Material flow and stock analysis and LCI analysis on forest products in Japan

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Introduction

Discussions on reducing greenhouse gas (GHG) emissions for the period after the first commitment period of the Kyoto Protocol expired at the end of 2012 will be concluded until the end of 2009. One of the possible GHG accounting systems is full carbon accounting (FCA), which means complete accounting of stock changes in all carbon pools related to a given set of landscape units in a given time period. In this accounting system, behavior of forest products which contain large amount of carbon might be carefully estimated. Material flow analysis (MFA) is a powerful tool to grasp the current situation of forest products. From viewpoint of CO_2 emissions, energy consumed in processing forest resources should be considered by LCI analysis as well. In this study, material flow and CO_2 emissions associated with the life cycle of forest products in Japan were investigated.

Material flow and stock of forest products

First, material flows and stocks of wood products in Japan were analyzed, in which intermediates (lumber, laminated wood and lumber, wooden board, wood chip, and pulp) and final products (buildings, construction, furniture and fixtures, pallet, and paper) were taken into account. Material flow of Japanese forest resources was investigated as shown in Fig.1. Material stock was estimated from time-series consumption data by using population balance model (PBM) which is often referred as a dynamic approach or a top-down approach. In the stock estimation by using PBM, stocks in buildings and paper were taken into account. Buildings were classified into twelve categories by construction type; wooden, steel-reinforced concrete, reinforced concrete, steel-frame, concrete block, and others, and by use application; dwellings and nonresidential buildings. Japanese carbon stock as in-use products was shown in Fig.2 from 1980-2003. The amount of carbon stock in buildings in Japan was estimated as 450 million t-C, which is larger than the total Japanese emissions of CO_2 in the year 2005, 350 million t-C.

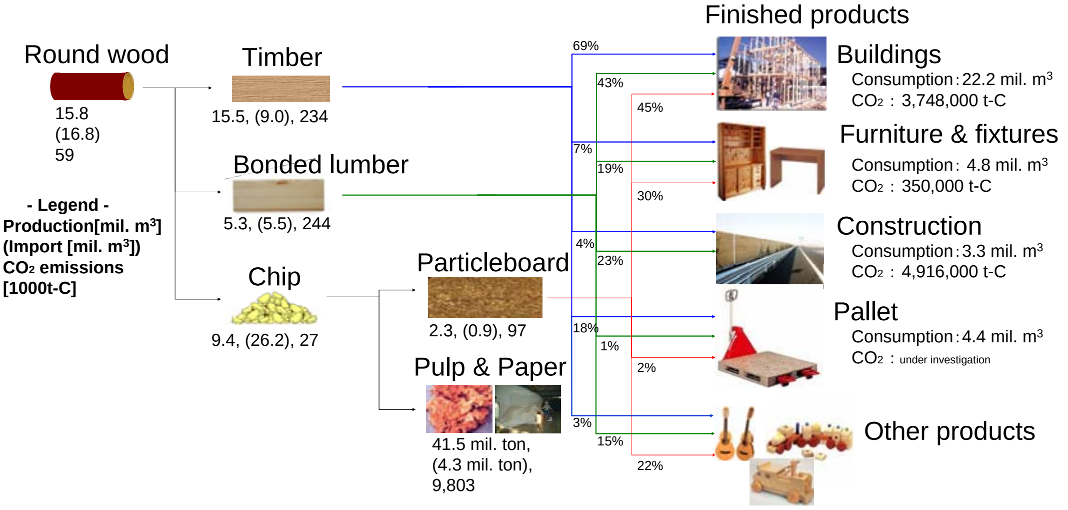

Figure 1: Material flow of Japanese forest resources in 2000.

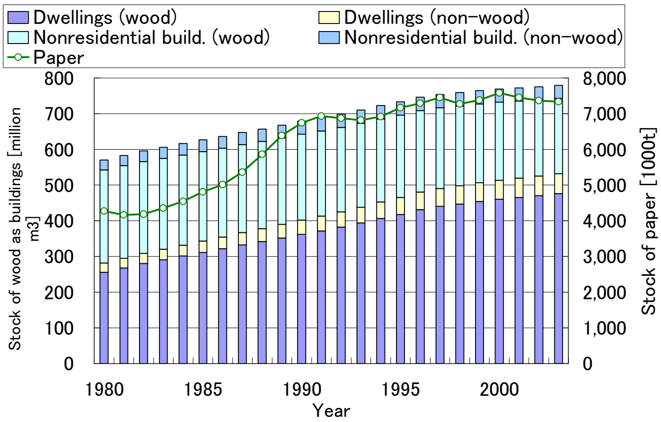

Figure 2: Carbon stock of in-use products in Japan from 1980 to 2003.

LCI analysis on forest products

Second, the energy consumptions were quantified for every process associated with the life cycle of forest products. The energy consumptions in major industries were obtained from official statistics, and those in other processes were estimated by using data on Japanese Economic input-output tables. Flow chart of our estimation procedure was shown in Fig.3. CO_2 emissions were calculated based on the energy consumption. Estimated energy consumption by fuel in each sector was shown in table 1. In actual, the emissions in the processes of buildings and construction were mainly caused by other materials than forest resources. Therefore, the CO_2 emissions in the processes were allocated by masses or prices of consumed materials. In the Fig.1, the amounts of CO_2 emissions before allocation were shown. After the allocation, share of CO_2 emissions by sector was shown in Fig.4. It was found that 51% of CO_2 emissions in production of forest products were attributable to paper and pulp production in the year 2000, followed by construction, 25%, and buildings, 14%. The share of furniture production, timber production, and chip board production were relatively small.

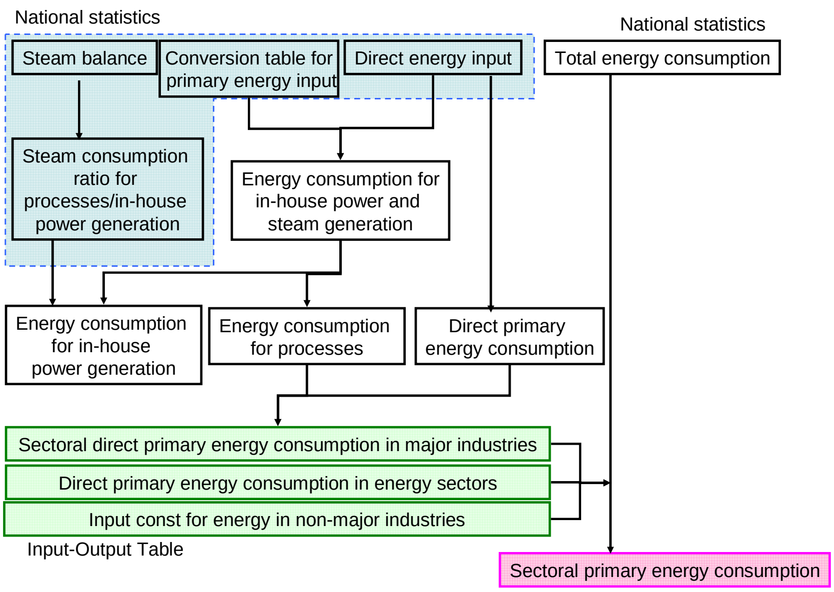

Figure 3: Flow chart of procedure to estimate energy consumption in each sector.

Table 1: Estimated energy consumption by fuel in 2000.

	Gasoline	Kerosene	Diesel	Bunker A	Bunker B and C	LPG	Natural gas	Electricity	
Unit	kl	kl	kl	kl	kl	t	1000m3	1000kWh	
Coefficient of CO2 emissions [t-C/Unit]	0.663	0.712	0.750	0.774	0.853	0.858	0.602	0.159	Total [t-C]
Round wood	361	7,059	48,109	1,696	0	2,537	11	89,231	58,982
Timber	1,061	17,924	14,123	17,087	0	274	109	1,241,361	234,429
Bonded lumber	431	7,297	13,339	28,044	23,165	1,063	22	1,176,205	244,392
Chip	804	40	3,508	0	0	0	0	151,523	27,219
Furniture	280	16,259	3,569	35,001	2,251	1,611	3,635	1,358,427	262,434
Fixtures	0	4,759	1,215	0	1,251	8,329	755	470,590	87,588
Dwellings (wood)	12,157	105,443	35,801	29,435	400	1,165	69,959	2,960,472	645,701
Dwellings (non-wood)	34,920	159,731	77,586	113,828	1,351	2,057	131,970	3,308,089	890,172
Nonresidential build. (wood)	1,142	5,948	3,000	2,174	50	103	3,941	188,665	41,347
Nonresidential build. (non-wood)	48,277	271,400	118,633	216,265	3,953	3,531	84,126	4,108,126	1,190,146
Maintenance of buildings	43,871	135,462	104,233	239,831	6,104	3,565	93,629	3,322,587	980,910
Construction	180,869	171,668	2,721,629	316,484	83,704	3,599	144,758	14,040,179	4,915,990
Pulp and paper	284	137,800	1,671	435,130	4,247,296	48,628	1,148,125	8,711,587	9,802,794

Other fuels; i.e. crude oil, jet fuel, naphtha, oil coke, coke, and LNG, were taken into account as well.

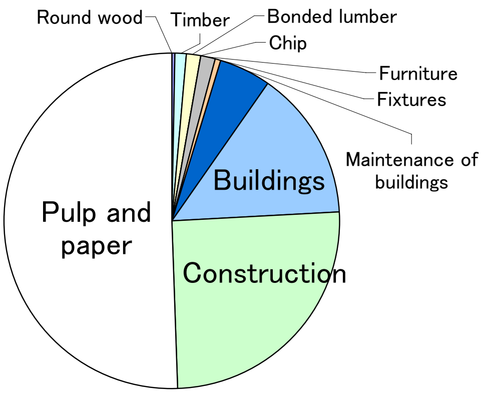

Figure 4: CO2 emissions associated with supply chain of wooden products in 2000.

Substitution effect of forest products

Finally, substitution effect of forest products on CO_2 emissions was estimated. One of major end uses of the forest products is buildings. We assumed that 10 % of non-wooden dwelling; e.g., steel framed dwelling, reinforced concrete dwelling, and etc., was substituted by wooden dwelling based on the floor area. General equilibrium model was applied for the estimation with Japanese Economic input-output table which has five sectors related to buildings; residential construction (wooden), residential construction (non-wooden), non-residential construction (wooden), non-residential construction (non-wooden), and repair of construction. We estimated the change of production associated with increase of residential construction (wooden) and decrease of residential construction (non-wooden). Furthermore, a ripple effect caused by the change of incomes in the two sectors was also estimated. The total of the substitution effect results in reduction of about 250 thousand tons of CO_2 emissions. The effect by each sector was shown in Fig.8.

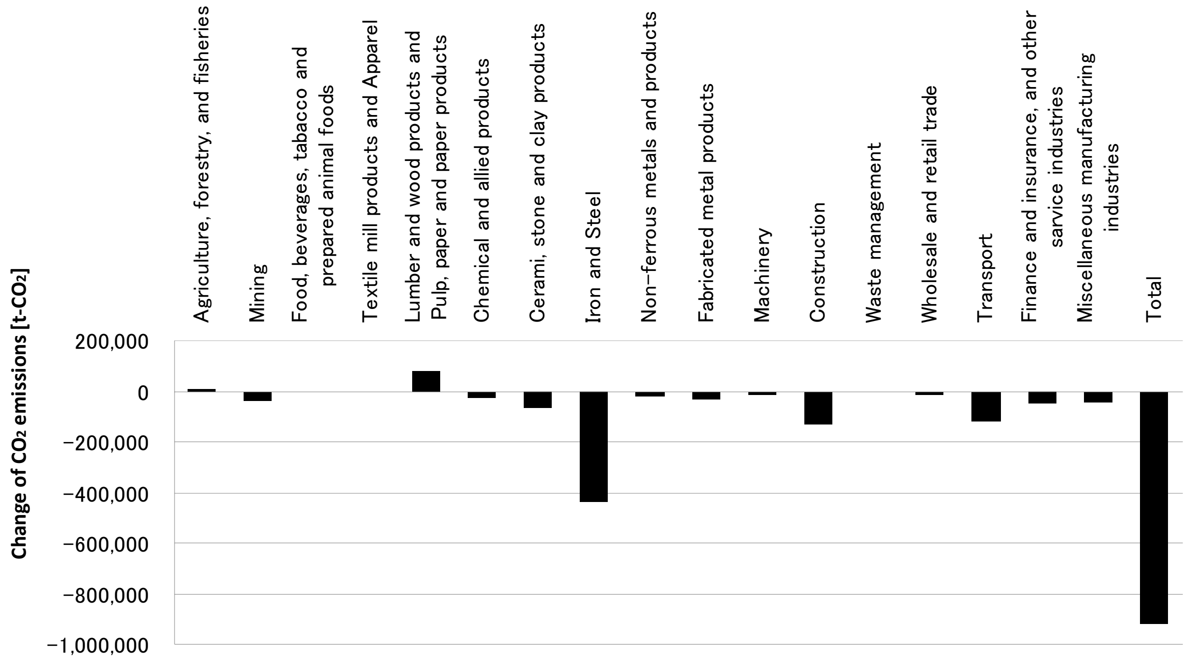

Figure 8: The substitution effect of CO_2 emissions by each sector in the year 2000.

Conclusions

In order to minimize carbon emissions associated with forest resources based on full carbon accounting system, fundamental information was prepared in this study. Material flow and stock of wood products was analyzed. Energy consumptions and CO_2 emissions were quantified for every process associated with material flow of wood products. CO2 emissions for a waste management processes; feedstock recycling in blast furnaces, were analyzed with Rist model and matrix approach. Furthermore, substitution effects of forest products were estimated.

References

[1] Carles M. Gasol & Ramon Farreny & Xavier Gabarrell & Joan Rieradevall, 2008: Life cycle assessment comparison among different reuse intensities for industrial wooden containers. Int J Life Cycle Assess 13: 421–431