ENERGY POTENTIAL AND UTILISATION OF PLANTATION CROPS IN MALAYSIA

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ABSTRACT

The major plantation crops currently cultivated in Malaysia are studied and their energy productivities are reported in the paper with reference to the concept of energy plantations. Further, the status of bioenergy utilisation from various available biomasses is also discussed. It is found that 14% of Malaysia's annual energy consumption is provided by roughly 24.5% of the total biomass. It is highlighted that this figure can be raised to about 59%, if all the unutilised biomass is harnessed for use as energy.

1. INTRODUCTION

The concern over the depletion of fossil fuels in the near future and an increasing awareness of energy conservation has drawn worldwide attention. Present energy resources such as coal, oil and gas are being used at an accelerating rate with fear of depletion in the next century, although coal might be an exception. Apart from this fear, there is also an increasing awareness about environmental pollution and ways of minimizing the same. There are nine general sources of energy on Earth. They are: solar, biomass, wind, wave, hydro, tidal, geothermal, nuclear and fossil. Except the last three the remaining six are generally called renewable sources of energy, as they are not depleted with time. One of the most promising renewable sources of energy is the energy from biomass.

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. Energy plantations have been a subject of study by many researchers to form a continuous supply of energy. Suitable crops that grow rapidly have been tested such as the Willow trees that are being used and tested in the United Kingdom. Other similar fast growing crops are also being studied such as the *Euphorbia Characias*⁸. In the Netherlands, Poplar and *Miscanthus* are the two most promising types of specifically grown biomass for energy generation³⁵. *Miscanthus* and other species such as *Sorghum* are C_4 crops characterized by high rates of Carbon assimilation. Sims³² comments that the greatest potential source of biomass fuels in New Zealand comes from energy plantations of a species known as *Pinus radiata*.

Most of the biomass material are found in the developing countries in Africa and Asia whose main sources of revenue are agriculture, timber logging, animal rearing, etc. where biomass is the main byproduct. The first impression is that biomass energy would be most viable form of energy in the developing countries. However, in recent years the developed countries in Europe in particular have promoted the importance of biomass energy^{5,7,26,27,28}. Hence, biomass energy is not only essential in the developing countries but has also aroused great interest in Europe. Sweden has continued to invest in the biomass energy program as a renewable energy source³⁴. The difficulties faced during the Second World War has always been a constant reminder to the Swedes and should be for most countries in the world whose prime dependence is on imported fossil. Since plants grow well in tropical regions because of abundant sunshine and adequate rainfall, the countries in that region should capitalise 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 plantation 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 utilisation scenario in the country as well as the energy productivity of the major plantation crops grown under local conditions and cultivation practices. This paper reports the details 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)⁶ and the Department of Statistics' Report (April 1997)²⁵ are respectively 2.567 million ha, 1.714 million ha, 0.639 million ha, 0.249 million ha and 0.235 million ha. Together they constitute more than 90% of the total area in the country that are cultivated with crops. In this report the cultivation of sugarcane 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 gauge 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 present results 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. OIL PALM CULTIVATION — ENERGY PRODUCTIVITY AND BIOMASS UTILISATION

In 1994, Malaysia produced 51% of the world production of palm oil, thus making her the world's largest producer⁶. It has been estimated that in 1996, 8.04 million tonnes of crude palm oil and 1.13 million tonnes of palm kernel oil were produced from an estimated planted area of 2.567 million hectares. Of these it was estimated that 2.326 million ha have mature oil palm trees⁶.

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 pollination⁴. 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), fibres 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 al²⁴ reported that roughly 11 dry tonnes of fronds are annually pruned from one ha of land. The energy content of these works out to be 206.02 GJ per ha per year as the calorific value of fronds is 18.73 MJ per kg oven dry weight¹². The current practice is to leave the fronds to rot on the plantation grounds.

Lim¹⁵ on the other hand reported that the dry matter yields of shells, fruit fibres and EFB are respectively 2.78, 1.853 and 1.483 tonnes per ha per year. The energy potentially available from these biomass are respectively 62.63, 36.16 and 30.36 GJ per ha per year.

Lim¹⁵ also estimated that at the time of replanting of 1 ha of land, 66 tonnes of dry palm trunks and 14.4 tonnes 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 2.64 dry tonnes of trunks and 0.58 tonnes of dry fronds. Energy of these are respectively 39.3 GJ and 10.86 GJ. From the above figures one can conclude that the dry lignocellulose

biomass yield from oil palm plantations is 20.336 dry tonnes per ha per year with an energy content of 385.32 GJ per ha 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 fibres 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 oil¹⁵. 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 ha 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 utilised.

From the data provided by 2 palm oil mills^{3,36}, we estimated that 3.54 m³ of POME are generated for each tonne of crude palm oil produced. Since in 1996 Malaysia produced 8.04 million tonnes of crude palm oil, the total amount of POME produced works out to be 11.09 m³ per ha 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 2 mills are doing this. The experience from one mill indicates that with their production of 680 m³ of POME per day, 19000 m³ of biogas per day can be produced in digester tanks³⁶. The biogas produced is found to have the following characteristics:

54 – 80% CH₄
20 – 46% CO₂
560 – 2580 ppm of H₂S
Calorific value of 19.84 – 25.74 MJ/m³

Assuming an average calorific value of 22.79 MJ/m³, the energy potentially available from the anaerobic digestion of 680 m³ of POME is 433.01 GJ per day.

As mentioned earlier, in 1996, Malaysia produced 28.46 million m³ of POME. This amount of effluent if digested to produce biogas, will result in an energy production of 18.2 x 10⁶ GJ and this comes from an area of 2.326 million ha of mature oil palm trees. Thus on a per ha basis of mature trees, the energy potentially available from POME is roughly 7.84 GJ per year.

The present data gathered from reports is that in one mill which produces about 13000 m³ of biogas per day, all the gas are utilised³¹ while in a second mill only about 17% of the biogas produced is used in a gas engine after H₂S removal while the remainder is flared³⁶. Thus the current total amount of biogas utilised is about 16000 m³ per day i.e. 365.88 GJ per day or 13.33x10⁴ GJ per year. This is less than 1% of the 18.2 x 10⁶ GJ that are available in 1996. Thus the potential of harnessing POME for fuel is still great indeed.

From the data of 1996, 3.94 tonnes of oil per annum can be harvested from 1 ha of land based on mature oil palm trees. The calorific value of palm oil is 39.357 MJ/kg¹. Since the calorific value of palm kernel oil is comparable to that of crude palm oil², 1 ha of land will

produce an energy equivalent of 154.25 GJ per annum 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 ha per year. Of these about 98.8 GJ have been used by the palm oil mills as energy in the extraction of oil. For a better visualization of the energy potential and its current utilisation, a Sankey diagram is also shown in Figure 1.

4. RUBBER CULTIVATION — ENERGY PRODUCTIVITY AND BIOMASS UTILISATION

Wastes generated by the rubber industry can be classified as coming from 3 principal sources. The first source consists of biomass generated in the fields, which includes fallen branches and 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 1.3×10^6 GJ of fuel per annum¹⁵. However this potential remains untapped.

The third source of biowastes is rubberwood, where large quantities become available during replanting activities. Lim¹⁵ estimated that the amount of dry rubberwood available from now till the year 2000 would average 3.3 million dry tonnes per annum. This amount however excludes branches that are smaller than 5 cm 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 are of branches that are less than 5 cm in diameter²⁰. The amount of available rubberwood due to replanting activities should average 3.47 million dry tonnes 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 ha per year.

Hong and Sim¹² reported that roughly 1/3 of the total supply of rubberwood is still not being used. This amount is usually discarded and burnt on the plantation grounds. Of those consumed which is 2.31 million dry tonnes per annum, Lew¹³ reported that about 67% are still being used for energy purposes. This would imply that annually Malaysia uses 1.55 million dry tonnes of rubberswood as fuel. The energy potentially available from that amount of biomass is some 30.65 million GJ per year. The rest of 0.76 million dry tonne per annum is used for the production of plywood, furniture, particle board, medium density fibreboards, 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 tonnes of dry matter per ha per year^{37,38}. Most estimates, however, gave values in the 6 to 7 tonnes range. A conservative estimate is made that, under normal cultivation practices, 6.5 tonnes of above ground dry matter are readily produced annually from one ha of land. This estimate also includes leaves and seeds. Wycherley³⁸ reported that on the average the dry weight of seeds produced is around 0.036 tonne per ha per year. Lim¹⁵ reported that the calorific value of rubber tree leaves and wood are respectively 19.40 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 ha per year while that from seeds is 0.86 GJ per ha per year. In Malaysia, the average yield of rubber when cultivated in estates is about 1200 kg per ha per year⁶. Since the calorific value of rubber is reported to be 45.2 MJ/kg²², the energy content of this product therefore works out to be 54.23 GJ per ha per year. Thus, in total the energy productivity of cultivated rubber trees is estimated to be about 182.02 GJ per ha per year.

Figure 1: Sankey diagram for oil palm tree.

5. PADDY CULTIVATION — ENERGY PRODUCTIVITY AND BIOMASS UTILISATION

In 1996, it was estimated that 2.128 million tonnes of paddy were produced in Malaysia⁶ from 639,000 ha of land²¹. From the data provided by rice millers, roughly 23% of paddy is husk. Therefore the amount of husk produced works out to be 489,440 tonnes. Since the moisture content of husk is 13 –14%, the amount of dry husk produced is therefore roughly 423,365 tonnes. The calorific value of rice husks as reported by Lim¹⁵ is 14.933 MJ/kg. Thus, the energy potentially available from the husks produced was about 6.322×10^6 GJ in 1996. The ratio of straw production to grain yield under local cultivation practices is about 1:2¹⁵. Thus roughly 1.064 million tonnes of straw were produced in 1996. Since the moisture content of straw is about 16% and the calorific value is 15.85 MJ/kg¹⁵, the energy potentially available from straw works out to be about 14.17×10^6 GJ for 1996. The above figures, therefore indicate that the total above ground wastes from the cultivation of paddy have an energy potential of 20.492×10^6 GJ which is roughly 1.4 % of Malaysia's 1996 energy consumption. This 20.492×10^6 GJ came from 639,000 ha of land. Thus the energy potential on a per ha basis of the above ground wastes from paddy cultivation is about 32.07 GJ per year. 1.638 million tonnes of rice were produced from the above 2.128 million tonnes of paddy. The moisture content of rice as determined in our 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 23.51×10^6 GJ. Thus on a per ha basis it is 36.77 GJ. Hence the total above ground energy productivity of rice cultivation works out to be 68.84 GJ per ha 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 fertilisers, 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.

6. COCONUT CULTIVATION — ENERGY PRODUCTIVITY AND BIOMASS UTILISATION

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 350,000 ha in the late 1970's to about 249,000 ha in 1995^{15, 25}. 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 paper¹⁵ are still valid so long as the decrease in cultivated area is taken into consideration.

Wastes from coconut cultivation can be classified into 3 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 century¹⁵.

Lim¹⁵ estimated that the dry weight of shed fronds is about 2340 kg per ha per year. With the current 249,000 ha cultivated, the amount of biomass generated in the form of fronds and debris works out to be about 0.583 million tonne 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 Rugayah¹⁸ estimated that the annual per capita consumption of fronds by poor rural households was about 0.41 tonne. In 1995 there were 421,400 such poor households with each having an average of 5.18 inhabitants²³. Lim and Rugayah¹⁸ 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 million tonne 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 Lim¹⁵, it is estimated that in 1995, 0.747 million tonne of dry husks was generated while the corresponding figure for dry shells was 0.374 million tonne. Hence the amount of energy potentially available from these 2 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 dryers¹⁵. 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 unutilised shells and husks for further energy use may not be economical.

From the above figures, we can conclude that the energy content of biowastes generated in the coconut industry works out to be roughly 120.4 GJ per ha 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 1.424 tonnes per ha²⁹. Since the calorific value of copra as determined in our laboratory is about 20.64 MJ/kg the energy content of the copra produced works out to be roughly 29.37 GJ per ha per year. From observations, we estimate 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 21m and its average trunk diameter is about 0.3 m. From these we estimate 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 ha, the energy potentially available from the above ground biomass of standing trees works out to be about 1.214×10^3 GJ per ha. 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 ha 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 ha per year.

7. COCOA CULTIVATION — ENERGY PRODUCTIVITY AND BIOMASS UTILISATION

Due to several unfavourable 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 452,000 ha in 1991 to 235,000 ha in 1996⁶. Thus it can be safely assumed that all the present cultivated hectareage are of mature trees which traditionally require pruning. Pruning is done in order to keep mature trees at a height of about 3 – 4 m so as to enable easy access for spraying and fruit harvesting. Lim¹⁵ reported that pruning generates about 25.2 tonnes of dry organic matter per ha per year. The energy content of this amount of biomass would be about 442.4 GJ per ha per year. Thus the total amount of pruning biomass generated in 1996 was about 5.92×10^6 tonnes 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 trees¹¹.

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. Lim¹⁵ estimated that the average yield of dry cocoa fruit husks is about 150 kg per ha per year which have an energy content of about 2.22 GJ per ha per year. Yield of cocoa beans under local cultivation practices is reported to be about 0.5 tonne per ha per year⁶. Since the calorific value of cocoa beans as determined in our laboratory is 21.2 MJ/kg, the energy content of this principal product works out to be about 10.61 GJ per ha per year. On replanting, Lim¹⁶ 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 ha, the amount of biomass generated at replanting is about 57.6 tonnes per ha; the energy content of which is about 1010.65 GJ per ha. 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 ha 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 ha 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.

8. SUGARCANE CULTIVATION — ENERGY PRODUCTIVITY AND BIOMASS UTILISATION

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 18,600 ha in 1976; 25,300 ha in 1980 and 18,000 ha in 1997^{6,33}. Malaysia currently produces 100,000 tonnes of sugar per year but the country requires 700,000 tonnes. Thus annually 600,000 tonnes have to be imported³³.

One tonne of sugar is produced from 10 tonnes of cane and 30% by weight of the cane end up as bagasse³³. Thus the total amount of bagasse produced in the country works out to be 300,000 tonnes/year. Since the moisture content of bagasse is roughly 50%, the amount of dry bagasse produced annually is 150,000 tonnes.

As the calorific value of bagasse is 17.33 MJ/kg¹⁵, the energy potentially available from bagasse works out to be 2.6×10^6 GJ per annum. Presently, all of these are used as boiler fuels in both the mills operating in the country.

Lim¹⁴ 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 1.84×10^6 GJ. This is with the assumption that cane tops are mostly leaves that have a calorific value of 17.88 MJ/kg¹⁵. 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/kg. The energy content of the total amount of 100,000 tonnes per year of sugar produced in Malaysia works out to be 1.67×10^6 GJ per year. From the above figures it is concluded that the energy potentially available from the above ground biomass from sugarcane cultivation is 6.1×10^6 GJ per year. These are all produced from roughly 18,000 ha of land. As such the energy productivity works out to be roughly 338.73 GJ per ha per year.

9. LOGGING AND TIMBER INDUSTRIES — BIOMASS GENERATION AND UTILISATION

From published data, Lim¹⁵ 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 minimised 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 sawlogs⁶. 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 Grewal¹⁰, 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 million tonnes of dry biomass. Using the calorific value of sawdust which is 18.855 MJ/kg¹⁵, the 6.239 million tonnes of dry biomass has an energy content of some 117.60 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 tonne of sawn timber produced, 0.0266 tonne of bark, 0.0565 tonne of sawdust, 0.1391 tonne of fuel wood and 0.11 tonne of small size timbers are produced. Similarly for every m³ of plywood produced, 0.83 m³ would be considered as wastes. Of this amount 0.037 m³ are bark, 0.33 m³ would eventually end up being used as fuel and the remainder of 0.463 m³ would be used in the manufacture of value-added products such as furniture, boards, pallets etc.

In 1995, Malaysia produced 6.954 million m³ of sawn timber and 3.506 m³ of plywood²⁵. From these figures and together with the above data, the following are estimated.

	Quantity (million dry tonnes)	Energy potentially available (million GJ)
Bark	0.181	3.412
Sawdust	0.226	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 6.17 million GJ per annum is available.

10. DISCUSSION

Starting in 1996 Lim^{15, 16, 17} 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 reexamination 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 1 is a summary of the data discussed in the paper. From the various entries, one observes 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 reemphasized here that these energy productivity data were obtained under current local cultivation practices where the main objective is to maximise the yield of the intended product and not biomass production. Nevertheless the data serve as an indicator for thought 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 we were to compare the energy potential of oil palms and cocoa trees 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 Sweden³⁰ give a biomass yield of about 12 tonnes of dry matter per ha per yr. This translates into an energy potential of roughly 236.310 GJ per ha per year assuming that the calorific value of the biomass produced is 19.7 GJ per dry tonne. 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 hectares 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 1 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 annum, about 24.5% are already utilized for energy purposes and roughly 75.5% are still unutilized and therefore wasted.

69.7% of the biomass that are currently wasted or unutilised are contributed by the oil palm industry; 12.7% by logging residues and 11.2% by 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.

Table 1: Biomass energy potential and utilisation

Crops/ Activities	Annual Energy Potential (million GJ)	Current Annual Amount Used For Energy Purposes (million GJ)	Current Annual Energy Potential Of Unutilised Biomass (million GJ)
Oil Palms	1273	Fruit shells 145.67 Fruit fibres 84.10 Effluents 0.136	Pruned fronds 479.19 EFB 70.61 Effluents 18.07 Replanting 79.82* Wastes
Rubber trees	311.97	Wood 30.65	Wood 22.87 Effluents 1.30
Paddy Plants	44.00	—	Rice husks 6.32 Rice straws 14.17
Coconut Trees	43.34	Fronds 9.74 Shells 4.84	Fronds 1.01
Cocoa Trees	116.47	—	Pruning Wastes 103.96 Pod husks 0.52 Replanting 3.89* Wastes
Sugarcane	6.1	Bagasse 2.60	Leaves and tops 1.84
Logging	—	—	Residues 117.60
Timber Processing	—	Waste wood 23.03 and some sawdust	Tree Bark 6.170 and Sawdust

• Annual average estimated from Lim¹⁶ from now till the year 2000.

Currently Malaysia consumes roughly 1789.3 million GJ per annum of commercial energy which does not include biomass¹⁹. If the latter were included, the total energy consumption for the country is some 2097.8 million GJ per annum. 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 realising this possibility. By so doing, the nation's fossil fuel reserves can be conserved¹⁹. Lim¹⁹ 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.

11. CONCLUSIONS

From the above study the following conclusions are drawn:

- (1) Oil palm trees appear to be the most efficient biomass plantation crop in utilizing the solar energy whereas the paddy plants are the least efficient ones.
- (2) Energy potential of oil palms and cocoa trees are superior to poplars, willows and Miscanthus which are currently being field tested in Europe.
- (3) Of the total biomass available in Malaysia, only 24.5% are being utilized for energy purposes and the rest are still unutilized. The major contribution of the unutilized biomass comes from oil palm industries.
- (4) Currently 14% of the country's energy consumption is contributed by the utilization of biomass. This contribution can be raised to about 59% by utilizing the currently wasted biomass potential. Thus the life of the nation's fossil fuel reserves can be conserved for a maximum of 40 years with no export of fossil fuels.

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