Title:

Biomass Resources Present in Japan

-Annual quantities grown, unused and wasted-

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Abstract

Based on the recent statistical data available in the literature, detailed survey on the virgin biomass resources and their residual (unused and wasted) portions was made in their quantities and available masses. In addition, a biomass flow in Japan was proposed. Total quantity produced and available mass were estimated to be about 360 and 76 Mt, respectively, in Japan in 1999. The latter value is equivalent to 125 Mt of carbon dioxide. This is an enormous quantity, which corresponds to about 11% of the carbon dioxide emitted in 1990 in Japan. The result shows that a large amount of biomass resources, which is a sufficient quantity for the target of the 6% reduction for carbon dioxide emission ratified in the Kyoto Protocol of the Third Conference of the Parties (COP3), are disposed without using effectively.

Keywords:

Biomass resources, Kyoto Protocol, Carbon dioxide

1. Introduction

Due to excessive use of fossil resources in the 20th century, environmental issues such as global warming and acid rain became increasingly serious in the world. Moreover, fossil resources are definitely exhaustible in the future. For such environmental situations, biomass resources, which are renewable, carbon-neutral, remarkably low-sulfur and remarkably massive in amount on the earth, will be more important as an alternative of fossil resources. However, enormous amount of biomass resources such as wood from thinning, sawdust, waste paper and others are disposed without effective utilization. Therefore, the utilization of these unused and wasted biomass resources for energy and chemicals is expected to contribute to solving our energy and environmental problems.

In Japan, fossil resources are scarce but forest resources are plentiful. The land area is about 37 Mha in Japan of which forestland occupies about two third (25 Mha) [1]. For sustainable development of our society in the future, it is important to utilize efficiently these forest resources. However, it is quite difficult to utilize all of them because a large part of them is present in deep mountains. It is, therefore, absolutely essential that not only such virgin resources but also their residues (unused and wasted resources) should be considered as valuable

resources. Under such situations in Japan, it is important to comprehend quantities of biomass resources annually produced and available masses.

However, only few studies have been made on the quantity of biomass available in our country. For example, Harada estimated the available mass of wood-based resources to be 42.7 Mt per year in Japan with excluding crop-, livestock- and fish-based resources [2]. The New Energy Foundation of Japan (NEF) estimated the amount of biomass-based wastes such as rice hull, rice straw, waste wood, kitchen garbage and others in their available masses and caloric values, but virgin biomass resources were not mentioned [3]. These studies are not satisfactory to understand the present situation of the biomass resources in Japan. Therefore, in this study, a detailed survey on virgin biomass resources and their residual portions (including unused agricultural, woody and industrial wastes) was made in their quantities and available masses to clarify the potential of total biomass in Japan, based on recent statistical data available in literature.

2. Estimation procedures

2.1 Scheme of the estimation

Biomass resources were classified as shown in Figure 1 where the quantity annually produced and available mass of each biomass resource were

estimated in Japan. In this figure, “Virgin resources” refers to resources primarily grown by the photosynthesis such as wood and crops, whereas “Residues” refers to resources which are generated from biomass-based materials used in our life, such as waste paper and municipal refuse, and those unutilized effectively, such as leftover treetop/branch and wood from thinning. In the quantity annually produced (M_{quantity}) of biomass, available mass ($M_{\text{available}}$) was defined by the following equation:

$$M_{\text{available}} = M_{\text{quantity}} - M_{\text{utilized}} \left(- M_{\text{uncollectable}}\right)$$

where M_{utilized} is the utilized mass and $M_{\text{uncollectable}}$ is the economically uncollectable mass. In this survey, therefore, phytoplanktons in hydrosphere were excluded. The detail information about estimation procedures is shown in the references [4, 5].

2.2 Estimations for the “Virgin resources”

2.2.1 Sugar and starch crops

Sugar crops such as sugar cane, sugar beet and sweat sorghum can be converted to ethanol by fermentation. Therefore, these resources are expected to

be energy crops. Table 1 shows harvested areas, yields and productions of various crops in Japan in 1999 from the statistical database of Food and Agriculture Organization of the United Nations (FAO) [6]. Productions of sugar cane and sugar beet were reported to be 1.57 Mt and 3.79 Mt, respectively. In addition, yields of them were higher than those of other crops. However, they were all effectively used for foodstuff, except for their leftover residues, so that their available masses were estimated to be null.

Starch resources such as rice, potatoes and maize can be also converted to ethanol by fermentation via saccharification by acid or enzymatic hydrolysis. These productions were reported to be 11.47 Mt for rice, 0.79 Mt for wheat, 2.96 Mt for potato, 1.01 Mt for sweet potato, 0.52 Mt for taro/yams and 4.80 Mt for maize, respectively, as shown in Table 1. Although yields of starch resources were relatively lower compared with those of sugar crops, but larger harvested areas of them resulted in larger quantity than those of sugar crops, especially for rice. All of them were also used for foodstuff so that their available masses were considered to be null.

2.2.2 Oil and fat crops

Vegetable oils composing mainly of triglycerides are high in calorific

value and can be converted to biodiesel fuel by its transesterification with methanol [7, 8]. Domestic productions of rapeseed, groundnuts and soybean, which could be raw materials of vegetable oil, were reported to be 87 t, 26.4 kt and 187.2 kt, respectively, which are small in amount compared with other crops. On the other hand, domestic demand of oils and fats in Japan was reported to be 2.92 Mt in 1999 [9], a large part of which was imported. Their available masses were estimated to be null, as in other crops.

2.2.3 Forest resources

Forest resources including hardwood, softwood, bamboo and sasa (like a small bamboo) contain abundant cellulose, which can be converted to ethanol by acid or enzymatic hydrolysis and subsequent fermentation. Table 2 shows a scheme of the estimation for woody plant. According to the statistic of the Forest Agency of Japan [1, 10], the quantity of standing wood in the forest was 3,138 Mm^3 in 1990 and increased about 346 Mm^3 in 5 years. Therefore, annual accumulation of wood to the forest was estimated to be 346/5 = 69 Mm^3 corresponding to about 35 Mt. In addition to this value, 170 Mm^3 of standing wood, which consists of about 100 Mm^3 of roundwood, 36 Mm^3 of leftover treetop/branch (36% of roundwood) and 34 Mm^3 of wood from thinning, was

harvested for forestry products in this period (mentioned in section 2.3.1). Therefore, as shown in Table 2, the quantity of wood annually grown was estimated to be 103 Mm^3 corresponding to about 52 Mt. In the 35 Mt of accumulated wood, about 3 Mt of wood economically available were found, assuming that woody resources present within 500 m from a forest road could be collected economically [4]. However, in the peak production years around 1965, about 55 Mm^3 of roundwood was produced for a year in Japan [11]. Therefore, adding 19.8 Mm^3 of sequent leftovers (36% of roundwood) to this value, about 74.8 Mm^3 of woody biomass are expected to be available for a year. Subtracting 170/5 Mm^3 of already lumbered wood (as mentioned above) from this value, 40.8 Mm^3 of wood, corresponding to about 20.4 Mt, was considered available. After all, according to these lines of estimation, the quantity of wood annually grown is about 52 Mt, in which the available mass is about 3 Mt to 20.4 Mt for a year.

On bamboo and sasa, they are also plentiful resources in Japan but not used effectively. About one hundred species of bamboo (e.g., *Phyllostachys nigra*, *Phyllostachys bambusoides*, *Phyllostachys heterocycla*) and sasa (e.g., *Sasa veitchii*, *Sasa palmate*, *Sasa kurilensis*) exist in Japan. The net primary productivity of bamboo is about 22 t/ha/year [12] whose value is relatively high. Therefore, about 3.3 Mt of bamboo was grown because the area of bamboo grove

was reported to be 1.5 Mha in 1995 [1]. In case of sasa, 6.07 Mt of primary growth was reported in 1991 [13]. However, their available masses remained unclear.

2.3 Estimation for the “Residues”

2.3.1 Wood residues

Residues from wood harvest (leftover treetop, branch, leaf and others) are generated as a result of felling and thinning, and they are left over in the forest without effective utilization. Table 3 shows a result of the estimation for the quantity of leftover treetop/branch, etc [4, 14]. 7.26 Mm^3 of leftovers was found, the value of which is corresponding to about 3.63 Mt. In addition, assuming that the leftovers are equivalent in price to wood chip for pulping, about 800 kt of them was economically available [4].

On the other hand, according to a statistic data of the Forest Agency of Japan [15], the quantity of wood from thinning was 6.89 Mm^3 in 1997, corresponding to about 3.45 Mt. In addition, about 43% of the thinned wood was utilized as roundwood, sawlogs and other materials. Therefore, a remaining of about 1.97 Mt in the thinned wood can be considered available. At present, however, the thinning has not been sufficiently carried out in the forest. If

sufficient thinning is carried out in the future, the available mass of thinned wood is expected to increase further.

Wood residues from factories such as sawdust, planar dust, bark and others are generated as a result of wood processing. It was reported that 111 Mm^3 of wood supply resulted in about 29 Mm^3 of the wood residues, half of which was from sawmill factories in 1971 [16]. The domestic supply of wood in 1998 was 94 Mm^3 in Japan [1], therefore, it was expected that wood residues generated were about $29 \times 94/111 = 25$ Mm^3, corresponding to 12.5 Mt. In case of sawmill factories, however, 93% of the residues were utilized effectively as solid fuels, woodchips and other agricultural applications [17]. Applying this ratio to all kinds of factory, about 0.88 Mt of wood residues was estimated to be available. Furthermore, an addition of 1.28 Mt of the residues utilized as fuels [17] to unutilized one makes 2.16 Mt of available wood residues for energy use [4].

Construction and demolition of building produce many kinds of wood residues referred to as construction residues. Table 4 shows a result of the estimation for the quantity calculated from floor spaces of construction and demolition in 1999 [18, 19]. It was found that 6.53 Mm^3 (3.27 Mt) of residues was generated from construction and demolition sites. On the other hand, according to a survey by Ministry of Construction of Japan in 1995 [20], 6.32 Mt of

construction residues was generated and about 37% of it was used effectively. Assuming that this ratio was equal to that in 1999, about 2.06 Mt of construction residues was considered available. At present, however, significant part of them is a mixture of wood, soil, roof tile and so on due to the demolition by heavy machinery. Therefore, separation of woody resources from other mixtures is considered as a key for utilization of the construction residues.

The quantity of waste paper was estimated based on the amount of paper production in 1999, which was 30.6 Mt, and 55.9% of waste paper was recycled as a raw material of paper [21]. However, all of remaining 44.1% was not available, because about 35% of paper productions was considered to be in sanitary use, construction materials and book stock, which could not be collected. Therefore, the available mass of waste paper was estimated to be about 30.6 × (100% - 55.9% - 35%) = 2.8 Mt.

2.3.2 Agricultural residues

Rice straw and rice hull are generated as by-products of rice cultivation. Table 5 shows quantities of the rice straw and hull and their applications in 1999 [22]. A large part of them was utilized for plowing back, compost, roughage and other agricultural uses, as shown in Table 5, therefore, remaining 465 kt and 572

kt of rice straw and hull wasted, were available, respectively.

Table 6 shows the quantities of other agricultural residues from crop harvest estimated based on their crop productions [6, 23]. 867 kt of wheat straw was produced as shown in Table 6 and 62.5% of them was plowed back or used as compost [24]. Therefore, a remaining of 37.5% (about 330 kt) was estimated to be available mass. However, available masses of other residues such as bagasse remained unclear.

2.3.3. Waste oil and fat

Waste oils/fats were generated from household, restaurant and industrial sectors. Table 7 shows a result of the estimation based on the amount of oils/fats supply [9] in Japan. 124~261 kt of waste oil/fat was from household and a large part of it was wasted with other municipal refuses. On the other hand, about 300 kt of wastes was found from restaurant and industrial sector and it was collected mainly by special collection traders. Actually, 240 kt of the wastes was collected and 86.5% of it (208 kt) was recycled for agricultural or industrial uses in 1993 [25]. Therefore, available mass of the waste oil/fat from restaurant and industrial sections was estimated to be about 300 × (100% - 86.5%) = 41 kt in 1999. However, the available mass of the wastes from household remained unclear.

2.3.4 Municipal refuses

In recent years, total annual quantity of the municipal refuse was reported to be about 50 Mt [26]. Based on the survey in various cities, depending on the location, proportions of waste paper, kitchen garbage and waste woods to the total municipal refuse were estimated to be 44%, 22% and 8%, respectively [4]. Therefore, the quantities of biomass resources in the municipal refuse were estimated to be 23 Mt for waste paper, 11 Mt for garbage and 4 Mt for waste woods. Although a part of them was consumed for waste power generation plants, whose capacity was 829 MW in total in 1999 [27], the available mass of the municipal refuse remained unclear.

3. Biomass resources present in Japan

Table 8 shows the quantities annually produced and available masses of the biomass resources in Japan estimated in this study. Furthermore, the biomass flow in Japan was proposed as shown in Figure 2, which was designed with the trade relations with abroad, based on the Table 8 and FAO statistical databases, etc [6, 28, 29].

In case of virgin resources, the total quantity annually produced was

estimated to be about 140 Mt in which the available mass, which was not used effectively, was 30 Mt. Although about 77 Mt of crops was produced, they were all effectively used so that its available mass was estimated to be null. For wood, 52 Mt was found. However, this value is rather small for the forest area in our country reported to be about 25 Mha [1]. By a simple calculation, it results in about 1 t of carbon per hectare (c-t/ha) for the annual carbon fixation, lower than the mean value of the temperate region, which is 6~7 c-t/ha (13 biomass t/ha [30]). This originates from the fact that over 50 years have already passed since plantation was afforested in our country after the Second World War; therefore, the photosynthetic activity of the forest has been decreased. Furthermore, the thinning of wood has not been sufficiently carried out in the forest. For the reduction of the carbon dioxide emission, therefore, an appropriate forest management with an adequate husbandry and long-range planning is necessary.

Turning our attention to the wood trade, about 80% of domestic demand is supplied from abroad, as shown in Figure 2, though a sufficient amount of wood (52 Mt) is grown to fulfill our demand. Until 45 years ago, actually, more than 90% of self-sufficient rate for wood had been kept. However, low-priced imported timbers resulted in a consecutive decrease of domestic production and obsolescence of rural forestry sector. For the efficient utilization of our forest

resources, therefore, a redevelopment of rural forestry should be necessary as part of the policy.

On the other hand, in case of the residues of biomass, the total quantities annually generated and available mass were estimated to be about 220 Mt and 46 Mt, respectively, whose values are larger than those of virgin resources. This large amount of residue is due to the amount of biomass imported (Figure 2). The quantities of wood, livestock and non-industrial residues were comparatively large in their proportions. However, most resources from livestock section are recycled mainly in the breeding farm. Therefore, actually, its available mass is small. Besides, the resources from wood and non-industrial section are not used effectively. Therefore, their available masses are estimated to be comparatively larger than that of other sections.

Based on these results, the total quantity and available mass were estimated to be about 360 Mt and 76 Mt, respectively. The latter value is, in fact, equivalent to 125 Mt in carbon dioxide weight. This is an enormous quantity, which corresponds to about 11% of the carbon dioxide emitted in Japan in 1990. It shows that a large amount of biomass resources, which is a sufficient quantity for the target of the 6% reduction for carbon dioxide emission agreed in the Kyoto Protocol of the Third Conference of the Parties (COP3), are disposed without

using effectively. Therefore, the biomass conversion technology for utilization of these resources effectively is important for environmental problems as well as energy in the future.

4. Summary

A detailed survey on virgin biomass resources and their residual portions was made in their quantity and available masses based on recent statistical data. As a result, the total quantity annually produced and available mass were estimated to be about 360 Mt and 76 Mt, respectively. The latter value corresponds to about 11% of the carbon dioxide emitted in 1990 in Japan. Therefore, the utilization of these biomass resources available in Japan for energy and materials as alternatives of fossil resources contributes to reducing our carbon dioxide emission and to mitigating our environmental and energy problems.

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(*Note*: W, wooden construction; SRC, steel reinforced concrete; RC, reinforced concrete; S, steel structure; *a, Data from reference [18]; CF, conversion factor of the residues from the floor space [19])

Table 5. Quantity of the rice straw and rice hull generated in Japan in 1999 [22].

Table 6. Quantity of the agricultural residues derived from wheat, sugar cane, potatoes and maize in Japan in 1999.

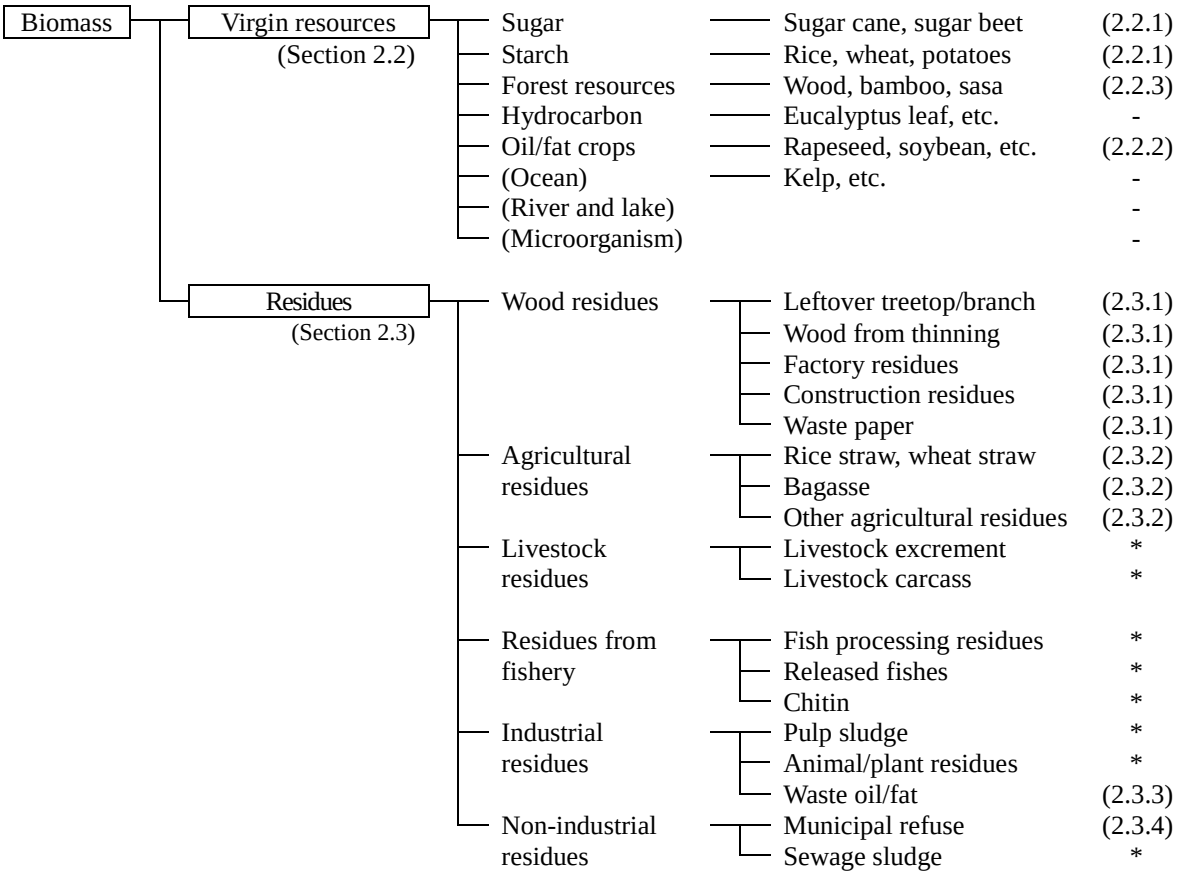
(*Note*: CF, Conversion factor of the agricultural residues from the crop production [23]; *a, See Table 1)

Table 7. Quantity of the waste oil/fat generated in Japan in 1999.

(*Note*: *a, Data from reference [9]; CF, conversion factor of the wastes from (1) number of the population, and (2,3) oil supply [25]; *b, Estimated assuming that the population of Japan is about 130,000,000)

Table 8. The quantities annually produced and available masses of the biomass resources in Japan. a (Mt/year)

(*Note*: *a: Updated version of the previous study [4], *b: Dry mass equivalent, *c: The value of M_{quantity} is overlapped with waste paper. *d: Absolute dry mass)


Biomass
Virgin resources
(Section 2.2)
Sugar
Starch
Forest resources
Hydrocarbon
Oil/fat crops
(Ocean)
(River and lake)
(Microorganism)
Sugar cane, sugar beet (2.2.1)
Rice, wheat, potatoes (2.2.1)
Wood, bamboo, sasa (2.2.3)
Eucalyptus leaf, etc. -
Rapeseed, soybean, etc. (2.2.2)
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-
-
Residues
(Section 2.3)
Wood residues
Agricultural residues
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Residues from fishery
Industrial residues
Non-industrial residues
Leftover treetop/branch (2.3.1)
Wood from thinning (2.3.1)
Factory residues (2.3.1)
Construction residues (2.3.1)
Waste paper (2.3.1)
Rice straw, wheat straw (2.3.2)
Bagasse (2.3.2)
Other agricultural residues (2.3.2)
Livestock excrement *
Livestock carcass *
Fish processing residues *
Released fishes *
Chitin *
Pulp sludge *
Animal/plant residues *
Waste oil/fat (2.3.3)
Municipal refuse (2.3.4)
Sewage sludge *

Figure 1

Table 1. Harvested areas, yields and productions of various crops in Japan in 1999 [6].

Items		Harvested area (ha)	Yield (t/ha)	Production (Mt)
Sugar crops	Sugar cane	22,800	68.9	1.571
	Sugar beet	70,000	54.1	3.787
Starch crops	Rice	1,788,000	6.4	11.469
	Wheat [a]	220,700	-	0.788
	Potato	97,700	30.3	2.963
	Sweet potato	44,500	22.7	1.008
	Taro, yams, etc. [b]	34,700	-	0.516
	Maize for forage/silage	100,000	48.0	4.795
Oil crops	Rapeseed [c]	449	1.9	0.00087
	Groundnuts	11,300	2.3	0.026
	Soybean	108,200	1.7	0.187
Others	Pasture grasses [d]	820,100	-	31.154
	Fruits	-	-	4.250
	Vegetables	-	-	12.809
	Other crops	-	-	2.118

Note: Water-containing mass; *a, Including wheat and barley; *b, Including taro, yams and other roots/tubers; *c, Estimated values [4]; *d, Including mixed grasses, legumes and other grasses for forage/silage

Table 2. Quantity of the virgin wood annually grown in Japan [4].

	Volume (10^6 m^3)
(1) Standing wood in the forest in 1990 [a]	3,138
(2) Standing wood in the forest in 1995 [b]	3,483
(3) Increased volume in 5 years; (2) - (1)	346
(4) Accumulation in 1 year; (3) / 5 years	69
(5) Harvested wood in 5 years [c]	170
(6) Harvested wood in 1 year; (5) / 5 years	34
Quantity annually grown; (4) + (6)	103

Note: *a, Data from reference [10]; *b, Data from reference [1]; *c, Estimated value [4] including leftover treetop/branch and wood from thinning

Table 3. Quantity of the leftover treetop, branch and others generated in Japan in 1999.

Species	Harvested wood [a] (10^3m^3)	Quantity of the leftovers [d] (10^3m^3)			
		Treetop	Branch /leaf	Others	Total
Sugi/hinoki [b]	11,993	240 (2)	959 (8)	600 (5)	1,799
Matsu [c]	5,181	155 (3)	570 (11)	259 (5)	984
Other softwoods	382	11 (3)	61 (16)	19 (5)	92
Hardwoods	4,667	233 (5)	933 (20)	467 (10)	1,633
Thinning	6,890	138 (2)	551 (8)	2,067 (30)	2,756
Total	29,113	778	3,075	3,412	7,264

Note: *a, Estimated values on standing wood equivalent [4]; *b, Sugi, Japanese cedar (*Cryptomeria japonica* D. Don), hinoki (*Chamaecyparis obtusa* Endl.); *c, Matsu, pinaceous woods; *d, Number in the parenthesis shows the volumetric percentage of the leftovers from the volume of harvested wood [14].

Table 4. Quantity of the wood residues from construction sector generated in Japan in 1999.

	Types of the structure						Total (10^3m^3)
	W	SRC	RC	S	Brick	Others	
Construction							
Floor space (ha) [a]	7,357	1,736	3,734	6,611	15	49	—
CF (m^3/m^2)	0.032	0.005	0.008	0.006	0.012	0.008	—
Quantity (10^3m^3)	2,354	87	299	397	2	4	3,142
Demolition							
Floor space (ha) [a]	2,211	977					—
CF (m^3/m^2)	0.14	0.03					—
Quantity (10^3m^3)	3,095	293					3,389
Total	5,449	1,082					6,531

Note: W, wooden construction; SRC, steel reinforced concrete; RC, reinforced concrete; S, steel structure; *a, Data from reference [18]; CF, conversion factor of the residues from the floor space [19]

Table 5. Quantity of the rice straw and rice hull generated in Japan in 1999 [22].

Items		Rice straw (Mt)	Rice hull (Mt)
Quantity annually generated		9.607	2.078
Applications	Plowing back	6.126	-
	Compost	0.993	0.461
	Roughage	0.967	-
	Other agricultural uses	1.056	1.045
	Wasted	0.465	0.572

Table 6. Quantity of the agricultural residues derived from wheat, sugar cane, potatoes and maize in Japan in 1999.

Items		CF (t/t)	Quantity (Mt)	
			Crop production [a]	Residues
Wheat	Wheat straw	1.1	0.788	0.867
Sugar cane	Bagasse	0.15	1.571	0.236
	Other residues	0.28		0.440
Potato		0.4	2.963	1.185
Sweet potato			1.008	0.403
Taro, yams, etc.			0.516	0.206
Maize		1.0	4.795	4.795
Total		-	11.641	8.132

Note: CF, Conversion factor of the agricultural residues from the crop production [23]; *a, See Table 1

Table 7. Quantity of the waste oil/fat generated in Japan in 1999.

Section	Oil supply [a] (kt)	CF			Quantity of waste oil/fat (kt)
		(1) Wastes per person (g/person)	(2) Rate of wastes (%)	(3) Rate of return (%)	
Household	650	950	40	-	124 [b]~261
Restaurant	710	-	30	-	212
Food industry	689	-	10	-	21
Oils/fats industry	429	-	-	5	69
Total	2,479	-	-	-	426~563

Note: *a, Data from reference [9]; CF, conversion factor of the wastes from (1) number of the population, and (2,3) oil supply [25]; *b, Estimated assuming that the population of Japan is about 130,000,000

Table 8. The quantities annually produced and available masses of the biomass resources in Japan. [a] (Mt/year)

Biomass		$M_{quantity}$	$M_{available}$
Virgin resources			
Sugar	Sugar cane	1.571	0
	Sugar beet	3.787	0
Starch	Rice	11.469	0
	Wheat	0.788	0
	Potato	2.963	0
	Sweet potato	1.008	0
	Taro/yams, etc.	0.516	0
	Maize for forage/silage	4.795	0
Forest resources	Wood	52	3~20.4
	Sasa	>6.068	<6.068
	Bamboo	3.3	<3.3
Oil/fat crops	Rapeseed	0.00087	0
	Groundnuts	0.026	0
	Soybean	0.187	0
Others	Pasture grasses	31.154	0
	Fruits	4.250	0
	Vegetables	12.809	0
	Other crops	2.118	0
Virgin resources; subtotal		~140	~30
Residues			
Wood residues	Leftover treetop/branch, etc.	3.63	0.8
	Wood from thinning	3.45	1.97
	Factory residues	12.5	2.16
	Construction residues	3.27	2.06
	Waste paper	30.63	2.79
Agricultural residues	Rice straw	9.607	0.465
	Rice hull	2.078	0.572
	Wheat straw	0.867	0.327
	Bagasse	0.236	<0.236
	Other agricultural residues	7.029	<7.029
Livestock residues	Livestock excrement	90	>0.64
	Livestock carcass	0.11	0.06
Residues from fishery [b]	Fish processing residues	0.84	0.13
	Released fishes	8	<8
	Chitin	0.39	<0.39
Industrial residues	Pulp sludge	4.9	0.62
	Animal/plant residues	3.13	1.47
	Waste oil/fat	0.426~0.563	>0.04
Non-industrial residues	Municipal refuse [c]	38	<15
	Sewage sludge [d]	2.4	1.66
Residues; subtotal		~220	~46
Biomass; total		~360	~76

Note: *a: Updated version of the previous study [4], *b: Dry mass equivalent, *c: The value of $M_{quantity}$ is overlapped with waste paper. *d: Absolute dry mass

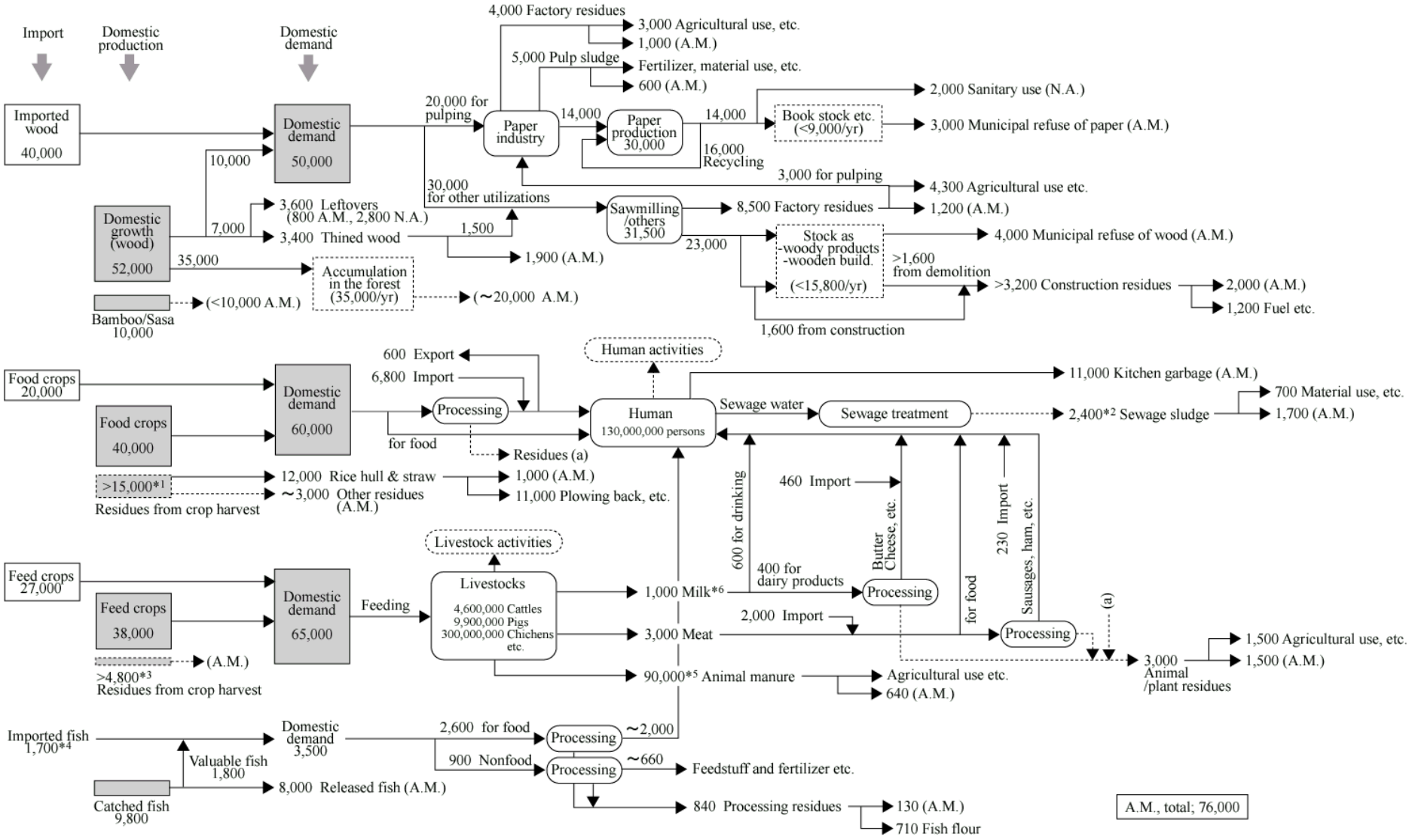
Import
Domestic production
Domestic demand
Imported wood 40,000
Domestic demand 50,000
10,000
Domestic growth (wood) 52,000
7,000
35,000
Accumulation in the forest (35,000/yr)
(~20,000 A.M.)
Bamboo/Sasa 10,000
(<10,000 A.M.)
3,600 Leftovers (800 A.M., 2,800 N.A.)
3,400 Thined wood
1,500
1,900 (A.M.)
4,000 Factory residues
3,000 Agricultural use, etc.
1,000 (A.M.)
5,000 Pulp sludge
Fertilizer, material use, etc.
600 (A.M.)
20,000 for pulping
Paper industry
14,000
Paper production 30,000
14,000
16,000 Recycling
2,000 Sanitary use (N.A.)
Book stock etc. (<9,000/yr)
3,000 Municipal refuse of paper (A.M.)
3,000 for pulping
4,300 Agricultural use etc.
1,200 (A.M.)
30,000 for other utilizations
Sawmilling /others 31,500
8,500 Factory residues
23,000
Stock as -woody products -wooden build. (<15,800/yr)
4,000 Municipal refuse of wood (A.M.)
>1,600 from demolition
>3,200 Construction residues
2,000 (A.M.)
1,200 Fuel etc.
1,600 from construction
Food crops 20,000
Food crops 40,000
Domestic demand 60,000
600 Export
6,800 Import
Processing
for food
Residues (a)
Human activities
Human 130,000,000 persons
11,000 Kitchen garbage (A.M.)
Sewage water
Sewage treatment
2,400*2 Sewage sludge
700 Material use, etc.
1,700 (A.M.)
>15,000*1
Residues from crop harvest
12,000 Rice hull & straw
~3,000 Other residues (A.M.)
1,000 (A.M.)
11,000 Plowing back, etc.
460 Import
600 for drinking
Butter Cheese, etc.
230 Import
Sausages, ham, etc.
for food
Livestock activities
Feed crops 27,000
Feed crops 38,000
Domestic demand 65,000
Feeding
Livestocks
4,600,000 Cattles
9,900,000 Pigs
300,000,000 Chichens
etc.
1,000 Milk*6
400 for dairy products
Processing
2,000 Import
3,000 Meat
Processing
(a)
(A.M.)
>4,800*3
Residues from crop harvest
90,000*5 Animal manure
Agricultural use etc.
640 (A.M.)
3,000 Animal /plant residues
1,500 Agricultural use, etc.
1,500 (A.M.)
Imported fish 1,700*4
Domestic demand 3,500
Valuable fish 1,800
Catched fish 9,800
8,000 Released fish (A.M.)
2,600 for food
Processing
~2,000
900 Nonfood
Processing
~660
Feedstuff and fertilizer etc.
840 Processing residues
130 (A.M.)
710 Fish flour
A.M., total; 76,000

Figure 2