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Current Status of Woody Biomass Utilization in ASEAN Countries

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1. Introduction

Renewable energy, including biomass, has received increasing attention because of worldwide efforts to prevent global warming and alleviate soaring oil prices. When biomass is used as an energy source, for example, it is converted to ethanol as an alternative to gasoline or burned in a boiler to generate heat and power. Cereals such as corn are promising candidates for easily convertible biomass for ethanol production. However, it is possible that the supply of such potential biofuels will become unstable because of conflicts with food production. For example, corn prices have doubled or have reached levels not seen in many years[11]. In contrast, woody biomass is inedible and thus may be a promising candidate as a future renewable energy source. Woody biomass can be collected in large amounts from forests or as a by-product of the forest industry. However, forests are unevenly distributed throughout the world, and so the distribution of woody biomass is uneven. Countries belonging to the Association of Southeast Asian Nations (ASEAN) have a vast range and abundance of forest resources. However, these resources have been considerably reduced because of unrestrained logging in some countries. Sustainable forest management is necessary for the continued use of the available biomass as a renewable energy source.

Our objective was to investigate the current status of the use and consumption of woody biomass to discuss future possibilities and difficulties in the use of woody biomass as an energy source. We focused on Cambodia, Indonesia, Laos, Malaysia, the Philippines, Thailand, and Vietnam. Hereafter, our use of the term "ASEAN countries," unless otherwise specified, refers to these seven countries.

2. Forests, forestry, and biomass

Table 1 is an overview of the biomass, including aboveground, belowground, and deadwood biomass, and growing stock in the forests of the ASEAN countries. Indonesia has the most extensive forest area and biomass stock, but the growing stock has been decreasing

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since 1990, probably because of illegal logging or forest fires. Malaysia has the highest biomass and growing stock by area, whereas Thailand has the lowest.

The data for the main forest products differs among the ASEAN countries because they were obtained from different sources. Nevertheless, we conducted our investigation using this data because it was uniform within each country (Table 2). Indonesia and Malaysia produce substantial amounts of sawnwood and plywood, whereas Thailand is active in the production of wood chips and particles. In Vietnam, the production of sawnwood is active and very high compared to that of industrial roundwood. Cambodia and Laos consume a large proportion of roundwood as fuel.

	Cambodia	Indonesia	Laos	Malaysia	Philippines	Thailand	Vietnam
Forest area (Kha)	10,447	88,495	16,142	20,890	7,162	14,520	12,931
Biomass stock (Mt)	2,811	13,090	3,301	8,073	2,156	1,592	2,606
Biomass stock by area (t/ha)	269	148	204	386	301	110	202
Growing stock (Mm^3)	998	5,216	957	5,242	1,248	599	850
Growing stock by area (m^3/ha)	96	59	59	251	174	41	66
Growing stock by area (m^3/ha)	96	59	59	251	174	41	66
Annual change in growing stock							
1990-2000 (m^3/y/ha)	-0.11	-3.33	0.00	1.94	0.13	0.00	-0.26
2000-2005 (m^3/y/ha)	-0.11	-4.61	0.00	1.94	0.08	0.00	-0.40

Table 1. Biomass* and growing stock in a forest

*Biomass includes above- and below-ground biomass, dead-wood biomass.
[5, 19]: Reference source modified by the authors

	Cambodia	Indonesia	Laos	Malaysia	Philippines	Thailand	Vietnam
Industrial Roundwood (Km^3)	118	35,551	194	25,169	2,869	8,700	5,850
Sawnwood (Km^3)	4	4,330	130	5,142	358	2,868	5,000
Plywood (Km^3)	5	3,353	24	5,601	235	120	70
Chips and Particles (Km^3)	-	1,100	-	501	-	2,080	2,500
Fiberboard (Km^3)	-	427	-	2,633	0	883	180
Particle Board (Km^3)	-	297	0	222	6	2,600	48
Wood Residues (Km^3)	-	388	-	-	-	-	350
Woodfuel (Km^3)	8,735	73,720	5,944	2,908	12,581	19,503	22,000
Wood Charcoal (Kt)	34	681	20	54	610	1,326	109
Total (Roundwood) (Km^3)	8,853	109,270	6,137	28,077	15,450	28,203	27,850

Table 2. The production of forest products in ASEAN countries (2008)

- : Insufficient data
[4, 19]: Reference source modified by the authors. The sum of wood product (= sawnwood + plywood + chips and particles + fiberboard + particle board + wood residues) does not coincide with the amount of industrial roundwood.

3. Energy consumption

In terms of energy supply and consumption in the ASEAN countries (Table 3), Indonesia has the largest total primary energy supply (TPES) at 191 million tons of oil equivalent (Mtoe), whereas Malaysia has the largest per capita TPES at 2.73 toe. The bulletin of the ASEAN Center for Energy (ACE) states that the energy consumption was approximately 1.41 Mtoe in Laos in 1999. The energy consumption in Laos was 0.27 toe per capita, based on population data reported by the National Statistics Center of the Lao PDR[16] in 2000. The consumption of renewable energy accounts for 2% of the TPES in Malaysia and 46% in Vietnam. Cambodia consumed 3.41 Mtoe of renewable energy from primary solid biomass, which accounts for 66% of the energy consumed in 2007. Laos consumes approximately 66% of its total energy from fuelwood, charcoal, and sawdust. However, the difficulties encountered in comparing these values are that the data source and the year the data was collected are different for each country, and Malaysia's dependency on biomass energy is insignificant, whereas Cambodia, Laos, and Vietnam depend heavily on these sources of energy. This is partly because few households have electricity; for example, in 2004, only 47% of households in Laos[15] and only 12% in Cambodia[14] had electricity.

	Cambodia	Indonesia	Laos	Malaysia	Philippines	Thailand	Vietnam
TPES (Mtoe)	5.13 [9]	190.64 [9]		72.59 [9]	39.98 [9]	103.99 [9]	55.79 [9]
TPES per population (toe/capita)	0.36 [9]	0.84 [9]		2.73 [9]	0.45 [9]	1.63 [9]	0.66 [9]
Consumption of renewable energy from primary solid biomass* (Mtoe) (Proportion to TPES)	3.41 [9] (66%)	50.50 [9] (26%)		1.38 [9] (2%)	4.87 [9] (11%)	8.79 [9] (9%)	23.28 [9] (46%)
Energy consumption (Mtoe)			1.41 [12]				
Energy consumption per population (toe/capita)			0.27 [12, 16]				
Data year	2007	2007	1999	2007	2007	2007	2007

Table 3. Energy supply and consumption

TPES: Total Primary Energy Supply = Indigenous production + imports - exports - international marine bunkers ± stock changes
* Data are also available for charcoal.
[9,12,14,16,19]: Reference source modified by the authors.

4. Woody biomass use

4.1 Logging residues

We investigated the use of logging residues in Cambodia[18, 24], Indonesia[17], and Malaysia.[6, 7, 13]. Although rubber plantations are generally expected to regenerate every 30–35 years, the tapping cycle of para rubber trees (PRT; *Hevea brasiliensis*) in Cambodia[18] is longer because of interruptions due to civil war. Woody residues that remain after cutting, such as tops or branches, are discarded. Fig. 1 shows the material flow in rubber tree plantations in Cambodia. The volume of these residues is equal to 30% of the cut volume. The harvesting cost of the residues is lower than that of the logging residues in natural forests. Hence, the selling price is US $5–7/m^3, including the transportation cost to the customer. The residues are used as fuel for kilns at neighboring brick factories, which are strongly dependent on logging residues for fuel.

Clearcutting of pine (*Pinus merkusii*) is carried out every 35 years in the national forest in Central Java, Indonesia. The trees are cut by chainsaw, and the logs are skidded by human power. The tops and branches that are generated, as residues are less than 10 cm in diameter and account for 10% of the tree volume. The local community can acquire the residues free of charge and use them as residential fuelwood. The investigation was conducted in Java, which is heavily populated, and all logging residues appeared to be used in this manner, i.e., residues are collected manually.

At a large-scale, natural wood production site in Saba, Malaysia, 20–50 m^3/ha of cracked and hollow logs are discarded in the forest and in the landing[7]. In Kalimantan, Indonesia, 63.3 m^3/ha of residues are discarded in secondary forests after clearcutting[8]. Average logging residues in Asia represent 25–200% of log production[13], i.e., the residues represent 20–67% of the growing stock, and the residues from natural forest cutting appear to be equal to the log production volume[13]. However, the difficulty in using these residues is that the transportation cost of industrial residues is higher than their selling price. The former is approximately US \$20/m^3 [13] or US \$16–20/m^3 [7], whereas the latter is only US \$3–5/m^3 [7] in Malaysia. Thus, even if transportation were free of charge, the price disadvantage of the logging residues is considerable.

4.2 Industrial wood residues

We investigated the industrial wood residues in Cambodia[18, 24], Indonesia[17, 26, 27], Laos[28], and Malaysia.[13] The residues from PRT plantations are a major source of woody biomass in Cambodia[18] because the processing of forest trees has been limited by a logging ban. The tapping cycle of PRT is longer than in other countries, i.e., approximately 50 years. Thus, there are many thick logs from rubber trees. Fig. 1 also shows the material flow of rubber trees in the wood industry. The production yield of sawing is 43%, and the residues are mainly used as drying fuel for timber or are sold as fuel for brick kilns. The residues are partially used as packing materials, and 55% of the logs are used for energy production. All wood used as fuel for kilns in brick factories is derived from rubber trees.

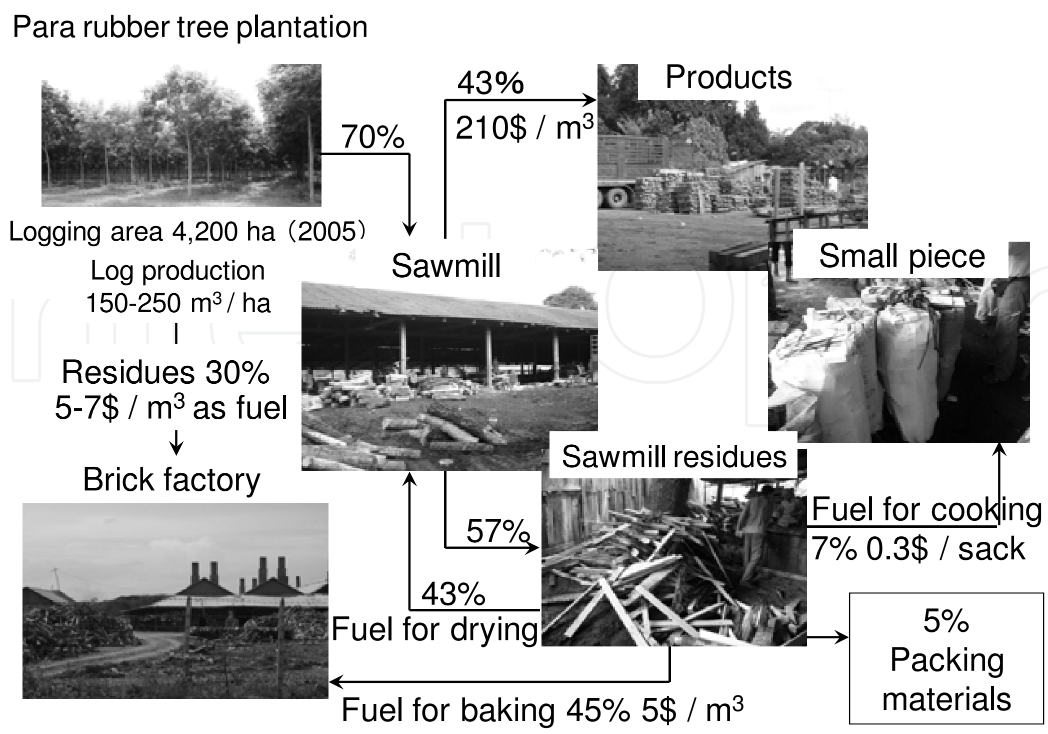


Fig. 1. An example of material flow in the para rubber tree industry in Cambodia [19]

Indonesia currently has 1,600 sawmills and 120 plywood factories[26]. For sawmills in Java, the production yield of teak (*Tectona grandis*) sawing is 50–60%, and the residues are used as fuel for drying ovens and by local people. For the plywood industry in the same area, the production yields from natural and planted wood are approximately 55% and 38%, respectively, because the average diameter of the former is approximately 70 cm, whereas that of the latter is less than 30 cm. One factory that we investigated used both natural and planted wood as raw materials and generated residues representing approximately 50% of raw wood consumption. A portion of these residues was used as raw material for laminated wood or blockboard. The rest of the residue was used as fuel to produce heat to dry veneer and for hot pressing. Some factories use both residues that are generated within and obtained from outside the factory to fuel combined heat and power supply (CHP) systems. Recently, the source of this raw material has been shifting from natural wood to planted wood because of the increase in natural wood prices and rising concerns about deforestation[17]. In Kalimantan, plywood factories are experiencing a shortage of large natural wood (Fig. 2). Most factories around Samarinda have ceased operations because of the decreasing amount of raw wood, which fell sharply from 150,000 m^3/month to 30,000 m^3/month[27]. Fig. 3 shows material flow in plywood factory A, not including materials other than wood such as adhesives.[29] The plywood yield was 50%, and this generated residue (primary residue). The primary residues consisted of sawdust, sander dust, log core, bark, log end and edges. The log cores were used for blackboard materials. Some log cores and edges were laminated and used for packing material. The remaining primary residues became secondary residues, and was used for fuel for the boiler. However, the factory lacked fuel that could be obtained there, and so it purchased wood fuel and brown coal externally. Fig. 4 and Table 4 show the energy consumption to produce plywood for the

Fig. 2. The raw wood in the plywood factory [19]

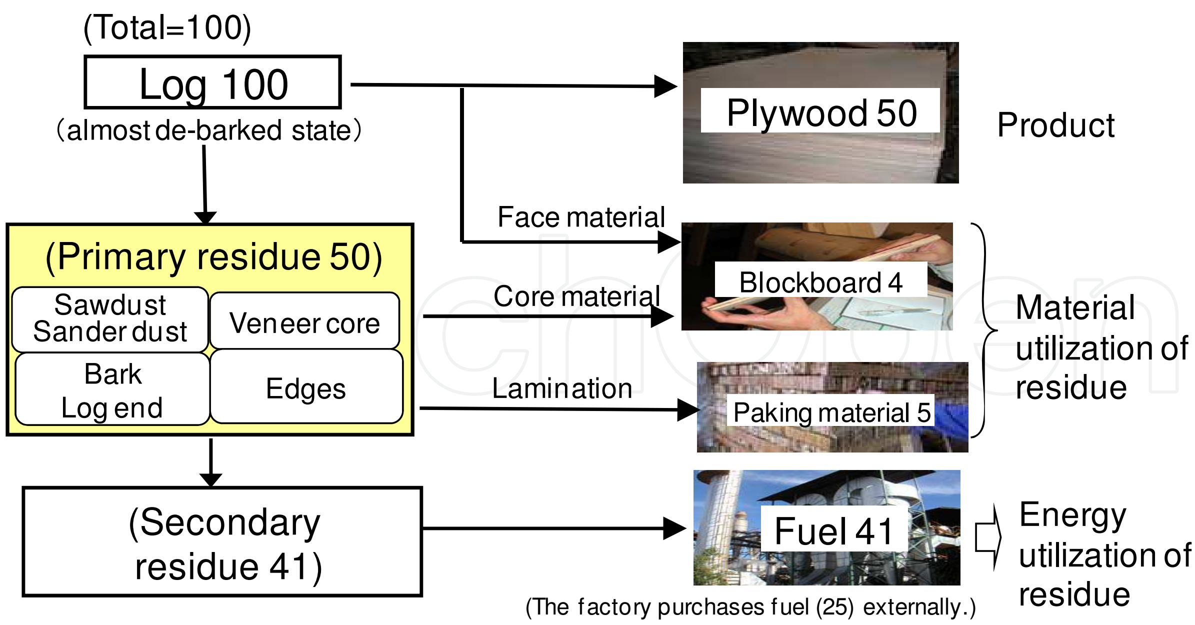
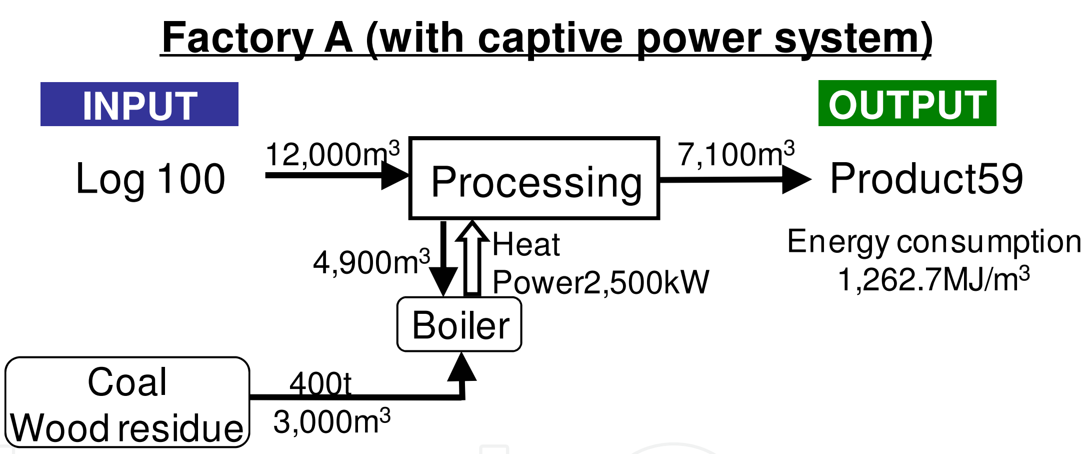


Fig. 3. Material flow in a plywood factory A in Indonesia [29]

(a)



(b)

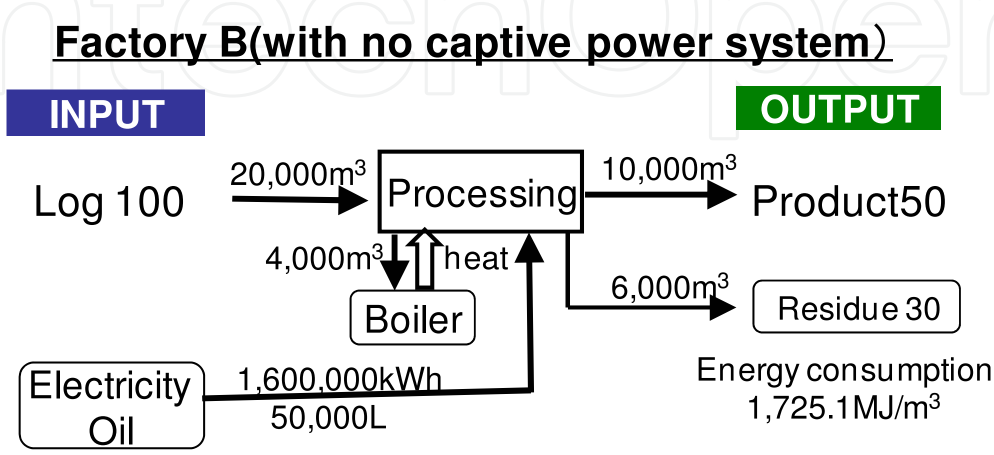


Fig. 4. Material and energy flow in plywood factory A (a) and B (b) in Indonesia [29]

Factory	Fuel consumption (kL-gas oil)	Power consumption (kWh)	Total energy consumption (MJ/m^3-product)
A	238	1,200,000	1,262.7
B	50	1,600,000	1,725.1

Table 4. Energy consumption for the plywood factory A and B in Indonesia
[29]: Reference source

plywood factories A and B. [29] The energy consumption was 1,263 and 1,725 MJ/m^3-product respectively. The smaller value for factory A was due to implementation of captive generation using wood fuel. According to reports, energy consumption during the making of plywood was 1,400 MJ/m^3-product. There is little significant difference between this data and our calculations.

Laos has 200 wood-processing factories, many of which are located near the capital Vientiane or in the southern part of the country. It has only one plywood factory. Charcoal factories are found everywhere because of the high demand of charcoal for residential use. Processing factories, which saw up to 15,000 m^3/year of logs for furniture, packing material, flooring, and doors, depend on wood from natural forests, including rosewood (*Dalbergia*) or meranti (*Shorea*), for raw materials. This natural wood is made available in the market in great quantities as a result of clearcutting for power dam development. The production yield in this industry is approximately 60%. All residues are used as fuel for boilers, and the sawdust is provided to the salt industry at no charge. However, in the southern part of Laos, unused sawing residues pile up in the backyards of sawmills.

In Malaysia, the total volume of the wood industry residues is 7.5 million m^3 annually[25]. Sawmill residues were highest in Sabah, and plywood mill residues were highest in Sarawak. The product yields in sawmills were 65% (western Peninsular Malaysia), 45% (Sabah), and 40% (Sarawak), and the yields in plywood mills were 50–60% (Peninsular Malaysia). The yields in molding factories were 74% (Sabah and Sarawak) and 70% (Peninsular Malaysia). According to a questionnaire conducted in the Kemena wood industry park of Sarawak by T.C. Wong (unpublished data), approximately 200,000 m^3 of logs were consumed per month and processed into plywood, timber, and fiberboard. The volume of wood residues was approximately 90,000 m^3 per month, of which 75% and 20% were generated by plywood mills and sawmills respectively. The percentage use of the original residues was 75%. Veneer core and slabs/offcuts were commonly used. In terms of application, steam/thermal use was dominant (48%), followed by fiberboard (40%), co-generation (7%), other use (4%), and manufacturing of charcoal briquettes (1%). Approximately 20,000 m^3 of residues were, however, disposed of directly or by incineration. Wong (unpublished data) noted that at least one additional briquette plant should be installed to use the remaining residues. In an industrial park in Bintulu, Sarawak, wood residues were sufficiently used as briquette charcoal, fiberboard material, and fuel for boilers. This was because of government incentives. To promote biomass use, the government remits duties in the implementation of related systems. In the Keningau area of Sabah, because wood-processing plants were small and separate from other plants, the residues, particularly sawdust, were not used and were usually incinerated at the plant. We estimated that the total unused sawdust remaining in the Sabah area is approximately 4,700 t/month.

5. Estimating the biomass energy potential

We estimated the biomass energy potential using the research data. We regarded all residues from the logging and wood industries as having biomass energy potential, although some residues had already been used as raw materials. The energy potential was estimated using the following equations[2]:

$$RV = MPV \times RPR/(100 - RPR) \tag{1}$$

$$EP = RV \times LHV \tag{2}$$

where RV is the residue volume (m^3), MPV is the main product volume (m^3), RPR is the residue production ratio (%), EP is the energy potential (toe), and LHV is the lower heating value (toe/m^3). Table 5 shows the EP of certain types of residues in some countries for which we were able to collect the required data. The main products of the PRT plantation residues and logging residues are logs. LHV is calculated from values stipulated by the International Energy Agency,[10] where the weight of 1 m^3 of wood is assumed to be 500 kg[10]. Cambodia has 0.16 Mtoe EP from PRT plantations and sawmills, accounting for approximately 6% of domestic energy consumption in 2001. In Thailand, PRT industries have the largest EP at 2.44 Mtoe (Table 5). Malaysia has an EP of 0.78 Mtoe from the logging residues in Sarawak, which is almost equal to the EP from sawmills.

It should be pointed out that ASEAN countries have high EP from oil palm industries[20, 21], which generate residues such as empty fruit bunches (EFB), fronds, and trunks, and a large portion of the EFB and almost all the frond and trunk residues are discarded in the plantation field. Table 6 shows the estimated amounts of EFB and fronds produced in Indonesia, Malaysia, and Thailand. Oil processing generates EFBs, and large quantities of fronds remain in the plantation area. A comparison to the data presented in Table 6 shows

	Item	MPV (Km^3)	RPR (%)	RV (Km^3)	LHV (GJ/m^3)	EP (Mtoe)
Cambodia	PRT plantation residue	840 [18, 24]	30 [18, 24]	360	7.4 [10]	0.06
	PRT sawmill	361 [18, 24]	57 [18, 24]	479	8.4 [10]	0.10
Indonesia	Plywood	3,353 [4]	50 [17]	3,353	8.4 [10]	0.67
	Sawmill	4,330 [4]	45 [17]	3,543	8.4 [10]	0.71
Laos	Sawmill	130 [4]	40 [28]	87	8.4 [10]	0.02
Malaysia	Plywood	5,601 [4]	50 [13]	5,601	8.4 [10]	1.12
	Sawmill	5,173 [4]	45 [13]	4,232	8.4 [10]	0.85
	Logging residue*	4,440 [13]	50 [13]	4,440	7.4 [10]	0.78
Thailand	PRT sawmill	10,800 [4]	53 [21]	12,179	8.4 [10]	2.44

Table 5. Potential energy from woody biomass in selective ASEAN countries

MPV: Main product volume, RPR: Residue production ratio, RV: Residue volume, LHV: Lower heating value, EP: Energy potential

* The value is limited to Sarawak.

[4, 10, 13, 17, 18, 19, 21, 24, 28]: Reference source

		Moisture content	Production		LHV	EP
		wt%	Mton (dry)	Mton (wet)	MJ/kg	Mtoe
EFB	Indonesia	8.81 [3]	3.46 [20]	3.79	16.44 [3]	1.49
	Malaysia		4.71 [20]	5.17		2.03
	Thailand		0.30 [20]	0.33		0.13
Frond	Indonesia	48.34 [3]	24.14 [20]	46.74	7.97 [3]	8.90
	Malaysia		32.93 [20]	63.74		12.14
	Thailand		2.05 [20]	3.97		0.76

Table 6. Energy potential of palm oil industries in Indonesia, Malaysia, and Thailand
[3, 19, 20]: Reference source

that the oil palm industries have much larger EP than woody biomass. The problem remains that because the fronds cannot be used without transportation, preferable uses must be found either as a source of energy or as a source of material such as fiber. The residues from oil palm industries are certainly a valuable source of biomass with great potential.

6. Discussion

Here, we will discuss the difficulties of woody biomass use in the future. Although some districts produce massive quantities of logging residues, their use will hardly increase because of high transportation costs. The commercial collection and use of logging residues does not appear to have advanced for some time and is confined to regional uses such as cooking fuel for local residents. Hence, in regions that have small populations, a surplus of biomass is present compared to the quantity of available resources. The Philippines[23] and Vietnam[22] follow policies to promote the use of tree plantations, and Indonesia is promoting a shift in the source of raw materials to planted wood. Thus, the use of planted wood is increasing in the wood industries. Planted wood has a short-term harvesting cycle and produces small logs compared to natural forests. These small logs result in inferior yields of the main wood products. As a result, industrial residues will likely increase in the future, although it is expected that the shortage of wood materials will become serious because of the decrease in the number of large logs and because of advances in technology that uses the remaining residues for other purposes. Consequently, the residues used as raw materials for by-products will increase, whereas the residues that can be used as energy sources will decrease.

The use of fuelwood from industrial residues cannot be immediately replaced by an alternative. Because there are no equally low-cost alternatives for fuelwood from residues, these residues are necessary for use in drying ovens in the wood industry. The amount of residues was intentionally increased in some factories because of their need for sufficient fuelwood to supply the energy required for drying. Alternatives to the use of residues cannot be found unless the cost of residues rises and cheaper heat sources become available. Nevertheless, in some wood-processing factories, residues are discarded or incinerated. In such cases, the conversion of sawdust to briquette charcoal can be an efficient use of residues. In Laos and Cambodia, the implementation of CHP systems in wood-processing factories to generate electricity in local areas is promising. Government incentives are needed to develop such systems, as in the case of a wood-industry park in Sarawak, Malaysia.

Woody biomass is essential for local residents and for the wood industry and other industries in ASEAN countries. A possible approach to expand the uses for woody biomass as an energy source is as follows: First, the amount of biomass resources that are consumed should be reduced through the use of more efficient heat-using technology. Traditional cooking stoves are inefficient. If they are replaced with upgrades, the Philippines and Thailand could generate a surplus energy of 5.07 and 0.85 Mtoe (2005) respectively[2]. Woody biomass needs to be used as efficiently as possible, not only to save resources, but also to protect forests and precious ecosystems. Second, logging residues that are not collected because of current high transportation costs must be used. This problem cannot be resolved in the short term, but the whole world, including the ASEAN countries, must adopt this approach in the long run. ASEAN countries must deal with forestry problems such as illegal logging or improper slash-and-burn agriculture. A system needs to be put into place that will resolve these problems collectively. There is a need for a policy to encourage the collection of logging residues, especially those in the landings, as well as technology that will allow the efficient use of oil palm residues.

According to ACE estimates[1], biomass energy will play a significant role as a renewable energy source by 2010 in all ASEAN countries. It will account for 70% of renewable sources in 2010, although it accounted for 77% in 2000. Biomass energy will be a necessary energy source for the future in ASEAN countries, which must make concrete steps toward resolving the problems outlined in this study.

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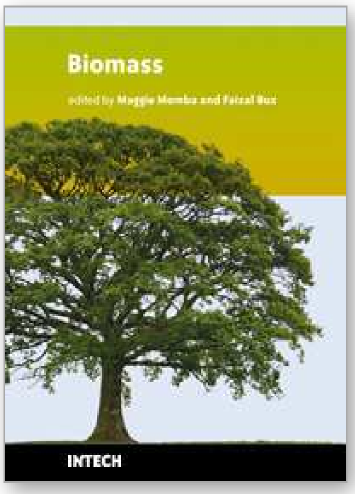

Biomass

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Due to demands placed on natural resources globally and subsequent deterioration of the environment, there is a need to source and develop appropriate technology to satisfy this requirement. For decades mankind has largely depended on natural resources such as fossil fuels to meet the ever increasing energy demands. Realizing the finite nature of these resources, emphasis is now shifting to investigating alternate energy source governed by environmentally friendly principles. The abundance of biomass and associated favorable techno-economics has recently changed global perceptions of harnessing biomass as a valuable resource rather than a waste. To this end this book aims to make a contribution to exploring further this area of biomass research and development in the form of a compilation of chapters and covering areas of ecological status of different types of biomass and the roles they play in ecosystems, current status of biomass utilization and deriving energy and other value added products from biomass. In this context biomass can be defined as large plants and trees and different groups of microorganisms. This book will serve as an invaluable resource for scientists and environmental managers in planning solutions for sustainable development.