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Bioconversion Energy Technologies: Catalysts for Bioeconomical Development in the ASEAN Region

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Abstract: Biomass energy or bio-energy in the form of forest and agricultural wastes in ASEAN is a potential substitute for the rapidly depleting fossil fuels. Recent RD/D has resulted in various efficient devices from cleaner cook stove, and kiln, the use of solid, liquid and gaseous fuels, for example, in the transportation sector which can convert biomass energy under cleaner conditions. Despite the several techno-economic merits and socio-cultural benefits offered through this environment-friendly biotechnology there are still barriers in ASEAN countries that must be overcome. Problems range from the gathering of raw materials, the use of environment-friendytechniques, code and standardisation as fuels, and disposal of harmful effluents. Biomass conversion processes also yield new biofuels such as ethanol and methanol.[1]

Keywords: Bioenergy, bioconversion technologies, ASEAN countries, CHP technology, biofuels.

Introduction

Biomass energy in the form of fuel wood or agricultural wastes, and also known as bio-energy, is the common source of energy in most ASEAN villages. The consumption of bioenergy from forest and non-forest resources in the ASEAN member countries was more than 25-40 per cent of the total national energy consumption (FAO/RWEDP[2], 1997). Vietnam in using the highest share of biomass energy sources was followed by the Philippines, Malaysia and Indonesia. The lowest use of biomass resources was reported to be in Thailand.

Biomass in most ASEAN countries is mainly used in stoves for the cooking of daily food though some may use it to produce traditional food such as *tohu,* cake and cookies, tobacco curing, red sugar and

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brick-making industries. The efficiency of the stoves, usually very low, and mostly around 5 per cent, contributes to a large portion of the energy being lost to the environment. Moreover, since the stoves do not conform to industrial standards and are low in efficiency, they emit toxic gases which could cause acute respiratory infections (ARI). With continuous population increase, access to this energy resource is becoming more difficult necessitating availability of better and more efficient stoves.

Utilization of biomass energy has other outlets such as in providing easily accessible biogas energy for cooking, the supply through CHP[3] technology of processed heat and electricity to industry and alternative biofuels for the transportation sector. In counteracting rapidly depleting fuel wood resources for cook stoves several efforts have been made to identify locally grown diverse bioresources like inedible seeds, algae, nuisance and inedible plants such as water hyacinth and *Jatropha curcas,* respectively and agro-industrial residues from the palm and coconut oil industries like ice mills, plywood mills, saw mills, and sugar mills. The quantity of these wastes alone could reach around 1.2 GWe .

As a consequence of the Kyoto Protocol with the substitution of fossil fuel coal with biomass especially the development of biobased energy generation progresses at a faster rate. ASEAN member countries—Indonesia, Malaysia, the Philippines, and Thailand having ratified the Kyoto Protocol are eligible to submit benefit from the Clean Development Mechanism (CDM). This scheme encourages the use of various biomass energy technologies to reduce global greenhouse gas emissions.

ASEAN Initiatives

Today, many ASEAN countries are beginning to use vegetable and plant oil as substitutes for the rapidly depleting fossil fuels.

Indonesia, a member of OPEC currently has become a net oil importing country. Due to the uncertainty of supply and an increasing trend of fossil fuel in the future, Indonesia, since 2005 has launched a massive national programme to produce biofuels like biodiesel and bioethanol to substitute the around a US$ 17.4 billion importation of fossil fuels. The fuel substitution plan of Indonesia envisages a conversion of 11 million tons of bioethanol from cassava and 600 million tons from molasses to produce 1.85 million kilo litres of bioethanol, 30.2 million tons palm oil, and 3.84 million tons of Jatropha oil to produce 1.24 kilo litres of biodiesel, and 4.8 million kilo litres of bio-oil in 2010.[4]

According to the *World Energy Council Report*, (2007) in Malaysia, the biodiesel *Envo Diesel* was launched in 2006. Malaysia currently produces 500,000 tons of biofuel annually and an increase in production is expected this year. *Envo Diesel* blends 5 per cent processed palm oil with 95 per cent petro-diesel whereas EU's B5 blends 5 per cent methyl ester with 95 per cent petro-diesel. Diesel engine manufacturers prefer the use of palm oil to methyl ester blends as diesel engines are designed to handle 5 per cent methyl esters meeting the EN14214 biodiesel standard, which palm oil cannot meet.

From the Philippines, coconut oil-based biodiesel is already being exported to Europe and especially to Germany. Plans are underway to export surpluses to Japan. The CME (Coconut Oil Methyl Ester) facility has an annual production of 60,000 tons which is an expansion from the original capacity of 15,000 tons.

Thailand now produces 500 k-litres/day of biodiesel from palm oil and expects to show from the expected 16000 km^2 of oil palm area in 2011 an increased yield by 2012 of 8.5 million litres/day, Thailand also produces gasohol from molasses, cassava, sorghum, rice and corn. Beside producing bio-fuel, bio-diesel and bio-ethanol for cooking, power generation and for transportation, many countries in ASEAN are also trying to make use of their respective biomass resources to generate power and heat from locally available biomass resources, namely rice husks, bagasse, other agricultural residues using CHP technology.[5]

In Vietnam, biodiesel is produced from waste cooking oil with an approximate investment of US$ 605000 by the Ho Chi Min (HCM) city's Waste Recycle Fund. A local commercial facility in HCM city district 3 invested VND 8.1 billion and it expects to recover its investment after a 3-year period.

Notwithstanding the huge biomass potential available in the ASEAN region and elsewhere in the world and the many facilitator efforts of governments and the private sector, the practical use of bioenergy is still hindered by a lack of social awareness of the merit of bioenergy resources. Other factors are the less expensive conventional CHP system; and the unavailability of the incentive (feed-in tariff, net metering) and RPS[6] schemes are not yet available on a general basis. To promote the use of renewable energy sources by incentives such as feed-in tariff and a special tariff imposed in a Distributed Small Power

Generation in Indonesia, more time is still needed for RD&D and for operational government regulations to make this competitive with subsidized power generation now existing in the ASEAN region.

Biomass and Biofuel Potential

Biomass it is now widely accepted has potential as a source of renewable energy. However its exact definition is yet to be agreed upon since biomass as fuel can have different forms, solid, liquid or gaseous fuels in relation to energy modeling such as in development planning. This is so particularly when a certain energy mix which include biomass energy become one of the probable scenarios to reduce green house gas emission. Sayigh (2003) for example, proposed the term modern biomass to differentiate bioenergy in the form of intact fuel wood with that of charcoal, which has been processed through conversion technology such using the pyrolysis process.

Biomass is defined as all organic matter except fossil fuels: that is all crop and forest materials, animal products, microbial cell mass, residues and byproducts that are renewable on a year-to-year basis.[7] This latter definition is used by the author of this contribution. Thus, for Indonesia, the targeted of >15 per cent of renewable energy share in 2025 would been surpassed this year from only the traditional fuel wood along with contributions from other renewables such as solar, wind, small hydro, geothermal and marine energy. Based on the Indonesian Presidential Instruction concerning biofuels (2006) the share of biofuel in 2025 should cover at least 5 per cent of the total national energy consumption.

Biomass consumption in rural areas of developing countries (including all types of biomass and end-uses) was about 1 ton (15 per cent moisture, 15GJ/t) per person/year and about 0.5 ton in semi-urban and urban areas.[8] The increasing interest in biomass for energy since the early 1990s is well illustrated by the large number of energy scenarios showing biomass as a potential major source of energy in the twenty first century. Hoogwijk *et al.* (2001) and Berndes et al. (2003) classified 17 such scenarios, into two categories: (i) Research Focus (RF), and (ii) Demand Driven (DD). For the period 2025-2050, the estimated potential of the RF varies from 67 EJ to 450 EJ whereas that of the DD varies from 28 EJ to 220 EJ. The share of biomass in the total final energy demand lies between 7 per cent and 27 per cent. For comparison, current use of biomass energy is about 55 EJ. Biomass will play an important role as one of major primary energy supply system in the year 2050.[9]

Biomass resources are potentially the world's largest and most sustainable energy source - a renewable resource comprising 220 billion oven-dry tons (about 4 500 EJ) of annual primary production.[10] The estimated annual bio-energy potential is about 2900 EJ, though only 270 EJ could be considered available on a sustainable basis and at competitive prices. Despite its huge potential and the difficulty of obtaining accurate data on biomass resources a resort to satellite data imagery may help estimate the vast area to be covered and the changes over time for data collection.

Many problems remain in the collection and delivery of the amount of supply of these potential resources as compared to oil and gas. Although data from different sources may differ from different sources, potential resources may be estimated using conversion factors such as those recommended by Wichakorn and Bundit (2004). Table 1 shows estimated biomass energy potential in the ASEAN region reported by the WEC (2001).

Biomass Conversion Technology — Solid, Liquid and Gaseous Fuels

Biomass can be converted into more useful solid, liquid and gaseous forms before being used as an ordinary fuel. Intact woody materials or agricultural residues usually have relatively low calorific value as compared to those from fossil fuel. A solid wood, for example, may have a calorific value of 16.3 MJ/kg which is much lower than diesel oil which has 43.1 MJ/kg. or coal, which has 26.3 MJ/kg (Stout, 1991). However, if biomass is transformed into bio-briquettes, its calorific value would increase between 13- 20 MJ/kg.[11] If converted to gaseous fuel 1 kg of rice husks, can produce about 44 Nm^3 of combustible producer gas.[12]

Table 1. Biomass Potential in some ASEAN Countries (million tons)

Biomass Type/	ASEAN Member Country		
	Indonesia	Philippines	Thailand
Sugar cane bagasse	6.5	7.0367	15.61
Rice husk	14.3	1.939	4.936
Coconut shells/fibres	2.1	5.638	n.a
Palm oil residues	8.5	-	n.a.

Source: Data extracted from WEC Report (2001).

Solid Biomass Fuels

Wood Wastes

Biomass as solid fuel can be produced using densification, pyrolisis, chipping or size reduction process. Pellets, biomass briquettes, and charcoal are solid fuels in this category. Characterization and standardization of these fuels may find potential applications in value added industries particularly to uplift the standard of living of the rural population in ASEAN countries.

Wood wastes such as sawdust or rice husks can be used directly as solid fuel for cooking, drying or other thermal processes using a simple stove. A used oil drum or a combination of a biomass stove and heat exchanger can provide a relatively constant heating temperature for drying agricultural and marine products.[13] Battacharya et al. (2003) have discussed the potential benefit of the gasification-based cooking system in the ASEAN region using intact or processed biomass fuel. These stoves have a relatively higher thermal efficiency and are cleaner than that of the traditional cook stove.

Briquettes

Briquetting of biomass has been studied extensively within the FAO Regional Wood Energy Development Programme (RWEDP) in Asia.[14] Basically the briquetting process produces solid biomass fuel with density between 1-1.2 g/cc using the Japanese design Shimada Screw Press (40 Hp) with different hard facing alloys for the screw in order to extend its service life. Tungsten carbide was the best hard facing alloy for the screw. Preheating of raw material to be densified has a significant effect on the screw life.[15]

Briquetting of biomass residue has been conducted at the Laboratory of Energy and Agricultural Electrification, Department of Agricultural Engineering, IPB.[16] Bio-briquettes from different kind of biomass wastes are made using the following procedure: Raw materials, dried and ground after sorting from foreign materials are fed into a pyrolysis reactor to produce charcoal. The charcoal flour is pressed using a simple manual press. Dried rice husks as raw materials are directly fed into a mechanical press to produce bio-briquettes.

The resulting briquette samples were then tested using the bomb calorimeter to determine their respective calorific values (CV). Corn cob and waste sludge bio-briquettes had the highest and lowest CVs, respectively (Table 2).

Table 2: Performance of the Briquetting Plant at IPB

No	Raw material for briquette production	Heating value (KJ/kg)
1	Sugarcane waste (sludge) briquette	17638
2	Rice husk charcoal briquette	13290
3	CPO waste (sludge/mud) briquette	10896
4	Saw dust briquette	18709
5	Grass briquette	16247
6	Coconut shell charcoal	18428
7	Corn cobs	15455
8	Corn cobs charcoal briquette	20174
9	Wood fuel (acacias)	17270
10	Bamboo	17503

Source: Augustinah (2007).

Wood Pelleting

Another method of densified biomass fuel making is pelletting. Wood pellets of compacted biomass increase make it more economic to transport over longer distances. Most pellets are made from sawdust and ground wood chips that are waste materials from house construction, furniture making, lumber, and residues from other activities that use wood.

Commercial pellets are sold in cylindrical form with (5-6 mm in diameter and 15-25 mm in length) with moisture content of 7-8 per cent (wet basis). Such pellets are suitable for wood stoves designed for space heating in countries located in cold regions. Some cooking stoves can produce a cleaner flame compared to that of the traditional stove. Beside wood chips and shavings, grass, nut shells, straw can also be used as pellet materials. Another type of stove which uses intact biomass materials such as cut twigs, fire wood is the Anagi stove developed in Sri Lanka by the Ceylon Electricity Board in 1986 and promoted by the ICS network of ARECOP.[17] The two-pot single-piece stove with a claim of 21 per cent efficiency has been produced and distributed to villages in the region through the ARECOP improve cook stove network.

Liquid Biomass Fuels

Pyrolysed-derived Biomass Fuels

The theory of pyrolisis of solid biomass has been described in great detail by Stout (1991) and Manurung (2003). The problem in defining the pyrolisis process is that it is process-oriented in time used both for char and tar processes.

Rice is a major crop in many ASEAN countries. About 20 per cent of the harvest is in the form of rice a husk which biomass resource is usually dumped or burnt near rice mills and that causes environmental pollution. Conversion into useful materials such as the Carbonized Rice Husk (CRH) or into solid, liquid and gaseous fuel via pyrolisis is recommended to counteract pollution. Pyrolysis of rice husks with a fixed bed converter has been studied thoroughly in Indonesia. A small pilot plant using rice husks as a feed has been established at the Bandung Institute of Technology (ITB), Indonesia[18]

Conversion of biomass into liquid fuels is also achieved through:

i) Fermentation of ethanol from sugarcane, cassava, rice;
ii) Synthesis of producer gas and from wood to produce methanol;
iii) Extraction of oil from seeds.

Plant Oils

The potential of plant oils as biofuels in the region to reduce the pressure of the oil crisis in the region has been considered only recently by ASEAN member countries. Indonesia, Malaysia, Thailand and the Philippines have launched national programmes to grow millions of hectares of palm oil plantations, the physic nut (*Jatropha curcas*), coconuts and various seeds. However, till to date individual ASEAN member country data on the availability and productivity of such plant bioresources is still meagre. An entrepreneurial facility in Indonesia has already invested in bio-ethanol production in Sumatra using cassava and its residues as raw materials. Another Indonesian commercial entity that has its core activity in sugar cane plantation is investing in the physic nut plantation for biodiesel production.

The current practice in the oilseed extraction industry is to use screw pressing (expeller), hydraulic press or solvent extraction to separate the oil-bearing seeds from physic nuts (Jatropha).

Screw pressing of Jatropha can extract around 25 per cent of oil. The pulp cake of Jatropha after oil extraction is bioconverted into a gaseous fuel using an anaerobic digester. A recent test at the ITB showed that 1.5 m^3 of digester fed daily with 25 kg Jatropha cake + 25 litres of water produces biogas adequate to substitute kerosene for one rural household family of four.

Despite several efforts to use Straight Vegetable Oil (SVO) for bio-diesel and bio-kerosene, there are several major problems in using unmodified plant oils as alternative diesel fuels. Use of SVO produces clogging of fuel lines and filters, polymerization of oil during storage, thermal or free radical polymerization in the combustion chamber, poor ignition and thickening or increased solids contamination of the lubricating oil. There are several sources of bio-diesel raw materials found in the ASEAN region.[19] These are:

1) ***Edible Sources:*** palm, coconut, peanut, *Moringa oleifera*, *Adenanthera pavonina*, *Carthamus tinctorius,* etc.,
2) ***Non-edible:*** *Jatropha curcas*, kapok, candle nut, neem (*Azadirachta indica*), *Calophyllum inophyllum*, kusum (*Schleichera oleosa*), *Bombax malabaricum*, *Jatropha multifida*, *Jatropha gossypifolia*, and many others.

Biodiesel blends used in the ASEAN region use the following: i) the Coconut Methyl Ester (CME) in the Philippines; ii) the Palm Oil Methyl Ester (POME) in Malaysia. Market products are: B20 in Indonesia; B10 in Malaysia, and B5 in Thailand.

Biomass Conversion to Ethanol and Methanol

Ethanol or grain alcohol is a good fuel for spark ignition engines. A heat value per liter of ethanol is nearly 20 MJ/litres, higher than that of methanol which is 15.88 MJ/litres. Ethanol and methanol are produced by completely different processes though using sometimes similar feedstock.

Ethanol can be made from molasses as a byproduct from the sugarcane industry and from wood chips through fermentation. When used as a gasoline blend, anhydrous ethanol as fuel can be graded up from 5 to 10 per cent in the ASEAN region. Whereas Indonesia has B10 and B15 for export to the US, the Philippines uses a 10 per cent bio-ethanol and 90 per cent gasoline mix.

Methanol or "wood alcohol" is synthesised by gasifying the feedstock to make a CO mix which is cleaned and pressurized in the presence of a catalyst to produce methanol that is used in transesterification of plant oil to produce biodiesel.

Biomass Conversion to Gaseous Fuel

Gaseous fuel from biomass can be produced through gasification or the biogas digester. Gasification is the conversion of carbonaceous solids in biomass into combustible gas, namely CO, by controlling or limiting the rate of oxygen (air) admitted to the fuel bed. Biogas is a product of the anaerobic digestion of biomass and is also commonly known as CH_4 (methane).

Biogas

Biogas is a product of the anaerobic digestion of biomass. This bacterial process is widely used in Indonesia and Malaysia, the Philippines, Thailand, and Vietnam. The amount of gas produced is dependent on the digester size, the volatile solids loading rate, the temperature within the unit and biodegradability of the feedstock. Mesophilic bacteria, one of the two methanogenic bacteria are most active at 35^{o} C whereas the thermophilic bacteria are active at 54 ^{o}C.

Biomass Energy Conversion to Electricity

Direct Combustion

Power or electric generation from biomass is obtained through conventional direct combustion to produce adequate high pressure steam to operate a turbine to generate electricity. A potential biomass resource is that of rice husks found abundantly in several ASEAN countries notwithstanding that this bioresource has a low caloric value. An example of rice husk power generation is in the Roi Et Province in Thailand.[20]

Conclusion

Biomass in the form of fuel wood, wood or agrowastes can be used directly for traditional food and cookies in cottage industries in the rural areas of ASEAN member countries. Electricity has been generated from waste rice husks.[21] It can also be used as the main heat source in rice processing industries as practiced in Thailand and Vietnam and as auxiliary heat in the solar drying system in Indonesia. Special furnaces fed with rice husk, corn cob or wood to supply heat for rough rice drying have been used in Vietnam. Commercial continuous fluidized bed dryer can be used to dry corn, rough rice and soy beans.[22]

Endnotes

1 Han et al, (2005).

2 The Regional Wood Energy Development Programme for Asia [for 16 member countries] was supported by FAO and the Government of the Netherlands from 1985 to 2001. The RWEDP office was finally closed down in December 2002 ; FAO-RWEDP (www.rwedp.org) and FAO (1999).

3 Combined Heat and Power Technology which is environment-friendly.

4 Soni (2007) and Soni et al. (2006).

5 Combined Heat and Power Technology which is environment-friendly.

6 Research Promotional Scheme that focuses on the development of innovations in established and use of newer technologies; concerning bioconversion technologies

a green certificate is issued by local governance in some countries in relation to the use of renewable resources.

[7] Hiler and Stout (1985).

[8] Rosillo-Calle (2001).

[9] Olesen and Kvetny (2001).

[10] Hall and Rao (1999).

[11] Agustinah (2007).

[12] Hoki, et al, (2006).

[13] Kamaruddin (2002).

[14] FAO (1999).

[15] Misra et al. (1995).

[16] Agustinah, (2007).

[17] The Asia Regional Cook Stove Program located in Jogjakarta, Indonesia was initiated in 1991 as a network that facilitates the development of effective improved cookstove and biomass energy programs at the household and small industry levels. The Network whose Member countries are Bangladesh, Bhutan, Cambodia, China, East Timor India, Indonesia, Lao P.D.R., Nepal, Philippines, Sri Lanka, Thailand and Vietnam provides a bridge-serving facility for exchanges of information, skills, expertise and resources among sectors as diverse as government institutions, NGO, academic and research institutions, community based organizations, international agencies and private institutions (www.arecop.org).

[18] Manurung, (2003).

[19] Soerawidjaja (2003).

[20] Thipwimon et a.l (2004).

[21] Hoki, M, and Orpilla, D.L. (2006).

[22] Soponronnarit (2002).

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