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Cost Assessment of Energy Security Improvement in East Asia Summit Region

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This report was prepared by the Working Group (WG) for the 'Cost Assessment of Energy Security Improvement in East Asia Summit Region' under the Economic Research Institute for ASEAN and East Asia (ERIA) Energy Project. Members of the WG, who represent the participating East Asia Summit (EAS) region countries, discussed self-sufficiency improvement measures with cost-effectiveness through a case study. The study is not developed for commercial or business use, but aims to derive policy implications. Therefore, the WG – not its study outcome – is not responsible for any loss caused by using the scenarios.

FOREWORD

Energy security is an indispensable element of energy policy in every East Asia Summit (EAS) country. In 2011–2013, we tried to quantify a change of status of energy security in each country in the past and in the future, and succeeded to derive some useful policy recommendations. In the study, we found that self-sufficiency is declining and is expected to become even worse than it is now in many EAS countries. Therefore, countries need to address this declining trend of self-sufficiency. Policy need to be cost-effective because the available financial resource is limited. In this light, this year we decided to focus on the choice of self-sufficiency improvement measures and their cost-effectiveness. With this analysis, we expect to provide some indication to select a more cost-effective policy option.

It is my hope that the outcome of this study will serve as a point of reference for policymakers in East Asian countries and will contribute to the improvement of energy security in the region as a whole.

Ichiro Kutani
Working Group Leader

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Ichiro Kutani

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LIST OF ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
CO_2	carbon dioxide
EAS	East Asia Summit
ERIA	Economic Research Institute for ASEAN and East Asia
IEA	International Energy Agency
IEEJ	The Institute for Energy Economics, Japan
MAFF	Ministry of Agriculture, Forestry and Fisheries, Government of Japan
METI	Ministry of Economy, Trade and Industry, Government of Japan
PV	photovoltaics
TPES	total primary energy supply
WG	Working Group

Chapter 1

Introduction

1.1 Background and Objective of the Study

Energy security is a central pillar energy policy in all East Asia Summit (EAS) countries. Self-sufficiency of energy supply forms the basis of energy security, and there are many policy options to improve it. Enhanced oil production, increased use of domestically available renewable energy, and improved energy efficiency are examples of effective policies.

Meanwhile, the government is requested to utilise its tax income in an economically effective manner. Since each policy option has different costs and effects, a careful assessment is required before choosing policies to gain the maximum utility under the limited budget.

This study will try to assess the cost and effect of different policy options, and compare them with each other to provide an indication for more economically effective policy options. This assessment is expected to help policymakers choose better policy options to improve the self-sufficiency of energy supply for the country's energy security.

1.2 Study Method

1.2.1 Study method and work stream

Based on the achievements of the Energy Security Index study since 2011, we decided to extend and deepen the study on energy security of the region in the following manner.

(A) Reassessment of the energy security situation in the region

Since possible policy options and their cost and effect naturally differ in each country, we will select one or two countries as subject of the study. Data availability is one of the important elements that shall be considered in this process.

(B) Development of an assessment method

The study will identify the assessment method of the cost and effect of policy options.

Index: 1 percent improvement of self-sufficiency

Policy options: to increase fossil fuel production
to increase renewable energy production
to increase nuclear power generation
to improve energy efficiency

(C) Cost and benefit assessment

A survey will be conducted to collect the necessary information. The cost and effect of each policy option will be assessed and described in a chart to make comparisons easier.

(D) Derivation of policy recommendations

The study will analyse the results to derive policy recommendations.

1.2.2 Country coverage

Policy implications will cover all ERIA member countries, but assessment work will be conducted only for one or two selected countries.

1.2.3 Working Group

To conduct the above-mentioned study, the Working Group (WG) was organised and a meeting was held. The WG consists of experts from the region and a research team from The Institute of Energy Economics, Japan (IEEJ) as the secretariat. The study outcome will be discussed and shared in the WG meeting.

1.3 Focus of FY2015 Study: Self-sufficiency

(A) Why focus on self-sufficiency?

Methods for improving energy security vary by country because of various restrictions and constraints.

(a) Natural resource endowment (fossil fuel, water, geothermal, wind, solar, etc.)
(b) Geographical constraints (unused land, flat land, national parks, etc.)
(c) Environmental consideration
(d) Policy restrictions

In 2011, the ERIA WG developed the Energy Security Index for assessing conditions of energy security quantitatively. The resulting index is presented below.

Table 1.1 Developed Energy Security Index in 2011

Components	Assessment Item	Index
Development of domestic resources	1. Self-sufficiency	1.1 TPES self-sufficiency ratio (including nuclear) 1.2 Reserve and production ratio 1.3 Reserve and consumption ratio
Acquisition of overseas resources	2. Diversity of import partner	2. Diversity of import partner for oil, gas, and coal
	3. Diversity of energy use	3. Diversity of energy use in TPES and electricity
	4. Dependence on Middle East	4. Dependence on Middle East for oil and gas
Transportation risk management	-	-
Development of reliable domestic supply chain	5.1 Reliability of energy supply	5.1.1 Reserve margin of generation capacity 5.1.2 Power outage frequency and duration
	5.2 Build supply infrastructure	5.2 Commercial energy access ratio
Demand management	6. Energy efficiency	6.1 TPES per GDP 6.2 TFEC per GDP
Readiness for supply disruptions	7. Strategic reserves	7. Days of on-land oil stocks
Environmental sustainability	8. CO_2 intensity	8.1 CO_2 emissions per TPES 8.2 CO_2 emissions per fossil fuel 8.3 CO_2 emissions per GDP 8.4 CO_2 emissions per capita

CO_2 = carbon dioxide, GDP = gross domestic product, TFEC = total final energy consumption, TPES = total primary energy supply.
Source: Economic Research Institute for ASEAN and East Asia Research Project Report 2011, No.13.

Among these indicators, for 2015 the focus was drawn to self-sufficiency from three vantage points.

(A) Self-sufficiency is a comprehensive indicator

Self-sufficiency is a comprehensive indicator that combines fossil fuel production (coal, oil, and natural gas); nuclear power generation; renewable energy use (hydro, geothermal, wind, solar, and others); diversity of total primary energy supply (TPES); diversity of power generation fuel; and energy efficiency.

Therefore, optimal measures to improve self-sufficiency are different among countries because of their unique conditions, such as endowment of natural resources and constraint in land use. In other words, a country can improve self-sufficiency by taking the approach most suited to its situation based on the presence of natural resources and methods of energy use.

(B) Worsening self-sufficiency is a trend in most countries

The following table presents self-sufficiency trends in the past and the outlook for self-sufficiency in the future. In most countries, especially developing countries in the Association of Southeast Asian Nations (ASEAN), self-sufficiency is declining and is expected to become even worse than it is now. This indicates that in developing countries in the ASEAN, the speed of increasing fossil fuel production cannot keep pace with that of increasing energy demand. Avoiding a drop in self-sufficiency is needed to reinforce energy security in the entire EAS region. Measures to address this are much anticipated.

Table 1.2 Self-sufficiency in the Past and Future Outlook

Country	Actual (IEA)					Estimation	
	1970s	1980s	1990s	2000s-1	2000s-2	2020	2035*
Australia	120%	162%	196%	232%	254%	377%	444%
Brunei	2186%	1089%	796%	837%	624%	721%	619%
Cambodia	-	-	83%	80%	16%	11%	12%
China	102%	105%	101%	97%	92%	62%	53%
India	92%	94%	87%	80%	67%	38%	32%
Indonesia	234%	194%	164%	151%	195%	126%	121%
Japan	11%	17%	19%	19%	18%	17%	12%
Korea	29%	27%	17%	19%	20%	18%	19%
Laos	-	-	92%	99%	80%	158%	100%
Malaysia	121%	206%	183%	155%	134%	85%	53%
Myanmar	98%	101%	98%	135%	235%	248%	209%
New Zealand	56%	79%	88%	81%	83%	79%	81%
Philippines	47%	62%	50%	51%	52%	51%	39%
Singapore	0%	0%	0%	0%	0%	0%	1%
Thailand	55%	62%	59%	57%	55%	29%	21%
Vietnam	91%	94%	116%	130%	145%	81%	48%
OECD Total	67%	77%	75%	72%	71%	-	-
ERIA Total	79%	87%	84%	84%	85%	63%	-

Note: * Indonesia, Malaysia, Myanmar: 2030; New Zealand: 2025.

Source: Economic Research Institute for ASEAN and East Asia (ERIA) Research Project Report 2011 and 2013.

(C) Data availability

Data on self-sufficiency can easily be obtained from International Energy Agency (IEA) statistics. Self-sufficiency is easy to use as an indicator for cross-cutting assessments.

1.4 Working Group Activities in FY2015

To conduct the above-mentioned study, the WG was organised. It consists of experts from the region and a research team from IEEJ as the secretariat.

In FY2015, the WG meeting was held one time in March 2016 in Bangkok, Thailand.

First, the meeting explained the study, which was followed by an interim report on case studies targeting Japan and Thailand and an accompanying discussion on the report.

In terms of assessment method, two major views were shared. First is the consideration for an effective and outside method of expression. For example, it was pointed out that if the cost of improving self-sufficiency could be expressed as the increased portion of electricity tariffs, it could make self-sufficiency easier to understand and could provide a stronger impression among policymakers and politicians. Second is the relationship between climate change and energy issues. This analysis narrows the focus on self-sufficiency, but climate change and energy issues are almost inseparable. It was pointed out that each choice aimed at improving self-sufficiency could be analysed for its impact on carbon dioxide (CO_2) emissions.

By energy type, the WG participants pointed out issues with fossil fuels and nuclear power. Developing fossil fuel resources domestically is an economically viable choice as regards increasing self-sufficiency rate. However, in some cases social acceptance could pose a problem to the development of fossil fuel resources, thus careful consideration is necessary. The massive environmental changes before and after the nuclear accident at the Fukushima Daiichi Nuclear Power Plant were ascribed to nuclear power. This, too, represents a problem related to social acceptance.

In addition to these, another important perspective was provided at the WG meeting. It is the examination of self-sufficiency for the entire region instead of an individual country. Self-sufficiency is an issue related to the security of a country, including its military affairs. Therefore, a general approach is essentially for an individual country to strive to increase its self-sufficiency. However, as seen from the example of the European Union, assuming a regional community that encompasses security issues, the conventional understanding of energy security and approaches to realising energy security can be interpreted differently. That is, importing energy is deemed a risk for the importer but not energy trade among countries comprising a community. Therefore, it is possible to assess self-sufficiency and energy security of an entire regional community. This philosophy matches perfectly with the concept of the ASEAN Economic Community established in December 2015 and represents an ideal approach for this region.

Chapter 2

Methodology of Analysis

2.1 Definition of Self-sufficiency

In this section, self-sufficiency, through analysis, will be defined. This research defines self-sufficiency as the increase as a result of a decrease in TPES or an increase in indigenous production.

Indigenous production represents the following energies.

Table 2.1 Component of Indigenous Production

Fossil fuel	
	Coal, lignite
	Crude oil including unconventional oil
	Natural gas including unconventional natural gas (tight or shale, CBM, methane hydrate)
Nuclear power generation*	
Renewable power generation	
	Wind (onshore, offshore)
	Geothermal
	Hydro (large, medium, small)
	Biomass, biogas, wastes, other biofuel
	Solar (rooftop PV, utility scale PV, solar thermal)
Biofuel (other than power generation)	
	Biomass
	Biogas
	Bioethanol
	Biodiesel
	Bio jet fuel

* Nuclear energy is regarded as quasi-indigenous production in this study.

CBM = coalbed methane, rooftop PV = rooftop photovoltaics.

Source: Study team.

On the other hand, energy efficiency improvement is a method for reducing TPES.

2.2 Definition of Energy Resource Potential

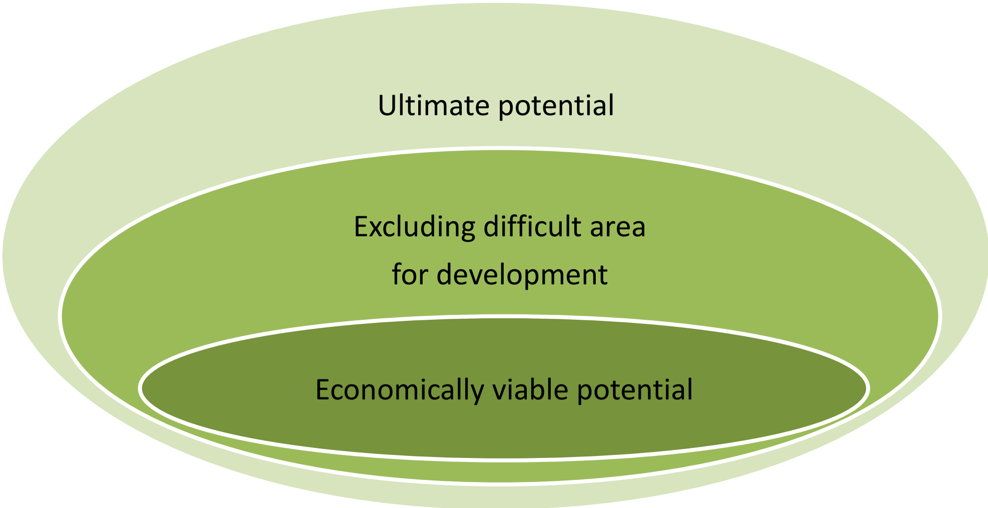
In conducting a study, the potential of energy resources must be defined.

Potential can be largely separated into three forms per the figure below: (1) 'Ultimate potential' is a form of potential calculated based on a country's land area, discharge of rivers, wind speed, sunlight, and among other factors; (2) 'Excluding difficult areas' is a form of potential excluding areas difficult for development from ultimate potential due to natural impediments, such as steep slopes, laws, policy, and environmental issues; and (3) 'Economically viable potential' is a form of potential for which economic viability is expected up to 2030 from among those excluding difficult areas.

Cost is an important element for increasing energy security. This is because even if a certain method can greatly increase energy security, if the cost is too high then increasing energy security is not realistic. The purpose of this study is to examine choices for increasing self-sufficiency based on both potential and cost. In this aspect, cost cannot be disregarded.

In the case of ultimate potential and excluding difficult areas, it is difficult to assess cost or they are expected to lack economic rationalities. Therefore, this study focuses on economically viable potential for which cost assessment is possible and for which there is a high probability that cost is within a reasonable range.

Figure 2.1 Definition of Potential in the Study



Source: Study team.

2.3 Case Study

The method used to increase self-sufficiency will vary by country depending on accessibility to natural resources, the presence of usable land, and the cost burden capacity of its people. Therefore, the relationship between cost and quantitative potential of the method for increasing self-sufficiency will differ by country. The following elements were considered in the selection of the target country for the case study.

(A) Data availability

In order to carry out this study, data on the cost and quantitative potential of each energy resource are necessary.

(B) Fossil fuel resources

Fossil fuel resources are heavily influenced by a country's energy mix. They also have an effect on the priority ranking for increasing self-sufficiency. For the case study, selecting a country where the development of fossil fuel resources is active and one where it is not will make comparison easier.

(C) National plan

The energy outlook or natural resources development plan formulated by a national government is an important source of information for conducting this study.

Considering the above elements, Japan was selected as a case study. It has huge publicly available data. The Government of Japan draws up its Long-term Energy Supply and Demand Outlook every 3 years, the most recent of which was published in July 2015. Also, it publishes detailed power generation cost analysis through the Procurement Price Calculation Committee and Power Generation Cost Verification Working Group. Although Japan has limited fossil fuel resources, it has an active development of fossil fuel resources, available data, and a national plan.

2.4 Data Source

Important data sources for conducting this study are presented below.

2.4.1 Potential

Self-sufficiency Improving Measures	Data Source
Fossil fuel production	- Hearing from experts
Nuclear power generation	- Long-term Energy Supply and Demand Outlook, METI - Asia and World Energy Outlook, IEEJ - Estimation by study team
Renewable power generation	- Study by the Ministry of the Environment
Biofuel production	- Hearing from experts - Biomass utilisation promotion Committee, MAFF
Energy saving	- Long-term Energy Supply and Demand Outlook, METI

IEEJ = The Institute of Energy Economics, Japan; MAFF = Ministry of Agriculture, Forestry and Fisheries, Government of Japan; METI = Ministry of Economy, Trade and Industry, Government of Japan.

2.4.2 Cost

Self-sufficiency Improving Measures	Data Source
Fossil fuel production	-
Power generation	- Report of power generation cost Verification Working Group
Biofuel production	-
Energy saving	- Long-term Energy Supply and Demand Outlook, METI

METI = Ministry of Economy, Trade and Industry, Government of Japan.

2.5 Base Year and Target Year

The base year of the assessment is set as 2013 and the assessment period up to 2030.

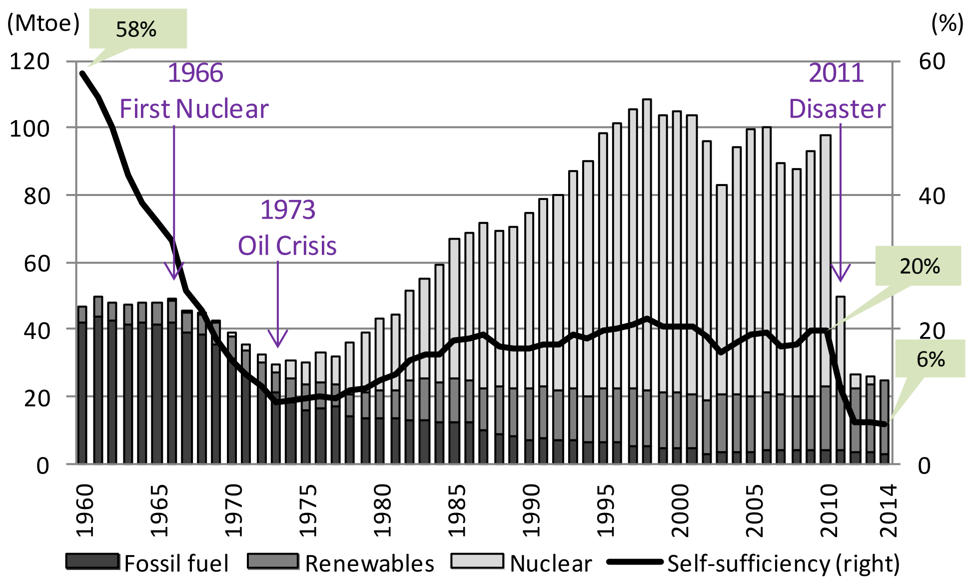
Chapter 3

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.

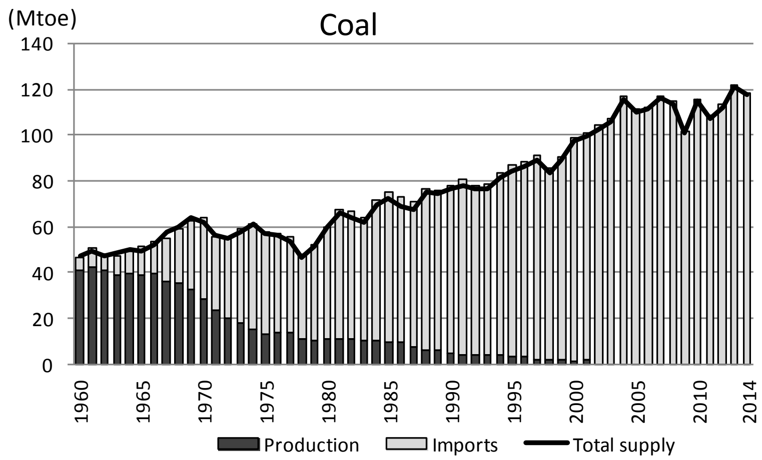
3.2 Quantitative Potential of Increasing Self-sufficiency

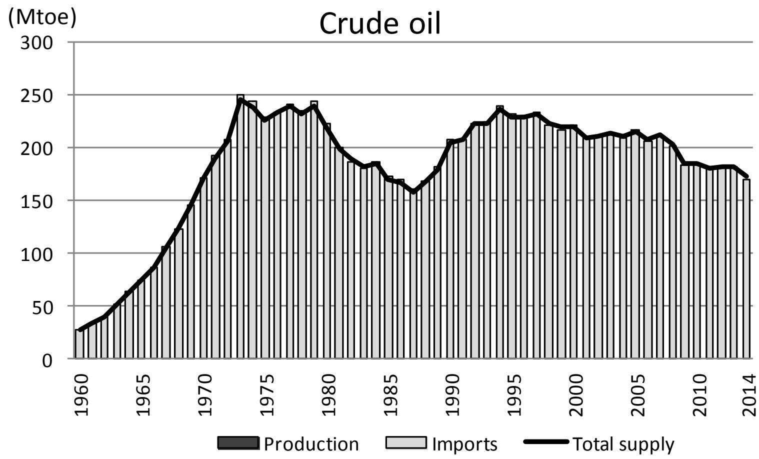
The quantitative potential of increasing self-sufficiency is assessed according to fossil fuel production, nuclear power generation, renewable power generation, and energy conservation and efficiency or energy savings.

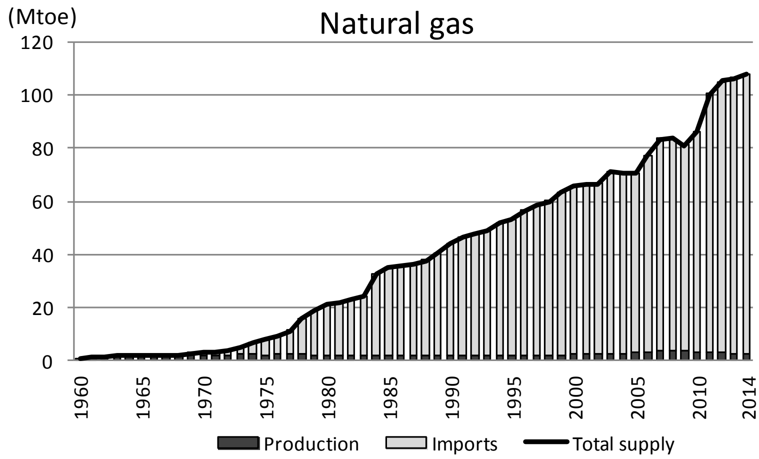
3.2.1 Fossil fuel production

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.

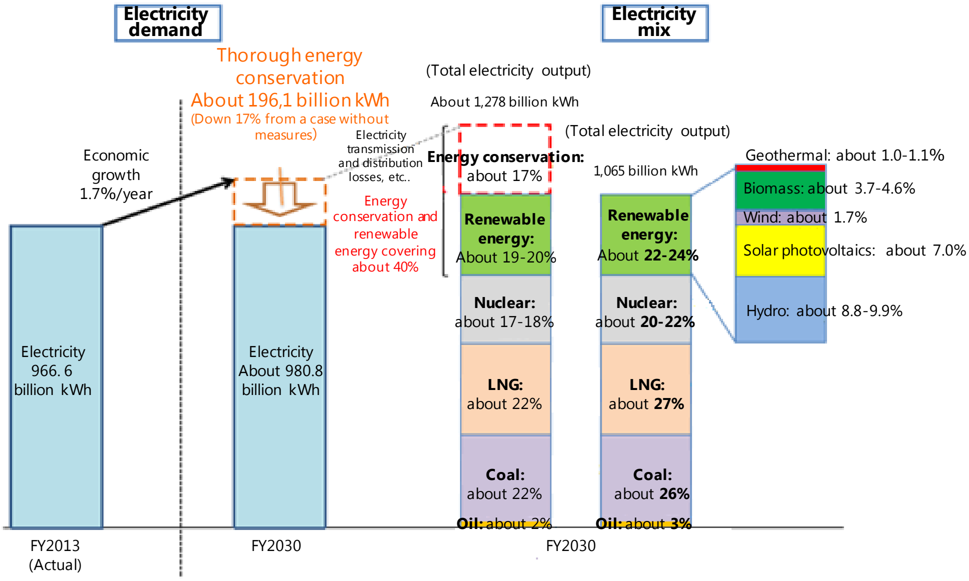
The following table indicates the potential of Japan's nuclear power generation in 2030.

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.

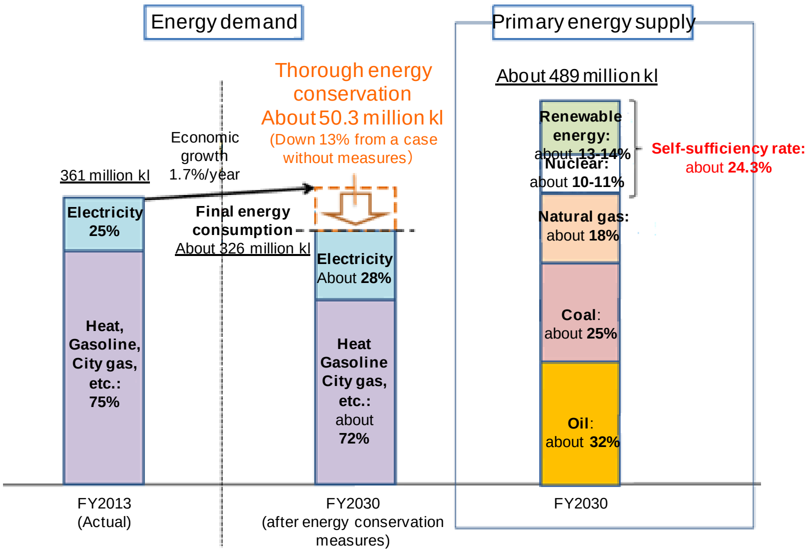
3.2.6 Energy conservation and efficiency

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)

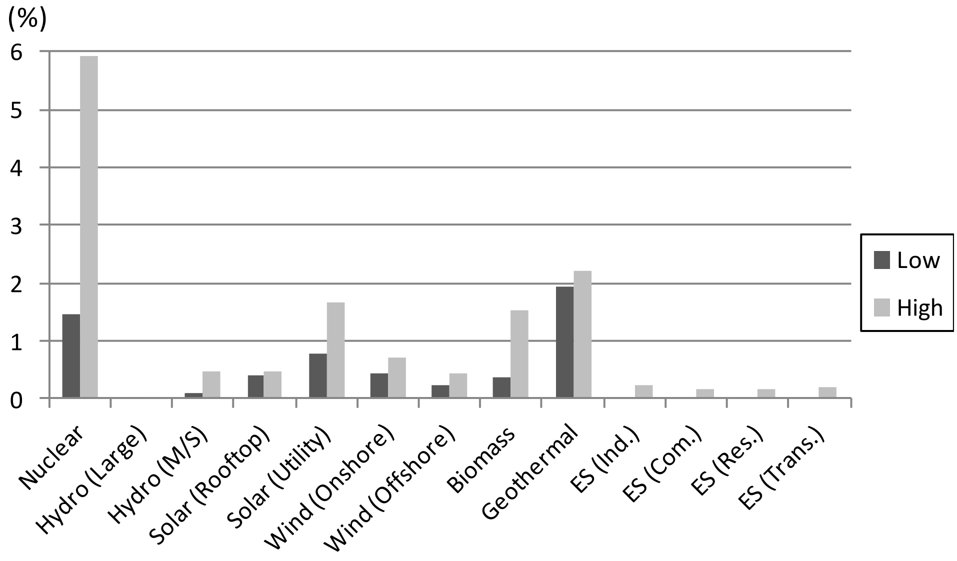
Base year: 2013	
Total indigenous production	27,958 ktoe
Total primary energy supply	454,655 ktoe
Self-sufficiency	6.1 %

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.

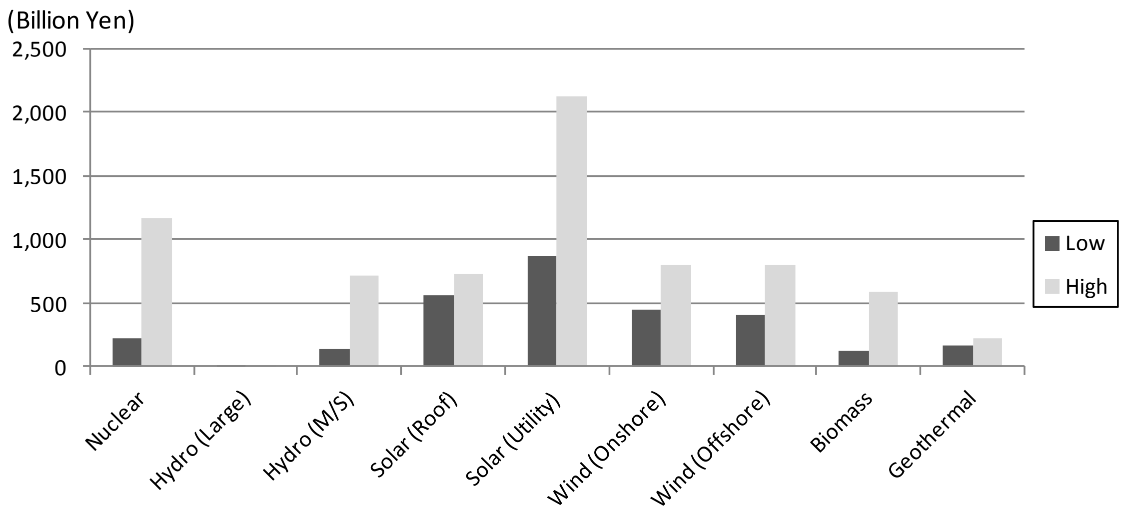
The table below indicates the total amount of the generation cost for each generation fuel. The total amount was calculated by multiplying net potential by generation cost (yen/kWh).

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).

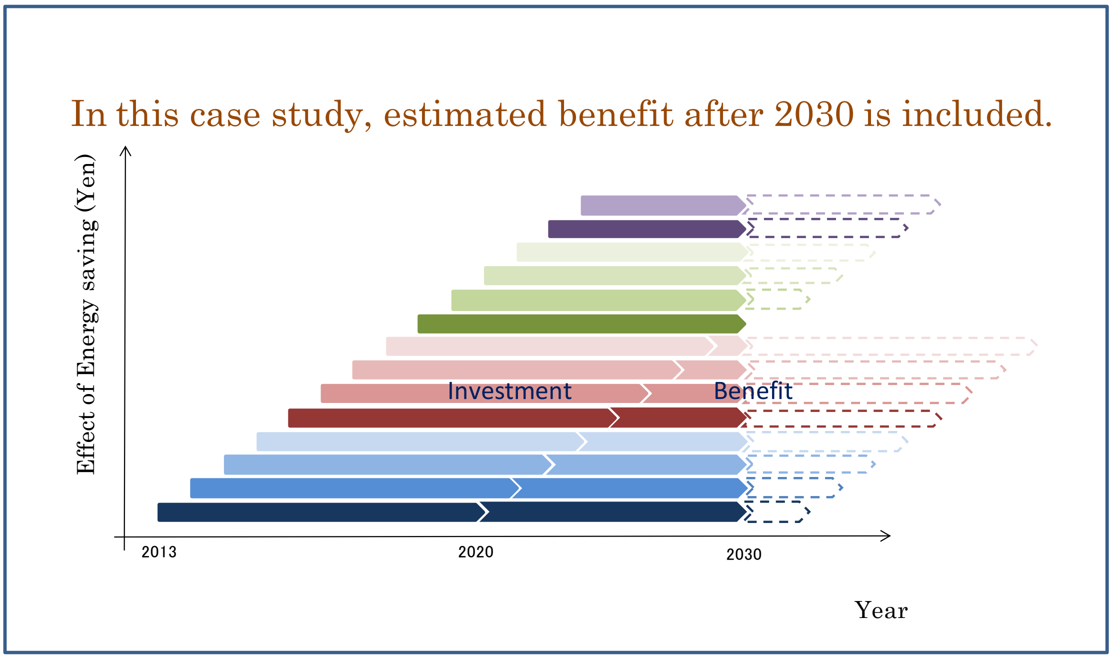
Source: Study team.

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.

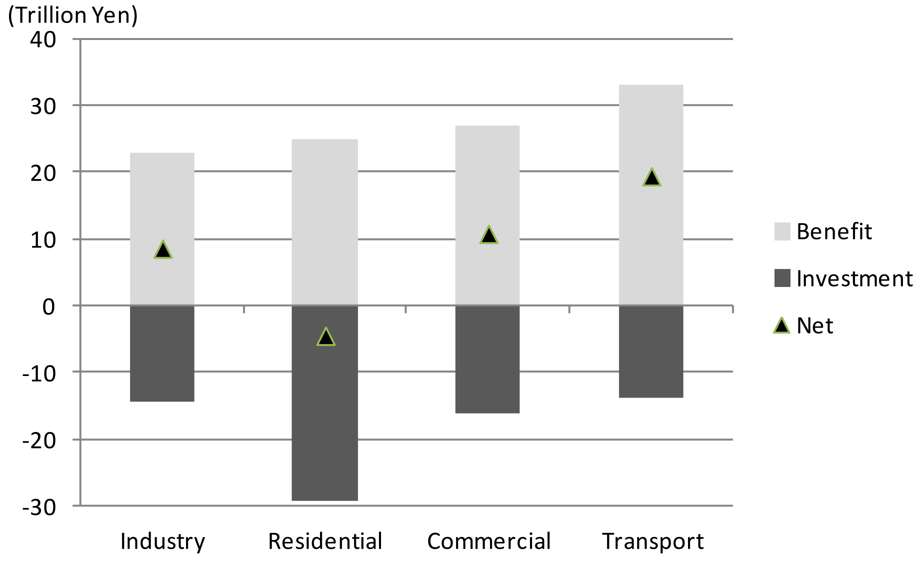
Table 3.10 Investment and Benefit by Sector

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.

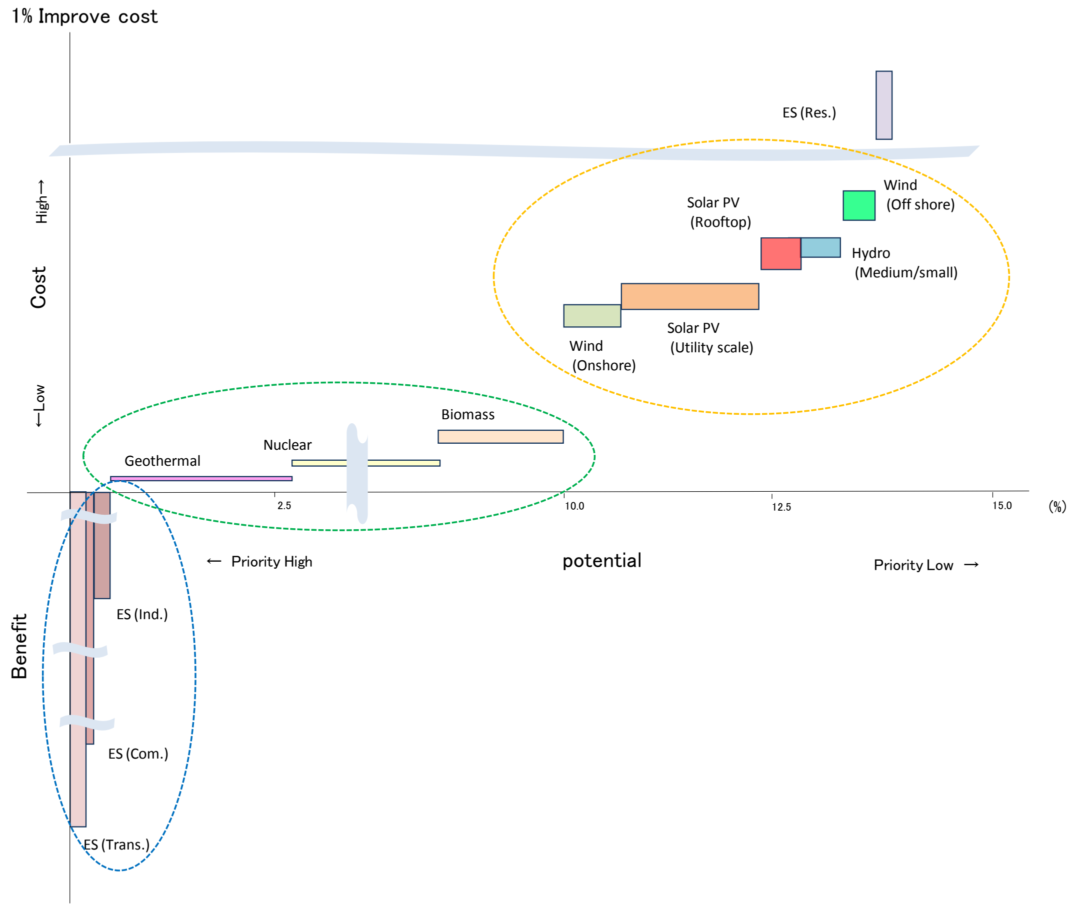
Source: Study team.

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.

Chapter 4

Policy Recommendation

4.1 Self-sufficiency Measures

The most appropriate method for a country to improve its self-sufficiency depends on the country's existing resources, level of economic development, available usable land, and the ability of the public to bear costs. Generally speaking, countries with rich fossil fuel resources will increase their fossil fuel production; countries rich in hydro resources will capitalise on their hydro resources; and agricultural countries or those with extensive undeveloped lands will increase biofuel (power generation and direct use) production. Utilising nuclear energy is also an effective method.

Among the many different methods to improve a country's self-sufficiency, energy efficiency and conservation (energy saving) are common for all countries.

The figure below shows primary energy supply per gross domestic product, one of the indices of energy-use efficiency. Many EAS countries have a figure above the Organisation for Economic Co-operation Development average (poor efficiency), inferring a high potential for energy saving. In the case study for Japan, while energy saving plays a limited role in improving self-sufficiency, it still has many benefits with the potential to reduce TPES by 10 percent or more versus the business-as-usual scenario (BAU). This validates that even though Japan has already achieved high energy efficiency, with the implementation of a powerful energy saving policy, potential can still be achieved.

There are methods that require large amount of investment to realise the energy saving potential. However, energy saving can be achieved also by modifying the energy consumption habit. For this reason, the promotion of the right mindset and sustained education among citizens are crucial.

Table 4.1 Total Primary Energy Supply per Gross Domestic Product

Country	1970s	1980s	1990s	2000s-1	2000s-2
Australia	0.321	0.299	0.280	0.250	0.243
Brunei	0.165	0.313	0.402	0.382	0.483
Cambodia	-	-	1.158	0.879	0.665
China	3.676	2.348	1.307	0.877	0.800
India	1.322	1.248	1.102	0.913	0.776
Indonesia	1.053	0.878	0.871	0.912	0.803
Japan	0.146	0.114	0.109	0.108	0.099
Korea	0.331	0.317	0.348	0.333	0.304
Lao	-	-	1.096	0.897	0.844
Malaysia	0.417	0.463	0.492	0.514	0.511
Myanmar	2.797	2.270	1.958	1.114	0.827
New Zealand	0.269	0.287	0.328	0.286	0.255
Philippines	0.509	0.498	0.535	0.470	0.363
Singapore	0.266	0.222	0.275	0.192	0.124
Thailand	0.658	0.517	0.542	0.612	0.593
Vietnam	2.178	1.911	1.369	1.168	1.074
OECD Average	0.299	0.247	0.217	0.196	0.180
ERIA Total	0.413	0.366	0.356	0.359	0.379

Note: 2000s-1: 2000–2006, 2000s-2: 2007–2009
ERIA = Economic Research Institute for ASEAN and East Asia, OECD = Organisation for Economic Co-operation and Development.
Source: ERIA Research Project Report 2011, No.13.

4.2 Challenges for Improving Self-sufficiency

4.2.1 Assessment of cost-effective potential

The assessment of cost is necessary to evaluate the potential for self-sufficiency improvement in a cost-effective manner. In the case of fossil fuel, market price should be considered in addition to research and production costs. The cost of electric power generation can be estimated using the generation cost calculation sheets created by the Government of Japan. This can be used to calculate cost for work done in Japan using the highest cost scenario and cost appropriate for other countries by modifying cost elements.

It must be noted, however, that although something may be cost-effective, still there will be an increased public burden except in the case of energy-efficiency improvement. Each country has a different cost-bearing capacity. It is essential to choose a method suitable for a country’s current conditions.

In the case study for energy saving in Japan, potential and cost were calculated as a sum of each method. While it is a possible approach for Japan, a country with extensive experience in energy saving, it is not for countries with little or no experience in energy saving, thus, calculation of potential and cost should be addressed first.

4.2.2 Balance between energy mix and carbon dioxide emissions

This study evaluated methods for improving self-sufficiency from an economic standpoint. While economy is one of the three pillars of energy policy, the other two perspectives, namely, energy security and environmental sustainability, were omitted from this evaluation. Based on the standpoint of energy security, sometimes it is necessary to choose an energy source outside of economic consideration since emphasis is put on the balanced use of various energies. The same is true from the perspective of environmental sustainability. Although economic rationality is an important factor, decisions cannot be based on it alone. The actual implementation of policies may take careful consideration to balance the three pillars – economy, energy security, and environmental sustainability.

4.2.3 Balancing cost of electricity supply

Renewable energy is a desirable form of energy that contributes to improving self-sufficiency since it is carbon neutral, environmental friendly, and does not lead to CO_2 emissions. However, power generation technologies, such as solar and wind, that are subject to weather conditions have the issue of output intermittency. When such power-generated technology flows into the grid in bulk, the unstable voltage and frequency will damage the stability of the grid. As a result, it becomes necessary to spend additional investment on stabilising the grid, such as installing backup thermal power or storage batteries. However, it is not clear what these additional costs aimed at system stability are, and thus they were omitted from the calculation. We hope to see an incorporation of balancing cost when evaluating the cost of solar and wind energy.

4.2.4 Public acceptance

Even if there is cost-effective potential, the people living in areas where fossil fuel is developed or where power generation plants are constructed will oppose such potential because of environmental destruction, which can delay or suspend the project. To avoid this, measures to prevent air and water pollution and soil contamination need to be implemented and a positive relationship with the local community established. Also, the government has to implement measures that provide incentives to the local community. As for nuclear power, the public mindset has changed since the nuclear accident at the Fukushima Daiichi Nuclear Power Plant, realising its potential.

4.3 Self-sufficiency by Region

There are many factors to consider as regards self-sufficiency on a country-by- country basis, such as natural resources and economic development, which limit the choices for increasing self-sufficiency. On the other hand, the number of choices expands when considering self-sufficiency from a regional perspective.

In some countries, energy access, such as electrification, takes priority over self-sufficiency. In such cases, it may be easier to achieve energy access targets by implementing measures on a regional scale instead of within a country.

It is essential that countries have trusting relationships with one another. Thus, the first step is to maintain positive bilateral relationships. For example, if a neighbouring country is fully trustworthy, energy imports from that country will not pose risks to the importer because these imports can be deemed roughly the same as domestic resources. In the Mekong Region, there is a movement to proactively utilise the abundant hydroelectric resources found in Lao PDR. If sufficient trust is found among neighbouring countries, there will be no risk of imports from energy trade with Lao PDR, and hydroelectric power will be a beneficial choice for contributing to the self-sufficiency improvement of the entire region.

Considering regional self-sufficiency under such a situation will result in new energy exports and imports between countries or an increase in such. Therefore, infrastructure to support exports and imports, such as distribution lines and pipelines, is essential.

4.4 Implication for Each Country

The WG deliberated and shared the implication for each of the EAS countries based on the results, which are presented below.

Country	Implication
Cambodia	• Cambodia has potential for coal and hydro energy. In the rural areas, there is potential for renewables. • Hydro energy has the highest potential and the lowest cost. There is potential for solar energy. • Coal-fired power plants are necessary to complement hydro energy in the dry season. • Cambodia has a plan to provide all villages with electricity generated by hydro or coal-fired power plants by 2020. The current electrification rate is 62 percent, and the government aims to boost this to 70 percent by 2030.
China	• China aims to decrease its coal consumption. This is being done as an environmental measure and takes priority over economic benefit. Coal currently accounts for 68 percent of TPES, but the 13th Five-Year Plan commencing in 2016 aims to bring this down to 66 percent by 2017 and under 60 percent by 2020. • One short-term initiative is to increase the usage of natural gas. The share of natural gas currently stands at 5.8 percent, but the government aims to boost this to 10 percent by 2020. • One long-term initiative is to develop renewable energy in the form of smart energy (i.e. internet-connected solar and hydro energy). Infrastructure has to be developed for solar and wind. • China will strengthen its distributed energy and distributed energy storage systems to increase the usage of clean energy. • In terms of energy efficiency, it aims to build green buildings using smart monitoring technology by 2020. In the transportation sector, the government will promote the usage of electric vehicles. It will also

		improve energy-use behaviour.
	•	The self-sufficiency rate currently stands at 90.7 percent, but this is expected to drop to 85 percent by 2030, so China is preparing for this decreased self-sufficiency.
	•	The cost elements are currently being examined.
India	•	India has to start by compiling data that can be used to assess the security situation.
	•	It has to take an all-South Asia approach, which includes cooperation with the ASEAN.
	•	Regarding energy demand, price sensitivity is high so the focus is on the impact that lower oil prices will have on energy efficiency.
	•	Energy intensity is high in the industrial and public sectors.
	•	India has set goals for renewable energy, one of which is to achieve 40 GW of rooftop solar.
	•	There is significant potential for hydro energy. There is also a large-scale pumped storage power project underway, but it is making little headway.
	•	Demand-side energy efficiency is particularly important in the transport sector.
Indonesia	•	Energy security is being discussed by the Dewan Energi Nasional; the development of energy resources, better usage of domestic energy, and effective energy usage are some of the measures that have been raised by the council.
	•	From the standpoint of energy security coal is vital, but discussions are ongoing with regard to the balance between coal usage and CO_2 emissions.
	•	Indonesia faces a dilemma: development would progress if it boosted the margins of the contractors in the production-sharing agreement (15 percent for coal and 30 percent for gas), but that would also increase costs.
Korea	•	The situation in Korea is similar to that in Japan.

	• To improve self-sufficiency, Korea must boost the shares of both nuclear and renewable energy and increase energy efficiency. • Nuclear energy is the cheapest in Korea.
Lao PDR	• Lao PDR plans to develop competitive sustainable energy by 2030 to become the 'battery' of the ASEAN. • The total potential for hydro power is 26,000 MW, but this is not enough for the entire region. • The development and usage of hydro energy in Lao PDR can help reduce the ASEAN-wide CO_2 emissions, so a regional block approach will be suitable.
Malaysia	• Malaysia is trying to reduce its dependence on coal. The government plans to build three or four natural gas-fired power plants. • It has to review potential power importation from Bakun Hydro, Sarawak, East Malaysia, as a long-term option since Sarawak has hydro power potential of more than 20,000 MW. • It has a lot of waste, biomass, biogas, and geothermal power which can be converted into renewable energy. • There is potential to build a power plant using biomass, but most palm oil mills are located in remote areas and facing difficulty obtaining long-term fuel (empty fruit bunches) as a source of fuel for renewable energy power generation. • The long-term plan is to promote the ASEAN Power Grid interconnection and conduct a bilateral agreement with neighbouring countries, such as Singapore, Thailand, and Indonesia, for power import or export and natural gas export to other ASEAN countries for gas usage optimisation.
Myanmar	• Oil production is on the decline, so priority has been placed on oil and natural gas development and domestic supply. • Potential for hydro energy is high, but it will take time to achieve. • There is a plan to interconnect the power grids of Myanmar and Lao PDR.

Philippines	•	There is potential for coal, oil, natural gas, and renewable energy in the Philippines. However, if dependence on coal rises, so will CO_2 emissions.
	•	To boost self-sufficiency, the fuel mix in the power generation sector must be taken into consideration.
	•	In the Philippines, energy access is more important than self-sufficiency.
	•	The Philippines has formulated a long-term energy plan.
	•	Incentives targeting the local communities are necessary to develop renewable energy.
Singapore	•	Coal produces a large amount of CO_2 emission, but this can be offset by biomass.
	•	To expand renewable energy, it is important to gain acceptance from the local communities, and communication is essential.
	•	It is important to recognise that intra-regional transactions do not threaten the security of the home country.
Thailand	•	Thailand has offshore oil and natural gas and is developing and using lignite inland.
	•	Increasing and developing the reserves of these resources represent an important part of Thailand's energy policy.
Viet Nam	•	Diversification of domestic resources for power generation is necessary.
	•	The share of renewable energy in the power sector is 10 percent.
	•	There is need for development of thermal power plants with appropriate rate, consistent with the supply and distribution of fuel. - Prioritise use of domestic coal to develop coal power plants in the North. - Build and put power plants using import coal for the South, due to the limitation in domestic coal production. - Develop power plants using liquefied natural gas to diversify fuel sources for electricity production.

- There is need to develop nuclear power plants to ensure stable power supply since the primary sources of domestic energy will be depleted.
- As regards import and export of electricity, Viet Nam has to implement efficient power exchange with the countries in the region (ASEAN and Greater Mekong Subregion).
- There is need to improve efficiency in energy use and energy conservation.

Annex 1 Energy Saving Measures in Japan
Industry and transformation sector

Sub-sector	Energy efficiency/conservation measure	Actual	Introduction/ prevention prediction	Energy savings (thousand kL)	items	
		FY2012	FY2030	FY2030	of which, electricity	of which, fuel
Iron and steel	Improving efficiency of electricity consuming equipments		3% improving electricity consumption per produced crude steel compared to 2005	430	430	
	Increment of using waste plastics	Used waste plastics 420 tons	Used waste plastics 1,000 tons	494		
	Introducing next generation coke-making technology	1 unit	9 units	416		360
	Improving heat efficiency of power generation	Joint thermal power: 16% Own generation: 14%	Joint thermal power: 84% Own generation: 82%	403		
	Increment of energy efficient equipments	For example, Low pressure loss TRT: 82% High efficiency CDQ: 93% Recovry of low pressure steam: 95%	100%	808		
	Introducing innovative iron making process (ferro coke)	0 unit	1 unit	194		194
	Introducing of environtally frendly steel making process (COURSE50)	0 unit	1 unit	54		
	Sub-total (Iron and steel)			2,799	430	554
Chemical	Introducing energy saving technologies in petrochumical	36%	100%	71		71
	Introducing energy saving technologies other than petrochumical	Caustic soda and steam generation equimpents: 20% Other chemical: 40%	100% 100%	597	88	436
	Introducing efficient distillation process technology using film	0%	4%	124		124
	Introducing CO2 raw-materialization technology	0 unit	1 unit	5		5
	Introducing chemical products producing technologies using inedible plants as feedstock	0 unit	1 unit	29		29
	Introducing waste-water treatment system generating electricity by microbial catalysts	0%	10%	14	14	
	Introducing sealed plant factories	0%	20%	54	54	
	Sub-total (Chemical)			894	156	665

Sub-sector	Energy efficiency/conservation measure	Actual	Introduction/ prevention prediction	Energy savings (thousand kL)	items	
		FY2012	FY2030	FY2030	of which, electricity	of which, fuel
Ceramics, stone and clay products	Introducing conventional energy saving technologies, ie Waste heat power generation, Slag grinding, Air beam cooler, Improving separator, Virtical coal mill			21	8	13
	Introducing heat energy subsutitution wastes use technologies	Heat energy substitution wastes 1,600 thousand tons	Heat energy substitution wastes 1,680 thousand tons	13	-1	14
	Intyroducing innovative cement producing technologies	0%	50%	151		151
	Introducing galss melting process	0%	5.40%	50	-6	56
	Sub-total (Ceramics, stone and clay products)			235	1	234
Paper and pulp	Introducing high efficient waste paper pulp producing technologies	11%	40%	36	36	
	Introducing high-temperature and high-pressure type black liquor recovery boiler	49%	69%	59		
	Sub-total (Paper and pulp)			95	36	0
Oil refinery	Promotion of effective use of heat Introducing sophisticated control system and high efficient equipments Improving efficiency of power system Large scale process improvement and sophistication	23%	10%	770		
Cross sub-sector, other sector	Introducing high efficient air conditioning			290	155	135
	Introducing industrial heat pump (for heating and drying)	0%	9.30%	879	-199	1,078
	Introducing industrial lighting	6%	almost 100%	1,080	1,080	
	Introducing low carbon industrial furnace	24%	46%	2,906	708	2,198
	Introducing industrial motor	0%	47%	1,660	1,660	
	Introducing high efficient boiler	14%	71%	1,733		
	Introducing co-generation	50.3TWh	103.0TWh	3,022		
	Direct use of recycled plastic flake			22		22
	Introducing hybrid construction equipments	2%	32%	160		160
	Introduction of energy efficient agricultural equipments	150 thousand units	450 thousand unit	1		1
	Introducing energy efficient equipments in greenhouse horticulture	50 thousand units, 80 thousand sites	170 thousand units, 350 thousand sites	513		513
	Conversion to energy efficient fishing boats	11%	29%	61		61
	Promoting energy efficiency cooperation between different businesses			100	20	80
	Sub-total (cross sub-sector)			12,427	3,424	4,248
Plant management	Implemantation of complete energy management in industry sector	4%	23%	672	223	449
Total				17,892	4,270	6,150

Commercial sector

Sub-sector	Energy efficiency/conservation measure	Actual	Introduction/ prevention prediction	Energy savings (thausand kL)	items	
		FY2012	FY2030	FY2030	of which, electricity	of which, fuel
Building	Promotion of energy efficiency/conservation standatrd adaptation in new buildings	22%	39%	3,323	1,623	1,700
	Energy efficiency/conservation in buildings (repair)			411	168	243
Hot water supply	Introducing business purpos water heaters Laten heat recovery water heaters Business purpos heat pumps High efficient boiler	7%	44%	611	103	508
Lighting	Introducing high efficient lightings	9%	almost 100%	2,288	2,288	
Air conditioning	Introducing manegament of refrigerant (chlorofluorocarbon)	0%	83%	6	6	
Power	Improving energy efficiecny of equipments by top runner			2,784	2,784	
	Top runner (FY2012 --> 2030) - Copy machine Electricity consumption: 169kWh/unit/y --> 106kWh/unit/y Prevalence: 3420 thousand units --> 3700 thousand units - Printer Electricity consumption: 136kWh/unit/y --> 88kWh/unit/y Prevalence: 4520 thousand units --> 4890 thousand units - High efficient router Electricity consumption: 6083kWh/unit/y --> 7996Wh/unit/y Prevalence: 1830 thousand units --> 1970 thousand units - Server Electricity consumption: 2229kWh/unit/y --> 1492Wh/unit/y Prevalence: 2970 thousand units --> 3190 thousand units - Storage Electricity consumption: 274kWh/unit/y --> 131kWh/unit/y Prevalence: 11790 thousand units --> 52920 thousand units - Refrigerator-freezer Electricity consumption: 13900kWh/unit/y --> 12390kWh/unit/y Prevalence: 2330 thousand units --> 2330 thousand units - Automatic vending machine Electricity consumption: 11310kWh/unit/y --> 7700kWh/unit/y Prevalence: 2560 thousand units --> 2560 thousand units					
Management, national campaign	Implementation of complete energy management in Commercial sector by BEMS, energy audit, etc.	6%	47%	2,353	1,294	1,059
	Efficient use of lightings	15%	almost 100%	423	423	
	Promotion and national campaign (Commercial sector)			66	66	
	Expansion of energy use to another offices			78		
Total				12,343	8,755	3,510

Residential sector

Sub-sector	Energy efficiency/conservation measure	Actual FY2012	Introduction/ prevention prediction FY2030	Energy savings (thausand kL) FY2030	items of which, electricity	 of which, fuel
Residence	Promotion of energy efficiency/conservation standatrd adaptation in new residences	6%	30%	3,142	786	2,356
	Promotion of insulation retrofit in existing residences			425	110	315
Hot water supply	Introducing high efficient hot water heaters			2,686	-263	2,949
	CO2 refrigerant heat pump hot water heaters	4000 thousand units	14000 thousand units			
	Laten heat recovery water heaters	3400 thousand units	27000 thousand units			
	Fuel cell	55 thousand units	5300 thousand units			
	Solar water heaters					
Lighting	Introducing high efficient lightings	9%	almost 100%	2,011	2,011	
Air conditioning Power	Improving energy efficiecny of equipments by top runner	-	-	1,335	1,048	287
	Top runner (FY2012 --> 2030) - Air conditioner (cooling) Electricity consumption: 229kWh/unit/y --> 188kWh/unit/y Prevalence: 2.71 units/family --> 2.79 units/family - Gas stove Gas consumption: 5823Mcal/unit/y --> 5565Mcal/unit/y Prevalence: 0.06 units/family --> 0.05 units/family - Oil stove Oil consumption: 720 litre/unit/y --> 716 litre/unit/y Prevalence: 0.74 units/family --> 0.54 units/family - Television (more than 32V) Electricity consumption: 79kWh/unit/y --> 63kWh/unit/y Prevalence: 0.47 units/family --> 1.29 units/family - Refrigerator (more than 300 litre) Electricity consumption: 337kWh/unit/y --> 271kWh/unit/y Prevalence: 0.82 units/family --> 0.94 units/family		Top runner (FY2012 --> 2030) - Computer Electricity consumption: 72kWh/unit/y --> 72kWh/unit/y Prevalence: 1.29 units/family --> 1.83 units/family - Magnetic disk Electricity consumption: 0.005kWh/GB --> 0.005kWh/GB Prevalence: 2.80 units/family --> 3.34 units/family - Router Electricity consumption: 31kWh/unit/y --> 26kWh/unit/y Prevalence: 0.5 units/family --> 1.0 units/family - Microwave oven Electricity consumption: 69kWh/unit/y --> 69kWh/unit/y Prevalence: 1.06 units/family --> 1.08 units/family - Rice cooker and warmer Electricity consumption: 85kWh/unit/y --> 82kWh/unit/y Prevalence: 0.69 units/family --> 0.69 units/family			
Management, national campaign	Implementation of complete energy management in resudential sector by HEMS, smart meter	0.20%	almost 100%	1,783	1,783	
	Promotion and national campaign (Residential sector)	-	-	224	107	117
	- Promotion of complete implementation of Coolbiz and Warmbiz Coolbiz (implementaion 80%), Warmbiz (implementation 81%) --> almost 100% - Implementatiopn of energy audit in residential sector Awareness of energy audit --> 3940 thousand families		- Promotion of replacement to energy efficient equipments (2012 --> 2030) Electric dehumidifier (compression type) 93.7kWh/unit/y --> 72.5kWh/unit/y Totally automatic electric washing mashine with dryer 66.0kWh/unit/y --> 36.9kWh/unit/y			
Total (Residential sector)				11,607	5,583	6024

Transport sector

Sub-sector	Energy efficiency/conservation measure	Actual	Introduction/ prevention prediction	Energy savings (thausand kL)	items	
		FY2012	FY2030	FY2030	of which, electricity	of which, fuel
Automobile	Improving fuel economy Prevalence of next generation automobiles	HEV 3%	29%	9,389	-1,001	10,390
		EV 0% PHEV 0%	16%			
		FCV 0%	1%			
		CDV 0%	4%			
Other	Other measure of transport sector	-		6,682	624	6,058
	- Promotion of trafic sream measures - Promotion of public transport system - Modal shift to freight railway - Comprehensive measure of green shipping - Reduction of land transportation distance by appropriate selection of port - Comprehensive low carbonazetion in ports - improving transport by truck - Improving energy efficiency of railway - Improvin energy efficiency of aviation - Promotion of energy efficient ship - Green truck transportation by promoting environmentally frendly automobiles - Promotin of cooperative transport - Pormotion of Intelligent Transportation System, ITS (centraized control of signals) - Improving transport safety eqipments (sophisticated signals, promoting substitution to LED lightings) - Promotion of automatic driving - Promotion fo Eco Drive - Car-sharing					
Total (Transport sector)				16,071	-377	16,448

Annex 2 Power Generation Cost Review Sheets in Japan

Cost elements of generation source and reference information (tentative translation by IEEJ)

Nuclear

Cost elements		Data from following four sample plants which started their operation within ten years and interview to relevant companies * Sample plants (Plant name, company name, capacity, operation year) Higashidori No1, Tohoku Elec., 1100MW, 2005, Hamaoka No5, Chubu Elec., 1380MW, 2005, Shiga No2, Hokuriku Elec., 1358MW, 2006, Tomari No3, Hokkaido Elec., 912MW, 2009	
Model plant capacity		1,200 MW	Average of sample plant capacities
Capacity factor		80% 70% 60%	Several conditions are set in order to compare them
Operation years		60 years 40 years	Based on life extension approval system stipulated by the Nuclear Reactor Regulation Law, 40 years and 60 years are set.
Capital cost	Construction cost	37,000 Yen/kW	Plant construction cost. Considering several units are constructed in one site, averaging correction of shared equipments, prices correction, etc are in place at model plants. Aditional safety mesures based on the Great East Japan Earthquake are excluded
	Rate of fixed asset tax	1.4%	
	Decommissioning cost	71.6 billion Yen	"Average cost per kWh based on estimated amount of nuclear generation equipment dismantle allowance" by "sample plant capacities"
Operation cost	Personal cost	2.05 billion Yen/y	Personal cost of generation plant operation. Payoff, allowance, welfare cost, retirement allowance, etc are included. Average of sample plants.
	Repair cost	2.2%/y (Percentage of construction cost)	Average of check and maintenance cost of generation equipments to keep normal operational conditions in specified operation years. Average of sample plants.
	Other cost	8.44 billion Yen/y	Waste disposal cost, supplies cost, leasehold cost, outsorcing cost, non-life insurance premium, miscellaneous wages, nuclear fuel tax, etc. Average of sample plants.
	Administartive cost	13.4%/y (Percentage of direct cost)	Nuclear generation business cost shared with total electricity business cost, of which, personal cost of headquarter, repair cost, other cost. Average of sample plants.
Fuel cost	Nuclear fule cycle cost (Front-end + back-end)	1.54 Yen/kWh (Front-end: 0.95, back-end: 0.59)	Considering current situation that all spent fuels are stored in apropriate period and reprocessed (current model), it is calculated preliminarily. Condition changes from 2011are reflected.
	Heat efficiency	34.7%	Net generation. Average of sample plants.
	Rate of own use	4.0%	Percentage of electricity own use against total generated electricty. Average of sample plants.
Price variation factor in 2020 and 2030	Technological innovation and volume efficiency	—	(Reference) In next generation light-water-reactor which is being developed by the joint project of the public and private sectors, target in 2030, rationalizations with safety improvement by seismic isolation tecnology, etc, are expected. For example, shortening of construction period by modularization technology.
Damage cost		9,108.8 billion Yen (Estimated minimum amount of countermesure for accident risks)	Expected maximum amount of damage of Fukushima Daiichi Nuclear Power Plant accident from quantitative information at present is corrected for model plant. * Damage cost is supposed to be reduced by implementation of additional safety mesures like prevention maesures of radioactive material, but these impacts are not reflected. * Calculation from "For Accelerating the Reconstruction of Fukushima From the Nuclear Disaster (Cabinet Decision on December 20, 2013)", "New Comprehensive special Business Plan (Approved change in April 2015, TEPCO)"、"TEPCO financial statement of Q3 2014", "Ministry of Finance HP", etc TEPCO: Tokyo Electric Power Company
Additional safety mesure cost		60.1 billion Yen	24 reactors of 15 nuclear power plants which new regulation statdard adaptation criterion are submitted to Nuclear Regulation Authority at present 1) latest prospect of additional safety mesure cost were provided from Electric Companies, 2) regarding four reactors of two nuclear power plants which application for permission of installement changes were approved at present, provided detail of cost were corrected to the model plant in order to improve precision, 3) reflecting these results, average of 24 reactors of 15 nuclear power plants was calculated.
Nuclear accident prevention		—	Disposition in political purpose expenses
Note		[Exchange rate] Exchange rate is assumed to be unchanged. it is used for preminary calculation of fuel cost. [Discount rate] Annual rate where future monetary value is discounted/converted to present value. If discount rate is high, present generation unit cost of generation sources which the share of fuel cost is high, is lower. For example, thermal is higher than nuclear and hydro generaly. [Direct expenses] Total of personal cost, repair cost and other cost	

Cost elements of generation source and reference information (tentative translation by IEEJ)

Hydro (Large)

Cost elements		Data from following three sample plants which started their operation within seven years and interview to relevant conpanies * Sample plants (Plant name, company name, capacity, operation year) 江卸, Hokkaido Elec. 13.8 MW, 2006, 新忠別, Hokkaido Elec. 10MW, 2006, 森吉, Tohoku elec., 11MW, 2013	
Model plant capacity		12 MW	Average of sample plant capacities
Capacity factor		45%	Based on actual perfomance, it was set.
Operation years		60 years 40 years	Based on actual perfomance, it was set. It is assumed 60 years because main equipments like water turbine will need to be replaced, if operation years exceeds 60 years.
Capital cost	Construction cost	640,000 Yen/kW	Construction cost of generation plant. Structure cost and equipments cost like generator are averaged.
	Plant decommisisoning cost	5% of construction cost	Data of preminary calculation of OECD/IEA"Projected Costs of Generating Electricity 2010 Edition"(2010), of which, no country provided specific decommissioning cost. (Same as Procurement Price Calculation Committee)
Operation cost	Personal cost	20 million Yen/y	Personal cost of generation plant operation. Payoff, allowance, welfare cost, retirement allowance, etc are included. Average of sample plants.
	Repair cost	0.9%/y (Percentage of construction cost)	Average of check and maintenance cost of generation equipments to keep normal operational conditions in operation years. Average of sample plants.
	Other cost	0.1%/y (Percentage of	Waste disposal cost, supplies cost, leasehold cost, outsorcing cost, non-life insurance premium, miscellaneous wages, taxes, etc. Average of sample plants.
	Administrative cost	13.3%/y (Percentage of direct cost)	Hydro generation business cost shared with total electricity business cost, of which, personal cost of headquarter, repair cost, other cost. Average of sample plants.
Fuel cost	Rate of own use	0.40%	Percentage of own use electricity against total generated electricty. Average of sample plants.
Price cariation factor	Technological innovation and volume efficiency	–	Technoligical innovation and volume efficiency which affect generation cost significantly are not expected.
	Rate of fuel cost increse	–	–
	CO2 reduction cost	–	–

Cost elements of generation source and reference information (tentative translation by IEEJ)

Hydro (Medium/Small)

	Cost elements		Procurement Price Calculation Committee, interview to hydro industry, etc
	Model plant capacity	200 kW	Same as Report of Power Generation Cost Verification Working Group and Procurement Price Calculation Committee
	Capacity factor	60%	Procurement Price Calculation Committee
	Operation years	40 years 30 years	Same as Coal-fired thermal, LNG-fired thermal and Oil-fired thermal. According to the interview to hydro indutry, there is no significant differencies between expected operation years of mini hydro and thermal power plants generally.
Capital cost	Construction cost	from 800,000 to 1,000,000 Yen/kW --> from 160 million Yen to 200 million Yen	Procurement Price Calculation Committee (Connection cost is included because it is difficlut to separate off connection cost from construction cost.)
Capital cost	Plant decommisisoning cost	5% of construction cost	Data of preminary calculation of OECD/IEA"Projected Costs of Generating Electricity 2010 Edition"(2010), of which, no country provided specific decommissioning cost. (Same as Procurement Price Calculation Committee)
Operation cost	Personal cost	7 million Yen/y	Procurement Price Calculation Committee
Operation cost	Repair cost	1%/y (Percentage of construction cost)	Procurement Price Calculation Committee
Operation cost	Other cost	2%/y (Percetage of	Procurement Price Calculation Committee
Operation cost	Administrative cost	14%/y (Percentage of direct cost)	Procurement Price Calculation Committee
Fuel cost	First year price	—	—
Fuel cost	Rate of own use	—	—
Fuel cost	Other fuel reelevant cost	—	—
Price variation	Technological innovation and volume efficiency	—	Significant technological innovation and volume efficiency which affect generation cost are not expected.
Price variation	Rate of fuel cost increase	—	—

Cost elements of generation source and reference information (tentative translation by IEEJ)

Solar PV (Rooftop)

Cost elements		Procurement Price Calculation Committee, interview to solar indusry, etc.	
Model plant capacity		4 kW	Same as Report of Power Generation Cost Verification Working Group and Procurement Price Calculation Committee
Capacity factor		12%	Procurement Price Calculation Committee
Operation years		25 years 20 years	Manufacturers' guarantee period are from 10 to 20 years as the longest generally, although they are vary between manufactures. Generally, 20 years or 25 years is adopted in cost analysis outside Japan.
Capital cost	Construction cost	364,000 Yen/kW	Procurement Price Calculation Committee
	Plant decommisisoning cost	5% of construction cost	Data of preminary calculation of OECD/IEA“Projected Costs of Generating Electricity 2010 Edition”(2010), of which, no country provided specific decommissioning cost.
Operation cost	Personal cost	–	–
	Repair cost	3,600 Yen/kW/y	Procurement Price Calculation Committee
	Other cost	–	–
	Administrative cost	–	–
Fuel cost	First year price	–	–
	Rate of own use	–	–
	Other fuel relevant cost	–	–
Price variation factor	Technological innovation and volume efficiency	Reduction of construction cost (thousand Yen/kW) <New policy scenario> 2020: 275 - 298 2030: 206 - 258 <Current policy scanerio> 2020: 280 - 303 2030: 220 - 274 Reduction of operation and maintenance cost (thousand Yen/kW) <New policy scenario> 2020: 2.72 - 2.95 2030: 2.04 - 2.55 <Current policy scenario> 2020: 2.77 - 3.00 2030: 2.17 - 2.71 Increase of operation years 2030: 20 - 30 years	Reduction of construction cost Module, Inverter Based on world accumulate production in New policy scenario and Current Policy Scanario of latest IEA World Energy Outlook, cost reduction is assumed progression rate 80%, learning effect. Installtion cost will not be changed. The case that module and inverter cost was convergent on global level was studied. Reduction of operation and maintenance cost Cost redudction is assumed as same as reduction rate of construction. Increase of operation yeras Based on technology development targets and the discussion of the Working Group, 2030 model plant operation years is capped 30 years. Decommissioning cost Without relation to the reduction of construction cost, the cost is same as 5% construction cost which calculated in 2014 model plant.
	Rate of fuel cost increase	–	–

Cost elements of generation source and reference information (tentative translation by IEEJ)

Solar PV (Utility scale)

Cost elements		Procurement Price Calculation Committee, interview to solar industry, etc	
Model plant capacity		2 MW	Same as Procurement Price Calculation Committee
Capacity factor		14%	Procurement Price Calculation Committee
Operation years		25 years 20 years	Manufacturers' guarantee period are from 10 to 20 years as the longest generally, although they are vary between manufactures. Generally, 20 years or 25 years are adopted in cost analysis outside Japan.
Capital cost	Construction cost	294,000 Yen/kW -->million yen 588	Procurement Price Calculation Committee (System cost included land preparation cost)
	Plant decommisisoning cost	5% of construction cost	Data of preminary calculation of OECD/IEA"Projected Costs of Generating Electricity 2010 Edition"(2010), of which, no country provided specific decommissioning cost. (Same as Procurement Price Calculation Committee)
Operation cost	Personal cost	3,700 Yen/kW/y	The operation and maintenance cost is provided by Procurement Price Calculation Committee, but land lease equivqlent cost is exluded in this study.
	Repair cost		
	Other cost		
	Administrative cost		
Fuel cost	First year price	—	—
	Rate of own use	—	—
	Other fuel relevant cost	—	—
Price variation factor	Technological innovation and volume efficiency	Reduction of construction cost (thousand Yen/kW) <New policy scenario> 2020: 233 - 249 2030: 2185- 222 <Current policy scanerio> 2020: 236 - 253 2030: 194 - 233 Reduction of operation and maintenance cost (thousand Yen/kW) <New policy scenario> 2020: 3.24 - 3.37 2030: 2.88 - 3.16 <Current policy scenario> 2020: 3.27 - 3.39 2030: 2.95 - 3.24 Increase of operation years 2030: 20 - 30 years	Reduction of construction cost Module, Inverter Based on world accumulate production in New policy scenario and Current policy scanario of latest IEA World Energy Outlook, cost reduction is assumed progression rate 80%, learning effect. Installtion cost will not be changed. The case that module and inverter cost was convergent on global level was studied. Reduction of operation and maintenance cost Cost redudction is assumed as same as reduction rate of construction. Increase of operation yeras Based on technology development targets and the discussion of the Working Group, 2030 model plant operation years was capped 30 years. Decommissioning cost Without relation to the reduction of construction cost, the cost is same as 5% construction cost which calculated in 2014 model plant.
	Rate of fuel cost increase	—	—

Cost elements of generation source and reference information (tentative translation by IEEJ)

Wind (Onshore)

	Cost elements		Procurement Price Calculation Committee, interview to wind industry, etc
	Model plant capacity	20 MW	Same as Report of Power Generation Cost Verification Working Group and Procurement Price Calculation Committee
	Capacity factor	20%	Procurement Price Calculation Committee
	Operation years	25 years 20 years	Almost all wind turbines in the world are designed and manufactured in compliance with the standard of International Electrotechnical Commission, IEC. IEC prescribes for design service life of wind turbine as 20 years. There are examples that wind turbines which exceed 20 yeras design service life continue to operate outside Japan.
Capital cost	Construction cost	284,000 Yen/kW --> \5.68 billion	Procurement Price Calculation Committee （Procurement Price Calculation Committee assumes construction cost as \300,000/kWh, 5.2% of which, equivalent connection cost, is excluded.)
	Plant decommisisoning cost	5% of construction costs	Data of preminary calculation of OECD/IEA"Projected Costs of Generating Electricity 2010 Edition"(2010), of which, no country provided specific decommissioning cost. (Same as Procurement Price Calculation Committee)
Operation cost	Personal cost	6,000 Yen/kW/y	Procurement Price Calculation Committee
	Repair cost		
	Other cost		
	Administrative cost		
Fiel cost	First year price	–	–
	Rate of own use	–	–
	Other fuel relevant cost	–	–
Price variation factor	Technological innovation and volume efficiency	Reduction of construction cost (thousand Yen/kW) 2020: 255 - 272 - 284 2030: 205 - 252 - 284 Reduction of operation and maintenance cost (thousand Yen/kW) 2020: 5.4 - 5.7 - 6.0 2030: 4.3 - 5.3 -6.0 Improving capacity factor 2020: 20 - 23% 2030: 20 - 23%	Construction, operation and maintenance cost in 2020 and 2030 Following three cases are set based on cost elements of 2014 model plant case 1) The cost is equal to 2014 unit price. Cost reduction is not expected. case 2) The cost will be reduced according to Technology Roadmap Wind Energy 2013, IEA case 3) Cost of turbines and eledctric installations will be convergent on global price. Capacity factor after 2020 Based on technology development like improving generation efficiency of wind turbine, growing in size, and improving reliability and capacity factor, the rate is capped 23%. Decommissioning cost Without relation to the reduction of construction cost, the cost is same as 5% construction cost which calculated in 2014 model plant.
	Rate of fuel cost increase	–	–

Cost elements of generation source and reference information (tentative translation by IEEJ)

Wind (Offshore)

Cost elements		Procurement Price Calculation Committee, interview to wind industry, etc	
Model plant capacity		30 - 100 MW	Based on the study of procurement price of onshore wind farm equipments, it is assumed.
Capacity factor		30%	Procurement Price Calculation Committee
Operation years		25 years 20 years	Same as onshore wind. IEC prescribes for design service life of wind turbine as 20 years. There are examples that wind foreign companies deliver them at design service life as 25 years.
Capital cost	Construction cost	515,000 Yen/kW --> billion yen 15.45 - 51.5	Construction cost which Procurement Price Calculation Committee assumed. Connection cost equivalent is excluded. (\50,000/kWh, which is mean of \30,000 - \70,000/kWh)
	Plant decommisisoning cost	5% of construction cost	Data of preminary calculation of OECD/IEA"Projected Costs of Generating Electricity 2010 Edition"(2010), of which, no country provided specific decommissioning cost. (Same as Procurement Price Calculation Committee)
Operation cost	Personal cost	22,500 Yen/kW/y	Procurement Price Calculation Committee
	Repair cost		
	Other cost		
	Administrative cost		
Fuel cost	First year price	—	—
	Rate of own use	—	—
	Other fuel relevant cost	—	—
Price variation factor	Technological innovation and volume efficiency	Reduction of construction cost (thousand Yen/kW) 2030: 446 - 515 Reduction of operation and maintenance cost 2030: 19.5 - 22.5	Construction, operation and maintenance costs in 2020 and 2030 Following two cases are set based on cost elements of 2014 model plant case 1) The cost is equal to 2014 unit price. Cost reduction is not expected. case 2) The cost will be reduced according to Technology Roadmap Wind Energy 2013, IEA Decommissioning cost Without relation to the reduction of construction cost, the cost is same as 5% construction cost which calculated in 2014 model plant.
	Rate of fuel cost increase	—	—

Cost elements of generation source and reference information (tentative translation by IEEJ)

Biomass

	Cost elements	Procurement Price Calculation Committee, interview to biomass industry, etc	
Model plant capacity		5,700 kW	Same as Procurement Price Calculation Committee
Capacity factor		87% (the Committee) 80% 70% 60% 50%	Procurement Price Calculation Committee and actual performance. Several conditions are set in order to compare them.
Operation years		40 years 30 years 20 years	Same as Coal-fired thermal, LNG-fired thermal and Oil-fired thermal. According to the interview to biomass industry, tipical biomass generation companies expect their plant operation years from 15 to 20 years. But it is possible to set 30 years operartion.
Capital cost	Construction cost	398,000 Yen/kW --> 2.267 billion Yen	Procurement Price Calculation Committee provided construction, but 70 million Yen as connection cost is excluded in this study.
	Plant decommisisoning cost	5% of construction cost	Data of preminary calculation of OECD/IEA"Projected Costs of Generating Electricity 2010 Edition"(2010), of which, no country provided specific decommissioning cost. (Same as Procurement Price Calculation Committee)
Operation cost	Personal cost	27,000 Yen/kW	Procurement Price Calculation Committee
	Repair cost		
	Other cost		
	Administrative cost		
Fuel cost	First year price	12,000 Yen/t	Procurement Price Calculation Committee
	Rate of fuel cost rise	—	Unused timbers from forest thinning While collection and transport cost are expected to decrease in the future by implementation of wood self-suficiency improving policy, for example, improving wood transport roads, Increase of wood demand for generation will lead to increase wood cost. Expected fuel cost will not be changed totally.
	Required fuel	60,000t	Procurement Price Calculation Committee (Required fuel in case of capacity factor 87%)
	Rate of won use	16%	Procurement Price Calculation Committee
	Fuel relevent other cost	\750/t	Procurement Price Calculation Committee
Price variation factor	Technological innovation and volume efficiency	—	Significant technological innovation and volume efficiency which affect generation cost are not expected.
	Rate of fuel cost increase	—	Unused timbers from forest thinning While collection and transport cost are expected to decrease in the future by implementation of wood self-suficiency improving policy, for example, improving wood transport roads, Increase of wood demand for generation will lead to increase wood cost. Expected fuel cost will not be changed totally.

Cost elements of generation source and reference information (tentative translation by IEEJ)

Geothermal

<table>
<tr><td colspan="2">Cost elements</td><td colspan="2">Procurement Price Calculation Committee, interview to wind industry, etc.</td></tr>
<tr><td colspan="2">Model plant capacity</td><td>30 MW</td><td>Same as Report of Power Generation Cost Verification Working Group and Procurement Price Calculation Committee</td></tr>
<tr><td colspan="2">Capacity factor</td><td>83%</td><td>Procurement Price Calculation Committee</td></tr>
<tr><td colspan="2">Operation years</td><td>50 years
40 years
30 years</td><td>The report of Power Generation Cost Verification Working Group was published in 2011.Expected operation years are supposed not to be changed significantly. Based on the report, actual performance at that time is assumed.</td></tr>
<tr><td rowspan="2">Capital cost</td><td>Construction cost</td><td>790,000 Yen/kW
--> 23.7 billion Yen</td><td>Procurement Price Calculation Committee</td></tr>
<tr><td>Plant decommisisoning cost</td><td>5% of construction cost</td><td>Data of preminary calculation of OECD/IEA“Projected Costs of Generating Electricity 2010 Edition”(2010), of which, no country provided specific decommissioning cost. (Same as Procurement Price Calculation Committee)</td></tr>
<tr><td rowspan="4">Operation cost</td><td>Personal cost</td><td rowspan="4">33,000 Yen/kW/y</td><td rowspan="4">Procurement Price Calculation Committee</td></tr>
<tr><td>Repair cost</td></tr>
<tr><td>Other cost</td></tr>
<tr><td>Administrative cost</td></tr>
<tr><td rowspan="3">Fuel cost</td><td>First year price</td><td>—</td><td>In case that steam supplyers supply their steam to geothermal developpers as fuel, fuel cost is allocated in their financial statments. In this study, tha case that one developer supplys steam to his/her generation plant is assumed. Fuel cost is not allocated in this case becuase fuel is that extracted hot water or steam from underground.</td></tr>
<tr><td>Rate of own use</td><td>11%</td><td>Procurement Price Calculation Committee</td></tr>
<tr><td>Other fuel reelevant cost</td><td>—</td><td>—</td></tr>
<tr><td rowspan="2">Price variation factor</td><td>Technological innovation and volume efficiency</td><td>—</td><td>Technological innovation and volume efficiency which affect generation cost significantly are not expected.
(Reference) More sophisticated geothermal reservoir assessment technology and scale or acid fluid provison development will be promised to improve economical efficiency</td></tr>
<tr><td>Rate of fuel cost increase</td><td>—</td><td>Fuel cost is not allocated because fuel is that extraced hot water or steam from underground.</td></tr>
</table>

Cost elements of generation source and reference information (tentative translation by IEEJ)

(Reference) Coal

Cost elements		Data from following four sample plants which started their operation within seven years and interview to relevant companies * Sample plants (Plant name, company name, capacity, operation year) New Isogo No2, J-Power, 600MW, 2009, Maiduru No2, Kansai Elec., 900MW, 2010, Hirono No6, Tokyo Elec., 600MW, 2013, Hitachinaka No2, Tokyo elec., 1000MW, 2013	
Model plant capacity		800 MW	Average of sample plant capacities
Capacity factor		80% 70% 60% 50% 10%	Considering actual performance, several conditions are set in order to comapre them.
Operation years		40 years 30 years	Considering actual performance, several conditions are set in order to comapre them.
Capital cost	Construction cost	250,000 Yen/kW	Plant construction cost. Considering several units are constructed in one site, averaging correction of shared equipments, etc, are in place at model plants. Replacements are included.
	Decommissioning cost	5% of construction cost	Data of preminary calculation of OECD/IEA"Projected Costs of Generating Electricity 2010 Edition"(2010), of which, no country provided specific decommissioning cost.
Operation cost	Personal cost	360 million Yen/y	Personal cost of generation plant operation. Payoff, allowance, welfare expenses, retirement allowance, etc are included. Average of sample plants.
	Repair cost	1.8%/y (Percentage of construction cost)	Average of check and maintenance expenses of generation equipments to keep normal operational conditions through operation years. Average of sample plants.
	Other cost	1.5%/y (Percentage of construction cost)	Waste disposal cost, supplies cost, leasehold cost, outsorcing cost, non-life insurance premium, miscellaneous wages, taxes, etc. Average of sample plants.
	Administartive cost	14.3%/y (Percentage of direct cost)	Coal-fired generation business expenses shared with total electricity business expenses, of which, personal cost of headquarter, repair cost, other cost. Average of sample plants.
Fuel cost	First year price	US$97.64/t ($0.004/MJ)	Customs value (CIF) of thermal coal in all Japan, average of 2014.
	Heat value	25.97 MJ/kg (LHV: 24.66 MJ/kg)	Standard heat value of imported termal coal. (Standard heat value used in Energy Balance and Carbon Emission Factor List)
	Heat efficiency	42%	HHV. Net generation. Average of sample plants.
	Rate of own use	6.4%	Percentage of generation plant own use electricty against total generated electricty. Average of sample plants.
	Other fuel relevant cost	2,000 Yen/t (0.077 Yen/MJ)	Petroleum and coal tax, import commission, coastal shipping freight, coal center usage fee, unloading auditors fee, etc. Average of latest actual cost of each companies
Price cariation factor	Technological innovation and volume efficiency	Improving heat efficiency 2014: 42% 2020: 42% 2030: 48%	Ultra Super Critical (USC) technology with heat efficiecny 42% is in commerial use at present. Target of heat efficiecny 48% will be achived by development Integrated coal Gasification Combined Cycle (IGCC) and advanced Ultra Super Critical (A-USC) technology by 2030.
	Fuel cost increase	IEA Current Policy Scenario IEA New Policy Scenario	First year price is $97.64/t above mentioned. From second year, price projections of Curent Policy Scenario and New Policy Scenario in IEA World Energy Outlook 2014 are adopted.
	CO2 reduction cost	IEA EU Current Policy Scenario IEA EU New Policy Scenario	Price in Current Policy Scenario The price is EU Current Policy scenario in 2020 - 2040, the price trend is extended in 2040 - 2070 (Logarithmic regression). Price in New Policy Scenario The price is EU New Policy Scenario in 2020 - 2040, the price rend is extended in 2040 - 2070 (Logarithmic regression). Price in 2014 and 2020 2014: Average ofEU-ETS in 2014. 2020: Linear interpolation.