Chapter

Current Situation and Future Outlook of Forest Biomass Production and Its Utilization in Japan

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Abstract

The current situation of forests and forestry as well as woody biomass utilization in Japan was described, and the future outlook for the use of forest biomass in Japan was presented. Many planted forests are now becoming mature, so the operational efficiency in forestry should be improved not only by the development of the forest infrastructure but also by the full mechanization of the logging system. The Kyoto Protocol adopted in 1997 promoted the energy utilization of waste woody biomass such as mill residues and wood-based waste materials, and the launch of the Feed-in Tariff scheme for renewable energy (FIT) in 2012 promoted the energy utilization of once-unutilized thinnings. In order to further expand the production of forest biomass and its utilization for energy, logging residues, small-sized trees, and short rotation woody coppices (SRWC) are promising. Thus, low-cost harvesting technologies should be developed as soon as possible, with reference to machines and systems operating in foreign countries where the utilization of such forest biomass is making steady progress.

Keywords: Forest Utilization, forest and forestry, woody bioenergy utilization, forest biomass harvesting, Japan

1. Introduction

The discipline of "Forest Utilization" in Japan was introduced with reference to the German "Forstbenutzung" at the end of the nineteenth century. The Forstbenutzung covers not only the processes of felling, processing, yarding/skidding, and transporting trees but also wood anatomy, wood physics, wood processing, and wood craft; therefore, it can be said that the Forstbenutzung pursues the rational utilization of forests and trees. In the case of Japan, the research subjects of wood anatomy, wood physics, wood processing, and wood craft went independent as the Wood Science after World War II; thus, the Forest Utilization has progressed to cover the fields of civil engineering, machine engineering, operational efficiency, and ergonomics in forestry. From this point of view, the current Japanese Forest Utilization is similar to the Forest Engineering developed in North America and the Forest Operations developed in Europe.

Research and development (R&D) in the Forest Utilization is very important to make the Japanese forestry economically viable. Now, the stumpage price, i.e., the price of standing trees per m^3, Q' (USD/m^3), is expressed as:

$$Q' = (P - Q) \times \frac{n}{100} \quad (1)$$

where P (USD/m^3) is the market price of roundwood, Q (USD/m^3) is the logging cost, and n (%) is the utilization percentage to standing tree volume. Q' contains the costs of reforestation and tending; thus, the forestry itself cannot be economically justified when Q' is cheaper than a certain level. Then, Q is expressed as a function of yarding/skidding distance, x (m):

$$Q = a + b \times x + c \quad (2)$$

where a (USD/m^3) is the cost of felling and processing trees, b ($USD/m^3/m$) is the yarding/skidding cost per unit length of yarding/skidding distance, and c (USD/m^3) is the overhead cost. In order to increase the income of forest owners, Q' of Eq. (1) must be increased, that is, Q of Eq. (2) must be reduced; therefore, a and b of Eq. (2) must be diminished by developing efficient forestry machines as well as by improving logging methods, and x of Eq. (2) must be shortened by developing forest road networks. Improving the utilization percentage, n of Eq. (1), is also effective. Utilization of residual forest biomass such as logging residues, that is, tree tops and branches that are generated during limbing and bucking, and small-sized trees that are felled at pre-commercial stages can raise the utilization percentage, leading to increase in the income of forest owners.

In this chapter, with the aim of showing the R&D of forest biomass production and its utilization within the framework of the Japanese Forest Utilization, the current situation of forests and forestry as well as woody biomass utilization in Japan is described, and the future outlook for the use of forest biomass in Japan is presented.

2. Current situation of forests and forestry in Japan

The current total forest area in Japan is about 25 million ha. As shown in **Table 1**, in densely populated countries such as the USA, Canada, and Germany,

Region	Country	Land area [A]	Forest area [B]	B/A	Population
		(x 1,000 ha)	(x 1,000 ha)	(%)	(x 1,000)
Asia	Japan	36,450	24,958	68.5	126,573
North America	USA	916,192	310,095	33.8	321,774
	Canada	909,351	347,069	38.2	35,940
Central Europe	Germany	34,861	11,419	32.8	80,689
	Austria	8,244	3,869	46.9	8,545
Northern Europe	Sweden	41,034	28,073	68.4	9,779
	Finland	30,390	22,218	73.1	5,503

Table 1.
Comparison of land area, forest area, and population.

slightly more than 30% of national land area is covered with forest [1]. Japan has a population size similar to the abovementioned countries; however, forest occupies almost two-thirds of the national land, which is the same level as in sparsely populated Sweden and Finland. This can be attributed to the steepness of so much of the land area in Japan.

Figure 1 shows the changes in the breakdown of the Japanese forest area [2]. The total forest area has been constant for more than a half century. Historically, naturally regenerated forests were converted to planted forests. During and after World War II, quite large numbers of trees were felled and harvested, so afforestation was actively promoted from the 1950s to the 1970s in order to compensate. Ten million hectares of man-made planted forests, which equals almost 30% of the total national land area, was established in the 1980s.

On the other hand, after World War II, the more the Japanese economy grew, the worse the profitability of forestry became. Young people left rural areas, and then the self-sufficiency rate of wood decreased continuously. Thus, the incentive for afforestation was gradually diminished. As shown in **Figure 2**, consequently, the current age distribution of planted forest is extremely imbalanced, so that 65% of planted forests that are older than 45 years reach the time for being harvested finally [2].

Figure 3 shows the changes in the growing stock [2]. The growing stock keeps increasing mainly because of the dominance of young planted forests. The current average stem volume per 1 ha of planted forest, 324 m^3/ha, is similar to that of Austrian forests, 325 m^3/ha. This means that an operational efficiency equivalent to that of Austria might be expected if the forest infrastructure was well developed and the logging system was fully mechanized, but in practice, this is very difficult to achieve.

The changes in the wood supply and demand are shown in **Figure 4** [2]. As mentioned previously, the self-sufficiency rate continuously decreased in inverse proportion to the economic growth during the latter half of the twentieth century. The trade in roundwood was completely liberalized in 1964, more than a half

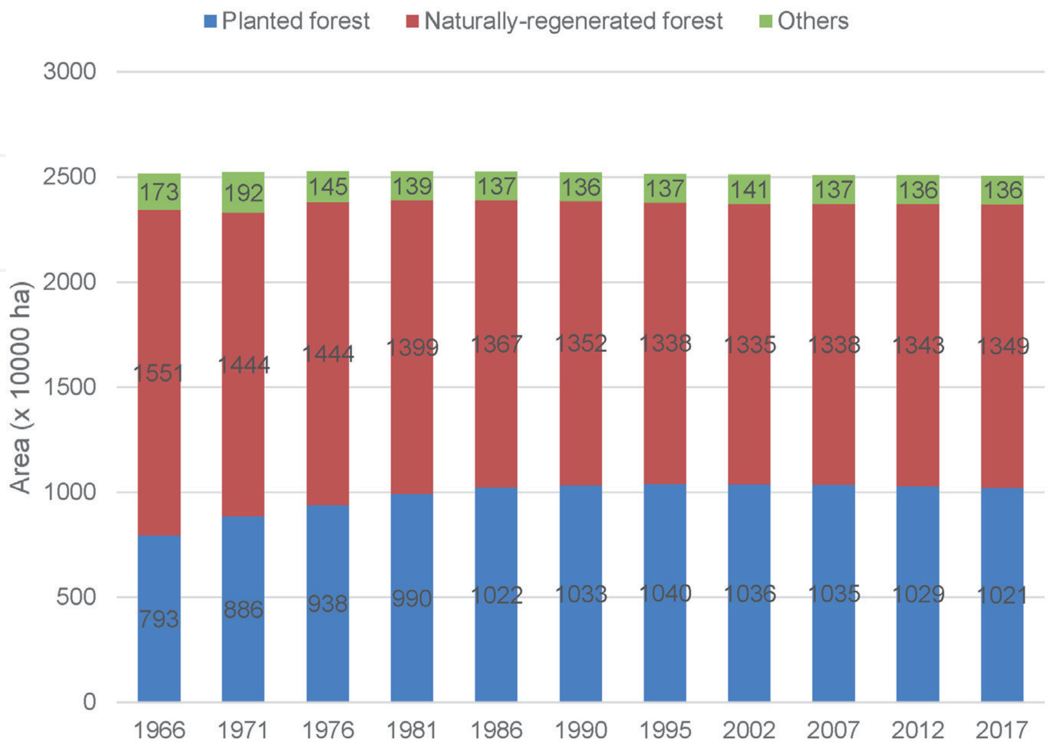


Figure 1.
Changes in the breakdown of the Japanese forest area.

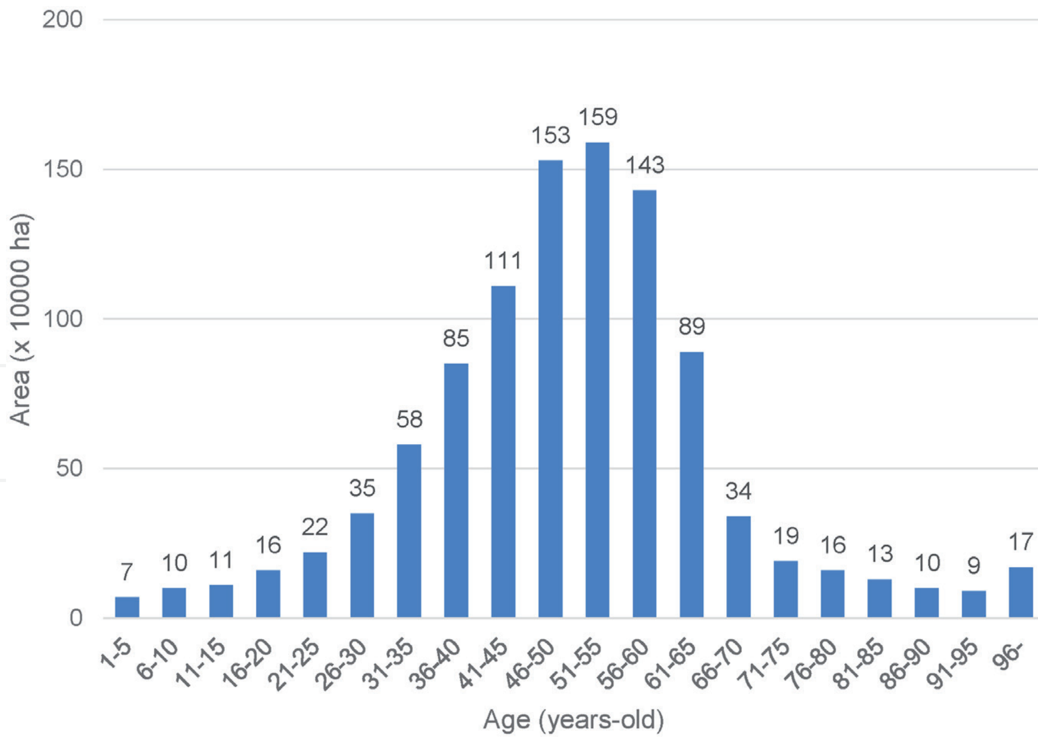


Figure 2.
Age distribution of planted forest (as of March 2017).

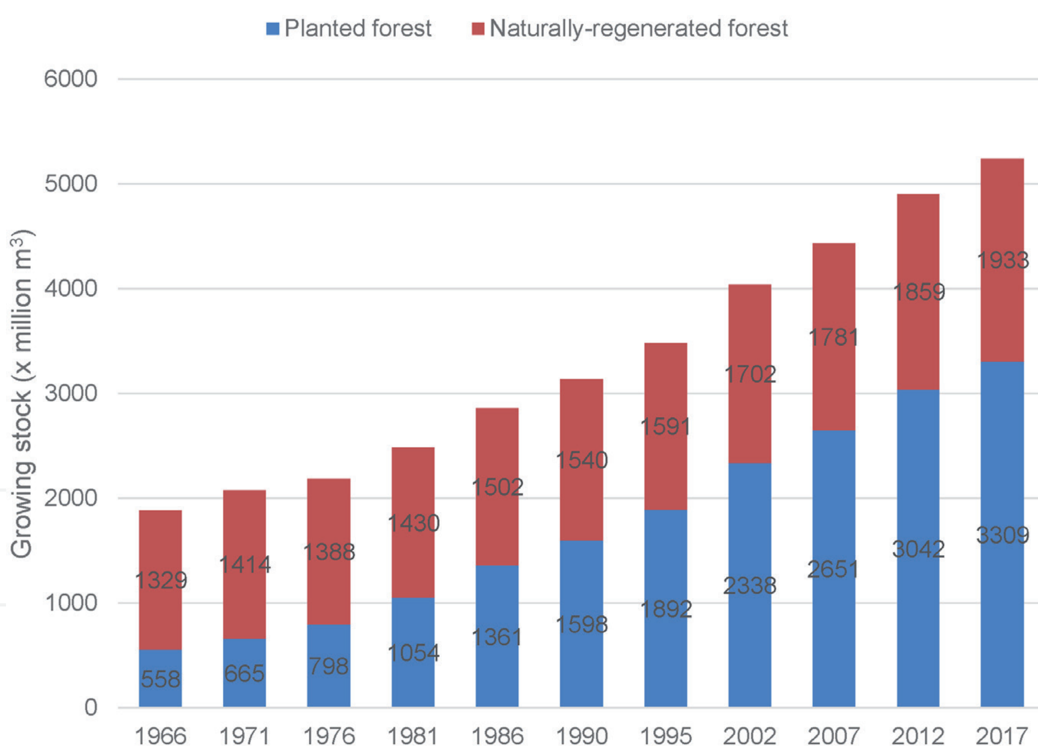


Figure 3.
Changes in the growing stock.

century ago. Since the middle of the 1990s, Japan has been in an economic slump, so the demand for wood is shrinking. On the other hand, planted forests are maturing, and thus, the supply of domestic wood is gradually increasing and the self-sufficiency rate itself is improving, the driving force for which will be explained later.

Figure 5 shows the number of workers that can be employed by 1 m^3 of standing Japanese cedar trees [3]. The number of workers is calculated by dividing the

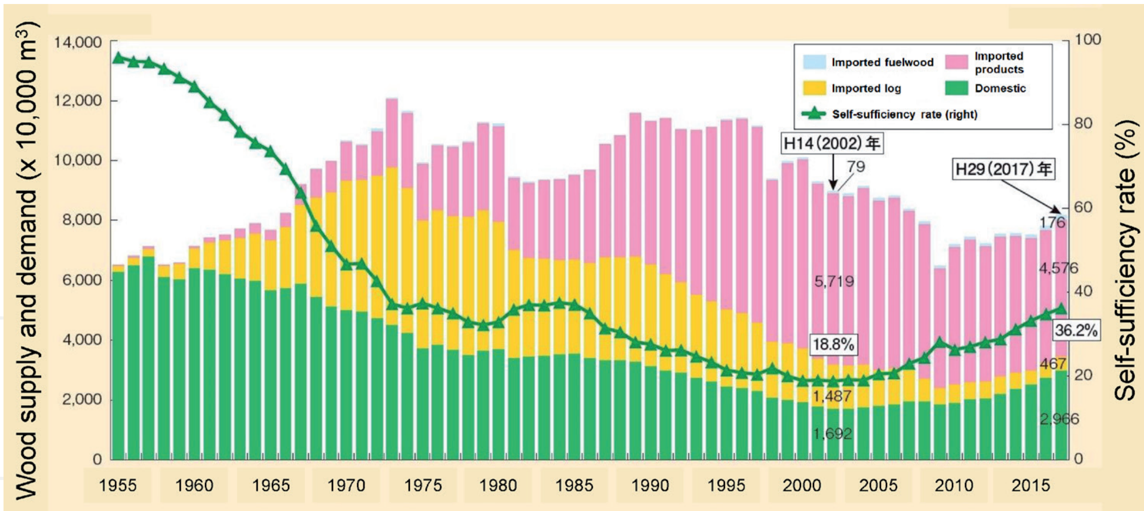


Figure 4.
Changes in the wood supply and demand.

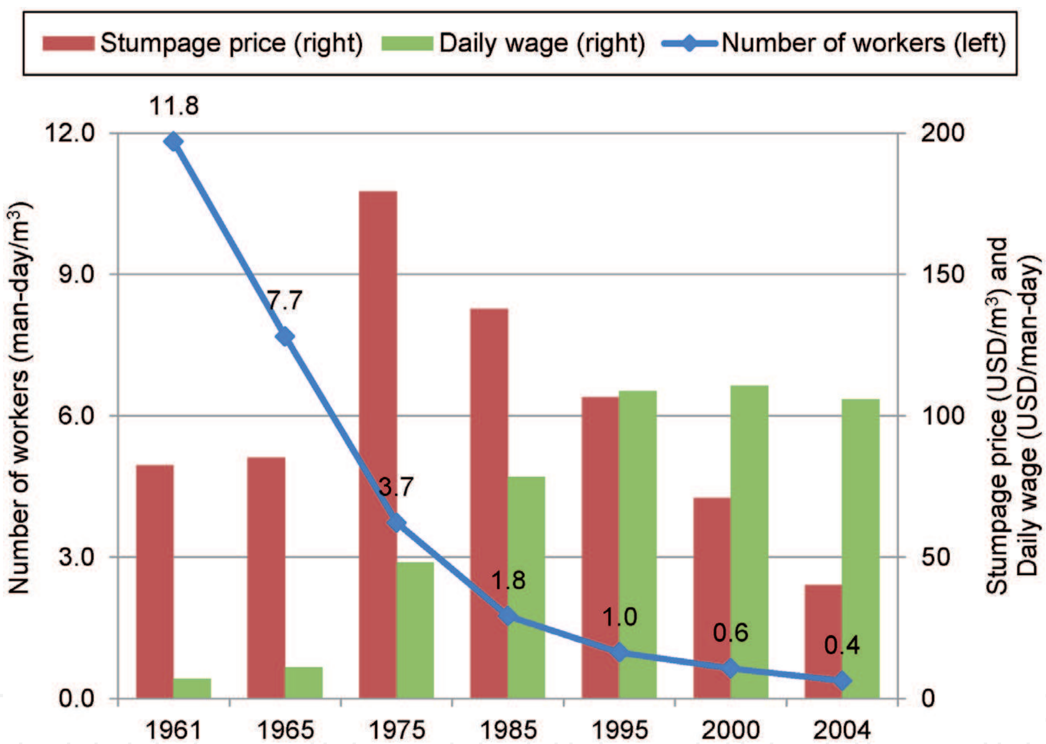


Figure 5.
Number of workers that can be employed by 1 m³ of standing Japanese cedar trees.

stumpage price of standing Japanese cedar trees by the daily wage of a forestry worker. It can be read from the graph that, even in Japan, labor-intensive work was possible during the 1960s.

The changes in the number of forestry workers are shown in **Figure 6** [2]. The number of forestry workers decreased by more than 100,000 in the past 35 years, and the percentage of aged workers (>65 years old) is relatively higher than that in other industries in Japan. On the other hand, forestry is the only industry in Japan in which the percentage of young workers (<35 years old) is increasing. The replacement of manual labor by mechanization in the limbing, bucking, and yarding/forwarding processes, but not in the felling process, seems to be contributing to this.

Figure 7 illustrates a typical mechanized logging system in Japan. The system is similar to that of Austrian mountainous areas. Nearly 10,000 advanced forestry

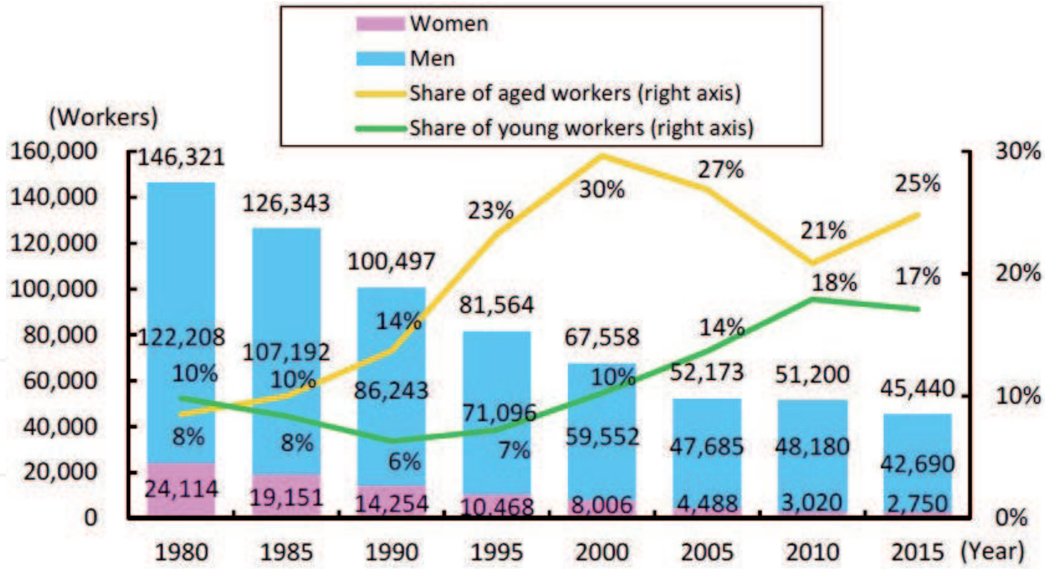


Figure 6.
Changes in the number of forestry workers.

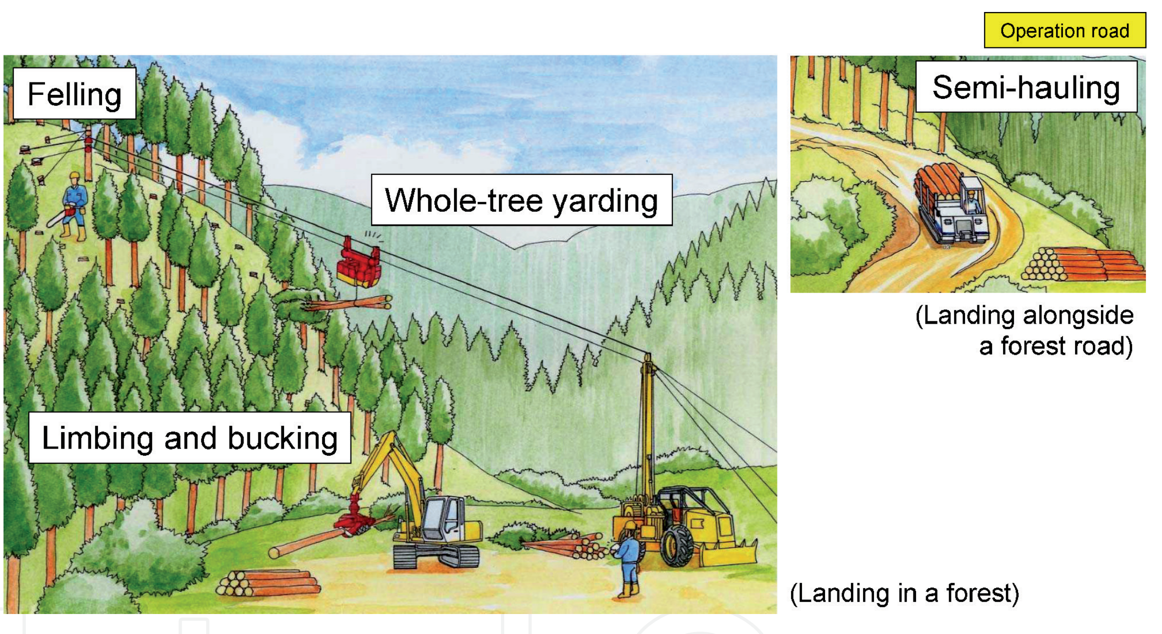


Figure 7.
Typical mechanized logging system in Japan.

machines such as processors, tower yarders, and forwarders have been introduced, and 70% of the logs produced are processed by such forestry machines. However, there are not enough forest roads, so supplemental lower-grade operation roads have been constructed, and a forwarder uses them to haul logs to a forest road.

A comparison of productivity and logging costs is given in **Table 2** [4]. In Japan, the rate of operation of advanced forestry machines remains at a low level, which makes the productivity low and the logging cost high. It is said that, in Austria, intensive investments were made in the development of a forest road network in the 1960s, when the price of wood was relatively higher. Although the price of wood fell and the labor cost rose after that, the productivity was improved by mechanization. The forest road network density in Japan, 19.7 m/ha (13.1 m/ha for forest roads and 6.6 m/ha for operation roads), is less than a quarter of that in Austria, 89 m/ha (45 m/ha for forest roads and 44 m/ha for operation roads). The development of a forest road network is relatively delayed in Japan.

Country	Productivity (m^3/man-day)	Logging cost (USD/m^3)
Japan (final cutting)	4.00	57.7
Japan (thinning)	3.45	84.8
Sweden	30	11.8 (final cutting) 21.8 (thinning)
Austria	7–43	29.1–50.0

Table 2.
Comparison of productivity and logging costs.

3. Woody biomass utilization in Japan

After the Kyoto Protocol was adopted in 1997, renewable and carbon-neutral biomass attracted widespread attention for its potential as an ideal primary energy resource in a sustainable society. In 2001, the Japanese government officially defined biomass as one of the new energy resources in the "Law Concerning Special Measures for Promotion of the Use of New Energy" [5], and the government decided on the "Biomass Nippon Strategy" in 2002 [6]. As mentioned previously, forest resources are abundant in Japan, and thus, the energy utilization of woody biomass is expected to contribute to a revitalization of the forestry and forest products industries, which have long been depressed. The annual available amount of woody biomass resources is estimated to be 31.7 million dry-t/y [7], which has a calorific value of 634 PJ/y, corresponding to 2.8% of the national primary energy supply, 23.0 EJ/y, and woody biomass utilization was expected to promote the tending of planted forests, many of which were being neglected when the Biomass Nippon Strategy was adopted. This triggered the energy and material utilization of waste woody biomass such as mill residues (**Figure 8**), wood-based waste materials (**Figure 9**), and tree trimmings.

Figure 8.
Mill residue.

Figure 9.
Wood-based waste material.

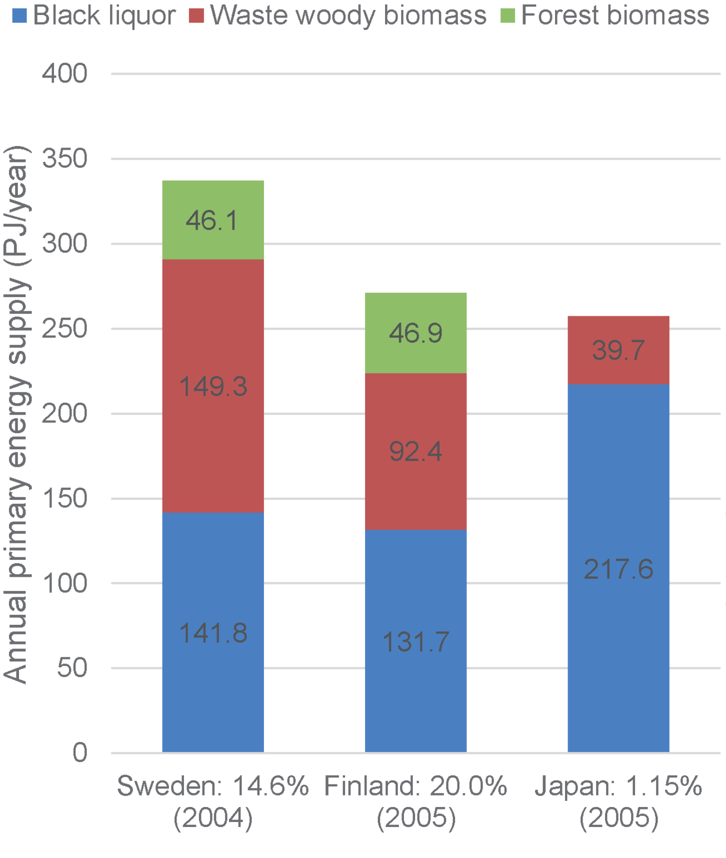


Figure 10.
Comparison of the woody bioenergy utilization around 2005 (Each percentage value means the share to the total domestic primary energy supply).

With respect to the actual situation of planted forests at that time, the thinning of largely established planted forests did not commonly take place because the trees were so small that there was little profitability on a business basis in thinning operations.

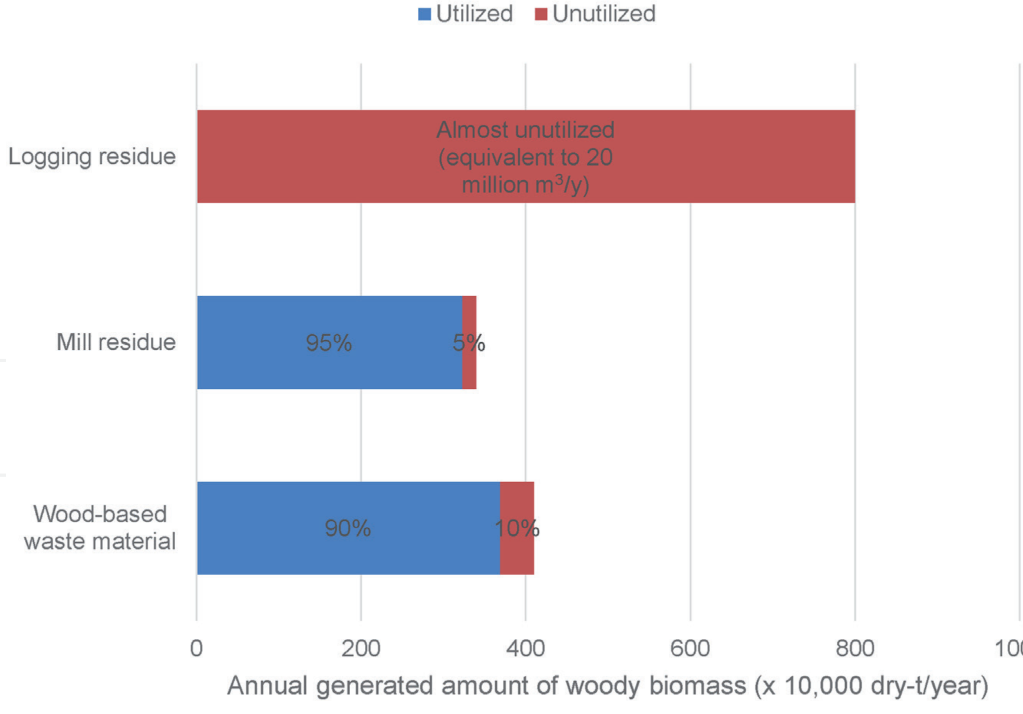


Figure 11.
Domestic woody biomass availability in 2010.

Figure 12.
Young planted forest contained large amounts of felled thinnings.

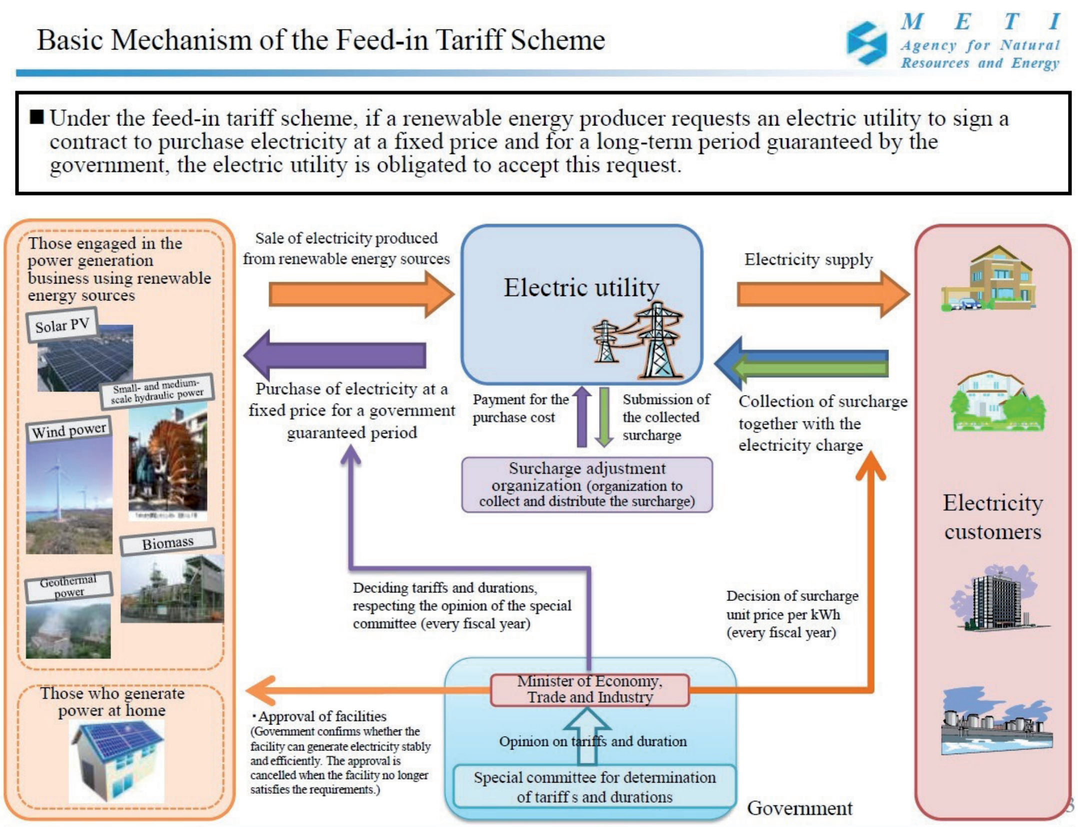
Figure 10 shows a comparison of the woody bioenergy utilization around 2005. From the point of view of the amount of woody bioenergy utilization itself, Japan was almost on a par with Sweden and Finland. This is because there has been a big pulp and paper industry in Japan, and the recycling of black liquor, that is, by-product from the kraft process when digesting pulpwood into paper pulp removing lignin, hemicelluloses, and other extractives from the wood to free the cellulose fibers, was promoted in the 1970s.

The domestic woody biomass availability in 2010 as estimated by the Japanese government is shown in **Figure 11** [8]. There was little available waste woody biomass such as mill residue or wood-based waste material, while logging residue went almost unutilized. It has been said since that time that logging residues should be utilized by developing dedicated harvesting machines as has been done in Sweden and Finland.

In these statistics, the term "logging residue" actually refers to unutilized thinning materials (**Figure 12**). In view of environmental conservation and global warming mitigation measures, huge amounts of subsidies were spent to fell trees for the purpose of thinning, but the felled trees were never harvested. Thus, the young planted forests contained large amounts of felled thinnings. So, the 20 million m^3/y of logging residue shown in **Figure 11** should have been classified as "forest biomass," most of which was composed of unutilized thinnings.

4. Launch of the FIT scheme 1 year after Fukushima

The Feed-in Tariff scheme for renewable energy (FIT) was launched in 2012, 1 year after the Fukushima nuclear disaster following the Great East Japan Earthquake, and the scheme increased the utilization of forest biomass. **Figure 13**



Energy source		Biomass				
Biomass type		Biogas	Wood fired power plant (Timber from forest thinning)	Wood fired power plant (Other woody materials)	Wastes (excluding woody wastes)	Wood fired power plant (Recycled wood)
Cost	Installation cost	3,920,000 yen/kW	410,000 yen/kW	410,000 yen/kW	310,000 yen/kW	350,000 yen/kW
	Operating and maintenance costs (per year)	184,000 yen/kW	27,000 yen/kW	27,000 yen/kW	22,000 yen/kW	27,000 yen/kW
Pre-tax IRR (Internal Rate of Return)		1%	8%	4%	4%	4%
Tariff (per kWh)	Tax inclusive	40.95 yen	33.60 yen	25.20 yen	17.85 yen	13.65 yen
	Tax exclusive	39 yen	32 yen	24 yen	17 yen	13 yen
Duration		20 years				

Figure 13.
Framework of the FIT.

shows the framework of the FIT [9]. In the case of biomass, the electric utilities have committed to buy the electricity derived from biomass at a higher price than the normal retail one for 20 years. However, this cost is passed down to the electricity consumers. Japanese public covered additional 18.8 billion US dollars in 2016 within the framework of the FIT. The price of electricity has already risen over 10% from the price before the implementation of the FIT.

With respect to the woody biomass resources for the FIT, "general wood" consists of mill residues and imported woods. From the point of view of power generation capacity, the construction project of a power generation plant which utilizes general wood as fuel accounts for the majority (**Figure 14**) [10]. There are plans to establish many large-scale plants with a power-generation capacity of more than 10 MW along seashores and to import a huge amount of woody biomass such as wood chips, wood pellets, and palm kernel shells (PKS).

Forest biomass utilization is also being done mainly in mountainous areas. The main source of forest biomass is the unutilized thinnings that were once abandoned in planted forests (**Figure 15**). Since the tariff on electricity derived from forest biomass is set to be hefty, the price of forest biomass as fuel is sometimes greater than that of forest biomass as pulpwood. In some areas, pulpwoods are also transported directly to power generation plants, and adjacent pulp mills located in such areas are obliged to import pulpwoods instead.

As a result, forest biomass utilization is rapidly increasing (**Figure 16**) [2]. The rapid increase in the utilized amount of forest biomass triggered by the FIT is the driving force behind the improvement of the self-sufficiency rate of wood.

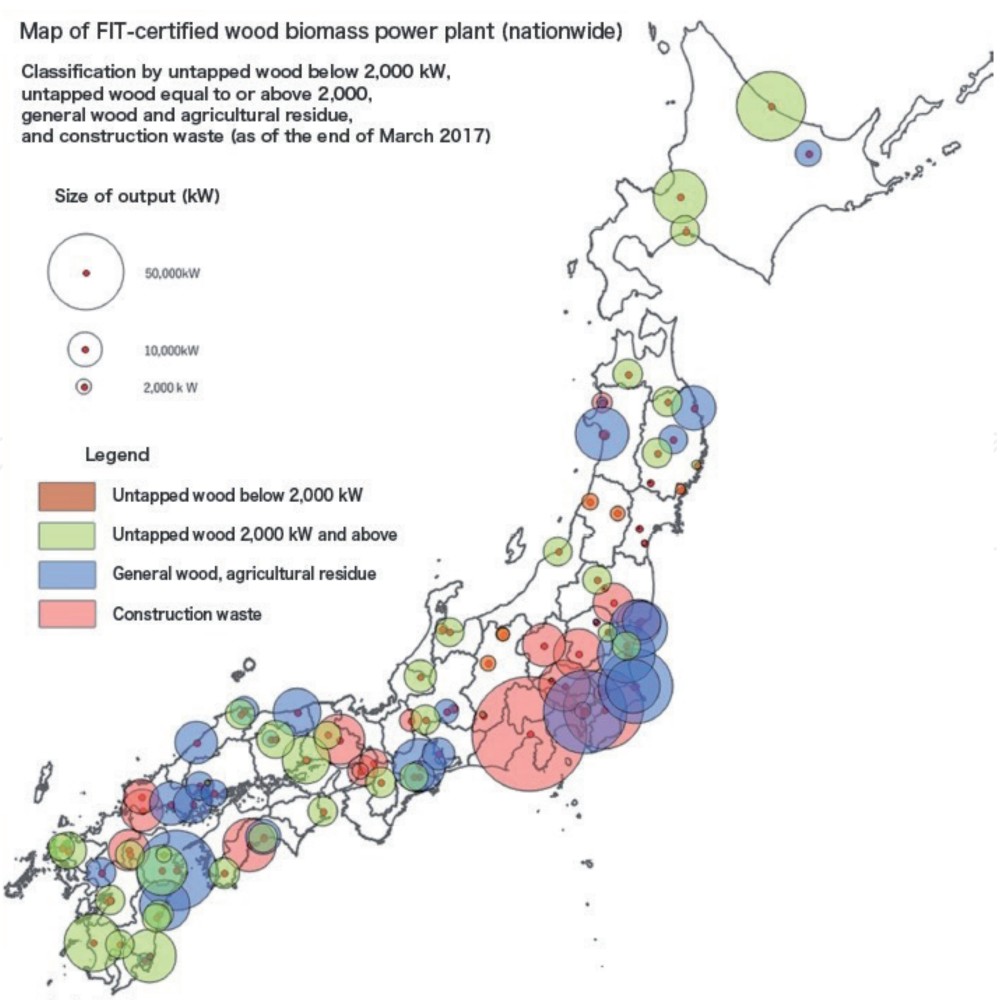


Figure 14.
Map of FIT-certified woody biomass power plants.

Figure 15.
Unutilized thinnings that were once abandoned in planted forests.

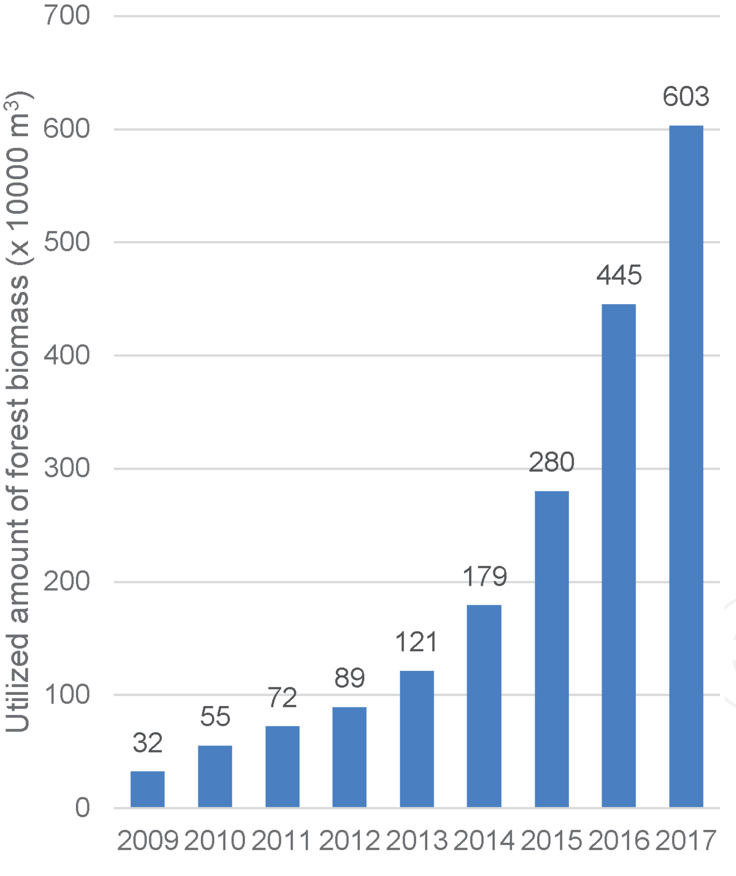


Figure 16.
Changes in the utilized amount of forest biomass.

The self-sufficiency rate of wood in 2017 as shown in **Figure 4** was 36.2%, but it goes down to 31.6% when the use of wood as fuelwood is excluded.

It is unclear whether unutilized thinnings can continue to be utilized as energy in the future. Planted forests are going to mature so that the value of the thinning material will increase and the amount available for energy use will decrease. On the other hand, "true" logging residues such as tree tops and limbs are not currently utilized much as energy sources. If this situation continues, the energy utilization of forest biomass might drop sharply after the completion of the FIT. Thus, a framework for the utilization of logging residues must be established as soon as possible.

5. Future perspectives on forest biomass in Japan

The use of the whole-tree logging system has increased through the spread of mechanization, such as the use of processors and harvesters. This situation makes logging residues easier to collect. So an efficient and low-cost harvesting, transporting, and chipping system for logging residues must be established. The author's

Figure 17.
Experimenting with a forwarder hauling of slashes.

Figure 18.
Comminution of logging residues with a tub grinder.

Figure 19.
Chipper-forwarder.

Figure 20.
Bundler.

research group experimented with the collection of logging residues by a forwarder (**Figure 17**) [11]. Comminution of logging residues was also investigated (**Figure 18**) [12], and the harvesting (collecting and comminuting) cost of logging residues was calculated as 76.0 USD/dry-t [13]. As compared to Sweden and Finland, where the energy utilization of forest biomass is making steady progress (see **Figure 10**), the calculated cost is relatively expensive, so that the development of dedicated machines such as the chipper-forwarder (**Figure 19**) [14] and bundler (**Figure 20**) [15] may be necessary [16].

The use of small-sized trees is also promising. The area covered by planted forests that have undergone final cutting and subsequent reforestation is now gradually increasing. Thus, a cleaning operation in young planted forests will be necessary 15–20 years from now, when the FIT will expire. So the development of

Figure 21.
Multi-tree feller-buncher.

Figure 22.
Harvesting small-sized trees with a truck-mounted multi-tree felling head.

efficient harvesting technology for small-sized trees will be necessary. An accumulative felling machine (**Figure 21**) may be effective [17, 18]. Harvesting small-sized trees with a truck-mounted multi-tree felling head was attempted (**Figure 22**), and the harvesting (felling, collecting, and comminuting) cost of small-sized trees was calculated as 99.4 USD/dry-t.

Figure 23.
Experiment of harvesting willow trees using a sugarcane harvester.

Short rotation woody coppices (SRWC) have a huge potential. Before and during World War II, an average of 50 million m^3/y of naturally regenerated forest was felled and harvested for energy use in the form of charcoal and firewood in Japan. The annual available amount of naturally regenerated broad-leaved trees used as SRWC is estimated to be 9 million dry-t/y [7]. The energy utilization of SRWC has already begun within the framework of the FIT. Moreover, the development of short rotation forestry in abandoned farmlands may be worth considering. Commercial willow plantations have been cultivated for bioenergy purposes in Sweden since the 1980s, and around 16,000 ha of short rotation willow plantations were established domestically from 1986 to 2000 [19]. In 2006, about 8,000 ha of the first commercial willow biomass crops in North America were started in upstate New York [20]. Growing and harvesting willow trees aimed at short rotation forestry was experimented with in northern Japan. A sugarcane harvester that was used in southern Japan was applied for harvesting willows during its agricultural off-season (**Figure 23**) [21]. The harvesting (growing, cutting, collecting, and comminuting) cost of SRWC was calculated as 136 USD/dry-t [22].

6. Conclusions

In this chapter, the current situation of forests and forestry as well as woody biomass utilization in Japan was described, and the future outlook for the use of forest biomass in Japan was presented. As a result, the following conclusions were drawn:

1. Many planted forests are now becoming mature, so the operational efficiency in forestry should be improved not only by the development of the forest infrastructure but also by the full mechanization of the logging system;

2. The Kyoto Protocol adopted in 1997 promoted the energy utilization of waste woody biomass such as mill residues and wood-based waste materials, and

then the launch of the FIT in 2012 promoted the energy utilization of once-unutilized thinnings;

3. In order to further expand the production of forest biomass and its utilization for energy, logging residues, small-sized trees, and SRWC are promising. Thus, low-cost harvesting technologies should be developed as soon as possible, with reference to machines and systems operating in foreign countries where the utilization of such forest biomass is making steady progress.

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Conflict of interest

The author declares no conflict of interest.

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