi, 2019). However, some banks are beginning to divest from coal-related assets. In April 2020, the SMFG and MUFG announced they will stop financing new coal power projects; the MUFG furthermore announced it will cut its

installation and operation of CO_2 capture, e.g. by ensuring sufficient space for the additional plant that would be necessary, or identification of reasonable routes to store or use CO_2. See IEA GHG (2007) for more information.

[4] In 2015, Japan supported the OECD commitment to limit export credit agency assistance for coal-fired power. The exceptions to this restriction include ultra-supercritical technologies, supercritical plants in countries facing energy poverty challenges and small subcritical plants in poorer, developing nations.

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outstanding balance in loans to coal power projects (USD 2.8 billion in March 2020) in half by 2030, and reduce it to zero by 2050 (Reuters, 2020b). This follows an announcement by the MUFG to stop investment in new coal-fired power generation in May 2019 (Reuters, 2019).

Assessment

Coal is an important energy source in Japan, accounting for 27% of TPES and 32% of electricity generation in 2019. Coal use is a large source of CO_2 emissions, and in 2018 accounted for 40% (coal in power generation for 28.8%; coal products for 12.4%) of Japan's total energy-related CO_2 emissions. Total coal demand has increased by 20% over the last two decades. It jumped up by 14% in 2011-13, due to the 2011 events, but has declined slightly since. Coal supply relies almost entirely on coal imports, mainly from Australia. Domestic coal production covered only around 0.4% of total demand in 2019. There are no support measures for domestic exploration and coal production in place.

The 5th SEP recognises coal as an important baseload power source in light of its low relative costs and risks. In 2030, the envisaged electricity generation from coal would be around 26%, similar to the level prior to the 2011 Great East Japan Earthquake. Japan has 47 GW of coal capacity currently in operation; another 8.4 GW under construction and about 2.6 GW in the planning phase. The 5th SEP recognises, however, that the relative importance of coal will likely decline as renewables and nuclear expand.

Japan's coal fleet, which is relatively young, is one of the most efficient in the world. Air pollution from coal-fired generation is low compared to other countries, which contributes to the local acceptance of this generation source. The CO_2 intensity of coal-fired power generation is one of the lowest among IEA countries and nearly 5% below the IEA average. Emissions from coal in power generation accounted for 29% of Japan's total energy-related CO_2 emissions in 2018. In 2012, Japan introduced a "global warming tax" as an add-on tax to the existing petroleum and coal tax, but the overall tax burden on coal use remains small.

The environmental impact of coal combustion is expected to decline modestly through the promotion of high-efficiency and next-generation coal technology. A 2016 regulation requires new plants to be at least ultra-supercritical. It also requires all electric power companies to increase their average thermal generation efficiency to at least 44.3% by the end of 2030. This compares to an average efficiency of around 42% of coal-fired plants in Japan today. However, even a 44% efficient coal plant still emits 30-60% more CO_2/kWh than a natural gas-fired plant.

The recent announcement to phase out most inefficient coal plants by 2030 will help improve the environmental footprint of coal-fired power generation even further. Inefficient coal-fired power plants (i.e. those with an efficiency level below USC) account for about 60% of installed capacity. Details on how this goal will be implemented have yet to be announced. Possibilities include regulatory measures to limit the permissible emission of CO_2/kWh, or the introduction of a robust carbon price on CO_2 emissions. A robust carbon price on CO_2 emissions would also provide an additional driver for CCUS technologies to become economically viable and provide an additional incentive for the deployment of renewable electricity technologies. There is currently no specific schedule to phase out efficient coal-fired power plants (i.e. those with an efficiency level of USC or above).

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As a major coal consumer, Japan recognises its strategic interest and became a world leader in the research and development of CCUS and carbon recycling technologies. Its Long-term Strategy Under the Paris Agreement states that the introduction of CCUS and carbon recycling for coal-fired power generation by 2030 will be considered. Given the long lifetime of coal-fired power plants (at least 40 years), it is advisable to require new plants to be constructed "capture-ready", so that CCUS and carbon recycling can be deployed when the economic or regulatory conditions require, thereby avoiding these plants from becoming stranded assets. A requirement to make new plants capture-ready had already been proposed in the 3rd SEP of 2010; the 5th SEP announced that the government would study options to introduce it as soon as possible. Japan also expects that retrofitting existing generation facilities with CCUS and carbon recycling may help ensure continued operation of coal-fired plants under more stringent climate constraints.

If, however, CCUS and carbon recycling cannot be deployed at a large scale, the anticipated high reliance on coal will make it difficult to reach Japan's goal of reducing GHG emissions by 80% by 2050. Whether CCUS and carbon recycling on coal will be economically viable depends to a large extent on the cost reductions to be achieved by CCUS and carbon recycling research. Japan's innovation programmes for CCUS and carbon recycling include a strong focus on improving CCUS and carbon recycling technology and bringing down their costs. Creating a stable and transparent regulatory framework will also be important to enable commercial investment in the technology.

The export of Japanese technology – including coal technologies – is a government priority. Japan states that coal-related investments and exports would only be available for countries "forced to choose coal as an energy source from the perspectives of energy security and economic viability" and that the equipment should in principle be at, or above, ultra-supercritical levels.

Recommendations

The government of the Japan should:

- ☐ Follow through with the announced phase out of inefficient power plants by 2030 and swiftly develop the necessary regulatory or fiscal tools to implement it.
- ☐ Evaluate the need for future coal-fired power generation capacity, taking into account GHG emission goals and the decreasing costs of alternatives like renewable electricity and LNG.
- ☐ Require new coal-fired power plants to be constructed "capture-ready", and gradually reduce the permissible CO_2/kWh emissions limits for existing coal-fired plants to remove subcritical and supercritical plants from the fleet.
- ☐ Implement the envisaged research programmes for CCUS and carbon recycling for coal-fired power generation, with dedicated subsidies for research and deployment, while creating a regulatory framework for CO_2 storage and removing other barriers to deployment.
- ☐ Together with the iron and steel industry, promote research and investments to reduce the CO_2 emissions from steelmaking processes.

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ENERGY SECURITY

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11. Nuclear energy

Key data

(2019*)

Number of reactors: 33 operable reactors (15 of these passed the review of the Nuclear Regulation Authority and 9 returned to operation)

Installed capacity: 31.6 GW_e (operable reactors)

Electricity generation:** 63.8 TWh, down from 288 TWh in 2010

Share of nuclear:** 6.4% of electricity generation in 2019, down from 24.8% in 2010

* Source: IAEA (2020), "Power Reactor Information System (PRIS): Japan", https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=JP.

** Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

Overview

Nuclear energy has played a significant role in Japan's energy policy since the 1970s, reaching over 25% of the electricity generation in 2010. The March 2011 Great East Japan Earthquake and subsequent tsunami caused a major accident at the Fukushima Daiichi Nuclear Power Plant which resulted in a radioactive release to the surrounding area. The accident has had a profound impact on the Japanese, and the global, nuclear sectors. Work to decommission the Fukushima Daiichi Nuclear Power Plant and to decontaminate nearby sites affected by the radioactive release is ongoing. Several ministries and government agencies are actively engaged in the social and economic recovery of the Fukushima region and its gradual return to normalcy.

The government response immediately after the Fukushima Daiichi accident considered a complete phase out of the commercial nuclear power programme in Japan. However, the 4th Strategic Energy Plan (SEP) of 2014 reconsidered the contribution of nuclear energy to the Japanese electricity mix, emphasising the importance of ensuring safety. The 5th SEP of 2018 seeks to achieve a 20-22% share of nuclear power in the electricity mix by 2030. According to the government, this goal is achievable with the existing fleet of the 33 remaining operable nuclear reactors, once approximately 30 of them complete the safety review of the Nuclear Regulation Authority (NRA), acquire local understanding, return to service and operate with an average capacity factor of 80%. As of May 2020, nine reactors had returned to operation. In 2019, nuclear power generated 63.8 terawatt hours (TWh), representing 6.4% of the total power generation that year (IEA, 2020) (Figure 11.1).

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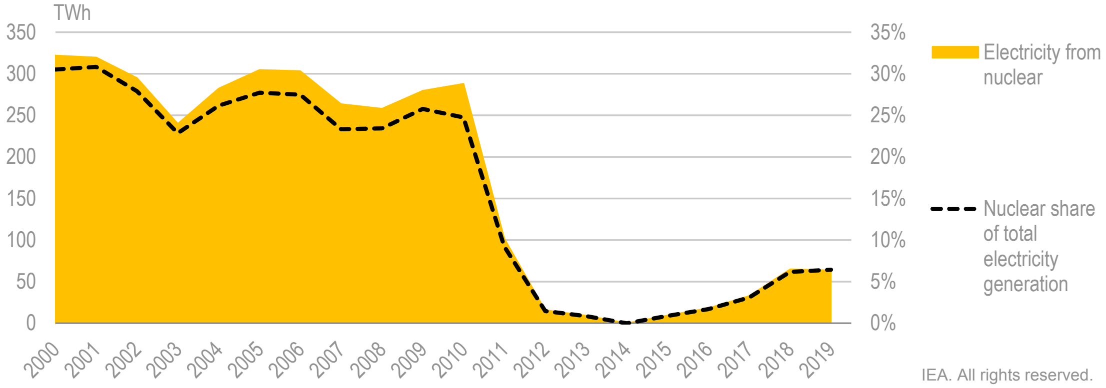
Figure 11.1 Nuclear electricity generation, Japan, 2000-19



After dropping to zero in 2014, the amount of electricity generated with nuclear power has rebounded in recent years, to reach 6.4% in 2019.

Note: TWh = terawatt hour.

Source: IEA (2020), *IEA World Energy Statistics and Balances* (database), www.iea.org/statistics.

History of nuclear power development in Japan

Japan initiated its nuclear research programme in 1954, closely followed by the 1955 enactment of the Atomic Energy Basic Law. This law strictly limits the use of nuclear technology for peaceful purposes and promotes public consensus, independence and transparency in the development and use of this technology, as well as international co-operation. The Japan Atomic Energy Commission,[1] whose role was to promote the development and utilisation of nuclear power, was created in 1956. The Nuclear Safety Commission (NSC) was formed in 1978 as a separate entity from the Japan Atomic Energy Commission, with responsibility over nuclear safety and regulation.

Also in 1956, the Japan Atomic Energy Research Institute and the Atomic Fuel Corporation were created. A merger of the Japan Atomic Energy Research Institute and the successor of the Atomic Fuel Corporation in 2005 created the Japan Atomic Energy Agency (JAEA) under the Ministry of Education, Culture, Sports, Science and Technology. The JAEA is Japan's primary nuclear research organisation, well-known for its experience in the design and operation of sodium fast reactors and high-temperature gas reactors.

Japan's first nuclear reactor to produce electricity, the Japan Power Demonstration Reactor (JPDR), was a prototype boiling water reactor that operated between 1963 and 1976. The first commercial nuclear power reactor in Japan was a 160 megawatt electrical (MW_e) gas-cooled reactor (Tokai 1) imported from the United Kingdom that operated from 1966 to 1998. The first three commercial light water reactors (LWRs) began operations in 1970. Afterwards, all commercial nuclear reactors built in Japan have been boiling water reactors (BWRs) or pressurised water reactors (PWRs). The LWRs were initially purchased from US suppliers, built in collaboration with Japanese companies, and included a license for Japanese companies to build similar units by themselves in Japan.

[1] Annex A provides detailed information about organisations and institutions with responsibilities related to the energy sector.

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Initially, Japanese nuclear reactors faced reliability problems that resulted in low capacity factors. In 1975, the Japanese nuclear power industry together with the Ministry of International Trade and Industry (now the Ministry of Economy, Trade and Industry, [METI]) launched the LWR Improvement and Standardisation Program with the goal of standardising LWR designs for the optimisation of construction, operation and maintenance of nuclear power plants. The Advanced BWR (ABWR) and the Advanced PWR (APWR), which included digital instrumentation and controls and significant use of advanced construction technologies, were a product of this programme. The ABWR, the first evolutionary nuclear reactor design ever built, was the result of a partnership between General Electric, Toshiba and Hitachi. The Japanese nuclear industry demonstrated its capabilities by building the first ABWRs in Kashiwazaki-Kariwa in 1996 on time and within budget in 36 months. Japanese capacity factors have also improved to reach a median of 70%, but this is still lower than the world's top performers (90%).

In the 1970s, Japan also initiated the development of the entire nuclear fuel cycle, from uranium exploration to the disposal of high-level radioactive wastes, including the development of fast breeder-reactor technology, domestic spent fuel reprocessing capabilities and the production and use of mixed-oxide (MOX) fuel. These latter activities were aimed at closing the fuel cycle in order to gain maximum benefit from the energy contained in imported uranium and to reduce the volume of high-level wastes.

Through the years, Japan has developed a world-class nuclear sector, including industry, academia and research. Companies such as Hitachi Co Ltd, Toshiba Co Ltd and Mitsubishi Heavy Industry Co Ltd have developed the capability to independently design and build LWRs and the Japanese industry has established its own domestic and global nuclear technology markets.

Despite the Fukushima Daiichi nuclear accident, the Japanese nuclear sector is well-regarded worldwide and there are opportunities for the deployment of Japanese nuclear technology outside of the domestic market, including in newcomer countries. The Japanese nuclear industry has been very open with the global nuclear community and has been keen to share best practices and lessons learnt from the 2011 Fukushima Daiichi nuclear accident.

Nuclear regulation

Between 1978 and 2001, regulation of nuclear energy facilities was the responsibility of the NSC. In 2001, the government reformed the overall organisational structure responsible for nuclear technology in Japan. The Nuclear and Industrial Safety Agency (NISA) was formed under the Agency for Natural Resources and Energy of METI to oversee matters of nuclear and industrial safety. The Japan Atomic Energy Commission and the NSC provided high-level independent advice to ministries and agencies with regards to nuclear energy. The Ministry of Education, Culture, Sports, Science and Technology was responsible for the regulatory oversight of nuclear research at national laboratories and educational institutions, while the responsibility for nuclear power regulation was shared between NISA and the NSC. This was a complex structure in which the oversight and the responsibility for nuclear safety was distributed among several organisations in various branches of the Japanese government, which had resulted in ineffective decision making. NISA had the competing missions of both regulating nuclear safety and promoting the use of nuclear energy.

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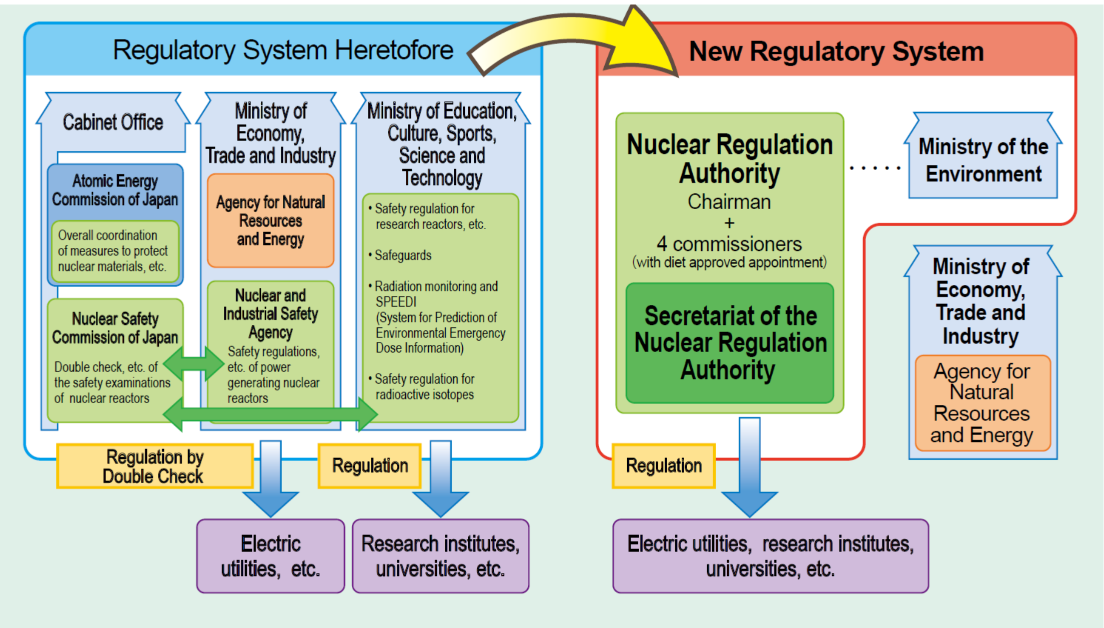
As a consequence of the lessons learnt from the 2011 events, the NRA was established in September 2012 as an independent regulatory authority. It is an external organisation of the Ministry of the Environment with “Article 3 Authority”, which makes it independent from the control or supervision of any ministry or governmental entity. The NRA governs regulations on nuclear energy, nuclear security, safeguards based on international commitments, radiation monitoring and regulations on the use of radioisotopes, which previously had been overseen by other administrative organs (Figure 11.2).

Figure 11.2 Evolution of the nuclear regulatory system in Japan



Note: The “Diet” is Japan’s bicameral legislature.

Source: NRA (2020), *Nuclear Regulation for People and the Environment*, www.nsr.go.jp/data/000067218.pdf.

The mission of the NRA is to protect the general public and the environment through the rigorous and consistent regulation of all nuclear activities by following five guiding principles: 1) independent decision making; 2) effective actions; 3) open and transparent organisation; 4) commitment to continuous improvement; and 5) readiness for emergency response. The NRA is tasked to ensure transparency and appropriate information disclosure on the regulations and the decision-making process, and to be open to opinions and advice from the Japanese and international communities. It must also keep abreast of the latest regulatory practices and be prepared for a swift and well-organised response to all emergency situations. The NRA’s successful performance of its mission is expected to help restore public trust, in Japan and abroad, in the nation’s nuclear regulatory organisation.

Since its establishment in 2012, the NRA has developed stringent new regulations, incorporated associated agencies to centralise regulatory functions and prepared a national emergency response plan. At the same time, it has been reviewing detailed applications for conformity assessments of reactors and fuel cycle facilities to the new regulatory requirements adopted after the 2011 events. The requirements were developed in line with the safety standards and guidelines of the International Atomic Energy Agency, incorporating the lessons learnt from the Fukushima Daiichi nuclear accident, as identified in the reports by the National Diet’s Nuclear Accident Investigation Commission, the

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government's Nuclear Accident Investigation Committee and the Independent Investigation Commission on the accident.

The new, more stringent regulations have been developed with the underlying assumption that severe accidents could occur at any moment, and fully considering the challenging natural conditions unique to Japan. In this regard, previous assumptions on the impact of earthquakes, tsunamis and other external events such as volcanic eruptions, tornadoes and forest fires have been re-evaluated and countermeasures for nuclear safety to face these external events have been enhanced. The new regulations also include strengthened countermeasures against internal fires and flooding, as well as mechanisms to ensure the reliability of on-site and off-site power sources to respond to possible station blackouts. The new regulations were open for public comment twice during their development (NEA, 2016).

The NRA took over the review of the restart applications of the Japanese nuclear plants.[2] This restarting process has two parts: 1) the safety assessment performed by the NRA based on the new regulatory requirements; and 2) the promoting activities of the nuclear power operators to help the local communities in the neighbouring regions understand and accept restarts. Japan's nuclear power fleet started reactivating in 2015 with a production of 9.4 TWh (0.9% of the total power production) and generation had increased to 6.4% of total power generation by 2019 (IEA, 2020). As of January 2020, the reviews of 15 reactors (out of 33 operable reactors) had been successfully completed, and 9 of these had returned to operation. Of the remaining 18 reactors, 10 were in the NRA review process, and 8 had not yet applied.

Several other new organisations were established as a reaction to the Fukushima Daiichi events. In 2012, the Japan Nuclear Safety Institute was established as an independent organisation that drives the voluntary efforts for continuous safety enhancement of the Japanese utilities. In 2014, the Nuclear Risk Research Center was established to support the development of advanced methodologies for evaluating the risks associated with external events such as earthquakes or tsunamis. The Atomic Energy Association was established in 2018 to help nuclear operators, manufacturers and other nuclear organisations with their efforts to improve nuclear safety.

Nuclear fuel cycle

Uranium mining

Japan has no indigenous reserves of uranium. Its annual requirements (about 8 000 tonnes of uranium (tU) prior to the Fukushima Daiichi accident) are normally met with uranium coming from Australia (about one-third), Canada and Kazakhstan primarily. Japanese companies have taken equity in overseas uranium projects to better manage the fluctuations in price of the global uranium markets.

[2] Following the 2011 events, the government ordered that all nuclear power plants comply with the new, more stringent regulations in order to resume operation after they suspended operation for regular maintenance. Consequently, all nuclear power plants were shut down by 2013.

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Enrichment

Although most of the Japanese enrichment services are imported, Japan Nuclear Fuel Ltd (JNFL) operates a commercial enrichment plant at Rokkasho, with an ultimate planned capacity of 1 500 tonnes of separative work units per year, enough to meet about one-third of the needs of domestic nuclear power plants.[3] This plant began operation in 1992, using indigenous technology, and has been upgraded several times since, using advanced centrifuge technology. The NRA has approved its operation in accordance with the new regulatory standards.

Japan has 6 400 tU recovered from reprocessing and stored in France and the United Kingdom, where the reprocessing was carried out. A domestic reprocessing plant is being built at Rokkasho and construction is expected to be completed in the second half of 2022 (see below).

Fuel fabrication

Japan has several companies capable of fabricating most of the nuclear fuel for BWRs, PWRs and high-temperature gas reactors domestically. Mitsubishi Nuclear Fuel Co., Ltd operates the 440 tU/yr Tokai fuel fabrication facility. Nuclear Fuel Industries, Ltd. operates two facilities, one in Kumatori (284 tU/yr) and one in Tokai (250 tU/yr). Global Nuclear Fuel – Japan Co., Ltd., part of the General Electrics-led Global Nuclear Fuel joint venture with Hitachi, has a 620 tU/yr plant in Yokosuka. All of these facilities have received the NRA's approval for operation in accordance with the new regulatory standards.

Spent uranium fuels are reprocessed and plutonium is recovered for MOX fuel fabrication. Although currently most of the MOX used in nuclear reactors in Japan was fabricated in France (WNA, 2017). However, the JNFL is currently constructing a MOX Fuel Fabrication Plant (J-MOX) in Rokkasho to allow for MOX fuel fabrication in Japan (see section below).

Reprocessing of used nuclear fuel

Japan has chosen a closed nuclear fuel cycle policy since the beginning of its nuclear power generation programme. The closed nuclear fuel cycle optimises the use of imported uranium resources and reduces the volume and radiotoxicity of the high-level radioactive waste that must be ultimately disposed of. This policy foresees that all used nuclear fuel from Japanese nuclear power plants will be reprocessed and reused in Japanese plants as uranium-plutonium MOX fuel.

In May 2016, the Japanese parliament amended the 2005 Spent Nuclear Fuel Reprocessing Implementation Act that establishes the funding mechanisms for the reprocessing of spent fuel and MOX fuel fabrication, in response to the deregulation of Japanese electricity markets. The law created a new entity responsible for reprocessing, the Nuclear Reprocessing Organisation of Japan (NuRO), which collects funds and contracts out reprocessing to the JNFL. NuRO is considering contracting the JNFL for MOX fuel fabrication to Jthe NFL. Japan's nuclear utilities pay annual fees to NuRO to cover the expected costs for reprocessing of all the spent fuel they produced in the

[3] In 1984, the Federation of Electric Power Companies initiated plans for the construction of a major nuclear complex at Rokkasho, including a uranium enrichment plant, a low-level waste storage centre, a high-level waste (used fuel) storage centre, a reprocessing plant and a MOX fuel fabrication plant. To undertake all these activities, the JNFL was created in 1992 as a joint stock company by the electric power utilities, with some wider shareholding.

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previous fiscal year, and for the fabrication of the MOX fuel. METI will approve NuRO's master plan, which shows the amount of reprocessing to balance between demand and supply of plutonium.

As of February 2020, according to METI, Japan's power companies had accumulated 19 000 tonnes of used nuclear fuel, which are stored at wet and dry storage facilities in Japanese nuclear reactor sites and the Rokkasho reprocessing plant, and represent about 79% of the available storage capacity. At the end of 2018, Japan had accumulated about 30 tonnes of fissile plutonium, including the amounts recovered in France and from the United Kingdom and from the hot testing in the Rokkasho reprocessing plant, as well as the amounts contained in the nuclear fuel stored at nuclear power plants and from the JAEA's research activities. As reprocessing capacity under construction in Japan will not be sufficient to treat all expected and accumulated spent fuel until it operates for a number of years, additional interim spent fuel storage facilities will need to be made available. Additional dry storage capacity is under consideration, undergoing regulatory review or under construction at various sites (Ikata, Genkai, Tokai Daini, Hamaoka). The Recyclable Fuel Storage Company was established in 2005 jointly by the Tokyo Electric Power Company (80%) and the Japan Atomic Power Company (20%) to construct a dry spent fuel storage facility with a 3 000 tonne capacity, with a potential expansion to 5 000 tonnes.

To date, the reprocessing of Japan's spent nuclear fuel has been largely undertaken by British Nuclear Fuels Limited[4] in the United Kingdom and Orano in France (with nearly 4 200 tonnes and 2 900 tU having been shipped to the two countries, respectively). Vitrified high-level wastes have been returned to Japan for disposal.

Between 1977 and 2007, the JAEA operated a pilot reprocessing plant at Tokai. It also operated the vitrification pilot facility for high-level liquid waste generated by the reprocessing plant from 1994 to 2007 that was restarted in 2016. The JAEA plans to complete the vitrification of all the high-level liquid waste by 2028, based on the decommissioning plan for the Tokai reprocessing plant, which was approved in 2018 by the NRA (NEI, 2019).

A much larger reprocessing plant has been built at Rokkasho. Itt was due to start commercial operation in 2008, but the start date was delayed to 2013 due to problems in the locally designed vitrification plant. The problems were resolved and the JNFL was ready to commission the reprocessing plant in October 2013, but had to implement additional enhancements to meet new NRA fuel cycle facility regulations. The JNFL's current expected completion date is 2021.

The J-MOX plant at Rokkasho, which would manufacture MOX fuel using the plutonium recovered in the adjacent reprocessing plant, is also under construction. It has applied for NRA review and the review is expected to be completed in 2022.

In 2018, the Federation of Electric Power Companies reiterated its members' intention to use MOX fuel in 16-18 nuclear units. The federation said it would be more specific once the Rokkasho reprocessing plant was closer to completion in 2021. Currently, four units use MOX fuel: Takahama 3 and 4, Ikata 3, and Genkai 3. The Ohma ABWR plant, which

[4] Since 2016, British Nuclear Fuels Limited is part of the Nuclear Decommissioning Authority of the United Kingdom. Orano, created in January 2018, was earlier a wholly owned subsidiary of the French government-owned AREVA. The JNFL and Mitsubishi each own 5% of Orano since February 2018.

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is under construction, is designed to run on a full MOX core. With the delay in construction of the J-MOX plant, several other utilities have used MOX fuel supplies from Orano in France.

Radioactive waste disposal

The Japanese legislation applicable to the management of radioactive waste resulting from nuclear reactor operation is the 1957 Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Reactor Regulation Act).

Based on the Designated Radioactive Waste Final Disposal Act of 2000, METI defines the country's final disposal plan, including timing and quantities of waste to be disposed of. Further, METI authorises, designates and supervises bodies for the implementation of the final disposal plan and the management of the associated funds. The act mandates the establishment of a deep geological repository for the final disposal of high-level radioactive waste in the form of vitrified waste from reprocessing. The Nuclear Waste Management Organisation of Japan, established in October 2000, is engaged in implementing safe geological disposal of radioactive waste. The site selection process will be undertaken in three stages: 1) selection of preliminary investigation areas based on literature survey; 2) selection of detailed investigation areas; and 3) selection of the final disposal site. In July 2017, the Nationwide Map of Scientific Features for Geological Disposal was published to show potential suitability of various geographic areas to host such a repository, but the actual siting process has not yet started and no specific schedule for the selection process has been prepared. The Radioactive Waste Management Funding and Research Centre is the body designated for the administrative management of the final disposal fund, and will be funded by the fees collected from utilities for the construction and other related project costs of this repository.

Part of low-level radioactive waste generated through operating nuclear power plants is currently disposed in a concrete pit at a depth of ten metres or more at the low-level radioactive waste disposal facility in Rokkasho, operated by the JNFL. The capacity of the facility is 80 000 m^3, with an expansion to approximately 600 000 m^3 under consideration.

Decommissioning

In the Japanese funding system, operators of nuclear power plants are to pay for the totality of the costs for decommissioning, used nuclear fuel reprocessing and final disposal of radioactive waste. As mentioned above, operators pay fees into the appropriate funds for used nuclear fuel reprocessing and for final disposal of radioactive waste. At the same time, they allocate a predefined annual sum in internal funds to cover future decommissioning liabilities. To cover their costs for decommissioning, operators of nuclear power plants have to hold internal funds that are accounted for on their balance sheets and controlled by METI.

As part of the special funding scheme for accident-affected reactors created after the 2011 events, nuclear operators have to pay annual fees to accumulate funds to offset their decommissioning liabilities under the management of the especially established Nuclear Damage Compensation and Decommissioning Facilitation Corporation. The corporation is jointly financed by the Japanese government and the affected nuclear operator.

In the context of the decommissioning of the Japan Power Demonstration Reactor, permanently shut down in 1976, the Japan Atomic Energy Research Institute (the

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predecessor of the JAEA) established techniques for the decommissioning of commercial power reactors. Phase I of the decommissioning programme started in 1981 and developed various techniques, while Phase II involved the actual dismantling of the JPDR from 1986 to 1996. In addition to the JAEA, following the Fukushima Daiichi accident, the International Research Institute for Nuclear Decommissioning was established in 2013 by the JAEA, the Japanese utilities and reactor vendors, with a focus on decommissioning of Fukushima 1-4.

In addition to the JPDR, 14 reactors are currently being decommissioned (excluding the 6 units at Fukushima Daiichi). In 2001, the decommissioning of Tokai-1, the oldest nuclear commercial reactor in Japan and which was permanently shut down in 1998, began. The reactors will be decommissioned over a period of 30 years and will be a learning opportunity for the Japanese nuclear decommissioning sector. In addition, Fugen ATR, a JAEA prototype reactor that started decommissioning in 2008, is planned to be decommissioned and completely demolished to clear the site by 2034. Monju FBR, a JAEA prototype reactor, started decommissioning in 2018. Chubu's Hamaoka units 1 and 2, which shut down permanently in 2009, were written off and started the decommissioning process.

In March 2015, METI encouraged operators to consider the possibility of earlier shutdown and decommissioning of older reactors, for which it introduced new accounting provisions in the Electricity Business Act. These new rules allow operators of nuclear power plants that decide to shut down their facility earlier than planned to depreciate the remaining book value of the facility in ten years (instead of a one-time charge as was previously the case). In addition, new remuneration rules allow operators of nuclear power plants to accumulate ten consecutive years of recognised losses all at once. This enhanced financial system for decommissioning encouraged several utilities to permanently shut down some of their older reactors and to be decommissioned. Overall, 24 reactors, including the 6 units at Fukushima Daiichi, are to be permanently shut down and then decommissioned (Table 11.1).

Under current law, the operating companies are responsible for the decommissioning of nuclear reactors. The decommissioning process is divided into 4 phases and each utility has formulated a plan to complete the decommissioning of each reactor in about 30 years. This decommissioning plan has to be approved by the NRA. The second and third phases are particularly critical, as large amounts of low-level waste are generated due to the dismantling of peripheral equipment and the reactor equipment itself. In early 2020, four plants were in the second phase of decommissioning and will reach the third phase (full-scale dismantling) in the mid-2020s (Figure 11.3). Japan has formulated, or is in the process of formulating, regulations for the ultimate disposal of the radioactive wastes generated by the decommissioning of nuclear reactors, but sites have not been identified for these materials.

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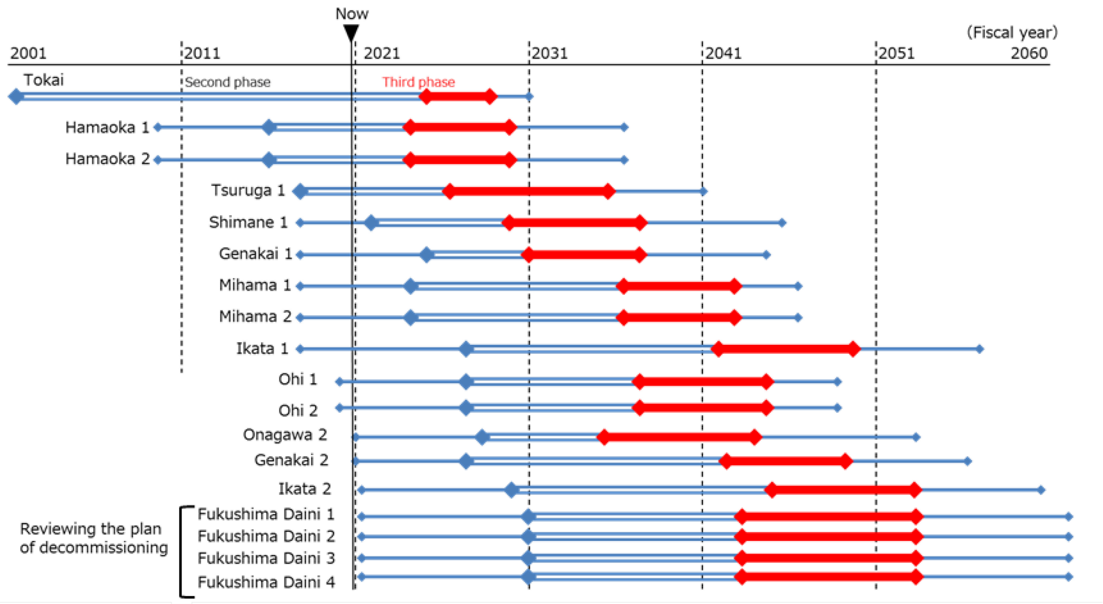
Figure 11.3 Decommissioning plans for Japan's nuclear fleet



Source: Figure provided by the Ministry of Economy, Trade and Industry.

Although Japan has accumulated significant decommissioning experience through the decommissioning of the JPDR, the concurrent decommissioning of these 24 reactors over the next 30 years will be a major challenge. At a global level, decommissioning has become a specialised and competitive sector in which utilities sell shut-down reactors to decommissioning companies that use accelerated decommissioning technologies. In Japan, however, each utility appears to be planning to manage the completion of its decommissioning projects internally. The uncertainty about Japan's ultimate plans for dealing with radioactive wastes from plant decommissioning and the lack of a competitive decommissioning sector may result in inefficient management of the process and the amount of available funds may ultimately define the costs.

Work to decommission the Fukushima Daiichi Nuclear Power Plant and to decontaminate nearby sites affected by the radioactive release is ongoing. Storing treated water is an ongoing challenge, as water continues to be injected into the reactors to cool the fuel debris. The "Subcommittee on Handling of the advanced liquid processing system Treated Water", a dedicated government committee, has identified technically feasible options to dispose of this treated water in a safe manner that will appropriately address the storage capacity issue, and gradually reduce the volume of treated water stored at the Fukushima site. The committee concluded that after repurification and dilution, release of treated water into the sea could be done more reliably than, for example, vapour release (METI, 2020; IAEA, 2020b). The government continues to listen to the opinions from a wide range of concerned parties and based on this will eventually decide on its policy.

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Table 11.1 Japan's 24 nuclear reactors to be decommissioned

Reactor	Type	Net capacity (MW_e)	Utility	Operating life	Start of decommissioning process
Tokai 1	Magnox	137	JAPC	07/66 - 03/98	2006
Hamaoka 1	BWR	515	Chubu	03/76 - 02/09	2009
Hamaoka 2	BWR	806	Chubu	11/78 - 02/09	2009
Fukushima I-1	BWR	439	TEPCO	03/71 - 04/12	–
Fukushima I-2	BWR	760	TEPCO	07/74 - 04/12	–
Fukushima I-3	BWR	760	TEPCO	03/76 - 04/12	–
Fukushima I-4	BWR	760	TEPCO	10/78 - 04/12	–
Fukushima I-5	BWR	760	TEPCO	04/78 - 01/14	–
Fukushima I-6	BWR	1 067	TEPCO	10/79 - 01/14	–
Genkai 1	PWR	529	Kyushu	10/75 - 03/15	2017
Genkai 2	PWR	529	Kyushu	06/80 - 02/19	2020
Ikata 1	PWR	538	Shikoku	09/77 - 03/16	2017
Ikata 2	PWR	538	Shikoku	03/82 - 03/18	2020
Mihama 1	PWR	320	Kansai	11/70 - 03/15	2017
Mihama 2	PWR	470	Kansai	07/72 - 03/15	2017
Ohi 1	PWR	1 120	Kansai	03/79 - 03/18	2019
Ohi 2	PWR	1 120	Kansai	12/79 - 03/18	2019
Onagawa 1	BWR	498	Tohuku	06/84 - 10/18	2020
Shimane 1	BWR	439	Chugoku	03/74 - 03/15	2016
Tsuruga 1	BWR	341	JAPC	03/70 - 03/15	2016
Fukushima 2-1	BWR	1 067	TEPCO	04/82 - 07/19	–
Fukushima 2-2	BWR	1 067	TEPCO	02/84 - 07/19	–
Fukushima 2-3	BWR	1 067	TEPCO	06/85 - 07/19	–
Fukushima 2-4	BWR	1 067	TEPCO	08/87 - 07/19	–

Notes: MW_e = megawatt electrical. BWR = boiling water reactor. PWR = pressurised water reactor. JAPC = Japan Atomic Power Company. TEPCO = Tokyo Electric Power Company.

Source: WNA (2020), "Nuclear power in Japan", www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx.

Nuclear power today

In 2019, nuclear power generated 63.8 TWh in Japan, representing 6.4% of the total power generation in 2019 (IEA, 2020).

The 5th SEP of 2018 presents nuclear power as "an important base-load power source contributing to the stability of the long-term energy supply-and-demand structure," and states that necessary measures will be taken to achieve a 20-22% share of nuclear power in the energy mix in 2030 (METI, 2018). According to the government, this goal is achievable with the existing fleet of nuclear reactors, once approximately 30 reactors

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complete the NRA safety review, acquire local understanding, return to service and operate with an average capacity factor of 80%.

The average capacity factor for Japanese nuclear plants is about 70%, compared with over 90% for the best performers worldwide, mainly due to the country's inspection requirements that set a default period of 13 months between inspections at Japanese reactors. If this period were to be extended 24 months, which is more in line with international practices, electricity companies could operate their power plants in a more cost-effective manner.

As mentioned earlier, as of January 2020, the reviews of 15 reactors (out of the 33 operable reactors) had been successfully completed, and 9 of these reactors had returned to operation. Another ten were still under review, and eight had not yet applied. Table 11.2 displays the Japanese reactors currently operable and their current status. In addition, three reactors are currently under construction. Of these, two are under the NRA's review and one has not yet applied (Table 11.3).

The reactor restarts are facing significant implementation costs ranging from USD 700 million to USD 1 billion per unit, regardless of reactor size or age. Although the NRA intended to increase its relicensing staff to about 100 people, the review process and the plant restarts have proceeded at a slower rate than previously anticipated for a number of reasons, including additional changes in regulatory requirements.

For example, in May 2019, the NRA ordered Kansai Electric Power Company to retrofit seven of its reactors based on a new analysis that considers the potential eruption of a dormant volcano, even though all the affected reactors had previously been cleared based on new regulatory standards. A month earlier, the NRA announced it would not extend the deadlines for utilities building facilities to meet new anti-terrorism guidelines, which could affect at least ten reactors, and could potentially result in temporary shutdowns. In March 2020, Kyushu Electric Power Company had to temporarily shut down its Sendai 1 unit because it had not completed the construction of the back-up control centre. The NRA had ruled in November 2015 that construction of such facilities must be completed within five years after regulatory approval of each plant's engineering and construction work programme, but it took almost three years for the NRA to review the plans of the facility itself. Realising the ambitious objective of 20-22% nuclear generation by 2030 will therefore require a concentrated effort by all stakeholders, including the NRA.

According to the current nuclear regulations, the operating period for a nuclear power station is 40 years. The regulations contemplate a 20-year extension to a total of 60 years' operating life. The extended shutdown period that many nuclear reactors have experienced since 2011 currently counts towards the 40-year initial plant life. Several Japanese nuclear reactors have reached the end of their 40-year life, and are now under redevelopment to extend the operating period. The entire fleet of the reactors would reach the end of the 40-year life before 2050. If the 20-year additional plant licenses were allowed for the entire current fleet, the last unit would be permanently shut down around 2070.

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Table 11.2 Status of operable Japanese reactors

Reactor	Type	Net capacity (MW_e)	Utility	Commercial operation	NRA compliance				Restart date
					Application	1. Basic design	2. Detailed design	3. Safety programme	
Genkai 3	PWR	1 127	Kyushu	March 1994	Dec 2013	Jan 2017	Sept 2017	Sept 2017	May 2018
Genkai 4	PWR	1 127	Kyushu	July 1997	July 2013	Jan 2017	Sept 2017	Sept 2017	June 2018
Hamaoka 3	BWR	1 056	Chubu	Aug 1987	June 2015				
Hamaoka 4	BWR	1 092	Chubu	Sept 1993	Feb 2014				
Hamaoka 5	ABWR	1 325	Chubu	Jan 2005					
Higashidori 1 Tohoku	BWR	1 067	Tohoku	Dec 2005	June 2014				
Ikata 3	PWR	846	Shikoku	Dec 1994	July 2013	July 2015	March 2016	Apr 2016	Aug 2016
Kashiwazaki-Kariwa 1	BWR	1 067	TEPCO	Sept 1985					
Kashiwazaki-Kariwa 2	BWR	1 067	TEPCO	Sept 1990					
Kashiwazaki-Kariwa 3	BWR	1 067	TEPCO	Aug 1993					
Kashiwazaki-Kariwa 4	BWR	1 067	TEPCO	Aug 1994					
Kashiwazaki-Kariwa 5	BWR	1 067	TEPCO	Apr 1990					
Kashiwazaki-Kariwa 6	ABWR	1 315	TEPCO	Nov 1996	Sept 2013	Dec 2017			
Kashiwazaki-Kariwa 7	ABWR	1 315	TEPCO	July 1997	Sept 2013	Dec 2017			
Mihama 3	PWR	780	Kansai	Dec 1976	March 2015	Oct 2016	Oct 2016		
Ohi 3	PWR	1 127	Kansai	Dec 1991	July 2013	May 2017	Aug 2017	Sept 2017	March 2018
Ohi 4	PWR	1 127	Kansai	Feb 1993	July 2013	May 2017	Aug 2017	Sept 2017	May 2018
Onagawa 2	BWR	796	Tohoku	July 1995	Dec 2013	Feb 2020			
Onagawa 3	BWR	796	Tohoku	Jan 2002					
Sendai 1	PWR	846	Kyushu	July 1984	July 2013	Sept 2014	March 2015	May 2015	Aug 2015
Sendai 2	PWR	846	Kyushu	Nov 1985	July 2013	Sept 2014	May 2015	May 2015	Oct 2015
Shika 1	BWR	505	Hokuriku	July 1993					
Shika 2	ABWR	1 108	Hokuriku	March 2006	Aug 2014				
Shimane 2	BWR	789	Chugoku	Feb 1989	Dec 2013				
Takahama 1	PWR	780	Kansai	Nov 1974	March 2015	Apr 2016			
Takahama 2	PWR	780	Kansai	Nov 1975	Mar 2015	Apr 2016			

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Takahama 3	PWR	830	Kansai	Jan 1985	July 2013	Feb 2015	Aug 2015	Oct 2015	Jan 2016
Takahama 4	PWR	830	Kansai	June 1985	July 2013	Feb 2015	Oct 2015	Oct 2015	Feb 2016
Tokai 2	BWR	1 060	JAPC	Nov 1978	May 2014	Sept 2018	Oct 2018		
Tomari 1	PWR	550	Hokkaido	June 1989	July 2013				
Tomari 2	PWR	550	Hokkaido	Apr 1991	July 2013				
Tomari 3	PWR	866	Hokkaido	Dec 2009	July 2013				
Tsuruga 2	PWR	1 108	JAPC	Feb 1987	Nov 2015				
Total: 33		**31 679**							

Notes: MW_e = megawatt electrical. ABWR = advanced boiling water reactor. BWR = boiling water reactor. PWR = pressurised water reactor. JAPC = Japan Atomic Power Company. TEPCO = Tokyo Electric Power Company.

Source: WNA (2020), "Nuclear power in Japan", www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx.

Table 11.3 Nuclear power plants under construction in Japan

Reactor	Type	Net capacity (MW_e)	Utility	Construction start	Operation
Shimane 3	ABWR	1 325	Chugoku	December 2005, suspended 2011	Applied to the NRA for safety checks in August 2018
Ohma 1	ABWR	1 325	EPDC/J-Power	May 2010, suspended from March 2011 to October 2012	Construction estimated to restart 2020 and finish in second half 2025
Tokyo Higashi dori-1	ABWR	1 325	Tokyo Electric Power Company	–	Not yet applied for the NRA review
Total: 3		**3 975**			

Notes: MW_e = megawatt electrical. ABWR = advanced boiling water reactor. NRA = Nuclear Regulatory Agency.

Sources: WNA (2020), "Nuclear power in Japan", www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx; information provided by the Ministry of Economy, Trade and Industry during the review visit.

Assessment

Until March 2011, nuclear power was the largest carbon-free baseload source in Japan's electricity mix. At that time, 54 nuclear reactors, with 48.9 GW capacity, supplied about 25% of Japan's electricity. There were plans to increase the share of nuclear energy generation to 50% by 2030.

The March 2011 Great East Japan Earthquake and subsequent tsunami caused a major accident at the Fukushima Daiichi Nuclear Power Plant. Four of the six units at the site suffered major damage, resulting in a radioactive release to the surrounding area. This accident has had a profound impact on the Japanese nuclear sector. By May 2012, all 50 remaining nuclear reactors in Japan were shut down for safety inspections. Plants were required to undergo stringent stress tests in response to potential severe accidents and to retrofit additional safety systems to comply with new regulatory requirements.

As a consequence of the lessons learnt from the 2011 Fukushima Daiichi nuclear accident, Japan established the NRA in September 2012 as an independent organisation of the Ministry of the Environment. Previously, responsibility for nuclear power regulation was

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shared among the Nuclear and Industrial Safety Agency and the NSC, which had resulted in ineffective decision making. NISA, which was part of METI, had the competing missions of both regulating nuclear safety and promoting the use of nuclear energy.

The NRA took over the review of the restart applications of the Japanese nuclear plants. This restarting process has two parts: first, the safety assessment performed by the NRA based on the new regulatory requirements; and second, the briefing of affected local governments by the operators. Japan's nuclear power fleet started reactivating in 2015 (with a production of 9.4 TWh, or 1% of total power production) and generation had increased to 7.4% of power generation by 2019. As of January 2020, the reviews of 15 reactors had been successfully completed, and 9 of them had returned to operation.

A 2015 revision of the accounting provisions in the Electricity Business Act enhanced the financial system for decommissioning and encouraged many utilities to permanently shut down some of their older reactors to be decommissioned. Twenty-four reactors, including the six units at Fukushima Daiichi, are to be permanently shut down and then decommissioned. Despite Japan's accumulated experience in nuclear power plant decommissioning, the decommissioning of these 24 reactors over the next 30 years or so will be a major challenge. At a global level, decommissioning has become a specialised and competitive sector, while in Japan each utility appears to be planning to manage the completion of its decommissioning projects internally. The uncertainty about Japan's ultimate plans for dealing with radioactive wastes from plant decommissioning and the lack of a competitive decommissioning sector may result in inefficient management of the process, and the amount of available funds may ultimately define the costs.

Japan's 5th SEP seeks to achieve a 20-22% share of nuclear power in the electricity mix by 2030. According to the government, this goal is achievable with the existing fleet of nuclear reactors, once approximately 30 reactors complete the NRA safety review, acquire local consent, return to service and operate with an average capacity factor of 80%. In the past, the default period between inspections at Japanese reactors was 13 months, which resulted in median capacity factors of about 70%. New regulations could extend this period to 24 months, which is more in line with international practices and typically results in 90% capacity factors. Realising the ambitious objective of 20-22% nuclear generation by 2030 will require a concentrated effort by all stakeholders.

Current nuclear regulations specify that the operating period for a nuclear power station is 40 years, with a possible extension of 20 years. Several Japanese nuclear reactors have reached the end of the 40-year life and are now under redevelopment to extend the operating period.

However, the extended shutdown period since 2011, when many nuclear reactors were not operated, currently counts towards the 40-year initial plant life. The entire fleet of the reactors would reach the end of the 40-year life before 2050. If the 20-year additional plant licenses were allowed for the entire current fleet, the last unit would be permanently shut down around 2070. If the utilities are able to show that the reactor has been properly maintained, excluding this idle time from the original 40-year license period would provide Japan with many additional reactor-years of operation for the current nuclear fleet.

The deregulation and unbundling of the Japanese electricity markets (see Chapter 7) is causing uncertainty in the future business model for nuclear power plants. Although nuclear power plants can operate flexibly to some degree, they are the most cost-effective when operated as baseload. The longer term evolution of the baseload markets, the

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capacity markets and the non-fossil fuel markets may have a significant impact on the economic viability of nuclear power plants going forward, but the effects of these markets on economics and energy security are currently uncertain.

Japan has chosen a closed nuclear fuel cycle policy since the beginning of its nuclear power generation programme. This policy foresees that all spent fuel from Japanese nuclear power plants will be reprocessed and reused in Japanese plants as uranium-plutonium MOX fuel. A full-scale reprocessing plant is currently undergoing NRA review. Until now, the reprocessing of a portion of Japan's spent fuel has been done in the United Kingdom and France with vitrified high-level radioactive wastes being returned to Japan for disposal. The remaining spent fuel is being stored at Japanese nuclear reactor sites in wet and dry storage facilities. The Designated Radioactive Waste Final Disposal Act mandates the establishment of a deep geological repository for the final disposal of high-level radioactive waste in the form of vitrified waste from reprocessing. In July 2017, the "Nationwide Map of Scientific Features for Geological Disposal" was published to show potentially suitable geographic areas to host such a repository, but the siting process has not yet started. A part of the electricity fees nuclear utilities collect from consumers is earmarked for the construction and other related project costs of this repository.

Work to decommission the Fukushima Daiichi Nuclear Power Plant and to decontaminate nearby sites affected by the radioactive release is ongoing. Storing treated water is an ongoing challenge, as water continues to be injected into the reactors to cool the fuel debris. A dedicated government committee has developed recommendations to dispose of this treated water in a safe manner that will appropriately address the current storage capacity issue, and gradually reduce the volume of treated water stored at the Fukushima site. The government continues to listen to opinions from a wide range of parties and will decide its basic policy. Several ministries and government agencies are actively engaged in the social and economic recovery of the Fukushima region and its gradual return to normalcy.

Public opinion towards nuclear energy has diversified since the 2011 events. While some people still continue to show strong support for nuclear energy even after the accident, a number of temporary injunctions have been filed by various stakeholders to halt the operation of the restarted reactors, adding to direct claims against nuclear utilities. Given the key role of nuclear energy in the 5th SEP, the government is committed to improve communication and engagement with civil society regarding nuclear energy.

Throughout the years Japan has developed a world-class nuclear sector, including industry, academia and research. The JAEA, its primary nuclear research organisation, is well-known for its experience in the design and operation of sodium cooled reactors, which are a key component of the closed fuel cycle policy for Japan. The JAEA's research in high-temperature gas reactors can be critical for the production of hydrogen. Despite the Fukushima Daiichi nuclear accident, the Japanese nuclear sector is well-regarded worldwide and there might be opportunities for the deployment of Japanese nuclear technology outside of the domestic market, including in newcomer countries. The Japanese nuclear industry has been very open with the global nuclear community and has been keen to share best practices and lessons learnt from the 2011 Fukushima Daiichi nuclear accident.

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Recommendations

The government of Japan should:

- Invest the necessary human and financial resources to accelerate the NRA's safety reviews of nuclear reactors.
- Undertake concerted efforts to promote the understanding of local communities and thereby accelerate the restart of nuclear power plants that have been confirmed of their compatibility with the NRA's safety regulations.
- Evaluate excluding from the 40-year license period the extended period during which nuclear reactors were under the NRA review on their restart applications and remained idle.
- To speed up and rationalise decommissioning:
  - regulate reactors slated for decommissioning separately from operating plants
  - develop and implement a clear and streamlined plan for the management, interim-term storage and disposal of radioactive waste from plant decommissioning
  - foster the development of a market-driven competitive decommissioning sector.
- Invest in attracting new talent to nuclear careers, thus ensuring the NRA's ability to perform all safety reviews in a timely and high-quality manner, as well as the long-term viability of the nuclear sector in Japan.
- Continue the progress in the decommissioning of the Fukushima site, the investment in the social and economic recovery of the Fukushima area, and the open exchange of information and lessons learnt from the accident.

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ANNEX A: Institutions

The **Ministry of Economy, Trade and Industry (METI)** has the primary responsibility for energy policy in Japan and for setting climate change mitigation policy in the energy sector. It also sets overall national targets for renewable energy. It is responsible for measures to promote the development of the economy and industry, such as enhancing the vitality of the private sector and facilitating economic relations with other countries.

Within METI, the **Agency for Natural Resources and Energy (ANRE)** is responsible for ensuring strategic energy security, realising an efficient energy supply, promoting environmentally friendly energy policies and energy efficiency, and implementing renewable energy policies. The ANRE is also responsible for the development of the strategic energy plans. It further is responsible for developing and implementing energy innovation policy and works with and through a range of affiliated agencies, such as the **National Institute of Advanced Industrial Science and Technology**.

Other government departments involved in the energy sector include the **Ministry of the Environment** (climate change and air pollution mitigation and geothermal and biomass energy); the **Ministry of Land, Infrastructure, Transport and Tourism** (energy efficiency, off-shore wind and ocean energy, transport infrastructure); the **Ministry of Agriculture, Forestry and Fisheries** (biomass and bioenergy); and the **Ministry of Foreign Affairs** (resource diplomacy). **Local governments** are also implementing their own initiatives in the energy and climate sector and take steps to implement their own energy efficiency efforts and promote renewable energies.

Also within METI, the **Electricity and Gas Market Surveillance Commission (EGC)** is the regulatory authority for the electricity, gas and heat power markets. Its decision are not enforceable and it is not fully independent from METI. It was initially created as the Electricity Market Surveillance Commission in 2015 as a regulator for the electricity sector only. In 2016, its remit was expanded to also cover the gas and heat power markets and its name was changed. The EGC audits and inspects utilities and recommends changes to the market rules to the METI.

The **Japan Fair Trade Commission** is responsible for monitoring competition in all sectors of the economy. For the electricity and natural gas industries, it is increasing its surveillance in line with market reforms. The Japan Fair Trade Commission is taking an active role towards the promotion of more flexible and liquid LNG markets.

Since 2015, the **Organization for Cross-regional Coordination of Transmission Operators (OCCTO)** oversees the electricity transmission and distribution companies. Its primary function is to balance the supply and demand for electricity on a nationwide level and to improve interconnections between the local markets. OCCTO also undertakes the functions of the former Electric Power System Council of Japan to set rules for access to the transmission grid and to enhance transparency, co-ordination and reliability. A new law passed in 2020 gives OCCTO the mandate to develop a master plan for the development of cross-regional grids.

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The primary role of the **Japan Oil, Gas and Metals National Corporation (JOGMEC)** is to manage the national emergency crude oil reserves and mineral resources. JOGMEC is an important vehicle for the government to provide support for coal, oil and natural gas exploration and development activities overseas. It also supports geothermal prospecting.

The **New Energy and Industrial Technology Development Organization (NEDO)** is the largest central institution involved in research and development in Japan. Its mission is to address energy and global environmental problems and to enhance industrial technology. The organisation is committed to advancing research, development and promotion of industrial and environmental technology, including new energy (renewable energy, hydrogen and fuel cells) and energy conservation. NEDO plays an important role in distributing funding for energy-related research, development and innovation and in fostering collaboration among industry, academia and the government. It supports activities ranging from basic research to pre-commercial demonstration and deployment.

The **Japan Electric Power Exchange (JEPX)** was established in 2003 as a private and voluntary power exchange. It was designated a wholesale electricity market under the provisions of the Electricity Business Act in 2016.

The **Japan Atomic Energy Agency (JAEA)** conducts basic and applied nuclear research, fast breeder reactor research, reprocessing technology, and high-level radioactive waste final disposal technology research and development. It is Japan's only comprehensive nuclear R&D institution.

In 2012, the **Nuclear Regulation Authority (NRA)** was established as a fully independent body in charge of regulations on nuclear energy, nuclear security, safeguards based on international commitments, and for protecting the general public and the environment. It is also tasked with the review of the restart applications of the Japanese nuclear plants. The NRA succeeded the Nuclear and Industrial Safety Agency, a special agency that was attached to the ANRE that regulated the nuclear energy sector until then.

The **Nuclear Waste Management Organisation of Japan (NUMO)** was established in 2000 as the sole organisation to implement geological disposal of high-level radioactive waste from nuclear power generation in Japan.

Keidanren is Japan's most important and largest business association representing mainly large businesses. In April 2019, its members included 1 412 companies, 109 industrial associations and 47 regional economic organisations. Keidanren actively promotes climate action through the voluntary actions plans of its members, which often include efforts linked to energy efficiency improvements.

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ANNEX B: Organisations visited

Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews conducted by the IEA. The Shared Goals are presented in Annex D.

Review team and preparation of the report

The in-depth review team visited Japan 3-10 February 2020. It met with government officials, energy suppliers, market participants, interest groups in the public and private sectors, consumer representative associations, research institutions, and other organisations and stakeholders.

The report was drafted on the basis of the information obtained during these meetings, the team's preliminary assessment of Japan's energy policy, the Japanese government's response to the IEA energy policy questionnaire, and information on subsequent policy developments from the government and private sector sources. The members of the team were:

IEA member countries

Mr Paul Simon, United States (team leader)

Ms Anna Andersson, Sweden

Mr Simon Koesler, Germany

Mr Mark Pickup, New Zealand

Mr Han Feenstra, the Netherlands

Mr Tim Wyndham, Australia

Mr Ho-Mu Lee, Korea

OECD Nuclear Energy Agency

Ms Sama Bilbao y Leon, Head of Nuclear Technology Development and Economics Division

International Energy Agency

Mr Aad van Bohemen, Head of Energy Policy and Security Division

Mr Heymi Bahar, Senior Energy Analyst

Ms Britta Labuhn, Energy Analyst

Ms Dagmar Graczyk, Senior Energy Policy Analyst and in-depth review co-ordinator

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The team is grateful for the co-operation and assistance of the many people it met with during the visit. Thanks to their kind hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable.

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The review was prepared under the guidance of Mr Keisuke Sadamori, Director, Energy Markets Directorate, IEA and Mr Aad van Bohemen, Head of the Energy Policy and Security Division, IEA. Ms Dagmar Graczyk managed the review and Ms Britta Labuhn is the main author of the report. Ms Bilbao y Leon wrote the chapter on nuclear energy, Mr Heymi Bahar wrote the chapter on renewables and Mr Milosz Karpinski wrote the chapter on oil. Mr Alessio Scanziani, Mr Oskar Kvarnström (former IEA staff), Ms Dahyeon Lisa Yu and Ms Clémence Lizé prepared and drafted the sections relating to energy data contained in each chapter.

Helpful comments, chapter reviews and updates were provided by the following IEA staff:

Mr Niels Berghout, Mr José Miguel Bermúdez Menéndez, Mr François Briens, Mr. Jean-Baptiste Debreuil, Ms Andrea Dertinger, Mr Carlos Fernández Alvarez, Ms Aracali Fernandez Pales, Mr Peter Fraser, Ms Marine Gorner, Mr Taku Hasegawa, Mr Simone Landolina, Mr Pharoah Le Feuvre, Ms Jinsun Lim, Ms Diana Louis, Ms Samantha McCulloch, Mr Jean-Baptiste Le Marois, Ms Sara Moarif, Mr Yannick Monschauer, Ms Mao Takeuchi, Mr Jakob Teter, Ms Tomoko Uesawa and Ms Tiffany Vass.

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Organisations visited

Carbon Disclosure Project

DNV GL

Electricity and Gas Market Surveillance Commission

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Federation of Electric Power Companies of Japan

Fuel Cell Commercialization Conference of Japan

CO_2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA)

Institute for Energy Economics Japan

Japan Association of Energy Service Companies

Japan Atomic Energy Commission

Japan Atomic Power Company

Japan Automobile Manufacturers Association

JEPX (Japan Electric Power Exchange)

Japan Gas Association

Japan Head Service Utilities Association

Japan Heat Supply Business Association

Japan Iron and Steel Federation

Japan Nuclear Fuel Limited

Japan Photovoltaic Energy Association

Japan Wind Power Association

J-Coal

JOGMEC (Japan Oil, Gas and Metals National Corporation)

J-Power

Kawasaki Heavy Industries

Keidanren (Japan Business Federation)

Marunouchi Heat Supply Corporation

Ministry of Economy, Trade and Industry

Ministry of the Environment

Ministry of Foreign Affairs

Ministry of Land, Infrastructure, Transport and Tourism

Mitsubishi Heavy Industries

NEDO (New Energy and Industrial Technology Development Organization)

Nippon Association of Consumer Specialists

Nuclear Regulation Authority

Nuclear Waste Management Organisation of Japan

OCCTO (Organization for Cross-regional Coordination of Transmission Operators)

Petroleum Association of Japan

Toyota Motor Corporation

World Wildlife Fund

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ANNEX C: Energy balances and key statistical data

Japan

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2017	2018	2019p
TOTAL PRODUCTION		**29.5**	**74.5**	**104.9**	**101.5**	**41.1**	**50.3**	**51.0**
Coal		17.9	4.5	1.5	0.6	0.8	0.7	0.4
Peat		-	-	-	-	-	-	-
Oil		0.8	0.6	0.6	0.7	0.4	0.4	0.4
Natural gas		2.3	1.9	2.3	3.2	2.6	2.2	2.6
Biofuels and waste[1]		-	4.5	5.3	11.3	13.8	14.5	14.3
Nuclear		2.5	52.7	83.9	75.1	8.6	16.9	16.6
Hydro		5.7	7.6	7.2	7.2	7.2	7.0	6.9
Wind		-	-	0.0	0.3	0.6	0.6	0.6
Geothermal		0.2	1.6	3.1	2.4	2.2	2.3	2.6
Solar/other		-	1.2	0.8	0.7	5.0	5.6	6.6
TOTAL NET IMPORTS[2]		**297.4**	**367.7**	**417.3**	**399.7**	**389.5**	**375.5**	**367.8**
Coal	Exports	0.4	1.4	1.9	0.5	0.9	1.0	1.1
	Imports	41.3	73.5	97.5	115.2	116.5	114.8	114.9
	Net imports	40.9	72.2	95.6	114.8	115.6	113.7	113.8
Oil	Exports	3.1	3.7	4.5	17.5	17.7	17.7	19.1
	Imports	276.2	267.0	274.5	229.5	203.5	195.5	188.6
	Int'l marine and aviation bunkers	-19.4	-10.0	-11.9	-10.1	-11.3	-11.7	-11.6
	Net imports	253.7	253.3	258.1	202.0	174.5	166.1	157.9
Natural gas	Exports	-	-	-	-	-	-	-
	Imports	2.8	42.3	63.5	82.7	98.2	94.3	94.6
	Net imports	2.8	42.3	63.5	82.7	98.2	94.3	94.6
Electricity	Exports	-	-	-	-	-	-	-
	Imports	-	-	-	-	-	-	-
	Net imports	-	-	-	-	-	-	-
TOTAL STOCK CHANGES		**-6.5**	**-3.6**	**-4.0**	**0.1**	**1.3**	**0.1**	**0.3**
TOTAL SUPPLY (TES)[3]		**320.4**	**438.7**	**518.2**	**501.4**	**431.9**	**426.0**	**419.1**
Coal		57.9	76.7	97.0	115.4	116.4	114.4	114.1
Peat		-	-	-	-	-	-	-
Oil		248.9	250.3	255.0	202.7	176.0	166.2	158.9
Natural gas		5.1	44.1	65.6	85.9	100.9	97.0	96.9
Biofuels and waste[1]		-	4.6	5.4	11.6	15.0	15.9	15.8
Nuclear		2.5	52.7	83.9	75.1	8.6	16.9	16.6
Hydro		5.7	7.6	7.2	7.2	7.2	7.0	6.9
Wind		-	-	0.0	0.3	0.6	0.6	0.6
Geothermal		0.2	1.6	3.1	2.4	2.2	2.3	2.6
Solar/other		-	1.2	0.8	0.7	5.0	5.6	6.6
Electricity trade		-	-	-	-	-	-	-
Shares in TES (%)								
Coal		*18.1*	*17.5*	*18.7*	*23.0*	*27.0*	*26.9*	*27.2*
Peat		-	-	-	-	-	-	-
Oil		*77.7*	*57.1*	*49.2*	*40.4*	*40.8*	*39.0*	*37.9*
Natural gas		*1.6*	*10.1*	*12.7*	*17.1*	*23.4*	*22.8*	*23.1*
Biofuels and waste[1]		-	*1.0*	*1.0*	*2.3*	*3.5*	*3.7*	*3.8*
Nuclear		*0.8*	*12.0*	*16.2*	*15.0*	*2.0*	*4.0*	*4.0*
Hydro		*1.8*	*1.7*	*1.4*	*1.4*	*1.7*	*1.6*	*1.7*
Wind		-	-	-	*0.1*	*0.1*	*0.2*	*0.2*
Geothermal		*0.1*	*0.4*	*0.6*	*0.5*	*0.5*	*0.5*	*0.6*
Solar/other		-	*0.3*	*0.2*	*0.1*	*1.1*	*1.3*	*1.6*
Electricity trade		-	-	-	-	-	-	-

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

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DEMAND						
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2017**	**2018**
TFC	**234.0**	**292.3**	**337.3**	**314.7**	**292.5**	**283.0**
Coal	24.1	27.1	20.9	22.9	21.7	21.2
Peat	-	-	-	-	-	-
Oil	171.1	181.8	206.6	167.1	151.3	144.3
Natural gas	3.1	13.6	21.3	29.0	29.5	29.1
Biofuels and waste[1]	-	2.7	3.3	5.6	6.2	6.2
Geothermal	-	0.1	0.2	0.1	0.1	0.1
Solar/other	-	1.2	0.8	0.4	0.2	0.2
Electricity	35.7	65.8	83.6	89.0	83.0	81.3
Heat	0.0	0.2	0.5	0.6	0.5	0.5
Shares in TFC (%)						
Coal	*10.3*	*9.3*	*6.2*	*7.3*	*7.4*	*7.5*
Peat	-	-	-	-	-	-
Oil	*73.1*	*62.2*	*61.2*	*53.1*	*51.7*	*51.0*
Natural gas	*1.3*	*4.7*	*6.3*	*9.2*	*10.1*	*10.3*
Biofuels and waste[1]	-	*0.9*	*1.0*	*1.8*	*2.1*	*2.2*
Geothermal	-	*0.0*	*0.1*	*0.0*	*0.0*	*0.0*
Solar/other	-	*0.4*	*0.2*	*0.1*	*0.1*	*0.1*
Electricity	*15.3*	*22.5*	*24.8*	*28.3*	*28.4*	*28.7*
Heat	-	*0.1*	*0.2*	*0.2*	*0.2*	*0.2*
TOTAL INDUSTRY[4]	**141.8**	**142.3**	**140.5**	**127.6**	**120.2**	**116.3**
Coal	18.7	27.0	20.9	22.6	21.5	21.1
Peat	-	-	-	-	-	-
Oil	96.4	71.7	73.5	57.9	53.5	50.2
Natural gas	1.6	4.7	7.5	11.2	11.6	11.7
Biofuels and waste[1]	-	2.5	2.6	3.4	3.8	3.8
Geothermal	-	-	-	0.0	0.0	0.0
Solar/other	-	-	-	-	-	-
Electricity	25.1	36.4	36.0	32.5	29.8	29.6
Heat	-	-	-	-	-	-
Shares in total industry (%)						
Coal	*13.2*	*19.0*	*14.9*	*17.7*	*17.9*	*18.1*
Peat	-	-	-	-	-	-
Oil	*68.0*	*50.4*	*52.3*	*45.3*	*44.5*	*43.1*
Natural gas	*1.2*	*3.3*	*5.3*	*8.8*	*9.6*	*10.0*
Biofuels and waste[1]	-	*1.7*	*1.9*	*2.7*	*3.1*	*3.3*
Geothermal	-	-	-	-	-	-
Solar/other	-	-	-	-	-	-
Electricity	*17.7*	*25.6*	*25.6*	*25.5*	*24.8*	*25.4*
Heat	-	-	-	-	-	-
TRANSPORT[3]	**40.8**	**71.9**	**89.0**	**78.6**	**71.4**	**70.6**
OTHER[5]	**51.5**	**78.1**	**107.8**	**108.4**	**100.9**	**96.1**
Coal	5.2	0.1	0.0	0.2	0.2	0.2
Peat	-	-	-	-	-	-
Oil	35.2	39.6	45.7	32.5	28.3	25.5
Natural gas	1.5	8.9	13.8	17.7	17.9	17.4
Biofuels and waste[1]	-	0.2	0.7	2.0	2.0	2.0
Geothermal	-	0.1	0.2	0.1	0.1	0.1
Solar/other	-	1.2	0.8	0.4	0.2	0.2
Electricity	9.5	27.9	46.1	54.9	51.6	50.2
Heat	0.0	0.2	0.5	0.6	0.5	0.5
Shares in other (%)						
Coal	*10.2*	*0.1*	-	*0.2*	*0.2*	*0.2*
Peat	-	-	-	-	-	-
Oil	*68.5*	*50.7*	*42.4*	*30.0*	*28.0*	*26.5*
Natural gas	*2.9*	*11.4*	*12.8*	*16.3*	*17.7*	*18.1*
Biofuels and waste[1]	-	*0.2*	*0.6*	*1.8*	*2.0*	*2.1*
Geothermal	-	*0.1*	*0.2*	*0.1*	*0.1*	*0.1*
Solar/other	-	*1.5*	*0.7*	*0.4*	*0.2*	*0.3*
Electricity	*18.5*	*35.7*	*42.7*	*50.7*	*51.2*	*52.2*
Heat	*0.1*	*0.3*	*0.5*	*0.5*	*0.5*	*0.6*

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Footnotes to energy balances and key statistical data

[1] *Biofuels and waste* comprise solid biofuels, liquid biofuels, biogases, industrial waste and municipal waste. Data are often based on partial surveys and may not be comparable between countries.

[2] In addition to coal, oil, natural gas and electricity, total net imports also include biofuels.

[3] Excludes international marine bunkers and international aviation bunkers.

[4] *Industry* includes non-energy use.

[5] *Other* includes residential, commercial and public services, agriculture and forestry, fishing, and other non-specified.

[6] *Inputs to electricity generation* include inputs to electricity and heat plants. *Output* refers only to electricity generation.

[7] Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for nuclear; 10% for geothermal; and 100% for hydro, wind and solar photovoltaic.

[8] Toe per thousand US dollars at 2015 prices and exchange rates.

[9] "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach methodology from the 2006 IPCC Guidelines. Emissions from international marine and aviation bunkers are not included in national totals.

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ANNEX D: International Energy Agency “Shared Goals”

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. Diversity, efficiency and flexibility within the energy sector are basic conditions for longer term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases, this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these shared goals. Decision makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the polluter-pays principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

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7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA ministers at the meeting of 4 June 1993 in Paris, France.)

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

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ANNEX E: Acronyms and abbreviations

In this report, abbreviations and acronyms are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention, this glossary provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

ABWR	advanced boiling water reactor
ANRE	Agency of Natural Resources and Energy
BAU	business-as-usual
BEV	battery electric vehicule
BWR	boiling water reactor
CCS	carbon capture and storge
CCUS	carbon capture, utilisation and storage
CO_2	carbon dioxide
DHC	district heating and cooling
EGC	Electricity and Gas Market Surveillance Commission
EIS	Environment Innovation Strategy
EPCO	electric power company
ETS	emissions trading system
EV	electric vehicule
FCEV	fuel cell electric vehicule
FIT	feed-in tariff
FY	fiscal year
GDP	gross domestic product
GHG	greenhouse gas
HEV	hybrid electric vehicule
IEA	International Energy Agency
IGCC	integrated coal gasification combined cycle
IGFC	integrated coal gasification fuel cell
JAEA	Japan Atomic Energy Agency
JAPEX	Japan Petroleum Exploration Company Limited
JCC	Japan custons-cleared crude
JCM	Joint Crediting Mechanism
JEPX	Japanese Electric Power Exchange
JNFL	Japan Nuclear Fuel Ltd
JOGMEC	Japanese Oil, Gas and Metals National Corporation
JPDR	Japan Power Demonstration Reactor
JPY	Japanese yen

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LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land use, land-use change and forestry
LWR	light water reactors
METI	Ministry of Economy, Trade and Industry
MOX	mixed-oxide (fuel)
MUFG	Mitsubishi UFJ Financial Group
NDC	Nationally Determined Contribution
NEDO	New Energy and Industrial Technology Development Organization
NESTI 2050	National Energy and Environment Strategy for Technological Innovation towards 2050
NISA	Nuclear and Industrial Safety Agency
NRA	Nuclear Regulatory Agency
NSC	Nuclear Safety Commission
NuRO	Nuclear Reprocessing Organisation of Japan
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
OECD	Organisation for Co-operation and Development
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
PPP	purchasing power parity
PV	photovoltaic
PWR	pressurised water reactor
R&D	research and development
RD&D	research, development and demonstration
SEP	Strategic Energy Plan
SMFG	Sumitomo Mitsui Financial Group
TCP	technology collaboration programme
TFC	total final consumption
TFEC	total final energy consumption
TPA	third-party access
TPES	total primary energy supply
TSO	transmission system operator
USC	ultra-supercritical
USD	United States dollar
VPP	virtual power plant
ZEB	zero-energy building
ZEH	zero-energy building

Units of measure

bcm	billion cubic metres
CO_2	carbon dioxide

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CO_2-eq	carbon dioxide equivalent
CO_2/kWh	carbon dioxide per kilowatt hour
g CO_2	gramme of carbon dioxide
GW	gigawatt
GW_e	gigawatt electrical
GWh	gigawatt hour
kb/d	thousand barrels per day
kg	kilogramme
kL	thousand litres
km	kilometre
km^2	square kilometre
kW	kilowatt
kWh	kilowatt hour
m^2	square metre
m^3	cubic metre
mb/d	million barrels per day
mBtu	million British thermal units
mcm	million cubic metres
MJ	megajoule
MJ/t-cem	megajoule per tonne of cement
Mt	million tonnes
Mt CO_2	million tonnes carbon dioxide
Mt CO_2-eq	million tonnes of carbon dioxide-equivalent
Mtoe	million tonnes of oil equivalent
MW	megawatt
MW_e	megawatt electrical
MWh	megawatt hour
Nm^3	normal cubic metres
PJ	petajoule
pkm	passenger-kilometre
T	tonne
T CO_2	tonnes carbon dioxide
toe	tonne of oil equivalent
tU	tonne of uranium
TWh	terawatt hour

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Energy Policy Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member countries. This process supports energy policy development and encourages the exchange of international best practices and experiences.

Nearly a decade after the 2011 earthquake and the subsequent Fukushima nuclear accident resulted in significant disruption to its energy supply, Japan has made visible progress towards realising its vision of an efficient, resilient and sustainable energy system. It has diversified its energy mix and embarked on a major reform of its electricity and natural gas markets. The gradual expansion of renewable energy sources, restart of some nuclear power plants and improvements in energy efficiency have reduced the need for imported fossil fuels and lowered greenhouse gas emissions below their 2009 level. Nevertheless, the carbon intensity of Japan's energy supply remains one of the highest among IEA members. It will need to move quickly to make headway on the steep emissions reductions that are needed to achieve its recently announced ambition of reaching carbon neutrality by 2050. In this report, the IEA provides energy policy recommendations to help Japan smoothly manage the transformation of its energy sector.