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Study on Biomass Supply Chain for Power Generation in Southern Part of Thailand

by

Han Phoumin

Shigeru Kimura

Wongkot Wongsapai

Yaowateera Achawangku

Economic Research Institute for ASEAN and East Asia

กระทรวงพลังงาน
MINISTRY OF ENERGY

Biomass Supply Chain for Power Generation in Southern Part of Thailand

Economic Research Institute for ASEAN and East Asia (ERIA)

Sentra Senayan II 6th Floor

Jalan Asia Afrika no.8, Gelora Bung Karno

Senayan, Jakarta Pusat 1270

Indonesia

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Foreword

Promoting the use of biomass in power generation is one option for Thailand to respond to the need to accelerate its share of renewable energy and to meet the growing energy demand in an affordable and sustainable manner. This is due to its potential supply, especially in its northern and southern provinces. Improving the biomass supply chain could also provide many opportunities for local people to engage in the activities, and thus increase their earnings and improve their well-being.

In this regard, the Ministry of Energy of Thailand requested the Economic Research Institute for ASEAN and East Asia (ERIA) to conduct a study on the biomass supply chain for power generation in southern Thailand. Acknowledging the country's need to respond to growing electricity demand in its southern provinces, ERIA deployed a professional team from its Jakarta headquarters to work with Thai experts comprising university professors and professional staff from its Ministry of Energy. Scoping the biomass supply chain and its supply potential is the first step to understand if expansion for new capacity of biomass power generation is viable or not. The expert team also analysed the levelized cost of energy to check the competitiveness of biomass power generation. The results suggest that expansion of biomass power generation in the southern provinces, supported by the government's policy on feed-in tariff, is very attractive for investment in biomass power generation. Thus, the study suggests that stable supply and competitive biomass price needs to be ensured through the improvement of the supply chain. The study also suggests that the current feed-in tariff policy is encouraged as it will attract more investments in the biomass power generation in Thailand's southern provinces.

Most importantly, the government, through its specialised agencies, should send a clear message to investors regarding the government's support to biomass power generation. The bureaucratic burden borne out by the administrative process, which could ultimately add cost to the investment, should also be minimised.

May I then take this opportunity extend my sincere appreciation to all those who supported and contributed to this study.

Professor Hidetoshi Nishimura
President
Economic Research Institute for ASEAN and East Asia

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We express sincere appreciation to the experts we met in the field during the interviews for their inputs and information, which are critical to the analysis of the study.

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The Authors

Project Contributors

From the Ministry of Energy and Thailand's Universities

Dr Poonpat Leesombatpaiboon, Executive Director of International Affairs Division, Ministry of Energy, Thailand

Dr Weerawat Chantanakome, Councilor on International Affairs, International Affairs Division, Ministry of Energy, Thailand

Dr Yaowateera Achawangkul, Project Coordinator, Department of Alternative Energy Development and Efficiency

Ms Krittiya Petsee, Plan and Policy Analyst, International Energy Cooperation Office, Ministry of Energy, Thailand

Prof Wongkot Wongsapai, Assistant Professor, Chiang Mai University, and leader of the local research team

Prof Watchara Loysmut, Engineer and Assistant Professor, Rangsit University

Mr Sakda Prasonguppatam, Engineer, Rangsit University

Prof Pongsiri Jaruyanon, Engineer Assistant and Professor, Silpakorn University

Ms Kannikar Srithunyalucksana, Engineer

From the Economic Research Institute for ASEAN and East Asia

Mr Shigeru Kimura, Special Advisor to the President for Energy Affairs

Dr Han Phoumin, Energy Economist

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Abbreviations and Acronyms

COD	commercial operation date
DEDE	Department of Alternative Energy Development and Efficiency
EGAT	Electricity Generating Authority of Thailand
FiT	feed-in tariff
LCOE	levelized cost of energy
MDF	medium-density fibreboard
O&M	operation and maintenance
RE	renewable energy
SCOD	scheduled commercial operation date
SPP	small power producer
US$	United States dollar
VSPP	very small power producer

Executive Summary

The study on 'Biomass Supply Chain for Power Generation in Southern Thailand' was initiated by the Ministry of Energy, Thailand under the leadership of His Excellency, Dr Siri Jirapongphan. His Excellency wishes to see biomass-fired power generation expand in southern Thailand to meet the growing energy demand. The study investigates the whole biomass supply chain, its potential to add capacity to biomass-fired power generation, and conducts an economic analysis of the introduction of biomass power generation. The study is divided into six chapters as briefly described below:

Chapter 1 reviews the status of small power producers (SPPs) and very small power producers (VSPPs) of renewable energy in Thailand, including the recent policy on, and privilege of, buying renewable energy.

Chapter 2 focuses on the estimation of biomass potential. There are two sources of biomass production: plantation areas and agricultural processing plants. The amount of biomass production, therefore, varies according to the amount of biomass-converting agricultural product, which also varies in proportion to the plantation area or the harvesting area. From this the biomass potentials are estimated.

Chapter 3 analyses the biomass supply from rubberwood in southern Thailand to plan for the promotion of power generation using biomass from rubberwood and ensure that the demand is consistent with the supply.

Chapter 4 analyses the supply chain of biomass to generate power in three southern border provinces of Thailand where a survey was conducted to collect cost data along the biomass supply chain until power generation. This chapter also analyses problems and suggests solutions for the supply of biomass to power plants in the southern Thailand.

Chapter 5 conducts the feasibility of biomass power generation by looking into the cost competitiveness of the levelized cost of energy using the biomass feedstocks at various price scenarios. This chapter also looks into the current government policy of feed-in tariff that supports the biomass power generation in southern Thailand, and analyses the possibility of expanding biomass power generation in the area.

Chapter 6 concludes and recommends policies to the government. The potential of biomass supply for power generation in the three northern territory provinces could be made available for an additional new capacity of about 250 MW. Considering the whole biomass in the southern provinces and the rest of Thailand, if infrastructure and transportation facilities with port/receiving terminal of biomass in the area were present, the potential of biomass power generation, if not subjected to any constraint, is huge. This study, using three price scenarios – US$25/ton, US$32/ton, and US$37/ton – generates very interesting results:

At the fuel price of US$25/ton, the levelized cost of electricity (LCOE) is estimated at US$8.2 cents/kWh.

At the fuel price of US$32/ton, the LCOE is estimated at US$8.84 cents/kWh.

At the fuel price of US$37/ton, the LCOE is estimated at US$9.69 cents/kWh.

These LCOE results are appealing and, if combined with the current feed-in tariff in the three southern provinces, the investment in biomass power plants in these provinces will become attractive to investors. Thus, the appropriate policy and mechanism are needed to attract investors.

Chapter 1

Status on Renewable Energy SPP and VSPP in Southern Thailand

This chapter reviews the status of small power producers (SPPs) and very small power producers (VSPPs) of renewable energy (RE) in Thailand, including the recent policy and privileges for purchasing RE.

1. History of Thailand's SPP Scheme

The SPP scheme was established on 17 March 1992 through an endorsement by Thailand's cabinet. The scheme aims to promote power generation by using alternative fuel and waste, including cogeneration, to efficiently use domestic alternative resources and by-product energy. This concept also decreases the government's duty to invest in power infrastructure.

The National Energy Committee, on 26 December 2006, endorsed the Electricity Generating Authority of Thailand (EGAT) to purchase 3,200 MW to 4,000 MW of electricity generated from all kinds of fuel. After that, EGAT, the Provincial Electricity Authority and the Metropolitan Electricity Authority issued the small power purchasing announcement in 2007. Purchasing would cover existing capacity of 10 MW–90 MW, which is classified by (i) SPP cogeneration firm contract, (ii) SPP firm contract (RE), and (iii) SPP non-firm contract.

In 2017, the Ministry of Energy launched a new SPP scheme called the 'SPP Hybrid-firm.' This allowed power producers to use two kinds of alternative fuel or more to generate power and sell to EGAT in order to increase production of stable power from RE. Several criteria were set under this scheme:

1) It is available to new RE power plants with an existing capacity of 10 MW–50 MW.

2) Power plants must operate 100% during peak time, and 65% in off-peak time.

3) Fossil fuel utilisation is prohibited (except during system start-up).

4) Purchasing rate is feed-in tariff (FiT) bidding at 3.66 baht (B)/kWh.

2. History of the VSPP Scheme of Thailand

The VSPP scheme started on 14 May 2006 when the Thai cabinet agreed to regulate the VSPPs. Power producers can enter into power purchasing contracts with the Metropolitan Electricity Authority or the Provincial Electricity Authority (depending on the power plant's location). This scheme aims to promote the use of domestic resources, increase the stability of national transmission by distributing power generation, reduce the government budget for the construction of new power plants, as well as contribute to the operation of conventional power plants during peak time.

At the beginning, the VSPP contract was available to power plants with an existing capacity of less than 1 MW. In 2007, the Energy Policy Administrative Committee endorsed to extend the maximum capacity of the VSPPs from 1 MW to 10 MW. Then, adder, or feed-in premium, was established by topping-up a special rate to the normal purchasing price (Table 1.1).

Table 1.1: Adder Rates for the VSPP

RE Sources	Adder Rate (B/kWh)	Subsidy Period (year)
Solar	8.00	10
Wind	2.50	10
Municipal solid waste	2.50	7
Small hydro (50–200 kW)	0.40	7
Small hydro (less than 50 kW)	0.80	7
Biomass	0.30	7
Biogas	0.30	7

B = baht, kWh = kilowatt-hour, RE = renewable energy, VSPP = very small power producer.
Note: Adder for solar decreased from B8.00/kWh to B6.50/kWh in 2010.
Source: Provincial Electricity Authority (PEA), Thailand Adder Rates as of 2013.

In June 2007, the National Energy Committee endorsed the premium adder rate to promote power plants in border southern provinces (Yala, Pattani, and Narathiwat) and four districts in Songkhla Province (Nathawee, Saba Yoi, Jana, and Thepha). Biomass, biogas, municipal waste, and small and micro hydropower earned more 1 baht (B)/kWh topping up from ordinary adder, whereas solar and wind obtained more B1.50/kWh rate to normal adder.

With the SPP hybrid-firm announcement, the VSPP semi-firm scheme was replaced to subsidise power producers that can generate more electricity during peak periods. This scheme was available to new RE power plants that use biomass, biogas from wastewater or energy crop, and municipal solid waste (also called trash or garbage, defined nationally as wastes consisting of everyday items, which generate 10 MW or lower). Power plants must be operating for 6 months under a firm contract (100% power operation in peak time, and lower than 65% during off-peak), which must cover the maximum power consumption period (March to June) and 6 months for non-firm condition. Like the SPP hybrid firm, fossil fuel can be used only during the start-up period, and an energy storage system can be applied.

3. Feed-in Tariff

Replacing adder, the FiT scheme for rooftop and ground-mounted solar photovoltaic power projects was introduced with a total capacity of 200 MW and 800 MW, respectively, and contract duration of 25 years. The target was to fulfil the allocated capacity cap by 2014. Then, for non-solar renewables, the Ministry of Energy launched the FiT scheme for the VSPPs with less than 10 MW installed capacity covering power from waste gasification, landfill gas, biomass, biogas, hydro, and wind in 2014.

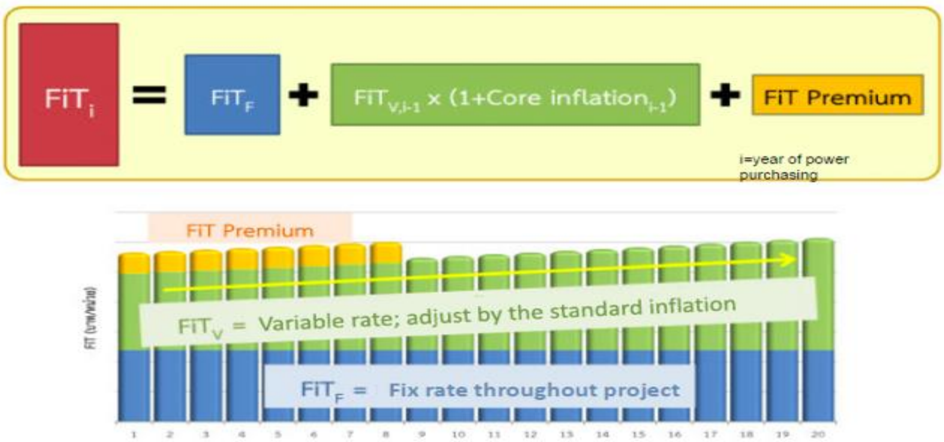
RE sources of power generation in Thailand are varied, such as hydropower, biomass, biogas, solar cell. These technologies must face the uncertain resource availability pattern and fluctuating fuel prices. Therefore, the FiTs for this group are formulated with three components, as follows:

1) a fixed-based tariff (FiT_F), which is calculated from capital, and operations and maintenance (O&M) costs of each renewable technology;

2) a variable-based tariff (FiT_V) for bioenergy (except landfill projects) calculated from the fuel cost and dependent on the inflation rate; and

3) an additional premium (FiT_P) for projects that use bioenergy (except landfill projects) for the first 8 years.

Figure 1.1: Structure of FiT for RE Technologies Using Bioenergy



FiT = feed-in tariff, RE = renewable energy.
Source: Energy Policy and Planning Office (EPPO), Ministry of Energy, as of 2015.

Table 1.2: FiT Rate for Electricity Generated from Bioenergy Sources

Capacity (MW)	FiT (B/kWh)			Support Duration (Years)	FiT Premium (B/kWh)	
	FiT_F	FiT_V	FiT*		Bioenergy projects (First 8 years)	Adder for Southern Provinces**
Bioenergy projects						
1. Waste-to-energy (integrated waste management)						
Installed capacity ≤ 1 MW	3.13	3.21	6.34	20	0.7	0.5
Installed capacity 1–3 MW	2.61	3.21	5.82	20	0.7	0.5
Installed capacity > 3 MW	2.39	2.69	5.08	20	0.7	0.5
2. Waste (landfill)	5.60	-	5.60	10	-	0.5
3. Biomass						
Installed capacity ≤ 1 MW	3.13	2.21	5.34	20	0.5	0.5
Installed capacity 1–3 MW	2.61	2.21	4.82	20	0.4	0.5
Installed capacity > 3 MW	2.39	1.85	4.24	20	0.3	0.5
4. Biogas (wastewater, manure)	3.76	-	3.76	20	0.5	0.5
5. Biogas (energy crop)	2.79	2.55	5.34	20	0.5	0.5
6. Hydro energy Installed capacity ≤ 200 MW	4.90	-	4.90	20	-	0.50
7. Wind energy	6.06	-	6.06	20	-	0.50

Notes: B/kWh = Thailand baht per kWh of electricity

FiT = feed-in tariff.

FiT_F = fixed-based tariff, calculated from initial investment of the power plant construction and the full lifetime of its operation and maintenance cost.

FiT_V = variable-based tariff, feed-in tariff variable, calculated from investment cost of raw materials used for power generation that changes according to time.

* = FiT = FiT_F + FiT_V. This FiT rate will only apply to projects that feed electricity into the system within the year 2017. After 2017, FiT_V rate will continuously increase according to the core inflation rate. This only applies to waste (integrated waste disposal), biomass, and biogas (energy crops) categories.

** = Projects in Yala, Pattani, Narathiwat and Chana, Thepha, Saba-Yoi, and Na-Thawi districts in Songkhla provinces.

Source: Energy Policy and Planning Office (EPPO), Ministry of Energy, as of 2015.

4. Status of the SPPs and the VSPPs in Southern Thailand

The Energy Regulatory Committee summarised the overall status of RE SPPs and VSPPs. In November 2018, 13 SPPs were using renewable sources with 347.90 MW in existing capacity, while the total purchasing capacity was 313.47 MW.

For the VSPPs, 122 plants were using RE, with total existing capacity of 534.20 MW and total purchasing electricity of 476.61 MW. Table 1.3 summarises the SPP and VSPP status.

Table 1.3: Status of Renewable SPPs and VSPPs in Southern Thailand

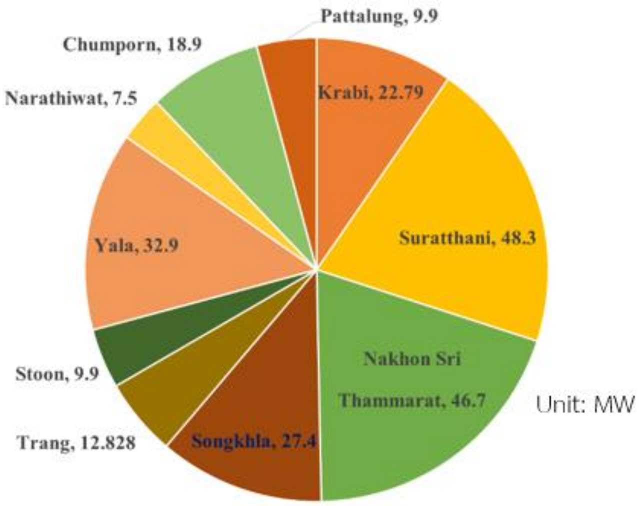
Type	SPP			VSPP		
	Amount of Plant	Existing (MW)	Purchasing (MW)	Amount of Plant	Existing (MW)	Purchasing (MW)
Accepted for purchasing (not yet PPA)	6	143	116.85	-	-	-
Already PPA (not COD yet)	2	46	41.62	25	134.33	129.80
Already COD	5	158.90	155	97	399.87	346.81
Total	13	347.90	313.47	122	534.20	476.61

COD = commercial operation date, PPA = power purchasing agreement, SPP = small power producer, VSPP = very small power producer.
Source: Energy Regulatory Commission (ERC), as of November 2018.

5. Biomass Power Plant in Southern Thailand

Southern Thailand is rich with biomass, such as rubberwood; entrepreneurs are thus attracted and interested to invest in biomass power plant projects in the area. Likewise, due to special privileges granted by the government in the southern provinces, both SPPs and VSPPs are mechanisms to encourage constructed and supplied electricity to the national transmission line.

Figure 1.2: Existing Capacity of COD Biomass Power Plant



Source: Energy Regulatory Commission (ERC).
http://www.erc.or.th/ERCSPP/default.aspx?x=0&muid=23&prid=41

In November 2018, biomass power plants had already sold 237.11 MW of electricity to the grid (COD). Suratthani and Nashon Sri Thammarat became the two power plants with the highest existing capacity (48.3 MW and 46.7 MW, respectively). These provinces have a large rubberwood plantation area. Also, Phuket, Pang Nga, Pattani, and Ranong do not have biomass power plants.

Chapter 2

Study on Biomass Potential in Southern Thailand

Biomass energy is energy derived from agricultural products, which can be converted to biomass, so-called 'biomass crop' or 'energy crop'. This includes a broad variety of raw materials such as wood, agricultural crops, by-products of wood processing, forestry industry products, manure, and the organic fraction of waste. The two sources of biomass production are plantation areas and agricultural processing plants. The amount of biomass production, therefore, varies according to the amount of biomass-converting-agricultural product, which also varies in proportion to the plantation or harvesting area. One basically needs to know the plantation area or the harvesting area to estimate the amount of biomass production.

The Office of Agricultural Economics, Ministry of Agriculture and Cooperatives extracted data on the plantation areas of 14 provinces in Southern Thailand. The extracted data was used to report the plantation area, harvesting area, and amount of biomass plant and other major agricultural products in the annual report, the report on situation and trend of major agricultural products, etc.

1. Biomass in Thailand

Biomass can be derived from several agricultural products. The collection, study, and development of a database of potential biomass is needed to estimate the amount of remaining biomass each year. In Thailand, there are 23 types of potential biomass from 9 energy crops as follows:

(1) **Major rice and second rice**
- Straw
- Rice husk

(2) **Sugarcane**
- Leaves
- Bagasse

(3) **Maize**
- Stem and leaves
- Corn cob

(4) **Cassava**
- Cassava root
- Cassava pulp
- Cassava peel

(5) **Coconut**
- Cluster
- Spathe
- Shell

(6) **Soybean**
- Stem and leaves

(7) **Oil palm**
- Trunk
- Leaves and fronds
- Empty fruit branch
- Fiber
- Shell

(8) **Rubberwood**
- Roots, stump, and branches
- Offcut
- Slab
- Residue, sawdust

(9) **Cashew nut**
- Shell

2. Biomass for Fuel

Three types of biomass have been widely used as fuel for energy generation: (i) rubberwood offcut, (ii) rubberwood slab, and (iii) rubberwood residues and sawdust.

These types of biomass are traded commercially like the conventional fuels of petroleum products and coal. Domestic consumption is so high that biomass is imported from neighbouring countries. For example, rubberwood offcut is imported from Myanmar. The prices of biomass depend on demand and supply. When the demand is high, the price goes up. To maximise the efficiency of fuel consumption and minimise the impact of price fluctuation, the use of the above three types of biomass should be monitored.

3. Potential Biomass for Fuel

The different types of biomass – roots, stumps, and branches – used as fuel should be promoted. At present, the use of empty fruit bunches, roots, stumps, and branches as fuel is limited despite its high potential. The factors influencing less utilisation are (i) the difficulty to collect biomass and inconvenient transport; (ii) needed preparation, with associated preparation cost, before biomass is used as fuel; and (iii) the disadvantageous characteristics of biomass such as high moisture content and high ash content after burning.

To promote the use of potential biomass, the following solutions have been proposed.

(1) Encourage the study of the feasibility and suitability to use biomass for power generation. As an example, the Department of Alternative Energy Development and Efficiency (DEDE) has studied the possibility of using cassava rhizomes as fuel to generate power.

(2) Encourage investors of power plants by supporting both technical, engineering, and financial aspects, such as increasing the difference in the purchase of electricity (adder or feed-in tariff).

(3) Support studies and research on harvesting and processing methods, such as briquette for economic value.

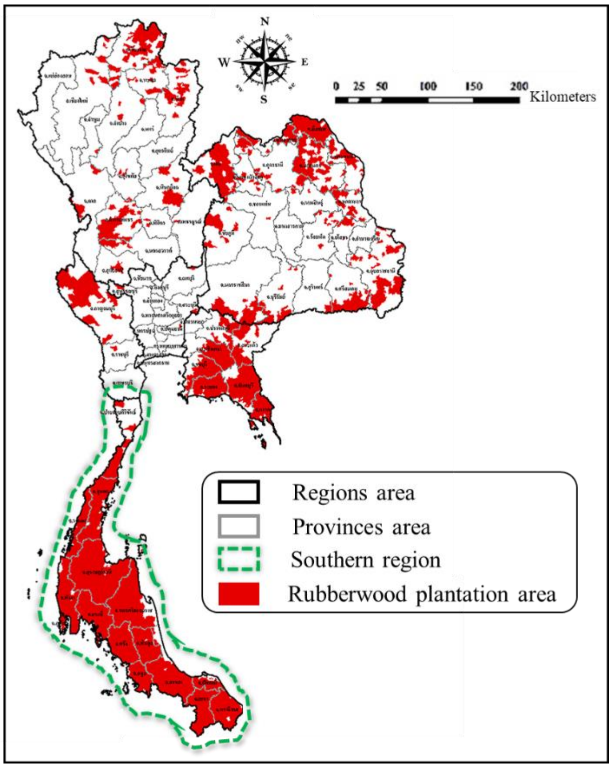
(4) Support studies and research on environment-friendly technologies to reduce anti-community problems.

(5) Promote and research on the use of ash or appropriate disposal methods

4. Biomass in the Southern Region

Data on biomass plantation areas was collected from 14 provinces of Southern Thailand. The data is based on the statistics from the Office of Agricultural Economics and Land Development Department (Figure 2.1), Ministry of Agriculture and Cooperatives. The data is reported in terms of plantation, harvesting, and production areas. In the south, four types of biomass come from rubberwood: (i) stumps, roots, and branches; (ii) offcut; (iii) slabs; and (iv) sawdust and wood residues.

Figure 2.1 Map of Rubberwood Plantation in Thailand



Source: Land Development Department (LDD), www. http://www.ldd.go.th

5. Analysis of Life Cycle of Biomass from Rubberwood

Rubber tree, a perennial plant, was first planted in Thailand in 1900 by the governor of Trang Province. The plantation area of rubber trees had been expanded and reached 22 million *rai* (as of 31 December 2017). Most rubber tree plantations are in southern Thailand (Figure 2.2).

The rotation of rubber trees is about 25–35 years, after which the trees give less latex. Therefore, they are felled and replanted. Rubber trees take 6–7 years to grow enough to give latex. In the past, felling the rubber trees was a problem as the trees were used only for fuelwood and for making charcoal. Rubberwood is also easily damaged by insects and fungi. But with state-of-the-art technology, rubberwood is now converted into valuable furniture at inexpensive cost. The stakeholders of rubberwood plantations are state enterprises, farmers, and private entities.

Figure 2.2 Rubberwood Plantation

Source: Para rubber Electronic Bulletin, Rubber Authority of Thailand (2018).

5.1. Life cycle of biomass from rubberwood

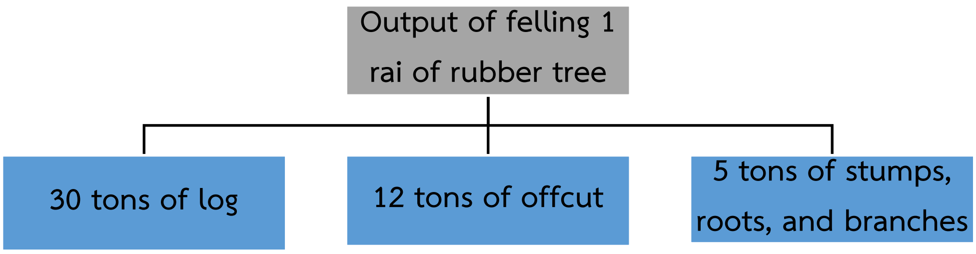
The life cycle of biomass from rubberwood starts from felling the retired rubber trees. The felled rubberwood can now be used. The logger will negotiate 3 months in advance with the farmer who will cut down the rubber trees. The factors influencing the biomass price are (i) density of rubber trees, at least 70 trees per rai; (ii) shape of strait trunk with small branches; (iii) accessibility of vehicle to transport the biomass; (iv) flat area to easily drag the felled wood; and (v) good quality of rubber trees (ex. RRIM 600[1]).

The logger needs expertise and skill to estimate the weight of biomass before cutting down the trees.

The biomass from rubberwood will be classified into logs; offcuts; and stumps, roots, and branches.

Felled rubber trees of 1 rai, on average, will give 30 tons of logs; 12 tons of offcut; and 5 tons of stumps, roots, and branches.

Figure 2.3 Output of Felled Rubber Trees (1 *Rai*)



Source: Author's field survey photo, 2019.

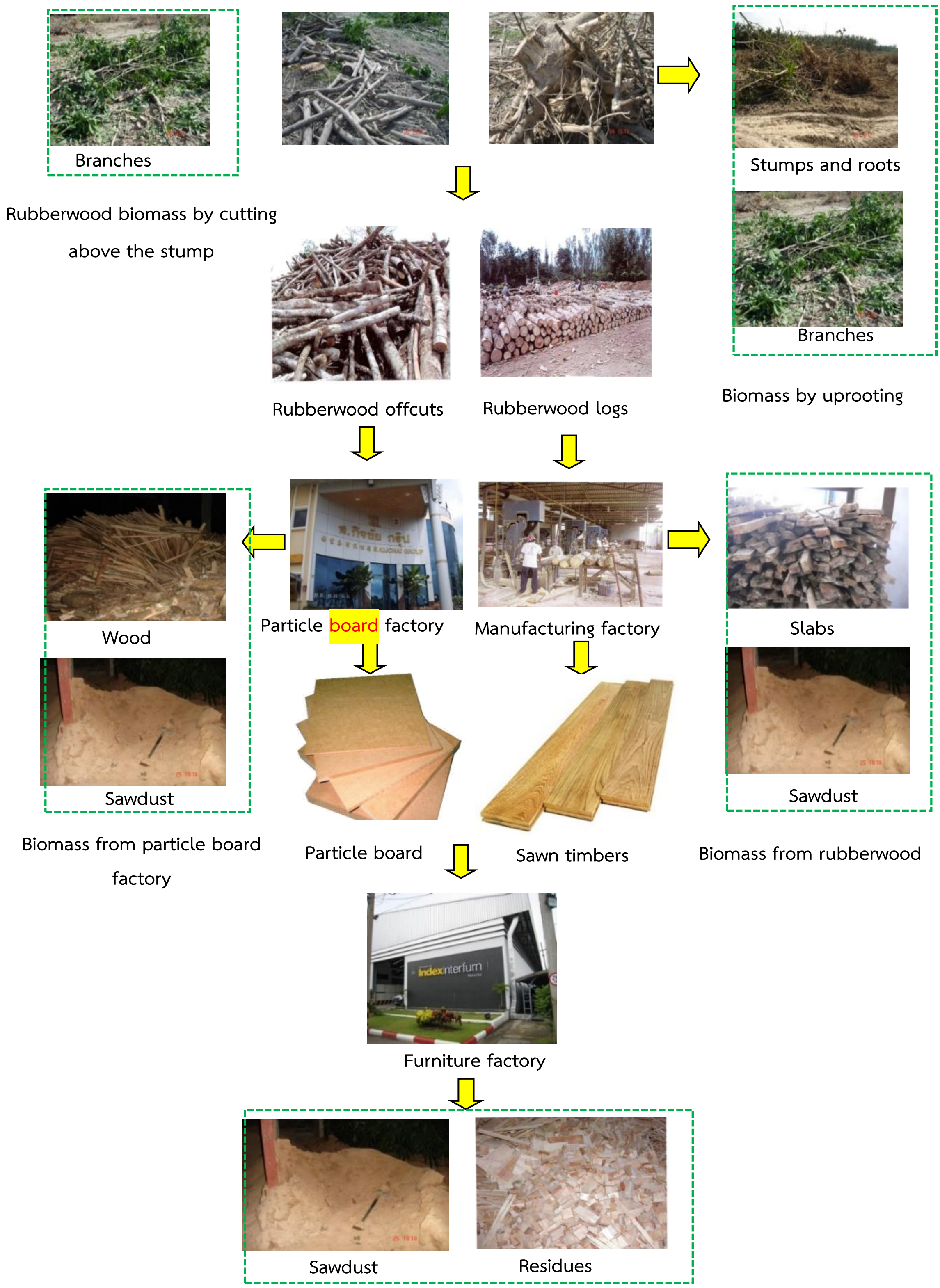
[1] RRIM 600: Natural rubber tree, cultivar of *Hevea brasiliensis*: high yield and high wood quality. RRIM 600 is recommended and identified as a moderately resistant cultivar.

Figure 2.3 shows that the biomass produced at the felling area is only stumps, roots, and branches. The rubberwood trunks are sent to the sawmill. Two types of rubberwood biomass, obtained at the processing factory, are slabs and sawdust as waste. The sawn timbers are sent to the furniture factory, which will produce sawdust and wood residues as waste from the process. The offcuts are used as raw material in producing particle boards and, in many industries, as source of heat.

This study focuses on two sources of rubberwood biomass: (i) stumps, roots, and branches at the felling area; and (ii) rubberwood slabs, sawdust, and wood residues at the rubberwood manufacturing factory, furniture factory, and particleboard factory.

The retired rubber trees can be felled into two ways: (i) cutting above the stump, and (ii) uprooting the stump. The first method uses a chainsaw to cut the trees but leaving the stumps under the soil. The second method uses a tractor to push and pull the rubber trees until their stumps are removed from the ground. The second method will give more rubberwood biomass than the first method but will cost about 10%–20% more than the first method. The trunks of at least 6 inches in diameter are then cut 1.05 metres long, so-called 'rubberwood log'. Small trunks of less than 6 inches in diameter are also cut into small pieces, so-called 'rubberwood offcuts. Both rubberwood types are processed by the manufacturing sector (Figure 2.4). The stumps, roots, and branches are also gathered for utilisation.

Figure 2.4 Life Cycle of Biomass from Rubberwood



Source: Author's field survey process diagram, 2019.

5.2. Production and use of stumps, roots, branches, and offcuts

○ *Production of stumps, roots, branches, and offcuts*

Farmers get stumps, roots, branches, and offcuts from felled rubber trees (Figures 2.5 and 2.6).

Figure 2.5 Stumps, Roots, and Branches

Source: Author's field survey photo, 2019.

The small trunks less than 6 inches in diameter are cut into small pieces, so-called 'rubberwood offcuts'.

Figure 2.6 Offcuts

Source: Author's field survey photo, 2019.

Felled rubber trees from 1 rai, on average, will give 30 tons of logs; 12 tons of rubberwood offcuts; and 5 tons of stumps, roots, and branches.

○ *Use of stumps, roots, branches, and offcuts*

When trees are cut above the stump, the branches are relatively difficult to collect to be used as a biomass energy source and are thus burnt at the field. When the stumps are taken out, the roots serve as additional rubberwood biomass. Stumps and roots are used as fuel in power plants and industries as their uprooting and reduction entail extra costs. Therefore, farmers prefer cutting the rubber trees above the stump to incur lower costs.

In this study, the survey and potential of rubberwood biomass are, therefore, focused on cutting above the stump.

Offcuts are used as raw material for particle board and as fuel in some industries, such as in oven of ribbed smoked sheet factory, boiler, brick-making kiln, lime factory, rubber glove factory, seafood processing factory, etc.

5.3. Production and utilisation of slab, wood residues, and sawdust

Rubberwood logs are trunks of rubberwood at least 6 inches in diameter. The trunks are cut 1.05 metres long for sending to sawmills within 48 hours to avoid the quality of rubberwood log from degrading, thus resulting in the logs' lower price. A limited amount of rubberwood logs (Figure 2.7) are sent to plywood factories.

Figure 2.7 Rubberwood Logs

Source: Author's field survey photo, 2019.

- *Production of slabs, wood residues, and sawdust in rubberwood process plants*

  As mentioned, felled rubberwood trees of 1 *rai* will give 30 tons of logs. Most logs are sent to sawmills or rubberwood processing plants where the logs are cut to produce sawn timber (Figure 2.8). The wastes from cutting are slabs and sawdust. In general, the slabs produced are about 40% of logs, or 12 tons of slabs. Sawdust produced is 10% of logs, giving 3 tons of sawdust. This production rate is inverse to the size of logs. Thirty percent of slabs and sawdust are used in-house in the drying process of sawmills, so 70% of slabs and sawdust will be available for selling.

Figure 2.8 Rubberwood Processing Plant

Source: Author's field survey photo, 2019.

Sawmills cut the rubberwood log to the specific size of ½" x 2" to 2" x 5" as per order. The sawn timber is then soaked in chemicals and dried. This helps protect timber from damage caused by insects and fungi. The sawn timber is then sent to furniture factories domestically and abroad to manufacture furniture, such as tables, chairs, photo frames, parquets, etc. The off-specification sawn timber is used to produce palette.

The wastes from sawing are slabs and sawdust, which can be used as energy in the boilers and ovens of mills. The remaining wastes can be sold to outsiders.

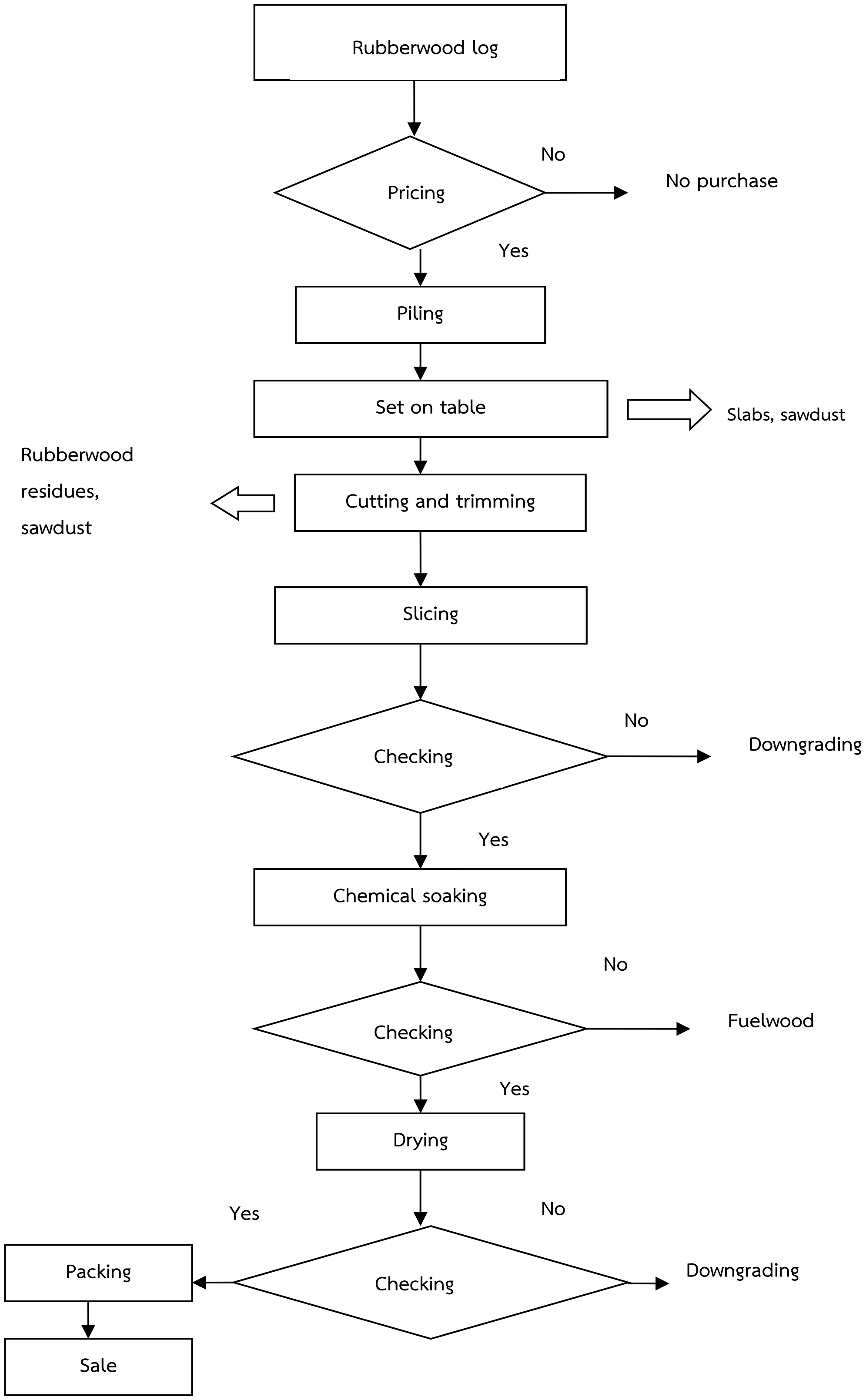
Since small sawmills do not have chemical soaking and drying, the sawn timber is then sold to the large sawmills. In this case, the slabs and sawdust from small sawmills are wholly sold to outsiders.

Data from the Ministry of Industry reveal that there are about 400 sawmills in southern Thailand. The combined sawmill capacity is over-installed compared to the availability of rubberwood logs. Therefore, most sawmills do not operate at full capacity. The competition to buy rubberwood logs is high; so, many small sawmills have to close down. At present, sawmills should have their own strategy to buy the rubberwood logs for their production, such as having direct contact with farmers and their own woodcutting team expanding the sawmill to locations near the felling area to reduce transport costs, etc.

The important machine of the sawmill is table saw, which is composed of saw and slice. The table saw can process 20 tons in 8 hours. Large sawmills have 10–20 table saws. Working hours are normally in shifts during the day. Some sawmills move their working hours to night-time (off-peak period) to reduce the electricity bill; however, the quality of the products also decreases.

Figure 2.9 shows the production process of sawmills.

Figure 2.9 Production Process of Sawmills



Source: Author's field survey process diagram, 2019.

○ *Use of slabs, wood residues, and sawdust in sawmills*

Slabs, wood residues, and sawdust produced in sawmills can be used as follows:

1) Sawmills that have a drying process use the rubberwood biomass as fuel in the boiler (Figure 2.10) to generate steam for the drying process. If the boiler can burn sawdust, sawdust is used as the main fuel and slabs, as the secondary fuel. If the boiler cannot burn sawdust, slabs are used as main fuel. The supplementary sawdust and slabs can be purchased from other sawmills. The excess biomass is sold to outsiders – slabs and wood residues are sold to factories; sawdust is sold to chicken farms, etc.

2) Sawmills that do not have a drying process sell all slabs, residues, and sawdust to outsiders.

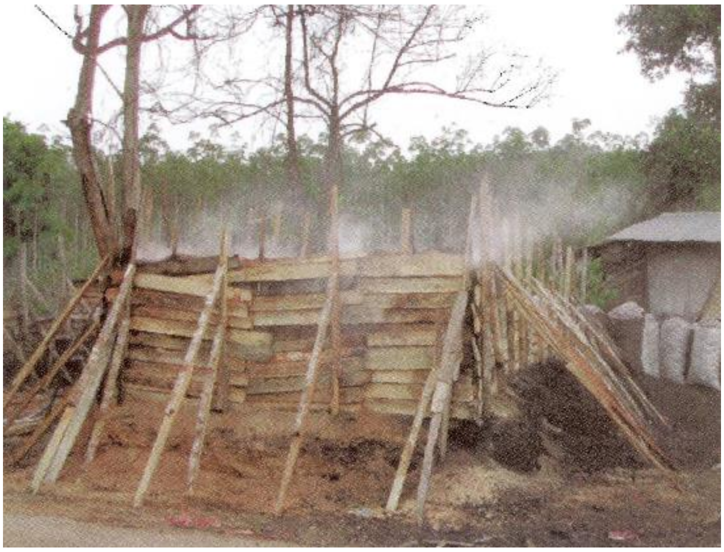
The survey found that slabs and sawdust from sawmills are used as follows:

1) Power plants use slabs and sawdust in the boiler of power plants.
2) Factories – cement plants, food manufacturers, ribbed smoked sheet factories – use slabs and sawdust as heat source in the manufacturing process.
3) Particle board factories use slabs and sawdust as raw material to produce particle boards.
4) Medium-density fibreboard (MDF) factories use the offcuts to produce MDF.
5) Households use slabs and sawdust to produce briquette.
6) Charcoal makers use slabs as raw material. Charcoal is made using two methods. First, in the simple charcoal-making stove (Figure 2.11), slabs are stacked in box-shaped containers and sawdust fills the gap. This method has low efficiency and low yield of about 10%. Second, in the charcoal-making kiln, clay is used to produce dome-shaped kiln, which costs about 10,000 baht (B)/set. This method is more efficient and has a yield of about 20%. The charcoal maker will get a high impact if the price of rubberwood slabs increases. Because if the price of charcoal increases, consumers may opt to use liquefied petroleum gas (LPG) instead.
7) Farmers use sawdust in agricultural farms, such as poultry and pig farms, or mushroom cultivation farms.

Figure 2.10 Rubberwood Slabs Used as Fuel in Boilers

Source: Author's field survey photo, 2019.

Figure 2.11 Simple Charcoal-making Stove



Source: Author's field survey photo, 2019.

5.4. Production of rubberwood residues and sawdust in furniture factories

Furniture factories are downstream manufacturing facilities from sawmills. The factories produce tables, chairs, toys, and kitchen utensils. The furniture produced from rubberwood has been growing for years as its cost is cheaper than hard wood, which is also less available.

○ *Production of rubberwood residues and sawdust in furniture factories*

Four types of furniture factories are classified by production:

1) Knockdown-type furniture factory – uses knockdown concept to make products, which commands the highest price.

2) Plywood or veneer factory – normally buys rubberwood timber with a diameter of more than 10” for peeling, gluing, drying, and cutting to the desired size.

3) Particle board factory – buys offcuts and slabs to shred and grind them to powder. It is then mixed with glue, formed, and pressed to the desired size.

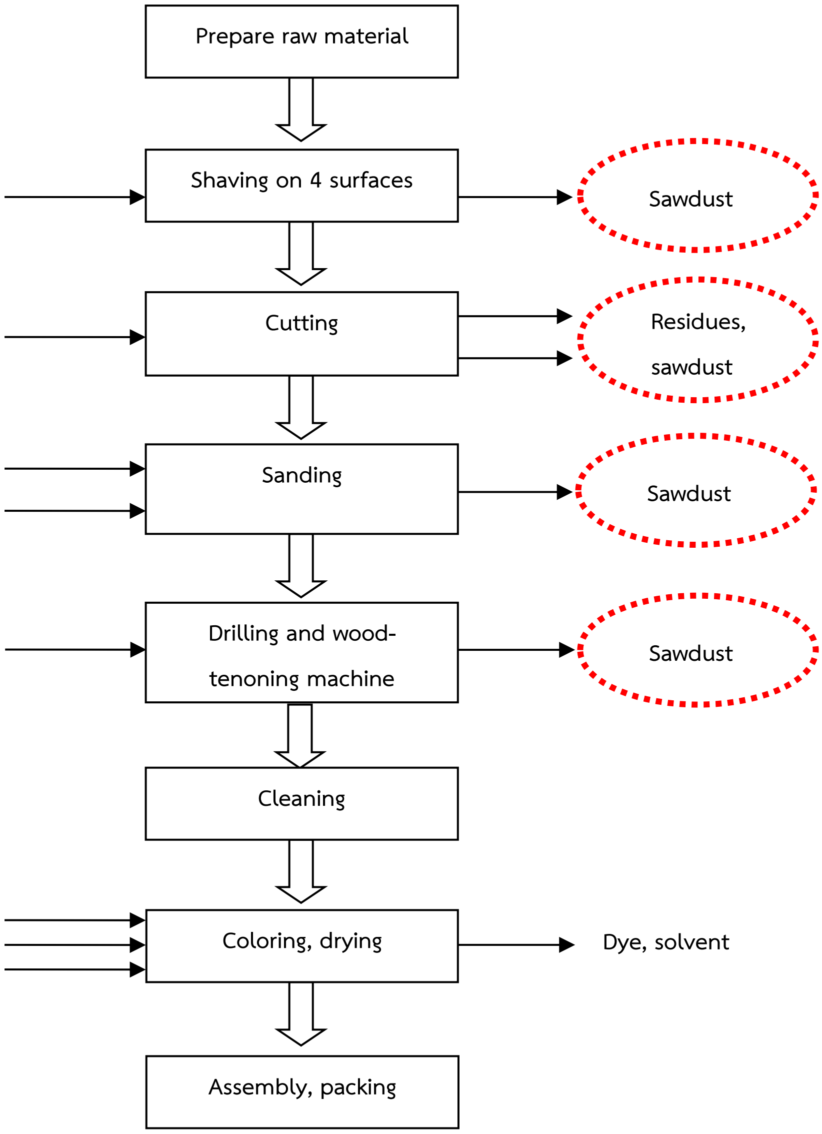
4) MDF factory – buys offcuts to be shredded to smaller size (does not use slabs).

All four types of furniture factories have a lot of waste materials – woodchips, wood dust, shavings, and wood or wood heads. These can be used as fuel for drying wood or be sold to outsiders.

The following are technology and production processes of rubberwood in each type of furniture factory.

1) Furniture factory – Figure 2.12 shows the production of rubberwood residues and sawdust in furniture

Figure 2.12 Production of Rubberwood Residues and Sawdust in Furniture



Source: Author's field survey process diagram, 2019.

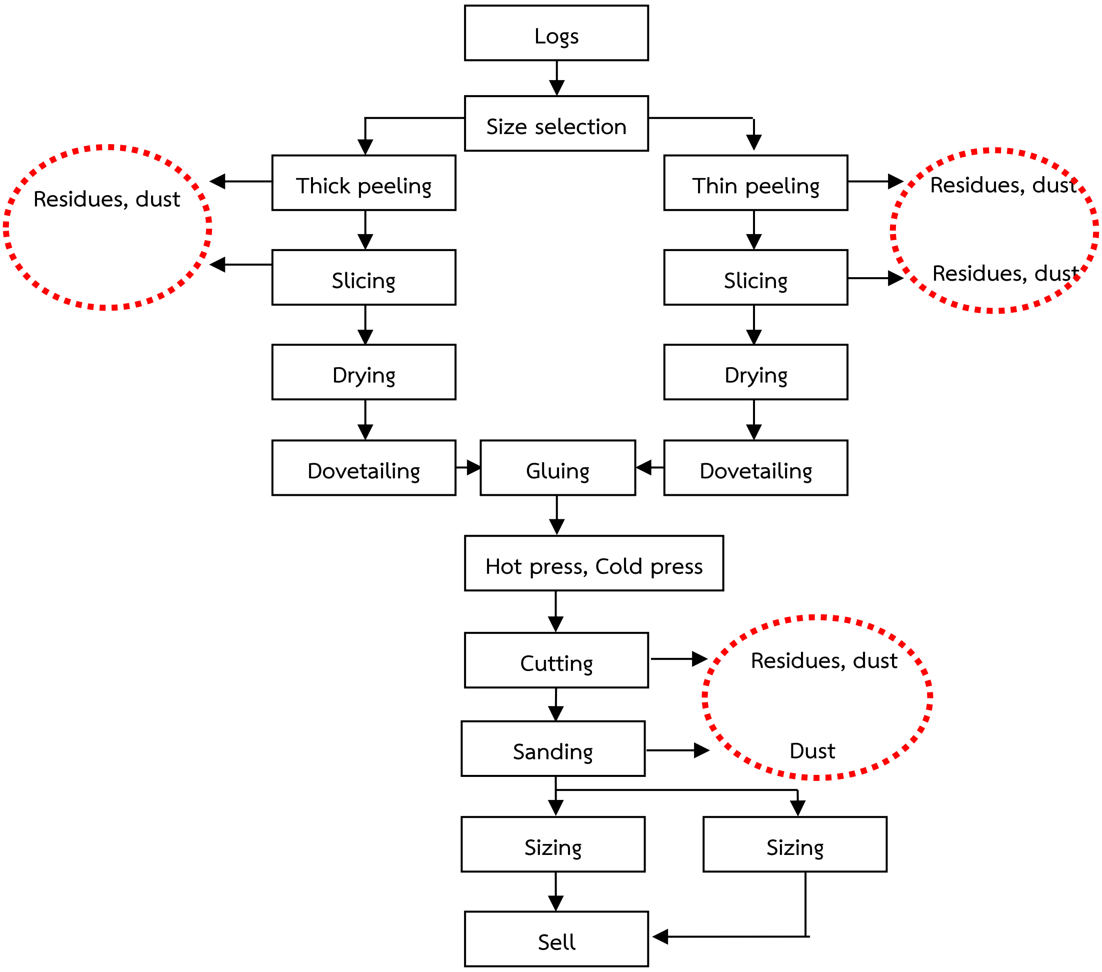
Figure 2.13 Cutting Edge of Rubberwood

Source: Author's field survey photo, 2019.

The study found that rubberwood residues and dust are produced at about 8% of rubberwood input to the furniture factory. In other words, a rubberwood input of 1 ton to the furniture factory will produce residues, sawdust, and dust of 0.08 ton.

2) Plywood or veneer factory – Figure 2.14 shows the biomass production process from the plywood factory.

Figure 2.14 Biomass Production from the Plywood Factory

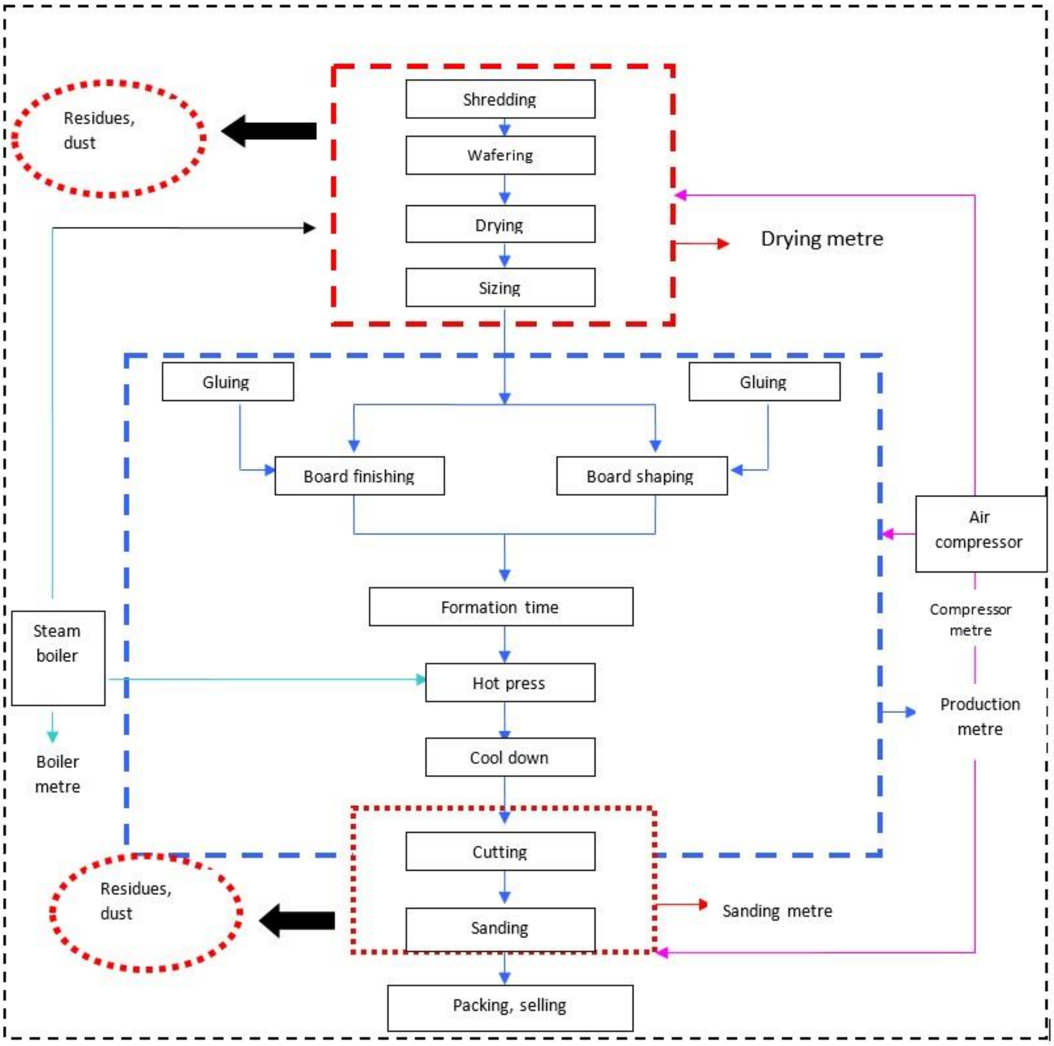


Source: Author's field survey process diagram, 2019.

The study found that rubberwood residues and dust are produced at about 5% of rubberwood input to the plywood factory. In other words, a rubberwood input of 1 ton to the plywood factory will produce residues, sawdust, and dust of 0.05 ton.

3) Particle board factory – Figure 2.15 shows the biomass production process from the particle board factory.

Figure 2.15 Biomass Production from the Particle Board Factory

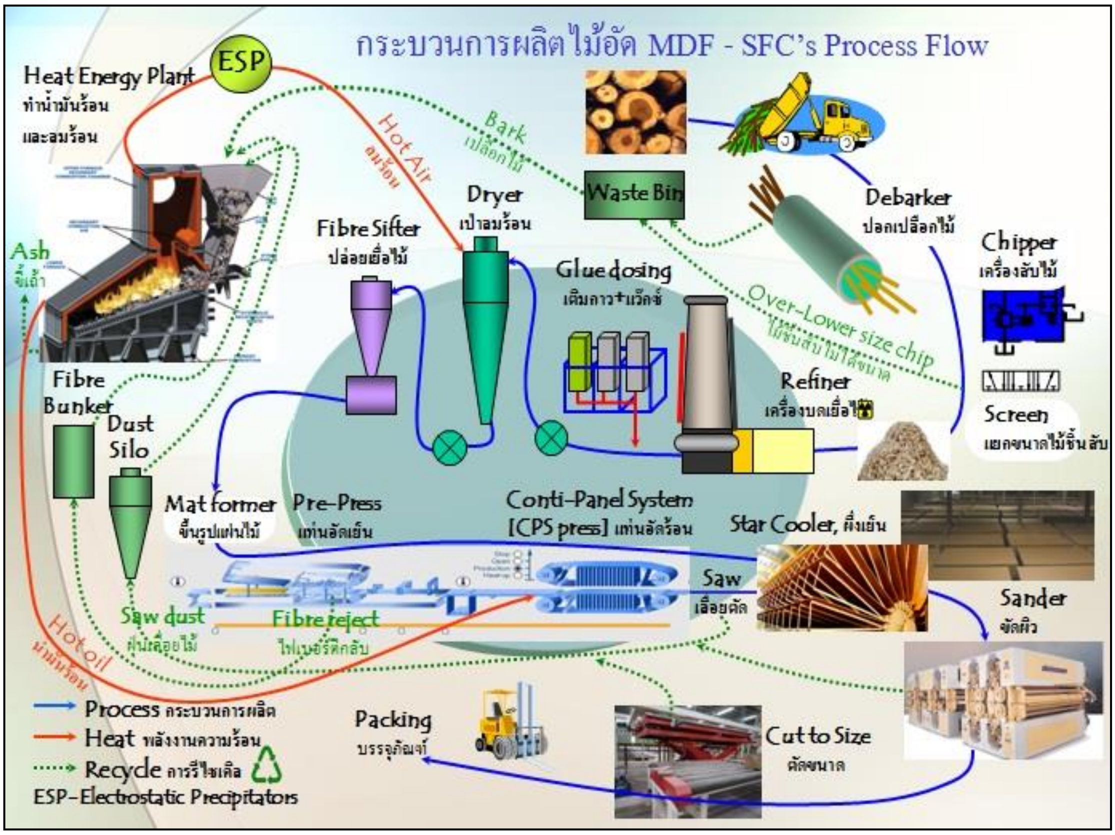


Source: Author's field survey process diagram, 2019.

The study found that rubberwood residues and dust are produced at about 5% of rubberwood input to the particle board factory. In other words, a rubberwood input of 1 ton to the particle board factory will produce residues, sawdust, and dust of 0.05 ton.

4) MDF factory – Figure 2.16 shows the biomass production from the MDF factory.

Figure 2.16 Production Process of the MDF



MDF = medium-density fibreboard.
Source: Author's data field survey process diagram, 2019.

Figure 2.16 shows that rubberwood residues are produced during shredding and screening. The off-specification-sized chip will be separated to produce hot oil and hot air in the energy plant. Sawdust is produced in cutting and sanding. Sawdust is also used in the energy plant. The study also found that rubberwood residues, sawdust, and dust are produced at about 3% of rubberwood input to the MDF factory. In other words, a rubberwood input of 1 ton to the MDF factory will produce residues, sawdust, and dust of 0.03 ton.

6. Potential of Biomass Obtained from Rubberwood

Felled rubber trees from 1 rai will give 30 tons of logs, most of which are sent to sawmills or rubberwood-processing plants. The logs are cut to obtain sawn timber. The wastes from cutting are slabs and sawdust. In general, the slabs produced from about 40% of logs give 12 tons of slabs. Sawdust produced is 10% of logs and gives 3 tons of sawdust. This production rate is inverse with the size of logs. Thirty percent of slabs and sawdust are used in-house in the drying process of sawmills so 70% of slabs and sawdust are sold.

Unlike the data on plantation and harvesting areas, the data on felling area of rubber trees is limited because rubber tree felling is uncertain. However, the Rubber Authority of Thailand (RAOT), established under Rubber Authority of Thailand Act 2015, has a mission to promote and support the farmers and all stakeholders to fulfil their needs. RAOT, therefore, has some information about the felling area.

Based on 2009 statistics, the felling area of rubber trees had increased. The target of felling area by RAOT is 400,000 rai/year.

Table 2.1 shows the ratio of biomass production and its heating value.

Table 2.1 Ratio of Rubberwood Biomass Production and its Heating Value

Source of Biomass	Type of Biomass	Ratio of Biomass per Area (ton/felling area)	Heating Value (MJ/ton)
Plantation area	Stumps and roots	5	6,570
Plantation area	Offcuts	12	6,570
Rubberwood processing plant	Slabs	12	6,570
Rubberwood processing plant	Sawdust	3	6,570

MJ = megajoule.
Source: Author’s data field survey results, 2019, while heating value is from DEDE.

Biomass consumption and biomass are described below:

Biomass consumption

Biomass is consumed in:

1) Power generation: Biomass (slabs, roots, and sawdust) consumption as fuel in the boiler is calculated from the installed capacity of the power plant (MW) based on the operating hours of 24 hours a day for 330 days per year with a plant efficiency of 20%.

2) Steam generation: Biomass (slabs and sawdust) consumption is calculated from steam consumption per ton of raw material and amount of rubberwood input per ton of steam consumed.

3) MDF and particle board factories: Biomass (slabs and sawdust) consumption as raw material in the MDF factory is obtained from the energy audit report of the management of controlled energy.

4) Wood pellet: Biomass (sawdust) consumption is estimated from the production of wood pellets.

Remaining biomass

The remaining biomass is the difference of biomass availability and biomass consumption. The estimation of rubberwood biomass by province in 2017 is elaborated below.

6.1. Rubberwood biomass by province in the southern region

- **Rubberwood biomass in Krabi Province**
  - Krabi has a rubber tree plantation area of 596,827 rai and a felling area of 847 rai.
  - The available biomass is 4,233.2 tons of roots; 2,539.9 tons of sawdust; 10,160 tons of slabs; and 10,160 tons of offcuts.
  - The remaining biomass is 4,233.2 tons of roots and 10,160 tons of offcuts.
- **Rubberwood biomass in Chumphon Province**
  - Chumphon has a rubber tree plantation area of 567,131 rai and a felling area of 5,245 rai.
  - The available biomass is 26,224.7 tons of roots; 15,734.8 tons of sawdust; 62,939 tons of slabs; and 62,939 tons of offcuts.
  - The remaining biomass is 26,224.7 tons of roots and 62,939 tons of offcuts.
- **Rubberwood biomass in Trang Province**
  - Trang has a rubber tree plantation area of 1,495,082 rai and a felling area of 4,726 rai.
  - The available biomass is 23,629.2 tons of roots; 14,177.5 tons of sawdust; 56,710 tons of slabs; and 56,710 tons of offcuts.
  - One power plant uses biomass from rubberwood. The installed capacity is 4.94 MW, requiring 107,191 tons/year of biomass for power generation.
  - Biomass consumption for steam generation is 99,808 tons/year.
  - The remaining biomass is 12,910.03 tons of roots.
- **Rubberwood biomass in Nakhon Si Thammarat Province**
  - Nakhon Si Thammarat has a rubber tree plantation area of 1,500,327 rai, and a felling area of 287,257 rai.
  - The available biomass is 1,436,284.6 tons of roots; 861,770.7 tons of sawdust; 3,447,083 tons of slabs; and 3,447,083 tons of offcuts.
  - Two power plants use biomass from rubberwood. The installed capacity is 19 MW, requiring 412,273.97 tons/year of biomass for power generation.
  - Biomass consumption for steam generation is 683,322 tons/year.
  - The remaining biomass is 1,319,058.04 tons of roots; 1,129,313.54 tons of slabs; and 1,553,140.44 tons of offcuts.

- **Rubberwood biomass in Narathiwat Province**
  - Narathiwat has a rubber tree plantation area of 1,007,135 rai, and a felling area of 1,068 rai.
  - The available biomass is 5,341.2 tons of roots; 3,204.7 tons of sawdust; 12,819 tons of slabs; and 12,819 tons of offcuts.
  - One power plant uses biomass from rubberwood. The installed capacity is 7.5 MW, requiring 162,740 tons/year of biomass for power generation.
  - Biomass consumption for steam generation is 3,857 tons/year.
  - The remaining biomass is 8,961.31 tons of offcuts.
- **Rubberwood biomass in Pattani Province**
  - Pattani has a rubber tree plantation area of 369,956 rai and a felling area of 1,908 rai.
  - The available biomass is 9,539.1 tons of roots; 5,723.4 tons of sawdust; 22,894 tons of slabs; and 22,894 tons of offcuts.
  - Biomass consumption for steam generation is 26,452 tons/year.
  - There is no remaining biomass in Pattani.
- **Rubberwood biomass in Phang Nga Province**
  - Phang Nga has a rubber tree plantation area of 686,095 rai and a felling area of 2,063 rai.
  - The available biomass is 10,316 tons of roots; 6,189.6 tons of sawdust; 24,758 tons of slabs; and 24,758 tons of offcuts.
  - Biomass consumption for steam generation is 250 tons/year.
  - The remaining biomass is 10,315.96 tons of roots and 24,758.31 tons of offcuts.
- **Rubberwood biomass in Phatthalung Province**
  - Phatthalung has a rubber tree plantation area of 891,023 rai and a felling area of 5,820 rai.
  - The available biomass is 29,098.3 tons of roots; 17,459.0 tons of sawdust; 69,836.0 tons of slabs; and 69,836.0 tons of offcuts.
  - One power plant uses biomass from rubberwood. The installed capacity is 9.9 MW, requiring 214,816 tons/year of biomass for power generation.
  - Biomass consumption for steam generation is 7,174 tons/year.
  - The remaining biomass is 7,616.69 tons of roots.
- **Rubberwood biomass in Phuket Province**
  - Phuket has a rubber tree plantation area of 67,115 rai and a felling area of 290 rai.

- The available biomass is 1,447.9 tons of roots; 868.7 tons of sawdust; 3,475 tons of slabs; and 3,475 tons of offcuts.
- The remaining biomass is 1,447.9 tons of roots and 3,474 tons of offcuts.

- **Rubberwood biomass in Yala Province**
  - Yala has a rubber tree plantation area of 1,248,238 rai and a felling area of 5,896 rai.
  - The available biomass is 29,482.4 tons of roots; 17,689.4 tons of sawdust; 70,758 tons of slabs; and 70,758 tons of offcuts.
  - One power plant uses biomass from rubberwood. The installed capacity is 9.9 MW, requiring 214,816 tons/year of biomass for power generation.
  - Biomass consumption for steam generation is 5,647 tons/year.
  - The remaining biomass is 6,606.99 tons of roots and 63,526.81 tons of offcuts.
- **Rubberwood biomass in Ranong Province**
  - Ranong has a rubber tree plantation area of 311,600 rai and a felling area of 2,057 rai.
  - The available biomass is 10,285.1 tons of roots; 6,171 tons of sawdust; 24,684 tons of slabs; and 24,684 tons of offcuts.
  - The remaining biomass is 10,285.06 tons of roots and 24,684.15 tons of offcuts.
- **Rubberwood biomass in Songkhla Province**
  - Songkhla has a rubber tree plantation area of 1,978,684 rai and no felling area.
  - Three power plants use biomass from rubberwood. The installed capacity is 28.4 MW, requiring 616,241 tons/year of biomass for power generation.
  - Biomass consumption for the MDF and the particle board factories is 676,805.40 tons/year.
  - Biomass consumption for steam generation is 1,281,522 tons/year.
  - There is no remaining biomass.
- **Rubberwood biomass in Satun Province**
  - Satun has a rubber tree plantation area of 435,640 rai and no felling area.
  - Biomass consumption for steam generation is 27,964 tons/year.
- **Rubberwood biomass in Surat Thani Province**
  - Surat Thani has a rubber tree plantation area of 2,544,461 rai and a felling area of 20,045 rai.
  - The available biomass is 100,224.2 tons of roots; 60,134.5 tons of sawdust; 240,538 tons of slabs; and 240,538 tons of offcuts.

- Biomass consumption for the MDF and the particle board factories is 648,811.20 tons/year.
- Biomass consumption for steam generation is 141,093 tons/year.
- The remaining biomass is 100,224.17 tons of roots and 113,931.31 tons of offcuts.

6.2. Rubberwood biomass by province in the southern region

The study, based on 2017 data, concluded that the remaining biomass from rubberwood in the southern region is as follows:

• Roots (from felling area)	1,498,922.71	tons
• Rubberwood slabs (from wood-processing plant)	1,129,313.54	tons
• Rubberwood offcuts (from wood-processing plant)	1,865,576.15	tons

Chapter 3

Available Biomass for Power Generation in Southern Thailand

This chapter assesses biomass supply from rubberwood in southern Thailand to promote its use in generating power and to ensure that the demand is consistent with the supply.

1. Three Border Provinces: At a Glance

To assess biomass supply from rubberwood in southern Thailand, this chapter divides the region into three groups (Figure 3.1):

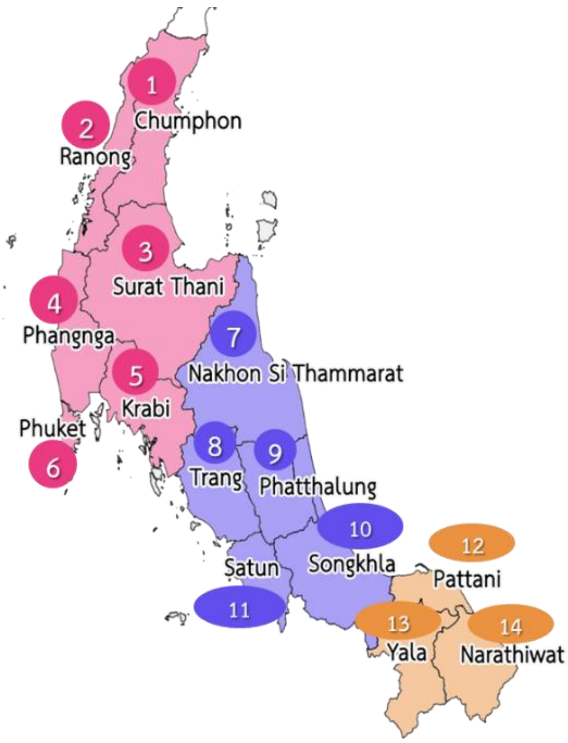
(1) Group 1: covering three border provinces – Pattani, Yala, and Narathiwat

(2) Group 2: covering other provinces within a 200-kilometre (km) radius of three border provinces

(3) Group 3: covering other provinces of more than 200 km radius of three border provinces.

This chapter focuses mainly on biomass in Group 1 and Group 2.

Figure 3.1: Provinces in Southern Thailand (14 Provinces)



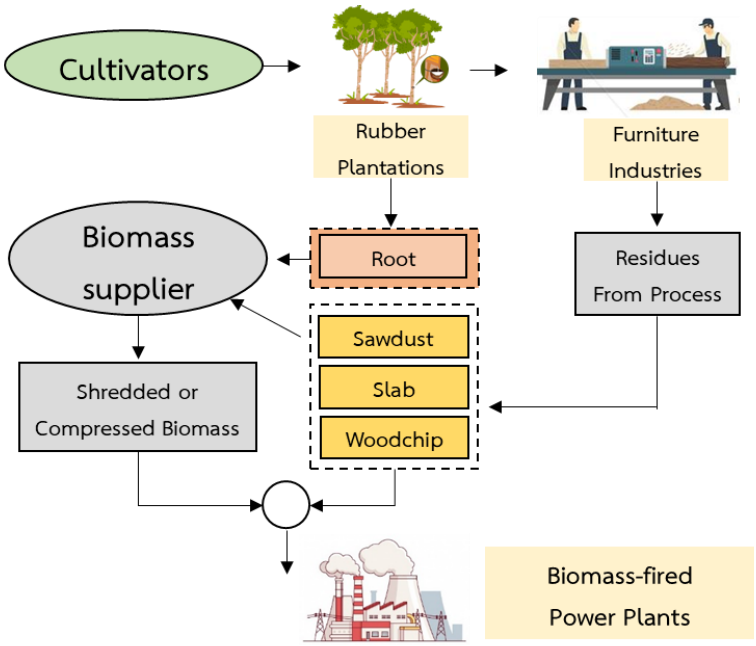
Province's radius exceeds 200 km	
1. Chumphon	4. Phangnga
2. Ranong	5. Krabi
3. Surat Thani	6. Phuket
Province's radius of 200 km	
7. Nakhon Si Thammarat	10. Songkhla
8. Trang	11. Satun
9. Phatthalung	
3 Border provinces	
12. Pattani	14. Narathiwat
13. Yala	

Source: Author's field survey photo, 2019.

2. Rubberwood for Power Generation

Biomass from rubberwood for power generation comes from felling 25–35-year-old rubber trees, which give less latex. The biomass derived from felled rubber trees are stumps, roots, slabs, wood tips, and branches while rubberwood trunks are sent to sawmills, producing sawdust as biomass. Normally, biomass traders collect biomass from felled areas and sawmills to sell to power plants. In brief, the key biomass rubberwood for power generation includes roots, sawdust, slabs, and wood tips (Figures 3.2 and 3.3).

Figure 3.2: Rubberwood for Power Generation



Source: Author's field survey process diagram, 2019.

Figure 3.3: Four Types of Rubberwood for Energy

Roots and Stumps **Slabs**

Sawdust **Wood tips**

Source: Author's field survey photo, 2019.

3. Assumptions of the Study

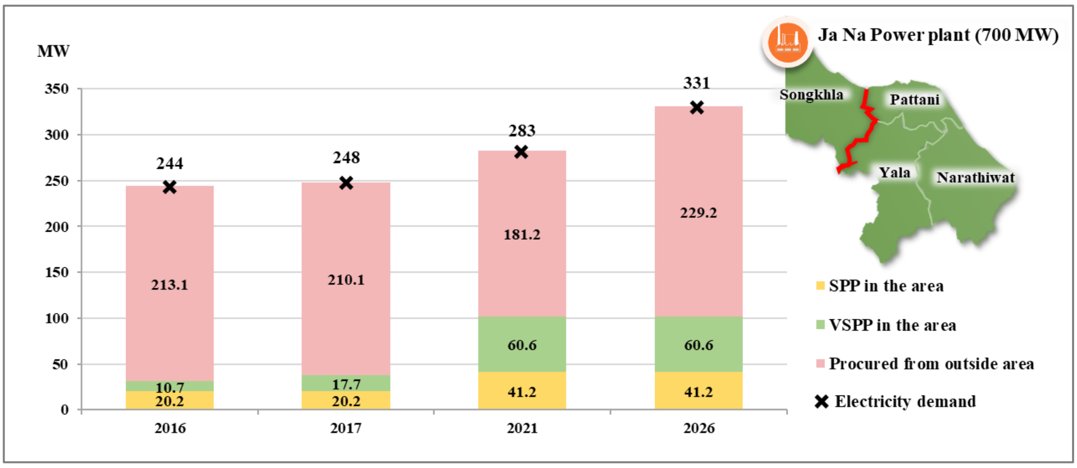
1) Focuses only on rubberwood in the southern region, including three border provinces.
2) Estimates the potential of the plantation data from the Office of Agricultural Economics.
3) Considers the current rubberwood consumption in power plants, industry heat generation, and other uses.
4) Conducts a field survey to assess the current situation of rubberwood power plants and to recheck data.
5) Estimates the 'remaining potential' of biomass from rubberwood for power generation in the areas of three border provinces and other provinces within a 200 km radius of the three border provinces.

4. Electricity Demand and Supply in the Three Border Provinces

4.1. Electricity demand

Electricity demand in the three border provinces has been increasing. Electricity demand in 2026 is estimated to be 331 MW. The existing capacity of power plants under SPP and VSPP contracts in the three provinces are lower than the current demand (Figure 3.4); therefore, importing electricity from other provinces is needed. The largest power plant closest to the three provinces is Jana Power Plant in Jana District, Songkhla Province. It has an installed capacity of 700 MW. It is, therefore, very critical for both the government and the private sectors to promote power generation to meet the demand.

Figure 3.4: Electricity Demand in the Three Southern Border Provinces



SPP = small power producer, MW = megawatt, VSPP = very small power producer.

Notes: (1) Demand forecasts are taken from the Load Demand Forecast Committee.

(2) SPP and VSPP information is from the Energy Regulatory Committee Office website.

Source: Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy (2018).

4.2. Electricity supply (current status)

All power plants in the three provinces generate 205.1 MW.

EGAT Power plant: 103.3 MW

- Hydro energy: 77.3 MW (Bang Lang Dam, Yala 76 MW/Ban Santi, Yala 1.3 MW)
- Diesel power generation (two plants) Narathiwat: 16 MW
- Diesel power plant (one plant) Pattani: 10 MW

Private power plant: 101.8 MW

- Renewable energy (RE) with government contract: 101.8 MW (Commercial operation date [COD] 40.7 MW/Only power purchase agreement [PPA], [not COD] 61.1 MW)

New project (as planned) in three provinces: 50.05 MW

- Power plant for bidding in the southern region: 4.05 MW (remaining slots)

- Community waste to power: 4 MW
- Pracharath (civil state) power plant project: 42 MW (Biomass = 12 MW, Biogas = 30 MW)

5. RE power plant in the three border provinces

The status of nine biomass-fired power plants in the three border provinces is as shown in Table 3.1. The COD of three power plants are in 2006, 2013, and 2017 while the scheduled commercial operation date (SCOD) of six power plants are in 2017, 2018, and 2019.

Table 3.1: Nine Operational Biomass Power Plants (COD and SCOD)

Name	Fuel	Installed Capacity (MW)	COD (MW)	Status	COD Year	Type
Narathiwat		**13.8**	15.3			
Prize of Wood Green Energy Co., Ltd	*Biomass*	7.5	7.0	COD	2560	FiT
TPCH Power 5 Co., Ltd.	*Biomass*	6.3	6.3	SCOD	2561	FiT Bidding
Pattani		**23.0**	25.8			
Pattani Green Co., Ltd	*Biomass*	23.0	21.0	SCOD	2562	Adder
Yala		**65.4**	60.7			
Gulf Yala Green Co., Ltd	*Biomass*	23.0	20.2	COD	2549	N/A
Yala Green Energy Co., Ltd	*Biomass*	9.9	8.7	COD	2556	FiT
P.C. Be Tong Green Energy Co., Ltd	*Biomass*	5.2	5.0	SCOD	2560	FiT
Be Tong Green Power Co., Ltd	*Biomass*	7.5	7.0	SCOD	2561	FiT
TPCH Power 1 Co., Ltd	*Biomass*	9.9	9.9	SCOD	2561	FiT Bidding
TPCH Power 2 Co., Ltd	*Biomass*	9.9	9.9	SCOD	2561	FiT Bidding
Total		**102.2**	101.8			

COD = commercial operation date, FiT = feed-in tariff, SCOD = scheduled commercial operation date.

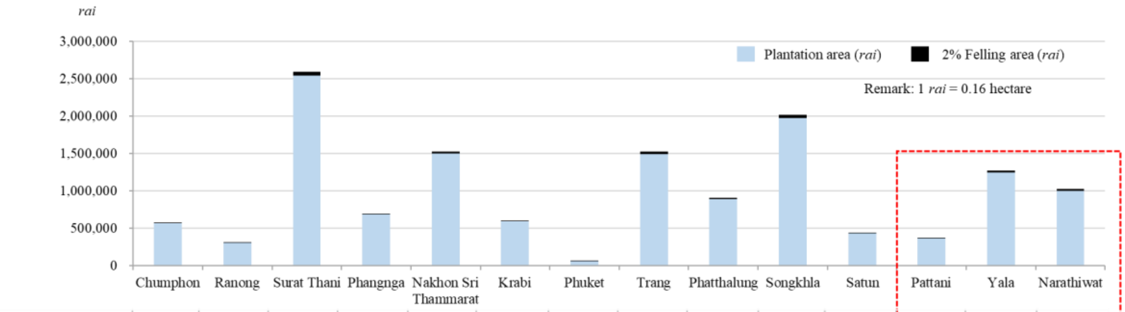
Source: SPP/VSPP database, Energy Regulatory Commission (ERC).

6. Rubberwood: From Plantation to Potential (2017)

6.1. Plantation and felling areas of rubber trees in the southern region

In 2017, the plantation area of rubber trees in the three border provinces is more than 2.6 million *rai* (1 rai = 0.16 hectare). Assuming that 2% of plantation areas are felling areas, biomass can be produced from 52,000-rai felling areas. The felling area in Yala is the largest, about 25,000 rai, followed by Narathiwat and Pattani, respectively. For the whole region, the province with the largest plantation of rubberwood, totalling 2.5 million rai, is Surat Thani. Figure 3.5 shows the plantation and felling areas of rubberwood by province in southern Thailand. Table 3.2 describes the plantation and felling areas of rubberwood by groups of provinces while Table 3.3 shows the biomass supply from rubberwood by province and by group of provinces.

Figure 3.5: Plantation and Felling Areas of Rubber Trees in Southern Thailand (2017)



	Chumphon	Ranong	Surat Thani	Phangnga	Nakhon Sri Thammarat	Krabi	Phuket	Trang	Phatthalung	Songkhla	Satun	Pattani	Yala	Narathiwat
Plantation area (*rai*)	567,131	311,600	2,544,461	686,095	1,500,327	596,827	67,115	1,495,082	891,023	1,978,684	435,640	369,956	1,248,238	1,007,135
Felling area (*rai*)	11,343	6,232	50,889	13,722	30,007	11,937	1,342	29,902	17,820	39,574	8,713	7,399	24,965	20,143

Source: Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives (2018).

Table 3.2: Plantation and Felling Areas in Three Groups of Provinces in Southern Thailand

Share Types	Plantation Area (rai)	Felling Area (rai)
Southern Region	13,699,314	273,986
Three provinces + provinces within a radius of 200 km	8,926,085	178,522
Provinces within a radius of 200 km	6,300,756	126,015
Provinces with radius exceeding 200 km	4,773,229	95,465
3 border provinces	2,625,329	52,507

Source: Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives (2018).

Table 3.3: Biomass from Rubber Supply Potential

Province	Biomass Potential of Rubberwood (ton)				
	Root	Sawdust	Slab	Wood Tip	Total
Chumphon	56,713	34,028	136,111	136,111	362,964
Ranong	31,160	18,696	74,784	74,784	199,424
Surat Thani	254,446	152,668	610,671	610,671	1,628,455
Phangnga	68,610	41,166	164,663	164,663	439,101
Krabi	150,033	90,020	360,078	360,078	960,209
Phuket	59,683	35,810	143,238	143,238	381,969
Nakhon Si Thammarat	6,712	4,027	16,108	16,108	42,954
Trang	149,508	89,705	358,820	358,820	956,852
Phatthalung	89,102	53,461	213,846	213,846	570,255
Songkhla	197,868	118,721	474,884	474,884	1,266,358
Satun	43,564	26,138	104,554	104,554	278,810
Pattani	36,996	22,197	88,789	88,789	236,772
Yala	124,824	74,894	299,577	299,577	798,872
Narathiwat	100,714	60,428	241,712	241,712	644,566
Southern region	**1,369,931**	**821,959**	**3,287,835**	**3,287,835**	**8,767,561**
Three provinces + provinces within a 200 km radius	**892,609**	**535,565**	**2,142,260**	**2,142,260**	**5,712,694**
Provinces within a 200 km radius	**630,076**	**378,045**	**1,512,181**	**1,512,181**	**4,032,484**
Provinces with radius exceeding 200 km	**477,323**	**286,394**	**1,145,575**	**1,145,575**	**3,054,867**
3 border provinces	**262,533**	**157,520**	**630,079**	**630,079**	**1,680,211**

Note: Gained for each rai of felling area is 5 tons of root, 3 tons of sawdust, 12 tons of slab, and 12 tons of wood tips.
Source: Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives (2018).

7. Estimation of 2017 demand of biomass from rubberwood (excluding power plant)

From the data on rubber tree plantation and felling areas in 2017, about 1.68 million tons of biomass from rubberwood are produced annually in the three border provinces. The biomass uses in industries and other uses are about 35,000 tons/year. The remaining amount of biomass for electricity generation is about 1.64 million tons/year. Therefore, the electricity generation using biomass from rubberwood is about 142.4 MW (Table 3.4). The existing capacity of nine operational biomass power plants is about 102.2 MW (COD = 40.4 MW and SCOD = 61.8 MW). Therefore, the remaining potential of biomass from rubberwood in the three border provinces for electricity generation is about 40.2 MW (Figure 3.6).

The total biomass, including the amount of biomass in other provinces within a 200 km radius is about 4 million tons/year. This can generate about 349.13 MW of electricity. The existing consumption is about 161.51 MW; therefore, 187.62 MW is remaining.

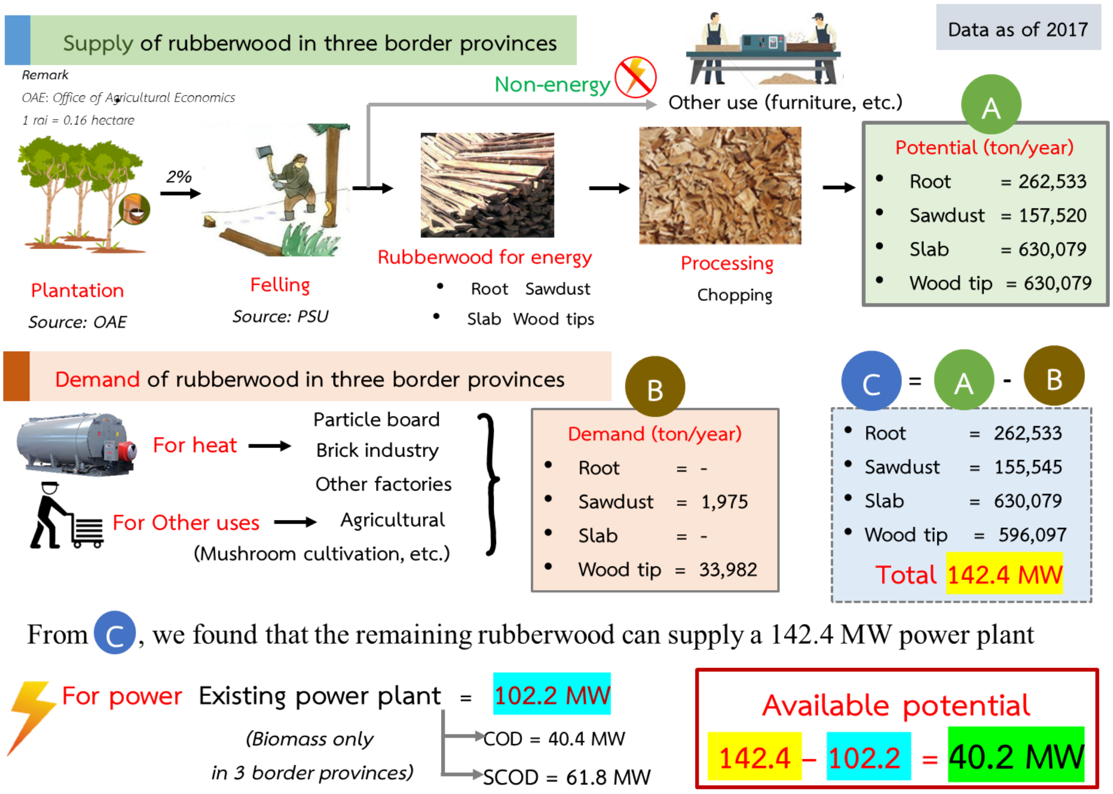
Table 3.4: Estimate of the 2017 Demand of Biomass from Rubberwood (excluding Power Plant)

Summary	Root	Sawdust	Slab	Wood Tip	Total
(1) Total biomass available in three border provinces (ton/yr)	262,533	157,520	630,079	630,079	1,680,211
(2) Total biomass for industry (ton/yr)	-	1,975	-	33,982	35,957
• Used by particle board	Surat Thani and Songkhla				
• Used by industry	-	1,975	-	33,982	35,957
• Other consumption	Other provinces exclude three border provinces				
(3) Available potential (3) = (1) – (2)	**262,533**	**155,545**	**630,079**	**596,097**	**1,644,254** ⬇ **142.4 MW**
If the areas outside the three border provinces are considered, the biomass potential is more.					
Total biomass available in provinces at radius of 200 km (ton/yr)	**630,076**	**378,045**	**1,512,181**	**1,512,181**	**4,032,484** ⬇ **349.13 MW**

Note: Biomass consumption data in industry is taken from the designated factory database, Department of Alternative Energy Development and Efficiency (DEDE); consumption in others is taken from the DEDE survey project.

Source: DEDE (2018) and author's data field survey, 2019.

Figure 3.6: Supply of Rubberwood in the Three Border Provinces



Source: Author's data , 2019.

8. Challenges in Using Rubberwood for Power Generation

1) The remaining potential from rubberwood for new power plants in the three border provinces is only 40.2 MW; more biomass needs to be imported from other provinces.
2) Other biomass crops in the three border provinces, i.e. palm and palm residues, are very few.
3) The available potential area for producing fast-growing feedstocks is low.
4) Increasing rubber trees may result in lower prices for rubberwood products.
5) Improving collection efficiency of roots of rubberwood is required.

Chapter 4

Cost Estimation of Biomass Supply Chain in Southern Thailand

This chapter discusses the results of the study on supply chain of biomass for power generation in three southern border provinces of Thailand. The study surveyed biomass power plants, assessed the cost throughout the supply chain, and analysed problems and solutions of biomass power plants in southern Thailand.

1. Data from Field Survey of Biomass Power Plants in the Three Southern Border Provinces

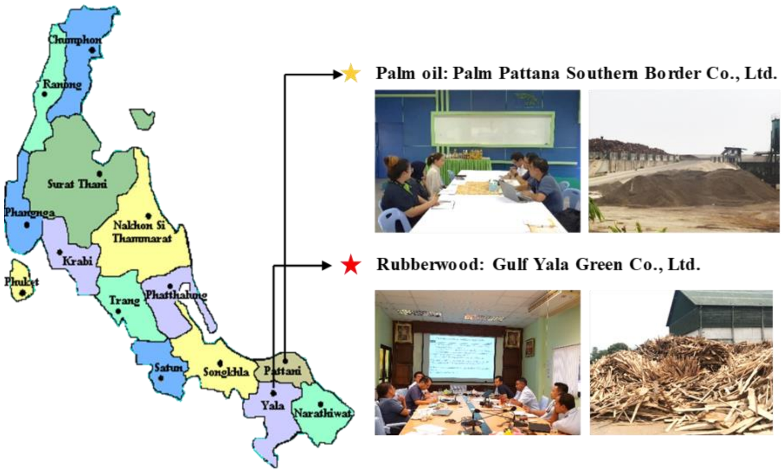
Data on the supply chain of biomass for power generation were collected by interviewing the representatives of two biomass power plants in the three southern provinces, Palm Pattana Southern Border Co., Ltd. in Pattani and Gulf Yala Green Co., Ltd. in Yala (Figure 4.1). The interview included detailed information on fuel sources, biomass potential to produce electricity and the opportunities to increase power generation in the future, etc. Table 4.1 summarises the data from the interview on 15 August 2018.

Table 4.1 Field Survey Results

Topics	Palm Pattana Southern Border Co., Ltd.	Gulf Yala Green Co., Ltd.
Address	No. 3/2 Moo 4 Petchkasem Road, Bang Khao Sub-district, Nong Jik District, Pattani	No. 80 Moo 1, Pron Sub-district, Muang District, Yala
Installed capacity	1.8 MW	23 MW (Consumption of power plant: 1.7 MW)
Commercial operating date (COD)	1 October 2014	28 November 2006 (25-year contract)
Type of biomass used	Shredded oil palm empty fruit bunch	Rubberwood slabs and rubberwood wastes (twigs, roots, sawdust)
Current fuel cost	B400–500/ton	B1.62 /ton (Current price of fuel is B973/ton)
Supporting measures from the government		Adder at B1.18/kWh (Biomass B0.18/kWh + Special adder for 3 southern border provinces amounting to B1/kWh)
Capacity expansion plan	Expand by 50% its existing capacity, planned to be completed by January 2019	Build a new power plant using all biomass from rubber root

Source: Author's data field survey, 2019.

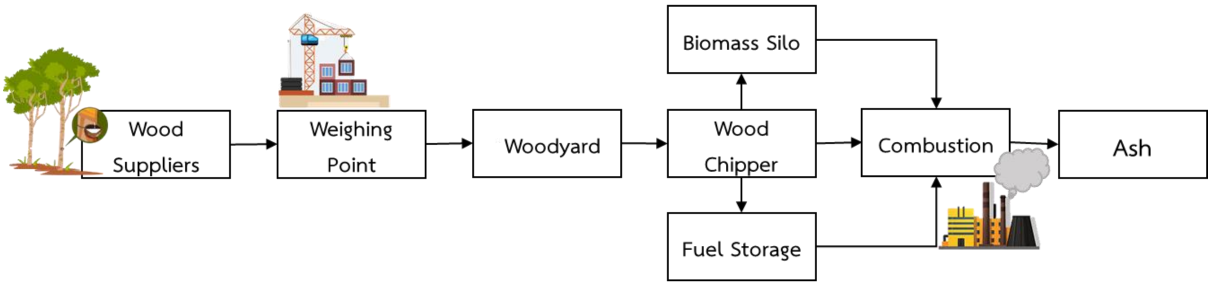
Figure 4.1:Palm Pattana Southern Border Co., Ltd. and Gulf Yala Green Co., Ltd.



Source: Author's field survey photo, 2019.

The consulting team conducted field surveys and interviewed representatives from two biomass-fired power plants – one power plant using biomass from oil palm and another using biomass from rubberwood – to collect data (as shown in the field survey process flow in Figure 4.2). Due to low production of palm oil in the three border provinces, the analysis focused mainly on power plants using biomass from rubberwood.

Figure 4.2: Supply Chain of Biomass for Power Generation (from Field Survey)



Source: Author's data field survey, 2019.

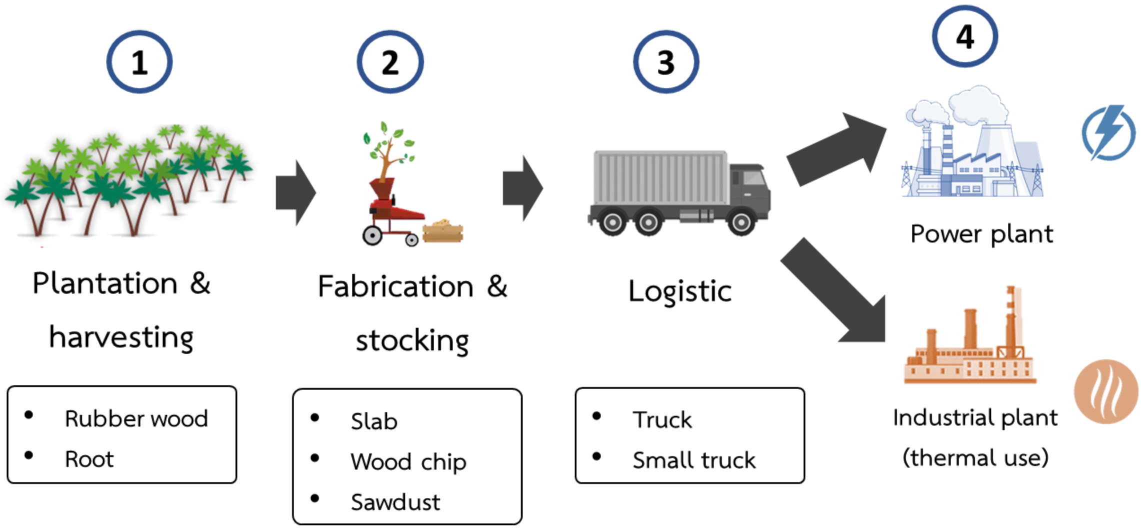
2. Supply Chain of Biomass

The supply chain of biomass for power generation is composed of four components: (i) plantation and harvesting, (ii) fabrication and stocking, (iii) logistic, (iv) power plant and industrial plant (Figure 4.3).

- The cost in the three border provinces is higher than other southern provinces for many reasons, such as higher insurance payment and no night-time construction.
- Rubberwood price frequently increases during the rainy season due to limited access to the rubberwood area.

- The particle board manufacturing business, located in Songkhla Province, is the cause of the rising selling price of rubberwood. These businessmen can pay more due to higher value added of their products.

Figure 4.3 Supply Chain of Biomass for Power Generation



Source: Author's data field survey, 2019.

2.1. Cost of raw materials (from field survey)

Tables 4.2 and 4.3 show that the price of rubberwood that the factory bought is based on the purchase price in Hat Yai, Songkhla. In the past when the number of manufacturing plants of the particle board in Songkhla was increasing, the price of rubberwood went up to B1,423/ton. This caused a loss to the power plant, rubberwood being the main raw material. In general, the highest acceptable price of rubberwood for the power plant to be operational is B1,500/ton, though at this price the factory must absorb a loss of as much as B1,200/ton.

Table 4.2 Buying Prices of Raw Materials of Gulf Yala Green Co., Ltd.

Type of biomass	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Conclusion
Rubberwood slabs	Ton	13,000	18,000	20,000	13,000	17,000	17,000	23,700	24,000	20,000	17,000	16,000	16,000	220,000
	B/ton	769	833	650	538	647	765	759	625	650	588	625	750	538-833
Rubberwood wastes (Twigs, Roots, Sawdust)	Ton	7,000	8,000	6,000	3,000	5,000	6,000	8,000	4,000	1,400	1,700	800	5,000	55,000
	B/ton	1,000	1,050	883	633	800	950	875	625	714	706	750	900	625-1,050

Notes: (1) US$1 = B32.
(2) It is found from the interviews that the price of rubberwood increases due to the expansion of particle board production. The expansion results in a higher demand of rubberwood (resulting in a price war).
Source: Author's field survey data, 2019.

Table 4.3 Share of Rubberwood and Sources

Raw Materials	Share (%)	Sources
Rubberwood slabs	80	• Songkhla: Thepa, Sabayoy, Natawee
Rubberwood wastes (twigs, roots, sawdust)	20	• Pattani: Yarung, Koke Pho, Thung Yang Daeng • Yala: All districts • Narathiwat: All districts

Source: Author's field survey data, 2019.

2.2. Cost of wood processing (chopping)

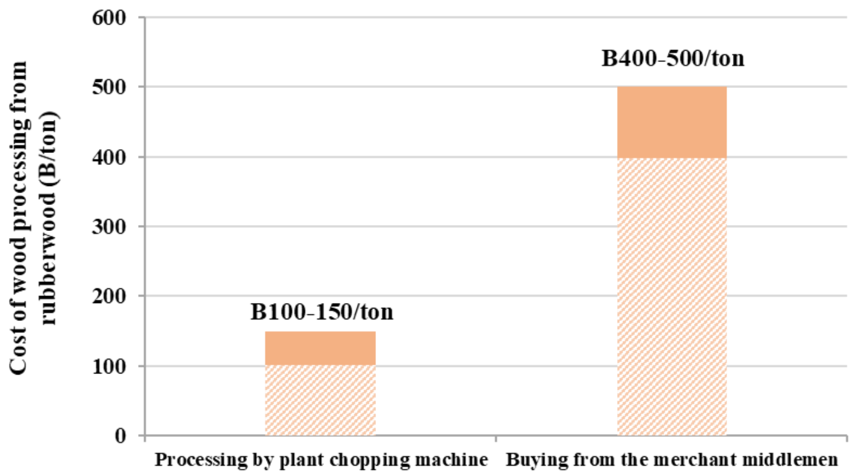
The field survey revealed that the main method for producing biomass from rubberwood is to chip residues from rubberwood, including wood slaps and rubberwood chips (branches, sawdust roots), into small pieces to make it easier for the power generation process (Figure 4.4). Wood pellets are not produced. The costs of processing rubberwood into woodchips include machinery and equipment (wood-chipping machine), labour, and electricity costs. The two practices in acquiring biomass from rubberwood are (i) processing rubberwood into woodchips and (ii) buying woodchips from middlemen (Figure 4.5).

Figure 4.4 Production of Biomass from Rubberwood

Source: Author's process diagram of the field survey, 2019.

- Buying processed rubberwood from merchant middlemen costs B300–350/ton higher than processing through the factory's own chopping machine.
- Power plants processing rubberwood using a chopping machine incur a 13% cost.
- Power plants processing rubberwood without a chopping machine (buying from middlemen) incur 34% cost.

Figure 4.5 Cost of Wood Processing (Chopping)



Source: Author's field survey data, 2019.

3. Logistic cost

The logistic cost is estimated from the rate of fuel consumption, capacity of vehicles, and distance. There are two types of vehicles in this assessment: small truck with 1.2-ton capacity and truck with 10-ton capacity. Also, the transportation distance ranges from 50 km to 200 km (Table 4.4). Key assumptions include:

- Fuel consumption rate from the Truck Data Service Center
  - Truck: 3.3 km/litre (capacity = 10 tons)
  - Small truck: 10.5 km/litre (capacity = 1.2 tons)
- Diesel retail prices in Yala on 31 October 2018 = B30.34/litre
- Adjusted factor for three provinces ≈ 1.1

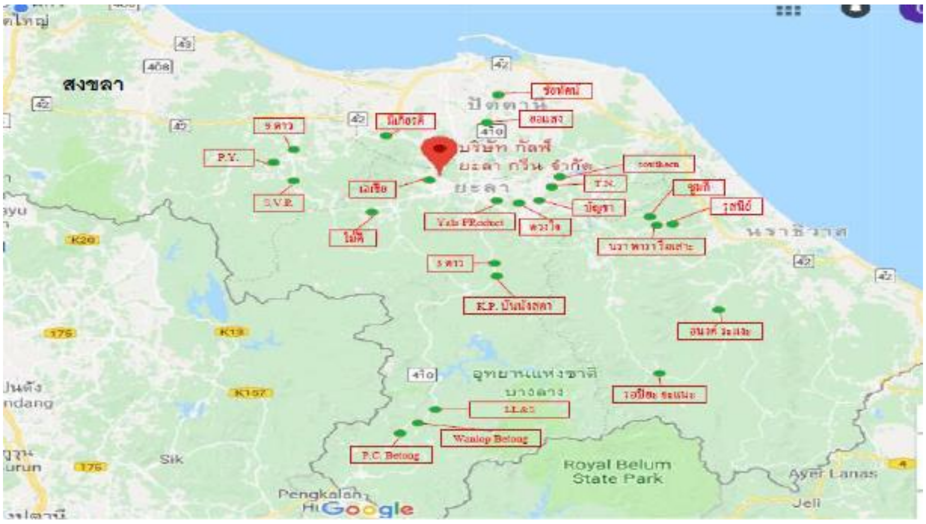
Figure 4.6 shows the location of selected large sawmill networking for supply biomass for one power plant (red pinned point). Some sawmills are located more than 200 km from the power plant, resulting in a higher logistic cost.

Table 4.4 Logistic Cost

Type	Distance	Fuel Consumption Rate (km/litre)	Capacity	Cost of Logistic (B/ton)
Truck	50	3.3	10	50
	100	3.3	10	100
	150	3.3	10	150
	200	3.3	10	200
Small truck	50	10.5	1.2	130
	100	10.5	1.2	260
	150	10.5	1.2	400
	200	10.5	1.2	530

Source: Truck Data Service Center (TDSC). http://www.thaitruckcenter.com/tdsc/GCS/index

Figure 4.6 Location of Large Sawmills Supplying Biomass to Power Plants



Source: Author's field survey data, 2019.

4. Assessment of labour through supply chain

This section assesses the jobs throughout the supply biomass chain. The supply chain starts from collecting biomass, processing, transporting, storing, and using (Table 4.5). The most labour-intensive process is collecting biomass, especially rubberwood roots, which requires a lot of labour and digging equipment.

The cost of biomass can be assessed by referring the buying–selling prices from the field survey, together with evaluating all expenditures incurred in the process (Table 4.6).

Table 4.5 Assessment of Labour through the Supply Chain

Biomass Production	Collection	Processing	Logistics	Storage	Usage
Slab	🧍🧍	🧍🧍	🧍	🧍	🧍
Root	🧍🧍🧍	🧍🧍	🧍	🧍	🧍
Sawdust	🧍🧍	🧍🧍	🧍	🧍	🧍
Wood tip	🧍🧍	🧍🧍🧍	🧍	🧍	🧍

🧍 = amount of labour.
Source: Author's field survey data, 2019.

Table 4.6 Cost of Biomass through the Supply Chain

Biomass Production	Raw Material	Processing[a]	Logistic[b]		Storage	Consumption[c]
Slab	365	150	50–200	130–530	-	565–1,045
Root	450	150			-	650–1,130
Sawdust	600	-			-	650–1,130
Wood tip	450	150			-	650–1,130

[a] Processing cost for rubberwood B100–150/ton
[b] Cost of logistics
[c] Cost of biomass consumption from the survey of power plants

- Fuel consumption rate from Truck Data Service Centre
  - Truck: 3.3 km/litre (capacity = 10 tons)
  - Small truck: 10.5 km/litre (capacity = 1.2 tons)
- Diesel retail prices in Yala on 31 October 2018 = B30.34/litre
- Transportation distance: 50–200 km

Source: Author's field survey data, 2019.

5. Barrier analysis on the biomass supply chain

The field survey revealed that barriers and constraints of the biomass supply chain can be classified in four aspects, i.e. policies and regulations, biomass supply, biomass price, and cost and investment (Table 4.7).

Table 4.7 Barriers and Suggestions on the Biomass Supply Chain

Barriers	Suggestions
1) Policies and Regulations • Changes in policies cause different electricity tariff rates. With limited supply, the price of biomass increases when demand rises. This places a heavier burden on power plants with lower electricity tariff.	• Need for flexible tariff based on biomass price/type, if possible.
2) Biomass Supply • Less rubberwood supply in the rainy season may cause supply shortage.	• Due to excess supply of rubber roots, increased use of rubber root can lessen the shortage in the short run.
3) Biomass Price • Price increases due to the demand from particle board production and new biomass power plants • High processing cost from middlemen	• Import the biomass (rubberwood) from other provinces or enter into a long-term contract with suppliers. • Provide chopping machines to those with large consumers.
4) Cost and Investment Barriers • Higher construction cost as well as O&M cost since the plants are located in the southern border provinces. • Higher insurance cost due to the unrest in the areas	• Three border provinces should have feed-in tariff premium.

O&M = operation and maintenance.
Source: Author's field survey data, 2019.

6. Data from the Field Survey of Biomass Power Plants in the Three Southern Provinces

From the previous study on the levelized cost of energy (LCOE) and information on power plants from the Thailand Energy Awards, the cost of electricity production of biomass-fired power plants covers investment cost of the power plants, fuel cost, and O&M cost (Tables 4.8–4.10).

Table 4.8 Investment Cost of Biomass-fired Power Plant (Capex)

9.9-MW Biomass Power Plant Capex	US$[a]	Baht
Consulting services, licences, and permits	483,871	5,781,307
Civil works	1,152,685	16,088,399,517
Installation (labour, electricity, mechanical)	1,228,520	6,744,731,900
Equipment (boiler, turbine, generator, others)	16,326,847	2,655,968,158
Land development costs	30,334	2,763,772,151
Design, engineering, project management	1,036,052	3,641,029,251
Grid connection	645,161	282,898,058
Others	2,806,208	5,781,307
Total	**23,709,678**	**782,893,568**
Capex per 1 MW	**2,394,917**	**79,080,158**

Capex = capital expenditure.
Notes: Calculated from the actual data of the biomass power plant (wood), size 9.9 MW.
[a] US$1 as of 27 November 2018, equal to B33.02.

Table 4.9 Fuel Cost of Biomass-fired Power Plant

9.9-MW Biomass Power Plant Fuel Cost	US$[a]	Baht
Fuel cost per 1 MW	**208,211**	**6,875,131**

Notes: Calculated from the actual data of the biomass power plant (wood), size 9.9 MW.
[a] US$1 = B33.02 (as of 27 November 2018).

Table 4.10 O&M Cost of Biomass-fired Power Plant

9.9 MW Biomass Power Plant O&M Cost	US$[a]	Baht
O&M escalation rate	5% per year	
Employment cost	322,581	10,651,625
Total	**2,155,674**	**71,180,356**
O&M Cost per 1 MW	**217,744**	**7,189,935**

O&M = operation and maintenance.
Calculated from the actual data of the biomass power plant (wood), size 9.9 MW.
[a] US$1 = B33.02 (as of 27 November 2018).

Table 4.8 shows that the initial investment cost per 1 MW of biomass-fired power plant is US$2,394,917. The fuel cost is US$208,211 (Table 4.9) and the O&M cost is US$217,744 (Table 4.10). Therefore, the total cost per 1 MW of power plant is US$2,820,872.

7. Merit Order of Biomass-fired Power Plants

The country's power system is an enhanced single buyer, with the Electricity Generating Authority of Thailand (EGAT) acting as system operator. The National Control Center under EGAT is the nerve centre of Thailand's power grid system. This is where economic merit order in power production and dispatch from all major power plants of both EGAT and private power producers are commanded and controlled to reliably meet the country's demand. It decides which power stations will generate electricity and when. The economic merit order in power production and dispatch from all major power plants are described as follows:

- The first priority is for the must-run power plants to ensure the security of the power system. Non-operation of these power plants may lead to a power outage.
- The second priority is the must-take power plants. These power plants signed a power purchase agreement with EGAT and EGAT guaranteed to purchase a certain amount of their electricity production. These power plants include small private power producers, SPP firms, and SPP non-firms. Also, some power plants of EGAT itself have contracts on minimum fuel supply such as natural gas. Thus, these power plants need to run or face high loss.
- The third priority is the power plants with the least production cost to meet the electricity demand. These are the remaining power plants from the first two, must-run and must-take plants.

8. Recommendations to Overcome Barriers and Crucial Policies to Promote New Power Plants

To overcome the above-mentioned barriers and to promote new power plants, this chapter recommends the following:

(1) On policies and regulations – The policymakers should consider the impact of certain policies on existing power plants before it formulates or implements such policies and regulations. It should consider that biomass supply is enough to ensure that the demand is not so high, thus, making the price unacceptable. The new tariff should not be much higher such that the existing power plants could not compete.

(2) On biomass supply – In case the government plans to promote biomass-fired power plants in the three southern provinces, it should consider the cost of transport as the biomass may come from all provinces in the south.

(3) On biomass price – the promotion of new power plants should consider the supply of biomass to ensure that the price of biomass would not rise too much.

(4) On cost and investment barriers – investment subsidy or higher production subsidy is needed for the promotion of new power plants to compensate for higher investment and insurance costs due to a greater risk of insurgency.

9. Conclusions for Biomass Resources for Power Generation in Southern Thailand

The interviews of the representatives from the Pattani and Yala power plants revealed the following:

- 1) The existing biomass **is not** adequate for the promotion of new power plants with a total capacity of 100 MW.
- 2) Currently, the three biomass-fired power plants in Yala have a total capacity of 40 MW, but there is shortage of biomass supply from December to January.
- 3) Some sawmills decrease their operations due to less demand; as a result, the biomass from sawmills decreases.
- 4) The shortage of biomass can be alleviated by imports from nearby provinces in the central and the upper parts of the south.

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Chapter 5

Cost Analysis of Biomass Power Generation in Southern Thailand

1. Introduction

Biomass is one kind of clean energy. The biomass power plant uses feedstock materials like agricultural straws, woodchips, rice husk, residues from palm oil such as empty fruit bunches, etc. which are smashed, briquetted, or gasified, then burned to produce high temperature and pressure steam. The heat energy in steam is transferred to electric energy and supplied to innumerable homes via highly efficient steam turbines. Biomass power normally uses condensing steam turbine for generation or cogeneration. The ash of biomass could be used as farmland fertiliser, providing green power for crops.

The southern provinces of Thailand have a huge biomass potential for power generation. Although some provinces may have a deficit of biomass for power generation due to the competing uses of biomass in other sectors, the region has a biomass surplus if the transport arrangement is well managed. The feedstock comes from oil palm and rubber plantation. For biomass power generation, the biomass supply chain should be secure in terms of supply and price, as these could affect the cost and stability of supplying the power.

For a better understanding of the situation of the biomass power plant in southern Thailand, this chapter explores the possibility of different price scenarios of biomass feedstock, and how these prices affect the levelized cost of energy (LCOE). This is important for policy if the introduction of more biomass power plants in the southern provinces will be economically viable or not. Currently, the government provides subsidies through the feed-in-tariff (FiT) scheme to different types of renewables, and some price premiums for the location in the southern provinces. For the biomass power plant of different installed capacity, the premium tariff is summarised in Table 5.1.

Table 5.1 Feed-in Tariff for Electricity Generated from Biomass Power Plant

Capacity (MW)	FiT (B/kWh)			Duration (Years)	FiT (Premium) (B/kWh)	
	FiT (Fix)	FiT (Variable)	FiT		Bioenergy project (first 8 years)	Adder for Southern Provinces
Installed capacity less than 1 MW	3.13	2.21	5.34	20	0.5	0.5
Installed capacity of 1–3 MW	2.61	2.21	4.82	20	0.4	0.5
Installed capacity of more than 3 MW	2.39	1.85	4.24	20	0.3	0.5

FiT = feed-in tariff.
Source: Klomgrich Tantravanich (2018)).

2. Local and International Cost of Biomass

In the supply chain analysis in Chapter 4, the price of biomass vary according to seasons (Tables 5.2.1 and 5.2.2).

Table 5.2.1 Price of Biomass (January to June, 2018), baht/ton

Type of Biomass	January	February	March	April	May	June
Rubber wood slabs	769	833	650	538	647	765
Rubber wood waste	1,000	1,050	883	633	800	950

Source: Authors' survey data, 2018.

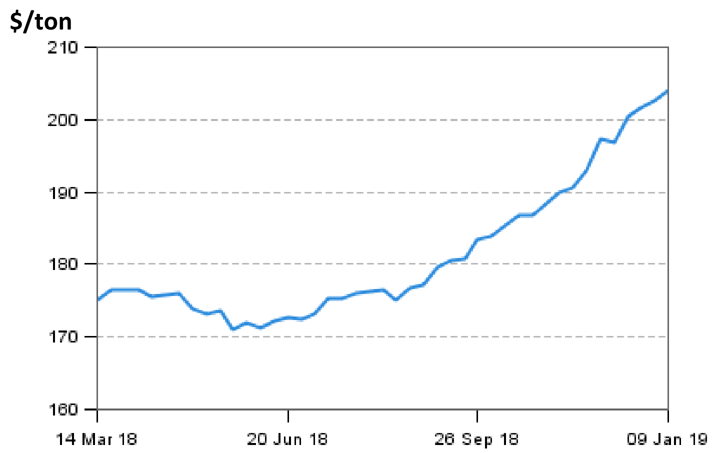
Table 5.2.2 Price of Biomass (July to December, 2018)

Type of Biomass	July	August	September	October	November	December
Rubber wood slabs	759	625	588	625	750	683
Rubber wood waste	875	625	714	706	750	900

Source: Authors' survey data, 2018.

Globally, wood pellets and woodchips are traded internationally at high prices (Figure 5.1) while local biomass, such as low-cost agricultural and forestry waste, is primarily traded locally. Therefore, prices of wood pellets and wood chips are generally higher than the local prices. Undoubtedly, Asia's demand for biomass is growing rapidly as many countries have accelerated the share of renewables into the energy supply mix.

Figure 5.1 Spot Market of Wood Pellets (90-day Index cif, US$/ton)



Source: Argus Media Ltd. (2017).

Wood pellet imports into South Korea and Japan have grown exponentially since 2015. In 2017, South Korea imported 2.4 metric tons (MT) of wood pellets, 20 times of imports in 2012. Japan is currently a smaller market, but its growth has also been impressive. Japan imported over 0.5 MT in 2017, a sevenfold increase from 2012.

The price of biomass in southern Thailand is very competitive and suitable for biomass power generation. The local biomass price is at least five times cheaper than the international biomass spot market, thus, making biomass price for power generation attractive.

3. Levelized Cost of Energy

The LCOE of renewable energy (RE) technologies varies by technology, country, and project, based on RE resources, capital and operating costs, and the efficiency/performance of the technology. The method of calculating the cost of RE technologies, adapted from the approach used by IRENA (2012), is based on discounting financial flows to a common basis, considering the time value of money. The weighted average cost of capital, often also referred to as the discount rate, is an important part of the information required to evaluate biomass power generation projects and has an important impact on the LCOE.

The formula used for calculating the LCOE of RE technologies is:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

LCOE = the average lifetime levelized cost of electricity generation;

I_t = investment expenditures in the year t;

M_t = operations and maintenance expenditures in the year t;

F_t = fuel expenditures in the year t;

E_t = electricity generation in the year t;

r = discount rate; and

n = life of the system.

3.1. Key assumptions

A few key assumptions are used in calculating the LCOE. These assumptions are based on the information given by the research team that conducted the survey of the supply chain for biomass power generation in southern Thailand.

Table 5.3. Key Assumptions Adopted from a Biomass Power Plant in Southern Thailand

Installed Capacity	9.9 MW
Net Plant Capacity	80%
Thermal Efficiency	27%
Capex	US$2,561/kW
Construction Financing Cost	US$166/kW
Economic Lifetime	25 years
Discount Rate	5%
Rate of Return on Equity	9.50%

Source: Authors' survey data, 2018.

Although biomass-fired electricity plants can achieve availabilities in the range 85% to 90%, they will not always operate at these levels. Thus, this study assumes a net plant capacity of 80%, rather than 90%. The thermal efficiency of biomass power plant ranges from 20% to 30%. However, we assume it at 27% as this information is provided by the study team.

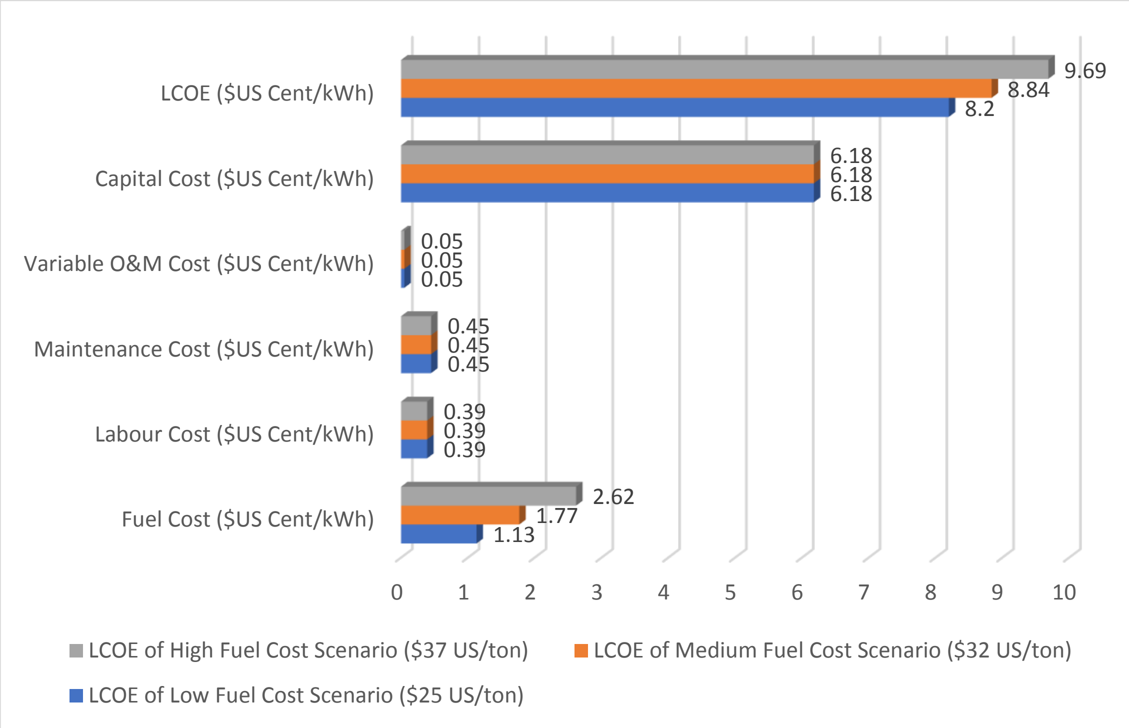
3.2. LCOE result estimates

The results of the LCOE are broken down into fuel cost, labour cost, fixed or capital cost, and variable operation and maintenance (O&M) costs. It is important to note that fuel cost contributes significantly to the overall cost. The study of IRENA (2012) on biomass for power generation concluded that the fuel cost could be the largest share in the overall cost; in some cases, its share could be as much as 30%–40% of the overall cost in terms of US dollars per kilowatt-hour. Luckily, the study of biomass for power generation in southern Thailand showed a favourable price for feedstocks. The study used three price scenarios: US$25/ton, US$32/ton, and US$37/ton. With certain assumptions, the three fuel price scenarios produced the following results (Figure 5.2).

- At the fuel price of US$25/ton, the LCOE is estimated at US$8.2 cents/kWh
- At the fuel price of US$32/ton, the LCOE is estimated at US$8.84 cents/kWh
- At the fuel price of US$37/ton, the LCOE is estimated at US$9.69 cents/kWh

The ASEAN Centre for Energy (ACE) conducted a study on the LCOE in selected renewable technologies in ASEAN member states in 2016 (ACE, 2016). The results showed that the LCOE of biomass ranges from US$5.70 cents/kWh to US$12.5 cents/kWh. The range is about US$9.2 cents/kWh. The 2012 study of IRENA on biomass for power generation also found that the LCOE ranges from US$6 cents/kWh to US$21 cents/kWh due to fuel cost and other factors (Figure 5.3).

Figure 5.2 LCOE Results of Fuel Cost Scenarios (25 Years of Plant Lifetime)

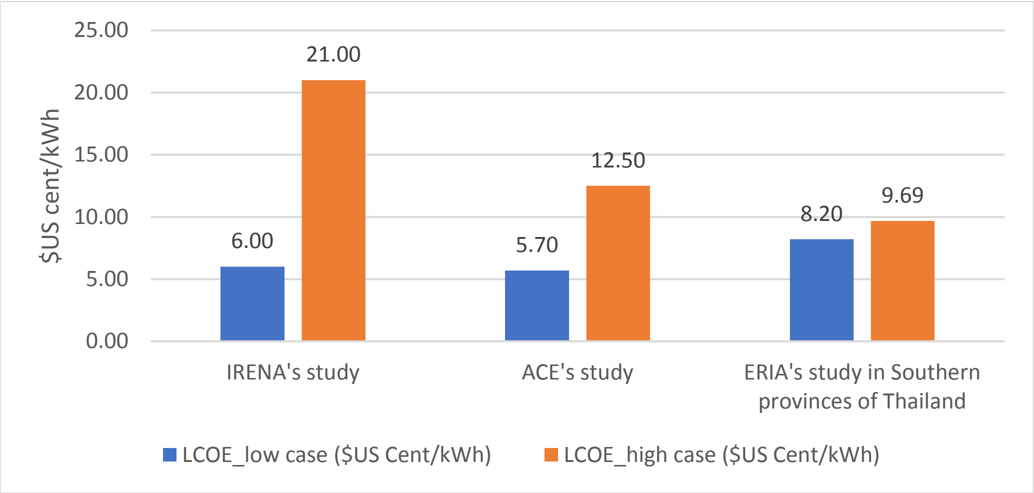


Source: Author's calculation.

Nonetheless, ERIA's study for biomass power generation in southern Thailand found that the LCOE ranges from US$8.2 cents/kWh to US$ 9.69 cents/kWh. This is a very competitive LCOE cost and is attractive for investment compared to the current FiT provided by the government to the biomass power generation in the southern provinces, which ranges from US$15.7 cents/kWh to US$19.8 cents/kWh. The FiTs of US$15.7 cents/kWh and US$19.8 cents/kWh are the tariff rates for electricity generated from the biomass power generation in southern Thailand for the installed capacity of more than 3 MW and of less than 1 MW, respectively (Figure 5.4).

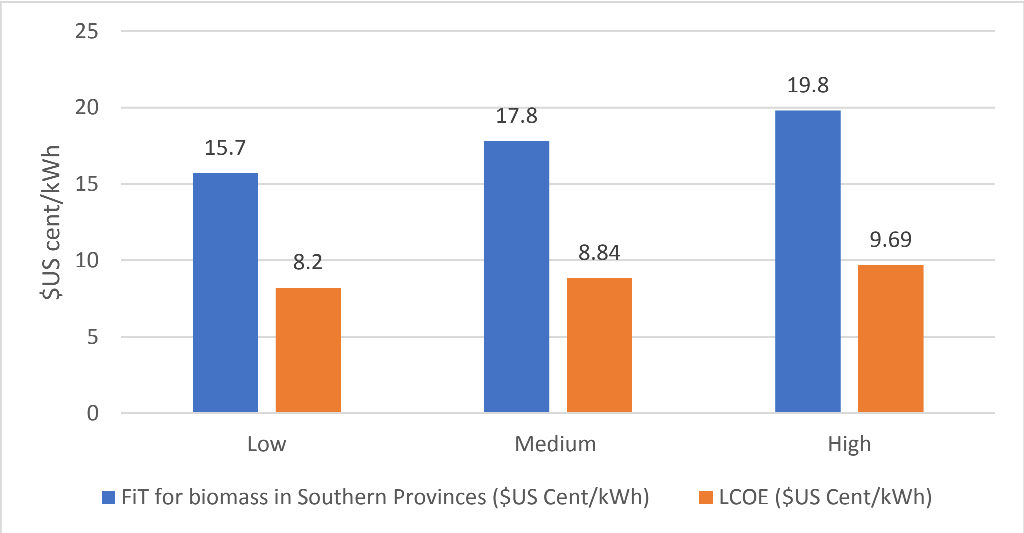
The study shows possibilities of increasing the biomass power generation in the southern provinces. The supply chain analysis in Chapter 3 illustrates that some provinces in southern Thailand may face a deficit in biomass supply. However, as a group, there is a surplus in the supply of biomass in the southern provinces. Thus, introducing additional capacity of biomass fired power generation will need to strengthen the supply chain through collection, transportation, and storing biomass feedstock.. The current scheme of FiT is generous, and it lasts for 20 years for the FiT (fix) and FiT (variable). However, the FiT (premium) lasts only 8 years. In addition, the FiT ladder (US$0.5 cents/kWh) is added to investment in biomass for power generation in southern provinces of Yala, Pattani and Narathiwat..

Figure 5.3 LCOE Results of Biomass Power Generation, Various Studies



ACE = ASEAN Centre for Energy, IRENA = International Renewable Energy Agency, LCOE = levelized cost of energy.
Source: Author's calculation.

Figure 5.4 Results of LCOE Study Compared with Current FiT



FiT = feed-in tariff.
Source: Author's calculation.

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Chapter 6

Conclusions and Policy Implications

The southern part of Thailand is rich with biomass, such as rubberwood, and is thus attractive for entrepreneurs to invest in biomass power plant projects in this area. Likewise, due to the special privilege that government provided in the southern provinces, both small power producers (SPPs) and very small power producers (VSPPs) had constructed and supplied electricity to national transmission lines.

The biomass from rubberwood is classified as (i) logs; (ii) offcuts; and (iii) stumps, roots, and branches. These types of biomass are traded commercially like the conventional fuels such as petroleum products and coal. This study focuses on two sources of rubberwood biomass: (i) stumps, roots, and branches at the felling area; and (ii) rubberwood slabs, sawdust, and wood residues at the rubberwood manufacturing factory, furniture factory, and particleboard factory.

In 2017, the plantation area of rubber trees in three border provinces is more than 2.6 million *rai* (1 *rai* = 0.16 hectares). Assuming 2% of the plantation area is felling area, biomass can be produced from 52,000-rai felling areas. The felling area in Yala is the largest, about 25,000 rai, followed by Narathiwat and Pattani, respectively (Table 6.1).

Table 6.1 Biomass Potential of Rubberwood (ton)

Share Types	**Biomass Potential of Rubberwood (ton)**				
	Root	**Sawdust**	**Slab**	**Wood tip**	**Total**
Southern region	1,369,931	821,959	3,287,835	3,287,835	8,767,561
3 provinces + provinces within a 200 km radius	892,609	535,565	2,142,260	2,142,260	5,712,694
Provinces within a 200 km radius	630,076	378,045	1,512,181	1,512,181	4,032,484
Provinces with radius exceeding 200 km	477,323	286,394	1,145,575	1,145,575	3,054,867
3 border provinces	**262,533**	**157,520**	**630,079**	**630,079**	**1,680,211**
Summary	**Root**	**Sawdust**	**Slab**	**Wood tip**	**Total**
(1) Total biomass available in 3 border provinces (ton/year)	262,533	157,520	630,079	630,079	1,680,211
(2) Total biomass for industry (ton/year)	-	1,975	-	33,982	35,957
• Used by particle board	Surat Thani and Songkhla				
• Used by industry	-	1,975	-	33,982	35,957
• Other consumption	Other provinces excluding the 3 border provinces				
(3) Available Potential (3) = (1) – (2)	**262,533**	**155,545**	**630,079**	**596,097**	**1,644,254** **142.4 MW**
If consider the area outside the 3 border provinces, we can have more biomass potential.					
Total biomass available in provinces within 200 km radius (ton/year)	**630,076**	**378,045**	**1,512,181**	**1,512,181**	**4,032,484** **349.13 MW**

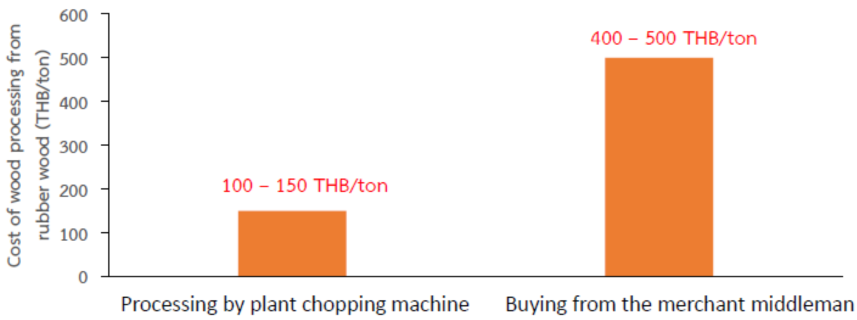
Source: Authors' calculations.

Based on the 2017 data on rubber tree plantation and felling areas, about 1.68 million tons of biomass from rubberwood is produced annually in the three border provinces. The remaining amount of biomass for electricity generation is about 1.64 million tons/year; therefore, electricity generation using biomass from rubberwood is about 142.4 MW. The existing capacity of nine operational biomass power plants is about 102.2 MW (commercial operation date [COD] = 40.4 MW and scheduled commercial operation date [SCOD] = 61.8 MW). Therefore, the remaining potential of biomass from rubberwood in the three border provinces for electricity generation is approximately 40.2 MW.

The supply chain of biomass for power generation comprises four components in general: (i) plantation and harvesting, (ii) fabrication and stocking, (iii) logistic, and (iv) power plant and industrial plant. On the cost of raw material, based on the field survey, in general, the highest acceptable price of rubberwood for the power plant to be operational is B1,500 /ton, though at this price the factory needs to absorb a loss of as much as B1,200 /ton.

On the cost of wood processing (chopping), there are currently two practices in acquiring biomass from rubberwood: (i) processing rubberwood into woodchips, and (ii) buying woodchips from middlemen.

Figure 6.1 Cost of Wood Processing from Rubberwood (B/ton)



Source: Authors' field survey data, 2018.

The logistic cost is estimated from the rate of fuel consumption, capacity of vehicles, and distance. There are two types of vehicles in this assessment: small trucks with 1.2-ton capacity and trucks with 10-ton capacity. Also, the transportation distance ranges from 50 km to 200 km.

Table 6.2 Assessment of Labour through Supply Chain

Biomass Production	Collection	Processing	Logistics	Storage	Usage
Slab	🧍🧍	🧍🧍	🧍	🧍	🧍
Root	🧍🧍🧍	🧍🧍	🧍	🧍	🧍
Sawdust	🧍🧍	🧍🧍	🧍	🧍	🧍
Wood tip	🧍🧍	🧍🧍🧍	🧍	🧍	🧍

Source: Authors' field survey, 2018

Table 6.3 Cost of Biomass through Supply Chain

<table>
<tr><th>Biomass Production</th><th>Raw Material</th><th>Processing [a]</th><th colspan="2">Logistic [b]</th><th>Storage</th><th>Consumption [c]</th></tr>
<tr><td>Slab</td><td>365</td><td>150</td><td rowspan="4">50–200</td><td rowspan="4">130–530</td><td>-</td><td>565–1,045</td></tr>
<tr><td>Root</td><td>450</td><td>150</td><td>-</td><td>650–1,130</td></tr>
<tr><td>Sawdust</td><td>600</td><td>-</td><td>-</td><td>650–1,130</td></tr>
<tr><td>Wood tip</td><td>450</td><td>150</td><td>-</td><td>650–1,130</td></tr>
</table>

Notes: [a] Processing cost for rubberwood: B100–150 /ton

[b] Cost of logistic

- Fuel consumption rate from Truck Data Service Center
  - Truck: 3.3 km/litre (capacity 10 tons)
  - Small truck: 10.5 km/litre (capacity 1.2 tons)
- Diesel retail prices in Yala on 31 October 2018 = B30.34/litre
- Transportation distance: 50–200 km

[c] Cost of biomass consumption from the survey of power plants

Source: Authors' field survey data, 2018.

Due to low potential land is available for producing fast-growing feedstocks. Therefore, since only 40.2 MW remaining potential for new power plant in three border provinces from rubberwood, more rubberwood needs to be imported from other provinces. Other biomass crops in the three border provinces are very few. Due to the significant potential from rubberwood in the future, improving the collection efficiency of rubberwood roots is required.

The rubberwood price frequently increases during the rainy season due to limited access to rubberwood areas. Likewise, the cost in the three border provinces is higher than that in other southern provinces for many reasons, such as higher insurance payment and no night-time construction. The significant particle board manufacturing business, located in Songkhla province, is the case of rising selling price of rubberwood in the market. Businessmen can pay more due to higher value added of their products.

The biomass price in southern Thailand is very competitive and suitable for biomass power generation. The local biomass price is at least five times cheaper than the international biomass spot market. Thus, biomass price for power generation is attractive.

The potential of biomass supply for power generation in the three southern provinces of Pattani, Yala, and Narathiwat could be made available for an additional new capacity of about 250 MW. Considering the whole biomass in the southern provinces and the rest of Thailand if infrastructure and transportation facilities with port/receiving terminal of biomass in the southern part is made available, the potential of biomass power generation is huge, and it is not subjected to any constraint.

The study of biomass for power generation in southern Thailand using three price scenarios (US$25/ton, US$32/ton, and US$37/ton) generates very interesting results:

- At the fuel price of US$25/ton, the LCOE is estimated at US$8.2 cents/kWh
- At the fuel price of US$32/ton, the LCOE is estimated at US$8.84 cents/kWh
- At the fuel price of US$37/ton, the LCOE is estimated at US$9.69 cents/kWh

These LCOE results are appealing and, if combined with the current FiT in the three southern provinces, the investment in biomass power plants in these provinces become attractive to investors. Thus, the appropriate policy and mechanism are needed to attract investors.