International Energy Agency
Secure
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Energy Policies of IEA Countries

Japan

2016 Review

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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1. EXECUTIVE SUMMARY AND KEY RECOMMENDATIONS

EXECUTIVE SUMMARY

Japan is a major player in the world of energy. The country is one of the largest energy consumers and importers. It is also a recognised leader in energy technology development and a major exporter in that sector. Security of supply has traditionally been critical to Japan, as it relies on imports for practically all of its fossil fuel supply.

Recent years have been challenging, however. Japan's energy policy has been dominated by efforts to overcome the impact from the 2011 Great East Japan earthquake and the subsequent nuclear accident. At the 15th Conference of the Parties (COP15) in 2009, Japan had pledged to reduce its greenhouse gas (GHG) emissions by 25% from 1990 to 2020. This ambitious pledge largely relied on plans to increase nuclear power's share in electricity supply from 30% to 50%. After March 2011, however, the country's entire nuclear power capacity was gradually shut down in the aftermath of the Fukushima Daiichi nuclear accident and came to a complete halt in 2013.

The nuclear shutdown left a gap of around 30% in electricity supply. This gap was closed mostly by at the time expensive fossil fuels, primarily by liquefied natural gas (LNG), but also by oil and, from 2013 on, by coal. Electricity savings and, since 2012, additional renewable electricity capacity also helped to close the gap. Yet by the end of 2013, import dependence had risen to 94% from 80% in 2010. Annual CO_2 emissions from power generation had grown by more than 110 million tonnes, or by one-quarter. Electricity prices had increased by 16% for households and 25% for industry, according to IEA data, and were set to continue to rise fast. The situation was unsustainable for the long term. Thus, the government decided to fundamentally rethink its energy policy.

NEW ENERGY STRATEGY AND PLANS TO 2030 AND BEYOND

In April 2014, the government adopted the fourth Strategic Energy Plan (SEP) and based on that plan, the Ministry of Economy, Trade and Industry (METI) prepared the 2015 "Long-Term Energy Supply and Demand Outlook" to 2030 which was adopted in July 2015. The SEP introduces safety among the key objectives of energy policy, alongside the three "Es" of energy security, economic efficiency and environmental protection. These objectives are intertwined and the government has been careful to balance them in the subsequent outlooks and strategies to 2030 and beyond.

The 2015 Outlook was prepared with climate change objectives in mind. A key part of the Outlook is the electricity supply mix for 2030, which projects declines in the share for natural gas, coal and oil, a comeback to nuclear energy and strong increases in renewable energy.

After the adoption of the 2015 Outlook, Japan announced its intended nationally determined contribution (INDC) for COP21 (held in Paris from 30 November to 12 December 2015) to reduce GHG emissions by 26% from 2013 to 2030. In May 2016, it adopted the Plan for Global Warming Countermeasures. The plan is based on the INDC

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and the Paris Agreement by which Japan pledges to head towards cutting emissions by 80% by 2050 under the condition that this is compatible with economic growth.

To support these promises, the government is working together with industry and academia to promote energy technology innovation under the 2016 National Energy and Environment Strategy for Technological Innovation towards 2050 (NESTI 2050).

The 2030 INDC is a balancing act between energy security, economic efficiency, environmental protection and safety. It builds on several well-founded existing policies and measures. Three areas are critical to its success: energy efficiency, increasing renewable energy supply and restarting nuclear power generation.

Japan has a long tradition of effective policies and measures related to energy efficiency, and these also partly explain why total primary energy supply (TPES), total final consumption of energy (TFC) and electricity demand all peaked in the last decade. The measures include the voluntary action plans of industry and the Top Runner Programme for appliances, equipment and vehicles. Both are very broad: the voluntary action plans cover around 80% of energy-related CO_2 emissions from manufacturing and energy industries, while the Top Runner Programme covers around 70% of TFC in households.

The most cost-effective way to begin implementing the SEP is to restart nuclear power generation at plants that the Nuclear Regulation Authority approves to be safe. All nuclear power plants are required to undergo safety inspections under the new regulatory requirements before they can restart. Restarts depend on passing a lengthy multi-stage safety review and, although restarts have begun, it remains unclear to what extent nuclear power will be restored. If nuclear power generation falls short of the 20-22% target for 2030 in the 2015 Outlook, it would be very challenging to fill the gap with renewable energy alone. In all likelihood, more natural gas and coal would be used and meeting the GHG target would be complicated, if not impossible, with domestic measures alone. The government should be prepared for a variety of outcomes.

It is important for the nuclear industry to be re-established in Japan, provided that safety is maintained at the highest standards possible. This hinges not only on safety approvals for nuclear plants to restart, but also on how effectively the critical issues related to the Fukushima Daiichi nuclear accident are addressed. These issues include the decontamination of the areas affected by radioactive releases, the successful resettlement of decontaminated areas and the provision of appropriate compensation for the serious disruption in the lives of large numbers of citizens. The decommissioning of the Fukushima Daiichi nuclear power plant must also continue as a high-priority project. Progress must continue to be made in all these areas and communicated openly and transparently to Japanese citizens. If difficulties arise, they must be clearly acknowledged and proposed solutions must be openly discussed and evaluated before taking decisions. All these measures are needed also to help regain public trust.

The 26% reduction in GHG emissions from 2013 to 2030 is feasible with existing technology. After 2030, however, considerable global efforts are required to meet the 2°C target referred to at COP21 and innovations will be needed to drastically reduce GHG emissions. In so doing, Japan launched the NESTI 2050 Strategy in April 2016. Japan is also a leader in research, development and deployment (RD&D) on carbon capture and storage. New solutions to help decarbonise energy supply and reduce energy demand would find global markets and benefit other countries, too.

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ELECTRICITY AND GAS MARKET REFORM

Japan is the world's fifth-largest electricity user. Electricity accounted for 28% of total final consumption of energy in 2014, a high share by international comparison. Government policy since the oil crises of the 1970s has been to diversify energy sources for electricity generation so as to increase security of supply in a country heavily dependent on fuel imports.

Electricity supply has been based on a system of regional monopolies relatively isolated from each other. Competition in the wholesale and especially retail markets has been limited, although independent power producers have been granted market entry since 1995 and power producers and suppliers have been allowed to supply electricity to large customers since 2000.

All this is changing now. The 2011 Great East Japan earthquake and the Fukushima Daiichi nuclear accident highlighted several weaknesses in the electricity system and prompted the government to begin an overdue reform of the electricity market. The reform has three objectives: to secure a stable supply of electricity, to suppress electricity rates to the maximum extent possible, and to expand consumer choice and business opportunities.

The reform is being implemented in three stages. First, in April 2015, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) began to operate. It is tasked with assessing generation adequacy and ensuring that adequate transmission capacity is available. It also has the power to order the construction of new transmission lines.

Second, full liberalisation of the retail market took effect in April 2016. All consumers may now choose their supplier and indeed around 820 000 consumers changed to a new one by the end of April. Before liberalisation, in September 2015, the Electricity Market Surveillance Commission (EMSC) was established as the regulatory authority for electricity under METI. In 2016, its remit was expanded to cover also the gas and heat power markets in order to prepare for the liberalisation of the gas and heat market, and its name was changed to the Electricity and Gas Market Surveillance Commission (EGC).

Third, in April 2020, the transmission and distribution segment of the electric power companies will be legally unbundled from the generation and retail segments.

The International Energy Agency (IEA) welcomes the electricity market reform and encourages the government to implement it as scheduled. In doing so, it should consider several steps for further market reform. Developing the transmission network is critical, as the system needs to be better interconnected across the former monopoly supply areas and across the East-West frequency divide. Over time, OCCTO should be developed into a fully independent transmission system operator. Price zones should be established to give sufficiently strong signals for locating generation where it is most valuable. This would be particularly helpful for optimising the location of solar and wind capacity.

A liquid and transparent wholesale electricity market, including a vibrant power exchange, should be further developed to facilitate effective competition. The development of demand-side response with economic instruments should be encouraged. If legal unbundling proves insufficient, ownership unbundling should be considered. Finally, it is essential to ensure that the regulator and competition authority have sufficient independence and resources.

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Turning to gas markets, Japan's gas industry remains dominated by a few vertically integrated companies that are based in large urban regions. They control the importation and regasification of LNG and the supply, marketing and transport of gas to larger individual customers and smaller gas distributors and retailers. They are regionally based with limited pipeline interconnectivity which makes effective competition in the sector challenging. The sector also needs wholesale trading markets and visibility of price drivers. Consumers (both large and small) would also benefit from access to better information on cost structures, for example.

Following the electricity market reform, the government has also embarked on a gas market reform, with the same three objectives: securing supply, decreasing prices as much as possible, and expanding consumer choice and business opportunities. The gas market reform consists of introducing full retail competition in 2017, improving access to pipelines and improving third-party access conditions and tariffs related to LNG terminals. The IEA welcomes this necessary reform. It also welcomes the recent proposals from METI on a new strategy for developing a more flexible international LNG market, including developing an LNG trading hub in Japan.

OIL SECURITY

Oil continues to account for more than two-fifths of Japan's TPES. Securing oil supplies has traditionally been a key part of the government's energy policy as reflected in its active resource diplomacy and upstream investments abroad by Japanese companies, often with government support.

Oil stocking policy was revised after the Great East Japan Earthquake to allow for stock release also when a supply shortage arises as a result of a natural disaster. The IEA applauds increasing the flexibility in the system. It also commends Japan's high level of oil stocks. Regarding the restructuring of the oil-refining industry, increasing the sector's competitiveness is important, but in the face of strong consolidation, sufficient competition in the retail market must be ensured to maintain room for consumer choice.

PROMOTING RENEWABLE ENERGY

Renewable energy is both a strategic opportunity and a practical challenge. Deploying a balanced renewable energy portfolio will diversify the supply base, thus increasing Japan's energy security. More distributed generation resources can enhance the system's resilience to natural disasters. Moreover, a substantially increased portfolio of renewables will be required to achieve Japan's emissions reduction targets to 2030.

Japan introduced a feed-in tariff system in July 2012 to increase generation as quickly as possible. However, the results of this approach have been mixed. While renewable energy experienced a significant and unexpectedly rapid boost, growth was concentrated in solar photovoltaics (PV) the total capacity of which has exceeded 32 gigawatts. The rapid scale-up of solar PV has translated into an urgent need to increase the flexibility of the overall power system, to significantly reduce generating costs and to increase the capacity of other renewables, such as wind and geothermal energy.

As in several other IEA countries, Japan's initial subsidy levels for solar PV proved too generous without due consideration to the underlying cost development. The overall

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subsidy cost for renewables is estimated at JPY 2.3 trillion in fiscal year 2016 and METI expects this to rise to between JPY 3.7 and 4.0 trillion by 2030, as renewable electricity generation is expected to increase by around 100 terawatt-hours over the level in 2014 to supply 22% to 24% of the country's electricity. Measures to control the costs of the feed-in tariff system are being taken. Tariffs for new facilities are reviewed every year and a comprehensive reform of the feed-in tariff system and other renewable energy support policies is currently under way. An auction system for large solar PV projects will be introduced in April 2017. At the same time, measures for increasing other renewables, such as wind and geothermal, will be also introduced.

All these reforms will have to be duly implemented. Additional actions will be needed to expand the portfolio of renewable energy technologies towards a more balanced mix, including renewable heat and distributed generation closer to demand centres. Those actions will also need to address non-economic barriers, e.g. through a better co-ordination and simplification of environmental impact assessments.

Grid integration of variable renewable electricity is challenging in Japan, owing to both the country's geography and the historical evolution of the electricity sector. To reap the full benefits from the electricity market reform, it will be critical to designate an independent body to advise on the technical issues of grid integration in a neutral way. Combining this with Japan's excellent research and development (R&D) infrastructure will create a positive environment to make further progress.

KEY RECOMMENDATIONS

The government of Japan should:

- ☐ *Strive towards a well-balanced and diversified energy mix, including renewable and nuclear energy, and efficient thermal power generation, taking into account safety, energy security, economic efficiency and environmental protection.*
- ☐ *Take all necessary measures to meet the 2030 objectives and to continue towards 2050 objectives, including by*
  - *facilitating increases in low-carbon sources of primary energy and electricity supply, while addressing safety, cost and public acceptance*
  - *continuing to gradually introduce fiscal incentives and stricter requirements for energy efficiency*
  - *ambitiously promoting Japan's proven and considerable potential for innovation in critical low-carbon technologies.*
- ☐ *Finalise the implementation of the electricity and gas market reforms as scheduled; ensure that the regulator and competition authority are adequately resourced; specifically for electricity, facilitate and encourage building infrastructure for creating a well-integrated national grid and a market design that includes strong signals to locate generation where it is most valuable to the system.*
- ☐ *Continue to support renewable energy deployment and focus on*
  - *controlling additional burden on consumer tariffs from support costs and aligning support towards global benchmarks*

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- *increasing the effectiveness of the support and reviewing it regularly to reflect advances in technology*
- *facilitating the deployment of a technologically and geographically balanced portfolio*
- *introducing neutral institutional arrangements to accelerate grid integration.*

References

METI (Ministry of Economy, Trade and Industry) (2015), "Long-Term Energy Supply and Demand Outlook", METI, Japan, www.meti.go.jp/english/press/2015/pdf/0716_01a.pdf.

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PART I
POLICY ANALYSIS

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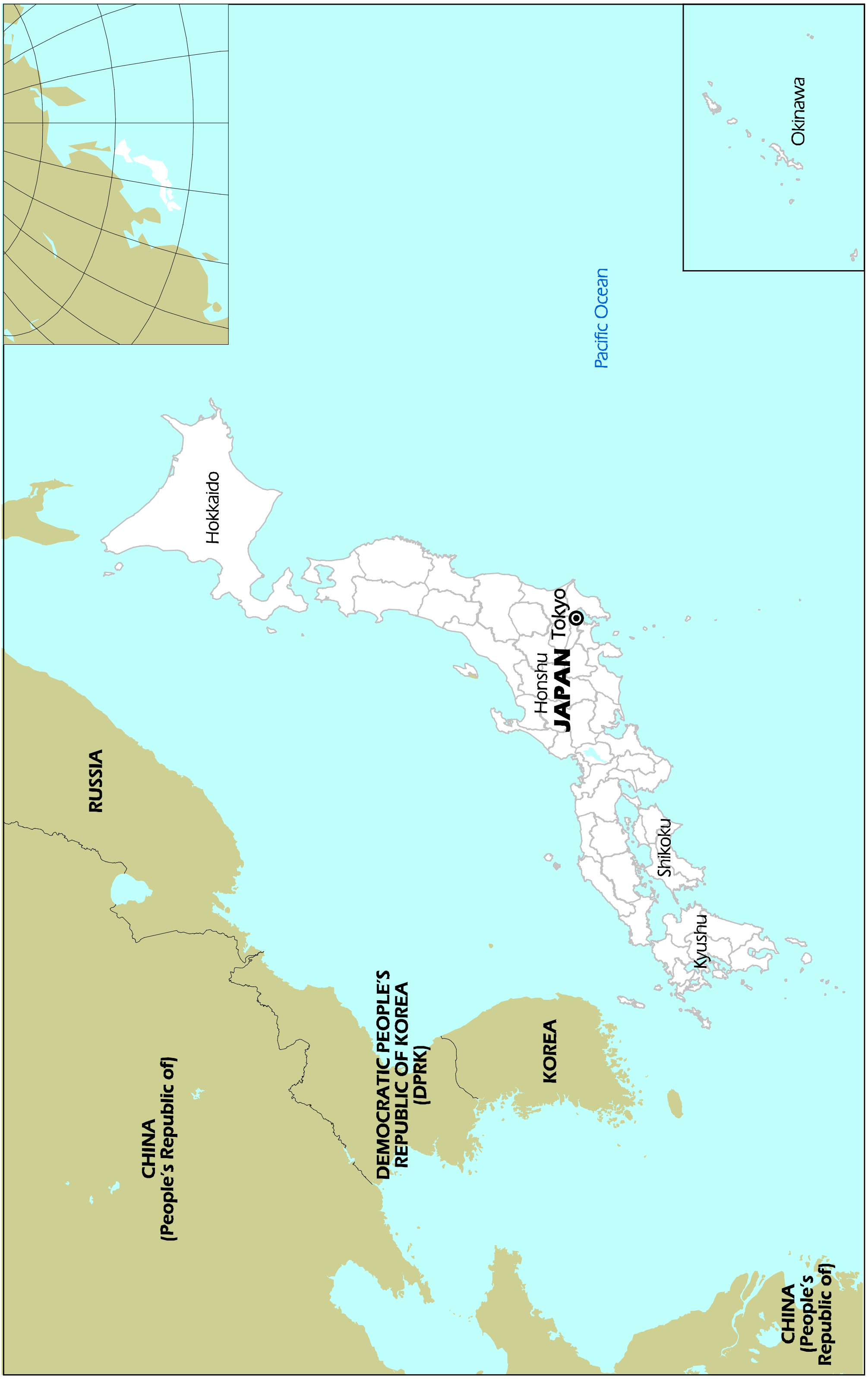
Figure 2.1 Map of Japan



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

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2. GENERAL ENERGY POLICY

Key data (2015 estimated)

Energy production: 30.4 Mtoe (biofuels and waste 37.5%, hydro 24.1%, natural gas 8.5%, nuclear 8.1%, solar 11%, geothermal 7.8%, oil 1.6%, wind 1.5%), -73.2% since 2005

TPES: 436 Mtoe (oil 42.9%, coal 27.5%, natural gas 23.3%, nuclear 0.6%, biofuels and waste 2.6%, hydro 1.7%, geothermal 0.5%, solar 0.8%, wind 0.1%), -16% since 2005

TPES per capita: 3.4 toe (IEA average: 4.5 toe)

TPES per GDP: 0.08 toe/USD 1 000 PPP (IEA average: 0.11 toe/USD 1 000 PPP)

Electricity generation: 1 009 TWh (natural gas 39.2%, coal 34%, oil 9%, nuclear 0.9%, hydro 8.4%, biofuels and waste 4.1%, solar 3.6%, wind 0.5%, geothermal 0.3%), -10.7% since 2005

Power generation per capita: 8 MWh (IEA average: 9.9 MWh)

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 378 000 square kilometres (km^2). The climate is largely temperate, though summers can be hot and tropical, particularly in the south, and winters can be quite cold throughout the country. Mountains cover around two-thirds of the country and arable land is just under 13%.

Japan has a population of 127 million and its population density is the fourth-highest among the International Energy Agency (IEA) countries, after Korea, the Netherlands and Belgium. The population is ageing fast by international standards and is expected to decline to 124 million by 2021, according to International Monetary Fund (IMF) projections. The working age population has peaked and the unemployment rate is very low, at 3.4% in 2015 (IMF, 2016).

One of the world's major economies, Japan's nominal gross domestic product (GDP) is the third-highest, after the United States and China. In 2015, GDP was USD 4.1 trillion and GDP per capita USD 32 500, according to the IMF. GDP was flat in 2014 and grew by 0.5% in 2015. In total, GDP was practically the same in 2015 as in 2007. As in many other Organisation for Economic Co-operation and Development (OECD) countries, slow economic growth has triggered government stimulus, and Japan's government debt to GDP ratio has risen to 250% in 2016, the highest among developed countries.

Services account for around three-quarters of the economy and industry for around one-quarter. The primary sector (agriculture, fishing, forestry) provides around 1% of GDP. The manufacturing sector is large and generally well-known for its high level of innovativeness and quality performance. Japan is the world's fourth-largest exporter,

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after China, the United States and Germany. The largest export goods are vehicles, machines and engines, and electronic equipment.

Japan relies heavily on imports for primary energy and industrial raw materials, as it has few mineral resources. It traditionally runs a trade surplus, but in 2011-15 its trade balance recorded deficits for the first time in decades, to a large part because of the increased imports of fossil fuels to fill the gap in power generation caused by the post-Fukushima shutdown of nuclear power plants.

The current government, in office since December 2012, is headed by Prime Minister Shinzo Abe of the Liberal Democratic Party (LDP). The fiscal year (FY) runs from 1 April to 31 March.

SUPPLY AND DEMAND

SUPPLY

Japan's total primary energy supply (TPES)[1] was 436 million tonnes of oil-equivalent (Mtoe) in 2015. TPES reached a peak of 521 Mtoe in 2004 and has been declining since. During 2008-09, energy supply declined by 8.5% in total, with a 5.9% partial rebound in 2010. In the five years since, TPES contracted by 13.1% (Figure 2.2).

Since the late 1970s until 2011, Japan's energy supply was dominated by fossil fuels and nuclear energy. The 2011 Great East Japan earthquake and the subsequent Fukushima Daiichi nuclear accident changed this set-up, however. The government ordered that the nuclear power plants (NPPs) comply with the new, more stringent regulations in order to resume operation after they suspended operation for regular maintenance. Consequently, all NPPs were shut down by 2013. After a prolonged review process under the new safety regulations, the first restarts occurred in the second half of 2015. The gap in electricity generation was filled mainly by fossil fuels, but also by renewable energy, encouraged by feed-in tariffs since 2012, and by energy efficiency and conservation.

In 2015, fossil fuels accounted for 93.7% of TPES, the highest among IEA member countries (Figure 2.3). The share of fossil fuels in TPES has increased from 80.9% in 2010. In 2014, there was no nuclear power generation in Japan for the first time in 40 years. While the share of nuclear energy in TPES fell from 15% to zero, the share of natural gas increased from 17.3% in 2010 to 23.3% in 2015, that of coal from 23.1% to 27.5%, and that of oil from 40.6% to 42.9%.

Renewable energy sources increased their share in TPES from 4.0% in 2010 to 5.7% of TPES in 2015 when they comprised biofuels and waste (2.6%), hydro (1.7%), geothermal (0.5%), solar (0.8%) and wind (0.1%). Renewable energy production grew by 56% over the ten years to 2015, mainly from new solar and wind sources since 2012. The share of renewables in TPES increased from 3.1% in 2005.

1. TPES is made up of production *plus* imports *minus* exports *minus* international marine bunkers *minus* international aviation bunkers *plus/minus* stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (for example refining) or in final use.

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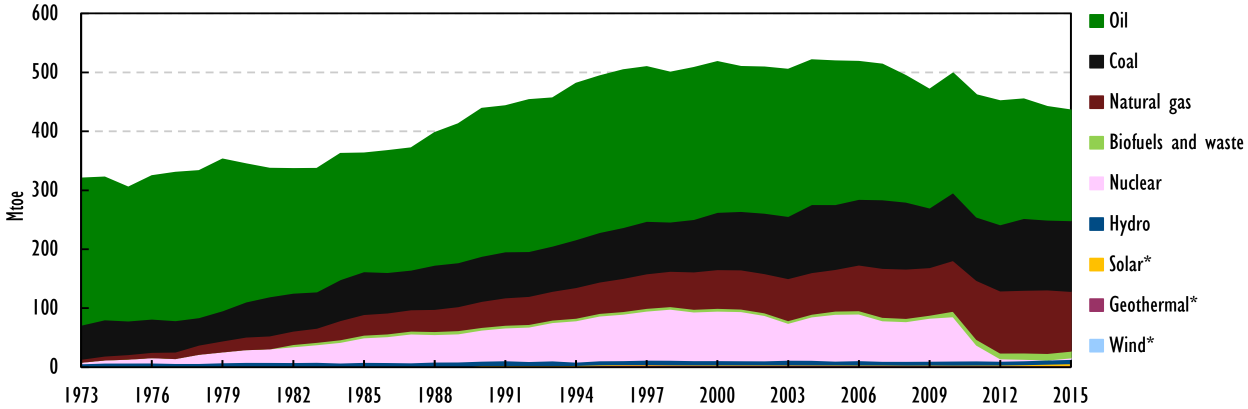
Figure 2.2 TPES, 1973-2015

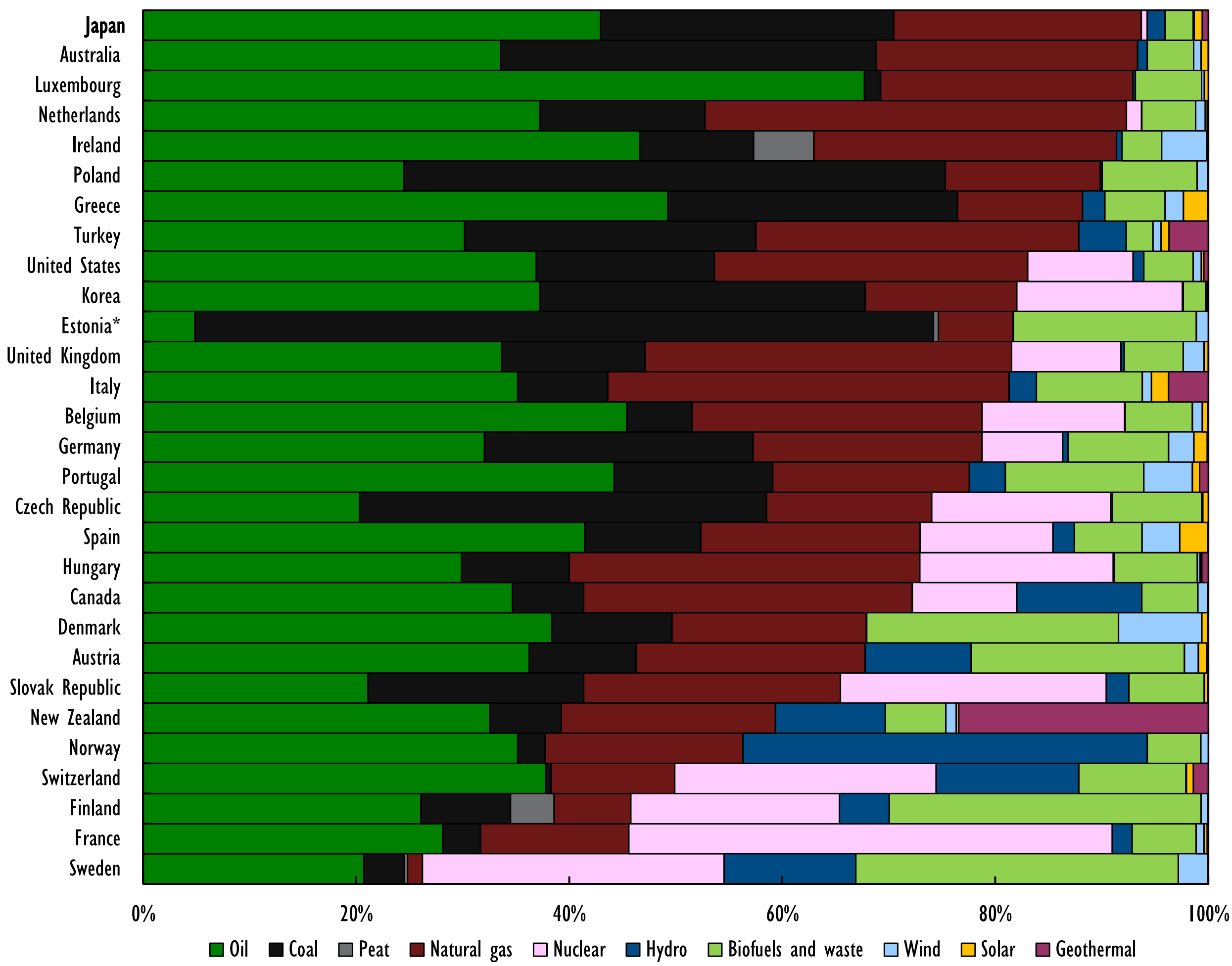


Note: Data are estimated for 2015.

* Negligible.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

Figure 2.3 Breakdown of TPES in IEA member countries, 2015



Note: Data are estimated.

* Estonia's coal represents oil shale.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

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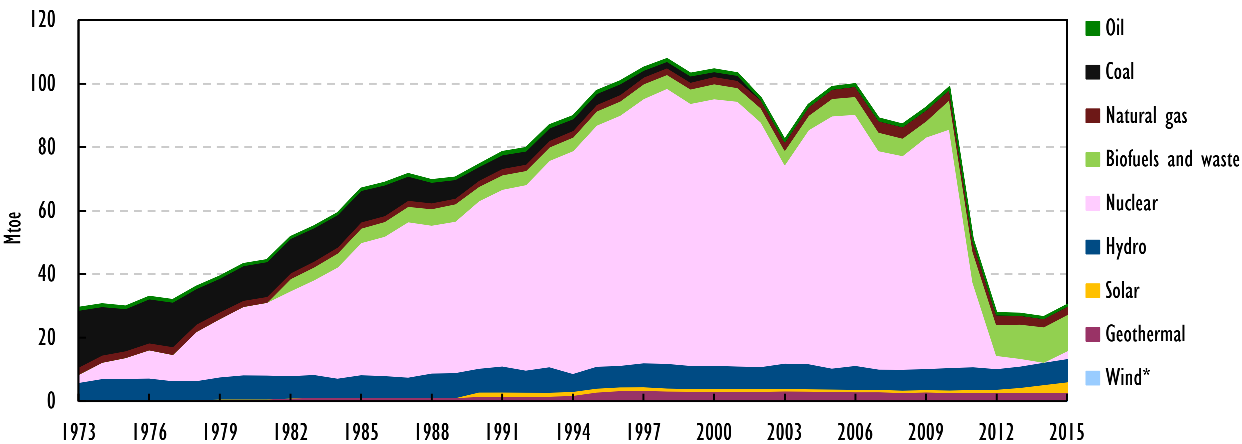
Japan is a large economy with few mineral resources. It relies on imports for almost all of its oil, natural gas and coal supply. Domestic energy production accounted for around 7% of TPES in 2015. Before the nuclear power shutdown, domestic production represented around 20% of TPES (15% from nuclear). Energy production in 2015 consisted of biofuels and waste (37.5%), hydro (24.1%), natural gas (8.5%), nuclear (8.1%), solar (11%), geothermal (7.8%), oil (1.6%) and wind (1.5%). In 2010, nuclear power accounted for 75.9% of domestic energy production, with the remainder made up of renewables (20.2%) and natural gas and oil (3.9%) (Figure 2.4). Most notably since 2010, solar energy production has increased by 207.8% and that of biofuels and waste by 19.7%.

In 2015, energy imports amounted to 434 Mtoe and exports to 19 Mtoe. Imports of crude oil and oil products totalled 215 Mtoe (49.5% of the total); coal 120 Mtoe (27.7%); and natural gas 99 Mtoe (22.7%). Exports were made up of oil products (18.3 Mtoe) and coal (0.5 Mtoe). Since 2010, imports have increased by 1.6% and exports by 4.5%. The strongest increase in imports came from natural gas (19.3%) and coal (4.3%), while oil imports declined by 6.2%.

Figure 2.4 Energy production by source, 1973-2015



Note: Data are estimated for 2015.

* Negligible.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

DEMAND

Japan's total final consumption (TFC)[2] amounted to 296 Mtoe in 2014 (the latest year for which consumption data are available). TFC represented around 67% of TPES in 2014, with the remainder used in power generation (including losses) and other energy industries. TFC peaked at 330 Mtoe in 2004 and has declined by 10.4% in the ten years to 2014 (Figure 2.5). The strongest decline was 7% in 2008, followed by a 3.2% rebound in 2010. Industry is the largest consuming sector with 41.9% TFC in 2014, or 124 Mtoe. Transport represented 24.2% and services and agriculture 18.8%, while households consumed 15.1%. Since the peak in 2004 to 2014, demand in transport declined by 12.1% and in industry by 13.1%. TFC decreased more slowly in households (by 8.6%) and services (by 2.4%).

2. TFC is the final consumption by end-users, i.e. in the form of electricity, heat, gas, oil products, etc. TFC excludes fuels used in electricity and heat generation, and in other energy industries (transformations) such as refining.

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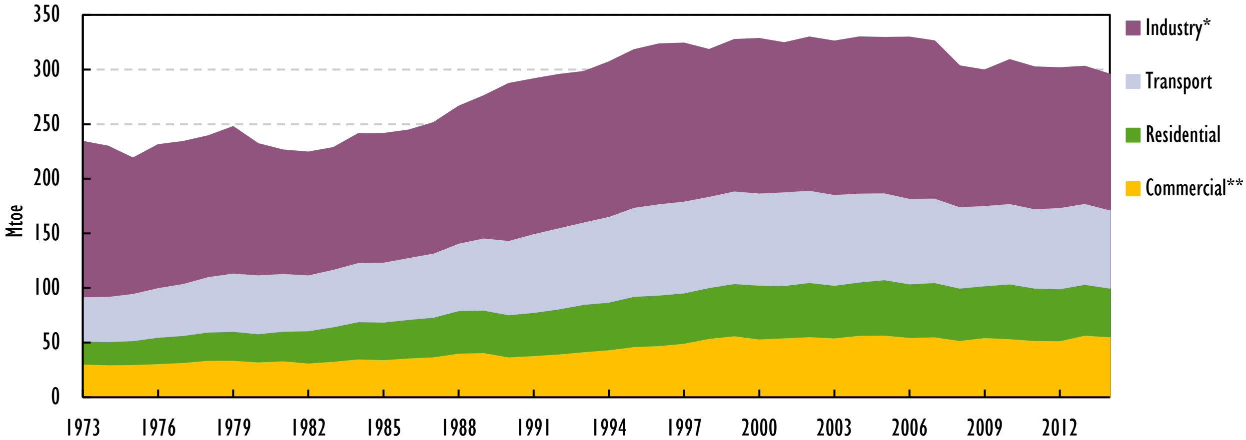
Figure 2.5 TFC by sector, 1973-2014



* *Industry* includes non-energy use.

** *Commercial* includes commercial and public services, agriculture, fishing and forestry.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

INSTITUTIONS

The **Ministry of Economy, Trade and Industry (METI)** has the overall responsibility for energy policy in Japan. Within METI, this policy has been delegated to the **Agency for Natural Resources and Energy (ANRE)**. ANRE is in charge of comprehensive energy policies to ensure strategic energy security, realise an efficient energy supply and promote environment-friendly energy policies. METI is also 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.

Other government departments involved in the energy sector include the **Ministry of the Environment** (climate change and air pollution mitigation), the **Ministry of Education, Culture, Sports, Science and Technology** (certain areas of energy research and development), the **Ministry of Land, Infrastructure, Transport and Tourism** (energy efficiency) and the **Ministry of Foreign Affairs** (resource diplomacy).

The **Electricity Market Surveillance Commission (EMSC)** was established in September 2015 under the Minister of Economy, Trade and Industry. EMSC monitors the electricity market and enforces strict regulations to ensure the neutrality of electricity networks. It can also suggest policy recommendations to the minister regarding rule making in the market. In April 2016, its authority was expanded to cover also the gas and heat markets and its name was changed to the **Electricity and Gas Market Surveillance Commission (EGC)**.

The **Japan Fair Trade Commission (JFTC**) is responsible for monitoring competition in all sectors of the economy. For the electricity and natural gas industries, it is increasing its surveillance as the market reforms advance.

The **Nuclear Regulation Authority** was established in September 2012 as a fully independent body in charge of protecting the general public and the environment through rigorous and reliable regulation and oversight of nuclear activities. Previously, it was the Nuclear and Industrial Safety Agency (NISA), a special agency attached to ANRE that regulated the nuclear energy sector.

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KEY POLICIES

In recent years, Japan's energy policy has been dominated by efforts to overcome the impact from the 2011 Great East Japan earthquake and the nuclear accident. At the 15th Conference of the Parties (COP15) in 2009, Japan had pledged an ambitious 25% cut in GHG emissions from 1990 to 2020. The pledge largely relied on plans to increase nuclear power's share in electricity supply from 30% to 50%. This increase was later envisaged in the third Strategic Energy Plan (SEP), dating from 2010.

In 2011, the plans to expand nuclear power were abandoned. Instead, the country's entire nuclear power capacity was gradually shut down by 2013 and is required to undergo safety inspections under the new rules before restarting. Restarts depend on passing a lengthy multi-stage safety review and the extent to which nuclear power will be restored remains unclear.

The nuclear shutdown left a gap of around 30% in electricity supply, mostly replaced by fossil fuels, primarily liquefied natural gas (LNG), but also by coal and oil and demand-side efforts. Import dependence shot to 94%, up from 80% in 2010. Electricity prices increased by 25% for households and by almost 40% for industry from FY2010 to FY2014. Annual carbon dioxide emissions from power generation rose by more than 110 million tonnes (Mt) or more than one-fifth from 2010 to 2013, according to IEA data. The situation was unsustainable for the long term. As a response, the government adopted the fourth SEP in April 2014 and based on it, METI prepared the "Long-term Energy Supply and Demand Outlook" to 2030, which was adopted in July 2015.

THE 2014 STRATEGIC ENERGY PLAN

The government outlines its energy policy in SEPs which are adopted every few years. The current one, the fourth SEP, was adopted in April 2014. It was developed in response to significant changes in the domestic energy policy landscape after the 2011 Great East Japan earthquake and the nuclear accident, as well as changes in global energy markets.

The SEP confirms the basic viewpoint of energy policy: energy security (stable supply), economic efficiency (cost reduction) and the environment (environmental suitability) on the premise of safety ("3Es plus S"). In addition, the SEP defines the position of each energy source and the government's policy direction.

The SEP characterises renewable energy as promising, multi-characteristic, important, low-carbon and domestic energy sources. It aims at accelerating their introduction as far as possible for three years, and then at continuing to promote them. The SEP sees it necessary to proceed with technology development in a way that maintains a good balance between economic efficiency and other factors, while taking into consideration the different characteristics of various energy sources.

Nuclear energy is described as an important baseload power source, as a low-carbon and quasi-domestic energy source, contributing to stability of energy supply-demand structure, on the major premise of ensuring its safety.

Coal is viewed as an important baseload power source in terms of stability and cost-effectiveness. Coal will be used while reducing its environmental load (e.g. utilisation of efficient thermal power generation technology).

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Oil, according to the SEP, is an important energy source as both an energy resource and a raw material, especially for the transport and civilian sectors, as well as a peaking power source.

Natural gas is an important energy source, whose role is expected to expand in various sectors. It plays the central role as an intermediate power source. Liquid petroleum gas (LPG) is a clean and distributed energy source that can be used both in everyday life and in emergency situations.

One of the many goals of the SEP is to build a flexible and diversified energy supply-demand structure and supporting policies. An important element of this is the electricity and gas market reform to open the retail markets to full competition, to unbundle the network operations (transmission and distribution) from the other business activities of the incumbents and to facilitate new entrants to the market.

The SEP also promotes a multi-layered resource diplomacy with countries exporting natural resources. It supports a continued government funding of energy supply projects abroad. It also suggests establishing a stable and flexible LNG supply-demand structure, including establishing Japan as a hub of a future Asian LNG market.

Further, the SEP promotes strong efforts on energy efficiency across sectors through standards, investment and innovation. It also aims at facilitating a more dynamic energy business sector and higher investment in research, development and deployment (RD&D). The SEP also includes actions related to the restoration and reconstruction of Fukushima and to ensuring nuclear safety.

THE 2015 LONG-TERM ENERGY SUPPLY AND DEMAND OUTLOOK

The 2015 Outlook describes a forecast but also a vision of a desired future energy supply and demand structure to be realised, in light of the SEP, by executing the policies based on the fundamental direction of the energy policy, and assuming the policy goals to be achieved regarding safety, energy security, economic efficiency and environment (see Figures 2.6 and 2.7). It aims at a self-sufficiency ratio of around 25%. Before 2011, the ratio was around 20%.

The 2015 Outlook aims to contribute to a GHG emissions reduction target in line with the European Union and the United States. In addition, it aims to lower electricity costs: restarts of nuclear power plants would help reduce the overall costs of generating electricity, even while subsidies to renewable energy would be increasing. Both these would replace imported fuels. Safety is paramount, and nuclear restarts would depend on the results of the safety reviews. Energy efficiency requirements are to be raised gradually to help meet the objectives.

The 2015 Outlook had been prepared with climate change objectives in mind. After its adoption, Japan announced its intended nationally determined contribution (INDC) to reduce GHG emissions by 26% from 2013 to 2030. It further approved to head for cutting emissions by 80% to 2050 under the condition of making this compatible with economic growth. To support these promises, the government is working together with industry and academia to promote energy technology innovation under the Environmental Energy Technological Innovation Plan (with a focus to 2030) and the 2016 NESTI 2050 Strategy. Furthermore, in May 2016, the government adopted the Plan for Global Warming Countermeasures, which defines a path to achieve the country's 2030 target set out in its INDC as well as the 2050 Strategy goal.

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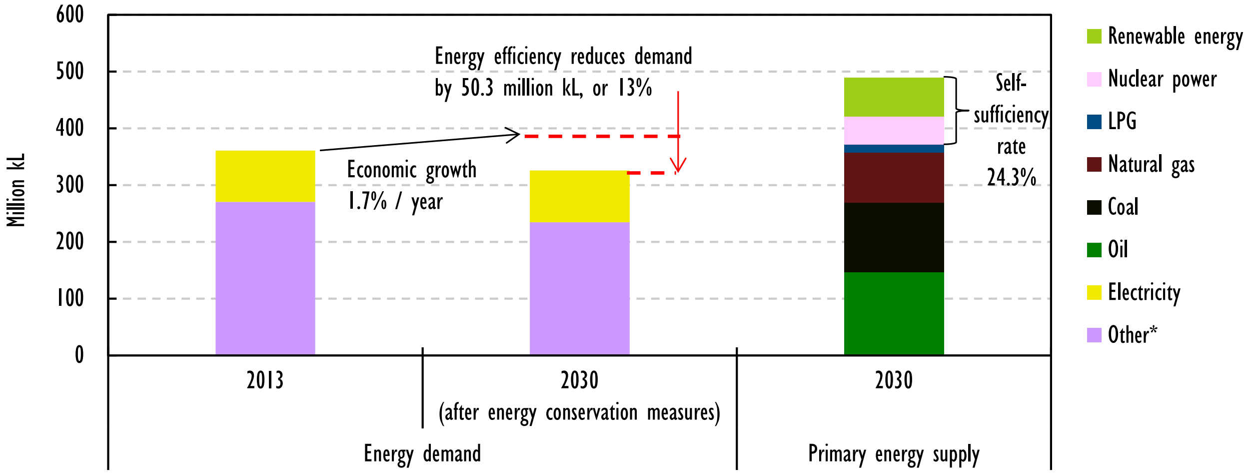
The 2015 Outlook is based on several assumptions, including power generation costs, technologies, and international fuel prices. To accommodate changes in the assumptions, the Outlook will be reviewed at least every three years, and as required, in response to the consideration of the SEP implementation.

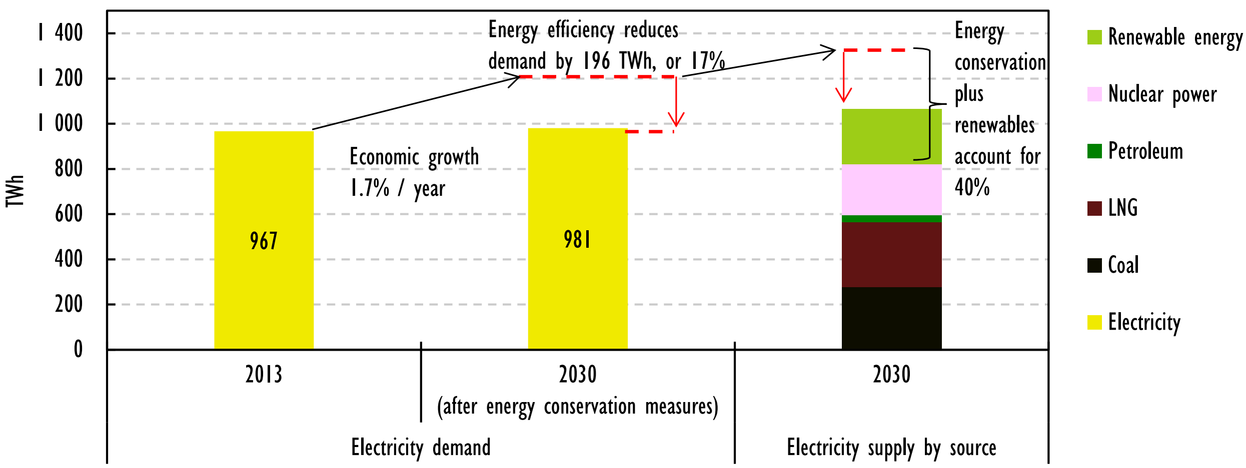
Figure 2.6 TPES and TFC in 2013 and projection to 2030



*Other includes heat, gasoline, town gas, etc.

Source: METI (2015), "Long-term Energy Supply and Demand Outlook".

Figure 2.7 Electricity supply by source in 2013 and projection to 2030



Source: METI (2015), "Long-term Energy Supply and Demand Outlook".

ASSESSMENT

The second-largest economy among the IEA member countries, Japan is the world's fifth-largest energy user and depends on imports for around 95% of demand. As in many other IEA member countries, securing energy supply has been the traditional driver for energy policy in Japan. Reflecting the combination of the country's limited domestic energy resources and its industrious and innovative qualities, Japan has long been a globally significant producer of highly efficient energy technology.

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Japan's successful efforts to balance energy security, economic efficiency and environment (the "3Es") in its energy policy were suddenly disrupted in 2011 by a natural disaster, the Great East Japan earthquake, followed by the Fukushima Daiichi nuclear accident. It can be said that Japan managed to recover from the direct physical impact of the natural disaster relatively rapidly, while the repercussions from the nuclear accident are still being felt in many ways.

From a domestic security of supply perspective, Japan's energy system has proved fairly resilient, but its energy self-sufficiency was only 7% in 2015, which puts Japan in a vulnerable and unsustainable situation in terms of securing affordable and environmentally sustainable energy supply.

The gap in the electricity supply-demand balance resulting from the complete shutdown of the Japanese nuclear capacity has been bridged by using fossil fuels and saving energy, and to some extent also by increasing renewable electricity generation. Japan is a pioneer in the use of LNG and its ample import capacity, the largest in the world, has been particularly crucial for maintaining security of electricity supply since 2011.

Japan will, however, face a challenge in scaling up significant volumes of low-cost, low-carbon electricity without nuclear power. This has been recognised in the April 2014 Strategic Energy Plan (SEP), which supports nuclear but with more prominence now being given to renewables. The 2015 "Long-term Energy Supply and Demand Outlook" assumes that nuclear will partially come back and reach 20% to 22% of electricity supply by 2030. Passing the multi-stage safety review is a precondition for the restarts. In practice, public acceptance also has a role. In general, the government should ensure well informed engagement of civil-society stakeholders in the energy policy-making process for effective achievement of those policy goals with better public acceptance.

Japan's future energy strategy should focus on limiting energy import costs and GHG emissions. The government should provide guidance on its vision for the future role of nuclear power, and consequently all other sources of power generation. Under all circumstances, significant potential remains to improve energy security.

Despite the current challenges, there is much to praise in Japan's domestic energy policies. It has a well-developed and robust energy RD&D programme, to which significant government resources continue to be devoted. Its commitment to energy RD&D spreads benefits beyond Japan. The country has shown leadership in particular in the Asia-Pacific region, helping to drive technology deployment and collaboration with its neighbours – helping expand energy efficiency and, as a result, increasing energy security and limiting GHG emissions. Japan is also a world leader in energy efficiency, particularly in improving the transport sector and Japanese industry, which is among the world's most efficient.

Reforming the electricity, gas and heat markets is high on the government's energy policy agenda. The electricity market reform will be crucial also for successfully transiting to a more sustainable and secure power system. The government should implement reforms in electricity and gas markets without delay to create more transparent, flexible and competitive markets. Independent regulators and ambitious competition law will help make market liberalisation a success which in turn should benefit consumers and the economy and help it return to growth.

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RECOMMENDATIONS

The government of Japan should:

- ☐ *Build on Japan's established track record of balancing sustainability, security of supply and economic efficiency in the energy sector, including on past success towards realising a low-carbon society and global leadership in energy efficiency.*
- ☐ *Continue to play a global leadership role on energy efficiency, sharing with others the lessons learned from its world-leading experience in delivering efficiency improvements, particularly in the transport and industrial sectors.*
- ☐ *Implement electricity and gas market reform as scheduled to create a more transparent, flexible and competitive market, while ensuring security of supply; make sure that energy regulators have sufficient independence, human resources and legal and regulatory powers.*
- ☐ *Ensure well-informed engagement of civil society stakeholders in the energy policy-making process for effective achievement of those policy goals with better public acceptance.*

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METI (Ministry of Economy, Trade and Industry) (2015), "Long-term Energy Supply and Demand Outlook", Tokyo.

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3. CLIMATE CHANGE

Key data (2014)

GHG emissions without LULUCF*: 1 364 $MtCO_2$-eq, +7.3% since 1990

GHG emissions with LULUCF*: 1 302 $MtCO_2$-eq, +7.5% since 1990

2008-12 target: -6% compared to 1990, **actual:** -8.4% compared to 1990

CO_2 emissions from fuel combustion: 1 189 $MtCO_2$, +14.2% since 1990

CO_2 emissions by fuel: oil 38.2%, coal 39.1%, natural gas 21.9%, other 0.9%

CO_2 emissions by sector: power generation 48.6%, manufacturing and construction 19.2%, transport 17.5%, commercial and other services 5.6%, residential 4.6%, other energy industries 4.5%

* Source: UNFCCC, 2016

GREENHOUSE GAS EMISSIONS

According to the United Nations Framework Convention on Climate Change (UNFCCC), carbon dioxide (CO_2) accounted for 92.8% of total greenhouse gas (GHG) emissions in Japan in 2014, methane (CH_4) for 2.6%, hydrofluorocarbons (HFCs) for 2.6% and nitrous oxide (N_2O) for 1.5%. Perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) collectively accounted for 0.5% of the total.

UNFCCC data show that Japan's energy sector accounted for 89.1% of total GHG emissions, followed by industrial processes (6.6%), agriculture (2.8%) and the waste sector (1.6%).

ENERGY-RELATED CO_2 EMISSIONS

SOURCES OF CO_2 EMISSIONS

Japan's CO_2 emissions from fuel combustion are estimated at 1 189 million tonnes (Mt) in 2014, 14.2% more than in 1990. Emissions increased steadily for decades to reach 1 221 Mt in 2007, before a 12.5% decline during 2008-09. Following the 2011 Great East Japan earthquake and the subsequent nuclear shutdown, increased use of fossil fuels in power generation pushed CO_2 emissions up by 11.8% from 2010 to 2014 (Figure 3.1).

The largest CO_2 emitting sector is power generation, accounting for 48.6% of the total in 2014. Industry accounts for 19.2% and transport for 17.5%. Services, households, other energy industries (including refining) and agriculture make up the remaining 14.7%.

From 1990 to 2014, CO_2 emissions grew in the power generation sector (by 46%), in other energy industries (11.7%) and in transport (4.4%). In all other sectors, emissions declined. Since 2010, the year before the decline in nuclear power began, emissions in power generation have increased by 17.5%. Over the same period, emissions from

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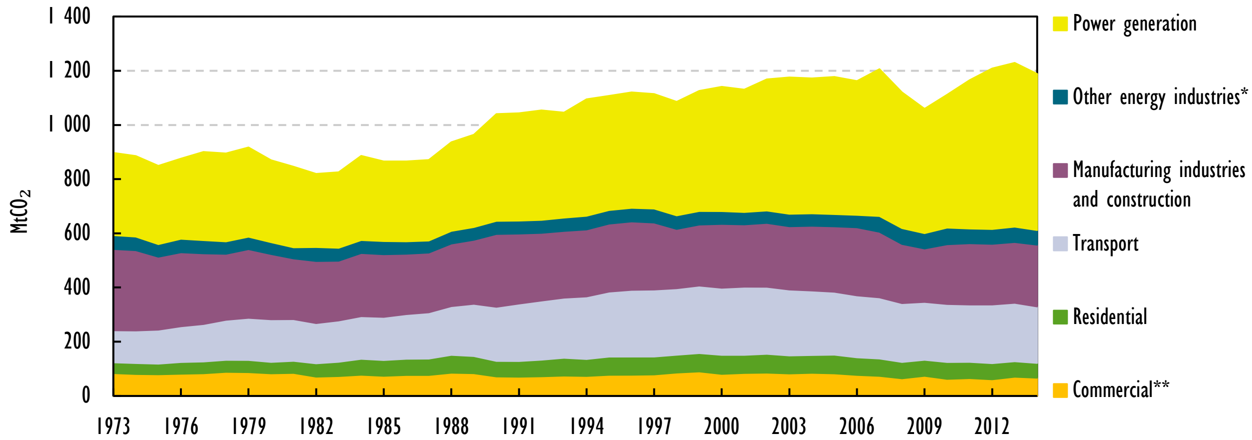
industry grew by 3.4% while emissions from other energy sectors declined by 11.9%. Over the same period (2010-14), emissions from households declined by 12.3% and from transport by 2.7%, but those from services increased by 6.9%.

Figure 3.1 CO_2 emissions by sector, 1973-2014

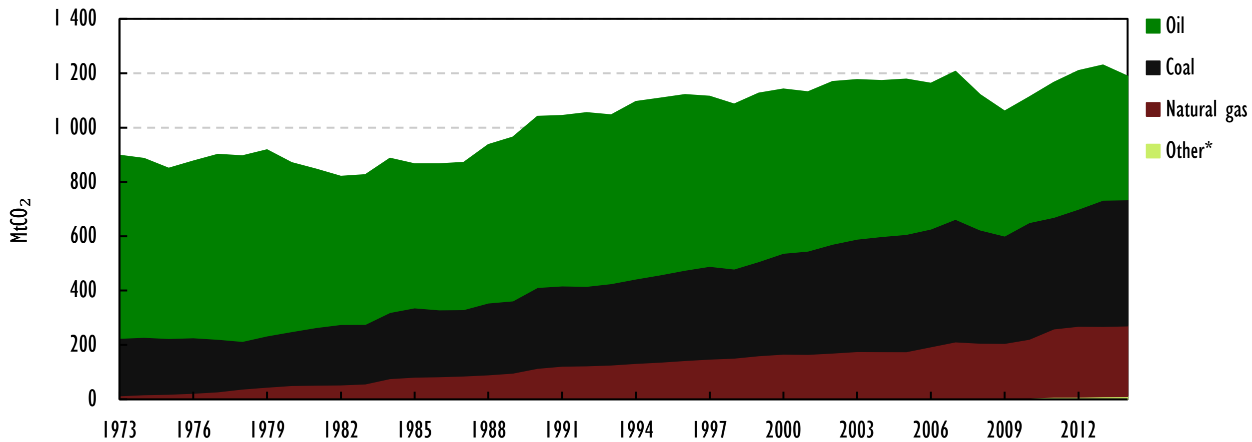


* *Other energy industries* includes other transformations and energy own-use.

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

Source: IEA (2016), *CO_2 Emissions from Fuel Combustion 2016*, OECD/IEA, Paris.

Figure 3.2 CO_2 emissions by fuel, 1973-2014



* *Other* includes industrial waste and non-renewable municipal waste (negligible).

Source: IEA (2016), *CO_2 Emissions from Fuel Combustion*, OECD/IEA, Paris.

By fuel, the largest CO_2 emitters are coal (39.1% of the total) and oil (38.2%). Oil is mainly consumed in the transport, industry and refining sectors, while coal is used in power generation and industry, mostly iron and steel production. Emissions from natural gas account for 21.9%, used across sectors apart from transport. Emissions from industrial and municipal waste are 0.9% of the total.

Compared to 1990, emissions from natural gas increased by 127%, those from coal by 56%, while those from oil decreased by 27.8%. From 2010 to 2014, however, emissions from natural gas increased by 20.2%, those from coal by 8.1%, while those from oil decreased by 1.6%.

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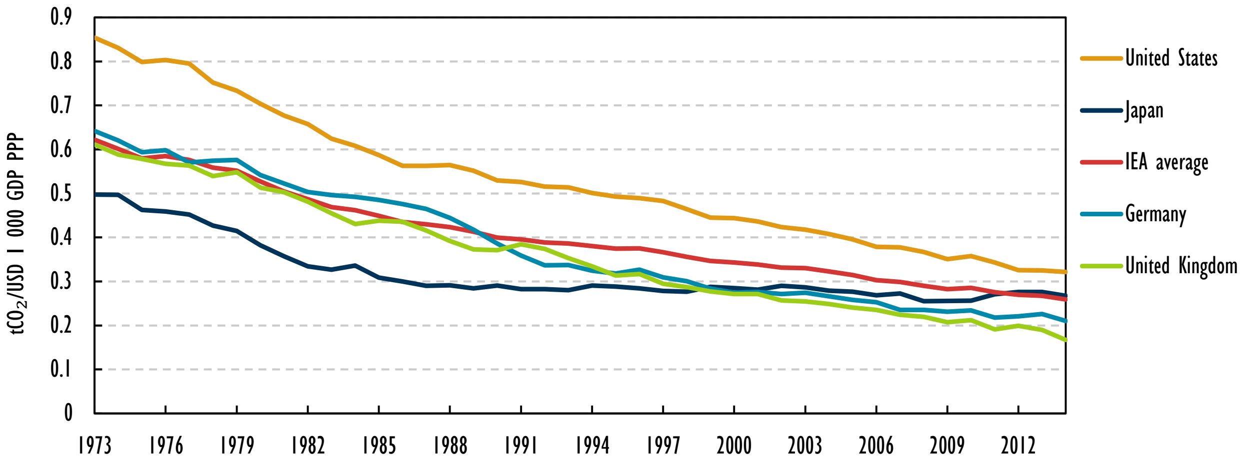
CARBON INTENSITY OF THE ECONOMY

Japan's carbon intensity, measured as CO_2 emissions per real gross domestic product (GDP) adjusted for purchasing power parity (GDP PPP), amounted to 0.27 tonnes of CO_2 per USD 1 000 PPP (tCO_2/USD 1 000 PPP) in 2014. Japan's carbon intensity is on par with the IEA average (0.26) but lower than the IEA Asia Oceania average of 0.29 tCO_2/USD 1 000 PPP. Carbon intensity was 8% lower in 2014 than in 1990 (Figure 3.3).

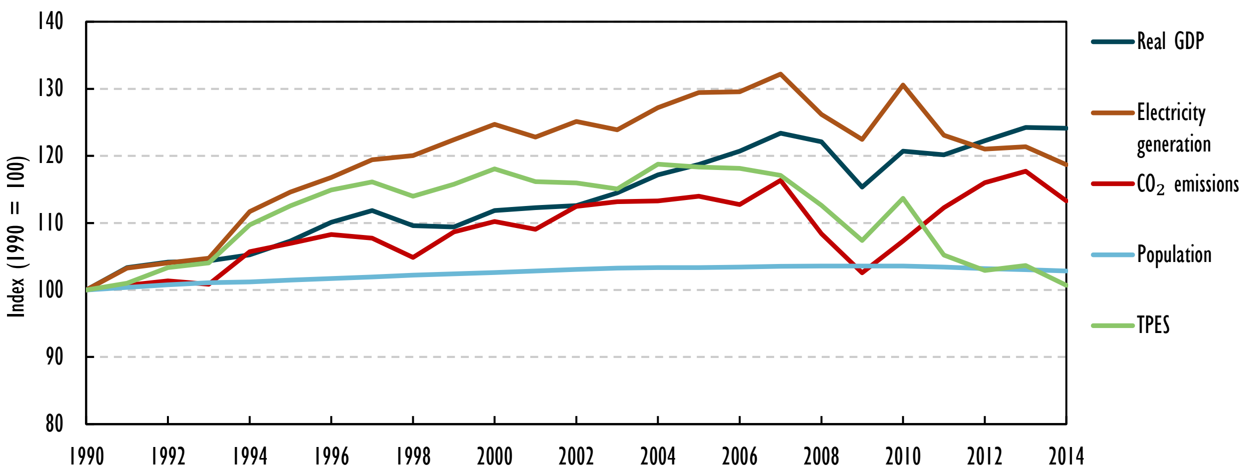
The recent increase in carbon intensity has been driven by the nuclear power shutdown and higher fossil fuel use in power generation. As shown in Figure 3.4, while TPES fell, CO_2 emissions continued to grow to 2013 which was quite exceptional among the IEA countries.

Figure 3.3 Energy-related CO_2 emissions per unit of GDP in Japan and in other selected IEA member countries, 1973-2014



Source: IEA (2016), *CO_2 Emissions from Fuel Combustion 2016*, OECD/IEA, Paris.

Figure 3.4 CO_2 emissions and main drivers in Japan, 1990-2014



Source: IEA (2016), *CO_2 Emissions from Fuel Combustion 2016*, OECD/IEA, Paris.

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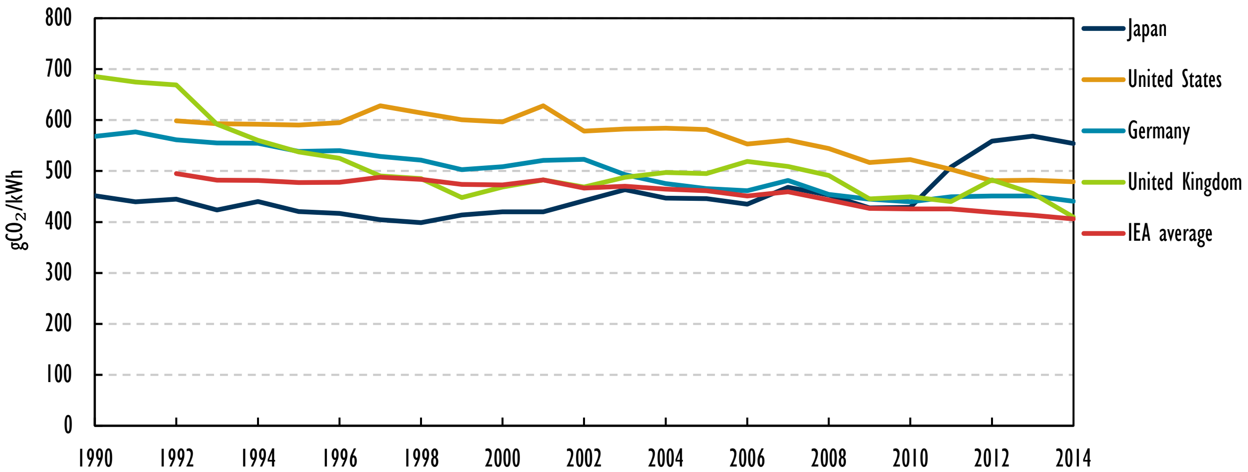
CARBON INTENSITY OF ELECTRICITY GENERATION

In 2010, before the Fukushima Daiichi nuclear accident, nuclear power was the second-largest source of electricity in the country, accounting for 25.3% of the total, and its carbon intensity was 429 grammes of carbon dioxide per kilowatt hour (gCO_2/kWh). By 2014, all nuclear power plants had been shut down and electricity generation relied more on natural gas, but also on oil and coal. From 2010, carbon intensity of electricity generation had increased to 554 gCO_2/kWh (by 29%). This was also the fifth-highest figure among the 29 IEA member countries. It was behind Australia (735 gCO_2/kWh), Estonia (732 gCO_2/kWh), Greece (667 gCO_2/kWh), Poland (630 gCO_2/kWh), but it preceded that of Korea (495 gCO_2/kWh).

Figure 3.5 CO_2 intensity of electricity generation in Japan and in other selected IEA member countries, 1990-2014



Source: IEA (2016), *CO_2 Emissions from Fuel Combustion 2016*, OECD/IEA, Paris.

INSTITUTIONS

The 1998 Act on the Promotion of Global Warming Countermeasures established the **Global Warming Prevention Headquarters (GWPH)** for the comprehensive, plan-based implementation of global warming countermeasures. The Prime Minister chairs the GWPH, while vice chairmen include the Chief Cabinet Secretary, the Minister of the Environment and the Minister of Economy, Trade and Industry. All other national ministers are members.

The GWPH prepares and executes the plan for global warming countermeasures, and co-ordinates their implementation from a long-term standpoint. The **Ministry of the Environment (MoE)** prepares the National Government Action Plan in line with the plan for global warming countermeasures and promotes climate change action. Governance on climate change at the local level is ensured by the **Regional Committees for Promoting Energy and Global Warming Countermeasures**.

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POLICIES AND MEASURES

TARGETS

Targets for 2008-12 and 2020

Japan's target under the Kyoto Protocol's first commitment period was to reduce GHG emissions from the base year (1990, except for F-gases 1995) to 2008-12 by 6%. The country met this target by using carbon sinks and international flexibility mechanisms. In 2008-12, Japan's annual GHG emissions averaged 1 278 $MtCO_2eq$, or 1.4% more than the base-year level (1990) of 1 261 $MtCO_2eq$. However, the net removals by forests and other carbon sinks averaged 48.7 $MtCO_2eq$ over the five years, equivalent to 3.9% of the base-year level. Moreover, Japan bought international carbon credits equalling 5.9% of the base-year GHG emissions. In total, the country's GHG balance in the 2008-12 commitment period was thus 8.4% below the base-year level.

At COP15 in Copenhagen in 2009, Japan did not take a commitment for the second Kyoto commitment period (2013-20), but pledged to reduce its GHG emissions by 25% from 1990 to 2020. This was one of the most ambitious pledges among the participating countries. The target was to be met largely by increasing the share of low-carbon power generation (nuclear and renewables) from 34% of the total in FY2007 to 70% in FY2020. Specifically, the share of nuclear was to increase from around 30% to 50%, according to the 2010 Third Strategic Energy Plan.

The March 2011 Great East Japan earthquake fundamentally changed the conditions for nuclear power and the national climate policy. Japan adopted in 2013 a new target of a 3.8% reduction in GHG emissions below 2005 levels to 2020, on the assumption that no nuclear reactors would restart during that period. The target meant a 3.1% increase over 1990 levels. The target is not enshrined in national law (OECD, 2015a).

Targets for 2030 and 2050

Ahead of COP21 held in December 2015, Japan announced in July 2015 its intended nationally determined contribution (INDC) to reduce GHGs by 26% from FY2013 to FY2030 (a reduction of 25.4% from 2005, or 1 079 $MtCO_2$-eq in 2030). The policies and measures to reach this target are listed in the Plan for Global Warming Countermeasures which was adopted by the government in May 2016 (see section on policies and measures below). In that context, the government also approved a long-term goal to head for cutting GHG emissions by 80% to 2050 under the condition that this is compatible with economic growth.

Meeting the 2030 target relies on the following three main assumptions for 2030:

- significant energy conservation efforts: in total final consumption (TFC), a 13% reduction from business-as-usual (BAU) and a 9.7% reduction from 2013 levels; in electricity demand, a 17% reduction from BAU and a 1.4% increase from 2013 levels, while simultaneously achieving 1.7% real GDP growth per year
- 20% to 22% share of nuclear power in electricity generation (0% in 2014)
- 22% to 24% share of renewable energy in electricity generation (14.4% in 2014).

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The 2030 plan is a balancing act between energy security, economic efficiency, environmental protection and safety. It is linked to and consistent with the 2015 "Long-term Energy Supply and Demand Outlook" (METI, 2015). (See Chapter 2 on general energy policy.)

After the 2011 Great East Japan earthquake and the subsequent shutdown of all nuclear power plants, Japan's dependence on energy imports rose to around 95%, electricity prices for households increased by 25% and for industry by almost 40% by the end of FY2014. CO_2 emissions from power generation rose by 86 Mt from 2010 to 2014, according to IEA data. The most cost-effective way to overcome all these negative developments is to restart nuclear power generation at plants that the regulator has approved to be safe.

Failing to meet the 20% to 22% share of nuclear power in electricity supply in 2030 will increase generating costs and, in the case of coal and gas use, CO_2 emissions. This is evident from METI's sensitivity analysis which calculates the impact on economic cost and CO_2 emissions when 1% of the share allocated to nuclear is substituted by coal, LNG or renewables (see Table 3.1). If the 20% to 22% share is entirely replaced by renewables, electricity costs will be JPY 4.3 to 4.8 trillion higher per year than the forecast for the INDC. Or, if nuclear is substituted with coal or gas, cost will increase less than with renewables, around JPY 0.8 to 2.2 trillion per year, but CO_2 emissions will increase by between 80 Mt and 185 Mt per year from the INDC (Arima et al., 2015).

Table 3.1 Sensitivity analysis of 2030 electricity source composition

	Coal -1%	LNG -1%	Nuclear power -1%	Renewables -1%
Coal +1%		+4.4 $MtCO_2$ -\64 billion	+8.4 $MtCO_2$ +\34 billion	+8.4 $MtCO_2$ -\184 billion
LNG +1%	-4.4 $MtCO_2$ +JPY 64 billion		+4.0 $MtCO_2$ +\98 billion	+4.0 $MtCO_2$ -\120 billion
Nuclear power +1%	-8.4 $MtCO_2$ -\34 billion	-4.0 $MtCO_2$ -\98 billion		±0.0 $MtCO_2$ -\218 billion
RES +1%	-8.4 $MtCO_2$ +\184 billion	-4.0 $MtCO_2$ +\120 billion	± 0.0 $MtCO_2$ +\218 billion	

Note: The calculation is based on the following assumptions: power generation efficiency ratio of 41% for coal and 48% for LNG. Unit fuel price of JPY 14 044/tonne for coal, JPY 79 122/tonne for LNG and JPY 1.54/kWh for nuclear. The unit price for coal and LNG refers to fuel import cost, and that for nuclear power refers to nuclear fuel cycle cost. Average feed-in tariff unit price for renewables: JPY 22/kWh.

Source: METI.

POLICIES AND MEASURES

For the first Kyoto commitment period (2008-12), Japan's industry opted for voluntary efforts to reduce CO_2 emissions. These efforts were organised by the industry sector under Keidanren, the Japan Business Federation. The first voluntary action plans date from 1997 and included 37 industries under Keidanren. By 2012, the number of industries had increased to 114, including 61 under Keidanren. Progress towards the voluntary targets is assessed every year by the individual companies, Keidanren's Industrial Structure Council and the government council, the meetings of which are open to the public.

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The voluntary action plans cover around 80% of manufacturing and energy industries' energy-related CO_2 emissions, or around half Japan's overall emissions. By FY2012, 84 out of 114 industries with voluntary action plans had reached their targets, resulting on average in a 12.1% reduction in manufacturing and energy industries' energy-related CO_2 emissions from 1990 to 2008-12.

Regarding targets for 2020, Keidanren has committed to build a low-carbon society. As of May 2016, 108 industries were making their plans to achieve their individual 2020 targets. Regarding targets beyond 2020, Keidanren presented its Action Plan towards Low-Carbon Society in July 2015, with a 2030 target. As of May 2016, the goals of the action plan, such as CO_2 reduction targets, were individually formulated for 96 industries in the industrial, commercial, transport and energy-conversion sectors.

Building on the voluntary efforts, the 2016 Plan for Global Warming Countermeasures lists two policies for industry: *a)* promoting and verifying action plans towards a low carbon society, i.e. towards CO_2 reduction targets based on maximum introduction of best economically available technology, and *b)* introducing highly energy-efficient equipment/devices, using Factory Energy Management System (FEMS) and promoting co-operative energy-efficient efforts between different businesses.

Policies and measures in the residential and commercial sectors include *i)* implementing the Top Runner Programme to improve the energy efficiency performance in equipment and devices, *ii)* introducing the mandatory building codes by 2020 for new buildings, and *iii)* supporting the deployment of combined heat and power. These measures are detailed in Chapter 4 on energy efficiency. The 2016 Plan for Global Warming Countermeasures foresees gradually stricter energy efficiency requirements for buildings, appliances and equipment. It also lists energy-saving renovations and promotion of net zero-energy houses. More intensive use should be made of Building Energy Management Systems (BEMS) and energy-saving diagnostics in companies, and Home Energy Management Systems (HEMS) and smart meters in homes. Finally, the 2016 Plan targets a 100% diffusion of highly efficient lighting, such as LED, by FY2030 and the introduction of 5.3 million house-use fuel cells by FY2030.

In the transport sector, measures include promoting next-generation low-emission vehicles, traffic flow improvements and eco-driving, use of public transport and modal shift (GOV, 2015). These measures are also included in the 2016 Plan for Global Warming Countermeasures. The Plan also introduces a target of 50% to 70% for the market share of next-generation low-emission vehicles in new automobile sales in 2030.

Purchases of next-generation cars are encouraged through taxation. The vehicle greening tax system includes reductions of vehicle taxes on the basis of emission levels and fuel efficiency. It also includes tax increases on polluting ageing cars. Under the eco-car tax reduction system, the vehicle acquisition tax and tonnage tax are exempted or reduced when purchasing a vehicle with excellent exhaust-gas performance and high fuel efficiency.

In the electricity sector, measures focus on supporting renewable energy to expand as much as possible, while decreasing the financial burden on the public, including by appropriate use and review of feed-in tariffs, grid system maintenance and consolidation of grid system operation rules. Measures also include increasing the efficiency of thermal power plants and facilitating the restarts of nuclear power plants that have received safety approval from the Nuclear Regulation Authority.

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Cross-sectoral measures include building low-carbon cities, urban structures and socio-economic systems. Related cross-sectoral strategies include the realisation of a hydrogen society (see Chapter 11 on RD&D), the Joint Crediting Mechanism (JCM, see International measures below), greening the tax system and using the Tax for Climate Change Mitigation. An emissions trading scheme (ETS) would be considered carefully, according to the 2016 plan.

The Tax for Climate Change Mitigation was introduced in October 2012 and gradually increased in April 2014 and April 2016 to reach a rate of JPY 289 per tonne of CO_2. The tax is levied on crude oil and oil products, natural gas and coal. The tax revenue, estimated at JPY 260 billion per year at the current rate, is used to support the reduction of emissions from energy use, e.g. renewable energy and energy efficiency projects.

The government sees a critical role for energy RD&D in helping Japan meet its climate targets in a cost-effective way. It has also adopted several strategies and programmes to this end. The September 2013 New Low-Carbon Technology Plan 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 April 2016, focuses on 2050.

The government is also active in several international efforts to promote energy technology innovation for climate change mitigation (see Chapter 11 on RD&D). At COP21, Prime Minister Abe announced Actions for Cool Earth (ACE2.0) which builds on the 2013 ACE. In ACE2.0, Japan proposes to provide, in 2020, JPY 1.3 trillion of public and private climate finance to developing countries, 30% more than the current level. In 2014, Japan launched an annual international conference called the "Innovation for Cool Earth Forum (ICEF)" to establish a global platform for governments, business and academia to promote innovation in low-carbon technologies including their dissemination. Furthermore, the April 2016 NESTI 2050 Strategy aims at reinforcing the development of innovative technologies in energy and environment, thus helping to significantly reduce GHG emissions.

International carbon credits

Japan proposed a new GHG emissions credit device, the joint crediting mechanism (JCM), in 2011 to facilitate the deployment of leading low-carbon technologies, products, systems, services and infrastructure as well as implementation of mitigation actions, and contribution to sustainable development of developing countries. Japan expects the JCM will contribute to the global actions for reducing GHG emissions complementing the clean development mechanism (CDM) under the Kyoto Protocol. For this, appropriately evaluating Japan's contributions to GHG emissions reductions or removals in a quantitative manner is required, by applying measurement, reporting and verification (MRV) methodologies, and using them to achieve Japan's emissions reduction target.

The government's plan to meet its 2030 reduction target, however, does not include the use of JCM, as some legal aspects remain unclear. Nevertheless, as of June 2016, Japan had consulted developing countries and signed bilateral JCM agreements with 16 countries.

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CARBON CAPTURE AND STORAGE

Strategic value of CCS

Carbon capture and storage (CCS) technologies can play an important role in reducing emissions from the use of fossil fuels. Applied to coal- and gas-fired power generation and industrial processes, CCS could deliver up to 13% of the cumulative emissions reductions needed globally to limit future average temperature increases to less than 2 degrees Celsius [IEA, 2015].

Japan recognises its strong strategic interest in the development and deployment of CCS technologies. The country is a major consumer of fossil fuels and currently has around 54 gigawatts (GW) of coal-fired and 47 GW of gas-fired power generating capacity. Coal and natural gas are expected to account for more than 40% of Japan's primary energy and 50% of electricity in 2030. The potential to retrofit CCS to existing and planned generation facilities may help to ensure their continued operation under the more stringent climate constraints anticipated in the future. Around 44% of Japan's coal is used in industry, and its steel and cement production is among the most energy-efficient in the world. However, CCS is recognised as the only technology option for achieving extensive emissions reductions in these processes.

Japan's R&D contribution

Japan is a world leader in researching and developing CCS technologies. It is host to a comprehensive R&D programme involving a number of public and private organisations, such as the New Energy Industrial Technology Development Organization (NEDO), the National Institute of Advanced Industrial Science and Technology (AIST), the Institute of Applied Energy (IAE), JCOAL and the Research Institute of Innovation Technology for the Earth (RITE).

Japan's R&D programme on CCS includes a strong focus on improving CO_2 capture technologies, including the development of new chemical solvents, amine solutions, solid absorbent and adsorbent materials, and CO_2 separation membranes. These technologies are being advanced in a number of operating pilot-scale demonstration projects. For example, the COURSE 50 project in Fukuyama is testing chemical absorption and physical adsorption technologies to deliver emissions reductions in iron and steel manufacturing. The Mikawa Post Combustion Capture (PCC) Pilot Plant is testing an amine-based chemical absorption system at the Mikawa coal-fired power plant in Fukuoka at a rate of 10 tonnes of CO_2 per day. This research is helping global efforts both to reduce the cost of capture technologies, and to position Japan as a major future supplier of CCS technologies to the world.

CO_2 storage

Over the past 15 years, Japan has been undertaking an extensive pre-commercial evaluation of its domestic geological storage potential. A USD 62 million R&D programme, launched by METI in 2000, found that Japan had an estimated 146 gigatonnes (Gt) of CO_2 storage capacity in onshore and offshore saline aquifers. In 2014, METI and the Ministry of the Environment commenced a detailed geological survey and assessment project which aims to identify at least three CO_2 storage sites around Japan. The project has received JPY 11 billion between FY2014 and FY2016 and is expected to continue until 2021.

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A pilot-scale storage demonstration has also helped to confirm the viability of CO_2 storage in Japan. Between 2003 and 2005, 10 400 tonnes of CO_2 were injected into a saline aquifer as part of the Nagaoka project. Monitoring of the stored CO_2 has continued well beyond the demonstration phase, providing valuable experience that has been shared internationally. The Tomakomai CCS Project (discussed below) will be another important step in improving the level of confidence in CO_2 storage opportunities in Japan. These efforts must continue to be prioritised, as the availability of CO_2 storage will be a major determinant of the country's ability to reduce emissions from its future use of fossil fuels.

Transport

Japan is investigating new and flexible approaches to CO_2 transport infrastructure through the use of so-called "shuttle ships". These relatively small (3 000 tonnes) ships would operate between the CO_2 emissions sources on the coast and offshore storage sites. The commercial feasibility of this approach will need to be explored through further research and pilot projects.

CCS projects in Japan

Japan has a number of CCS pilot projects under construction or operating which are demonstrating capture technologies and storage across several applications. These include the COURSE 50 project; Mikawa PCC Pilot Plant; Nagaoka CO_2 storage project; and the Osaki CoolGen project. The latter project will demonstrate oxygen-blown integrated gasification combined-cycle technologies on a 166 MW facility, including CO_2 separation and capture technology.

The Tomakomai CCS project is significant in that it will be Japan's first integrated CCS project, demonstrating the entire CCS value chain across capture, transport and permanent storage. The project, supported by METI, has a planned total budget of JPY 50 billion (USD 414 million) and is expected to commence operation in 2016.

The Tomakomai project will capture more than 100 000 tonnes of CO_2 per year from a hydrogen production unit at Idemitsu Kosan's Hokkaido Refinery at Tomakomai port. The CO_2 compression and injection facilities are onshore, but inject the CO_2 into two offshore reservoirs at different depths, the Moebetsu Formation (1 100 m) and the Takinoue Formation (2 400 m). The project will operate for three years, with environmental monitoring continuing for a further two years post-injection.

The project is being delivered by Japan CCS Co. Ltd, which was established in 2008 and is a venture between 35 Japanese companies with a strong interest in CCS, including the oil and gas industry, power generators and technology providers. This structure brings together a wealth of technical expertise and facilitates widespread diffusion of the knowledge gained through the project.

CCS communications

Lack of public awareness and acceptance of CCS is a significant potential barrier to future deployment and has been highlighted as a key priority in IEA's CCS Roadmap. Japan has recognised the importance of public acceptance and has been active in communicating the role of CCS. For example, the Japanese Knowledge Sharing Network has developed a detailed communications framework for CCS in Japan, in co-operation with the Global

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CCS Institute. Project-specific communications activities have also been prioritised. For example, the Tomakomai CCS project has undertaken extensive outreach with the local community and more than 1 000 people visited the Tomakomai site in 2015.

International collaboration

The extent of Japanese involvement in international CCS projects is commendable. The Japanese government and industry are actively involved in multi-lateral partnerships, including the Carbon Sequestration Leadership Forum and the Global CCS Institute. Japan also chairs the capture working group, and co-chairs the storage working group, of the International Standards Organization (ISO) Technical Committee 265 on carbon dioxide capture, transportation and geological storage, contributing to the development of recognised international best practice in these areas.

Japanese technology providers are involved, or have been involved, in significant projects throughout the world. These include the In Salah project in Algeria; the Lula Oil Field CCS Project in Brazil; the Callide Oxyfuel Project in Australia; and the Plant Barry CCS project in the United States. Mitsubishi Hitachi Power Systems has recently partnered with Saskpower in Canada to establish a Carbon Capture Test Facility (CCTF) at Saskpower's Shand power station. The CCTF, which was opened in June 2015, provides technology developers with an opportunity to test new and emerging carbon capture systems for coal-fired power plants.

Policy and regulatory frameworks

Japan has taken steps to implement an enabling regulatory framework for CCS. In 2009, METI released guidelines for the development of CCS projects ("For safe operation of a CCS demonstration project") and the government made amendments to offshore legislation, the Marine Pollution Prevention Act, to facilitate offshore CO_2 storage.

Japan's 2014 Strategic Energy Plan acknowledges a role for CCS and contemplates CCS deployment from 2020 onwards. It also states that a study "will be conducted on introducing CCS-ready facilities as early as possible with due consideration given to the possible timing of the commercialisation of CCS".[1] Japan does not currently have any specific policies to support deployment of CCS.

ASSESSMENT

Climate change

Japan successfully met its target under the Kyoto Protocol to reduce GHG emissions by 6% from the base year (1990, but 1995 for F-gases) to 2008-12. It did this by a combination of domestic measures and international carbon credits. The GHG target from 2013 levels is now -3.8% to 2020 and -26% to 2030. The May 2016 Plan for Global Warming Countermeasures lists measures across all sectors for meeting the 2030 target. It builds on several well-founded policies and measures, such as the voluntary action plans in industry and the Top Runner Programme for appliances, equipment and vehicles. The measures also include a carbon tax introduced gradually since October 2012, the revenue of which is used for curbing energy-related CO_2 emissions.

1. www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf.

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In many countries, environmental-related taxation has proved to be a cost-effective way to address GHG emissions, and achieve other environmental objectives, such as reducing local air pollution. Such taxes broadly follow the polluter-pays-principle which the OECD generally advocates. Raising carbon taxes typically boosts revenue while helping to curb energy-related CO_2 emissions. However, under the circumstance of high ex-tax energy prices, it is important to consider their economic impacts carefully. In the above context, the IEA welcomes Japan's plans to assess the effectiveness of its environmental-related taxation.

Meeting the 2030 GHG target critically depends on a nuclear comeback. If nuclear power generation falls short of the 20% to 22% target for 2030, renewable energy alone would be very expensive at current deployment costs to fill the gap, and its integration into the electricity system at the required volumes would be challenging. In all likelihood, more natural gas and coal would be used and meeting the GHG target would be complicated, if not impossible, with domestic measures alone. The government should be prepared for a variety of outcomes and several scenarios for the share of nuclear to 2030 and beyond could be used.

The 26% reduction in GHG emissions between today and 2030 is feasible with existing technology, but the leap from 2030 to 2050 to head for an 80% reduction from today requires radically more efficient, low-carbon technology to be first developed and then deployed. The government is fully aware of this, and considers innovation as key to effectively addressing the long-term climate change challenge. Together with the country's technologically very advanced industry, it has developed a long-term strategy to that end, the NESTI 2050 Strategy (see Chapter 11 on energy technology RD&D). Japanese companies are already world leaders in manufacturing low-carbon technology, such as vehicles, batteries and various appliances, but also lower-carbon power generation technology. New solutions to help decarbonise energy supply and demand would find global markets and benefit other countries, too.

Japan has been one of the leaders in international climate change discussions. The IEA encourages the government to continue its global efforts to combat climate change. Examples include enhancing international co-operation on the Action for Cool Earth (ACE2.0) and increasing bilateral co-operation with emerging economies on the Joint Crediting Mechanism (JCM).

Carbon capture and storage

Regarding CCS, the government recognises that, as Japan is a major user of coal and natural gas, it has a strong strategic interest in the development and deployment of CCS technologies where Japan is a world leader. The IEA also commends the government's active involvement in international projects and encourages it to continue its efforts in developing carbon capture and storage technologies.

The government should consider targeted policy support to bring forward investment in early CCS projects, particularly CO_2 storage development. It should also try and identify "sweet spots" where CCS can be deployed in the most cost-effective manner. These early investments will help accurately assess the future prospects for CCS in Japan, including the size and commercial viability of CO_2 storage resources. This will be essential to inform decisions on Japan's future energy mix and near-term investments in fossil fuel-based infrastructure.

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The IEA welcomes the government's plans to introduce CCS-ready facilities as early as possible, recognising that CCS-ready requirements can provide a form of "insurance" against the risk of stranded assets. The government and industry should also consider options to leverage the knowledge gained from the three-year Tomakomai project, including around CO_2 storage, to support future deployment of large-scale CCS projects.

RECOMMENDATIONS

The government of Japan should:

Climate change

- ☐ *Ambitiously work to meet the 2030 target and to head for the 2050 goal of reducing GHG emissions by implementing the 2016 Plan for Global Warming Countermeasures, and, with a view to 2050, by aggressively and consistently stimulating RD&D in energy technology.*
- ☐ *Continue to work closely with stakeholders to develop cost-effective climate change measures, including*
  - *regularly reassessing the voluntary action plans to ensure the adoption of higher standards*
  - *supporting the meeting of targets within the Keidanren Voluntary Action Plan towards 2030*
  - *securing the contribution of fiscal mechanisms to achieve long-term decarbonisation objectives.*
- ☐ *Continue its global efforts to combat climate change such as by enhancing international co-operation on the Action for Cool Earth 2.0 (ACE2.0) and by increasing bilateral co-operation with emerging economies on the Joint Crediting Mechanism (JCM).*
- ☐ *Promote low-carbon sources of energy, such as nuclear power, and energy efficiency to replace fossil fuels, wherever cost-effective and safe.*

CCS

- ☐ *Continue its efforts in developing carbon capture and storage technologies and focus future efforts on:*
  - *investing in the evaluation of CO_2 storage potential in and around Japan, with the aim of providing confidence in the availability of CO_2 storage to support future investment decisions by industry*
  - *continued leadership in CCS research and development, including a focus on reducing the cost of capture technologies*
  - *developing and implementing policies and measures to support the accelerated deployment of CCS in Japan, taking into account the results of the CO_2 storage site survey*
  - *maintaining Japan's strong contribution to international efforts to develop and deploy CCS, including through technology-led initiatives.*

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4. ENERGY EFFICIENCY

Key data (2015 estimated)

Energy supply per capita: 3.4 toe (IEA average: 4.5 toe), -15.5% since 2005

Energy intensity: 0.08 toe/USD 1 000 PPP (IEA average: 0.11 toe/USD 1 000 PPP), -19.7% since 2005

TFC (2014): 296 Mtoe (oil 52.7%, electricity 27.7%, natural gas 10.1%, coal 8%, biofuels and waste 1.1%, heat 0.2%, solar and geothermal 0.2%), -10.4% since 2004

Consumption by sector (2014): industry (41.9%), transport (24.2%), commercial and other services, including agriculture (18.8%), residential (15.1%)

FINAL ENERGY USE

FINAL CONSUMPTION BY SECTOR

Japan's total final consumption (TFC) of energy was 296 million tonnes of oil-equivalent (Mtoe) in 2014. Energy demand peaked at 330 Mtoe in 2004 and has been falling since, with a sharp contraction of 7% in 2008. TFC declined each year after 2006 aside from a 3.2% recovery in 2010 and a marginal 0.4% increase in 2013. Overall, demand was 10.4% lower in 2014 than the peak in 2004.

Industry is the largest consuming sector in Japan, with final consumption of 123.8 Mtoe in 2014 or 41.9% of TFC. Industry demand declined faster than overall demand from 2004 to 2014, by 13.1%. As such, its share in TFC has fallen from 43.2%. The most significant decline occurred in 2008 when demand fell by 10.5%.

In 2014, TFC in the transport sector amounted to 71.6 Mtoe (24.2% of the total) and services and agriculture to 55.5 Mtoe (18.8%). From 2004 to 2014, energy demand in transport contracted by 12.1%. Unlike in industry, demand in transport has been falling consistently without a deep dip in 2008. Transport accounted for 24.7% of demand in 2004.

TFC in services and agriculture was 55.5 Mtoe in 2014, only 2.4% lower than in 2004 when it accounted for 17.3% of total TFC in Japan. It declined by 5.3% in the three years after 2009, but increased by 9.8% in 2013.

Residential consumption amounted to 44.6 Mtoe in 2014, an 8.6% decline from 2004, however its share in TFC has increased from 14.8% to 15.1%. Demand by households has been declining for a decade, falling by 4.6% in 2008-09 albeit with a 5.7% increase in 2010. Variations in temperature and therefore in the need for heating and cooling partly explain changes in households' energy consumption year-on-year.

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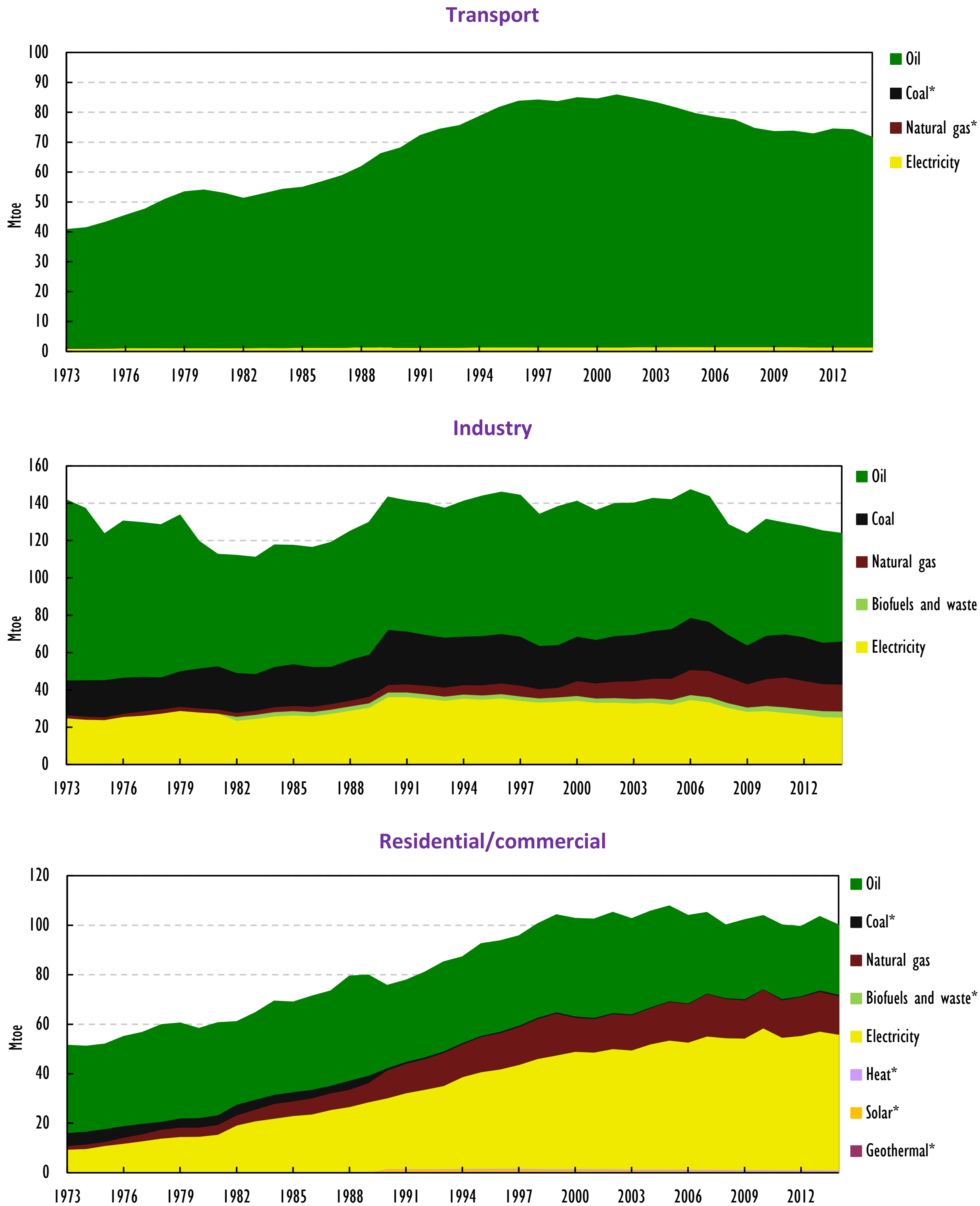
Figure 4.1 TFC by sector and by source, 1973-2014



* Negligible.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

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Oil is the main energy source in transport, accounting for almost 98% of the energy use in the sector. Electricity accounts for 2.1% and natural gas for 0.1%. Biofuels are not consumed in the Japanese transport sector.

Industry relies on oil for 46.5% of its energy demand, with the remainder made up by electricity (20.5%), coal (18.7%), natural gas (11.6%) and biofuels and waste (2.7%). Over the past decade, industry demand moved away from oil and electricity towards more gas use. The share of oil and electricity in TFC fell from 49.7% and 23.4% in 2004, respectively, while the share of gas increased from 7.4%.

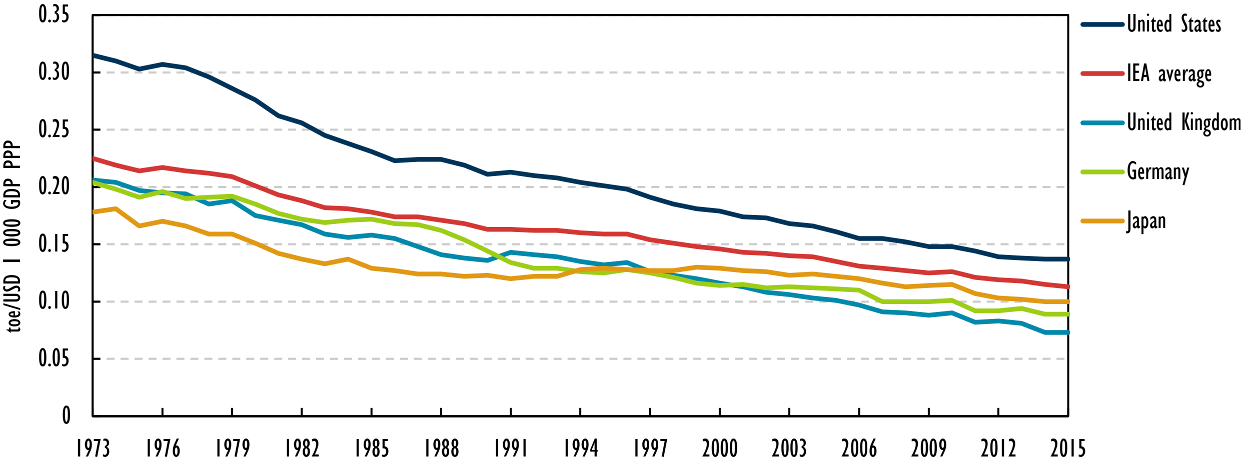
The residential and commercial sectors together consume mostly electricity (54.8% of total sectoral demand in 2014), followed by oil (27.9%) and gas (15.6%). Other sources accounted for 1.7% of demand. Over the past decade, demand has significantly moved from oil use towards more electricity and gas. In 2004, electricity accounted for 47.9% of TFC and natural gas for 13.8%, while oil held a share of 36.6%.

ENERGY INTENSITY

Energy intensity, measured as the ratio of total primary energy supply (TPES) per unit of real gross domestic product adjusted for purchasing power parity (GDP PPP) was 0.08 tonnes of oil-equivalent per USD 1 000 PPP (toe/USD 1 000) in 2015. The ratio is lower than the IEA averages of 0.11 toe/USD 1 000 PPP. Japan's energy intensity is ranked fifteenth-highest among IEA member countries, or around a median level. Japan's energy intensity in 2015 was 19.7% lower than ten years earlier, while the average IEA intensity declined by 15.4% over the same period (Figure 4.2).

A further common indicator for international comparisons is energy consumption per capita (see Figure 4.3). Japan's rate of 3.4 toe per capita per year is thirteenth-lowest among IEA member countries, around a median level.

Figure 4.2 Energy intensity in Japan and in other selected IEA member countries, 1973-2015



Note: Data are estimated for 2015.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

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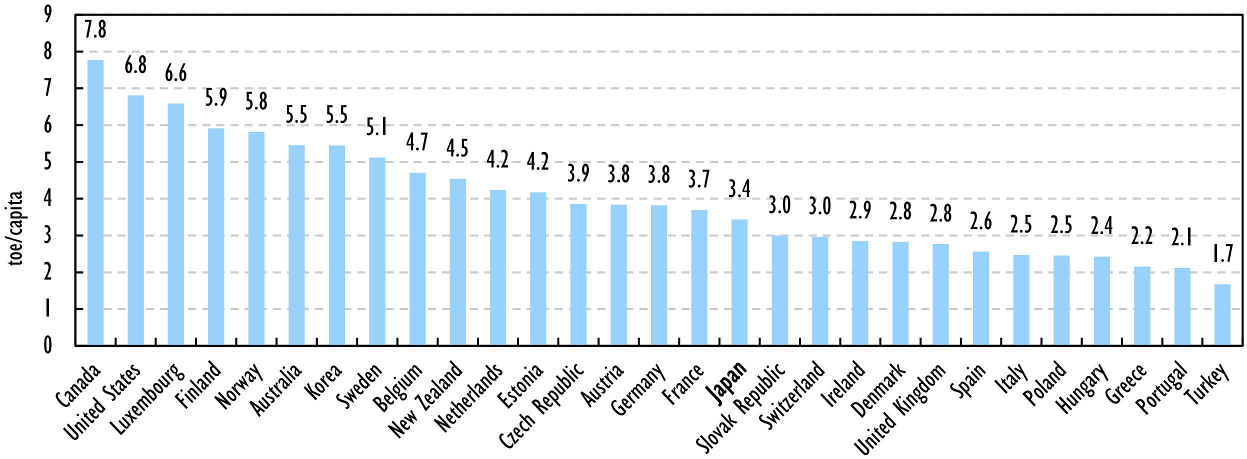
Figure 4.3 TPES per capita in IEA member countries, 2015



Note: Data are estimated.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

INSTITUTIONS

Institutional responsibilities for energy efficiency have not changed since the 2009 IEA in-depth review. METI's **Agency for Natural Resources and Energy (ANRE)** continues to be responsible for energy matters. It leads national efforts to promote energy conservation measures, in co-operation with the **Ministry of Land, Infrastructure, Transport and Tourism (MLIT)** and other ministries that are responsible for the relevant sectors. While the central government thus promotes energy conservation measures for the country as a whole, local governments are taking steps to implement their own energy conservation efforts.

POLICIES AND MEASURES

THE STRATEGIC ENERGY PLAN AND THE LONG-TERM ENERGY SUPPLY AND DEMAND OUTLOOK

Japan has a long tradition of effective energy efficiency policies and measures. The 2014 Strategic Energy Plan (SEP) sees a continuous strong role for energy efficiency in helping Japan meet its fundamental objectives of energy policy: energy security, economic efficiency, environmental protection and safety (the 3Es + S). The 2015 Long-term Energy Supply and Demand Outlook, which is based on the 2014 SEP, presents the ideal structure of energy supply and demand by 2030.

It highlights the importance of energy efficiency and conservation in reaching the expected demand reductions by 2030 in the industrial, commercial, residential and transport sectors. By FY2030, energy efficiency and conservation are expected to reduce energy demand by 13% (or 50.3 billion litres of crude oil-equivalent) to 326 billion litres compared to the baseline (376 billion litres) assuming economic growth at 1.7% per year from FY2013 to FY2030. This translates into a 10% reduction in final energy consumption from FY2013. For electricity demand, the SEP foresees marginal growth from 967 TWh in FY2013 to 980 TWh in FY2030, but expects energy efficiency and conservation to save 196 TWh, or 17% from this baseline by FY2030.

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The specific energy efficiency measures highlighted in the Outlook include:

- In the industrial, commercial, residential and transport sectors, further promotion to make facilities and equipment more efficient, optimal use of energy by energy management, and efforts to make energy consumption visible by a detailed survey and an analysis of the actual situation in energy consumption should aim to create smart and finely-tuned energy efficiency and conservation.
- In the industry sector, development and introduction of factory energy management, innovative technologies and highly-efficient facilities are promoted.
- In the commercial or residential sector, energy management using buildings and home energy management systems (BEMS/HEMS) is aimed to impose energy efficiency and conservation standards for newly constructed buildings/houses in stages, and to promote people's willingness to save energy at every level.
- In the transport sector, the aims include promotion of next-generation vehicles, fuel efficiency improvement, and traffic flow improvement. Also, use of hydrogen-related technologies, such as residential fuel cells (e.g. Ene-Farm) and fuel-cell vehicles, is promoted through subsidies.
- In addition, negawatt trade and other demand responses are promoted or considered.

GENERAL

The 1979 Act on the Rational Use of Energy is a key piece of legislation underpinning many energy efficiency programmes. The law was enacted in an effort to ensure energy security and reduce oil dependence. It has been revised several times to reflect changes in priorities. Most recently, it was revised in May 2013 and enacted in April 2014. It covers the major sectors: industry, transport, residential and commercial.

The law requires business operators to annually measure and report their energy consumption to the government. It also sets energy efficiency standards for residential and commercial buildings and houses. These measures are detailed in the sections below. Finally, the law includes the Top Runner Programme which is applied to household appliances, equipment, vehicles and, since 2013, building materials.

The Top Runner Programme, first introduced in 1998, sets energy efficiency target values for energy-using machinery, equipment, and other items. It is mandatory for companies (manufacturers and importers) to meet these efficiency targets within three to ten years, depending on the nature of the product. This encourages competition and innovation among the companies without increasing consumer prices.

The Top Runner standards are set by considering as base value the most energy-efficient technology available on the market at the time and factoring in the potential for efficiency improvement in the following years. Over the years, the programme has delivered significant results, including reductions by three-quarters in energy consumption of new passenger gasoline cars from 1996 to 2012, air-conditioners by 33% from 2001 to 2011, refrigerators by 43% from 2005 to 2010 and TV sets by 60% from 2008 to 2012.

The Top Runner Programme covers around 70% of household energy consumption. As of March 2015, it includes the following 31 categories of products: passenger vehicles;

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freight vehicles; air conditioners; electric refrigerators; electric freezers; electric rice cookers; microwave ovens; lighting equipment; electric toilet seats; TV sets; video cassette recorders; DVD recorders; computers; magnetic disk units; copy machines; space heaters; gas cooking appliances; gas water heaters; oil water heaters; vending machines; transformers; routers; switching units; multifunction devices; printers; electric water heaters; air-conditioner motors; self-ballasted LED lamps; insulation materials; sashes, multipaned glazing.

BUILDINGS

From 1993 to 2013, the number of occupied dwellings (flats and houses) in Japan increased by 11.4 million from 40.8 million to 52.2 million. The average floor area of these dwellings increased from 91.9 m^2 to 94.4 m^2 in the same period, resulting in a total floor area of 4.9 billion m^2. In addition, Japan has around 750 000 commercial buildings with a total floor area of 1.1 billion m^2. In 2013, there were also 8.5 million empty dwellings, out of which 3.2 million had been vacant for long or were to be demolished, according to MLIT and Statistics Japan.

From 1991 to 2013, however, 24.1 million dwellings were constructed. This implies a high demolition rate, which enables improvements in energy efficiency. This also means that the building stock is relatively new: only one dwelling in four has been built before 1980 and only 2% date from before 1950. At the same time, a relatively high share of dwellings, 62% of the total in 2013, is rented, which may lead to principal-agent challenges in encouraging energy efficiency investment and behaviour.

The Top Runner Programme covers around 70% of energy use in households, the breakdown of which is presented in Figure 4.4. Sashes and multipaned glazing were added to the Top Runner Programme in late 2014, following a renewed recognition of the importance of construction materials to facilitate energy efficiency in the residential and commercial sector.

Several of the products in the Top Runner Programme are also part of the energy labelling systems (see below section on labelling). The existing voluntary labelling system for housing in Japan, the Housing Performance Indication System, covers around one-fifth of new buildings.

Following the 2011 Great East Japan earthquake, the government asked households and companies to make extensive efforts to save electricity, such as switching off lights and limiting the use of air conditioners or electric heating at peak usage times in both summer and winter to reduce peak demand and limit the risk of power cuts. This *Setsuden* (electricity saving) programme was implemented from 2011 to 2015. For summer 2016, this programme is no longer in effect as energy saving practices have become standard and severe power shortages are unlikely with sufficient reserve margins projected at major electricity utility companies.

The government has also been promoting home energy management systems (HEMS) and, for offices, building energy management systems (BEMS). Both systems attempt to provide real-time information on electricity use and cost, to help in demand response and to offer energy-saving advice.

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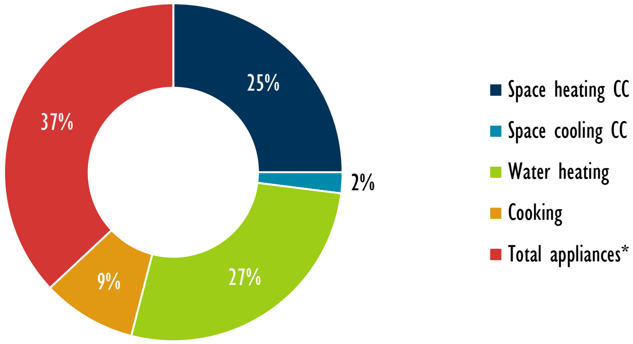
Figure 4.4 Breakdown of residential energy use by technology, 2014



* Includes lighting.

Note: CC = climate-corrected

Source: IEA Energy Efficiency Indicators (2016).

Companies that introduce BEMS can choose among three types of incentives: *a)* a tax exemption equivalent to 7% of the equipment acquisition cost for small and medium-sized enterprises (SMEs), or *b)* a special depreciation of 30% of the equipment acquisition cost in the year of acquisition, in addition to ordinary depreciation (this applies also to large companies), or *c)* support for SMEs' introduction of energy efficiency and conservation equipment (subsidies to support businesses for promoting rational use of energy, etc.).

Building codes

The Act for the Improvement of the Energy Consumption Performance of Buildings was adopted by the Diet in July 2015 and has been partially enacted. The main pillars of this law are to oblige new buildings to meet efficiency standards (to be enacted in April 2017) and to create a system to certify the energy-saving performance of buildings (in effect since April 2016). The mandatory efficiency standards will first apply to large new buildings and will be extended to cover new residential buildings by 2020.

Before the new law comes into full effect, the Act on the Rational Use of Energy provides the regulatory base for nationwide building codes. It applies to buildings of at least 300 m^2 of floor area and requires building developers constructing, extending, reconstructing or repairing a building to report their energy conservation measures to the relevant authority beforehand. Developers are also required to periodically (every three years) report on the state of maintenance of a building (this does not apply to houses). The relevant authority may give orders or penalties (in addition to official announcements) to the developers, especially in the case of unsatisfactory performance on energy conservation.

The Act also requires house suppliers (with sales of 150 houses or more per year) to make efforts to meet the energy efficiency standards under the Top Runner Programme, but meeting these standards is not a legal obligation.

Policies and measures for existing buildings seem limited to financial incentives and performance labelling with no regulatory obligations. For example, tax incentives were introduced in 2009 for home renovation to improve energy efficiency (e.g., thermal insulation of windows, floors, walls and ceilings, or installation of solar photovoltaic equipment). Under this scheme, 10% of the renovation cost (up to JPY 2.5 million or

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JPY 3.5 million when installing solar panels) can be deducted from that year's income tax. Another example is the Building-Housing Energy-efficiency Labelling System (BELS), introduced in 2013, under which a third-party certification for energy efficiency performance of both existing and new buildings is provided. This system will be further utilised under the new law which requires building developers to make efforts to disclose the energy efficiency performance of their buildings.

Zero-energy buildings

In the 2014 SEP, the government set a target of net zero-energy consumption for new public buildings by 2020 and net zero-energy on average for all new buildings in the country by 2030. With regard to houses, it aims to achieve net zero energy consumption for standard new houses by 2020 and for all new houses by 2030. These targets are included in the energy demand target for 2030 laid out in the 2015 Long-term Energy Supply and Demand Outlook.

In order to promote the deployment of net zero-energy consumption in buildings, subsidies have been available since 2012 for new and existing buildings to introduce highly energy-efficient systems and/or high-performance equipment. Subsidies have also been available since 2012 for high-performance insulation and energy-efficient materials/equipment in new and existing houses as well as for renewable power generation systems, such as solar photovoltaics (PV). Total budget allocation for the ZEB (net zero-energy buildings) and ZEH (net zero-energy houses) support programmes were JPY 15.7 billion for FY2015.

For FY2016, subsidy schemes continue to be available for ZEH and ZEB. The subsidy under the ZEH programme is JPY 1.25 million per house (down from JPY 1.3 million in FY2015) and additional support is provided if a power storage system is introduced. The budget allocation for the ZEB and ZEH support programmes for FY2016 is JPY 11 billion.

To further promote the deployment of ZEB and ZEH, METI adopted roadmaps for ZEB and ZEH in December 2015. They lay out various measures to be taken by the government and the industry up to 2020, which go beyond the current support programmes. For example, the roadmap for ZEB suggests that the government formulate the guidelines for ZEB designs and that relevant industry organisations set up voluntary targets and regularly follow up on progress. The roadmap for ZEH also recommends that relevant industry organisations and home builders set up voluntary targets. It also suggests that the government support small and medium-sized home builders to accumulate know-how on building energy-efficient houses.

TRANSPORT

Japan has made significant gains in the energy efficiency of its transport fleet. Policies that have contributed to this include the Top Runner Programme, mandatory reporting for operators with large fleets of vehicles (combined with targets to decrease the rate of energy use), vehicle taxation, eco-driving campaigns, promotion of alternative fuels and promoting public transport and traffic management. The efforts focus on road transport which is by far the largest energy user among different modes of transport (Figure 4.5).

Passenger transport is mostly by road. The latest statistics that include also non-commercial passenger transport dates from FY2009 when, according to Statistics Japan, passenger cars and buses accounted for 66% of all passenger-kilometres in the country.

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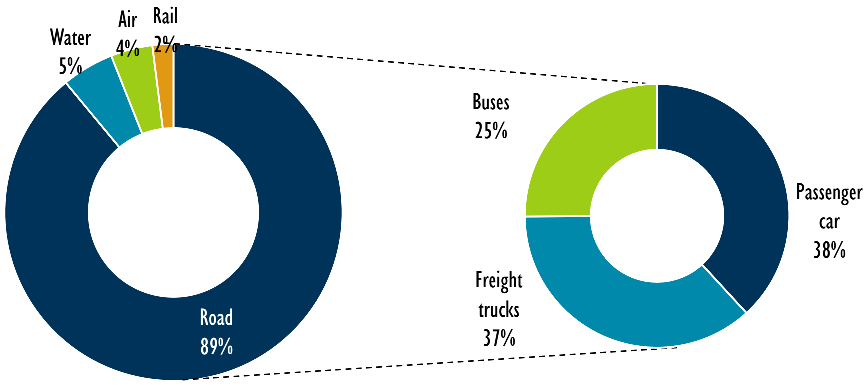
This is a relatively low share. For example, in both the European Union and the United States, the share was 92% in 2013, according to Eurostat and US National Transportation Statistics. In contrast, Japan has a high share of rail transport (29%). Air travel accounted for 5% of the total.

Railways, positive for energy efficiency, are relatively more important for passenger transport in Japan than in most developed countries, for both short- and long-distance travel. The world's busiest railway stations are in Japan which is also home to the original high-speed train, the Shinkansen. Passenger-kilometres by rail increased by 2.5% from 2009 to 2012 (the year of the latest data available from Statistics Japan).

Regarding freight transport, in 2012, half of all freight volume (measured in tonne-kilometres) was transported by road, but a high share of 44% was transported by waterways and only 5% by railway.

Figure 4.5 Energy use in transport by mode and in road transport by vehicle type, 2014



Source: IEA Energy Efficiency Indicators (2016).

Under the Act on the Rational Use of Energy, transport business organisations (freight-transport companies, passenger-service companies, and consignors) that are larger than a certain size (i.e. freight-transport companies with 300 railway cars or more, 200 trucks or more, 200 buses or more, 350 taxis or more, gross tonnage of ships of 20 000 tonnes or more, and a maximum take-off weight of 9 000 tonnes or more for aircrafts) are defined as "specified carriers". Such carriers are required to prepare and submit energy conservation plans as well as an annual report on their energy consumption amounts and other related matters. Business organisations that consign their own freight with 30 million tonne-kilometres are defined as "specified consignors". Such consignors are required to prepare and submit energy conservation plans as well as annual reports on their energy consumption amounts.

Fuel efficiency standards have been gradually made more stringent under the Top Runner Programme (see Table 4.1). Since 1996, they have improved by 34% when measured in litres per 100 kilometres (L/100 km) and by 50% when measured in kilometres per litre (km/L).

More will follow: the standard for passenger cars for 2020 has been set at 20.3 km/L. Fuel efficiency has increased as a result of technological progress, including improved engine efficiency and powertrain performance, and reduced vehicle weight, aerodynamic drag and rolling resistance. According to the Japan Automobile Manufacturers Association (JAMA), actual fuel efficiency is better than what the

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standards require: in FY2013, average fuel efficiency of a new passenger car was 21.3 L/km. This is partly explained by the increasing share of energy-efficient next-generation cars.

In March 2015, METI and MLIT set new standards for fuel efficiency for small freight vehicles (Top Runner Standards) to be achieved in FY2022. If the numerical targets in the new standards are successfully achieved, fuel efficiency in the target FY2022 is expected to improve by 26.1% from the actual level in FY2012.

Table 4.1 Vehicle fuel-efficiency standards, 2015

Vehicle category	Fuel efficiency standard, (km/L)	Gain compared with 2004 standards (actual), %
Passenger cars	16.8	23.5
Commercial vehicles (maximum 3.5 tonnes)	15.2	12.6
Buses (maximum 3.5 tonnes)	8.9	7.2
Trucks and buses (over 3.5 tonnes)	7.09	12.2

Source: Japan Automobile Manufacturers Association.

Since 2001, the government has promoted the use of clean-energy vehicles through its automobile green tax. This measure reduces the automobile tax by about 50% and the acquisition tax by about 2.7% on eco-friendly cars such as electric vehicles, cars running on compressed natural gas (CNG)"and hybrid cars, as well as on fuel-efficient cars and low-exhaust certified cars (see Chapter 3 on climate change).

The government has also attempted to promote eco-driving through a range of measures, including information ("Ten recommendations for eco-driving") and public awareness campaigns. These campaigns are carried out in particular in November which the government designates as "eco-drive promotion month", as it is the high tourist season.

Japan is the world's second-largest producer of passenger cars after the People's Republic of China, and its car manufacturers are actively developing so-called next-generation vehicles. These include clean diesel vehicles, natural gas vehicles, fuel-cell vehicles, electric vehicles, plug-in hybrid vehicles and hybrid vehicles. At the end of FY2014, the country had around 5.2 million of such next-generation vehicles (or 6.7% of all vehicles), according to JAMA. In March 2016, METI set a target for the deployment of fuel-cell vehicles and hydrogen refuelling stations as follows: for fuel cell vehicles, 40 000 by 2020, 200 000 by 2025, and for hydrogen-refuelling stations, 160 by FY2020 (up from 80 now) and 320 by FY2025 on a cumulative basis. For 2030, METI is targeting 800 000 fuel cell vehicles.

INDUSTRY AND COMMERCIAL SECTORS

Japan uses a mix of regulatory measures, voluntary actions by industry and a combination of subsidies, tax exemptions and loans for investment to encourage energy efficiency improvement in industry. The energy-saving policy in Japan's industrial sector was developed with strong co-operation between the public and private sectors.

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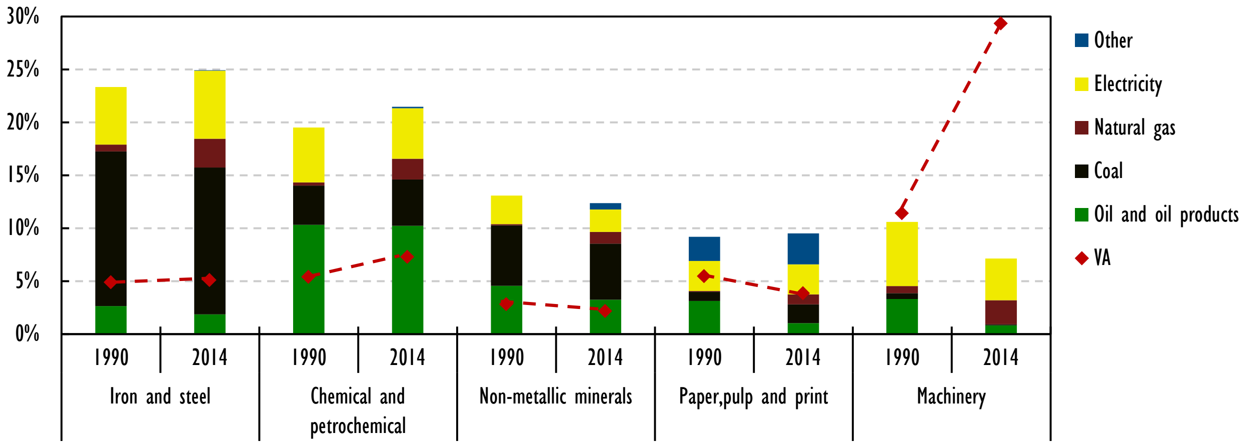
The Act on the Rational Use of Energy places several requirements on companies in the manufacturing and commercial sectors that use at least 1 500 kilolitres (crude oil-equivalent) of energy over a fiscal year. These companies must report annually on the amount of energy they actually consume, and submit medium-term (3- to 5-year) plans for a rational use of energy. They must also assign persons responsible for energy management. The measures aim to reduce energy consumption intensities by 1% or more a year (on average) in the medium term. The Act considers franchised chains of stores as single businesses and applies to them also. In total, the Act and other energy efficiency regulations cover around 90% of energy consumption in industry and about 40% in the commercial sector.

The Act also encourages companies in certain energy-intensive sectors to meet energy efficiency benchmarks. The sectors in question are iron and steel, cement, pulp and paper, power generation, oil refining and chemicals. Iron and steel, and chemicals and petrochemical each accounts for more than 20% of industry's energy use in Japan (see Figure 4.6). The benchmarks are set at the performance level of the top 10% to 20% in each sector. The companies must report annually on progress towards the benchmarks.

A key part of Japan's industrial energy efficiency policy is the Keidanren Voluntary Action Plan to reduce CO_2 emissions. The first Keidanren plan was laid down by Nippon Keidanren (Japan Business Federation) in 1997. The most recent one dates from November 2015 and is called the Keidanren Action Plan towards a Low-Carbon Society. It lists pledges and efforts from 54 sectors in manufacturing and energy industries, services and transport (see Chapter 3 on climate change).

Figure 4.6 Share of industry TFC and industry value added (VA) in selected sectors, 1990 and 2014



Source: IEA Energy Efficiency Indicators (2016).

LABELLING

The voluntary Energy Saving Labelling Programme was introduced to provide consumers with necessary information concerning the energy efficiency performance of products covered by the Top Runner Programme. The labels affixed to the products indicate the achievement ratio of the energy efficiency and conservation standards. The scope of products under the system has been expanded, and 19 categories of products are subject to the labelling as of March 2015.

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Japan also has another labelling programme, the Uniform Energy Saving Label, which applies to retailers and indicates a multistage rating of energy-saving performance based on an achievement ratio. The programme was introduced in 2006 and currently covers six categories of products (air conditioners, TV sets, electric refrigerators, electric freezers, electric toilet seats, and lighting equipment for fluorescent lamps).

In addition, the "simplified labelling system" displays the achievement ratio, annual electricity consumption and standard electricity charge, etc. In 2015, it covered eight products: electric rice cookers, microwave ovens, DVD recorders, LED lamps, video players, gas cooking appliances, gas water heaters and oil water heaters.

COMBINED HEAT AND POWER GENERATION

The April 2014 SEP recognises that co-generation helps save energy, works well with renewable energy sources, limits peak power demand, helps diversify and decentralise electricity sources, and is resistant to disasters. As of the end of March 2014, Japan's co-generation capacity for electricity was 10 046 MW, of which 7 973 MW was for industrial use and 2 073 MW for residential/commercial use. Co-generation is supported through subsidies for adopting distributed power systems provided by the City Gas Promotion Center, and for adopting fuel cells for residential/commercial consumers, provided by the Fuel Cell Association, among others.

Co-generation by using micro combined heat and power (CHP) and fuel cells has been gaining ground in Japan with a steady increase in the number of systems installed. Japan envisages to promote fuel cells on two fronts: automobiles and residential storage. Similar to micro-CHP, the fuel-cell system enables using the heat energy, for instance to boil and/or supply hot water to residential homes. In December 2014, the country had 100 000 residential hydrogen fuel cells already installed. The government is aiming for 5.3 million households, or roughly one in ten, to have fuel cells by 2030. Subsidies have been provided since 2009 to encourage purchasing fuel-cell systems. These systems are sold and installed by energy companies, such as gas utilities and liquefied petroleum gas (LPG) suppliers. As the volume of installations has increased from a mere 22 000 in 2011, the average installation cost by customers has dropped from JPY 2.6 million in 2011 to JPY 1.49 million in 2014.

DISTRICT HEATING AND COOLING

District heating and cooling (DHC) was first introduced in Japan in the city of Osaka in 1970. The primary driver to its deployment was improvement of local air quality and energy efficiency. DHC saw a dynamic increase in the 1990s and there are currently 77 companies operating 139 DHC systems in Japan. These systems are particularly common in large densely populated cities, where they are often installed as part of a larger property development.

Japan is currently not a member of the IEA District Heating and Cooling Technology Collaboration Programme (formerly known as implementing agreement. District heating and cooling is covered by the Heat Supply Business Law, which does not seek active promotion of DHC. The widespread use of air-conditioning systems in Japan's urban centres makes DHC systems a possibly attractive option to increase overall system efficiency and also to facilitate the large-scale uptake of variable renewable energy via thermal energy storage. In the colder areas of the country, such as the island of Hokkaido, DHC networks used primarily for supplying heat could be used in a similar

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manner. Some DHC developments feature co-generation. Co-generation in DHC may increase the resilience of the energy supply system. For example, certain DHC grid-connected developments in the Tokyo area that had co-generation units installed, were able to provide a stable electricity supply despite the blackout of the main grid following the Great East Japan earthquake. A possible barrier to an enhanced uptake of co-generation in DHC networks is the lack of an appropriate remuneration framework for sales of excess electricity, such as a liquid wholesale spot market.

ASSESSMENT

Japan continues to be a global leader in energy efficiency. The country has improved the energy intensity of its economy by around 40% over the last 40 years and its TPES per unit of GDP is at the IEA median. The government continues to give a high priority to delivering energy efficiency improvements and significant advances have been made since the last in-depth review in 2008. Further improvement will be a key factor in delivering the 4th Strategic Energy Plan.

The role that energy efficiency can play in managing overall energy demand has been further emphasised by the successful deployment of energy efficiency policies and measures to help manage the impacts of the Fukushima Daiichi nuclear accident on energy supply. Traditionally, Japan has relied on a mix of voluntary measures and regulations to drive improvements, though there has been a shift towards more binding requirements since the last review, particularly in the buildings sector. Electricity price Increases of 25% for domestic consumers and by almost 40% for industrial consumers from FY2010 to FY2014 as a result of increased energy imports since the Fukushima Daiichi nuclear accident have also acted as powerful drivers for further action as total final energy consumption continues to fall.

Japanese industry is among the world's most energy-efficient. The result of a range of measures, including the Keidanren Voluntary Action Plans (see Chapter 3 on climate change) and the requirements for energy management, has been the adoption of medium- and long-term plans for energy efficiency and progress reporting under the Act on the Rational Use of Energy combined with a range of subsidies and fiscal incentives for investment. Key to this result is the government's oversight role in ensuring that the commitments made are both challenging and effectively implemented. However, the IEA considers that these programmes should continue to demonstrate high levels of ambition in the future and build in "stretch" for industry beyond the level of autonomous improvements in efficiency that could be expected under business-as-usual scenarios. In that context, the recent introduction of a benchmarking element to the target-setting process for several energy-intensive sectors is a welcome development and one that should be extended to other sectors. However, the number of industries in some sectors that have achieved the benchmark target remains small and guidance should be given to those that fail to achieve the target. There is also scope to apply some of the lessons learnt from applying the regulations to inform voluntary action in the small and medium-sized enterprises (SME) sector not currently covered by the Act.

The highly successful Top Runner Programme, first introduced in 1998, has set dynamic energy efficiency targets for a range of products. The programme has stimulated continuous improvements in fuel economy for vehicles and energy-using products (primarily those used in the residential sector) with over 70% of household energy consumption now covered by the programme. As recommended in the previous in-

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depth review, product coverage has been extended in recent years. It now includes the first standards for building components (windows and insulation), and in total 31 products and materials are now covered. The IEA welcomes this ongoing expansion of the programme and encourages the government to extend its focus from the residential sector to products used in the commercial and industrial sectors.

The last in-depth review in 2008 highlighted the buildings sector's considerable potential for additional action. Since then, a welcome and significant development has been the decision to move to mandatory energy efficiency standards for buildings, including homes, with requirements to be phased in over the period to 2020 replacing the voluntary standards which have had varying levels of compliance, particularly in the residential sector. This is a major step forward, particularly when combined with the new Top Runner Standards for building components. However, it will be important that the standards set are ambitious, with the aim to move to a zero-energy standard as soon as possible.

An effective enforcement regime as well as supporting economic/financial incentives for consumers will also be needed if the full benefits of the regulations are to be realised. Building regulations and the new building component standards together will help ensure that all new buildings are more efficient. However, the existing building stock also has considerable energy-saving potential: around one million new buildings are added to the stock each year while existing buildings already number more than 50 million. Realising this potential remains a significant challenge for the government. A clear strategy comprising a mix of policy measures to promote awareness, installation of energy-saving measures and deep renovations reflecting differing regional circumstances will need to be developed in order to drive progress. An important policy lever in this context can also be the provision of better information and recommendations for cost-effective action to building owners and tenants through the use of building labels or requirements for energy performance certificates when a building is sold or rented. The existing voluntary labelling scheme in Japan, the Housing Performance Indication System, covers around one-fifth of new buildings. The IEA believes that consideration should be given to moving towards a mandatory system.

Subsidies and fiscal incentives are widely used in Japan to promote action and investment in energy efficiency in buildings as well as in other sectors. While these subsidies have helped drive action, particularly in bringing new products such as fuel cells and next-generation vehicles to the market, they bring with them the risk of free-riding and such subsidies can also impose considerable burdens on public budgets. A longer-term, and more sustainable, solution could be the development of a market for the delivery of energy efficiency improvement measures through the expansion of the emerging energy services companies (ESCO) sector and the deployment of tools such as energy performance contracting and other pay-as-you-save financing models. The government should therefore continue its efforts to facilitate the development of the sector.

Following the Fukushima Daiichi nuclear accident, Japan had extraordinary success in driving consumer behaviour change in the short term through the *Setsude*n electricity-saving effort and subsequent campaigns to deliver significant energy savings in order to cope with energy supply shortfalls caused by the closure of nuclear power plants. The challenge now will be to ensure that consumers maintain these efforts into the longer term to both reduce overall energy demand and manage peak loads. Tools that provide consumers with information and allow them to be active participants in the market, such

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as the anticipated roll-out of smart meters by 2024, transparent pricing and time-of-use tariffs, smart appliances and use of home energy management systems, will all have an important role to play. Promotion of these tools should form part of the government's ongoing strategy to manage energy demand.

Japan has a world-leading approach to delivering energy efficiency in the transport sector, combining fuel efficiency standards for cars and trucks under the Top Runner Programme (with an improvement in fuel efficiency of gasoline cars of 50% from 1996 to 2015), investment in public transport, promotion of modal shift, action to improve the efficiency of freight carriers, promotion of eco-driving, and provision of tax incentives for efficient vehicles. Penetration of next-generation vehicles has now reached about 6.7% of the vehicle stock. It is increasing rapidly and will do so further in order to meet Top Runner Standards for 2015 and 2020. In this context, the government should consider the wider implications for grid management and integration of the potential increase in electric vehicles and plug-in hybrids.

RECOMMENDATIONS

The government of Japan should:

General

- ☐ *Continue to expand the use of benchmarking in target setting in the service sector.*
- ☐ *Continue to develop policies that will deliver energy efficiency improvements in small and medium-sized enterprises.*

Buildings

- ☐ *Move forward with the design and implementation of ambitious energy efficiency standards for new buildings by 2020, with the aim of realising zero-energy buildings as soon as possible, and an effective enforcement regime.*
- ☐ *Adopt a comprehensive strategy for identifying and realising the energy-saving potential in the existing building stock.*
- ☐ *Consider implementing an effective labelling scheme for buildings to be applied when a building is sold or rented.*
- ☐ *Continue to promote and facilitate the development of the Energy management business, including the energy services companies model to support investments in energy efficiency.*

Transport

- ☐ *Continue the successful policy to introduce stricter fuel efficiency standards and efforts to promote next-generation vehicle technology.*

Products

- ☐ *Build on the success of the Top Runner Programme, expanding the range of products covered particularly in the commercial and industrial sectors.*

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District heating and cooling, including co-generation

- ☐ *Investigate increased use of district heating and cooling (including co-generation) for more integration of renewable energy sources, increased resilience of the electricity supply system, and for wider use of municipal waste while also building international collaboration with countries featuring high penetration of DHC.*
- ☐ *Ensure that operators of co-generation plants receive a remuneration on excess electricity sales that is in line with the avoided costs resulting from the injection of this electricity into the grid.*

References

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PART II
SECTORAL ANALYSIS

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5. OIL

Key data (2015 estimated)

Crude oil and NGLs production: 0.4 Mt (negligible)

Crude oil and NGLs imports: 168 Mt, -21% since 2005

Oil products net imports: 25 Mt, -37.8% since 2005 (imports 42.7 Mt, exports 17.8 Mt)

Share of oil: 42.9% of TPES and 9% of electricity generation

Supply by sector (2014): 192 Mtoe (transport 37.5%, industry 30.9%, power generation 11.9%, commercial and public services 8.7%, residential 6.3%, other energy 4.7%)

SUPPLY AND DEMAND

SUPPLY

Oil is the largest source of energy in Japan, representing 42.9% of total primary energy supply (TPES) in 2015 or 187 million tonnes of oil-equivalent (Mtoe). However, oil supply has been declining for two decades, down from a peak volume of 267 Mtoe in 1996. Oil's share in TPES has been declining since the 1970s, when it supplied around 80% of Japan's primary energy. Oil supply revived slightly during 2010-12, increasing by around 4.4% in total. From 2013 to 2015, it fell by 11.1% to finish 23% lower than in 2005.

Crude oil and natural gas liquids (NGLs)

Japan relies on imports for practically all of its crude oil needs, as domestic production amounted to around 0.2 million tonnes (Mt) of crude oil and 0.2 Mt of natural gas liquids (NGLs) in 2015. The combined production has declined by 36% from 0.7 Mt in 2005.

Japan is the world's fourth–largest crude oil importer, after the United States, the People's Republic of China (hereafter "China"), and India. In 2015, imports amounted to 162 Mt and over 80% of the total was sourced from the Middle East, mostly from Saudi Arabia (35.8% of total imports), the United Arab Emirates (26%), but also from Kuwait (9%), Qatar (6.2%) as well as Iran, Iraq and Oman (5.3% in total). The remainder came from Russia (8.3%), Indonesia (2.2%) and other countries (Figure 5.1).

From 2005 to 2015, crude oil imports declined by 22%. Imports from Saudi Arabia decreased by 9.6% and imports from the United Arab Emirates by 18.8%. Imports from other countries from the Middle East (Kuwait, Qatar, Iran, Iraq, Oman) also declined, on average by 29.6%. In contrast, Russian imports surged to 8.3% of total from negligible levels in 2005. Japan does not export any crude oil.

Japan imported 6.5 Mt of NGLs in 2015, 38.8% more than ten years earlier. Imports came mostly from Qatar (52.4%) and Iran (41.6%) in 2015. Imports from Qatar grew by 103% from 2005 to 2015, and from Iran by 77.7%, replacing imports from Indonesia, Nigeria and Australia. Japan does not export any NGLs.

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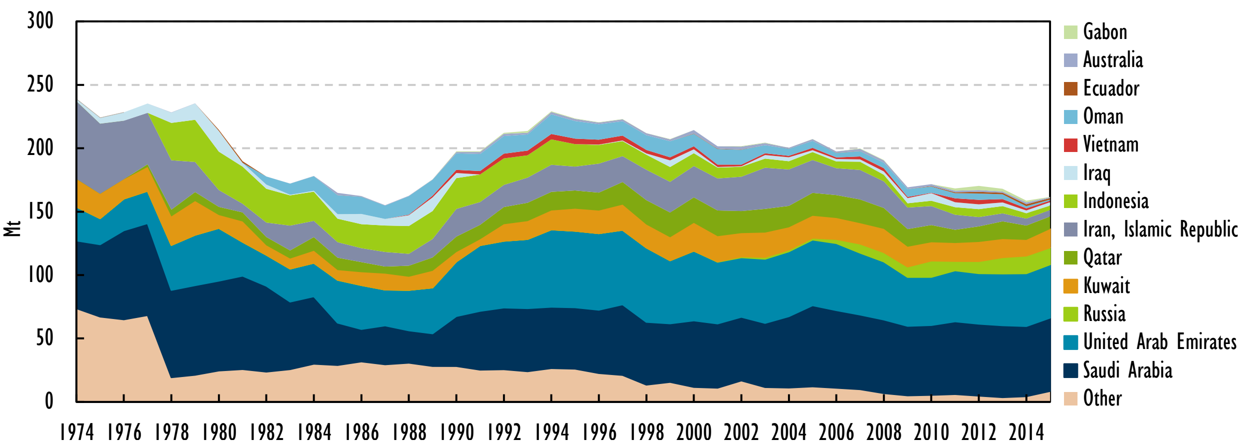
Promoting supply

The almost complete reliance on imports for crude oil and their large volume explains why the government actively pursues resource diplomacy with supplier countries. The government is also supporting direct investments in a diversified portfolio of foreign oil (but also gas, coal, uranium and metals) exploration and production junior companies through the Japan Oil, Gas and Metals National Corporation (JOGMEC). JOGMEC provides support for exploration and development activities overseas. In broad terms, the companies in question include vertically-integrated ones and those engaged in development in conjunction with other players.

JOGMEC has been active in supporting oil exploration and development in jurisdictions outside Japan's traditional supply area, the Middle East. As of 2014, JOGMEC has invested around USD 3 billion in 45 companies globally. It has also provided liability guarantees to 13 companies, totalling almost USD 6 billion.

The government also plans to carry out three-dimensional geophysical exploration by 2018 covering around 62 000 square kilometres (km^2) in the seas around Japan. Generally, exploration and development of oil within and outside Japan is conducted primarily by private-sector companies.

Figure 5.1 Crude oil imports by source, 1974-2015



Note: Data are estimated for 2015.

Source: IEA (2016c), Oil Information 2016, www.iea.org/statistics/.

Oil products

Imported crude oil is refined domestically. Japan produced 164 Mt of oil products in 2015, which is 20% less than in 2005. Refinery output peaked at 215 Mt in 1997 and has been on a downward trend since. In 2015, Japan's oil products output constituted gas and diesel oil (28%), motor gasoline (24.6%), fuel oil (10.5%), naphtha (8.6%), kerosene other than kerosene-type jet fuel, mostly for space heating (7.8%), kerosene-type jet fuel (7.5%) and others. The product mix has remained mostly unchanged over the past decade.

Japan is also the largest net importer of oil products in the world, with net imports of 25 Mt in 2015 (imports 42.7 Mt *minus* exports 17.8 Mt). As oil demand has declined, imports have contracted over the past decade while exports have boomed. Net imports declined by 37.8% from 2005 to 2015, with imports down by 12.7% and exports up by

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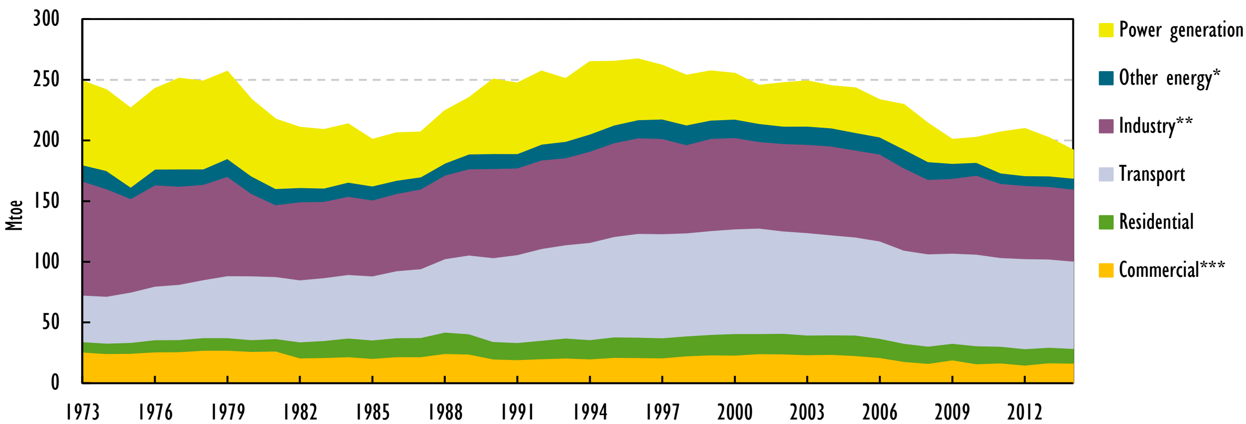
101%. The top four countries from which Japan imported oil products in 2015 are the United States (16.5%), Qatar (13.9%), the United Arab Emirates (10.8%) and Saudi Arabia (8%). Exports were destined for Singapore (23.3%), Hong Kong (17.1%), Australia (21.6%), Korea (10.6%) and China (8.3%).

DEMAND

Japan's consumption of oil is mainly in transport and industry. In 2014, transport accounted for 37.5% of total demand and industry for 30.9% (Figure 5.2). Power generation consumed another 11.9%, while the remainder was consumed by commercial and public services and agriculture (8.7%), households (6.3%) and refineries and energy-own use (4.7%). From 2004 to 2014, oil consumption declined in all sectors, in total by 21.6%, from 245 Mtoe to 192 Mtoe. Transport, the largest consuming sector, decreased oil consumption by 12.7%, commercial and public services (including agriculture) by 30.4% and the refining sector by 39.2%. Over the same period, oil consumption in households contracted by 24.5% and in industry by 19%.

In power generation, oil consumption declined by one-third from 2004 to 2014. However, in the aftermath of the nuclear shutdown following the March 2011 Fukushima Daiichi nuclear accident and the subsequent shutdown of all nuclear power plants, old oil-fired power plants were brought back to use to respond to the electricity supply challenge. Oil demand for power nearly doubled from 20.3 Mtoe in 2010 to 38.5 Mtoe in 2012, and power generation's share in total oil demand increased from 10% to 18.4%. Demand levelled off in 2013, as power generators turned to more natural gas use. The increase in oil use for power generation has been temporary, and the government expects oil-fired power generation to decline from around 11% of total electricity supply in 2014 to around 3% in 2030, as cheaper and cleaner generating capacity comes online. The government expects oil demand to continue to decline, owing to decreasing population, stricter vehicle fuel-efficiency standards and fuel switching from oil, to mainly natural gas and electricity.

Figure 5.2 Oil supply by sector, 1973-2014



Note: TPES by consuming sector.

* Other energy includes refineries and energy own-use.

** Industry includes non-energy use.

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

Source: IEA (2016a), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

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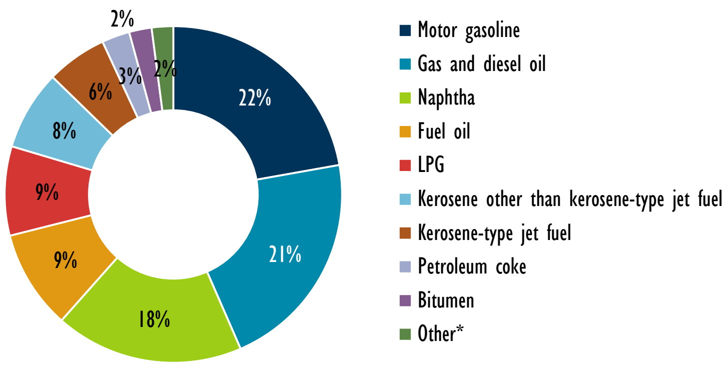
Motor gasoline and diesel and gas oil each account for more than 20% of oil products consumption in Japan. Naphtha represents 18.1%, fuel oil 9.5% and liquefied petroleum gas (LPG) 8.6% (Figure 5.3). Since 2004, the largest shift in Japan's oil consumption has been a modest increase in demand for gasoline, naphtha and LPG, while demand for diesel and gas oil, and kerosene fuel other than kerosene-type jet fuel has contracted moderately.

Figure 5.3 Oil consumption by product, 2014



* Other includes lubricants, white spirit, paraffin waxes, aviation gasoline, gasoline-type jet fuel and other non-specified oil products.

Source: IEA (2016c), *Oil Information 2016*, www.iea.org/statistics/.

OIL STRATEGY

The Strategic Energy Plan (SEP) approved in April 2014 set out the key areas for Japan's oil policy stating that: "It is essential to promote diversification of supply sources, co-operation with oil-producing countries, enhancement of crisis management, including stockpiling, effective utilisation of crude oil, diversification of fuels for transportation, and utilisation of oil thermal power as load following power source."

Further, the Plan also noted that since oil will be an energy source of "last resort" in the event of a disaster, it is necessary to further strengthen the resilience of oil supply networks and to enhance the management foundation of the oil industry in order to maintain the nationwide supply networks in normal times.

Specifically, the 2014 SEP sets out to address three key challenges with respect to the oil sector: *i)* responding to the uncertainty of energy resource provision from overseas; *ii)* constructing an energy supply and demand system that is to be prepared in times of disaster; and *iii)* rebuilding the operating base of the refining industry that is responsible for energy provision.

INDUSTRY AND INFRASTRUCTURE

The constant gradual decline in oil demand since the 1990s has reduced margins in the oil industry and triggered extensive consolidation among the refiners and primary oil distributors (so-called *motouri*). This has been the case in particular after 1999 when fuel imports were liberalised. Today, the sector has five major groups active in refining, wholesale and retail: JX Nippon Oil and Energy, TonenGeneral, Idemitsu Kosan, Showa Shell and Cosmo Oil (Figure 5.4). The groups are not completely independent of each other, but have formed business alliances in their operations.

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Consolidation in the sector continues and two major mergers were announced in the second half of 2015: Idemitsu Kosan, Japan's number two refiner, announced in November 2015 a merger with Showa Shell. The merger is expected to be completed in 2016/17. More recently, JX Holdings and TonenGeneral Sekiyu, first and third in terms of refining capacity, also announced a merger which is expected to be completed in 2017 and would control half the domestic market. These mergers would leave Japan with only two large oil companies. They are encouraged under the Law on Special Measures for Industrial Revitalization, also through financial incentives. Before METI approves the merger plans, the law mandates a close consultation with the competition authority (Japan Fair Trade Commission, JFTC) to address possible concerns over dominant market position. In the retail sector, the number of filling stations has declined from 60 000 in 1995 to 33 500 in March 2015. As a measure to increase productivity, self-service stations were introduced in 1998 and by March 2015 their number had increased to 9 500, or 28% of all service stations (PAJ, 2015). The filling stations are either independent or owned by the large oil companies. The independent stations are typically supplied by these large oil companies.

REFINERIES

In the refining sector, Japan has long had excess capacity and demand for oil products. In 2009, the Ministry of Economy, Trade and Industry (METI) introduced a plan to improve the industry´s competitiveness. The first phase runs from 2010 to March 2014 and the second will run from 2014 to March 2017. On the basis of the 2009 Act on the Promotion of Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Materials by Energy Suppliers, METI issued a so-called Refining Ordinance to promote the optimisation of refinery facilities by March 2014. It aimed at raising the ratio of residue cracking units to crude distillation units from around 10% (relatively low by international comparison) in 2010 to 13% by March 2014. The refineries could increase this share by investing in residue cracking capacity, or closing down crude distillation capacity, or by a combination of the two. In effect, the measure was aimed at reducing crude distillation capacity, as oil product demand in Japan is expected to continue its structural long-term decline. The Ordinance included small sanctions, but compliance has not been an issue, as an understanding of the need to reduce overcapacity has been shared by the refiners.

As a result of the METI requirements and some capacity reduction planned independently, Japan´s crude oil distillation capacity was reduced by 18.6% from 4 846 thousand barrels per day (kb/d) in 2009 to 3 947 kb/d at the end of March 2015. This helped increase the operational ratio of the country´s refinery sector from 74.5% to 82.4% (PAJ, 2015). Although the crude oil distillation capacity has declined by one-third from its peak at 5 940 kb/d in 1980, at the end of 2014, Japan still was the world's fourth-largest oil refiner. METI launched the second phase of the optimisation of oil refining facilities in July 2014, on the basis of the 2009 Act. In effect, the requirement will lead refineries to close down another 400 kb/d (around 10% of the total) of distillation capacity by March 2017. As opposed to phase I, phase II is aimed at encouraging synergies between refineries to boost the overall cracking ratio (IEA, 2015b).

Altogether, refining companies have announced more than 400 kb/d of capacity reductions from 2014 to 2017: Cosmo Oil would cut 100 kb/d in Chiba and 63 kb/d in Yokkaichi, while JX would reduce by 121 kb/d, Idemitsu Kosan/Showa Shell by 54 kb/d and TonenGeneral by 72 kb/d. In addition, there are local refinery mergers, such as the linking of the refineries of TonenGeneral and Cosmo Oil in Chiba (IEA, 2016b).

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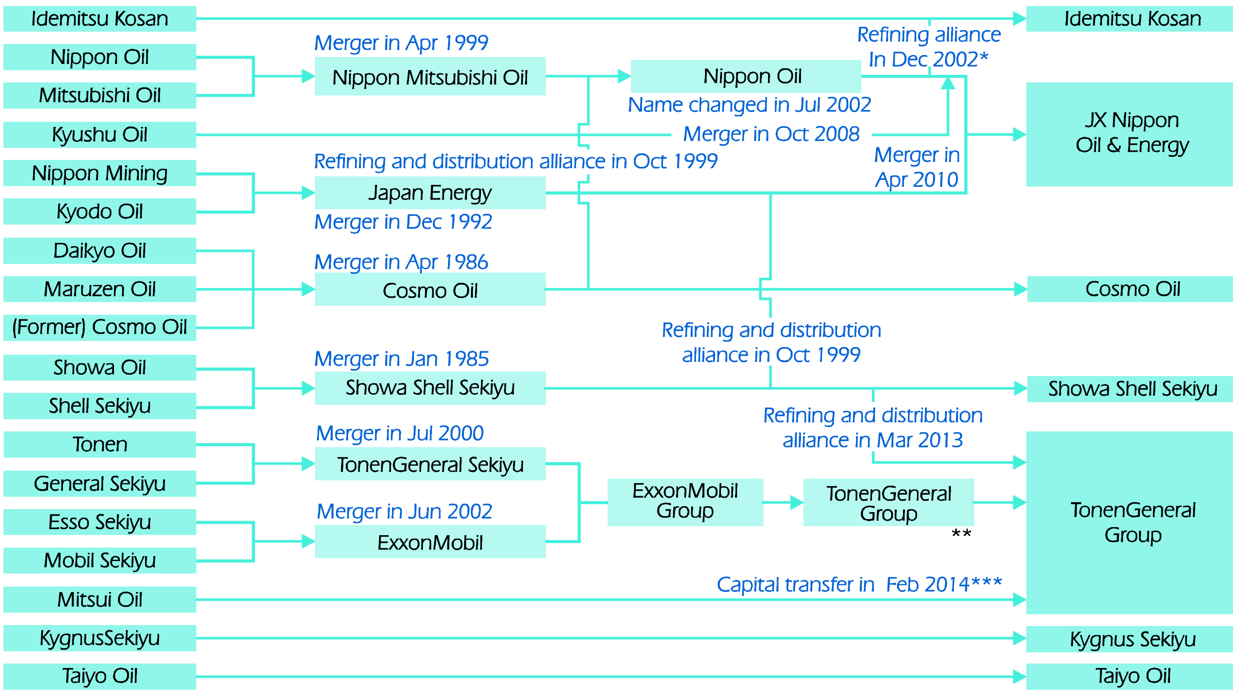
Figure 5.4 Reorganisation of Japan's oil companies, as of June 2015



* Nippon Oil and Idemitsu Kosan concluded distribution alliance in 1995.
** On June 1, 2012, Japan's ExxonMobil Group transited to the new organisation, headed by TonenGeneral Sekiyu, and ExxonMobil Y.K. Changed its name to EMG Marketing G.K.
*** On Feb 4, 2014, Mitsui Oil became a subsidiary of Tonen General Sekiyu and changed its name to MOC Marketing KK.

Source: PAJ (2015).

PORTS AND PIPELINES

As Japan is an island country, crude oil and petroleum products are imported by oil tankers. The country has five main oil ports which are located in Chiba, Yokohama, Yokkaichi, Shibushi and Okinawa. The Chiba port unloads crude oil to supply 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. Oil products are delivered from refineries to consumers mainly by coastal tankers, tank trucks and railroad tankers. There is only one oil pipeline in the country, which transports jet fuels from the Chiba refinery to the Narita International Airport.

STORAGE

Storage capacity in Japan was estimated at around 900 million barrels (mb) at the end of March 2014. Within the supply chain, private companies own 241 mb of storage capacity for crude oil – mainly located at refineries. The country also has 283 mb of storage capacity for oil products in the refining and distribution sectors, according to the Petroleum Association of Japan.

In addition, JOGMEC is delegated to manage national emergency crude oil reserves at ten national stockholding bases (34 million cubic metres or about 215 mb) and in 13 industry-leased tanks (14.3 mcm or about 90 mb). National stockholding bases are sited in the coastal areas and include above-ground tanks, underground rock caverns, floating tanks, and in-ground tanks.

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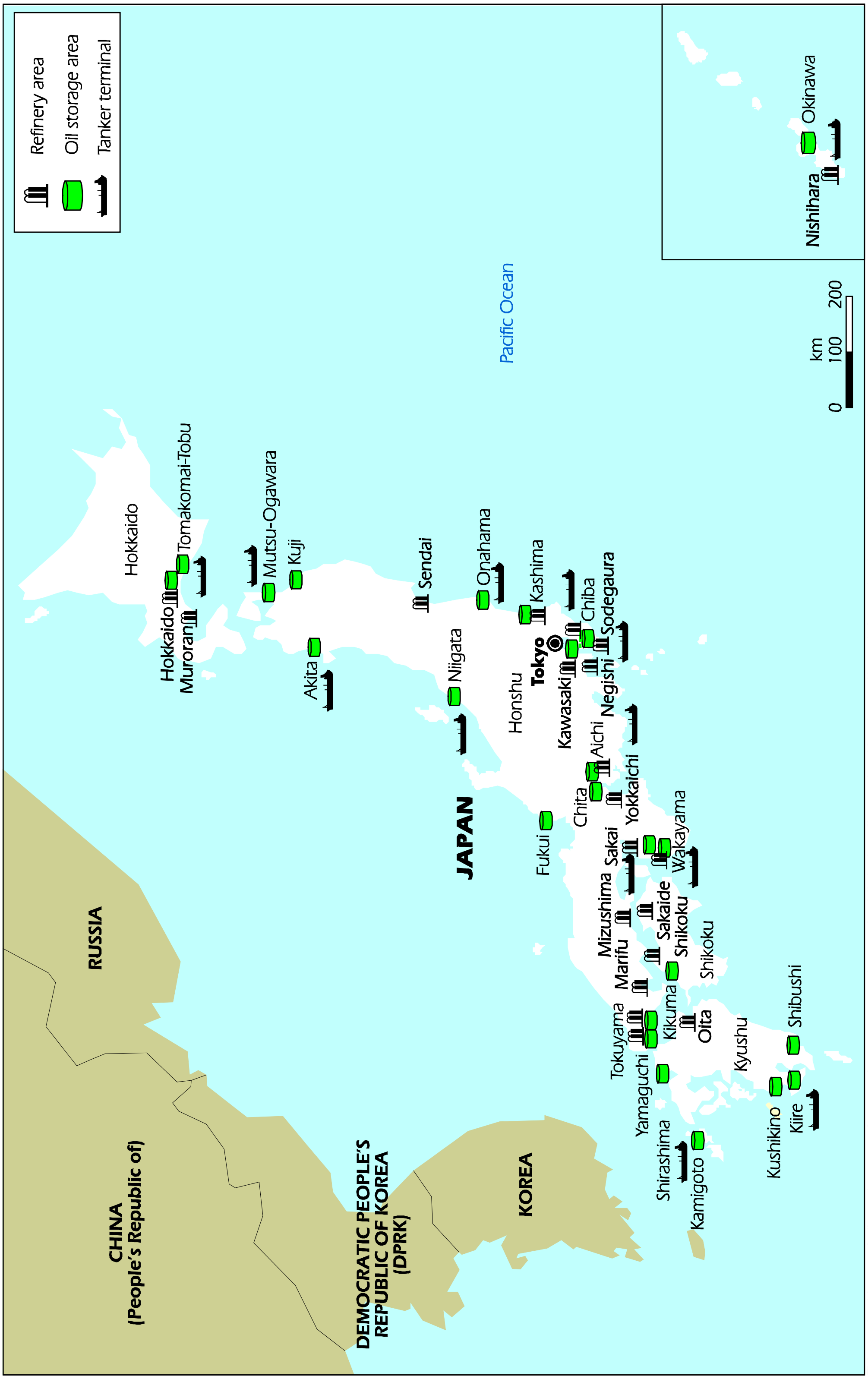
Figure 5.5 Map of Japan's oil infrastructure, 2015



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

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EMERGENCY RESPONSE POLICY

DECISION-MAKING STRUCTURE

The Petroleum Refining and Reserve Division of the Natural Resources and Fuel Department acts as a secretariat and forms the core of the Japanese National Emergency Strategy Organisation (NESO) 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 (METI) to decide to release government stocks or lower industry's obligation. According to a decision by the minister, the Petroleum Refining and Reserve Division co-ordinates government stock releases with JOGMEC which is responsible for managing the stocks. When lowering industry's obligation, the division co-operates closely with the Petroleum Association of Japan (PAJ).

2012 AMENDMENT TO THE OIL STOCKPILING ACT

As a response to the Great East Japan earthquake of March 2011 and the regional shortages of oil products that ensued, the Oil Stockpiling Act was amended in 2012. The amended Act allows the release of government stockpiles not only in case of a shortage of supplies from overseas, but also in case of a shortage of supply in a specific area of Japan owing to a disaster. It also obliges oil companies to jointly prepare emergency oil supply co-operation plans in order to ensure a smooth supply of oil products to end-users in the event of a disaster.

In addition to the amendments mentioned above, Japan is strengthening the shipping capability of its jetties, storing petroleum products in medical institutions and shelters for disaster response, promoting stockpiling by consumers and strengthening the emergency power supply at refineries.

STOCKS

Stockholding structure

Japan meets its stockholding obligation to the IEA by holding government emergency stocks and by placing a minimum stockholding obligation on industry. Under the Oil Stockpiling Act, METI delegates JOGMEC to manage government emergency stocks. The country has accomplished its national stockholding target of holding 50 million kilolitres (kL) (equivalent to 315 mb) since 1998. JOGMEC also manages around 952 kt (around 7 mb) of national stocks for LPG, accounting for 32 days of imports held at five national LPG stockholding bases as of March 2015.

According to the Act, refineries, specified distributors and importers are obliged to hold from 70 to 90 days of their average daily imports, sales or refined production in the previous 12 months. Since 1993, the stockholding obligation on industry has been set at 70 days. In addition, LPG importers are obliged to maintain 50 days of daily LPG imports. METI is responsible for ensuring the implementation of the oil stockpiling obligations. It is empowered to set the quantities of oil to be stockpiled on an annual basis and to supervise the compulsory stocks and their use. One significant role of private-sector oil stocks in Japan is to promptly supply oil to the market as an initial response to an oil crisis. The government estimates that it will take around 10 days for national stocks of crude oil to reach the market, and private-sector stocks are expected to fill the time lag.

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Crude or products

Japan held around 530 mb of oil stocks (310 mb of government stocks and 210 mb of industry stocks) at the end of February 2016, equal to 165 days of 2015 net imports (98 days of government stocks and 67 days of industry stocks) to more than meet its IEA obligation. Around 78% of total stocks were held in the form of crude oil, and crude oil accounted for around 97% of public stocks. However, in accordance with the 2012 amendments of the Oil Stockpiling Act, since 2014 the government has been holding four days of refined products such as gasoline, heating oil, fuel oil and diesel oil in the national emergency oil inventory. It fulfilled this objective in 2014.

In terms of industry stocks, crude oil makes up 41% of the stocks, followed by natural gas liquids and feedstocks (23%), middle distillates (14%) and motor gasoline (4%). Industry may substitute crude oil for oil products it is obliged to hold.

Location and availability

Japan has a bilateral agreement with New Zealand that allows it to hold stocks on New Zealand's behalf (using petroleum reserve ticket contracts) that count towards New Zealand's IEA obligation. Public crude oil stocks are widely dispersed at ten national stockholding bases and in 16 domestic private terminals. Around 70% of public stocks are held at national stockholding bases. Compulsory stocks are commingled with commercial and operational stocks.

DEMAND RESTRAINT

Demand restraint is considered a secondary emergency response measure that could complement an oil stock release. As Japan has abundant amounts of emergency oil stocks, demand restraint measures would only be deployed in the event of a severe oil supply crisis.

Demand restraint measures would range from light-handed measures (e.g. accurate information sharing and energy-saving campaigns) to heavy-handed measures (e.g. limitations of oil use in specific industrial sectors, oil products mediation for end-users and allocation of oil). The latter measures would be taken under the Petroleum Supply and Demand Optimization Act. According to the Act, the Prime minister can announce the necessary demand restraint measures based on a cabinet council decision

PRICES AND TAXES

Oil product prices in Japan are some of the lowest among the IEA member countries. This is mainly explained by relatively low taxation (see Figure 5.6). Imported crude oil and oil products are levied a tax of JPY 2.54 per litre. In addition, product-specific taxes are levied when refined products are delivered to the Japanese market. For gasoline, this tax is JPY 53.8 per litre, for diesel JPY 32.1, for jet fuel JPY 18 and for LPG JPY 9.8.

In addition to an excise tax, oil products are levied a consumption tax which was raised from 5% to 8% in April 2014. The government is planning to increase the consumption tax to 10% in April 2017. It is refunded for commercial users, i.e. industry, power generation and truckers. For fiscal year 2015 (April 2015 to March 2016), the total oil-related tax revenue in the government budget was estimated at JPY 6.1 trillion, of which JPY 4.4 trillion from petroleum products taxes and JPY 1.7 trillion from consumption tax.

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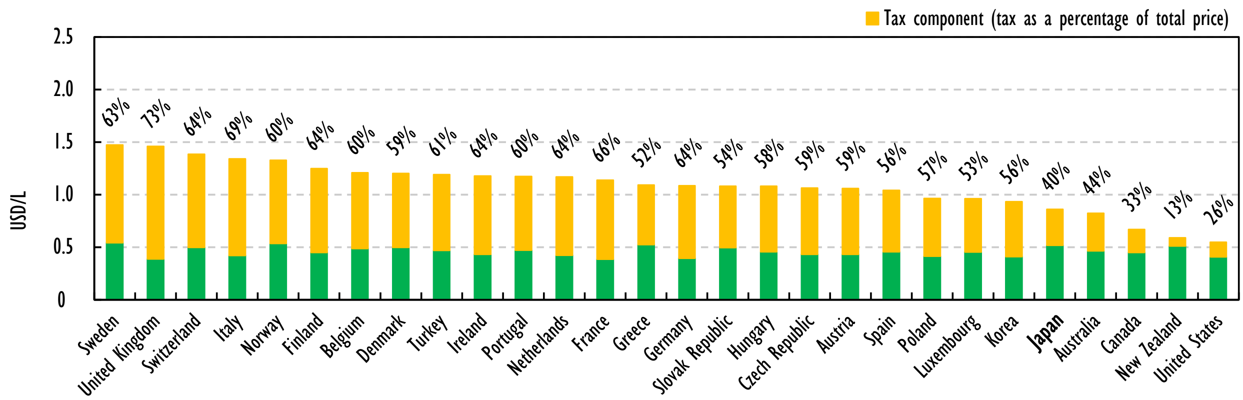
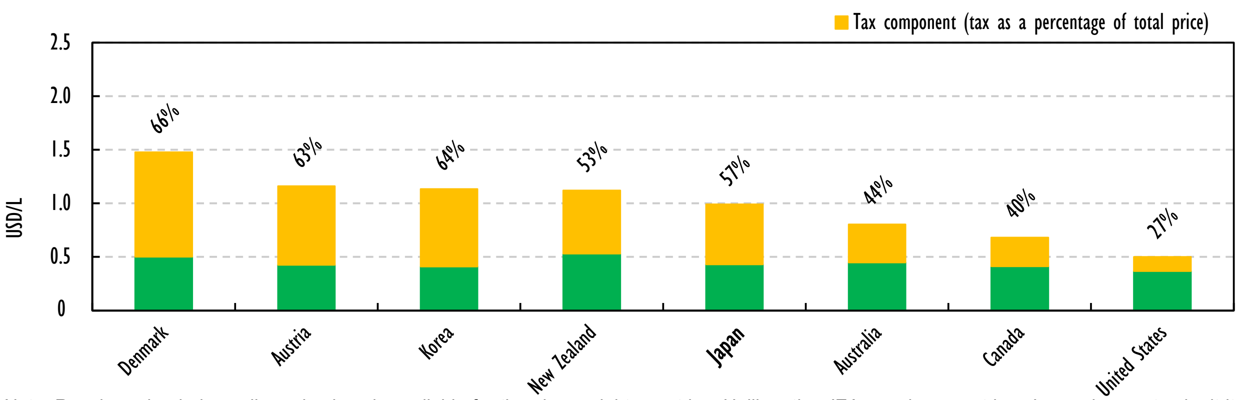
Figure 5.6 Fuel prices in IEA member countries, first quarter 2016

Automotive diesel

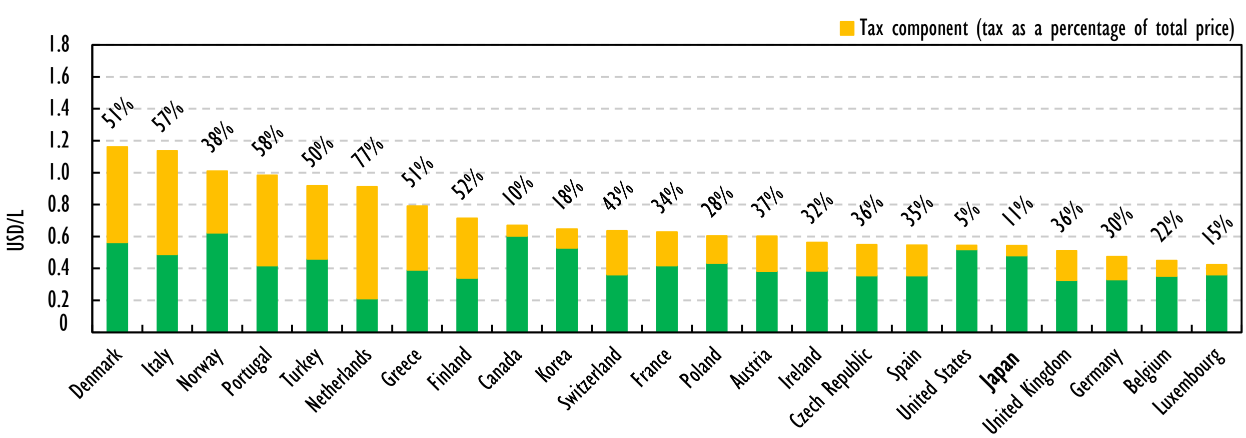


Regular unleaded gasoline



Note: Regular unleaded gasoline price is only available for the above eight countries. Unlike other IEA member countries, Japan does not submit its prices of premium unleaded gasoline.

Light fuel oil



Note: Data are not available for Australia, Hungary, New Zealand, the Slovak Republic and Sweden.

Source: IEA (2015d), *Energy Prices and Taxes 2016*, Q1, www.iea.org/statistics/.

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ASSESSMENT

Oil remains the main source of energy in Japan, although its share in TPES has declined considerably since the early 1970s, from 77.7% in 1973 to 42.9% in 2015. The country relies on imports for almost all of its crude oil needs, and the Middle East continues to be its main supplier, accounting for more than four-fifths of the total in 2015. Despite the almost 20-year decline in oil demand, Japan remains one of the world´s largest oil importers.

In the April 2014 Strategic Energy Plan, the government sees oil as an important energy source to be continuously utilised in the future from the viewpoints of its wide range of uses (power generation, transport, etc.) and its high level of convenience (portability and excellent infrastructure). At the same time, the government expects oil demand to continue to decline, owing to decreasing population, stricter vehicle fuel efficiency standards and fuel switching from oil mainly to natural gas and electricity. In responding to the uncertainty of energy resources provided from overseas, Japan engages in active resource diplomacy with supplier countries. The IEA encourages the government to continue to support upstream investment and vertical integration in oil exploration and development abroad in order to secure long-term oil supply.

The Japan Oil, Gas and Metals National Corporation (JOGMEC) is an important vehicle for the government in supporting overseas exploration and development activities of Japanese companies, also outside the Middle East, Japan´s traditional supply area. The IEA commends Japan's ongoing efforts to diversify sources of oil supply in order to enhance its energy security.

Additionally, since the last IEA in-depth review of Japan´s energy policies in 2008, there have been several amendments to legislation aimed at optimising refinery equipment and improving oil security. After the Great East Japan earthquake of 2011, the Oil Stockpiling Act was amended in 2012 making the release of government stockpiles possible not only when there is a shortage of supplies from overseas, but also when there is a shortage of supply in specific regions due to a disaster. The new Act also requires the creation of a joint plan for "co-operation in oil supply at times of disaster" that stipulates areas of co-operation such as enabling the joint use and provision of facilities, and sharing information on stocks between industry players and the government.

Further, the Great East Japan earthquake of 2011 severely tested Japanese petroleum infrastructure. As a result, the government, in conjunction with the petroleum sector, has implemented a range of initiatives to improve the overall emergency preparedness and resilience of the petroleum industry in Japan. The IEA applauds the government's efforts in improving its disaster preparedness framework with respect to the petroleum industry.

Japan has also made advances in rationalising its refining industry. As a result of the amendment to the Act on Sophisticated Methods of Energy Supply Structures, which required refiners to increase their ratio of heavy oil cracking equipment, Japan's crude oil processing capacity decreased by 19% from 4.85 mb/d in 2009 to 3.95 mb/d at the end of March 2015.

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Domestic demand for petroleum products is expected to continue its decline, largely as a result of improvements in vehicle energy efficiency and the continued switching from oil to city gas and electricity in both the industry and households.

The refining, transport and storage of oil is conducted by private-sector companies. Domestic refining capacity far exceeds domestic demand with the operating rate in FY2014 at just 82.4%. Coupled with projected decreases in the demand for petroleum products, refinery rationalisation will be necessary in the near term. In this regard, the IEA recognises the efforts of the government to rationalise the oil refining sector in order to keep the sector viable, efficient and globally competitive. The sector is consolidating and, as a result of mergers already announced, two very large oil groups will emerge in 2017. It can be expected that these groups will have a strong position in wholesale and retail, and issues related to competition may arise. The government should continue to closely monitor competition, especially in the retail sector, and address any legitimate concerns effectively.

RECOMMENDATIONS

The government of Japan should:

- ☐ *Continue steps to secure oil supply from new markets in order to enhance oil security.*
- ☐ *Continue to support non-domestic upstream investment of Japanese companies in petroleum exploration and development in order to secure long-term petroleum supply.*
- ☐ *Continue to support emergency preparedness and resilience of the domestic petroleum sector to better manage recovery from natural disasters.*
- ☐ *In light of decreasing demand, take steps to ensure that the rationalisation of the refining industry maximises its efficiency, profitability and global competitiveness; continue to monitor competition in the oil sector as consolidation advances.*

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6. COAL

Key data (2015 estimated)

Production: Nil

Hard coal imports: 191.6 Mt of hard coal, +7.8% since 2005

Share of coal: 27.5% of TPES and 34% of electricity generation

Inland consumption (2014): 118.5 Mtoe (power generation 58.8%, coke ovens and blast furnaces 21.1%, industry 19.6%, services and agriculture 0.5%)

SUPPLY AND DEMAND

SUPPLY

Total coal supply was 118 million tonnes of oil-equivalent (Mtoe) in 2014, or 26.8% of total primary energy supply (TPES). Coal supply declined by 2.8% from 2013, after years of volatility. Supply grew for decades to reach 116 Mtoe in 2007, after which it declined by a total of 13% during 2008-09. It recovered by 13.7% in 2010 and continued to grow to a peak of 122 Mtoe in 2013. Coal use in power generation increased following the gradual nuclear shutdown from 2011 on as load factors were increased. Also, 1.6 gigawatts (GW) of new coal-fired capacity (Hirono 6 and Hitachinaka 2) came online in 2013.

Japan relies on imports for all of its coal supply, as domestic production ceased in 2002. Coal imports totalled 192 million tonnes (Mt) in 2015: 73.7% steam coal and 26.3% coking coal. Imports originated from Australia (64.9% of the total), Indonesia (18.6%), Russia (7.4%), Canada (4.3%) and other countries (Figure 6.1). Over the ten years since 2005, imports from Russia have increased by 34.5%, from Indonesia by 23.7%, from Australia by 21.9% and from Canada by 12.5%. In contrast, imports from China have declined significantly, from 13.4% of the total in 2005 to 1.3% in 2015.

Coal imports often come from mines developed independently by Japanese companies (with coal-mining rights). This independent development ratio is around 70% for imports from Australia, according to the Japan Coal Energy Center (JCOAL). To help ensure coal supply, the government is promoting the acquisition by Japanese companies of more coal-mining rights and development of coal mines abroad, for example in Indonesia.

DEMAND

In 2014, around 59% of coal was used in power generation and 21% in coke ovens and blast furnaces that serve mainly iron and steel but also cement production. A further 19.6% was consumed directly by industry where, again, iron and steel is the largest user. The other sectors (services, agriculture, transport) accounted for 0.5% (Figure 6.2).

Over the decade to 2014, the driver of growing coal demand was the power generation sector. Coal use in power generation increased by 9.6% from 2004 to 2014, while the

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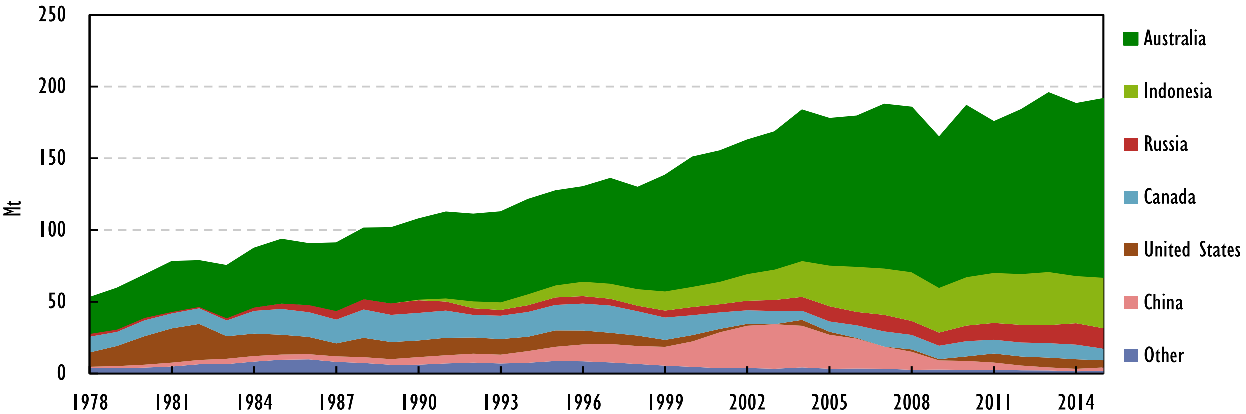
overall coal use was up by 2.6% (2013 was a peak year in coal demand). Demand for coke production grew by 1.2% over the same period. Conversely, demand for direct industry use declined by 13.4% over the same period.

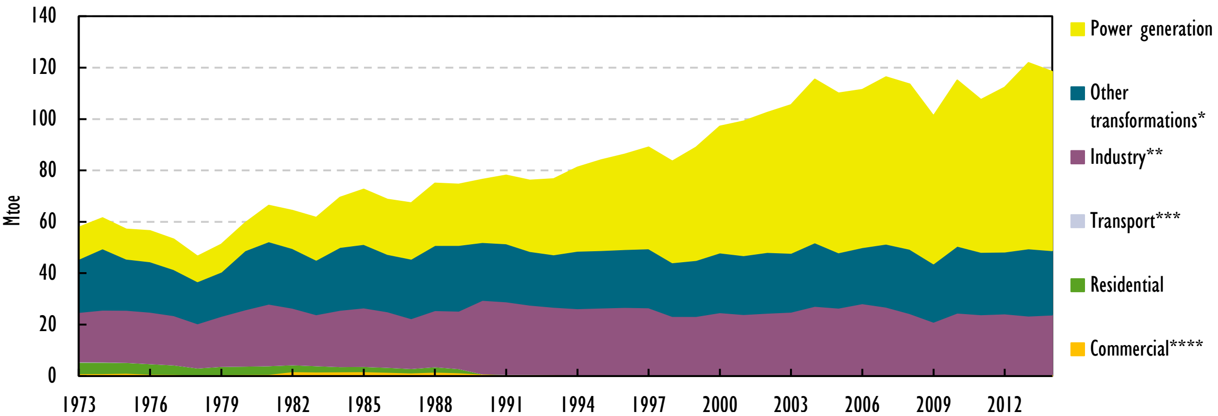
Figure 6.1 Coal imports by country, 1978-2015



Note: Data are estimated for 2015.

Source: IEA (2016a), *Coal Information 2016*, www.iea.org/statistics/.

Figure 6.2 Coal supply by sector, 1973-2014



Note: TPES by consuming sector.

* *Other transformations* includes transformations such as coke ovens and refining, and energy own-use.

** *Industry* includes non-energy use.

*** Negligible.

**** *Commercial* includes commercial and public services, agriculture/forestry and fishing (negligible).

Source: IEA (2016b), *Energy Balances of OECD Countries 2016*, OECD/IEA, Paris.CD/IEA, Paris.

POLICY

The 2014 Strategic Energy Plan (SEP) sets out a vision for the future energy mix based on the specific policy targets of energy security, economic efficiency, environment and safety (3Es + S). On the basis of the Plan, the government set out in 2015 its energy mix targets for each energy source: the role of coal in Japan's energy mix will be maintained to 2030, at around 25% of TPES. Coal's contribution to power generation will be around 26%, down from 31% in 2014 but similar to levels before the Great East Japan earthquake.

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Japan's coal policy centres on three key priorities. The first is to secure stable coal supply at a low cost. Japan imports all the coal it needs, with more than 80% from Australia and Indonesia. Power plants typically use high-calorific value coal and this has led to an increased reliance on Australian coal over time. Japan is seeking to further diversify its suppliers, including through providing financial support for coal exploration to overseas geological surveys and for the development of new mine infrastructure. Japan is also developing technologies to facilitate the efficient use of low-quality coal.

The second coal policy priority is the promotion of efficient coal-fired power plants. Japan's coal fleet is the most efficient in the world averaging 864 grammes of carbon dioxide per kilowatt-hour (gCO_2/kWh) (compared with the global average of 958 gCO_2/kWh). Japan is also a world leader in the development and deployment of lower-emission coal technologies. For example, the Isogo thermal power station in Yokohama is one of the most efficient coal-fired power stations in the world, operating at around 44% efficiency, and its sulphur dioxide (SO_X), nitrogen oxide (NO_X) and particulate matter (PM) emissions are comparable to gas-fired power plants (see Box 6.1).

Up to 20 GW of new coal-fired capacity is planned to be commissioned in the coming years, as the electricity markets are liberalised and coal prices remain low relative to natural gas. Some of this new capacity may replace older, less efficient plants and some may either be delayed or ultimately not built, given the government measures introduced in April 2016 that require an ultra-supercritical level efficiency for new coal-fired plants (at least 42% of thermal efficiency in gross calorific value) on the generation side and, on the retail side, at least 44% of electricity to originate from non-fossil fuel sources by 2030. Japan is also focusing research, development and deployment (RD&D) efforts on carbon capture and storage (CCS), a critical technology for making large-scale long-term coal use compatible with long-term goals to limit CO_2 emissions (see Chapter 3 on climate change).

The third coal policy priority for Japan is supporting exports of Japanese low-carbon technologies, including through projects to demonstrate lower carbon coal utilisation technologies and transfer of Japanese operation and maintenance expertise. Japan is aiming to support the global deployment of the most efficient coal-fired power technologies in countries that will continue to use coal. In November 2015, Japan supported an agreement by OECD countries to limit export credit financing for coal-fired power. The exceptions to this restriction include ultra-supercritical technologies, super-critical plants in countries facing energy poverty challenges and small sub-critical plants in poorer, developing nations.

Around 40% of Japan's coal is used in industry, directly and indirectly (in the form of coke). This is mostly for iron and steel production where coal/coke is a process input. Unlike in electricity generation, coal cannot be fully substituted in iron and steel production without increasing costs and losing efficiency. Japan's steel production is the most energy-efficient in the world and the sector has established a voluntary action plan to reduce CO_2 emissions, including through next-generation coke-making processes and chemical recycling of waste plastic at steel plants.

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Box 6.1 The Isogo coal-fired power plant

J-POWER's high-efficiency, low-emission Isogo plant is located in central Yokohama, the second-largest city in Japan with a population close to four million. The plant consists of two ultra-supercritical units of 600 megawatts (MW) each. The first unit started operation in 2002 and the second unit in 2009. They replaced two units (2 x 265 MW) built in the 1960s. New Unit 1 was built while the old units were in operation, which was a challenge on the plant's 12-hectare site. Build, scrap, and build was the method for this unit's construction.

Isogo has a gross thermal efficiency of 45% (referred to as lower-heating value), using steam conditions of 600 degrees centigrade (°C) for the main steam and 620°C for reheated steam (610°C in the case of Unit 1), as well as pressure of 25 megapascals (MPa). Following internal consumption, net thermal efficiency is 43.5%, which means a 17% emission-factor decline when compared with the old units.

In addition to reducing emissions by increasing efficiency, Isogo uses the most advanced systems to improve local air quality and minimise sulphur, NO_x and particle emissions. These advanced systems include passing flue gas through a selective catalytic reduction system where nitrogen oxides are decomposed to water and nitrogen, and then through a desulphurisation denitrification system based upon regenerative activated coke technology. From there, multiple pollutants are removed simultaneously with a high yield: 98+% of sulphur, 20% to 80% of NO_x and 90+% of mercury. Dust is also removed by using an efficient dry system (>100 times more efficient in reducing water consumption) to under 30 milligrammes per normal cubic metre (mg/Nm^3). Finally, flue gas passes through an electrostatic precipitator to further clean the gas of dust before being released by the stack. Following this cleaning process, pollutant concentration surrounding Isogo is extremely low: 1 to 6 parts per million (ppm) of sulphur, 10 to 15 ppm of NOx, 1 to 3 mg/Nm^3 of dust and 0.14 to 0.25 microgrammes per normal cubic metre ($\mu g/Nm^3$) of mercury, which are levels more generally expected for gas turbines rather than for coal plants.

The environment-friendly concept in practice at Isogo goes much further. Both flying and bottom ashes are recycled, and by-products from activated cokes are also passed forward to recycling partners in both the chemical industry (sulphuric acid) and other industries (gypsum). Coal is transported on conveyor belts inside sealed pipes and stored in silos to prevent coal dust dispersion. This makes Isogo an unusual coal plant, as coal is not actually visible in any part of the plant.

In order to avoid accidents and malfunctions, strict control is used throughout the process, such as flue gas monitoring, spilt oil control, coal-dust litter control and water pollution control. Additionally, noise pollution is reduced through a strategic organisation of noisy equipment indoors and predominant use of low-noise equipment.

Additional environment-friendly elements include carefully planned architectural and landscape designs where the arrangement of buildings and their colour is in harmony with their surroundings. One-fifth of the site is dedicated to flowers and trees, including an artificial hill and a Japanese garden. Athletes are delighted to find a tennis court on the roof of one building and a football pitch on the ground.

Source: IEA (2014).

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ASSESSMENT

Coal plays an important role in Japan's energy mix. In 2015, it was the second-largest primary energy source after oil, providing 27.5% of TPES, and the second-largest source for electricity after natural gas, generating 34% of the total. Reliance on coal for electricity generation has grown since the Great East Japan earthquake, from around 27% of total generation in 2010. After the nuclear shutdown, increasing coal use for power generation has helped limit the growth in electricity generating costs.

Under current government policy, the role of coal in Japan's energy mix will largely be retained until 2030, at around 25% of TPES. Coal is globally abundant at relatively low cost, and therefore is seen to help the government meet its energy security and economic efficiency objectives. Although coal will maintain a significant share of the energy mix, proposed energy efficiency measures in the electricity sector will mean that the overall growth in coal demand over this period will be limited.

Japan has the most efficient coal fleet in the world and has prioritised the development and deployment of new, higher-efficiency technologies for coal. Technologies capable of achieving efficiencies of more than 45%, such as advanced ultra-supercritical and integrated gasification combined cycle (IGCC), will increasingly be available in the 2020s. Integrated coal gasification fuel-cell combined system (IGFC) technology has the potential to achieve efficiencies of 55% or more, and may become available from 2030. These technologies have the potential to make a major contribution to reducing emissions from coal, with every 1% increase in efficiency (up to 50% efficiency) equivalent to more than a 2% decrease in CO_2 emissions per kWh generated.

The Strategic Energy Plan assumes an increase in average efficiency of coal-fired power plants of 6.7% in 2030, which is equivalent to an ultra-supercritical plant. Achieving such an ambitious target may require that older, supercritical plants are retired and replaced with ultra-supercritical technology (or better). Japan is encouraging the replacement of older plants by accelerating the environmental assessment process from roughly three years to less than one year to replace thermal plants. The government also introduced, in April 2016, requirements for new coal-fired power plants to have ultra-supercritical-level high efficiency. The IEA welcomes these policy developments.

Even with these future efficiency improvements, however, Japan faces a major challenge in reconciling its continued reliance on coal with its commitment to reducing emissions by 26% by FY2030 below FY2013 levels. A significant level of unabated coal use will also be incompatible with the government's long-term target to reduce emissions by 80% by 2050.

RECOMMENDATIONS

The government of Japan should:

- ☐ *Continue efforts to develop high-efficiency coal power plant technology and promote the replacement of older, less efficient plants with high-efficiency plants to achieve the average efficiency levels proposed in the Strategic Energy Plan.*

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7. NATURAL GAS

Key data (2015 estimated)

Natural gas production: 2.9 bcm (negligible)

Natural gas imports: 117 bcm, +44.6% since 2005

Share of natural gas: 23.3% of TPES and 39.2% of electricity generation

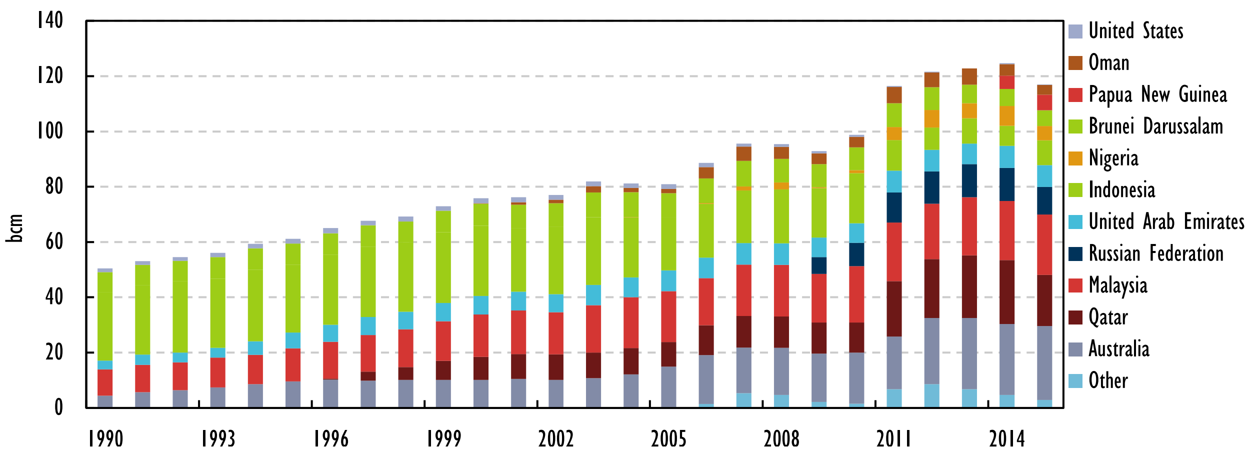
Consumption by sector (2014): 130.7 bcm (power generation 69.8%, industry 13%, residential 8%, commercial and public services and agriculture 6.1%, other energy 3.1%, transport 0.1%)

SUPPLY AND DEMAND

Natural gas accounts for around a quarter of total energy supply in Japan and is the main fuel used in power generation. In 2015, 23.3% of total primary energy supply (TPES) and 39.2% of electricity generation came from natural gas. Supply amounted to 101.4 million tonnes of oil-equivalent (Mtoe) or around 117 billion cubic metres (bcm). It was 44.6% higher than in 2005, and has been growing steadily for decades, with a boost of 16.3% in 2011.

Japan relies on natural gas imports as indigenous production is negligible, some 2.9 bcm in 2015. Imports totalled 117 bcm that same year, originating from Australia (22.9% of the total), Malaysia (18.7%), Qatar (15.8%), Russia (8.5%), the United Arab Emirates (6.7%) and others (Figure 7.1).

Figure 7.1 Japan's natural gas imports by country, 1990-2015



Note: Data are estimated for 2015.

Source: IEA (2015), *Natural Gas Information (database)*, www.iea.org/statistics/.

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From 2005 to 2015, imports have increased by 44.6%, with a surge of 17.9% in 2011 alone. Imports from three countries have grown significantly faster than total imports, namely from Australia (83.3%), Qatar (107%) and Oman (126.8%). Conversely, imports from Indonesia declined by 53.6% over the ten years, down from 23.8% of the total in 2005 to 7.6% in 2015.

Imports from Nigeria started in 2004 and increased from negligible levels to 4.4% of total imports in 2015. Imports from Russia started in 2009 at 6.5% of the total, increasing to 8.5% in 2015. Gas was imported from Papua New Guinea for the first time in 2014 and accounted for 4.8% of the total in 2015.

DOMESTIC PRODUCTION

Domestic production of natural gas in 2015 was 2.9 billion cubic metres (bcm), equivalent to around 2.2 million tonnes (Mt) of liquefied natural gas (LNG). Japan has very limited natural gas resources and around 98% of the demand is met by imported LNG. According to the Ministry of Economy, Trade and Industry (METI), proven reserves of natural gas were estimated at 35.7 bcm in March 2015.

Further offshore petroleum and natural gas activities have been proposed in the Plan for the Development of Marine Energy and Mineral Resources, which was updated in December 2013. By 2018, METI will carry out three-dimensional geophysical exploration of an approximate area of 62 000 km^2 (about 6 000 km^2 per year since 2013) in the seas around Japan, and carry out test drilling in waters with suitable potential.

The government expects that technological developments may facilitate the commercialisation of methane hydrate by 2018. Offshore gas production tests for deep methane hydrates, using depressurisation technologies, were conducted in the Eastern Nankai Trough area in March 2013. Around 120 000 cubic metres (m^3) of gas was produced over a six-day period. Furthermore, in order to assess reserves of shallow methane hydrates, wide-area surveys and other studies are under way since 2013. In 2014, a budget of JPY 12.7 billion was allocated for methane hydrate development projects.

DEMAND

Power generation is the largest natural gas-consuming sector in Japan, with a share of 69.8% in 2014. In 2003, the share of power generation was 67.4%; however, in the mid-2000s, gas demand grew faster in commercial and public services than in power generation whose share in total gas consumption declined to 63.6% in 2010. In 2011, demand from power generation surged in the aftermath of the nuclear power plant shutdown and its share increased to 67%, growing steadily since.

In 2014, industry accounted for 13% of total gas demand, households for 8%, services and agriculture for 6.1% and energy own-use and LNG/regasification plants (see Figure 7.2, "other energy") for 3.1%. Transport demand is negligible at 0.1%. From 2004 to 2014, total natural gas demand increased by 49.3%. By sector, demand from commercial and public services increased by 21.4% and other energy by 286.7%, while industry demand grew by 37.6%. Residential demand declined by 0.3% over the same period, with its share in total consumption falling from 11.9% in 2004 to 8% in 2014.

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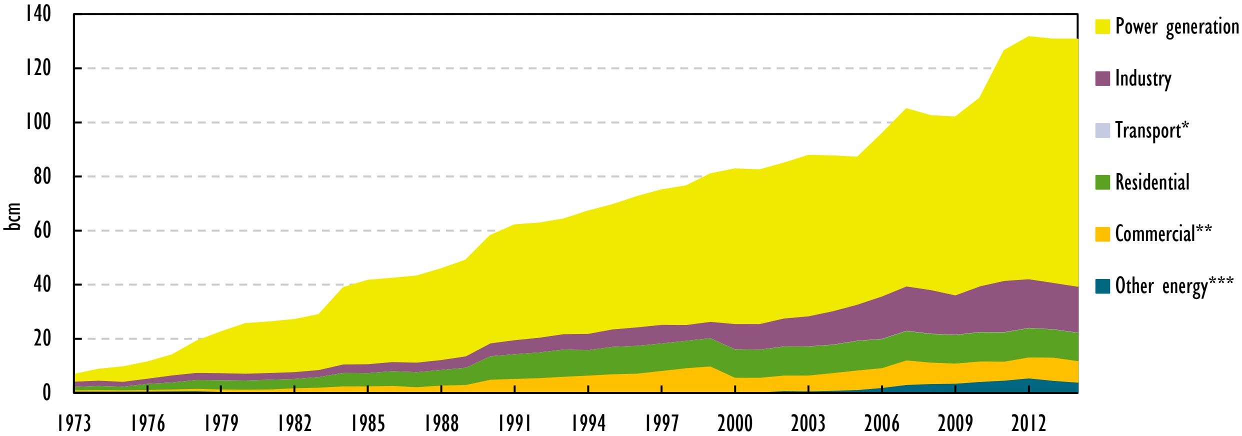
Figure 7.2 Natural gas demand by sector, 1973-2014



Notes: TPES by consuming sector.

* Negligible.

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

*** *Other energy* includes LNG/regasification plants and energy own-use.

Source: IEA (2016a), *Natural Gas Information 2016*, www.iea.org/statistics/.

INDUSTRY AND MARKET STRUCTURE

Natural gas is used for the production of electricity and city gas. The city gas industry remains fragmented into many vertically integrated regional companies. As of the end of 2014, Japan had 206 city gas utilities, of which 180 were private companies and 26 were public utilities (JGA, 2015). City gas is supplied via pipeline to around 30 million users, out of which 28 million are residential customers.

Table 7.1 City gas utilities in Japan, 2015

District	No. of public utilities	No. of private utilities	Total number of customers (000)
Chugoku	1	11	880
Hokkaido	1	9	857
Kanto	15	74	14 792
Kinki	2	17	7 469
Kyushu	-	28	1 718
Tohoku	6	30	917
Tokai-Hokuriku	1	10	2 829
Shikoku	-	1	280

Source: JGA (2015), *Gas Facts in Japan 2015*.

According to data on gas sales volumes for 2014, the three largest gas utilities – Tokyo Gas, Osaka Gas and Toho Gas – held a combined market share of 71%. Tokyo Gas had a share of 37%, Osaka Gas 23%, Toho Gas 11% and the rest of the market 29%, according to the Japan Gas Association.

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Nine gas companies import through their own LNG facilities. The other gas companies purchase gas from the wholesale market or from LNG importers and domestic natural gas producers. The wholesale market is unregulated, and since the procurement sources for each company are not made public, the details of their transactions are unclear. Gas companies and gas transporters are obliged to publish gas transportation contract details, and accounting unbundling is imposed.

LNG MARKET

Japan is the world's largest LNG import market, both by capacity and by import volumes. Its dominant import position is not expected to change. With the commercial start-up of the Hibiki LNG terminal in November 2014, the country's overall LNG receiving capacity increased to 190 Mt/year (262 bcm/year), equivalent to 26% of the world's total (IGU, 2015). Three additional large-scale terminals, or terminal expansions, with a combined capacity of 3.5 Mt/year were under construction during 2015. Capacity utilisation stood at 47% in 2014, a minor decrease from 48% in 2013. Utilisation rates generally averaged 50% as a result of import seasonality.

LNG imports in 2014 increased by 1.5% from 2013. Demand has grown rapidly since the Fukushima Daiichi nuclear accident in March 2011, which led to the progressive shutdown of all of Japan's nuclear power plants and increased demand for LNG from the power sector. As of early 2016, all but two of the country's nuclear power plants remained offline, though a number of other reactors have been cleared to restart operations. Nonetheless, the exact timeline for restarts remains unclear and, in the future, Japan's LNG demand will be dictated by the pace of nuclear restarts, as well as the cost and availability of alternative energy sources.

Traditionally, Asian LNG prices have been linked to Japan's crude oil import prices, which rose sharply from 2008 to 2014. Japan's higher natural gas demand for power, a tighter LNG supply market over the past few years, and higher oil prices led to a significant increase in Asian spot LNG import prices, climbing from an average of USD 10 per million British thermal units (MBtu) before the Fukushima Daiichi nuclear accident to around USD 18/MBtu in mid-2012. Japan has been negotiating lower prices for long-term LNG contracts that historically have been linked to international crude oil prices.

High oil prices for Asian buyers until the end of 2014 caused Japanese utilities, particularly those affected by the Fukushima Daiichi nuclear accident, to incur significant costs for higher gas and oil purchases, resulting in net revenue losses, as these costs could not be passed on to consumers in full because of retail price regulation. In response to the rising fuel acquisition costs and attendant power price increases, some Japanese buyers have signed LNG contracts that are based on US market prices, which are lower, rather than being tightly linked to crude oil prices.

High prices and surging import needs in the aftermath of the Fukushima Daiichi nuclear accident tipped Japan's trade balance into deficit since 2011, but the rapid global oil price decline since late 2014 has greatly benefited large Japanese LNG importers. LNG markets are expected to remain in oversupply for several years, and increases in oil prices since early 2016 are seen to come with a low risk of higher LNG import prices for the next three to five years, as a result of the low price sensitivity of short-term LNG production.

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DOMESTIC CITY GAS MARKET

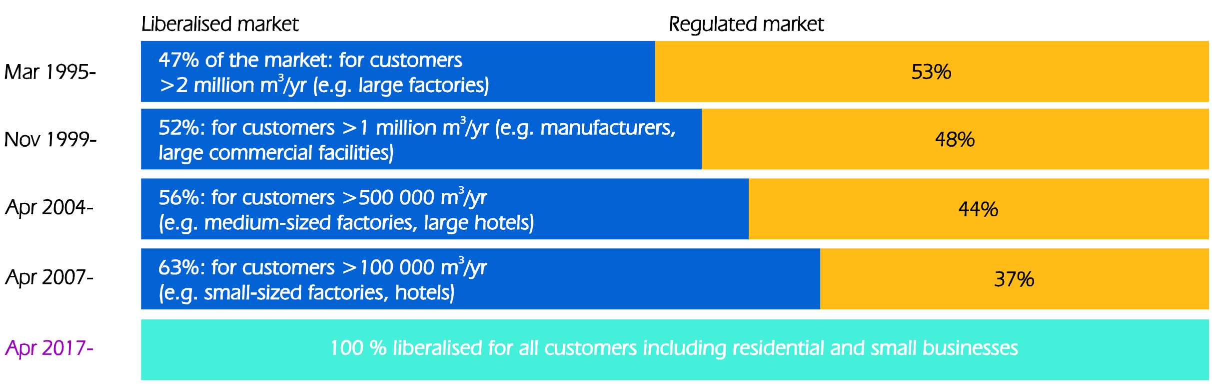
The city gas market is divided into two parts: the regulated sector, comprising small-volume customers, and the deregulated sector, which is made up of large customers and wholesale businesses. In the regulated sector, city gas companies designated by the Minister of Economy, Trade and Industry are permitted monopolistic supply within their supply districts. Supply and safety obligations and tariff regulations are imposed on those companies. The deregulated sector comprises customers with annual gas usage of 0.1 million cubic metres (mcm) or more. Suppliers are allowed to enter this sector freely and are not restricted to specific supply areas. Gas tariffs are determined by means of negotiations between the supplier and customers.

At the end of FY2014, the city gas market consumed 37.1 bcm of natural gas: the industrial sector consumed 20.3 bcm (55%), the household sector 9.6 bcm (26%), the commercial sector 4.2 bcm (11.6%) and the remaining sectors accounted for 2.9 bcm (7.4%). In FY2014, 11.7% of the liberalised market was supplied by new entrants, mostly those who own pipelines and/or LNG terminals such as power utilities, oil and gas upstream and oil-refining companies. This share is higher than in electricity retail where new entrants served 5.2% of the liberalised market in the same fiscal year.

The retail market for city gas has had four phases of liberalisation starting in 1995 (for users consuming more than 2.0 mcm), then again in 1999 (more than 1.0 mcm), in 2004 (more than 0.5 mcm), and in 2007 (more than 0.1 mcm). In addition, tariff increases require the approval of the Minister of Economy, Trade and Industry. Conversely, tariff reductions can be carried out with notice. Market entry to the segment for users with annual contracts of more than 0.1 mcm and its tariff rates are fully liberalised.

In November 2013, the Advisory Committee for Natural Resources and Energy's Gas System Reform Subcommittee began a review of the gas system reform, including full market opening and third-party access (TPA) conditions and tariffs of LNG terminals. Based on the results of this review process, a revision of the Gas Business Act was submitted to the Diet which adopted it in June 2015. As shown in Figure 7.3, liberalisation of the natural gas industry will be complete in April 2017, one year after deregulation of the power sector. The revised Gas Business Law will also separate pipeline management from the major city gas firms in Tokyo, Nagoya and Osaka in April 2022 in order to allow new entrants greater access to infrastructure.

Figure 7.3 Phases of retail gas market liberalisation in Japan



Note: The share of the liberalised market (%) represents the ratio of 10 large city gas providers' gas sales volume in the liberalised market to their total gas sales volume in FY2012. The balance represents the share of the regulated market (%).

Source: IEA (2016b).

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The changes to both the electricity and natural gas markets are expected to facilitate not only the entry of new participants into the sector but also to help power and gas companies enter each other's markets. Over the long term, the government hopes that increased competition will result in lower electricity and gas bills for consumers and support the introduction of new services, including the sale of green power. In 2016, a number of electricity utilities have announced that they will enter the natural gas market and undercut existing incumbents.

STRATEGY FOR FUTURE GAS MARKET DEVELOPMENT

The April 2014 Strategic Energy Plan (SEP) includes four goals for the gas market reform:

- Secure the stable supply of natural gas, including the reinforcement of supply during disasters, through increasing gas pipeline networks, maintenance and interconnection.
- Lower gas prices to the maximum extent possible by promoting market competition among natural gas procurement and retail services and improve the lifestyle of citizens.
- Expand gas choice for consumers and bring about innovation by means of market entry of other industries and expansion of gas companies to other areas, by offering them greater diversity of retail choices and pricing plans for gas consumers.
- Expand natural gas use by promoting the participation of businesses that can build new gas pipelines, develop new markets for gas, and propose new utilisation methods for natural gas such as fuel cells and co-generation.

The Long-term Energy Supply and Demand Outlook, which was adopted by METI in July 2015, forecasts that the import volume of LNG will be around 85 bcm in 2030, thereby remaining a strategically important resource for Japan. Over the period between 2015 and 2030, the Japanese focus on securing a stable energy supply is likely to shift from securing long-term stability and sufficient quantity, to securing flexibility, resilience and better market utilisation.

On this basis, METI has opened a dialogue with major consumers and suppliers of LNG. In light of the information obtained through these discussions, METI decided to develop a new Strategy for LNG Market Development which was adopted in May 2016. This strategy will focus on the creation of a flexible international LNG market and the development of an LNG trading hub in Japan. In order to enhance the flexibility of LNG and develop an LNG trading hub, METI will work with LNG producers to remove destination clauses, create a price discovery mechanism, and introduce greater access to LNG infrastructure.

INFRASTRUCTURE

STORAGE CAPACITY AND LNG TERMINALS

While Japan has no underground facilities to store natural gas in its gaseous state, it has 31 operational LNG receiving terminals with a total LNG storage capacity equivalent to around 10 bcm of natural gas storage capacity at the end of 2015. Most of the LNG terminals are located in the main population centres of Tokyo, Osaka, and Nagoya, near major urban and manufacturing hubs, and are owned by local power companies, either

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alone or in partnership with gas companies. These same gas companies also own much of Japan's LNG tanker fleet. The three terminals now under construction or undergoing trial operations are expected to come online by 2016, adding at least 4.0 bcm of capacity per year, and other projects are proposed for construction by 2020. Japan's total storage capacity meets close to 30 days of domestic natural gas consumption. The country plans to build new LNG facilities or expand storage capacity at existing terminals, which will give the country 2.2 bcm extra storage capacity in the near future.

Table 7.2 LNG terminals in Japan, 2015

LNG terminal name	Location	Owner	Total volume (kL)	No. of tanks	Year
Ishikari LNG terminal	Hokkaido	Hokkaido Gas	180 000	1	2012
Gas Bureau City of Sendai LNG terminal	Miyagi	City of Sendai	80 000	1	1997
Joetsu thermal power plant LNG terminal	Niigata	Chubu Electric Power	540 000	3	2012
Niigata terminal	Niigata	Nihonkai LNG (Tohoku Electric Power, Development Bank of Japan, Niigata Prefecture, JAPEX, etc.)	720 000	8	1984
Naoetsu LNG terminal	Niigata	INPEX	360 000	2	2013
Futtu terminal	Chiba	Tokyo Electric Power	1 110 000	10	1985
Sodegaura LNG terminal	Chiba	Tokyo Gas Tokyo Electric Power	2 660 000	35	1973
East Ohgishima terminal	Kanagawa	Tokyo Electric Power	540 000	9	1984
Ohgishima LNG terminal	Kanagawa	Tokyo Gas	850 000	4	1998
Negishi LNG terminal	Kanagawa	Tokyo Gas Tokyo Electric Power	1 180 000	14	1969
Shimizu LNG Sodeshi terminal	Shizuoka	Shimizu LNG (Shizuoka Gas and TonenGeneral Sekiyu)	337 200	3	1996
Chita LNG joint terminal	Aichi	Toho Gas Chubu Electric Power	300 000	4	1978
Chita LNG terminal	Aichi	Chita LNG (Chubu Electric Power and Toho Gas)	640 000	7	1983
Chita Midorihama LNG terminal	Aichi	Toho Gas	400 000	2	2001
Yokkaichi LNG terminal	Mie	Toho Gas	160 000	2	1991
Yokkaichi LNG centre	Mie	Chubu Electric Power	320 000	4	1988
Kawagoe thermal power plant LNG facilities	Mie	Chubu Electric Power	840 000	6	1997
Senboku I terminal	Osaka	Osaka Gas	90 000	2	1971
Senboku II terminal	Osaka	Osaka Gas	1 585 000	18	1977
Sakai LNG centre	Osaka	Sakai LNG (Kansai Electric Power, Cosmo Oil, Iwatani-Sangyo and Ube Industries)	420 000	3	2006

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Himeji terminal	Hyogo	Osaka Gas	740 000	8	1984
Himeji LNG terminal	Hyogo	Kansai Electric Power	520 000	7	1979
Mizushima LNG terminal	Okayama	Mizushima LNG (JX Nippon Oil & Energy and Chubu Electric Power)	320 000	2	2006
Hatsukaichi LNG terminal	Hiroshima	Hiroshima Gas	170 000	2	1996
Yanai terminal	Yamaguchi	Chubu Electric Power	480 000	6	1990
Sakaide LNG terminal	Kagawa	Sakaide LNG (Shikoku Electric Power, Cosmo Oil, and Shikoku Gas)	180 000	1	2010
Oita LNG terminal	Oita	Oita LNG (Kyushu Electric Power and Oita Gas)	460 000	5	1990
Tobata LNG terminal	Fukuoka	Kitakyushu LNG (Kyushu Electric Power and Nippon Steel & Sumitomo Metal Corporation)	480 000	8	1977
Fukukita LNG terminal	Fukuoka	Saibu Gas	70 000	2	1993
Nagasaki LNG terminal	Nagasaki	Saibu Gas	35 000	1	2003
Kagoshima LNG terminal	Kagoshima	Nihon Gas	86 000	2	1996
Yoshinoura thermal power plant LNG facilities	Okinawa	Okinawa Electric Power	280 000	2	2012
Hibiki LNG terminal	Fukuoka	Hibiki LNG (Saibu Gas and Kyushu Electric Power)	360 000	2	2014

Source: METI.

LNG terminals are owned and operated by electricity utilities, city gas companies and other industries such as steel companies, and local governments. Electricity companies own close to half the total LNG storage capacity, followed by gas utilities (over 40%). Of the 31 operational LNG terminals, 11 are co-sponsored by power companies, gas utilities, industry or local governments. Total nominal regasification capacity in LNG terminals represented around 252 bcm of natural gas per year (or 170 mcm/d) with 238 vaporisers as of February 2016.

PIPELINES

Japan does not have any cross-border gas pipelines. According to Japan Gas Association, total gas pipeline length in 2014 was 258 358 km, of which around 86% are low-pressure networks for local distribution, and the remainder high-pressure transmission lines. There are around 43 main interconnection points between areas, but the trunk-line networks are not necessarily connected to each other as they have tended to be developed separately around LNG terminals.

Unlike in Europe and the United States, Japan's gas pipeline network is fragmented. Relying on LNG imports for 97% of natural gas demand, Japan has built its pipelines primarily to connect LNG receiving terminals on the coast to high-demand areas. As a result, the geographic coverage of the pipelines is only 5.7% (or 17.5% when excluding mountain and wilderness areas), serving 65% of domestic gas demand. In the rest of the country, demand is mostly met by liquefied petroleum gas (LPG) (IEA, 2016b).

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Figure 7.4 Map of high-pressure natural gas infrastructure, 2015

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

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There is no single operator of the national transmission system in the country, as the trunk-line networks are not necessarily connected with each other. Each industry (mainly electricity utilities and city gas companies) owns and operates its gas pipelines. Third-party access to trunk pipelines and distribution networks was introduced in 2004 although the lack of interconnections between regions may limit the ability to increase competition through third-party access.

GAS MARKET REGULATION

The Ministry of Economy, Trade and Industry regulates gas supply businesses and there is no independent regulator in the sector. The Gas Business Act regulates the city gas businesses (which supply gas to households and industry via pipeline), large-scale gas businesses (which supply to large users who exceed 0.1 mcm each year), and gas transporter-suppliers (which supply gas to the liberalised and wholesale market, using their own pipelines). The use of natural gas outside this Act is ruled by related laws and regulations, such as the Electricity Business Act or the High Pressure Gas Safety Act.

ACCESS TO PIPELINES

Third-party access (TPA) to gas pipeline is obligatory for pipeline operators, who are required to publish TPA access tariffs and conditions and report them to METI. TPA applications cannot be declined without legitimate reason, and discriminatory treatment is also prohibited. TPA tariffs are calculated on a cost-plus basis. When constructing new pipelines for gas transportation and distribution, a number of different regulations apply depending whether the proposal lies within or outside an existing city gas supply area. In addition, if it is a high-pressure pipeline, a construction plan is submitted to METI for safety reasons. Furthermore, for larger pipes, TPA tariffs and conditions are published and reported to METI although exemptions from TPA may be applied in certain cases.

LNG ACCESS

No regulations are in place for third-party access to LNG terminals and such access is based on bilateral negotiations. To promote TPA, government guidelines suggest that each LNG terminal should create and publish its own rules on third-party access.1 As a result, over 80% of LNG terminals have established guidelines but there is little evidence of TPA under these guidelines.

NATURAL GAS EMERGENCY RESPONSE

POLICY

The key elements of Japan’s natural gas security policy are: diversification of the long-term LNG supply contract portfolio; ensuring that existing supply contracts include flexibility to increase imports in the event of a supply disruption; and reliance on the presence of commercial LNG buffer stocks held voluntarily by industry.

1. The revised Guidelines for Proper Gas Trade prepared by the Agency for Natural Resources and Energy and Fair Trade Commission of Japan, which were released in August 2004.

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According to Article 25 of the Gas Business Act (1954), gas utilities are obliged to compile and submit gas supply plans to the government each fiscal year. These plans, which are evaluated by government, are required to cover gas supply and demand during certain periods. There is no legal obligation for industry to hold emergency stocks in the form of natural gas, LNG or alternative fuels.

The Agency for Natural Resources and Energy (ANRE) is supposed to take a leading role in co-ordinating the necessary action and liaising with industry. There is no single transmission system operator in the country and as the high-pressure pipeline networks have developed separately around LNG terminals with limited interconnection, each gas company is asked to ensure its natural gas supply to its distribution area.

MEASURES

Even though industry is not obliged to maintain any emergency natural gas stocks, electric power companies and city gas companies have commercial stocks equivalent to about 20 to 30 days of consumption. In addition, upstream production can increase by 10% by using spare production capacity of unaffected gas production projects. If LNG imports are disrupted, importers (seven electricity companies and less than ten gas utilities) can also reallocate their gas imports by means of reciprocal backup supply.

Japan does not have any legislation that allows the government to oblige electricity utilities to switch fuels from natural gas to alternative sources during an emergency. The country has 23 dual-fired power generation units with a total generating capacity of 9.0 GW; however, it has very limited scope to reduce gas demand, as more than 350 TWh of electricity is generated by natural gas. During a supply disruption, transmission system operators (TSOs) will reduce gas supplies based on interruptible contracts. Tokyo Gas, which has around 34% of total sales of city gas, can reduce its supply to customers using over 0.5 mcm per year, except 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. In order to strengthen resilience to disasters such as earthquakes, the Japanese gas industry has replaced aged low-pressure gas pipelines with polyethylene pipes and highly seismic-resistant pipes. For prevention of secondary disasters, it has also developed a shut-off system, which uses block formations and devices for automatic remote shutdown.

PRICES AND TAXES

City gas businesses that supply gas via pipeline are regulated by the Gas Business Act. Although general gas supply businesses enjoy a monopoly over their supply area, they have a supply obligation to serve users with annual contracts of less than 0.1 mcm. In addition, tariff increases require the approval of the Minister of Economy, Trade and Industry while rate reductions can be carried out with notice. Other supply conditions are approved by METI. Entry to the segment and rates for users with annual contracts of more than 0.1 mcm are liberalised. Regulated users are around 31 million, which accounts for about 35% of city gas sales volume.

Retail price levels for natural gas for both households and industry are among the highest in the OECD. The government expects that the liberalisation of the household market in 2017 will likely exert downward pressure on prices as new suppliers, including electricity utilities, enter the market.

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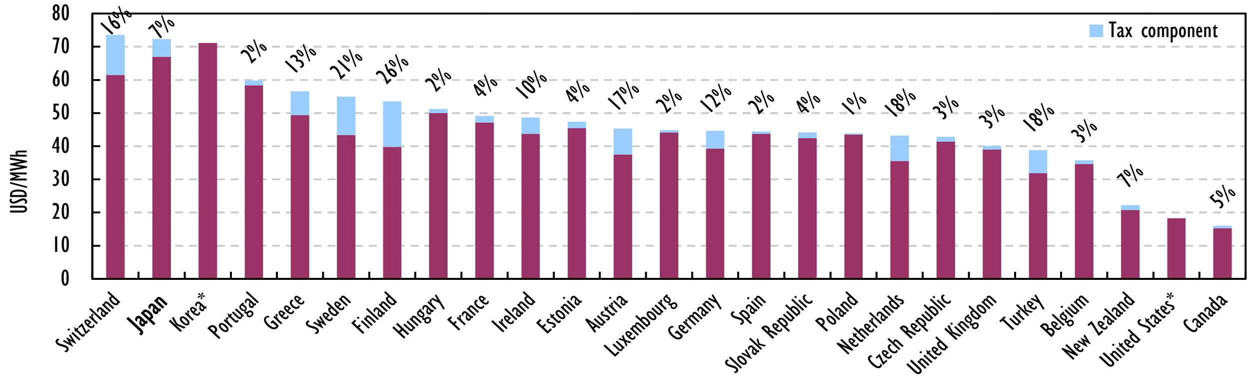
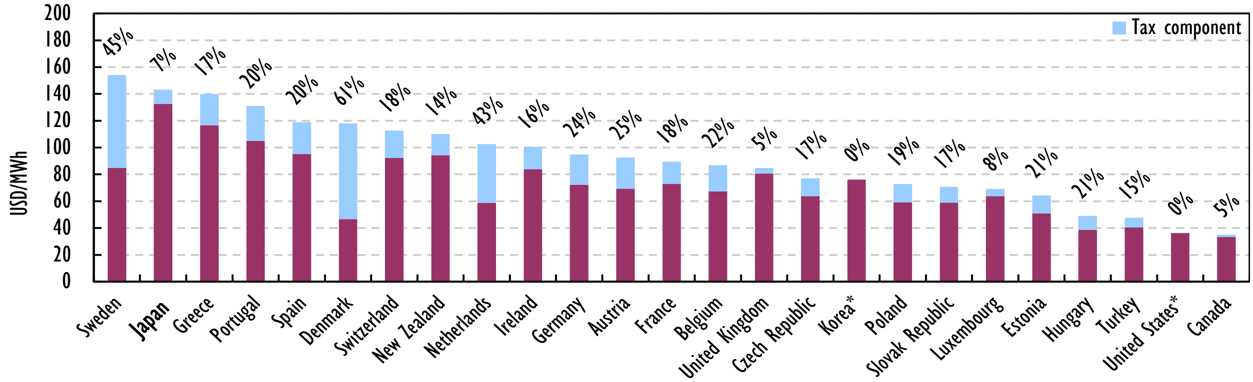
Figure 7.5 Natural gas prices in IEA member countries, 2014

Industry



Note: Data are not available for Australia, Denmark, Estonia, Italy and Norway.

Households

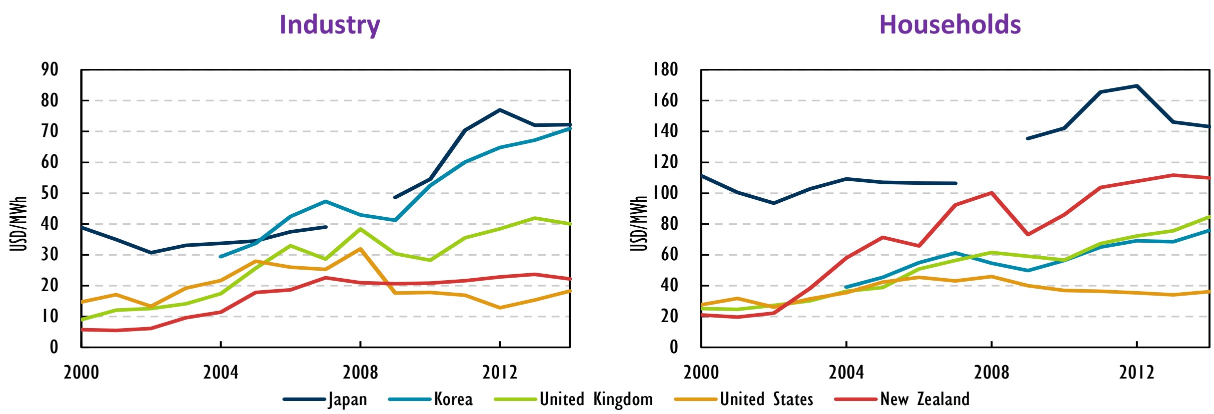


Note: Data are not available for Australia, Estonia, Finland, Italy and Norway.

* Tax information is not available.

Source: IEA (2015a), *Energy Prices and Taxes 2015*, www.iea.org/statistics/.

Figure 7.6 Natural gas prices in Japan and in selected IEA member countries, 2000-14



Note: Data are not available for Japan for 2008 and for Korea's industry before 2004.

Source: IEA (2015a), *Energy Prices and Taxes* (database), www.iea.org/statistics/.

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ASSESSMENT

In common with other energy sources in Japan's energy mix, natural gas has faced significant challenges and change since the last in-depth review in 2008. After the Great East Japan earthquake and tsunami of March 2011 and the shutdown of Japan's nuclear generation sector following the Fukushima Daiichi nuclear accident, gas became a significantly larger component of Japan's energy mix. The share of gas in TPES grew from 17.3% in 2010 to 23.3% in 2015 and in electricity generation from 28% to 39.2%. Nearly all this gas was imported as high-value liquefied natural gas (LNG).

Japan has recognised the challenges associated with the increased importance of natural gas (and implicitly the import of LNG) in the energy mix through its 2014 Strategic Energy Plan. These challenges include the balance of trade and energy security issues associated with an increased dependence on imported LNG; rising gas and electricity costs associated with oil-linked international LNG prices; and an increase in GHG emissions since the shut-down of nuclear power plants (while noting that gas is a comparatively clean fossil-fuel energy source).

As the world's oldest and largest importer of LNG, Japan has a strong interest in addressing these challenges. The 2014 Strategic Energy Plan sets out a number of priorities, including diversifying sources of gas supply, such as shale gas imports from the United States. The Plan also calls for Japan to diversify the way natural gas is used domestically and to increase its efficiency in power generation. The Plan recognises the need to improve domestic gas systems and to increase the resilience of gas supply systems.

There have been further changes and challenges in the international gas market since the release of the Plan that highlight the importance of maintaining an adaptable and responsive energy policy, especially in relation to natural gas. Since July 2014, global oil prices have fallen consistently and, despite some recovery in early 2016, were in the region of USD 45 per barrel (West Texas Intermediate) in May 2016. This largely unforeseen oil price drop alongside greater availability of LNG has reduced Japan's LNG import costs considerably under long-term contracts linked to the oil prices.

The oil price fall highlights that international energy markets are dynamic, difficult to predict and subject to a range of geopolitical and economic influences which are often not immediately apparent. In this environment, the IEA welcomes Japan's position that its energy security (and especially natural gas security) cannot be founded on a single procurement strategy. Energy security is best served by a combination of long-term contractual arrangements, trusted investment partnerships and diverse sources of supply and pricing mechanisms. The development of international trading markets and financial products which facilitate the management of financial and supply risk are also important. Japan and other countries are moving to facilitate their establishment.

Japan's important work with the annual LNG Producer-Consumer Conference is providing a vehicle to pursue reform in this area. LNG spot markets have expanded considerably over the past three years, and the development of LNG trading hubs and financial markets is important in making a spot market more efficient and liquid.

Supply diversity is increasing with Papua New Guinea emerging as a new entrant in the global LNG market in 2014. Shipments of LNG from the lower 48 states of the United States and from Australia commenced in 2016, and further projects in both the

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United States and Canada are possible. While Russia has the potential to increase gas (either pipeline or LNG) supply, uncertainty surrounds its potential at present. East Africa requires much work both to understand the resource and to build the physical and governance frameworks required to support the industry.

In this more dynamic and liquid market, Japan will need to weigh the advantages of gas supply security traditionally sourced through long-term contractual arrangements against the risks and opportunities available through different pricing formulas and contractual arrangements, including the removal of specific obligations such as destination clauses.

Japan also faces a range of challenges and opportunities in its domestic gas market. The 2008 in-depth review highlighted the importance of undertaking a full re-examination of the Gas Business Act which governs the Japanese domestic market. After the understandable delay caused by the urgent need to respond to the energy emergency in the wake of the Great East Japan earthquake, the government is now reforming the gas market to liberalise it and to improve accessibility to pipelines, TPA conditions and tariffs related to LNG terminals.

While reforms associated with changes to the Act are welcome, structural issues associated with Japan's gas industry remain of concern. The industry is still dominated by a few large gas companies which are vertically integrated and control the importation and regasification of LNG and the supply, marketing and transport of gas to larger individual customers and smaller gas distributors and retailers. The large, integrated gas companies are regionally based with limited pipeline interconnectivity which makes effective competition in the sector problematic. The sector lacks wholesale trading markets or visibility of price drivers. While there is some information available on transport costs and some regulation of prices, consumers (both large and small) lack other information and transparency of the cost structure which would assist in making choices on gas use.

There are examples of efficient gas markets elsewhere which could provide guidance on further energy reform. Since there are some potential competitors who import LNG and operate LNG terminals in Japan, such as electric utilities, further reform of gas regulations, including gas market liberalisation, can enhance competition and market efficiency. Common reforms across sectors which would do so include:

- independent competition and industry regulators to set and enforce the rules and frameworks within which a market would operate
- the collection and dissemination of supply, demand and price information through arrangements such as gas market bulletin boards
- trading hubs to facilitate the development of physical markets and appropriate financial instruments
- improving pipeline interconnections which both facilitate supply and increase resilience and security of supply in the market
- the unbundling of the current gas near-monopolies that control the supply, distribution and marketing of gas.

In this regard, recent proposals from METI on a new strategy for international LNG market development, alongside liberalisation of the market in 2017, could make a significant contribution to energy market reform should they proceed.

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Finally, Japan is making significant efforts in developing alternate sources of gas, such as indigenous methane hydrates, and in expanding the market for gas through the deployment of technologies such as fuel cells, and the deployment of hydrogen as a fuel source based on gas. While these efforts may deliver significant benefits to the Japanese economy in the longer term, the government should carefully monitor and benchmark progress on these initiatives to ensure that their potential is realisable.

RECOMMENDATIONS

The government of Japan should:

- ☐ *Continue to take a leadership role in the global dialogue between LNG producers and consumers to promote stable, competitive, flexible and diverse international LNG markets which facilitate gas trade and the development and use of appropriate financial instruments.*
- ☐ *As part of efforts to create a transparent, liquid and efficient domestic gas market, pursue the current review of the Gas Business Act, including the unbundling of the vertically integrated gas supply sector, and including the legal or ownership unbundling of the large, integrated gas utilities which have large pipeline networks and hold dominant positions in the gas market.*
- ☐ *Ensure that the gas market regulatory framework facilitates a competitive and resilient domestic market and sufficient infrastructure for the benefit of energy consumers.*
- ☐ *Continue government support for programmes and technologies which aim to diversify supply or increase the uptake of gas in Japan.*

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8. ELECTRICITY

Key data (2015 estimated)

Total electricity generation: 1 009 TWh, -10.7% since 2005

Electricity generation mix: natural gas 39.2%, coal 34%, oil 9%, hydro 8.4%, biofuels and waste 4.1%, solar 3.6%, nuclear 0.9%, wind 0.5%, geothermal 0.3%

Installed capacity (2014): 315.3 GW

Peak demand (2014): 159.1 GW

Electricity consumption (2014): 964.9 TWh (commercial and public services and agriculture 37.7%, industry 30.6%, residential 28.4%, transport 1.8%, energy sector 1.4%)

OVERVIEW

Japan is the world's fifth-largest electricity user, but its energy supply structure is vulnerable, as it depends on imports for around 95% of its primary energy supply. Following the two oil crises in the 1970s, Japan diversified its energy sources through nuclear energy, natural gas and coal as well as energy efficiency and conservation. Electricity meets around 28% of energy demand (total final consumption), a high share by international comparison. Japan's electricity network is historically relatively fragmented and it is also isolated from the neighbouring countries. The prospects for importing electricity remain limited.

The March 2011 Great East Japan earthquake and the subsequent Fukushima Daiichi nuclear accident triggered a fundamental change in the electricity sector. A three-phase electricity market reform is being implemented, and the traditional industry structure built on regional monopolies will give way to wholesale and retail competition. For the government, ensuring security of electricity supply remains a policy priority, but it pays equal attention to safety, economic efficiency and environmental conservation. To help meet all these priorities, in June 2015 the government outlined a plan for electricity supply in 2030.

SUPPLY AND DEMAND

GENERATION

As Japan is not interconnected with other countries, domestic generation accounts for the entire electricity supply. Electricity generation peaked at 1 153 terawatt-hours (TWh) in 2007 and has been on a downward trend since then. In 2014, electricity generation totalled 1 009 TWh, the lowest level since 1997 and 10.7% less than in 2005.

Before the 2011 Great East Japan earthquake and subsequent shutdown of nuclear power generation (Box 8.1), installed generating capacity in the country was well

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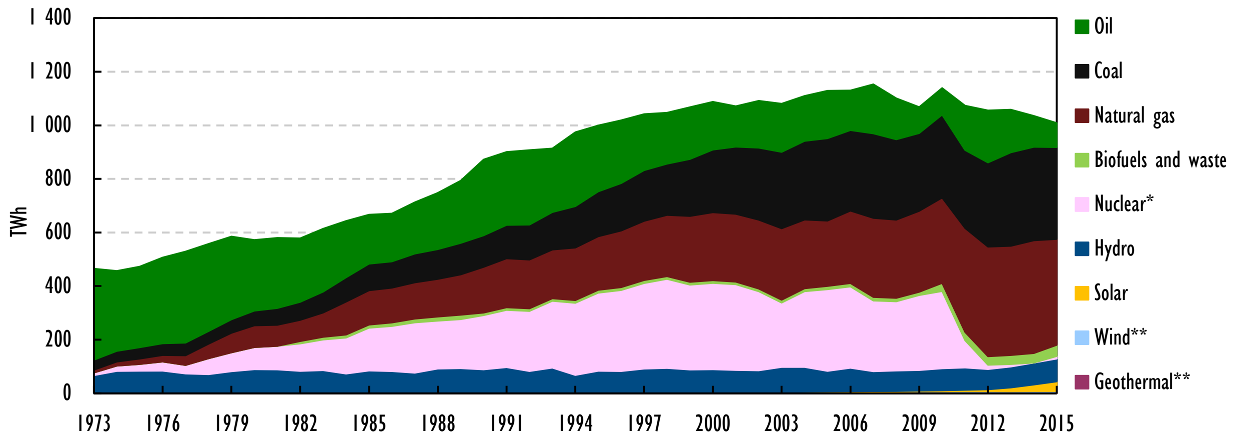
diversified, as no single source of electricity accounted for more than 30% of the country's total generating capacity.

Figure 8.1 Electricity generation by source, 1973-2015



Note: Data are estimated for 2015.

*No nuclear power generation in 2014

** Negligible.

Source: IEA (2016a, forthcoming), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

Table 8.1 Electricity generation by source, 2010-15 (TWh)

Year	Coal	Oil	Natural gas	Nuclear	Hydro	Wind	Geo-thermal	Solar	Biofuels, waste	Total
2010	309.6	101.1	318.6	288.2	82.2	4.0	2.6	3.8	30.2	1 139
2011	291.2	166.4	387.9	101.8	83.2	4.6	2.7	5.2	30.9	1 074
2012	314.1	195.2	409.1	15.9	75.5	4.7	2.6	7.0	31.8	1 056
2013	348.9	160.2	407.6	9.3	78.1	4.3	2.6	14.3	33.6	1 059
2014	348.8	116.4	420.8	-	81.8	5.0	2.6	24.5	35.5	1 036
2015	342.7	90.8	395.2	9.4	85.1	5.3	2.6	36	41.8	1 009
2015, %	34	9	39.2	0.9	8.4	0.5	0.3	3.6	4.1	100

Note: Data are estimated for 2015.

Source: IEA (2016a, forthcoming), Energy Balances of OECD Countries 2016, www.iea.org/statistics/.

The supply gap left by nuclear power shutdown was initially bridged by additional gas- and oil-fired power and energy efficiency measures, later also by coal and renewables. In 2015, only 0.9% of electricity was generated from nuclear power, and the share of liquefied natural gas (LNG) rose to 39.2% of total supply and that of coal to one-third. Nuclear power plants remained out of operation for two years until August 2015 when the Sendai 1 reactor restarted, followed by Sendai 2 in October 2015.

Supply of electricity produced from renewable sources has increased quickly from July 2012, thanks to generous feed-in tariffs introduced then. It was expected that renewables would never fill the gap immediately and that an increase in fossil fuel

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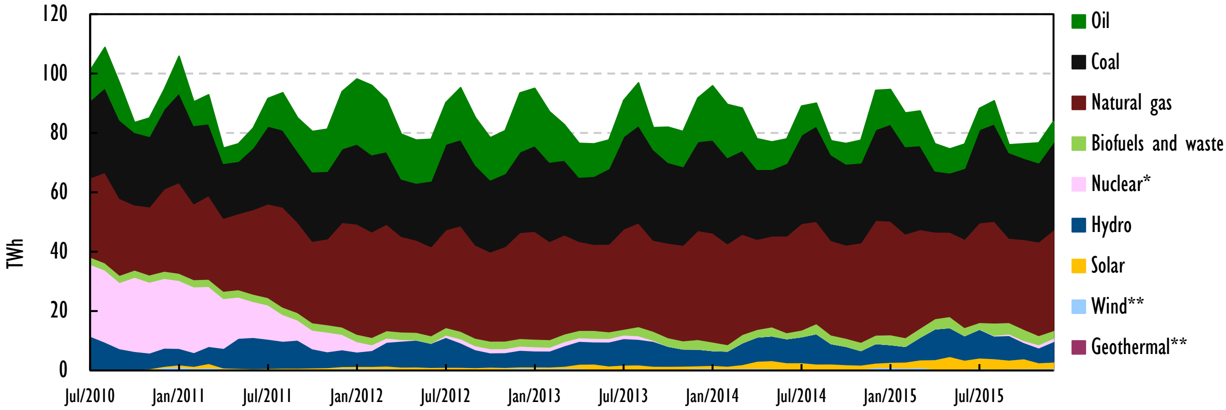
imports (such as LNG) to meet demand would be needed in the short term. However, the nuclear gap undeniably established a long-term goal for domestic, and clean, energy supplies.

Fossil fuels generated 82% of all electricity in Japan in 2015, the fifth-highest share among IEA member countries (Figure 8.2). The share of renewables (including hydro and biomass) was 16.9% and the tenth-lowest.

In July 2015, METI adopted the Long-term Energy Supply and Demand Outlook, which includes the electricity generation mix to 2030 (see Chapter 2 on general energy policy). The Outlook has nuclear at 20% to 22%, renewables at 22% to 24%, coal at 26% and LNG at 27% of total electricity supply in 2030. In 2030 CO_2 emissions would be 21.9% lower than in 2013, and the primary energy self-sufficiency rate would increase from 6.3% in 2012 to 24.3%.

Figure 8.2 Monthly electricity generation by source, July 2010 to December 2015



* Nuclear power ceased from September 2013 and restarted in August 2015.

** Negligible.

Source: IEA (2016a, forthcoming), Energy Balances of OECD Countries 2016, www.iea.org/statistics/.

Box 8.1 The aftermath of the Great East Japan earthquake

The March 2011 Great East Japan earthquake caused a tsunami which, in turn, triggered a nuclear accident at the Fukushima Daiichi power plant. The accident has permanently changed Japan's electricity industry. The government suspended the operations of the country's nuclear power plants until they pass the new safety standards set by the Nuclear Regulation Authority (NRA). The NRA required all reactors to adopt the latest safety measures which imposed costly overhauls, especially for reactors with designs from 1975 or earlier, before restarting.

Japan is a resource-poor country with high dependence on imports for primary energy supply. Therefore, the unavailability of nuclear plants necessitates the use of oil and LNG plants, which consequently increases the generation cost. Dependence on foreign fossil-fuel supply increased from 64% of total electricity generation in 2010 to 87% in 2012 and 2013, making the industry more vulnerable as it is easily affected by the domestic/international energy situation. Power companies passed on the escalating costs due to fuel imports, which resulted in higher tariffs with around a 20% rise in electricity price. Moreover, increased use of fossil fuels also increased GHG emissions from power generation (see Climate change chapter).

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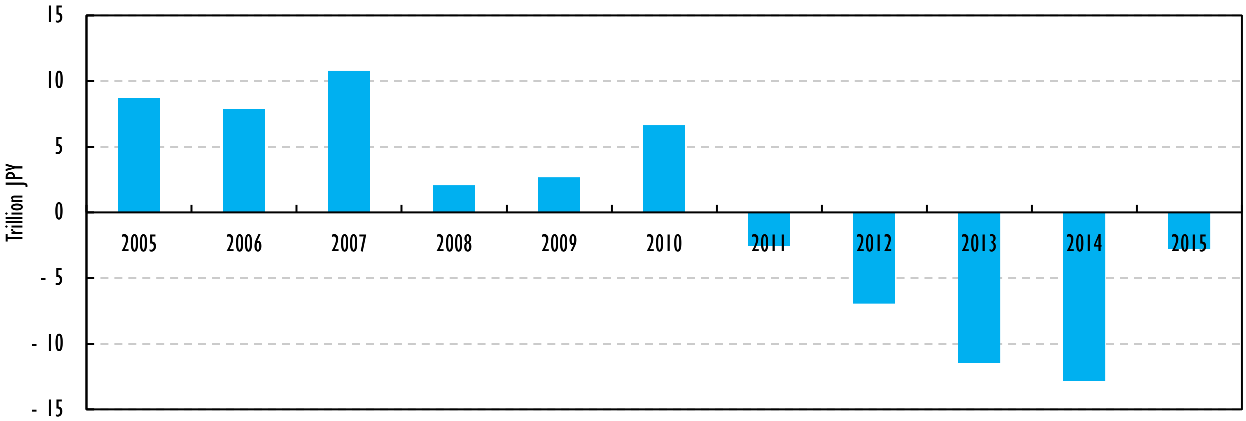
Box 8.1 The aftermath of the Great East Japan earthquake (continued)

Tokyo Electric Power Company (TEPCO), the owner of the Fukushima plant, started in April 2011 to pay compensation to people who had to be evacuated. TEPCO extended the compensation to farmers and fishermen and related industries as their products were banned from the market owing to contamination risks.

In August 2011, the Diet (national parliament) adopted the Nuclear Damage Compensation Facilitation Act which obliges nuclear operators to pay into the Nuclear Damage Compensation Facilitation (currently Nuclear Damage Compensation and Decommissioning Facilitation) for helping them implement compensation measures promptly and appropriately. In case the Nuclear Damage Compensation Facilitation does not have sufficient funds, the government may grant aid. On 31 July 2012, TEPCO received a capital injection of one trillion yen (USD 12.5 billion) from the Nuclear Damage Compensation Facilitation. TEPCO continuously received financial support both from the Nuclear Damage Compensation and from the Decommissioning Facilitation.

The shutdown of nuclear reactors and increasing fossil fuel cost put the Japanese utilities under severe financial pressure. More than half the utilities had losses for three years in a row (from April 2011 to March 2014). However for FY2014, eight out of the ten main utilities posted a profit (FEPC, 2015). The decline in LNG and oil prices since mid-2014 has helped the utilities regain some profitability. The hardest-hit utility was Kansai Electric Power Co. in western Japan, which traditionally relies heavily on nuclear power. The company posted a record JPY 176.7 billion (USD 1.66 billion) net loss for the fiscal year through March 2014, following a JPY 243 billion (USD 2.49 billion) net loss the previous year. Lost nuclear capacities and the increased use of fossil fuel generation, in particular natural gas-fired generation, brought additional costs to the Japanese economy. For instance, LNG imports amounted to 85.0 Mt in 2011, up from 70.0 Mt in 2010. Consequently, in 2011, Japan saw the first trade deficit for over 30 years. In 2014, mineral fuels (oil, gas and coal) accounted for 32% of Japan's import bill, compared to 26% in 2005. The decline in global oil, LNG and coal prices since mid-2014 has, however, reduced the pressure on the economy and in 2015 the trade deficit declined markedly (see Figure 8.3). The share of mineral fuels in total imports also declined, to 23% in 2015.

Figure 8.3 Japan's trade balance, 2005-15



Source: Trade Statistics of Japan, Ministry of Finance.

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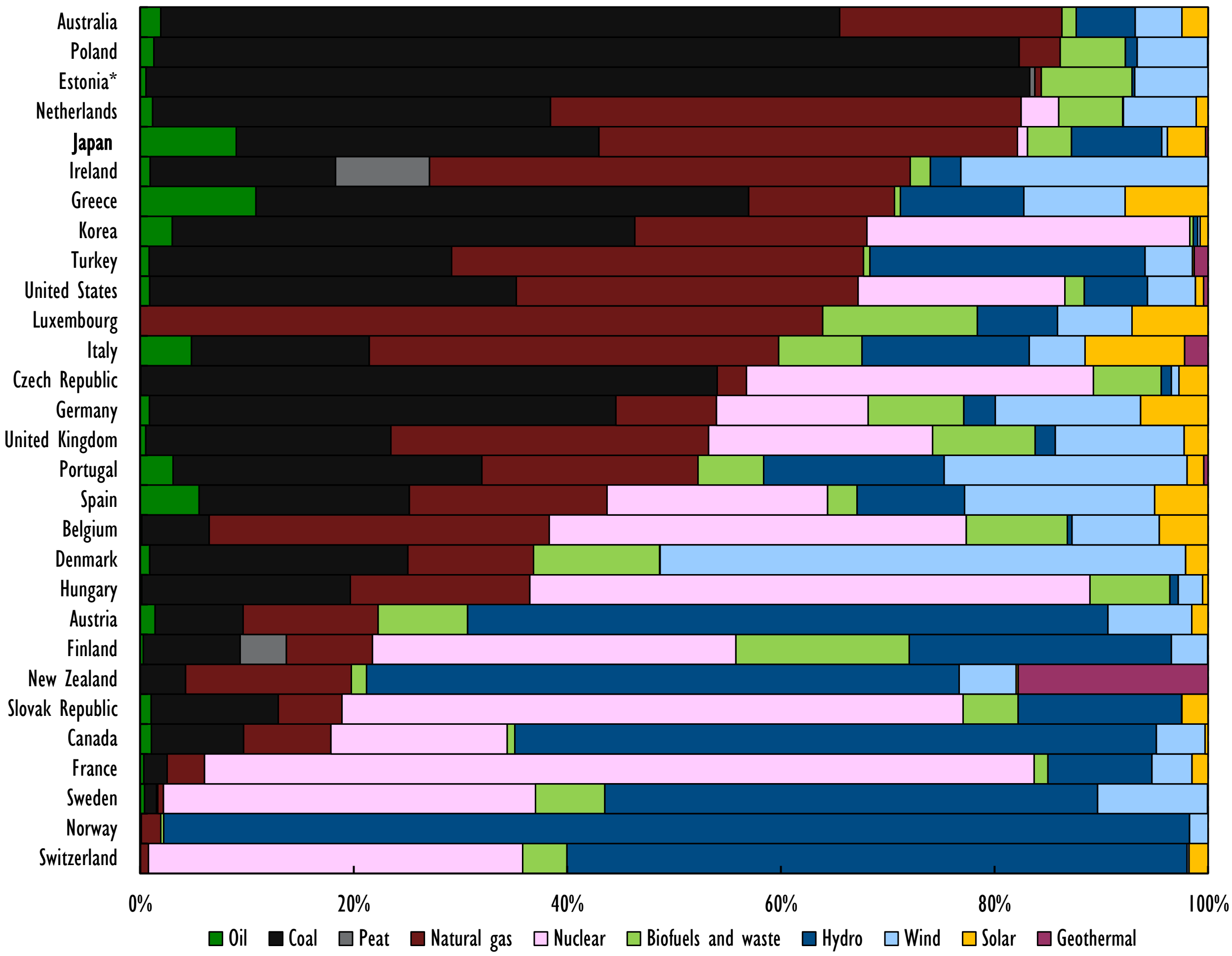
Figure 8.4 Electricity generation by source in IEA member countries, 2015



Note: Data are estimated.

* Estonia's coal represents oil shale.

Source: IEA (2016a, forthcoming), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

Generating capacity

At the end of 2014, Japan's net maximum generating capacity totalled 315 GW, up from 303 GW in 2013 (see Table 8.2). Around two-thirds of this total capacity is owned by the 10 general electric utilities (or commonly referred as the electric power companies, EPCOs) while the rest is owned by the wholesalers, Power Producers and Suppliers (PPS) or private owners. Since the introduction of a feed-in tariff system in 2012, solar PV capacity has increased particularly fast (see Chapter 9 on renewable energy).

Since the last in-depth review, the decline in the use of nuclear plants has led to a drastic change in the technologies covering baseload generation. Traditionally this has been coal and nuclear; however, after the Fukushima Daiichi nuclear accident, LNG has taken the role for both baseloads while also covering middle load. Before 2011, capacity factors in oil-fired plants were low, indicating that they made up peak and reserve capacity. Oil-fired capacity is old (average age 35 years), depreciated and expensive to operate. However, in this critical period, it has been used to cover middle load, which has led to higher overall generating costs.

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Table 8.2 Electricity generating capacity by technology, 2013-14 (GW)

	2013	2014
Nuclear	44.3	44.3
Hydro	48.9	49.6
Geothermal	0.5	0.5
Solar PV	13.6	23.3
Wind	2.6	2.8
Combustible	192.8	194.9
Total	**302.7**	**315.3**

Source: IEA (2016b).

DEMAND

Japan is the third-largest electricity user in Asia, after the People's Republic of China and India, but it has one of the lowest growth rates of electricity demand in the region. Electricity demand peaked at 1 050 TWh in 2007 and declined continuously during this decade. It dropped by 5.9 % in 2011 and has plateaued to around 965 to 980 TWh since then.

This decline resulted partly from the nationwide energy efficiency and conservation efforts (called *Setsuden*) were carried out in 2011 and 2012 mainly to cope with the tight balance between electricity supply and demand after the earthquake. The efforts include shifting industry's operational hours and days, and avoiding unnecessary electricity use in the residential and commercial sectors to reduce peak demand.

Part of the effort includes the Energy Conservation Label, primarily for household equipment. Households' motivation for saving electricity has shifted from helping to avoid a national supply shortage to reducing the impact of higher electricity bills. As a result, electricity demand per capita has declined since peaking in 2007 at 8.4 MWh to around 7.6 MWh in 2014. The challenge will be to maintain consumer efforts of energy conservation in the long term. Demographics may help: Japan's population is declining and projected to reach 94.6 million by 2060 from 128 million in 2010, according to the National Institute of Population and Social Security Research. This trend can be expected to have an impact also on electricity demand.

As shown in Figure 8.5, the commercial and public sector is the largest electricity consumer with a 37.7% share in 2014, overtaking the industrial sector as the largest consumer in 2009. At around 28.4%, the share of the residential sector is marginally lower than that of the industrial sector. The transport sector has held relatively steady at 1.8%.

Electricity demand peaks in the summer months of July and August, with the use of air conditioning. The winter peak is slightly lower. By region, the only exception to this rule is Hokkaido in the north where the peak is in winter because of space-heating needs. The government and electricity companies strongly promote electricity saving in the peak season, for example by information campaigns, subsidies for energy-saving equipment, contracts for peak shift and promoting demand response measures.

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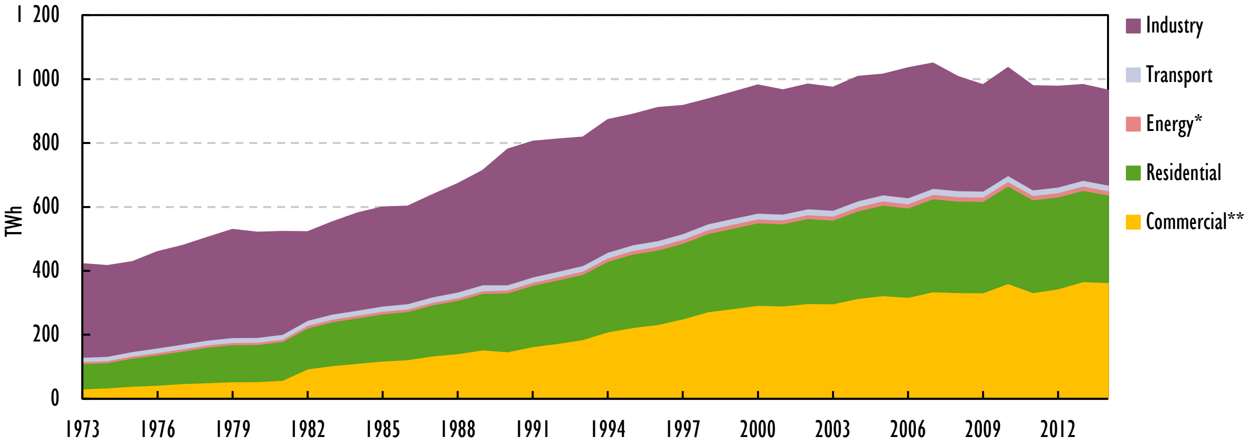
Figure 8.5 Electricity consumption by sector, 1973-2014



* *Energy* includes coal mining, oil and gas extraction, and refining.

** *Commercial* includes commercial and public services, agriculture, fishing and forestry.

Source: IEA (2016b, forthcoming), *Electricity Information 2016*, www.iea.org/statistics/.

INSTITUTIONS AND REGULATORY FRAMEWORK

INSTITUTIONS

The **Ministry of Economy, Trade and Industry (METI)** is responsible for governing the electricity sector. METI may issue licences to electricity utilities, order utilities to improve their operations and to provide a wheeling service. In the event of a disaster or other emergency, METI may also instruct any utility to supply electricity to another utility. Regarding renewable energy, METI determines the purchase price and the contract period for renewable electricity under the feed-in tariff system and may order a utility to enter into a purchase agreement or an interconnection agreement with a renewable energy electricity producer.

Within METI, the **Agency of Natural Resources and Energy (ANRE)** is responsible for electricity policy. One of its responsibilities is to set forth Japan's Strategic Energy Plan (SEP).

The **Electric Power System Council of Japan (ESCJ)** was formed in 2003 mainly to regulate third-party access. It is a fully independent, private and non-profit body governed by its membership composed of participants from the academic world, representatives of utilities, new entrants, end-users and other social groups. The Council established the **Market Monitoring Subcommittee** in 2005 with responsibility to monitor dispute settlement, results of METI inspection and regulation, and current electricity market conditions. ESCJ was replaced in 2015 by the **Organization for Cross-regional Coordination of Transmission Operators (OCCTO)**.

The **Electricity Market Surveillance Commission (EMSC)** was established in September 2015 under the Minister of Economy, Trade and Industry. EMSC monitors issues related to consumer protection, market power and the neutrality of network operators. It can also recommend changes to the market rules to the minister. Since April 2016, it is also tasked with monitoring the gas and heat markets.

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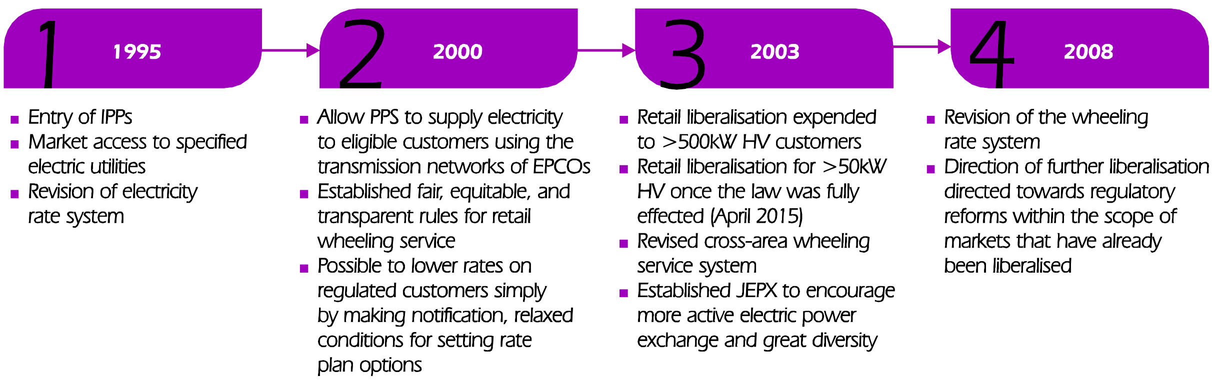
The **Japan Fair Trade Commission (JFTC)** is responsible for monitoring competition in all sectors of the economy. For the electricity industry, it has increased its surveillance since the market reform was initiated. In 1999, the JFTC and METI issued Guidelines for Proper Electric Power Trade which, within the Antimonopoly Act and the Electricity Business Act, describes the principles and practices for trade that may violate the Act, with a primary focus on the behaviour of the EPCOs.

ELECTRICITY MARKET REFORM

Reforming Japan's electricity market has been a long and gradual process. The first reform in 1995 granted market entry to independent power producers (IPPs). The second reform in 2000 partially opened the retail market and allowed power producers and suppliers (PPS) to supply electricity to large customers using the transmission networks of EPCOs. Nevertheless, the market share of the PPS grew over time, but remained relatively limited, at 6.8% of the liberalised sector in 2015 (METI, 2016). Besides, there has been almost no competition across regional boundaries, and the generation and delivery of electricity has generally been bundled together by the same EPCO.

Figure 8.6 Electricity market reforms before 2011



Note: HV: high voltage; JEPX: Japan Electric Power Exchange.

Source: METI.

Figure 8.7 The three phases of the current electricity market reform, 2015-20

Source: METI.

the Fukushima Daiichi nuclear accident revealed several weaknesses in the regional monopoly system (vertically integrated EPCOs) which includes the lack of transmission capacity across regions. The absence of competition may have kept electricity prices too high and limited flexibility to modify the electricity mix, especially to increase the share of renewables. To address these weaknesses, the cabinet approved the Policy on

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Electricity System Reform in April 2013 (METI, 2013). It includes three objectives: securing a stable supply of electricity, decreasing electricity prices as much as possible, and expanding consumer choice and business opportunities. To achieve these objectives, the electricity market is being reformed in three phases (Figure 8.7).

First, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) began to operate in April 2015, on the basis of the 2013 revision of the Electricity Business Act. OCCTO's main functions include prescribing utilities to increase power generation and interchange when the supply-demand balance becomes tight; reviewing utilities' power supply and demand plans; and constructing transmission lines between regions in response to an increase in demand. OCCTO also undertakes the functions of the former Electric Power System Council of Japan (EPSCJ) to set rules for access to the transmission grid and to enhance transparency, co-ordination and reliability.

After the establishment of OCCTO, the Electricity Market Surveillance Commission (EMSC) was established in September 2015 in order to strengthen monitoring of the electric power trading market for the implementation of the electricity system reform. By law, the EMSC has rights to collect reports, conduct on-site inspections, provide recommendations to businesses, and exercise sole authority in mediation/arbitration. It may also make suggestions and proposals to the Minister of Economy, Trade and Industry regarding the assessment of network tariffs and retail electricity suppliers.

With the development of electricity markets and the introduction of competition between generators, other entities are playing a role. The former EPSCJ also conducted supply reliability assessments, but stops at providing information. This organisation is now replaced by OCCTO. All electricity companies, including the main electric power companies (EPCOs) as well as new retailers, are obliged to become a member of OCCTO. The electricity market reform passed in 2013-15 also redefines the responsibilities of different stakeholders regarding resources adequacy.

The newly created OCCTO plays a critical role in securing stable supplies through monitoring of power supply and demand. OCCTO will be empowered to issue instructions for power supply to power utilities during conditions of tight supply. The new entity will conduct supply reliability assessments based on new supply plans that will be submitted by all power utilities and can implement the capacity bidding system introduced through the revised Electricity Business Act in 2014. In terms of network adequacy, OCCTO's influence over the TSOs must also extend to promote risk/cost sharing and co-ordination for more cross-regional transmission and grid reinforcement.

Second, full liberalisation of the retail market took effect in April 2016 (Electricity Business Act of 2014) and, according to OCCTO, around 820 000 customers switched supplier by the end of April. Retail competition may bring innovative tariff structure and services such as packaging electricity with other services, including gas and telecommunication. All consumers, including households, may choose their supplier which also means that the geographic boundaries among operators are eliminated. EPCOs have started to offer retail business in other EPCOs' regions while non-EPCO companies (including gas and telecom companies) increasingly enter the retail market. As part of this process, regulated tariffs for the 10 EPCOs will be maintained until at least 2020.

The retail market has been gradually opened to competition since 2000 when the extra high-voltage customers (with a connection of more than 2 MW) became eligible to freely

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choose their supplier. High-voltage customers above 500 kW became eligible in April 2004 and HV customers above 50 kW in April 2005.

Third, in 2020, the transmission and distribution segment of the EPCOs will be legally unbundled from the generation and retail segments.

The EPCOs will be responsible for system security and continuity of supply. They will also remain responsible for providing universal service to every resident in the country regardless of cost or location. Although the unbundling is slated for the third phase of the reform, TEPCO has already started to organise its operations into three individual companies (thermal power generation, network operations, and retailing) under one holding company.

INDUSTRY AND INFRASTRUCTURE

INDUSTRY STRUCTURE

Before the reform, electricity business operators were classified as general electric utilities (10 EPCOs), wholesale electric utilities (J-Power and Japan Atomic Power Company), independent power producers (IPP), power producers and suppliers (PPS), and specified electric utilities.

In April 2016, the electricity retail sector became fully liberalised. The EPCOs are now involved in all three businesses and retain regional monopoly over transmission and distribution lines; they are hence responsible for maintaining frequency and providing last-resort service. Other industry players, i.e. power generation owners and retailers, must be registered to become eligible to conduct generation or retail business in this new structure.

The electricity sector has traditionally been dominated by the EPCOs, which had a monopoly in their respective service areas. Japan has ten power companies in this category, namely Hokkaido Electric Power Company, Tohoku Electric Power Company, Tokyo Electric Power Company (TEPCO), Chubu Electric Power Company, Hokuriku Electric Power Company, Kansai Electric Power Company, Chugoku Electric Power Company, Shikoku Electric Power Company, Kyushu Electric Power Company, and Okinawa Electric Power Company. Among these companies, the biggest ones are the Tokyo, Kansai and Chubu electric power companies, all three with nuclear capacity exceeding 10% of their total capacity portfolio.

The 1995 Electric Utilities Industry Law initiated the liberalisation of power generation. Besides the biggest wholesale supplier J-Power (see Box 8.2), there are numerous other electricity suppliers such as municipal utilities and autonomous distributed generators.

Each EPCO has a large number of shareholders. However, the major ones are mainly cities, financial institutions and securities/insurance companies. For example, the largest shareholder of Kansai Electric Power Co (KEPCO) is the city of Osaka, while other shareholders include the cities of Kyoto and Kobe. Before nationalisation in 2012, Tokyo became the largest shareholder of TEPCO after Daiichi Life Nippon Life Insurance Co. and Nippon Life Insurance Co. sold their stakes. Tokyo EPCO and Chubu EPCO formed a comprehensive partnership and established a new company, JERA, to jointly cover the entire energy supply chain, from upstream investments and fuel procurement to power generation, although they remain as competitors in the retail market (TEPCO, 2015).

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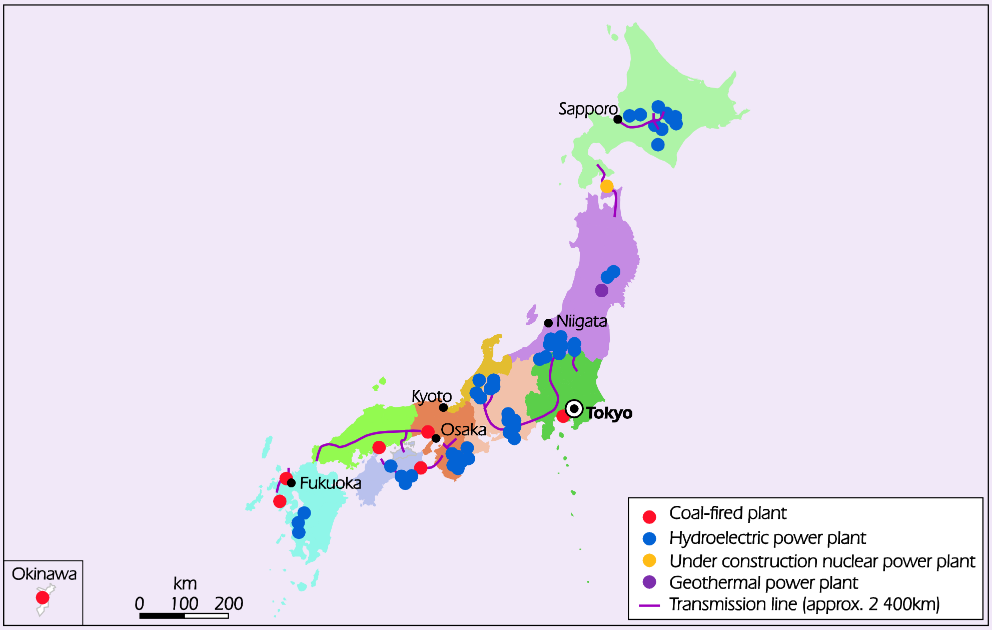
Box 8.2 J-Power

Electric Power Development Co. Ltd. (J-Power) was incorporated in 1952. J-Power currently generates and provides electricity to service areas of ten electric power companies through its regional and inter-regional transmission lines with a total length of about 2 400 km, four substations, four alternating current/direct current converter stations, and a frequency converter station (Sakuma).

Map of J-Power plants and transmission lines



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

J-Power operates 59 hydropower plants with a total capacity of 8 570 MW, seven thermal power plants totalling 7 799 MW and one 15 MW geothermal plant. J-power owns around 20% of coal-fired capacity and 19% of hydropower capacity in Japan. Its 16.4 GW of total capacity ranks it sixth among power generators in Japan. As the company does not have any nuclear power plants, it has been shielded from the financial impact from the prolonged nuclear shutdown.

TRANSMISSION AND INTER-AREA INTERCONNECTIONS

Japan's electricity network is divided regarding the frequency used: eastern Japan operates at 50 Hertz (Hz) and western Japan at 60 Hz. This difference has historical roots as, in the early days of electrification, the Tokyo area adopted German-made generators, while Osaka opted for US-made ones. To connect the eastern and western networks, frequency converter facilities (FCFs) are needed. As of August 2014, the country had three frequency converters: Sakuma FCF and Higashi-Shimizu FCF in Shizuoka Prefecture and Shin-Shinano FCF in Nagano Prefecture with total capacity of 1.2 GW. Eastern Japan has a generating capacity of around 130 GW and the western part around 160 GW. The transmission network is around 100 000 km-long, according to the Federation of Electric Power Companies of Japan.

Before the establishment of OCCTO, the Electric Power System Council of Japan (ESCJ) formulated rules and ensured fairness and transparency in the use of these systems.

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These rules comprise four sections:

- facility establishment rules that lay out provisions for the new establishment and reinforcement of power distribution facilities
- system access rules that lay out provisions for technical conditions when establishing and connecting power generation facilities
- system operation rules that lay out provisions for the operation of systems by general electric utilities
- information disclosure rules related to distribution facilities.

Accordingly, EPCOs publish their respective rules containing the detailed conditions.

Under the new market reform arrangement, the duties which were carried out by ESCJ are taken over by OCCTO, which includes nationwide system planning (Report of the Electricity System Reform Expert Subcommittee). This will then be deliberated and considered by the Advisory Committee on Energy and Natural Resources (ACENR) under METI.

There are plans to reinforce transmission and distribution networks (METI, 2015). One example is the project to increase interconnection capacity between Hokkaido and Honshu from 600 MW to 900 MW by 2019. According to HEPCO, the construction of the additional 300 MW DC line began in 2014. The line will help promote wind power generation and ensure stable supply in the Hokkaido region. The capacity of east-west grid connection is planned to be increased from 1.2 GW in 2014 to 2.1 GW by FY2020.

Japan is not interconnected with its neighbouring countries. The transmission and distribution losses in Japan amounted to around 4.9% in 2014, according to the Federation of Electric Power Companies of Japan, and are among the lowest among IEA countries. They are on a comparable level with other densely-populated, often smaller countries, but lower than most of the larger IEA countries.

DISTRIBUTION

The distribution network is mainly made up of overhead lines; at the end of FY2014, only 5.7% (or 77 500 km) of the total network of the 10 EPCOs was underground, according to TEPCO[1]. Overhead lines reduce investment and maintenance costs as well as installation times. Other advantages may include easier fault location and faster supply restoration. However, overhead power lines can be damaged by wind-borne tree branches, debris and high wind, and ice-loading conditions from extreme weather. During earthquakes, the system may also suffer from toppled poles blocking roads and posing safety hazards and causing extended power outages. Although underground cables are much more costly they are aesthetically pleasing, safer and more robust as they are less exposed to the environment. In connection with the full liberalisation of the retail sector, all electricity companies aimed to deploy smart meters so as to facilitate information capture such as energy usage volume to retail operators, concentrating first on high-voltage users for whom the installation is expected to be completed in FY2016. Full-fledged installation for low-voltage users is expected to be initiated at the latest in FY2016, with completion expected sometime between FY2020 and 2024.

1. http://www.tepco.co.jp/en/corpinfo/illustrated/electricity-supply/distribution-underground-e.html.

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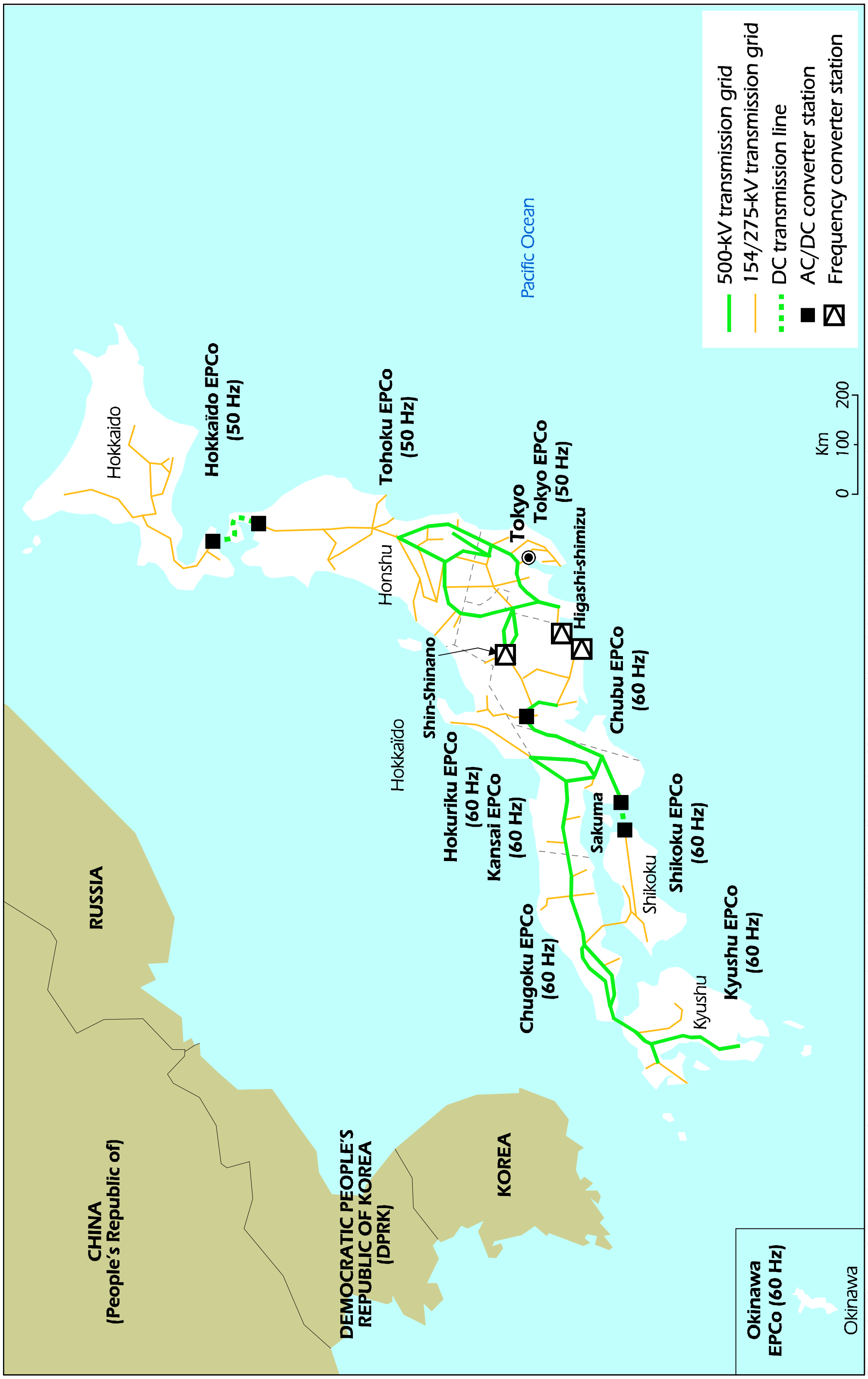
Figure 8.8 Map of Japan's electricity network, 2015



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WHOLESALE MARKET STRUCTURE AND DESIGN

Japan's wholesale electricity market mainly comprises bilateral transactions via power purchase agreements (PPAs) between the EPCOs and either the wholesale electric utilities (J-Power and Japan Atomic Power Company) and IPPs. Liquidity[2] in the Japan Electric Power Exchange (JPEX), which is a private and voluntary wholesale power exchange, is still marginal but increasing. Liquidity measured by trading in JPEX corresponded to 1.8% of total retail market sales in 2015, up from 0.9% in 2012 and 0.5% in 2011. Overall, JEPX plays a marginal role in the exchange of electricity along the supply chain from generation to final consumption. The products available at JEPX are in the spot market, hour-ahead market trading, forward market and the distributed/green electricity market (bulletin board products). In 2015, the day-ahead market (spot market) accounted for around 90% of total volume at the exchange. Bidding is done by a single price auction system. Under this system, a bid is made for the combination of price and quantity of each product. A point of intersection where the buying and selling conditions comply with each other is sought, and the price and contract quantity are decided at this point. Electricity prices at JEPX are relatively uniform and highly correlated with average spot prices among different regions in Japan. In 2013, five regions operated at 60 Hz; Hokuriku, Kansai, Chugoku, Shikoku and Kyushu registered no difference in spot prices for all hours throughout the year. The region with the lowest average spot prices, Hokkaido, was merely 4.3% lower than the average recorded by the above five regions, which also had the highest prices. While the high degree of price convergence may suggest that there are no congestions at the borders, the reality is probably that market liquidity is too low and prices do not necessarily reflect costs. The ongoing reform is expected to increase liquidity and the volume of transactions at JEPX. This can be done by reducing the monopoly of the ten EPCOs and helping new entrants to the market.

BALANCING MARKET

Before the market reform, real-time balancing of supply and demand is managed individually by the transmission system operation units of the ten EPCOs. Each EPCO decides how best to acquire the necessary resources to manage this task: regulating power, operational reserve capacity and other ancillary services. Producers and suppliers are required to ensure a balance between supply and actual demand every 30 minutes with the support of the EPCOs, and are charged a balancing fee, depending on the size of the deviation between actual demand and supply. The fee has two tiers: one fee is on low-tier imbalances below 3% and the other, significantly higher fee is on imbalances above 3%. Each EPCO calculates the balancing fee in accordance with the rules established by METI on the basis of internal pricing calculation within the EPCO. Procurement of these balancing services is not based on a competitive bidding process. It is not directly linked to real costs and is not charged uniformly from all market players. The government has plans to set up a real-time market to minimise imbalance. This will also reduce penalty charges for imbalance, which may have affected smaller market players in the current set-up. Existing PPAs between the ten EPCOs and IPPs, especially those extending beyond 2020, may also be affected by the new market arrangement.

2. A competitive electricity market that gives incentives for optimal dispatch and investment and that allows market participants to manage the risks related to operation and investment is based on a liquid spot market and a liquid market for long-term financial contracts.

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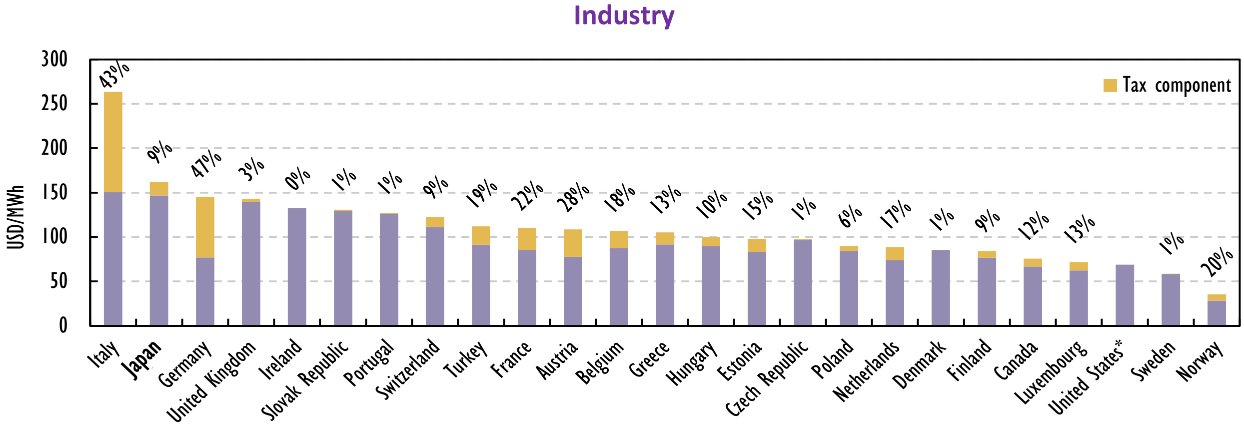
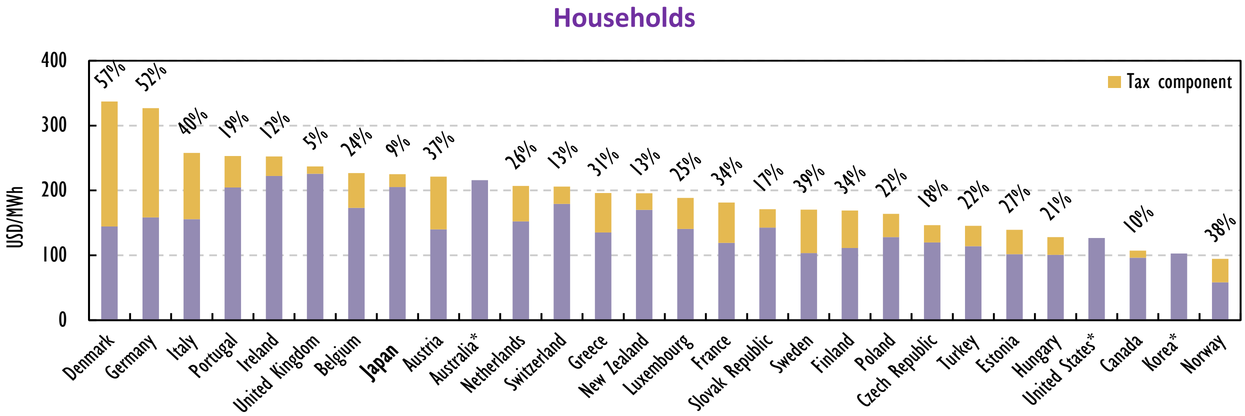
RETAIL MARKET AND PRICES

Retail prices for both industry and households have increased significantly (in local currency) since the 2011 Fukushima Daiichi nuclear accident and the gradual nuclear shutdown. The average electricity price for the industry sector was JPY 14.23 per kWh in 2010 and increased to JPY 19.60 per kWh in 2015, or by 37.4%. The average electricity price for households was JPY 21.39 per kWh in 2010 and increased to JPY 27.24 per kWh in 2015, or by 27%. This upward trend of retail prices reflects only the change in fuel mix and the increase in fuel costs.

Figure 8.9 Electricity prices in IEA member countries, 2015



Note: Data are not available for Australia, Korea, New Zealand and Spain.



Note: Data are not available for Spain.

* Tax information is not available.

Source: IEA (2016c), *Energy Prices and Taxes 2016*, Q1, www.iea.org/statistics/.

Electricity prices in Japan are relatively high by IEA standards, although the tax component, at 9% for industry and 9% for households on top of the ex-tax price, is considered low. Retail prices can be expected to decline in the future, following the significant decline in fuel prices since 2014 and the full retail market opening in April 2016. Retail tariff regulation will be abolished gradually as part of the third phase of the electricity market reform in 2020, provided that retail market competition among

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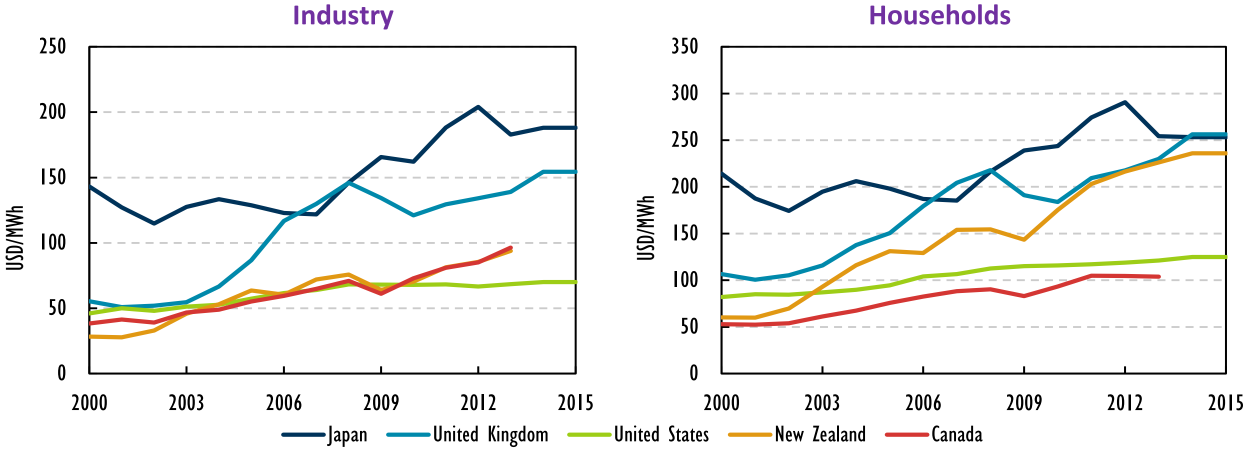
suppliers is ensured by that time. For consumers under 50 kW (mostly residential customers), regulation on retail tariff will be maintained to the incumbent ten EPCOs at least until 2020.

Figure 8.10 Electricity prices in Japan and in other selected IEA member countries, 2000-2015



Note: Data are not available for New Zealand's and Canada's industrial prices 2014-15; Canada's households prices for 2014-15.

Source: IEA (2016c), *Energy Prices and Taxes 2016, Q1*, www.iea.org/statistics/.

ELECTRICITY SECURITY

Japan has one of the most reliable electricity systems in the world. Electricity supply was interrupted for approximately 20 minutes per customer per year in FY2014 (FEPC, 2016), substantially lower than in most other IEA countries. In 2011, the Japanese power system also proved to be extremely resilient to a major shock.

The government and the utilities took several measures to ensure that power supply met demand during the power crisis right after the March 2011 Great East Japan earthquake. On the supply side, measures to maximise output from power plants using fossil fuels included restoring some of the disaster-affected plants, relaxing regulations on inspections, and restarting mothballed oil-fuelled generation units. On the demand side, the government promoted power restrictions for consumers in the disaster-affected areas in 2011 and 2012. In summer 2011, METI issued an order to restrict the use of electricity by large power consumers owing to the anticipated tight supply of electricity within the area supplied by TEPCO.

As power generation from fossil fuels increased and demand declined, electricity rationing only lasted a few weeks. Lower demand due to decreased activity in the days following the disaster made it possible to attenuate the electricity shortfall, and electricity outages ended by the end of March 2011. Combined efforts by the public sector, companies and citizens reduced electricity demand by more than 15%, thus almost offsetting the decline in supply capacity. Although electricity demand is highest during July and August, no blackouts occurred.

METI also invoked a 15% power reduction on end-users of the Kansai Electric Power Company (KEPCO) during the summer of 2012 and encouraged other demand-side measures, especially during the peak summer seasons from 2011 to 2015.

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FUEL SECURITY

Following the Great East Japan earthquake and the Fukushima Daiichi nuclear accident, the use of gas- and oil-fired power plants increased immediately to fill in the supply gap. The use of coal-fired power increased significantly year-on-year from 2013 on compared to 2010, as new plants came online.

The growth in imports of fossil fuels increased the dependence on some resource suppliers. In 2013, Japan depended on the Middle East for 83% of its oil imports and 30% of its LNG imports. Any instability in the Middle East may have a profound and direct impact on Japan's energy supply structure. To prevent such a situation, Japan made progress quickly in further diversifying the supply sources, including LNG supply from North America. From this perspective, the decline in LNG prices since 2014 and the new LNG capacity starting operations are relaxing the tensions on the natural gas market. As for oil, Japan's large emergency stocks provide a buffer in the event of a supply disruption.

Looking ahead, the Long-term Energy Supply and Demand Outlook to 2030 maintain a significant role for nuclear power. The targeted electricity supply mix in 2030 would see LNG at 27% of the total, coal at 26%, renewables at 22% to 24% and nuclear power at 20% to 22%. The share of nuclear would be lower than the 30% it held before the Fukushima Daiichi nuclear accident, but it would still mean a restart of the majority of Japan's nuclear power plants.

GENERATION AND NETWORK ADEQUACY

Historically, the EPCOs sought self-sufficiency in their service area. Supplying electricity to meet demand with a high reliability of electricity is one achievement of EPCOs that is *de facto* responsible for ensuring resource adequacy.

The electricity security crisis also made evident that while excess capacity was available in the west, it could not be used to meet demand in the east, because of the weakness of interconnection between the two regions. Furthermore, Japan is still facing a shortage of capacity during summer and winter peaks. With the aim of improving supply reliability during a large-scale drop in power supply, there are plans to strengthen the interconnections between some EPCOs service areas. For example, OCCTO will increase the capability of the frequency conversion facility connecting Tokyo Electric Power Company and Chubu Electric Power (1.2 million kW) by 0.9 million kW, to 2.1 million kW by 2020. Transmission network capacity has to be increased between Hokkaido and Tohoku, and between the 50 Hz and 60 Hz zones. In addition, OCCTO may also hold an auction for generating capacity if and when a power supply shortage seems likely owing to insufficient investment. Furthermore, introducing a capacity mechanism could be an option to explore to ensure generation adequacy.

Some elements of capacity obligation have already been introduced in the legislation. The second stage of reform, which fully liberalised the retail market, puts the obligation on retailers to ensure adequate supply to match their demand. Government will oversee and administer by checking all retailers' plans at the point of entering the market. Additionally, on a yearly basis the retailers will have to submit a 10-year supply and demand plan. Fulfilling this adequacy obligation may mean that the retailers should secure reserve margins to cater for upward variation of forecast. Additionally, retailers are obliged to ensure procurement of enough quantity in the electricity market.

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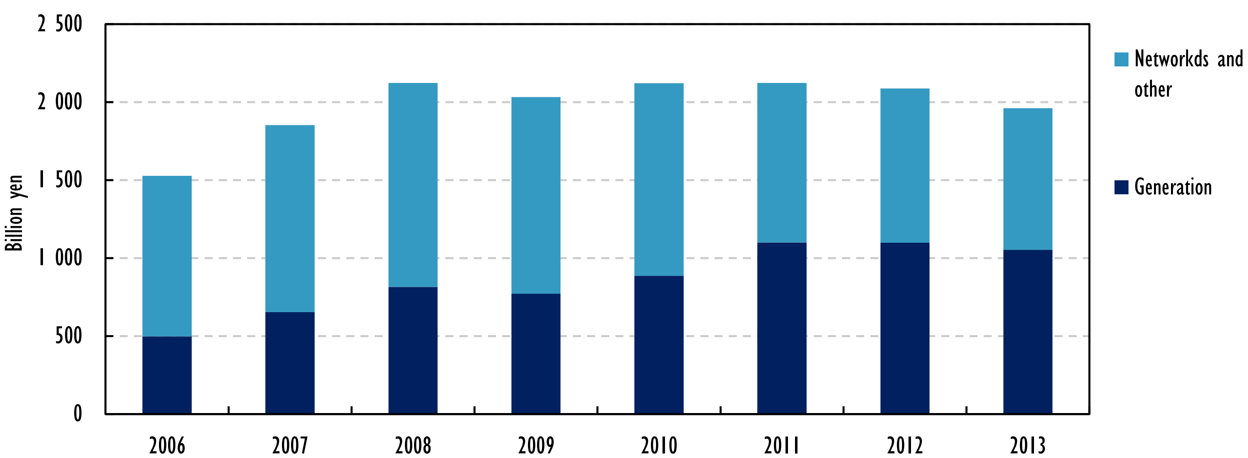
The role of renewables in meeting adequacy objectives should also be recognised. In this perspective, support schemes should be continually reviewed (see Chapter 9 on renewable energy) with the aim not only to achieve efficient investment into renewables, which helps to decarbonise the power system, but also to ensure supply affordability to consumers and to increase security of electricity supply.

Setting up smart communities can increase distribution system reliability. For the three prefectures that were the most affected by the earthquake in 2011 (Fukushima, Miyagi and Iwate), support is being provided for the construction of smart communities at the community level, and the introduction of distributed power generation systems at the facility level.

INVESTMENT

Investments in the power sector by electric power companies remain at a sustained level. Figure 8.11 presents historical investments by the ten EPCOs. While network investment represented two-thirds of total investments in 2006, generation investments increased gradually and are exceeding them since 2011.

Figure 8.11 Investment by type of power facility by the ten EPCOs, 2006-13



Source: Electricity Review Japan 2015.

FOSSIL-FIRED GENERATION

Since 2011, substantial investment in capacity addition has been seen in the Japanese power sector. In the immediate aftermath of the Fukushima Daiichi nuclear accident, a substantial capacity addition in combined-cycle gas turbines (CCGT) was recorded as it is a technology quicker to install than coal plants. A total of 8 537 MW of natural gas-fired power plants have commenced operation over the period 2011-14. New coal capacity amounting to 1 600 MW started operation in 2013, including the start of commercial operation of Hitachinaka Unit 2 and Hirono Unit 6 in the Tokyo Power Company area.

In the coming years, Japan plans to build new coal-fired power plants to replace old thermal plants and to make up for lost nuclear capacity. Table 8.3 represents some of the plans for large capacity (more than 500 MW) coal-fired generation plants in Japan for 2017 to 2020.

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Table 8.3 Plans for large new coal-power plants in Japan until 2020

Company	Technology	Capacity, MW	Starting date (FY)
J-POWER	USC	1x600	2020
Tokyo Electric Power	IGCC	1x500	2020
Tokyo Electric Power	IGCC	1x500	2020
Tokyo Electric & Chubu Electric	USC	1x650	2020
J-POWER & NSSMC	USC	1x640	2020
Kyushu Electric Power	USC	1x1 000	2020
Kyushu, Idemitsu & Tokyo Gas	USC	2x1 000	2020
Chugoku, JFE Steel & Tokyo Gas	USC	1x1 000	2020
Tohoku Electric Power	USC	1x600	2020
Kashima Power Company	USC	640	2020

Note: Technologies: USC (ultra-supercritical), IGCC (integrated gasification combined cycle).

Source: Endcoal (2015) Global Coal Plant Tracker, http://endcoal.org/global-coal-plant-tracker/.

Interestingly, there is also a trend towards building smaller capacity coal plants ranging around 100 to 200 MW with biomass co-firing, for example the 110 MW Nagoya power station at Taketoyo and similar-sized Nippon Paper Akita power station at Akita. A related concern with this trend is that small coal-fired projects do not fall under the regulator’s scrutiny on their environmental impact assessment while they are required to meet the new efficiency standard.

Retail competition encourages existing players and newcomers to invest in new or expansion of power plants to secure generation sources. In particular, other energy utilities are developing their generation activities. For instance, a city gas provider Tokyo Gas and an oil refiner Showa Shell added 400 MW capacity to their jointly run gas-fired (CCGT) Ohgishima power station in 2016 (Tokyo Gas, 2016a).Tokyo Gas also announced with an oil refiner JX Nippon Oil & Energy that they will double power output at their jointly run natural-gas-fired plant in Kawasaki (Tokyo Gas, 2016b). A city gas provider Saibu Gas is planning to build a 1.6-GW CCGT power plant.

In this context of competition, existing EPCOs are forging partnerships. For instance, Tokyo EPCO and Chubu EPCO formed a comprehensive partnership to jointly procure fuel, operate related businesses (upstream investment, transportation and trading), construct and replace thermal power plants, although they are competitors in the retail market. Kansai EPCO announced it will collaborate with Tokyo Gas for LNG purchases and sharing technologies for gas-fired power plant operations (KEPCO, 2016).

NUCLEAR POWER

Despite the Fukushima Daiichi nuclear accident, nuclear energy is a low-carbon technology which may contribute to economical grid operation and security of fuel supply. While the first priority is to safely restart existing reactors, the government’s Strategic Energy Plan foresees a share of nuclear of 20% to 22% of the electricity generation mix by 2030. Consequently, the government wishes to keep open the

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possibility of and create the conditions for investments in new nuclear power plants in the future.

In the context of the electricity market reform, the future of nuclear investments in competitive electricity markets must be carefully considered. Traditionally, the Japanese market and regulatory conditions were favourable for nuclear, because of its competitive price compared to the high price of imported LNG and regulated electricity tariffs that secure long-term cash flows for utilities, and low interest rates and financing costs. However, new nuclear investment has been slow in the deregulated markets in Europe and the United States. Nuclear is a capital-intensive investment. Exposing it to electricity market price risk in a competitive environment may increase the risks for investors and therefore increase the financing costs, which have a very detrimental effect on the competitiveness of nuclear.

In addition, although the theoretical lifetime of a nuclear plant will be 40 years (with a possible extension of 20 years), investors need to consider the risk of policy changes which may abruptly shorten the plant's operating life. This is especially the case in Japan after the Fukushima Daiichi nuclear accident, where a large percentage of the population is hostile to nuclear energy.

Consequently, the future of nuclear will remain largely influenced by government policy and the Nuclear Regulation Authority's decision on restart/new start of each reactor. Should the Japanese government authorise the construction and financing of new nuclear in the future, there may be a need to provide more certainty to investors, in particular if retail competition develops rapidly. Such investment support schemes have been introduced in competitive electricity markets, for renewables and for nuclear in the United Kingdom for instance.

NETWORKS

According to METI, investments in transmission and distribution networks will increase. An effort of JPY 81 billion will be needed in order to response to grid issues facing the country and in order to accommodate more renewable energy. Investment in new transmission lines and grid upgrades towards better grid integration, while minimising bottlenecks, will enable surplus capacity from any region to support demand. Since the main aim of OCCTO is to enable national-level co-ordinated planning and operation, it makes sense to reshape the overall grid and perhaps link the existing plants to the main grid not based on ownership, but on the nearest existing grid. This will facilitate access to the grid throughout the country and promote generation competition.

In addition, transmission lines and grid reinforcement would also support a higher integration of renewable energy sources. For example, most of the onshore wind power potential is located in northern rural areas, Hokkaido and Tohoku, which are very far from demand centres, and the existing capacity of transmission lines between supply and demand regions is insufficient. It is difficult, however, for the power utilities in the region (namely, Hokkaido Electric and Tohoku Electric) to pass through the costs of the required transmission upgrades to their limited customer bases, and as a consequence additional funding from national sources may be needed to fund the transmission upgrades, which would serve to benefit a larger area of Japan. To help to bridge this funding gap, the national government has established a subsidy to fund special-purpose companies (SPC) to demonstrate upgrading of transmission lines in areas with concentrated wind power resources suffering from inadequate transmission support

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(Kae Takase, 2014). The concept involves charging transmission fees to wind power companies, as they will benefit from the use of the upgraded transmission line. Offshore potential, which is available near Tokyo, Nagoya and Fukuoka, also becomes attractive because of the relative proximity to the major load areas. Additionally, the speed of solar photovoltaics (PV) expansion in recent years has also strained the grid's capacity, resulting in grid access restriction to new solar farms. To alleviate the grid restrictions and congestion, the government planned financial support to develop and expand grids so as to allow more integration of renewable energy.

ASSESSMENT

Since the last in-depth review, Japan's electricity sector experienced a crisis triggered by the Great East Japan earthquake, the Fukushima Daiichi nuclear accident and the subsequent closure of all nuclear power plants. Overall, the electricity system proved to be resilient in the face of a major and continued supply crisis. A national movement, called *Setsuden*, to save electricity during the 2011 summer played an important role in reducing demand by 22 GW. At the same time, fossil fuels imports increased, which in turn led to higher CO_2 emissions and electricity prices. Many power companies were hard hit financially.

The electricity security crisis also made evident several issues of the Japanese electricity sector. In particular, while excess capacity was available in the west, it could not be used to meet demand in the east, because of the weak interconnection between the two regions. Japan is still facing a shortage of capacity during summer and winter peaks. The government diagnosed also a lack of competition that kept electricity prices too high and a lack of flexibility to modify the electricity mix, especially to increase the share of renewables.

One year after the Fukushima Daiichi nuclear accident, Japan introduced new feed-in tariffs in order to increase the share of renewable energy. This has led to the rapid installation of 9.1 GW of solar capacity within only two years. While the high level of the feed-in tariffs (FIT) led to a pipeline of around 79 GW of registered solar PV projects as of the end of 2015, the system failed to encourage a more balanced growth across renewable energy technologies. Five of the ten EPCOs are restricting new applications for grid connection on the grounds of technical difficulties.

Many of the issues revealed since 2011 come from the fragmentation of the electricity sector into ten vertically integrated geographical monopolies. The EPCOs are either poorly interconnected or their transmission lines are not used efficiently enough, which also hampers the integration of wind and solar power. Competition has been gradually introduced in the years 2000-05 but the ten EPCOs are dominant on the market of their respective regions.

Against this background, the government decided in April 2013 to introduce a major electricity market reform. The reform should be implemented in 2015-20 and its objectives are threefold:

- securing a stable supply of electricity
- reducing electricity rates as much as possible
- expanding business opportunities and choices for consumers.

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A new independent regulatory authority (the Electricity Market Surveillance Commission, EMSC) was created in 2015. Its task is to "fully prepare for the formulating and monitoring of rules for electricity trading in the liberalised market, strict implementation of tariff regulation and code of conduct regarding transmission/distribution businesses." (Cabinet decision of 3 April 2013).

In order to improve co-ordination between service areas, the government established the Organisation for Cross-Border Coordination of Transmission Operators (OCCTO) in 2015. The new organisation gathers all the stakeholders of the electricity sector. The main functions of OCCTO are to assess generation adequacy and take actions to ensure that adequate transmission capacity is available. OCCTO also has the power to order the construction of new transmission lines.

The framework for allocating interconnection capacity is also important. The design of wholesale markets is currently providing price information for nine different interconnected price zones, corresponding to the geographic supply areas of the EPCOs. The efficient dispatching of generation assets and efficient management of network congestion could be facilitated by reducing the fragmentation of system operators and increasing the number of zones to provide price information with a higher temporal resolution. For instance, the creation of system operators in charge of network management and operational security over large service areas would help increase efficiency in using existing infrastructure. It would also help provide transparent information about the locational value of different generation technologies.

Concerning retail competition, four EPCOs have already announced that they are preparing to compete on the retail market of other EPCOs' areas. Gas companies and companies outside the energy sector have also announced that they will be active on the retail market after 2016. To date, however, EPCOs located in different areas do not compete against each other. Liquidity on the Japanese Power Exchange remains very low, because of tight supply and demand conditions. A liquid and transparent wholesale electricity market should be further developed in order to ensure that competitors will have access to electricity and can effectively compete on the electricity market.

From the perspective of consumers, one of the objectives of introducing retail competition is to develop new competitive services. After the national movement, called *Setsuden*, to save electricity after the 2011 earthquake through behavioural changes, the government has sought to maintain this demand-side response potential that contributes to security of supply and reduces investment needs. In this perspective, the development of demand-side response with economic instruments should be encouraged. The deployment of smart meters scheduled by 2024 will enable the development of dynamic pricing.

The electricity market reform will also legally unbundle transmission and distribution. Tokyo EPCO already decided to unbundle the transmission and distribution company in 2016, before the reform is passed. Legal unbundling will ensure an equal treatment between competitors for the access to the network infrastructure. As the electricity networks remain regional monopolies, the access charges to the unbundled electricity networks will have to be regulated in order to avoid distortions of competition on the retail market. The creation of an independent regulator, the Electricity Market Surveillance Commission (EMSC), will greatly contribute to ensure access to transmission and distribution networks without distortions of competition.

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The supply and demand situation remains tight. In addition to the measures already taken, it is extremely important that the government continues to ensure a high level of security of electricity supply and define the reliability standards needed given Japan's unique circumstances. While OCCTO has the information needed to assess security of supply, there is also a need for an independent assessment of adequacy and reliability in order to ensure that market participants reach the targets that should be set by the government.

Furthermore, the government adopted in July 2015 the generation mix to 2030 which describes a vision of a desired future, in particular regarding the share of nuclear and renewables as sources of fuel diversification, security of supply and low-carbon power. For instance, nuclear is referred to as an "important source of baseload generation" in the 4th Strategic Energy Plan of April 2014.

In order to encourage investment in certain technologies, the government already introduced feed-in tariffs for renewables. Investing in new nuclear plants, however, can also be challenging in competitive markets. Other technologies, such as coal, are often less expensive and more profitable to develop for private investors. In the future market-based environment, the government could have to continue to encourage investment in certain technologies. A simple and sound architecture is needed to avoid undue complexity.

To sum up, Japan has to address several objectives simultaneously: ensuring security of supply, improving efficiency thanks to liberalisation and reducing CO_2 emissions in a context of high uncertainty concerning nuclear power. The success of the electricity market reform requires active and timely government action in setting up an appropriate market structure and market design. It also requires regulations that the industry should follow to ensure security of supply and the implementation of the electricity generation mix policy.

RECOMMENDATIONS

The government of Japan should:

- ☐ *Continue efforts to unbundle network and generation activities of power companies and seek to develop competition among electricity business operators by, among others*
  - *facilitating new entrants' access to generation from existing sources of generation*
  - *developing wholesale market liquidity to facilitate new entry to the retail market*
  - *ensuring that the regulator has sufficient human resources and legal and regulatory powers*
  - *preventing mergers of companies that would lead to undue market dominance.*
- ☐ *Ensure the timely construction of new transmission lines in order to improve security of supply and enable competition across historic service areas.*
- ☐ *Promote efficient trade over larger geographic areas in order to integrate larger shares of wind and solar power and the use of transmission network capacity; consider the creation of system operators in charge of network management and operational security over large service areas.*

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- *Design short-term electricity markets with a higher geographical resolution in order to reveal the locational value of the different generation sources.*
- *Facilitate the active participation of consumers in the energy market, and demand-side response through swift deployment of smart meters, and dynamic pricing.*
- *Further clarify the regulatory framework for security of supply by introducing reliability standards and other mechanisms, taking into account the unique circumstances of Japan. The Organisation for Cross-regional Coordination of Transmission Operators has a key role to play in the implementation of the reliability regulation decided by the government.*
- *Develop national integrated resource planning, including network and renewable generation costs, while developing different scenarios to recognise key uncertainties, such as future nuclear generation, and set up a framework in order to encourage investments in new capacity.*

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9. RENEWABLE ENERGY

Key data (2015 estimated)

Total supply: 24.9 Mtoe (5.7% of TPES) and 170.7 TWh (16.9% of electricity generation). IEA average: 9.9% of TPES and 23.5% of electricity generation

Biofuels and waste: 11.4 Mtoe (2.6% of TPES) and 41.8 TWh (4.1% of electricity generation)

Hydro: 7.3 Mtoe (1.7% of TPES) and 85.1 TWh (8.4% of electricity generation)

Solar: 3.4 Mtoe (0.8% of TPES) and 36 TWh (3.6% of electricity generation)

Geothermal: 2.4 Mtoe (0.5% of TPES) and 2.6 TWh (0.3% of electricity generation)

Wind: 0.5 Mtoe (0.1% of TPES) and 5.3 TWh (0.5% of electricity generation)

OVERVIEW

In the context of Japan's energy policy objectives, renewable energy is both a strategic opportunity and a practical challenge. Following the 2011 Great East Japan earthquake and tsunami and the subsequent shutdown of its nuclear power fleet, Japan is left with extremely high import dependence. In addition, the gap that nuclear power has left in the electricity mix, despite successful efforts to rapidly reduce consumption peaks, had to be filled with fossil generation in the short term, which increased both the country's domestic carbon dioxide (CO_2) emissions and import costs. Accelerated deployment of renewable energy can help in several ways. As a domestic resource, renewable energy reduces import dependence and increases energy security by diversifying the energy mix. As a low-carbon source of energy, it also helps Japan reduce its CO_2 emissions. Finally, renewable energy can also help meet the government's stated objective of minimising the use of nuclear energy as far as possible.

Japan has a variety of renewable energy resources, including geothermal, hydropower, wind and solar energy as well as biomass. However, the country's high population density and mountainous geography constrain available land for developing renewable energy projects, leaving good and available resources often in locations that are far away from population centres. In addition, the technical and regulatory structure of Japan's electricity system sometimes complicates renewable electricity deployment. For example, the mainland electricity grid is divided into nine balancing areas, each controlled by a regional monopoly, which makes the integration of variable renewable energy challenging.

The introduction of a feed-in tariff (FIT) system in 2012 marked a turning point for renewables in Japan. Driven by the desire to attract large investments quickly, the government established generous incentives in favour of renewable energy sources. However, non-economic barriers, such as lengthy environmental approval processes, inhibited the uptake of most sources, apart from solar photovoltaics (PV). The result was a rapid increase in solar PV capacity, and its penetration reached high levels locally.

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Combined with high incentive levels, this has created both a sizeable cost for the electricity system and a challenge for the operation and planning of the grid.

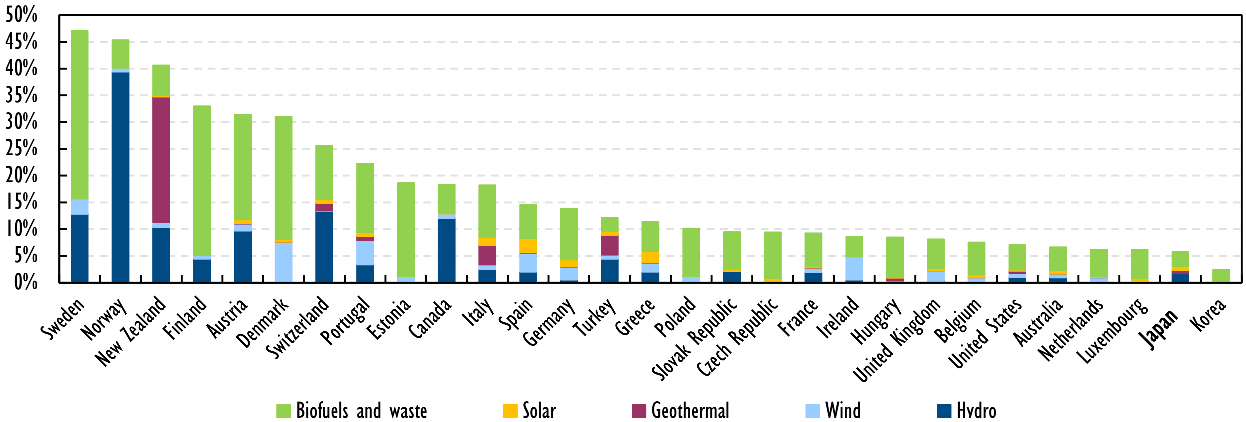
The concentrated, rapid expansion of solar PV provides the background against which three main priorities of renewable energy policy have emerged:

- maintaining momentum in renewable energy deployment to increase diversification of energy sources and energy self-sufficiency, and to reduce CO_2 emissions
- reducing the cost of renewable energy expansion by further decreasing incentive levels and better balancing deployment across technologies and energy sectors
- integrating variable renewable energy into the electricity grid and system cost-effectively.

SUPPLY AND DEMAND

Japan has the second-lowest share of renewables in total primary energy supply (TPES) among IEA member countries, higher only than Korea (see Figure 9.1). Its share of geothermal energy in TPES is seventh-highest among IEA countries, the share of solar power is ninth-highest while the share of wind is the fourth-lowest. The hydropower share is at a median level.

Figure 9.1 Renewable energy as a percentage of TPES in Japan and in IEA member countries, 2015



Notes: Data are estimated.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

Renewable energy accounted for 24.9 million tonnes of oil-equivalent (Mtoe) or 5.7% of Japan's TPES in 2015. Renewables included biofuels and waste (11.4 Mtoe or 2.6% of TPES), hydropower (7.3 Mtoe or 1.7%), solar energy (3.4 Mtoe or 0.8%), geothermal energy (2.4 Mtoe or 0.5%) and wind power (0.5 Mtoe or 0.1%).

Renewable energy as a share of TPES increased from 3.1% in 2005 (or 16 Mtoe). This was mainly driven by electricity generated from solar and, less so, wind power, as well as by an increase in biofuels and waste (Figure 9.2). Wind power increased on average at 11.7% per year from 2005 to 2015 and solar power, coming from a larger base, by 15.9%. Biofuels and waste grew by 7.6% per year, while geothermal energy declined at an annualised rate of 2.3%. Hydropower was 11.3% higher in 2015 compared to 2005, although it varies year-on-year, depending on climatic conditions.

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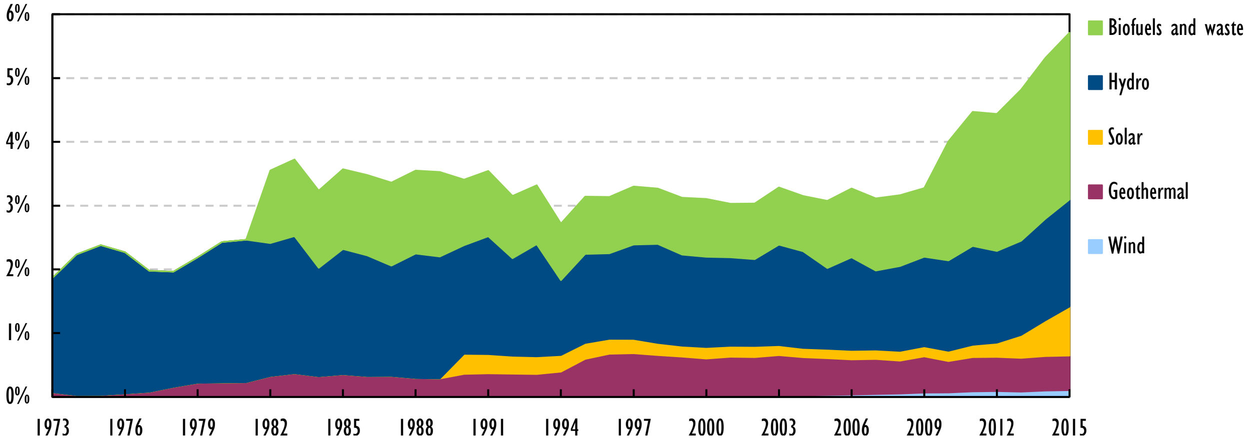
Figure 9.2 Renewable energy as a percentage of TPES, 1973-2015

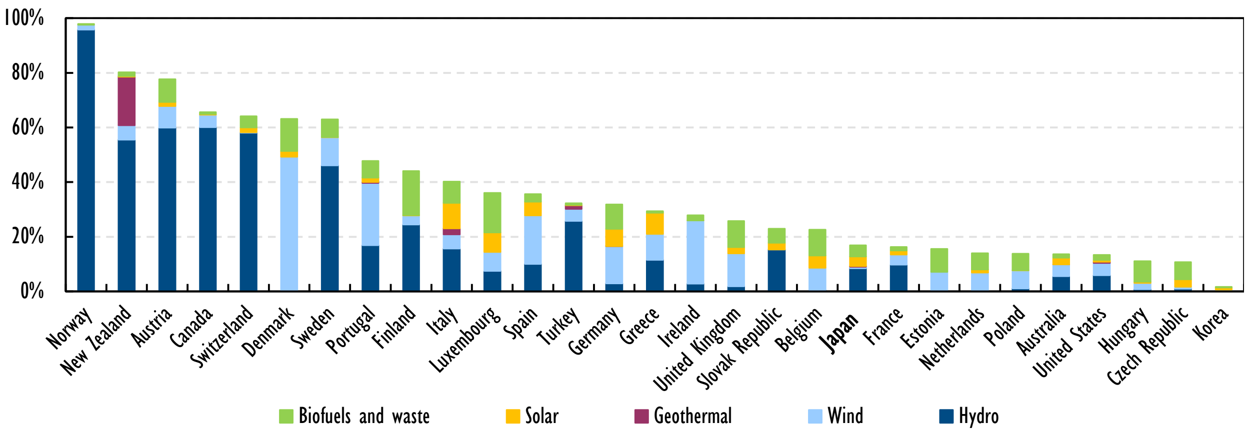


Note: Data are estimated for 2015.

Source: IEA (2016), *Energy Balances of OECD Countries2016*, www.iea.org/statistics/.

Biofuels and waste are mainly consumed for electricity and heat generation (7.8 Mtoe or 70.4% of biofuels and waste supply), while the remainder is consumed in industry and a marginal amount in households. Wind and hydropower are used to generate electricity, while some 85% of solar energy is used for commercial electricity and heat generation and the remainder by households.

Figure 9.3 Electricity generation from renewable sources as a percentage of all generation in Japan and in IEA member countries, 2015



Note: Data are estimated.

Source: IEA (2016), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

Electricity from renewable sources amounted to 170.7 terawatt-hours (TWh) in 2015, or 16.9% of total generation. Renewables in electricity generation include hydropower (85.1 TWh or 8.4% of total electricity generation), biofuels and waste (41.8 TWh or 4.1%), solar power (36 TWh or 3.6%), wind power (5.3 TWh or 0.5%) and geothermal energy (2.6 TWh or 0.3%). The share of renewables in the mix has increased from 8.4% in 2005 (or 95.2 TWh) due to a surge primarily in solar power. Solar power grew 20-fold from 2005 to 2015, while wind power increased by 201.8% and electricity from biofuels

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and waste by 241.9%. Among the IEA member countries, Japan has the tenth-lowest share of renewables in electricity generation.

Table 9.1 Renewable electricity generating capacity, 1990-2014 (MW)

Technology	1990	2000	2004	2008	2009	2010	2011	2012	2013	2014
Hydro	37 830	46 324	46 737	47 341	47 243	47 736	48 418	48 934	48 932	49 597
Pumped storage	*17 005*	*24 305*	*18 979*	*19 779*	*19 749*	*19 749*	*20 649*	*21 119*	*21 119*	*21 724*
Solar PV*	1	330	1 132	2 144	2 627	3 618	4 914	6 632	13 599	23 339
Wind	0	84	769	1 756	1 997	2 294	2 419	2 562	2 645	2 753
Municipal waste	0	1 322	1 501	1 501	1 501	1 501	1 501	1 501	1 501	1 501
Geothermal	270	533	535	532	535	537	537	512	512	508
Total capacity	**38 101**	**48 593**	**50 674**	**53 274**	**53 903**	**55 686**	**57 789**	**60 141**	**67 189**	**77 698**
Solar collectors surface (1 000 m^2)*	0	0	7 726	6 316	6 316	6 319	6 578	6 578	6 578	6 578
Capacity of solar collectors (MW_{th})**	0	0	5 408	4 421	4 421	4 423	4 605	4 605	4 605	4 605

* Data are estimated.

** Converted at 0.7 kW_{th}/m^2 of solar collector area, as estimated by the IEA Solar Heating & Cooling Programme.

Source: IEA (2015), *Renewables Information*, www.iea.org/statistics/.

INSTITUTIONS

The **Ministry of Economy, Trade and Industry (METI)** has jurisdiction over general energy policy, including overall national targets for renewable energy by 2030. Within METI, the **Agency for Natural Resources and Energy** (ANRE) is responsible for implementing renewable energy policies. METI also has the central role in collaboration with other ministries over renewable energy.

The **Ministry of the Environment (MOE)** is in charge of policy measures to reduce greenhouse gas (GHG) emissions. Because of its jurisdiction over parks and nature conservation, it is involved in policies regarding wind, geothermal and biomass energy. For example, METI has developed demonstration projects to expedite environmental impact assessments in co-operation with MOE, since most of resource-rich areas (in terms of wind and geothermal energy) are located in national parks or areas where MOE's regulation protects nature.

The **Ministry of Agriculture, Forestry and Fisheries (MAFF)** enacts policies to foster agriculture, fishery and forest development. It is involved in policies regarding biomass energy. It supports local farmers or forestry associations interested in developing bioenergy projects.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has jurisdiction over the development of infrastructures. It is involved in policies regarding offshore wind and ocean energy.

Local governments promote renewable energy by granting subsidies to local residents or companies. The aim is to activate the local economy and to create jobs.

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POLICIES AND MEASURES

THE STRATEGIC ENERGY PLAN AND THE LONG-TERM ENERGY SUPPLY AND DEMAND OUTLOOK

The objective of policies and measures for renewable energies is to guide their deployment in line with Japan's overall energy strategy. The latest version of this strategy is enshrined in the Strategic Energy Plan (SEP), published in April 2014.

The revised plan provides a roadmap for reforming the energy sector following the accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi nuclear power plants. The plan mainly focuses on measures for the timeframe between 2018 and 2020 and it already incorporates the first set of lessons learned after the introduction of the FIT system in 2012.

The plan targets: a more diversified evolution of renewable energy sources (in particular thanks to measures to strengthen wind and geothermal power); the promotion of distributed renewable energy resources (including biomass, medium/small hydropower, solar power and renewable heat); a reform of the FIT system; and the establishment of Fukushima as a centre of the renewable energy industry.

The Strategic Energy Plan was supplemented by the Long-term Energy Supply and Demand Outlook, published in July 2015. The 2015 Outlook includes a detailed quantification of the desired evolution of the Japanese energy mix out to 2030. The Outlook foresees an increase in the self-sufficiency rate to reach just above 24%, driven by an increase in renewable energies to reach 13% to 14% of TPES and a resumed use of nuclear energy at a level of 10% to 11%. Other significant changes are a reduction of liquefied natural gas (LNG) and petroleum and an increase in the use of coal.

More specifically for renewables, it indicates a contribution larger than in previous plans, which translates into shares above 13.5% of the electricity generated in 2020 and above approximately 23% in 2030. Hydropower, according to the plan, will account for about 9% (corresponding to 93.9 to 98.1 TWh), followed by solar power (7%, corresponding to 74.9 TWh) and biomass (about 4.1%, corresponding to between 39.4 and 49 TWh).

ELECTRICITY

The introduction of the FIT system in 2012 marked a paradigm shift in Japan's approach to renewable power deployment. Before the FIT system, the primary policy emphasis had been on research and development (R&D), complemented by a certificate system for renewable energy sources that targeted a fairly low share in total power supply (1.19%). At the time of its introduction, the objective of the FIT system was clear: increase generation as quickly as possible, in the context of tight electricity supply, rising import dependence and a public in favour of more renewables. However, the results of this approach have been mixed. While renewable energy experienced a significant and unexpectedly rapid boost, growth was concentrated to certain regions and to solar PV. This has brought the cost of support and grid integration concerns to the top of the renewable energy policy agenda. Under the FIT system, electric power companies are obliged to purchase electricity generated from renewable energy sources on a fixed-period contract at a fixed price. The cost for purchasing the electricity is recovered from all electricity consumers through a surcharge per unit of electricity consumed. Electric power companies also contribute to FIT payments at an amount equal to their avoided generation costs.

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The initial level of the FIT was set following a government consultation process that integrated the views of experts and of the renewable energy industry. The resulting tariffs were quite high by international standards, even considering the country-specific circumstances, such as the high cost for acquiring land. According to the FIT law, tariff levels are revisited on an annual basis. Solar PV tariff levels for newly installed plants have been reduced several times (Table 9.2).

Table 9.2 Feed-in tariff purchase prices, FY2012 to FY2016

Technology	Size	Eligibility period [years]	Purchase prices (tax excluded) (JPY/kWh)				
			FY2012	FY2013	FY2014	FY2015	FY2016
Solar	<10 kW	10	42	38	37	33-35	31-33[1]
	10 kW or more	20	40	36	32	29-27[2]	24
Wind onshore	<20 kW	20	55	55	55	55	55
	20 kW or more	20	22	22	22	22	22
Wind offshore		20	-	-	36	36	36
Geothermal	<15 MW	15	40	40	40	40	40
	More than 15 MW	15	26	26	26	26	26
Hydro – new facilities	<200 KW	20	34	34	34	34	34
	200-1 000 kW	20	29	29	29	29	29
	1 -30 MW	20	24	24	24	24	24
Hydro – existing facilities	<200 kW	20	-	-	25	25	25
	200-1 000 kW	20	-	-	21	21	21
	1 -30 MW	20	-	-	14	14	14
Biogas		20	39	39	39	39	39
Biomass – forest thinning	<2 MW	20	32	32	32	40	40
	2 MW or more	20	32	32	32	32	32
Biomass – wood or crop residues		20	24	24	24	24	24
Biomass – waste materials from building demolition		20	13	13	13	13	13
Biomass – waste material		20	17	17	17	17	17

Note: Fiscal years (FY) start in April.

1. From April 2015; if generators are not required to have output control equipment installed, they are entitled to the lower tariff; otherwise, they are entitled to the higher tariff.

2. From April 2015: JPY 29/kWh, from July 2015: JPY 27/kWh.

Source: METI.

Since its introduction, the FIT system has triggered significant investments, although predominantly in solar PV. From July 2012 to January 2016, 26.9 GW of renewable energy capacity was installed under the FIT system (22.1 GW commercial and utility-scale PV, 3.8 GW residential solar PV, 0.4 GW onshore wind, 0.5 GW biomass).

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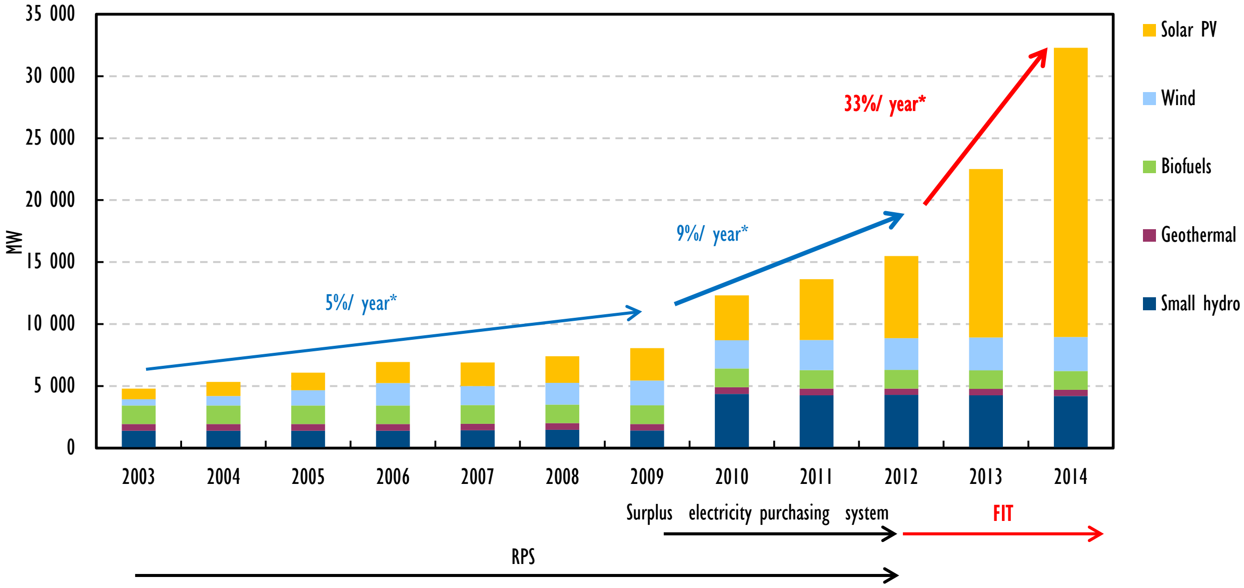
Figure 9.4 Renewable electricity generating capacity (excluding large hydro), 2003-14



*Growth rates numbers from METI.

Source: IEA (2015), *Renewables Information*, www.iea.org/statistics/.

As of January 2016, the volume of registered projects in the feed-in tariff system that had not yet been commissioned totalled 59 GW of capacity (including 53 GW of commercial PV, 2.2 GW of wind and 2.4 GW of biomass). In general terms, there is a good match between the PV generation profile and the demand, which peaks in the afternoons of the warm season. However the project pipeline of solar PV is more concentrated by balancing areas, which increases grid integration challenges. The geographical mismatch, in the absence of sufficient interconnection, prevents from reaping the potential benefit of the good temporal match. For example, in the case of Kyushu, the registered PV capacities exceed the peak of 15.2 GW (FY2014, summer).

The technology concentration in solar PV was the result of a number of barriers holding back the deployment of alternative renewable energy sources. As a previous IEA analysis has shown (IEA, 2011, *Deploying Renewables*), such non-economic barriers can effectively inhibit deployment, despite the presence of attractive economic support.

Such barriers have been particularly relevant for wind and geothermal power. Introducing generation facilities for wind power requires co-ordination with local communities and conducting environmental impact assessments, as well as efforts to adapt to various regulations and restrictions on construction. As for geothermal power, there is a significant risk associated with initial drilling to access resources.

Recognising these issues, the government of Japan added measures to facilitate wind and geothermal power deployment in its 2014 Strategic Energy Plan, including simplified permitting for wind projects in resource-rich areas of the country and risk mitigation instruments for geothermal projects.

Reforming the FIT system

While in principle the total amount of registered PV projects does not seem incompatible with total demand patterns in a fully interconnected balancing area over

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all of Japan, in the current context, regional concentration has caused significant technical concerns regarding grid integration and economic concerns about total policy costs. While this situation commands timely government intervention and policy improvement, a delicate balance is needed between containing costs, maintaining investor confidence and sustaining deployment momentum at high levels, in line with government targets and the need to substitute costly imported fuels. In August 2014 METI announced a set of measures to streamline the registered projects. Developers who have halted the solar PV installations certificated by METI need to submit proof of land acquisition and procurement of system components in order to maintain their eligibility for the system.

The total cost of the FIT scheme for FY2016 is estimated at JPY 2.3 trillion. The resulting surcharge on the electricity bill is JPY 2.25/kWh, according to METI. In an effort to contain the cost of renewable energy deployment, a comprehensive reform of the FIT system and other renewable energy support policies is currently under way.

In February 2016, the cabinet approved the introduction of an auction system for large-scale PV capacities as of April 2017. Since March 2016, METI terminated the tax relief (accelerated depreciation) on PV installations.

The introduction of competitive price discovery holds the promise of reducing costs along the entire value chain of solar PV. As experience in European countries has shown, sustaining high FIT levels can lead to increased prices not only for PV systems, but for many steps along the project value chain, including the cost of land. The competitive pressure of auctions gives project developers a strong argument to return such costs to more efficient levels.

However, since 2015 EPCOs are allowed to curtail power generation from new-built PV and wind generation without compensation for up to 360 hours a year for PV plants and for 720 hours a year for wind plants: this may implicate an uncompensated curtailment of up to one-third of possible energy production. This measure increases the risk for investors to lose revenues, which translates into higher cost of capital and hence overall higher costs. Hence, improving the integration of power from variable renewable energies, as discussed below, should be part of any strategy to reduce the cost of their deployment and associated support policies.

HEAT

Renewable heat is supported by a capital grant t scheme. This scheme grants subsidies to local governments (subsidy rate 1/2) and private-sector operators (subsidy rate 1/3) for projects to introduce renewable heat utilisation facilities. The amount of its FY2014 budget is JPY 4.0 billion.

Moreover, a loan scheme for investments in non-fossil energy equipment for heat production in small and medium-sized enterprises is in place. The limit for loans is JPY 720 million and the payback period is within 15 years (or 20 years with a period of deferment of two years in cases in which this is particularly necessary).

The national R&D project on renewable heat is aiming to promote the renewable energy heating technology by reducing the system cost through R&D project on a more energy-efficient heat pump system or methods to measure solar thermal system performance.

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TRANSPORT

Oil companies have been obliged to introduce biofuels for transport since FY2011. They are required to introduce 500 000 crude oil-equivalent thousand litres (kL) of biofuels by FY2017 (November 2010). As of 2014, 320 000 crude oil-equivalent kL of biofuels are being blended, mainly imported ethanol produced from Brazilian sugarcane.

In order to achieve wider adoption of biofuels, in the FY2014 budget, subsidies to support petroleum refiners to help them develop the necessary infrastructure (facilities for mixing, storage, receipt, and shipping of biofuels) amounted to JPY 1.18 billion. In addition, subsidies equal to JPY 0.7 billion support the building of raw materials procurement and distribution systems locally in order to encourage the use of biodiesel.

METI has supported biofuels promotion by giving financial support to private companies which conduct RD&D projects on biofuel production. The R&D projects supported by METI have developed the method to make advanced biofuel (bioethanol) production more efficient, so that the production costs will reach commercial level comparing to oil cost. In order to increase energy security, the demonstration project to produce biofuel from algae also will start in 2016.

INTEGRATION OF VARIABLE RENEWABLE ENERGY SOURCES

A number of factors make the integration of variable renewable energies challenging in Japan: owing to its island geography, it is not interconnected to any other country. Japan's mainland power system is fragmented into nine balancing areas that are each operated by vertically integrated monopolies in a largely isolated fashion. For historic reasons, there are also two different system frequencies used in the country, 60 Hz in the west and 50 Hz in the east. While there is some interconnection capacity available between the different EPCO areas, this is not used for a dynamic, short-term exchange of electricity. The only way to exchange power across the two frequency areas is via a back-to-back direct-current converter that has fairly limited capacity (Figure 9.5).

Given the historically insignificant shares of variable renewable energies, EPCOs do not have much experience with operating the power system at a high share of variable generation. Consequently, the rapid scale-up of solar PV has translated into an urgent need to upgrade the system's operation with a view to increase the flexibility of the overall power system. The situation is somewhat complicated by the fact that technical knowledge about the power system rests almost exclusively with the EPCOs, which have little or no commercial incentive to foster a very rapid uptake of alternative generation resources. Consequently, it is not always clear to what extent technical concerns and proposed solutions are brought forward in the most proactive way. Recognising this potential issue, METI established an *ad hoc* working group to provide an independent assessment of how much solar PV capacity can be integrated into the system given current circumstances.

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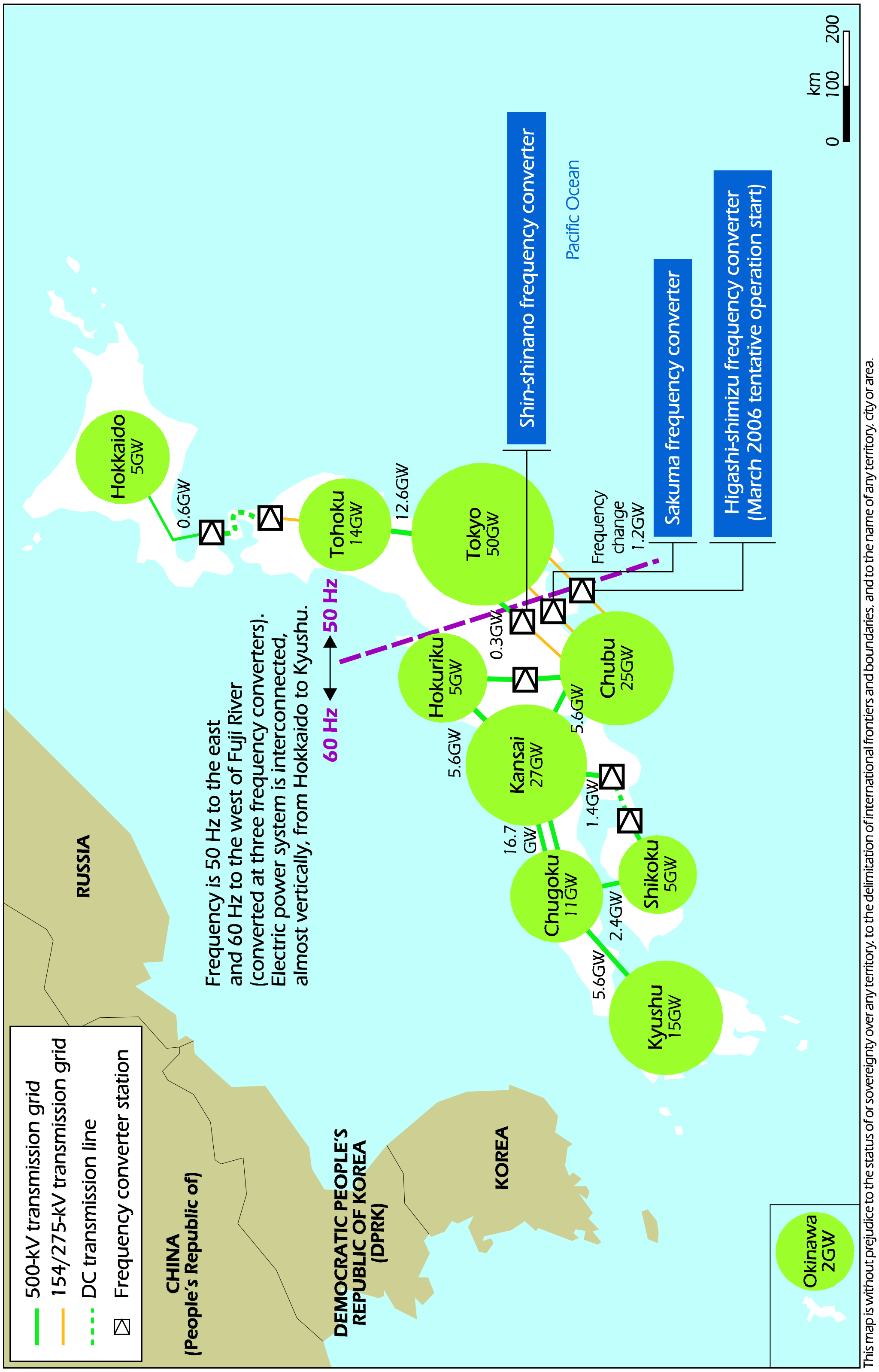
Figure 9.5 Peak load and interconnection between different EPCO areas, 2014



Source: METI.

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The assessment was performed following the announcement of five EPCOs (Hokkaido, Tohoku, Shikoku, Kyushu, Okinawa) in mid-2014 to defer the connection of capacity registered after 1 October 2014 or all registered capacity in the case of Kyushu. The result of the assessment has since been published for seven areas (Table 9.3). It is important to note that the EPCOs of Tokyo, Chubu and Kansai were not included in the assessment. In addition, a more detailed technical integration study could highlight ways to increase available grid integration capacity and suggest options to increase power system flexibility.

It can be expected that discussions about technical feasibility of various operating procedures for renewable energy integration will continue. This includes the maximum level of interconnections that can be used for dynamic, short-term exchanges of power or the technical capability of large thermal units to adjust their output dynamically. Such discussions are very common in countries where generation from variable renewable sources is picking up and it is critical to acknowledge that incumbent generators have a strong commercial interest to downplay available flexibility in order to protect the profitability of current assets and the opportunities for future investments.

Table 9.3 Total solar and wind grid connection capacity by selected EPCOs in 2014 and 2015 (GW)

	Hokkaido	Tohoku	Hokuriku	Chugoku	Shikoku	Kyushu	Okinawa
2014							
Solar	1.17	5.52	1.1	5.58	2.57	8.17	0.495
Wind	0.36	2	0.45	1	0.6	1	0.025
2015							
Solar	1.17	5.52	1.1	<u>6.6</u>	2.57	8.17	0.495
Wind	0.36	<u>2.51</u>	<u>0.59</u>	<u>1.09</u>	<u>0.64</u>	<u>1.8</u>	<u>0.183</u>

Note: Underlined numbers indicate change in capacity.

Source: METI.

In this context, having an independent body with a sufficient degree of technical expertise can help the policy-making process considerably. In Europe, this role has been assumed by transmission system operators and in the United States by independent system operators. The establishment of the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) as part of the electricity market reform is a step in this direction. However, to become fully effective in providing an independent assessment and catalysing a more flexible operation of the system, OCCTO will need to have true independence and sufficient resources to carry out its tasks. The experience gained as part of the *ad hoc* group for determining feasible grid connection capacities could serve as an input for such a development.

Options to increase the flexibility of the power system in the longer term are currently being investigated. A recent study by New Energy and Industrial Technology Development Organisation (NEDO) assesses the feasibility of increasing the solar PV 2030 target from 64 GW to 103 GW and the land-based wind target from 11 GW to 32 GW through the use of demand-side response and management as well as storage. In the absence of such measures, the study projects significant levels of variable renewable energy curtailment by 2030 under the more ambitious scenario (15% in energy terms).

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Such studies are relevant to facilitate a stronger system-wide perspective on renewables integration, which is not yet consistently adopted by all power system stakeholders. For example, the 2015 Long-Term Outlook states that “solar power and wind power fluctuate greatly in output depending on the weather conditions and need to be accompanied by thermal power as adjusting power source”. However, there are flexible resources beyond thermal generation (including hydropower, demand-side response, grid infrastructure and storage) that can be used to balance variability. For example, Japan already has ample pumped hydro storage capacities with the highest installed capacity per peak demand of all IEA countries, and could develop them further. It was also the first, and remains the only, country to develop seawater pumped-storage hydropower. In addition, one can also argue that it is not the variability of wind and solar power that needs to be balanced by flexible resources, but the variability of net load, i.e. power demand minus the generation from variable renewable sources.

Furthermore, there is a good temporal match between PV generation and load peaks in Japan, partly driven by air conditioning and other cooling needs. Distributed PV, in particular on large flat roofs in the commercial and industrial sectors, could potentially reduce transmission and distribution issues. If largely based on self-consumption, it would not increase the support policy costs.

In summary, it is clear that Japan faces a somewhat particular situation in terms of grid integration, owing to both its geography and historical evolution of the electricity sector. It will be critical to reap the full benefit from the electricity market reform to create an independent body that can advise on the technical issues of grid integration in a neutral way. Combining this with the excellent R&D infrastructure of Japan will create a positive environment to make further progress.

ASSESSMENT

In the context of Japan’s energy policy objectives, renewable energy is both a strategic opportunity and a practical challenge. Deploying a balanced renewable energy portfolio will diversify the supply base, thus increasing Japan’s energy security. A higher number of distributed generation resources can enhance system resilience in face of natural disasters. The high marginal generation costs in the Japanese power system give a high economic value to additional renewable electricity generation, especially during peak and mid-merit hours when the price is set by imported oil- or LNG-fired generation. Moreover, substantial increase of a portfolio of renewables will be required to achieve long-term decarbonisation objectives across a wide range of energy supply scenarios.

Japan has significant geothermal resources, its solar resource shows a good match with electricity demand (national peak demand occurs in the summer during daylight hours) and parts of the country (the far north and south-west) also have substantial wind resource potential. However, the majority of geothermal resources is situated in natural protection areas and the wind resources are far from the consumption centres.

In reforming the FIT scheme, the government has already identified non-technical and non-economic barriers, such as lengthy permitting procedures for wind and geothermal projects, as a key obstacle to a more balanced technology portfolio and has taken measures to streamline these. However, given recent advances in low wind-speed turbine technology, it may be worthwhile to further expand streamlined permitting procedures to more areas of the country.

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Regarding the cost and pace of deployment, solar PV has grown much more quickly than expected and the generation cost of solar PV appears high in Japan compared to international benchmarks. The planned introduction of an auction mechanism for solar PV is a positive sign from the perspective of reducing costs. However, the details of the auction design will be critical for its success, in particular measures to ensure a balanced regional deployment of resources. Furthermore, the possibility granted to utilities to curtail large fractions of renewable electricity could translate into a higher perceived risk for investors, which would in turn increase financing costs. Ultimately, this could drive up bid prices under the new auction system.

In addition, if the new system is effective in pushing down deployment costs, this may call for a revision of the targets expressed in the Long-term Energy Supply and Demand Outlook for 2030. As it stands, the Outlook foresees a significant slow-down in the uptake of renewables and a ramp-up of coal-fired generation.

While discussed primarily as a technical issue, current grid integration challenges in Japan appear to be equally of a technical and institutional nature. However, electric power companies are still gaining experience with system operation in the presence of growing shares of variable renewable energies. There also appears to be a need for more sophisticated analytical tools to assess available grid capacities and optimise system flexibility.

Moreover, current institutional arrangements between EPCOs appear unsuited to facilitate the efficient short-term trade of electricity in order to smooth solar PV and wind generation variability. While international experience clearly suggests that challenges can be overcome, a more proactive approach on the side of electric power companies appears indispensable. The ongoing reform of the Japanese electricity market can be expected to further improve this situation.

Finally, Japan's approach to renewable energy deployment shows a very strong emphasis on the power sector. A more integrated approach, including heating, cooling and transport, will be crucial in maximising the contribution of renewable energies to meeting energy policy objectives.

RECOMMENDATIONS

The government of Japan should:

- ☐ *Enhance the contribution of renewable energy to energy security and energy system resilience by facilitating the rapid uptake of a balanced portfolio of renewable energy sources through a combination of economic incentives and other policy measures.*
- ☐ *Ensure that policy costs are minimised and policies contribute to ambitious cost-reduction targets by frequently reducing support levels (monthly for PV) depending on deployment levels, by better aligning with international best-practice, and/or by using price discovery mechanisms such as auctions for larger-scale projects. Consider implementing a transitory cap on annual financial support payments to keep total policy costs under control.*
- ☐ *Continue to identify and remove non-technical and non-economic barriers, including through a better co-ordination and simplification of environmental impact assessments and permitting procedures for geothermal and wind energy.*

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- *Prioritise an accelerated adoption of operational measures to increase the efficient integration of variable renewable energies, such as effective use of production forecasts and maximum use of interconnection capacities. Engage with electric power companies to establish an effective system for setting and enforcing clear targets for improving system operations. Aim at maximising the value of wind and solar generation when and where most needed, including by fostering PV self-consumption in commercial and residential settings.*
- *Develop a strategy for heat production from renewable sources, particularly for solar energy to replace oil, natural gas and electricity in water heating.*

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10. NUCLEAR ENERGY

Key data (2015 estimated)

Number of reactors: 43 operable, five others permanently shut down in 2015; 24 reactors in process of restart approvals. The first two reactors (Sendai 1&2) restarted in the second half of 2015.

Installed capacity: 40.3 GW_e in August 2015

Electricity generation: 9.4 TWh, down from 288 TWh in 2010

Share of nuclear: 0.6% of TPES and 0.9% of electricity generation in 2015, down from 15.1% of TPES and 25.3% of electricity generation in 2010

OVERVIEW

As a quasi-domestic electricity source, nuclear power has played an important role in Japanese energy policy in terms of security of supply, economic performance and greenhouse gas (GHG) emissions reductions, garnering strong government support. Because of these attributes, electricity generating capacity by nuclear power has been built up since the 1970s to provide over 25% of domestic electricity generation in 2010. The capacity build-up was accompanied by efforts to localise fuel production and close the fuel cycle in order to gain the greatest amount of energy from imported uranium and to reduce the volume of final wastes. Resources have also been directed towards fuel cycle research and development (R&D), including fast reactor development.

Despite these strategic advantages and the significant cumulative effort and resources expended, nuclear power in Japan has been affected by a number of events that have undermined public confidence in the technology and in the organisations operating the facilities. The Fukushima Daiichi nuclear accident in early 2011 following a major earthquake and tsunami further significantly eroded public confidence in nuclear power. Uncontrolled off-site releases of radioactivity over a large area forced the evacuation of over 150 000 citizens and the clean-up, compensation to those affected and the decommissioning of damaged reactors are consuming significant resources.

The initial government response after the accident included consideration of a complete exit from the nuclear power programme. Following the 2012 general election and the formation of a new government, however, a new Strategic Energy Plan was formulated in 2014. The Plan restated the importance of nuclear energy, provided safety could be assured, founded on the energy security, economic and environmental benefits of the technology. Another important step for a sustained nuclear comeback is the 2015 Long-term Energy Supply and Demand Outlook that envisions nuclear power supplying 20% to 22% of electricity in the country in 2030. Reactor restarts and rejuvenation of the industry is, however, proving challenging given the prolonged review process under the stringent new regulatory requirements and public resistance. Therefore, the restart of Kyushu Electric Power Company's Sendai 1 reactor in August 2015 and Sendai 2 reactor

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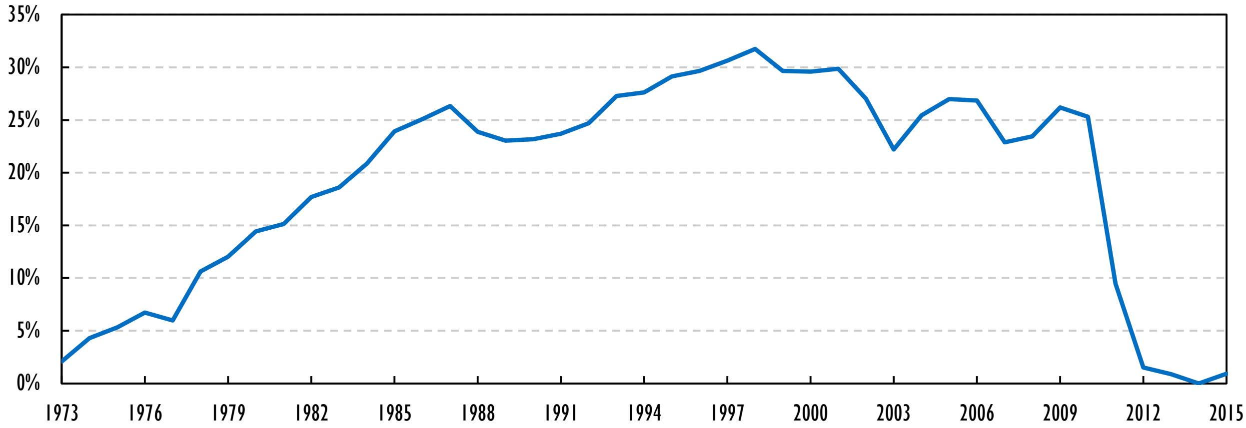
in October 2015, the first reactors to restart under the new regulation, was a major achievement for the post- Fukushima Japanese nuclear industry.

Figure 10.1 The share of nuclear power in electricity generation in Japan, 1973-2015



Source: IEA (2016, forthcoming), *Energy Balances of OECD Countries 2016*, www.iea.org/statistics/.

BACKGROUND

The high energy content of nuclear fuel means that multi-year fuel supply capable of producing significant amounts of electricity can be stored with relative ease and is readily accessible, easing security of energy supply concerns and minimising import requirements of alternative energy supplies, in particular fossil fuels that require much larger volumes of imports on a continual basis. Since the Fukushima Daiichi nuclear accident and the progressive shut-down of all nuclear power plants (NPPs), Japan has spent more than USD 100 billion in additional fuel imports for electricity generation, significantly affecting the country's trade balance.

Nuclear power plants have comparatively low and stable operating costs and are capable of generating significant amounts of baseload electricity. This is an important consideration for Japan, the fifth-largest electricity consumer in the world. Since the Fukushima Daiichi nuclear accident and the progressive shut-down of all NPPs to the end of FY2014, electricity prices increased by around 25% for households and by almost 40% for industry, principally because of the cost of importing large volumes of fossil fuels for electricity generation.

The government sees further development of nuclear energy as a means of generating significant amounts of carbon-free electricity. The Fukushima Daiichi nuclear accident and the progressive shut-down of all NPPs led to an increase in CO_2 emissions from electricity generation by 100 million tonnes (Mt), or 21% (from 477 Mt in 2010 to 594 Mt in 2013, declining to 577 Mt in 2014). The drop in 2014 can be attributed to energy efficiency gains and a shift from oil to natural gas and solar PV in power generation.

These characteristics explain why nuclear power has been a prominent feature of energy policies in Japan. Before the Fukushima Daiichi nuclear accident, the third Strategic Energy Plan (2010) outlined a roadmap that would see zero-emission power sources (mainly nuclear energy and renewable energy sources, including hydro) accounting for around 70% of electricity generation by 2030. The 2010 Plan included the construction of nine new reactors and an increase in the capacity factor of the reactor fleet to 85% by

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2020, with an additional 14 new reactors and a further improvement in fleet capacity factor to 90% by 2030, pushing the contribution of electricity generation at NPPs to about 50% of total electricity supply in Japan in 2030.

The 2015 Long-term Energy Supply and Demand Outlook (see Chapter 2 on general energy policy) envisions nuclear power providing 20% to 22% of the country's total electricity output by 2030. Although this target is lower than the policy before the Fukushima Daiichi nuclear accident, it reflects the important role for nuclear power in both securing energy supply and limiting CO_2 emissions over the long term. The government plan for electricity generation to 2030 aims to reduce CO_2 emissions by 22% from the 2013 level, and to improve the energy self-sufficiency rate to about 25% from the 6% in 2013.

DEVELOPMENT HISTORY

Activities to support nuclear research, development and use in Japan began when the Atomic Energy Basic Law, which strictly limits the use of nuclear technology to peaceful purposes, was passed on 19 December 1955. This law specified that development of nuclear power would be promoted, with assurances of safety and transparency, in order to secure future energy resources and to promote science and industries that would contribute to the improvement of living standards. On 1 January 1956, the Atomic Energy Commission was established in order to implement national policies, and nuclear energy policy in general, to pursue these goals in a democratic manner.

Nonetheless, the rapid expansion of Japan's industrial sector in post-war years relied heavily on fossil fuel imports, in particular oil from the Middle East, which accounted for two-thirds of electricity generation in 1974. However, the vulnerability of a heavy reliance on fossil fuel imports was underlined during the first oil crisis in 1973 that featured a rapid fourfold increase in the price of oil. At the time, Japan had a relatively small nuclear industry consisting of six operating reactors. Re-evaluation of domestic energy policy in the aftermath of the oil price shock gave high priority to reducing dependence on oil imports. Subsequent efforts to diversify electricity generation initiated a significant nuclear power plant construction programme.

The subsequent development of nuclear energy in Japan focused on light water reactors (LWRs) utilising enriched uranium – both boiling water reactors (BWRs) and pressurised water reactors (PWRs). Japanese utilities purchased designs from vendors in the United States and built them in partnership with Japanese companies, that would then receive a licence to build similar plants in Japan. Hitachi Co Ltd, Toshiba Co Ltd and Mitsubishi Heavy Industry Co Ltd subsequently developed the capacity to design and construct LWRs domestically and for export. By the end of the 1970s, Japanese industry had largely established its own domestic nuclear power production capability. Japanese companies recently demonstrated this capability and expertise by constructing Generation-III reactor designs in less than four years, well below the time required for the construction of advanced reactor designs in the People's Republic of China, Europe and the United States.

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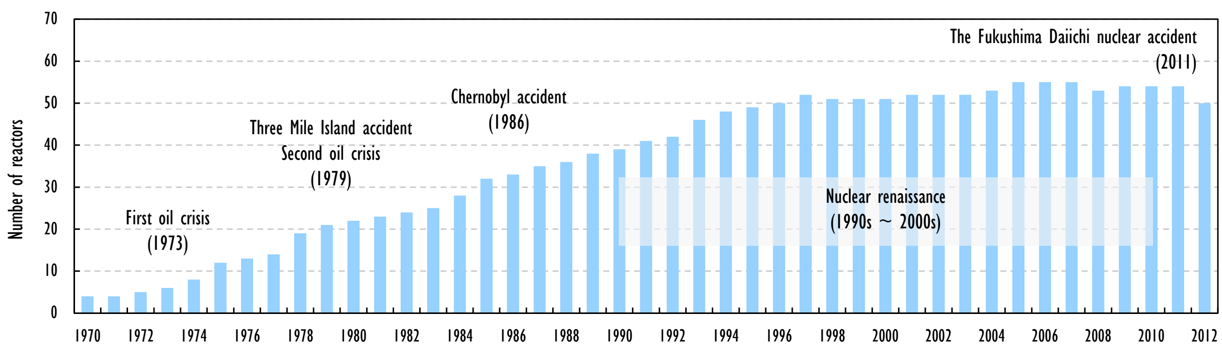
Table 10.1 Development of nuclear power generating capacity in Japan (1970-2012)

	1970	1980	1990	2000	2010	2012
Number of reactors	4	22	39	51	54	50
Total capacity	1.3 GW	15.5 GW	31.5 GW	44.9 GW	49 GW	46.1 GW
Generation share	1.6%	16.9%	27.3%	34.3%	28.6%	1.5%

Source: METI.

Figure 10.2 Development of nuclear power generating capacity in Japan (1970-2012)



Source: METI.

The earliest reactors faced, however, reliability problems. Long maintenance outages were required and, as a result, capacity factors were low. To address this issue, a three-phase improvement and standardisation programme was launched in 1975. In phases 1 and 2, the existing BWR and PWR designs were modified to improve operation and reduce maintenance outages. In phase 3, new designs were developed with increased power output (1 300 to 1 400 MW_e), as represented by the advanced BWR and PWR (ABWR, four of which have been built, and APWR, advanced to the planning stage only, but none have been built). Even though nuclear power fleet capacity factors improved from about 50% in the mid-1970s to over 80% by 2000, they remained below factors achieved by the top performers globally (90% or more).

Activities were also launched in the 1970s that encompassed development of the entire nuclear fuel cycle, from uranium exploration to the disposal of high-level radioactive wastes and the development of fast breeder-reactor technology, domestic spent fuel reprocessing capabilities and the production and use of mixed-oxide (MOX) fuel. The latter three activities are 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.

These policies resulted in the rapid development of a large fleet of nuclear reactors (Figures 10.2 and 10.3) that, among other things, eased the country's dependence on fuel imports.

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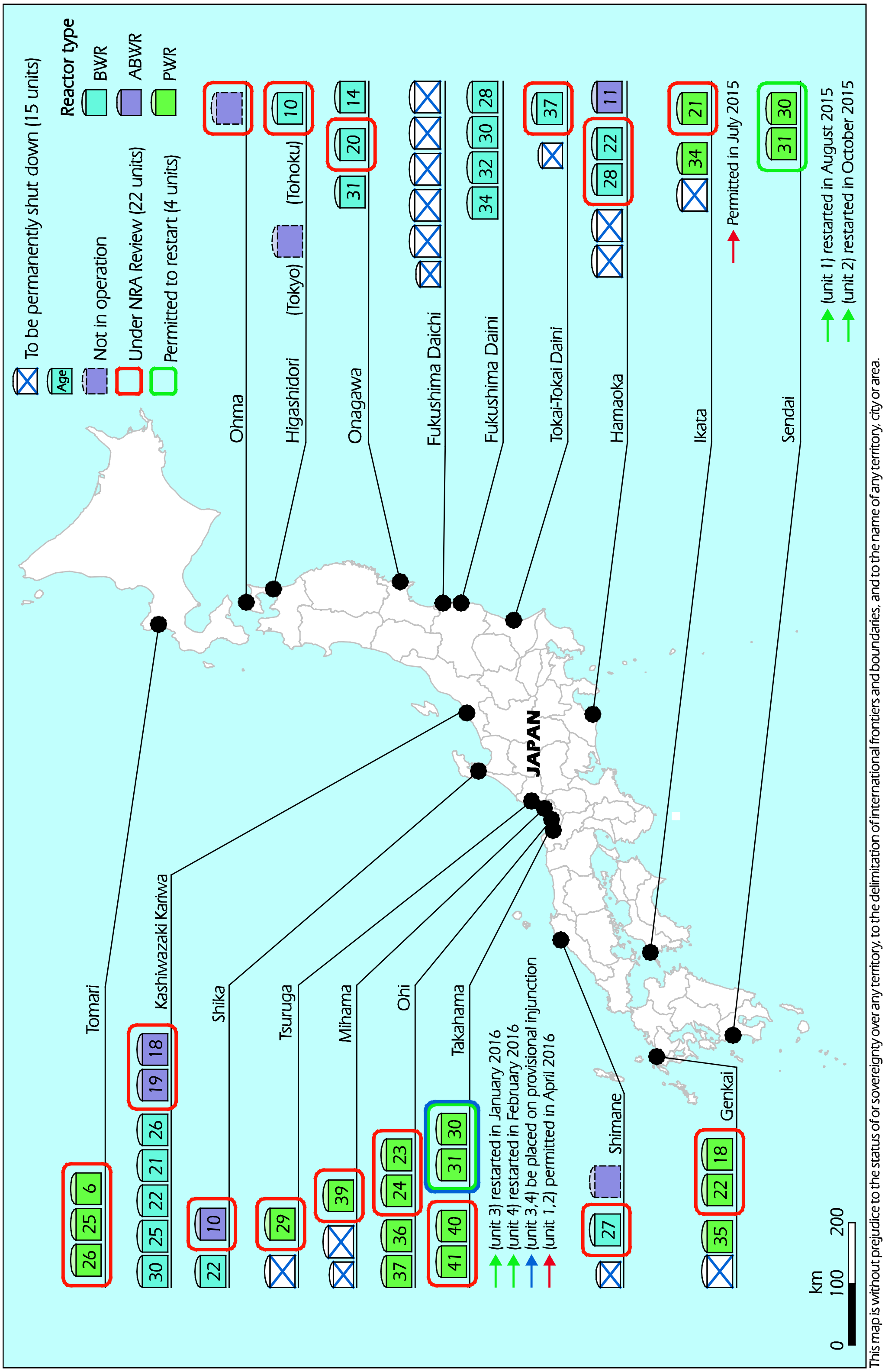
Figure 10.3 Name, location and status of nuclear power plants in Japan, May 2016



Notes: ABWR: advanced boiling water reactor; BWR: boiling water reactor; PWR: pressurised water reactor.

Source: METI.

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Dependence on imported fossil fuels decreased from 90% of TPES in 1973 to 82% in 2010 as the fleet of nuclear power reactors was expanded. This also helped limit electricity price increases. Import dependence increased to 92% in 2013 as NPPs were shut down following the Fukushima Daiichi nuclear accident, contributing to increases in electricity prices of 20% (for households) to 30% (for industry) since 2010.

Despite these benefits, nuclear energy in Japan has been controversial, principally owing to a number of incidents and accidents that have undermined public trust in the industry, including: falsified safety records; a fire caused by a sodium leak at the Monju sodium-cooled fast reactor in 1995, the full extent of which was not initially reported; poor working practices and safety culture that led to the death of two workers; off-site radiation releases at the Tokai-Mura fuel cycle facility in 1999; and the Fukushima Daiichi nuclear accident in 2011.

After the discovery of falsified safety records in the early 2000s, NPP capacity factors declined again following the closure of 13 plants to allow the regulator to confirm the safety of the reactors. Regulatory inspections and decision making processes lengthened, exerting further downward pressure on capacity factors. Further reductions in capacity factors occurred after damage from an earthquake resulted in the large (7.97 GW_e net), seven-unit Kashiwazaki-Kariwa plant being taken off line for a lengthy safety check and upgrades to ensure safe operation.

On 16 July 2007, a 6.8-magnitude earthquake centred 16 km from the seven-unit Kashiwazaki-Kariwa plant caused units 2, 3, 4 and 7, which were either operating or being started up, to automatically shut down as designed. These four units were safely brought to cold shut-down in between 9 to 20 hours after the earthquake. Because the strength of this earthquake exceeded the reactor's maximum design characteristics, the nuclear regulator launched an investigation into the integrity of the facilities in order to confirm the safety of all seven units. The plant owner and operator, Tokyo Electric Power Company (TEPCO), began checking the facilities immediately after the earthquake and subsequently identified some 3 600 deviations from the required state of the facilities, of which 85 were regarded as important to safety and four were considered necessary to report to the nuclear regulatory body under legal provisions (a fire in a building housing a transformer in unit 3, a leak of slightly radioactive water from a spent fuel pool in the unit-6 reactor building, damage to a coupling of an overhead crane in the unit 6 reactor building and flooding of the operator floor with slightly radioactive water caused by sloshing in spent fuel pools in the reactor buildings of units 1 and 7). After upgrades and comprehensive reviews to confirm the safety of the plant, units 7, 6, 1 and 5 (in that order) were returned to service in 2010 (units 6 and 7 are ABWRs). Although no leaks of radioactive water occurred outside the facility and the water accumulations in the units did not pose a risk to human health, public trust in nuclear power was weakened.

GREAT EAST JAPAN EARTHQUAKE

The magnitude 9 Great East Japan earthquake (the largest ever recorded in Japan, powerful enough to move Japan's main island Honshu 2.4 m eastward) and massive tsunami waves on 11 March 2011 caused widespread devastation and significant loss of life in north-east Japan. This natural disaster also triggered a serious accident at the Fukushima Daiichi plant (level 7, the most severe on the international nuclear event scale) that led to significant off-site radiation releases arising from fuel meltdowns in the three reactors in operation at the time at the six-unit facility. Although the three

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operating reactors shut down safely following the earthquake despite the loss of regional electricity supply, the backup generators supplying on-site electricity failed when the ensuing large tsunami waves overwhelmed the facility's defences less than one hour after the earthquake. With all power sources cut and cooling capabilities lost, core degradation began and the hydrogen released from the melting fuel built up, causing explosions in the buildings that housed the reactors.

Some 19 000 lives were lost as a direct result of the earthquake and tsunami, but no loss of life has been reported as a result of the radiation releases resulting from the nuclear accident, although there remains some uncertainty about the health impacts of long-term exposure to low levels of radiation. However, the evacuation of over 150 000 inhabitants from the affected area disrupted the lives of evacuees, causing enormous stress and loss of life.

Table 10.2 Applications to NRA for power reactor conformity assessment to new regulations

Reactor	Licence	Type	Application date	Restart date
Tomari 1, 2	Hokkaido	PWR	08-Jul-13	
Tomari 3	Hokkaido	PWR	08-Jul-13	
Takahama 3, 4	Kansai	PWR	08-Jul-13	Restarted in Jan-16, Feb-16, halted in Feb and Mar
Ohi 3, 4	Kansai	PWR	08-Jul-13	
Ikata 3	Shikoku	PWR	08-Jul-13	
Sendai 1, 2	Kyushu	PWR	08-Jul-13	Aug-15, Oct-15
Genkai 3, 4	Kyushu	PWR	12-Jul-13	
Kashiwazaki-Kariwa 6, 7	Tokyo	ABWR	27-Sep-13	
Shimane 2	Chugoku	BWR	25-Dec-13	
Onagawa 2	Tohoku	BWR	27-Dec-13	
Hamaoka 4	Chubu	BWR	14-Feb-14	
Takahama 1, 2*	Kansai	PWR	17-Mar-15	
Tokai Daini	JAPC	BWR	20-May-14	
Higashidoro 1	Tohoku	BWR	10-Jun-14	
Shika 2	Hokuriku	ABWR	12-Aug-14	
Ohma 1**	J-Power	ABWR	16-Dec-14	
Mihama 3	Kansai	PWR	17-Mar-15	
Hamaoka 3	Chubu	BWR	16-Jun-15	
Tsuruga 2	JAPC	PWR	05-Nov-15	

* Applied for 20-year life extension of both reactors on 30 April 2015.

** Under construction; the world's first nuclear power plant to be powered exclusively by MOX fuel.

Source: Nuclear Regulation Authority; METI.

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As the accident progressed and off-site radiation releases occurred, the authorities established evacuation areas up to 30 km from the plant location, taking account of anticipated radiation doses. The time to respond and notify citizens of the unfolding accident, the emergency response itself and the evacuation all suffered from a lack of preparation, appropriate actions and a clear chain of command. As much as 1 800 km^2 of the land area of 14 000 km^2 of Fukushima prefecture received measurable radiation doses. Clean-up standards were established and work is under-way, with evacuation orders lifted in areas cleaned up. Understandably, evacuees have many questions about the impact of the accident on their long-term health and the government must continue to inform evacuees of the risks and uncertainties associated with the doses received.

Decommissioning the Fukushima NPP will be a complex, multi-decade endeavour. The accident dramatically ended the operational life of the facility in an unplanned fashion, and the resulting melted fuel, damage and prohibitively high radiation in some areas of the facility mean that certain aspects of the decommissioning will be very challenging. Progress is nonetheless being made. Spent fuel has been successfully removed from the reactor-4 spent fuel pond and, thanks to site clean-up activities, radiation releases have been significantly lowered and stabilised at about 1/70 of the natural radiation dose. There is, however, much left to do. Efforts are complicated by the need to store and treat very large volumes of contaminated water on the site. Until the damaged reactors no longer require cooling with water and the inflow of groundwater to the site is better controlled, large volumes of water will continue to be captured and need to be treated appropriately before release.

As a result of the accident and investigations into its causes, the remaining 48 operational reactors in Japan were gradually taken offline during regularly scheduled maintenance outages. The new, independent Nuclear Regulation Authority (NRA) was established in 2012 and new, stringent regulations were enacted in 2013. The government released the fourth Strategic Energy Plan in 2014 to pursue energy security, economic efficiency and environmental objectives by continuing to use nuclear power as an important baseload power source, provided that safety can be assured. The government stated that it will follow NRA’s judgement (using its new conformity assessment process) and proceed with authorised reactor restarts while working to lower dependence on nuclear power to the extent possible (mainly through energy conservation measures and adding to renewable energy capacity).

As of March 2016, utilities and operators had applied to the NRA for a review of the safety systems of 26 reactors for conformance with the new, stringent regulatory requirements established by the NRA (Table 10.1). Although conformance has been determined for five reactors (Sendai 1 and 2, Takahama 3 and 4 and Ikata 3), as of March 2016 only Sendai 1 and 2 had been brought back into operation. The other reactors remain offline, pending local government approval, documentation, back fitting and other issues being addressed. Following prestart-up inspections by the NRA, Takahama-3 reactor had returned to the grid on 1st February 2016. However, Kansai Electric shut down the reactor shortly after (in March) in response to a court injunction acting on a request file filled by local residents. Takahama 4 was restarted on 26 February, but has remained offline since 29 February following an automatic shut-down of the reactor due to a technical problem.

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NUCLEAR REGULATION AUTHORITY AND NEW REGULATORY REGIME

The NRA was established in September 2012 as an independent authority, not controlled or supervised by any other organisation. As a result, the NRA Secretariat will take decisions independently (that is, free from outside pressure or bias) based on the latest scientific and technological information, discarding the previous ineffective approach to regulatory work and stressing the importance of a field-oriented approach. In order to further ensure independence and neutrality, staff members of the NRA will not be redeployed to administrative bodies with jurisdiction over matters related to the promotion of nuclear energy (the so-called “no return rule”) after a five-year period of transitional measures that began in 2012.

The mission of the NRA is to protect the general public and the environment through rigorous and reliable regulation of nuclear activities with five guiding principles: independent decision making; effective actions, open and transparent organisation; improvement and commitment; and emergency response. It is expected to ensure transparency and appropriate information disclosure on the regulations and the decision-making process to be open to opinions and advice from the Japanese and international communities, keep abreast of latest regulatory know-how and practices, and prepare for a swift and well-organised response to emergency situations.

Since NRA’s establishment, legislation on the regulation of reactors has been consolidated. The regulatory authority 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 regime.

The new regulatory requirements were developed in line with the safety standards and guidelines of the International Atomic Energy Agency (IAEA), taking into account the lessons learned from the Fukushima Daiichi nuclear accident identified in the reports by the National Diet’s Nuclear Accident Investigation Commission, the government’s Nuclear Accident Investigation Committee and the Independent Investigation Commission on the accident and harsh natural conditions unique to Japan. In addition to recognising that the so-called “safety myth” (i.e. a serious nuclear accident could not happen if regulatory requirements had been met) had critically undermined nuclear safety in Japan before the Fukushima Daiichi nuclear accident, more stringent regulations have been developed with the assumption that severe accidents could occur at any moment. Discussion meetings during the development of the regulations were open and public comments were solicited twice during the process.

Based on the “defence-in-depth” concept, importance has been placed on the third and fourth layers of defence and on the prevention of loss of safety functions due to common causes. 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 in the face of these external events were enhanced. Furthermore, strengthened countermeasures against internal fires and flooding are required, and the reliability of on-site and off-site power sources to deal with possible station blackouts has been enhanced. In addition, countermeasures for severe accident response against core damage, containment vessel damage and release of radioactive materials, but also enhanced measures for water

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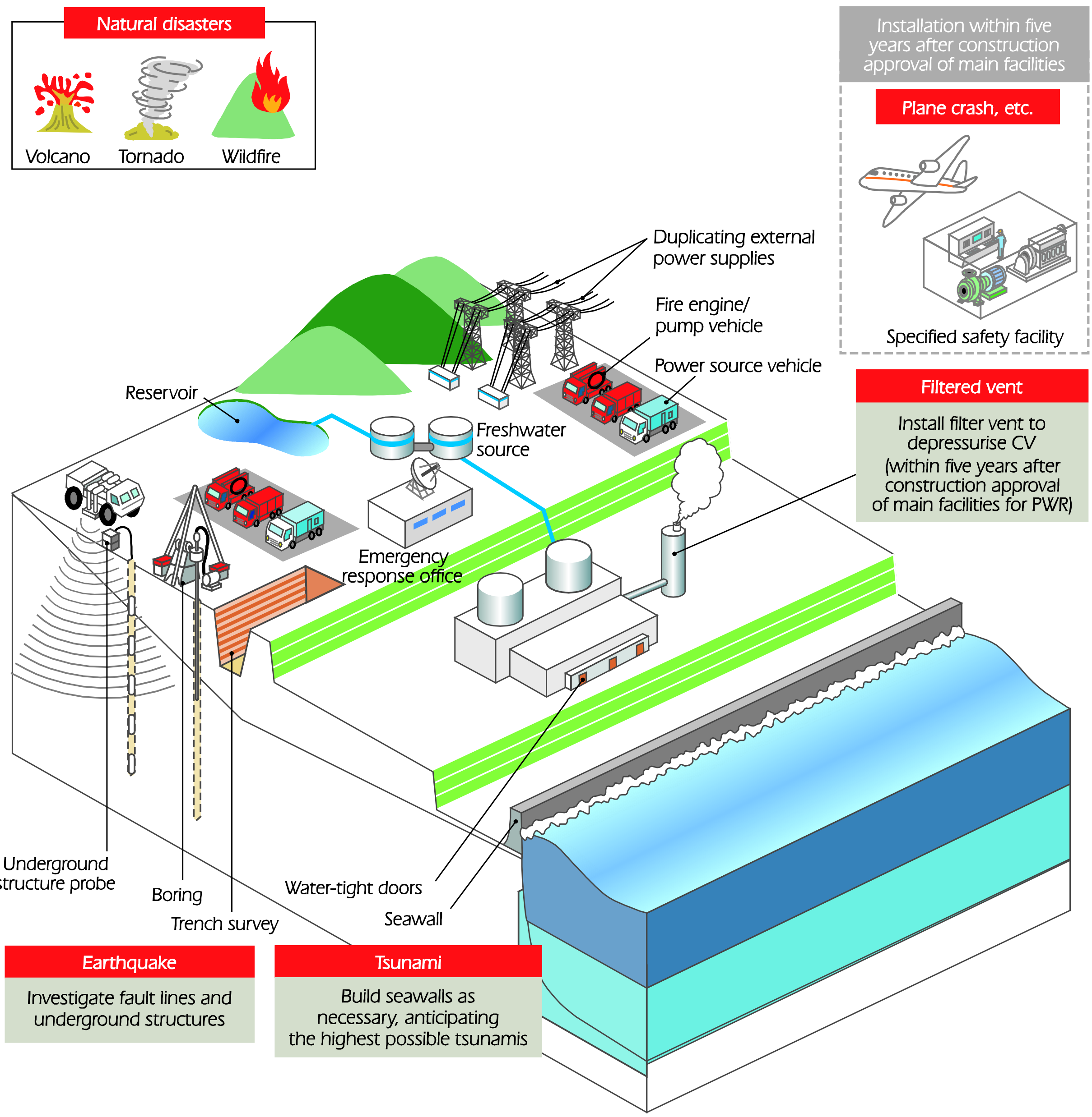
injection into spent fuel pools, and countermeasures against malicious events, such as airplane crashes and the installation of an emergency response office located at a distance from the reactor building are also required (Figure 10.4). Provisions were also included that require technological improvements to meet the new requirements in existing nuclear facilities in a process referred to as "back fitting".

Figure 10.4 Representation of enhanced safety requirements in Japan



Source: The Federation of Electric Power Companies of Japan, *Electricity Review of Japan 2014*.

Licensees are obliged to guarantee financial reserves to cover decommissioning costs of nuclear facilities, fuel reprocessing costs and costs associated with the disposal of high-level radioactive wastes. The amount of reserve funding required is determined by METI at the end of each financial year once the estimates by licensees on each of these costs

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are reviewed and approved. Legislation restricts the use of reserve funding for anything other than the stated purpose.

In accordance with the new regulations, NRA may conduct on-site inspections to the extent necessary for enforcement. During these inspections, NRA staff may enter the offices or business establishments of licensees and inspect documents, records and other articles, and can question personnel. These inspection rights extend to manufacturers, allowing the NRA to directly inspect those involved in the design or construction of nuclear facilities, as well as those involved in the manufacture of equipment for nuclear facilities.

The new regulatory regime also places a 40-year limit on the operation of power reactors, although operators may apply for a one-time life extension of no more than 20 years, provided that regulatory approval is obtained before the normal 40-year expiration date. For the management of reactors more than 30 years old, ageing assessments of structures, systems and components are required every 10 years in order to establish long-term maintenance and management policies for regulatory approval of operational safety programmes. In order to be granted a 20-year extension, facilities must conform to the latest technical standards and that condition must be maintained throughout the extension period. When filing a life extension application, operators are required to carry out special inspections of equipment subject to deterioration-related events, conduct a technical assessment of the expected deterioration during long-term operation and establish appropriate maintenance and management policies for the extension period.

Utilities operating reactors over 40 years old were required to declare by July 2015 if they would pursue a life extension application. In March 2015, utilities announced that five reactors would be permanently shut down (Genkai 1, Mihama 1 and 2, Shimane 1 and Tsuruga 1) as opposed to investing in life extension. These closures resulted in the reduction of installed net nuclear generating capacity by just over 2 GW_e, reducing the Japanese fleet eligible for restart to a total of 43 reactors with a combined net generating capacity of 40.3 GW_e.

The limits on lifetime operation of reactors combined with the stringent new regulatory regime means that other older, smaller-capacity reactors as well as those near active fault lines, and those that will not be able to obtain local political support for restart could be decommissioned before their planned lifetime operation age is reached. As a result, a thorough re-evaluation of the adequacy of decommissioning funding is required along with an assessment of the ability of the utilities responsible for decommissioning costs to fund the effort.

In October 2013, the government changed the system used to control payments into the decommissioning funding reserve. In the past, the annual reserve was calculated on the amount of electricity produced each year by each reactor, whereas today utilities are required to set aside adequate funds each year from the start of operation of each reactor for a total of 50 years, regardless of the amount of electricity produced. This new system means that when reactors are shut down, operators are still required to contribute funds to the decommissioning reserve. As of March 2015, about JPY 1.66 trillion of the estimated JPY 2.84 trillion total decommissioning cost for the entire NPP fleet (assumed to be 50 reactors) had accumulated in the fund.

Electricity generators also began taking voluntary measures after the Fukushima Daiichi nuclear accident to reduce chances of another serious accident at a nuclear facility. They

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have added emergency power source vehicles, air-cooled emergency power generators, filtered ventilation systems, emergency response centres and fire engines, and updated procedure manuals in order to minimise impacts and to better respond to accidents in a timely manner. The industry has also voluntarily committed itself to reaching the highest level of safety in the world. To enable these efforts, the Japan Nuclear Safety Institute was established in November 2012 to evaluate safety improvement activities, to provide technical advice through strong leadership from an independent entity and to drive the development of robust safety cultures within these companies, beginning with the top levels of management and extending throughout the organisations.

In addition, the Nuclear Research Risk Center was established in October 2014 within the Central Research Institute of the Electric Power Industry. Staff in this organisation (about 100) will perform R&D on safety-enhancing technologies that go beyond fulfilling regulatory requirements and propose solutions to issues at currently operating plants to the NRA.

FUEL CYCLE STRATEGY AND STATUS

As noted above, Japan has devoted considerable effort to localising fuel production and closing the nuclear fuel cycle, as well as fuel cycle R&D, including fast reactors.

In line with a firmly declared policy of transparent use of nuclear technologies strictly for peaceful purposes, the government maintains a policy of not possessing reserves of plutonium without specified purpose. Before the Fukushima Daiichi nuclear accident, Japan intended to use plutonium in spent fuel to produce MOX fuel for use in 16 to 18 reactors by 2015. As of early 2011, MOX fuel had been loaded into four reactors (Genkai 3, Ikata 3, Fukushima Daiichi 3 and Takahama 3). In 2014, the government restated its policy of not possessing reserves of plutonium and committed to moving ahead with the use of MOX fuel to reduce the plutonium stock.

Japan has no domestic uranium production or conversion capabilities, but Japan Nuclear Fuel Ltd (JNFL) operates a commercial enrichment facility at Rokkasho and capacity has been built up towards a goal of 1.5 million separative work units (SWU) per year by 2022. In 2010, installed capacity of 1.15 million SWU/yr met less than 20% of annual national requirements and the balance of enrichment services was purchased on the international market. Fuel fabrication services are mainly sourced domestically, with installed fabrication capacity more than adequate to meet national BWR and PWR fuel requirements.

Japan’s nuclear fuel cycle strategy includes reprocessing and the use of extracted plutonium and uranium that would not be required to fuel the fast reactor programme, with the installation of commercial fast-breeder reactors planned by 2050. Since the reprocessing plant (in operation since 1977) at the Tokai-Mura fuel facility does not have sufficient capacity (120 t/yr heavy metal, or hm) to meet domestic requirements (about 1 000 t/yr hm), Japan has been a major customer for French and British reprocessing services. In 2014, it was announced that the Tokai-Mura reprocessing plant would be permanently shut down owing to the cost of upgrades required under the new regulations established in 2013 by the newly created regulatory authority after the Fukushima Daiichi nuclear accident.

A new reprocessing plant with a capacity of 800 t/yr hm has been under construction for several years at Rokkasho (Aomori Prefecture). When operational, the capacity of this

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JNFL facility will be sufficient for about 80% of annual spent fuel discharges. Spent fuel in excess of capacity will continue to be stored until it is treated at the reprocessing plant. Originally scheduled to open in the late 1990s, the Rokkasho reprocessing facility has been delayed several times, in part owing to difficulties with the locally-designed vitrification plant. This was completed in May 2013 and, in November 2014, JNFL applied for a conformity review of the facility to the new regulatory standards and it is currently under review. It also announced that commercial operation would be delayed until early 2016, pending regulatory approval. The construction of the Rokkasho spent fuel reprocessing plant has been delayed to September 2018. The MOX fuel production plant is expected to be built a year later on the same site.

In 2010, JNFL began construction of a MOX fuel fabrication plant at Rokkasho with a capacity of 130 t/yr hm. In January 2014, JNFL applied for a conformity review of the facility to the new regulatory standards and it is currently under the authority's review. The MOX fabrication plant for both PWRs and BWR fuel is planned to start operation in 2019. In addition, the Agency for Natural Resources and Energy (ANRE) within METI is trying to review the financial mechanism to fund the reprocessing and MOX fuel production. A new legal entity will be put in place to collect fees from electricity utilities.

Since reprocessing capacity under construction in Japan will not be sufficient to treat all expected and accumulated spent fuel until operating for a number of years, additional interim spent fuel storage facilities will need to be made available for fuel that has decayed sufficiently for removal from the spent fuel ponds at NPPs (typically after 10 years or more). Dry spent fuel storage casks are used at some power plants. The Recyclable Fuel Storage Company (RFSC) was accordingly established in 2005 jointly by TEPCO (80%) and the Japan Atomic Power Company (20%) to construct a dry spent fuel storage facility. Construction of the facility to store 3 000 t hm of spent fuel safely for up to 50 years began in Mutsu (Aomori Prefecture) in 2010, with a planned expansion to 5 000 t hm. Once in operation (currently expected in October 2016 after several delays), spent fuel is to be delivered to the facility in four annual shipments of 200 to 300 t hm each. Originally expected to be completed in 2012, the facility was 90% complete in 2013. In January 2014, RFSC applied to the Nuclear Regulation Authority for a conformity review.

Given the difficulties experienced in developing and operating the sodium-cooled fast reactor Monju and the re-evaluation of energy policy following the Fukushima Daiichi nuclear accident, the deployment of fast reactors by 2050 to produce additional nuclear fuel envisioned in pre-2011 energy plans may be delayed. The government now intends to position Monju as an international research centre for technological development, such as reducing the amount and toxicity of radioactive wastes and contributing to the resolution of nuclear non-proliferation issues. The government will continue to promote fast reactor R&D through international co-operation with the United States and France as opposed to the development of a domestic fast reactor.

WASTE DISPOSAL

Low-level radioactive wastes are currently sent in cemented drums for disposal in a shallow underground pit at the low-level radioactive waste disposal facility in Rokkasho operated by JNFL. Since 1992, the No 1 disposal site at this facility has been receiving wastes and in 2000 the No 2 Disposal site was commissioned. The current capacity of the facility is 80 000 m^3, with an expansion to approximately 600 000 m^3 under

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consideration. In addition, there are plans to carry out intermediate-depth disposal of relatively high-level radioactive waste materials (such as channel boxes and control rods), but siting for such a facility has not been undertaken.

The Designated Radioactive Waste Final Disposal Act of June 2000 governs the systematic disposal of high-level radioactive wastes and TRU[1] wastes containing long-lived nuclides that are generated at reprocessing facilities. The Nuclear Waste Management Organisation of Japan (NUMO), established by the electric power companies and authorised by the government in October 2000, intends to construct a deep (at least 300 m) underground repository in a stable rock formation. The site selection process was to be undertaken in three stages: selection of preliminary investigation areas based on literature survey, selection of detailed investigation areas, and selection of repository construction site.

Since its inception, NUMO had held seminars and symposiums throughout Japan to inform the public of the importance and safety of the proposed disposal method. Toyo-cho (Kochi Prefecture) was the only community that expressed interest in accepting a preliminary literature survey in 2007 but, soon after discussions ended when the incumbent mayor promoting the project was defeated in an election. The Fukushima Daiichi nuclear accident further delayed the site selection process, owing to the time required to develop national policies on nuclear power following the accident.

Given the accumulation of wastes in Japan, geological disposal is a necessity, regardless of the scale of future nuclear power generation, and the government stated in the fourth Strategic Energy Plan in 2014 that geological disposal should not be postponed by the extended storage of high-level waste. As a result, NUMO re-activated public outreach activities at a national scale in 2014, enhanced activities with international agencies in order to benefit from experiences in other countries, and carried out an internal reorganisation to more effectively develop a public understanding of the importance of deep geological disposal sites. NUMO also established an initial goal of developing a generic deep geological disposal safety case with essential information on such a facility in Japan. Since no host facilities had volunteered by early 2015, the government decided to help focus siting activities by presenting the output of nationwide scientific screening in the country. The Japanese repository is to be constructed to accommodate reversibility and retrievability of materials in order to give future generations the option of selecting a more suitable treatment method.

After that, the government revised the "Basic Policy for Final Disposal of Specified Radioactive Waste" that includes the contents of strategic energy plan in May 2015. After the decision of new basic policy, the government has proceeded to encouraging public and regional understanding. The government aims to present the output of nationwide scientific screening in 2016 after creating an environment that allows for a calm reception by the public as the first step on the long road to the implementation of geological disposal.

1 Low-level radioactive wastes containing more than a specified concentration of long-lived radionuclides, generated by the operation and dismantling of reprocessing plants and by the MOX fuel fabrication plant.

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ASSESSMENT

The Fukushima Daiichi nuclear accident has set back the nuclear industry in Japan and around the world. Owing to its low-carbon generation of significant amounts of baseload electricity at competitive prices, it is important for the industry to be re-established in Japan, provided that safety is maintained at the highest standards possible.

The re-establishment of the industry hinges on a number of important issues, including the decontamination of the areas affected by radioactive releases from the Fukushima Daiichi nuclear accident, the successful resettlement of decontaminated areas and the provision of appropriate compensation for the serious disruption in the lives of large numbers of citizens. The decommissioning of the Fukushima Daiichi plant must also continue as a high priority project. Progress must continue to be made in all of these areas and communicated openly and transparently to the Japanese public. If difficulties arise, they must be clearly acknowledged and proposed solutions must be openly discussed and evaluated with the public before taking any decision.

With respect to the restart of power reactors, the NRA is the key agency for establishing regulatory requirements and regulating the industry effectively in order to ensure that safety remains the top priority for all organisations at all nuclear facilities. In order to conduct these important tasks effectively and efficiently, the NRA requires an adequate number of well-trained staff and sufficient resources. One positive step in this direction is the establishment of the NRA Human Resource Development Centre. The government should continue to ensure that the NRA has all the resources it requires to do its vital work. It is also critical that the NRA remain an independent agency focused on the safe operation of nuclear power facilities without influence or interference from industry and government involved in the promotion of nuclear power.

Of all the issues that must be addressed in order to revive Japan's nuclear industry, the loss of public trust may be the most challenging to overcome. All parts of the industry (the regulator, government and utilities) need to provide information and be ready to interact with the local community and the general public. It is necessary to effectively listen to and deal with questions and concerns in a way that gradually builds trust. Simply dispensing factual information will likely not be enough to regain confidence. Uncertainties and challenges must also be acknowledged and fully explained.

The government (METI) is holding public meetings to inform citizens. It is essential that this interaction is conducted in an open, balanced and transparent manner. METI should continue to release videos and minutes of important government meetings on nuclear power, such as the meeting of the Advisory Committee on Energy and Natural Resources, to allow citizens to have easy access to timely information on the technology. The NRA should also continue with the timely release of information on assessments of the conformity of nuclear power facilities to the new regulations. Priority should be given to the government plan to enhance public trust on the basis of scientific evidence and objective information on such matters as the risks associated with nuclear fuel cycle technology, the impacts of the Fukushima Daiichi nuclear accident and the development of emergency response plans. Ultimately, however, public acceptance of nuclear power will likely only be restored after several years of successful operation, completely free of the issues that created public distrust over the course of the past 20 years.

A robust safety culture needs to be instilled in both the industry and the NRA, and this promises to be challenging given that the lack of an effective safety culture in the past

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was at least partly due to reflexive obedience, reluctance to question authority, devotion to "sticking to the programme", groupism and insularity. The "safety myth" of nuclear power that prevailed before the Fukushima Daiichi nuclear accident also prevented senior management from taking the required leadership in developing an effective safety culture. A deep understanding that a severe accident could occur at any time must replace erroneous earlier beliefs that prohibited developing an effective safety culture. Industry's efforts to instil a safety culture by benefiting from international experience and expertise are a step in the right direction.

An important component of the Japanese nuclear power programme is completing the development of spent fuel reprocessing and recycling facilities that have been reviewed and approved as conforming to the new, stringent safety requirements, as this helps use more of the energy contained in uranium and reduce the amount of wastes for disposal. Successful deployment of the technology will not, however, completely negate the need for a deep geological repository for spent fuel and other high-level radioactive wastes. The government should therefore continue with its efforts to find acceptable solutions and locations for the final disposal of high-level radioactive wastes, consulting with the public throughout this process. It should be recognised, however, that with the prevailing distrust in the nuclear industry in Japan, it will be extremely challenging to find a volunteer host community.

In addition to decommissioning all six Fukushima Daiichi reactors before the end of their planned operational lifetime, other reactors that utilities may decide not to restart because of their age or other factors will also need to be decommissioned before the end of their operational lifetime (e.g. the five reactors permanently shut down in 2015). This raises the possibility that the accumulated industry funding for decommissioning may be insufficient to cover all costs. As a result, the estimated costs of decommissioning NPPs and the ability of utilities to fund the activity need to be thoroughly reassessed in light of recent decommissioning costs in other countries, with due consideration of regulatory requirements and specific circumstances in Japan. This is particularly important to the financial health of the nuclear power generators, as Japan has moved to a fully liberalised retail electricity market in April 2016 where competition is increasing.

RECOMMENDATIONS

The government of Japan should:

- ☐ *Ensure that the Nuclear Regulation Authority has all the tools necessary to retain experienced staff, recruit new staff and continue developmental training as required in order to maintain the high level of expertise essential to conduct its vital work.*
- ☐ *Provide the Japanese public with all the information necessary to take informed decisions on nuclear power and consult with citizens on its role in the national energy mix in a neutral, interactive, open and transparent fashion.*
- ☐ *Facilitate restarting nuclear power plants, once safety is assured, to contribute to a secure, low-cost and low-carbon electricity supply.*
- ☐ *Encourage industry efforts to benefit from international assistance in order to establish and maintain a strong culture of safety that is championed and consistently reinforced by senior managers and practised by all staff members.*

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- *Review the adequacy of the existing funding arrangements to cover the costs of decommissioning reactors by applying international experience and learning to the situation in Japan.*

Reference

IEA (International Energy Agency) (2016, forthcoming), *Energy Balances of OECD Countries 2016*, OECD/IEA, Paris. www.iea.org/statistics/.

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PART III
ENERGY TECHNOLOGY

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11. ENERGY TECHNOLOGY RESEARCH, DEVELOPMENT AND DEMONSTRATION

Key data (2015 estimated)

Government spending on energy RD&D: JPY 292.4 billion (in 2014, JPY 346.3 billion)

RD&D per capita: JPY 2 303

Share of GDP: 0.06%

RD&D STRATEGY

Japan is one of the leading energy technology providers and developers in the world. Energy technology is linked to the country's energy policy at large, but increasingly driven by efforts to prevent global warming.

Since the mid-1970s, Japan has been strengthening research and development (R&D) of technologies in the field of energy and environment, including photovoltaic cells, heat pumps and fuel cells, through adopting national strategies based on long-term perspectives such as the "Sunshine Project" and the "Moonlight Project". As a result, ahead of the rest of the world, Japan has achieved breakthrough innovations ranging from widespread diffusion of solar energy generation to the commercialisation of fuel-cell vehicles.

Japan sees developing innovative technologies as the key to acting against climate change without sacrificing economic growth. Following the 21st Conference of the Parties (COP21) under the United Nations Framework Convention on Climate Change, held in Paris in December 2015, and its pledge to reduce GHG emissions by 26% from 2013 to 2030, the government adopted in May 2016 the Plan for Global Warming Countermeasures.

After 2030, considerable efforts are required to meet the goal for 2050. To meet the 2°C target referred to at COP21, global efforts to facilitate innovations are needed to drastically reduce GHG emissions. To that effect, Japan has launched the National Energy and Environment Strategy for Technological Innovation towards 2050 (NESTI 2050) in April 2016. This strategy aims at reinforcing research, development and demonstration (RD&D) on innovative technologies for drastic radical reduction of GHG emissions, with the long-term perspectives looking ahead to the year 2050.

NESTI 2050 strategy includes eight specific technology categories related to energy saving, energy storage and energy generation, among others (see Figure 11.1). The government will now move to strengthen RD&D in these areas.

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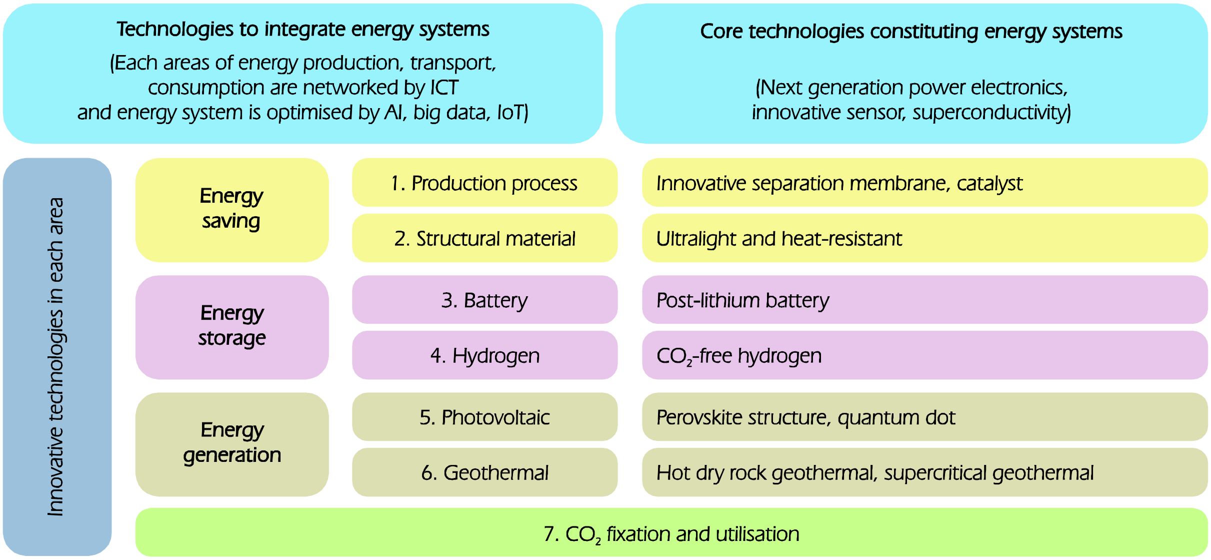
Figure 11.1 Technology focus areas in NESTI 2050



Source: METI.

INSTITUTIONS

The **Council for Science, Technology and Innovation** is the top decision-making body in Japan's R&D policy. Its members include the Prime minister, the Minister of Economy, Trade and Industry and other ministers, along with knowledgeable stakeholders. Because of the parliamentary system of government, its mechanism is designed to give sufficient political consideration to funding activities. In addition, there is also the **Research and Development Subcommittee** under the Industrial Structure Council that serves as an advisory body to the Minister of Economy, Trade and Industry. Japan's energy technology strategy is developed by this subcommittee.

Additional responsibilities lie with particular government ministries, including:

- The **Ministry of Economy, Trade and Industry (METI)**, which has a focus on funding for renewable energy, energy efficiency, the rational use of fossil fuels and power generation (including nuclear power), and technologies relating to climate change.
- The **Ministry of Education, Culture, Sports, Science and Technology (MEXT)**, which has a focus on nuclear R&D and basic research carried out in universities and institutes.

The **National Institute of Advanced Industrial Science and Technology (AIST)**, an affiliate of METI, is one of the largest independent administrative institutions in Japan. AIST covers six research fields: environment and energy; life science and biotechnology; information technology and electronics; nanotechnology, materials and manufacturing; geological survey and applied geoscience; and metrology and measurement science. In the field of energy, AIST conducts R&D on four areas: new energy (e.g. renewable energy and methane hydrate), energy storage (e.g. batteries), energy conservation (e.g. advanced semiconductors for power electronics), and safety and sustainability evaluation (e.g. on the use of hydrogen). In FY2014, AIST had a budget of JPY 94 billion, one-third of which was dedicated to energy.

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The **New Energy and Industrial Technology Development Organization (NEDO)** is the largest central institution involved in R&D in Japan. 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 (energy supply and end-use). In FY2014, NEDO had a budget of JPY 148.4 billion.

The **New Energy Foundation (NEF)** is involved in investigative research on the development and use of new energy resources, advising and giving proposals to related organisations, working to raise citizens' awareness of new energy sources among the citizens, and working for the healthy development of new energy industry and local economies in order to contribute to the improvement of Japan's energy supply.

PROJECT EVALUATION

The agencies of the central government evaluate R&D projects in accordance with the National Guideline for R&D Evaluation. METI conducts *ex ante* evaluations, interim evaluations, and *ex post* evaluations of R&D projects in fields such as energy saving and CO_2 reduction based on the METI Guideline for R&D Evaluation developed in accordance with the National Guideline. External evaluations are used at the Industrial Structure Council.

Also, for incorporated administrative agencies, such as NEDO, METI's Commission on Evaluation of Independent Administrative Institutions conducts annual evaluations in accordance with the Act on General Rules for Incorporated Administrative Agency.

SELECTED PROGRAMMES

Japan is active in almost 40 areas of energy RD&D. Two important areas of ambition and efforts are hydrogen, and fuel cells and solar photovoltaics (PV). These areas are also interlinked, as hydrogen could be produced from solar power which in turn could help avoid the challenges to the electricity system of the variation in solar power output.

HYDROGEN AND FUEL CELLS

Japan sees hydrogen as an important form of secondary energy that can help decarbonise the economy in the long term. For this to happen, the government will promote collaborative efforts in a three-phase process together with academia and industry, while resolving the imbalance between supply side and demand side (Figure 11.2).

Phase 1. Dramatic expansion of hydrogen use

The aim is to greatly expand the use of stationary fuel cells and fuel-cell vehicles, which are in the process of being realised, leading to the successful acquisition of a global market in the field of hydrogen and fuel cells, in which Japan leads the world.

Phase 2. Full-fledged introduction of hydrogen power generation/Establishment of a large-scale system for supplying hydrogen

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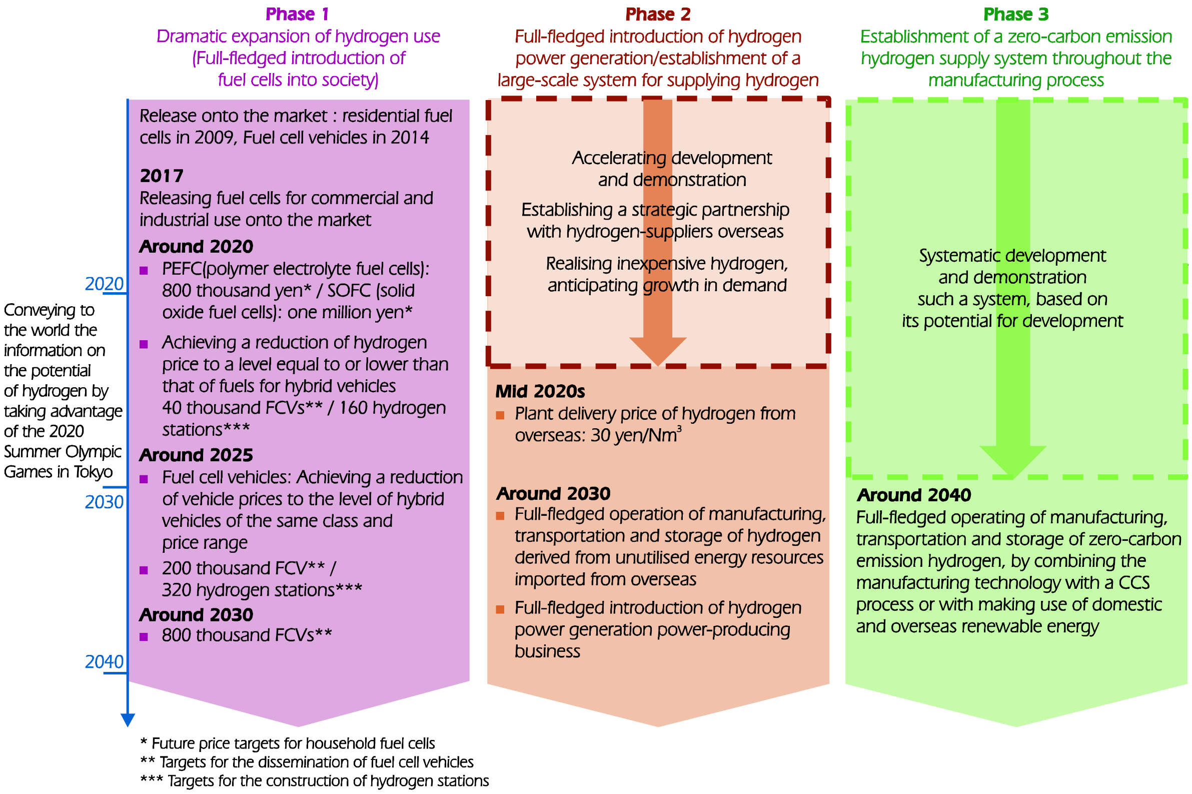
The aim is to further expand the demand for hydrogen, while widening the scope of hydrogen sources to include unutilised energy, so as to establish a new secondary energy structure in which hydrogen will be added to existing resources, namely electricity and heat (gas).

Phase 3. Establishment of a zero-carbon-emission hydrogen supply system throughout the manufacturing process

Figure 11.2 METI strategic roadmap for hydrogen and fuel cells



Source: METI.

The aim is to combine the technology for manufacturing hydrogen with a carbon capture and storage (CCS) process, or with making use of hydrogen derived from a renewable energy resource, so as to establish a zero-carbon-emission system for supplying hydrogen throughout the manufacturing process.

NATIONAL RD&D PROGRAMME ON SOLAR PV[1]

The primary Japanese framework for solar PV R&D is described in the 2014 NEDO PV Challenges document, a strategy for supporting the mass introduction of solar PV to Japan. As part of this framework, NEDO has established high-level technology cost and performance targets (see Table 11.1).

1 This section is based on the Distributed solar and storage – Innovation for Cool Earth Forum Roadmap 1.0 (ICEF, 2015).

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Table 11.1 NEDO's targets for solar PV cost and performance by 2020 and 2030

Topic	Target	Date
LCOE of PV comparative to business electricity price	JPY 14/kWh	2020
Module efficiency and lifetime	22%, 25 years	2020
LCOE of PV compared to conventional thermal power	JPY 7/kWh	2030
Module efficiency and lifetime	25%, 30 years	2030

LCOE: levelised cost of electricity.

Source: NEDO.

To support the 2030 system-level targets, NEDO has also developed technology-specific subtargets for c-silicon (JPY 100/W, 25% efficiency), triple-junction concentrator III-V (JPY 125/W, 30% efficiency), and perovskites (JPY < 15/W, 20% efficiency). NEDO's programme focuses on four areas:

- reducing the levelised cost of electricity (LCOE) from solar PV
- enhancing system reliability
- enlarging the range of PV applications
- establishing a recycling system.

Key recent results of the research programme include:

- crystalline silicon cells with 25.1% efficiency
- triple-junction III-V concentrator cells with 44.4% efficiency
- triple-junction thin-film silicon cells with 13.6% efficiency.

NEDO conducts a range of domestic and collaborative international projects to demonstrate the integration of distributed solar PV systems and energy storage, including stabilising distribution networks with batteries (in Spain), providing customer autonomy during cold-weather grid outages (in Canada), and enabling community-level self-generation and consumption with PV and storage (in Germany).

In addition to the NEDO programme, AIST conducts extensive solar PV research at its Research Center for Photovoltaics, including advanced processing, module reliability research, and calibration and standards. In 2014, AIST established the Fukushima Renewable Energy Institute (FREA), whose programme of research includes a focus on thin-film silicon PV technology and advanced III-V concepts, as well as tandem nano-wire silicon PV. AIST conducts energy-storage-related research at its Research Institute of Electrochemical Energy, opened in April 2015. The Japan Science and Technology Agency (JST) also conducts basic research related to solar PV and energy storage under three programmes: ERATO (Exploratory Research for Advanced Technology), CREST (Core Research for Evolutional Science and Technology), and PRESTO (Precursory Research for Embryonic Science and Technology).

FUNDING

In 2014, Japan ranked third in the world in terms of public and private spending on all research and development, behind the United States and the People's Republic of China.

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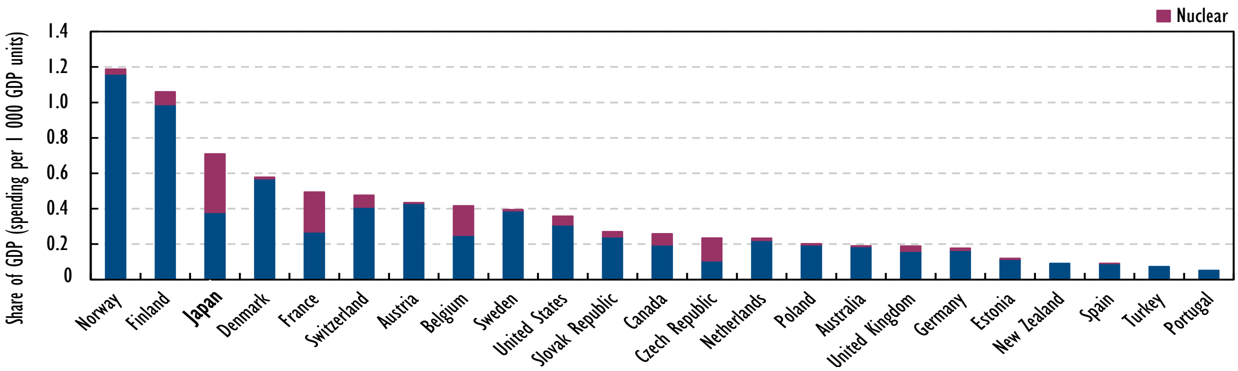
Japan's total spending of USD 167 billion (at purchasing power parity) equalled 3.6% GDP, also the third-highest in the world, after Korea and Israel, according to the *OECD Main Science and Technology Indicators*. Regarding government spending on energy RD&D per GDP, Japan was the third-highest in 2014 among 23 IEA countries, after Norway and Finland (Figure 11.3). Japan has traditionally had the highest share of the large (G7) economies, however. In absolute terms, it spends on energy RD&D more than any other IEA government, apart from the United States.

Figure 11.3 Government energy RD&D spending as a ratio of GDP in IEA member countries, 2014

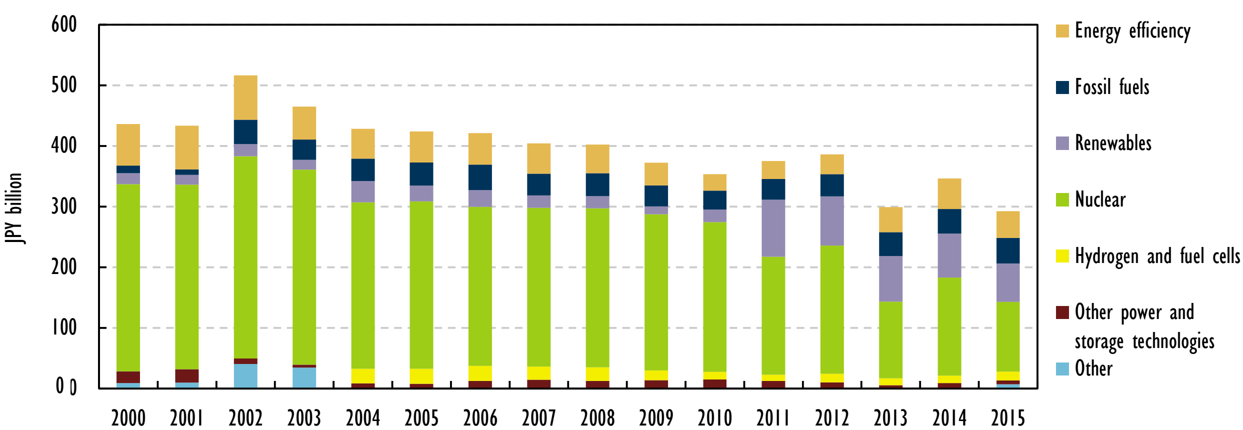


Notes: Includes demonstration. Data are not available for Greece, Hungary, Ireland, Italy, Korea and Luxembourg.

Source: IEA (2015), "RD&D budget", IEA Energy Technology RD&D (database), www.iea.org/statistics/.

Japan's government spending on energy RD&D amounted to JPY 346 billion in 2014. This was at the same level as in 2010 and the third-lowest amount since 1990. Japan has traditionally had a high share of nuclear RD&D, averaging 68% of the total in 1990-2014. In recent years, that spending has declined in both absolute and relative terms. In 2014, nuclear accounted for 47% of government spending on energy RD&D, while renewables accounted for 21%, energy efficiency for 15% and fossil fuels for 12%.

Figure 11.4 Government energy RD&D spending in Japan, 2000-15



Note: Data are estimated for 2015.

Source: IEA (2015), "RD&D Budget", IEA Energy Technology RD&D Statistics (database), www.iea.org/statistics/.

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INTERNATIONAL COLLABORATION

Japan participates in many bilateral and multilateral international collaboration efforts on energy technology and innovation. These include participation by Japanese entities in 31 IEA Technology Collaboration Programmes (TCPs), second only to the United States (36 programmes). Japanese participation covers all sectors: end-use in industry, transport and buildings, fossil fuels, renewables and hydrogen, and nuclear energy. Some recent multilateral initiatives where the government of Japan participates are listed below.

MISSION INNOVATION

On 30 November 2015, leaders from 20 countries came together to launch Mission Innovation to reinvigorate and accelerate public and private global clean energy innovation with the objective to make clean energy widely affordable. Additional countries will be encouraged to join in the future. Each participating country will seek to double its governmental and/or state-directed clean energy R&D investment over five years. New investments would be focused on transformational clean energy technology innovations that can be scalable to varying economic and energy market conditions that exist in participating countries and in the broader world.

R&D projects would be designed and managed to attract private investors willing to advance commercialisation. While each participating country's clean energy innovation portfolio is unique and reflects national priorities, all participating countries share the common goal to accelerate in a suitable manner the pace of the clean energy revolution now under way. This endeavour should help facilitate affordable access to critical technologies. Japan participates in Mission Innovation, as the initiative is very much in line with what Japan has consistently tackled throughout the years.

CLEAN ENERGY MINISTERIAL (CEM)

The Clean Energy Ministerial is a global forum to share best practices and promote policies and programmes that encourage and facilitate the transition to a global clean energy economy. The CEM was launched in 2010 with the goal of accelerating the global transition to clean energy.

Japan is a participant in CEM, and in eight CEM initiatives: the Electric Vehicles Initiative (EVI); the Energy Management Working Group (EMWG); the Super-Efficient Equipment and Appliance Deployment (SEAD); the Multilateral Solar and Wind Working Group; the Global Lighting and Energy Access Partnership (Global LEAP); the International Smart Grid Action Network (ISGAN); the Clean Energy Education and Empowerment (C3E) and the Clean Energy Solutions Center (CESC).

ASIA-PACIFIC ECONOMIC COOPERATION (APEC) ENERGY WORKING GROUP

APEC is a regional economic forum established in 1989 to leverage the growing interdependence of the Asia-Pacific. APEC's 21 members aim to create greater prosperity for the people of the region by promoting balanced, inclusive, sustainable, innovative and secure growth, and by accelerating regional economic integration. A major programme within APEC is the Cooperative energy activities and research programme.

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Japan is a major player in APEC's energy activities and research. In addition to leading and participating in many projects, it hosts APEC's Asia-Pacific Energy Research Center and chairs work on energy data and statistics, and on low-carbon model towns. METI also has established a specific APEC sub-fund to support energy projects.

THE INNOVATION FOR COOL EARTH FORUM (ICEF)

In 2014 Prime Minister Shinzo Abe announced that the government of Japan will host a global conference, the Innovation for Cool Earth Forum (ICEF**),** every year in October in Tokyo. ICEF aims at providing a global platform to promote discussions and co-operation among researchers, business persons, and policy makers from around the world in order to address climate change through innovation of energy and environmental technologies, including their dissemination.

There are two main features of ICEF: the Annual Conference is in October every year, and the On-line Discussion Forum is to promote year-round discussions among ICEF participants (primarily academics). ICEF is hosted by METI and NEDO and co-hosted by the Ministry of Foreign Affairs (MOFA) and the Ministry of the Environment (MOE).

ASSESSMENT

Japan's current energy situation, which is characterised by a strong reliance on imports, by the need to reduce GHG emissions and uncertainty about the future contribution of nuclear, calls for large and efficient research activities. The IEA is therefore pleased to find that Japan's public energy RD&D spending is one of the highest as a share of GDP among the IEA member countries, and the second-highest in absolute terms. The organisation of the public energy RD&D sector and human resources support the country's efforts. Japan's steady and strong commitment to energy RD&D benefits not only Japan, but the global energy sector in general. The government should be recognised for spending significant resources, which is crucial for climate change mitigation and energy security, and thereby being a model for other countries. The IEA is also pleased to see that the government is providing funding to a wide variety of technology topics in areas such as energy efficiency, renewables, vehicles, cleaner fossil fuels, fuel cells and nuclear.

However, there is some room for improvement. Research priorities on the grid integration of renewable energy need to reflect the fast deployment of renewables in the country. Buildings, both new and existing, is an area for further energy efficiency interventions, thus suggesting that system aspects in different types of buildings, including indoor climate, would be relevant research areas. The IEA also encourages a broad dissemination of the results of energy-related demonstration projects, such as smart-grid systems.

RD&D into new energy sources is critical to long-term security of supply and achieving long-term energy policy goals. Japan has maintained its commitment to this area, particularly through its support of research technologies in the early stages of RD&D. It is very welcome that Japan has formulated the NESTI 2050 strategy in order to further promote R&D of innovative technologies that enable a significant reduction of GHG emissions in the long term. The strategy identifies promising technologies and will announce policies to concentrate R&D on these technologies with a view to accelerating practical realisation.

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In general, Japan's energy RD&D funding is linked to its overall energy policy goals and co-ordinated with other policies. Furthermore, the road mapping that exists for all priority areas explicitly links the government's policy objectives with its RD&D priorities. This is to be applauded. However, the government should monitor the need for additional public funding in favour of energy RD&D to ensure that resources match the newly declared long-term ambitions.

METI is also overall responsible for applied research and innovation whereas the Ministry of Education Culture, Sports, Science and Technology is responsible for basic research. One organisation, NEDO, plays an important role in distributing funding, although METI also funds research projects directly, on a yearly basis. The IEA considers that NEDO generally allocates funding in a transparent, independent and professional manner. The IEA is also impressed by the ambitious process for evaluating projects under way.

Research is carried out by industry, universities and institutes (AIST being the largest). The co-operation between agencies and industry appears to be effective. Power companies also co-finance research. Funding agencies could consider offering research co-operation on socio-economic issues that would encourage power companies to adapt more rapidly to the changing market situation.

Japan is in many technological areas a global leader. It is also very actively engaged in international co-operation both in multilateral forums as well as in bilateral co-operation. In addition, Japan is active in technology dissemination to developing countries, especially in the Asian region. The IEA acknowledges Japan's important role in international energy RD&D collaboration.

RECOMMENDATIONS

The government of Japan should:

- ☐ *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 in order to accelerate innovation and diffusion of technology.*
- ☐ *Maintain a high level of funding for energy RD&D and, if needed, increase it to match the long-term ambitions as laid out in the NESTI 2050 strategy.*
- ☐ *Increase support for developing and introducing technologies for renewable energy and their system integration, smart grids, energy efficiency, especially in buildings, and other low-carbon technologies, such as clean coal with carbon capture utilisation and storage.*
- ☐ *Broadly disseminate the results of energy-related demonstration projects, such as smart-grid systems.*
- ☐ *Encourage funding agencies to expand research co-operation with energy sector stakeholders on socio-economic issues, and stimulate more rapid adaptation to changing market conditions.*

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IEA (International Energy Agency) (2015), "RD&D Budget", *IEA Energy Technology RD&D Statistics* (database). DOI: http://dx.doi.org/10.1787/data-00488-en, accessed on 4 September 2015.

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PART IV
ANNEXES

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ANNEX A: ORGANISATION OF THE REVIEW

REVIEW CRITERIA

The Shared Goals, which were adopted by the 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 C.

REVIEW TEAM AND PREPARATION OF THE REPORT

The IEA in-depth review team visited Japan from 15 to 19 December 2014. The team met with government officials, energy suppliers, interest groups and other organisations. This report was drafted on the basis of the review team's preliminary assessment of the country's energy policy and information on subsequent policy developments from government and private sector sources. The members of the team were:

IEA member countries

Dr. Phyllis Yoshida, the United States (team leader)

Mr. Tom Bastin, United Kingdom

Mr. Richard Lavergne, France

Mr. Christopher Piercey, Canada

Mr. Michael Rantil, Sweden

Mr. Dale Rentsch, Australia

IEA association countries

Mr. Sugeng Mujiyanto, Indonesia (observer)

OECD Nuclear Energy Agency

Dr. Robert Vance

International Energy Agency

Dr. Manuel Baritaud

Mr. Kijune Kim

Mr. Simon Mueller

Mr. Miika Tommila

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The team is grateful for the co-operation and assistance of the many people it met throughout the visit. Thanks to their kind hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable. The team wishes to express its gratitude to Mr. Shinichi Kihara, Director for International Affairs, Agency for Natural Resource and Energy, Ministry of Economy, Trade and Industry, his staff, and the staff of the International Cooperation Group of the Institute of Energy Economics, Japan.

Miika Tommila managed the review and drafted Chapters 1 to 5 and Chapter 11. Chapter 6 (coal) and the section on CCS in Chapter 3 (climate change) were drafted by Samantha McCulloch. Chapter 7 (natural gas) was drafted by Kieran McNamara and Chapter 8 (electricity) by Manuel Baritaud with Noor Miza Muhamad Razali. Chapter 9 (renewable energy) was drafted by Simon Mueller and chapter 10 (nuclear energy) by Robert Vance. Sonja Lekovic, Soyeon Park and Yunji Suh drafted the supply and demand sections of the report.

The report was prepared under the guidance of Aad van Bohemen, Head of Country Studies Division. Helpful comments and updates were provided by the review team members and the following IEA staff: Emanuele Bianco, Carlos Fernandez Alvarez, Paolo Frankl, Rebecca Gaghen, Takashi Hattori, Costanza Jacazio, David Morgado, Cédric Philibert, Carrie Pottinger, Keisuke Sadamori, Yasuhiro Sakuma, Sam Thomas, Laszlo Varro, Maki Yamaguchi, Takuro Yamamoto and Luminita Grancea (OECD/NEA). The report benefited particularly from the input of Yoko Nobuoka who updated and reviewed all chapters.

Sonja Lekovic, Soyeon Park, Yunji Suh, Oskar Kvarnström and Bertrand Sadin prepared the figures. Roberta Quadrelli, Zakia Adam, Loic Coent, Rémi Gigoux, Gianluca Tonolo and Urzsula Ziebinska provided support on statistics. Astrid Dumond and Katie Russell managed the production process. Viviane Consoli and Therese Walsh provided editorial assistance.

ORGANISATION VISITED

Electric Power System Council of Japan (ESCJ)

Federation of Electric Power Companies of Japan (FEPC)

Fuel Cell Commercialization Conference of Japan (FCCJ)

Institute of Energy Economics, Japan (IEEJ)

Japan Automobile Manufacturers Association (JAMA)

Japan Gas Association

Japan Iron and Steel Federation (JISF)

Japan Oil, Gas and Metals National Corporation (JOGMEC)

Keidanren

Ministry of Economy, Trade and Industry (METI)

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

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Ministry of the Environment (MOE)

National Institute of Advanced Industrial Science and Technology (AIST)

New Energy and Industrial Technology Development Organisation (NEDO)

Japanese Consumer Co-operative (CO-OP)

Nuclear Regulation Authority (NRA)

Petroleum Association of Japan

Toyota Motor Corporation

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ANNEX B:
ENERGY BALANCES AND KEY STATISTICAL DATA

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Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2013	2014	2015E
TOTAL PRODUCTION		**29.5**	**74.6**	**104.6**	**99.0**	**27.7**	**26.6**	**30.4**
Coal		17.9	4.3	1.5	-	-	-	-
Peat		-	-	-	-	-	-	-
Oil		0.8	0.7	0.8	0.7	0.5	0.5	0.5
Natural gas		2.3	1.9	2.3	3.2	2.8	2.6	2.6
Biofuels and waste[1]		-	4.5	4.7	9.3	10.8	11.2	11.4
Nuclear		2.5	52.7	83.9	75.1	2.4	-	2.5
Hydro		5.7	7.5	7.3	7.1	6.7	7.0	7.3
Wind		-	-	0.0	0.3	0.4	0.4	0.5
Geothermal		0.2	1.6	3.1	2.5	2.4	2.4	2.4
Solar/other[2]		-	1.4	0.9	0.8	1.6	2.5	3.4
TOTAL NET IMPORTS[3]		**297.4**	**367.7**	**417.3**	**399.5**	**426.6**	**412.3**	**405.2**
Coal	Exports	0.4	1.4	1.9	0.5	0.9	0.4	0.6
	Imports	41.3	73.4	97.6	115.5	122.8	118.8	120.5
	Net imports	40.9	72.1	95.8	115.0	121.9	118.5	120.0
Oil	Exports	3.1	3.7	4.5	17.6	17.0	15.5	18.3
	Imports	276.2	267.0	274.5	229.4	228.5	214.0	215.2
	Int'l marine and aviation bunkers	-19.4	-10.0	-11.9	-10.2	-10.6	-9.9	-10.4
	Net imports	253.7	253.3	258.1	201.7	201.0	188.6	186.5
Natural Gas	Exports	-	-	-	-	-	-	-
	Imports	2.8	42.3	63.5	82.8	103.7	105.3	98.8
	Net imports	2.8	42.3	63.5	82.8	103.7	105.3	98.8
Electricity	Exports	-	-	-	-	-	-	-
	Imports	-	-	-	-	-	-	-
	Net imports	-	-	-	-	-	-	-
TOTAL STOCK CHANGES		**-6.5**	**-3.6**	**-3.9**	**0.1**	**0.5**	**2.8**	**0.3**
TOTAL SUPPLY (TPES)[4]		**320.4**	**438.7**	**518.0**	**498.6**	**454.7**	**441.7**	**435.9**
Coal		57.9	76.5	97.2	115.1	121.9	118.5	120.0
Peat		-	-	-	-	-	-	-
Oil		248.9	250.4	255.2	202.4	202.2	192.0	187.2
Natural gas		5.1	44.2	65.7	86.0	106.3	107.8	101.4
Biofuels and waste[1]		-	4.5	4.7	9.3	10.8	11.2	11.4
Nuclear		2.5	52.7	83.9	75.1	2.4	-	2.5
Hydro		5.7	7.5	7.3	7.1	6.7	7.0	7.3
Wind		-	-	0.0	0.3	0.4	0.4	0.5
Geothermal		0.2	1.6	3.1	2.5	2.4	2.4	2.4
Solar/other[2]		-	1.4	0.9	0.8	1.6	2.5	3.4
Electricity trade[5]		-	-	-	-	-	-	-
Shares in TPES (%)								
Coal		*18.1*	*17.4*	*18.8*	*23.1*	*26.8*	*26.8*	*27.5*
Peat		-	-	-	-	-	-	-
Oil		*77.7*	*57.1*	*49.3*	*40.6*	*44.5*	*43.5*	*42.9*
Natural gas		*1.6*	*10.1*	*12.7*	*17.3*	*23.4*	*24.4*	*23.3*
Biofuels and waste[1]		-	*1.0*	*0.9*	*1.9*	*2.4*	*2.5*	*2.6*
Nuclear		*0.8*	*12.0*	*16.2*	*15.1*	*0.5*	-	*0.6*
Hydro		*1.8*	*1.7*	*1.4*	*1.4*	*1.5*	*1.6*	*1.7*
Wind		-	-	-	*0.1*	*0.1*	*0.1*	*0.1*
Geothermal		*0.1*	*0.4*	*0.6*	*0.5*	*0.5*	*0.5*	*0.5*
Solar/other[2]		-	*0.3*	*0.2*	*0.2*	*0.4*	*0.6*	*0.8*
Electricity trade[5]		-	-	-	-	-	-	-

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.

2015 estimated data are only available for energy supply and economic indicators.

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Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2013**	**2014**	**2015E**
TFC	**234.0**	**287.0**	**328.2**	**308.9**	**302.8**	**295.5**	**..**
Coal	24.1	30.5	24.4	23.5	22.8	23.7	..
Peat	-	-	-	-	-	-	..
Oil	171.1	170.7	194.5	163.5	161.7	155.6	..
Natural gas	3.1	15.2	21.7	30.0	30.6	30.0	..
Biofuels and waste[1]	-	2.6	2.7	2.8	3.2	3.3	..
Geothermal	-	0.1	0.2	0.2	0.2	0.2	..
Solar/other[2]	-	1.4	0.9	0.5	0.4	0.4	..
Electricity	35.7	66.3	83.3	87.9	83.3	81.8	..
Heat	0.0	0.2	0.5	0.6	0.5	0.5	..
Shares in TFC (%)							
Coal	*10.3*	*10.6*	*7.4*	*7.6*	*7.5*	*8.0*	..
Peat	-	-	-	-	-	-	..
Oil	*73.1*	*59.5*	*59.3*	*52.9*	*53.4*	*52.7*	..
Natural gas	*1.3*	*5.3*	*6.6*	*9.7*	*10.1*	*10.1*	..
Biofuels and waste [1]	-	*0.9*	*0.8*	*0.9*	*1.1*	*1.1*	..
Geothermal	-	-	*0.1*	*0.0*	*0.0*	*0.0*	..
Solar/other [2]	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	..
Electricity	*15.3*	*23.1*	*25.4*	*28.4*	*27.5*	*27.7*	..
Heat	-	*0.1*	*0.2*	*0.2*	*0.2*	*0.2*	..
TOTAL INDUSTRY[6]	**141.8**	**143.3**	**141.1**	**131.4**	**125.2**	**123.8**	**..**
Coal	18.6	29.5	23.9	23.3	22.2	23.1	..
Peat	-	-	-	-	-	-	..
Oil	96.4	70.9	72.3	62.1	59.6	57.6	..
Natural gas	1.6	4.0	7.9	14.3	14.5	14.3	..
Biofuels and waste[1]	-	2.5	2.6	2.7	3.2	3.3	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	-	-	-	..
Electricity	25.1	36.4	34.4	28.9	25.6	25.4	..
Heat	-	-	-	-	-	-	..
Shares in total industry (%)							
Coal	*13.2*	*20.6*	*16.9*	*17.8*	*17.7*	*18.7*	..
Peat	-	-	-	-	-	-	..
Oil	*68.0*	*49.5*	*51.2*	*47.2*	*47.6*	*46.5*	..
Natural gas	*1.2*	*2.8*	*5.6*	*10.9*	*11.6*	*11.6*	..
Biofuels and waste [1]	-	*1.7*	*1.9*	*2.1*	*2.6*	*2.7*	..
Geothermal	-	-	-	-	-	-	..
Solar/other [2]	-	-	-	-	-	-	..
Electricity	*17.7*	*25.4*	*24.4*	*22.0*	*20.5*	*20.5*	..
Heat	-	-	-	-	-	-	..
TRANSPORT[4]	**40.8**	**68.1**	**84.4**	**73.7**	**74.1**	**71.6**	**..**
OTHER[7]	**51.5**	**75.7**	**102.7**	**103.9**	**103.5**	**100.1**	**..**
Coal	5.2	0.9	0.5	0.2	0.6	0.6	..
Peat	-	-	-	-	-	-	..
Oil	35.2	33.2	39.4	29.5	29.6	28.0	..
Natural gas	1.5	11.2	13.7	15.6	16.1	15.6	..
Biofuels and waste[1]	-	0.1	0.0	0.0	0.0	0.0	..
Geothermal	-	0.1	0.2	0.2	0.2	0.2	..
Solar/other[2]	-	1.4	0.9	0.5	0.4	0.4	..
Electricity	9.5	28.5	47.4	57.3	56.1	54.9	..
Heat	0.0	0.2	0.5	0.6	0.5	0.5	..
Shares in other (%)							
Coal	*10.2*	*1.2*	*0.5*	*0.2*	*0.5*	*0.6*	..
Peat	-	-	-	-	-	-	..
Oil	*68.5*	*43.9*	*38.3*	*28.4*	*28.6*	*27.9*	..
Natural gas	*2.9*	*14.9*	*13.4*	*15.0*	*15.5*	*15.6*	..
Biofuels and waste [1]	-	*0.1*	-	-	-	-	..
Geothermal	-	*0.1*	*0.2*	*0.0*	*0.0*	*0.0*	..
Solar/other [2]	-	*1.8*	*0.9*	*0.5*	*0.4*	*0.4*	..
Electricity	*18.5*	*37.7*	*46.1*	*55.2*	*54.2*	*54.8*	..
Heat	*0.1*	*0.3*	*0.5*	*0.6*	*0.5*	*0.5*	..

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Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2013**	**2014**	**2015E**
ELECTRICITY GENERATION[8]							
Input (Mtoe)	93.1	181.1	229.4	231.5	197.7	188.2	..
Output (Mtoe)	40.0	75.0	93.6	98.0	91.1	89.1	86.8
Output (TWh)	465.4	872.6	1088.1	1139.4	1058.8	1035.5	1008.9
Output Shares (%)							
Coal	*8.0*	*13.5*	*21.5*	*27.2*	*32.9*	*33.7*	*34.0*
Peat	-	-	-	-	-	-	-
Oil	*73.2*	*32.5*	*16.5*	*8.8*	*15.1*	*11.2*	*9.0*
Natural gas	*2.3*	*19.6*	*23.3*	*28.0*	*38.5*	*40.6*	*39.2*
Biofuels and waste [1]	-	*1.1*	*0.9*	*2.7*	*3.2*	*3.4*	*4.1*
Nuclear	*2.1*	*23.2*	*29.6*	*25.3*	*0.9*	-	*0.9*
Hydro	*14.3*	*10.0*	*7.8*	*7.2*	*7.4*	*7.9*	*8.4*
Wind	-	-	-	*0.3*	*0.4*	*0.5*	*0.5*
Geothermal	*0.1*	*0.2*	*0.3*	*0.2*	*0.2*	*0.2*	*0.3*
Solar/other [2]	-	-	-	*0.3*	*1.3*	*2.4*	*3.6*
TOTAL LOSSES	**92.0**	**144.3**	**178.1**	**179.4**	**151.6**	**143.1**	**..**
of which:							
Electricity and heat generation[9]	53.0	105.9	135.4	133.1	106.3	98.7	..
Other transformation	19.6	17.3	20.8	17.3	17.5	17.9	..
Own use and transmission/distribution losses[10]	19.3	21.2	21.9	29.0	27.8	26.5	..
Statistical Differences	**-5.6**	**7.3**	**11.7**	**10.4**	**0.3**	**3.1**	**..**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2013**	**2014**	**2015E**
GDP (billion 2010 USD)	2293.55	4553.11	5093.20	5498.72	5644.66	5642.89	5669.57
Population (millions)	108.90	123.61	126.83	128.04	127.33	127.12	126.93
TPES/GDP (toe/1000 USD)[11]	0.14	0.10	0.10	0.09	0.08	0.08	0.08
Energy production/TPES	0.09	0.17	0.20	0.20	0.06	0.06	0.07
Per capita TPES (toe/capita)	2.94	3.55	4.08	3.89	3.57	3.48	3.43
Oil supply/GDP (toe/1000 USD)[11]	0.11	0.06	0.05	0.04	0.04	0.03	0.03
TFC/GDP (toe/1000 USD)[11]	0.10	0.06	0.06	0.06	0.05	0.05	..
Per capita TFC (toe/capita)	2.15	2.32	2.59	2.41	2.38	2.32	..
CO_2 emissions from fuel combustion ($MtCO_2$)[12]	897.5	1040.6	1141.6	1108.1	1228.3	1188.5	..
CO_2 emissions from bunkers ($MtCO_2$)[12]	62.2	31.4	36.9	31.5	32.5	30.6	..
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-12**	**12-13**	**13-14**	**14-15**
TPES	1.9	1.7	-0.4	-4.8	0.7	-2.8	-1.3
Coal	1.7	2.4	1.7	-1.2	8.5	-2.8	1.3
Peat	-	-	-	-	-	-	-
Oil	0.0	0.2	-2.3	1.8	-3.6	-5.0	-2.5
Natural gas	13.6	4.0	2.7	10.6	0.9	1.4	-6.0
Biofuels and waste[1]	-	0.4	7.0	2.1	11.0	3.4	2.3
Nuclear	19.6	4.8	-1.1	-76.5	-41.6	-100.0	-
Hydro	1.6	-0.2	-0.4	-4.2	3.5	4.7	4.1
Wind	-	-	43.8	9.1	-9.1	17.3	5.1
Geothermal	12.0	7.0	-2.3	-0.7	-0.5	-0.7	-1.0
Solar/other[2]	-	-3.8	-1.5	11.9	62.1	51.7	35.4
TFC	1.2	1.4	-0.6	-1.2	0.4	-2.4	..
Electricity consumption	3.7	2.3	0.5	-2.9	0.5	-1.7	..
Energy production	5.6	3.4	-0.5	-46.9	-0.8	-3.8	14.5
Net oil imports	-0.0	0.2	-2.4	2.2	-4.5	-6.2	-1.1
GDP	4.1	1.1	0.8	0.6	1.4	-0.0	0.5
TPES/GDP	-2.2	0.5	-1.1	-5.4	-0.7	-2.7	-1.8
TFC/GDP	-2.8	0.2	-1.4	-1.9	-0.9	-2.2	..

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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Footnotes to energy balances and key statistical data

1. Biofuels and waste comprises 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. Other includes tide, wave and ambient heat used in heat pumps.
3. In addition to coal, oil, natural gas and electricity, total net imports also include peat, biofuels and waste and trade of heat.
4. Excludes international marine bunkers and international aviation bunkers.
5. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
6. Industry includes non-energy use.
7. Other includes residential, commercial and public services, agriculture/forestry, fishing and other non-specified.
8. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
9. 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 and solar thermal, 10% for geothermal and 100% for hydro, wind and solar photovoltaic.
10. Data on "losses" for forecast years often include large statistical differences covering differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
11. Toe per thousand US dollars at 2010 prices and exchange rates.
12. "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach from the *2006 IPCC Guidelines.* In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals. Projected emissions for oil and gas are derived by calculating the ratio of emissions to energy use for 2013 and applying this factor to forecast energy supply. Projected emissions for coal are based on product-specific supply projections and are calculated using the IPCC/OECD emission factors and methodology.

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ANNEX C: 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 Paris, France.)

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

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ANNEX D: GLOSSARY AND LIST OF 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.

ABWR	advanced boiling water reactors
AC	alternating current
ACENR	Advisory Committee on Energy and Natural Resources
AIST	Advanced Industrial Science and Technology (National Institute of)
ANRE	Agency for Natural Resources and Energy
APEC	Asia-Pacific Economic Cooperation
APWR	advanced pressurised water reactors
BELS	building-housing energy-efficiency labelling system
BEMS	building energy management systems
BWR	boiling water reactors
CCGT	combined-cycle gas turbines
CCS	carbon capture and storage
CDM	clean development mechanism
CEM	Clean Energy Ministerial Forum
CHP	combined heat and power
CNG	compressed natural gas
CO_2	carbon dioxide
DC	direct current
DHC	district heating and cooling
EGC	Electricity and Gas Market Surveillance Commission
EMSC	Electricity Market Surveillance Commission
EPCO	electric power company
ESCJ	Electric Power System Council of Japan
ESCO	energy services company
EVI	Electric Vehicles Initiative
FCF	frequency converter facility
FEPC	Federation of Electric Power Companies (Japan)
F-gases	hydrofluorocarbon, perfluorocarbon, sulphur hexafluoride (SF_6)
FIT	feed-in tariff
FY	fiscal year
GDP	gross domestic product
GHG	greenhouse gas
GWPH	Global Warming Prevention Headquarters

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HEMS	home energy management systems
HEPCO	Hokkaido Electric Power Company
hm	heavy metal
IAEA	International Atomic Energy Agency
ICEF	Innovation for Cool Earth Forum
IDR	in-depth review
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
IGFC	integrated coal gasification fuel-cell combined system
IMF	International Monetary Fund
INDC	intended nationally determined contribution
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
ISO	Independent System Operator
JAMA	Japan Automobile Manufacturers Association
JAPC	Japan Atomic Power Company
JCM	joint crediting mechanism
JCOAL	Japan Coal Energy Center
JFTC	Japan Fair Trade Commission
JGA	Japan Gas Association
JNFL	Japan Nuclear Fuel Ltd
JOGMEC	Japan Oil, Gas and Metals National Corporation
JPEX	Japan Electric Power Exchange
JST	Japan Science and Technology Agency
KEPCO	Kansai Electric Power Company
LCOE	levelised cost of electricity
LED	light-emitting diode
LNG	liquefied natural gas
LPG	liquid petroleum gas
LULUCF	land use, land-use change and forestry
LWR	light water reactors
MAFF	Ministry of Agriculture, Forestry and Fisheries
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MOE	Ministry of the Environment
MOX	mixed oxide fuel
MRV	measurement, reporting and verification
NEDO	New Energy and Industrial Technology Development Organization
NESO	national emergency strategy organisation
NESTI 2050	National Energy and Environment Strategy for Technological Innovation towards 2050
NGL	natural gas liquids

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NISA	Nuclear and Industrial Safety Agency (until 2012)
NO_x	nitrous oxides
NPP	nuclear power plant
NRA	Nuclear Regulation Authority
NUMO	Nuclear Waste Management Organisation of Japan
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
OECD	Organisation for Economic Co-operation and Development
PAJ	Petroleum Association of Japan
PCC	post-combustion capture
PFC	perfluorocarbons
PM	particulate matter
PPA	power purchase agreement
PPS	power producers and suppliers
PV	photovoltaics
PWR	pressurised water reactors
RD&D	research, development and deployment
RFSC	Recyclable Fuel Storage Company
RITE	Research Institute of Innovation Technology for the Earth
SEP	Strategic Energy Plan
SME	small and medium-sized enterprise
SO_2	sulphur dioxide
TCP	Technology Collaboration Programme
TEPCO	Tokyo Electric Power Company
TFC	total final consumption of energy
TPA	third-party access
TPES	total primary energy supply
TSO	transmission system operator
USC	ultra-supercritical
UNFCCC	United Nations Framework Convention on Climate Change
WTI	West Texas Intermediate (Texas light sweet crude oil)
ZEB	zero-energy building
ZEH	zero-energy house

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Units of measure

b/d	barrels per day
bcm	billion cubic metres
Gcal	gigacalorie
gCO_2	grammes of carbon dioxide
gCO_2/km	grammes of carbon dioxide per kilometre
GJ	gigajoule
GW	gigawatt
GWh	gigawatts per hour
Hz	Hertz
kb/d	thousand barrels per day
km^2	square kilometres
kt	kilotonne
$ktCO_2$	thousand tonnes of carbon dioxide
kW	kilowatt
kWh	kilowatt-hour
m^2	square metre
mb	million barrels
mb/d	million barrels per day
MBtu	million British thermal units
mcm	million cubic metres
MPa	megapascal
Mt	million tonnes
$MtCO_2$-eq	million tonnes of carbon dioxide-equivalent
Mtoe	million tonnes of oil-equivalent
MW	megawatt
MW_e	megawatt electrical
MW_{th}	megawatt thermal
SWU	separative work unit
tCO_2	tonne of carbon dioxide
toe	tonne of oil-equivalent
TJ	terajoule
TWh	terawatt-hour

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Energy Policies of IEA Countries

Japan

One of the largest economies in the world, Japan has long been a major consumer and importer of energy and a recognised leader in energy technology development. Japan's energy policy has been dominated in recent years by its efforts to overcome the fallout from the 2011 earthquake and the subsequent Fukushima nuclear accident. One consequence of the accident was a gradual shutdown of all nuclear power plants, which has led to a significant rise in fossil fuels use, increased fuel imports and rising carbon dioxide emissions. It has also brought electricity prices to unsustainable levels.

Faced with these challenges, the government of Japan has revised its energy policy in recent years to focus on further diversifying its energy mix (less use of fossil fuels, more reliance on renewable energy, restarting nuclear plants when declared safe) and curbing carbon emissions. Building on these plans, Japan has outlined ambitious goals to cut greenhouse gas emissions by 26% between 2013 and 2030.

This emissions reduction commitment requires a balancing act between energy security, economic efficiency, environmental protection and safety. This International Energy Agency (IEA) review of Japan's policies highlights three areas that are critical to its success: energy efficiency, increasing renewable energy supply and restarting nuclear power generation. The IEA encourages Japan to increase low-carbon sources of power supply. It also recognises that nuclear power can only be restored provided that the highest safety standards are met and the critical issues following the Fukushima accident are addressed, including decontaminating areas affected by the radioactive release and regaining public trust.

This review analyses the energy policy challenges facing Japan and provides recommendations for further policy improvements. It is intended to help guide the country towards a more secure, sustainable and affordable energy future.