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Bioenergy and renewable energy situation, emissions level and reduction methods in Japan

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Abstract

Recently climate change is one of the serious issues nowadays. Generating energy is considered to be one of the contributors to it. Therefore, renewable energy could be one solution to tackle the problem. Finland and Japan are similar in terms of its high forest rate. Bioenergy business is advanced in Finland, however, bioenergy business in Japan has not been spread yet unlike Finland. But still, there are woody biomass power stations in operation.

The thesis was dedicated to find out what woody bioenergy and renewable energy situation, how woody bioenergy is produced, emissions level and reduction methods are available in Japan. To do the research, literature review and interviews were conducted, and case studies were analyzed.

In this study, the woody bioenergy situation in Japan revealed how woody bioenergy business could be a part of local business to revitalize local society and Japanese forestry. However, there are still conflicts between citizens and local administrations. They should be satisfied with the decisions. In this way, the sustainable business could be built. In the future, it would be recommended to raise awareness of the importance of woody bioenergy and spread throughout Japan.

Keywords

Woody bioenergy; air pollution reduction methods; local business

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1 INTRODUCTION

Human activities are the main cause of global environmental problems. To name a few, these are overpopulation, pollution, and waste disposal. (Singh 2016). In addition, climate change is one of the most urgent problems which we should tackle. It contributes not only to rising temperature globally, but also to ecosystem and climate system (National Geographic 2020). According to the Paris Agreement, putting efforts to limit the temperature increase below 1.5 centigrade compared to the time before industrial revolution is mentioned. It also states the amount of greenhouse gas emission is aimed to be reduced by 80 % by 2050. One of the major contributions to climate change is generation and the use of energy. If we continue burning fossil fuel as we have been done, it naturally means we emit greenhouse gases and are not able to pursue the goals given in The Paris Agreement. However, fossil fuel is not the only one being able to generate energy, but also renewable energy. Japan is not the only one where renewable energy has been introduced. The major types of renewable energy include hydropower, solar, wind, geothermal, and biomass (EIA 2019). We should reduce the amount of energy consumption, make the effective use of energy, and use renewable energy (Somewrite 2019).

Burning biomass is regarded as carbon neutral. It is because biomass absorbs and fixes carbon dioxide when it grows, and such carbon dioxide would be emitted when it is burnt. However, such carbon dioxide would be absorbed again by it if planted. Therefore, burning biomass instead of fossil fuel to generate electricity and heat enables to control the emission of carbon dioxide and contributes to the prevention of climate change. In addition, woody biomass coming from sawing industries and demolished timber would be waste unless they are utilized. If they are used as bioenergy, it is possible to reduce waste and contributes to the circular economy. (IEA Bioenergy 2018.)

Biomass includes waste from agriculture, animal husbandry, households, sewage waste, and wood (NEDO 2018). In this thesis, woody biomass is focused on because bioenergy derived from wood is dominant in Finland. In fact, it accounts for about 27 % of the total energy consumption in 2018 in Finland (Ministry of

Agriculture and Forestry of Finland no date). Therefore, it would be better to gather the related information from Japan and compare the two countries.

This study was part of the “NOxOpti - Monitoring and management of the emissions form energy production” project. The NOxOpti project is funded by the ELY Centre for South Savo via European Regional Development Fund, the Tiina ja Antti Herlin Foundation and Etelä-Savon Energia Oy. The thesis aims to find out the followings:

a) To find out the renewable energy and woody bioenergy situation in Japan, and how it is produced;
b) To find out what the emission levels in bioenergy, what reduction methods are available.

2 BACKGROUND

Nowadays, investors tend to evaluate the enterprises contributing to sustainable society development. For example, Apple and Google aim to change their electricity to renewable energy 100 % and they even require their supply chains to their electricity to renewable one. Therefore, there is a possibility that a company would be removed from a major company’s supply chain, if it does not comply with it. (Somewrite 2019.)

The above is about the world trend surrounding renewable energy. On the contrary, Japanese trend is somewhat different. Before finding the information on the aforementioned points in the introduction, it is essential to provide the information regarding a brief history and the system of Japanese forestry, because woody bioenergy cannot be separated from it.

2.1 The brief history of Japanese forestry

The description in this chapter about a brief history of Japanese forestry is based on Food and Agriculture Organization of the United Nations (2010), Ohno (2014) and Kinoshita (2019).

Japan is rich in wood, approximately 66 % of the land is covered with forests, the total forest area is 25.1 million hectares (Kinoshita 2015). This is similar to Finnish forests which cover approximately 73 % of the land and the total forest covered area have 26.2 million hectares (IRENA et al. 2018). However, the forests in Japan has not been utilized greatly due to decline in forestry for a variety of reasons. The history gives hints about them.

In the Edo period, forests were controlled under Shogunate. But deforestation was proceeded because forest policy was not defined in Meiji era and excessive cutting of fuelwood. To deal with the problem, River Act was established in 1896, Erosion Control Act and Forest Act were established in 1897. Deforested area was changed to forests.

After The Second World War, the demand for wood increased to revive the Japanese economy. However, since deforestation proceeded again during the war and natural disaster, there were not enough supplies. As a result, there was wood shortage and the price got higher. Therefore, the government adopted Afforestation Policy which was started in the latter half of the 1950s (Ouchi 1987). Conifers grow faster and have more economical value. Hence, what had been done was planting conifers on the felling site and cutting broadleaf trees to plant conifers. The government convinced that wood is necessary resource for the future, and it would contribute to the economic growth. To improve wood production rate and obtain a large quantity of wood, afforestation went ahead with the policy.

However, Afforestation Policy was carried out exactly at the same time when the energy revolution started. At this time, the fuel was changed from charcoal and firewood to electricity and fossil fuel. Charcoal and firewood used to be cut from copse which is grown around Satoyama. Satoyama is woodland close to the living area and used to be a part of traditional village life. But because of the energy revolution, charcoal and firewood were regarded as not suitable for the current way of living. In addition, as the demand increased, the timber cost also increased. These accelerated the replacement for broadleaf trees, so conifers were planted more than ever.

In order to meet the need for wood demand, liberalization of tree got started step by step, and importing wood became fully liberalized in 1964. Imported wood was inexpensive compared to domestic ones and fairly large quantity of wood could be imported stably every time. The demand increased further, and the import rate had been increased year by year.

As a result, forest management in Japan has been getting difficult. Although wood self-sufficiency rate was more than 90 % in 1955, it has been decreased to 20 % nowadays. Currently, more than 80 % of the supplied wood are imported though Japan is rich in wood as mentioned before.

Moreover, when Afforestation Policy was adopted, actively building practical logging roads should have been built. However, making artificial forest roads for sightseeing and the promotion of industries except for forestry were focused on. Due to lack of enough budget assignment, building such required roads for forestry were not proceeded. (Forest Management Association of Japan 2010).

Presently, if maintaining forests including thinning and felling trees for sale have been made, there would be a deficit. Because of this, the motivation among forestry managers get lower and younger generation goes to urban districts to seek jobs. Also, as forestry declining, regional vitality decreases. Being away from forestry leads to lack of successor, the employed gets older, problems and marginally viable community in the mountain villages where there are no other characteristic industries arise.

For those which had been planted during afforestation reached their cutting season. We need to cut them, plant new ones, let them grow, and then cut. We need such a cycle of forest. It is time to utilize grown forests. However, many of them are abandoned due to the above reasons. To revitalize Japanese forestry, Green Employment Project begun in 2003 (The Japan times 2019). In this project, the people who would like to engage in forestry learn the necessary technologies, skills, and the project enables to promote obtaining new workers and their training. Actually, newly employed workers in the forestry field were about only 2000 per annum before 2002, but more than 3000 people have come into the field after the project begun (Kinoshita 2015).

2.2 The forestry system and wood utilization in Japan

In Finland, there are powerful companies in woody bioenergy industry (Säilä & Hagström 2017). Finnish and Japanese forestry systems are different. Figure 3 shows how timber supply chain works in Japan.

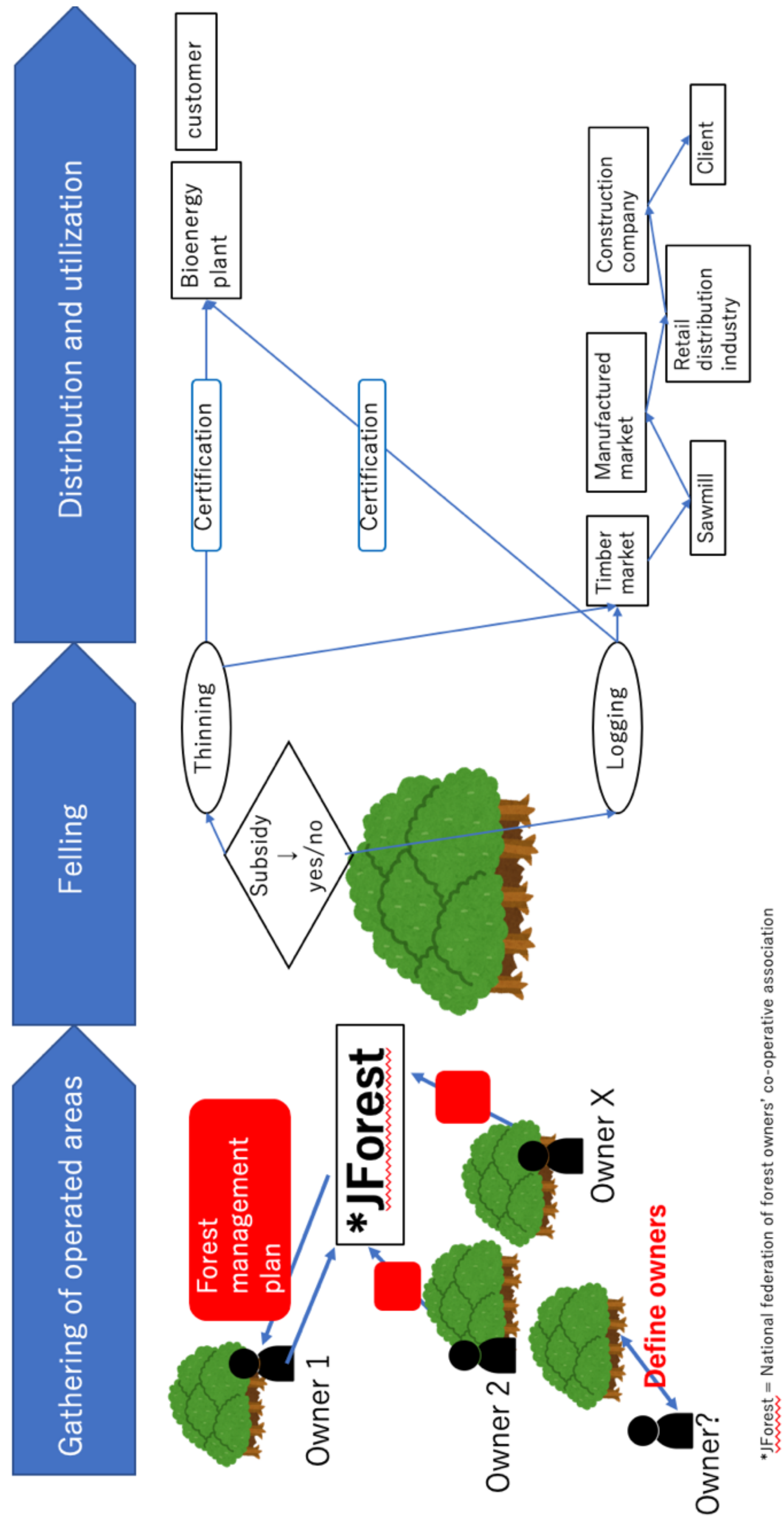

Figure 1. Timber supply chain in Japan (NEDO 2018)

In Japanese timber supply chain, there are more people involved compared to European and American countries, so it makes the system complicated. Therefore, the structure is not the one where wood resource suppliers change the amount of felling as the amount of need changes. The resources used as fuel are carried out from forests when better quality timber is carried out. It is recommended to simplify the supply chain system more, in order to stabilize the amount, quality, and price of wood resource. (NEDO 2018.)

In Japan, cascading use of wood is not structured enough. It is strongly related to the aforementioned system. Better quality timber is carried out for building timber and woody products. It means that the ones which are not worthy of them are left in mountains or forests. But this kind of conventional way is not suitable recently, therefore, the introduction of whole tree logging system has started. However, this system requires skids, tower yarders, processors, and grapple loaders. These cannot be used if there are no logging roads. (Kumazaki 2013.)

Wasteful system has also been found at sawmills. Although bark and sawdust were generated even in small-scale sawmills, energy utilization could not be done. It is because there are only a few kinds of materials, boilers cannot accept them. The disposal fee is required when bark is wasted, and heavy oil was used to dry timber. If sawdust fired boilers could be used, it would be possible to cover the cost for drying timber at own expense. The advantages of sawmills were not utilized. (Kumazaki 2013.)

As Figure 3 shows, defining owners is one of the facing problems. Since April 2012, it is obliged to submit who the owner of each forest is to head of municipalities to understand how ownerships had been changed before Geographic Information System (GIS) was introduced and manage them. However, finding the true owners of certain forests is hard sometimes. It is because even if they know they are owners but do not know where the owned forests are. Thus, the use of standardized data is urgently required. (Iwashita 2013.)

It seems that wood is wastefully used in Japan. Yet, here is one example utilizing wood material, that is disposable wooden chopsticks. They are made from mill ends which is otherwise going to be disposed. The origin is from mill ends of Japanese cedar, which was generated when barrels were made in Yoshino, Nara. Still, Japanese disposable wooden chopsticks are made of mill ends, there is no wood cutting for making the chopsticks solely. In short, Japanese disposable wooden chopsticks are one of creative products, utilization of mill ends. If thinned wood besides mill ends could be used to make them, it contributes to a growth of healthy forests. (Kinoshita 2009.)

Another example is the wood used at the ceremony is going to be used as biofuel. The last year, Japanese former emperor was changed to the new emperor, so the era name was changed from Heisei to Reiwa. Daijosai (Great Thanksgiving Ceremony) is regarded as one of the most important ceremony that the succession to the emperor. The total construction fee for Daijokyu Halls (temporary halls for Daijosai) cost about 2.4 billion, and it would have been used as a part of facilities at parks or so. However, it was changed, it will be consumed as biofuel after the demolition of Daijokyu Halls. (The Sankei News 2019.) (Fukuishimbun online 2019.)

3 MATERIALS AND METHODS

In order to proceed the research, literature review and interviews were conducted, case studies were analyzed.

3.1 Literature review

The Book 林業地域が成功する条件とは何か (Woody biomass business, what is the successful conditions for forestry regions?) written by Aikawa was used to understand the overall woody bioenergy situation in Japan. It reveals how weak Japanese forestry and woody bioenergy business are. The author writes the suggestions how successful wooden bioenergy business as a local business can be built to revitalize society.

The web pages listed as follows are mostly used to get the information related to air pollution control law, emission levels, renewable energy and woody bioenergy situation in Japan. The main sources are: Ministry of the Environment, Bureau of Environment, Learning Museum of the Forest and Forestry (the site is developed by Kinoshita), Japan Woody Bioenergy Association (JWBA), New Energy and Industrial Technology Development Organization (NEDO). To get technology related issues, the reports published from MHPS (Mitsubishi Hitachi Power Systems) and HITACHI were referred. In order to reach these articles, Google Scholar was used.

3.2 Interviews

The interviews were done by face-to-face and email. The face-to-face interview was organized at Kiko Network Kyoto office in 26th December 2019. The interviewee was Toyota Y. who is the chief researcher at the organization. This aimed to make sure Japanese woody bioenergy business is far behind the one in Europe. The aforementioned book and the case-studies were also recommended by him.

The email interview was made with the help of Kiko Network in January. The interviewees were Sakamoto and Ozeki working at Meiken Lamwood corporation. The company is one of the leading ones operating woody bioenergy power plants in Japan. It is dealing with laminated wood and cross laminated timber (CLT) for buildings. It uses the wooden materials which is otherwise going to be discarded as materials for bioenergy. The main question was what kind of emission reduction methods are available in Japan. The answer is shown in chapter 4.3.

3.3 Case-studies

The case studies including seminars held at Kiko Network were analyzed. The seminars were about the relationships between forestry, woody bioenergy and municipality given by Mori H. (2019) and Nakano K. (2019). The given materials were used as reference. Although there are a great number of case studies, this thesis covers case studies including Maniwa city, Shiwa town, and Shimokawa town as succeeded examples. The case study of Nankan town is from the report written by New Energy and Industrial Technology Development Organization (NEDO) and Bamboo Energy Corporation.

4 RESULTS

The following chapters demonstrate the findings on what the thesis was dedicated to. Renewable energy situation and bioenergy situation in Japan is shown at first, then the laws and emission levels, reduction methods of emissions, and case studies are demonstrated.

4.1 Renewable energy situation and bioenergy situation in Japan

4.1.1 Renewable energy situation in Japan

Figure 1 indicates the composition of power supply in 2016 in Japan. As it shows, the energy generated from fossil fuel is still dominant. bioenergy contributes to only 1.7% of the total energy supply (ISEP 2017). On the other hand, fossil fuel accounts for 41 % and bioenergy accounts for 26.4% of the total primary energy supply in Finland in the same year (IEA Bioenergy 2018).

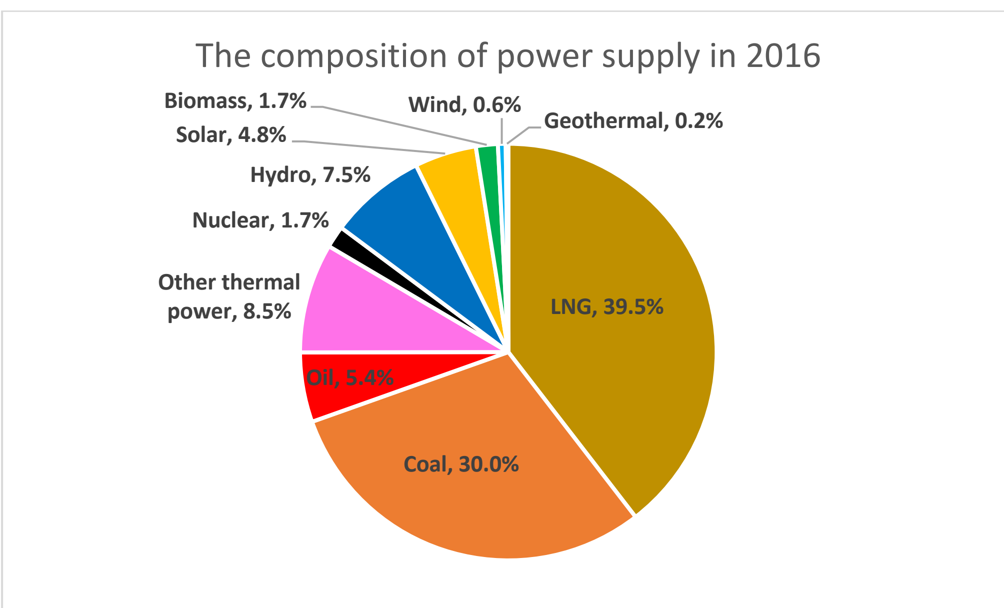

Figure 2. The composition of power supply in 2016 (According to: ISEP 2017)

According to Agency for Natural Resources and Energy, introduction of renewable energy has been accelerated after Feed-in Tariff (FIT) applied in July 2012 in Japan (2018). As the following Figure 2 and Table 2 show, solar energy has been spread greatly compared with other renewable energy. It was because the established procurement cost and restrictions on technologies related to the equipment installation were small compared to other renewable energy (JWBA 2018).

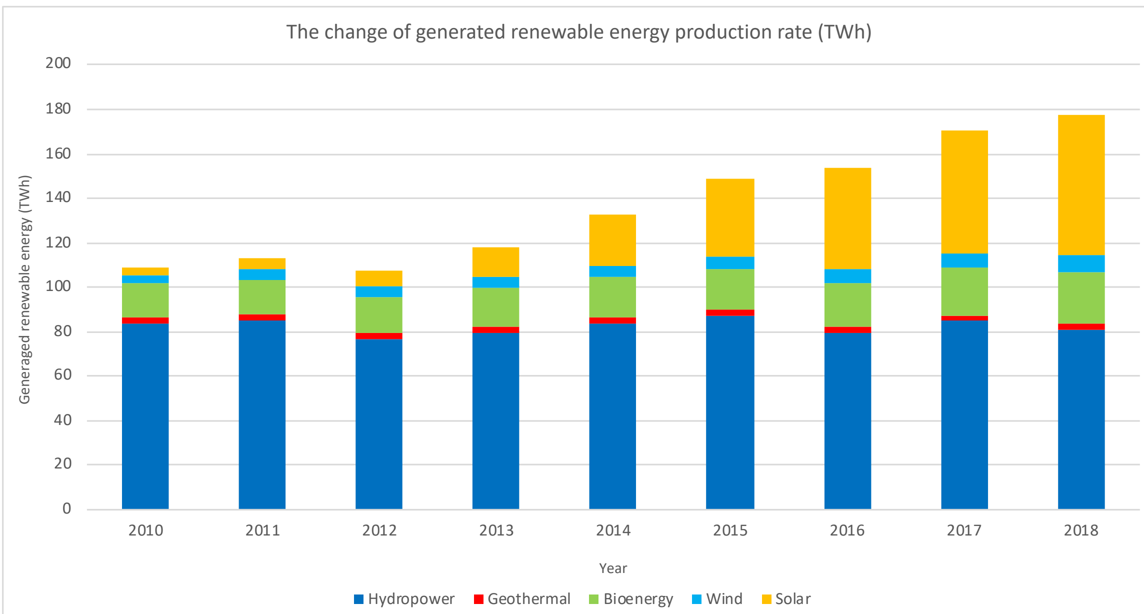

Figure 3. The change of generated renewable energy production rate in Japan (According to: Renewable Energy Institute 2019)

Table 1. The generated renewable energy production (TWh) in Japan (According to: Renewable Energy institute 2019)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Solar	3.5	4.8	6.6	13.1	23.4	34.8	45.8	55.0	62.7
Wind	4.0	4.7	4.8	5.2	5.2	5.6	6.2	6.5	7.5
Bioenergy	15.2	15.9	16.8	17.8	18.2	18.8	19.7	21.5	23.6
Geothermal	2.6	2.7	2.6	2.6	2.7	2.6	2.5	2.5	2.5
Hydropower	83.8	84.9	76.5	79.4	83.5	87.1	79.5	84.9	81.0

Generated and purchased electric power from bioenergy has increased after the year. This bioenergy consists of not only the energy generated from wood but also waste, however, wood-based bioenergy has also increased. (JWBA 2018).

There was Renewables Portfolio Standard (RPS) which imposes an obligation on retail electricity suppliers to sell the energy including the fixed renewable energy came into force before Feed-in Tariff (FIT) had been applied in order to spread the introduction of renewable energy. In Japan, RPS was in effect from April 2003 for nine years. However, three main problems were left because of its characteristics. The first was the goal setting. Although it would have been better to be set the goal high and strict, the level was not strict as soon as RPS had started. The second problem was lack of ways to promote investment due to putting a high priority on economics in the introduction of renewable energy. Finally, there were no clear rules how the society as a whole pays for the electricity procurement and increasing a cost to customer of electricity. As a result, thought it seems the system achieved its goal of spreading the renewable energy, it burdened renewable energy producers with the profitability risk. (Ito 2015.)

It is obvious that renewable energy is not introduced extensively in Japan compared to Finland. However, there are companies participating in RE100. This is the campaign to achieve the use of renewable energy 100 % in their production. Moreover, there is another campaign called “Japan Climate Initiative”, started by Renewable energy institute, WWF Japan and CDP Japan. It is the network to support the achievement of The Paris Agreement. In July 2018, only about 100 companies were involved in it, but the number of participated companies increased to more than 340 in February 2019. It means that Japanese companies have also noticed the importance of renewable energy and decarbonized society. (Somewrite 2019.)

Optimal energy mix targets to reach 44% of zero-emission powers including renewable energy and nuclear power in total energy supply in 2030, and the introduction of renewable energy more than 24% is required. Furthermore, more bioenergy should be introduced, if the government considers global trend towards decarbonized society. The introduction of bioenergy should reach 7.28 GW as the indispensable goal in the optimal energy mix in 2030. It is required to seek the promotion of bioenergy further, when we take other renewable energy into account. (Sawa 2019.)

4.1.2 Current bioenergy situation in Japan

The number of Feed-in Tariff (FIT) - authorized big-scale woody bioenergy plants using imported biomass dramatically increased between 2016 and 2017. The imported biomass which can be used as ordinal woody biomass and biomass liquid fuel are wood, palm kernel shells (PKS), palm trunk, and palm oil. As of March 2018, 23 % of them uses the one containing palm oil, and the rest 77 % of them uses wood and PKS as fuel. (Agency for Natural Resources and Energy 2018.) Such imported biomass are the products certified by Forest Stewardship Council (FSC) and Roundtable on Sustainable Palm Oil (RSPO) as security for sustainability. However, FSC and RSPO certifications are not supposed to be for fuel, but for wood, food and industrial use. These cannot be as security for reduction of greenhouse gases. In addition, although the amount of greenhouse gases emitted during the production stage cannot be ignored, the import rate of PKS included in FIT is rapidly increasing. PKS grows up in the farms which have been exploited from peat land discharges a quantity of greenhouse gases. It reaches 112 times higher amount of emission compared to the case if there are no any land use changes. Therefore, it is not suitable for FIT. (ISEP et al. 2019.)

It seems that a large number of bioenergy power plants consume PKS. However, it is better to note that woody bioenergy could be one of the solutions to revitalize local areas and mountainous villages in Japan. It may not be a good idea to just rely on it as generating energy solely, although FIT exists. It is recommended to support local business including local industries dealing with heat and energy demand. In this way, woody bioenergy could be a sustainable business. In addition, it is also possible to create different level of business as “existent business as the main occupation and new business. The development of local society” by making more valuable products from wood resources can also be made. It is important to discuss among the parties concerned to rank woody bioenergy business within local business and society to realize the sustainable bioenergy. (NEDO 2018.) In short, woody bioenergy can be a part of a community development. The five important points for this are: involved people should participate in the community as a whole, there should be the active role, everyone should be satisfied, business is manageable, and business risk is appropriate. (Mori 2019.) In chapter 4.4 and 4.5.5, there are local examples showing how locals activate their society with woody bioenergy business.

Another use for bioenergy is cogeneration. It is the system enabling the utilization of waste heat generated from power generation. This system was already applied in Europe at the end of 19th century. From this moment, cogeneration spread throughout Europe. It was because of cold European climate, heat demand was high. Unlike Europe, the spread of the introduction just started in Japan from the latter half of the 1980s because the awareness of energy efficiency was raised. It accounted for five percent of the total power in 2013. (NIES 2019.) One more reason that cogeneration has not been introduced yet in Japan is that Organic Rankin Cycle (ORC) system is not defined in Electricity Business Act. Therefore, ORC should be ranked as a steam turbine and a boiler for power generation to follow the Act, when it is introduced. (Hisagi 2014.)

All in all, according to Japan Woody Bioenergy Association, as of March 2017, the number of authorized woody bioenergy power plants is 491 places and approximately 12 GW of generation capacity is authorized. Among these, about 84 % of authorized places and about 95 % of authorized generation capacity are the electricity generation from ordinal wood and agricultural residues. (JWBA 2018.) The below Figure 4 indicates where woody bioenergy power plants are located with their scale from 500 kW to 20000 kw. The figure indicates how much each scale power plant is whether in operation, under development, or at design stage. For those where the power plants are co-firing system with coal and woody biomass are calculated based on how much woody biomass is burnt as fuel. For those where electrical output is less than 500 kW or more than 20000 kW, they are regarded as 500 kW and 20000 kW respectively. (Forest energy research institution corporation 2020.)

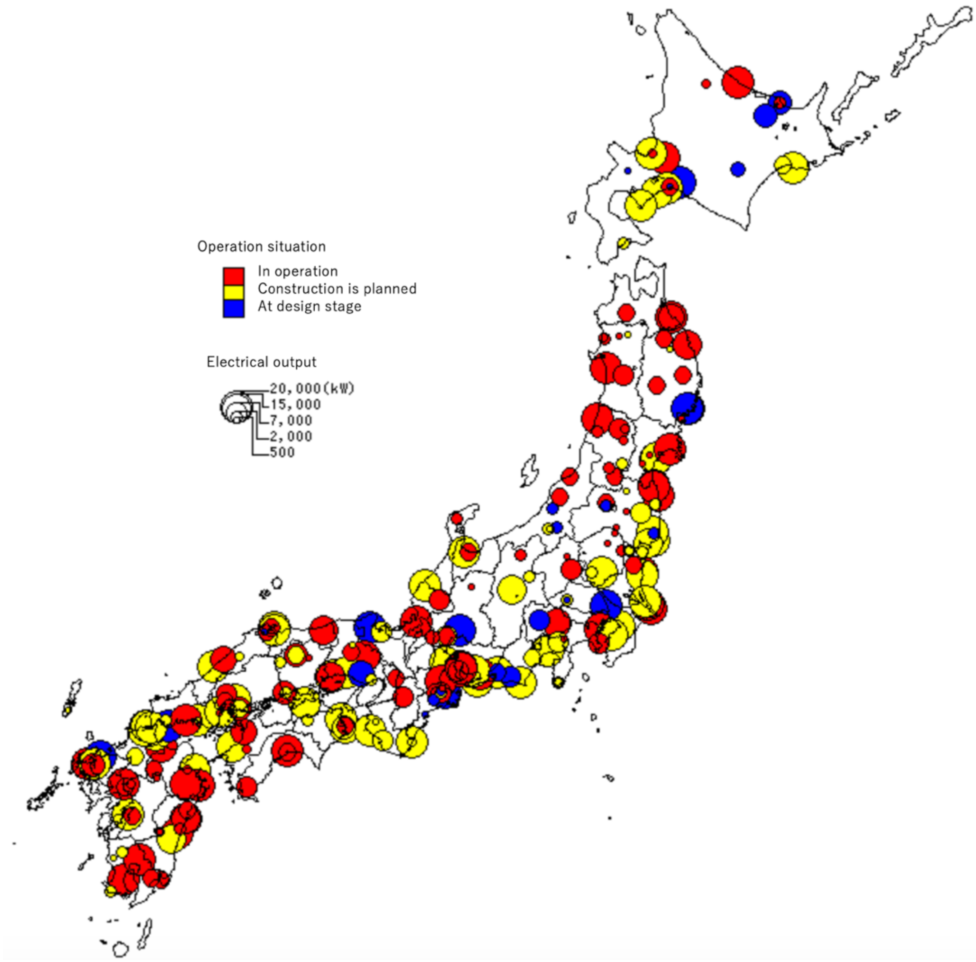

Figure 4. Woody bioenergy power plants location in Japan with their scale from 500 kW to 20000 kW (According to: Forest energy research institution corporation 2020)

4.2 The Laws and emission levels

It seems that burning biomass for energy use is clean, however, it emits pollutants, such as NOx, SOx, and dusts. The EU, Directive (EU) 2015/2193 indicates the limitation of emission levels (Directive (EU) 2015/2193). Similarly, the air pollution control law exists in Japan. However, these two have different criteria. (Regulatory measures against air pollutants emitted from factories and business sites and the outline of regulation – emissions standards for soot and dust, and NOx.) In addition to concerning air quality, comparing environmental quality standards in Japan and air quality standards in the EU cannot be done directly. It is because the former one is the criteria which is desirable for sustaining health, on the other hand, the criteria in the EU is not to give any harmful effects to health and the environment. (Tomita and Hayazaki 2019.) The below chapters describe how each emission is calculated and considered to be safe.

4.2.1 Air pollution control law

There are differences on the renewable energy and bioenergy situation in Finland and Japan. The laws on permitted emission levels are also different from each other. The following paragraph explains what the air pollution control law defines.

According to the air pollution control law, combustion of fuel should follow the regulations updated on 10th April 1998.

a) NOx: The allowed amount of NOx depends on each facility type. The following formula (1) is used to compare the allowed amount of NOx. (Bureau of Environment 2019).

$$C = \frac{21 - On}{21 - Os} \cdot Cs \tag{1}$$

where	*C*	The amount of NOx	[ppm]
	On	The standard concentration of O_2	[%]
	Os	The concentration of O_2 in exhaust gas	[%]
	Cs	The measured amount of NOx	[ppm]

Regarding the value of *Os*, if the concentration of O_2 in exhaust gas is more than 20%, Os = 20 %. The measurement of the amount of NOx should be according to JISK0104 (Tokyo environmental measurement center no date).

b) SO_2: There are mainly two kinds of restrictions: Amount system (K value system) and area-wide total emission control.

・Amount system (K value system)

The following formula (2) is how amount system is calculated. The permitted limitation which should be based on the effective stack height (He) and the value of the constant K which is defined by each area, and the restriction becomes stricter if the value of the constant K gets smaller. The allowed emission amount is under 0 ℃ and the pressure of 1 atmosphere.

$$q = K \cdot 10^{-3} \cdot He^2 \tag{2}$$

where	*q*	Allowed emission amount	[Nm^3/h]
	K	1.17 ~ 2.34, 3.0 ~ 17.5	[-]
	He	The effective stack height	[m]

The value of the constant K varies depending on each area. K for general emission standard and special emission standard are between 1.17 ~ 2.34 and 3.0 ~ 17.5 respectively.

If a facility is equipped with outlets, *He* should be calculated as follows. If the shape of a tower is H- and T-shape or so, the below calculation is not required, thus *He* = *Ho*.

$$He = Ho + 0.65(Hm + Ht) \tag{3}$$

$$Hm = \frac{0.795\sqrt{\mathrm{Q}\ \cdot \mathrm{V}}}{1 + \frac{2.58}{V}} \tag{4}$$

$$Ht = 2.01 \cdot 10^{-3} \cdot Q \cdot (\mathrm{T\text{-}288}) \cdot (2.30 log J + \frac{1}{J} - 1) \tag{5}$$

$$J = \frac{1}{\sqrt{\mathrm{Q} \cdot \mathrm{V}}}(1460 - 296 \cdot \frac{v}{T - 288}) + 1 \tag{6}$$

where	*He*	The effective stack height	[m]
	Ho	Height from the ground level to the stack	[m]
	Q	Wet base exhaust gas at 15 ℃	[m^3/s]
	V	Speed of exhaust gas	[m/s]
	T	Absolute temperature of exhaust gas	[K]

The figure shows where *Ho* is.

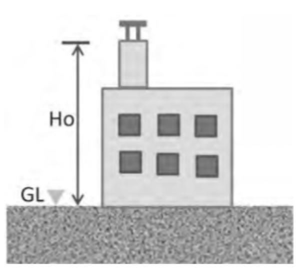

Figure 5. The height of *Ho* (According to: Bureau of Environment 2017)

・Area-wide total emission control

If the place is concentrated with factories and offices, and seems to be difficult to follow the above-mentioned amount system, the country specifies where the area is and each governor makes a total emission reduction plan based on the following calculation. Currently, there are 24 areas where this control is applied.

$$Q = a \cdot w^{b} \tag{7}$$

where	*Q*	Allowed emission amount	[Nm^3/h]
	w	Total amount of fuel used	[kl/h]

a is the constant value which the area is able to follow the restriction amount defined by each governor, and *b* is the constant value which should be $0.8 \leqq b < 1.0$.

In addition, the stricter total amount restriction can be applied for new specific factories and extended facilities.

$$Q = a \cdot W^{b} + r \cdot a\{(W+W_{i})^{b} - W^{b}\} \tag{8}$$

where	*Wi*	Total amount of fuel used after defined	[kl]
	r	$0.3 \leqq r \leqq 0.7$	[-]

In addition, in order to deal with the air pollution caused by heating, governors define the amount of fuel usage in the areas such as inner-city areas where the concentration of the facilities emitting SOx is rather high and seasonal changes occur. The sulfur content in fuel should be below 0.5 ~ 1.2 %. (Ministry of the Environment 2012.)

c) Dust: Each facility and scale's emission criteria (concentration)

General emission standards: 0.04 ~ 0.7 g/Nm^3

Special emission standards: 0.03 ~ 0.2 g/Nm^3

The allowed amount of dust emission is defined under the condition that the amount of dust is in the 1 m^3 of exhaust gas at 0 ℃ and the pressure of 1 atmosphere. In order to prevent not to meet the limited amount by diluting the exhaust gas with the air, the below calculation (9) is applied.

$$C = \frac{21 - On}{21 - Os} \cdot Cs \tag{9}$$

where	*C*	The amount of dust	[g]
	On	The standard concentration of O_2	[%]
	Os	The concentration of O_2 in exhaust gas	[%]
	Cs	The measured amount of dust	[g]

Regarding the value of *Os*, if the concentration of O_2 in exhaust gas is more than 20%, Os = 20 %. The measurement of the amount of dust should be according to JISZ8808 (Ministry of the Environment 2012).

As the air pollution control law defines, the emission standards vary in each area. However, they should follow the aforementioned law as the basis. General emission standards mean the standard which the country defines for each facility emitting smoke. Special emission standards are the severer ones which can be applied for those areas where air pollution is a serious problem and new facilities emitting smoke are going to be built. The allowed amounts of emission standards for dust and NOx are shown in Appendix 1. In other words, the above formulas are for the comparison whether those calculated values meet the values shown in Appendix 1.

It is also necessary to know how often measurements should be done. The Table 2 indicates the frequency of the measurements related to the facility emitting smoke.

Table 2.Frequency of the measurement related to the facility which emits smoke (According to: Air Pollution Control Law 1971)

<table>
<tr><td colspan="3"></td><td colspan="2">SOx</td><td colspan="2">NOx</td><td rowspan="2">Dust</td></tr>
<tr><td>Facility type</td><td>SOx emission level</td><td>Amount of emission (m^3N/h)</td><td>The plants Inside of the total restricted area</td><td>Outside of the total restricted area</td><td>The plants Inside of the total restricted area</td><td>Outside of the total restricted area</td></tr>
<tr><td rowspan="4">Single gas boiler, gas turbine, gas engine</td><td rowspan="2">More than $10m^3N/h$</td><td>More than 40000</td><td rowspan="2">Always</td><td rowspan="2">More than once in two months</td><td>Always</td><td>More than once in two months</td><td rowspan="4">More than once in five years</td></tr>
<tr><td>Under 40000</td><td colspan="2">More than two times in a year (*)</td></tr>
<tr><td rowspan="2">Under $10m^3$ N/h</td><td>More than 40000</td><td colspan="2" rowspan="2"></td><td>Always</td><td>More than once in two months</td></tr>
<tr><td>Under 40000</td><td colspan="2">More than two times in a year (*)</td></tr>
</table>

*The amount of the emission is less than 40000 m^3N/h, the facility which suspend for more than six months without interruption, NOx measurement frequency can be more than once in a year.

4.2.2 Comparison of the EU Directive and air pollution control law

In the EU, the Directive (EU) 2015/2193 defines the emission limit values for SO2, NOx, and dust. There are some differences between the Directive (EU) 2015/2193 and Air Pollution Control Law in Japan. They are about the classification of fuels and sizes of facilities.

In the Directive (EU) 2015/2193, the emission limit values are classified by fuel types: solid biomass, other solid fuels, gas oil, liquid fuels other than gas oil, natural gas, and gaseous fuels other than natural gas. Air Pollution Control Law does not provide the emission limit value for each fuel type, but facility types which what kind of fuel they burn as Appendix 1 shows. Unlike the directive, although it defines in accordance with facility types, there are no restrictions for solid biomass specifically. Thus, when biomass boilers are installed, we need to refer the numbers written in solid fuel boiler type section (Japan wood energy Co., Ltd. no date).

・SO_2: Because the emission limit values vary at each area, it is not possible to directly compare between the Directive and the Law.

・NOx: To find out whether there are any differences between the emission limit values, the unit conversion is required. The unit is mg/Nm^3 in the Directive (EU) 2015/2193, on the other hand, it is ppm in Air Pollution Control Law. The formula (10) shows how to convert the unit.

$$P \cdot \frac{22.4}{MW} \tag{10}$$

where	*P*	The amount of NOx	[mg/Nm^3]
	MW	The molecular weight of NO_2	[g/mol]

According to the Directive, the emission limit values for existing medium combustion plants (more than 1 MW thermal input) is 650 mg/Nm^3, and for new medium combustion plants is 300 mg/Nm^3. When convert them into ppm, they are 317 ppm and 146 ppm respectively. Based on the emission standards shown in Appendix 1, the emission limit value is 200 ppm ~ 350 ppm regardless of whether the facilities were built or are going to be built.

・Dust: The directive defines the emission limit values for the existing medium combustion plants with a rated thermal input 1 ~ 5 MW thermal input, more than 5 MW, and new ones, and are 50, 30, and 20 mg/Nm^3 respectively. Also, based on the emission standards in Appendix 1, the emission limit value is 150 ~ 300 mg/Nm^3.

4.2.3 The current emission levels in Japan

Although there is the emissions data separated by fuel including biomass in Finland, there is no such data in Japan. However, it was possible to find the data giving the overall amount of SOx, NOx, and dust emissions provided by the Ministry of the Environment. Figure 6 shows the results from 1978 to 2017. The result of each emission in 2017 is a prompt number, meaning that it excludes any data answered later than the end of August 2019.

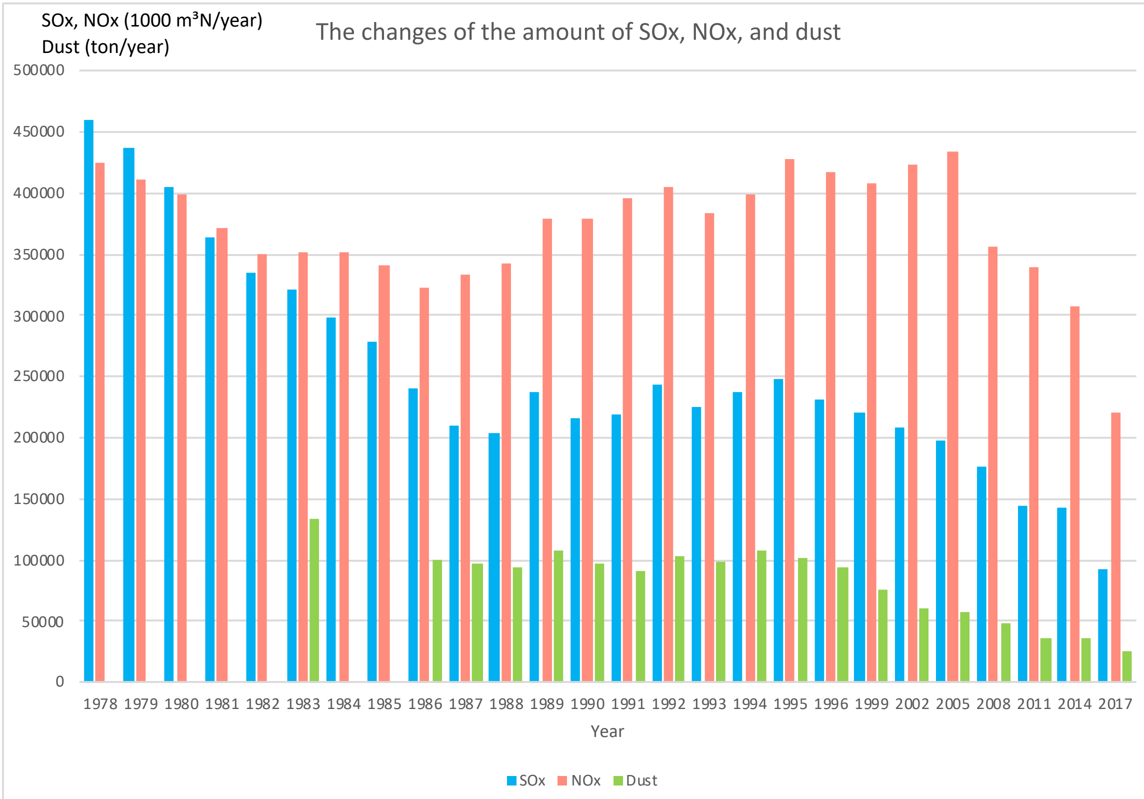

Figure 6. The changes of the amount of SOx, NOx, and dust (According to: Ministry of the Environment 2019)

According to the Ministry of the Environment, the electric power industry accounts for 44 % of SOx emission, 36 % of NOx emission, and 16 % of dusts (2019).

There are 1873 general environment air monitoring stations and 409 vehicle exhaust monitoring stations, which monitor six substances including PM2.5, Ox, NO_2, SO_2, CO, and SPM set in the environmental criteria. How much each SO_2 and NO_2 achieves its limitation of the emission level as of 2016 fiscal year is the followings.

・SO_2: 99.8 % was achieved at general environment air monitoring stations, and 100 % was achieved at vehicle exhaust monitoring stations.

・NO_2: 100 % was achieved at general environment air monitoring stations, and 99.7 % was achieved at vehicle exhaust monitoring stations.

4.3 Reduction methods of emissions

Whether reduction methods for particular emission is developed and applied in Japan was uncertain, therefore, the interview done by email was made. According to Sakamoto and Ozeki, since wood contains sulfur a few, SOx is considered hardly and desulfurization equipment is not necessary for 100 % wood biomass-fired power plants. Likewise, NOx is not contained much in wood, therefore, NOx coming from the fuel is not considered. However, thermal NOx could be generated, if the temperature gets high when wood is burnt. To not to generate it, manufactures design combustion chambers not to have high-temperature combustion. Thus, NOx removal equipment is not established. In short, reduction equipment is not necessary to reduce NOx and SOx. Dissimilar to former two substances, bag filters or electrostatic precipitator is required to remove dusts at general biomass power plants. Majorities are equipped with bag filters. (Sakamoto & Ozeki 2020.)

The above reduction methods are for wood biomass-fired power plants. It would be welcomed if such power plants are promoted. But biomass co-firing in coal power plants are also promoted in Japan since Japan will rely on 26 % of total energy from thermal power plants in 2030 fiscal year. (Agency for Natural Resources and Energy 2018.) The below technology developed by Mitsubishi Hitachi Power Systems (MHPS) can also be applied to not only wood biomass-fired power plants but also thermal power plants as well. The following explanations are based on the article “Efforts toward steam power plant utilized pulverized biomass exclusive firing technology” published by MHPS in 2019. MHPS developed the pulverized biomass fired boiler. The noteworthy developments are the pulverized biomass firing system and the ash removal technology.

a) Pulverized biomass firing system

This system can do biomass exclusive firing without any substantial changes of equipment. If the particle size of woody pellet is about 75 μm, the same as pulverized coal, the differential pressure and required power of mills substantially increase. It is because fibers remain in biofuel and is inferior to grindability, smaller than 1 mm is economically feasible and appropriate. However, the ground pellet particle is rougher than the conventional pulverized coal. The decrease in the emission rate of biomass particles from mills, ignition stability of biomass, and obtaining effective combustion were huge issues.

The amount of primary air was increased compared to the conventional coal mills in order to improve the emission rate of biomass particles from mills. The velocity of conveying was also increased for the same reason. To solve the problems on ignition stability of biomass and obtaining effective combustion, circular ultra firing system was applied. Injecting pulverized particles and the air from a burner to the center of a furnace make a whirl flame. This formation creates the condition of the mixture of fuel and the air satisfy to proceed the highly efficient biomass combustion. Figure 7 shows how the system looks like.

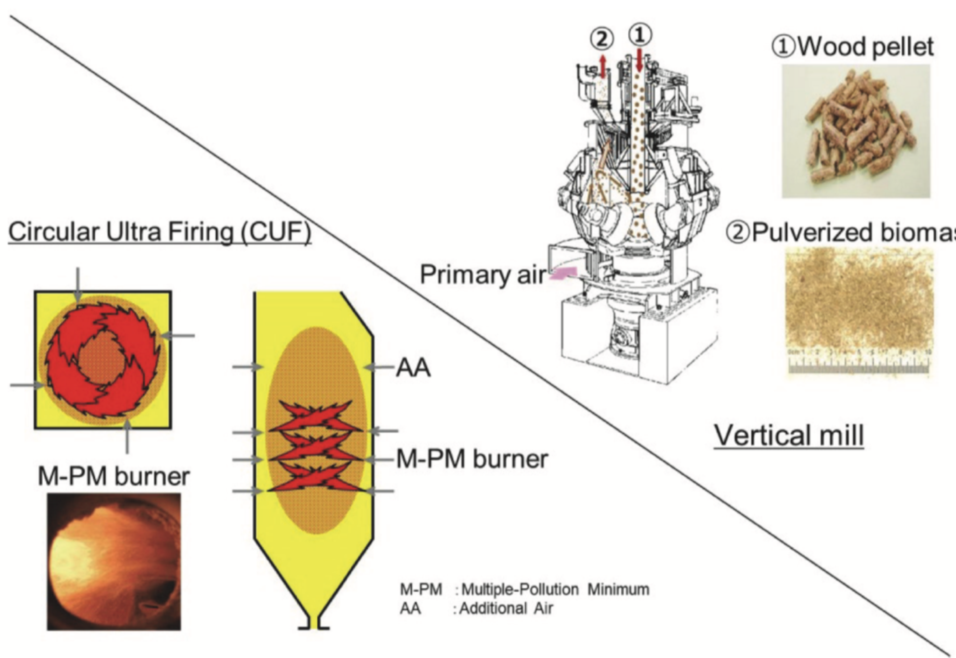

Figure 7. Pulverized biomass firing system (Ikeda et al. 2019)

The applied burner is M-PM (Multiple Pollution Minimum) burner which reduces the amount of NOx emission and developed by MHPS. The below Figure 8 shows the mechanism of M-PM.

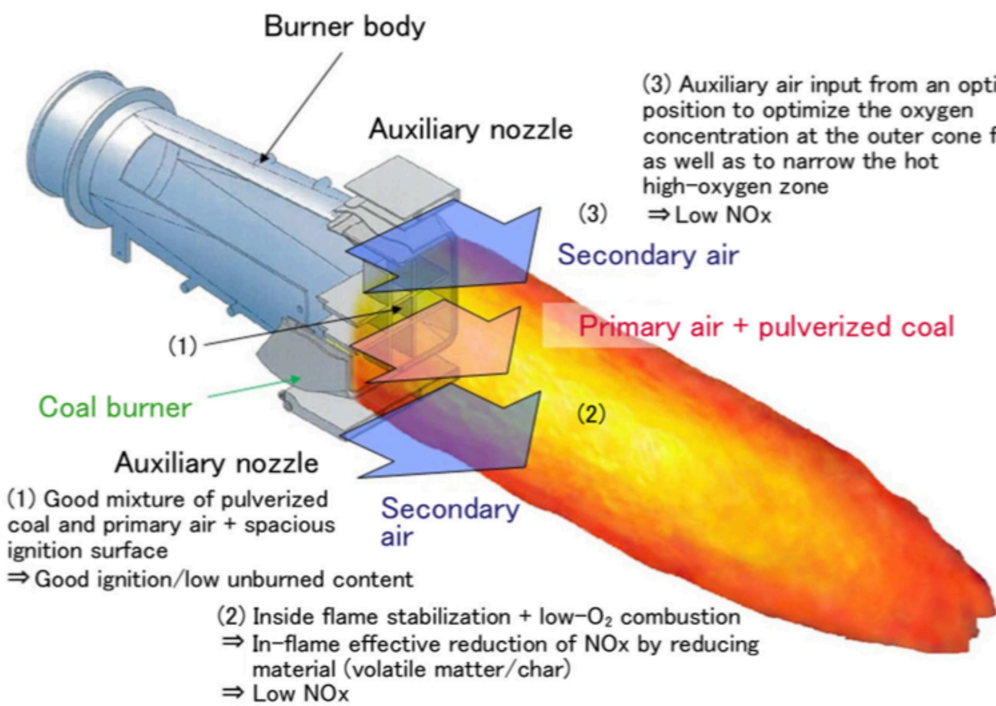

Figure 8. The mechanism of M-PM burner (Matsumoto et al. 2015)

MHPS applied this burner to 4t/h furnace as an experiment. The combustion level was as good as the former conventional NOx A-PM burner or better. It was possible to reduce NOx by 20 ~ 40 %, and unburned content by 25 ~ 50 % compared to A-PM in coal with the intermediate fuel ratio. These reduction rates would vary depending on operating conditions and boiler sizes, but MHPS confirmed that the amount of NOx and unburned content are decreased with using actual-scale burner. NOx was reduced from 158 ppm to 110 ppm compared with the same facility equipped with A-PM in actual operation (600 MW output, 6 burner stages, variable pressure operating once-through boiler, 4 corner turning combustion), it means that changing the burner from A-PM to M-PM enables to decrease the amount of NOx by 30 % using the coal with the intermediate fuel ratio of 10 ~ 15 % ash content. Not only NOx reduction but also the amount of unburnt content was decreased from 4.6 % to 3.0 %. (Matsumoto et al. 2015.)

b) Ash removal technology

Generally, woody biomass contains more alkali metals than coal. Such alkali metals volatilize and NaCl gas and KCl gas are generated in a furnace. The amount of these gases increases as the temperature in a furnace gets higher. These gases are cooled down and condensed, then cause ash deposition. The pulverized biomass exclusive firing technology requires higher temperature in a furnace compared to other combustion systems. The ash removal technology was needed to be improved.

To decrease the ash deposition, MHPS injected coal ash into a furnace and made it chemically react with NaCl and KCl gases, reduced the amount of volatilization of alkali metals. The system enabled to control ash deposition as Figure 9 indicates.

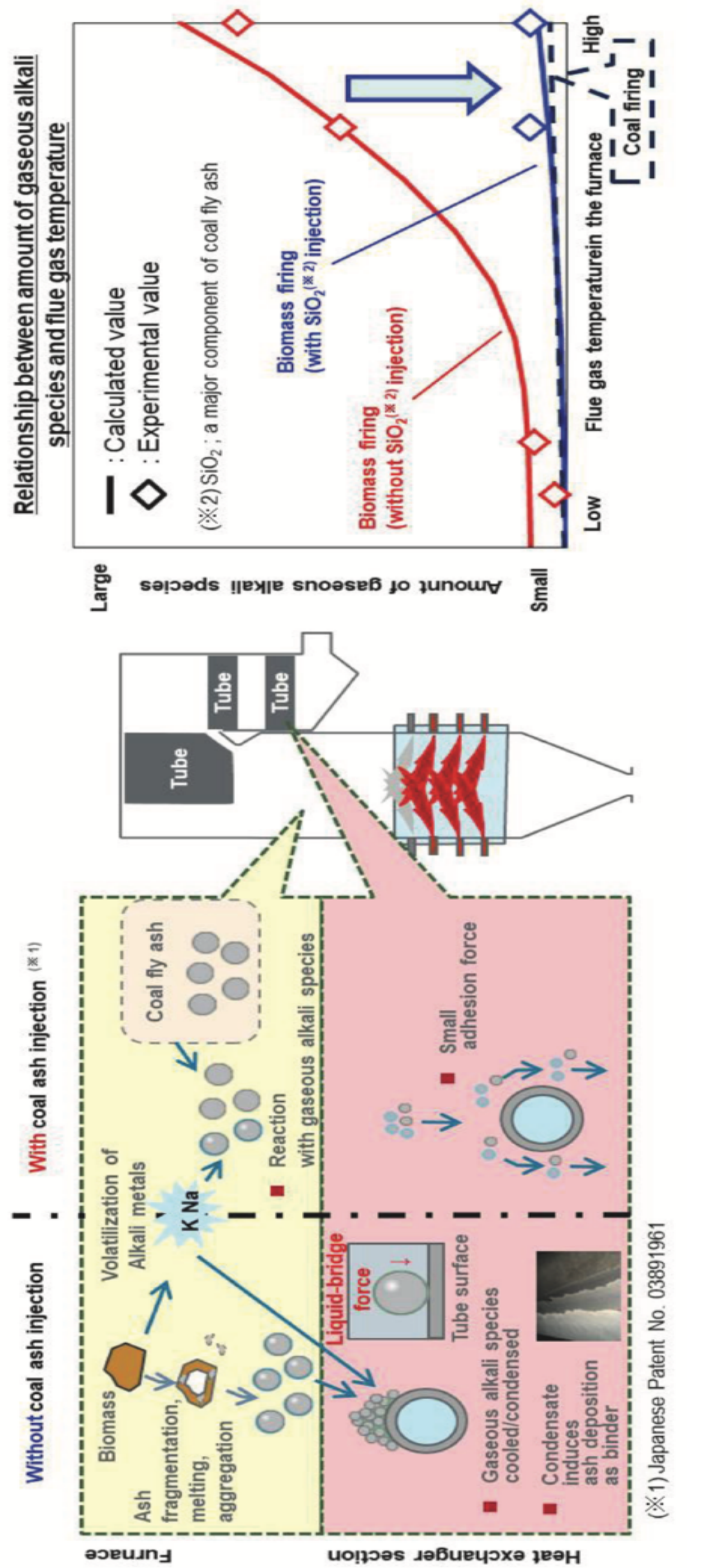

Figure 9. The theory of ash deposition and the effect of ash deposition control by injection of coal ash (Ikeda et al. 2019)

By injecting the appropriate amount of coal ash based on the characteristics of biomass and coal ash, it is possible to apply the system for biomass-fired boilers as equivalent to conventional pulverized coal-fired boilers with the same heating surface design.

This system has already been applied in some places including Denmark, England, and Canada. In Denmark, the power plants work as coal-fired in summer and as biomass-fired power plants in winter. The applied power plant works as a biomass-fired power plant throughout the year in England, and one-third of a year in Canada. (Ikeda et al. 2019)

4.4 Utilizing Bamboo for Bioenergy with new technology

It would be useful that providing another Japanese characteristic bioenergy technology trying to solve the ongoing problems. Here are examples being under development.

4.4.1 Bamboo

Bamboo has been used for years in Japan. For example, there are baskets, colanders, and rakes made of bamboo. Some Japanese traditional tools, such as tea things, flower arrangements, martial arts, and some instruments are also made of bamboo. Bamboo charcoal contains a lot of minerals including potassium and sodium, and is porous compared to charcoal. It can be used for the effective improvement of soil and deodorization. Bamboo is a part of Japanese lifestyle. (Forest Agency 2018.)

However, the circumstances surrounding bamboo in Japan is similar to what Japanese forestry faces. The following chapter explains what is happening.

4.4.2 Problems related to bamboo in Japan

In 2012, 0.6 % out of the area covered with forest is covered with bamboo, and the rate is slightly increasing in a long period. Bamboo used to be managed by daily goods and food production. But Japanese bamboo came into bloom all together around 1965, it means that such bamboo was going to die. Once it blooms, it ends its live. Therefore, a large amount of bamboo died around 1965. It triggers the increase of the amount of imported bamboo, the original Japanese bamboo was not utilized anymore, and bamboo grove started to be abandoned. These were also because of the spread of plastic goods. There are still some areas where bamboo is managed appropriately, however, it is also true that there are some forests where bamboo invades. (Forest Agency 2018.)

Once bamboo grove gets abandoned, the dead bamboo is left and the area gets darker and darker, people eventually cannot go in. Bamboo's underground stem can grow two to three meters in a year, and it can even grow eight meters at the maximum. It saves nutrition in its underground stem. This enables bamboo to grow even in gloomy forests. If they grow taller than the lower trees which originally growing there, those trees cannot grow, bamboo invades and dominates the area. In short, the forests dominated by bamboo would face the risks of lacking plant diversity and hindrance of the potential for public interests. (Forest Agency 2018.)

In order to restore abandoned bamboo groves, felling and using herbicide are possible ways to reduce the number of bamboos. In fact, the latter method is more effective than the former one. Because underground stems save nutrients, the new bamboo would grow even if bamboo is cut down. However, there is another way to manage bamboo groves recently, that is the utilization of bamboo for bioenergy. (Forest Agency 2018.)

4.4.3 Bamboo as bioenergy

The utilization of bamboo for bioenergy was regarded as unsuitable for years. Because burning bamboo in a large-scale boiler causes the melt of ash and forms clinker. This results in occurring corrosion of fire-resistant materials and heat transfer tubes. Clinker is formed because the initial deformation temperature of bamboo is between 680 and 900 ℃, which is lower than the one of woody biomass, 1100 ℃. In addition, if bamboo is burnt at low temperature, dioxins are generated, and dioxins are synthesized again at the temperature between 200 and 500 ℃ due to its high concentration of chlorine. (HITACHI 2017.)

In order to make bamboo possible to use as bioenergy fuel, HITACHI developed the new technology.

4.4.4 The technology developed by HITACHI

To solve the creation of clinker, Hitachi got rid of potassium and chlorines from bamboo. It had been proceeding the development of the improvement of bamboo as biofuel. The company focused on bamboo's porous structure. They found water-soluble potassium and chlorines can be easily eluted, when bamboo is atomized and let the particles into water. Based on this, lowering the concentrations of chlorines and potassium was achieved by atomizing bamboo smaller than six-millimeter particle size, soaking them to elute potassium and chlorines, and dehydrating them. As a result, the initial deformation temperature of the ash rose to more than 1100 ℃ and the concentration of chorines lowered as almost the same level as what woody biomass pellet fuel standard is. This technology can also be applied to other kind of bamboos, weeds, and unused cedar bark, giving the similar effects. Appendix 2 shows the overall results.

This technology is not only for biofuel, but also produces fertilizer. When defining whether extracted material contains any toxic materials, a little amount of three main macronutrients, nitrogen and phosphorus besides potassium were found. In fact, there were no toxic materials found. To make sure if the highly concentrated extracted material is usable as a plant growth-promoting agent, the company experimented it by growing komatsuna, a kind of colza. The result shows that komatsuna grew 1 ~ 2 cm taller than the additive-free komatsuna, and the weight is 1.24 ~ 1.44 heavier than the additive-free komatsuna. In addition, the komatsuna has less color changes compared to the additive-free komatsuna.

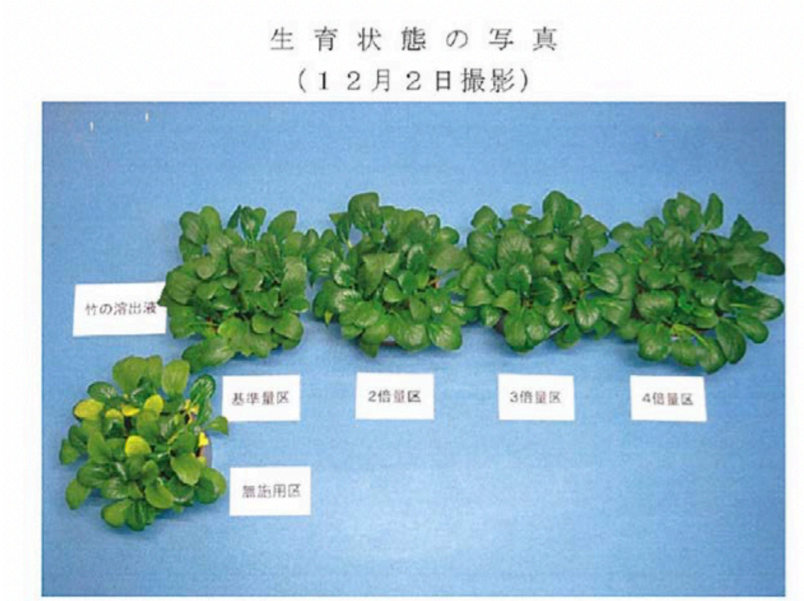

Figure 10. Growth condition with the specific concentration of the concentrated extracted material taken on 2nd of December (According to: HITACHI 2017)

The above Figure 10 shows the differences on each growth condition among them. From the left, additive-free komatsuna, the standard, two times concentrated added, three times concentrated added, and four times concentrated added.

These findings seem to be useful, however, it has not yet been decided when it would be commercially applied (HITACHI 2017).

4.4.5 The demonstrative example

There is the biomass plant which is equipped with ORC co-generation system completed by Bamboo Energy corporation in Nankan town, Kumamoto on 29 August 2019. According to the plan, it utilizes 8750 tons of bamboo per a year, and electrical output is 995 kW and heat output is 6795 kW. The generated electricity and heat would be used at the adjoining factory. The amount of heat meets the demand for a drying process at the adjoining bamboo manufacturing factory. The system uses bamboo and bark in the ratio of three to seven to avoid generating clinker. The ash generated from burning bamboo and from bark work as antibacterial deodorizers. Therefore, the company aims to sell them as products. (Bamboo Energy Corporation & NEDO 2019.)

The system is now on the validation phase. The company proceeds the project towards the commercialization around 2023. After the commercialization, it plans to employ more than 120 people as a whole. In other words, creation of jobs at the local and preservation of the local bamboo resources are considered. In addition, it thinks contributing to the disaster-resistant and sustainable community development by cooperating with the local and improves abandoned bamboo groves. Moreover, it aims to spread this type of community or society to the whole country. (Bamboo Energy Corporation & NEDO 2019.)

4.5 Local societies’ developments with woody bioenergy business

It is important to note each local example including the local society’s development because as already mentioned in the chapter 4.1.2. Each has characteristic points, and the following examples are succeeded ones in terms of the point that woody bioenergy business is socially involved.

4.5.1 Maniwa city

This chapter is based on Ishida (2017) report at Renewable Energy Institute.

Maniwa city is located in northern part of Okayama prefecture, middle part of Japan. About 80 % of the city is covered with forests. The city is famous for prosperous forestry and dairy farming and is especially known as Japanese cypress district. There are approximately 30 wood manufacturing companies. To use up abandoned wood in forests and mill ends generated from sawmills, woody bioenergy business has started since April 2015. The Maniwa biomass power plant can generate the power equivalent to the enough amount for 22000 households in a year.

The city has been working on the utilization of woody biomass for 20 years to activate forestry and spread renewable energy. As a part of it, wood industry arranged “Maniwa biomass collection base” in 2009. In this way, it made the system that being able to sell chips which is manufactured from the collected unused timbers and bark as fuel.

Then, to use those collected local wood materials effectively, the plan of woody bioenergy business has started. At the same time, Feed-in Tariff (FIT) was also started in 2012 fiscal year.

All the operators working at the power station are from the city. It means that the gained profit is returned to the city, therefore, the business contributes to the local economy. It is better to mention that there are still operators at the power plant. According to Sakamoto, changing the operation system based on the internal boiler temperature automatically is possible. However, it is hard to continue generating electricity under the condition which various kinds of chips are mixed. Therefore, it is required to adjust the type of fuel and the amount of fuel carefully based on the flame condition in the boiler and the constituents of the exhaust gas.

Although the profit is returned to the city, it is not possible to do so without profit. The business will not be applicable to FIT in 2035 because FIT guarantees buying and selling of renewable energy for 20 years. Fuel costs almost 1.3 billion yen (≒ 10.8 euros) in a year. Hence, the current concerning point is what could be involved in the business besides generating electricity to get earnings.

Woody biomass power generation generates a large amount of heat at the same time. It would be highly beneficial if the company could also sell it. At present, the surplus steam is provided to the adjoining cross laminated timber (CLT) industry which is owned by Meiken Lamwood Corp. The steam is used for drying wood and heating there, but there are no other ways to use. The power station is located in the place where only some industries are located, and there are no such infrastructures being able to provide heat to the surrounding areas.

It might not be seemed the business involves the society, the city organizes biomass tour to tell the business model. The tour includes not only the woody biomass power station visit, but also a stroll in traditional rows of houses. Participants would learn how wood is related to their daily lives and local business through the tour. (Biomass Tour Maniwa no date.)

4.5.2 Shiwa town

Shiwa town is located in Iwate prefecture, northern part of Japan. 57.8 % of the town, 13821 ha is covered with forests, however, such forests are abandoned due to the long-lasting price weakness of domestically produced timber. Therefore, the town works on forest resources circulation as a promotion policy, and when new public buildings are going to be built, the use of town-made timber is promoted. Ordinary houses which use town-made timber are exempt for property tax since 2003 fiscal year, and subsidy institution has been applied to the same kind of houses since 2006 fiscal year. From 2010 fiscal year, “Shiwa eco bee coupons” are given to the forest owners who has afforested, and townspeople carried out lumber. The coupons can be used at the certain authorized shop “Eco shop Shiwa”. These projects aim to encourage activation of forestry and reduction of carbon emission. (Shiwa 2012.)

Needless to say, not only the projects as part of local business, but also putting declaration into effect is significant. “The future declaration of new century” was announced in June 2000 to declare preservation, creation, and handing over the Shiwa’s environment to the future generations. With this declaration, the town has been proceeding the business development related to resource circulation aiming at building the circular economy. (Shiwa 2012.)

To revitalize forestry and forestry resource circulation, Shiwa town, Iwate central forestry association, and town’s sawmill corporate together and work on securing pulverized charcoal, pellet, chip, and utilizing timber originally from the town. In addition, foresters, forest owners, forest managers, and construction workers, such residents deeply related to forest resources corporate with each other. Shiwa future institution named “mountain and forest club” which was organized to work on the utilization and conservation of forest and townspeople hold forest studies together. By circular utilization of unused forest resources and active utilization of town-made timber, it is expected the activation of forestry business and the conservation of publicly beneficial function that forest has. As the result, 96.2 % of wood residues are used as fuel and compost in 2012 fiscal year. (Shiwa 2012.)

4.5.3 Shimokawa town

This chapter is based on biomass business strategy in Shimokawa town forest comprehensive business promotion section (2017).

Shiomokawa town is located in Hokkaido prefecture, northernmost of Japan. In 2004 fiscal year, the woody biomass boiler was introduced to Gomi hot spring firstly in this town in Hokkaido. The reason why Gomi hot spring is the first place in Hokkaido is because it emitted a lot of carbon dioxide among public facilities. In March 2005, 180 kW woody biomass boiler was introduced there, implemented carbon dioxide emission and cost reduction, the local energy fund flow. (Shimokawa town hall 2020.) There are 11 boilers providing heat to 30 public facilities and covering 64 % of total heat demand from public facilities for now. Each boiler's output is 165 kW, the total power generation is 1815 kW (if the amount which is consumed at the power station is deduced, it is 1727 kW) which is able to provide approximately 2000 households. This co-generation business has mainly four purposes: improvement of fundamental infrastructures for local sustainable development, activation of forestry (increase in production and employment), activation of local economy (ripple effect on local economy, increase in tax revenue), and improvement of local security and comfortable living environment (realization of comfortable living environment by heating without using fire inside buildings and inexpensive heating system). To achieve these four points, the town set the target that the town is going to be able to be self-sufficient in energy which forest biomass energy would be central.

The town introduced wooden pellet gasification co-generation system because we can utilize heat even if the scale is small and feasibility is expected due to its high total efficiency. Therefore, the town produces wooden pellets, sells generated electricity to electric power companies, and heat makes warm water which is used as district heating. In addition, the material for wooden pellets is collected at the town. Approximately 15000 m^3 of raw lumber is consumed to produce 10000 tons of wooden pellets in a year.

By introducing woody biomass boilers, there are several advantages. First of all, the saved fuel cost which otherwise would have been paid for fossil fuel reached 19 million yen (≒ 158 euros) in 2014 fiscal year. The half of it is allotted to child raising support. The rest of it is allotted to accumulated reserves for the future boiler facilities and the investment for the future Shimokawa town. Three were newly employed at a woody material production facility, and two were also employed additionally at a transportation company for transportation of wooden chips.

The fourth-generation district heating system is planned to be adopted. This system is introduced in Denmark where most developed district heating technology is possessed. With the system, it is possible to utilize hot water (50 ~ 70 ℃) compared to the former generation systems. In this case, controlled sufficient amount of supply of hot water would be supplied at the time when heating and hot water are needed by using high thermal insulation performance heat supply pipelines. It can reduce heat loss and the power required to move pumps. This is not yet in operation, but the town has started to discuss the size of thermal storage tank for efficient use of heat and the buying cost of heat.

5 DISCUSSION

Both technologies and local examples in Japan follow developed cases in Europe. According to Toyota working at Kiko Network, Japanese woody bioenergy business is behind the European ones for about five to ten years (2019). One of the reasons could be the meteorological reason, the climate in Japan is not as cold as European climate. It might have not been necessary to develop the bioenergy related technologies and systems. Because of this, the appropriate and effective system were not developed. In addition, the energy revolution happened, the main source of energy was changed to fossil fuel.

However, the time has changed. Climate change becomes a major problem nowadays, and we have started to be concerned about it. Generating energy is one of the contributors to climate change, meaning that changing energy sources which do not emit greenhouse gases could control and reduce them. People realized that renewable energy can be a business, and bioenergy could also be a part of local business.

If bioenergy is carried out as a local business, local administrators have to be skilled at implementation of the plans. Without agreements between local administrators and citizens, it is not possible to accomplish business. Local business is built based on cooperation and involvement of every citizen living in the area. Without the both sides' satisfaction, local business would have potential to go wrong. Thus, building steady relationships between local administrations and citizens is crucial.

When good relationships are built, bioenergy business could begin. In order to cut and sort parts of woods, certain types of machineries are required. Geographic Information System (GIS) is not only for management of ownerships as Iwashita (2013) mentions, but also examinations of logging roads (Yamazaki et al. 2019). Even though it is hard to make roads for transportation, this is one of the urgent issues that should be solved. When we talk about local business, building roads also creates jobs and increases workers. If the workers live in the area where the roads are built, they would pay living expenses to the area. Thus, making roads is the prior matter.

At sawmills, mill ends and dust are generated. These should be utilized as biofuel instead of disposal. In this way, we could reduce the amount of waste, and become part of local business, too.

The circular flow within the area through bioenergy is encouraged to activate the region. When it seems to be successful, the next step would be globalization. Localization should be kept going at the same time. In other words, woody bioenergy has potential to grow from small scale business to even international scale.

6 SUGGESTIONS FOR THE FUTURE IMPROVEMENTS

There are woody biomass power plants and they are in operation. However, the amount of how much they generate is not enough for the amount of the demand yet. In this chapter, several kinds of thoughts on woody bioenergy business toward the future are discussed.

6.1 The necessity of sawmills getting involved in woody bioenergy business

Cascading use of wood is not structured well as chapter 2.2 mentions, the energy generation is not involved in it. Therefore, the fundamental of sawmill industry is unstable. But the sawmill scale gets bigger recently at the same time. Thus, building concrete cooperation relationships between the use of material and sawmill industry on this occasion would be better to be considered. (Kumazaki 2016.)

6.2 Satoyama capitalism

For Aikawa (2014), the ideal picture is coexistence of the set of large-scale sawmills and bioenergy power stations, and the set of local sawmills and biomass boilers. In other words, balancing nationwide and local needs would work. This has something in common with Satoyama. If there are skilled residents, they may be able to make roads for the transportation of timber by themselves. If there are not such people living in, they may ask JForest, cooperate together, and proceed the business consolidation. Once road networks are built, working at forests by themselves is possible.

6.3 Design of how people can get involved

This chapter is based on what Mr. Nakano gave the presentation at Kiko Network on 9th July 2019. He worked at Ministry of the Environment from 2006 to 2010, then worked at Shimokawa town hall from 2010 to 2018. After that, he became independent and set up the community self-reliance support center (general incorporated association). He was a part of the development of woody biomass power generation business in Shimokawa town.

Woody biomass power generation is spreading gradually in Japan after FIT was in effect in 2012. Woody biomass power generation business is getting accepted as a part of local business. However, there are still conflicts.

For example, if the business is a part of local ones, it would be better that people engaged in politics understand and agree the advantages of the business. However, they likely to think it would be better to start other business instead of it at first, and may not even understand the importance of it. Of course, the people who did not use to take woody biomass power generation business into account start to consider about it is welcomed. At the same time, it also depends on what each governor intends to shape local industrial policies. If they focus on renewable energy, such policies would be related to it. If they do not consider about it carefully, they may focus on other business. In fact, there are a few people willing to change or make revolution at local administrations. They most likely lack a sense of crisis.

Even if woody bioenergy business is decided to be carried out, it is not possible to realize it without agreement with residents. Explanatory meetings are held to explain what kind of benefits could be brought to the area and how the possible negative effects could be overcome. However, the majority of participants would be those who disagree with the business and they would not get the comprehensive explanation well at the meetings.

Although it seems hard to realize woody bioenergy business as a local business, improving design, planning, and breakthrough skills would help for it. First of all, one of the reasons why local administration personnel tend to refuse is because their horizons may not be broad. Therefore, imagining and having ideas, broadening mind, changing viewpoints, varying the information resources, and getting to know unknown fields and people are recommended to develop. Secondly, it is recommended to know the basics of informational, regulative, and applicable economical techniques. Finally, they should clearly define what the plan is. Without trust, plans never start. Getting supports from surroundings as much as possible, being positive, preparing materials which someone who received the information can explain to the others with confidence are required. Fundamentally, it is important to make plans by the ones who implement them in practice.

The example of Shimokawa town is the one which above mentioned points were satisfied. The organizational and comprehensive governance, each planning, ranking visions, and effective use of subsidy were the succeeded reasons. The following Figure 11 shows what the ideal governance is.

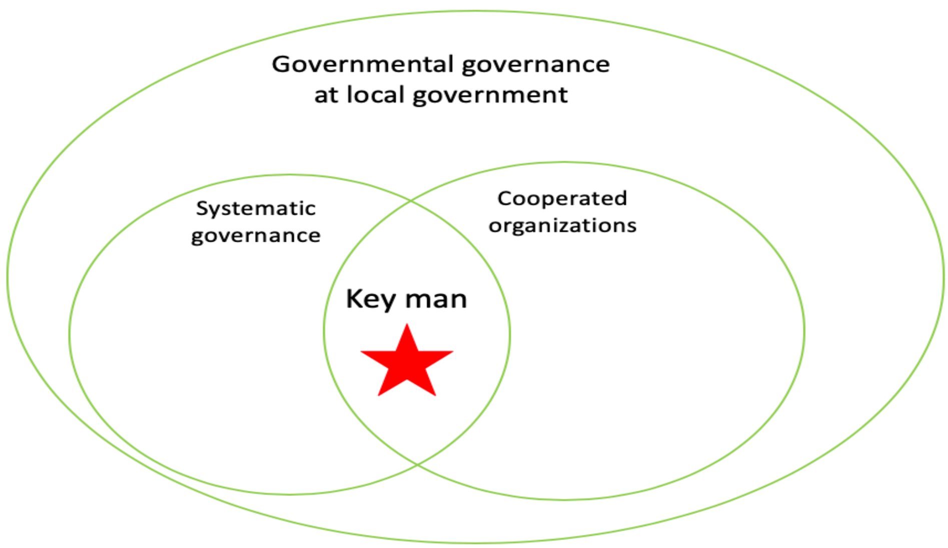

Figure 11. The ideal governance (According to: Nakano 2019)

The town ranked the bioenergy business as a strategy, this also contributes to the project with success, too. In addition, the power of local media cannot be ignored. If the majority of readers are opposition forces, the trend would be on that side.

7 CONCLUSION

The bioenergy business as a local business has just started. Noteworthy SOx reduction methods applied to woody biomass power stations could not be found. However, Japan finds Japanese characteristic problems, such as decline in Japanese forestry, regional vitality, bamboo, and invented the utilization of it as fuel. Solving these problems and everything related to nature take long time. It is better to consider about bioenergy related issues on a long-term basis. Woody bioenergy in Japan has potential for growth with supports from other developed countries in terms of bioenergy sector.

Finally, some of the wood used at the Daijosai is going to be used as biofuel as already mentioned. This phenomenon is a good start that such timber can be used as biofuel because the emperor who is the Japanese symbol decided to do so. Japanese citizens would also follow the idea and realize the importance of biofuel.

REFERENCE

Agency for Natural Resources and Energy. April 2018. なぜ、日本は石炭火力発電の活用をつづけているのか？ 2030 年度のエネルギーミックスと CO2 削減を達成するための取り組み (Why does Japan continue coal-fired power generation? Works on the energy mix in 2030 fiscal year and the achievement for carbon reduction.) WWW document. Available at: https://www.enecho.meti.go.jp/about/special/johoteikyo/qa_sekitankaryoku.html [Accessed 17 February 2020].

Agency for Natural Resources and Energy. June 2018. 日本のエネルギー、150 年の歴史⑥ 震災と原発事故をのりこえ、エネルギーの未来に向けて (Japanese energy, the history of 150 years No.6, overcome the Great East Japan Earthquake of 2011 and nuclear power plant accident, forward the future of energy.) WWW document. Available at: https://www.enecho.meti.go.jp/about/special/johoteikyo/history6mirai.html [Accessed 8 January 2020].

Aikawa T. December 2014. 林業地域が成功する条件とは何か (Woody biomass business, what is the successful conditions for forestry regions?) The first edition. Minato-ku: Zenrinkyou.

Biomass tour Maniwa. No date. Tour details. WWW document. Available at: http://biomass-tour-maniwa.jp/english/ [Accessed 26 February 2020].

Biomass Power Association. November 2016. バイオマス発電事業の普及促進策について (About the promotion measure of bioenergy business.) PDF format. Available at: https://www.meti.go.jp/shingikai/santeii/pdf/026_01_00.pdf [Accessed 24 January 2020].

Bureau of Environment. March 2019. 窒素酸化物に係る規制基準 (NOx regulation standard.) WWW document. Available at:

https://www.kankyo.metro.tokyo.lg.jp/air/air_pollution/emission_control/emission_control/Soot_Smoke_NOx.html [Accessed 17 February 2020].

Bureau of Environment. March 2019. 硫黄酸化物に係る規制基準 (SOx regulation standard.) WWW document. Available at: https://www.kankyo.metro.tokyo.lg.jp/air/air_pollution/emission_control/emission_control/Soot_Smoke_SOx.html [Accessed 17 February 2020].

Bureau of Environment. April 2020. 大気汚染・悪臭関係基準集 (Air pollution and odor related standards.) PDF document. Available at: https://www.kankyo.metro.tokyo.lg.jp/data/publications/air/standard_collection.files/202003_all.pdf [Accessed 1 May 2020].

Energy information institute. June 2016. 日本の再エネ普及を左右した RPS 制度の歴史を見る、2017 年度から 5 年間で段階的に廃止 (The history of RPS system which affects the spread of renewable energy in Japan, step by step abolition for five years.) WWW document. Available at: https://pps-net.org/column/19090 [Accessed 16 December 2019].

Food and Agriculture Organization of the United Nations, Regional office for Asia and the Pacific. 2010. Asia-Pacific forestry sector outlook study II Working paper series, Working Paper No. APFSOS II/WP/2010/30 Japan Forestry Outlook Study. PDF document. Available at: http://www.fao.org/3/am625e/am625e00.pdf [Accessed 4 May 2020].

Forestry Agency. October 2018. 竹の利活用推進に向けて (The promotion of bamboo utilization.) PDF format. Available at: https://www.rinya.maff.go.jp/j/tokuyou/take-riyou/attach/pdf/index-3.pdf [Accessed 13 February 2020.]

Forest management association of Japan. March 2010. 今後の森林管理・林業経営に向けた提言 (The proposal for the future forest management and forest industries.) WWW document. Available at: https://www.rinkeikyo.jp/about/00000008.htm [Accessed 5 February 2020].

Forest energy research institution corporation. January 2020. 全国木質バイオマス発電所一覧地図 (The national woody biomass power station map.) WWW document. Available at: http://www.mori-energy.jp/hatsuden1.html [Accessed 22 January 2020.]

Fukuishimbun online. November 2019. 大嘗宮の建設関係費 24 億円 (The construction of Daijokyu costs 2.4 billion yen.) WWW document. Available at: https://www.fukuishimbun.co.jp/articles/-/973596 [Accessed 3 February 2020.]

Hisagi Y. February 2014. ORC 発電システムの国内への適用の可能性と課題 (Possibilities and issues regarding the application of ORC power generation system to Japan.) PDF document. Available at: https://www.npobin.net/research/data/140220Kuki.pdf [Accessed 1 May 2020].

IEA Bioenergy. September 2018. Finland – 2018 update Bioenergy policies and status of implementation. PDF format. Available at: https://www.ieabioenergy.com/wp-content/uploads/2018/10/CountryReport2018_Finland_final.pdf [Accessed 21 January 2020].

IEA Bioenergy. January 2018. Is energy from woody biomass positive for the climate? WWW document. Available at: https://www.ieabioenergy.com/iea-publications/faq/woodybiomass/ [Accessed 1 May 2020].

Ikeda A., Shimo H., Tsujikawa H., Yamashita T., Sudo M., Nakajima H. September 2019. Efforts Toward Steam Power Plant Utilized Pulverized Biomass Exclusive Firing Technology. Mitsubishi Hitachi Power Systems (MHPS). PDF format. Available at: https://www.mhps.com/randd/technical-review/pdf/index_70e.pdf [Accessed 6 December 2019.]

ISEP. August 2017. データでみる日本の自然エネルギーの現状 2016 年度 電力編 (The present situation of renewable energy in Japan with the data, 2016 fiscal year electricity part.) PDF document. Available at: https://www.isep.or.jp/wp/wp-content/uploads/2018/01/REdata20170822Japan.pdf [Accessed 21 January 2020.]

Ishida M. June 2017. バイオマス発電を支える地域の木材と運転ノウハウ (The local wood supports biomass power generation and operation expertise.) PDF format. Available at: https://www.renewable-ei.org/activities/column/img/20170620/column_REapplication02_20170620.pdf [Accessed 7 December 2019.]

Ito Y. August 2015. 再生可能エネルギー支援策の変遷 国内外の制度事例から得る日本の FIT 見直しへの示唆 (Changes of renewable energy support measures, suggestions gaining from domestic and foreign countries for the review of FIT in Japan.) PDF document. Available at: https://eneken.ieej.or.jp/data/6241.pdf [Accessed 1 February 2020].

Iwashita N. No date. 森林のゾーニングから森林所有者登録まで、GIS を活用した効率的な森林管理 (From the zoning of forests to registration of forest owners, effective forest management with GIS.) WWW document. Available at: https://www.esrij.com/industries/case-studies/35984/ [Accessed 26 February 2020].

Japan woody bioenergy association. 2018. Wood biomass energy data book 2018. PDF document. Available at: https://www.jwba.or.jp/データベース/一般公開用データ-目次/木質バイオマスエネルギー-データブック 2018/ [Accessed 8 January 2020].

Japan wood energy Co., Ltd. No date. ボイラー導入時の注意点 (The attentions to the introduction of boilers.) WWW document. Available at: http://www.mori-energy.jp/database/boiler/notice.html [Accessed 17 February 2020].

Kinoshita N. 2019. 日本の林業の現状 (The present situation of Japanese forestry.) WWW document. Available at: https://www.shinrin-ringyou.com/ringyou/ [Accessed 3 February 2020].

Kinoshita N. 2015. 林業就業者数と高齢化 (The number of employed workers in the forestry and aging.) WWW document. Available at: https://www.shinrin-ringyou.com/ringyou/koureika.php [Accessed 4 February 2020].

Kinoshita N. 2009. 割り箸(割箸)とその現状 (Chopsticks and its present situation.) WWW document. Available at: https://www.shinrin-ringyou.com/topics/waribashi.php [Accessed 10 February 2020].

Kinoshita N. 2015. 日本の森林面積と森林室 (Forestry area and the forest rate in Japan.) WWW document. Available at: https://www.shinrin-ringyou.com/forest_japan/menseki_japan.php [Accessed 16 January 2020].

Kumazaki M. October 2013. 鍵を握る木質バイオマスのカスケード利用 (The key cascading use of woody biomass.) WWW document. Available at: https://www.jwba.or.jp/新規ページ-2/熊崎-実レポート-目次１/カスケード利用/ [Accessed 15 December 2019].

Kumazaki M. March 2016. 国際化の進む木質ペレット市場と取り残される日本 (6・完) これから日本はどうするか (Globalization of woody pellet market and Japan is left behind from it, what Japan will do from now on.) WWW document. Available at: https://www.jwba.or.jp/president/国際化の進む木質ペレット市場と取り残される日本-6-完/ [Accessed 25 February 2020].

Matsumoto K., Kasai J., Saeki T., Takei Y., Suto T. June 2015. Development of Ultra-low NOx Coal Firing M-PM Burner and Successfully Operational Results. Mitsubishi Hitachi Power Systems (MHPS). PDF document. Available at:

https://www.mhps.com/randd/technical-review/pdf/index_09e.pdf [Accessed 14 February 2020].

Ministry of Agriculture and Forestry of Finland. No date. Wood fuels in energy generation in Finland. WWW document. Available at: https://mmm.fi/en/en/forests/use-of-wood/wood-based-energy [Accessed 2 February 2020].

Ministry of the Environment. August 1971. 大気汚染防止法の「ばい煙量等の測定」について (About “the measurement of dusts” mentioned in air pollution control law.) PDF format. Available at: https://www.env.go.jp/air/info/pp_kentou/pem02/mat01_2.pdf [Accessed 2 December 2019].

Ministry of the Environment. March 2019. 大気汚染状況について (About the condition of air pollution in 2017 fiscal year.) WWW document. Available at: https://www.env.go.jp/press/106609.html [Accessed 17 February 2020].

Ministry of the Environment. April 2012. ばいじん規制 (Dust restriction.) WWW document. Available at: https://www.env.go.jp/air/osen/law/t-kise-2.html [Accessed 17 February 2020].

Ministry of the Environment. April 2012. 硫黄酸化物(SOx)規制 (SOx restriction.) WWW document. Available at: https://www.env.go.jp/air/osen/law/t-kise-1.html [Accessed 17 February 2020].

Ministry of the Environment. April 2012. 工場及び事業場から排出される大気汚染物質に対する規制方式とその概要 (The restriction method for the air pollution substances emitted from industries and offices and its summary.) WWW document. Available at: https://www.env.go.jp/air/osen/law/t-kisei1.html [Accessed 17 February 2020].

Ministry of the Environment. September 2019. 大気汚染物質排出量総合調査 (The total research on air pollution emission.) PDF document. Available at: http://www.env.go.jp/air/h30-1.pdf [Accessed 7 January 2020].

Ministry of the Environment. April 1998. Regulatory measures against air pollutants emitted from factories and business sites and the outline of regulation – emission standards for soot and dust, and NOx. WWW document. Available at : http://www.env.go.jp/en/air/aq/air/air4_table.html [Accessed 2 December 2019].

Mori, H. 2019. 木質バイオマスエネルギー利用の現場から (The possibility of forest biomass use and the recent trend.) Conference in 13, Ikenouchicho, Fukakusa, Fushimi-ku, Kyoto city. 24 August 2019. Handout.

Nakano K. 最近のあれこれ (Current news.) 2019. #305 Takakura Bldg. Takakura-dori, Shijo-agaru, Nakagyo-ku, Kyoto. 9 July 2019. PowerPoint.

National Geographic. January 2020. Effect of global warming. WWW document. Available at: https://www.nationalgeographic.com/environment/global-warming/global-warming-effects/ [Accessed 15 January 2020].

National Institute for Environmental Studies. April 2019. コージェネレーション (Cogeneration.) WWW document. Available at: http://tenbou.nies.go.jp/science/description/detail.php?id=8 [Accessed 11 February 2020].

New Energy and Industrial Technology Development Organization. March 2018. バイオマスエネルギー地域自立システムの導入要件・技術指針 (The introduction requirements and technology guides of biomass energy local independent system.) PDF document. Available at: https://www.nedo.go.jp/content/100888133.pdf [Accessed 3 February 2020].

New Energy and Industrial Technology Development Organization, Bamboo Energy Corporation. August 2019. 国内初の竹を有効利用した ORC 熱電併給設備

が完成、実証開始へ (The first completion of the ORC co-generation system which utilizes bamboo, demonstration starts.) PDF document. Available at: http://bamboo-f.com/wp/wp-content/uploads/2019/08/20190829_news.pdf [Accessed 14 February 2020].

Ohno A. November 2014. 森林面積の長期的変遷 (The long-term changes of forest area.) PDF document. Available at: http://www.lij.jp/news/research_memo/20141128_3.pdf [Accessed 16 January 2020].

Ouchi, S. 1987. 拡大造林政策の歴史的展開過程 (The historical development process of Afforestation Policy.) PDF document. Available at: https://www.jstage.jst.go.jp/article/jfe/1987/111/1987_KJ00005719203/_pdf/-char/ja [Accessed 20 January 2020].

Renewable energy institute. November 2019. 自然エネルギーの発電量の推移 (The change of generated renewable energy production rate in Japan.) WWW document. Available at: https://www.renewable-ei.org/statistics/energy/?cat=electricity [Accessed 2 February 2020].

Sakamoto T., Ozeki K. Biomass business department. Email 26 January 2020. Meiken Lamwood Corp.

Sawa I. June 2019. バイオマス発電の主力電源化に向けて Asia Biomass Community の構築 (Bioenergy towards main power source, The construction of Asia Biomass Community.) PDF document. Available at: http://need.co.jp/wp/wp-content/themes/need-2017/assets/pdf/doc-20190619.pdf [Accessed 1 May 2020].

Säilä A., Hagström C. March 2017. The world's leading forest cluster 2030. PDF document. Available at: https://www.metsateollisuus.fi/uploads/2017/03/30041804/890.pdf [Accessed 3 May 2020].

Shimokawa town hall. 2020. 森林バイオマスエネルギーについて (About forest biomass energy.) WWW document. Updated 25 February 2020. Available at: https://www.town.shimokawa.hokkaido.jp/section/2020/01/post-92.html [Accessed 1 May 2020].

Shiwa town. March 2012. 紫波町バイオマス活用推進計画 (The biomass utilization promotion in Shiwa town.) PDF format. Available at: https://www.maff.go.jp/j/shokusan/biomass/b_kihonho/local/pdf/siwa.pdf [Accessed 1 May 2020].

Singh R.L., Singh P.K. October 2016. Global environmental problems. WWW document. Available at: https://link.springer.com/chapter/10.1007/978-981-10-1866-4_2 [Accessed 1 February 2020].

化石からの脱却。自然エネルギーがもたらす地域社会の未来を考える (Getting out of fossil fuel, consider what renewable energy brings to local society in the future.) 2019. Somewrite. WWW document. Updated 20 February 2019. Available at: https://miraimedia.asahi.com/renewable_energyinstitute/ [Accessed 5 February 2020].

The European parliament and the council of the council. November 2015. Directive (EU) 2015/2193 of the European parliament and of the council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants. WWW document. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L2193 [Accessed 2 December 2019].

The Institute of Energy Economics, Japan. July 2016. 日本：国内で石炭と木質バイオマスの混焼発電の導入が拡大 (Introduction of co-firing system with coal and woody biomass is increasing in Japan.) PDF document. Available at: https://eneken.ieej.or.jp/data/6823.pdf [Accessed 27 January 2020].

The Japan times. December 2019. As forestry work gets easier in graying Japan, young hires opt for paths less taken. WWW document. Available at: https://www.japantimes.co.jp/news/2019/12/01/business/forestry-work-graying-japan-young-hires/#.XjnlhS2KVQI [Accessed 04 February 2020].

The sankei news. December 2019. 大嘗祭木材、バイオマス発電に再利用 (The wood of Daijokyu will be reused as bioenergy.) WWW document. Available at: https://www.sankei.com/life/news/191209/lif1912090032-n1.html [Accessed 3 February 2020.]

Tokyo environmental measurement center. No date. 大気ばい煙測定・分析 4 (Dust measurement and analysis in the air, 4.) WWW document. Available at: https://www.toukansoku.co.jp/products/taiki-baienn4.html [Accessed 16 February 2020].

Tomita. S., Hayazaki. M. 2019. 日欧米の大気環境基準比較と濃度実態 (Comparison of the air quality standards criteria and the actual conditions of concentrations in Japan, Europe, and America.) PDF document. Available at: http://www.nikkoken.or.jp/pdf/publication/2019j/2019j-036.pdf [Accessed 21 January 2020].

Toyota Y. 2019. Chief Researcher. Interview 26 December 2019. Kiko Network Kyoto.

United Nations Climate Change. 2015. The Paris Agreement. PDF document. Available at: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf [Accessed 17 January 2020].

U.S. Energy Information Administration. June 2019. Renewable energy explained. WWW document. Available at: https://www.eia.gov/energyexplained/renewable-sources/ [Accessed 17 January 2020].

Yamazaki M., Suzuki Y., Watanabe N. March 2019. 林業事業体における GIS の導入と活用について (About the introduction and utilization of GIS in forestry business body.) WWW document. Available at: https://www.jstage.jst.go.jp/article/jfsc/130/0/130_413/_article/-char/ja/ [Accessed 26 February 2020].

APPENDICES

Appendix 1

The allowed amount of Dust and NOx emission by facility type

Type	Specification	Type	Dust Scale	Dust General	Dust Special	NOx Scale	NOx Standard
Boiler*[1]	Heating area*[2]: 10 m^2 or above.	Gas boiler*[4]	40000 m^3 ~	0.05 g	0.03 g	500000 m^3 ~	60 ppm
	Burner combustion rate: 50 L/h*[3] or above					40000 ~ 500000 m^3	100 ppm
			~ 40000 m^3	0.10 g	0.05 g	10000 ~ 40000 m^3	130 ppm
						~ 10000 m^3	150 ppm
		Liquid boiler or gas and liquid boiler*[4]	200000 m^3 ~	0.05 g	0.04 g	500000 m^3 ~	130 ppm
			40000 ~ 200000 m^3	0.15 g	0.05 g	10000 ~ 500000 m^3	150 ppm
			10000 ~ 40000 m^3	0.25 g	0.15 g		
			~ 10000 m^3	0.30 g	0.15 g	~ 10000 m^3	180 ppm
		Black liquor boiler or black liquor fuel boiler*[4]	200000 m^3 ~	0.15 g	0.10 g	500000 m^3 ~	130 ppm
			40000 ~ 200000 m^3	0.25 g	0.15 g	10000 ~ 500000 m^3	150 ppm
			~ 40000 m^3	0.30 g	0.15 g	~ 10000 m^3	180 ppm
		Liquid fuel boiler (heating area is less than 10 m^2)*[4]		0.30 g	0.15 g		260 ppm
		Solid fuel boiler*[4] (others whose heating area is 10 m^2 or above)	40000 m^3 ~	0.30 g	0.15 g	7000000 m^3	200 ppm
						40000 ~ 700000 m^3	250 ppm
			~ 40000 m^3	0.30 g	0.20 g	~ 40000 m^3	300 ppm
		Solid fuel boiler (heating area is less than 10 m^2)*[4]		0.30 g	0.20 g		350 ppm
		Boilers*[4] (others)	40000 m^3 ~	0.30 g	0.15 g	500000 m^3 ~	150 ppm
			~ 40000 m^3	0.30 g	0.20 g	10000 ~ 500000 m^3	150 ppm
						~ 10000 m^3	180 ppm
Gas generating furnace and heating furnace used for generating water gas or oil gas	Raw materials (coal or cokes) consuming capacity: 20 t/day or above.	Gas generating furnace		0.05 g	0.03 g		150 ppm
	Burner combustion rate: 50 L/h*[3] or above.	Heating furnace		0.10 g	0.03 g		

Appendix 2

The comparison of several raw material and reforming with the technology

Items	Units	Base	Moso bamboo		Japanese timber bamboo		Black bamboo		Weeds		Bark		Woody pellet
			raw material	reforming	raw material	reforming	raw material	reforming	raw material	reforming	raw material	reforming	
Total heating value	kJ/kg	air-dried	18500		18000		18400		17400		18000		16000 ~ 19000
Total water	wt%	received	39.2		47.9		34		53.6		40.7		10 >
Ash	wt%	anhydrous	3.7		3.6		3.9		6.7		3.2		3
Cl	wt%	anhydrous	**0.17**	0.01	**0.19**	0.02	**0.15**	0.02	**0.31**	0.04	0.02	< 0.01	0.03 ≧
K	wt%	anhydrous	0.8	0.23	1.27	0,25	0.54	0.18	0.87	0.32	0.16	0.10	
The initial deformation temperature of ash	℃		**800**	1400	**760**	1270	**920**	1400	**1030**	1160	**1100**	1140	1100 ≦
The melting point of ash	℃		850	1400	820	1400	1040	1400	1190	1210	1200	1310	