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ORIGINAL ARTICLE

Calculation of CFP and verification of effect on CO_2 emission reduction for the use of certified wood in Kyoto Prefecture

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Abstract The representative carbon footprint of product (CFP) value of “certified wood in Kyoto Prefecture” was calculated as 241 kg-CO_2/m^3. The CFP value was 158 kg-CO_2/m^3 when wood was not kiln dried and final processing was not involved, whereas that of “kiln-dried, finished wood” was 284 kg-CO_2/m^3. Comparisons of different types of wood were also conducted to examine CO_2 emission-reducing effects of “certified wood in Kyoto Prefecture”. We compared the CFP of lumber produced (in Japan) from logs supplied from Japan and other countries and that of “certified wood in Kyoto Prefecture”; the lumber products as a target for comparison are shipped to markets throughout the country. The CFP of “certified wood in Kyoto Prefecture” was approximately 50% lower compared to that of North American wood lumbered in Japan and shipped to markets throughout the country, and about 30% lower compared to the mean CFP of lumber produced (in Japan) from logs supplied from Japan and other countries and shipped to markets throughout the country. We then compared the CFP of “products imported from other countries after being cut into lumber” to that of “certified wood in Kyoto Prefecture”. The CFPs of lumber products from North America and Europe were lower than that of “certified wood in Kyoto Prefecture” (kiln-dried, finished wood). However, when only woodchips were used as a heat source in the process of kiln drying, the CFP of “certified wood in Kyoto Prefecture” was lower than any other kiln-dried lumber products. Regarding “certified wood in Kyoto Prefecture”, the use of woodchips as a heat source in the process of kiln drying or a shift to air drying decreases the CFP.

Keywords Certified wood in Kyoto Prefecture · Carbon footprint of products · Local production for local consumption · Lumber

Introduction

In the previous report [1], we calculated the carbon footprint of products (CFPs) of “certified wood in Kyoto Prefecture (lumber products)[1]” produced by multiple mills to examine the effects of differences in their processes. The results were as follows: (1) different heat sources were used by multiple mills in the process of kiln drying, and these differences had a significant influence on the CFP of kiln-dried lumber products. (2) There were marked differences in CO_2 emissions in the process of transportation even among mills involved in “local production for local consumption” and, in some cases, CO_2 emissions in the process of transportation accounted for about 20% of the CFP. (3) Differences in the rates of air drying and precutting had marked influences on the mean CFP of the total

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[1] The lumber products were certified by the Kyoto Prefecture as having traceable histories in the processing and transporting and their raw materials, logs, were produced in the Kyoto Prefecture.

amount of “certified wood in Kyoto Prefecture” stored in each mill.

In this study, we first calculated the mean CFP of lumber products produced from “certified wood in Kyoto Prefecture” by mills, the subjects of the previous report [1], and adopted it as the representative CFP value of “local production for local consumption-based” lumber products in Kyoto. We then compared the representative value to the CFPs of other products to examine CFP-reducing effects of a “local production for local consumption” approach in the trading of lumber products.

Previous studies have conducted assessments of greenhouse gas (GHG) emissions generated when producing lumber products based on the principle of “local production for local consumption” and suggested a shift of the heat source in the process of kiln drying from fossil to woody fuels [2, 3]. However, few studies have examined the process of transportation based on the actual distribution of “local production for local consumption-oriented” products in the community.

To calculate the mean transport distance for the subject of the study, i.e., “certified wood in Kyoto Prefecture,” we examined the detailed process of transportation (routes between the producers of logs and consuming areas) and determined the transport distance for individual products or materials. Therefore, the values of GHG emissions generated in the transportation process reflected the actual distribution of “local production for local consumption-oriented” products in Kyoto Prefecture. Most system boundaries, used to calculate GHG emissions generated in the process of producing “local production for local consumption-oriented” lumber products, which had been adopted by previous studies, did not include the “use and maintenance control stage” or “disposal and recycling stage”. The system boundaries in this study covered different areas.

Experimental methods

In this study, we first calculated the mean CFP of lumber products produced from “certified wood in Kyoto Prefecture” by mills, the subject of the previous report [1], and adopted it as the representative CFP value of “certified wood in Kyoto Prefecture”.

We then compared the representative value to the CFPs of other lumber products, which are produced using logs from areas other than Kyoto by mills usually involved in the processing of “certified wood in Kyoto Prefecture”, to examine CFP-reducing effects of the transportation process based on a “local production for local consumption” approach.

To examine CFP-reducing effects of a “local production for local consumption” approach in the trading of lumber products, we compared the mean CFP of “certified wood in Kyoto Prefecture” and that of other lumber products (produced in other countries) distributed throughout Japan.

Finally, we conducted simulations to develop a method for reducing the mean CFP of “certified wood in Kyoto Prefecture”.

This study was conducted to examine CO_2 emission-reducing effects of “local production for local consumption-oriented” lumber products, and develop measures required to establish production/distribution systems designed to reduce the CFP of lumber products as much as possible.

A functional unit of 1 m^3 was used for all products and materials in this study. In the calculation of the CFP of products, the range of assessment and conditions for calculation were determined in accordance with the product category rule (PCR) for wood and wood materials [4], stipulated in the “Carbon Footprint System” (trial project until 2011) [5] implemented by the Ministry of Economy, Trade and Industry et al.

Calculation of the representative CFP value of “certified wood in Kyoto Prefecture”

Since 2003, Kyoto Prefecture has implemented “the lumber certification system from Kyoto” [6]. The system allows the certification body to check distribution records of a certified product, including the route from a producing to consuming area. In 2010, 2635 m^3 of lumber products were certified as wood produced and consumed in Kyoto. In this study, we calculated the representative CFP value of lumber products certified by the system in 2010.

In the previous report [1], CFPs were calculated in six mills, and 1506 m^3 of certified products were produced by the six mills. This accounted for 57% of the total amount of “certified wood in Kyoto Prefecture”, and we concluded that the representativeness of the six mills had been established. We then calculated the weighted mean of the CFPs of “certified wood in Kyoto Prefecture” produced by the six companies (weighted by the amount of products) and adopted the mean value as the representative CFP value of “certified wood in Kyoto Prefecture”.

A functional unit of 1 m^3 was used for the measurement of “certified wood in Kyoto Prefecture”. Figure 1 shows a flowchart representing the life cycle of “certified wood in Kyoto Prefecture”. GHG (six types of gas designated in the Kyoto Protocol: CO_2, CH_4, N_2O, HCF_S, PFC_S and SF_6) emissions in each of the processes were converted and appropriated for CO_2, using the global warming potential (GWP).

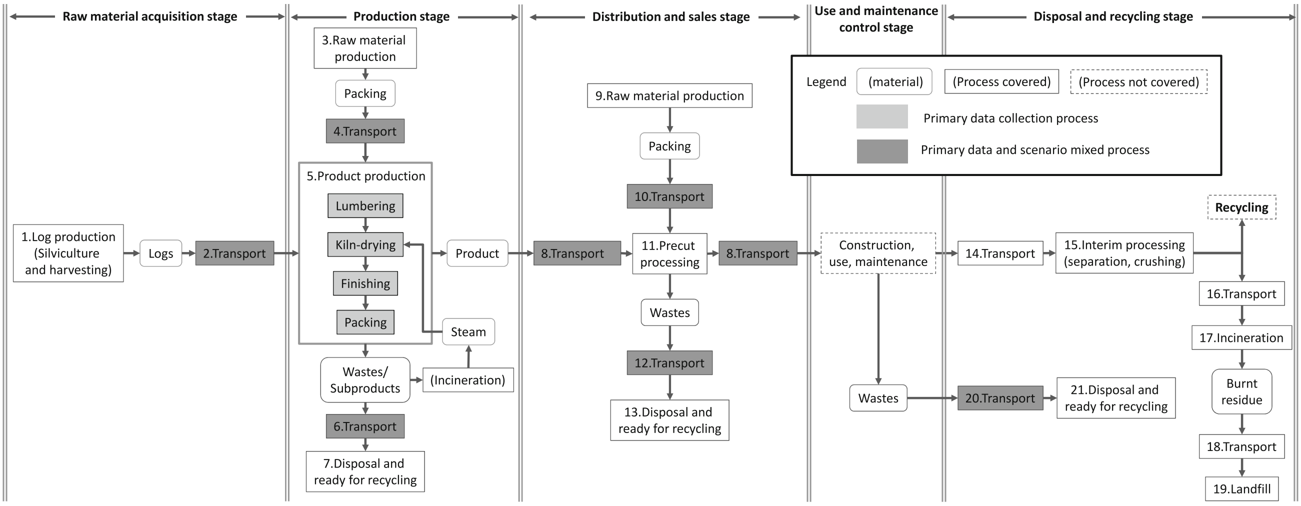


Fig. 1 Life cycle flowchart of surveyed product

We employed methods for data collection, CO_2 emission factor and distribution similar to those used in the previous report [1].

Effects of “local production for local consumption” on the reduction of CO_2 emissions generated in the process of transportation

We specifically examined CO_2-reducing effects in the process of the transportation of “certified wood in Kyoto Prefecture”. We calculated the CFP of lumber products produced (by mills usually involved in the processing of “certified wood in Kyoto Prefecture”) using logs from areas other than Kyoto and compared it to the representative CFP value of “certified wood in Kyoto Prefecture”.

We chose Canada as the producing area for comparison because Canada was the largest exporter of logs to Japan in the 2010, the coniferous wood fiscal year according to trade statistics database [7]. We calculated the mean transport distance required to ship logs for the domestic production of lumber products (and CO_2 generated in the process of transportation), which was also used for comparison. Import partners and import volumes of logs for lumber products were quoted from appendix table 37 in Sinrin-Ringyo hakusyo [8].

Life cycle flowcharts for comparison are shown in Fig. 1 along with the flowchart representing the life cycle of “certified wood in Kyoto Prefecture”.

Tables 1 and 2 show the conditions for the process of transporting logs.

In any table, transport conditions were quoted from the attached document C in PCR (Wood, Wood Materials) [5] and the density of wood was quoted from the attached document D in PCR (Wood, Wood Materials) [5]. Furthermore, the international transport of Table 2 was quoted from the wood miles manual [8].

The process of transporting logs (Table 1) is included in the stage of raw material acquisition. To obtain the mean transport distance required to ship logs for the domestic production of lumber products, we first calculated the transport distance for logs from each foreign country (including those produced in Japan) and then the weighted mean of them (weighted by the level of supply). “Other imported wood” in the table was excluded from the calculation because it accounted for only 1.5% of the total and production areas were unknown. To obtain the mean transport distance (weighted mean by the amount of “certified wood in Kyoto Prefecture” processed by each mill), calculations were made on the assumption that imported logs were transported from Maizuru Port in Northern Kyoto to mills.

The process of transportation included in the distribution and sales stage (Table 2) was categorized into two groups: distribution in Kyoto Prefecture and Japan. The transport distance in the case of consumption in Kyoto (104 km) is the weighted mean by the transport distance of “certified wood in Kyoto Prefecture” processed by six sawmills made in the previous report [1].

We developed two scenarios for the transportation of logs (stage of raw material acquisition) and lumber products (distribution and sales stage) each, a total of four patterns (A–D), and calculated the CFPs in these four cases.

Comparison of the representative CFP values of “certified wood in Kyoto Prefecture” and other lumber products distributed in Japan

Komata et al. [2] pointed out to the small amounts of CO_2 emission generated in production processes overseas, and

Table 1 Supply quantity of Logs for Lumber and Transport scenario of logs

Production area	Supply quantity (2009) $\times 10^3$ m^3	Domestic transport in overseas country		International transport		Domestic transport	
		km	Means of transport	km	Means of transport	km	Means of transport
Domestic	11981	–		–		69	10 t truck, loading ratio of outward is 62%; homeward is 0%
North America	4337	250	20 t truck, loading ratio of outward is 62%; homeward is 0%	7710	Bulk carrier (80000 DWT or less)	58	10 t truck, loading ratio of outward is 62%; homeward is 0%
Southeast Asia	147	250	20 t truck, loading ratio of outward is 62%; homeward is 0%	4528	Bulk carrier (80000 DWT or less)	58	10 t truck, loading ratio of outward is 62%; homeward is 0%
Russia	1486	250	20 t truck, loading ratio of outward is 62%; homeward is 0%	1106	Bulk carrier (80000 DWT or less)	58	10 t truck, loading ratio of outward is 62%; homeward is 0%
New Zealand	725	250	20 t truck, loading ratio of outward is 62%; homeward is 0%	9116	Bulk carrier (80000 DWT or less)	58	10 t truck, loading ratio of outward is 62%; homeward is 0%
Others	130	–	20 t truck, loading ratio of outward is 62%; homeward is 0%	–	Bulk carrier (80000 DWT or less)	–	10 t truck, loading ratio of outward is 62%; homeward is 0%
Total	18806	–		–		–	

Density of green wood is 0.699 t/m^3 (Same as "certified wood in Kyoto Prefecture")

Table 2 Transport scenario of lumber (from sawmill for consuming region)

	Product transport		Density of air-dried wood (t/m^3)
	km	Means of Transport	
(A) Domestic average (consumption in Kyoto)	104	10 t truck. Loading ratio of Outward is 62 %. Homeward is 0%	0.391
(B) Domestic average (consumption in the whole country)	500	10 t truck. Loading ratio of Outward is 62 %. Homeward is 0%	0.391
(C) North American wood (from Canada, consumption in Kyoto)	104	10 t truck. Loading ratio of Outward is 62 %. Homeward is 0%	0.51
(D) North American wood (from Canada, consumption in the whole country)	500	10 t truck. Loading ratio of Outward is 62 %. Homeward is 0%	0.51

cited as reasons the use of woodchips as a heat source in the process of kiln drying and low levels of CO$_2$ emission factor from electricity in countries that export large amounts of lumber products to Japan. Therefore, we calculated the CFPs of lumber products produced in North America and Europe (Quote the appendix table 37 in Sinrin-Ringyo hakusyo [8].), the leading exporters, and compared them to that of "certified wood in Kyoto Prefecture".

Life cycle flowcharts are shown in Fig. 1 along with the flowchart representing the life cycle of "certified wood in Kyoto Prefecture". Logs were processed, kiln dried, finished in North America and Europe, and exported to Japan. An assumption was made as follows: imported lumber products are distributed nationwide; all products are kiln dried using woodchips as a heat source in accordance with the previous literature [2].

Table 3 shows the scenarios for the transportation of logs (stage of raw material acquisition) and lumber products (distribution and sales stage). Transport conditions were quoted from the attached document C of Ref. [5] and the density of wood was quoted from the attached document D of the reference. Furthermore, the international transport was quoted from the wood miles manual [9].

Regarding the stage of raw material acquisition, the processes of "development of paths in the forests, thinning, logging, and gathering" were determined based on values quoted from the literature on Canada (Products from North America) [10] and Sweden (Products from Europe) [11]. Table 3 shows the scenarios of the process of transporting logs.

Table 3 Transport scenario of comparative products

Production area	Domestic transport in overseas country				International transport		Domestic transport	
	km	Means of Transport	km	Means of Transport	km	Means of Transport	km	Means of Transport
North America	50	20 t truck, Loading ratio of Outward is 62%. Homeward is 0%	100	Railway	7710	Bulk carrier (80,000DWT or less)	500	10 t truck, Loading ratio of Outward is 62%. Homeward is 0%
Europe					22570			

← logs → ← Lumbering →

Density of green wood is 0.699 t/m^3. Density of air-dried wood is 0.391 t/m^3. (Same as "certified wood in Kyoto Prefecture").

Regarding CO_2 emission factor from electricity in the process of production, we used the values adopted by each country [12, 13]. On the assumption that there is no marked difference in other processes and input energy between Canada, Sweden, and Kyoto, data on equivalent items for "certified wood in Kyoto Prefecture" were used.

Regarding the stage of distribution and sales, we assumed that there is no marked difference in the precutting process between the areas, and thus data on equivalent items for "certified wood in Kyoto Prefecture" were used.

Regarding the stages of "use and maintenance control" and "disposal and recycling", we assumed that there is no marked difference between the areas, and data on equivalent items for "certified wood in Kyoto Prefecture" were used.

Comparison of the CFPs of "certified wood in Kyoto Prefecture" with different heat sources in the process of kiln drying

Woodchips and kerosene accounted for 60 and 40%, respectively, of the heat source used in the process of kiln drying "certified wood in Kyoto Prefecture". In this section, we examine the effects of heat sources used in the process of kiln drying on the CFP of "certified wood in Kyoto Prefecture".

Assumptions made for calculation were: the use of only woodchips and kerosene as a heat source. Values used for calculations regarding other processes are shown in Sect. 2.1.

Results and discussion

Calculation of the representative CFP of "certified wood in Kyoto Prefecture" and discussion

Table 4 shows collected data for estimation of CFP of "certified wood in Kyoto Prefecture". Table 4 shows the mean CFP of the total amount of "certified wood in Kyoto Prefecture" produced by six sawmills, the CFP of "kiln-dried (KD) products (involved kiln-dried, finished processing)" and the CFP of "air-dried (AD) products (not involved kiln-dried, finished processing)". Figure 2 shows CFP of "certified wood in Kyoto Prefecture".

The total CFP of AD products was 49% lower than that of KD products. The CFP at the production stage of AD products was 62% lower.

The difference in the CFP of air- and kiln-dried products is mainly due to CO_2 emissions generated in the process of kiln drying. Regarding AD products, the CFP of the production stage accounted for 47% of the total; although comprising the largest proportion of the total, it was not markedly larger than the CFP of other stages. These are consistent with the results of the previous report [1], in which the CFP of "certified wood in Kyoto Prefecture" was calculated by each lumber mill.

Results of an examination of the effects of "local production for local consumption" on the reduction of CO_2 emissions generated in the process of transportation and discussion

Figure 3 shows the results. In the case of D, the CFP was the largest, 491 kg-CO_2/m^3. The CFP of "local production for local consumption" was the smallest, approximately half that in Case D.

The CFP of "local production for local consumption" was 30% lower than that of a normal product produced in Japan as shown in B.

CO_2 emissions generated at the stage of raw material acquisition significantly varied depending on the log-producing area. The level of CO_2 emissions in the case of North American wood was about 6.3 times as high when compared with that of "certified wood in Kyoto Prefecture". The mean level of CO_2 emissions generated in the domestic supply of logs was approximately 2.8 times higher when compared with "certified wood in Kyoto Prefecture".

Table 4 Collected data for estimation of CFP of “certified wood in Kyoto Prefecture”

Stage	Process	Active mass			CO_2 emission (kg-CO_2/m^3)		
		Entry	Quantity	Unit	Air drying	Kiln drying	Weighted mean
Raw material acquisition	1. Log production (silviculture and harvesting)	Logs	2.02E+00	m^3	1.83E + 01	1.83E + 01	1.83E + 01
	2. Transport (outward)	10 t truckload (loading ratio: 62%)	7.76E+01	tkm	1.07E+01	1.07E+01	1.07E+01
	2. Transport (homeward)	10 t truckload (loading ratio: 0%)	5.49E+01	km	7.67E+00	7.67E+00	7.67E+00
Intermediate total					3.67E+01	3.67E+01	3.67E+01
Production	3. Raw material production (submaterials)	Packing of polypropylene series	1.28E−01	kg	2.65E−01	2.65E−01	2.65E−01
	4. Transport (submaterials) (outward)	10 t truckload [loading ratio: 62%]	6.42E−02	tkm	9.56E−03	9.56E−03	9.56E−03
	4. Transport (submaterials) (homeward)	10 t truckload (loading ratio: 0%)	5.00E+02	km	6.82E−03	6.82E−03	6.82E−03
	5. Product production						
	Lumbering	Electricity	1.14E+02	kW h	5.45E+01	5.45E+01	5.45E+01
	Kiln drying (66% of all the products)	Electricity	6.15E+01	kW h	0.00E+00	2.95E+01	1.95E+01
		Kerosene	2.84E+01	L	0.00E+00	7.42E+01	4.90E+01
		Woody fuel	1.71E+02	kg	0.00E+00	4.97E+00	3.28E+00
		Tap water	2.07E−01	m^3	0.00E+00	7.20E−02	4.75E−02
		10 t truckload [loading ratio: 62%] (outward)	7.02E−01	tkm	0.00E+00	4.47E−01	2.95E−01
		10 t truckload [loading ratio: 0%] (homeward)	4.27E+00	km	0.00E+00	1.77E−01	1.17E−01
	Finishing (64% of all the products)	Electricity	3.41E+01	kW h	0.00E+00	1.63E+01	1.04E+01
		10 t truckload [loading ratio: 62%] (outward)	7.02E−01	tkm	0.00E+00	4.47E−01	2.86E−01
		10 t truckload [loading ratio: 0%] (homeward)	4.27E+00	km	0.00E+00	1.77E−01	1.13E−01
	Others	Light oil	4.05E+00	L	1.11E+01	1.11E+01	1.11E+01
	6. Transport (wastes) (outward)	10 t truckload (loading ratio: 25%)	1.24E+00	tkm	3.90E−01	3.90E−01	3.90E−01
	6. Transport (wastes) (homeward)	10 t truckload (loading ratio: 0%)	5.00E+01	km	3.28E−01	3.28E−01	3.28E−01
	7. Disposal and ready for recycling (wastes)	Crush processing	2.49E−02	t	2.26E−01	2.26E−01	2.26E−01
	6. Transport (wastes) (outward)	10 t truckload (loading ratio: 25%)	4.44E−02	tkm	1.39E−02	1.39E−02	1.39E−02
	6. Transport (wastes) (homeward)	10 t truckload (loading ratio: 0%)	5.00E+01	km	1.17E−02	1.17E−02	1.17E−02
	7. Disposal and ready for recycling (wastes)	Incineration disposal	8.89E−04	t	2.97E−02	2.97E−02	2.97E−02
	6. Transport (wastes) (outward)	10 t truckload (Loading ratio: 25%)	8.63E−03	tkm	2.70E−03	2.70E−03	2.70E−03
	6. Transport (wastes) (homeward)	10 t truckload (Loading ratio: 0%)	5.00E+01	km	2.27E−03	2.27E−03	2.27E−03
	7. Disposal and ready for recycling (wastes)	Landfill disposal	1.73E−04	t	6.54E−03	6.54E−03	6.54E−03
	6. Transport (subproducts) (outward)	10 t truckload (Loading ratio: 62%)	1.52E+01	tkm	4.74E+00	4.74E+00	4.74E+00
	6. Transport (Subproducts) (homeward)	10 t truckload (Loading ratio: 0%)	5.00E+01	km	3.99E+00	3.99E+00	3.99E+00
	7. Disposal and ready for recycling subproducts)	Crush processing	1.42E−01	t	1.29E+00	1.29E+00	1.29E+00

Table 4 continued

Stage	Process	Active mass			CO_2 emission (kg-CO_2/m^3)		
		Entry	Quantity	Unit	Air drying	Kiln drying	Weighted mean
Intermediate total					7.69E+01	2.03E+02	1.60E+02
Distribution and sales	8. Transport (outward)	10 t truckload (Loading ratio: 62%)	4.08E+01	tkm	6.08E+00	6.08E+00	6.08E+00
	8. Transport (homeward)	10 t truckload (Loading ratio: 0%)	1.04E+02	km	4.34E+00	4.34E+00	4.34E+00
	9. Raw material production (submaterials)	Packing of polypropylene series	6.56E−02	kg	1.53E−01	1.53E−01	1.53E−01
	10. Transport (submaterials) (outward)	10 t truckload (Loading ratio: 62%)	3.28E−02	tkm	4.89E−03	4.89E−03	4.89E−03
	10. Transport (submaterials) (homeward)	10 t truckload (Loading ratio: 0 %)	5.00E+02	km	3.49E−03	3.49E−03	3.49E−03
	11. Precut processing	Electricity	7.58E+01	kW h	1.77E+01	1.77E+01	1.77E+01
	12. Transport (subm aterial wastes) (outward)	10 t truckload (Loading ratio: 25%)	3.14E−03	tkm	9.83E−04	9.83E−04	9.83E−04
	12. Transport (submaterial wastes) homeward)	10 t truckload (Loading ratio: 0%)	5.00E+01	km	8.28E−04	8.28E−04	8.28E−04
	13. Disposal and ready for recycling (submaterial wastes)	Crush processing	1.88E−05	t	1.71E−04	1.71E−04	1.71E−04
	13. Disposal and ready for recycling (submaterial wastes)	Incineration disposal	3.89E−05	t	1.24E−01	1.24E−01	1.24E−01
	13. Disposal and ready for recycling (submaterial wastes)	Landfill disposal	5.02E−06	t	1.90E−04	1.90E−04	1.90E−04
Intermediate total					2.84E+01	2.84E+01	2.84E+01
Use and maintenance control	–	–	–	–	0.00E + 00	0.00E + 00	0.00E + 00
Disposal and recycling	14. Transport (outward)	10 t truckload (Loading ratio: 25%)	1.95E+01	tkm	6.10E+00	6.10E+00	6.10E+00
	14. Transport (homeward)	10 t truckload (Loading ratio: 0%)	5.00E+01	km	5.14E+00	5.14E+00	5.14E+00
	15. Interim processing (separation, crushing)	Crush processing	3.90E−01	t	3.54E+00	3.54E+00	3.54E+00
	15. Transport (outward)	10 t truckload (Loading ratio: 25%)	6.96E−01	tkm	2.18E−01	2.18E−01	2.18E−01
	16. Transport (homeward)	10 t truckload (Loading ratio: 0%)	5.00E+01	km	1.84E−01	1.84E−01	1.84E−01
	17. Incineration	Incineration disposal	1.39E−02	t	4.65E−01	4.65E−01	4.65E−01
	18. Transport (outward)	10 t truckload (Loading ratio: 25%)	1.35E−01	tkm	4.23E−02	4.23E−02	4.23E−02
	18. Transport (homeward)	10 t truckload (Loading ratio: 0%)	5.00E+01	km	3.56E−02	3.56E−02	3.56E−02
	19. Landfill	Landfill disposal	2.70E−03	t	1.02E−01	1.02E−01	1.02E−01
	20. Transport (submaterial Wastes) (outward)	10 t truckload (Loading ratio: 25%)	6.56E+00	tkm	2.05E−03	2.05E−03	2.05E−03
	20. Transport (submaterial wastes) (homeward)	10 t truckload (Loading ratio: 0%)	5.00E+01	km	1.73E−03	1.73E−03	1.73E−03
	21. Disposal and ready for recycling (submaterial wastes)	Crush processing	3.93E−05	t	3.57E−04	3.57E−04	3.57E−04
	21. Disposal and ready for recycling (submaterial wastes)	Incineration disposal	8.13E−05	t	2.58E−01	2.58E−01	2.58E−01
	21. Disposal and ready for recycling (submaterial wastes)	Landfill disposal	1.05E−05	t	3.98E−04	3.98E−04	3.98E−04

Table 4 continued

Stage	Process	Active mass			CO_2 emission (kg-CO_2/m^3)		
		Entry	Quantity	Unit	Air drying	Kiln drying	Weighted mean
Intermediate total					1.61E+01	1.61E+01	1.61E+01
Total					1.58E+02	2.84E+02	2.41E+02

The numbers in the process columns correspond with those in Fig. 1

The level of CO_2 emissions generated in the process of distribution to Kyoto Prefecture was 2.4–2.6 times lower compared to other areas in Japan. The results show that the level of CO_2 emissions generated in the process of transportation significantly influenced the CFP.

In the following chapter, we compare the representative CFPs of "certified wood in Kyoto Prefecture" and other products distributed in Japan, and examine the proportion of the CFPs in each process to the total CFP.

Results of comparison of the representative CFPs of "certified wood in Kyoto Prefecture" and other products distributed in Japan and discussion

Figure 4 shows the results. Of all kiln-dried lumber products, the CFP of products from North America was the smallest, 230 kg-CO_2/m^3. The CFP of products from Europe was almost similar to that of "certified wood in Kyoto Prefecture". Differences in the CFP of products from North America and Europe were mainly due to differences in the transport distance by ship.

There was a marked difference in the proportion of the CFPs in each process to the total CFP between "certified wood in Kyoto Prefecture" (kiln-dried products) and lumber products from Europe. CO_2 emissions from "certified wood in Kyoto Prefecture" (kiln-dried products) were mainly generated in at the production stage, particularly in the process of kiln drying. The CFP in the process of kiln drying accounted for approximately 38% of the total, whereas that in the process of transporting logs and products accounted for 6 and 4%, respectively.

On the other hand, in the case of products from Europe, the CFP in the process of transportation accounted for 50% of the total. Regarding the production stage, the CFP in the processes of lumbering, kiln drying and finishing accounted for 11, 7 and 3% of the total, respectively. Energy consumption volumes in the processes of lumbering and finishing of "certified wood in Kyoto Prefecture" and other products were based on Table 4. The differences in energy consumption were attributed to CO_2 emission factor from electricity. It is difficult for lumber mills and local governments to improve this point. Differences in the CFP in the process of kiln drying were caused by the kind of heat source. A shift from kerosene to woodchips is an improvement that can be made by lumber mills and local governments. In the following chapter, we examine and compare the CFPs in the process of kiln drying using different heat sources to develop a method for reducing the CFP of "certified wood in Kyoto Prefecture".

Results of comparison of the CFPs of "certified wood in Kyoto Prefecture" with different heat sources in the process of kiln drying and discussion

Figure 5 shows the results. The use of woodchips instead of kerosene as a heat source reduced the CFP of "certified wood in Kyoto Prefecture" (kiln-dried products) by 48%. The obtained value (202 kg-CO_2/m^3) is even smaller than the CFPs of lumber products from Europe and North America calculated in Sect. 3.3. The results showed that the use of woodchips as a heat source in the process of kiln drying further enhanced the CFP-reducing effects of the "local production for local consumption" approach.

On the other hand, the CFP of lumber products that did not undergo the process of kiln drying was 158 kg-CO_2/m^3 (Fig. 4), the lowest of all products. The establishment of a system to ensure the stable supply of air-dried products to the market is another theme for CFP reduction in "the system for the certification of wood from Kyoto".

Conclusion

In this study, we calculated the mean CFP of lumber products produced from "certified wood in Kyoto Prefecture" by mills, the subjects of the previous report [1], and adopted it as the representative CFP value of "local production for local consumption-based" lumber products in Kyoto. We then compared the representative value to the CFPs of other products distributed throughout Japan to examine the CFP-reducing effects of a "local production for local consumption" approach.

The results were as follows:

1. The representative CFP value of "certified wood in Kyoto Prefecture" was calculated to be 241 kg-CO_2/

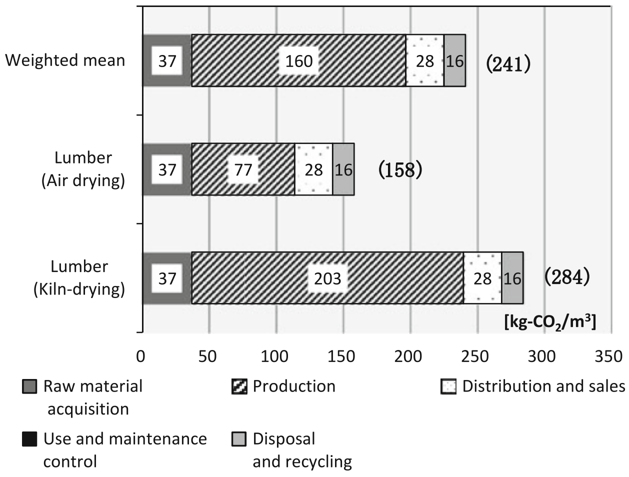
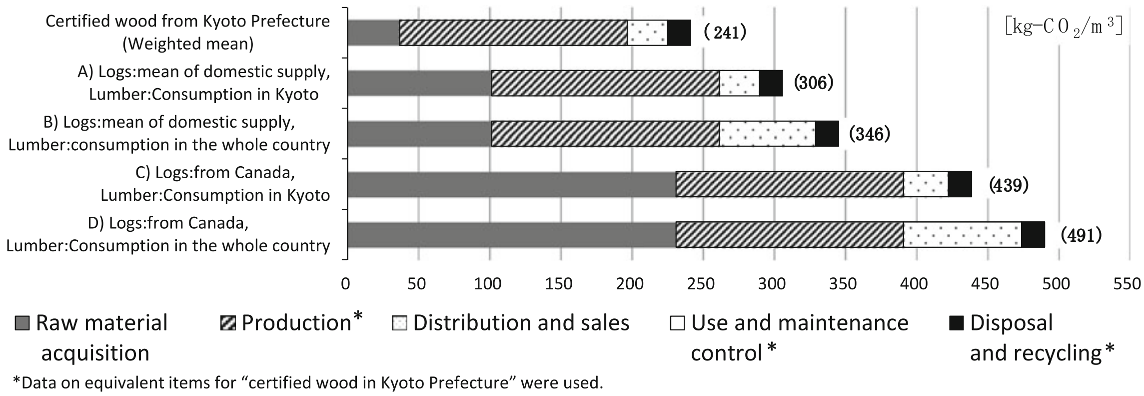


Fig. 2 CFP of "certified wood in Kyoto Prefecture"

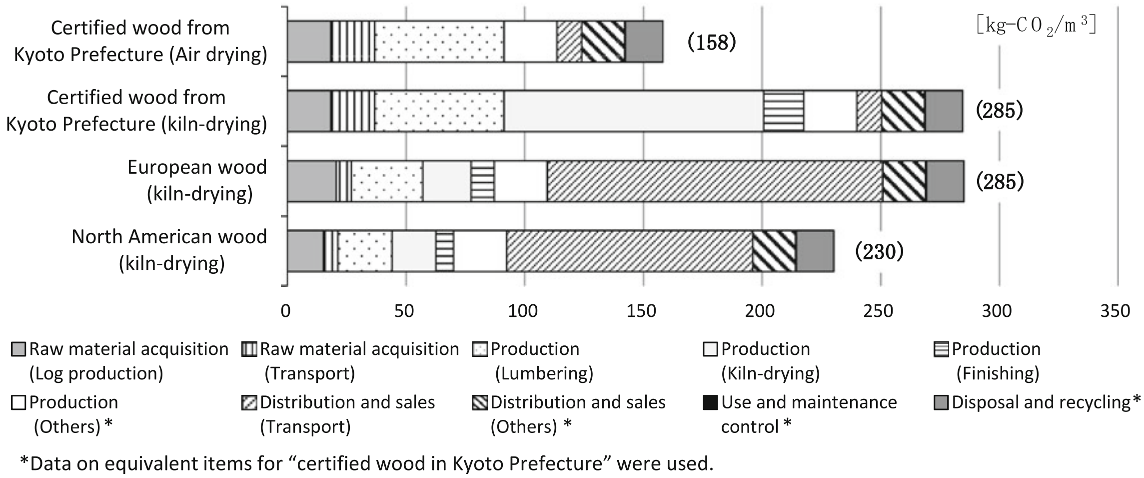
m^3.The CFP value was 158 kg-CO$_2$/m^3 when wood was not kiln dried and final processing was not involved, whereas that of "kiln-dried, finished wood" was 284 kg-CO$_2$/m^3.

2. To examine the effects of CO$_2$ emissions generated in the process of transportation on CFP reduction, we selected patterns of trading (combinations of producing and consuming areas) at mills usually involved in the processing of "certified wood in Kyoto Prefecture". The CFP was the highest, 491 kg-CO$_2$/m^3, when "products made from North America were shipped for domestic consumption". Based on the mean transport distance required to ship logs for the domestic production of lumber products and to ship products to markets throughout the country, we calculated the CFP in a representative example of distribution and obtained the value of 346 kg-CO$_2$/m^3. As the representative CFP value of "certified wood in Kyoto



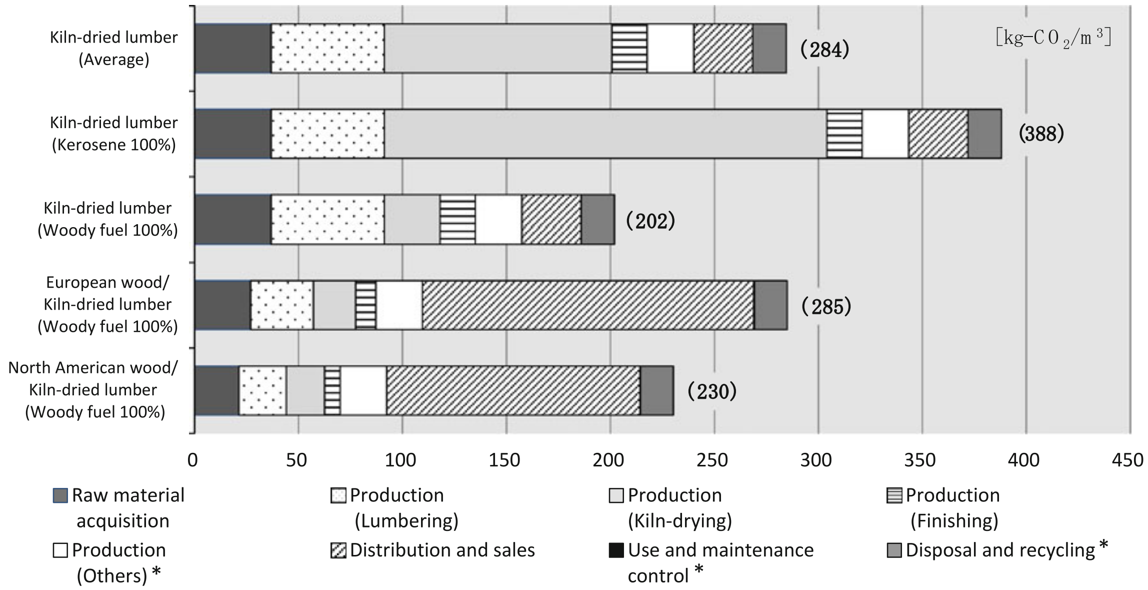
*Data on equivalent items for "certified wood in Kyoto Prefecture" were used.

Fig. 3 Effect of the difference in the transport process of logs and products on CFP



*Data on equivalent items for "certified wood in Kyoto Prefecture" were used.

Fig. 4 Comparison of CFP of "certified wood in Kyoto Prefecture" with the product sawed up at overseas



*Data on equivalent items for “certified wood in Kyoto Prefecture” were used.

Fig. 5 CFP of the kiln-dried lumber (according to heat source of the kiln-dried process)

Prefecture” was 241 kg-CO_2/m^3, “local production for local consumption” reduced the CFP by 50 and 30% when compared with the cases of “North American wood for domestic consumption” and “logs distributed in Japan”, respectively.

3. We calculated the CFPs of typical overseas lumber products distributed in Japan. The CFPs of (kiln-dried) products from North America and Europe were 230 and 285 kg-CO_2/m^3, respectively. In these two cases, different from the trading of “certified wood in Kyoto Prefecture”, CO_2 emissions produced in the process of transportation accounted for the highest proportion of the total, whereas the level of CO_2 emissions generated in the process of production was small. The CFPs of lumber products from North America and Europe were lower than that of kiln-dried products using “certified wood in Kyoto Prefecture”. This means that a “local production for local consumption” approaches alone did not provide “certified wood in Kyoto Prefecture” with a competitive advantage regarding CFP reduction.
4. If only woodchips were used as a heat source in the process of kiln drying, the CFP of “certified wood in Kyoto Prefecture” would be 202 kg-CO_2/m^3, markedly lower than that of other products. A combination of “local production for local consumption” and the use of woodchips as a heat source would provide a product with a competitive advantage.

A “local production for local consumption” approach and the use of woodchips as a heat source in the process of kiln drying enhanced the superiority of lumber products regarding CFP reduction. However, we could not conduct the comparison of work efficiency by the difference in the scale between mills in Japan and other countries, as data on the process of producing overseas lumber products were unavailable. We consider this point as our future challenge.

References

1. Fuchigami Y, Kojiro K and Furuta Y (2012) Effect of the difference in the process of lumber locally produced for local consumption on carbon footprint of products. Mokuzai Gakkaishi (in press) (in Japanese)
2. Komata H, Ishikawa Y, Kato K (2010) Estimation of CO_2 emissions in production and transportation process of domestic and foreign wood building materials. In: Proceedings of the 5th Meeting of The Institute of Life Cycle Assessment, Japan, pp 368–369 (in Japanese)
3. Nanbu Y, Ikaga T, Oshiro K, Otsu Y, Kawakubo S, Okumura K (2010) Inventory analysis of local lumber on each stage of forestry, manufacturing and distribution. In: proceedings of the 5th Meeting of The Institute of Life Cycle Assessment, Japan, pp 62–63 (in Japanese)
4. CFP Pilot Project Secretariat, Japan Environmental Management Association for Industry (JEMAI) (2009) Carbon Footprint of Products. http://www.cfp-japan.jp/english/pcr/pdf/55-I_PCR_PA-CC-01.pdf. Accessed 20 July 2011
5. CFP Pilot Project Secretariat, Japan Environmental Management Association for Industry (JEMAI) (2009) Carbon Footprint of Products. http://www.cfp-japan.jp/english/. Accessed 20 July 2011
6. Kyoto Prefecture (2005) A system for the certification of wood from Kyoto (in Japanese). http://www.pref.kyoto.jp/rinmu/14100081.html. Accessed 20 July 2011
7. Japan External Trade Organization (JETRO) (2011) http://www.jetro.go.jp/cgi-bin/nats/cgi-bin/top.cgi?PGID=000&REP_CNT=0. Accessed 20 Dec 2011

8. Forestry Agency (2010) Sinrin-Ringyo hakusyo for the 2010 edition (in Japanese)
9. The Woodmiles Forum (2011) http://woodmiles.net/cgi-2008/cgi-manual/data/upfile/6-1.pdf. Accessed 20 July 2011
10. Leonard R. Johnson, Bruce Lippke, John D. Marshall, Jeffrey Comnick (2005) Life-cycle impacts of forest resource activities in the pacific northwest and southeast united states. Wood and Fiber Science, 37 Corrim Special Issue, pp 30–46
11. Timo Karjalainen, Bernhard Zimmer, Staffan Berg, Johannes Welling, Hannes Schwaiger, Leena Finer, Patricia Cortijo (2001) Energy, carbon and other material flows in the life cycle assessment of forestry and forest products. European Forest Institute, Discussion Paper 10
12. The Institute of Energy Economics, Japan (2005) http://www.meti.go.jp/policy/global_environment/report/chapter1.pdf. Accessed August 20, 2011 (in Japanese)
13. The Federation of Electric Power Companies of Japan (2008) The collection of reference data (in Japanese). http://www.kantei.go.jp/jp/singi/tikyuu/kaisai/dai03/03siryou3_2.pdf. Accessed 20 Aug 2011