GENI Global Energy Network Institute

How is 100% renewable energy in Japan possible by 2020?

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Abstract

This report focuses on how 100% renewable energy in Japan is possible by 2020. As you know, Japan is now in severe condition about their energy because of last year's nuclear power plant disaster caused by earthquake and tsunami. Since last year, Japan has been suffering from managing their energy in a peak time. To solve this problem, Japan government and the Japanese people are trying to shift their energy to renewable energy. Certainly, it is obvious that the chance of fruition is exceedingly low even if possible. However, this report takes a strong position on energy issues. The purpose of this report is to show a lot of people including decision makers and political leaders the feasibility of 100% renewable energy country.

In this report, 1st chapter is about current energy demand and supply situation. 2nd chapter is about what kind of law or system is currently applied to renewable energy. 3rd chapter shows main reasons why Japan can manage their energy only with renewable energy. 4th chapter describes potential of each renewable energy. 5th chapter is practical assumption of generated energy and 6th chapter concludes above all those ideas.

As a result of research, this report reveals that Japan has a enough possibility to attain renewable energy society. This is because Japan has strong public mind toward clean energy such as solar power of wind power, has high technology about renewable energy, and strong system such as Feed in tariff system.

Therefore, Japan has high potential and need to be a leader in a global renewable energy field. As Japan does not have any natural resources, trying to promote renewable energy will create a lot of job in this country and will enable Japanese people be satisfied their country.

1 Current situation related to renewable energy

1.1 Analysis of Energy source

Japan does not have significant domestic energy resources of fossil energy except for a bit amount of coal. Therefore, Japan is current No.1 hard coal and natural gas importer in the world. In fact, for a long time since 1970s with high economic growth, Japan has mainly relied on oil from Middle East area. Although Japan depended on oil for 75.5% of their entire energy resources in 1973, due to oil shock Japan gradually shifted their energy resources from oil to other resources, such as nuclear energy, natural gas and coal or had tried to develop new energy. As a result, diversification of energy resources has been promoted; current energy supply in Japan includes not only oil but also coal, natural gas, nuclear energy and renewable energy, such as hydropower, natural energy and ground heat. Here is a chart of current energy source in Japan.

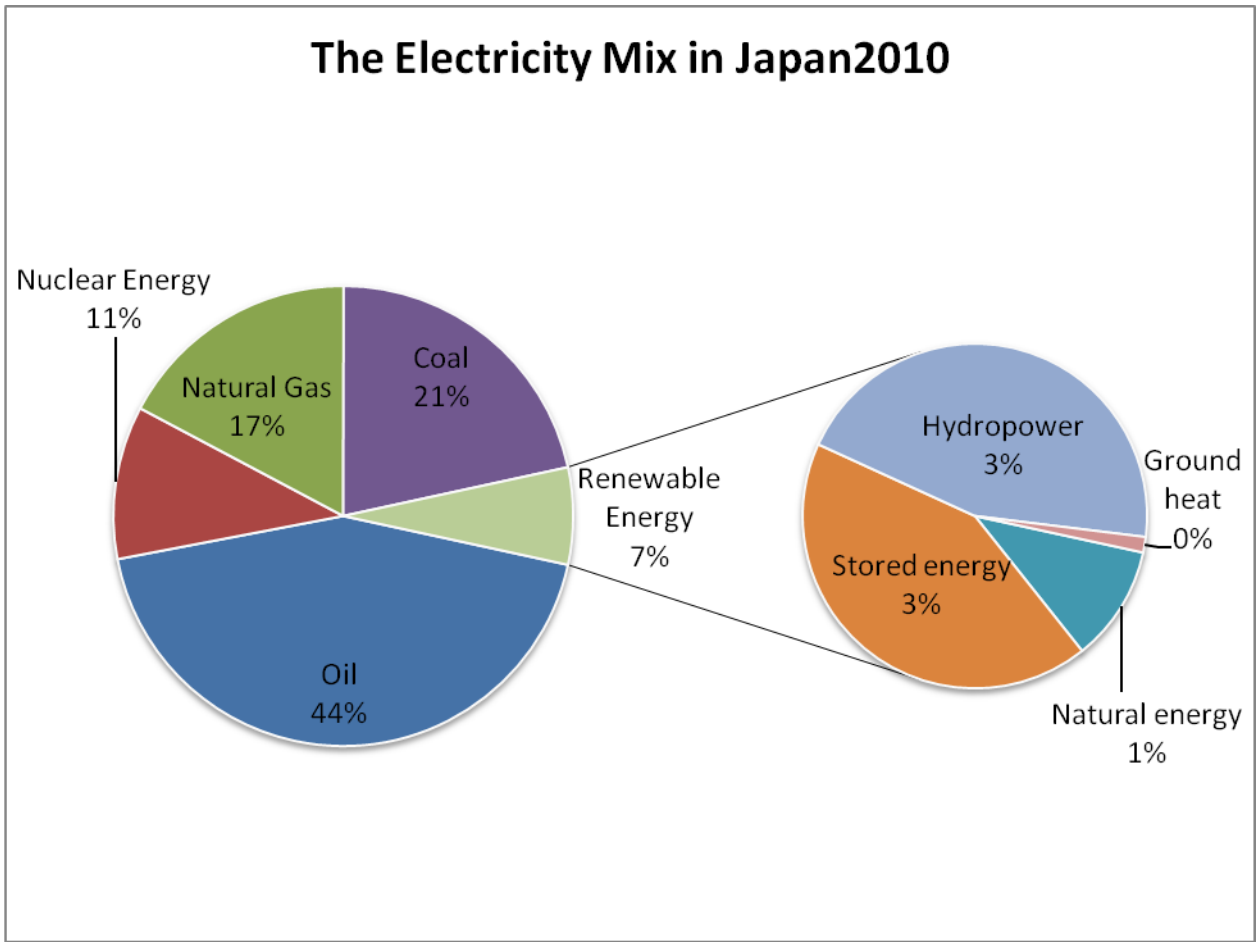

Figure 1 Energy Source in Japan 2010

As shown in Figure 1, even in 2010, oil is used as a main energy source and it accounts 44% of whole energy. The second largest energy demand comes from coal, and the demand of natural gas and nuclear follows them. Japan is the third largest consumer of nuclear power in the

world, after the United States and France. As for renewable energy, it accounts only 7% of energy source. It means that the self-sufficient rate in energy is absolutely low in Japan, compared to natural energy advanced countries like France or Germany.

Based on the Japan's government statement in 2010 the government has to reduce 25% of their carbon dioxide emissions compared to 1990 levels by 2020. In order to realize sustainable environment, this goal should be achieved and there should be a need to show a clear plan and actual results to other countries.

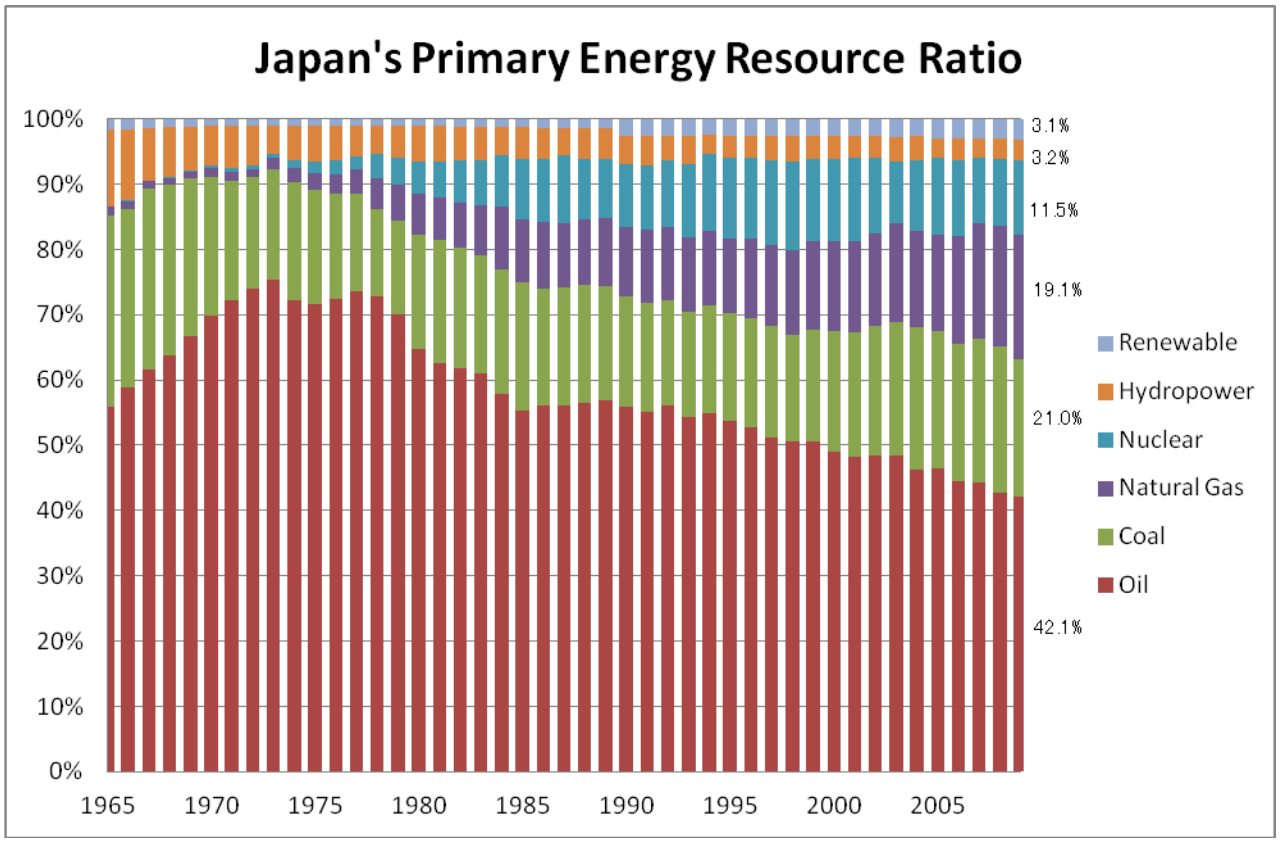

Figure 2 Japan's Primary Energy Resource Ratio

Figure 2 shows that 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' ratio has increased from almost nothing to about 20%. As is concerned with sustainable energy, the share is less than 10% now. What can be inferred from this chart is that there many steps to overcome to be sustainable country.

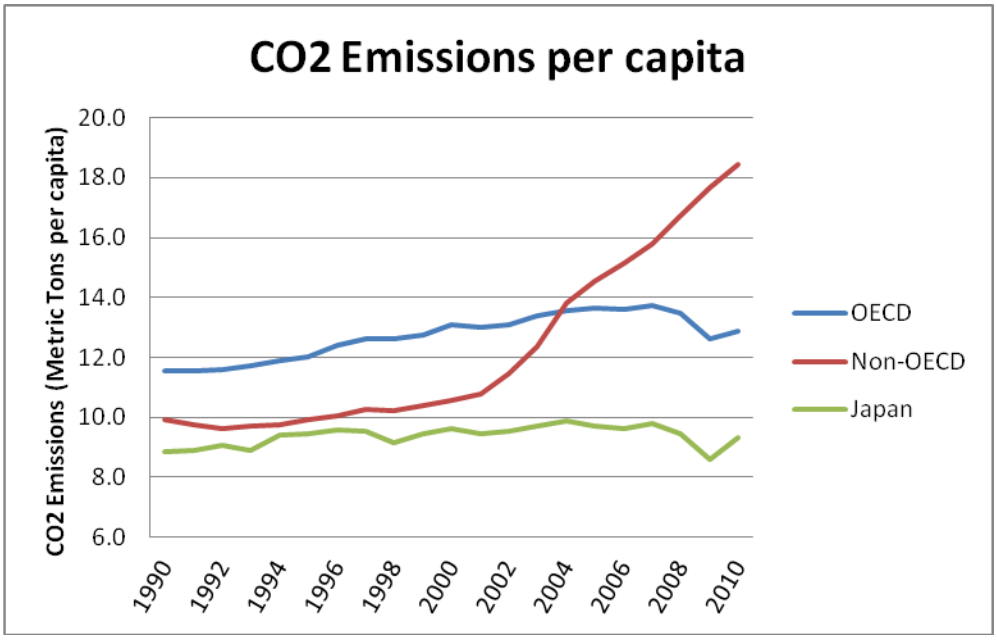

Figure 3 CO2 Emissions per capita

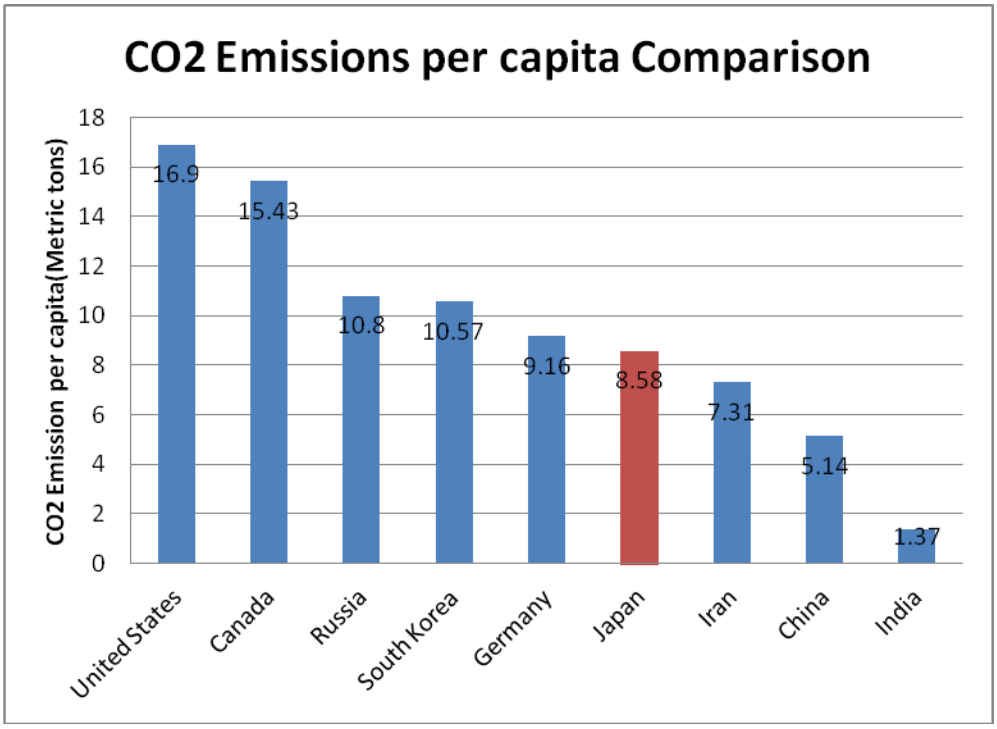

Figure 4 CO2 Emissions per capita Comparison[1]

[1] Long-term trend in global CO2 emissions. 2011 report , PBL Netherlands Environmental Assessment Agency, The Hague, 2011

In the past 20 years Japan has tried to reduce its carbon dioxide emission, but Japan could not have been succeeded very much. However, as Figure 3 shows, carbon dioxide emissions per capita in Japan is actually less than OECD average for over 20 years. Also, Figure 4 shows that Japan emits less Carbon dioxide than other big energy consuming countries in 2009. In other words, Japanese people have high interests in global environment. It means Japanese people are positive to aim at sustainable environment and Japan has high potential to be environmental country.

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[2], Japan consumed 858.5billion kilowatt-hours of electricity. Japan has approximately 282 GW 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 electricity generation is consumed and distributed throughout several kinds of sectors including industry, transport, commercial and public, and residential. Ministry of economy, trade and industrial tracks national energy consumption in four broad sectors: industrial, transportation, residential, and commercial. The breakdown of energy consumption in Japan is shown in below Figure 5. Industry and transport account for two thirds of energy consumption in Japan.

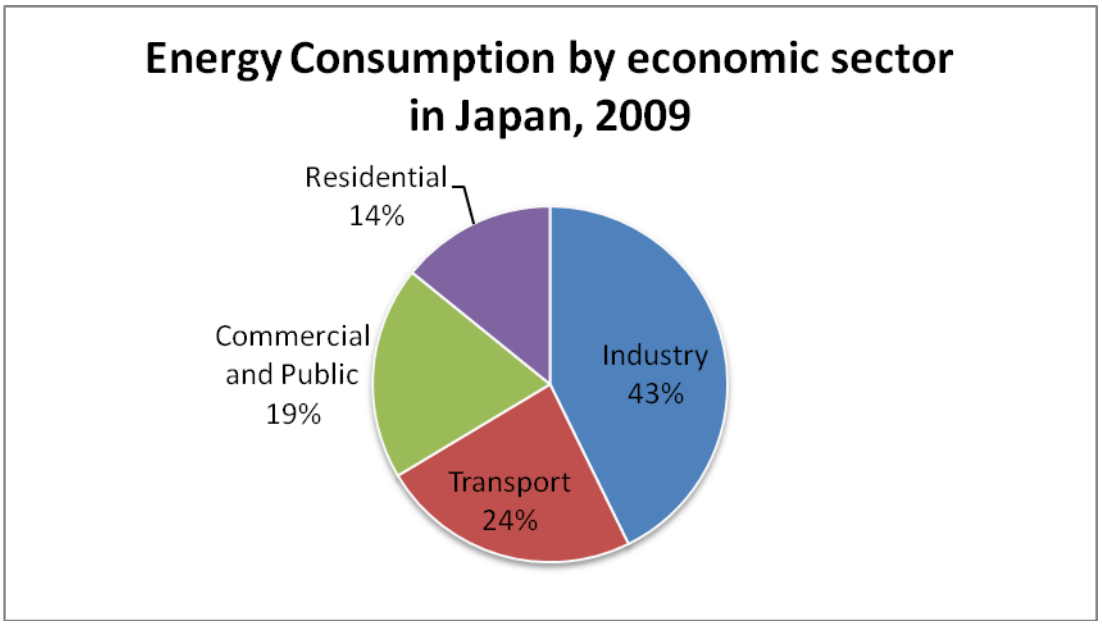

Figure 5 Energy Consumption in Japan, 2009 (source: エネルギー白書 2011 [3])

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

[3] http://www.enecho.meti.go.jp/info/statistics/jukyu/resource/pdf/120413_gaisoku.pdf

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 sector.

The total energy consumption has gone as far as it can go, and it has been decreasing for a couple of years. After Tohoku 3.11 earthquake, the total amount of energy consumption decreased more rapidly than before, because there was not enough energy supply. As Japanese people, especially people of Kanto and Tohoku area survived one year with this total supply of energy, they will probably be able to deal with the same amount from next year. Some concerns are make-up for nuclear power, because all nuclear power plants are currently stopped. Currently, Japan government deals 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 LNG imports rose 52 percent to 5.4 trillion yen in the 12 months through March this year.

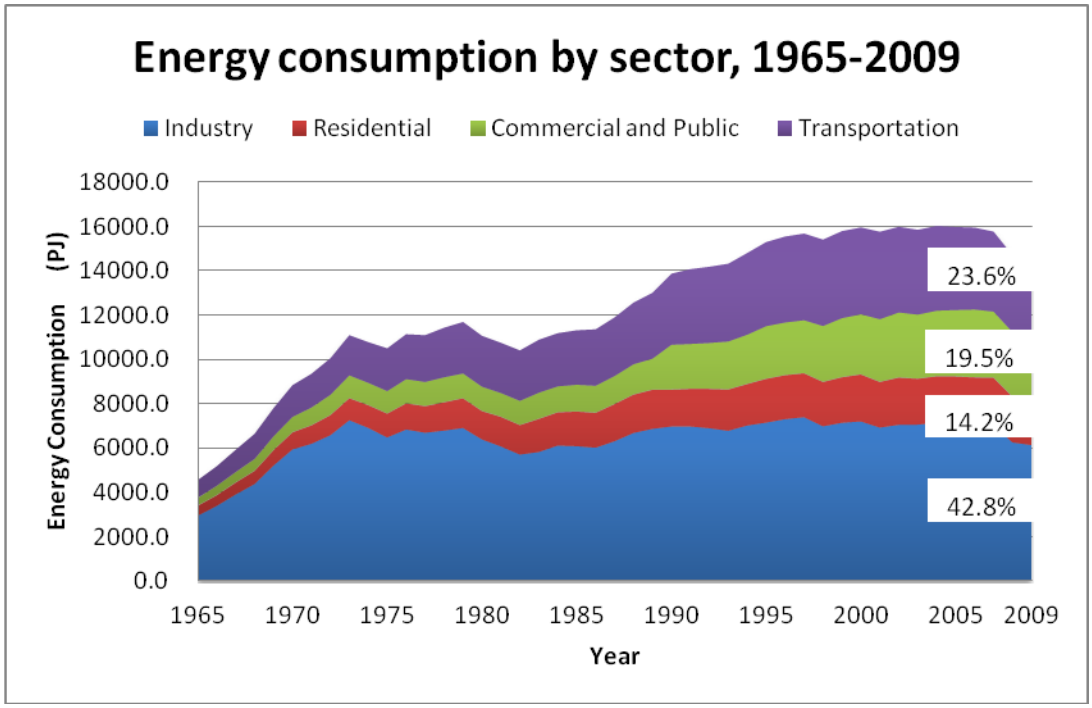

Figure 6 Energy Consumption by Sector, 1965-2009
(Source: 資源エネルギー庁 総合エネルギー統計[4])

[4] http://www.enecho.meti.go.jp/info/statistics/jukyu/resource/pdf/120413_gaisoku.pdf

1.3 Relevance between energy source and demand

The below Figure 7 shows that how energy demand and supply are related with each other. Generally, energy can be various kinds of energy through the process of transmitting and modifying. Broadly speaking, Energy, especially electric energy is made from raw material like oil, natural gas and coal through power plants. There are a lot of energy losses through this process because energy loss occurs when energy is generated with or transmitted. For example, if the primary energy supply were estimated 100, energy consumption would have been 70. Primary energy supply consists of oil, natural gas, LP gas, coal, nuclear power, solar power, and wind power, whereas energy consumptions consist of oil products, electricity and heat. Looking with classification 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.

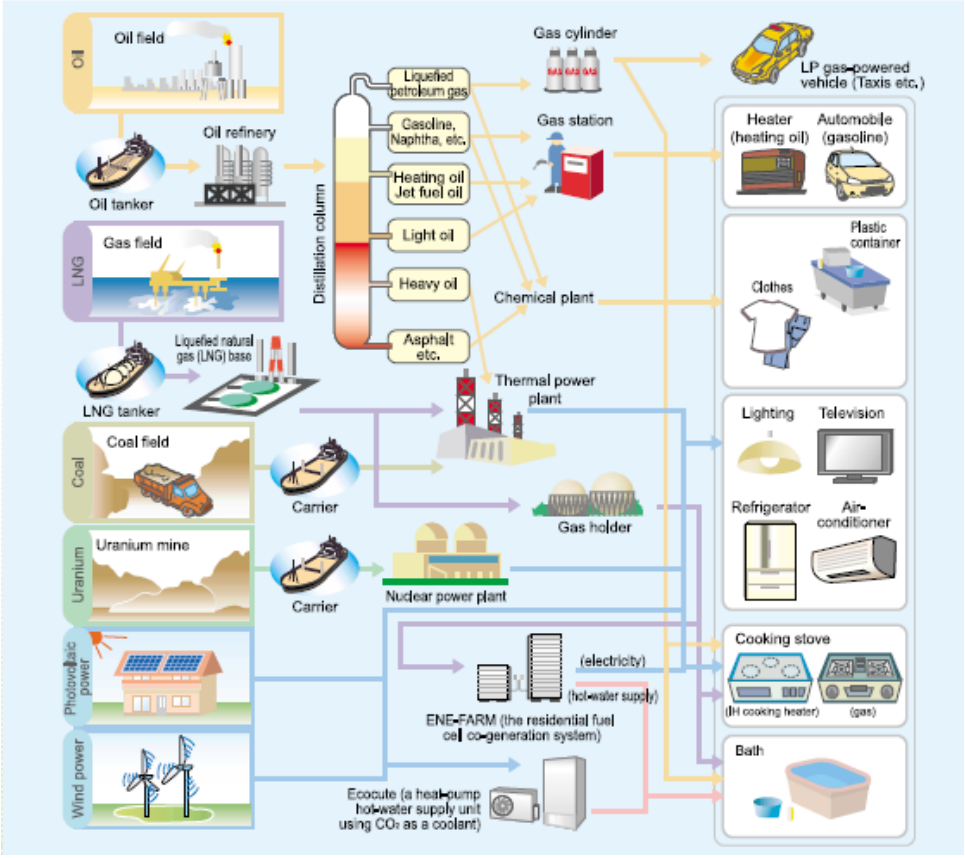

Figure 7 Process of Energy and Form of Use (source: Energy in Japan 2010, Agency for Natural Resources and Energy, 2010 [5])

[5] Energy in Japan 2010, Agency for Natural Resources and Energy, 2010 (p. 2)

2 Current Energy policy, law, and strategy

According to Swedish Agency for growth policy analysis[6], Japan's current policy, law, and strategy are mainly "Basic Energy Plan" and "New Growth Strategy". Each plan is described as follows.

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 next amendment will be changed drastically because of last year's nuclear power disaster caused by huge earthquake and tsunami. Although it will be changed, the targets under 2010 Basic Energy Plan[7] are as follows;

1) Double the energy self-sufficiency ratio in energy supply and the self-developed fossil fuel supply ratio , and as a result raise the energy independence ratio from current 38% to about 70%.
2) Raise the zero-emission power source (nuclear and renewable energy) ratio from current 34% to about 70%.
3) Half CO2 emissions from the residential sector.
4) Maintain and enhance energy efficiency in the industrial sector at the highest level in the world.
5) Maintain or obtain top-class shares of global markets for energy-related products and systems.

2.1.2 New Growth Strategy

In June 2010, the Japanese government finalized its "New Growth Strategy" high aims to achieve economic growth by FY2011 by boosting demand in 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 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.

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[6] http://www.tillvaxtanalys.se/tua/export/sv/filer/publikationer/working-paper-pm/WP_PM_2010_06.pdf

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

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

These projects were selected in the "New Growth Strategy" to contribute the 2020 targets, and the Strategic Projects regarding energy and its resources are as follows[8].

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

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

2.2 Surrounding environment of renewable energy

2.2.1 Kyoto protocol and Post Kyoto protocol

Kyoto protocol is a multi-national agreement aimed at controlling the 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 entered force on 16 February. Almost all countries in the world except 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, 6% reduction, targets with nuclear energy. However, because of last year's meltdowns at the Fukushima Dai-ichi plant caused by devastating earthquake and following tsunami, Japan is estimated to produce about 15 percent more greenhouse gas emissions this fiscal year than 1990 level. In spite of these problems, Prime Minster Yoshihiko Noda has pledged to reduce reliance on nuclear power, although Japanese government is eager to restart some nuclear reactors to make up for its electricity shortage during 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.

Speaking of Post-Kyoto negotiations, part of United Nations Framework Convention on Climate Change seems to be the first conference which concerns the period after the first" commitment period" of 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 development nations are the Kyoto-protocol, only few countries are on track to reach each emission reduction goals. To make matters it worse, most of the countries which will be likely to reach their goals will have reached because of the recent global recessions. In response to this, now the leaders of Russian, Japan, and Canada confirmed that they would not join a new Kyoto-style agreement. There are mainly two reasons for this. One reason is that developing countries do not sign Kyoto protocol, especially China and India, which are not required because they are not considered yet major industrial nations. They do not think it is fair that China or India, even though they expel greenhouse gas emissions more than them, do not have to sign the treaty. Another reason is that the U.S., the world's biggest economy, does not sign post Kyoto protocol. Furthermore, U.S. does not even sign 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 effort on reducing their greenhouse gas emissions. Japan tries to attain their original goal without regarding to multi-national agreement. According to Japan's Vision and

Actions toward Low-Carbon Growth and a Climate-Resilient World[9], which was announced in COP 17 held last December in Durban, Japan will help 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 including a lot of emerging countries the launching of the Bilateral Offset Credit Mechanism. In this mechanism, Japan can use credit earned from their technologies to reduce their greenhouse gas emissions as a part of international greenhouse gases mitigation of each country. Japan is now trying to improve environmental performance with deploying their environmental business.

[9] http://www.mofa.go.jp/policy/environment/warm/cop/lowcarbongrowth_vision_1111.html

2.2.2 Current situation especially after Fukushima accident

Since huge 3.11 earthquakes and devastating accident at Fukushima No.1 nuclear power plant, energy policy has been the biggest controversial issue in Japan. These events put a question to people all over the world that nuclear energy is no longer safe resource.

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

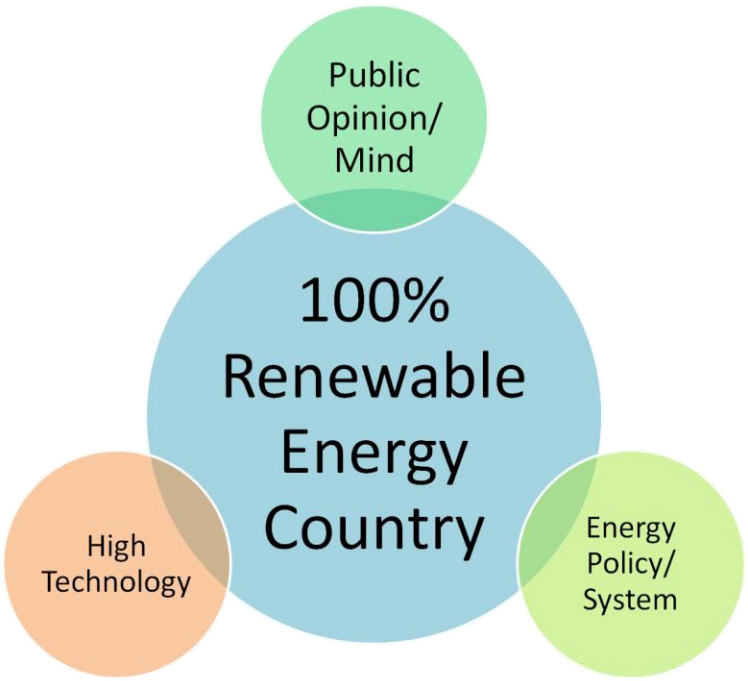
2.2.3 Threats of nuclear power

Nuclear energy has a lot of issues to be discussed. One of the biggest mistakes everyone has because of some politicians or people from electric company is that nuclear power is by no means cheap energy. On the surface, the cost of nuclear power looks very cheap. However, it does not include the invisible cost which only arises when some accidents happen. In detail, “the invisible cost” includes health damage, crop damage, reputation damage, environmental problem, decline of tax revenue and so on. The cost of nuclear power is likely to exceed the cost of other energy source if these invisible costs are taken into consideration.

3 Feasibility of 100% renewable energy

Apparently, only based on those facts mentioned above, 100% renewable energy in Japan by 2020 might sound impossible. However, there are three strong points to support that Japan will manage their energy only by sustainable energy. Three reasons are shown below picture;

1) Public Opinion/Mind
2) High Technology
3) Energy Policy



These reasons are described in detail from next page. Summaries of each reason are as follows. Public mind and opinion greatly changed after Fukushima nuclear reactor accident and more and more Japanese people wish their country to shift away from a reliance on nuclear power after the Fukushima disaster. Japan actually has high technology like renewable energy patents, and Japanese government had established Feed in tariff system and put it into practice to improve sustainable country and tries to come to an end.

3.1 Public opinion/mind

3.1.1 Main issues after 3.11

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 decided after earthquake and nuclear accident is the attitude of government towards nuclear power. Here are several issues about nuclear problem and their aftereffect.

Energy policy issues after 3.11 (including unofficial documents)

1. Convergence of Fukushima nuclear power plant accident
2. Stable electricity supply without nuclear power plant
3. Avoidance of financial crisis caused by TEPCO
4. Compensation to victims in Fukushima
5. How to minimize national burden rate
6. Fair burden of stakeholders and satisfaction of the people
7. Radical review of Japan's whole nuclear system
8. Radical review of electric business regulation
9. Determination and implementation of regeneration Current situation

Furthermore, Japan has abandoned most of their nuclear resources since March 11th last year. Utilization rate of nuclear power plant fall down from 70% to less than 10% in March this year. Instead of that, Japan imports more and more oils or natural gas from foreign country to compensate for nuclear plant. Actually, total imports of LNG, which is a kind of natural gas, climbed approximately 10% to 85.5millon tons. This trend will be supposed to continue for a long time in the future if nothing is changed. Therefore, new type of energy source which is clean and safe is strongly needed by Japanese people. Now that two-thirds of people are against nuclear power, whereas two thirds of people were for nuclear power. In this way, peoples' attitudes toward energy are gradually but surely changing.

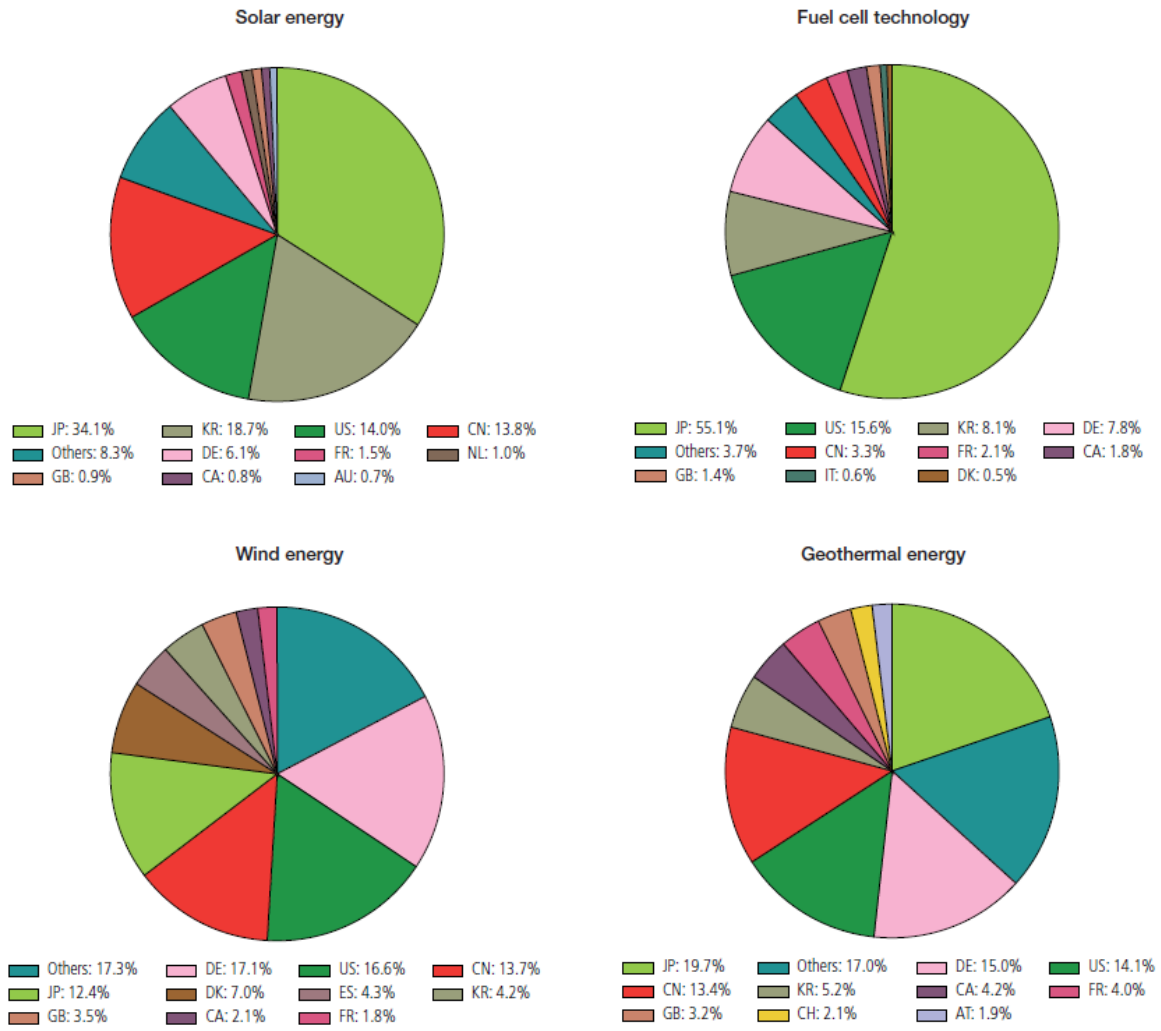
As for the Japanese people, more and more people oppose the idea of using nuclear energy as a main source of power. Since last year's accidents of Fukushima No.1 reactor, a large number of people who take part in an anti-nuclear gathering has been increasing rapidly. As can be seen in these situations, it is needed for Japanese government to shift their energy resources from nuclear to other resources. Moreover, there is further good news about Japan. On 5th May 2012, Japan became first developed country in the world which stops using nuclear power plant. Public consensus has prevented the government to stop not to restart using such sources. Actually, most of Japanese do "setsuden" (power saving in Japanese) this year and "setsuden" is becoming growing movement in Japan. And this energy saving mood sweeping the country is a new trend which gives an opportunity to push for clean energy over national policy that favours nuclear power. By making 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 World Intellectual Property Organization (WIPO)[10], Japan has 55% of world's renewable energy patents applications, and is followed by the U.S with 22%, EU 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 field, wind power field and geothermal generation technologies have maintained equivalent position to the US and EU nations. Figure 8 shows the breakdown chart 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 most of their technologies on imports from the US or Europe countries. Additionally, Japan's market of energy needs is small and some people think the small domestic market and Japan might be slow to commercialize. However, almost all fields of renewable energy, Japan still has a lot of strong points to lead other countries in renewable energy field.

[10] http://www.eco-online.org/2011/08/15/%E6%97%A5%E6%9C%AC%E3%81%AF%E5%86%8D%E7%94%9F%E5%8F%AF%E8%83%BD%E3%82%A8%E3%83%8D%E3%83%AB%E3%82%AE%E3%83%BC%E6%8A%80%E8%A1%93%E3%81%AE%E3%83%88%E3%83%83%E3%83%97%E3%83%A9%E3%83%B3%E3%83%8A%E3%83%BC/



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 8 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, Japanese government established energy and environment council to correct the distortion of energy system- vulnerability, and to formulate safe, efficient, and environmental policy. According to Energy and Environment Council, Japan will try to realize the following three principles.

1) To realize new optimum mixture of power sources
2) To realize the new energy system
3) To achieve the Japanese people's consensus

Japanese government will announce "Basic Energy Plan" and plan to put "Energy and Environmental Policy" together in fall 2012. As a basic viewpoint, Japan will incorporate "Ensure the safety" "Public participation" to the basic principles, which are "Secure 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 offers 20-contracts for photovoltaic plants for large scale plants and 10-years contracts for small scale photovoltaic plants. This tariff system went into effect on July 1st, 2012. In this system, the price of tariff is much more expensive than other countries' tariff system. Therefore, it is expected for Japan to develop the solar system and Japan has high possibility to lead renewable industry. However, as a whole, policy change and law change about energy related problems have not been established enough yet to realize 100% renewable energy.

Instead of government, a lot of private institution have been announced or advised a lot of proposal. For instance, according to Japanese Consumers' Co-operative Union's report, Japan should try to make emphasis on these five issues in order to keep the sustainable energy system in a long term.

1) Conversion to a energy which is independent from nuclear power
2) Large scale electricity reduction by power saving
3) Expansion of renewable energy
4) Shift from oil firepower to natural gas firepower
5) Construction of 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 as follows shown in Figure 9

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 9 Generating Costs for Each Type of Energy (source: コスト等検証委員会報告書, The Energy and Environment Council [11])

Caused by a series of accidents which have happened after 11th of March, sustainable energies such as solar power, biomass, wind power and other kinds of renewable energies have been growing in importance and have been expected very much by the Japanese people.

Figure 10 shows the range of generating costs for each types 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 is expected to drastically fall down. 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 a few decades.

[11] http://www.npu.go.jp/policy/policy09/pdf/20111213/siryo1.pdf

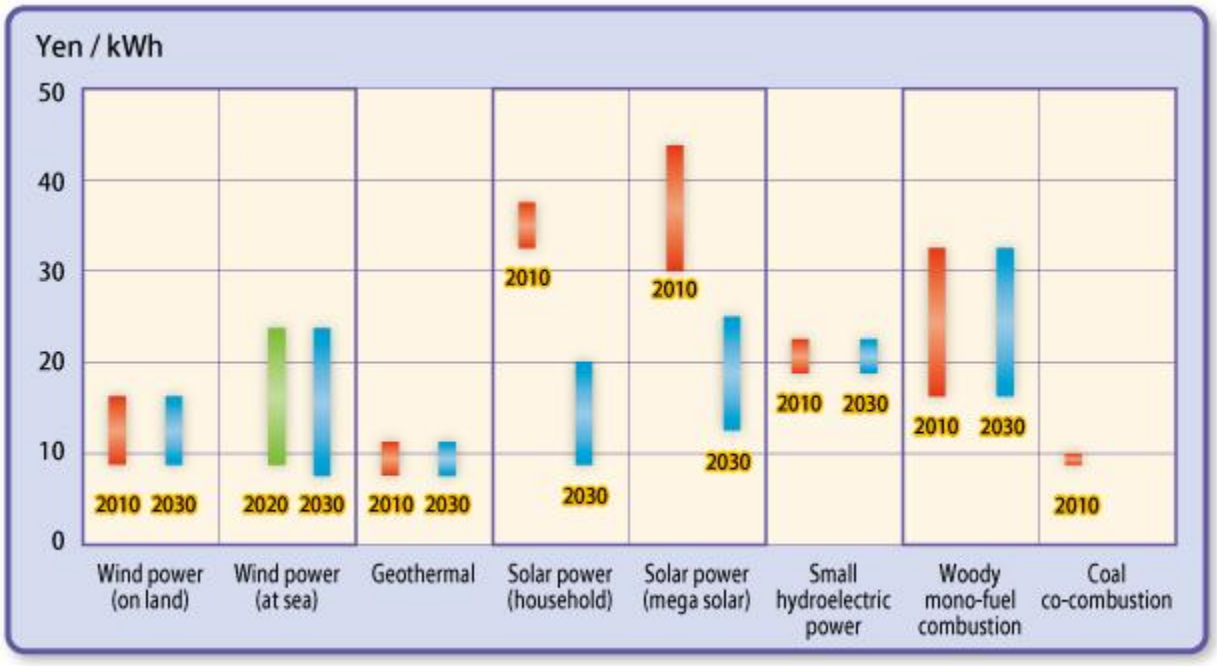


Figure 10 Generating Costs for Each Type of Energy
(Source: コスト等検証委員会報告書, The Energy and Environment Council[12])

In order to popularize renewable energies it will be important to reduce Japan's generating costs of renewable energy and promote the local production and consumption of electricity, whereby electricity is generated from the renewable energies that are most suited to the local region and then consumed in said region. The shorter the distance between generated area and consumption area becomes, the cheaper the cost of generating and transmitting energy is.

[12] http://www.npu.go.jp/policy/policy09/pdf/20111213/siryo1.pdf

3.3.3 Feed-in Tariff system in Japan

A feed-in tariff is a policy mechanism designed to accelerate investment in renewable energy industry. It achieves this by offering long-term contracts to renewable energy producers or companies. According to SustainableBusiness.com News[13], Japan government announced pricing for the country's landmark renewable energy feed-in tariff. Solar stocks rallied on the premium price that will be paid for solar, which many think will boost this country to the world's largest solar market. Utilities will pay 42 yen/ 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 its government has a very important meaning, because this system has a great deal of cost impacts caused by what is called the merit order effect. 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. Below[14] is a chart of estimation about each renewable energy cost trend.

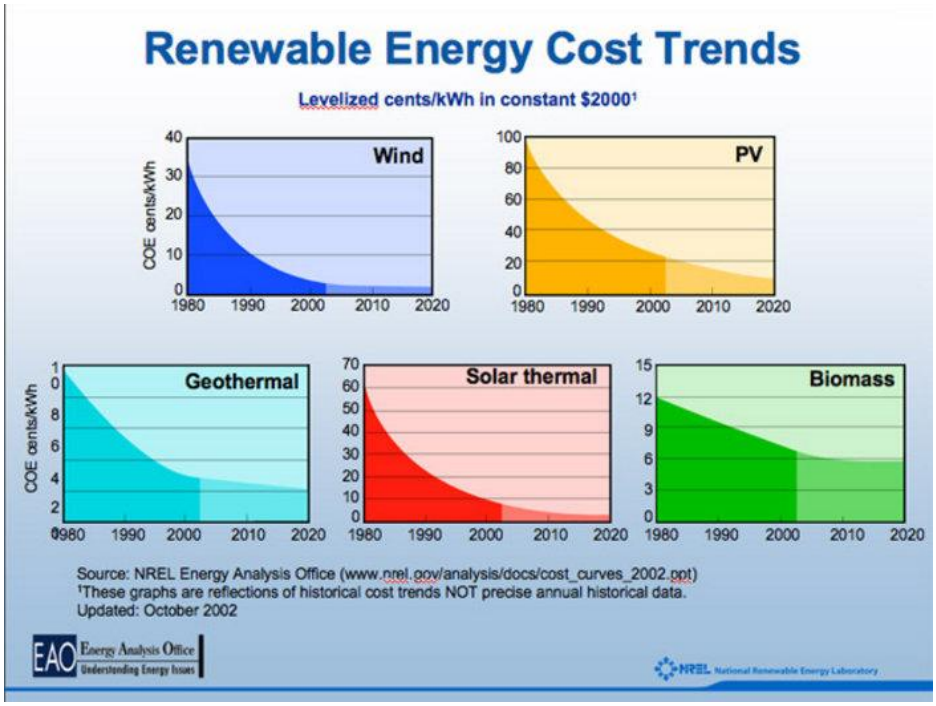


Figure 11 Renewable Energy Cost Trends (source: The Asia-Pacific Journal)

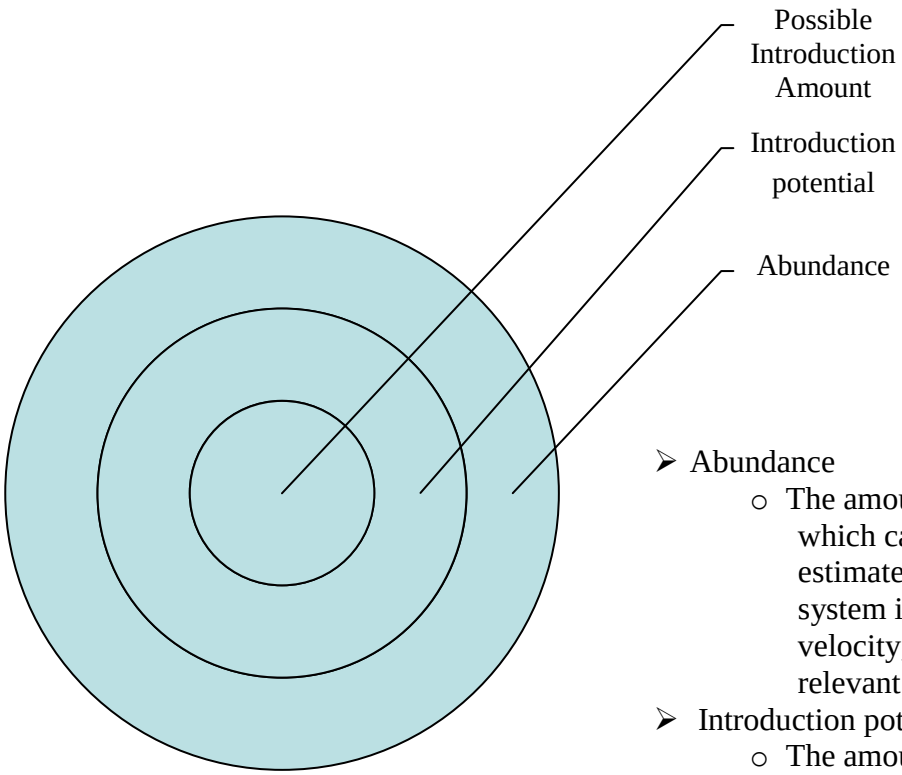
[13] http://www.sustainablebusiness.com/index.cfm/go/news.display/id/23798

[14] http://www.japanfocus.org/-Andrew-DeWit/3249

4 Assumption about 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 like Figure 12[15].



- Abundance
  - The amount of energy resources which 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 which take various limiting factors for energy collection and utilization into consideration.
- Possible introduction
  - This is a portion of the introduction potential which can hopefully be realized for actual use under a specific assumptions for project viability.

Figure 12 Definition of potential
(resource: Cost Estimation and Review Committee Report, Energy and Environment Council)

[15] http://www.npu.go.jp/policy/policy09/pdf/20111213/siryo1.pdf

4.1.1 Wind Power in Japan

Wind power experienced drastic growth over the last decade. Wind technology is becoming popular and is regarded one of the biggest resource of renewable energies all over the world. As for this country, Japan currently generates about 2.2GW per year, whereas Germany or United States produce over 20GW per year. Global installed capacity currently is over 200GW. Compared to these top renewable energy countries, Japan produces only one tenth as much as those countries.

According to Ministry of the Environment research[16], the potential capacity of wind power in Japan is estimated to be around 1800GW in theory including 283GW from onshore turbines and 1572GW from offshore turbines. Particularly, Tohoku area is estimated ideal area to have wind power plant due to the wind tendency or land shape. The breakdown of wind power energy by regions is shown in Figure 13 below. Hokkaido, which is located at the north end of Japan, is estimated to have best onshore potential in all these areas. Tohoku, Kyushu and Kansai follow Hokkaido. As for offshore wind power potential, Kyushu is estimated to be top region. Hokkaido, Tohoku and Kyushu follow Kyushu. Another fact shown in the above table is that offshore potential is estimated much higher than onshore potential.

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 13 Wind Power theoretical Potential by Region

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

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 1500GW. Below is the estimation table of solar power. From this table, not only Feed in tariff and subsidy but also expanded area and technological innovation scenario is 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 14 Estimation of Installed Geothermal Capacity by Scenario in Japan (source: Ministry of the Environment research)

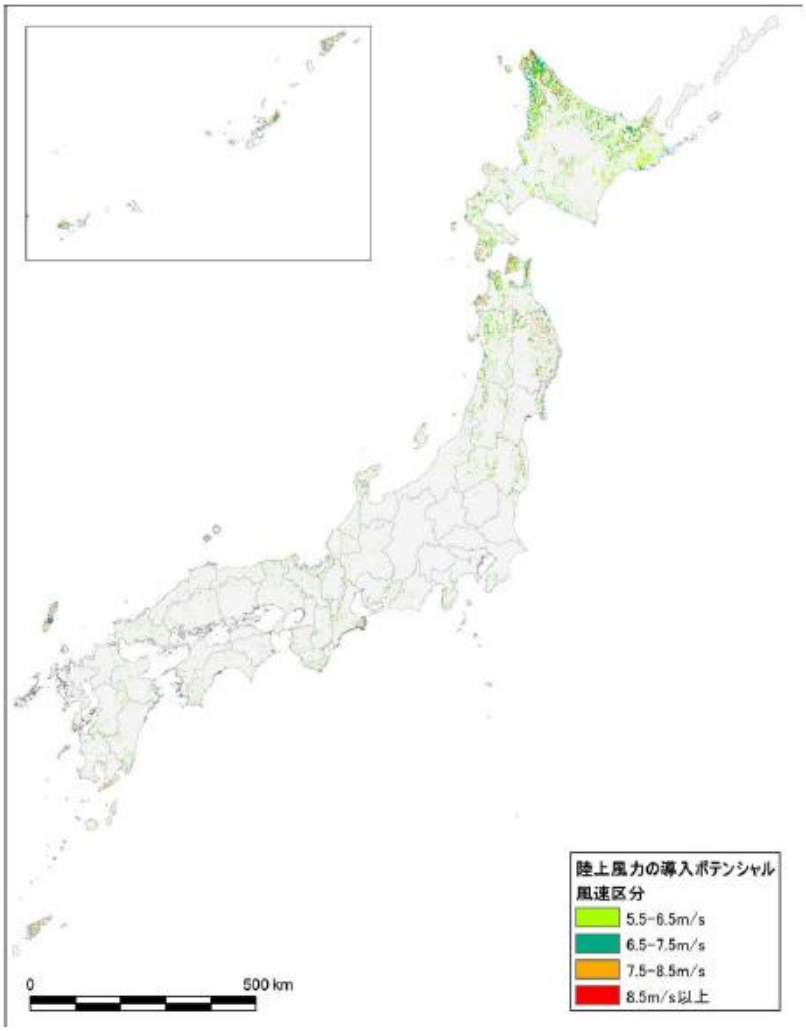


Figure 15 On-shore Wind Introduction Potential

4.1.2 Solar Power in Japan

Solar photovoltaic was the fastest-growing renewable power technology these 10 years all over the world. Actually, it did not result well around 20years ago, so this energy market is considered a re-emerging market. According to some estimates, cumulative installed capacity of solar power plants reached about 40GW last year. In addition to this, the growth rate of solar PV is increasing year and year. For instance, at least 17 GW were added in 2010. As far as Japan is concerned, Japan continues to lead this sector in Asia, and Japan produced 4.7GW in 2011. Also, Japan's strength is that almost all solar PV is connected with grid. It means Japan is likely to build smart city easier than other countries.

According to Ministry of the Environment research[17], the total potential solar power is theoretically estimated over 350GW including 200GW from residential and 150GW from commercial (non-residential). The breakdown of residential solar PV is as follows. Half is consisted of cooperative housing and the rest half is consisted of individual units. As for commercial sector, it includes utility buildings, factory, unused land and abandoned fields. These numbers are calculated with the premise that power generation efficiency is 20% at best. However, if efficiency rose to 25%, the total potential power would be estimated up to 700GW.

At present, there is one problem about economic efficiency. But Japanese government tries to deal with this problem with well paid FIT (Feed-in tariff) system. The tariff of solar power in Japan is ¥42/kwh and highest in the world. It is almost three times higher than France or Germany which are considered top renewable energy countries. What made tariffs so high is that there is specific section in the new tariff law that demands 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 to this, Japan government is planning to unveil with a bold plan that will mandate solar panels on the top of every new building constructed in Japan, and is willing to standardize this by 2030.

As for technical potential of Japan's geothermal energy, the total installed capacity of solar power plants in Japan is estimated to be between 0GW to 100GW depending on each scenario. Below is the estimation table of solar power. From this table, not only Feed in tariff and subsidy but also expanded area and technological innovation scenario is required in order to achieve 100% sustainable country.

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

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 16 Estimation of Installed Photovoltaic Capacity by Scenario in Japan (source: Ministry of the Environment research)

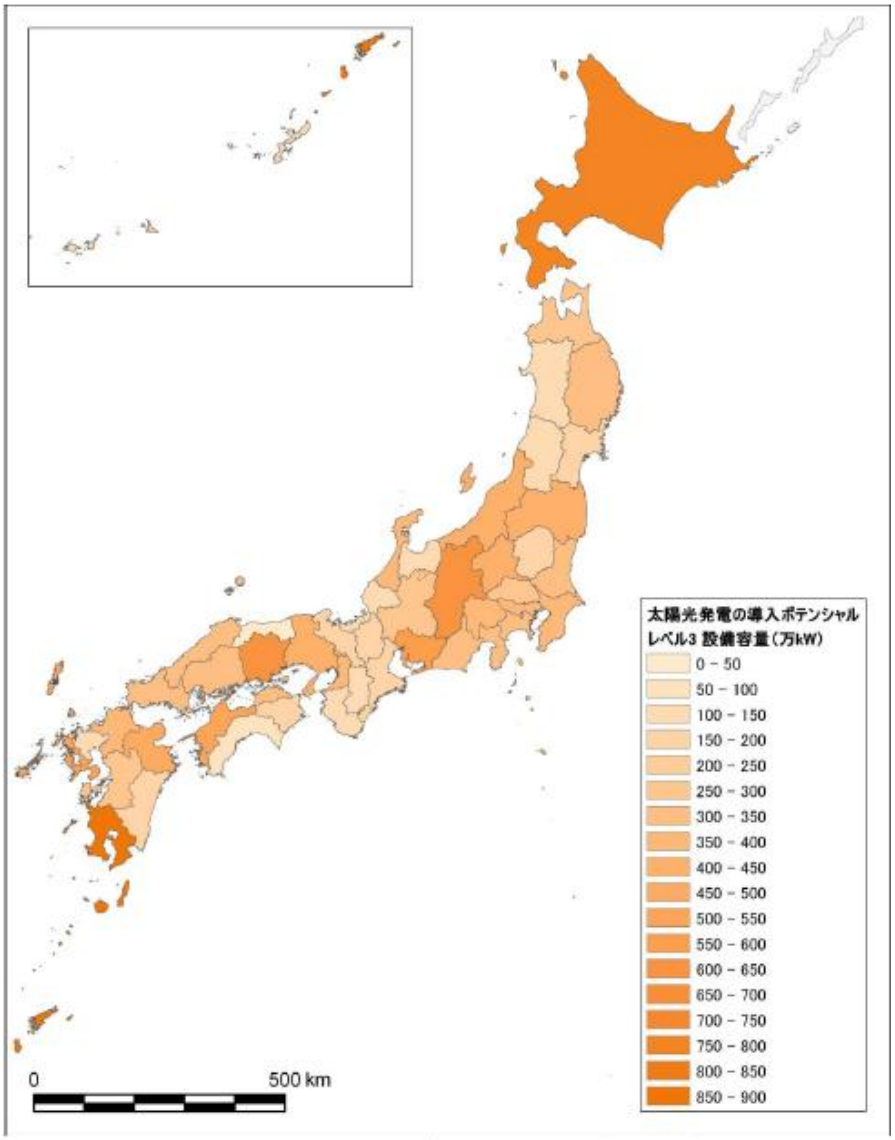

Figure 17 Solar Energy Introduction Potential

4.1.3 Geothermal Energy Production in Japan

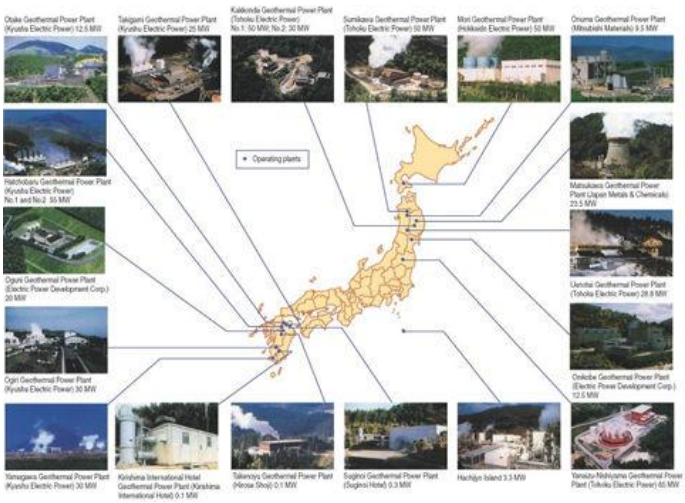

Figure 18 Geothermal Power plant location in Japan

Japan is not commonly regarded as a significant player in geothermal energy. It was not until recently that Japan considers using geothermal plant as an important source of energy. As it is, Japan currently produces only 0.5GW 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.[18] The ratio of geothermal energy only accounts for less than 1% of Japan's total electricity mix. However, geothermal energy is considered to be able to contribute more significantly in Japan. This has something to do with the Japan's location. Japan is one of the most distinguished volcanic countries in the world, because 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, at the same time, Grounds in Japan can produce a lot of heat. And head can be used in a variety of ways. For example, for over centuries, the Japanese have enjoyed "onsen" which is Japanese traditional hot springs. Onsen is heated by the volcanic activity which frequently causes huge earthquakes in this country. In this way, ground heats have be helpful to peoples' life. The more Japan tries to use ground heats, the more effectively Japan uses this heat resource.

According to Min Ministry of the Environment research[19], the abundance of geothermal power is estimated around 30GW30GW in theory. In addition to this, the total potential of geothermal power is estimated around 14GW. But this estimation does not include national park area, where more than 80 percent of the nation's resources are. That is, Japan would be likely to acquire more capacity if national park areas are included. As regards technical potential of

[18] http://www.geothermal-energy.org/WGCBali2010/

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

Japan’s geothermal energy, however, it is estimated to produce between 1.1GW and 5.2GW, depending on Feed in Tariff and technology innovation.

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.

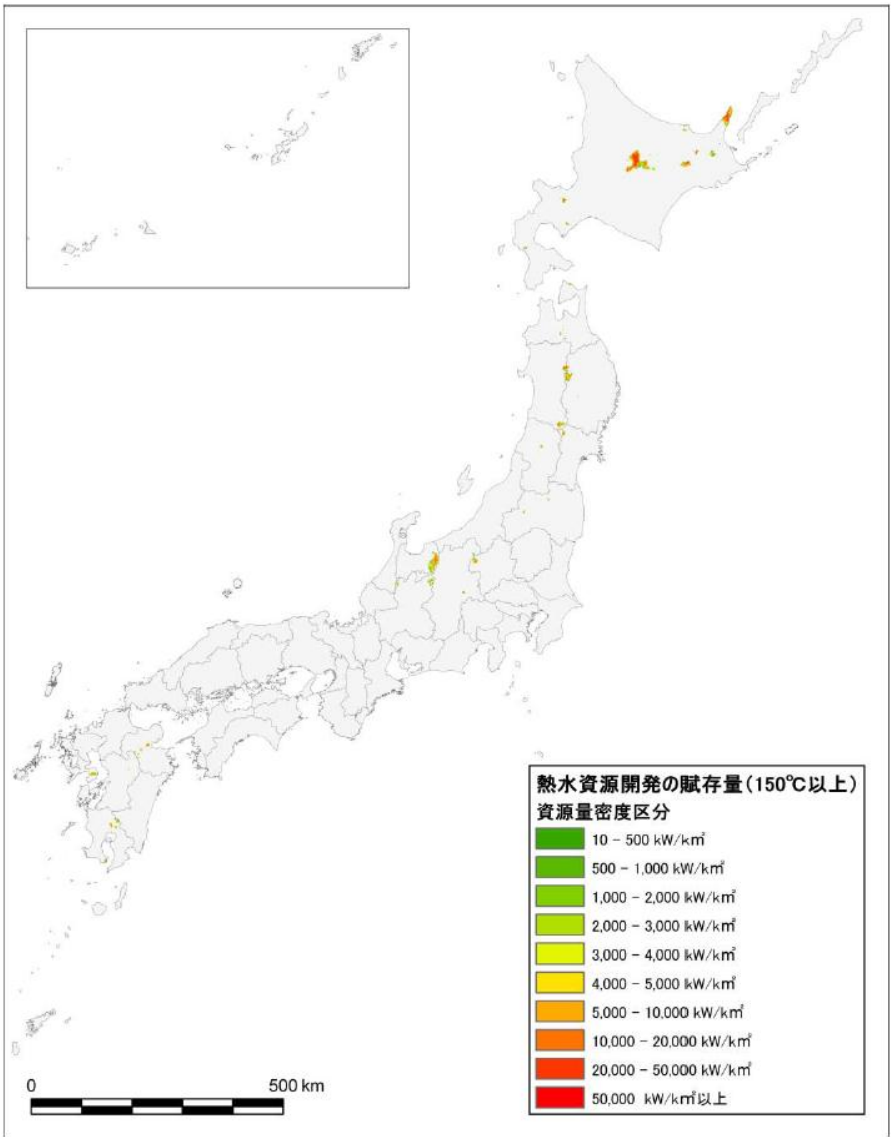

Figure 19 Geothermal Energy Introduction Potential

4.1.4 Hydropower in Japan

To begin with, it might be controversial issue whether hydropower is a renewable energy or not. The answer is it depends on the scale of hydropower plants. Small and Medium- scale hydropower is regarded as renewable energy resources. One of the common definitions for small and medium hydropower is a rated capacity of approximately 300kW capacity or less. The reason why the limit is set to 300kW capacity is that 300kW is the maximum size for most stand alone hydro systems not connected to the grid, and suitable for "run-of-the-river" installations.

Electricity generation through water power has had the biggest share in renewable energy. Japan's current installed capacity of hydropower is, though the number is including large scale hydropower plant, about 27GW. According to Agency for natural resources and energy under the Japanese Ministry of Economy, Trade and Industry, total installed capacity of small and medium hydropower plants is about 10GW in2011.

Speaking of Japans' features, Japan is abundantly watered because rivers of Japan are characterized by their relatively short lengths and considerably steep gradients due to the narrow and mountainous topography of the country. It is sometimes told by foreign people that rivers in Japan are almost waterfalls. It means, however, by making the most of this feature, Japan will be able to produce a large amount of energy with hydropower plants.

As regards technical potential of Japan's small and medium hydropower energy, it is estimated to produce between 1.1GW and 7.4GW, depending on Feed in Tariff, technology innovation and subsidy. Figure 20 is the table of estimated total capacity of hydropower energy in Japan. As shown in this chart, total installed capacity differs very much in accordance with each scenario. However, the estimated capacity of this energy is not higher than other type 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 20 Estimation of Installed small and medium hydropower Capacity by Scenario in Japan (source: Ministry of the Environment research[20])

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

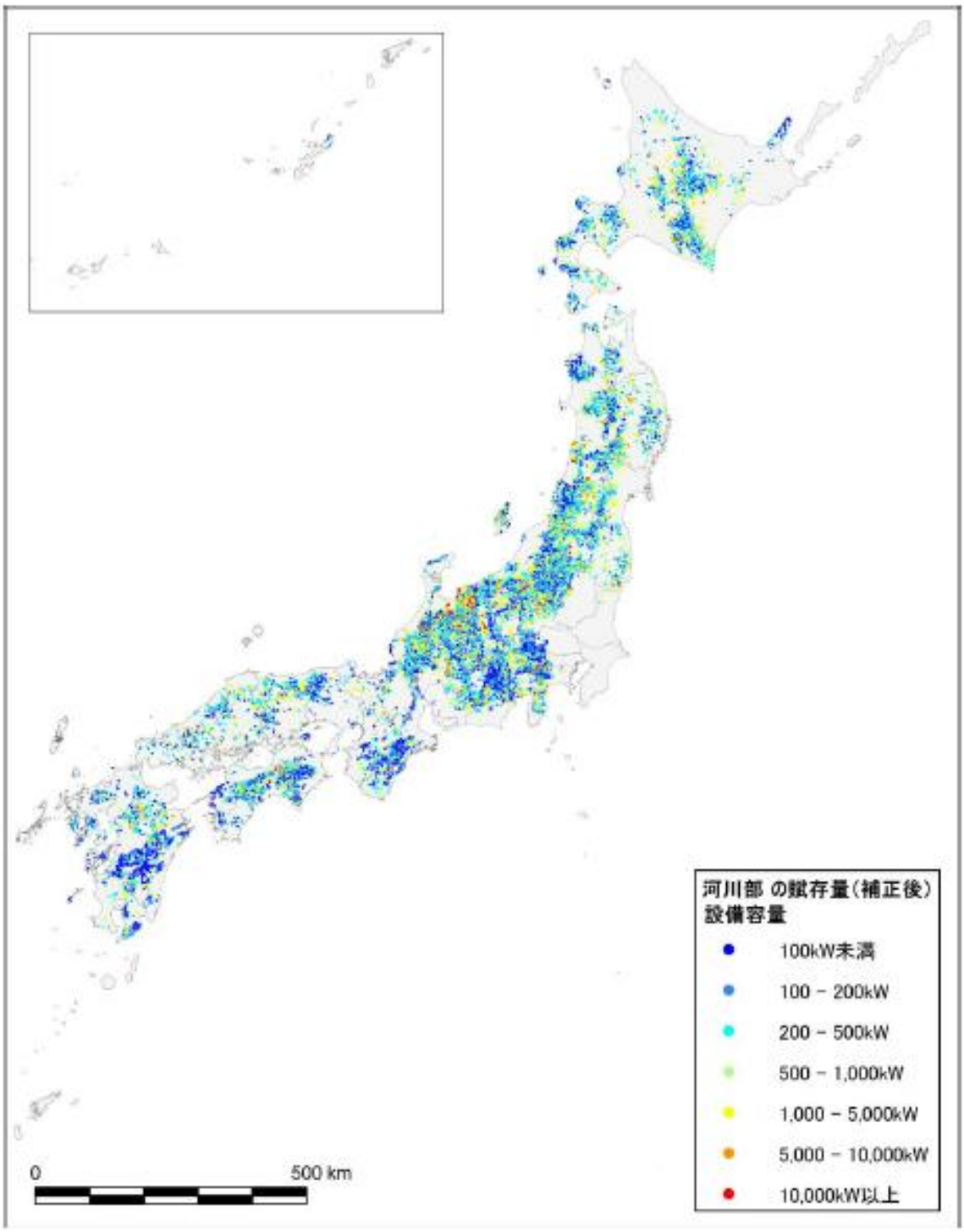

Figure 21 Hydro Introduction Potential

4.1.5 Biomass Energy in Japan

Biomass power generator is a system which generates energy and electricity by burning lumber, agricultural or construction/ demolition wood wastes and driving turbine. The mechanism of this energy generator is same as that of firepower energy. The difference between biomass energy and firepower is whether the fuel is fossil fuel or not. Because biomass technologies use 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 3.2GW. The ratio of biomass energy in Japan's energy mix is less than 1%, and most of the results came from waste.

After 3.11 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 will be used as a source of biomass energy. As can be seen in this example, Japan is positively trying to utilize biomass energy.

Biomass energy could be one of the best energy resources when it is used as not 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 carbons which are a part of biomass are part of the natural carbon cycle, whereas carbons which are in fossil fuels are not part of the natural carbon cycle system.

Incidentally, as described in the previous section, Japanese government announced that it will introduce one of the best Feed in tariff system in the world. The reason why it is regarded as best system is that the preferential rate, known as a feed in tariff is recommended at 42yen(= 52 U.S. cents), which is much more expensive than those of other countries. This system is also applied to biomass energy.

Unfortunately, numerical target 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.

5 Practical steps under this plan

5.1 Roadmap (100% Renewable Energy plan by 2020)

As noted in chapter4, 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 for assumptions of 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 22 Estimation of Installed Renewable Energy Capacity by Scenario in Japan (source: Ministry of the Environment research[21])

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

Above all, this section will focus on FIT+subsidy scenario. The reason why this scenario was selected is that Japan actually put FIT system into practice and is likely to subsidize renewable energy. On the other hand, drastic technological innovation might not be advanced due to some factors like technical limitation or cost efficiency.

Based on above table, below is a chart about installed capacity comparison between current installed capacity and estimated installed capacity under FIT+Subsidy scenario. As you can see, the estimated installed capacity under FIT+Subsidy scenario largely exceed the current nationwide capacity. It means that the potential of renewable energy is huge enough to replace current unsustainable energy resources. The maximum estimated installed capacity is about three times as large as current capacity. This owes largely to off shore windpower energy. Developments of offshore wind power plant would be an essential key to achieve 100% renewable country.

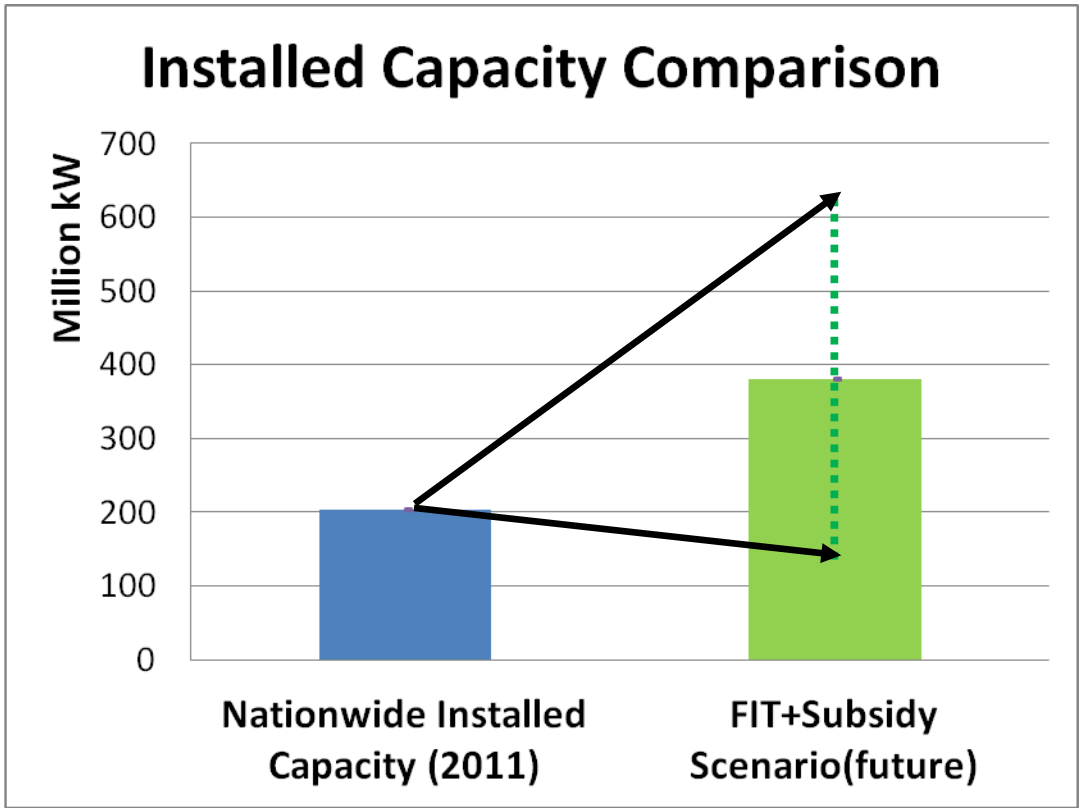

Figure 23 Installed Capacity Comparison(source: Ministry of the Environment research[22])

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

In this scenario, highlighted cells shown in Figure 24 show the assumptions of total generated energy for each resource. This numerical analysis is based on some capacity factor assumptions. Each capacity factor is assumed as follows; the assumed capacity factor of wind power is 24%, that of solar power is 12%, that of geothermal power is 75%, and that of hydropower is 65%.

Below is a chart which indicates the comparison between current generated power and future estimated generated energy under FIT+subsidy scenario. According this assumption, although it would be hard to manage Japan's whole energy only by renewable energy resources, there is a enough possibility that 100% renewable energy is possible in Japan if Japan government and the Japanese people try hard. Under FIT and subsidy scenario, the potential of renewable energy can exceed current generated power.

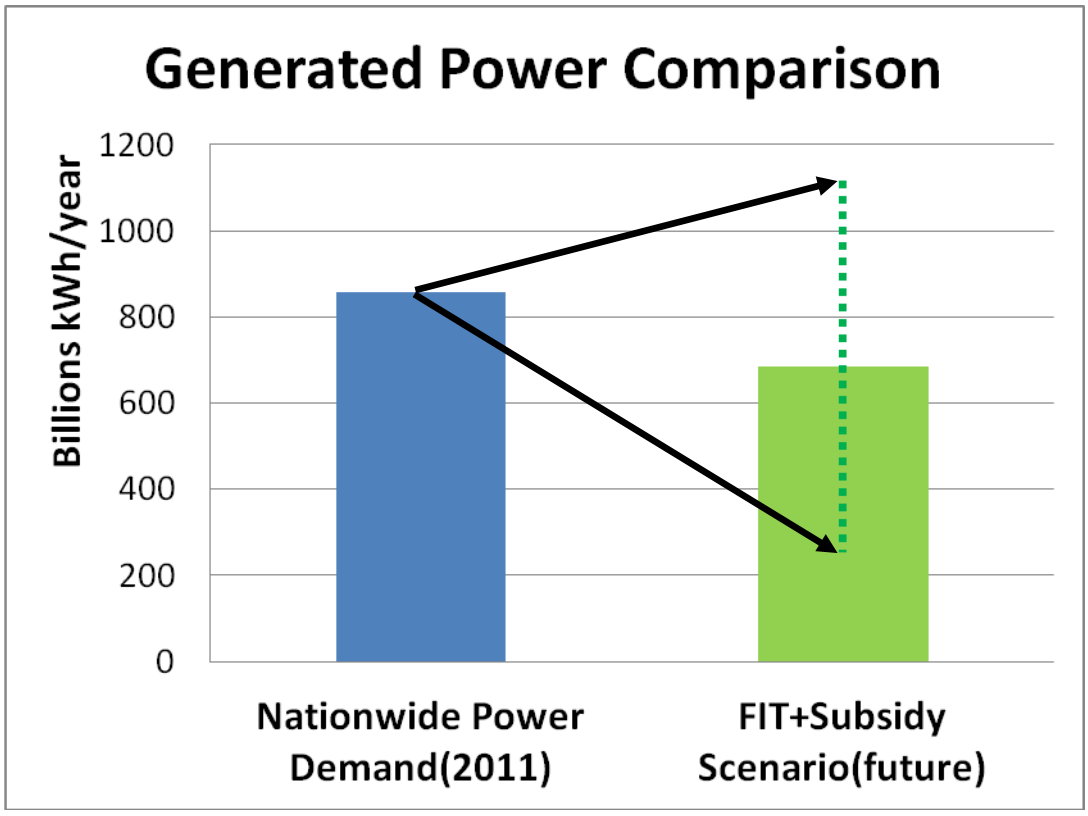

Figure 24 Generated Renewable Power Comparison (source: Ministry of the Environment research[23])

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

6 Conclusion

Since last year's huge earthquake, tsunami and nuclear power disaster, energy has been one of the biggest controversial issues in Japan. Until then, Japan's government has thought of nuclear energy as main energy resource and has been about to shift from pro-nuclear to anti-nuclear. Under this circumstance, it might sound that it is very difficult for 100% renewable energy to be possible in Japan. However, if Japan tries good steps, Japan will be able to become 100% renewable energy country. Although there are a lot of reasons to support this idea, three of the most preeminent reasons are public mind/opinion, high technology, and energy policy/system.

First of all, there is a good public mind and public opinion in Japan. Actually, after last year's disasters, more and more Japanese people are opposed to nuclear power and the movement of those people are about to change government policy or attitude. This is because they saw how dangerous the nuclear disaster might be when nuclear power is damaged. A strong public opinion and mind is needed when a country try to make a drastic change to that country, because peoples' cooperation toward energy is required to achieve sustainable country.

Another reason is that Japan high technology. As everyone might know, Japan has a high technology not only in electronics industry but also in energy industry. Regarding this matter, checking patents related to renewable energy industry is a good indicator to show how much technologies Japan has. According to WIPO, Japan has the highest number of patent applications in the field of renewable energies with 55 percent. Japan's research and development in the renewable energy field is very advanced both in academic area and private sectors. It means that Japan has a enough possibility to lead world's renewable energy industry.

Furthermore, Japan has a lot of excellent systems and policies which facilitates renewable energy. Of course, though there are a lot of systems to facilitate those sustainable energies, the most notable system is Japan's Feed in tariff system. Under this system, Japan government decided to buy renewable energy with good price. Regarding this feed in tariff system, 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 limit, and feasibility. However, by making the most of their public mind, technology, and systems, we believe that 100% energy in Japan by 2020 is possible.