Chapter 3

Case Study for Japan

September 2016

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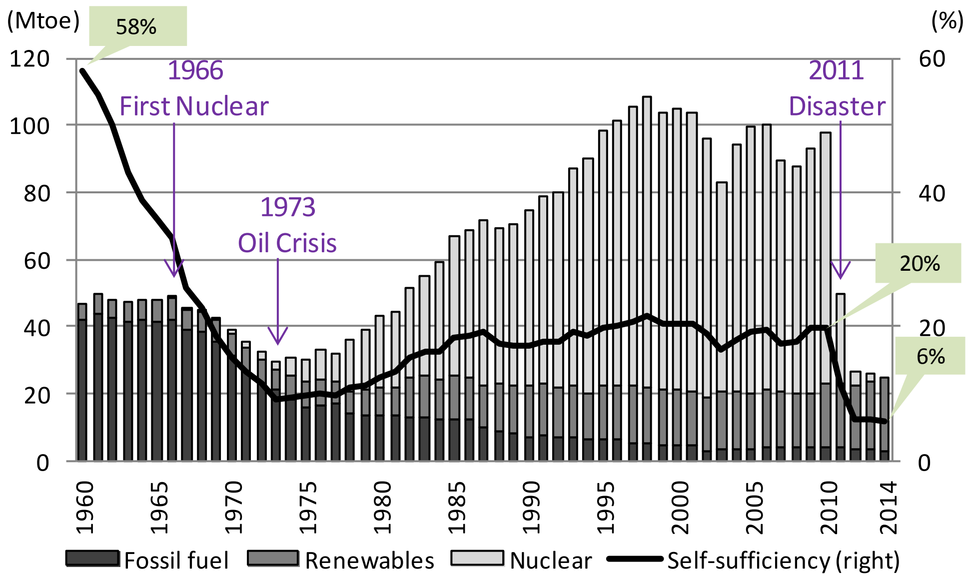
Chapter 3

Case Study for Japan

3.1 Past Performance of Self-sufficiency in Japan

The figure below illustrates trends in Japan's energy production volume and self-sufficiency since 1960.

Figure 3.1 Past Performance of Self-sufficiency in Japan



Source: Energy Balance of Organisation for Economic Co-operation and Development (OECD) Countries 2015, International Energy Agency (IEA).

(A) Before 1960

Japan had coal resources, and coal was the mainstay of Japan's energy after World War II in 1945. However, when cheap oil from abroad began to flow into the country, domestic coal gradually lost its cost competitiveness, and Japan's mainstay of energy shifted to oil. In 1955, two important laws were passed that would create the framework of Japan's self-sufficiency.

These were the Coal Mining Restructuring Law, which rationalised the coal mining and led to a shift to cheaper imported coal, and the Atomic Energy Basic Law. These greatly increased Japan's self-sufficiency.

(B) From 1960 to 1973

As of 1960, coal accounted for close to 60 percent of Japan's primary energy supply. Most coal was supplied from domestic sources, so the self-sufficiency rate was at 58 percent. In 1961, domestic coal production volume peaked. However, beginning 1962, domestic coal production continually decreased while energy demand increased, causing a sharp decline in the self-sufficiency rate. In 1973, the oil crisis year, the self-sufficiency rate fell below 10 percent. In 1966, Japan began generating nuclear power, but it was not on a scale that could increase the self-sufficiency rate.

(C) From 1973 to 2010

Coal production volume continued to decrease, but Japan's self-sufficiency rate recovered momentarily by 20 percent because of an increase in renewable energy production, which was mainly hydroelectric, and nuclear power generation.

(D) After 2011

The Fukushima Daiichi Nuclear Power Plant disaster that occurred on 11 March 2011 resulted in the shutdown of all of Japan's operational nuclear power plants in stages. Thus, Japan's self-sufficiency rate declined sharply and stood at below 6 percent in 2013.

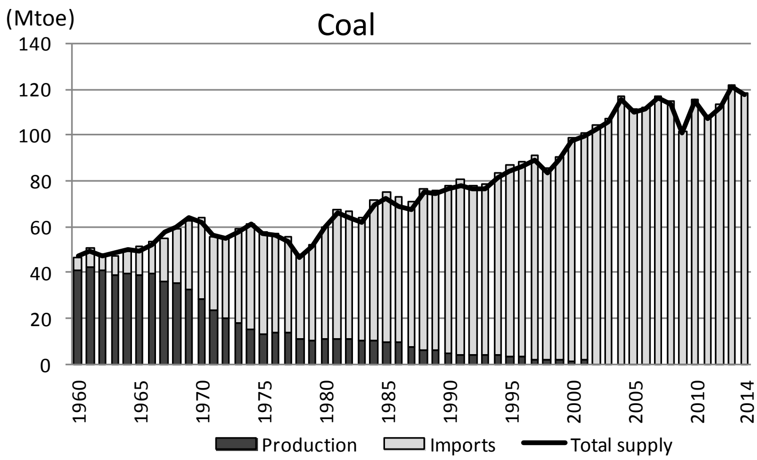
3.2 Quantitative Potential of Increasing Self-sufficiency

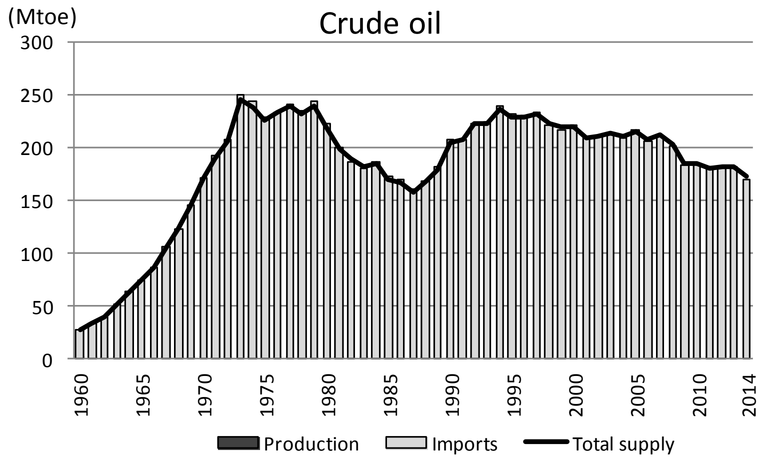
The quantitative potential of increasing self-sufficiency is assessed according to fossil fuel production, nuclear power generation, renewable power generation, and energy conservation and efficiency or energy savings.

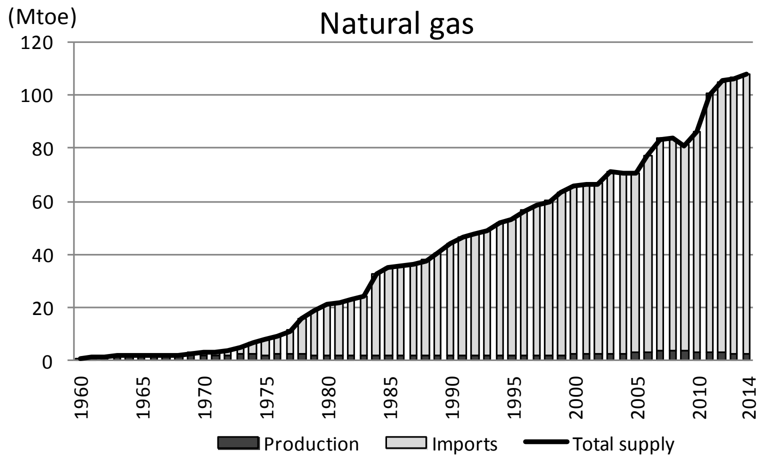
3.2.1 Fossil fuel production

The figure below indicates Japan's fossil fuel supply balance from 1960 to 2013. Although Japan has coal resources, its coal lags behind in terms of price competition with imported coal, so in recent years coal production has not taken place per statistics. Japan has almost no crude oil resources, and its crude oil production is at an ignorable level. Natural gas is the only form of fossil fuel for which domestic production can actually be statistically verified, but it accounts for only 3 percent of the country's natural gas supply.

Figure 3.2 Fossil Fuel Supply Balance in Japan







Source: Energy Balance of International Energy Agency (IEA) Countries 2015, IEA.

(A) Coal

Japan has coal resources, but strong government policy is required to resume coal production on a commercial scale that exceeds economical rationality. At present, however, Japan does not have such policy, which is not even mentioned in the country's latest long-term plan. Therefore, it was determined that there would be no potential for an increase in domestic coal production.

(B) Crude oil

Japan's crude oil resources are negligible, and so it was determined that there would be no potential for an increase in domestic crude oil production.

(C) Natural gas

There has been no new commercial-scale natural gas field discovered in Japan in recent years. Japan's natural gas prices are at an elevated level compared to those of the rest of the world. The fact that no new development projects have been put together even with such high prices makes it possible to determine that there is no potential for conventional natural gas.

Methane hydrate resources have been confirmed to exist in Japan's coastal waters, and a pilot project is underway. However, according to experts, there is little possibility to commercially produce methane hydrate before the year 2030.

Therefore, it was determined that there would be no potential for an increase in domestic natural gas production.

3.2.2 Nuclear power generation

Japan has a large number of nuclear power plants, but in March 2011 all of these plants were shut down in stages following the massive earthquake and tsunami that hit the country. Currently, a few nuclear power plants have restarted operation, but there are various viewpoints regarding the state of Japan's nuclear power generation in 2030.

This study uses two outlooks to gauge the potential of nuclear power generation in 2030. First is the national government's Long-term Energy Supply and Demand Outlook, which was published on 16 July 2015. According to this outlook, the government anticipates the share of nuclear power to be between 20 percent and 22 percent with a generating capacity of 1,065 TWh in 2030. This study adopts 22 percent as the share of nuclear power generation and determines that the nuclear power generation outlook is 234,300 GWh. This number is viewed as the high potential. Second is the Asia/World Energy Outlook 2015 of IEEJ, which contains reference and advanced technologies scenarios. This study adopts the reference scenario where nuclear power generation totals 156,500 GWh. This number is viewed as the low potential.

The potential of nuclear power generation is the generating capacity from new nuclear power plants. The generating capacity of new nuclear power plants was determined using the following calculation.

(a) The average utilisation rate of existing and new nuclear power plants is assumed to be 70 percent.

(b) The necessary nuclear power generating capacity in 2030 is assumed using an average utilisation rate of 70 percent based on the assumed generating capacity of 2030.

(c) The generating capacity of existing nuclear power plants in 2030 is assumed to be 21.4 GW.

(d) The necessary new nuclear power generating capacity for 2030 is assumed to be (b) – (c).

(e) The new generating capacity calculated in (d) is multiplied by the 70 percent utilisation rate to assume the generating capacity from new nuclear power plants in 2030.

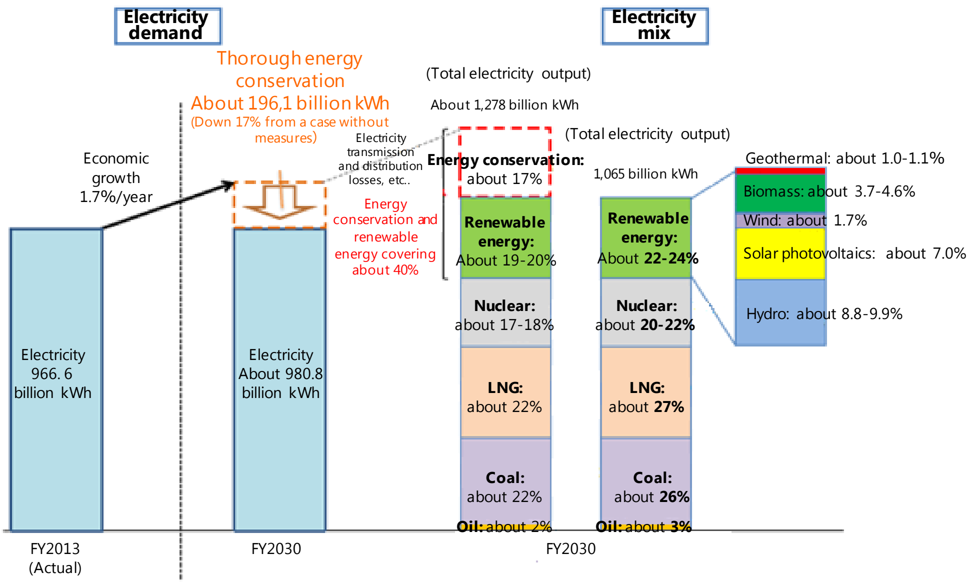
The following table indicates the potential of Japan's nuclear power generation in 2030.

Table 3.1 Nuclear Power Generation Potential

Description	IEEJ (low potential)	Government (High potential)	Note
Nuclear power generation outlook in 2030 (GWh)	156,500 (Reference scenario)	234,300 (Nuclear share :22%)	
Premised operational rate (%)	70	70	
Required nuclear power generation capacity (GW)	25.5	38.2	
Exisiting nuclear power generation capacity in 2030 (GW)	21.4	21.4	Estimated by IEEJ WG Member
Required new nuclear power generation capacity in 2030 (GW)	4.1	16.8	
Power generation from new nuclear power plants in 2030 (GWh)	25,410	103,210	

Source: Study team.

Figure 3.3 Long-term Energy Supply and Demand Outlook (Electricity)



Source: Ministry of Economy, Trade and Industry, Government of Japan.

3.2.3 Renewable power generation

Research data from the Ministry of the Environment, Government of Japan was used for the supply volume of renewable power generation in 2030. The following table indicates the potential of Japan's renewable power generation. The net potential, which is the difference between potential and actual, is the self-sufficiency improving potential.

Table 3.2 Renewable Power Generation Potential in Japan

Energy	Actual (GWh)		Potential (GWh)		Net potential (GWh)	
			Low	High	Low	High
Hydro (Large)	23,500	(CY2009)	25,000	25,000	1,500	1,500
Hydro (Medium/small)	46,600	(FY2013)	51,700	70,800	5,100	24,200
Solar PV (Rooftop)	7,300	(FY2013)	29,200	32,200	21,900	24,900
Solar PV (Utility scale)	7,700	(FY2013)	48,500	95,800	40,800	88,100
Wind (Onshore)	4,700	(FY2013)	28,000	41,500	23,300	36,800
Wind (Offshore)	70	(FY2013)	13,000	23,100	12,930	23,030
Waste	19,900	(CY2005*)	19,900	19,900	0	0
Biomass	3,100	(FY2013)	7,100	19,300	4,000	16,200
Geothermal	3,200	(FY2013)	13,400	14,800	10,200	11,600

Note: * Estimation.
Source: Ministry of the Environment, Government of Japan.

3.2.4 Indigenous production increase in power generation

Here, the supply of primary energy was calculated based on the heat efficiency from the generated amount (GWh) of the potential of nuclear power generation and net potential of renewable power generation. This supply of primary energy is the domestic production volume that can be included in the calculation of self-sufficiency. To ensure consistency in the unit of assessment, watt hours were converted to tons of oil equivalent. The conversion factor was 1 GWh = 86 toe.

In the low case, geothermal and nuclear power generations have a high potential, while in the high case, nuclear, geothermal, biomass, and solar (utility scale) represent a high potential.

Table 3.3 Renewable Power Generation Net Potential in Japan

Energy	Net potential				Heat efficiency	Estimated 'Production' (ktoe)	
	(GWh)		(ktoe)				
	Low	High	Low	High	(%)	Low	High
Nuclear	25,410	103,210	2,185	8,876	33	6,622	26,897
Hydro (Large)	1,500	1,500	129	129	100	129	129
Hydro (Medium/small)	5,100	24,200	439	2,081	100	439	2,081
Solar PV (Rooftop)	21,900	24,900	1,883	2,141	100	1,883	2,141
Solar PV (Utility scale)	40,800	88,100	3,509	7,577	100	3,509	7,577
Wind (Onshore)	23,300	36,800	2,004	3,165	100	2,004	3,165
Wind (Offshore)	12,930	23,030	1,112	1,981	100	1,112	1,981
Waste	0	0	0	0	20	0	0
Biomass	4,000	16,200	344	1,393	20	1,720	6,966
Geothermal	10,200	11,600	877	998	10	8,772	9,976

Source: Study team.

3.2.5 Biofuel

(A) Bioethanol and biodiesel

Currently, there is no commercial scale production of bioethanol or biodiesel in Japan. IEA statistics indicate a production volume of zero. Based on the results of interviews with experts, it was determined that commercial scale production of bioethanol and biodiesel would not take place in Japan.

(B) Bio jet fuel

The International Air Transport Association and its member airlines, including those based in Japan, have established the following targets as part of the aviation industry's efforts to address global warming.

(a) Fuel efficiency improvement of 1.5 percent per annum on average between 2009 and 2020

(b) Carbon-neutral growth from 2020

(c) Fifty-percent net emission reduction in 2050 compared to that in 2005

The key to achieving these targets is the commercial-scale production of bio jet fuel at affordable prices.

Japan's Ministry of Land, Infrastructure, Transport and Tourism and Ministry of Economy, Trade and Industry are now examining the use of bio jet fuel at the 2020 Tokyo Olympic and Paralympic Games. According to the road map of this review, scale-up demonstration testing will take place after 2020 outside of Japan, and commercialisation reviews will be conducted in 2025 and later. Therefore, this study determined that there would be no commercial scale bio jet fuel production in Japan in 2030.

(C) Boiler fuel

In October 2010, Japan's Cabinet approved the Basic Plan on Biomass Utilization as part of the country's global warming prevention measures. This plan established the target of utilising approximately 26 million ton-C of biomass. The table below indicates the current utilisation rate of each biomass type and the utilisation target set for 2020. Certain types see a high utilisation rate.

The problem posed by examining the potential of biomass fuel for boilers is the lack of data. Analyses of the amount of biomass converted to electricity carried out by the Government of Japan are available and can be utilised. However, information about the extent to which heat is converted and utilised from biomass fuel inputs, the conversion rate, and the costs required for conversion cannot be sufficiently obtained. Therefore, this research had to forgo the assessment on the heat utilisation of biomass.

In recent years, there has been an increase in the number of public sector facilities installing biomass boilers fuelled by wood chips. This is due to soaring oil prices and efforts to reduce CO_2 emissions, but the absolute figure is rather small. In the past, wood chips in Japan were mainly made out of waste construction materials that had little water content. If forest thinning, which is seldom used today, were utilised, the potential could become large. The greatest issues are the large amount of moisture in forest thinning and price competition with oil and natural gas.

Table 3.4 Targets for Biomass Utilisation by Type

Biomass	Resources (000 tons)	Utilization rate		Note
		Current	Target	
Livestock waste	88,000	90%	90%	Compost, Gasifiction then energy use
Sewage sludge	78,000	77%	85%	Construction material, Gasification then energy use
Black liquor	14,000	100%	100%	Energy use
Waste paper	27,000	80%	85%	Reuse, Gasification then energy use
Waste food	19,000	27%	40%	Fertilizer, Feedstuff, Gasification then energy use
Waste lumber	3,400	95%	95%	Papermaking material, Energy use
Construction waste	4,100	90%	95%	Papermaking material, Energy use
Agricultural residue (excluding plow)	14,000	30%	45%	Fertilizer, Feedstuff, Energy use
Agricultural residue (including plow)		85%	90%	
Forest thinnings	8,000	0%	30%	Papermaking material, Energy use

Note: Energy use: Heat production and power generation.

MAFF = Ministry of Agriculture, Forestry and Fisheries, Government of Japan.

Source: Biomass Utilization Promotion Committee, MAFF.

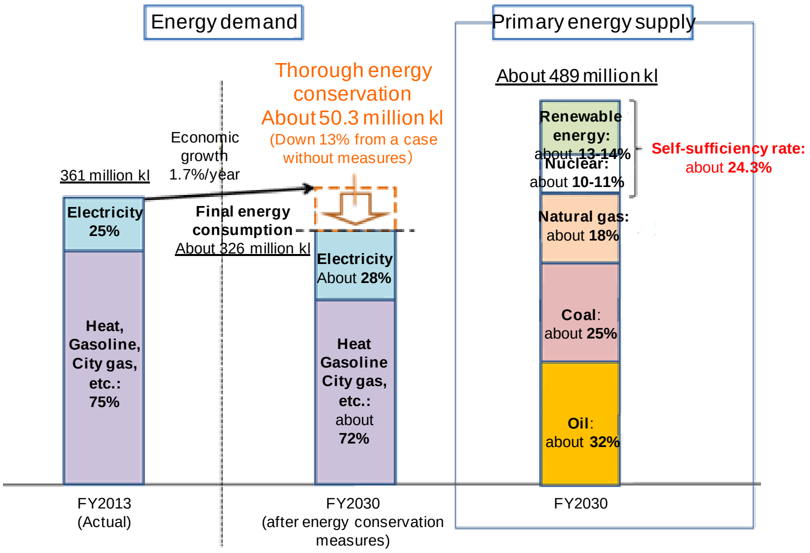
3.2.6 Energy conservation and efficiency

The Government of Japan has set ambitious energy saving targets in the Long-term Energy Supply and Demand Outlook (July 2015) based on strong energy saving policy. The targets are a reduction in final energy consumption of 50.3 Mkl compared to business-as-usual scenario (BAU) in 2030 and energy consumption of 7.6 Mkl by the transformation sector.

This study set the government’s energy saving targets as the TPES reduction potential.

Figure 3.4 Long-term Energy Supply and Demand Outlook

(TPES)



Note: Above figure shows only final energy consumption stage.

Source: Ministry of Economy, Trade and Industry, Government of Japan.

The table below indicates Japan's energy saving targets for each sector. The TPES target is to achieve a reduction of approximately 54 Mtoe versus business as usual scenario (BAU) by 2030. This is equivalent to more than 10 percent of TPES in 2013. Japan's detailed energy saving methodology can be found in the Annex.

Table 3.5 Energy Saving Potential in Japan

Sector	Energy saving target in 2030 from BAU	
Industry	17.9 Million KL of crude oil equivalent	16,546 ktoe
Commercial	12.3 Million KL of crude oil equivalent	11,415 ktoe
Residential	11.6 Million KL of crude oil equivalent	10,735 ktoe
Transport	16.1 Million KL of crude oil equivalent	14,863 ktoe
Total	57.9 Million KL of crude oil equivalent	53,559 ktoe

Note: 1 kl crude oil = 0.924834 toe.

Source: Ministry of Economy, Trade and Industry, Government of Japan.

3.3 Impact for Self-sufficiency Improvement in Japan

The table below indicates the calculation results for self-sufficiency improvement due to indigenous production increase and energy saving. The base year is 2013.

The potential for self-sufficiency improvement for the low case is 1.9 percent for geothermal and 1.5 percent for nuclear. Meanwhile, the potential for self-sufficiency improvement for the high case is 5.9 percent for nuclear, 2.2 percent for geothermal, 1.7 percent for solar PV (utility scale) and 1.5 percent for biomass.

Table 3.6 Self-sufficiency Improving Potential in Japan

(Base year: 2013)

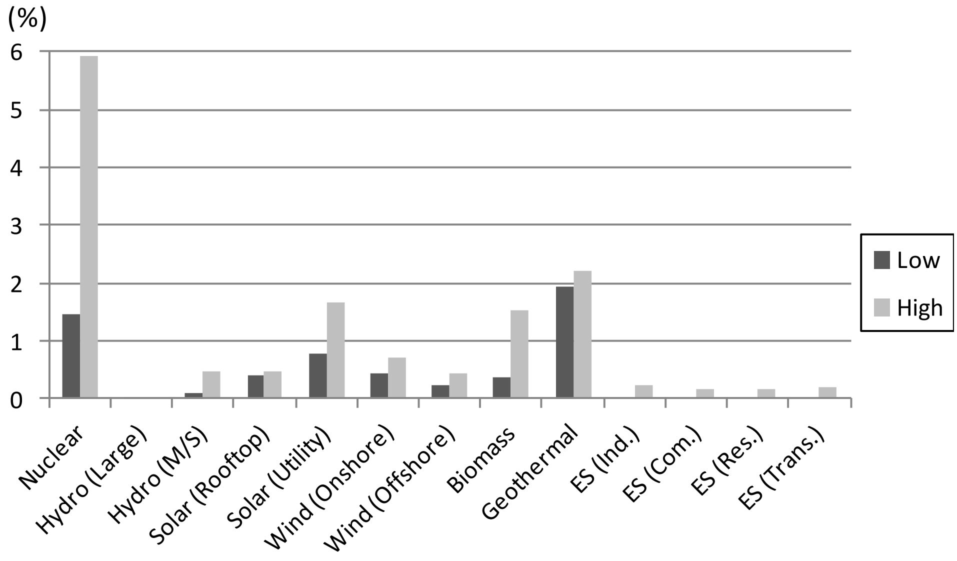
Base year: 2013	
Total indigenous production	27,958 ktoe
Total primary energy supply	454,655 ktoe
Self-sufficiency	6.1 %

Energy	Indigenous production increase		Self-sufficiency improvement	
	Low	High	Low	High
Nuclear	6,622 ktoe	26,897 ktoe	1.5 %	5.9 %
Hydro (Large)	129 ktoe	129 ktoe	0.0 %	0.0 %
Hydro (Medium/small)	439 ktoe	2,081 ktoe	0.1 %	0.5 %
Solar PV (Rooftop)	1,883 ktoe	2,141 ktoe	0.4 %	0.5 %
Solar PV (Utility scale)	3,509 ktoe	7,577 ktoe	0.8 %	1.7 %
Wind (Onshore)	2,004 ktoe	3,165 ktoe	0.4 %	0.7 %
Wind (Offshore)	1,112 ktoe	1,981 ktoe	0.2 %	0.4 %
Biomass	1,720 ktoe	6,966 ktoe	0.4 %	1.5 %
Geothermal	8,772 ktoe	9,976 ktoe	1.9 %	2.2 %
Sector	Energy saving		Self-sufficiency improvement	
Industry	16,546 ktoe		0.2 %	
Commercial	11,415 ktoe		0.2 %	
Residential	10,735 ktoe		0.1 %	
Transport	14,863 ktoe		0.2 %	
Total	53,559 ktoe		0.8 %	

Source: Study team.

Figure 3.5 Self-sufficiency Improving Potential in Japan

(Base year: 2013)



ES (Com.) = energy saving (commercial), ES (Res.) = energy saving (residential), ES (Trans.) = energy saving
(transport), ES (Ind.) = energy saving (industry), hydro (M/S) = hydro (medium/small.
Source: Study team.

Although energy saving has the potential of a greater than 10-percent reduction in TPES, there is only a total potential of self-sufficiency improvement of 0.8 percent. This is because the total indigenous production in 2013 was low, at approximately 28 Mtoe. Since indigenous production was extremely low, even if TPES was reduced by 10 percent, it would have only a minimal effect on reducing self-sufficiency. The reason for the low indigenous production in 2013 was the shutdown of Japan’s nuclear power plants.

The table below contains the self-sufficiency improvement with the base year set as 2010, when most of Japan’s nuclear power plants were operational. Total indigenous production for 2010 was approximately 99 Mtoe, which was more than three times the level of 2013, so the self-sufficiency improvement effect from energy saving was 2.4 percent.

Table 3.7 Self-sufficiency Improving Potential in Japan

(Base year: 2010)

Base year: 2010	
Total indigenous production	99,327 ktoe
Total primary energy supply	498,920 ktoe
Self-sufficiency	19.9 %

Energy	Indigenous production increase		Self-sufficiency improvement	
	Low	High	Low	High
Nuclear	6,622 ktoe	26,897 ktoe	1.3 %	5.4 %
Hydro (Large)	129 ktoe	129 ktoe	0.0 %	0.0 %
Hydro (Medium/small)	439 ktoe	2,081 ktoe	0.1 %	0.4 %
Solar PV (Rooftop)	1,883 ktoe	2,141 ktoe	0.4 %	0.4 %
Solar PV (Utility scale)	3,509 ktoe	7,577 ktoe	0.7 %	1.5 %
Wind (Onshore)	2,004 ktoe	3,165 ktoe	0.4 %	0.6 %
Wind (Offshore)	1,112 ktoe	1,981 ktoe	0.2 %	0.4 %
Biomass	1,720 ktoe	6,966 ktoe	0.3 %	1.4 %
Geothermal	8,772 ktoe	9,976 ktoe	1.8 %	2.0 %
Sector	Energy saving		Self-sufficiency improvement	
Industry		16,546 ktoe		0.7 %
Commercial		11,415 ktoe		0.5 %
Residential		10,735 ktoe		0.4 %
Transport		14,863 ktoe		0.6 %
Total		53,559 ktoe		2.4 %

Source: Study team.

3.4 Self-sufficiency Improvement Cost

3.4.1 Power generation

For generation cost (yen/kWh), generation cost calculation sheets prepared by the Power Generation Cost Verification Working Group and Procurement Price Calculation Committee were used. The plant models provided were those of 2014, 2020, and 2030, but this study used the 2014 model. As for offshore wind, there was no 2014 model, so the WG used the 2020 model. Cost elements for each generation fuel can be found in the Annex.

Capacity factor and operation years were changed as factors of change to calculate a low case and high case for generation cost. The table below indicates the calculation results for generation cost.

Table 3.8 Unit Cost of Power Generation by Fuel

Energy		Capacity factor (%)	Operation years (Years)	Generation cost (Yen/kWh)
Nuclear	High	60	40	11.3
	Low	80	60	8.7
Hydro (Large)	High	45	40	11.0
	Low	45	60	9.6
Hydro (Medium/small)	High	60	30	29.4
	Low	60	40	27.1
Solar PV (Rooftop)	High	12	20	29.4
	Low	12	25	25.7
Solar PV (Utility scale)	High	14	20	24.2
	Low	14	25	21.2
Wind (Onshore)	High	20	20	21.6
	Low	20	25	19.0
Wind (Offshore)	High	30	20	34.7
	Low	30	25	31.2
Biomass	High	50	20	36.5
	Low	87	40	29.7
Geothermal	High	83	30	18.7
	Low	83	50	15.8

Source: Generation cost calculation sheets.

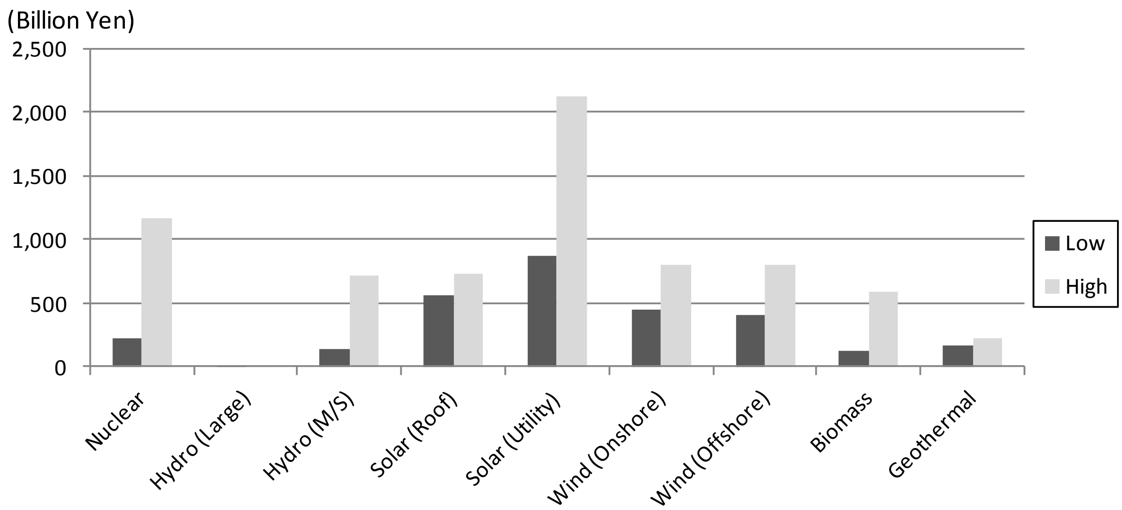
The table below indicates the total amount of the generation cost for each generation fuel. The total amount was calculated by multiplying net potential by generation cost (yen/kWh).

Table 3.9 Lifetime Cost of Power Generation by Fuel

Energy	Net potential (GWh)		Generation cost unit (Yen/kWh)		Generation life time cost (Billion Yen)	
	Low	High	Low	High	Low	High
(a)	(b)	(c)	(d)	(e)	(f)= (b)*(d)/1000	(g)= (c)*(e)/1000
Nuclear	25,410	103,210	8.7	11.3	221	1,166
Hydro (Large)	1,500	1,500	9.6	11.0	14	17
Hydro (Medium/small)	5,100	24,200	27.1	29.4	138	711
Solar PV (Rooftop)	21,900	24,900	25.7	29.4	563	732
Solar PV (Utility sacle)	40,800	88,100	21.2	24.2	865	2,132
Wind (Onshore)	23,300	36,800	19.0	21.6	443	795
Wind (Offshore)	12,930	23,030	31.2	34.7	403	799
Biomass	4,000	16,200	29.7	36.5	119	591
Geothermal	10,200	11,600	15.8	18.7	161	217

Source: Study team.

Figure 3.6 Lifetime Cost of Power Generation by Fuel



Hydro (M/S) = hydro (medium/small).

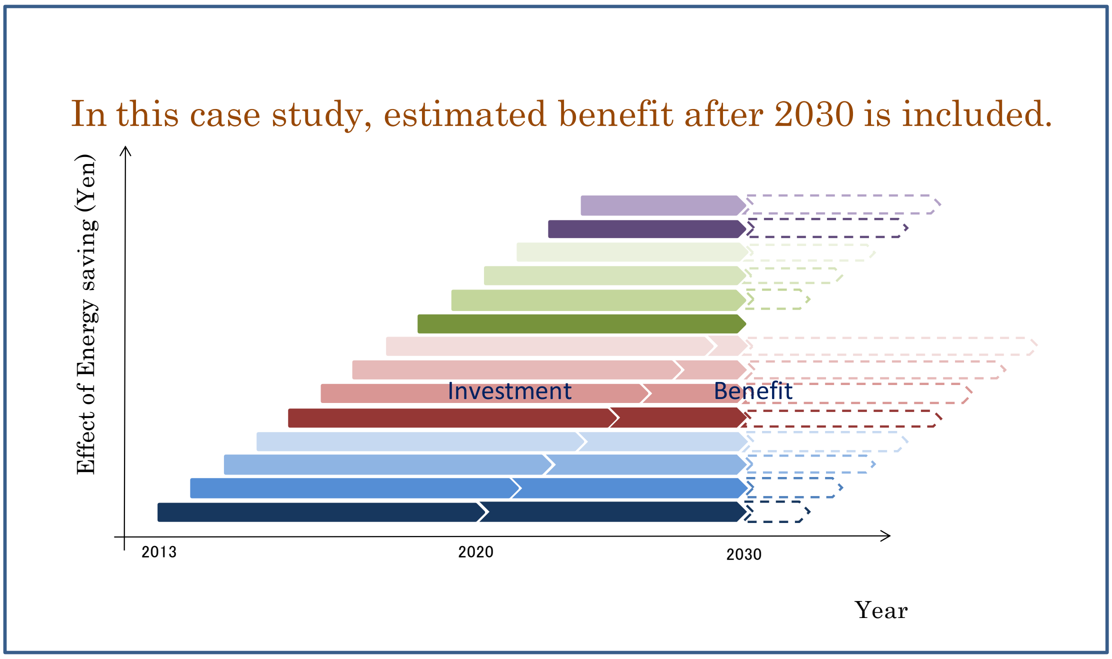
Source: Study team.

3.4.2 Energy saving

The payment of energy tariffs can be reduced as a result of energy saving investments, and such investments can be deemed a benefit. Individuals who carry out energy saving investments can recoup part or, in some cases, all of the costs of investment. In other words, the effective economic burden for the investor is the result of subtracting the benefit from the investment amount. This study defines the difference between the investment amount, or the effective economic burden, and the benefit as the energy saving cost.

This study includes investment amounts that will be executed up to 2030 and benefits that will be realised in 2030 and thereafter. The benefit period is the statutory service life. The figure below indicates the time frame of investment and benefit.

Figure 3.7 Time Frame of Investment and Benefit



Source: Ministry of Economy, Trade and Industry, Government of Japan.

This investment and benefit study used data calculated at the time the Long-term Energy Supply and Demand Outlook was formulated. The table below shows investment and benefit for each sector. The benefit is expected to outweigh the investment in every sector except for the residential sector.

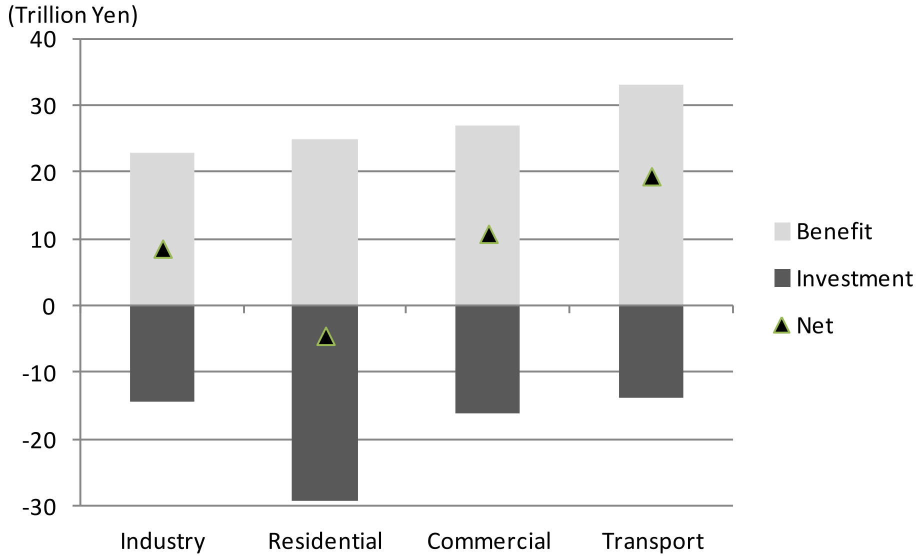
Table 3.10 Investment and Benefit by Sector

Unit: Trillion Yen

	Industry	Residential	Comemrcial	Transport	Total
Investment	-14.46	-29.33	-16.25	-13.78	-73.82
Benefit	23.06	24.84	27.07	33.24	108.21
Net	8.6	-4.49	10.82	19.46	34.39

Source: Ministry of Economy, Trade and Industry, Government of Japan.

Figure 3.8 Investment and Benefit by Sector



Source: Ministry of Economy, Trade and Industry, Government of Japan.

3.5 Cost of 1 Percent Self-sufficiency Improvement

In the previous section, the total cost needed to increase self-sufficiency was calculated for each method. In this section, the necessary cost for increasing self-sufficiency by 1 percent will be calculated to examine cost-effectiveness.

The table below contains a comparison of costs needed to increase self-sufficiency by 1 percent.

Table 3.11 Comparison of Costs Needed to Increase Self-sufficiency by 1 Percent

Measures	Improvement potential (%)		Improvement cost (Billion Yen)		1% Improvement cost (Billion Yen/ %)	
	Low	High	Low	High	Low	High
Nuclear	1.5	5.9	221	1,166	152	197
Hydro (Large)	0.0	0.0	14	17	508	582
Hydro (Medium/small)	0.1	0.5	138	711	1,433	1,554
Solar PV (Rooftop)	0.4	0.5	563	732	1,359	1,554
Solar PV (Utility scale)	0.8	1.7	865	2,132	1,121	1,279
Wind (Onshore)	0.4	0.7	443	795	1,004	1,142
Wind (Offshore)	0.2	0.4	403	799	1,649	1,834
Biomass	0.4	1.5	119	591	314	386
Geothermal	1.9	2.2	161	217	84	99
Enery saving (Industry)		0.2		-8,600		-37,030
Energy saving (Residential)		0.2		4,490		28,352
Energy saving (Commerciqal)		0.1		-10,820		-72,765
Energy saving (Transport)		0.2		-19,460		-93,640

Solar PV = solar photovoltaics.

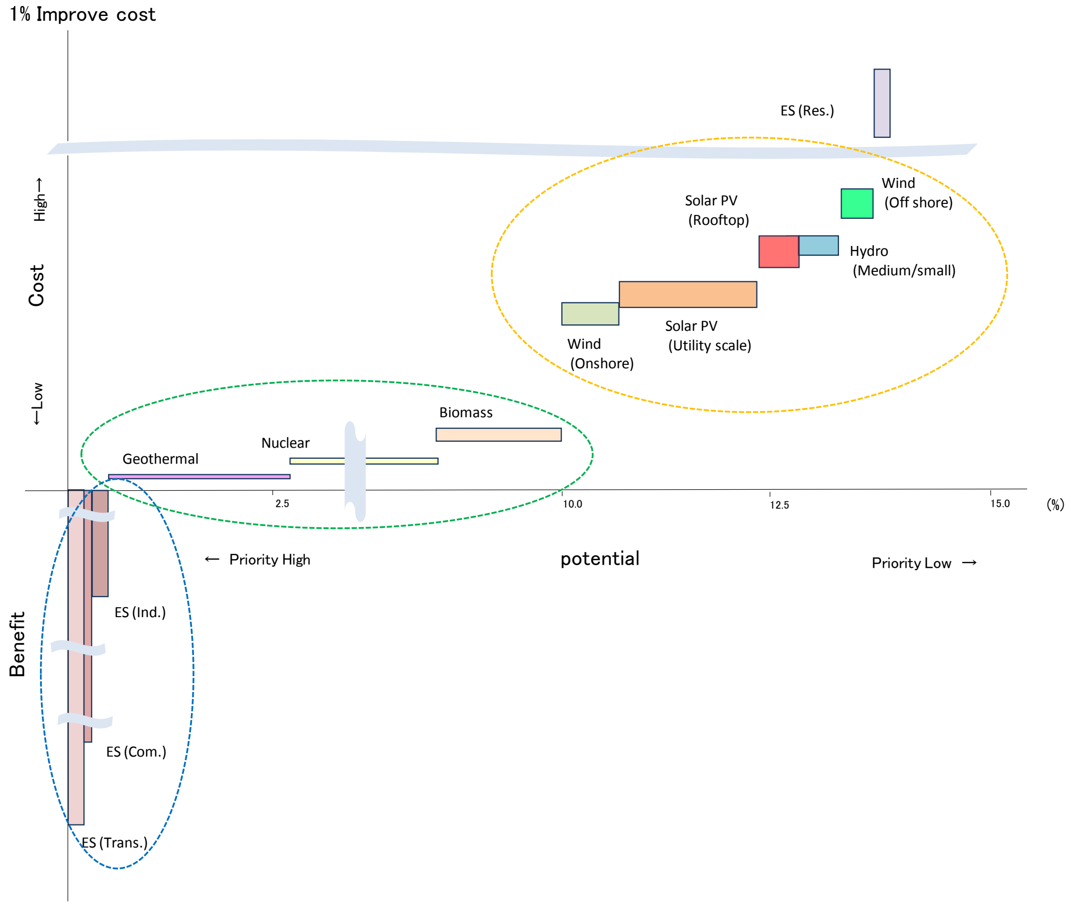
Source: Study team.

The following figure shows the cost-effectiveness of each method. Methods with a high cost-effectiveness of self-sufficiency appear in order from the left. These methods can be largely categorised into three groups: (1) Group 1 is the energy saving of the transport, residential, and industry sectors where the benefit exceeds the cost; (2) Group 2 is the geothermal, nuclear, and biomass resources where cost-effectiveness is high; and (3) Group 3 is wind (onshore and offshore), solar (utility scale and rooftop), and hydro resources where cost-effectiveness is low. Large hydro energy is fully developed in Japan, so there is little potential in this regard and, therefore, does not appear in the figure.

If everything were executed up to Group 2, where cost-effectiveness is comparatively higher, self-sufficiency could possibly increase by close to 9 percent.

However, it is important to note that this study does not take into account the energy mix.

Figure 3.9 Comparison of Cost-effectiveness of Each Method (High Case)



ES (Com.) = energy saving (commercial), ES (Ind.) = energy saving (industry), ES (Res.) = energy saving (residential), ES (Trsns.) = energy saving (transport), Solar PV = solar photovoltaics.

Source: Study team.

3.6 Change in Generation Cost Based on Presence of Potential Realisation

This section looks at the changes in burden placed on the people of a country when potential is realised and not realised.

The table below contains a cost comparison of generation for the 2014 model from the Long-term Energy Supply and Demand Outlook. Attention must be paid to the fact that assumed capacity factor and operation years differ from those used in this study.

If the potential examined in this study is realised or not, the electricity supply balance will be adjusted by increasing or decreasing thermal power generation. Consequently, the basis of the cost comparison is coal fired or natural-gas-fired power generation.

(1) Nuclear power

Nuclear power costs less to generate than do coal and natural gas. Therefore, if nuclear power generation is not augmented the public burden will increase, and if nuclear power generation is augmented the public burden will be reduced.

(2) Renewable energy

Renewable energy costs more to generate than do coal and natural gas. Therefore, if the potential of renewable energy is realised self-sufficiency will increase, but the public burden will increase as well. In contrast, if the potential of renewable energy is not realised, self-sufficiency will not increase and neither will the public burden.

Table 3.12 Generation Cost Comparison

Fuel	2014 Model Plant			
	Capacity (MW)	Capacity Factor (%)	Operation years (Years)	Generation Cost (Yen/kWh)
Coal	800	70	40	12.3
Natural gas	1,200	70	40	13.7
Nuclear	1,200	70	40	10.1
Hydro (M/S)	0.2	60	40	27.1
Solar (Residential)	0.004	12	20	29.4
Solar (Mega)	2	14	20	24.2
Wind (Onshore)	20	20	20	21.6
Wind (Offshore)	100	30	20	30.3
Biomass	5.7	87	40	29.7
Geothermal	30	83	40	16.9

hydro M/S = hydro medium/small, kWh = kilowatt-hour, MW = megawatt.

Note: Wind (Offshore): 2020 Model.

Source: Long-term Energy Supply and Demand Outlook.

The table below calculates the burden of the people based on whether potential (high case) is realised based on the previous understanding. The basis for this calculation was the median value between coal and natural gas, which was 13.0 yen/kWh. The amount of electric power sold for the calculation of the burden per kWh was assumed to bear an equal burden across the entire electric power consumption sector. The total amount of electric power sold by Japan's 10 electric power companies in 2013 (849 TWh) was used. The basis for the effect on households was the average household electricity tariff for 2013, which was 24.8 yen/kWh.

The cost burden in realising the potential of nuclear power is negative, but this means that the realisation of this potential will mitigate the public burden. The group with the largest effect on households is solar PV (utility scale) and hydro (medium/small) power. The group with the next largest effect is solar PV (rooftop), wind (onshore and offshore), and biomass.

Table 3.13 Public Burden Resulting from the Realisation of Potential

Fuel	Difference in generation cost (Yen/kWh)	Net potential (GWh)	Public burden (billion Yen)	Public burden (Yen/kWh)	Impact for residential
Nuclear	-2.9	103,210	-299	-0.4	-1.4%
Hydro (Medium/Small)	14.1	70,800	998	1.2	4.7%
Solar PV (Rooftop)	16.4	32,200	528	0.6	2.5%
Solar PV (Utility scale)	11.2	95,800	1,073	1.3	5.1%
Wind (Onshore)	8.6	41,500	357	0.4	1.7%
Wind (Offshore)	17.3	23,100	400	0.5	1.9%
Biomass	16.7	19,300	322	0.4	1.5%
Geothermal	3.9	14,800	58	0.1	0.3%

GWh = gigawatt hour, solar PV = solar photovoltaics, Yen/kWh = Yen/kilowatt-hour.

Source: Energy Prices and Taxes Q4 2015, International Energy Agency, The Federation of Electric Power Companies of Japan.

3.6 Conclusion

Nuclear power has the potential to greatly increase self-sufficiency and is also comparatively cost-effective. If Japan wants to increase self-sufficiency that is cost-effective, nuclear power is the best choice.

Excluding the residential sector, energy saving is the method with the highest cost-effectiveness for increasing self-sufficiency. However, when the base year is set as 2013, energy saving will not have a large potential in increasing self-sufficiency.

Japan has geothermal resources. Tapping geothermal energy is highly cost-effective for Japan to increase self-sufficiency. If it were able to fully utilise the potential of geothermal power, Japan would be able to increase self-sufficiency by 2 percent.

Tapping biomass is the second most cost-effective method next to utilising the potential of geothermal energy. Utilising other renewable energy has a higher cost, and from an economic perspective other forms of renewable energy are not recommended. However, renewable energy technology is causing cost to fall rapidly, and biomass can be a competitive choice economically speaking.

3.7 Impact for Carbon Dioxide Emissions

This section calculates the impact of realising the potential of increasing self-sufficiency will have on CO_2 emissions. This study will focus only on power generation because it is difficult to identify energy reduced due to energy saving.

In the case of Japan, the potential for newly developing fossil fuels at present until 2030 is zero. The potential for increasing self-sufficiency depends, in all cases, on non-fossil energy. In other words, the realisation of potential means a decrease in power generation using fossil fuels, which mainly rely on imports. The impact on CO_2 emissions (reduction in the case of Japan) is affected by the extent of the potential. The impact from nuclear power is the largest and its impact on total CO_2 emissions is more than 7 percent.

Table 3.14 Impact for Carbon Dioxide Emissions

Base year: 2013

CO_2 emissions from Fuel Combustion (a)	1,235.06 million tonnes of CO_2
Sector: Main activity producer electricity plants	
CO_2 emission	
Main activity prod. Elec. and heat - coal	263.69 million tonnes of CO_2
Main activity prod. Elec. and heat - gas	172.36 million tonnes of CO_2
Main activity prod. Elec. and heat - oil	78.92 million tonnes of CO_2
total (b)	514.97 million tonnes of CO_2
Power generation	
Main activity prod. Elec. - coal	287,980 GWh
Main activity prod. Elec. - gas	389,222 GWh
Main activity prod. Elec. - oil	118,912 GWh
total (c)	796,114 GWh
CO_2 emission/kWh (d)=(b)/(c)	647 g-CO2/kWh

CO_2 = carbon dioxide, GWh = gigawatt hour, prod. elec. = producer electricity.

Fuel	Net potential (GWh) (e)	Impact for CO_2 emissions (million tonnes) (f)=(c)*(e)	(g)=(f)/(a)
Nuclear	103,210	67	5.4%
Hydro (Medium/Small)	70,800	46	3.7%
Solar PV (Rooftop)	32,200	21	1.7%
Solar PV (Utility scale)	95,800	62	5.0%
Wind (Onshore)	41,500	27	2.2%
Wind (Offshore)	23,100	15	1.2%
Biomass	19,300	12	1.0%
Geothermal	14,800	10	0.8%

CO_2 = carbon dioxide, GWh = gigawatt hour, solar PV = solar photovoltaics.

Source: CO_2 Emissions from Fuel Combustion 2015, International Energy Agency.