How is 100% Renewable Energy Possible in Japan by 2020?

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Table of Contents

Table of Figures

Abstract

This report focuses on how 100% renewable energy in Japan is possible by 2020. Japan is now in a severe condition with their energy because of the 2011 nuclear power plant disaster caused by earthquake and tsunami. Since then, Japan has struggled to manage its energy in peak times. To solve this problem, the Japanese government and people are trying to shift their energy to renewable sources. So far, achieving this goal has been exceedingly low, even if it is possible. Despite this outcome, this report takes a strong position on energy issues. The purpose of this report is to demonstrate the feasibility of 100% renewable energy for Japan to decision makers, political leaders and the public.

Section 1 is about the current energy demand and supply situation. Section 2 addresses the current law or system applied to renewable energy. The third section outlines the main reasons Japan can manage its energy based solely on renewable energy. The remaining sections describe the potential of each form of the renewable energy, the practical assumptions for generating energy and a summary of all the ideas presented in this paper.

As a result of extensive research, this report reveals that Japan can become a renewable energy society. This is because Japan has strong public support for clean, renewable energy, such as solar power and wind power. In addition, it has or is developing the technology necessary to utilize renewable energy and has strong systems, such as the feed-in-tariffs to support renewable energy initiatives.

In conclusion, Japan has high potential and can be a leader in the global renewable energy field. As Japan does not have any other natural energy resources, promoting renewable energy will create many jobs in the country and enable the Japanese people be proud of their country.

Current Situation Related to Renewable Energy

1.1 Analysis of Energy Sources

Japan does not have significant domestic fossil fuel resources, except for a small amount of coal. Therefore, Japan is the top hard coal and natural gas importer in the world. In fact, since

1970s, Japan has mainly relied on oil from the Middle East. Although Japan depended on oil for 75.5% of its entire energy resources in 1973, due to oil costs, the country gradually shifted its energy use resources from oil to other resources, such as nuclear energy, natural gas and coal, or it tried to develop new energy technologies. As a result, Japan has promoted the diversification of its energy resources and the current energy supply, including not only oil and coal, but also natural gas, nuclear energy and renewable energy, such as hydropower, natural energy and geothermal(ground heat) energy. The following chart summarizes the energy sources in Japan as of 2010.

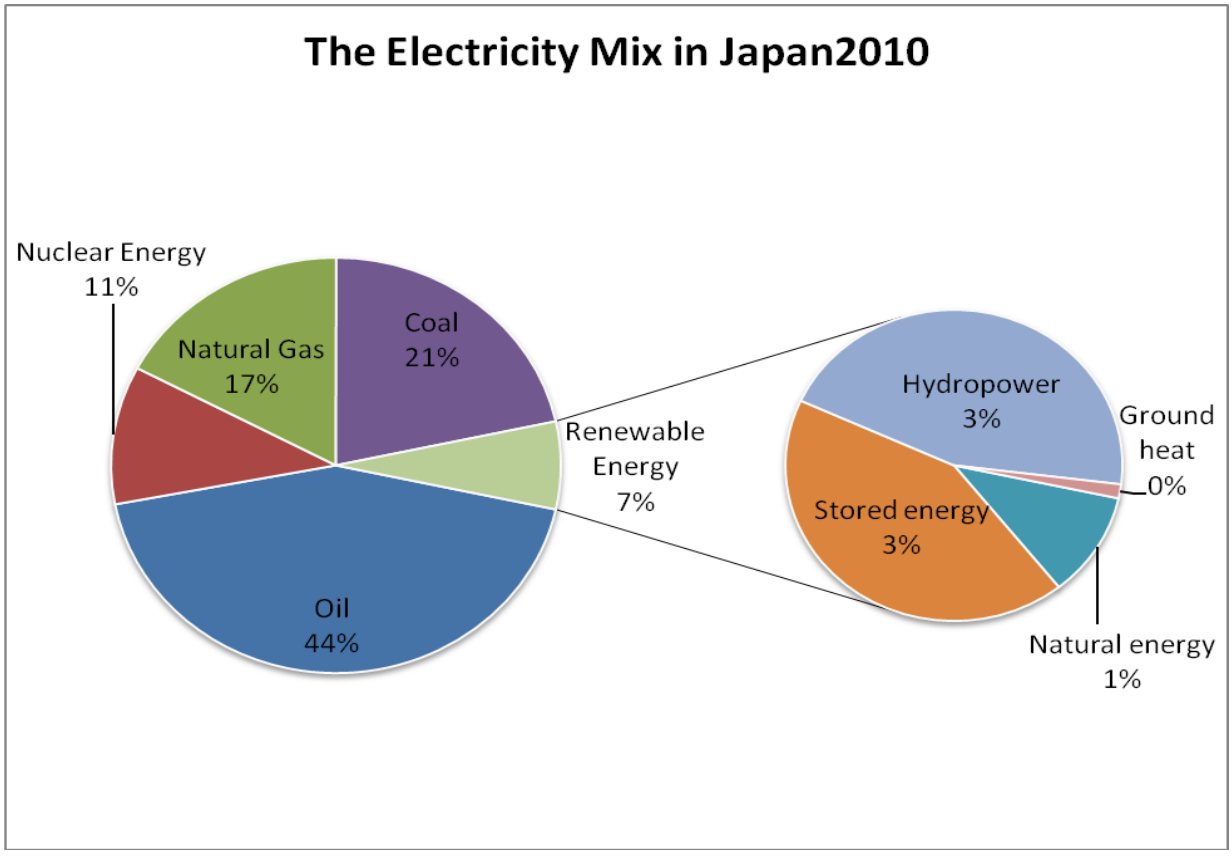

Figure 1 Energy Sources in Japan 2010

Source: Ministry of Economy Trade and Industry, *2010 Summary Report on Energy*

In 2010, oil was used as a main energy source and accounted for 44% of all energy used in Japan. The second largest energy demand was for coal, followed by natural gas and nuclear energy. Japan is the third largest consumer of nuclear power in the world, after the United States and France. As for renewable energy, it accounted for only 7% of energy used in 2010. This means that the self-sufficiency energy rate in Japan is low, compared to the rate in other countries like France or Germany.

Based on the Japanese government statement in 2010, the nation must reduce 25% of its CO_2 emissions by 2020 compared to 1990 levels. In order to achieve a sustainable environment, this goal should be met, and there needs to be a clear plan based on actual results in other countries.

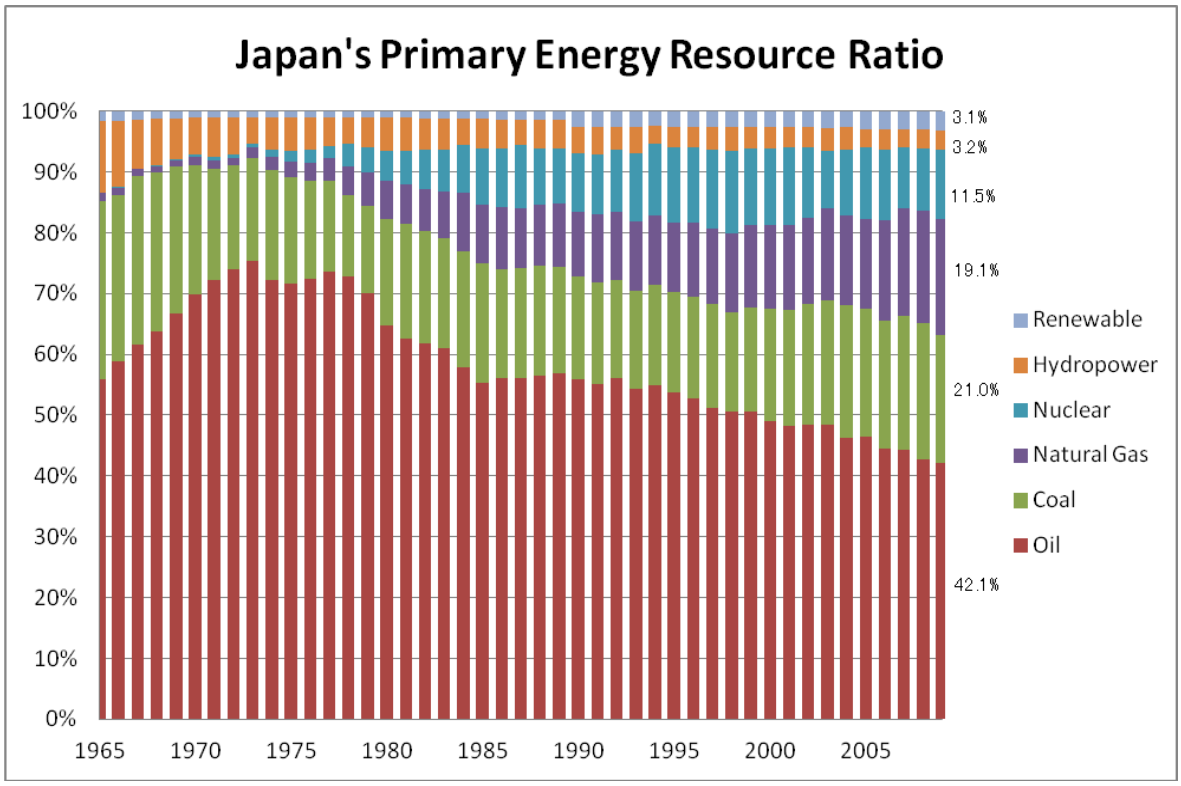

Figure 2 Japan's Primary Energy Resource Ratio

Source: Ministry of Economy Trade and Industry, *2010 Summary Report on Energy*

Figure 2 shows how the energy resource ratio in Japan has changed over the past 45 years. This graph shows that Oil's share of total energy consumption has declined from about 80% to about 42% today. Instead of oil, natural gases' use has increased from almost nothing to about 20%, while the sustainable energy share is less than 10%. What can be inferred from this chart is that there are many steps for Japan to take to become a sustainable energy country.

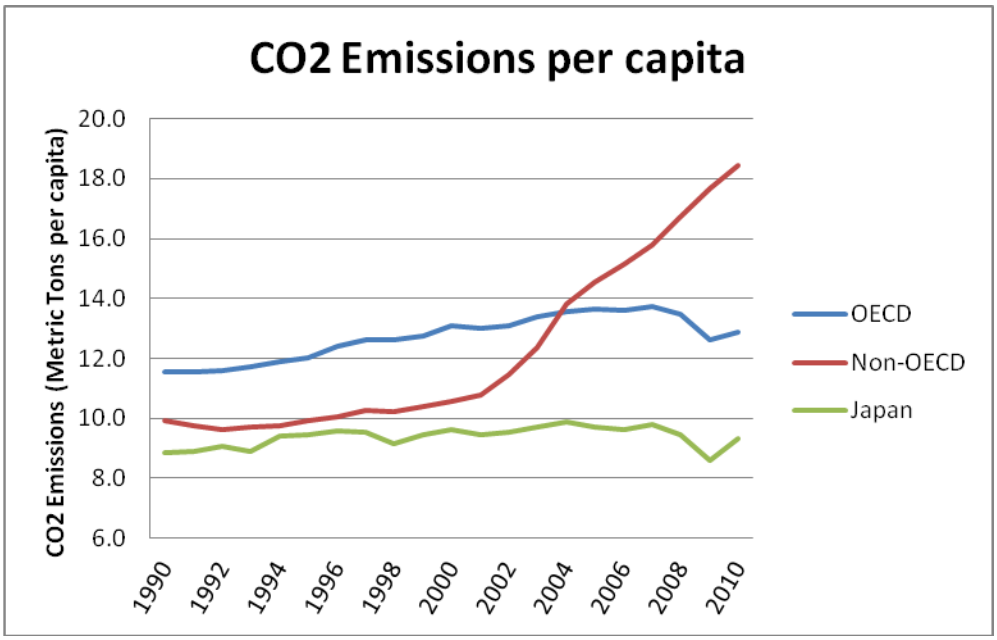

Figure 3 CO_2 Emissions Per Capita
Source: PBL Netherlands Environmental Assessment Agency, *Long-term Trend in Global CO2 Emissions*, 2011

In the last 20 years, Japan has tried to reduce its carbon dioxide emissions, but has not made much progress. However, as Figure 3 shows, carbon dioxide emissions per capita in Japan is actually less than the OECD average for over 20 years. In other words, Japanese people have high interests in global environment. It means that the Japanese people are committed to sustainable energy, and Japan has the potential to be an environmentally friendly country.

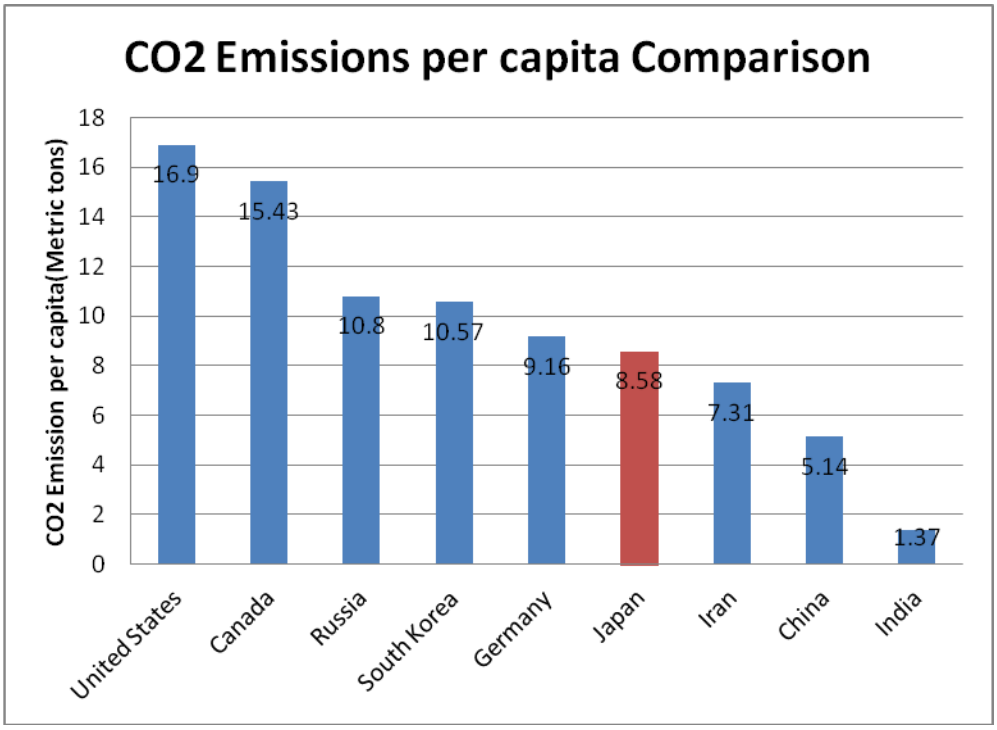

Figure 4 CO_2 Emissions Per Capita Comparison
Source: PBL Netherlands Environmental Assessment Agency, *Long-term Trend in Global CO_2 Emissions*, 2011

1.2 Analysis of Current Emissions

Japan is one of the biggest energy consuming countries in the world. In 2011, according to the World Bank[1], Japan consumed 858.5 billion kilowatt-hours (kWh) of electricity. Japan has approximately 282 gig watts (GW) of installed power capacity; but, after the huge damage to power generator caused by the March 2011 Tohoku earthquake, IHS Global Insight estimates capacity fell to around 243 GW in mid-2011.

Japan's Ministry of Economy, Trade and Industry tracks national energy consumption in four broad sectors – industrial, transportation, residential, and commercial. The breakdown of energy consumption in Japan is shown in the Figure below. Industry and transport account for two-thirds of energy consumption in Japan.

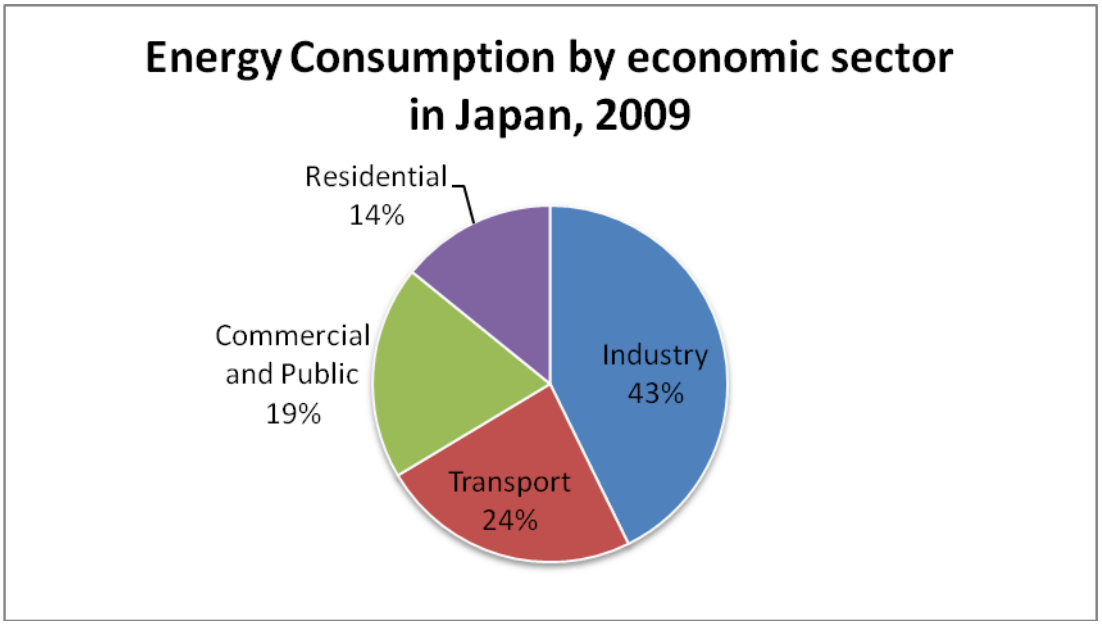

Figure 5 Energy Consumption in Japan, 2009
Source: Ministry of Economy Trade and Industry, *2010 Summary Report on Energy*

Energy consumption by sector is shown in Figure 6. The industrial sector has long been the country's largest energy user, currently representing 42.8% of the total. Next in importance is the transportation sector, followed by the commercial and public sectors.

[1] http://data.worldbank.org/data-catalog/world-development-indicators

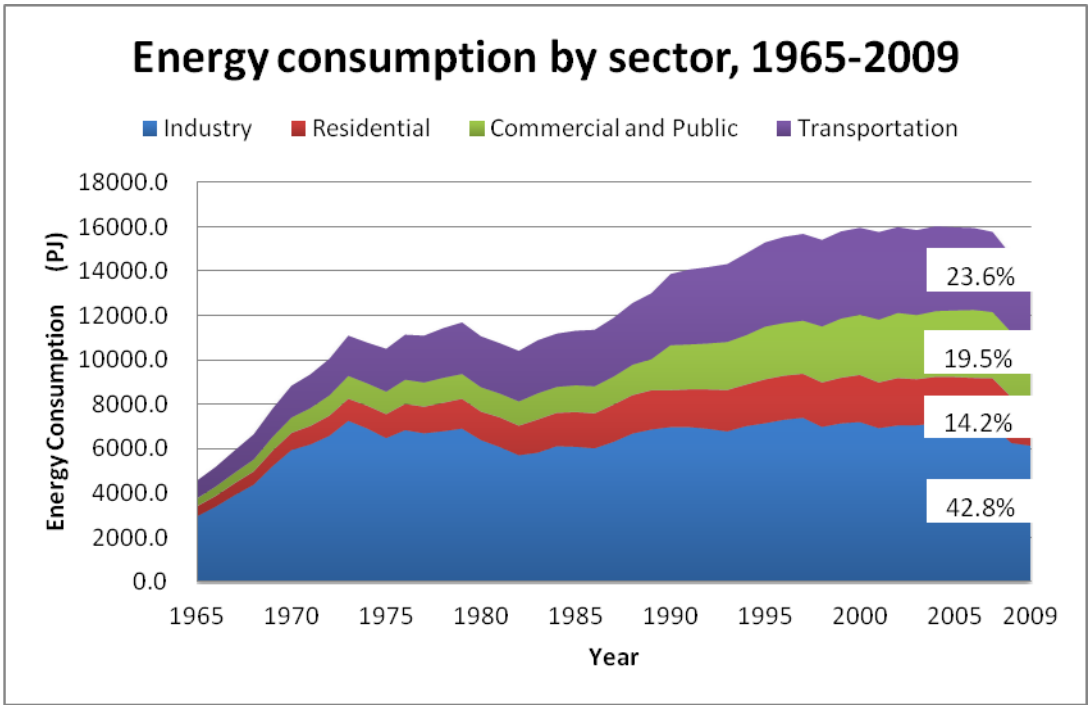

Figure 4 Energy Consumption by Sector, 1965-2009
Source: Ministry for Economy, Trade and Industry, General Energy Statistics Agency for Natural Resources and Energy Consumption

The total energy consumption has gone as far as it can go, and it has been decreasing for a couple of years. After the Tohoku 2011 earthquake, the total amount of energy consumption decreased more rapidly than before, because there was not enough energy supply. Since the Japanese people, especially those in the Kanto and Tohoku area, survived for one year with this total supply of energy, they will probably be able to deal with the same amount from next year. A major concern is how to make up for the loss of nuclear energy, because all nuclear power plants are shut down. Currently, the Japanese government is dealing with this problem by increasing its dependence on fossil fuels, like natural gas, coal and oil for use in thermal power stations. The value of its liquid natural gas (LNG) imports rose 52% to 5.4 trillion yen in the 12 months through March, 2012.

1.3 Relevance of energy Source and Demand

Figure 5 below shows how energy demand and supply are related to each other. Generally, energy can take various forms through the process of transmitting and modifying. Broadly, electric energy is generated by burning raw material like oil, natural gas and coal in power plants. This process results in energy loss in both the generation and transmission phases. For example, if the primary energy supply is estimated at 100, energy consumption would be 70. Primary energy supplies consists of oil, natural gas, liquid propane (LP) gas, coal, nuclear power, solar power, and wind power, whereas energy consumptions consist of oil products, electricity and heat. When classified by energy supply category, most of nuclear power and renewable energy is converted into electricity, whereas natural gas is converted not only into electricity but also heat.

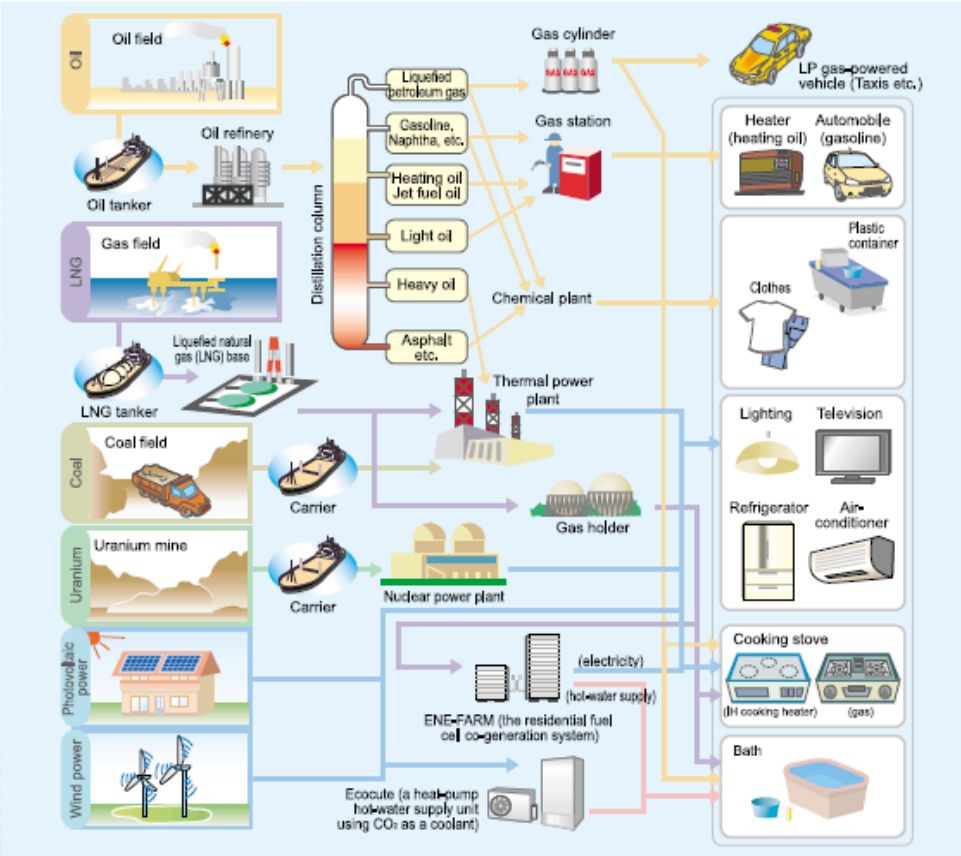

Figure 5 Process of Energy and Form of Use
Source: Agency for Natural Resources and Energy, *Energy in Japan*, 2010

2 Current Energy Policy, Law, and Strategy

According to the Swedish Agency for Growth Policy Analysis[2], Japan's current policy, law, and strategy are mainly the *Basic Energy Plan* and *New Growth Strategy*. Each plan is described below.

2.1.1 Basic Energy Plan

The first comprehensive energy policy, the *Basic Energy Plan*, was enacted in June, 2002. This law outlined Japan's energy policy and basic principles. Amendments to this plan are made every three years. The most recent amendment was announced in June 2010; the 2013 amendment will be changed drastically because of the 2011 nuclear power disaster caused by the huge earthquake and tsunami. Although it will be changed, the targets under 2010 *Basic Energy Plan*[3] are as follows:

- Develop the energy self-sufficiency ration in energy supply and self-developed fossil fuel supply ratio, and as a result raise the energy independence ratio from the current level of 38% to about 70%.
- Raise the zero-emission power source (nuclear and renewable energy) ratio from current 34% to about 70%.
- Half CO_2 emissions from the residential sector.
- Maintain and enhance energy efficiency in the industrial sector to reach the highest level in the world.
- Maintain or obtain top-class shares of global markets for energy-related products and systems.

[2] Japan Energy Situation Policy – Trends in Policies and Technologies Working Paper 2010 – 06

[3] *METI Press Release, June 18, 2010 " Establishment of the Strategic Energy Plan of Japan*

2.1.2 New Growth Strategy

In June 2010, the Japanese government finalized its *New Growth Strategy.* This strategy aims to achieve economic growth by FY 2011 by boosting demand for green innovation, including renewable energy and other key areas, with escape from deflation as top priority. The *green innovation* targets for 2020 are to create over 50 trillion yen (JPY) in new environmental-related markets and 1.4 million new environment sector jobs, and to reduce carbon dioxide emissions by using Japan's private sector technology.

2.1.3 21 National Strategic Projects for Revival of Japan for the 21st Century

These projects are part of the *New Growth Strategy* and are designed to meet the 2020 targets for energy and its resources[4].

- Strategic Project for Increasing Renewable Energy through a Feed-in Tariff System
- Strategic Project for Creating a "Future City"
- Strategic Project for Forest and Forestry Revitalization Plan

[4] *The New Growth Strategy: Blueprint for Revitalizing Japan, Japanese Cabinet, June 18,2010*

2.2 Surrounding Environment of Renewable Energy

2.1.1 Kyoto Protocol and Post Kyoto Protocol

The *Kyoto Protocol* is a multi-national agreement aimed at controlling greenhouse emissions like carbon dioxide, water vapor, nitrous oxide, methane, and ozone that cause global warming in our climate. This protocol was initially adopted in Kyoto, Japan, and went into effect on February 16, 2005. Almost all countries in the world, except the United States, ratified this protocol. Under this protocol, Japan makes a legally binding promise to reduce its greenhouse emissions by 6% from 1990 level including emissions trading. Japan had originally planned to meet its carbon emissions reduction target with nuclear energy. However, because of the 2011 meltdowns at the Fukushima Dai-ichi plant caused by the devastating earthquake and following tsunami, Japan is estimated to produce about 15% more greenhouse gas emissions in 2012 than the 1990 level. In spite of these problems, Prime Minster Yoshihiko Noda has pledged to reduce its reliance on nuclear power, although Japanese government is eager to re-start some nuclear reactors to make up for its electricity shortage during the summer. Therefore, Japan will have no choice but to shift its energy resources into some new types of resources. In other words, Japan seems favorable for developing renewable energy.

In the post-Kyoto negotiations, part of United Nations Framework Convention on Climate Change seems to be the first conference that concerns the period after the first *commitment period* of the *Kyoto Protocol*, which is due to expire at the end of 2012. In addition, these negotiations about greenhouse gas emissions have been mandated by the adoption of the *Bali Road Map and Decision 1/CP.13* called *The Bali Action Plan*. However, although most nations use the Kyoto Protocol, only a few countries are on track to reach each emission reduction goal. To make matters worse, most of the countries that reach their goals will do so because of the recent global recessions. In response to this, the leaders of Russian, Japan, and Canada confirmed that they would not sign a new Kyoto-style agreement. There are two reasons for this. One reason is that developing countries such as China and India are not required to sign Kyoto protocol, because they are not yet considered major industrial nations. Other nations do not think it is fair that China or India do not have to sign the treaty, because they expel more greenhouse gas emissions than more developed nations. Another reason is that the United States, the world's biggest economy, did not sign the Kyoto Protocol or the Kyoto Treaty.

While it may be true that Japan will not sign a new Kyoto Treaty, it does not mean that Japan will not make efforts to reduce their greenhouse gas emissions. Japan is working to attain its original goal regardless of the multi-national agreement. According to Japan's *Vision and Actions Toward Low-Carbon Growth and a Climate-Resilient World*[5], which was announced at the *Conference of the Parties 17* (COP 17) held in December 2011, Japan will shift to a low-carbon society and build new market mechanisms in closer collaboration with emerging countries. In other words, Japan will promote regional cooperation to complement post-Kyoto negotiations. With regard to bilateral initiatives, Japan will discuss with relevant nations the launching of *the Bilateral Offset Credit Mechanism*. In this mechanism, Japan can use credit earned from its technologies to reduce greenhouse gas emissions as a part of international greenhouse gases mitigation of each country. Japan is working to improve environmental performance by deploying their environmental businesses.

2.2.2. Current Situation, Especially After the Fukushima Accident

Since the 2011 earthquake and devastating accident at the Fukushima No.1 nuclear power plant, energy policy has been the biggest controversial issue in Japan. These events caused people all over the world to question the safety of nuclear energy.

Although Japan has made little progress until now, it is certain that the country will shift its energy resources from nuclear to other resources to ensure that clean energy is provided to the Japanese people. Under the present circumstances, Japan relies on imports of oil, natural gas and coal from foreign countries most of their energy needs. However, as Japan ratified Kyoto Protocol, too many imports of fossil fuels should not be continued for a long time to control of release of carbon dioxide quantity. In order to attain sustainable environment, Japan will work to be 100% renewable energy country.

2.1.2 Threats of Nuclear Power

Nuclear energy has many issues to be discussed. One of the biggest misconceptions people have is that nuclear power is cheap energy. On the surface, the cost of nuclear power looks very cheap. However, it does not include the hidden costs that arise when accidents happen. These hidden costs include health damage, crop damage, reputation damage, environmental problems, and the decline of tax revenue. The cost of nuclear power will exceed the cost of other energy sourced when these hidden costs are taken into consideration.

[5] Ministry of Foreign Affairs, *Japan's Vision and Action Toward Low Carbon Growth and a Climate Resilient World,* 2011

3 Feasibility of 100% Renewable Energy

Based on the facts mentioned above, 100% renewable energy in Japan by 2020 might sound impossible. However, there are three strong points to support Japan's efforts to manage their energy only by sustainable energy. These points are illustrated in following chart

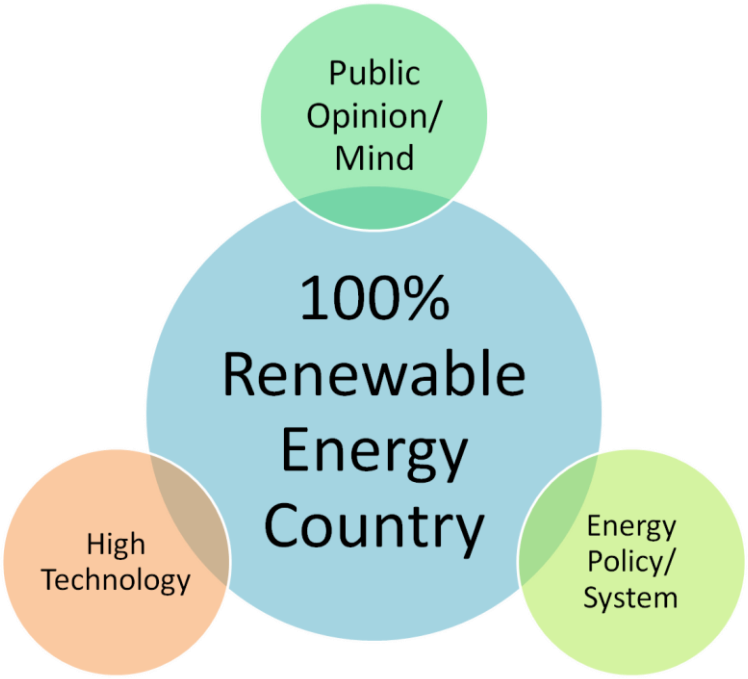

Figure 8 Support for Renewable Energy in Japan
Source: Author

These reasons are described in the following pages. Public opinion changed significantly after Fukushima nuclear reactor accident. More and more Japanese people want their country to shift away from a reliance on nuclear power. Japan has many high technology patents for renewable energy, and the government has established a *feed-in-tariff* to support development of renewal energy resources. The *feed-in-tariff* provides financial incentives to renewal energy companies to encourage their investment in Japan.

3.1 Public Opinion

3.1.1 Main Issues After March 2011 Earth

In the latest information, subsequent fears about the safety of nuclear power have resulted in the shutdown of all of Japan's 54 nuclear reactors. Another big change after the earthquake and nuclear accident is the attitude of government towards nuclear power. Here are several issues about nuclear problem and their after-effect:

- Convergence of Fukushima nuclear power plant accident
- Stable electricity supply without nuclear power plant
- Avoidance of financial crisis caused by Tokyo Electric Power Company (TEPCO)
- Compensation to victims in Fukushima
- Minimize the national burden rate
- Fair burden for stakeholders and satisfaction of the people
- Radical review of Japan's whole nuclear system
- Radical review of electric business regulation
- Determination and implementation of regeneration

Furthermore, Japan has abandoned most of its nuclear resources since 2011. The utilization rate of nuclear power plant dropped from 70% to less than 10% in March 2012. Instead, Japanese imports more and more oil or natural gas from foreign counties to compensate for nuclear energy. The total imports of LNG climbed approximately 10% to 85.5 million tons in the last year. This trend will continue for a long time if nothing is changed. Therefore, new types of clean and safe energy source are being demanded by the Japanese people. More than two-thirds of people in Japan are against nuclear power.

Figure 9 Anti-nuclear Protestors in Tokyo

Source Ear to Earth News for a Sustainable Planet

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Source Ear to Earth News for a Sustainable Planet

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Source Ear to Earth News for a Sustainable Planet

Figure 9 Anti-nuclear Protestors in Tokyo
Source Ear to Earth News for a Sustainable Planet

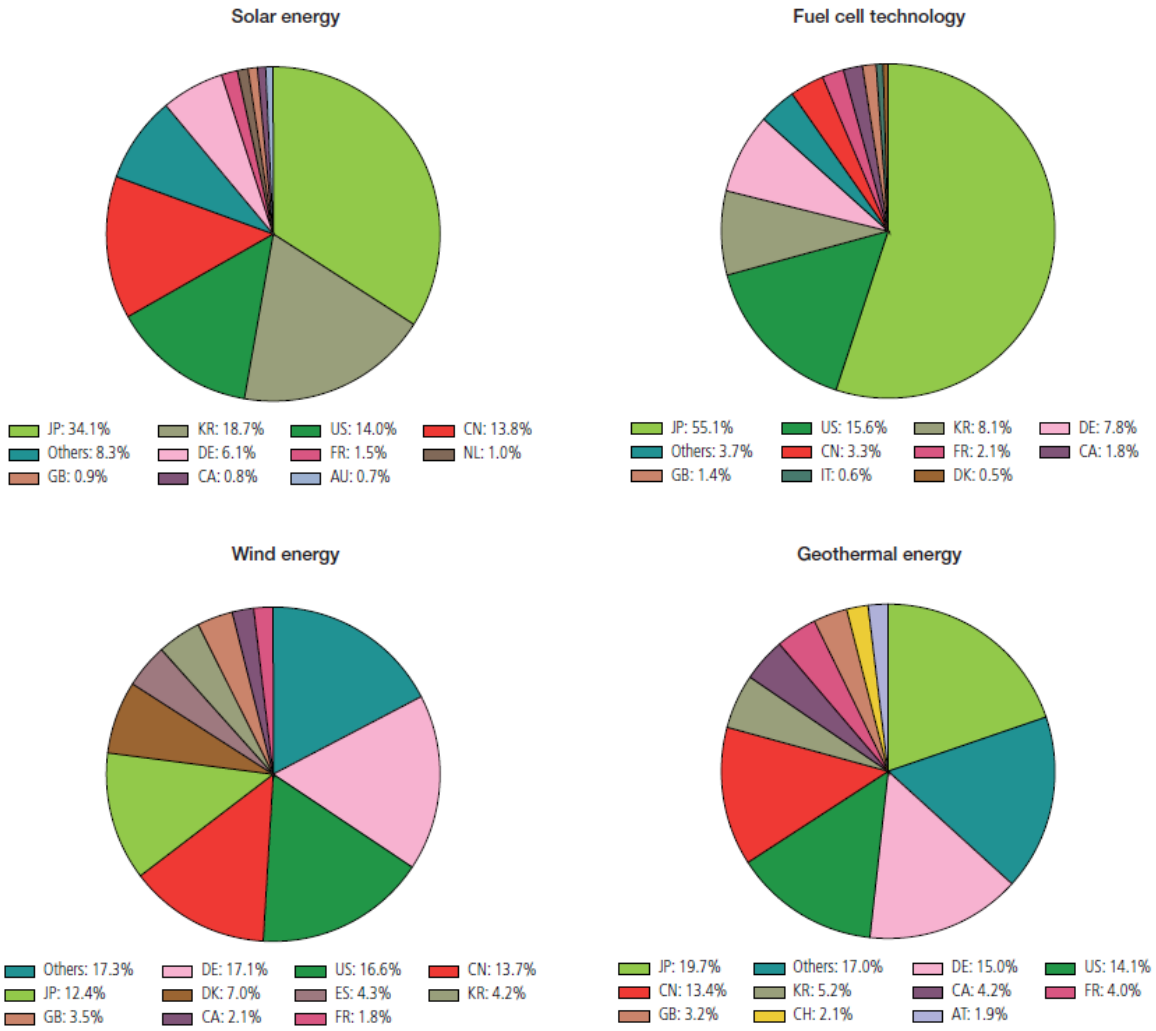
As can be seen in these situations, the Japanese government must shift its energy from nuclear to other resources. Moreover, there is further good news about Japan. On May 5, 2012, Japan became the first developed country in the world to stop using nuclear power plant. Most people in Japan practice *setsuden* (power saving) and this *setsuden* supports the push for clean energy over national policy that favors nuclear power. By making the most of this opportunity, Japan could possibly be a leader in renewable energy field.

3.2 High Technology Related to Renewable Energy Industry

3.2.1 Patents in Renewable Energy Field

According to the *World Intellectual Property Organization* (WIPO)[6], Japan holds 55% of the world's renewable energy patent applications. It is followed by the U.S. with 22% and the European Union with 7%. Japan's research and development in the renewable energy field is "very advanced" both in academic and public research institutes and private sector. Japan is leading the world in the field of solar cells and wind power field, and geothermal generation technologies have maintained equivalent position to the US and EU nations. Figure 10 shows the breakdown of renewable energy. As shown in these charts, Japan is considered the biggest technology country in the world. When it comes to the field of biomass, Japan relies on imported technology from the U.S. and Europe countries. Additionally, Japan's market for energy is small and some people think that because of this small domestic market, Japan may be slow to commercialize. However, Japan still leads other countries in almost all fields of renewable energy.

[6] Ecology Online, *Forefront of Renewable Energy Technology in Japan*, August, 15, 2012



Note: For definitions of the technologies, refer to Annex B. Country codes: AT (Austria), AU (Australia), CA (Canada), CH (Switzerland), CN (China), DE (Germany), DK (Denmark), ES (Spain), FR (France), GB (United Kingdom), IT (Italy), JP (Japan), KR (Republic of Korea), NL (Netherlands) and US (United States of America).
Source: WIPO Statistics Database and EPO PATSTAT Database, October 2011

Figure 10 Number Distribution of Energy-Related Technologies and Top Origins, 2005-2009
Source: *World Intellectual Property Indicators - 2011 Edition*

3.3 Energy Policy and System in Japan

3.3.1 Main Policy or Law Change after Fukushima

In June 2011, the Japanese government established an energy and environment council to correct the distortion in the energy system and to formulate safe, efficient, and environmental policy. According to the Energy and Environment Council, Japan will try to achieve the following three principles.

- Realize new optimum mixture of power sources
- Realize the new energy system
- Achieve the Japanese people's consensus

Japanese government will announce "*The Basic Energy Plan"* and a plan to put the *Energy and Environmental Policy* together in fall 2012. As a basic viewpoint, Japan will incorporate '*ensure the safety'* and *'public participation'* to the basic principles of the policy, which are 'to s*ecure a stable energy supply*, *environmental compliance* and *utilize the market force*.'

The biggest change in law in Japan is a system of feed-in tariffs for renewable energy generation for the nation, including rates of JPY 42 kWh for solar photovoltaic generation. This system, which went into effect on July 1, 2012, offers 20 contracts for photovoltaic plants for large scale plants and 10-years contracts for small scale photovoltaic plants. In this system, the price of tariff is much more expensive than other countries' tariff system. Therefore, it is expected that Japan will develop a solar energy system, and the country can become a leader in this renewable energy industry. However, as a whole, no policy or law changes have been established which are yet sufficient enough to realize 100% renewable energy.

Instead of government, it is private institution initiatives that have been announced or proposed. For instance, according to the Japanese *Consumers' Co-operative Union* report, Japan should focus on these five issues in order to build a long term the sustainable energy system.

- Conversion to an energy system that is independent of nuclear power
- Large scale electricity reduction by power saving
- Expansion of renewable energy
- Shift from oil firepower to natural gas firepower
- Construction of a smart grid system

3.3.2 Power Generation Cost for Each Type of Power Source

According to the Energy and Environment Council established by the Japanese government, generating costs for each type of energy are shown in Figure 11:

Energy (Yen per kWh)		2010	2020	2030
Wind power	Wind power on land	9.9-17.3		8.8-17.3
	Wind power at sea		9.4-23.1	8.6-23.1
Geothermal		8.3-10.4		8.3-10.4
Solar power	Household solar power	33.4-38.3		9.9-20.0
	Mega solar	30.1-45.8		12.1-26.4
Small hydroelectric power		19.1-22.0		19.1-22.0
Woody biomass	Woody mono-fuel combustion	17.4-32.2		17.4-32.2
	Coal co-combustion	9.4-9.7		
Coal power		9.5-9.7		10.8-11.0
LNG power		10.7-11.1		10.9-11.4

Figure 11 Generating Costs for Each Type of Energy
Source: The Energy and Environment Council, *Committee Report and Cost Verification*, 2011

Due to a series of accidents that have happened after March 11, 2011, sustainable energies such as solar power, biomass, wind power and other kinds of renewable energies have been growing in importance throughout the country.

Figure 11 shows the range of generating costs for each type of energy. Although generating costs for solar power are expensive, at more than 30 yen per kWh in 2010, the generating cost of solar power, including household and mega solar arrays, is expected to drop dramatically. This price may potentially fall to half or one-third of its present levels on account of the efficiency from mass production or some other factors in the next few decades.

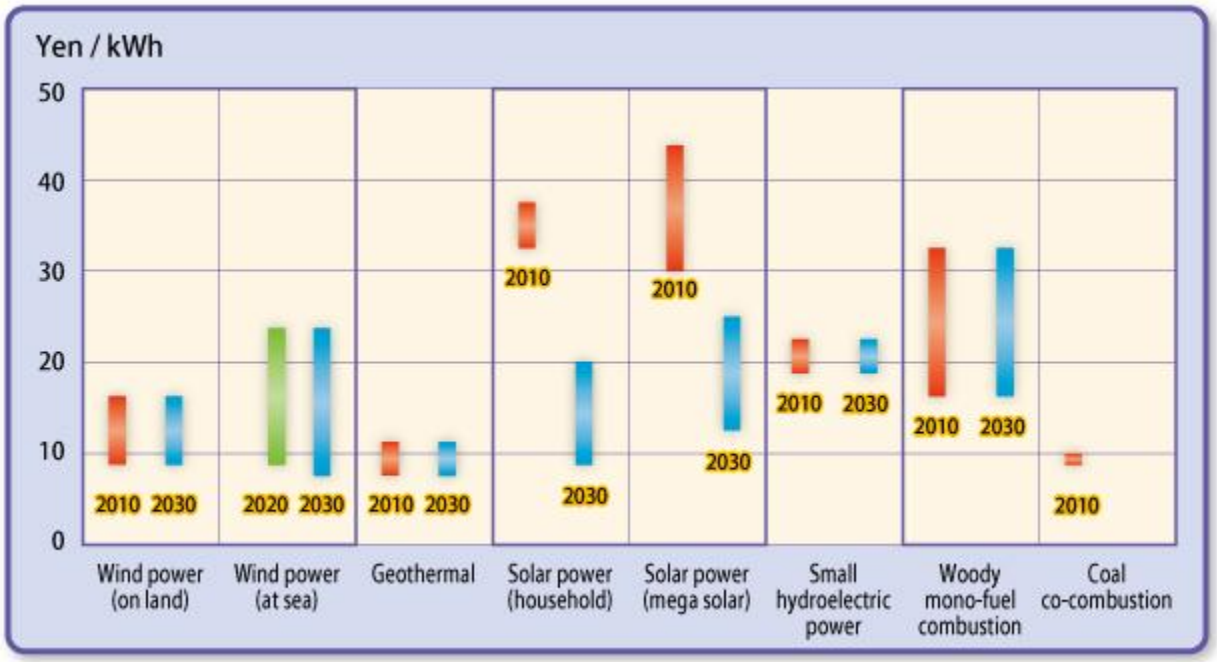


Figure 12 Generating Costs for Each Type of Energy – Yen per Kilowatt Hour
Source: The Energy and Environment Council, *Committee Report and Cost Verification*, 2011

In order to popularize renewable energies, it will be important to reduce Japan's generating costs for renewable energy and promote local production and consumption of electricity, using renewable energies sources that are most suited to the local region and then consumed in that same region. The shorter the distance between the point of power generation and the consumption area becomes, the lower the cost is for generating and transmitting energy.

3.3.3 Feed-in Tariff System in Japan

A *feed-in* tariff is a policy mechanism designed to accelerate investment in renewable energy industries. It achieves this by offering long-term contracts to renewable energy producers or companies. According *to SustainableBusiness.com News*[7], the Japanese government announced pricing for the country's landmark renewable energy feed-in tariff. The premium price that will be paid for solar stocks may make Japan the leader in world's largest solar market. Utilities will pay 42 yen per kilowatt hour for solar generated electricity, double the tariff offered in Germany and more than three times that paid in China. This expensive price set by the government has a very important meaning, because this system has a great deal of cost impacts caused by the merit order effect which is used to rank order renewable energy resources based on their marginal cost of production. [8] This system is widely used in many countries and areas. The reason why this is used is that experience curves have been well established throughout industry as models that show logarithmic correlations between cost declines and cumulative output. The chart below shows estimates for each renewable energy cost trend.

[7] Sustainable Business, *Pricing Set for Japan's Feed-In Tariff, Goes Into Force July*, June 18, 2012

[8] RE New Economy, *The Merit Order Effect – Actually It IS a Good Thing,* March, 2012

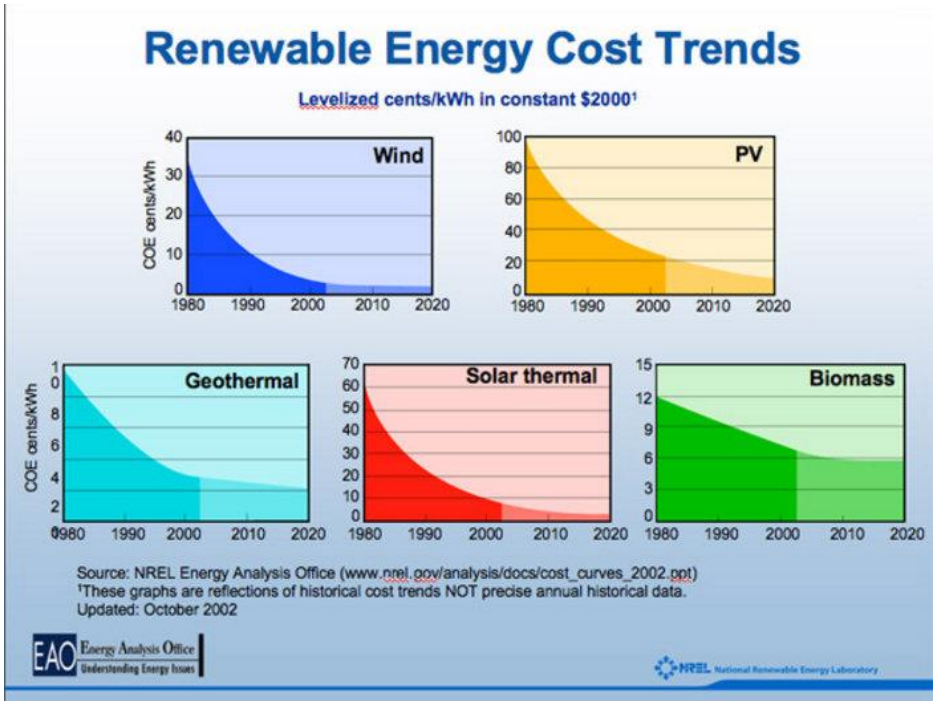
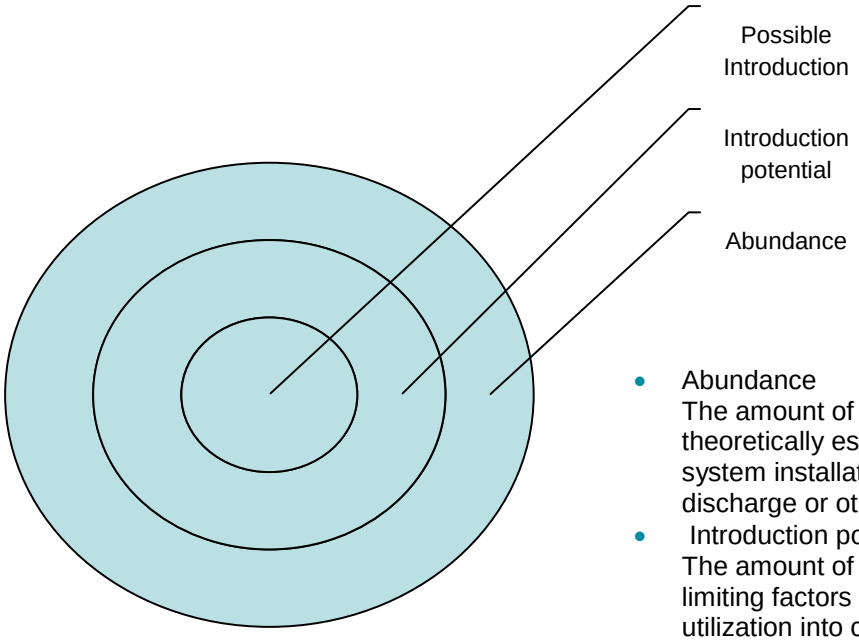


Figure 13 Renewable Energy Cost Trends 2002
Source: The Asian Pacific Journal

4 Assumptions About the Potential of Renewable Energy

4.1 Introduction of Renewable Energy Resources

The potential total installed capacities of each renewable energy resources will be shown in this section. In the following sections, abundance, introduction potential, and feasible potential will be shown and be compared for each renewable energy resource. Abundance, introduction potential, and feasible potential are defined in Figure 14.



- Abundance
  The amount of energy resources that can be theoretically estimated by the feasible area for system installation, mean wind velocity, river discharge or other relevant factors.
- Introduction potential
  The amount of energy resources with various limiting factors for energy collection and utilization into consideration.
- Possible introduction
  The portion of the introduction potential that can be realized for actual use under a specific assumption for project viability.

Figure14 Definition of Potential
Source: *Cost Estimation and Review Committee Report*, Energy and Environment Council

4.1.1 Wind Power in Japan

Wind power has experienced drastic growth over the last decade. Wind technology is becoming popular and is regarded as one of the biggest resources of renewable energies worldwide. Japan currently generates about 2.2 gigawatts (GW) per year, whereas Germany and United States produce over 20 GW per year. Global installed capacity currently is over 200 GW. Compared to these top renewable energy countries, Japan produces only one tenth as much as those countries.

According to Ministry of the Environment Research[9], the potential capacity of wind power in Japan is estimated to be around 1800 GW in theory, including 283 GW from onshore turbines and 1572 GW from offshore turbines. The Tohoku area is ideal for wind energy due to the wind tendency and land shape. The breakdown of wind power energy by regions is shown in Figure 15 below. Hokkaido, which is located at the north end of Japan, is estimated to have the best on-shore potential of all these areas – Tohoku, Kyushu and Kansai follow Hokkaido. As for off-shore wind power potential, Kyushu is estimated to be top region. Hokkaido, Tohoku and Kyushu follow Kyushu. Another fact shown in the table that follows is that offshore potential is estimated much higher than onshore potential.

[9] http://www.env.go.jp/earth/report/h23-03/full.pdf

Wind power potential by region (GW)		
Region	onshore	offshore
Hokkaido	139.66	403.14
Tohoku	72.63	224.79
Tokyo	4.11	79.38
Chubu	4.81	62.12
Hokuriku	7.95	38.69
Kansai	12.9	25.42
Chugoku	9.24	151.99
Shikoku	4.91	41.67
Kyushu	20.98	454.67
Okinawa	5.74	90.74
Total	282.93	1572.61

Figure 15 Wind Power Theoretical Potential by Region
Source: Ministry of Environmental Research, *Research Potential of Renewable Energy*, 2003

In terms of technical potential of Japan's wind power energy, the total installed capacity of wind power plants in Japan is estimated to be up to 1500 GW. Below is the estimation table of solar power. Both the feed-in tariff and subsidy along with an expanded area and technological innovation scenario are required in order to achieve 100% sustainable country.

Installed Capacity (million kW)	Abundance	Introduction Potential	FIT Scenario	FIT*1 + Technological Innovation*1 Scenario	FIT + Subsidy*2	FIT + Technological Innovation + Subsidy*3
Onshore	1,300	280	24 ~ 140	270	130 ~ 260	280
Offshore	-	1,600	0 ~ 3	140	0.3 ~ 330	1,200
Total	-	1,900	24 ~ 140	410	130 ~ 590	1,500

Figure 16 Estimation of Installed Geothermal Capacity by Scenario in Japan
Source: Ministry of Environmental Research, *Research Potential of Renewable Energy*, 2003

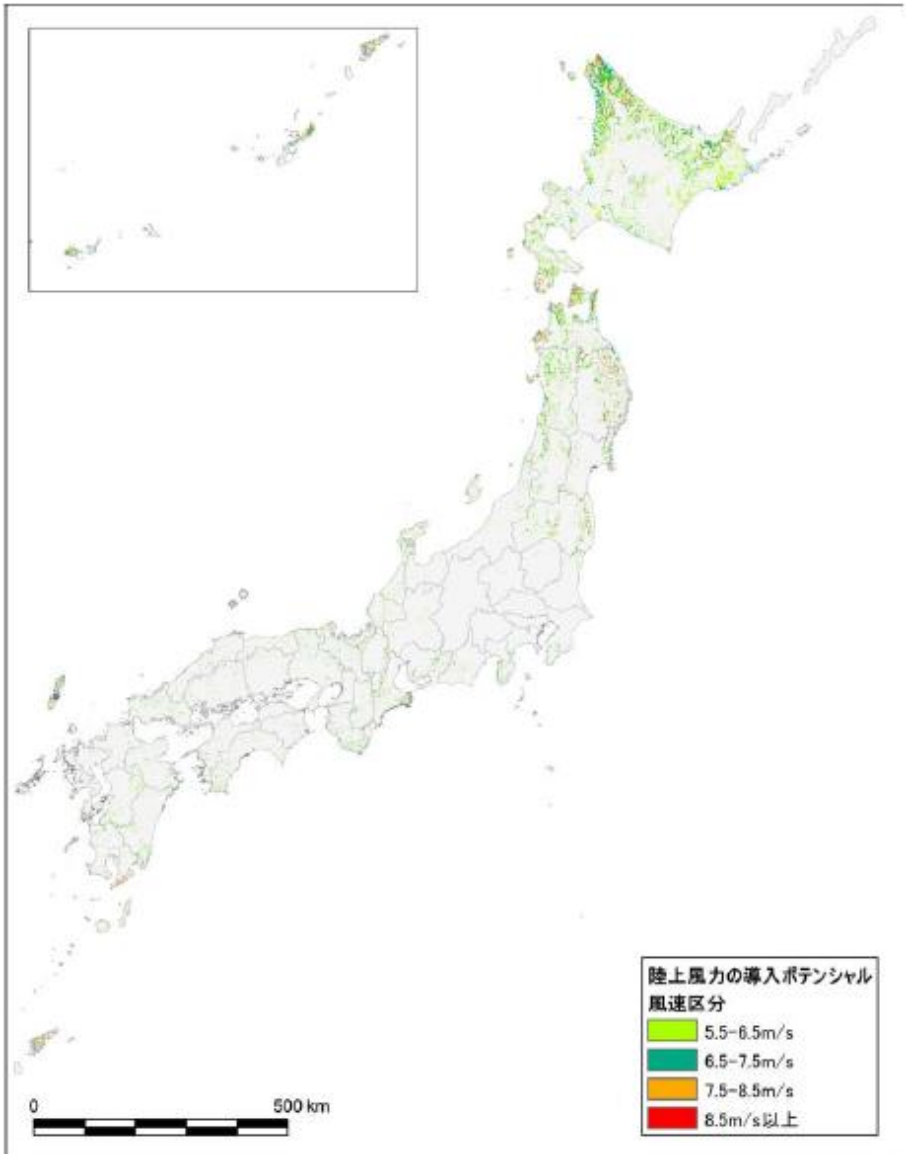


Figure 17 On-shore Wind Introduction Potential
Source: Ministry of Environmental Research, *Research Potential of Renewable Energy*, 2003

4.1.2 Solar Power in Japan

Solar photovoltaic (PV) power has been the fastest-growing renewable power technology over the last 10 years all over the world. Solar energy is considered a re-emerging market because early efforts were not effective. According to some estimates, cumulative installed capacity of solar power plants reached about 40 GW in 2011. In addition, the growth rate of solar PV is increasing each year. For instance, at least 17 GW were added in 2010. Japan continues to lead this sector in Asia, and Japan produced 4.7 GW in 2011. In Japan, almost all solar PV is connected to the power grid. It means that Japan is likely to build smart cities easier than other countries.

According to Ministry of the Environment research[10], the total potential solar power is theoretically estimated over 350 GW, including 200 GW for residential and 150GW for commercial (non-residential). Half of residential solar PV consists of cooperative housing and half is of individual units. As for the commercial sector, it includes utility buildings, factories, unused land and abandoned fields. These numbers are calculated based on the premise that power generation efficiency is 20% at best. However, if efficiency rises to 25%, the total potential power could increase to 700 GW.

At present, economic efficiency is a problem. But the Japanese government is dealing with this problem with generous feed-in tariff system. The tariff for solar power in Japan is ¥42/kwh and is the highest in the world. It is almost three times higher than that of France or Germany, which are considered top renewable energy countries. What made tariffs so high is that there is a specific section in the new tariff law that requires the Ministry of Economy, Trade and Industry to aim for large-scale renewable energy use over the first few years of the new tariff system.

In addition, the Japanese government will unveil a plan that will mandate solar panels on the top of every new building constructed in Japan and will standardize this by 2030.

[10] Ministry of Economy, Trade and Industry *Research Potential of Renewal Energy*, FY 2012

As for the technical potential of Japan's geothermal energy, the total installed capacity of solar power plants in Japan is estimated to be between 0 GW to 100GW depending on each scenario. Below is the estimation table of solar power. From this table, in addition to feed-in tariffs and subsidies, expanded area and technological innovation scenarios are required in order to achieve 100% sustainable country.

Installed Capacity (million kW)	Introduction Potential	FIT Scenario	FIT*1 + Technological Innovation*1 Scenario	FIT + Subsidy*2	FIT + Subsidy *2+ Enlarged Area of Installation *3
Public Buildings (schools, city halls, etc.)	23	0	0 ~ 10	0 ~ 10	10 ~ 20
Power Stations and Factories, etc.	29	0	0.2 ~ 14	0 ~ 14	14 ~ 20
Low Use or Unused Land (final disposal sites, etc.)	27	0	0 ~ 1.3	0 ~ 1.3	1.3 ~ 2.9
Abandoned Farmland (that which has become woodland or waste land)	70	0	0 ~ 47	0	43 ~ 58
Total	150	0	0.2 ~ 72	0 ~ 26	69 ~ 100

Figure 18 Estimation of Installed Photovoltaic Capacity by Scenario in Japan
Source: Ministry of the Environment Research

The following map illustrates the potential for solar PV energy in Japan.

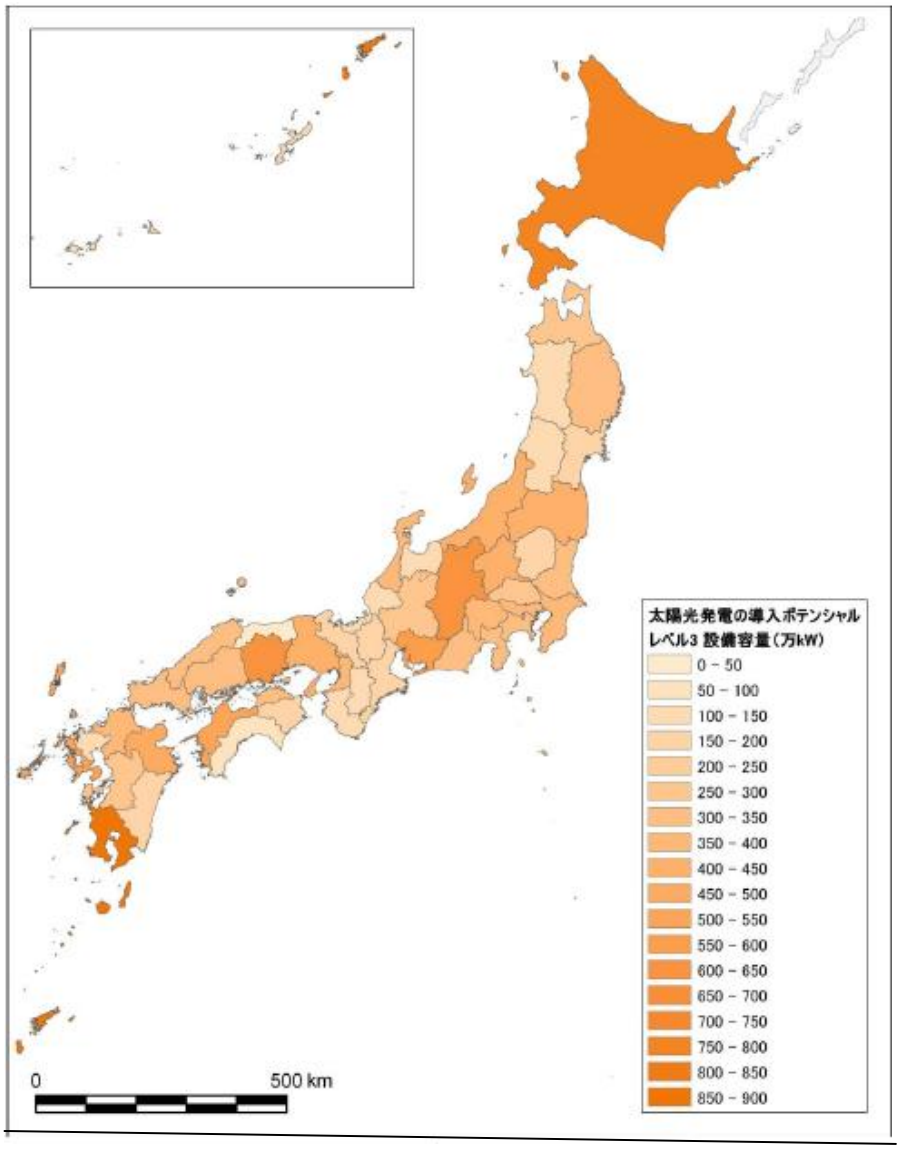


Figure 19 Solar Energy Introduction Potential
Source: Ministry of Environmental Research, *Research Potential of Renewable Energy*, 2003

4.1.3 Geothermal Energy Production in Japan

Japan is not commonly regarded as a significant player in geothermal energy. It was not until recently that Japan considered using geothermal plant as an important source of energy. As it is, Japan produces only 0.5 GW with 18 existing geothermal power plants, whereas global installed geothermal power capacity is now nearly 11GW. Japan ranks eighth in the world for installed geothermal capacity, according to the 2010 Geothermal Congress at Bali, Indonesia.[11] Geothermal energy accounts for less than 1% of Japan's total electricity mix. However, because the country is one of the most active volcanic countries in the world, geothermal energy in Japan will be able to contribute more significantly. Japan lies at the meeting point of several of the world's major tectonic plates, with nearly 200 volcanoes and some 28,000 hot springs. This means that there is an ever present threat from a range of natural hazards - earthquakes, volcanoes and tsunami. However, this also means that Japan can produce a lot of heat which can be used in a variety of ways. For example, for over centuries, the Japanese have enjoyed *onsen,* which is a Japanese traditional hot springs. Onsen is heated by the volcanic activity that frequently causes huge earthquakes in the country. In this way, ground heat is helpful to people. The more Japan tries to use ground heat, the more effectively this heat resource will be used. The following graphic shows the locations of Japan's geothermal power plants.

[11] 2012 World Geothermal Conference, Bali

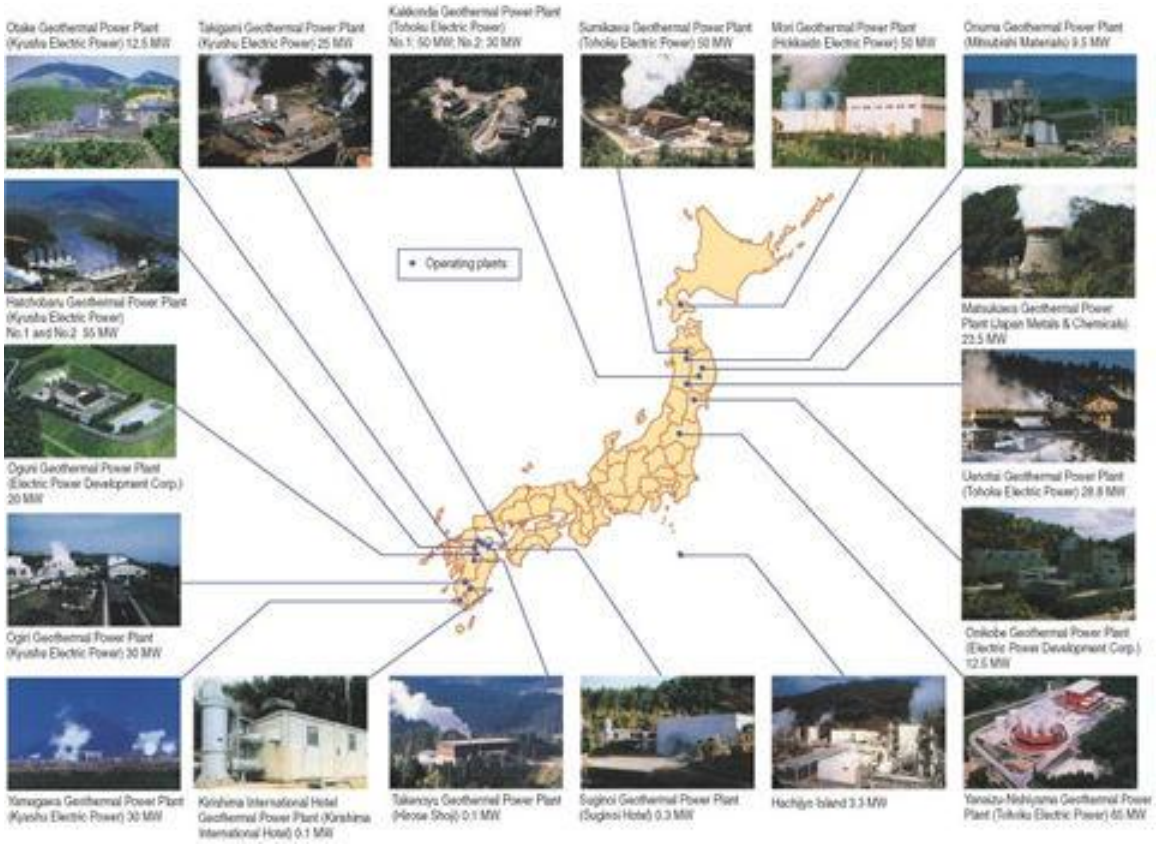


Figure 20 Geothermal Power Plant Locations in Japan
Source: 2012 World Geothermal Conference, Bali

According to the Ministry of the Environment Research[12], the abundance of geothermal power is estimated around 30 GW. In addition, the total potential of geothermal power is estimated around 14 GW. But, this estimation does not include national park area, where more than 80 percent of the nation's resources are located. That is, Japan would be likely to acquire more capacity if national park areas are included. As regards technical potential of Japan's geothermal energy, however, it is estimated to produce between 1.1GW and 5.2GW, depending on feed-in-tariffs and technology innovation.

12 http://www.env.go.jp/earth/report/h23-03/full.pdf

Below is the table of estimated total capacity of geothermal energy in Japan. As shown in this chart, total installed capacity differs very much in accordance with each scenario.

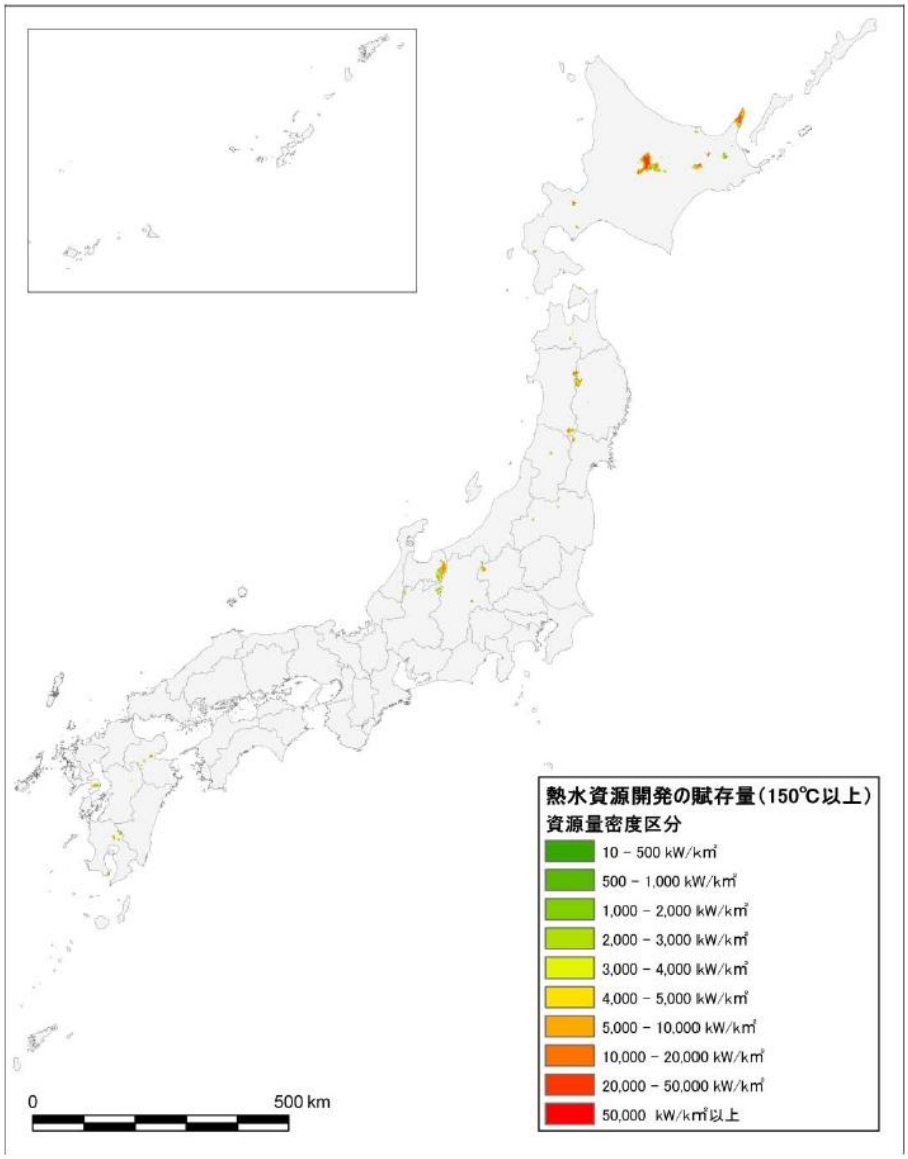


Figure 21 Geothermal Energy Introduction Potential
Source: Ministry of Environmental Research, *Research Potential of Renewable Energy*, 2003

4.1.4 Hydropower in Japan

To begin with, there is some controversy of the issues of hydropower as a renewable energy or not. It depends on the scale of hydropower plants. Small and medium-scale hydropower power plants are regarded as renewable energy resources. One of the common definitions for small and medium hydropower is a rated capacity of approximately 300 kW capacity or less. The limit is set as the maximum size for most standalone hydro systems not connected to the grid, and suitable for "run-of-the-river" installations that require little or no water storage.

Electricity generation through water power makes up the biggest share in renewable energy in Japan. Current installed capacity of hydropower is about 27 GW, although the number includes large scale hydropower plants. According to Agency for Natural Resources and Energy in the Japanese Ministry of Economy, Trade and Industry, the total installed capacity of small and medium hydropower plants is about 10GW in2011.

Japan has abundant water resources because rivers in the country are characterized by their relatively short lengths and considerably steep gradients due to the narrow and mountainous topography of the land. Visitors to Japan frequently comment that the rivers are almost waterfalls. It means that Japan, by making the most of this feature, will be able to produce a large amount of energy with small to medium hydropower plants that take advantage of the country's topography.

Japan has the potential to produce between 1.1 GW and 7.4 GW through small and medium hydroelectric plants, depending on feed-in tariffs, technology innovation and available subsidies. Figure 22 shows the estimated total capacity of hydropower energy in Japan. As shown in this chart, total installed capacity varies greatly in accordance with each scenario. However, the estimated capacity of this energy is not higher than other types of energy resources.

Installed Capacity (million kW)	Abundance	Introduction Potential	FIT Scenario	FIT*1 + Technological Innovation*1 Scenario	FIT * Subsidy*2	FIT + Technological Innovation + Subsidy*3
Rivers	17	14	(0.9 ~ 2.8)	(4)	(2.4 ~ 5.2)	(7.1)
Agricultural Canals	0.32	0.3	(0.16 ~ 0.2)	(0.2)	(0.22 ~ 0.26)	(0.29)
Water Supply, Sewerage and Water for Industrial Use*4	0.18	0.16				
Total	17	14	(1.1 ~ 3)	(4.3)	(2.7 ~ 5.4)	(7.4)

Figure 22 Estimation of Installed Small and Medium Hydropower Capacity by Scenario in Japan
Source: Ministry of the Environment Research

The following map shows the potential for hydroelectric power throughout Japan

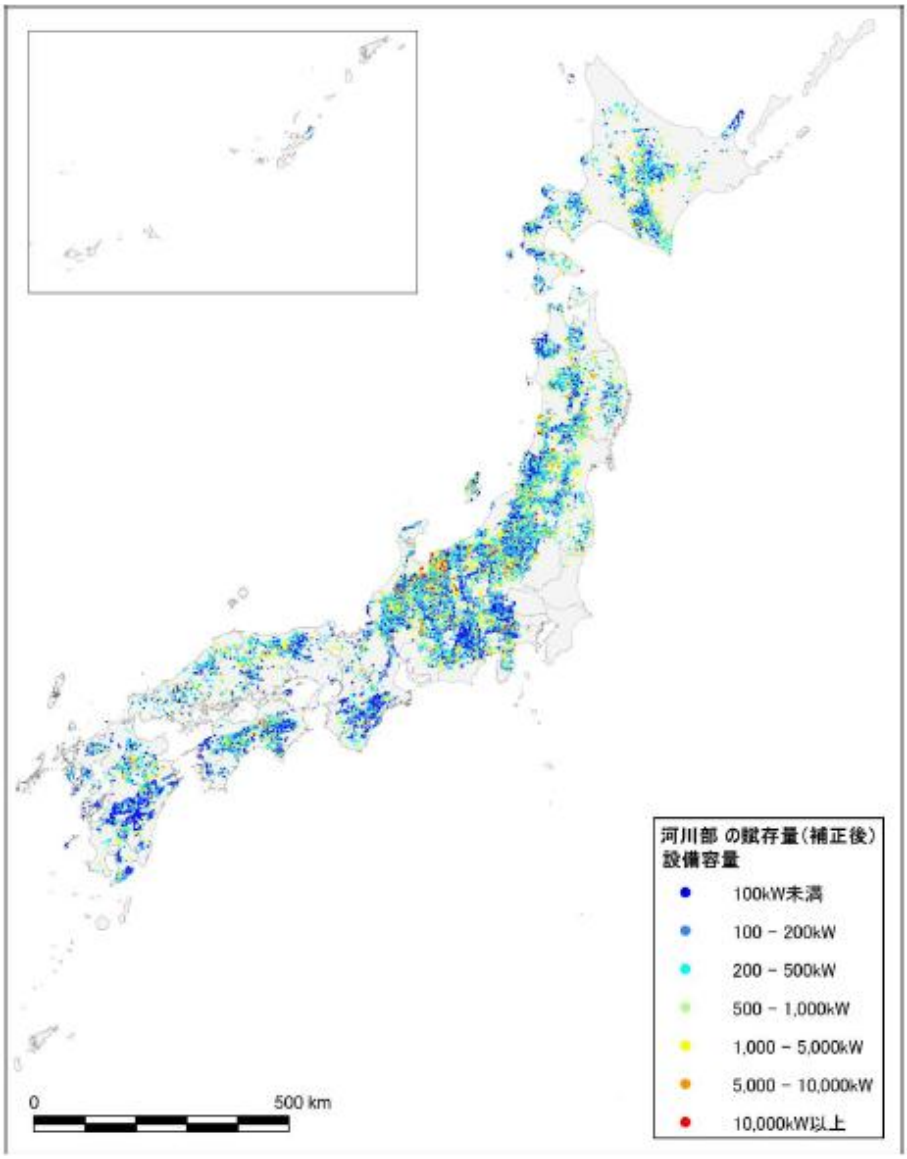


Figure 23 Hydropower Introduction Potential
Source: Ministry of Environmental Research, *Research Potential of Renewable Energy*, 2003

4.1.5 Biomass Energy in Japan

Biomass power generates energy and electricity by burning lumber, agricultural or construction/demolition wood waste that drives a turbine. The mechanism is the same as that of firepower energy. The difference between biomass energy and firepower is the form of the fuel. Firepower uses fossil fuel. Because biomass technologies use a combustion processes to produce electricity, they can generate electricity at any time, unlike wind and most solar technologies, which only produce when the wind is blowing or sun is shining. Japan's current installed capacity of biomass energy is 3.2 GW. The ratio of biomass energy in Japan's energy mix is less than 1%, and most of the results came from waste.

After the 2011 Tohoku earthquake and tsunami, which caused the worst nuclear disaster since Chernobyl, an interesting and possibly foreshadowing event is taking place in Japan. Woods from the nuclear power plants is being used as a source of biomass energy. As can be seen in this example, Japan is making every effort to utilize biomass energy.

Biomass energy could be one of the best energy resources when it is used, not as electricity but as heat. The use of biomass in heating system is beneficial because it uses agricultural, forest, urban and industrial residues and waste to produce heat and electricity with less effect on the environment. This is because the carbon, which is part of biomass, is part of the natural carbon cycle, whereas the carbons in fossil fuels are not part of the natural carbon cycle system.

Figure 24 Examples of Biomass Energy Resources
Source: Biomass Magazine, May, 2011

As described in the previous section, the Japanese government announced that it will introduce one of the best feed-in tariff systems in the world to encourage the development of biomass and other renewable energy resources. The recommended rate is 42 yen per kWh (52 U.S. cents), which is much higher than those of other countries. [13]

Unfortunately, numerical targets of estimation of installed capacity of biomass energy could not be set in this thesis, because the potential of biomass power is very difficult to measure, and it is not adequate to measure biomass power in terms of total installed capacity.

[13] Clean Technica, *Japan Creates Potential $9.6 Billion Boom* with FITs, June 21, 2012

5 Practical steps under this plan

5.1 Roadmap (100% Renewable Energy plan by 2020)

As noted in *Section 4*, the renewable energy power plants in Japan are likely to produce a large amount of electricity or heat. This section will mainly focus not on total installed capacity but on energy power demand (generation).

Below is a table of assumptions for renewable generated energy with each scenario; Abundance scenario, Introduction potential scenario, Feed-in Tariff scenario, Feed-in Tariff and Technological Innovation scenario, Feed-in Tariff and Subsidy scenario, and Feed in Tariff and Technological Innovation and subsidy scenario.

Installed Capacity (million kW)		Abundance	Introduction Potential	FIT Scenario	FIT+ Technological Innovation Scenario	FIT+Subsidy	FIT + Technological Innovation + Subsidy
Wind Power			**1900**	**24~140**	**410**	**130 ~ 590**	**1,500**
	Onshore	1,300	280	24 ~140	270	130 ~260	280
	Offshore		1,600	0 ~ 3	140	0.3 ~ 330	1,200
Solar Power			**150**	**0**	**0.2 ~ 72**	**0 ~ 26**	**69 ~ 100**
	Public Buildings		23	0	0 ~ 10	0 ~ 10	10 ~ 20
	Power Stations and Factories		29	0	0.2 ~ 14	0 ~ 14	14 ~ 20
	Low Use or Unused Land		27	0	0 ~ 1.3	0 ~ 1.3	1.3 ~ 2.9
	Abandoned Farmland		70	0	0 ~ 47	0	43 ~ 58
Geothermal		**33**	**14**	**1.1 ~ 4.8**	**5.2**	**1.5 ~ 4.3**	**4.6**
	Development of Hydrothermal Resources (150°C)	24	6.4	0.51 ~ 4.1	4.5	1.5 ~ 4.3	4.6
	(53 ~ 150°C)	9.6	7.8	0	0	0	0
	Hot Spring Power Generation	0.72	0.72	0.57 ~ 0.68	0.72		
Hydropower		**17**	**14**	**1.1 ~ 3**	**4.3**	**2.7 ~ 5.4**	**7.4**
	Rivers	17	14	0.9 ~ 2.8	4	2.4 ~ 5.2	7.1
	Agricultural Canals	0.32	0.3	0.16 ~ 0.2	0.2	0.22 ~ 0.26	0.29
	Water Supply, Sewerage and Water for Industrial Use	0.18	0.16				

Figure 25 Estimation of Installed Renewable Energy Capacity by Scenario in Japan
Source: Ministry of the Environment Research, *Study of Potential for the Introduction of Renewable Energy FY 2010*

Above all, this section will focus on Feed-in Tariff + Subsidy scenario. This scenario was selected because Japan put the feed-in tariff system into practice and is likely to subsidize renewable energy. On the other hand, drastic technological innovation might not be advanced due to factors like technical limitation or cost efficiency.

Based on the above table, the following chart illustrates the installed capacity comparison between current installed capacity and estimated installed capacity under Feed-in-Tariff + Subsidy scenario. The estimated installed capacity under this scenario greatly exceeds the current nationwide capacity. It means that the potential of renewable energy is huge enough to replace current unsustainable energy resources such as fossil fuels. The maximum estimated installed capacity is about three times as large as current capacity. This is due largely to off-shore wind power energy. Developments of offshore wind power plant would be an essential key to achieving a 100% renewable energy country.

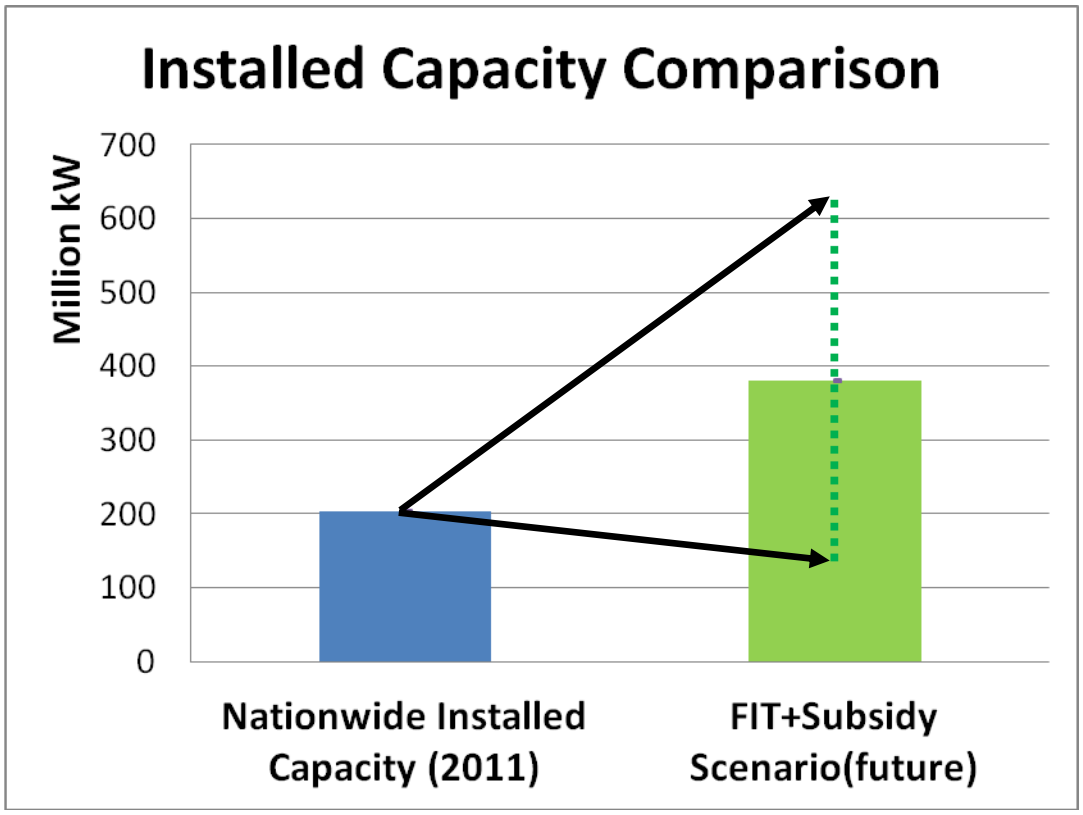


Figure 26 Installed Capacity Comparisons
Source: Ministry of the Environment Research, *Study of Potential for the Introduction of Renewable Energy FY 2010*）

In this scenario, highlighted cells shown in Figure show the assumptions for total generated energy for each resource. This numerical analysis is based on some capacity factor assumptions. The assumed capacity factor of each type of renewal energy is as follows:

- Wind power = 24%
- Solar power = 12%
- Geothermal power = 75%
- Hydropower is 65%.

The following chart compares current generated power and future estimated generated energy under Feed-in-Tariff +Subsidy scenario. Although it would be hard to manage Japan's whole energy with only renewable energy resources, there is a enough possibility that 100% renewable energy is possible in Japan if the government and the people work together to use energy wisely. Under the Feed-in-Tariff + Subsidy scenario, the potential of renewable energy can exceed current generated power.

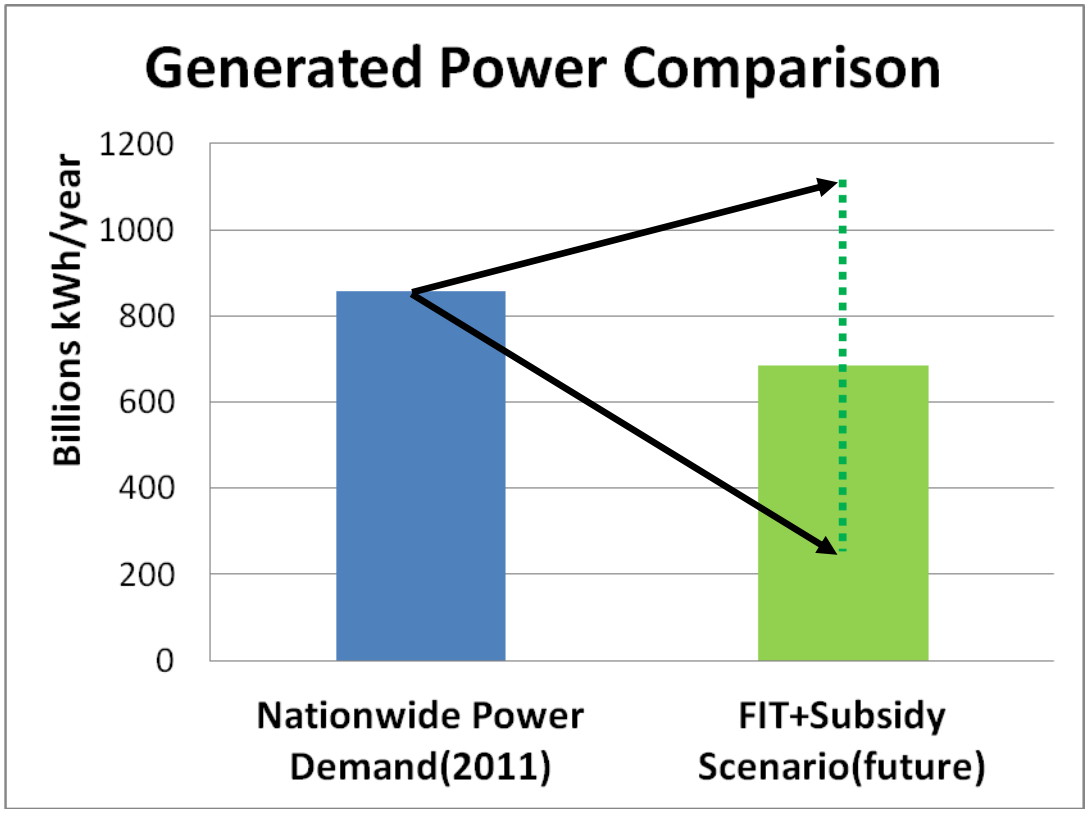


Figure 27 Generated Renewable Power Comparison
Source: Ministry of the Environment Research, *Study of Potential for the Introduction of Renewable Energy FY 2010*

6 Conclusion

Since the 2011 earthquake, tsunami and nuclear power disaster, energy has been one of the most controversial issues in Japan. Until then, Japan had thought of nuclear energy as its main energy resource. Since then, the country has shifted from a pro-nuclear to anti-nuclear position. Under these circumstances, it might seem very difficult for Japan to achieve 100% renewable energy. However, with discussion and public support, Japan will be able to become a 100% renewable energy country. Although there are a many reasons to support this goal, three of the most preeminent reasons are public opinion, high technology, and energy policy/system.

First of all, there is a good public support for renewable energy. Actually, after the 2011 disasters, more and more Japanese people are opposed to nuclear power and the movement of those people is about to change government policy This is because they saw how dangerous the nuclear power can be when a plant is damaged. Strong public opinion is needed when a country must make a drastic change to that country, because peoples' cooperation is required to achieve sustainable energy country.

Another reason is that Japan has extensive technology not only in electronics but also in the energy industry. According to World Intellectual Property Organization (WIPO) Japan has 55% of the patent applications in the field of renewable energies. Japan's research and development in the renewable energy field is advanced both in the academic area and private sectors. It means that Japan may lead world's renewable energy industry.

Furthermore, Japan has many excellent systems and policies that facilitate renewable energy, the most notable of which is Japan's feed-in tariff system. Under this system, Japan government decided to buy renewable energy with good price. Many think this tariff will boost this country to the world's largest solar market.

Based on all the reasons mentioned above, Japan could manage their energy only by renewable energy. Certainly, there are many obstacles like cost, nuclear power, time, and feasibility. However, by making the most of their public opinion, technology, and systems, we believe that 100% energy in Japan by 2020 is possible.

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