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Research paper

Evaluation of biomass energy potential towards achieving sustainability in biomass energy utilization in Sabah, Malaysia

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ABSTRACT

The potential of biomass energy in Sabah, Malaysia was analyzed by data which was established from literature, statistic data and available documents for estimating the potential of biomass energy derived from oil palm, coconut shell, rice, livestock and forest. Nowadays, the issue of solid biomass residues including effluent from the palm oil milling process has become a big concern for the industry and the public in Sabah, because oil palm residues provide a huge potential of biomass energy in Sabah. This paper showed that biomass energy potential in Sabah was around 267,179,818 GJ/year in total, which was derived from oil palm EFB, shell, OPF (oil palm frond), OPT (oil palm trunk), coconut shell, rice, livestock and forest. Potential of biomass energy from oil palm, coconut shell, rice, livestock and forest was 263,635,079 GJ/year, 95,713 GJ/year, 710,028 GJ/year, 750,696 GJ/year and 1,988,301 GJ/year, respectively. Most biomass energy came from oil palm, which was around 98.7% of total potential. If this total energy potential is applied at a power plant with efficiency ratio of 25% and 8000 h per year of operation, this has potential of 2,288 MW, which is equivalent to around 3.8 times of total supply of electricity in 2010 in Sabah. This paper also suggests that relevant policy and innovative technology be developed based on the result to effectively utilize biomass.

1. Introduction

In the twentieth century, large amounts of natural resources including food and energy were used to maintain a lifestyle of mass production, mass consumption and mass disposal. Considering limitation of such resources on the earth in the years to come, this type of lifestyle has to be changed and there has been strong desire and pressing need to build a sustainable society, where limited resources can be used in a sustainable manner. One factor necessary for developing a sustainable society is decreasing, or at least not increasing, the total amount of energy used. Another factor is to reduce the dependence on petroleum as a source of energy [1]. It has been also said that current agricultural practices which had been dependent on a large amount of petroleum might be defined as “converting oil into food” [2]. In this light, our challenge is to reduce dependence on petroleum as a source of energy. In other words, our society requires food and energy independence so that the area either at national, regional or local level can become independent both materially and in terms of energy usage [3].

The National Renewable Energy Policy and Action Plan in Malaysia stated that renewable energy in Malaysia had an insignificant impact on power generation. Ensuring the nation's sufficient and affordable supply of energy is paramount to ensure its stability in pursuit of economic development. Until now, renewable energy facilities cannot compete with conventional energy in terms of scale on unit sizes, and renewable energy is expensive compared to conventional energy sources. Coal will be more economic, and there are large coal reserves globally. But as coal affects

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environment by CO_2 emission and air pollution, coal is not sustainable energy. The continuation of Malaysia's use of natural gas to provide the fuel for energy generation cannot be sustained for the long term due to limited reserves. Also the impact of using carbon-based fuels for energy generation leads to environmental degradation and climate change. Thus, it is high time for Malaysia to consider renewable energy as a choice for sources of fuel for future power generation. As Malaysia is the second largest producer and the largest exporter of crude palm oil, biomass in the form of oil palm residue has a large potential of renewable energy. Finally, the development cost for renewable energy is expected to decline whilst the development cost for conventional energy is expected to rise [4].

Malaysia is blessed with many indigenous renewable energy sources 1) biomass and biomaterials such as oil palm residues, palm oil mill effluent, forestry biomass, solid waste, waste from agro-based and farming industries, 2) mini-hydro power, 3) solar power, and 4) wind energy. Thus, Malaysia has a huge potential of renewable energy for power generation. The detailed renewable energy resources potential, however, has not been yet fully examined and verified [4] and utilization pathways for the residuals should be explored. This research was carried out to evaluate the potential for power generation from renewable energy for the first time at each district in Sabah, focusing on biomass energy among a variety of renewable energies in the State.

2. Materials and method

2.1. Data collection

Data were collected through the official publications such as Yearbook of Statistics Sabah [5], Report on Crops Hectarage and Production in Sabah [6], Malaysian Oil Palm Statistics 2013 [7], and Sabah Electricity Supply, Industry Outlook 2014 [8]. Some data that was not found in the official publications was collected through individual hearings from organizations/agencies concerned. In case that basic energy information and date were not available in Sabah, reference data was collected through official documents available in Japan. Among the potential biomass, collected data included oil palm, coconut shell, rice, livestock (buffalo, cow, goat and pig), and forest. Published statistic data was mostly dated 2010. Data of 24 districts was collected while data on livestock had 32 districts and sub-districts in total. Thus, for the purpose of calculation, this difference was adjusted by integrating data of some districts and sub-districts such as Menumbok, Membakut, Bongawan, Pulau Banggi, Telupid, Sook and Putatan into one with their administratively neighboring districts.

2.2. Data analysis and calculation

Energy conversion factor (Calorie or Joule per kg or tonne) of each biomass was identified. Then, biomass energy of each biomass was calculated as follows.

2.2.1. Oil palm

In the process of oil extraction from dry FFB (fresh fruit bunch) and water, various products such as crude oil, MF(Mesocarp Fiber), seeds, shell, EFB (empty fruit bunch) and dirt are made. Among such products, EFB and shell are regarded as potential for biomass energy. Malaysian Oil Palm Statistics says that FFB in Sabah as a whole in 2010 is 20.16 tonne per hectare. As oil palm area (1,414,624.9 ha) can be found in the official statistics, production of FFB is around 30 million tonne. From 100 kg FFB, 23 kg EFB and 7 kg shell as a biomass can be produced [9]. Thus, EFB and shell produced annually in Sabah are 6.9 M tonne and 2.1 M tonne, respectively. In the mill process palm oil mill effluent (POME) is wasted and treated in anaerobic and aerobic ponding systems [10]. Recently for the POME treatment, anaerobic fermentable biogas systems are used to achieve wastewater treatment and electric power generation simultaneously. Since 67 kg of POME is wasted from 100 kg of FFB, 20.1Mtonne of POME is wasted in Sabah [10].

On the other hand, a huge amounts of biomass are left in oil palm plantation, typically oil palm frond (OPF) and Oil Palm Trunk (OPT). OPF is removed when FFB is harvested from the oil palm tree. OPT is left at the re-plantation period usually every 20 years. Since 50 kg dry OPF is produced from 100 kg of FFB, 15.0 M tonne of dry OPF must be produced annually in Sabah [10]. Since 20 kg dry OPT is produced from 100 kg of FFB, 6.0 M tonne of dry OPT must be also produced in Sabah [10].

Calorie conversion factor of biomass (EFB, shell, OPF and OPT) is set out as 4,300 kcal/kg [11]. Given that EFB shell, OPF and OPT contained 60%, 30%, 80% and 70% water, respectively, and that latent heat of water (neglecting any sensitive heat) is 560 kcal/kg; the calorie per kg of EFB, shell, OPF and OPT are calculated as 1,400 kcal/kg ($4,300 \times 0.4 - 0.6 \times 560$) 2,800 kcal/kg ($4,300 \times 0.7 - 0.3 \times 560$),410 kcal/kg ($4,300 \times 0.2 - 560 \times 0.8$) and 900 kcal/kg ($4,300 \times 0.3 - 560 \times 0.7$).

2.2.2. Coconut shell

In coconut shell, 1.8 M tonne of the shell was produced from 14.8 M tonne of coconut in case of the project in Philippines [12]. By utilizing this ratio, the amount of coconut shell in Sabah was measured. Calorie conversion factor (kcal per kg) was obtained from the case of Someya Corporation (3500–4000 kcal/kg) [13], and then it was averaged to 3750 kcal/kg.

2.2.3. Rice

Report on Crops Hectarage and Production in Sabah (2010) [6] showed paddy and rice production. The ratio of rice to paddy production was around 63% at all districts. Here, although it is a rough calculation, the rest (37%) was regarded as a potential for biomass energy. Considering this was rice husk, the energy conversion factor, 14.2 GJ/tonne was used by reference from the practical case in Japan [14].

2.2.4. Livestock (buffalo, cow, goat and pig)

Biogas from livestock waste can be considered as biomass energy. The number of livestock was obtained from Department of Veterinary Services and Animal Industry, Sabah. As it was difficult to find energy conversion factor in the official publication in Sabah, the available figures from research paper and documents in Japan were used for calculation [15,16]. Buffalo and cow have the same energy conversion factor as 7,665 MJ/year/head, while 1,260 MJ/year/head for goat and 1,533 MJ/year/head for pig were used.

2.2.5. Forest

Sabah Forestry Department makes an annual publication of forest reserves and other type of forest land [17]. Forest reserves consist of 7 different types, namely, Protection Forest Reserve, Commercial Forest Reserve, Domestic Forest Reserve, Amenity Forest Reserve, Mangrove Forest Reserve, Virgin Jungle Reserve and Wildlife Reserve. Other forest land includes Sabah Parks, Wildlife Sanctuary, Wildlife Conservation Area, and Timber Plantation. Most of forest reserves as protected area are strictly regulated for usage of forest resources inside the reserves. Among these forest reserves, here in this paper, data of commercial Forest Reserve, Domestic Forest Reserve and Timber Plantation, which are allowed to utilize forest resources in a sustainable manner, were analyzed to estimate forest-driven biomass potential energy. Even though it is small area compared to above-mentioned forest reserves, forests outside the