Review

Utilization of Forest Products for Energy Resources

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Abstract

The energy crisis is reviewed by paying attention to forest biomass in the world and in Japan as an energy resource.

According to one of the recommendations made at the Nairobi Conference on energy, mechanization system of afforestation, which is presently being pursuied in South Sumatra by the Japanese-Indonesia cooperation, is described.

Wood residues in Japan are surveyed and not much used as for energy. A typical example of very local power generation utilizing saw-dust, is given. New solid and liquid composit fuels are introduced and a CCOM is explained by an example. Special charcoal is also shown for comparison with the Asian black charcoal.

1. Introduction

Since 1973, when the drastic increase in OPEC oil price established, a very significant portion of the world has become aware of future energy supplies. An energy has become most fundamental problem in all industries and livings in every country. So we must find out the way (1) to extend the use of fossil fuels and (2) to increase alternative renewable resources.

As the short term resolution in Japan, oils have been stored on the sea and land for the amount meet to several months' consumption for the national needs and reestablished the economy disturbance from the oil crisis by evening and absorbing the increase in oil price into every field of industry cutting any excess in manufacturing processes and home air-conditioning and cooking. However on the long run, although Japan emphasizes on developing atomic power and LNG plant, we have to search and survey every surces of energy. Soft energy path has more been attentioned, due to renewable and most evenly distributed on the earth, therefore as local and national as well. Among soft energies, biomass which has long been used for thousand years, is most important and feasible alternatives for the fossile energy.

2. Biomass in world

Biomass is a renewable resources and everlasting under the sun. The amount of stock mass is important as a resouce, but our most interest is upon an annual production (Table 1) to be used every year without destroying ecological system.

The forest biomass shows characteristic due to its productivity that the stored mass in forestry amounts to $1{,}700\times 10^9$ ton of the whole stock, and annual production of 80×10^9 ton but accounts for 46% of overall annual biomass production and 4.7% of the forestry stock. On the contrally, the annual biomass production in the sea amounts to 32% of whole annual biomass production although

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Table 1. Inventory of plant biomass on the earth and productivity[11]

		Whole	Land	Forest	Sea
Stock	Dry 10^9t	1841	1837	1700	3.9
	%	100	99.8	92.3	0.2
Produc-tivity	10^9 t/y	172.5	117.5	79.9	55.0
	% to Stock	9.4	6.4	4.7	1410

its stock mass shows only 0.2% of the whole stock. This is mainly owing to plankton. However this topic is out of my coverage.

Many developing countries and the rural parts of the developed countries rely much on the traditional renewable energy source such as fuel wood, charcoal, crop residue, animal excrement and so on. As seen in Table 2, in worst case one half to three quaters of whole energy consumption consists of these types of renewable ones. Even in the middle group of the developing countries, to people in rural area and the lower class of urban area, this type of energy is common in cooking and amounts to 20 to 25% of national energy consumption. The demand to the fuel wood used in home exceed the supply

Table 2. Wood energy consumption in world[4,8,16]

Country	Energy from wood (eq. coal 10^6 t)	% of whole* energy consumption	Fuelwood+charcoal Round wood (%) 1966 (1967)	1971	1978
World	357.8	4.0	49	47	47
Canada	1.1	0.5	5	3	2
U S A	4.5	0.2	9	4	4
Brazil	42.3	32.6	88	85	74
Mexico	2.5	2.8	71	65	49
F R D	0.5	0.1	9	7	7
Sweden	0.9	1.7	7	5	6
France	0.8	0.3	25	13	9
Rumania	—	—	31	25	24
Czechoslovak	0.4	0.4	(12)	11	8
Poland	0.5	0.3	(10)	10	7
U S S R	24.7	1.7	27	22	22
Ethiopia	—	—	95	95	95
Uganda	—	—	93	92	93
Iran	0.6	1.0	(22)	15	31
India	35.7	19.8	92	91	90
Indonesia	33.5	52.0	93	86	80
Phillippines	—	—	64	61	71
Thailand	—	—	77	77	78
Korea	0.9	2.1	(78)	80	66
China	42.9	6.7	76	75	71
Australia	0.3	0.3	19	16	7
Japan	0.2	0.04	14	4	2

Based on Sp. gr. 0.47 and 4,500 kcal/kg for drywood

* Nikkei Business Sept. 10, 1979.

further and further. Villagers used to get easily in the forest nearby, but today they have to walk about to collect wood fuel spending half a day or whole day long. People in city pay to get fuel wood in some large part of the income. The situation is very common through almost all developing countries. One to 1.5 million hectares of the forest are consumed every year and this amounts to 1.3% of overall forest in developing countries. Especially in those areas of semiarid and mountain range, where, as kown, faeces of animal is dried and used as fuel to cook. Not only disturb the organic balance but huge amount of nitrogen and phosphorous is burned out and the soils become poorer.

To improve this energy crisis, Nairobi Conference of the UN on new and renewable sources of energy made the recommendations[9,22]. In particular the conference recognizes that meeting the rural energy requirements within the context of integrated rural development programmes including agricultural production, small scale and rural industries, household requirements and sociocultural aspects is of great urgency. Of particular concern to developing countries is the fuelwood deficit area, of alarming dimensions (Table 3). The priority action may be as follows.

(1) Selection of more productive and fast grown species, and promote and support programmes and activites to establish large-scale plantations including afforestation in deficit area.

(2) Improving the efficiency of stoves and cooking utensils, developing low cost stoves and promote their widespread use for consideration to the social and cultural acceptability.

(3) Improve processing fuels from waste twigs, branches and leaves to use in direct combustion, and charcoal production and gasification.

Table 3. Grouping the developing countries having fuel wood shortage in view of energy demonds[23]

Country exporting oils		Countries importing oils			
		% (imported oils/comm, energy consumption)			
OPEC	Non-OPEC	0~25	26~50	51~75	76~100
Equador	Angola	India	Bangladesh	Afghanistan	Cameroon
Indonesia	Burma		Pakistan	Ghana	Morocco
Nigeria	China				Phillippines
	Congo				Thailand
	Zaire				

Energy Problems on Developing Country, Jap. edition, 1980 World Bank. Include those countries of GNP per capita is under $300 and 0.75 m^3 of fuelwood, under $600 & 0.50 m^3, and under $900 and 0 m^3, cannot use continuously to the year 2000 without serious destruction of natural ecology.
Countries listed are limited only to produce oils or/and natural gas.

3. A system for mechanized afforestation[7,18]

The paper will not cover the area for the priority action by the Nairobi recommendations but only one example which is very much feasible in Indonesia. Introducing here how to promote the mechanization in large scale plantation is of the bilateral project between Japan-Indonesia in progressing afforestation in South Sumatra. The original report has been made by a member of this project Mr. Y. Sakamoto of Japanese Forestry Agency who engaged for last two years at this project.

The system is rather perspective but the project has been started and some are in reality. The reason why developing mechanization of afforestation especially in South Sumatra is as follows.

a) To secure the sufficient labour for a large-scale afforestation is difficult in the less populated area here.

b) In planting seedling in pot for a large scale, handling and transferring are main process. In promoting mechanization of nursery, whole process in nursery should be fixed in a same area. Whereas a new planting area shall go to distance year after year. For carrying such heavy load which is mostly dirt with seedling, human labour is not suitable but for the machinery.

c) Since the energy crisis, the recent national policy is taken account for securing wood resources on a vast waste land, the mechanization of plantation is the best means to accomplish this policy.

On the way promoting mechanization of afforestation may not be smooth and there needs a big effort to overcome the trouble lying on. To improve the system presently carrying on, Mr. Sakamoto made some proposals. Lets look into them.

The processes for the mechanization of plantation are classified into (1) fully mechanized process,

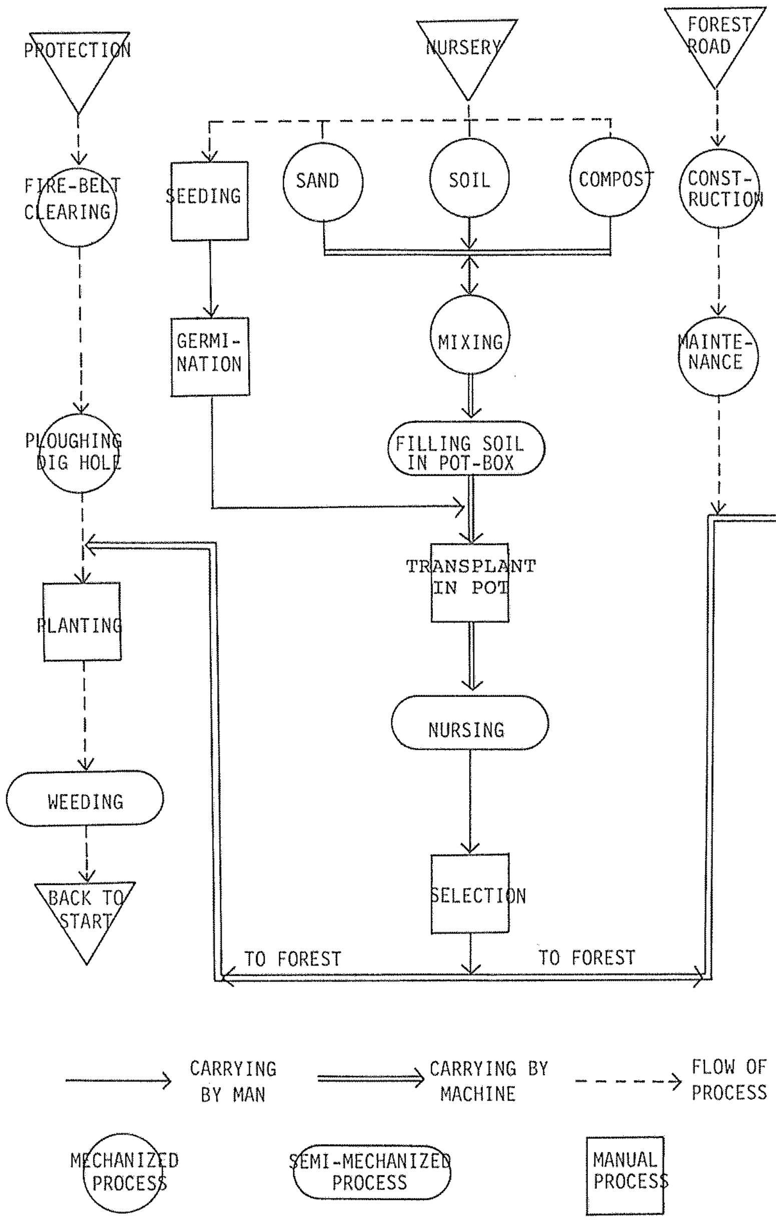

Fig. 1. Scheme for Mechanized Afforestation[7, 18]

(2) man-power process, and (3) semi-mechanized process consisting human labour and machinery. Between processes, connections are also managed by man-power or machine. Whole process is cycling in a year round (Fig. 1).

1) Carrying process by human labour

Such light, small matters and delicate seedling can better be handled by man-power.

2) Carrying process by machine

Transferring heavy materials between processes can be done by employing dumptruck, cargotruck, cranetruck, tractor with trailer, or belt conveyer. Through the system, almost all processes consist of transferring, the object materials may be soil, sand, compost, seedlings in pot with soil, and are characterized by volume and weight. According to a given object and succeeding process can be used a certain machine. The key point to consider in order to display the full function in the system is how to arrange smoothly between the connection of process-transfer-process with less human power (Fig. 2).

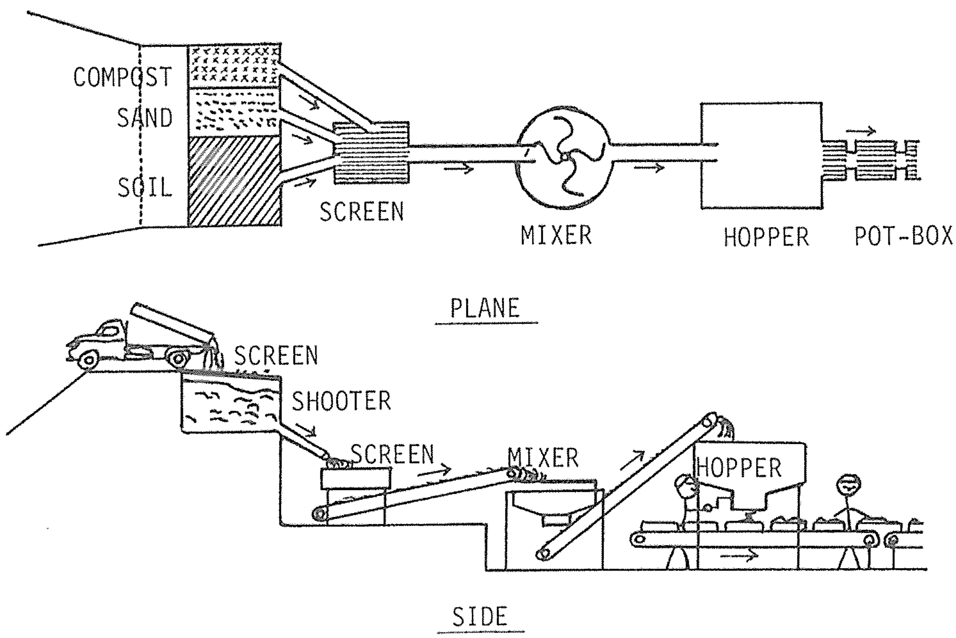

Fig. 2. System for the Process of Preparring and Transferring the Soils for Nursery[7, 18]

3) Sand for the seedling in pot

At the present project, the sand is delivered by the supplyer and being piled in a part of the yard ground. So the first step, the sand on the ground must be shoveled up and carried to the following process. For an example, the proposal suggested (1) keep the potential energy in height and piled on some height when the supplyer brought in, considering the next step, or (2) the alternative, if possible, diging or collecting sand directly from a given place, shovel trailer truck of wheel type is better used especially to transport some distance to the nursery yard and connect to the next process directly without losing energy in height.

4) Soil for seedling in pot

The same trouble as in sand has been exercised. Some improvement may be suggested considering the transportation to a distance and connecting processes.

5) Compost preparation

It takes time to mature the compost. So it must start at least half a year ahead of the time to be used. This process consists of many small steps such as cutting and collecting grass, conveying, moistening, fermantation, mixing, shoveling up on the truck, and so on. The process itself need a small system in making a large volume with reason. An example is shown in Fig. 3.

6) Mixing for nursery bed-soil in pot

Schematic flow is drawn in Fig. 2. A balanced flow of soil, compost, sand, fertilizer, etc. is most important. In reality, at present, much man power in handling is added to process smoothly.

7) Putting bed-soil into pot

Almost all processes at present are done by hand using a folded bag of round shape vinyl pot. More than half of the labour in nursery is absorbed by this process of the soil powering. Through the entire nursery work from the preparation of bed-soil to plantation, the unit of working is always an each single pot. Therefore, mechanization of this process is most important. The following new system of pot-box and subjecting work are shown in Figs. 4 to 6.

Multi-pot system employs an assemled box of multi-pot (Fig. 4) rather than an indivisual round pot at present and one man carries two boxes of 30 seedlings each, weighed 9 kg each. A large box is handled by two man, 120 seedlings in a box with weight of 36 kg. Fig. 5 explains (1) one man operates the handle of the soil hopper, then the soil shall fall down from the upper hopper. (2) Soil on the pot-box is pressed slightly and an excess of soil is expelled by means of sweeping with a flat board.

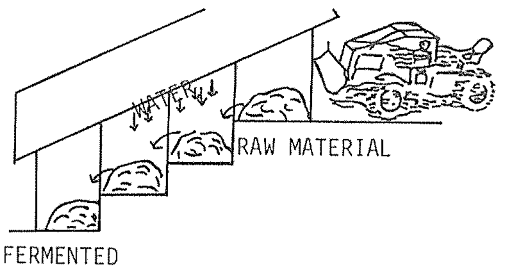

Fig. 3. A Stepwise System for Maturing Compost[7, 18]

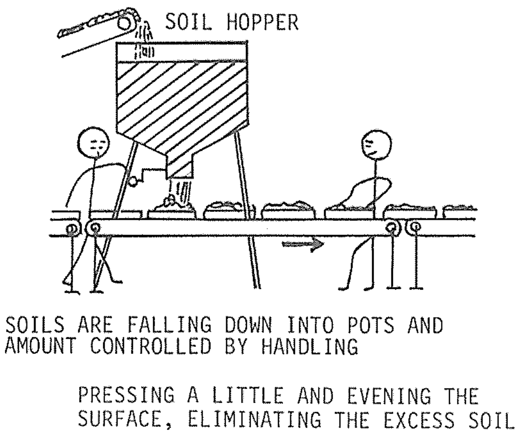

Fig. 5. An Example for Filling Soil into Pot-box[7, 18]

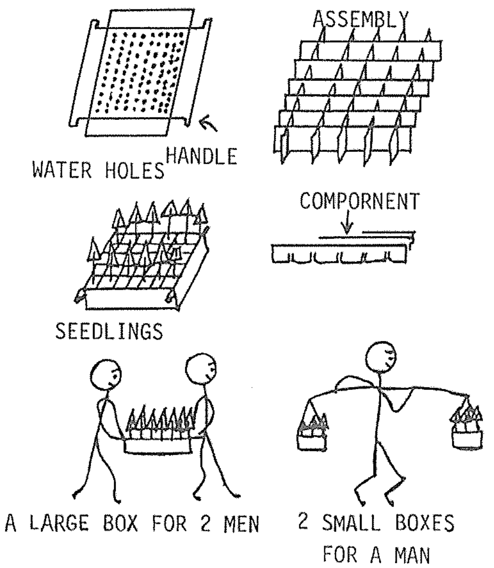

Fig. 4. Seedlings' Pot-box[7, 18]

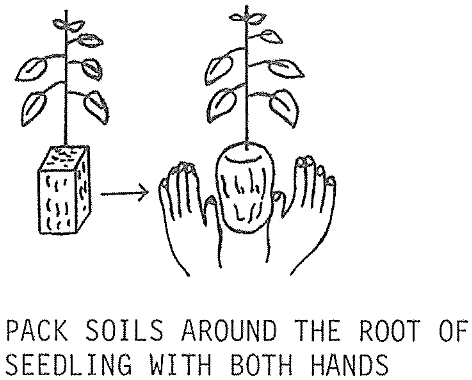

Fig. 6. Handling Method of each Seedling on the Trailer Right Before Distributing it on the Ground[7, 18]

(3) Pot-box soil shall be carried to the nursery field by forklift or beltconveyer and arranged in a given place. (4) Young seedlings shall be planted to each compartment of the pot-box. (5) After nursing seedlings for some period, the pot-box with mature seedlings shall be carried to the forest land by trailer. (6) Pot-box shall be disassembled on the trailer and the soil around the seedling's root shall be packed with both hands by means of pressing (Fig. 6), then it shall be distributed to a given spot to be planted.

8) Planting seedlings

Planting seedling shall be done by hand in a hole made by a digging machine.

9) Nursery

Seeding and nursery of seedlings are carried out in the nursery field on the unit of pot-box. All such handlings as splaying agricultural chemicals, isolation from disease, sprinkling water, etc. are done with the array of pot-box unit.

10) Selection of seedlings for plantation

A number of matured good seedlings in a pot-box is more than a given percent (say 70–80), then those pot-box shall be transported to the forest land. Unsuitable seedlings are disposed when unit of pot-box is disassembled on the trailer. The inadequit units of pot-box are disassembled on the nursery yard and some of good seedlings in that box are recovered by transplanting to a vacant pot-box for a next plantation or for the following year.

11) Plantation

Forest land is first ploughed by tractor, followed by distributing seedlings on the trailer down to the forest ground with a given distance. Three men work together in a party, two on the triler, disassemble the pot-box and pack the root soil (Fig. 6) of each seedling, then hand it to a man on the ground who puts it on a given ground (Fig. 7). The disassembled box will be reused. Seedlings on the ground will be set by 4–5 men without delaying time, thus avoiding drying root of seedling. Labour balance among works is very important.

Although Mr. Sakamoto made suggestions such as extending forest road and keeping it in good condition, preparing forest land for plantation by machines, weeding and bush-cutting in the plantation, etc., these descriptions have been omitted.

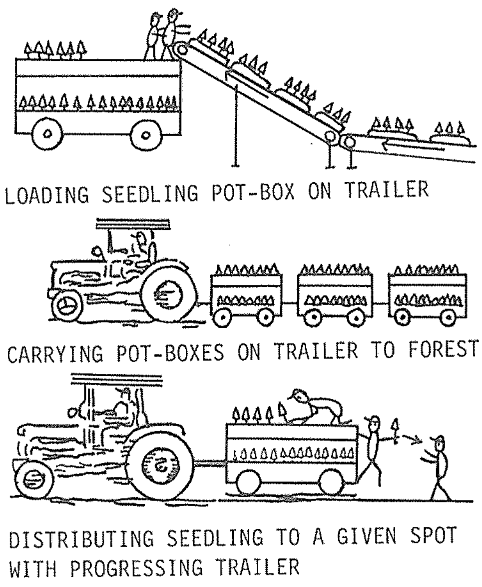

Fig. 7. Transporting System from the Nursery Yard to each Planting Spot in Forestry[7, 18]

4. Forestry in Japan

Japan is a country with a 66% of the forest area to her land and many kinds of trees and shrubs cover the land in contrast to such countries as USA 33%, FRG 29%, France 27%, and USSR 41%, according to the recent (1980) investigation by National Institute of Resources, Science and Technology Agency. Biomass is estimated as 14.75×10^9 ton of which 94.3% is in forestry. Yearly production of biomass amounts to 1.628×10^9 ton and 11% of whole biomass present. The 1.018×10^9 ton will be used for energy use and amount to 6.9% of the whole and 62.5% of yearly production. Biomass production consists 49.3% of forest, 19.1% of farm residue and animal faeces, and 12.2% of home disposal.

Forest resources is shown in Table 4.

The stock volume of $2{,}185\times10^6$ m^3 is equivalent to $4{,}621\times10^{12}$ kcal (Sp. Gr. 0.47 and 4.5 kcal/kg). On the other hand, the reported felled volume in the same year 1976 is 45×10^6 m^3 (eq. 95×10^{12} kcal) and about 2% of stock inventory. According to the project by Japanese Forestry Agency, with increasing stock volume through improving the management of the stand and targeting the production of 127×10^6 m^3 in a year at the destination of the year 2021. This figure corresponds to 5.2 m^3/ha·yr of yearly production. With this ideal maximum forest stand, we would cut every year 60×10^6 ton (eq. 268×10^{12} kcal) of round bole. In 1978, Japanese national energy consumption was $3{,}790\times10^{12}$ kcal, then our yearly production of wood in the year 2021 amounts to 7% of the above energy consumption in 1978.

According to Prof. Tadaki, whole biomass (from the tip of bole and leaves to the tip of root system) productivity has been shown in Table 5.

As an another reference, biomass production for several species, areas, and forest type in outside of Japan is shown in Table 6. Biomass distribution in a tree is also shown in Table 7. The author of

Table 4. Forest resource in Japan in 1976[17)]

	Area 10^3 ha	Weight (dry) 10^6 t	Stock Volume 10^6 m^3 N+L	N	L
Total	25,263	1,027	2,185	1,215	971
Plantation	9,377	375	798	788	10
Natural	14,437	651	1,386	426	959
Others	1,301	0.8	1.8	0.5	1.4
Bamboo	148	—	—	—	—

Table 5. Forest productivity (dry matter)[21)]

Type of Forest	Net Production t/ha/yr
Deciduous Hardwood	8.7±3.0
〃 Softwood	10.1±4.4
Evergreen 〃	13.5±4.2
Pine	14.8±4.1
Sugi	18.1±5.6
Evergreen Hardwood	18.1±4.9
All Forest in wt Average	13.9±5.9

Table 6. Forest biomass production[3)]

Species or Forest type	Location	Forest Biomass: Stemwood Age[8]	m^3/ha/yr	OD ton /ha/yr	Other[2] % stem-wood	Source	Plantation or Natural Stand
CONIFEROUS:							
Pinus radiata[5]	NZ N. Island	18	23.9[3]	9.6	—	Will 1966	P
〃	〃 〃	20	28.8	11.5	—	Sutton 1977	P
〃	〃 〃	23	25.1	10.0	—	〃	P
〃	〃 〃	25	30.0	13.5	—	Whyte 1978	P
〃	〃 〃	29	19.8	7.9	—	Sutton 1977	P

P. nigra	N.E.Scotland	48	4.2[4]	2.0	64	Ovington 1965	P
P. sylvestris	E. England	55	4.4[4]	1.8	66	〃	P
Picea abies	Sweden	58	3.6[4]	1.5	101	〃	N
Pseudotsuga menziesii	Wash. State USA	52	7.6[4]	3.4	24	〃	N
HARDWOOD:							
Eucalyptus globulus	Australia	4	5.7[4]	3.4	85	Cromer et al. 1976	P
〃	Fertilizer A 〃	4	14.7[4]	8.6	80	〃	P
〃	Fertilizer B 〃	4	21.6[4]	12.3	74	〃	P
〃	Fertilizer C 〃	4	29.1[4]	16.3	86	〃	P
E. tereticornis	India	5	7.8[4]	6.4	51	Singh & Sharma 1976	P
〃		6	7.4[4]	6.2	47	〃	P
〃		7	13.0[4]	11.2	49	〃	P
〃		8	10.6[4]	9.3	66	〃	P
〃		9	20.5[4]	18.4	41	〃	P
Nothofagus truncata	New Zealand	110	3.2[4]	2.0	38	Ovington 1965	N
Quercus borealis	Minn. State USA	57	3.2[4]	2.0	80	〃	N
Salix smithiana hyb	Sweden	10	7.0[4]	2.1	33	Siren 1976	P
Betula verrucosa	USSR (Moscow)	67	4.2[4]	2.3	38	Ovington 1965	N
Quercus robur	Czechoslovakia	100	24.8[4]	14.9	23	Vyskot 1976	N
Fraxinus excelsior	〃	100	7.5[4]	4.5	28	〃	N
Tilia vulgaris	〃	100	3.1[4]	1.4	35	〃	N
FOREST TYPES:							
West European[6]			12.9[4]	5.8	68	Earl 1975	N
Temperate rain[6]			14.5[4]	9.3	70	〃	N
Tropical high forest[6]	0–500 m elevation		22.0[4]	11.0	82	〃	N
〃	500–1500 m 〃		16.0[4]	9.6	82	〃	N
Cool coniferous			4.1[7]	3.0	—	〃	N
Temperate mixed			5.5[7]	4.0	—	〃	N
Warm temperature			5.5[7]	4.3	—	〃	N
Equitorial rain			8.3[7]	6.0	—	〃	N

1 See Table 7 for biomass of bark, root, branches and levaves; biomass values for other plant crops can be found in DSIR 1976 (p. 12), The potential for energy farming in New Zealand. Proc. of Symposium, Physics & Eng. Lab. 26 Nov. 1975, DSIR Information Series #117. Lower Hutt, 130 p.

2 Bark, roots, branches and leaves, total dry weight expressed as a % of stemwood. Varying detail in original source — by components; above ground biomass; stem, roots and crown. Additional data given in Table 7.

3 Harvested volume plus thinning at age 10; current annual increment (CAI) at 18 years 45.5 m^3/ha; mean annual increment (MAI) at 18, without the thinning at age 10 is 16.9 m^3/ha, equivalent to 6.79 ton/ha at 400 kg/m^3 density.

4 Volume calculated from biomass on basis of average densities published in the literature.

5 Calculated, where not given, on a density of 400 kg/ha for young radiata, upto about eight years; density not corrected for older trees.

6 Average of data from two sources cited in Earl, D.E., 1975. Forest energy and economic development. Clarendon Press, Oxford, 128 p.

7 All wood above ground; apparent densities questionable (over 730 kg/m^3).

8 Additional data on *P. radiata* biomass for different ages will be found in Table 7.

Table 7. Biomass distribution in trees[3)]
portions as % of total dry weight[1]

Source:	Stem-wood	Roots	Bark	Branches	Needles	Total weight ton/ha
Madgwick — North Is. NZ						
22 yr. *P. radiata*[2]	75	—	9	13	3	—
Will — North Is. NZ.						
18 yr. *P. radiata*[2,4]	67	11	9	13	(w branches)	305.5
Removed as thinnings[5]	(54)	(16)	(5)	(24)	(w branches)	68.9
Ovington-Canberra, Aust.						
8 yr. *P. radiata*[2]	40	16	—[3]	27	16	66
〃 England						
32 yr. *P. sylvestris*	36	26	—[3]	17	18	24.2
Stangenberger-California[8]						
12 yr. *P. radiata*	39	—	6	34	21	43.6
〃						
19 yr. 〃	58	—	7	30	5	162.5
〃						
30 yr. 〃	46	—	11	38	6	160.3
Taras & Clark — Mississippi						
30–110 yr. *P. echinata*	64	—	12	18	4	Natural stand[7]
〃 — Alabama						
50–82 yr. *P. taeda*	42	—	6	12	5	Natural stand
〃						
34–64 yr. *P. palustris*	85[6]	—	11	—	4	Natural stand[7]
Clark & Schroeder-N. Carolina						
21–81 yr. *L. tulipifera*	78[9]	—	15	7	—	Natural stand[9]
Baker & Blackman-Miss.						
1st yr. growth *P. deltoides*[2]	35	22	—[3]	19	24	3.7

1 Methods of calculation and basis differ between sources; mostly on above-ground portion only; some values are expressed as stemwood, branches and foliage (crown).
2 Mineral nutrient content also given in original.
3 Where not given, may be included in stemwood.
4 Calculated 20.8 ton/ha/yr.
5 Additional yield from thinning; 22.5% increase.
6 Includes wood in branches which contained 11% of total wood.
7 Total weight *P. echinata* 20.4 ton in 34 trees; total weight *P. palustris* 43.0 ton in 47 trees.
8 Additional data on *P. radiata* biomass for different ages will be found in Madgwick, H. A. I., D. S. Jackson & P. J. Knight 1977. Above-ground dry matter, energy, and nutrients of trees in an age series *Pinus radiata* plantations. N. Z. Jour. For. Sci. 7(5): 445–468.
9 Total weight of 39 trees (from 15.2 to 71.1 cm diameter), w/o leaves and roots, 31.7 ton; 91% stem, 9% branches; 85% wood, 15% bark; basic densities wood 0.407, branchwood 0.424, bark 0.325 to 0.350.

these tables, Prof. Ellis[3)] summerizes that the neighbourhood of 58% of biomass is stemwood and bark, 20% is in branches, 10% is foliage (leaves and needles), and 10% is in the root system, bark average about 14%.

We also made the survey on the biomass productivity in Sugi (*Cryptomeria japonica* D. Don) plantation of 10–60 years in our Mie University Forest, central Japan and summerizes the result in Table 8[20)].

Table 8. Biomass for 60 year Sugi plantation (dry t/ha)[20]

Part	Stock		Thinning		Total	
Stem	181.0	81.4%	111.6	66.7%	292.6	75.1%
Bank	16.0	7.2	10.6	6.3	26.6	6.8
Branch	11.6	5.2	19.6	11.7	31.2	8.0
Leaves	13.8	6.2	25.6	15.3	39.4	10.1
Total	222.4	100% 57.1%	167.4	100% 42.9%	389.8	100%
Yearly Productivity for an Average of 60 years (t/ha/yr)						
Stock (Total)	3.71		2.79		6.50	
Stem	3.02		1.86		4.88	

The 60 year stand holds the inventory 222.4 ton/ha (excluded root system) and the productivity 3.7 ton/ha•yr, even if we consider the thinnings made previously, the total volume obtained upto 60 year is 390 ton/ha and the productivity 6.5 ton/ha•yr. This figure is much less than 18.1 ton/ha•yr for Sugi stand by Prof. Tadaki (Table 5).

According to Prof. Young who made the study on the complete forest biomass on the mixed stand of the public lots in Maine, U. S. A. (Table 9)[25]. Merchantable bole of the industrial species larger than 12.5 cm DBH is a little less than 50% of the whole biomass in forestry.

We extend the productivity in Sugi stand to whole Japan's present (1976) managed forest area and set the biomass production in a year;

6.5 ton/ha•yr $\times$ 23,814 $\times 10^3$ ha $= 155 \times 10^6$ ton/yr ($= 697.5 \times 10^{12}$ kcal). Our 60-year Sugi stand has the productivity of merchantable bole, 3 ton/ha•yr $\times$ 0.85 $=$ 2.55 ton/ha•yr (15% is unmerchantable top

Table 9. Composition of the complete forest based on forest biomass inventory data on the public lots in Maine.[25]

Forest Component	Percent Complete Forest	Percent Merchantable Bole
A. Larger than 12.5 cm. diameter Breast High		
1. Industrial Species		
a. merch. boles	48.06	100.0
b. tops	21.84	45.4
c. stump-roots	17.48	36.4
	87.38	181.8
2. Non-Industrial Species		
a. boles	0.76	1.6
b. tops	0.34	0.7
c. stump-roots	0.28	0.5
	1.38	2.8
B. Less than 12.5 cm. diameter Breast High		
3. Industrial Species		
a. boles	5.34	11.1
b. tops	2.42	5.0
c. stump-roots	1.94	4.0
	9.70	20.1
4. Non-Industrial Species		
a. boles	0.54	1.1
b. tops	0.24	0.5
c. stump-roots	0.20	0.4
	0.98	2.0
5. Shrub Species		
a. boles	0.30	0.6
b. tops	0.14	0.3
c. stump-roots	0.11	0.2
	0.55	1.1
Total	99.99	207.8

bole). Then, Japan's managed natural and plantation forest area in 1976 would produce, 2.55 ton/ha•yr $\times$ 23,814 $\times 10^3$ ha = 60.7 $\times 10^6$ ton/yr (= 273 $\times 10^{12}$ kcal/yr).

According to the best stand condition after the year 2021 in Japan, the projecting volume per hectare for the plantation, 2,018 $\times 10^6$ m^3/13.14 $\times 10^6$ ha = 153.6 m^3/ha, and 72.2 ton/ha, expecting yearly cut volume, 5.2 m^3/ha•yr = 2.44 ton/ha•yr.

The stock volume per unit area and productivity in our Mie University Forest appears a little high to about same as that of the ideal forest condition in Japan after the year 2021. We presume the Sugi stand of our Mie. Univ. Forest is upmost artificial stand with balancing ecological condition.

5. Residue from woodworks

Wood residues are very divergent in shape, quality and quantity (volume or weight) owing to the types of manufacture, kinds of raw materials and some other factors. Recently survey for the residues in woodworks shows as in Table 10[5].

Table 10. Estimated residues in lumber-mills (1979)[5] (1000m^3)

		Round	Slab	End	Thin irreg.	Sawdust	Planer dust	Chip. dust	Others	Total	Bark
	Soft W.	17,804	2,563	298	12	1,520	46	83	13	4,535	1,032
Domestic	Hard W.	3,242	722	64		324	118	37	1	1,266	336
	Total	21,046	3,285	362	12	1,844	164	120	14	5,801	1,368
	Soft W.	24,784	3,010	518		2,306	95	128	43	6,100	1,204
Imported	Hard W.	9,122	1,898	205	105	975	17	27	26	3,253	143
	Total	33,906	4,908	723	105	3,281	112	155	69	9,353	1,347
Grand	Total	54,952	8,193	1,085	117	5,125	276	275	83	15,154	2,715

Total residue from lumber mill amounts to 15 $\times 10^6$ m^3 (28% of round wood) and 2.7 $\times 10^6$ m^3 of barks. The estimated residues from plywood (veneer), laminated wood, and flooring are 4,020 $\times 10^3$ m^3, 94 $\times 10^3$ m^3, 241 $\times 10^3$ m^3, respectively. The lumber mill produces highest of other type of woodworks and has been estimated the yield of slabs 17–20%, sawdust 7–10% as well[10].

Small boards for the light container box and some small members for the furniture frame and living utensils are recovered from the residues in lumber mills. The final residues will be used as a fuel wood for selling and a direct heating in one's own factory or home. Almost none is left for the materials in an energy conversion, the base materials in mushroom culture, and a bed-litter of animals. The barks are for a direct combustion heating, compost, and soil conditioner[19]. As shown before, wood fuel and charcoal give only 0.1% of total energy consumption of Japan for the year 1978.

About 7 $\times 10^6$ m^3 of a used wood would annually be recovered from the torn down building, in which 30.7 $\times 10^6$ m^3 of wood has been used. But little of recovered wood is used except for chips due to such difficulties as with nails and metals, decay, paint and glue resines, wood preservatives. It is also difficult to collect them from spreading out widely in a small quantity. Much is burnt in the air without any recovery or collected as city disposals of nuisance.

When we consider a certain industries (commercial, middle scale or larger) using of a wood residue, we must think of the amounts available in a given area to collect, say within 80 km, due to the low value to recover, low volume density, the mixture of different type of residue. In these circumustances, the use of residue is restricted as very local and small. Here gives a typical example of a power generation system using sawdust.

6. Power generation system utilizing sawdust[1,2,6]

Mr. Suzuki, the owner of the Shin-ei Mokuzai, situated in Shimotage, Misugi-mura, Ichishi-gun, Mie Prefecture, Japan, has developed non-utility power generation system utilizing sawdust produced in his mill. On the process developing his system, beside his eagerness and everlasting effort, Mr. Deguchi, Chief of Chemistry Department and Mr. Tsubouchi of the same Department, Industrial and Technological Centre, Mie Prefectural Government have worked together in analyzing generated gas, improving each installation, and developing whole system. As for the modernization of the lumber mill, a subsidy assistance of the local government has also been made.

This system essentially consist of a gas generating furnace, a gas scrubber unit, a cyclone and dehumidifyer, rotary engines and a generator. The system is shown in Fig. 8.

The gas generating furnace is made of fire-brick, and inside upper diameter 1,800 mm, bottom one 2,000 mm of a circular plane, 3,800 mm in height, and inside capacity 10 m^3. The outer shell of duplex construction is made of an iron-concrete wall, its upper diameter 4,000 mm. Between two walls, about 1,000 mm belt is filled with soil and sand for the insulation of heat and gas. Within this soil belt, the water pipe of vinyl surrounds the inner brick wall and is embedded in a packed soil. The water pipe absorbs heat and transfers to water.

A sawdust is filled in the hopper on the second floor and automatically supplied downwards through the shooter which provides forks in order to feed without intermitence by rotating shooter with circular board by hand in case necessary.

The furnace of capacity 10 m^3 can accomodate 400 kg of sawdust. At the lower part of the furnace, sawdust or particles of partially pyrolized sawdust can combust being supplied with sufficient air through the bottom grates, where reaches over 1,000°C and provides for pyrolysis of sawdust on upper dry layer around 300°C. All gas flow is done by the suction of the combution engines at the end of the system except beginning at which the motor fan initiates the move of gas flow. The raw pyrolytic gas gets out the furnace and first comes to the water washer where dust particles and larger ingradient as well as heat of the gas are eliminated. The gas comes to the scrubber unit of three successive tower pathway (diameter 700 mm, 3,750 mm high) where all contaminants are scrubbed and cooled by water shower. At the following cyclone, water and liquid mist are removed and humidity is absorbed by the dry sawdust in a large volume of the dehumidifyer. The dried combustion gas is mixed with air by means of regurator and combusted in two rotary engines (which will be added two more in near future).

This particular power generation system used two rotary engines of 1,200 cc each, which were recovered from the used Mazda cars. These drove a 55-kw generator by means of belt, thus generating an electricity. To get stable revolution of rotary engines the electronics control the valve of regulator. In the beginning before securing settled gas composition the gas is blasted out to air through the by-path.

The sampled combustion gas at the air supply of 1.5 m^3/min has been analyzed: CO 17–24%, H_2 9–12%, Co_2 6–7%, O_2 4–5%, N_2 & others 52–64%[2]. This given gas gives about 1,000 kcal/Nm^3. From 400 kg of sawdust, 300–400 m^3 gas would be generated and mixed with supplied air, thus makes the volume 800–900 m^3. Total heat values will be estimated as $8\text{–}9\times 10^5$ kcal which is about a half of the potential energy by direct combustion of 18×10^5 kcal, but make it possible to generate about 1,000 kwh of electricity.

This system features, 1) saw dust from his own mill is used for generating ample electricity to his own use. 2) Initiating gas generation and stopping the system are very simple and just shutting the pathway of the gas (once ignited the fire is not died out so long as sawdust supply continued). 3) Heat is recovered to water (a) in cooling pipe surround the furnace, (b) in cooling the exaust pipe from engine, and (c) in cooling radiator of coolant for engine. 4) Heated air by exchange is used for drying lumber in three compartment rooms. 5) Hot water can be used in heating at home and factory, and

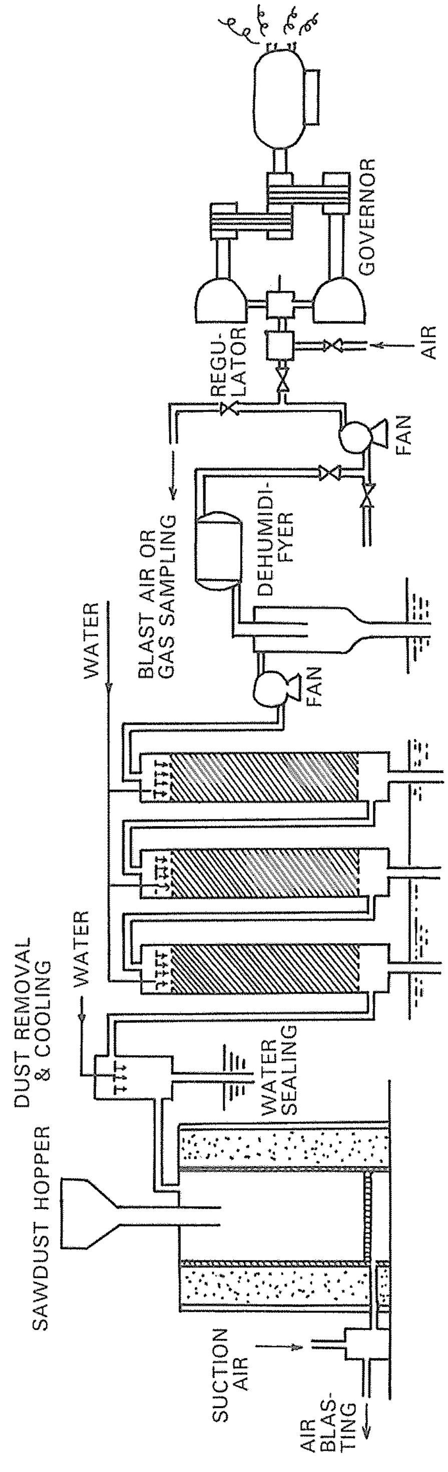

Fig. 8. Schematic Diagramme of Sawdust Power Generation System[6]

as bath water. An extra hot water may be extended to culture fish and to greenhouse.

In terms of system economy, the total cost including housing and development came to around ¥10,000,000. Since whole lumber system, sawing and drying can be operated by means of a generated electric system, the investment cost can be recovered in 5 to 6 years[6)].

7. Converted wood fuel[12~15)]

The character of wood as an energy source is (1) high energy elements of C and H amount to 55% of the wood weight, (2) a calorific value 4,500 kcal/kg in dry but reducing to 3,000 kcal/kg with 50% of moisture due to easiness of taking up water from surroundings, (3) a ratio of weight/volume being as low as 0.47 in mean for all kinds of wood and 0.1 for sawdust. Therefore wood residues are only as for local energy source as mentioned earlier.

In order to become as an industrial fuel, wood fuel must be improved in terms of (1) fluidity in use and transport, and (2) calorific value over 6,000 kcal/kg. Liquification of wood is not feasible in very near future. Mr. Murayama, Forestry and Forest Products Research Institute, Japan, has considered the combustion with oils in many forms and made the proposal of colloidal woodfuels. Some are promissible and in preparation of pilot plants (Fig. 9).

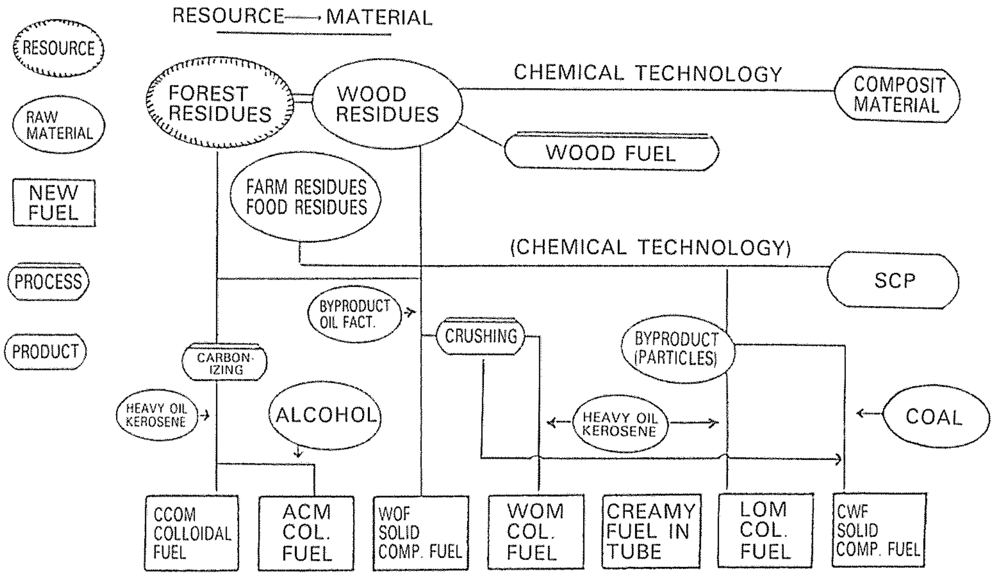

Fig. 9. Scheme for Developing Colloidal and Composit Fuel[14)]

Here explains only as an example way of CCOM (CharCoal Oil Mixture). Forest residues or/and wood residues are carbonized using movable iron-kiln or a like. Charcoal is first crushed and mixed with kerosene 1 : 1 in weight. To an immiscible mixture, a certain surfactant and a promoting additive are added and finally added about 20% of water to whole weight. In adjusting the ratio of surfactant and additive, there may be obtained a geled mixture. Fuel value for a mixture 1 : 1 is 9,000 kcal/kg and one for 20% of water 7,200 kcal/kg. An effect of water on colloidal fuel CCOM is not well understand, an evenly distributed liquid water molecule expands as much as 1,700 times in volume when they become gas phase, in this moment, the molecular particles of hydrocarbon crushed and broke the chain to small molecules, thus the fuel is easily reacted with oxygen to a complete combustion. This results in a good combustion with less soot, smoke, or ash.

A projecting scheme for a trade base of the raw materials for CCOM is shown in Fig. 10.

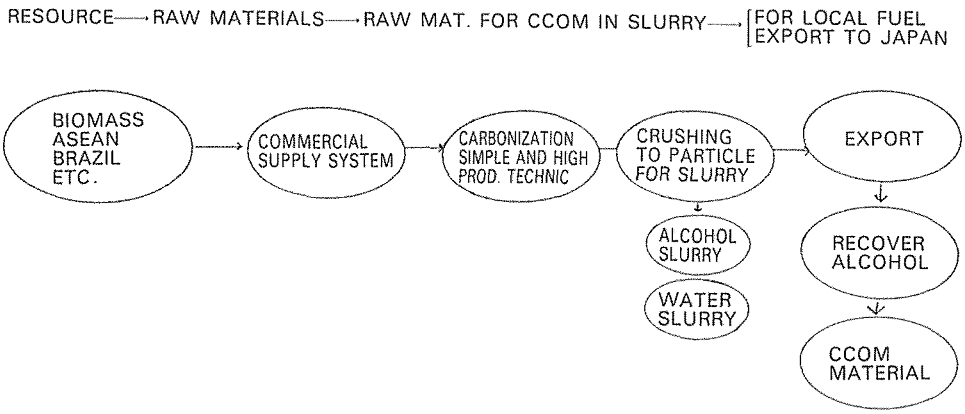

Fig. 10. Scheme for CCOM Production with Imported Charcoal Particles[14]

8. Charcoal

Charcoal for CCOM is, in a sense, made in low quality, high yield, economic (in a cost), mass-productive process of carbonization. On the contrary to the above, we have, so-called white charcoal generally made of the wood of *Quercus* species, especially best of UBAME-KASHI, *Quercus phillyaeoides.* The white charcoal is very likely used in Kabayaki eel-broil or beef-broil. The calorific values are the same but the burning character of the surface oxidation is very slow. The trial carbonization of white charcoal from two mangrove woods has been carried out in Wakayama Prefecture. The properties of them are similar to those of Quercus species. Black charcoal made of mangrove wood with Beehive-kiln in Thai is also examined. The properties such as hardness, electrical resistance, calories, and some feature of the differential thermal analytic curves (DTA), are shown in Table 11[24].

Table 11. Properties of mangrove charcoal[24]

Country Produced	Char-coal	Wood Species	Hardnes.	Elect. Resist.	Calorie	Exothermic Peak on DTA °C			
						Beg,	Small	Main	End
Thai	Black	*Bruguiera parviflora*	6~7	∞	7,294	215	338	437.452	497
〃	〃	*Xylocarpus granatum*	6	〃	7,268	222	332	422.446	491
〃	〃	*Bruguiera gymnorrhiza*	7	〃	6,927	195	339	469	505
〃	〃	*Ceriops tagal*	5~7	〃	7,553	212	328	434	492
〃	〃	*Rhizophora mucronata*	Out 1 Insid 11	〃	7,296	218	344	453.462	497
〃	〃	*Rhizophora apiculata*	9~11	〃	6,502	213	330	429	490
〃	〃	*Bruguiera cyindrica*	Out 2 Insid 8	〃	7,258	204	343	455	507
〃	〃	*Xylocarpas moluccensis*	Out 1 Insid 9	〃	6,895	209	341	443	493
Japan, Okinawa	White	*Bruguiera coniugata*	7~9	1Ω	7,694	354	—	523	554
〃 〃	〃	*Rhizophora mucronata*	11	〃	7,268	369	—	530	549
〃 Wakayama	〃	*Quercus* sp.	9	〃	7,585	270	—	543	572
〃 〃	〃	*Quercus phillyraeoides*	16	〃	7,792	461	—	610	626

Calories: Average of two determinations about 1 g each (dry) by Nenken bomb calorimeter
DTA: 2.9~3.1 mg each, in air, 10°C/min program, Mettler Thermoanalyzer Type 1.
Mangrove grown in Iriomote island, brought to Wakayama and made white charcoal there.

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摘　　要

エネルギー資源としての林産物の利用

吉　村　　貢

二度にわたるオイルショックを経て，1978年12月の第33回国連総会において決定された「新・再生可能エネルギーの開発・利用の促進」に関する国連会議が1981年8月ケニア国ナイロビ市において，125ヶ国（加盟国154）の代表4000名の参加を得て開催され，この問題に対して国際社会が取るべき方策の基本的枠組を策定し，ナイロビ行動計画を採択した。それによると，化石エネルギー以外の新・再生可能エネルギーとして，薪材，木炭，バイオマス変換，太陽，地熱，水力，風力，潮力，波力等14種類のエネルギー源を対象に各エネルギー毎の個別措置の行動計画が決められている。この行動計画にもり込まれた木質系エネルギーに関する個別措置のうち，優先行動分野として開発途上国の農山村地域の農業生産，農村工業，家庭エネルギーを確保するため，

(1) 早期生長樹種の選択
(2) 低コスト・効率的燃焼器具の開発
(3) 木炭製造方法の改善
(4) 薪材不足地域での薪材用の植林の促進

の緊要課題が採択されている。

このような国際情勢を背景に経済大国日本の開発途上国援助の一環として，研究開発と普及，技術移転を目的とした日本―インドネシア両国間のグリーンエネルギーセミナーが1982年9月ジャワ島のボゴール農科大学を拠点にして開かれ，川村登教授（京大・農）を団長とする6名が日本学術振興会の援助によって派遣され，開会式に引続き，夫夫の発表と討議を行った。この論文はこのセミナーにおける林業部門全般を担当した私の報告の全文である。

概　要

世界ならびに日本における，エネルギー資源としての森林バイオマスに留意して，エネルギー危機を概括する。

まず，現在，南スマトラで，日本―インドネシア両国の協力によって実施されている森林造成の機械化システムを述べる。

日本における木材の残廃材量が推測されるが，エネルギー用としてはほとんど使われていない。鋸屑を用いた，極めて局地的な小発電の例を示す。固状及び液状の新しい複合燃料を紹介する。その例として，CCOM（木炭・原油混合燃料）を説明する。また，特殊の木炭（白炭）を東南アジアの黒炭と対比するため示す。