Estimation of Woody Biomass Energy Supply Curve for Hokkaido

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Abstract

In this study, a supply curve of woody biomass energy (fuel log) for Hokkaido was developed. An annual supply potential of fuel log in Hokkaido is estimated to be 2.7 million m^3, which is about three times of current supply. However, the regional supply potential varies greatly from -20% to +30% per year compared to the period average since the amount of thinning would decrease in the mid-term. As for supply costs, the proportion of log volume with total revenue exceeding total cost is 71% for Hokkaido as a whole. The profitability of woody biomass energy could be greatly influenced by transportation distance, indicating the importance of local production for local consumption. The annual variation of regional unit supply costs of fuel log was relatively small in the analyzed forests. However, it should be noted that unit supply costs also generally vary from year to year, which is natural, given that only a small portion of the forest is harvested in each year and the cutting age is several decades or longer.

Key words: Woody biomass energy, Hokkaido, Supply potential, Supply cost, Supply curve

1. Preface

Forests account for approximately two-thirds of Japan's land area, and possess multifaceted functions including a mountain disaster prevention function, a soil conservation function, a water resource cultivation function, an environmental conservation function, a timber production function, a cultural function, a biodiversity function and a health and recreation function1).

As a result of factors including growth in woody biomass power plants, demand for fuel logs is steadily increasing, but in 2022 reliance on imports was high, at 41%. Although the utilization rate of domestic forest residues is also increasing in regard to the quantity of such residues being generated, as of 2021 it remained at around 35%2).

The fuel log supply potential with regard to Japan as a whole and Hokkaido, the subject of this research, was compared by means of the actual supply demand figures for 2022 3), 4), the 2030 targets in the Forest and Forestry Basic Plan5), the volume of woody biomass power generation anticipated to be introduced in the 6th Strategic Energy Plan6) (case of enhanced policy response), and prior research (**Table 1**).

To begin with, if we look at the Forest and Forestry Basic Plan, when it comes to both the demand forecasts and the supply targets, the actual results for 2022 already exceed the figures assumed for 2030. Furthermore, if we look at the estimates for supply potential, within the three prior research papers assembled here, the Ministry of the Environment's7) estimates for potential supply are the largest – when compared against actual supply they represent around eight times the figure for the entire country and around 11 times the figure for Hokkaido. The corresponding power generation facility capacity is estimated at 3,910 MW for the entire country, which is close to the 6th Strategic Energy Plan's anticipated figure for the volume of woody biomass power generation to be introduced. The supply potential estimated by the Center for Low Carbon Society Strategy, Japan Science and Technology Agency (JST)8) is roughly at a level close to the Ministry of the Environment's study. On the other hand, the estimated results from Matsuoka et al.9) are at a small level compared to the previous two parties. Additionally, Matsuoka et al. also estimate supply potential that takes profitability into account, and those estimates are around half the estimates for supply potential that does not take profitability into account. The supply potential that takes profitability into account is around the same as the actual supply in Hokkaido's case, and below the actual supply for the country as a whole.

Table 1 Potential supply of fuel log according to prior research, and actual supply and demand etc.

Item		Nationwide	Hokkaido
Supply	Actual, 2022	10 million m^3	963,000 m^3
	Forest and Forestry Basic Plan 2030	9 million m^3	-
	Ministry of the Environment (corresponding power generation facility capacity)	78 million m^3 (3,910 MW)	11,070,000 m^3 (598 MW)
	JST	60 million m^3	-

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	Matsuoka et al. (taking commercial viability into account)	13 million m^3 (6.2 million m^3)	1,999,000 m^3 (1,068,000 m^3)
Demand	Actual, 2002	17 million m^3	1,085,000 m^3
	Forest and Forestry Basic Plan 2030	16 million m^3	-
	6^{th} Strategic Energy Plan, Power Generation 2030	4,340 MW	-

Note) Actual supply for Hokkaido are estimated by the authors based on statistics4)

If we examine the estimation methods used in the prior research, the Ministry of the Environment and JST employs a top-down approach according to the proportional division of national and prefectural statistical data, while Matsuoka et al. utilize forest GIS and forest registration and employ a bottom-up approach that estimates the supply potential and supply cost for each minimum unit of forest area, known as a sub-compartment. Forests serve a variety of functions in addition to supplying wood, and there are also many forest stands where felling restrictions are in place, such as nature reserves and forest reserves. Additionally, supply costs are dependent on factors such as choosing the work system according to gradient and undulation, the extraction distance to roads in the vicinity, and the transportation distance to the point of use. A bottom-up approach is suited to accurately taking geographical conditions such as this into account. On the other hand, Matsuoka et al. estimate supply potential by assuming a situation in which the felling volume and growth volume are balanced in the long-term. This ideal state is known as a normal forest, but as discussed below, a current state forest deviates from a normal forest, and the supply potential in the process of leading to a normal forest from a current state forest is not explored. Furthermore, if looked at from the perspective of competition with other energies, it is necessary to build a supply curve that plots the unit supply costs on the vertical axis and the supply potential on the horizontal axis rather than estimating the relationship between supply potential and supply costs as a point, but this has not been carried out in any of the prior research introduced.

Based on the above, in this research, we attempted to build a supply curve for woody biomass energy that covered Hokkaido, which possesses Japan's largest forested land area, based on a bottom-up approach using forest GIS and forest registration.

2. Data and method

2.1 Commonly used data and forest covered by the analysis

Where forest GIS and forest registration were concerned, for privately-owned forests (general privately-owned forests and Hokkaido-owned forests) we utilized data made publicly available by Hokkaido 10), 11), while for state-owned forests we obtained the data from digital national land information12). The forest GIS and forest registration (privately-owned forests only) we obtained were combined, and information such as area, stand age, forest type (planted forest, natural forest, etc.), forest category (the designated condition, such as forest reserve), multilayer classification (single layer forest/multilayer forest) and tree species was prepared for each sub-compartment.

In terms of the forests covered by the analysis, of privately-owned forests and state-owned forests within Hokkaido we limited our analysis to planted, single layer forests, and furthermore, even within that we assumed them to be standing where conceivably, managed forests whose goal is wood production are possible, and we set two zone categories with reference to regional forest plans: forests for producing wood, etc., and water resource cultivation forests (forests that have a function of storing rainwater, preventing sediment runoff and cleaning up water quality). Specifically, when it came to privately-owned forests, of the planted, single layer forests covered we took regular forests to be forests for producing wood, etc., and headwater conservation forests and drought prevention forests to be water resource cultivation forests. When it came to state-owned forests, of the planted, single layer forests, among stands classified as water resource cultivation-type we took regular forests, headwater conservation forests, and drought prevention forests to be water resource cultivation forests. The tree species covered were the main coniferous species found within Hokkaido: Japanese cedar, fir class trees (Todo fir, spruce, Yezo spruce, hiba false arborvitae, Manchurian ash) and larch class trees (pines outside the fir class). Hokkaido's forested land area when arranged based on forest GIS and forest registration is as shown in **Table 2**, and the area of the forests covered in the analysis was 1,096,000 ha, which accounts for 76% of all the planted forests within Hokkaido. Incidentally, because Matsuoka et al. covered all stands of Japanese conifer, Japanese cypress, akamatsu (Japanese red pine) and kuromatsu (Japanese black pine) and Japanese larch in privately owned forests and state-owned forests, the area of the Hokkaido forests covered in that research was 1,363,000 ha, which is 24% greater than the area covered in this research.

Managed forest patterns such as the number of trees planted, the cutting age, the periodic thinning ratio and the years periodic thinning is carried out were established according to 13 plan areas, according to zone and according to tree species, based on regional forest plans. For the cutting age for water resource cultivation forests, a figure was derived by adding 10 years to the date for forests for producing wood etc. For the yield (yield table) per unit area for each stand age corresponding to the managed forest pattern, we used the Local Yield Table Construction System (LYCS3.3) from Matsumoto et al.[13)] With regard to tree species, for fir class trees we referred to Todo fir yield tables and for larch class trees we referred to Japanese larch yield tables. Additionally, with the LYCS3.3 it is also necessary to input site quality, but because this information was not available, we set an intermediate value of 2.

Table 2 Forest land area (1,000 ha)

Classification		General privately-owned forests	Hokkaido-owned forests	State-owned forests	Total
All regions	Planted forests	652	133	655	1,441
	Natural forests	1,111	460	2,212	3,783
	Treeless land etc.	70	15	200	286
	Total	1,833	608	3,068	5,509
Planted forests covered by the analysis		543	76	477	1,096
Planted forest coverage ratio		83%	57%	73%	76%

2.2 Estimating supply potential

In order to estimate woody biomass energy supply potential, it is necessary to assess the sustainable permissible yield of forests. When forests are in an ideal state, estimating their permissible yields is simple. That is to say, in forests (normal forests) where equal areas of stand exist for each stand age up to the cutting age (50 years, for example), stands that have reached their cutting ages are clear felled and immediately planted so that it is possible to harvest a certain amount of wood every year for eternity, and the permissible yield across the course of a year at that time is a figure in which the yield at the overall cutting ages for the forest in question is divided by the cutting age. However, because Japan's planted forests were planted intensively during a period of expanded forestation around 1960-1970, the area proportion where the harvest time is around the 50th to 60th year forms a protruding arc in terms of stand age distribution, and this trend is the same in Hokkaido. Consequently, based on the current situation there is a need to assess the permissible yield in the process of leading a current state forest to a normal forest. In this report, we sought this using the simple linear programming shown below, with reference to Tanaka et al.[14)] Here, we put constraints to the forest reaching a normal forest after the one felling period, and furthermore assuming that replanting occurs immediately after the regeneration felling.

$$V_{i,j} = X_{i,j} \cdot g_j \tag{1}$$

$$A_{i,j} = A_{i-1,j-1} - X_{i-1,j} \tag{2}$$

$$A_{i,1} = \sum\nolimits_{j'} X_{i-1,j'} \tag{3}$$

$$\sum\nolimits_j V_{i,j} = \sum\nolimits_j V_{i-1,j} \tag{4}$$

$$\begin{aligned} A_{n+1,j} &= \sum\nolimits_{j'} A_{1,j'}/n \qquad (1 \le j \le n) \\ A_{n+1,j} &= 0 \qquad\qquad\qquad (j > n) \end{aligned} \tag{5}$$

$$max \sum\nolimits_{i,j} V_{i,j} \tag{6}$$

Here, the indices i, $(1 \sim n+1)$, j represent period and forest age class, respectively, and n represents plan period. Period and forest age classes were made to be a five-year interval, while n was made the cutting age. The decision variables are $A_{i,j}$ (ha), being the forest area at the beginning of the period; $X_{i,j}$ (ha), being the felling area; and $V_{i,j}$ (m^3), being the regeneration felling (clear cutting) volume, and the recent forest area was derived by aggregating the areas of each sub-compartment as prepared at 2.1. The parameter is the timber volume g_j (m^3/ha) of the trees (main forests) covered in the regeneration felling per unit of area, as obtained from the yield tables, and was made the same for all sub-compartments. With formula (1) we calculate the regeneration felling volume based on yield tables. Formula (2) is a transition formula for forest area. Formula (3) shows the implementation of replanting promptly after felling, and formula (4) shows the regeneration felling volume of each period is made constant. Formula (5) shows that a normal forest is reached after the first felling. Under these constraints, with formula (6) the total regeneration felling during the period is maximized. The optimized calculation was implemented for each managed forest case (general privately-owned forests/Hokkaido-owned forests/state-owned forests x plan area x zone x tree species, giving 130 cases in total) as set at 2.1. That is to say, calculations were carried out on the premise that in each managed forest case current state forests are led to normal forests. Incidentally, the optimized calculation does not include the periodic thinning since it is carried out according to a schedule, but the final yield volume includes the periodic thinning volume also. Furthermore, both the regeneration felling and periodic thinning only take the volume of the trunk portion into consideration, and do not include the branch portion.

2.3 Estimating supply costs

The supply cost estimate followed the methods adopted in the prior research 9), 15) and covered extraction route creation, periodic thinning and regeneration felling (the felling process, gathering the logs and extraction to roads in the vicinity), transporting the timber to the point of use, replanting and repayments to the forest owners. For replanting costs (including weeding, improvement cutting and nursery thinning), standard costs were sought from the forestry industry's actual results16) for fiscal 2022, and costs of 1.8 million yen/ha were adopted for Japanese cedar, 1.37 million yen/ha for larch class (Japanese larch) and 1.82 million yen/ha for fir class trees (Todo fir). However, when carrying out replanting a reforestation subsidy (= standard costs x assessment coefficient 1.7 x subsidy rate 0.4) is applied, and so this was also taken into account in this research. For the costs of extraction route creation, the felling process, gathering the logs and extraction to roads in the vicinity, in line with the prior research a working system was established according to the topographical factors (gradient and undulation) of each sub-compartment and the unit cost (yen/ha or yen/m^3) of each work was estimated as a function15) of the topographical factors (gradient, undulation and extraction distance). Here, because thinning is also eligible for a subsidy, in this research also a thinning subsidy (= estimated cost x assessment coefficient 1.7 x subsidy rate 0.4) was applied to sub-compartments with an area of 5 ha or more and a yield volume of 10 m^3/ha or more. Additionally, the extraction distance was taken to be the shortest distance in a direct line from a sub-compartment's center to roads in the vicinity. With regard to the cost of transporting the timber to the point of use, for a unit cost (yen/m^3) we referred to the estimated figure (a function of transportation distance) for a 15 t truck from Shirasawa et al.17) The point of use for timber was considered to be the lumbermill18) in the vicinity. It is not possible to specify points of use for fuel log in the future but given that local production for local consumption is desirable, the point of use was set as the municipal town hall19) in the vicinity. The transportation distance should by rights be set as the distance by road, but in this report, we simply made it a figure of 1.5 times the direct distance on a flat surface. For repayments to the forest owners, we referred to in-forest standing timber prices (end of March 2023)20) and set them as 3,878 yen/m^3 for Japanese cedar (Tohoku average) and 5,446 yen/m^3 for larch class and fir class (Hokkaido/pine).

Using the unit costs (yen/ha or yen/m^3) set and estimated for each sub-compartment and work item, total costs were calculated by multiplying the area of each sub-compartment and yield volume, and unit supply costs per volume (yen/m^3) were determined by dividing by the yield volume of the cutting ages overall. In addition, in order to consider profitability we also estimated the revenue from selling the timber harvested from each sub-compartment. Timber prices and the production rates for each wood purpose were set as the figures in Hokkaido (and parts of Aomori) in 2022 based on statistics21) (**Table 3**).

Table 3 Production rates and prices for timber from regeneration felling

Item		Production rate (%)			Price (1,000 yen/m^3)		
		Japanese cedar	Larch	Fir	Japanese cedar	Larch	Fir
Timber	Sawing	70	48	42	15.5	14.9	14.9
	Plywood etc.	5	17	20	13.8	13.8	13.8
	Woody chip	0	10	13	7.2	7.2	7.2
	Total	75	75	75	-	-	-
Fuel log		15	15	15	7.2	7.2	7.2
Loss		10	10	10	-	-	-
Total		100	100	100	-	-	-

Here, Matsuoka et al. set the timber ratio accounted for by the trunk volume at 75%, the ratio of unused materials (fuel log) at

15% and the loss at 10% in the case of both wood from regeneration felling and wood from periodic thinning. It is conceivable that when it comes to wood from periodic thinning the ratio destined for fuel log will be large, but no direct statistics exist. That being the case, in this research, for wood from regeneration felling we assumed the same ratios as Matsuoka et al., and for wood from periodic thinning, we estimated the ratio of timber as 40% and the ratio of fuel log as 50% at levels consistent with Hokkaido's Wood Supply and Demand Results[4), 22)]. For the price of fuel log we referred to the figure for wood chip, as did Matsuoka et al.

2.4 Constructing a supply curve

We constructed a fuel log supply curve by integrating the supply potential in 2.2 and the supply costs in 2.3. To that end, we added index k, which designates sub-compartments, to each variable in the yield maximization model we constructed in 2.2 and came up with a model in which the object function changed from the yield maximization during the period to profit maximization (sales – costs). In formula (7), $Reve_k$ and $Cost_k$ are revenue and cost per unit yield, respectively, r is the discount rate and dt is the time increment (five years). Each of the limiting conditions is the same as the model in 2.2. However, where $Cost_k$ is concerned we gave the unit supply cost in the overall cutting ages for each sub-compartment estimated in 2.3, while for $Reve_k$ we set a sufficiently large figure compared to the unit supply cost and made r zero also. As a result of this setting, because ultimately yield maximization is being sought in this model also, the results of the yields for each period correspond to 2.2.

$$max \sum\nolimits_{i,j,k} \frac{(Reve_k - Cost_k) \cdot V_{i,j,k}}{(1+r)^{i \cdot dt}} \tag{7}$$

3. Results

3.1 Supply potential

It was estimated that the supply potential of wood (timber and fuel log) for Hokkaido as a whole will be 10.5 million m^3/year in 2025, of which 2.7 million m^3, or 26%, will be fuel log (**Fig. 1**). However, because the periodic thinning volume is not constant, the supply potential will change depending on the year. The periodic thinning volume will decline towards 2040 and is increasing subsequently, and this is reflecting the stand age distribution of current state forests. That is to say, because the proportion of young stand ages is low currently, in the medium term the stands that will be the subject of periodic thinning will decline. In the long term the periodic thinning volume will recover because stands that have undergone regeneration felling and reforestation will grow and become the subject of periodic thinning. It is assumed that the proportion of fuel log that will be derived from periodic thinning will be large, and consequently, the changes over time will be larger than for timber. Additionally, as we will discuss later, in some cases the changes will be even larger for specific regional units.

When the wood supply potential for 2025 is compared to that after normal forests have been reached (**Fig. 2**), the supply potential arising from regeneration felling increases by 20%. As we have already stated, in current state forests because the ratio of stands that are already reaching their cutting ages is large, if we assume forestation occurs after regeneration felling it will be possible to increase the regeneration felling volume more than it will be after normal forests are achieved. On the other hand, the supply potential arising from periodic thinning declines somewhat.

The supply potential in this research is significantly larger compared to actual felling/production results and cumulative felling plans in regional forest plans (the felling results are for conifers in planted forests; other results are figures for conifers). When compared to the prior research, the reason the supply potential after normal forests is achieved is smaller than estimates by Matsuoka et al. is conceivably due to differences in the forests covered by the analysis, as mentioned in 2.1. On the other hand, in the supply potential estimates from the Ministry of the Environment, the fuel log alone is equivalent to the total wood volume in this research. There are two main causes. In the Ministry of the Environment's estimates, the woody biomass energy reserves are considered to be the sum total of the volume of unused resources generated with regard to the felling volume and the volume of unused resources generated with regard to the annual cumulative increase in forests. Here, the volume of unused resources generated out of the annual cumulative increase is derived by multiplying the annual cumulative increase by 53.8% (national figure), a ratio of unused resources generated that is derived from recent felling volume and timber production volume. However, as is shown in **Fig. 2**, because the ratio of thinned wood making up the recent felling volume in Hokkaido is large, in this method the estimated volume of unused resources generated with regard to the annual cumulative increase is conceivably a volume that includes a large amount of wood that could by rights be utilized as timber. Additionally, the Ministry of the Environment estimates also cover broadleaf trees, and furthermore, the branch portion is also included as an unused resource, but in this research, we covered the trunk portion only (and 90% extraction ratio). As was the case with Matsuoka et al., because the price of the branch portion is unclear it is excluded from this research, but in a case where the biomass magnification factor is 1.3, in 2025 the supply potential of fuel log will increase substantially, from 2.7 million m^3 to 5.9 million m^3.

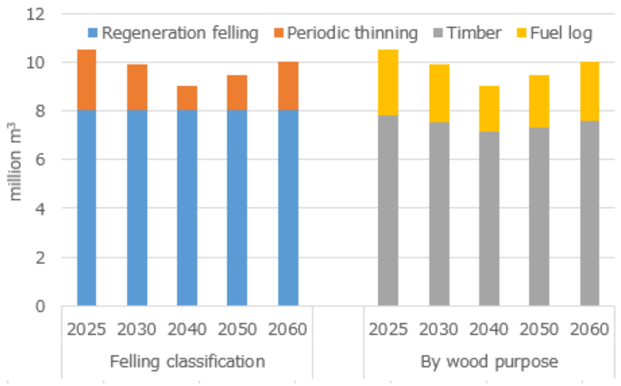

Fig. 1 Wood supply potential estimation results

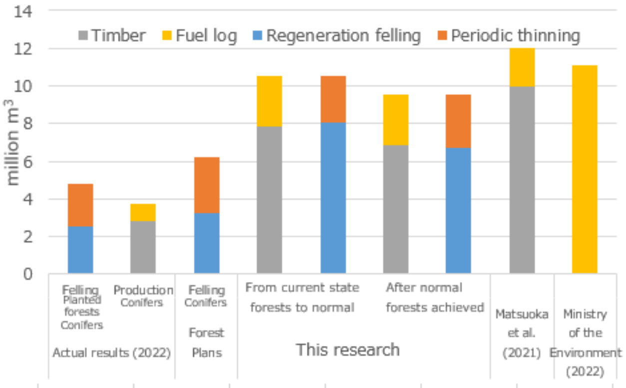

Fig. 2 Comparison of wood supply potential

3.2 Supply costs

The unit supply cost of wood in Hokkaido as a whole was estimated to be 10,600 yen/m^3. In terms of items that are major contributors to that cost, repayments to forest owners account for 36%, felling costs 25% and transport costs 17%. In addition, the log volume proportion for sub-compartments where the revenue exceeded the costs was 71%. This is a larger figure than the 53% estimated by Matsuoka et al., but transport cost is conceivably one cause of that. Matsuoka et al. assumed the consolidation points for timber to be cooperative sales locations, and the consolidation points for fuel log to be FIT-certified power plants that were utilizing unused woody material as fuel and were operating as of June 2020, and for many sub-compartments the transportation distance exceeded 100 km. On the other hand, in this research, we set the consolidation points for timber as lumbermills and the consolidation points for fuel log as municipal town halls, which meant the transportation distance of the volume-weighted average shortened to 45 km for timber and 17 km for fuel log. If, for argument's sake, the cost is calculated for a case where the travel distance for the fuel log was three times that figure (52 km on average), the log volume proportion for sub-compartments where the revenue exceeds the costs declines to 66%, so transportation distance could be described as an important factor on the profitability. However, it is necessary to note that the profitability figure is also dependent to a large extent on repayments to forest owners (in-forest standing timber prices) and assumed sales unit prices for wood. In reality, these prices change as a result of the supply and demand balance for wood and so on. Furthermore, in these estimates, we have not taken caps on afforestation subsidies and periodic thinning subsidies into account, but the reality is that there are limits to such sources of funding.

Looked at in terms of each region (forest plan area), the unit supply cost of wood is between 9,600 yen/m3 and 11,500 yen/m^3 and the profit ratio is between 52% and 89% (**Fig. 3**). In regions where the topographical conditions (gradient and undulation) are comparatively severe, such as West Abashiri, Ishikari Sorachi and Oshima Hiyama, the costs associated with felling (extraction route creation, periodic thinning and regeneration felling) become somewhat large, but in 46% of the sub-compartments covered by the analysis the gradient was less than 15 degrees, and in 98% it was less than 30 degrees, so as a whole Hokkaido's topographical conditions are suited to forestry.

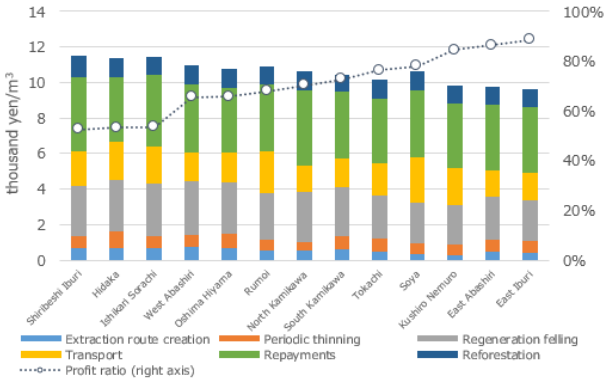

Fig. 3 Unit supply cost of wood by forest plan area

3.3 Supply curve

The supply curve for fuel log (woody biomass energy) in Hokkaido is shown in **Fig. 4**. Where the horizontal axis is concerned, the right end of the year-by-year supply curve corresponds to the supply potential in the process of leading to a normal forest from a current state forest that was shown in **Fig. 1** (the regeneration felling volume is constant but the periodic thinning varies from year to year, and consequently the total supply potential at each point in time does not match). Where the vertical axis is concerned, for the unit supply cost as fuel log, common cost items were sought by apportioning revenue from timber and fuel log, and for transport cost, only the fuel log cost was posted. The fuel log supply curve for Hokkaido as a whole is shifting gently in a shape that is for the most part close to horizontal, and furthermore, although it differs depending on the year, approximately 70% of the supply potential is below the recent fuel log price of 7,200 yen/m^3. With regard to the supply potential and unit supply cost of fuel log by region, if we examine the size of the rate of change in each year (minimum value to maximum value) against the average value for 2025-2060 (Fig. 5), the supply potential changes by a range of around -20% to +30% compared to the average value over the period, but the unit supply cost is comparatively stable even when looked at by region. Taking into account the fact that the sub-compartments felled each year are only a small portion of the whole, and that the cutting age is several decades or longer, it would be natural for the unit supply cost to also change each year. However, in the forests covered by our analysis, even when looked at by region there was little variation in the unit supply cost of sub-compartments.

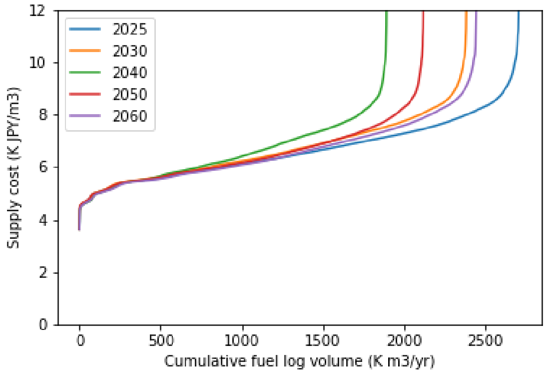

Fig. 4 Fuel log supply curve

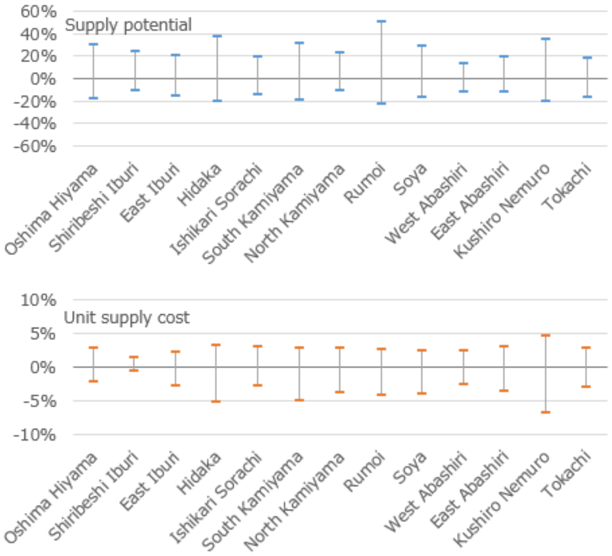

Fig. 5 Size of change of fuel log supply potential and unit supply cost in each year (minimum value to maximum value of the rate of change against the average value for 2025-2060)

4. Conclusions

In this research, we built a supply curve for woody biomass energy (fuel log) that covered Hokkaido. We arrived at three key conclusions. The first is that although the fuel log potential (not including branches) of Hokkaido as a whole is estimated to be up to 2.7 million m^3, which equates to around three times the current supply, that may change significantly from year to year. The reason for this is that when the stand age distribution of current state forests is taken into account, in the process of leading to normal forests from current state forests while it is possible to increase the regeneration felling volume more than after normal forest is achieved, the periodic thinning volume will decline in the medium term. Because it is anticipated that the ratio of fuel log derived from periodic thinning will be large compared to that for timber, the change in supply potential over the years will be larger than for timber.

The second conclusion is that local production for local consumption conceivably will exert a major impact on the competitiveness of woody biomass energy. Across Hokkaido as a whole the log volume proportion for sub-compartments where total revenue exceeds total cost (profit rate) was 71%. In this research we set the fuel log consolidation points as municipal town halls and assumed a shortish average transportation distance of 17 km but if, for argument's sake, the cost is calculated for a case where the travel distance for fuel log is three times that figure (52 km on average), the proportion of the supply volume where the revenue exceeds the cost declines to 66%. That said, if considered up to the biomass' consumption stage, there is a possibility long-distance transport would be justified as a result of economies of scale, such as efficiency improvements resulting from increasing the size of power generation facilities[23].

The third conclusion is that the fuel log unit supply cost may also change each year, not just the fuel log supply potential. Taking into account the fact that the sub-compartments felled each year are only a small portion of the whole, and that the cutting age is several decades or longer, it would be natural for the unit supply cost to also change each year. However, in the forests covered in this research, even when looked at by forest plan area the variation was only around -5% to +5%.

In addition to widening the coverage of the analysis to Japan as a whole, other issues to be addressed in the future include taking into account branches, which were not covered in the estimates in this research; estimating costs for a case in which an upper limit is imposed on the total amount of subsidies; and making timber price assumptions based on future supply and demand.

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