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Biomass energy in Japan: Current status and future potential

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Abstract

The Fukushima accident has pushed Japan to further develop its renewables initiative, particularly the biomass energy commodity. Their projection for the 2030 energy mix includes a biomass share of 4%. Further, a policy was introduced in 2002 called the Biomass Nippon Strategy. This was revised in 2006, fortifying the creation of Biomass Towns. Another major step forward came in 2009 with the Basic Act for the Promotion of Biomass Utilization. New goals were set with the introduction of the Basic Energy Plan. To meet the target, an agenda for the supply of domestic and imported biomass is needed. Domestic supply, such as wood pellets and agricultural residue has a small future potential. However for import scemes including wood and Palm Kernel Shell (PKS) from Indonesia and Malaysia are currently in place. There are also several future potential sources of biomass as yet untapped. In the future, the supply of biomass energy commodity could be increased to meet the target of 4% of the energy mix including comoddities such as biodiesel from sunflower, Jatropha Curcas as well as EFB (Empty fruit bunch), Sugarcane, Bagasse, Algae, Cotton seed, Coconut oil, Coconut Shell.

Keywords: Biomass; energy; status; future; potential; policy

1. Introduction

Japan is one of the most developed Asian countries with the largest economy after the USA and China in gross domestic product (GDP) which is seriously shifting their energy mix to incorporate renewable energy sources (RES). Japan has a large electricity market with a total installed power plant capacity of 293 GW, including 44 GW of nuclear power, the third highest in the world. Nuclear power plants had a big share of this installed capacity before the Fukushima incident, approximately 29%. However, it reduced drastically. Currently, most nuclear plants are shut down due to safety concerns. Consequently, the import of energy commodities especially fossil fuels such as crude oil, gas and natural gas (LNG) to ensure sufficient supply, have been increased. Japan is the largest importer of LNG, the second biggest importer of coal, and third biggest crude oil importer. Crude oil is the biggest import of Japan, comprising 23.3% of all imports [1].

To reduce carbon dioxide emissions and the dependency on fossil fuels, Japan has begiun expanding renewable energy sources to meet energy mix policy goals for 2030. One of these renewable energy sources is biomass. It is hoped that biomass can be introduced to reduce the consumption of fossil fuels. With 5th largest biomass market in the world, the government aims to double biomass generation to 32.8 TWh by 2030 [2]. According to the proposed 2030 energy mix, Japan will generate 4% from biomass energy. This paper discusses the status and future potential of biomass in Japan. This paper also includes an assessment of domestic biomass potential and necessary imports to ensure the biomass supply for

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power plants.

2. Biomass Resources and Policies

Japan's biomass resource policy was set in 2002 with the Biomass Nippon Strategy. This was a basic national strategy to realize a sustainable society by promoting full biomass utilization. A small-scale experiment in comprehensive biomass utilization came with the construction of the first Biomass Town in 2004. In this town, various area stakeholders cooperated to link each step from biomass generation, conversion, and distribution in a stable and appropriate way for the community. In 2005, the Kyoto Protocol Target Achievement Plan added special promotion of biofuels, including fuel for transportation, with a goal of 500,000 kL by 2010. Japan continued building Biomass Towns and developing energy conversion technologies. The Biomass Nippon Strategy was revised in 2006, fortifying the creation of Biomass Towns with a goal of 300 established by 2010, and refining aims to use biomass energy in ways including transportation.

Another major step forward came in 2009 with the Basic Act for the Promotion of Biomass Utilization. This aimed for comprehensive and planned promotion of biomass use for energy. As part of the act, a National Plan for the Promotion of Biomass Utilization was drawn up, and the National Biomass Policy Council was established. By February of 2010, the goals of the Biomass Nippon Strategy were nearly met with 286 municipalities nominated as Biomass Towns of Japan [3]. New goals were set with the Basic Energy Plan. Renewable energy would be increased to 10% of the primary energy supply by 2020. For transportation, biofuel would be increased at a volume equivalent to 3% of the gasoline demand nationwide by 2020. In the same year, the Act Concerning Sophisticated Methods of Energy Supply Structure required oil refiners to produce a certain amount of biofuel. In FY2011, that amount would be 210,000 kiloliters, and by FY2017 it would increase to 500,000 kL.

3. Production of Domestic Biomass Residue

Besides wood pellet production from forests, a potential source of biomass for renewable fuels comes from agricultural crop residue. One of the concerns around biofuels is that growing them will conflict with nutritional needs by diverting food supplies. However, making use of biomass that is the non-edible portion of food crops allows for the cultivation of a domestic fuel supply alongside food production. For Japan, making use of crop residue for biofuels may be an efficient use of already available materials as a source of energy.

In particular, crops with a high residual ratio produce a high amount of biomass relative to the food content which is their main product. Barley, for example, has a residual ratio of about 2.5, and while its production in 2015 was 176,900 tons, it also left 442,250 tons of biomass such as straw as shown in Table 1. Wheat has an even higher residual ratio of 2.53, so that food production of 996,200 tons in 2015 was accompanied by residue production of 2,520,386 tons. Meanwhile rice, while its residual ratio is smaller at 1.43, is produced in vast amounts in Japan, so that food production of 7,989,000 tons is accompanied by residue production of 11,424,270 tons that could potential be harnessed for energy generation. Potatoes also have a lower residual ratio of 1.14, but a production of 2,354,000 tons ensures a residue production of 2,683,560 tons. Other crops, such as sugarcane, have relatively high production (1,159,000 tons in 2014) but a low residual ratio (0.52) so that residue production is considerable only because of bulk (in the case of sugarcane, 2014 residue production was 602,680 tons). There are also crops like soybeans, which have a high residual ratio of 2.14 tons but low production in Japan (231,700 tons in 2014) means that the resulting residue production is just 495,838 tons. The additional use of residue for energy production may increase demand for higher residual ratio crops, however, in several cases the crops favored in Japan for food production are not the most efficient for biomass production and vice-versa.

Overall, agricultural residue can produce some energy from domestic sources, but likely only a small amount of what the country actually needs. Imports represent another approach to fulfilling overall biomass needs.

Table 1. Biomass residue production in Japan [1], [4]

Crop	Production (A) (t year)	Year	Residual ratio (B)	Residue production (A)*(B) (t year)
Rice	7,989,000	2015	1.43	11,424,270
Wheat	996,200	2015	2.53	2,520,386
Barley	176,900	2015	2.5	442,250
Soybean	231,700	2014	2.14	495,838
Sugarcane	1,159,000	2014	0.52	602,680
Sweet potato	814,200	2015	1.14	928,188
Potato	2,354,000	2015	1.14	2,683,560

4. Imported Biomass Commodities

As shown in Fig. 1. Japan's agricultural imports were nearly $60 billion in 2013, making Japan the world's fourth-largest importer, after the United States, China, and the European Union (EU) [5]. Imported commodities include oilseed and associated products at 600 billion yen in 2013, down from a high of about 700 billion in 2008.This goes against the general trend, and the impact of the global financial crisis is clear. The sharpest drop came in 2009, to a low of less than 500 billion yen. Overall, the trend has shown significant growth in imports over the past twenty years. The comparative popularity of these commodities has not changed significantly.

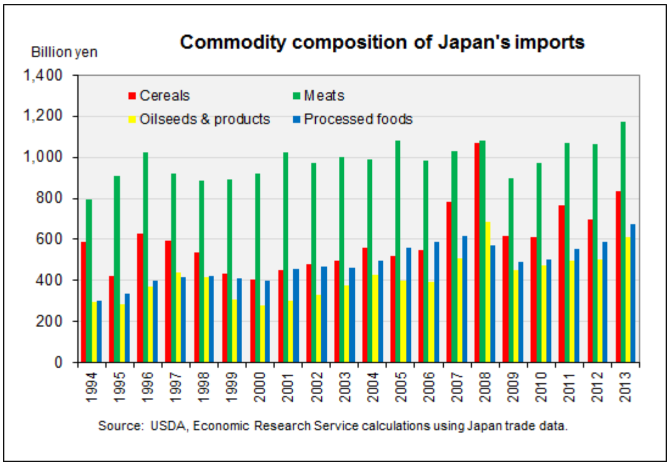

Fig. 1. Composition of Japan’s commodity imports [5].

For most of the past two decades, the United States has consistently supplied a majority of Japan’s agricultural imports as shown in Fig. 2. However, this percentage has dropped steadily from 35% in 1994 to less than 25% in 2013. In 2012, United States-based imports were overtaken by imports from countries from the rest of the world (ROW), which now supply the greatest share; approximately 30% of Japan’s imports. Overall, the ROW share of Japanese imports has increased steadily from 25% in 1994. Other significant importers include Australia, China, the ASEAN-10 states, and the EU28. Imports from ASEAN (the Association of Southeast Asian Nations, which include Brunei, Burma, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam) have grown steadily from 10% of total imports in 1994 to a peak of about 18% in 2011, and a level of about 15% in 2013.

Australia’s share has always been on the low end, dropping from 10% in 1994 to about 7% in 2013.

Starting at 10%, China's share steadily increased with only a minor drop to around 12.5% in 2003. Until 2008 China's share dropped so steeply, such that all the growth it had seen since 1994 was cancelled out. It has since grown irregularly to a share of 13-14%. In 2008, the drop in imports from China and Australia were made up for by increased imports from the US, which supplied about 32% of Japanese agricultural imports (reversing a drop to 25% in 2006) and from ASEAN countries (which provided 15% of imports in 2008 and 2009, then continued growing to their 2011 peak).

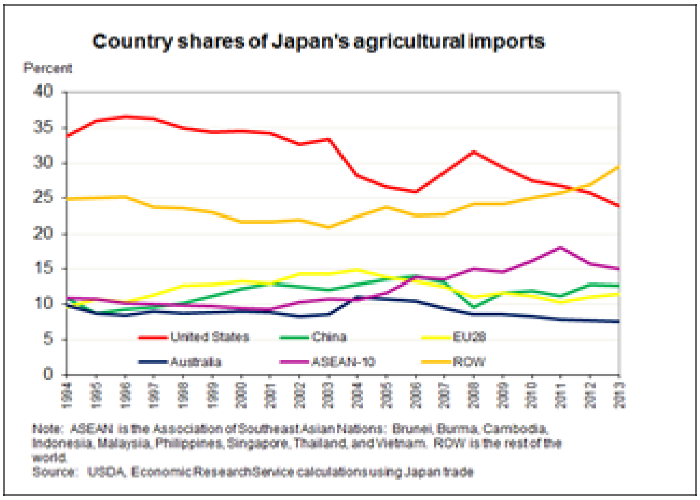

Fig. 2. Country shares of Japan's agricultural imports [5].

One of the biomass commodities for energy production is the palm kernel shell (PKS) which is imported from Indonesia and Malaysia as shown in Fig. 3. It's import has grown rapidly from 2009 to 2015. In 2012, Japan received just 26,000 tons of PKS through imports, however, this amount nearly quintupled in 2013, when 131,000 tons were imported. In 2012 PKS cost approximately 9,200 yen per ton to import, including the raw material cost, shipping expenses, and insurance premiums. The vast growth in imports saw a rise in price to 11,791 yen per ton in 2013. Thus, Japan spent 239,200,000 yen on PKS imports in 2012 and 1,544,621,000 yen in 2013 - a 6.45 time increase.

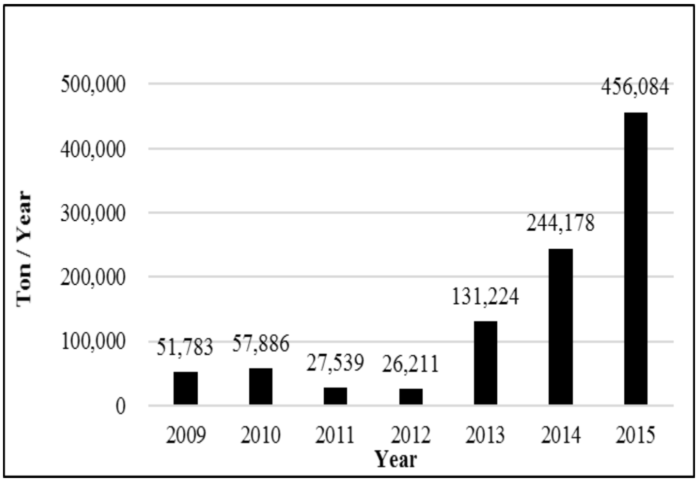

Fig. 3. Import of palm kernel shelll [6].

Japan also imports wood pellets alongside domestic production, as shown in Fig. 4. The data for production is taken from the Ministry of Agriculture, Forestry and Fisheries over the period 2009 – 2015. The import data is taken from Trade Statistics of Japan's Ministry of Finance between 2003 and 2013. In

2003, only 3,800 tons of pellets were produced domestically. This almost doubled to 6,018 tons in 2004. The sharpest increase was yet to come, and in 2005, Japan's domestic production of wood pellets was 21,538 tons, or 358% that of the previous year. By 2006 it had increased to 24,901 tons and in 2007, the supply climbed again to 29,920 tons.

In 2009, 50,693 tons of wood pellets were produced domestically and 59,143 tons were imported. In 2010, domestic production was up to 58,243 tons, and jumped again by nearly a third for 78,259 tons produced in 2011. By 2012 domestic production alone was nearly equal to the total supply in 2009, with 98,184 tons of wood pellets produced from Japanese sources. In 2013, domestic production of wood pellets in Japan had grown to 110,092 tons per annum. Between 2009 and 2014 there was no big difference in the imported amount of wood pellets. However in 2015, the total import level jumped to 232,425 tons. This showed that the need for wood pellets had increased drastically to meet the needs of power plants in the future.

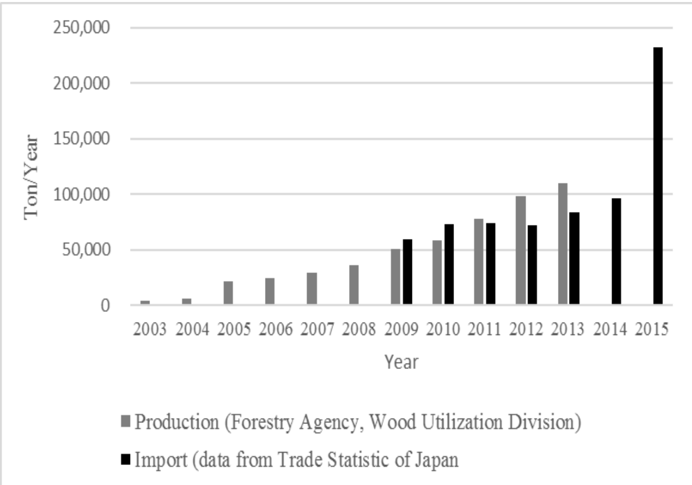

Fig. 4. Production and import of wood pellet in Japan [6].

5. Potential of Biomass Energy Crops

Recognizing the geographic situation of Japan and their need for biomass for future power generation, Table 2 shows the potential of biomass crops that can be imported as well as those that can be developed domestically. It begins with biodiesel production from sun flower as an edible biomass crop. The crop seeds contain 22-36% oil and this oil does not require significant refining. Sunflower oil can be imported from countries throughout the Commonwealth of Independent States (CIS), and this crop has an annual yield of 200 L/Ha and an oil price of $16.48/CWT. Jatropha Curcas is a flowering plant whose oil can also be used as a biofuel. It is a non-edible crop and it is easy to grow as it is resistant to drought. It requires a comparatively low amount of water and can survive in extremely harsh environments [7]–[11]. It has an annual yield 1.75 tons/Ha. Japan could import Jatropha Curcas from countries including India, China, Indonesia, Thailand, Vietnam, and Nicaragua.

The widespread utility of palm oil is increasing its demand. Such high demand is leading to the deforestation of some parts of Indonesia and Malaysia. Palm oil, used for biodiesel fetches a price of around $590 US per ton. It has a low production cost of around $0.37/L and its annual yield is 4,374-7000 L/Ha. Palm kernel shell (PKS) is much cheaper at $70-$90 per ton and can be used as a solid fuel. About 1100 Kg of PKS can be produced per hectare. A third palm product, the empty fruit bunch (EFB), is also used as a solid fuel with a yield of 4,400 kg per hectare [12].

Sugar cane is used for the formation of molasses and sugar. The sugar from sugar cane can be used for the production of ethanol (first generation ethanol) and by-products of sugar cane, bagasse can be used as solid fuel in a boiler. Sugarcane is imported from India and Brazil. Its production cost is less than wheat at $0.60 US per liter and its annual yield has the potential to be higher, between 6,800-8,000 L/Ha.

Table 2. The potential of energy crops that can be imported japan

No	Biofuel crop	advantages and disadvantages	Price	Large plantation countries	Annual Yield L/Ha	Production cost (US$/liter)	Fuel	World production (million tons)
1	Sun flower oil	Edible oil	16.48$/CWT	CIS	679 [13]	0.93 - 1.30 [14]	Biodiesel	14.8
2	Jatropha	Can be grown in marginal soils [7]–[11]		India Brazil	1.75 ton/Ha [15]	0.376 - - 0.85 [12], [16]	Biodiesel	
3	Palm Oil	Edible oil	590 US$/ton	Indonesia, Malaysia	4374 - 7000	0.37	Biodiesel	53.67
4	PKS (Palm Kernel Shell)	HHV 20.7 MJ/kg [17]	$70- $90/ ton		1100 Kg		Solid	
5	EFB (Empty fruit bunch)	HHV 16.96 MJ/kg	-		4400 [12]		Solid	
6	Sugarcane	HHV oil 34.91 MJ/kg [18]		India, brazil	6800 - 8000	0.6 [19]	Ethanol	
7	Bagasse	Heating value 17.7 MJ/kg [17]					Solid fuel	
8	Algae	Grows faster [20], [21] High yield ratio [20] Absorbs CO_2 [22] Does not compete with agricultural products [23], [24] Waste water [25], [26]			58,700 – 136,900 [27]	0.27 [21]		
9	Cotton seed	Edible oil		USA, Uzbekistan, Argentina, Kazakhstan	325 [28]			5.09
10	Coconut oil	Edible oil		Philippine, Indonesia, India	500 kg	0.3 - 0.7 [29]	Biodiesel	2.99 [30]
11	Coconut Shell	Heating value 20.5 MJ/kg [17]					Solid fuel	62.45 [31]

As a biofuel crop, algae have many benefits. It grows naturally in the water and at a faster rate than other than other conventional biofuels like corn, sunflower, and soybean [20], [21]. It also has a high yield ratio [20]. While growing, algae absorb CO2 from the atmosphere [22]. It is produced domestically in Japan, with a considerable annual yield of 58,700-136,900 L/Ha [27]. Algae do not compete with agricultural products [23] and can be grown in wastewater [25], [26]. Unused domestic land can also be used for their growth the production cost is very low at $0.27 US/liter [21]. These characteristics of algae make it a desirable source of biomass energy. All of these sources of biofuel can help Japan to achieve its target of biomass energy generation while keeping the cost of electricity low and preserving the environment.

6. Conclusion

Due environmental degradation caused by fossil fuels and the nuclear disaster at Fukushima, Japan plans to introduce more renewable energy sources by 2030 including biomass energy for some 4% of their planned energy mix, in an attempt to phase out fossil fuels. The journey towards biomass usage began in 2002 with the Biomass Nippon Strategy. The journey continued with the Kyoto Protocol in 2005, then by 2009 the Basic Act for the Promotion of Biomass Utilization was introduced. The Great Eastern Japan Earthquake and the Fukushima accident in 2011 pushed forward Japan's strategy with greater urgency and in 2012, the Biomass Industrialization Strategy was put into place for the purpose of setting forth policies to boost and fortify green industries.

There is significant potential for biomass usage in Japan in the future, especially with the considerable amount of waste wood. However, the current energy policies need to be examined before biomass is implemented on a larger scale to incorporate proper infrastructure, and to assess the support given by the government. In addition, stakeholder engagement and support from citizens is also likely to push forward the biomass initiative. The energy mix proposed for 2030 shows the vision for renewables in Japan, where the current percentage of 10% would be raised to 24%, of which biomass will play a role of approximately 4% of the generation mix. The goal for biomass is ambitious, meaning that Japan will need to generate 32.8 TWh from biofuel alone. Ultimately, the anticipated generation mix will significantly reduce CO_2 emissions.

Crop potential for biomass usage in Japan is limited, despite its square mileage, owing to the disparity of climate between northern and southern Japan. Thus, many crops will likely need to be imported, although sunflower shows potential as an edible crop which does not require significant additional refining. It can be developed domestically and imported. Jatropha Curcas, a non-edible plant, has great potential for development and usage, owing to its ability to thrive in harsh environments. In the case of Japan, it is expected that this crop will be a target for import only. There are many crop options from around the world for Japan to consider.

There are currently several challenges for the development of biomass energy use in Japan. Energy security is the topmost concern, and one particular roadblock to the immediate use of biomass energy is the presence of nuclear power. While nuclear power is experiencing strong opposition from the public, it is still a necessary generation source to fulfill Japan's energy and economic needs. Japan has limited domestic natural resources for biomass energy, meaning that an import scheme must continue to be pursued and implemented.

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