PRE-FEASIBILITY STUDY ON A PROPOSED WOOD WASTE BASED POWER AND HEAT PLANT IN BINTULU, SARAWAK

NATURAL RESOURCES AND ENVIRONMENT BOARD

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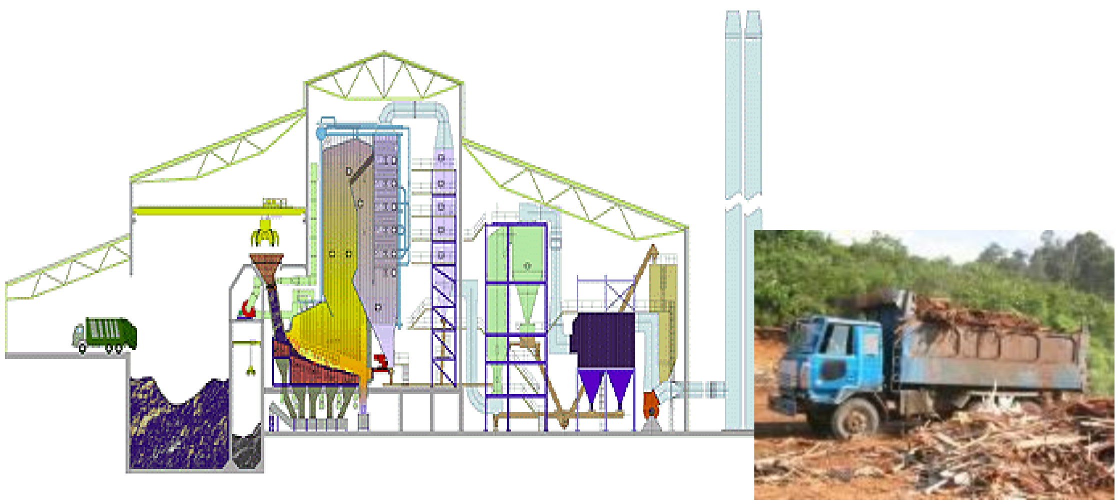

APRIL 2006

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SARAWAK GOVERNMENT/DANIDA

Implementation of an Urban Environmental Management System (UEMS) in Sarawak, Malaysia

PRE-FEASIBILITY STUDY ON A PROPOSED WOOD WASTE BASED POWER AND HEAT PLANT IN BINTULU, SARAWAK

Final Report

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List of Abbreviations

BDA	Bintulu Development Authority
CDM	Clean Development Mechanism
DANCED	Danish Cooperation for Environment and Development
DANIDA	Danish International Development Assistance
EQA	Environmental Quality Act
DOE	Department of Environment
GHG	Greenhouse Gas
IPP	Independent Power Producers
ITA	Investment Tax Allowance
KIE	Kemena Industrial Estate
LNG	Liquid Natural Gas
MDF	Medium Density Fibreboard
MLNG	Malaysia Liquid Natural Gas
NREB	Natural Resources and Environment Board
R.R.	Recovery Rate
SESCO	Sarawak Electricity Supply Corporation
SREP	Small Renewable Energy Power Programme
STIDC	Sarawak Timber Industry Development Corporation
TNB	Tenaga Nasional Berhad
UNFCCC	United Nations Framework Convention for Climate Change
WW	Wood Waste

1 BACKGROUND OF STUDY

1.1 Project Background

Sarawak is one of the largest tropical hardwood timber exporters in the world. It is estimated that Sarawak's forest produces around 9-10 million cubic metres of logs annually.

In 2003, Sarawak contributed to 53% of the timber export of Malaysia (Figure 1). As the main timber and timber product exporter in Malaysia, the timber processing industry is one of the main sources of income to Sarawak State. The timber and its downstream industries contributed RM1.019 million (5.9%) in 2001 and are predicted to yield RM1.037 million (5.2%) to the state gross domestic product (GDP)[1] in 2004.

Sarawak State aims to utilise more timber harvested for value-added timber processing activities within the state instead of exporting unprocessed logs. In line with this, a "log quota policy"[2] is currently in place. Under this policy, 60% of the total log production in Sarawak is to be reserved for processing in Sarawak. To further promote downstream processing, several integrated "timber based industrial zones", including the Kemena Industrial Estate of Bintulu, have been set up in Sarawak. Processed timber products constitute approx. 70% of the sector's exports (Figure 2). Out of this, plywood is the largest export, follow by sawn timber, veneer, mouldings and dowels.

[1] State Planning Unit, Sarawak. http://www.spu.sarawak.gov.my

[2] STIDC, 2003. Annual report 2003: Sarawak Timber Industry Development Corporation. PUSAKA, Sarawak.

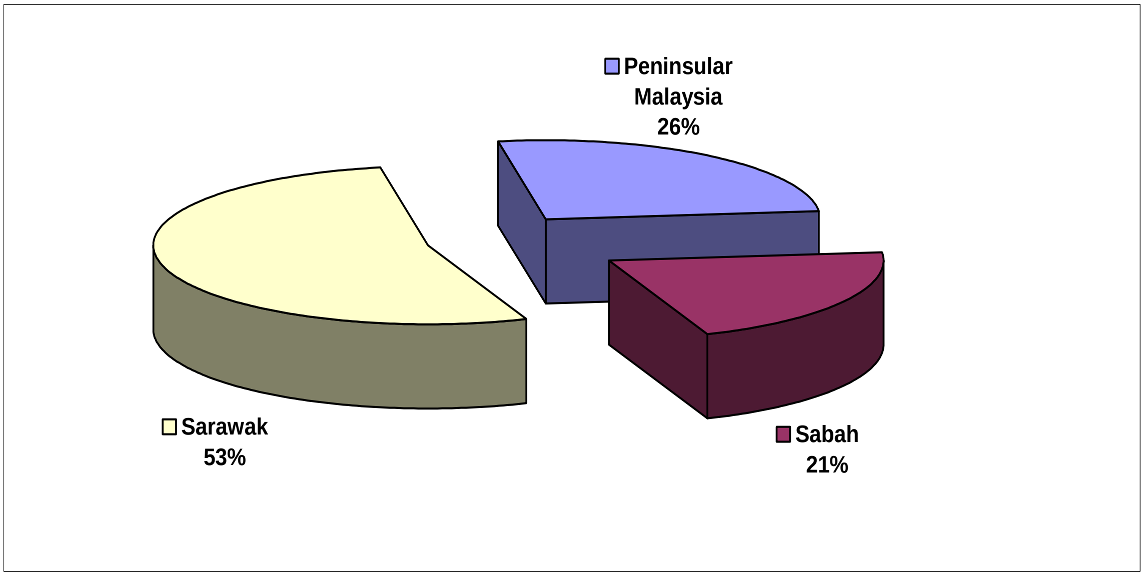

Figure 1: Malaysia timber export in 2003
(Source: STIDC)

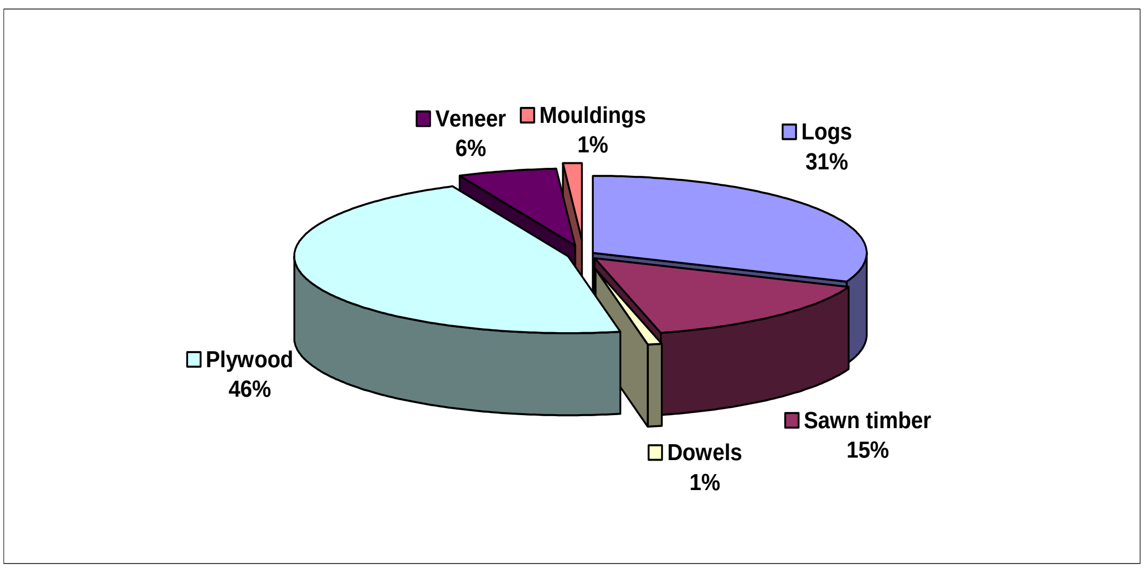

Figure 2: Sarawak timber sector export in 2003
(Source: STIDC)

Like any other processing industries, generation of waste is inevitable along with valuable products from timber based industries. The handling and disposal of large amounts of wood waste have been recognised as a problem by these industries for many years.

Wood waste is one of the biggest solid waste fractions in Sarawak[3]. The vast amount of wood waste could cause environmental problems if mishandled. The mill operators can either build incinerators to burn the waste or dispose of it at a landfill. The cost of constructing incinerators is relatively high compared to e.g. the present cost of RM12 per trip (3-tonne truck) charge for wood waste to be landfilled at the existing Segan landfill site in Bintulu. To reduce costs, some industries indiscriminately dump or openly burn their wood waste. The dumping of wood waste in rivers pollutes and reduces the river capacity and affects river transportation. Furthermore, decomposition of landfilled wood waste contributes to global warming. Uncontrolled open burning, on the other hand, creates nuisance and pollution.

Frequent public complaints have been received on indiscriminate disposal and open burning of wood waste by the wood based industries in Sarawak. Hence there is a need for immediate action to find an overall solution to this issue.

1.2 Wood Waste – An Energy Source?

In line with the call for reuse and recycling throughout the country, the handling and disposal of wood waste must be reconsidered.

Wood waste is a type of biomass which can be converted into energy by direct combustion. Wood waste is normally a homogenous fuel, and possesses a high combustion value as compared to other biomass. For optimum conversion of biomass to energy, the fuel however, also has to be relatively homogeneous in terms of size distribution. Therefore, if wood waste is to be used as fuel by combustion, it has to be processed into wood chips. This can be achieved using a chipper, hammer mill or similar equipment.

The combustion value of wood waste depends on the moisture content. For recently harvested timber with a moisture content of approx. 40-50%, a combustion value of approx. 13 MJ/kg can be assumed. The moisture content of kiln-dried wood waste is approx. 5-10%, with a combustion value of approx. 18 MJ/kg[4]. Other wood waste will normally have moisture content in the range of 12-15%, with combustion values ranging between 14 and 18 MJ/kg[5]. A recent study by SIRIM[6] used an average combustion

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[3] DANIDA-Sarawak Government. 2003. *Solid Waste Management in Kuching*. Implementation of an Urban Environmental Management System Project, Kuching, Sarawak, Malaysia.

[4] Arcate, Jim. n.d. *Waste wood for fuel on Oahu, Hawaii*. http://www.techtp.com/archives/waste%20wood.htm accessed 12 January 2005.

[5] Arcate, Jim. n.d. *Waste wood for fuel on Oahu, Hawaii*. http://www.techtp.com/archives/waste%20wood.htm accessed 12 January 2005.

value of approx. 13 MJ/kg; COGEN[7] estimated an average wood combustion value of 11.4 MJ/kg. Other sources recorded a lower combustion value of sawdust[8] at approx. 9 MJ/kg. On the other hand, a combustion value of 11.7 MJ/kg for the residue of a plywood mill was used by Jebsen & Jessen Engineering (M) Sdn. Bhd. for a steam turbine power generation under a FAO study[9]. Consolidating the various sources mentioned above, an average combustion value of 12 MJ/kg for mixed wood waste is used in this study.

Apart from direct energy recovery from combustion, wood waste can also be carbonised into briquettes which are a fuel that can be transported. In developed countries like Sweden, new ideas such as fermentation of wood waste to produce alcohol or reacted in bioreactors to yield carbon and hydrogen for fuels or industrial chemicals are being tested.

Reuse and recycling of wood waste is already practised to some extent by the wood industries in Sarawak for various purposes, e.g. for medium density fibre-boards (MDF) or particle boards, off-cuts for stacking of sawn timber etc. However, recovery of energy from residues is still relatively rare in Sarawak. Many of the mills which are equipped with incinerators and plywood mills especially tend to have heat recovery facilities. However, it was reported that the efficiency of these boilers is generally low. Very few wood based industries recover both power and heat from wood waste for their internal processes today.

Of the various ways of wood waste utilisation mentioned above, the most direct way is energy recovery from direct combustion. Other options will involve higher capital investments, more complexity in technological requirement, availability of product market etc.

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[6] Environment and Bioprocess Technology Centre SIRIM Berhad. 2004. *Comprehensive biomass energy resource inventory in Malaysia – R070/04*. Submitted to Pusat Tenaga Malaysia.

[7] EC-ASEAN COGEN Programme. 1998. Final report evaluation of conditions for electricity production based on biomass. Bangkok. Http://www.eppo.go.th/encon/encon-DANCED-Cogen.html

[8] Inforse-Europe, International Network for Sustainable Energy. 2002. *Wood waste heating improves environment and saves money in Campeni, Romania*. Http://www.inforse.dk/europe/su_ro_wood.htm. Accessed 12 January 2005.

[9] FAO. 1998. Proceedings of the regional expert consultation on modern applications of biomass energy. 6-10 January, Kuala Lumpur. FAO Regional Wood Energy Development Programme in Asia, Bangkok.

1.3 The Project and Existing Governmental Policy

1.3.1 Integrated Waste Management and Environmental Quality

The Sarawak Government prepared an "integrated waste management strategy" in 1997. Under the strategy, the improvement of waste management is foreseen to contribute to the improvement of the environmental quality of the state. The strategy is in line with the National Government of Malaysia's call for increasing the reuse and recycling of waste in the country.

In this context, the State Government of Sarawak, through the Natural Resources and Environment Board and Bintulu Development Authority in cooperation with DANIDA, has undertaken a study on the possibility of utilising wood waste as an energy source.

An initial proposal based on a centralised wood based cogeneration (combined heat and power) plant was prepared and a preliminary financial assessment of the cogeneration plant was carried out in 2003[10]. In order to further assess the feasibility of such a facility, additional studies were required.

A possible concept for an integrated wood waste management system for Bintulu is illustrated in Figure 3 below:

[10] Proposal for a project study: Waste wood bio energy plant in Sarawak. 2003.

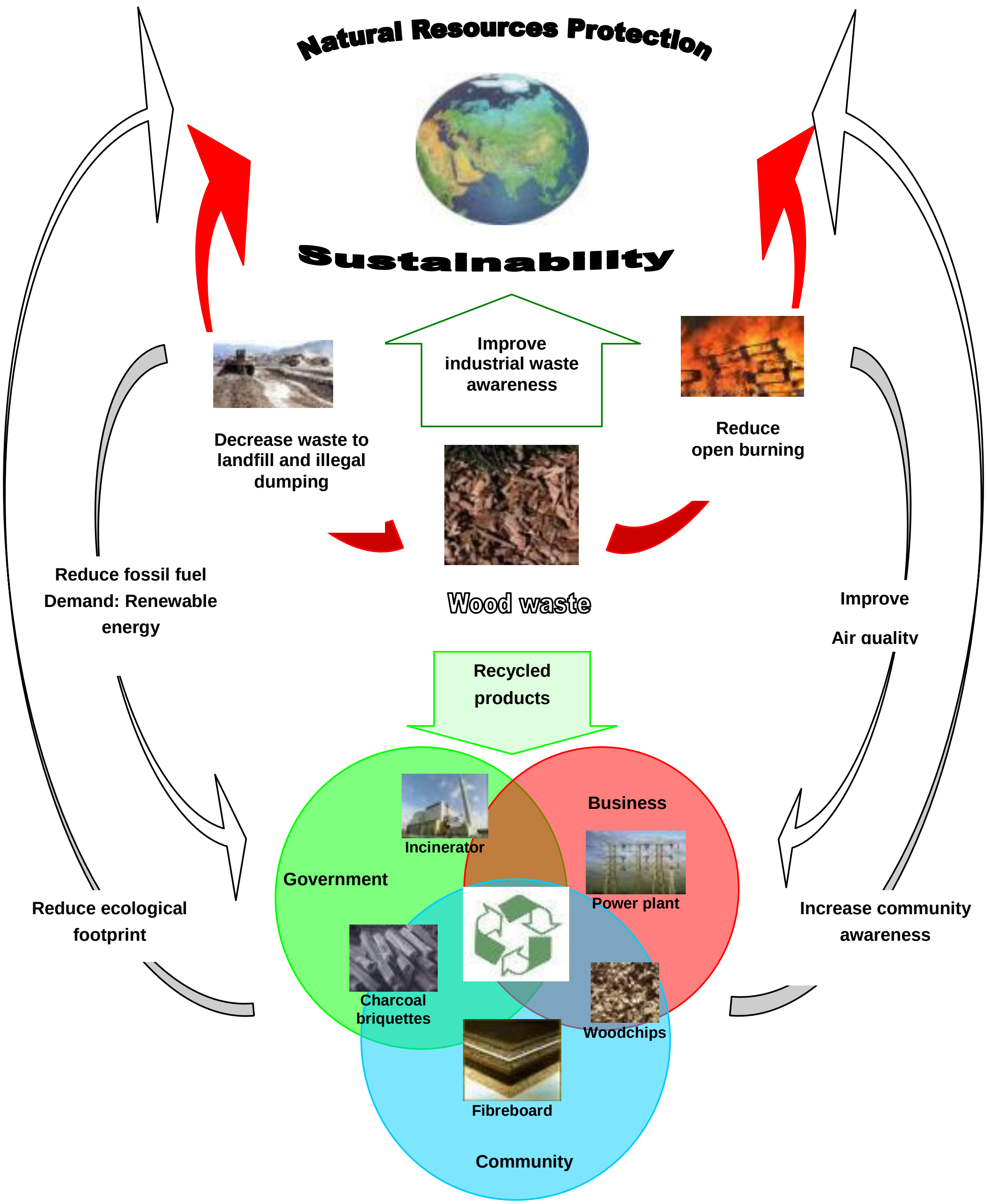

Figure 3: Conceptual management of wood waste management in Bintulu

1.3.2 Wood Waste as Renewable Energy

According to estimations from 2002, the approximate life-span of Malaysia's oil and gas reserves was 17 and 34 years respectively[11]. Therefore, although Malaysia has plenty of gas reserves entailing low power generation costs, the gas reserves are finite and therefore alternatives will be required eventually.

Renewable energy has been promoted, especially since the outset of the 8th Malaysian Plan. In accordance with the Malaysia national energy policy[12], the four-fuel diversification policy of gas, hydro, coal and oil, has been expanded to the 5th fuel policy under the 8th Malaysia Plan which gives emphasis to renewable resources, including biomass (where wood waste is included), biogas, landfill gas, solar energy and mini hydropower.

The 5th fuel policy of Malaysia aims at 5% of electricity generation coming from renewable energy by the end of 2005. According to a DANCED feasibility study, the target of 5% renewable energy (equivalent to approx. 650 MW[13] power installed capacity for Malaysia) can be easily achieved from renewable fuels such as palm oil biomass, wood waste from timber industries etc.

Under the 8th Malaysia Plan, a number of strategies promote the utilisation of renewable energy and encourage energy efficiency in the industrial sector. For example, the Government of Malaysia launched the Small Renewable Energy Power Programme (SREP) in 2001. This programme encourages and intensifies the use of renewable energy in power generation, by promoting the development of small grid-connected renewable energy power plants. However, it is unfortunate that the SREP is not applicable to State of Sarawak and Sabah as the programme was designed only for Peninsula Malaysia with involvement of Tenaga Nasional Berhad.

However, other incentives are provided by the Government of Malaysia to encourage energy generation using biomass. These include income tax exemption of 70% on statutory income for 5 years or an investment tax allowance (ITA) of 60% of capital expenditure incurred within 5 years, to be used against 70% of the statutory income; and import duty and sales tax exemption on machinery and equipment which are not

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[11] Floyd, Neil. 2002. Malaysia sector in market report. Trade Partners UK. Http://www.tradeparners.gov.uk

[12] The main objective of Malaysia National Energy Policy is to achieve adequate, clean and affordable energy supplies to ensure sustainable economic development.

[13] Lalchand, G. 2004. Renewable energy as a fifth fuel option for power generation in Malaysia. Jurutera – The monthly bulletin of the Institution of Engineers, Malaysia. No. 12 December.

produced locally. Sales tax exemptions will be given for locally produced machinery and equipment[11].

The sources of biomass predefined for the above incentives are palm oil mill/estate waste, rice mill waste, sugar cane mill waste, timber/sawmill waste, paper recycling mill waste, municipal waste and biogas (from landfills, palm oil mill effluent (POME), animal waste, etc). The energy may be electricity, steam, chilled water or heat. Hence, the wood waste based power plant proposed will be eligible for these incentives.

1.3.3 Reduction of Greenhouse Gas Emissions

Apart from renewable energy, other environmental benefits of the proposed project should be highlighted. An important direct benefit is the reduction of greenhouse gas (GHG) emission by the substitution of non-renewable fossil fuel with wood waste (considered a carbon neutral fuel). Additional GHG reduction can probably be derived from avoiding the methane formation from wood waste degradation in landfills.

Malaysia signed and ratified the Kyoto Protocol in 2002. The Kyoto Protocol is a legally binding global commitment to reduce the effect of global warming due to anthropogenic greenhouse gas emissions. With the Kyoto Protocol coming into force in February 2005, the effort to comply with the agreement is expected to be intensified.

The clean development mechanism (CDM) is one of the flexible mechanisms introduced to promote the reduction of GHG by the Kyoto Protocol. It is a financing tool to reduce the compliance cost for developed countries to meet their GHG reduction targets, while assisting developing countries to meet sustainable development goals through environmentally friendly investments.

The Government of Malaysia is currently intensifying its effort to promote CDM, and the proposed wood waste based power plant has the potential to qualify as a CDM project. Similar biomass recovery projects, mainly based on palm oil mill residues, have been proposed and approved already.

2 OBJECTIVES AND METHODOLOGIES

2.1 Objectives

As delineated above, a proposal for establishing a wood waste based cogeneration (combined power and heat) plant in Bintulu has been initiated. Detailed feasibility studies are required to sustain the proposal. As a point of departure, it is necessary to assess the potential supply of wood waste and the future demand for energy recovered from the waste before further work is carried out.

Thus, the specific objectives of this study are:

i. To collect, review and assess the existing information on the amount and types of wood waste generated from the timber processing industries in Bintulu

ii. To assess the trends in timber industry development in Bintulu (2005-2015) and subsequently predict the wood waste generation

iii. To collect, review and assess the existing management of the wood waste. This should include estimation of existing recycling of wood waste

iv. To assess the trends in the management of wood waste in Bintulu, including the public opinion on a communal cogeneration plant

v. To assess the present and future power and heat supply/demand (2005-2015) in Bintulu

vi. To assess whether a detailed feasibility study of the project should be carried out.

2.2 Study Area

In the 1980's, almost all the logs from Sarawak were exported, with little processing done locally. However, in recent years, the State Government of Sarawak has imposed quota on the volume of logs to be exported so as to encourage local downstream timber processing industries.

In Sarawak, there are around 388 timber processing mills[14]. Approx. 20% of the mills are concentrated in Bintulu (See Figure 4) and approximately 30% of the timber products in Sarawak are processed in Bintulu (please refer to Appendix A).

In general, spatial land use in Bintulu is well demarcated. Residential, commercial and industrial zones are clearly allocated in specific locations. Currently several industrial

[14] Data provided by the State Timber Industrial Development Corporation, 2004.

zones are being developed in Bintulu, namely Bintulu Light Industrial Estate (BLIE) and Kidurong Light Industrial Estate (KLIE), Kidurung Industrial Area (KINDA), and Kemena Industrial Estate (KIE) (Figure 5). Timber based industries are all located in Kemena Industrial Estate (KIE), which is designated as an integrated timber processing zone.

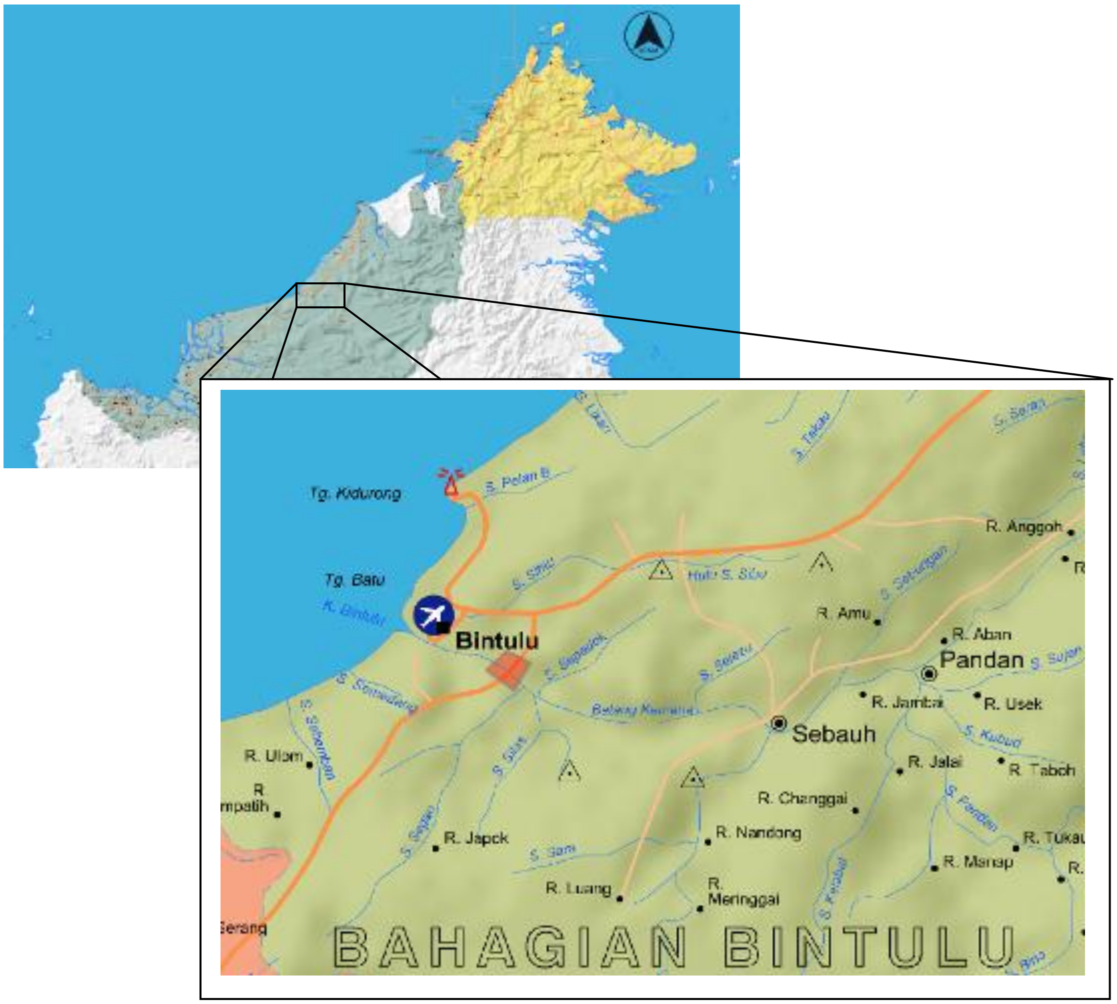


Figure 4: Study area at Bintulu Division, Sarawak

This study is focused on the evaluation of wood waste generation and the power and heat demand within the KIE.

2.2.1 Kemena Industrial Estate - KIE (Timber Based Industries Zone)

Considering that Bintulu is easily accessible and richly endowed with tropical timber, the KIE (Figure 5) was established to cater for timber related industries. The Kemena

Industrial Estate (KIE) was located along the banks of Kuala Bintulu in the early 90's[15]. This makes the possible collection and transportation of wood waste to a communal cogeneration plant easier and more cost efficient, as the means of transportation and the distances have a strong impact on final biomass fuel costs. In view of the strategic distribution of mills within the same dedicated area, the prospect of establishing a communal cogeneration plant is considered good.

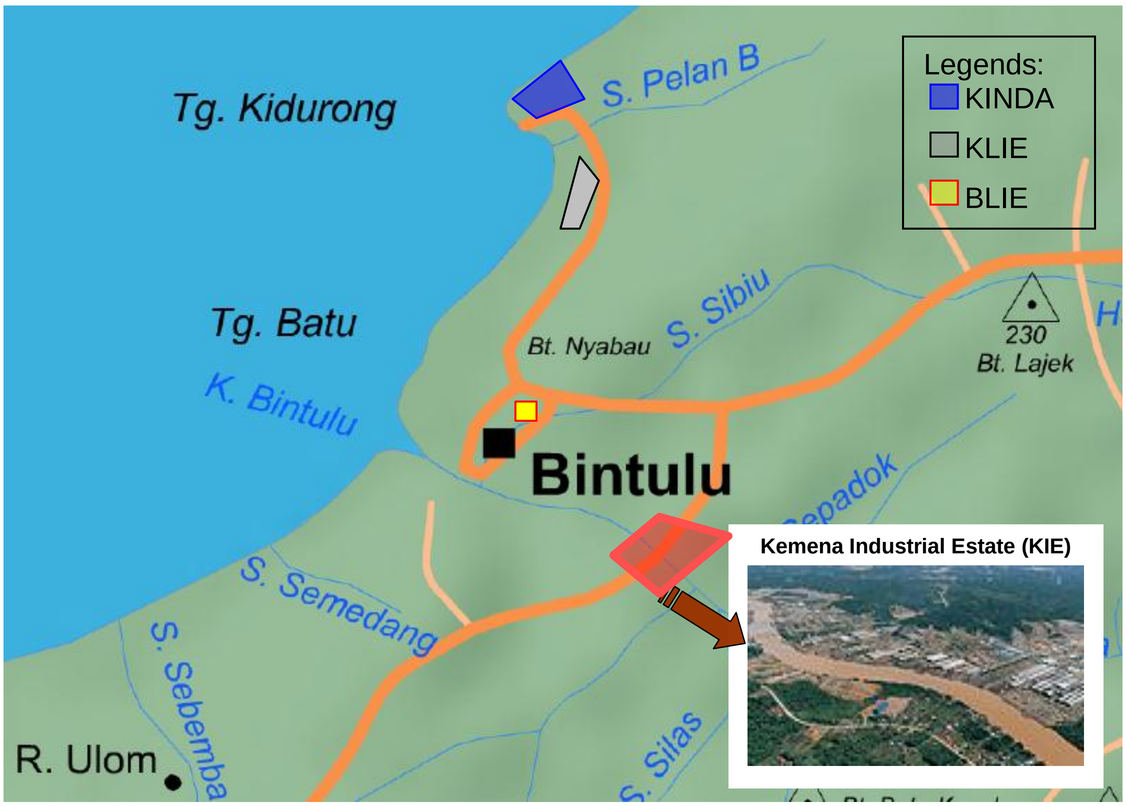


Figure 5: Locality map of Bintulu and KIE area

The development of KIE was divided into 2 phases. Details of the KIE phases are illustrated in Table 1 below. KIE currently provides approximately 1.3 million m^3 of wood based processing capacity per month and this figure is expected to grow as phase 2 of the KIE is fully implemented.

[15] Personal communication with Senior Officer in Planning & Industrial Development Section, STIDC

Table 1: Basic information on the Kemena Industrial Estate, phases 1 and 2

Description	Kemena Industrial Estate phase I (KIE I)	Kemena Industrial Estate phase II (KIE II)
Distance from town	13 km	14 km
Total area developed	174 hectares	200 hectares
Total area saleable	144,39 hectares	170 hectares
Type of industry	Timber-based industries	Timber-based industries
Selling price per sq. m. -with river frontage -without river frontage	RM40.36 RM40.36	RM75.35 RM54.12
Area sold	144,39 hectares	65,65 hectares
Remaining area	0	104,35 hectares
Number of factories	62	0

(Source: BDA & STIDC, 2003)

2.3 Methodologies

The methodologies employed in this study include:

- Literature review: Information was gathered from relevant governmental departments, related associations, utility companies, research institutions as well as the private sector, including timber industries. Information includes general information, statistics, past studies, research etc.
- Field studies: Interviews and discussions with relevant authorities, site visits to existing recycling and disposal facilities, consultation and visits to representative timber factories etc.

Data and information obtained were assessed and compiled. Verification and counter-checks with information obtained from other sources were carried out to assess the quality of the information. When data was not readily available, best estimates and relevant assumptions were adopted.

2.4 Structure of the Report

The report is divided into different sections. Section 1 above provides the background. Section 2 describes the objectives and methodologies. Section 3 elaborates on the current timber market and production outlook. Section 4 describes the wood waste amount and its current management, including the assessment of potentially available amounts of wood waste for a communal cogeneration plant. Section 5 outlines the energy supply and demand within the Kemena Industrial Estate as well as in Bintulu. Finally, the report is concluded in section 6 with a number of recommendations.

3 STATUS AND PROJECTION OF THE TIMBER MARKET IN BINTULU

3.1 Introduction

The efforts of the State Government of Sarawak to bring forth Sarawak as an industrial centre for timber and resources based activities have borne results, resulting in massive growth of the downstream wood processing industry since the mid 90's.

This fact is supported by the gradual decline in raw log export since the introduction of the "log quota policy" in 1994 (see Figure 6). This effort has increased the competitiveness of the downstream timber processing sector to produce value-added products. Although the total log production declined, domestic supplies increased enormously. The log quota policy was the turning point when all the large-scale timber companies started to invest in timber processing to compensate for the decline in logs harvested. These processing plants were mostly located in timber processing estates (e.g. Kemena Industrial Estate) developed by the local councils.

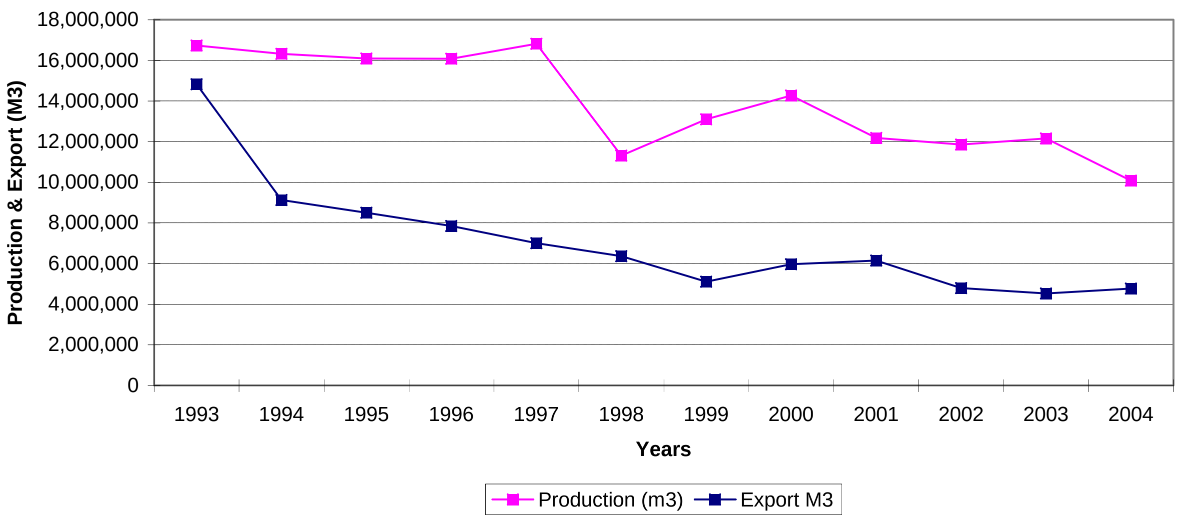


Figure 6: Production of logs in Sarawak 1993-2004
(Source: STIDC, 2003)

3.2 Production of Timber Products in Sarawak

In 2003, 6 million m^3 of the log production were reserved for domestic processing in Sarawak. According to the statistics, plywood production has almost doubled over the past 8 years compared to other timber based products (Figure 7). An average annual increase of production of 5% was observed. Sawn timber remained the second largest timber product. However, the production has not shown any growth. Other smaller wood based products include veneer, dowels/moulding, laminated board, particle board, MDF and woodchips. These industries are mostly subsidiary activities of the main timber processing i.e. plywood mills and sawmills.

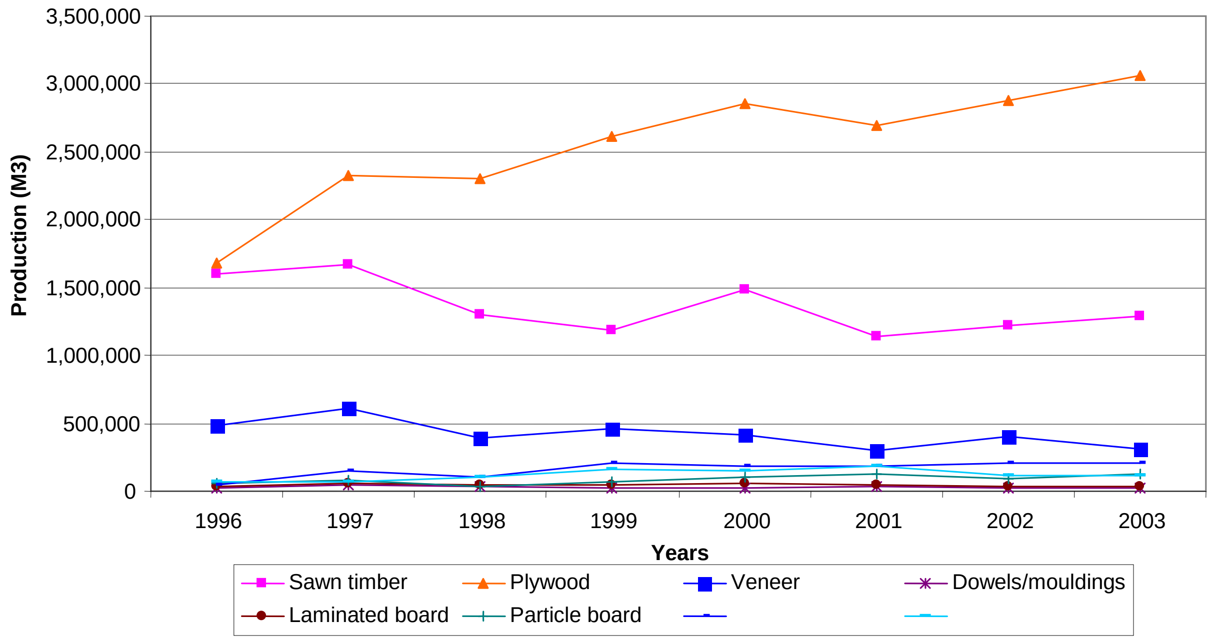


Figure 7: Production of timber products for Sarawak: 1996 - 2003
(Source: STIDC, 2003)

3.3 Timber Processing Capacity in Bintulu

As indicated earlier, Bintulu is one of the largest timber processing centres in Sarawak. The total installed milling capacity is 1,290,300 m^3 per month, which caters for approximately 29% of the wood manufacturing capacity of the state (Appendix A). 30% of the wood manufacturing capacity is located in Sibu, while Kuching, Miri, Sarikei (including Tanjung Manis), Mukah, Limbang constitute 15.5%, 12.1%, 6.2%, 6.1% and 0.4% respectively.

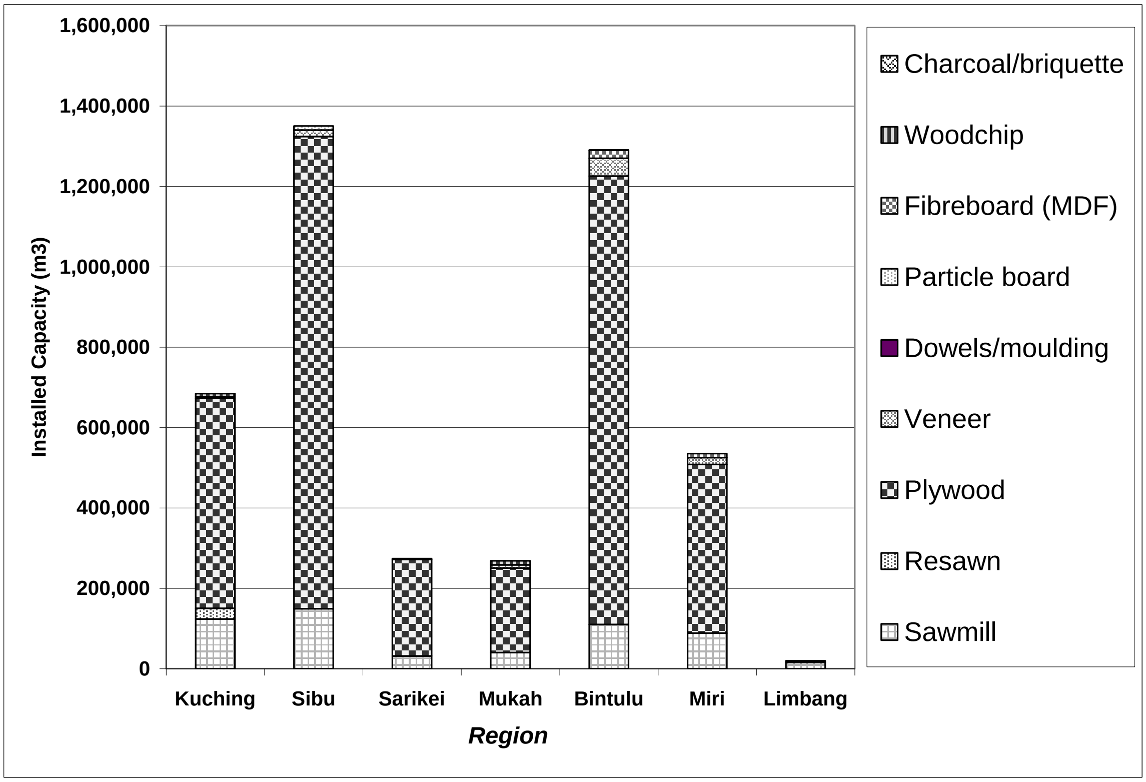


Figure 8: Wood based milling installed capacity (m^3) for Sarawak, 2003
(Source: STIDC, 2004)

62 mills are located in Bintulu Kemena Industrial Estate. Sawn timber processing makes up the highest numbers of mills, however, all of them are categorised as Class C with a capacity of < 50,000 m^3/month[16]. This means that sawmills in Bintulu are small-scale, ranging from a 100 m^3 to a 8400 m^3 production capacity per month. The total installed capacity at sawmills (8.5% of total processing capacity) is much less than for plywood production (86%) which is installed at only 10 mills (Table 2).

The plywood mills comprise 5 Class A mills (> 100,000 m^3/month), 3 Class B mills (50,000-100,000 m^3/month) and 2 Class C mills (< 50,000 m^3/month).

Other, smaller product types include 11 veneer mills (3.4%), 2 MDF mills and a charcoal briquette manufacturing mill which together encompass less than 2% of the total production. All the veneer mills are Class C mills, with a production capacity ranging from 2,000-6,000 m^3/month.

[16] Please refer to Appendix B for the categories of classification

Table 2: Status of the wood based industry in Sarawak, 2003

Types of mill	No. of mills	
	Sarawak	Bintulu (installed capacity m^3/ MTH)
Sawmill	246	38 (109,700)
Plywood	30	10 (1,116,000)
Veneer	24	11 (44,000)
Dowels/moulding	23	-
Laminated board	7	-
Particle board	1	-
Medium density fibreboard (MDF)	3	2 (20,000)
Woodchips	4	-
Charcoal briquette	3	1 (500)
Kiln drying plant	47	-
Total	388	62 (1.3 mil)

(Source: STIDC, 2004)

3.4 The Current Bintulu Timber Market and Future Projection

On the demand side, it is expected that the world market for timber products, as predicted by the FAO[17] (Table 3), will grow (especially for wood based panels), thus the demand is not expected to be a limiting factor for the growth of timber products.

Table 3: Forecasts for forest products markets – world production & demand (million m^3)

Product	1996		2010	
	Production	Consumption	Production	Consumption
Sawn wood	430	426	501	498
Wood based panels*	149	148	180	179

* Wood based panels include plywood, veneer, MDF and particle boards.

The limiting factor is more likely to be log supply available to the timber industries. For the determination of the trend in log input (supply) for the next 10 years (2005-2015), historical records for 5 years (1999-2003) were used. This analysis was recommended by a senior officer from the Sarawak Timber Industries Development Corporation

[17] Pleydell, Geoffrey & Tomaselli, Ivan. 1999. Report on the downturn in the international tropical timber market: A study arising from decision 6 (XXIV) of the international tropical timber council. ITTO.

(STIDC), an organisation with in-depth knowledge and experience of the timber industry in Sarawak. The 1997 and 1998 records were not included, to avoid the unusual market distortion due to the regional economic downturn during that period.

For simplicity, assessments were carried out only for the two dominant types of timber processing industries i.e. plywood/veneer and sawn/resawn timber industries. The log input and production capacity for these two types are plotted in Figure 9 and Figure 10. A significant increase in this production can be observed in 1998-1999 due to the introduction of the “log quota policy”. Since 1999, the trend has been a relatively static production.

Figure 9: Log input to Bintulu downstream main wood based processing sector 1996-2003

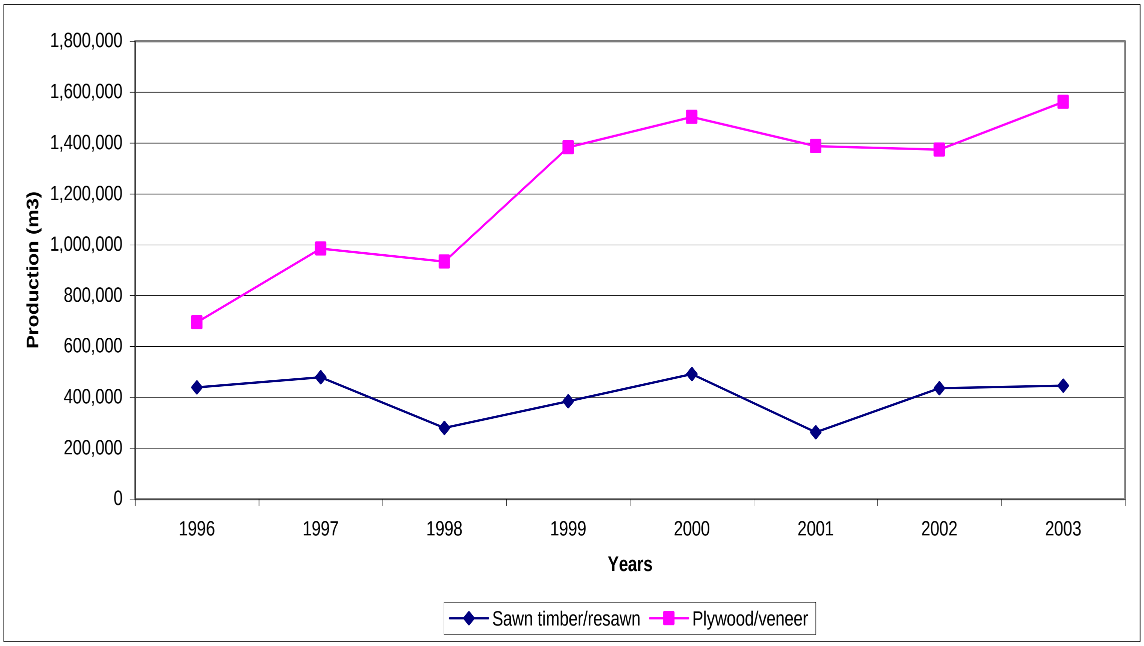


Figure 10: Production of Bintulu downstream wood based processing sector 1996-2003

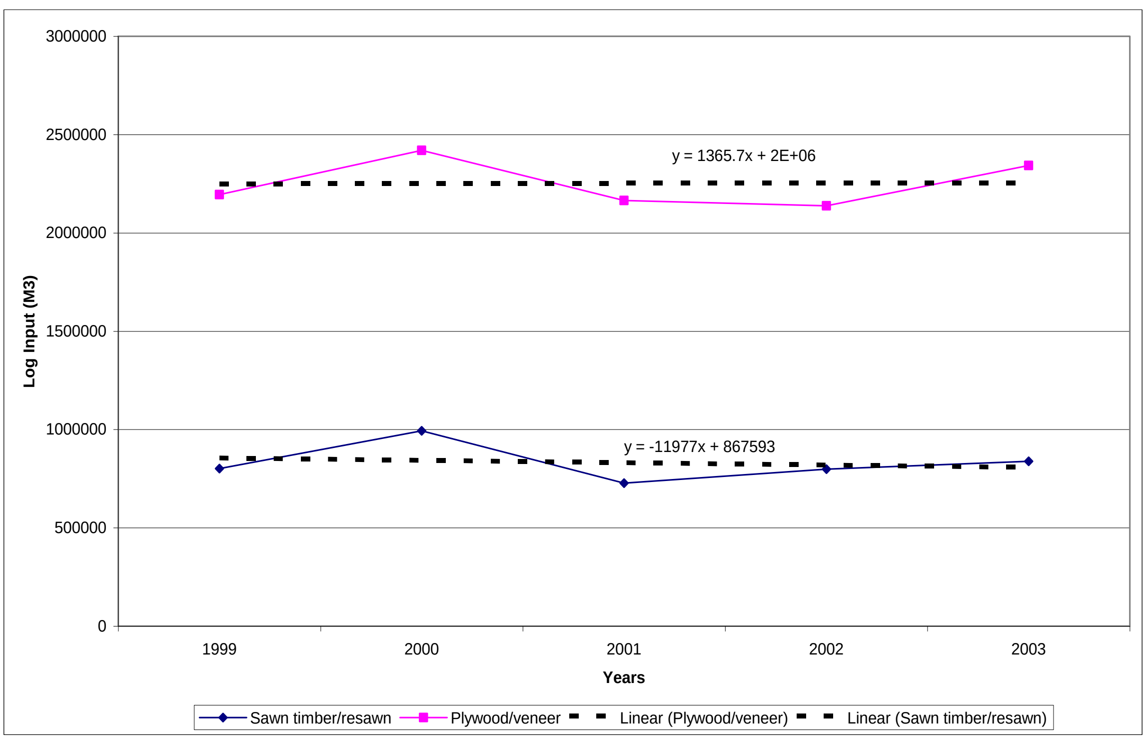


Figure 11: Log input to Bintulu 1999-2003

The equations for the predicted market for log input are presented in figures 11 and 12:

Sawn timber/resawn input projection: $y = -11977x + 867593$

Plywood/veneer input projection: $y = 1365.7x + 2(10^6)$

Where,

Y = log input

X = number of years (1999 = year 1 and 2015 = year 17, etc)

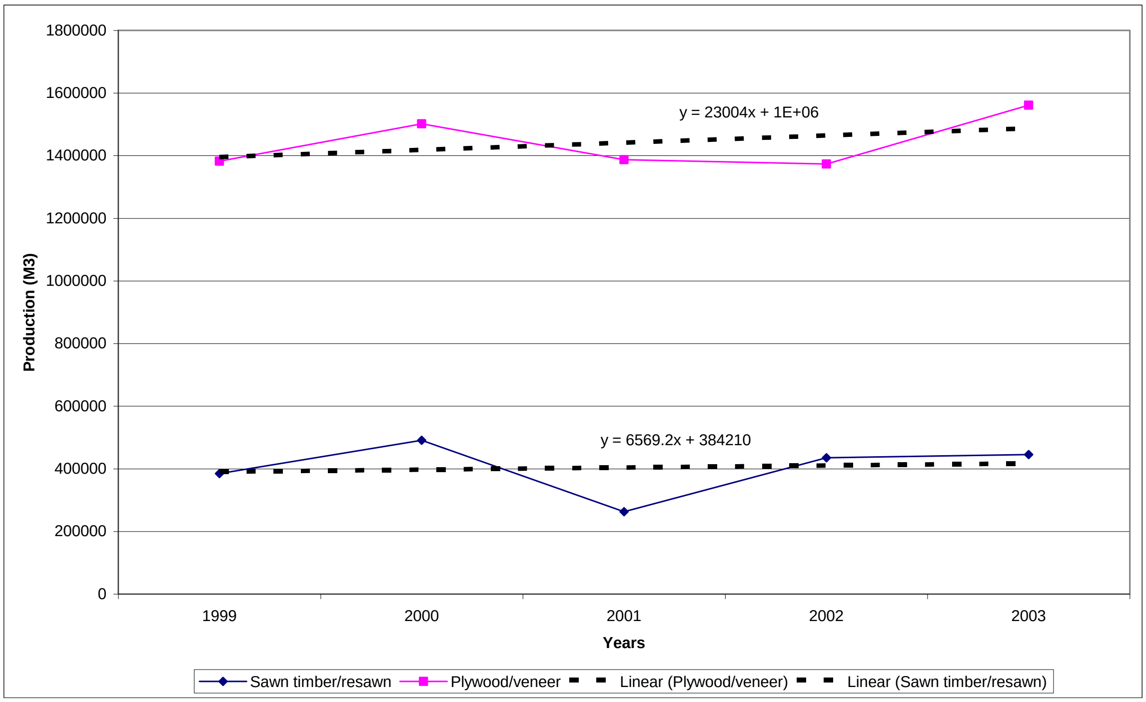


Figure 12: Production based on 5 years' consistent trend

The equations below present the predicted timber product output:

Sawn timber/resawn output projection: $y = 6569.2x + 384210$;

Plywood/veneer output projection: $y = 23004x + 10^6$.

Where,

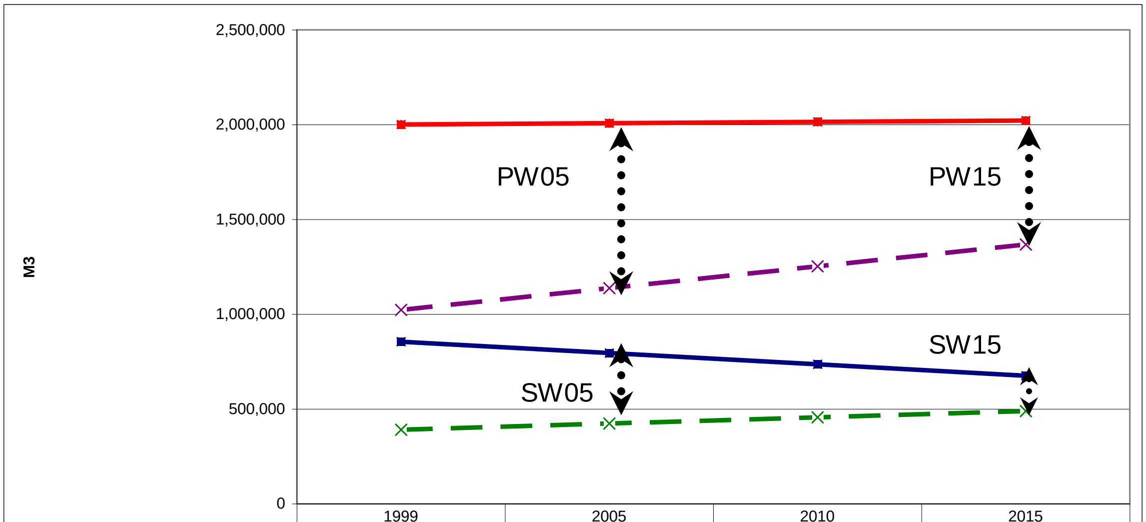
Y = product output

X = number of years (1999 = year 1 and 2015 = year 17, etc)

Figure 10 and Figure 12 show that the plywood/veneer sector has a slightly better development than the sawmill sector. This is the situation based on the log input as well as production.

In 2003, sawmill/resawn operators only received 838,467 m^3 of logs, while plywood/veneer operators received of 2,342,657 m^3 of logs. Over the past 5 years, the average annual growth of log input and products yielded for plywood/veneer mills and sawmill/resawn mills was at 1% and 3% respectively.

The future production is projected using a linear regression method based on the 5 years' data as shown in Figure 13 below. This projection is based on the assumption that the log supply will follow the same trend as that of the past 5 years, while the demand for the timber products will not be a limitation. Another assumption is that the government policy on timber processing and markets will not change drastically over the next 10 years.



	1999	2005	2010	2015
Sawn timber/resawn input	855,616	795,731	735,846	675,961
Sawn timber/resawn output	390,779	423,625	456,471	489,317
Plywood/veneer Input	2,001,366	2,008,194	2,015,023	2,021,851
Plywood/veneer output	1,023,004	1,138,024	1,253,044	1,368,064

Years

Sawn timber/resawn input — Sawn timber/resawn output — Plywood/veneer Input — Plywood/veneer output

Figure 13: Projection on main timber production sectors in Bintulu 1999-2015

From the linear regression line projected to 2015 (Figure 13), it is predicted that log input for sawmills will decline about 15-20% while input for plywood and veneer will remain relatively constant in the coming years. Based on the projection, growth in output for both sawn timber and plywood/veneer products is predicted in the future. This is based on the assumption that the technological development of the mills over the next 10 years will result in higher product conversion efficiency. The optimistic estimation of the increase in production efficiency is at approx. 10-15%, which will bring the existing average of 50% to around 60-65% overall efficiency.

Thus, the projection of timber waste generation in this study can be considered rather conservative. For example, there could be certain barriers to the improvement in milling efficiency, such as limitation of skills and capacity, availability of capital outlay for technological improvement, reluctance to change etc. On the other hand, the wood waste projection can also be higher should the log supply increase (based on the current situation, log supplies from neighbouring countries may be processed in Sarawak).

A rough estimation of the wood waste generated in 2015 is tabulated in Table 4, where the amount of sawmill waste and plywood/veneer mill waste decline at a rate of approx. 7 and 3% respectively.

Table 4: Future estimation on wood waste

Type of mill	Wood waste amount (m^3)		Growth rate (%)
	2005	2015	
Sawmill (SW)	372,106	186,644	-6.7
Plywood mill (PW)	870,170	653,787	-2.8

The Bintulu timber sector will not grow much unless the Government reviews the "log quota policy". Further reduction of raw log export will promote further local timber processing.

In summary, the outlook for the timber industries and market in Bintulu can be concluded as follows:

1) The quantity of log input to the timber industries is expected to be relatively stable or slightly reduced, due to a projected reduction in log input (supply)
2) The output of timber products is projected to be slightly increasing, due to the improvement of milling technology leading to higher processing efficiency
3) The global demand for timber products is not anticipated to be a limitation for Bintulu timber industries.

4 WOOD WASTE GENERATION AND CURRENT MANAGEMENT

4.1 Types of Wood Waste

The wood waste referred to in this study is that generated from downstream timber processing industries. The waste from logging activities is not considered in this study as it is mostly generated at the logging area which is far from the wood processing area.

Wood waste can be defined as biomass that is not converted into useful products by processing mills[18]. In general, there are 8 types of wood waste which can be further categorised into 3 main groups[19]:

* Bulk residue: Barks, slabs, peeler cores, long off-cuts and short off-cuts
* Particle residue: Sawdust, shaving and sander dust
* Rejects: Rejected products.

This section mainly discusses wood waste generated from plywood mills and sawmills. Waste generation from other industries is relatively insignificant in amount.

4.1.1 Waste from Plywood Mills

Plywood mills involve more processes than saw-milling (Appendix D). Due to their larger capacity and better processing technologies most of the plywood mills are classified as Class A (Appendix B). However, although they have large capacity,, most plywood mills are under-utilised, with an average output per design capacity as low as approx. 12%.

During the processing of plywood, firstly, logs are cut to the length required and debarked. After the preparatory operations, logs are sliced by a knife and peeled to form veneer in a rotating machine. Further, the sliced veneers are cut into the sizes required and dried. The dried veneers are then sorted, and quality checked. Veneers with sheets with holes, irregularities or other fades will be rejected. The sheets are glued and hot pressed into plywood sheets. Finally the plywood sheets are trimmed, sanded and graded.

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[18] FAO. 2001. Trash or Treasure? Logging and Mill Residues in Asia and the Pacific. ASIA-PACIFIC FORESTRY COMMISSION. Regional Office Bangkok, Thailand.

[19] Wong, E. et.al, 1999. The Issue of Wood Residues in Kuching Region. In Proceeding 2nd TRTTC/STA Forest Products Seminar, Sarawak.

The recovery rate depends on the technologies used as well as the diametre and quality of logs. The main forms of waste are log ends and trims, barks, veneer cores, green veneer waste, dry veneer waste, trimmings and rejected plywood.

4.1.2 Waste from Sawmills

As mentioned earlier, all sawmills in Bintulu are classified as Class C according to their installed capacity (Appendix B). Most sawmills are not fully utilised. However, the average output per installed capacity is approx. 34%, which is better than for plywood mills. Although there are 38 sawmills in KIE Bintulu, only approx. 10 operate actively[20]. This is due to the competitiveness of log supply between sawmills and often with plywood mills as well. The rest of the mills are either not in operation or operate only occasionally.

The recovery rate of sawmill operation (Appendix D) varies according to practices as well as the species of sawn. Approx. 12% of raw logs are barks which are considered as waste. However, most of the logs received by mills are debarked. The waste generated during the milling process are slabs, edgings and trimmings, which account for approx. 34%, and sawdust which makes up another 12% of the log input. Hence the waste yield factor is almost 50% for debarked logs.

4.2 Estimation of Wood Waste Generation

The following equation was used to estimate the total amount of wood waste generated from primary wood processing (plywood and sawmills).

WW	=	L.I – [R.R% X L.I]	
		WW	= Total volume of wood milling waste;
		L.I.	= Total volume of log input to the wood processing mill;
		R.R.%	= Average percentage of mill recovery rate
			= Total product output/total log input x 100
WW%	=	100 % - % of R.R.	

The estimation is illustrated in table 5 below. The total amount of wood waste generated in 2003 for sawmills and plywood mills is estimated at approximately 1.2 million m^3 or 288,000 tonnes[21].

[20] Personal communication with the manager of one of the sawmills operating actively.

[21] Density of wood residues is 240 kg/ m^3 as adopted in Environment and Bioprocess Technology Centre SIRIM Berhad. 2004. *Comprehensive biomass energy resource inventory in Malaysia – R070/04*. Submitted to Pusat Tenaga Malaysia.

Table 5: Estimated wood waste generated from the two main contributor sectors in Bintulu, 1996-2003

Product		Year							
		1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Sawn timber/ Resawn	Input (m^3)	891,564	943,271	636,232	800,978	993,042	727,466	798,412	838,407
	Output (m^3)	438,411	478,451	279,780	384,836	491,035	262,836	435,365	445,517
	Recovery Rate (%)	49	51	44	48	49	36	55	53
	Residues (m^3)	453,153	464,820	356,452	416,142	502,007	464,630	363,047	392,890
	Residue (%)	51	49	56	52	51	64	45	47
Plywood/ Veneer	Input (m^3)	1,639,849	1,654,892	1,638,618	2,194,804	2,420,230	2,164,275	2,138,181	2,342,657
	Output (m^3)	694,909	985,143	933,061	1,382,312	1,501,552	1,387,178	1,373,439	1,561,387
	Recovery Rate (%)	42	60	57	63	62	64	64	67
	Residues (m^3)	944,940	669,749	705,557	812,492	918,678	777,097	764,742	781,270
	Residue (%)	58	40	43	37	38	36	36	33

4.2.1 Comparison with Site Visit Information

In order to assess the estimation made and the current status of wood waste generation and management, site visits were carried out. Visits included the Bintulu Development Authority and several of the timber processing companies (3 plywood mills and 2 sawmills). Waste generation rates and current waste management for the mills visited are tabulated in Table 6 and Table 7 below:

Table 6: Summary of findings on waste generation from site visits

Company	Installed capacity (m^3/MTH)	Maximum input* (Timber) (m^3/MTH)	Maximum output (Product) (m^3/MTH)	Annual recovery rate (%)	Output/ capacity
P1	180,000	50,000	26,000	53-54	0.1
P2	150,000	38,000	20,000	54-60	0.1
P3	120,000	48,000	22,000	46-48	0.2
S1	6,000	15,000	8,000	53	1.3
S2	1,000	3,700	1,000	27	1.0

Note: P1, P2, P3-Plywood mill

S1, S2-Sawmill

* The timber input might not be utilised within one month; the surplus will be brought to the following months. This is particularly true for sawmills where the processing capacity is limited by their installed capacity.

Table 7: Summary of wood waste characteristics and current management

Mill types	Type of milling residue from total production (%)					Residues Utilised internally (%)	Residues Utilised externally (%)	Disposed (%)
	Off-cuts/ slabs	Veneer core/ waste	Sawdust/ sanding dust	Trimmings/ shavings	Logs bark/ ends			
P1	5-10	15	5-10	5-10	<5	45	8	47
P2	2	36	2	1-2	2-3	74	8	18
P3	1	37	0.5	-	1	74	10	16
S1	25	-	15	-	-	0	100	0
S2	15	-	15	20	-	0	100	0

Note: P1, P2, P3-Plywood mill

S1, S2-Sawmill

The recovery rate of the visited plywood mills is lower (averagely 53%) than the average recovery rate (67%) for the state obtained from STIDC (Table 5). This may mean that the estimation of waste generation in section 4.5 below might be on the conservative side. On the other hand, the recovery rate for the visited sawmills is approximately 55% and is comparable with the average waste recovery rate (53%) for 2003 documented by STIDC.

The visits also documented that the internal wood waste utilisation rate is higher in plywood mills than sawmills. This is probably due to the existing demand for heat in the plywood process for which most mills utilise their own waste as an energy source (steam generation). In comparison, sawmills have no heat demand. Utilisation of waste from sawmills therefore depends on the by-product companies.

In most cases, plywood and veneer mills operate 22 hours per day (8 hour basic + 3 hour overtime- 2 shifts), 7 days per week, while most sawmills only operate on one shift of 8-10 hours, 6 days per week. Surprisingly, the sawmills visited are maximising the utilisation of their milling capacity, which contradicts the data showing that installed sawmill capacity is mostly under-utilised. However, the 2 sawmills visited are among the largest and most active. As expected, the plywood mills only utilise 10-20% of their installed capacity.

Due to the fact that only few mills were visited and that the mills visited were among the largest and the most active, some of the information, especially regarding the installed and operation capacity, might not be representative for the industries. The large mills were selected as they were believed to contribute with a large share of the wood waste.

4.3 Current Utilisation of Wood Waste

4.3.1 Utilisation On-site (Internally)

Currently, many of the plywood manufacturing industries already recover heat through wood waste incinerators on site, since the main process requires high thermal energy for veneer drying and hot pressing. The waste is mainly burnt in boilers to yield steam. The entire thermal demand can be fulfilled by the wood residues. Only one plywood mill in Bintulu utilises wood residues for a cogeneration plant (combined power and heat). Another mill operator is showing interest in investing in a similar cogeneration plant.

Sawmills do not usually require heat for their processes, and thus recovery of energy is not a common practice. On-site utilisation of wood waste is normally relatively insignificant in terms of amount. An example of reuse is to use off-cuts in the stacking of timber products.

4.3.2 Utilisation Off-Site (Externally)

Utilisation of wood waste off-site refers to the wood waste transported away (either delivered by the timber company or collected by other private companies) for processing into products (recycling). In Bintulu, 3 major mills are established which convert wood waste into products (Table 8). Among these, 2 are medium density fibreboard (MDF) plants and one is a charcoal briquette plant with a total installed capacity of 246,000 m^3/year. These 3 companies will be able to consume a total of 206,000 m^3 of wood waste per year, which is approximately 18% of the total waste generated in 2003.

Table 8: Mills utilising wood waste in Bintulu, 2003

Type of company	No. of companies	Installed capacity (m^3/yr)	Utilised capacity (m^3/yr)	Output (m^3/yr)	Recovery rate (%)	Residues generated (m^3/yr)
MDF	2	240,000	200,000	114,000	57	86,000
Charcoal briquette	1	6,000	6,000	6,000	100	0

(Source: STIDC, 2004)

4.3.2.1 Utilisation of Wood Waste as Raw Material to MDF (Medium Density Fibreboard) Manufacturing

Certain types of wood waste can be chipped and disintegrated into fibres for manufacturing fibreboard. Medium density fibreboard (MDF) is a type of wood panel product manufactured from wood fibres compressed with synthetic resins depending on the density of the composite mixture. Modern MDF production facilities allow the usage of a broad spectrum of fibre raw materials, including a mixture of heterogeneous milling residue species. MDF has a density in the range of 600-800 kg/m^3.

The MDF plants in Bintulu utilise wood waste from wood based industries like sawmills and plywood mills. Almost all species can be used in the production but raw material is procured and sorted into 3 different species groups: Meranti (20%), hard species (10%) and mixed species (70%)[22]. The mixing of these species groups depends on the type of board they wish to produce. Only wood waste that is clean and not polluted by mud during transportation and the primary milling process is selected.

Wood waste for MDF production in Bintulu is either collected by the MDF company or delivered by individual timber industries to the plant. The majority of the raw material is purchased from timber industries located in the Bintulu wood based industrial area, and

[22] Ravn, M.B. 1999. Potential Use of Mill Residue. Workpaper presented in workshop of Potential Use of Mill Residue in Peninsular Malaysia. Kuala Berang, Terengganu.

occasionally from other timber industries in Sarawak, especially Tanjung Manis timber processing zone.

The MDF plants purchase this “waste” at a relatively low price (estimated at approx. 2-3% of the total MDF production cost). Including transportation costs, it is estimated that the MDF plant pays RM10-15 per tonne[22].

Synthetic resins, on the other hand, constitute approx. 20% of the total production costs. This is significantly higher than the cost of manpower, electricity and raw material[22]. Although the MDF factories consume wood waste as raw material, vast amounts of waste are generated from the process, mostly from the rejected fibres. All of this secondary wood waste is currently disposed of at the Kuala Segan landfill[23].

Figure 14: Bintulu MDF (Daiken) Factory and chipper plant in Kemena

4.3.2.2 Utilisation of Wood Waste as Raw Material for Charcoal Briquette Manufacturing

Charcoal briquette is another industry that utilises wood waste for high value-added products. Charcoal briquette is a substitute product to wood charcoal. The raw material is sawdust obtained from sawmills within a 5 km radius of the plant. Sawdust from heavy hardwood (high density) is preferred. Medium density hardwoods may be used after mixing it with sawdust from heavy species. Light hardwood species are not used, as they give low density charcoal with a low energy content and rapid burning. The

[23] BDA. 2004. Record of Wood Waste Dumped at Segan Landfill for the year of 2004. Detail of Tonnage of Waste Summaries from Jin San Transport Sdn. Bhd. Monthly Report.

charcoal briquette plant collects the sawdust from sawmills free of charge. The sawdust is collected and stored in special containers which are placed in the mills. These containers are collected by the charcoal briquette plant from time to time.

This fine and loose wood dust can be converted into dense, compact and consolidated wood briquettes through the application of elevated temperature and pressure. The production flow begins with drying the sawdust, sieving it to a suitable size. Compression takes place in Shimita briquette machines under high pressure and temperature. The briquettes are then carbonised in brick ovens with an oxygen deficit (1 load takes 3 days) and finally sorted and packed. The briquettes are of high quality, containing 8150 Kcal per kg, and the chemical composition is 92% carbon, 6% volatile material and 2% ash. These briquettes are mainly exported to countries like Japan and Korea for barbecue and indoor heating during winter and sometimes for industrial purposes.

However, the market for charcoal briquette is limited and relatively inconsistent. Excess production, low price and decreasing demand are some of the limiting constraints[22]. The local market is very limited and only accounts for less than 2% of the production. The local demand is mostly for household purpose.

Figure 15: The only charcoal briquetting company in Bintulu

4.4 Incineration and Landfilling of Wood Waste

4.4.1 Incineration

As discussed above, many of the plywood mills have installed incinerators on-site to recover heat via boilers. Other mills have installed incinerators without energy recovery purely for waste disposal. For some large mills (e.g. in excess of 300 tonnes/day[24]), the installed boilers only cater for a portion of the total waste, the rest (especially waste not considered suitable for boilers i.e. unchipped log barks and green veneer waste) are either burnt in separate incinerators or disposed of off-site.

Many of the factories have no management policy regarding proper disposal of their wood waste. Only a minority of the factories have installed incinerators for the above purposes. As a result, the existing Segan wood waste landfill is reaching its capacity earlier than anticipated (this will be further discussed in section 4.4.2 below). In response to this, the Bintulu Development Authority (BDA) is planning to install a RM 1.5 million centralised incinerator with no energy recovery. The proposed incinerator plant consists of two units with a capacity of 6 tonnes per hour each; resulting in a total installed capacity of 12 tonnes per hour[24]. Personal communication with the officer in charge at the BDA revealed that the incinerator is currently under construction, with 40% having been completed. It is anticipated that upon completion, the plant is capable of managing 95,000 tonnes[25] of wood waste annually, including sawdust, off-cuts, shaving and wood chips. The log barks are not included due to the low combustion value.

4.4.2 Landfilling - Segan Landfill

A landfill designated for timber waste disposal has been established in Bintulu. The landfill is located at Segan and covers approximately 8 hectares (20 acres). The Segan Landfill is partitioned into 2 areas for timber waste disposal. The life expectancy of the landfill was originally estimated at approx. 6 years, with an estimated volume of waste disposed of approximately 15,000 tonnes or 63,500 m^3 per year and a maximum waste height of 12 metres. The design of the landfill is simple; it is basically a well managed dumping ground solely for wood waste.

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[24] Ling, S. 2003. The Design, Guarantee, Construction and Commissioning of the Incinerator Including Ancillary Facilities at Kemena Industrial Estate, Bintulu. BDA, Bintulu

[25] Assuming running 330 days per year, 24 hours per day.

Figure 16: Overview of Segan Landfill

The landfill came into operation in May 2002. The Bintulu Development Authority (BDA) oversees the management of the landfill while the operation is contracted to a private company - Jin San Transport Contractor Sdn. Bhd.

The types of waste dumped at Segan Landfill are mostly wood residues, sawdust, rejected fibre and palm seeds. The contractor levels the waste each day and covers it with earth when it approaches a height of 3 metres. The total waste disposed of at Segan Landfill during 2004 was estimated at111,000 tonnes or 470,000 m^3 [26] as recorded in Table 9.

The amount of waste actually received is several times higher than the amount for which the landfill was designed. In February 2004, the amount of wood waste received exceeded the amount estimated for the whole year. According to the manager of Environmental Sanitation at the BDA, the landfill is expected to close down, most probably at the end of 2005, as one partition is already 12 metres high after only one and half years of operation.

Table 9: Record of wood waste dumped at Segan Landfill, 2004

Month	Total (Tonnage)	Cumulative (Tonnes)
January	9,621	9,621
February	8,312	17,933
March	10,244	28,177
April	12,137	40,314
May	8,422	48,736
June	8,692	57,428

[26] Amount estimated based on number of vehicles of different sizes registered

July	10,606	68,034
August	10,931	78,965
September	8,971	87,936
October	11,267	99,203
November	12,130	111,333
December	n.a.	n.a.
Total		111,333

(Source: Jin San Transport Contractor Sdn. Bhd., BDA 2004)

4.5 Estimation of Potentially Available Wood Waste for a Communal Wood Waste Cogeneration Plant

As indicated above, the wood waste generated in Bintulu, especially from KIE, is currently managed in several different ways. In order to estimate the available amount of wood waste in Bintulu for a new cogeneration plant, findings from field visits combined with available information from literature and assumptions were used.

Wood waste generation estimates from the field visits were compared with other sources of literature (table 10). There are a number of variations among these figures. Based on the local situation, the best estimation was determined and tabulated in table 11. These values were adopted for the calculation and estimation of wood waste amounts available.

Table 10: Comparison of wood waste generation from various sources

Mill type	Source	Recovery rate (%)	Type of milling residue In Total Production (%)					
			Off-cuts/ slabs	Veneer core/ waste	Sawdust/ sanding dust	Trimmings/ shavings	Logs bark/ ends	Others
Plywood	Koopmans, A. & Koppejan J. [27], 1997	45-55	-	30	5	4	12	1
	Salleh, L.T and Lissem N.A. [28], 1999	50-55	-	36	2.9	6.8	2.9	-

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[27] Koopmans, A. and Koppejan J. 1997. Agricultural and Forest Residues-Generation, Utilisation and Availability. *Paper Presented in Regional Consultation on Modern Application of Biomass Energy.* Kuala Lumpur, Malaysia

[28] Salleh, L.T and Lissem N.A., 1999. Management and Utilisation of Milling Residues in Sarawak. Paper presented at the TRTTC/STA Forest Product Seminar 12-14 October, Kuching, Sarawak

	FAO[29], 2001	49	-	24.9	0.7	2.0	3.5	19.9
	Survey[30], 2004	53	3.5	29.3	3.3	3.0	2.5	-
Sawmill	Koopmans, A. & Koppejan J. [27], 1997	50	34	-	12	6	12	2
	Salleh, L.T and Lissem N.A, 1999	40-60	35	-	6.5	4.6	-	-
	FAO [29], 2001	43	23.2	-	8.9	4.7	1.6	18.3
	Survey, 2004[30]	60	20	-	15	10	-	-

Table 11: Adopted assumptions used for wood waste estimation

Type of mill	Current recovery rate (Year 2003) (%)	Solid waste (%)	Particle waste (%)	% Total waste utilised/burnt Internally
Sawmill	53%	35%	12%	0%
Plywood mill	67%	30%	3%	45-70%*
MDF	57%	42%	1%	-

Note: * Most of the plywood mills claim that they burn up to 70% of the wood waste generated. However it was reported that some mills utilise as little as 45% of the wood waste for internal heat supply.

The estimation of the available wood waste for incineration was based on the following equation:

> Wood waste for incineration/landfill = available wood waste – (utilised internally + recycled externally)

[29] FAO. 2001. Trash or Treasure? Logging and Mill Residues in Asia and the Pacific. ASIA-PACIFIC FORESTRY COMMISSION. Regional Office Bangkok, Thailand.

[30] Average of Survey Finding on Plywood Residues and Sawmill Residues in 2004

The estimation is tabulated in Table 12 below:

Table 12: Estimation of potential wood waste and reuse activities in Bintulu (based on 2004 data)

<table>
<tr><th>Type of mills</th><th>Wood waste generated* (m^3/yr)</th><th>Utilised internally (m^3/yr)</th><th>Waste as MDF raw material (m^3/yr)</th><th>Waste as charcoal briquette raw material (m^3/yr)</th><th>Surplus wood waste (tonnes** /yr)</th></tr>
<tr><td>Plywood/veneer</td><td>781,000</td><td>(469,000)</td><td rowspan="3">(200,000)</td><td rowspan="3">(6,000)</td><td rowspan="3">123,000</td></tr>
<tr><td>Sawn timber/ resawn</td><td>393,000</td><td>-</td></tr>
<tr><td>Others[31]</td><td>13,000</td><td>-</td></tr>
<tr><td>Total wood waste</td><td>1,187,000</td><td>(469,000)</td><td>(200,000)</td><td>(6,000)</td><td>123,000</td></tr>
</table>

** Rounded to '000.*

*** using a density of 240 kg/m^3 (source: Environment and Bioprocess Technology Centre SIRIM Berhad[21])*

The results indicate that the total wood waste generated from KIE primary wood processing is approx. 1,187,000 m^3/year, which is around 40% of the total log input to the Kemena Industrial Estate.

Approximately 40% of the waste (Figure 17) are utilised internally on-site by the industries, while a further 17% are recycled into products such as MDF and charcoal briquettes. The excess amount of wood waste is estimated at approx. 123,000 tonnes[32] per year. An amount of 111,000 tonnes (approximately 80% of the excess wood waste) is currently believed to be landfilled at Segan Landfill, while the remaining is mainly combusted or incinerated at the mills. Minor amounts are disposed of uncontrolled, either openly burned, or disposed of on land and in rivers.

[31] Estimated to be 1% of total plywood + sawmills + MDF

[32] The secondary wood waste generated from MDF manufacturing is not accounted into and will be further discussed later (refer to Table 13).

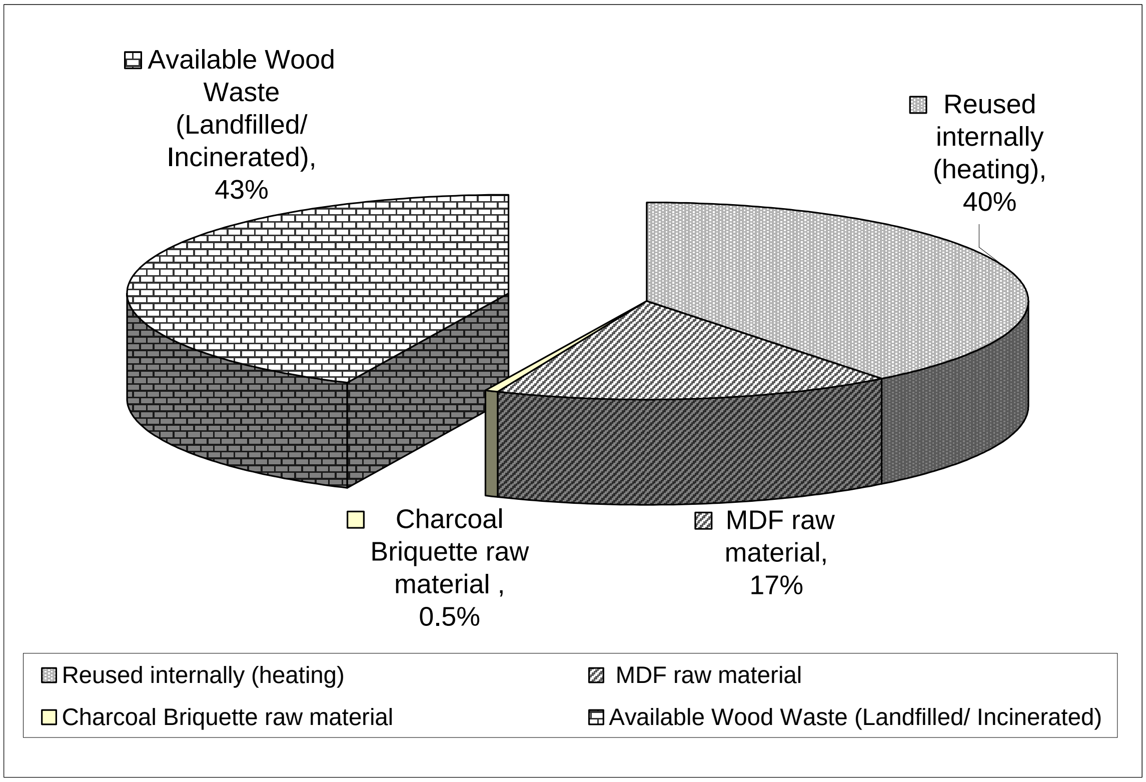

Figure 17: Potential wood waste and handling in Bintulu

4.5.1 Estimation of Wood Waste Availability for a Proposed Wood Waste Based Cogeneration Plant

The estimation of the available amounts of wood waste in this study is based on the scenario that a financially and technically efficient wood waste based cogeneration (combined heat and power) plant is established in Bintulu. The estimation of the available amount of wood waste supply is based on a market driven approach with competitive demand for wood waste. In order words, it is assumed that the waste generators will choose the legal option(s) that bring the biggest financial return and ease of management. It is also assumed that the authorities will enforce regulation on illegal dumping.

The potential amount of wood waste available for a cogeneration plant can be estimated by means of the following main categories:

1) Surplus wood waste which is currently not utilised, i.e. including the waste landfilled at Kuala Segan or designated for the proposed non-energy recovery incinerator

2) Wood waste that is currently utilised internally in wood waste processing plants but can be made available due to alternative costs of maintenance, operation and renewal of existing incinerators

3) Other potential sources: Waste used for other downstream products e.g. MDF, charcoal briquettes etc. – made available due to collapses/fluctuation of the market for these secondary products. Another potential source is wood waste generated from other districts or areas within a distance where logistic costs make sense.

Surplus Wood Waste Currently Not Utilised

The current total surplus wood waste amount is approximately 123,000 tonnes/year. The proposed centralised non-energy recovery incinerator is designed with the maximum capacity of 95,000 tonnes per year.

It is assumed that some of this waste would be delivered to the cogeneration plant due to the economic feasibility. It is assumed that the cogeneration plant covers transportation and provides free wood waste disposal service while a charge[33] of RM 12 for every tonne of wood waste incinerated has been proposed for the non-energy recovery incinerator system. Considering the fact that not all of this waste can be collected, and that some of it is heavily soiled log bark with a lower combustion value, a conservative estimate of approx. 55-65% of the total surplus wood waste (of the 123,000 tonnes per year), equivalent to approx. 70,000-80,000 tonnes per year is expected to be available for the proposed cogeneration plant. This would mostly include wood with a higher combustion value, while the residue is expected be delivered to the proposed non-energy recovery incinerator.

Other Potential Sources – Other Secondary Product Industries

The study assessed that the market demand for other secondary products from wood waste, especially charcoal briquettes, fluctuates and is relatively inconsistent, and therefore it is not assessed.

For this study, it is assumed that the demand for wood waste by the secondary product industries will remain constant, and therefore no wood waste from these industries will be made available for the cogeneration plant, except for the MDF industry. For the MDF industry, approximately 86,000 m^3/year (or 20,000 tonnes/year) of waste is generated. However it is expected that only approx. 50%-75% (10,000 – 15,000 tonnes/year) can

[33] As per communication with Deputy General Manager of BDA dated 29 November 2004.

be made available to the communal cogeneration plant, as some of the wood waste may not be suitable for combustion or may not be available.

Further detailed assessment of production cost and comparison with the cost-benefit for delivering to a newly established wood waste energy plant needs to be carried out.

Potential Amount of Wood Waste Currently Available to Energy Recovery Plant

Summarising the above, the current amount of wood waste available is as follows:

Table 13: Summary of wood waste availability for proposed wood waste to energy plant based on current scenario

Sources of wood waste for cogeneration plant	Total amount available (tonnes/yr)	Estimated actual amount available (tonnes/yr)
Unutilised wood waste	123,000	70,000-80,000
Waste from MDF[a]	10,000 - 20,000	10,000 – 15,000
Other sources	Insignificant	Insignificant
Total (range)		**80,000-95,000**

[a] *Waste generated from MDF production is not included in the total wood waste generation to avoid double counting, as the raw materials for MDF production come from wood waste generated in other wood processing. However, waste generated from MDF processing is taken into consideration when estimating the available wood waste remains that may be used for energy generation. From the 20,000 tonnes/year of waste generated by MDF processing, only 50-75% is expected available for the communal cogeneration plant, as some of the wood waste may not be suitable for combustion or may not be available.*

[b] *Estimated on average, an excess of 15% of the wood waste utilised internally can be available.*

In summary, the total estimated amount between ***80,000–95,000 tonnes/year*** (from existing unutilised and existing internal use by wood processing mills) of wood waste is potentially available for a new communal cogeneration plant in Bintulu, based on the current scenario.

Wood Waste Availability for Waste to Energy Plant for the Next 10 years (2005-2015)

As discussed in section 3.4, it is expected that the total amount of wood waste will decline over the next 10 years. The improvement in milling technology is expected to further reduce the waste generation. At the same time other waste recycling activities such as MDF (other products may be introduced in future) may bloom and further consume the limited amount of wood waste generated.

The amount of wood waste generated is predicted to be reduced by 30% (based on 15% log input reduction and 15% technology efficiency improvement) in 2015 compared to the 2003 basis, and the total wood waste yield in 2015 is predicted to be 830,000 m^3

(200,000 tonnes), compared to 1,187,000 m^3 (285,000 tonnes) in 2003. This prediction assumes that there is no growth or even a slight decline in the log input for the secondary wood industry. Government efforts to encourage the secondary or tertiary wood products rather than raw logs may, however, boost the secondary wood industries. The decline of wood waste generation may not be as high as estimated if any of the below scenarios occur:

- There is growth in the log input for secondary and tertiary wood processing
- The technological advancement is not as good as predicted

Similarly, by assuming that the total wood waste generation is reduced by 30% as compared to the 2005 level, the total available amount of wood waste for a cogeneration plant may be reduced to 56,000 – 63,000 tonnes progressively towards 2015.

On the other hand, the incinerators which are currently operated by most existing mills are quite old and will reach the end of their life-span within a few years. When investment in new boilers is more expensive than the cost for sending the waste to the communal cogeneration plant and acquiring piped steam from the plant, the waste could be available to the plant.

It may be predicted that approximately 20% of the total amount of wood waste currently combusted for steam generation will be made available due to the closure of existing old boilers over the next 10 years. Hence, by 2015, the extra wood waste which is diverted from previously internally combusted is estimated to amount to as much as 23,000-25,000 tonnes.

Combining the above information, a relatively constant amount in the range of 80-90,000 tonnes of wood waste is predicted to be available for the new cogeneration plant over the next 10 years.

Table 14: Summary of wood waste availability for communal cogeneration plant in 2015

Source of wood waste supply	**Estimated amount (tonnes/yr)**
currently available wood waste for cogeneration plant[a]	56,000 - 63,000
Diverted from internal combustion of plywood mills due to closure of current boilers/incinerator	23,000 - 25,000
Other sources	Insignificant
Total (estimated range)	**80,000 – 90,000**

[a] *Estimated 30% reduction in wood waste amount generated in 2015 as compared to 2005.*

Shipment of wood waste from other wood processing areas in Sarawak has not been assessed in this study. Bulk shipment by coaster or barge of additional wood waste from other wood processing areas (Baram, Tanjong Manis, Kuching) may be financially feasible due to the economy of scale for a large, centralised cogeneration plant. Bulk shipment of wood waste for power production has proved financially viable in many places worldwide.

5 POWER AND HEAT SUPPLY IN SARAWAK

5.1 *Generation and Distribution of Electricity*

There are 6 major power plants in Sarawak, with a total installed capacity of 819 MW. Among these, 3 are gas fired while the rest are fired by coal, fuel oil and hydro.

Due to the high power demand from industries and the availability of natural gas near Bintulu, 2 of these large power plants are situated in Bintulu and contribute half of the total capacity. A few, smaller power plants located all over the state supply off-grid areas. Except for some isolated areas, the main cities and towns in Sarawak are connected to the grid supply. The peak demand of grid[34] supplied power in 2003 and 2004 was 608.7 MW and 650.7 MW respectively. The grid supply is distributed by 765 km of 275kV transmission grid interconnecting the 6 main power stations and 128 km of 132kV transmission grid connecting substations and the main towns in Sarawak.

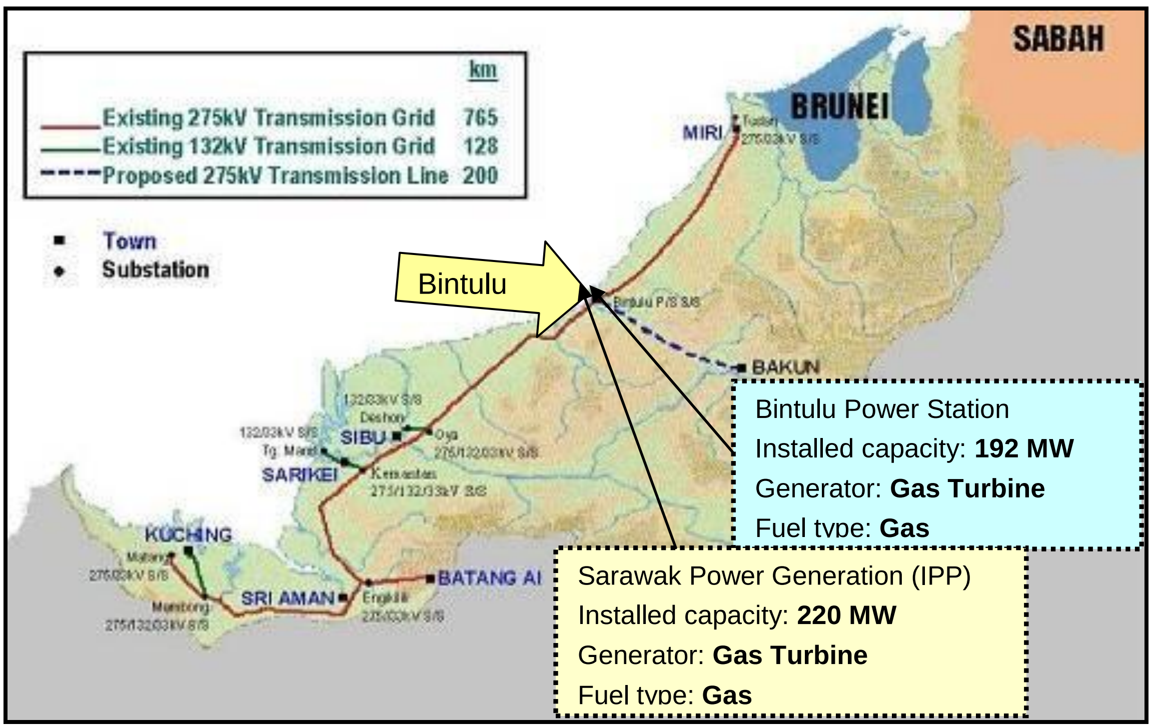

Figure 18: Power transmission systems and power plants in Bintulu
(Source: SESCO Website)

[34] Total demand distributed into the grid which is equivalent to the total demand of the state connected to grid.

5.2 Development of Electricity Supply and Demand

Data on the electricity sold in Bintulu in 1997 and 2003 and the forecast sales predicted by SESCO for 2004 to 2015 are shown in Figure 19. The demand is projected to increase gradually in a linear correlation from 2001. The economic downturn in 2001 lead to a slight decrease in power demand. The demand growth rate for 2004 and 2005 is predicted to increase slightly faster and then stabilise from 2005 provided there is no major economic downturn. For 2005 the growth rate is predicted at 6.5 % and for the next 10 years the rate is predicted to be 3.5-5%.

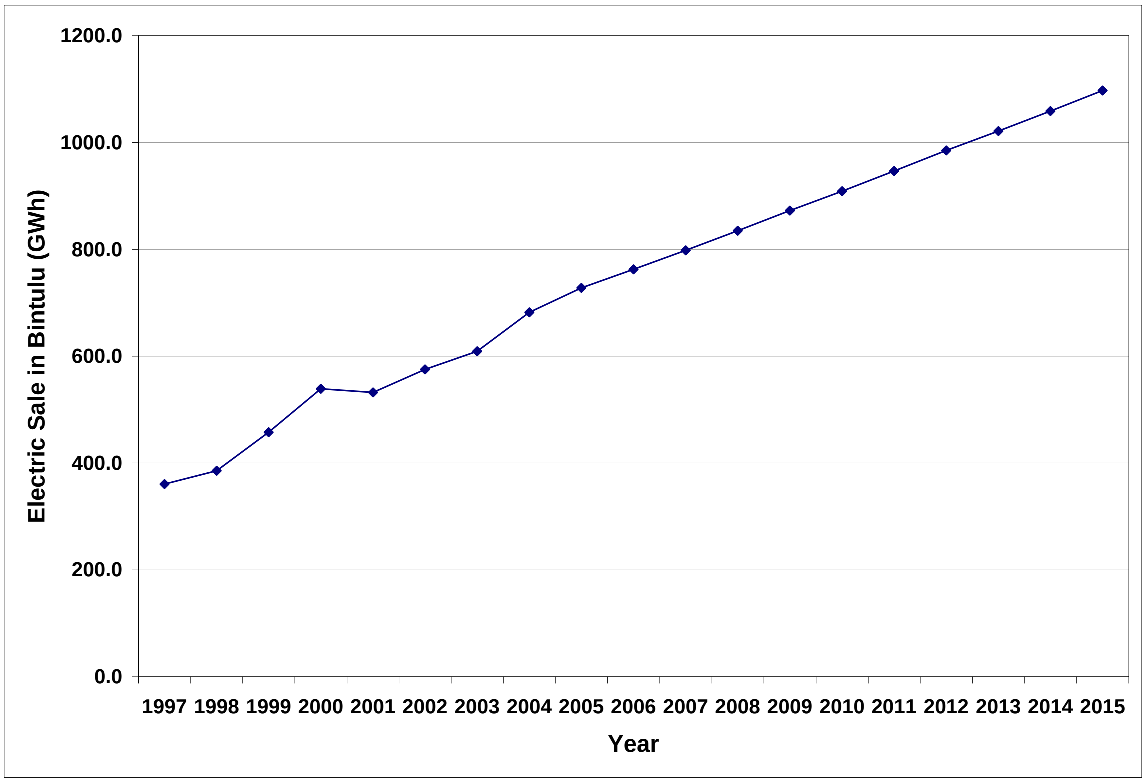

Figure 19: Electricity sale in Bintulu
(Source: SESCO)

As Bintulu is grid connected, the assessment of the future power supply and demand should take into consideration the power generation and demand of the whole state.

The sales and growth rates for electricity in Sarawak, for Bintulu for 1990-2004, and the expected sales and growth rates for the coming 10 years as predicted by SESCO are plotted in Figure 20 below.

There has been a growth in electricity sales in the previous 10 years, and the same is expected for the next 10 years. However, slower growth will be expected despite the commissioning of the Bakun Dam with a capacity of 1GW. When the state's economic growth stabilises, the electricity demand growth rates become slower. Besides, in the future, energy efficiency is expected to be a dominant aspect of development, thus reducing the growth in energy consumption.

The implementation of the Bakun Dam project is expected to attract highly energy consuming industries. The capacity of the dam project is planned for 1GW. The effect of the Bakun Dam project is not reflected in the below figures. From Figure 20 it can be seen that most of the electricity consumption is provided by the grid. In 2004, approx. 96% of SESCO's total sales were provided by the grid. The remaining 4% are local off-grid power generation operated by SESCO.

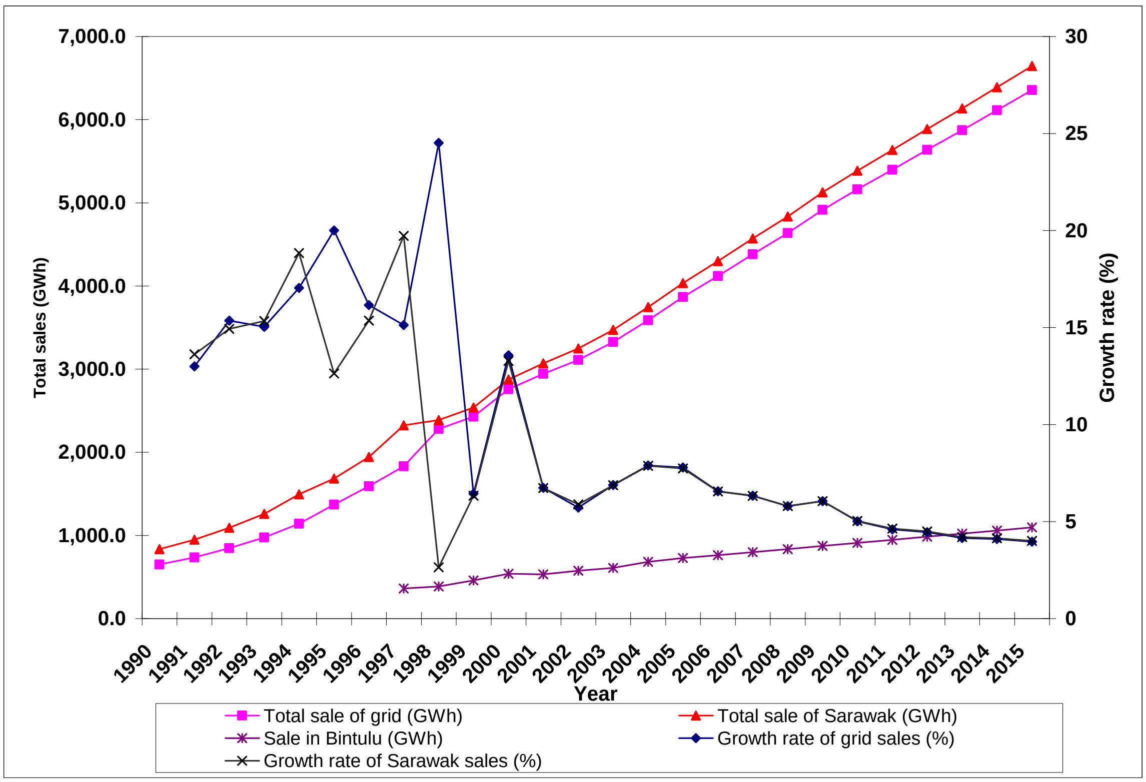

Figure 20: Electric sales and growth rates for Sarawak, total grid and Bintulu
(Source: SESCO)

From Figure 20 it can further be seen that in 1997 and 2001, due to the regional economic downturn, the state electric sale growth rate dropped dramatically. However, despite the decrease in demand, the sale from the grid increased. With economic recovery since 2002, the electricity growth rate is expected to gradually decrease, as the economic growth of the state is expected to become stable.

As regards the peak grid demand, a gradual growth is expected. The peak grid demand for 1990-2004 and the projected peak demand within the next 10 years are shown in Figure 21.

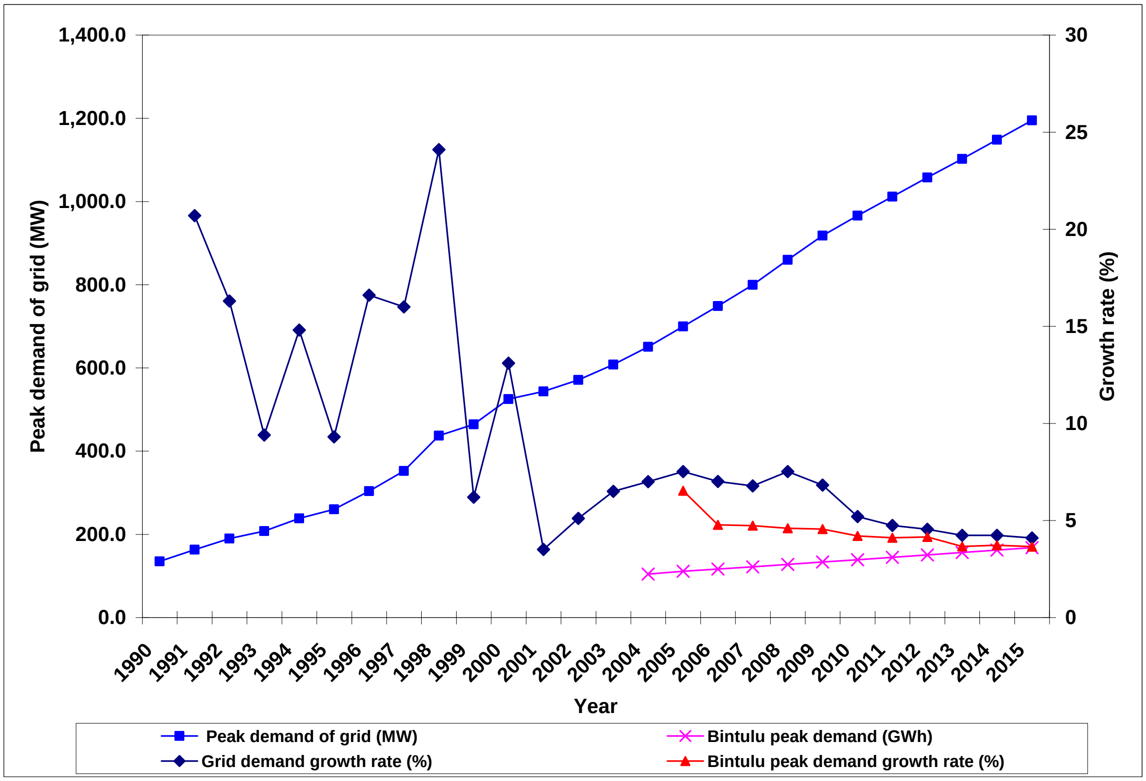

Figure 21: Peak demand of Bintulu and grid in the state of Sarawak
(Source: SESCO)

Figure 21 shows that the current peak grid demand is approaching 80% of the total grid capacity, where the power plants currently connected to the grid have a total combined capacity of 819 MW. In 2005, the state grid peak demand is predicted to increase by approx. 7.5% from the previous year. By 2006, the peak grid demand is estimated at approx. 749 MW, which is 90% of the installed power generating capacity. Therefore it is predicted that from mid-2006, additional power capacity is urgently required before the Bakun hydro power plant is in operation. The Bakun plant with a design capacity of 1GW is planned to start operating in 2009. In other words, there is a potential gap of supply between 2006 and 2009, for which additional power generating capacity has to be installed by SESCO. The proposed wood communal cogeneration plant may contribute to fill this shortage and save investments by SESCO to increase power capacity.

5.2.1 Cost of Power Supply

The electricity price for industries is generally subsidised; the selling price of SESCO is RM 0.178 per kWh. In comparison, the average power generation cost of the SESCO system is RM 0.17 per kWh. By adding transmission and distribution cost, the cost of 1 kWh electricity will be approx. RM 0.25 on average. However, due to the availability of an LNG gas fired facility, Bintulu generates electricity at a lower cost of RM 0.09/ kWh[35].

SESCO has indicated that the purchase price of the electricity from the possible cogeneration plant must be able to meet the alternative cost for SESCO (i.e. other options such as expanding the existing power plant).

5.3 Power and Heat: Supply and Demand in Bintulu

Energy in the form of electricity and heat (commonly in the form of steam) are both required in an industrial town like Bintulu. Steam is required by industries while power is a daily need for all sectors.

The two main power plants in Bintulu are the two largest power stations in Sarawak with a total power generating capacity of 412 MW. One of these power plants is owned and operated by the MLNG plant as an independent power producer (IPP) with a capacity of 102 MW.

As an industrial area, Bintulu has a high demand for electricity. From Table 15 below, it can be seen that Bintulu on average accounts for approx. 17% of the total state power demand and approx. 16% of the peak grid demand. The demand for power in Bintulu shows a growth rate of 9.3%/year while the total demand of Sarawak grew by 7% annually over the last 6 years[36]. Bintulu's power demand is expected to grow continuously, due to the rapid industrial development in Bintulu.

Table 15: Power Generated/Distributed and Sold

Year	Total for Sarawak		Bintulu Station	
	Generated/distributed (MWh)	Sold (MWh)	Generated/distributed (MWh)	Sold (MWh)
1997	2,652,984	2,324,716	387,321	360,560
1998	2,812,334	2,385,984	412,355	385,276
1999	2,959,257	2,537,037	488,941	457,572
2000	3,347,789	2,873,849	592,134	538,932

[35] Personal communication with Mr. Jason Eng, General Manager (Strategic Service) of SESCO, 7 January 2004.

[36] Strategy Planning Department, SESCO.

2001	3,554,010	3,067,124	593,217	532,009
2002	3,797,964	3,247,461	641,629	575,129
2003	4,058,980	3,470,613	674,925	608,691

(Source: Annual report of Sarawak Electricity Supply Corporation, 1998-2003)

Instead of purchasing electricity from the grid, individual power generation (independent power producers) is allowed, subject to approval by the State Government. In addition to the MLNG Plant, the urea/ammonia plant in Bintulu is also equipped with steam turbines with a total capacity of 16 MW.

Regarding heat, it has been difficult to gather sufficient data to estimate the total supply and demand in Bintulu. In general, the supply is handled by the individual companies themselves.

There is no centralised steam supply in Bintulu at the moment. Centralised steam generation and distribution would be an interesting consideration since, apart from timber industries, a number of other industries within the area have steam demands. Details of steam demand for the various industries were, however, not covered by this study. Some of the large industries demanding steam include:

- Liquefied natural gas plant (LNG)
- Asean Bintulu fertilizer (ABF)
- Shell middle distillate synthesis (SMDS) plant
- Sarawak Shell Bintulu plant (SSBP)
- Medium density fibreboard (MDF) plant
- Clinker grinding plant
- Bintulu deepwater port
- Palm oil bulking installation
- Palm oil refinery plant
- Glue/adhesive factory
- Plantation & agro based projects
- Charcoal briquette plant
- Pulp and paper plant (proposed)
- Dubal aluminium plant (proposed)

Since the proposed communal cogeneration plant would most likely be located within the KIE, the following section will focus on the power and steam demand of the KIE, i.e. timber based processing industries.

5.4 Wood Waste Power and Heat: Supply and Demand

5.4.1 Estimation of Power and Heat Demand of Wood Industries in Bintulu

The power and heat demand of some plywood/veneer mills and sawmills was assessed during site visits. The information obtained is tabulated in Appendix E (electricity consumption) and Appendix F (steam demand). The findings were compared to the EC-ASEAN COGEN results and summarised in Table 16. The findings from the two sources are comparable. However, an Australian study (ANU Forestry) showed significantly higher energy demands for wood industries (double the value of the two sources). This may be due to the differences in locality, climatic situation, types of wood and milling practices, and the technologies used. The energy efficiency could also have increased since 1982 (when the ANU study was carried out) and thus the current energy demand might be lower today.

Table 16: Energy requirement for the plywood/veneer and sawmill in Bintulu, 2003

Type of mill	Energy requirement	Average from survey	ANU[37] Forestry	EC-ASEAN COGEN, 1998[38]	Adopted for this study
Plywood/ veneer mills	Electricity requirement (kWh/m^3)	92.7	200-300	110	100
	Steam requirement	0.87 tonnes/m^3	4,600 MJ/m^3 (1.27 MWh/m^3)	1.2 tonnes/m^3	1.0 tonnes/m^3 (0.84 MWh/m^3)*
Sawmills	Electricity requirement (kWh/m^3)	12.5	80	35-45	40
	Steam requirement	0	860-4,000 MJ/m^3	0	0[39]

[37] ANU Forestry. n.d. Wood residue as an energy source for the forest product industry. http://sres.anu.eduau/associated/fpt/nwfp/woodres/woodres.html accessed 31 Jan 2005.

[38] EC-ASEAN COGEN Programme. 1998. Final report evaluation of conditions for electricity production based on biomass. Bangkok. Http://www.eppo.go.th/encon/encon-DANCED-Cogen.html

[39] The sawmills visited do not use steam.

	(tonnes/m^3)				

Note: * Assuming that one tonne of steam equals 0.7 MWh.

The annual power and steam demand of the wood based industry in Bintulu was estimated on the basis of the average assumptions above. The results are tabulated in Table 17 below. At 2003 level, approx. 268 GWh/year of power (corresponding to a 40 MW power plant) are required for the two main sectors of the timber processing industries.

The annual steam demand for plywood and veneer mills is approx. 2.3 million tonnes (corresponding to approximately 1.6 million MWh) per year. According to the ANU study, there is also a steam requirement by sawmills in Australia. However, as described earlier, sawmills processing in Bintulu do not require steam.

Table 17: Estimation for power and heat demand of wood industries in Bintulu

Type of mill	**Current input (year 2003) (m^3)**	**Annual milling hours**	**Electricity consumption**			**Steam consumption**	
			Consumption (kWh/ m^3)	**Annual consumption (MWh)**	**Power capacity (MW)**	**Consumption (tonnes/ m^3)**	**Annual consumption (tonnes)**
Plywood/ veneer	2,342,657	7,920[a]	100	234,266	30	1.2	2,340,000
Sawmill	838,407	3,432[b]	40	33,536	10	-	-
Total				267,802	40	2,340,000 tonnes (1,638,000 MWh)[c]	

Notes:

a) Based on daily milling operation of 22 hours and 30 days per month for plywood mill.
b) Based on daily milling operation of 11 hours and 26 days per month for sawmill.
c) Based on assumption that one tonne of steam under 22 bar pressure and 220 ^oC is equal to 0.7 MWh.

5.4.2 Energy Generating Potential of Wood Waste in Bintulu

As discussed in section 4.5.1, the amount of wood waste available for the possible cogeneration plant will be 85,000 tonnes/year. Therefore, a cogeneration plant with 85,000 tonnes/year capacity can be implemented.

Based on the design capacity of 85,000 tonnes of wood waste per year and the assumption that the average combustion value of wood waste is 12 MJ/kg, the energy prediction is approximately 1,020 million MJ or 284 million kWh[40] annually.

There are several technical options for energy recovery. In this case, a modern steam turbine cogeneration is assumed. The overall cogeneration (power plus heat) efficiency can be around 80%. An electrical energy conversion rate of 17-34% and a heat recovery rate of 50% can be expected[41]. By assuming an electrical conversion efficiency of 26% and a heat recovery efficiency of 50%, it is expected that 73,800 MWh of electricity and 510 million MJ (142,000 MWh or 202,000 tonnes) of steam can be generated. The potential power and steam generating capacity yielded from the available wood waste will be 9-10 MW_e and 16 MW_{heat} respectively (table 18). A comparison of results with earlier estimates made by ENCO is tabulated in Table 18 below.

Table 18: Energy Generating Capacity of Wood Waste

Description	ENCO[42]	This study
Potential wood waste for energy recovery	216,000 mt/year	85,000 mt/year
Total electricity generated	129,744 MWh/yr	73,800 MWh/yr
Power capacity[a] (MWe)	20	9-10
Total heat generated	0[b]	142,000 MWh/yr
Heat capacity	0	18.5 MW

[a] based on 318 production days

[b] No heat recovery for ENCO's proposal

Based on the current energy demand of wood industries, the amount of energy generated by the cogeneration plant can potentially supply up to 28% of the electricity demand and 9% of the steam demand by the wood industries in Bintulu. The distribution between electricity and steam generation can be adjusted based on demand. In the short term, electricity is expected to be the main source of revenue. If plywood mills, which currently generate steam internally are to be supplied by the cogeneration plant, the external steam supply must be able to fulfil the demand of the mills at all times.

To ensure this, the capacity provided by the second phase of the cogeneration plant should be considered to generate only steam as and when current internal boilers are

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[40] 1MJ equivalent to 0.278 kWh.

[41] Mathias, Arul Joe. 2004. *Overview of cogeneration technologies and applications*. Presented at 2004 Cogeneration week in the Philippines, Manila. EC-ASEAN COGEN Programme Phase III.

[42] Based on a proposal on a biomass wood waste power generation plant prepared by Wambeck, Noel from ENCO Systems Sdn. Bhd. (December 2003).

being phased out. An estimated 133,000 MWh of heat or 190,000 tonnes of steam can be generated by the second phase.

6 CONCLUSIONS AND RECOMMENDATIONS

Timber processing industries at Kemena Industrial Estate are important resource based industries in Bintulu. In line with the state's policy to encourage local processing of logs, the timber processing industries have grown substantially over the past decade. For the next 10 years, the industries, especially the plywood processing sector, are expected to continue to grow. Combined with sawmills, these two sectors constitute almost 95% of the volume of timber products in the Kemena Industrial Estate in Bintulu.

Wood waste has been a continuous challenge for mill owners, government authorities and the affected community. It is estimated that approximately 1.2 million m^3 of wood waste per year (equivalent to 40% of the log input) is generated in Kemena, Bintulu. Currently, this wood waste is handled in several different ways.

Approximately 46% of this waste is utilised in the timber processing industries on-site. This is mainly done through locally established boilers. Heat is recovered via boilers mainly for plywood milling processes. Certain types of waste (e.g. sawdust), are delivered to or collected by private companies that manufacture value added products from them. The main products are medium density fibreboard (MDF) and charcoal briquettes. This off-site recycling is estimated to constitute around 17% of total wood waste generated.

The remaining wood waste (including waste from MDF manufacturing) is currently landfilled at Segan landfill, incinerated or disposed of by means of open burning or dumping on land or in rivers. As the Segan landfill is approaching its capacity, an incinerator without energy recovery is currently being constructed by the BDA. With this facility in place, and when utilised at the optimum capacity, the remaining waste for wood waste energy recovery is not likely to be sizable for an energy plant. However, should the current incinerator not be implemented or not operated fully as proposed, a potential amount of 85,000 tonnes of wood waste can be considered for energy recovery. With this amount, based on cogeneration of heat and power, it is expected that the available wood waste generated in Bintulu has a power generating potential of 9-10 MW and a steam supply of 200,000 tonnes. This amount can potentially supply approx. 28% of the electricity demand and 9% of the steam demand of the timber processing industries at Kemena, Bintulu. A summary of the results is illustrated in Figure 22 below.

Besides supplying directly to the timber processing industries, the electricity generated from the wood waste could be sold to SESCO by connecting to the grid. The grid demand is predicted to exceed supply by 2006 and it is foreseen that the wood waste to energy plant can fill the gap before Bakun is commissioned in 2009. When Bakun is in place, the wood waste energy plant can be operated as a back-up power supply, while dedicated as the centralised steam supplier for industries in Bintulu.

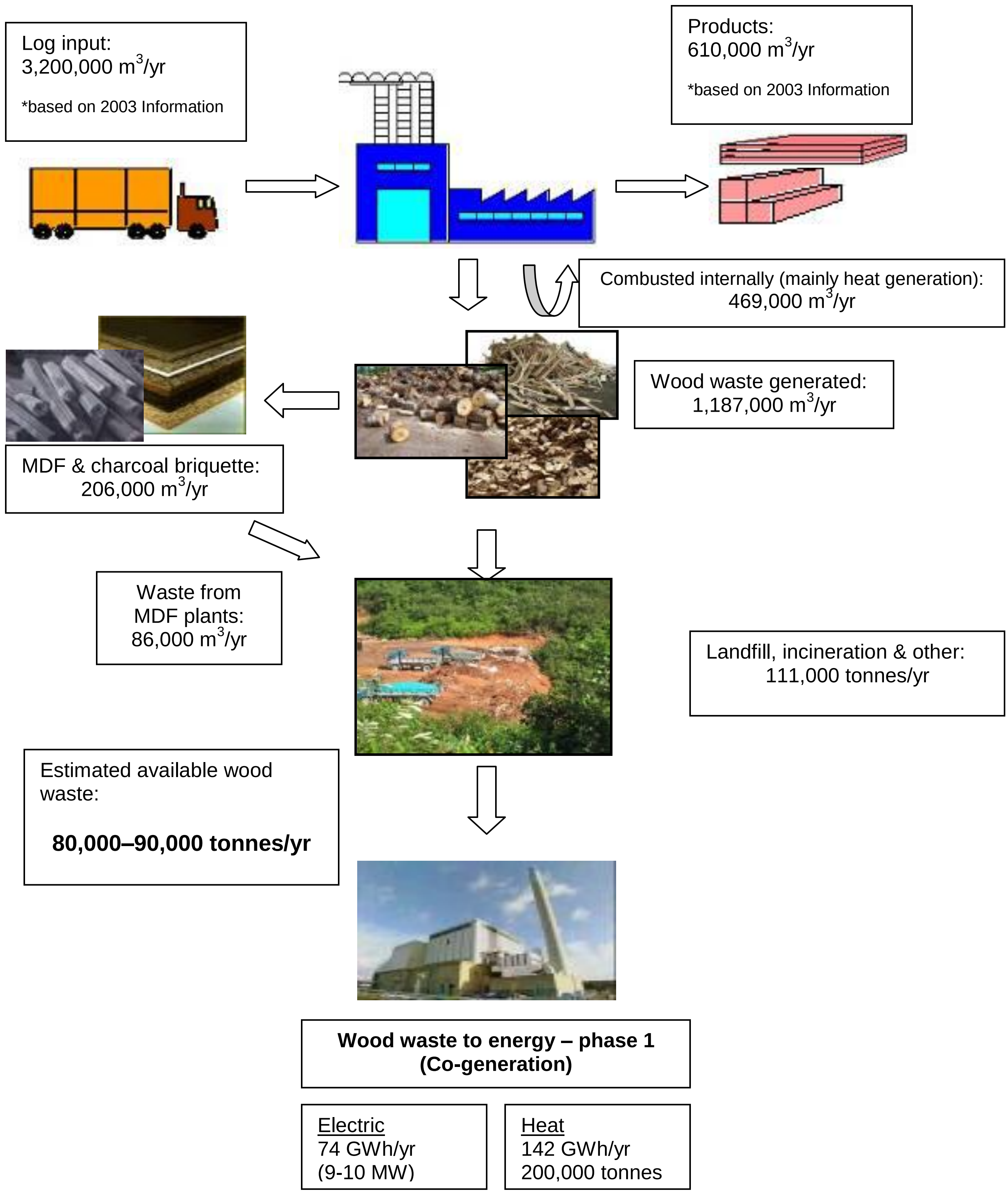

Figure 22: Overview of wood processing industry and the wood waste potential

6.1 Limitation of Study

The purpose of the study was to generate a better understanding of the timber processing industries and their current waste management practices, and to identify whether there is sufficient wood waste for a proposed wood waste to energy facility.

Constrained by the time frame and limitation in data, only a preliminary assessment was carried out. Besides that, difficulty was encountered while gathering the data and information. As the data used for the estimation is mostly based on average values, the accuracy of the results can be questioned. Many assumptions based on other cases and the field studies were used, and uncertainties on these certainly require further studies. Since only a few industries were covered in this study, they do not necessarily represent all industries.

6.2 Recommendations

Based on the findings, the proposed wood waste to energy project will, if implemented, compete with the incinerator project on the wood waste supply. However, the proposed wood to energy project will have better chances of obtaining the wood waste supply if the plant provides a free transportation service to collect the wood waste, but the BDA will impose charges on the wood waste burnt by their incinerator.

If this is the case, a detailed financial and technical feasibility study of a wood waste to energy plant should be carried out. This would include detailed assessment of logistics and collection supply and demand chain, the selling and purchasing, types of technology used, technical design, environmental aspects such as air pollution and emission factors of the power plant, financial analysis of the project stages, as well as the possibility to incorporate this energy project into a BDA incinerator plant etc.

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Appendices

Appendix A: Wood Based Milling Installed Capacity (m^3) for Sarawak, 2003

Activity	Region							Total
	Kuching	Sibu	Sarikei	Mukah	Bintulu	Miri	Limbang	
Sawmill	123,600	149,100	31,900	40,200	109,800	88,200	15,700	558,500
Resawn	26,700	-	-	-	-	-	-	26,700
Plywood	522,000	1,175,000	240,000	210,000	1,116,000	420,000	-	3,683,000
Veneer	4,000	16,000	2,000	8,000	44,000	17,000	-	91,000
Dowel/moulding	-	-	-	-	-	-	4,000	4,000
Laminated board	-	-	-	-	-	-	-	0
Particle board	-	10,000	-	-	-	-	-	10,000
Fibreboard (MDF)	-	-	-	-	20,000	10,000	-	30,000
Woodchip	8,000	-	-	10,000	-	-	-	18,000
Charcoal/ briquette	-	-	-	-	500	-	-	500
Total	684,300	1,350,100	273,900	268,200	1,290,300	535,200	19,700	4,421,700

Note: (-) refers to NIL or no available data

(Source: STIDC, 2004)

Appendix B: Mill Classification

Description of mill classes:

The descriptions of mill classes depend on the product type and the capacity that the mill can produce.

Process/ operation	Product types	Classification by capacity		
		C	B	A
Sawmilling	Sawn timber	< 10,000	10,000-20,000	>20,000
Board manufacture	Veneer/ plywood	<50,000	50,000-100,000	>100,000

Appendix C: Wood Waste Types and Definition

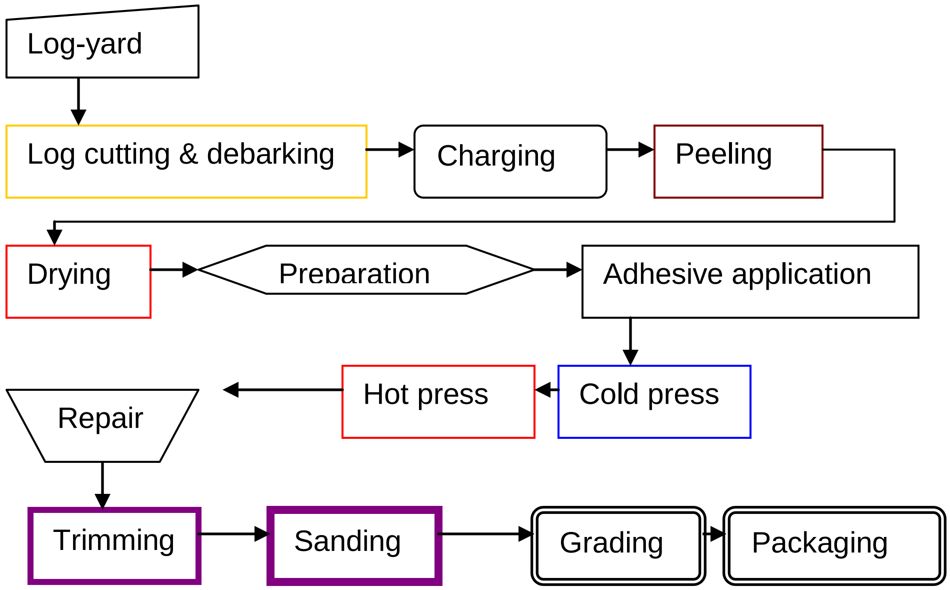
Detailed description[43] of wood residues resulting from the production of sawn timber, veneer and plywood manufacture.

Wood residue type	Definition
Barks	The outer covering of a tree trunk or branches which does not contain base wood.
Slabs	Waste consisting of bark and some degree of base wood resulting from length wise cutting of the outer layer of logs.
Long off-cuts (trimmings)	Waste derived from length-wise cutting of sawn timber during resizing process.
Short off-cuts (short-ends)	Waste from the cross cutting of a sawn timber during resizing, moulding or other wood process activities.
Sawdust	Small particles generated from sawing process during shaving or planning process.
Shavings/ sander dust	Fine particles generated during shaving/sanding process.
Rejects	Materials (raw or finished) that do not meet the standard (lower quality) or specifications.

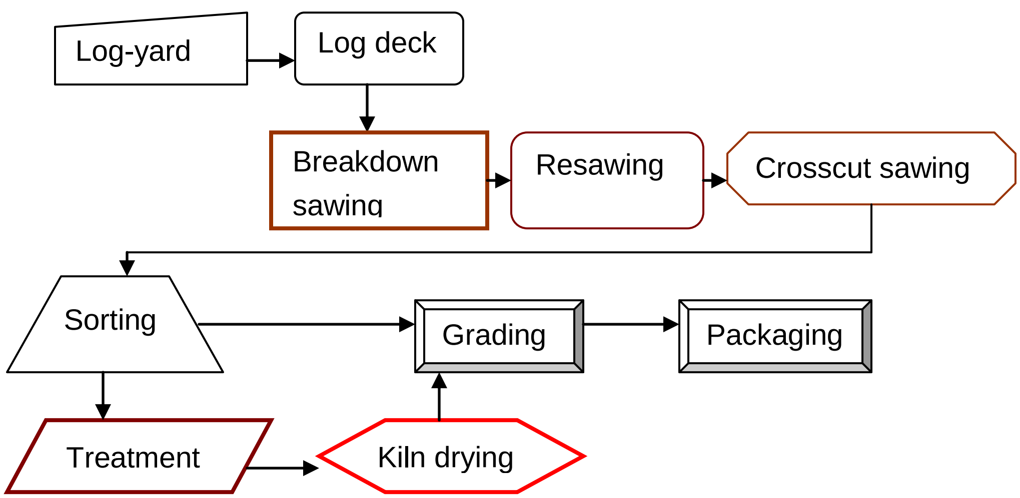
[43] FIRM & DOE, 1998. Guidelines for management of wood waste from the wood processing industry. FIRM Technical Information Handbook No. 23.

Appendix D: Plywood and Sawmill Production Processing Stages

Plywood Processing



Sawn Timber Processing



(Source: STIDC, 2003)

Appendix E: Electricity Consumption of Respondents

Company	Installed capacity (m^3/MTH)	Maximum input (Timber) m^3/MTH	Maximum output (Product) (m^3/MTH)	Mill power requirement (kW/MTH)	Energy consumption (kWh/MTH)	Energy consumption (kWh/ Input m^3)
P1	180,000	50,000	26,000	5,000	3,600,000	72
P2	150,000	38,000	20,000	6,500	4,116,208	108
P3	120,000	48,000	22,000	7,000	4,704,000	98
S1	6,000	15,000	8,000	600	126,000	8
S2	1,000	3,700	1,000	250	63,120	17

Note: P1, P2, P3-Plywood mill

S1, S2-Sawmill

Appendix F: Milling Heat Requirement

Company	Installed capacity (m^3)	Maximum input (Timber) (m^3)	Installed boiler (units)	Flow rate (tph)	Daily mill operation (hours)	Monthly mill operation (days)	Steam consumption (Tonnes/ month)	Steam consumption per m^3 of input
P1	180,000	50,000	2	30	24	30	43,200	0.86
P2	150,000	38,000	2	28	24	26	34,944	0.92
P3	120,000	48,000	2	30	24	28	40,320	0.84

Note: P1, P2, P3-Plywood/ veneer mill