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Journal of Cleaner Production 14 (2006) 87–93
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

Renewable energy from palm oil – innovation on effective utilization of waste

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Received 26 September 2003; accepted 14 July 2004
Available online 22 September 2004

Abstract

Protecting the environment has been the priority of many sectors in our endeavor to ensure sustainable development. Implementation of green energy development based on the use of biomass is in the right path in adopting a holistic approach in the promotion of renewable energy. Malaysia has very substantial potential for biomass energy utilization given its equatorial climate that is ideal for dense tropical forest growth and agricultural vegetation. Biomass power potentials from wood processing and palm oil were estimated at 280 TJ and 250 TJ, respectively. By the year 2010, the biomass energy potential is expected to increase to 820 TJ. The paper describes the effective use of biomass as the first of the renewable energy sources to be developed for large-scale applications, especially in the palm oil industry and the methodology for energy harness by innovative utilization of waste from palm oil cultivation and processing.

Keywords: Sustainable development; Renewable energy; Palm oil biomass; Utilization of palm oil waste

1. Introduction

Malaysia is with a plentiful and relatively cheap supply of conventional fossil energy resources such as oil, gas, and coal as well as renewable energy sources such as hydropower, biomass and solar. Past and current economic growth in the country have been primarily fueled by fossil fuels. The energy intensity (energy use per unit GDP) has worsened over time, while the electricity elasticity, i.e. use growth rate to GDP growth rate has been about 1.5 over several decades. Malaysia's demand for energy is relatively high in comparison with most developed countries – Japan, Taiwan, USA, Indonesia, Thailand energy intensities were 0.11, 0.22, 0.28, 0.33, and 0.35 ktoe per US$ million, respectively. Projections of maximum energy demand were 10,775 MW, 20,870 MW and 40,515 MW for the year 2000, 2010 and 2020, respectively. As of 1999, the remaining reserves for oil and natural gas were 3.6 billion barrels and 85.8 trillion standard cubic foot, respectively. The natural gas reserves are expected to meet the country's need only for the next 50–60 years while for oil they will meet our needs for only the next 20 years [1].

There has been very little necessity to curb energy use in Malaysia in the past, or to be concerned about energy use efficiency, as rapidly expanding use of energy was seen as a measure of the pace of national industrial development. However, recently, the economic recovery upward trend combined with recent strategies to minimize cost as much as possible has developed a supportive environment to incorporate energy conservation and energy efficiency measures as part of the nation's "Vision 2020" industrialization objectives. This is also in line with the primary national energy policy objectives of the country, under its utilization objective,

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doi:10.1016/j.jclepro.2004.07.005

namely, to promote and encourage the efficient utilization of energy as well as discourage wasteful and unproductive patterns of energy consumption [2].

2. Overview of Malaysia palm oil industry in Malaysia

Over the last few decades, the Malaysian palm oil industry has grown to become a very important agriculture-based industry, where the country is today the world's leading producer and exporter of palm oil. Indigenous to Africa, the oil palm (*Elaeis guineensis* Jacq.) has been domesticated from the wilderness and transformed to become a plantation-based industry. During the late 1950s the expansion of the industry started as part of government's diversified cautious policy from rubber to oil palm and also to raise the socio-economic status of the expanding population in the country. Today, Malaysia is the world's largest producer and exporter of palm oil, replacing Nigeria as the chief producer since 1971. Malaysia is blessed with favourable weather conditions which prevail throughout the year which is advantageous for palm oil cultivation. Thus, it is not surprising that the highest yields have been obtained from palms grown in this region, which is far from its natural habitat.

The palm oil industry is an important contributor to the country's GDP. Export earnings from palm oil, palm kernel oil and its products in 1998 amounted to almost US$5.6 billion, equivalent to 5.6% of GDP. The crop has also played a significant role in the socio-economic development of rural areas by providing employment and raising the income level.

2.1. Production

There are two main products produced by the oil palm fruit namely crude palm oil (CPO) and crude palm kernel oil (CPKO). CPO is obtained from the mesocarp and CPKO is obtained from the endosperm (kernel). Malaysia exported a record of 9.2 million tons, or 65% of global palm oil exports. Palm oil export alone contributed RM14.42 billion or 75.1% of the total export revenue of the country.

The main by-product and wastes produced from the processing of palm oil are the empty fruit bunches (EFB), palm oil mill effluent (POME), sterilizer condensate, palm fibre and palm kernel shell. EFB and POME have been used extensively as mulch and organic fertilizer in oil palm areas while palm fibre and shell are used as fuel, making the palm oil mill self-sufficient in energy. The excess shells have been used for road surfacing on estates. Tables 1–4 in the sections below show the various compositions and components of the oil palm.

Table 1
Composition of fresh ripe fruit and mesocarp (%) – dry weight

Fruit		Mesocarp	
Palm oil	29	Palm oil	46–50
Water	27	Palm oil (dry basis)	77–81
Residue	8	Moisture	36–40
Shell	30	Non-fatty solids	13–15
Kernel	6		

2.2. Future outlook

Palm oil production is expected to grow 4.57% annually over the next five years to 26.2 million tons by 2005. Exports are expected to grow 5.6% to reach 18.1 million tons by 2005, capturing 41% of the global oils and fats market.

2.3. The efficiency of oil palm

Oil palm is a perennial tree crop, which is cultivated extensively in the humid tropical land. Average planting cycle of a palm tree is about 25 years for efficient productivity. Because of the conversion of solar radiation to plant growth by photosynthesis, the chemical energy content of the harvested palm fruit and biomass exceeds the energy input through the farming system. Thus, oil palm can act as a net source of useful energy [3]. The oil palm plantations in Malaysia are planted with a density of 148 palms per hectare. One stand of oil palm tree occupies 0.0068 ha of land. Each palm yields about 150 kg of fresh fruit bunches (FFB) per year. Therefore, the average total production of FFB per palm tree for 23 productive years is 3.45 tons.

Pruning of fronds is carried out at each round of harvesting in order to allow cutting of ripe fruit branches. The dry weight of fronds from annual pruning is about 11.6 tons/ha [3]. For 23 years of productive period for a palm tree that bears fruit, the total dry weight of frond per palm from pruning is 1.8 tons. On the other hand, total biomass that fell during the replanting after 25 years, estimated by Chan [3], is about 0.71 ton of trunk and fronds per palm. With estimated calorific value of 10 GJ/ton, the total biomass energy available per palm tree, excluding the FFB is 25.1 GJ [4].

Table 2
Dry matter production by oil palm

Period	Part	Dry matter (t/ha)
Annual (mature palm)	Pruned fronds	10.4
	Empty fruit bunches	1.6
At replanting	Trunk	75.5
	Fronds and rachis	14.4

Source: Chan et al. [17].

Table 3
Availability of fresh and dry weight of efb, shell, fibre and effluent in tons per hectare per year after milling from 1 ha of mature palms

	1 ha of mature palms	
	Fresh wt. (t/ha/year)	Dry wt. (t/ha/year)
FFB	20.08	10.60
EFB at 22% of FFB	4.42	1.55
Fibre 13.5% of FFB	2.71	1.63
Shell 5.5% of FFB	1.10	1.10
(i) Sterilizer condensate 12% FFB	2.41	0.12
(ii) Clarification sludge 50% of FFB	10.04	0.50
(iii) Hydrocyclone washing 5% FFB	1.00	0.05
Total POME	13.45	0.67

These palm residues contain high nutrient value. Based on nutrient content estimations [5], an equivalent energy of 683.2 MJ is saved from the production of chemical fertilizers if the palm residues are used as fertilizers. The main products and the wastes from a palm oil mill contain high-energy value. The estimated calorific value for CPO and palm kernel oil is 40 GJ/ton [6]. Thus, the oils from 3.45 tons of FFB (22% of CPO and 6% palm kernel oil) will produce 38.6 GJ of energy. However, the market value for both oils is presently high and has not been used for commercial energy generation. Research in methyl esters converted from palm oil, as a diesel substitute is very promising and direct burning of CPO to generate electricity has also been tested recently in Malaysia.

The pressed fibre and shell are used, as fuel to generate steam and energy required for the operation of the mill with surplus energy left over. The dry calorific values are 18.6 GJ/ton and 20.8 GJ/ton of fibre and shell, respectively [6]. Thus, the total energy from shell and fibre of a palm tree is 14 GJ. The empty fruit branch (EFB) can also be used to generate power. To make it more easily combustible, EFB has to be shredded and dehydrated to a moisture content below 50% [7]. EFB has a heat value of about 1950 kcal/kg at 50% moisture. Biogas from anaerobic digestion of POME has also been explored. The biogas generated from 1 ton of FFB is estimated at 19.6 m^3 with a calorific value of 22.9 MJ/m^3 [6]. Thus, total biogas energy from 3.45 tons of FFB is 1.55 GJ. Furthermore the digested effluent also contains nutrient value that can be applied as fertilizer to the palm forest.

Table 4
Biomass generated by palm oil mills in 1997

Biomass	Quantity (million tons)	Moisture content (%)	Oil content (%)	Heat value (dry) (kcal/kg)
EFB	10.6	65	5	3700
Fibre	6.6	42	5	4420
Shell	2.7	7	1	4950
POME	32.0	95	1	–

Figures are based on estimate of 148 palms/ha. *Note:* EFB – empty fruit bunch. POME – palm oil mill effluent. *Source:* Adapted from Chua [12].

3. Environmental problems in the palm oil industry

Within the last few years, environmental issues are increasingly becoming more important in Malaysia and the world over. The palm oil industry is aware of the environmental pollution and is striving towards quality and environmental conservation through 'sustainable development and cleaner technology' approach. Thus, to remain competitive, the oil palm industry must be prepared for the new challenges ahead.

Rapid development in the palm oil industries over the years should be in tandem with the development of its environmental technical know-how. There are still many environmental pollution issues that need to be addressed on a dynamic basis even though the existence of environmental laws and regulations since the implementation of the Environmental Quality Act (EQA) [17] and the specific regulations to govern the management of crude palm oil mills has helped to facilitate the overall environmental pollution problems in the country.

The formulation of the crude palm oil mill effluent discharge standards by phases has brought about catalytic impact in the development of effluent treatment technology in the form of innovative or newly created technology. However, the present air pollution control measures in CPO mill are adequate but still insufficient for full compliance of regulatory requirements. More studies should be conducted in areas like boiler design technology, solid fuel treatment and combustion, fly ash control system, and energy conservation concept in relation to complete combustion [8]. More stringent water quality standards might also be stipulated in the future as deterioration of inland water quality continues. Thus, new and improved treatment technology would be required in order to meet the new requirements. A proposed environmental management by river basin might govern different sets of more stringent effluent discharge standards.

Self regulated environmental management tools like the ISO 14000 EMS and life cycle assessment (LCA) have also been adopted by the palm oil industries where systematic assessment checklists on the whole operation and unit processes and pollution prevention strategies could be effectively formulated and implemented. The self-regulation approach by the industry will certainly complement the present environmental management system and the national environment as a whole.

Nevertheless, studies by Henson [9] and Anderson [10] concluded that oil palm cultivation under existing practices posed no threat to the environment while

Wood and Corley [11] concluded that oil palm was a more energy friendly crop than others.

3.1. Utilization of solid by-products press fibre and shell

Press fibre and shell generated by the palm oil mills are traditionally used as solid fuels for steam boilers. The steam generated is used to run turbines for electricity production. These two solid fuels alone are able to generate more than enough energy to meet the energy demands of a palm oil mill.

The problems associated with the burning of these solid fuels are the emissions of dark smoke and the carryover of partially carbonized fibrous particulates due to incomplete combustion of the fuels. There are many reasons contributing to the incomplete combustion of the fuels. However, these problems have been overcome, to a great extent, through a controlled fuel feeding system and multi-clone dust collectors to trap the particulates. The flue gases from the boiler chimneys are also being used as a heat source for drying of decanter solids.

3.2. Empty fruit bunches

The empty fruit bunches (EFB) are traditionally incinerated for its ash which is a very good fertilizer/soil conditioner. However, due to the "white smoke" problem, the DoE discourages incineration of EFB. The "white smoke" is mainly contributed by the high moisture (>60%) in the EFB. Though harmless, it has an aesthetic effect to the beautiful surroundings. EFB has been shown to contain high plant nutrient and fertilizer equivalent. Experimental results have indicated that on the inland soils and on some of the less fertile coastal soil, EFB can be used as much to improve foliar nutrient levels and vegetative growth. Increases in EFB yield by 8–23% have also been reported. With the rising costs of inorganic fertilizers, there is now a growing interest in the utilization of EFB as mulch for oil palms. In establishments where plantations are near the palm oil mills, all the EFB is being utilized as mulch. However incineration is still being practiced in mills with no estates.

Lim et al. [4] have conducted research to find alternative ways to beneficially utilize EFB, e.g. composting. In areas where there are energy intensive subsidiary industries near a palm oil mill, EFB can be considered as an energy source similar to press fibre and shell. A pretreatment process is required to prepare the EFB for efficient combustion [12].

The cultivation of any crop needs inputs of fertilizers, pesticides, herbicides and energy. The inputs and outputs for oil palm and three other major soil seed crops (soybean, sunflower and rapeseed) are as reported by FAO [18]. The data clearly show that oil palm is the most efficient (needing least artificial inputs per ton of oil) and is the least polluting. A comprehensive review on nitrogen use [13] has also ruled out the possibility of pollution by nitrogen fertilizers caused by the current practices in the use of fertilizers in oil palm.

From an environmental point of view other sources of vegetable oil, e.g. soybean are seen to be less friendly. The energy needed to produce the inputs should also be taken into consideration, for example, the total N and hence the energy required to produce the soybean oil will be six to seven times that needed for oil palm. Similarly for herbicides and pesticides the need for soybean production is about 15 times more. Of greater consequence is the depletion of a non-renewable resource (fuel oils) to produce the products and more importantly the negative contribution of the use of the fuel oil to global warming.

4. Energy from palm oil

Rising income and growing populations have increased energy demand. Energy is required in almost all aspect of every day life including agriculture, drinking water, lighting health care, telecommunication and industrial activities. Presently, the demand of energy is met by fossil fuels (i.e. coal, petroleum and natural gas). However, at the current rate of production the world production of liquid fossil fuel (petroleum and natural gas) will decline by the year 2012.

As energy consumption grows, so too will emissions of greenhouse gases, with significant impact on global climate change. Scientific assessment based on the available instrumental observational records from the industrial era to the present day showed that global mean temperature has increased by between 0.3 and 0.6 °C since the 19th century, while the mean sea level has risen between 10 and 25 cm over the same period.

Renewable energy technologies are environment friendly and contribute effectively towards sustainable development. Recognizing the importance of the energy availability and stability to stimulate economic growth, the Malaysian government introduced the four-fuel strategy namely petroleum, natural gas, hydropower and coal to reduce the over dependence upon petroleum and to ensure reliability and security of supply. The success of the diversification policy is reflected in the reduced dependence on petroleum. Petroleum dependence for the power generation sector has been cut down from 98% in 1980 to 8% in 1999. Recently, the government has included renewable energy as the fifth fuel and thereby, increased the role of renewable energy as an alternative to the other sources of energy.

The Malaysian government has announced the Fifth Fuel Policy, with renewable energy being added to the four-fuel strategy (petroleum, natural gas, coal and hydro) introduced in the early 1980s. The four-fuel strategy has been very successful since it has cut down dramatically the share of petroleum as the main component of the fuel used. The Fifth Fuel Policy indicated that 5% of the electricity generated to the grid must be from renewable energy by the year 2005. Biomass has been identified to be the most suitable candidate to contribute towards achieving this goal due to the huge amount of oil palm waste in the country.

Biomass consists of forestry, purpose-grown agricultural crops, trees and plant types, organic waste, residue and effluent of agricultural, ago-industrial and domestic origin (sewage and municipal solid waste). Applying biomass technology is both an environmental and human necessity whether on a local scale to get rid of slurries, waste and refuse, or on a global scale reduce carbon dioxide content in the atmosphere and hence reduce global warming. Biomass fuel obtained from purpose-grown energy crops as well as forests and agricultural waste can be used in power plants and it is very competitive in price and quality with fossil fuels. It has also been used as industrial raw material for the production of polymers and chemicals [14]. It is worth mentioning that if we compare the CO_2 emissions from electrical power plants we find that using coal or oil to generate electricity produces 1100 g of CO_2 per kW h and using gas reduces this figure to 600 g of CO_2 per kW h. However, using biomass will reduce it dramatically to 16 g of CO_2 per kW h [3].

On a worldwide scale biomass contributes about 12% to today's primary energy supply rising to between 40% and 50% in most developing countries [15]. Examples of energy obtained from biomass include production of crops which yield starch, such as sorghum; sugar such as artichoke or sugarcane; cellulose such as poplar, eucalyptus trees or other wood-forming trees; and oil such as sunflower, euphoria etc. In Malaysia, there is abundant supply of oil palm waste and this provides a strong reason for selecting biomass as the first of the renewable energy sources to be developed for large-scale application especially in the palm oil industry. In addition, oil palm waste can be regarded as energy crop. The palm oil industry has had more than 40 years of experience in operating biomass cogeneration systems and has available working experience in using oil palm waste for heat and power generation in the country [6].

5. The small renewable energy programme

The Ministry of Energy, Communications and Multimedia Malaysia launched the small renewable energy programme (SREP) in May 2001. In this programme, the government targets palm oil wastes as the major form of renewable energy (RE) making up the fifth fuel in Malaysia's energy policies. Renewable energy (RE) will comprise 5% of our electricity supply, or some 700 MW, in the year 2005.

Among the guidelines found in the programme are that the small renewable energy programme (SREP) shall apply to all types of renewable sources of energy, including biomass, biogas, municipal waste, solar, mini-hydro and wind. The renewable energy (RE) power plant must meet all environmental regulations set by the Department of Environment (DoE), and the developer of the project is responsible for obtaining the necessary approval of DoE, and any other statutory approvals required.

5.1. Power plant operation in a typical palm oil mill

The operation of power plants within a palm oil mill is not so complex. These plants are normally staffed by local steam drivers and engineers. Fig. 1 below shows the case of a typical 60 tons FFB (fresh fruit bunches) per hour mill operating 20 h a day [16]. A total of 23% by weight EFB (empty fruit bunches) or 13.8 tons of EFB per hour is sent back to the estate to be used as mulch in the fields.

The fuel produced from the waste comes from:

- Shell amounting to 6%, out of which about 30% is dry enough to be used as boiler fuel, or 1 ton/h and
- Fibre amounting to 14% or 8.4 ton/h

The power requirement of the mill is 15–17 kW per ton FFB or 1020 kW for a 60 tons FFB per hour mill. This is typically met by a non-condensing turbine using steam with a pressure of 21-bar gauge and exhausting at 3-bar gauge. The size of the generator is about 1.2 MW. When the mill is not in service, a diesel generator takes over to supply security lighting and domestic supply. Two units are usually installed: one of 800 kW and another of 250 kW. In a mill break down which may last a while, the large diesel generator will be operated to supply power to some plants in the nut station, effluent

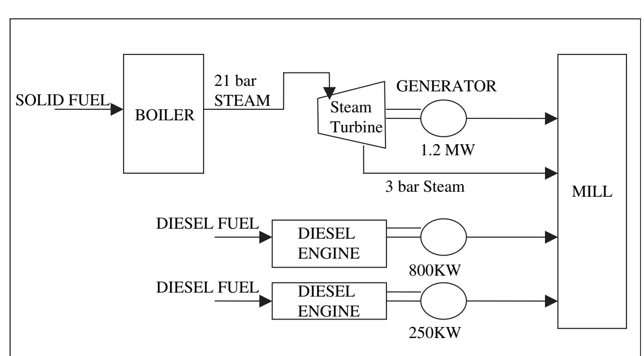

Fig. 1. Schematic diagram of a typical power house in palm oil mill.

plant, water works, lighting etc. The diesel generating sets are not required if the mill is close to the national electricity board grid and is connected to it [16].

New schemes for grid-connected power plants under the small renewable energy programme involve the construction of boilers burning EFB and producing up to 10 MW of power, which can be sold to the national electricity board. It is envisaged that such a plant will serve several mills. Another concept is to produce methane gas from POME, and burning the gas in boilers, gas engines or gas turbines. It has been shown that such plants can meet the power and steam needs of the mills and still allow power export.

5.2. Environmental compliance

The national board and the independent power producers are required to carry out environmental impact assessment (EIA) studies and comply with strict environmental regulations. In fact, some power plants in Malaysia have already obtained ISO 14000 certification for environmental management. Continuous emissions monitoring are becoming the norm with many anti-pollution systems included.

The ability to sell excess power to the grid is also a new business opportunity for the palm oil sector. The plantation sector is a very seasonal business while power generation offers steady income. Renewable energy can then become a more acceptable form of energy, based on the government's target to achieve 5% of grid-connected power by 2005.

6. Conclusion

Renewable energy is a commodity just like any other from of energy. It has a major role to play in meeting the needs of global energy demand and in combating the danger of global warming. Presently, renewable energy represents 5% of all prime energy use, but by the year 2060, it is strongly predicted that it will reach 70%. In the Malaysia, 5% of the electricity generated by renewable energy can easily be met by renewable sources. Hence, to comply with the target sets by the recent Malaysian government renewable energy policy is practical and achievable by the year 2005. The target is very realistic considering the huge quantities of oil palm waste in the country and the existence of over 300 palm oil mills that are operating using solid waste from palm trees.

Renewable energy initiatives in the development of its technologies require adequate and predictive policies and regulatory framework for effective market development. It has been observed by lessons learned from many countries that grid-connected renewable energy has been fastest in countries that offered favourable policies and regulations.

For effective long-term development of the renewable energy technologies, government financial incentives should be continuously reviewed and revised, if necessary, to lead to an increasingly commercial market. Development of innovative financial mechanisms is essential for loan financing schemes that are acceptable to the users and provide adequate profits for lenders. The presence of a dedicated financial institution is very useful due to the riskier nature of renewable energy technologies. Awareness and information dissemination campaigns on the advantages of systems operating on renewable energy resources are also essential for the market development. Higher up-front costs of some renewable energy technologies are a deterrent for potential users and intensification of R&D effort is required to improve the technologies and to reduce these costs.

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