Plant Based Energy Potential and Biomass Utilization in Malaysia

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ABSTRACT

The paper assesses the energy productivity of the major plantation crops in Malaysia as well as the status of bioenergy utilization in the country. Of the crops studied and under present local cultivation practices, oil palms and cocoa trees stand out as good trappers of solar energy while paddy plants are the least efficient. Presently Malaysia consumes roughly 2097.8 million GJ of energy per year. Of this amount 14% are contributed by biomass. However of the total amount of biowastes generated in the country roughly 24.5% are utilized for energy purposes while the rest are wasted. They are either left to rot or simply burnt as a means of disposal. If all of these unutilized biomass can be harnessed for use as energy, then the contribution of biomass to the nation's energy consumption can be raised to about 59%, a figure that is indeed attractive and therefore should be given serious attention.

1. INTRODUCTION

The recently concluded Kyoto Protocol of December 1997 indicates that the world community has now accepted the threat of global warming and has pledged to cut greenhouse gas emission levels. From the energy utilization perspective, this would mean the cutting down of fossil fuel use. To achieve this, fossil fuels from now on must be utilized in as efficient a manner as possible and where feasible, alternatives to fossil fuels should be utilized. This would mean that from now on renewable sources of energy would be given more prominence.

Currently biomass or bioenergy is considered by many countries as an alternative energy source that is most likely to gather momentum and to succeed in the not too distant future. Since plants grow well in tropical regions because of abundant sunshine and adequate rainfall, the countries in that region should capitalize on this and develop their biomass potential as soon as possible.

Malaysia is located within the tropics and it also has vast experiences in cultivating plantations crops. The country is now giving some serious consideration to the biomass option, which incidentally also includes the concept of energy crops or energy plantations. To assist in providing the country with a better perspective of that option, a study was initiated to assess both the current biomass utilization scenario in the country as well as the energy productivity of the major plantation crops grown under local conditions and cultivation practices. This is a report of that study.

2. THE STUDY

The major plantation crops currently cultivated in Malaysia are oil palms, rubber, paddy, coconut and cocoa. The planted acreages according to the Ministry of Finance's Economic Report (1996/97) [1] and the Department of Statistics' Report (April 1997) [2] are 25 670 km^2, 17 140 km^2, 6390 km^2, 2490 km^2 and 2350 km^2, respectively. Together they constitute more than 90% of the total area in the country that are cultivated with crops. In this report the cultivation of sugar cane though not on a large scale is also studied as sugarcane is known to be a good trapper of solar energy.

To better assess the energy productivity of crops one should perhaps work with experimental plots where crops are cultivated under different conditions. However the intention of the present study is not to gage how energy productivity can be optimized but rather to provide an indication of the production of the above-ground biomass of crops grown under present local cultivation practices. The results presented should only be regarded as a rough working estimate for future pursuits.

In order that the biomass utilization scenario be more complete, biowastes generated and used by the logging and timber industries are also included in this study.

3. ENERGY PRODUCTIVITY AND BIOMASS UTILIZATION

3.1 Oil Palm Cultivation

In 1994 Malaysia produced 51% of the world production of palm oil, thus making the country the world's largest producer [1]. It has been estimated that in 1996, 8.04 billion kg of crude palm oil and 1.13 billion kg of palm kernel oil were produced from an estimated planted area of 25 670 km^2. Of these it was estimated that 23 260 km^2 have mature oil palm trees [1].

In Malaysia, the oil palm tree is cultivated for its oil. Oil extracted from the pericarp/mesocarp of ripe fruits is called palm oil while oil extracted from the kernels of the nuts of the fruit is called palm kernel oil. These oils are presently used by the world community for a variety of purposes but not as a source of energy.

To get to the ripe fruit bunches so that they can be harvested, palm fronds may have to be cut. This is called pruning. Pruning can also be done on a periodic basis and not necessarily at the time of fruit harvesting. This practice generates large quantities of lignocellulosic biomass. Besides easier harvesting, other beneficial effects of pruning include easier visual assessment of fruit ripeness and easier access for pollination [3]. The harvested fruit bunches called fresh fruit bunches (FFB) are then gathered and transported to palm oil mills where oil extraction takes place. The process of oil extraction results in the production of both solid and liquid wastes. The solid wastes which are mostly lignocellulose are in the form of empty fruit bunches (EFB), fibers from the pericarp/mesocarp of the fruits, and shells from the nuts of the fruit. The liquid waste produced is the result of the extraction process, which requires large quantities of water. The liquid waste is called palm oil mill effluents (POME).

Because of declining yields, palm trees are replanted after 25 to 30 years. The replanting activity if carried out on a large scale will also result in the generation of large quantities of biomass in the form of felled tree trunks and fronds. Presently most of these wastes are either left to rot or burnt on the plantations sites.

Mohamad Husin, et al. [4] reported that roughly 11 000 kg of dry fronds are annually pruned from 10 000 m^2 of land. The energy content of these works out to be 206.02 GJ per 10 000 m^2 per year as the calorific value of fronds is 18.73 MJ per kg oven dry weight [5]. The current practice is to leave the fronds to rot on the plantation grounds.

Lim [5] on the other hand reported that the dry matter yields of shells, fruit fibers and empty fruit bunches are respectively, 2780 kg, 1853 kg and 1483 kg per 10 000 m^2 per year. The energy potentially available from these biomass are respectively 62.63 GJ, 36.16 GJ, and 30.36 GJ per 10 000 m^2 per year.

Lim [5] also estimated that at the time of replanting of 10 000 m^2 of land, 66 000 kg of dry palm trunks and 14 400 kg of dry fronds are generated. Assuming that replanting is after 25 years, the average annual amount of biomass available as a result of replanting works out to be 2640 kg of dry trunks and 580 kg of dry fronds. Energy of these are respectively 39.3 GJ and 10.86 GJ.

From the above figures it can be concluded that the dry lignocellulose biomass yield from oil palm plantations is 20 336 kg per 10 000 m^2 per year with an energy content of 385.32 GJ per 10 000 m^2 per year.

The extraction of oil from FFB requires energy in the form of electricity and steam. Currently the energy requirements of all palm oil mills in Malaysia are met by the use of fibers and shells where cogeneration is widely practised. In fact in some mill, there is an excess of shells which are then sold to other mills that further refine the crude palm oil [5]. This situation has been going on since the inception of palm oil mills in the 1960's. Of the 385.32 GJ that are available per 10 000 m^2 per year, roughly 98.8 GJ are currently being put to use as a source of energy. The EFB are normally incinerated and therefore not utilized.

From the data provided by two palm oil mills [6, 7], it was estimated that 3.54 m^3 of POME are generated for each tonne of crude palm oil produced. Since in 1996 Malaysia produced 8.04 billion kg of crude palm oil, the total amount of POME produced works out to be 11.09 m^3 per 10 000 m^2 per year.

Attempts have been initiated in a couple of palm oil mills to utilize the POME for biogas production. As far as the authors know only two mills are doing this. The experience from one mill indicates that with their production of 680 m^3 of POME per day, 19 000 m^3 of biogas per day can be produced in digester tanks [7] as shown in the flow diagram in Fig. 1. The biogas produced is found to have the following characteristics:

54	-	80% CH_4
20	-	46% CO_2
560	-	2580 ppm of H_2S
Calorific value of 19.84	-	25.74 MJ/m^3

Assuming an average calorific value of 22.79 MJ/m^3, the energy potentially available from the anaerobic digestion of 680 m^3 of POME is 433.01 GJ per day.

As mentioned earlier, in 1996, Malaysia produced 28.46 million m^3 of POME. This amount of effluent if digested to produce biogas, will result in an energy production of 18.2 x 10^6 GJ and this comes from an area of 23 260 km^2 of mature oil palm trees. Thus on the basis of mature trees, the energy potentially available from POME is roughly 7.84 GJ per 10 000 m^2 per year.

The present data gathered from reports is that in one mill which produces about 13 000 m^3 of biogas per day, all the gas are utilized [8] while in a second mill only about 17% of the biogas produced is used in a gas engine after H_2S removal while the reminder is flared [7]. Thus the current total amount of biogas utilized is about 16 000 m^3 per day, i.e., 365.88 GJ per day or 13.33x10^4 GJ per year.

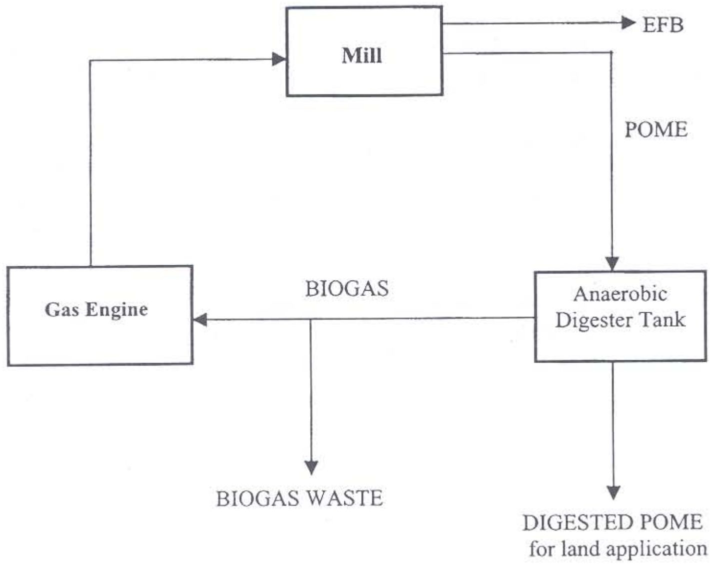

Fig. 1. Flow chart for oil palm potential and utilization.

This is less than 1% of the 18.2 x 10^6 GJ that are available in 1996. Thus the potential of harnessing POME for fuel is still great indeed.

From the data of 1996, 3940 kg of oil per year can be harvested from 10 000 m^2 of land based on mature oil palm trees. The calorific value of palm oil is 39.357 MJ/kg [9]. Since the calorific value of palm kernel oil is comparable to that of crude palm oil [10], 10 000 m^2 of land will produce an energy equivalent of 154.25 GJ per year if all the oil produced are used for energy purposes.

The above data indicate that the total energy that can potentially be harnessed from the above ground lignocellulosic biomass and the crude palm oil is roughly 547.28 GJ per 10 000 m^2 per year. Of these, about 98.8 GJ has been used by the palm oil mills as energy in the extraction of oil.

3.2 Rubber Cultivation

Wastes generated by the rubber industry can be classified as coming from three principal sources. The first source consists of biomass generated in the fields, which includes fallen branches, twigs, shed leaves and rubber seeds. Presently most of these biomass are left to rot on the plantation grounds though some branches and twigs are collected for use as domestic fuel. This practice is not without its benefits in that it provides nutrients to the fields and as such one should perhaps not attempt to gather them for other purposes. Furthermore the shed leaves and seeds are scattered all over the plantation grounds, thus making collection uneconomical.

The second source of wastes consists of effluents that are produced as a result of latex processing. The energy potential of these effluents, if converted to biogas will result in the production of some 1.3 x 10^6 GJ of fuel per year [5] or 0.76 GJ per 10 000 m^2 per year. However this potential remains untapped.

The third source of biowastes is rubberwood, where large quantities become available during replanting activities. Lim [5] estimated that the amount of dry rubberwood available from now until the year 2000 would average 3.3 billion kg per year. This amount however excludes branches that are smaller than 50 mm in diameter. On visual inspection of mature rubber trees that are due for replanting one can perhaps estimate that roughly 5% by weight of the rubber tree is of branches that are less than 50 mm in diameter [11]. The amount of available dry rubber wood due to replanting activities should average 3.47 billion kg per year. The energy content of this amount of biomass works out to be about 68.61 million GJ per year or 40.04 GJ per 10 000 m^2 per year.

Hong and Sim [12] reported that roughly 1/3 of the total supply of rubber wood is still not being used. This amount is usually discarded and burnt on the plantation grounds. Of those consumed which is 2.31 billion kg per year, Lew [13] reported that about 67% is still being used for energy purposes. This would imply that annually Malaysia uses 1.55 billion kg of dry rubber wood as fuel. The energy potentially available from that amount of biomass is some 30.65 million GJ per year (17.88 GJ per 10 000 m^2 per year). The rest of 0.76 billion kg per year is used for the production of plywood, furniture, particle board, medium density fiberboards, parquet, panelling, kitchenware as well as other value-added products.

Depending on clones and cultivation practices, various estimates have been made of the total above ground dry matter yield of tapped rubber trees. The estimates range from a low of 6 to a high of 13 000 kg of dry matter per 10 000 m^2 per year [14, 15]. Most estimates, however, gave values in the 6000 kg to 7000 kg range. A conservative estimation is made that under normal cultivation practices, 6500 kg of above ground dry matter are readily produced annually from 10 000 m^2 of land. This estimate also includes leaves and seeds. Wycherley [15] reported that on the average the dry weight of seeds produced is around 36 kg per 10 000 m^2 per year. Lim [5] reported that the calorific value of rubber tree leaves and wood are respectively 19.40 MJ/kg and 19.77 MJ/kg oven dried weight, while the corresponding value for seeds is 24.41 MJ/kg. Using an average figure of 19.6 MJ/kg for both the wood and leaves, the energy potentially available from them works out to be some 126.67 GJ per 10 000 m^2 per year while that from seeds is 0.86 GJ per 10 000 m^2 per year. In Malaysia the average yield of rubber when cultivated in estates is about 1200 kg per 10 000 m^2 per year [1]. Since the calorific value of rubber is reported to be 45.2 MJ/kg [16], the energy content of this product therefore works out to be 54.23 GJ per 10 000 m^2 per year. Thus in total the energy productivity of cultivated rubber trees is estimated to be about 182.02 GJ per 10 000 m^2 per year.

3.3 Paddy Cultivation

In 1996, it was estimated that 2.128 billion kg of paddy were produced in Malaysia [1] from 6390 km^2 of land [17]. From the data provided by rice millers, roughly 23% of paddy is husk. Therefore the amount of husk produced works out to be 489.44 million kg. Since the moisture content of husk is 13% to 14%, the amount of dry husk produced is therefore roughly 423.365 million kg. The calorific value of rice husks as reported by Lim [5] is 14.933 MJ/kg. Thus the energy potentially available from the husks produced was about 6.322 x 10^6 GJ in 1996. The ratio of straw production to grain yield under local cultivation practices is about 1:2 [5]. Thus roughly 1.064 billion kg of straw were produced in 1996. Since the moisture content of straw is about 16% and the calorific value is 15.85 MJ/kg [5], the energy potentially available from straw works out to be about 14.17 x 10^6 GJ for 1996. The above figures, therefore indicate that the total above ground wastes from the cultivation of paddy have an energy potential of 20.492 x 10^6 GJ which is roughly 1.4% of Malaysia's 1996 energy consumption. This 20.492 x 10^6 GJ came from 6390 km^2 of land. Thus the energy potential on a per 10 000 m^2 basis of the above ground wastes from paddy cultivation is about 32.07 GJ per year. 1.638 billion kg of rice were produced from the above 2.128 billion kg of paddy. The moisture content of rice as determined in laboratory is around 10.3% while the calorific value is 16 MJ/kg dry weight. The energy potentially available from the rice grains works out to be 23.51 x 10^6 GJ. Thus on a per hectare basis it is 36.77 GJ. Hence the total above ground energy productivity of rice cultivation works out to be 68.84 GJ per 10 000 m² per year. Attempts have been made to use rice husks for energy but so far with little success. Husks have also been processed into value added products such as fertilizers, mosquito coils, chicken feed and boards while straws are used for mushroom cultivation and the manufacture of paper and boards. Even so most of the husks and straws are still disposed off by burning or left to rot in the fields as well as in the vicinity of the rice mills.

3.4 Coconut Cultivation

As far as the authors are aware, the coconut cultivation industry has undergone practically no change over the years except that the total area cultivated has decreased from about 3500 km² in the late 1970's to about 2490 km² in 1995 [5, 2]. This decrease not only occurs in estate scale plantations but in small holdings as well. In 1995 the percentage of acreage cultivated under estate management was only 5.6% of the total, compared to a figure of about 9% in the mid 1980's. Since the industry has not undergone much changes the figures indicated in Lim's paper [5] are still valid so long as the decrease in cultivated area is taken into consideration.

Wastes from coconut cultivation can be classified into three categories, namely fronds and debris that are shed throughout the year, wastes generated by the processing and consumption of the fruits and wastes generated during replanting. Replanting, however, is not significant at this point in time. It will only take place well into the 21st century [5]. Lim [5] estimated that the dry weight of shed fronds is about 2340 kg per 10 000 m² per year. With the current 2490 km² cultivated, the amount of biomass generated in the form of fronds and debris works out to be about 0.583 billion kg whose energy potential is about 10.75 million GJ. Though some fronds and debris are left unattended in the fields, a large proportion is used as domestic fuel by villagers and some are used for the manufacture of articles such as brooms. Lim and Rugayah [18] estimated that the annual per capita consumption of fronds by poor rural households was about 410 kg. In 1995 there were 421 400 such poor households with each having an average of 5.18 inhabitants [19]. Lim and Rugayah [18] also estimated that about 59% of these poor rural households used mainly coconut fronds as fuel. Thus in 1995, a total of about 0.528 billion kg of coconut fronds was used as fuel in rural villages. This works out to be some 90% of the total amount of fronds generated.

From the data of Lim [5], it is estimated that in 1995, 0.747 billion kg of dry husks was generated while the corresponding figure for dry shells was 0.374 billion kg. Hence the amount of energy potentially available from these two sources of wastes works out to be 12.3 million GJ and 6.92 million GJ, respectively. It is estimated that 70% of shells produced are used as fuel in copra kiln dryers [5]. An unknown amount is also used for charcoal and coconut shell flour production and as kindling material. Husks on the other hand are used as kindling material, as filling material for seats and mattresses, as material for the manufacture of brushes, as mulch or are just left in the fields to rot. The exact amount used for each of the above is difficult to estimate but a substantial amount of husks are used as mulch or are just left to rot in the fields. Since most of the coconuts are planted by small holders the potential of large-scale gathering of the unutilized shells and husks for further energy use may not be economical.

From the above figures, it can be concluded that the energy content of biowastes generated in the coconut industry works out to be roughly 120.4 GJ per 10 000 m² per year.

To estimate the above ground energy productivity when coconuts are cultivated, it is also necessary to estimate the energy potential of the copra produced as well as that from the biomass of standing trees. In Malaysia, the annual production of copra is about 1424 kg per 10 000 m² [20]. Since the calorific value of copra as determined in the laboratory is about 20.64 MJ/kg the energy content of the copra produced works out to be roughly 29.37 GJ per 10 000 m² per year. From observations, it was estimated that for mature trees the amount of leaves on each tree is equivalent to about 20 mature fronds which will therefore have an energy content of about 0.56 GJ per tree. The average height of a tree of about 50 years is roughly 21 m and its average trunk diameter is about 0.3 m. From these it is estimated that the dry weight of such a tree trunk is about 590 kg with an energy content of about 9.564 GJ. Since the local planting density is about 120 trees per 10 000 m^2, the energy potentially available from the above ground biomass of standing trees works out to be about 1.214 x 10^3 GJ per 10 000 m^2. This quantity is only available after about 50 years. Therefore, the energy available from the above ground standing biomass is about 24.31 GJ per 10 000 m^2 per year. It must be emphasized that this figure is only a very rough estimate. From the figures worked out above it is concluded that the energy productivity of coconut tree cultivation under local practices is roughly 174.06 GJ per 10 000 m^2 per year.

3.5 Cocoa Cultivation

Due to several unfavorable factors, one of which being declining monetary returns, cocoa cultivation has not progressed as previously anticipated. In fact there is a decline in planted area from a peak of 4520 km^2 in 1991 to 2350 km^2 in 1996 [1]. Thus it can be safely assumed that all the present cultivated areas are of mature trees which traditionally require pruning. Pruning is done in order to keep mature trees at a height of about 3 m to 4 m so as to enable easy access for spraying and fruit harvesting. Lim [5] reported that pruning generates about 25 200 kg of dry organic matter per 10 000 m^2 per year. The energy content of this amount of biomass would be about 442.4 GJ per 10 000 m^2 per year. Thus the total amount of pruning biomass generated in 1996 was about 5.92 billion kg whose energy content is roughly 103.96 million GJ. Currently pruning wastes are left to rot in the fields. The above amount of wastes, however, is envisaged to decrease in future as more and more cocoa plantations are converted to the cultivation of other crops. Furthermore some planters have also discontinued the practice of tree pruning as they are of the opinion that pruning hurts the trees [21].

To estimate the energy productivity of cocoa cultivation, it is necessary to estimate also two other contributions, namely the energy content of the cocoa fruits and the energy content of the leafy and woody biomass generated during replanting. Lim [5] estimated that the average yield of dry cocoa fruit husks is about 150 kg per 10 000 m^2 per year which have an energy content of about 2.22 GJ per 10 000 m^2 per year. Yield of cocoa beans under local cultivation practices is reported to be about 500 kg per 10 000 m^2 per year [1]. Since the calorific value of cocoa beans as determined in laboratory is 21.2 MJ/kg, the energy content of this principal product works out to be about 10.61 GJ per 10,000 m^2 per year. On replanting, Lim [22] estimated that the dry organic matter generated from one tree is about 48 kg. Thus with a planting density on a sole crop equivalent basis of 1200 trees per 10 000 m^2, the amount of biomass generated at replanting is about 57 600 kg per 10 000 m^2; the energy content of which is about 1010.65 GJ per 10 000 m^2. Since cocoa tree are normally replanted after about 25 years, the energy potentially available from replanting wastes works out to be about 40.41 GJ per 10 000 m^2 per year.

From the above figures one can therefore estimate the energy productivity when cocoa trees are cultivated. The figure works out to be about 495.64 GJ per 10 000 m^2 per year. As for the pruning wastes and husks generated in 1996 about 104.89 GJ were potentially available for use. However their potential is currently not being harnessed.

3.6 Sugarcane Cultivation

Sugarcane cultivation is only successful in the Northern regions of Peninsular Malaysia where a more distinct dry season is experienced. As such the industry has stagnated. The areas under sugarcane cultivation was roughly 186 km² in 1976; 253 km² in 1980 and 180 km² in 1997 [1, 23]. Malaysia currently produces 100 million kg of sugar per year but the country requires 700 million kg. Thus annually 600 million kg have to be imported [23].

One thousand kg of sugar is produced from 10 000 kg of cane and 30% by weight of the cane end up as bagasse [23]. Thus the total amount of bagasse produced in the country works out to be 300 million kg per year. Since the moisture content of bagasse is roughly 50%, the amount of dry bagasse produced annually is 150 million kg.

As the calorific value of bagasse is 17.33 MJ/kg [5], the energy potentially available from bagasse works out to be 2.6 x 10^6 GJ per year. Presently all of these are used as boiler fuels in both the mills operating in the country.

Lim [24] reported the ratio of dry weight of leaves and cane tops to the dry weight of canes as 0.685. Thus on an annual basis the energy potentially available from the leaves and cane tops works out to be 1.84 x 106 GJ. This is with the assumption that cane tops are mostly leaves that have a calorific value of 17.88 MJ/kg [5]. The current practice in Malaysia is to burn the leaves and cane tops in the fields before the canes are harvested. This practice not only is harmful to the environment, it also wastes potential valuable biofuels. Therefore, ways have to be found to better use this potential source of energy.

The calorific value of granulated sugar is 16.64 MJ per kg. The energy content of the total amount of 100 million kg per year of sugar produced in Malaysia works out to be 1.67 x 10^6 GJ per year. From the above figures it is concluded that the energy potentially available from the above ground biomass from sugarcane cultivation is 6.1 x 10^6 GJ per year. These are all produced from roughly 180 km² of land. As such the energy productivity works out to be roughly 338.73 GJ per 10 000 m² per year.

4. BIOMASS GENERATION AND UTILIZATION

4.1 Logging and Timber Industries

From published data, Lim [5] attempted an estimate of the amount of wastes generated at logging sites. However due to improved logging management techniques and practices it is deemed appropriate to relook at the estimates made earlier.

From recent visits to logging sites, it is estimated that on the average about 15% of a felled tree, i.e., its top branches and leaves, are not removed to be processed into timber but are left as wastes on the logging sites. Thus for each cubic meter of sawlogs produced the amount of unwanted branches and leaves that end up as logging residues works out to be about 0.176 m³.

The process of tree felling itself inevitably results in the destruction of smaller trees that happen to be in the path of the falling tree. This destruction however is minimized wherever possible. From personal communication with workers at the logging sites and also a visual inspection of the site, it is estimated that the amount of unwanted trees that get in the way of a falling tree is comparable to the amount of unwanted branches and leaves of the felled tree. As such for one cubic meter of sawlogs produced the amount of biomass residues generated is roughly 0.35m³.

For 1996 it was estimated that Malaysia produced 31 million m³ of sawlogs [1]. Therefore, the amount of logging residues generated works out to be about 10.85 million m³ which is mainly woody biomass. From the data of Grewal [25], it can be estimated that the dry weight of one m³ of woody biomass is about 575 kg. Thus the 10.85 million m³ of wood wastes is equal to about 6.239 billion kg of dry biomass. Using the calorific value of sawdust which is 18.855 MJ/kg [5], the 6.239 billion kg of dry biomass has an energy content of some 117.6 million GJ. All these potential which represent roughly 7.8% of Malaysia's 1996 energy needs are currently left in the forest to rot.

The second source of biowastes generated by the country's timber industry is wastes produced when logs are processed either into sawn timber or into plywood. If not exported these are then used locally for downstream activities such as the construction and furniture industries. The wastes generated by these downstream activities are scattered and most would end up as construction and industrial wastes. Therefore no attempt will be made to estimate the biowastes generated by these downstream activities.

From the studies done at sawmills and plywood mills, it is estimated that for every 1000 kg of sawn timber produced, 26.6 kg of bark, 56.5 kg of sawdust, 139.1 kg of fuel wood and 110 kg of small size timbers are produced. Similarly for every m^3 of plywood produced, 0.83 m^3 would be considered as wastes. Of this amount 0.037 m^3 are bark, 0.33 m^3 would eventually end up being used as fuel and the remainder of 0.463 m^3 would be used in the manufacture of value-added products such as furniture, boards, pallets etc.

In 1995, Malaysia produced 6.954 million m^3 of sawn timber and 3.506 m^3 of plywood [2]. From these figures and together with the above data, the quantity and energy potential of bark, sawdust and fuelwood are estimated as shown in Table 1.

Table 1 Quantity and Energy Potential of Bark, Sawdust and Fuelwood

	Quantity (billion kg of dry matter)	Energy potentially available(million GJ)
Bark	0.1810	3.412
Sawdust	0.2260	4.263
Fuelwood	1.2217	23.033

In most mills, barks, if not already removed at logging sites, are either burnt/incinerated or allowed to decompose within the grounds of the mills. Though in some mills, sawdusts are also combusted to produce energy and in a few situations briquetted to produce charcoal, the fate of most sawdust is similar to that of barks. From the above estimates, if these two sources of wastes are harnessed for energy purposes an amount of about 6.171 million GJ per year is available.

5. DISCUSSION AND CONCLUSION

Starting in 1996 Lim [5, 22, 26] published a series of papers that estimated the energy potential and the then current utilization of agriculture and logging biowastes in Malaysia as well as the future availability of biomass as a result of replanting activities. Since then, Malaysia's economy has undergone substantial changes in that manufacturing activities are given greater emphasis as opposed to agricultural activities. In addition, certain agriculture and logging practices have also undergone changes in that sustainable forest management procedures are now widely implemented and certain available biomass produced have been processed into value-added products. This paper is to a certain extent a re-examination of the scenario reported in 1986 and 1990. In addition the energy productivities of the major plantation crops cultivated are also assessed. This last aspect is essential for consideration if one were to contemplate introducing the concept of energy crops or energy plantations.

Table 2 Energy Productivity and Biomass Production and Utilization

Crops/ Activities	Energy Productivity (GJ per ha per year)	Current Annual Amount Used For Energy Purposes (million GJ)	Current Annual Energy Potential Of Unutilised Biomass (million GJ)
Oil Palms	547.28	Fruit shells 145.67 Fruit fibres 84.10 Effluents 0.136	Pruned fronds 479.19 EFB 70.61 Effluents 18.07 Replanting Wastes 79.82*
Rubber trees	182.02	Wood 30.65	Wood 22.87 Effluents 1.30
Paddy Plants	68.84	-	Rice husks 6.32 Rice straws 14.17
Coconut Trees	174.06	Fronds 9.74 Shells 4.84	Fronds 1.01
Cocoa Trees	495.64	-	Pruning Wastes 103.96 Pod husks 0.52 Replanting Wastes 3.89*
Sugarcane	338.73	Bagasse 2.60	Leaves and tops 1.84
Logging	-	-	Residues 117.60
Timber Processing	-	Waste wood and some sawdust 23.03	Tree Bark and Sawdust 6.170

* Annual average estimated from Lim [13] from now till the year 2000.

Table 2 is a summary of the data discussed in the paper. From the various entries, it can be observed that of all the crops considered, oil palm trees appear to be the most efficient trapper of solar energy while cocoa trees come as a close second. The least efficient trapper however are paddy plants. It must be re-emphasized in this study that these energy productivity data were obtained under current local cultivation practices where the main objective is to maximize the yield of the intended product and not biomass production. Nevertheless the data serve as an indicator to be considered should energy plantations be contemplated. Crops such as oil palm and cocoa trees should be given serious consideration, while crops such as paddy and coconuts are obviously bad candidates.

If the energy potential of oil palms and cocoa trees is to be compared to the various plant species such as poplars, willows and Miscanthus that are currently being field tested as potential energy crops in Europe, oil palm and cocoa trees stand out as a much superior energy crop. For example, willows cultivated in Sweden [27] give a biomass yield of about 12 000 kg of dry matter per 10 000 m^2 per year. This translates into an energy potential of roughly 236.31 GJ per 10 000 m^2 per year assuming that the calorific value of the biomass produced is 19.7 GJ per 10 000 m^2 dry matter. Similar figures can be calculated for the other plant species.

Though there are many other crops cultivated in Malaysia such as tapioca, pepper, pineapple, groundnuts, tea, tobacco, fruits and vegetables, the hectarages involved are small and therefore the amount of biowastes generated from these crops would be small and moreover scattered. Thus the total amount of biomass shown in Table 2 can be considered to be fairly close to the total amount of biowastes produced in the country. From the various entries of the table, it is observed that of the total 1229.68 million GJ currently generated per year, about 24.5% are already utilized for energy purposes and roughly 75.5% are still unutilized and therefore wasted.

The percentages of biomass that are currently wasted or unutilized are: 69.7% from oil palm industry; 12.7% from logging residues and 11.2% from cocoa tree prunings. Therefore, attempts should seriously be made to harness their energy potential though it is admitted that in the years to come the contribution from cocoa tree prunings would decrease as more and more cocoa plantations are converted to other crops and as pruning practices are reduced.

Currently Malaysia consumes roughly 1789.3 million GJ per year of commercial energy which does not include biomass [28]. If the latter were included, the total energy consumption for the country is some 2097.8 million GJ per year. This means that about 14% of the country's energy consumption is contributed by biomass. If the biomasses that are currently wasted can be harnessed for energy, the contribution of biomass can be raised to around 59% of the country's total energy consumption. This is not a small figure and therefore efforts ought to be directed towards realizing this possibility. By so doing, the nation's fossil fuel reserves can be conserved [28]. Lim [28] estimated that in a situation where there is no net export, Malaysia's reserves of fossil fuels could sustain its needs for another 40 years or so. Under the current economic climate, where net exports cannot be avoided, the lifespan figure of 40 years will undoubtedly be reduced, a situation that should not be ignored.

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