

BIOMASS IN MALAYSIA: FORESTRY-BASED RESIDUES

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Abstract

This paper reviews forestry biomass specifically material derived from natural forest, plantation forest, and rubber plantation of Malaysia, material collected upon log production and primary wood manufacturing activities. The information helps to foresee the potential of these promising waste resources to be used for energy products. As Malaysia forest covers from inland to coastal vegetation and natural forest as well as forest plantations plus rubberwood plantation in Peninsular, Sabah and Sarawak, therefore, a lot of residues have been generated. It is estimated that the total number of energy generated from waste in 2012 is 0.720, 0.381, and 1.657 Mtoe of Peninsular, Sabah, and Sarawak respectively. As Malaysia is expected to grow in population and economy, hence, sourcing an alternative for energy feedstock and biomass industry is crucial and forestry based biomass are seen as an opportunity.

Keywords: biomass, forestry, Malaysia, natural forest, plantation forest, rubberwood plantation, renewable energy

1. Introduction

The biomass sector in Malaysia has shown significant progress, in relation to its positive carbon balance with regards to fossil fuels, and sustainability and economic growth due to consumption of locally renewable material. This includes the indication of utilization and commercialization of 1st, and 2nd generation biomass feedstock with wide array of different feedstock ranging from lignocellulosic such as forestry based to municipal solid wastes. And now the 3rd generation of biofuels is extended to algal material and could also be linked to CO₂ as feedstock.

As the national biomass strategy expands its collection of biomass which initially focused on palm oil industry, the new scope has included biomass from other resources such as rubber, wood and rice husk. For instances, woody biomass available in Sarawak alone produced 2.7 million tonnes from predominantly existing plantations [1] and if this sources is extended to log-processing residues and potentially new plantations then the figure is expected to increase [2].

In Malaysia, its forest resources have significant contribution to the socio-economy and this luxuriant tropical forest is one of the most diverse and complex ecosystems of the world. From this forest land, Peninsular encompasses approximately 95% dipterocarp forests, 3.34% peat swamps, and 1.84% mangrove forests (Figure 1). In Sabah, there is gradual succession of forest vegetation from the coastal beach forests and mangrove forests to lowland dipterocarp forest and eventually Montane forests (Figure 2). In Sarawak, five types of forest are found abundantly: Hill mixed dipterocarp forest, peat swamp forest, mangrove forest, kerangas forest (heat forest)

and Montane forest (Figure 3).

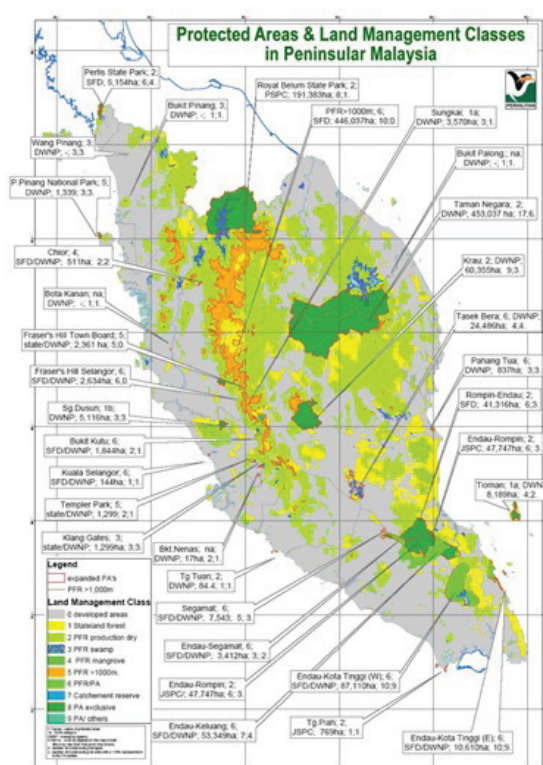
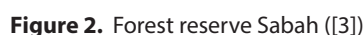


Figure 1. Protected areas and land management classes in Peninsular (courtesy, http://www.fairwood.jp/forest/world/img/CA_PM.JPG) Source: Department of Wildlife and National Parks, Peninsular Malaysia, 2005.

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The scope of this review is of forestry-based industry specifically where the log for woody-industries comes from natural forests, forest plantations, and rubber plantations. Availability of log production for different wood purposes somewhat indicates the amount of the residues which could be used in energy sector. This paper aims to estimate waste generated and to calculate their energy value from these particular materials and ultimately, to forecast the potential of this feedstock.

Figure 4. Forest Cover of Malaysia (forest area)

Year	Hill Logs (m³)	Swamp Logs (m³)	Total Production (m³)
2000	12.3	2.0	14.3
2001	10.8	1.5	12.3
2002	10.5	1.2	11.8
2003	10.8	1.4	12.2
2004	10.8	1.3	12.1
2005	11.0	1.1	12.1
2006	11.0	0.9	11.9
2007	11.2	0.8	12.0
2008	10.8	0.5	11.3
2009	10.2	0.3	10.5
2010	10.0	0.4	10.4
2011	9.2	0.4	9.6

Figure 5. Log production from hill and swamp forest area in Sarawak

In another publication, land area set aside for conservation, forest management and protection for selected regions in Malaysia is 6.50, 3.88 and 5.50 million ha for Sarawak, Sabah and Peninsular Malaysia respectively [5]. However, Table 1 shows permanent reserved forest in Malaysia in 2010 reported by the three forestry departments.

Table 1. Permanent Reserved Forest in Malaysia, 2010 ('000,000 ha)

Region	Protection Forest	Production Forest	Total PRFs
Peninsular Malaysia	1.98	2.82	4.80
Sabah	1.04	2.55	3.59
Sarawak	1.10	5.00	6.10
Malaysia	4.12	10.37	14.49

Sources: Forestry Department, Peninsular Malaysia, Sabah, Sarawak (2011)

Table 2 shows the distribution and extent of major forest types in Malaysia. As Malaysia is divided into three main regions: Peninsular Malaysia, Sabah and Sarawak, we will notice slight different in term of its topography. For example, Peninsular Malaysia has been characterized by extensive coastal plains in the east and west, hilly and mountainous region with steep slopes in the central and undulating terrain in other parts of the peninsular. Meanwhile, Sabah is marked by characteristics like the western lowlands, the Crocker Range, the central uplands and the eastern lowlands whereas Sarawak is characterized by a seaward fringe of peat swamps beyond which the terrain is sharply and frequently dissected with ridges often knife edged.

Table 2. Distribution and extent of major forest types in Malaysia, 2010 ('000,000 ha)

Region	Land Area	Natural Forests			Total Forested Land	% of Total Land Area
		Dry Inland Forest	Swamp Forest	Mangrove Forest		
Peninsular Malaysia	13.18	4.58	0.24	0.10	5.86	44.4
Sabah	7.37	3.17	0.12	0.32	3.61	49.0
Sarawak	12.30	7.98	1.12	0.14	9.24	75.1
Malaysia	32.85	15.73	1.48	0.56	17.77	54.1

Sources: Forestry Department, Peninsular Malaysia, Sabah, Sarawak (2011)

Forest vegetation depends much on the altitude, soil conditions and water regime, Dipterocarp forest is found in the interior, upriver areas extending up to the upper limit of 1,500 m. Montane forests is found above this altitude, peat swamp forests are found in the low lying coastal plains. Mangrove forest is found in tidal and estuarine stretches extending from mud flats to where the saline waters end. Kerangas forest on the other hand, occurs on poor and sandy terrain.

Forest types in Peninsular Malaysia are divided into inland forest, peat swamp forest, mangrove forest, and forest plantation [4]. The Forestry Department of Peninsular Malaysia reported that 5.79 million hectares are allocated for forested land by end of 2012. Out of this total, 4.89 million hectares have been gazette as Permanent Reserved Forests (PRFs) under the National Forestry Act, 1984.

In Sabah, the forest reserve has been classed according to, Class I-protection forest reserves, Class II-commercial forest reserves, Class III-Domestic forest reserves, Class IV-amenity forest reserves, Class V-mangrove forest reserves, Class VI-virgin jungle reserves, Class VII-wildlife reserves, State Parks and wildlife sanctuaries, Timber plantations, and agricultural plantations within the Class II forest reserve (Figure 2).

In Sarawak, the land use classification as at 31 December 2011 can be forested, secondary forest, agriculture, settlement, and water body. Permanent forest estate (PFE), totally protected area (TPA), and stateland are land use categorized under forestry area. The logging activities are happening in the permanent forest estate which about 35.3% encompassed of the total land area under this classification.

2.2 Forest- and Wood Processing Production, Products and Residues

The forestry based biomass has been categorized by the Malaysia's National Biomass Strategy as follows:

- Sawmill and veneer mill residues and woodchip
- Wood from existing plantations established for proposed pulpmills and chiplogs from plantations established for veneer and sawlogs
- Harvest residues produced as a by-product of log production from existing plantations (e.g. pruning, thinning)
- New plantations on pulpwood regimes established primarily for producing biomass
- New woody and non-woody short rotation plantations such as grasses, canes and bamboo

These categories however did not include woody residues from logging in natural forest area. The forestry upstream and downstream materials are among the best sources for adding value to the waste generated. This is because the downstream uses in forestry sector cover engineered wood, pulp and paper, furniture, pelleting, biofuels, energy, and bio-based chemicals for these fibers. Ministry of Natural Resources and Environment Malaysia has estimated under annual coupe area of 9th (2006-2010) and 10th (2011-2015) Malaysia Plan for Permanent Reserve that Malaysia will cut down 266, 955 and 254,873 hectares respectively. In addition, it was projected that average annual log production from natural forest for 2006-2020 from Permanent Forest Reserve, State, and Alienated land will be 19.4, 15.5, and 14.0 Mm³ of five year period between 2006-2010, 2011-2015, and 2016-2020 respectively.

Meanwhile, the projected average annual production of logs from forest plantations of five year period are 3.3, 11.8, and 16.7 Mm³ for 2006-2010, 2011-2015, and 2016-2020 respectively. The existing forest plantations species namely rubber (getah), Acacia mangium, Eucalyptus, Teak, Sentang, Karas, Kapur, Mahagony, Paraserianthes, Merawan, Pine, and others. For rubberwood plantation, Malaysia projected average log production from existing operation from Peninsular and Sabah are 2.1, 2.0, and 1.8 Mm³ of 2006-2010, 2011-2015, and 2016-2020 of five year period respectively. Therefore, wood residues from these resources for different types of wood-industries products were estimated 9.83 Mm³ in 2006.

Utilization of wood from the rubber tree is both used as fuel and as timber. In particular in the last decade, rubber wood has become an important source of timber for the furniture industry. In Malaysia, about 62% of the rubber wood was used a fuel, 5% for other purposes while for the remaining 30-35% no information is available [6]. He also stated that rubber trees have a production life of about 25-35 years. The sustainability of the rubberwood sector in Malaysia has been examined by Ratnasingam et al. [7]. From present view, the life cycle has been shorten with the cultivation of new clone specifically consume for wood production. Therefore, the application of log wood from this new clone has been modified and it has tremendous potential to utilize it residues for energy purpose.

Peninsular Malaysia

A total of 35,538 hectares of Permanent Reserved forests were harvested in 2012, whereas 23,884 and 14,760 hectares were harvested from stateland forest and alienated land respectively. The production of selected timber products from these forest areas are log (4.5 million m³), sawn timber (2.8 million m³), plywood (415 thousand m³), veneer (61 thousand m³), and moulding (244 thousand m³) in 2012. All production recorded an increment from 2011 and veneer recorded the highest increase of 12.3% [4].

Sabah

Log production from Natural forests of Sabah by land status in 2011 showed total of 2.2 Million m³ that encompass forest reserves, other/alienated lands, and state land, 1.8 million, 397k, and 41k respectively [5].

The production of main timber products from log production in Sabah is changing yearly based on the demand consumer and legislator. Product output from log in 2011 like sawn timber (355,649 m³), Composite (veneer, plywood, blockboard, laminated board =959,327 m³), chips (261,995 m³), kiln dried timber (144,018 m³), moulding (123,372 m³), paper (116,363 m/t), particle board (48,043 m³), treated timber (33,180 m³), briquette/carbon rod (4,478 m/t), and bamboo furniture (965 m³).

Sarawak

Two types of log production in Sarawak come from hill logs and

swamp logs, as shown in Figure 6. The total of log production fluctuated from 14 Million meter cubic in 2000 to 10 Million meter cubic in 2011. In total, 4% of the production was obtained from swamp logs and about 96% remaining was by logging at hilly area (hill logs).

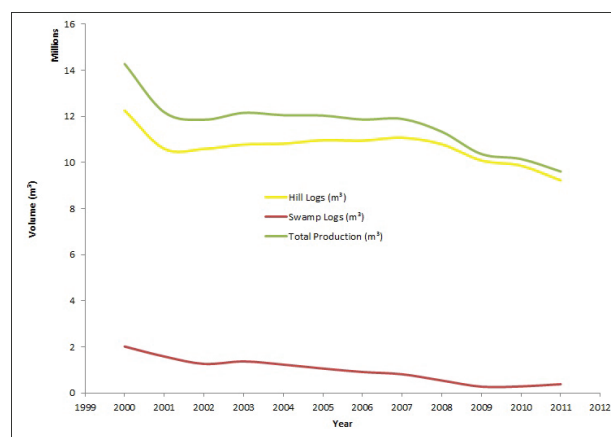


Figure 6. Log production from hill and swamp forest area in Sarawak

2.2.1 Forest- and Wood Processing Residues

Consumption of forest and wood processing residues has been started way back in the eighties. For example, usage of rubberwood for the generation of energy has been going on for the past 50 years.

Malaysia produces large amount of forest- and wood processing mass which has a huge renewable energy potential, where logging residues are produced during the various phases of logging operations in the form of bark, stumps, tops, branches, broken logs and injured standing trees from natural forest and plantation forest resources. Saw milling residues comprises of sawdust, off-cuts, slabs, shavings, and bark, meanwhile in plywood mills residues generated in the form of veneer cores, defective ends and irregular pieces of veneer sheets. The secondary processing residues are produced during the process of planning mills, moulding plants, and furniture factories in the form of sawdust, plane shavings, small pieces of lumber trimming, edging, bark and fragments. In addition, the composite wood-based products processing residues also generating same type of waste products like the secondary processing.

Nonetheless, the recovery rates vary depending on the local conditions and for Malaysia, FRIM (1992) [8] reported 30% logging wastes and Harun et al. [9] indicated recovery rate of 66% with 34% being residues (stumps, branches, leaves, defect-cuts & sawdust). Meanwhile, Kong stated that about 43% of the total tree volume is left behind in the forest during the logging operation [10]. We believe that the difference between these two authors was due to

the fact that Kong (2000) reports include unwanted species that are felled intentionally or accidentally.

Annex 1 shows an estimate of the amount of wood residues generated in Malaysia in 1997 that has been reported by Koopmans and Koppejan (1997) [11].

Annex 1 : Estimated Amount of Wood Residues Generated in Asia (1997)

Forestry-based Wood Residues (1,000 ton)

Process	Residue type	Rate %	
Logging	Solid	40	16325
Saw-milling	Solid	38	3981
	Sawdust	12	1257
Plywood	Solid	45	2399
	Dust	5	267
Particle board	Dust	10	92
Chemical pulp	Black Liquor		1.3
Field Based Residues			16325
Processing Based-solid wood			6380
Processing Based-Fines Dust			1616
Processing Based-Liquids			1.3
Total Wood Residues			24322
Annual yield (ton/ha)			
Rubber tree (25 year)	Solid	2.59	4382

2.3 Amount of Residues Generated

In general wood residues in Malaysia that generated from forest residues are divided into logging (5.1 million m³), primary manufacturing (2.92 million m³), plywood (0.91 million m³), secondary (million m³) and total 9.83 million m³ [12].

In aggregate, the values look attractive if not staggering as a distinction has been made between residues generated in the field and those generated during the processing. Either generated in the field or processing that will determine its use, for instance as a source of energy, or disposal more easy and spread over large areas and may remain in the field.

Figure 7, 8 and 9 showed the statistic of waste forestry waste production and amount of biomass waste generated in Malaysia. The calculation was derived by applying formulae on that ratio of waste production of 1.17 (t/t) under industrial logs of biomass species [13]. It should be noted with clear distinction between forests of industrial logs, fuel logs and wood waste as classified by Hall et al. [14].

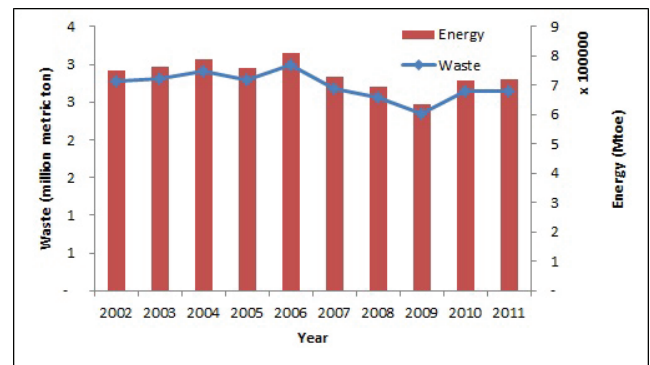


Figure 7. Waste generation from industrial logging in Peninsular Malaysia

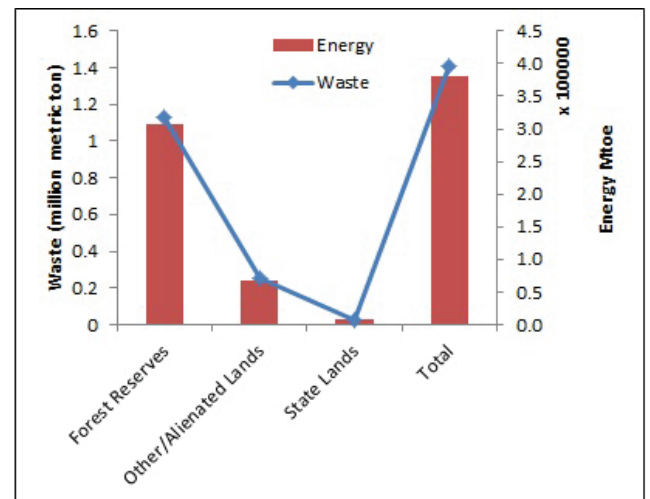


Figure 8. Waste generation from industrial logging in Sabah

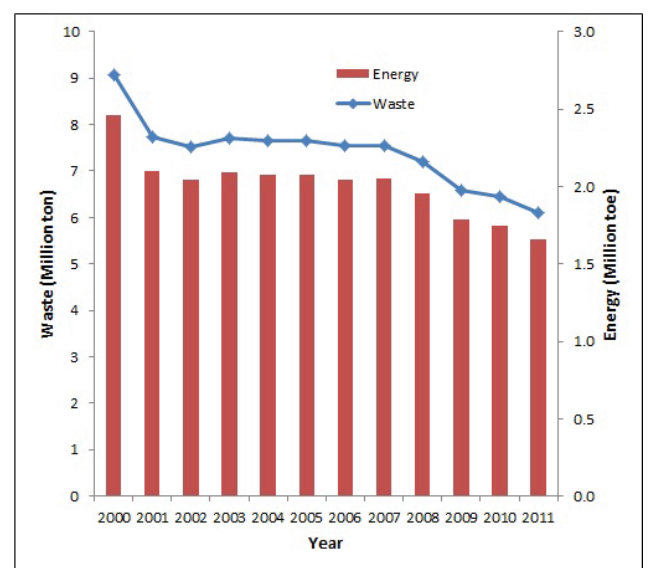


Figure 9. Waste generation of logging industrial in Sarawak

Figure 7 shows the waste generation from industrial logging in Malaysia since 1947 till 2010. Data which includes Peninsular Malaysia and Sabah for forest area and production of logs from 1947-1963 and 1947-1963 respectively are provided to observe the trend of waste generation. Maximum logging waste was generated between the ends of the ninth year (1900) till the beginning of the twentieth year (2000). And, at the end of the twentieth year, there was a drastic drop of waste produced from this sector. This could be due to modification of rules of logging operation and processing procedure to comply with international regulation as to minimize waste from this sector.

Figure 8 includes the waste generated in Sabah for 2011 from forest reserves, other/alienated lands, and state lands. The total is also projected with major waste are generated by forest reserves area. This setting is for industrial log with the assumption that biomass species follows Hall et al. [14] definition. Production of logs in Sabah covers both natural forest and forest plantation. And the declined in log production and directly implicate the reduction of residues generated from this production since 1989 was attributed to the implementation of sustainable forest management license agreement in 1997 and the phasing out of short-term licenses.

In Sarawak, the amount of waste declined as to date from 1999 to 2011, in the middle of the twentieth year the waste generated from forest was pretty consistent at least for 5 years (Figure 9). This may be a result of the sustainable management system that the forestry department of Sarawak obey to sustain the production and growth of forestry sector in the state. Also, the log production quota is based on recommendation by the International Tropical Timber Organization (ITTO) for permanent reserve forest.

3. Demand for the Resources

The application of the residues has expanded greatly for the recent years to be used for various purposes, besides being used as fuel which can be also considered as being one of the "6 F's", residues also used as Fodder, Fertilizer, Fibre, Feedstock and Further uses.

In 2013, the logs, plywood and sawn timber exported to Europe and other countries and regions are influenced by the Euro zone crisis, no clear demand from European Union and Arab spring turmoil. Logging in the tropical rainforest is an important export revenue earner in the East Malaysia and northern states of Peninsular.

Presently, residues has been so attractive and consumed for different reasons. Firstly, energy needs continue to grow as population inclining. And, under the socio and economy scenario, the projection shows a 30% growth in the next 70 years and this growth was supported by Mekhilef et al. [15]. Secondly, renewable and energy efficiency for a sustainable future has determine that

forestry biomass as one of its potential resources and this is in line with the National Biomass Strategy 2020. And thirdly, sourcing different type of feedstock other than agricultural based is a must and forestry based is a supplementary feedstock to the present biomass as feedstock need to be secured for sustainability of energy sources. Therefore, forestry based is most likely the right choice.

4. Conversion of woody biomass to Energy

The word biomass and energy are synonym and bioenergy has been used interchangeable in our daily living. The production of energy from woody biomass has become profound in Malaysia as supported by National Biomass Strategy 2020. From previous section we have seen the amount of woody biomass material available however what is most important is the amount that can be converted to energy.

The energy content of biomass is always reported as dry biomass, and the term higher heating value HHV refers to the energy released in combustion when the water vapor resulting from the combustion is condensed thus realizing the latent heat of evaporation meanwhile the lower heating value or LHV reports the energy released when the water vapor remains in a gaseous state. In this reports the data will be using HHV values. How do we estimate the energy content of wood and how much can realistically be utilized as no conversion of wood to energy is 100% accurate.

How to calculate energy content is done by sampling the loads for moisture content and using the relationship between moisture content and energy content to derive energy content in GJ/tonne and applying that to the weight (mass) of the individual load. The most commonly used unit for the measurement of wood biomass is the cubic metre solid volume (m^3), the volume of log can be calculated in cubic metres (m^3).

We estimated the biomass energy potential using the following equations ([16];[17]);

$$RV \text{ (ton)} = [TPV \times 1.17] / 1.842 \quad (1)$$

$$EP = RV \times MC \times CV \quad (2)$$

Where RV Residue volume (m^3), TPV Total product of log in loose volume (m^3), 1.17 is ratio of waste production, CV is GJ/tonne, and MC is moisture content (dry basis). LHV and the weight of 1 m^3 of wood to be 543 kg as are referred to Kofman 2010 [17].

Table 3 shows the potential energy collected from the wood waste generated in Peninsular, Sarawak, and Sabah. The total potential energy from 2000 till 2011 in Malaysia combining the three regions is shown in Figure 10. The main products of the forest residues and

logging residues are coming from the logs. Once the primary manufacturing take place, the waste or residue from the processing activities become prominent. The annual energy estimated in a dry basis from Peninsular, Sarawak, and Sabah were 0.72, 1.66, and 0.38 Million tonne oil equivalent in 2011. When we combine log production from natural forest, forest plantations, and rubber plantations for five year period from 2006 to 2010 of the three regions, the annual energy (dry base) increased double to 6.73 Mtoe as compare to 2011. Prediction of five years period shown that the annual energy climbed steadily at 7.63 and 10.42 Mtoe of 2011-2015 and 2016-2020 years. Hence, this value explicitly indicates the convincing energy resources from forestry biomass.

Table 3. Potential energy from waste woody biomass (log) in Malaysia, 2011

Region	Annual Generation	Moisture	Calorific value (LHV, dry base)	Annual energy (dry base)	
	million t-wet/y			PJ	Mtoe
Peninsular Malaysia	2.653	40.0	19	30.2	0.720
Sarawak	6.105	40.0	19	69.6	1.657
Sabah	1.405	40.0	19	16.0	0.381
Total	10.163	-	-	116	2.759

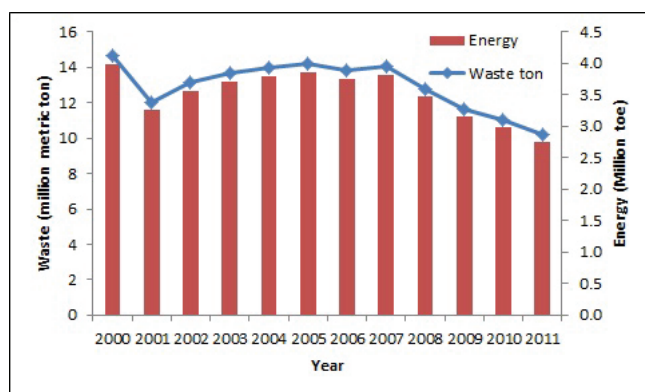


Figure 10. Waste and potential energy generation of log production in Malaysia

5. Concluding Remarks

Malaysia is blessed with the tropical and humid climate all year round that giving significant opportunity to tap this resource exclusively. Complementing energy sources from forest biomass is another ways to support its population and commercial energy demand.

The data have shown that considerable quantities of residues remain unused in the field of forestry. However, this statement is

based on data that can be considered far from the satisfactory and incomplete. Its only shows the gross amounts of residues, which are generated theoretically as Malaysia do not have a complete data of it waste from forestry sector. Therefore, much more information will have to be gathered on the generation and availability of the residues. In line with this demand, collection of relevant data by our researchers and analyses will be conducted. This information will be presented in the next chapter as a continuation of this paper.

6. Acknowledgement

The authors wish to thank Mitsubishi Educational Trust Fund custodian for the financial support and also appreciation goes to Mr Muhammad Akmal Jamil and Nurfarahin Burhanuddin for their help in gathering data.

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