Chapter 2

Potential and Use of Bioenergy in The Association of Southeast Asian Nations (ASEAN) Countries – A Review

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/51917

1. Introduction

Bioenergy is considered to be the largest renewable and sustainable energy source of the world's total primary energy supply. At the same time biomass provides fuel for production of 1% of the global electricity generation. It provides 26% of the total primary energy supply and accounts for 87% of the renewable energy supply in Southeast Asia [1]. A very strong community similar to the European Union has emerged consisting of ten member countries: Indonesia, Malaysia, Philippines, Singapore, Thailand, Brunei Darussalam, Vietnam, Lao People's Republic, Myanmar, and Cambodia; and known as the Association of Southeast Asian Nations (ASEAN). Biomass is an important source of energy in these countries and its use is still increasing. The rural population of this region and small industries use it as their energy source. Many countries of this region are among the top producers of agricultural products such as rice, sugar, cane, palm oil, coconut and rubber. The other important biomass resources are the agricultural residues such as bagasse, rice husk, palm oil waste, wood waste, logging wood residues, rice straw, sugar cane trash and coconut shells which accounts for more than 120 million tonnes per year [1]. Bioenergy can be converted into heat, electricity, liquid fuels, such as biodiesel bioethanol, methanol, dimethyl ether (DME), or gaseous biofuels like biogas and hydrogen indicating that it is capable of replacing each type of fossil fuel as well as producing clean energies. Literature reports that ASEAN countries produce $30\,million\,m^3$ of wood residue, $19\,million\,tonnes$ of rice husk and more than $27\,million\,tonnes$ of palm oil residues which can produce approximately $41,\,000\,MW$ of power [2]. A substantial amount of these residues are disposed through open burning and dumping while only a small fraction of it is used as a fuel for heat, electricity generation and household cooking indicating that the use of biomass not only provides alternatives to current energy sources but also eliminates disposal problems associated with generated agricultural residues [1].

The United Nations Framework Convention on Climate Change (UNFCCC) has established an international policy framework for reducing greenhouse gas (GHG) emissions through a programme known as “Clean Development Mechanism” (CDM). A number of such projects have been initiated in ASEAN countries which are beneficial to reduce emission of GHG due to open field burning of forest as well as agricultural residues. With these projects not only the emission of GHG is reduced but more sustainable methodologies in managing natural resources to achieve more efficiency has also been demonstrated.

The objective of this study is to report the potential and the present use of bioenergy in the ASEAN countries focusing on power generation potentials using available biomass resources and the utilisation of CDM projects to achieve energy sustainability.

2. Clean Development Mechanism (CDM)

The United Nation Framework Convention on Climate Change (UNFCCC) established international policy framework for reducing greenhouse gas emission that was adopted at the third Conferences of the Parties (COP-3), the Kyoto Protocol aims to stabilize atmospheric concentrations of greenhouse gases at a level that would prevent dangerous climate change. To make this target achievable and cost effective, provision was given that reduction in GHG could be carried out at any location on the globe because ultimately it has the same effect on the environment. Therefore, it is economically more feasible if developed countries reduce GHG emissions in developing countries rather than at home. This flexible mechanism to reduce GHG emission introduces a new concept known as “the Clean Development Mechanism, (CDM)”. The CDM enables developed countries to invest in emission reduction projects in developing countries. It will provide the opportunity to the developing countries to achieve sustainable development and assist developed countries in achieving reduction in GHG in cost effective way [2].

The host country undertaking the CDM projects reduces GHG emission and has the potential to earn carbon credits that can then be traded with a buyer (developed country) providing an additional revenue to finance the project. The introduction of this idea provides new opportunities for developing countries to set up projects that would not be otherwise possible without carbon credits and have the potential to [3]:

- improve local waste management practices (disposal of waste through composting or combustion, landfill gas recovery)
- support the use of renewable energy (e.g. combined heat power production from biomass, biogas, solar, wind)
- encourage energy efficiency initiatives (cogeneration, efficient chillers, energy saving lamps, heat recovery)

http://dx.doi.org/10.5772/51917

- waste to energy (disposal and management of municipal solid waste, agricultural and forest residues)

The host country is directly responsible for assessing the sustainability of CDM projects as per Bonn agreement "The Conference of parties agrees to affirm that it is the host party's prerogative to confirm whether a clean development mechanism project activity assists it in achieving sustainable development" (UNFCCC, 2001). The developing countries of ASEAN community (Cambodia, Lao PDR, Myanmar and Vietnam) are lacking in technical know-how along with non availability of data for assessing the sustainability of proposed CDM projects make it difficult to compute the net reduction in GHG emission on completion of the proposed project. Feasibility studies are carried out by hiring foreign expertise to compete for such projects which is time consuming and usually responsible for delay leading to fewer approved CDM projects for these countries [2]. The priority areas identified by the member of ASEAN nations for CDM projects are tabulated in Table 1.

Cambodia [4]	**Indonesia** [5]	**Lao, PDR** [6]
Wetwaste Biogas-electricity Rice husk/woodwaste gasification Waste management Waste to Energy Agro-forestry	Clean Energy Conservations CHG friendly agriculture and husbandry practices Sustainable waste management GHG mitigation in industries and transportation sectors	Afforestation & reforestation Biomass and biogas Energy efficiency
Malaysia [7]	**Myanmar** [8]	**Philippines** [9]
Energy efficiency and Renewable energy Biogas: POME & animal manure Landfill gas Biomass CHP Biofuels Waste management	Energy crops & biofuels Renewable Energy Afforestation & forest conservation	Waste management Renewable energy Afforestation & reforestation
Singapore [10]	**Thailand** [5]	**Vietnam** [11]
Environmental sustainability Economic sustainability Social sustainability	Biomass and biogas Solar and Wind Biofuels Fuel switching (oil to biofuels) Production process improvement Waste to energy	Energy efficiency, conservation and saving Fuel switching Methane recovery and utilization from waste disposal sites and coal mining Application of renewable energy sources Afforestation & reforestation

Table 1. The ASEAN countries proposed priority areas for CDM projects

The registered CDM projects in different ASEAN countries as of 1st November 2009 are given in Table 2.

Country	Total	Active	Rejected
Cambodia	5	5	0
Indonesia	117	95	23
Lao PDR	2	2	0
Malaysia	167	128	41
Philippines	89	75	15
Singapore	8	8	0
Thailand	119	112	7
Vietnam	93	85	8

Table 2. CDM projects in ASEAN countries (adopted from Status and barriers of CDM projects in ASEAN Countries, UNEP) [3]

These projects concentrate on agriculture, biomass, landfill gas to electricity, biogas from wastewater treatment and biogas from biomass. The developed countries of the region: Indonesia, Malaysia, Philippines and Thailand have a large number of active projects in the pipeline while Cambodia, Lao and Singapore have only a few projects. Brunei Darussalam and Myanmar have no CDM projects because Brunei Darussalam has no designated national authority (DNA) or recently established DNA and Myanmar's previous closed-door international policy made it unfavourable. Recently Japan showed interests to support CDM projects for sustainable development in Myanmar. The development of CDM projects highlights the efforts of the host country to opt renewable energy which are available and its potential yet to be realized.

3. Brunei Darussalam

Brunei Darussalam has an annual waste of 189,000 ton and there are six landfill sites: one in Brunei/Muara, two in Tutong, two in Belait and one in Temburong districts. There is a potential of bioenergy from this solid waste equivalent to $1.3 \times 10^{5}\,kWh\ year^{-1}$[12]. Schnitzer and Ngoc [13] reported that Brunei with a population of 383,000 persons has a waste generation of $0.66\,kg\,cap^{-1}\,day^{-1}$consisting of 22% paper, 44% food waste, 2% plastic, 5% metals, 4% of glass and 13% others. Research and development projects are underway to study the feasibility for generation of electricity from solid wastes.

http://dx.doi.org/10.5772/51917

4. Cambodia

Cambodia consisting of 21 provinces has 24 isolated diesel power systems located in provincial towns and cities. Per capita consumption is only about 48 $kW\ year^{-1}$ and less than *15%* of households have access to electricity (urban 53.6%, rural 8.6%) and the amount of electricity consumption is as follows: private sector 0.5%, service sector 40%, industrial sector 14%. The supply requirements are projected to increase on average by 12.1% per year, and the peak load is expected to reach to *1,000 MW* in 2020 [19, 21]. 85% of the Cambodian population lives in rural areas and less than 10% of the rural households have access to electricity. Most of energy resources of the urban population are dependent on forest and 98% use woodfuel for cooking [14] and as a result its natural forests have been severely degraded due to logging over the last three decades. Researchers recommend that intervention is needed to ensure a sustainable supply of woodfuel exists in the long term. They are optimistic that increasing woodfuel production, better management of forests and firewood plantations, and introducing non-forested sources such as shrubs for cooking can lead to forest sustainability in Cambodia. Kampong Thom Providence has the highest potential of biomass as an energy source. Top et al. [14] and Top et al. [15] claimed that the potential supply was higher than demand indicating that forest resources and use of woodfuel in this providence are sustainable. Top et al. [16] stated dependence on woodfuel should be decreased by replacing traditional cooking methods with more efficient stove types. Abe et al. [17] studied the potential of rural electrification based on biomass gasification in Cambodia and reported that small scale gasification systems capable of generating electrical power in the range of 4kW would be the most appropriate for rural mini-grid electrification. This study revealed that besides the agricultural residues consisting of rice husks, cashew nut shells and sugarcane which have high energy potential, the proper tree farming and plantation could provide sufficient sustainable sources to supply a biomass gasification system. Koopmans [18] reported that total wood biomass for the year 1994 was 82,022 *kton* and for the year 1990 was16, 900 $ton\,km^{-2}$. However, biomass gasification is economically competitive compared with diesel generation but a comprehensive study to quantify biomass production across multiple rotations and with different species across Cambodia is urgently needed.

Japan Development Institute (JDI) and Kimura Chemical Plants Co., Ltd. based on the request of the Office of the Council of Ministers conducted a study on “Cambodia Bio-energy Development Promotion Project” which was partially supported by Engineering Consulting Firms Association (ECFA), Japan and reported that bioethanol and biodiesel can be developed using cassava and Jatropha, respectively and can be grown in Cambodia without intensive irrigation systems. It was recommended that in order to meet the future target for bioenergy production, Cambodia should expand planting for cassava and Jatropha to a few million hectors each by 2020 targeting to become a net exporter of energy [19]. This study provided a foundation for substantial investments from both local and foreign (Thailand, Malaysia, Koeria, China and Singapore) sources in the development of bioethanol and biodiesel. Almost 5% of the Cambodian national land area is given to private companies for the development of agro-industrial plantations [20]. The Government of Cambodia has been providing special concession scheme to investors to invest in biodiesel production that is mainly focused on Jatropha as feedstock crops. A number of initiatives are still under either planning or implementation stages.

Bioenergy, energy efficiency, waste management, deforestation and forest degradation are the potential areas for CDM projects in Cambodia. There are four approved project on biogas, one on waste/heat gas utilisation and one on biomass and completion of these projects would be able to reduce an annual emission of CO_2 of 204, 308 $t\ year^{-1}$[4]. Literature reports that the country lost 29% of its primary evergreen forests to severe degradation between 2000 and 2005 [21]. A case study is under validation to manage these degraded evergreen primary forests in Cambodia for sustained flow of timber and other ecosystem services that could lead to financial incentives through a carbon payment scheme under global climate change mitigation through reduction emissions from deforestation and forest degradation (REDD-plus) scheme [22].

The aggregate technical potential for electricity generation from biomass consisting of forest products, agricultural crops and residues, municipal waste and sewerage has been estimated using computer simulation techniques at18, 852 $GWh\ per\ year$. The findings do not explicitly indicate the provision of efficiency in this analysis. Small scale projects based on simplified technologies are most appropriate as CDM projects for Cambodia. However several CDM projects are in implementation or registration/validation phases but low awareness among policy makers and the private sector, weak institutional capacity, lack of human and technical resources, inappropriate policies and strategies are the major limitations to avail opportunities for carbon trading through CDM [3]. Four out of five active CDM projects on rice husk cogeneration, rubber plantation, improved cookstove and biogas in Cambodia would reduce emission by $4.2\ MT\ CO_{2e}$ over a period on 7-30 years.

5. Indonesia

There is a severe reduction in fossil fuel supplies in Indonesia. The current oil and gas reserves are reported to be approximately 747 million cubic meters (94.7 billion barrels) of oil and *2557* million cubic meters (*90,300* billion cubic feet) of natural gas representing a 13% reduction in supplies which is significant because the demand for fossil fuels has already exceeded the supply capacity of Indonesian oil industry [23]. Among the several alternative renewable energies available for the country to be harnessed, bioenergy has generated considerable interests and shows theoretically an adequate potential to overcome the energy shortage and create a balance between the energy demand and supplies for Indonesia. Bioenergy is renewable and reduces CO_2 emissions when substituted for fossil fuels [23].

Indonesia is an agrarian country and has approximately 90 million hectares of forest indicating that it should concentrate on the development of biomass-based energy programs. At the same time it was ranked among the top ten countries on the globe encountering a net loss of forest area during the era 2000-2005 [23] indicating that bioenergy development projects should be designed in such a way that do not aggravate the loss of forests for sustainability and viability for long term applications. There was approximately *13 million Mg* oven-dry-weight of forest biomass in 2005 [24] another study reports that aboveground forest biomass ranged from ~ 5000 *to* $11,000$ *million Mg*[25]. It is reported that the quantity of wet biomass that can be harvested from 'production forest' and 'other land with tree cover' could be approximated in three ranges which are: *5083 million Mg* (a lower bound), *5410 million Mg* (a moderate bound) and *10,726 million Mg* (an upper bound). The wet biomass was converted to dry weight equivalent using data from the Global Forest Resources Assessment 2005: Indonesian Country Report [26], State of the World's Forest 2005 [24]; and global Forest Resourses Assessment 2005: progress towards Sustainable Forest Management [27]. Suntana et al. [23] reported that if Indonesia converts forest biomass into bio-methanol for electricity generation and as a gasoline substitute then annually 10,063,731 households could be provided with electricity continuously using a *1kW* fuel cell. The results reported are obtained using widely accepted calculation methods due to Vogt et al. [23A] which uses the quantity of biomethonal produced from the annually collected forest biomass and the amount of electricity and transportation fuel that could be substituted by the biomethanol produced from the annually forest materials. With the use of only 5% of forest biomass and converting it to bio-methanol as a gasoline substitute would be equivalent to the total quantity of gasoline consumed in Indonesia during the year 2005. The use of bio-methanol as a substitute for fossil fuel to power vehicles could avoid the emissions of 8.3-34.9% of the total carbon emitted in Indonesia. Timber extraction data from the 1980s reveal that *7.5 million* m^3 *per year* log wastes are generated during harvesting operation that corresponds to about *3.75 million Mg* biomass and is equivalent to collecting biomass materials from $124,000\ ha\ year^{-1}$ of forest land. 29.5 million litres of bio-methanol can be produce with an efficiency of 25% and could avoid *21.7* Gigagrams *(Gg)* of carbon if it is substitute for natural gas-methanol in fuel cells or *1.97 Gg* of carbon when it is used to supplement gasoline.

Indonesia is the third-largest producer of rice in the world and produced 65,150,764 metric ton in 2010 compared with 64,398,890 metric ton in 2009. Rice bran containing 13.5% oil has a potential for extraction of biodiesel. Gunawan et al. [28] studied rice bran for a potential source of biodiesel production in Indonesia and claimed that 96,000 ton of biodiesel can be obtained from rice bran per year.

Oil palms is another energy crop which were grown on 3.6 Mhectares of land in 2005 and Indonesia is strengthening its production with the increasing worldwide demand for biodiesel derived from oil palms. These trees start bearing fruits approximately 30 months after planting in field and continue to be fertile for a period of 20-30 years ensuring a consistent supply of oil. The estimate for the additional land demands for palm oil plantation in 2020 range from *1 to 28 Mha* in Indonesia that can be met to a large extent by degraded land as well as agricultural management such as implementation of best management practices and earlier replanting with higher yielding plants. Palm oil production has played a major role in land use change in Indonesia [29] and it produces 44% of the world's palm oil as per records for the year 2009. It is predicted that palm oil would be the leading internationally traded edible oil by the year 2012 [30] and the palm oil industry in Indonesia looks forward for high pressure modern power plants to cope with future demand. It is estimated that the residue of palm oil consisting of empty fruit bunch, fiber, shell, wet shell, palm kernel, fronds and trunks has a potential for annual power generation of *5000 GWh* [31]. The transition of energy scenario from fossil fuels to biomass has been underway using existing technologies. In order to make it practically effective requires substantial investments in infrastructure, conversion technologies and in research and development (R&D) for palm oil biomass.

The other feedstocks for biofuel in addition to palm oil, forest biomass and rice bran are crops waste (rubber truck, coconut, sugarcane), waste of food crop products (cassava, sjatropha, sorghum,, soybeans, peanuts, maize, paddy) account for 12.77×10^{6}tonnes per year and 87.45×10^{6}tonnes per year, respectively [32]. The crops waste are residues left in field after grain harvest. The Government of Indonesia is in the process of preparing additional land for growing high-yield feedstocks to meet the country's biofuel production goals of 5.57 million kiloliters of biodiesel and 3.77 million kiloliters of bioethanol [33].

The U.S. Department of commerce claimed that biomass installed capacity for energy source in Indonesia is *445MW* which is only 1% of the total resource potential of 49,810MW. The country has targeted 810MW with a conversion efficiency of about 30% of biomass power by 2025 with an increase of 83% but still it is far less than the potential contribution [33].

Research conducted at BPPT-LSDE in Indonesia reported on a plan to construct 1500 litre per day capacity biodiesel using palm oil waste. The domestic manufacturing capacity of biomass gasifier is improved and capable of producing $15-100\,kWe$for rice mill and wood mill power supply as well as for rural electrification. The Indonesian Government has been focusing its policy on bioenergy diversification and introduced a huge plantation of Jatropha curcas as an additional biodiesel source which is non-edible and has well known potential to be converted into biodiesel [34].

Jupesta [35] studied technological changes in the biofuel production system in Indonesia using mathematical modelling consisting of two scenarios: the base scenario and the technology scenario. The base scenario assumes the conditions and data set in the Indonesian Government's Mix Energy policy that relies on an increase in biofuel production by increasing the land allocation for biofuel while the technology scenario concentrates technical change consisting of growth in yield and a cost reduction in addition to the growth in land allocation. The author reported that the highest contribution is likely to come from palm oil that accounts for 93% and 64% of the technology scenario and the base scenario, respectively. The excess production for export increases in both scenarios. But the technology scenario gives more competitive results.

The substantial amount of bagasse in sugar mills can provide fuel for electricity-generating projects in Indonesia that will most probably be considered for the Clean Energy Development Mechanism (CDM) scheme. A recent study concluded that this source has a potential of $260,\,253\,MWh$ that could generate a Greenhouse Gas (GHG) emission reduction of 240, 774(large scale) or 198, $177\,tCO_2$(small scale) annually. The present low efficiency cogeneration for those values lead to the earning of about US$1.36 or 1.12 million respectively.

Out of six regional grids in Indonesia where the electricity from the project activities can be grid-connected, primary emission reductions potentials exist in Java, Bali and Southern Sumatera grids [36].

Utilization of palm oil mill effluent (POME) to generate electricity by minimising the emanation of methane gas could reduce GHG emission of 47, 222 tCO_2 per year. The feasibility study of this project that was funded by NEDO Japan is completed and is expected to be considered for CDM scheme and be financed by developed countries. The expected finance for this project could be from Japan [37].

A study financed by the World Bank revealed that the country has a potential to mitigate GHG emissions of over 3 billion tons of carbon dioxide equivalent (CO_{2e}). There are large scale possibilities for emission reductions in the energy sectors. Biomass offers a large potential for CDM projects [3].

6. Lao, P. D. R.

Wood and charcoal were the most dominated traditional energy resources for the period 1996 to 2002 that account for about 75% of the total national energy consumption. Wood is mainly used for cooking and space heating and in rural areas still accounts for up to 90% of the energy consumption. An increase of 4.8% in the total energy use with reference to period 1996-2002 is noted. The Government is keen to develop bioenergy for which more than 2 million hectares of ideal land has been initially identified for biofuels feedstock plantations which is a major step to produce enough biofuels by 2020. Protected area management system is enforced in Lao PDR and a recent study on improvement and implementation of protected area management with positive interaction between people and the natural environment was conducted using a simple simulation model, the “Area Production Model” aiming at evaluating different options for land use and primary production. The findings of this research reveal that the integrated land-use planning approach was found to be well adapted to the needs of the protected area management system [38]. The Ministry of Planning and Investment signed a Memorandum of Understanding in June 2008 with private companies to construct two biodiesel factories with a production capacity of 50,000 tones each by 2010 [39]. A production of the Biodiesel (B100) was reported on July 7, 2011 at a rate of 40,000 Litres/month (*www.linkedin.com/groups/Green-Energy-in-Cambodia-Lao-3991528)*. A rural Renewable Energy Initiative in the great Mekong Subregion reports that Lao produces 223,300 tones of sugarcane and 55,500 tones of cassava in the year 2007 indicating that Government policy towards the development of bioenergy is progressing.

A study on “Application of biofuel supply chains for rural development and Lao energy security measurements” was conducted in March 2008 which claims that bioethanol could substitute for 20% of gasoline use in 2030 with the production of commercially viable Jatropha biofuel in four different phases starting from 2008 to 2030 over a total land of 1.1 million hectares [40]. Bush [41] discussed that bioenergy holds enormous potential of 18907 $MWh\ year^{-1}$,equivalent to 1922 $million\ l\ year^{-1}$of diesel fuel in Laos, with an abundance of biomass from agricultural residues (rice husk and livestock manure) and forestry residues (firewood, sawdust, off cuts and woodchips). The author did not elaborate on the conversion efficiency and the heating values which were assumed for these calculations.

A vigorous growth of bamboo is reported in the northern part of Laos that traditionally can be used for construction and handicraft to food and feed. A recent study attributed to bamboo a high potential as a biomass resource for biofuels or fiber, giving a rough review on the potential of three varieties of Japanese origin grown in USA [42]. Northern Laos is considered to be one of the most under-researched regions of the globe and requires further scientific research to investigate bamboo's properties as a biofuel crop.

Lao has only one registered CDM project and another is at its validation stage. The country has a huge potential of CDM projects in forestry but it still has long way to go for capitalizing on the CDM opportunities [3].

7. Malaysia

The palm oil industry is one of the leading industries of Malaysia that produces more than 13 million tonnes of crude palm oil annually resulting pam oil mil effluents (POME) that is approximately three times the quantity of crude palm oil. Wu et al. [43] conducted research on the biotechnological use of POME and reported that in additional to its conversion into useful substitutes for animal feed and fertilizer its fermentation leads to development of antibiotics, bioinsecticides, solvents (acetone-butanol-ethanol: ABE), Ployhydroxyalkanoates (PHA), organic acids, enzymes and hydrogen production. It could also be used as supplementary food in poultry farming. They emphasised that palm industries in Malaysia take appropriate steps to promote cleaner production for POME and their subtle actions could accelerate the research and development for an enhanced POME management. Palm oil is the most suitable and abundantly available feedstock due to its low production cost. The impact of the palm industry on the environment is an important factor which was conducted by Yee et al. [44] by conducting research on life cycle assessment of palm biodiesel consisting of three main phases: agricultural activities, oil milling and transesterification process for production of biodiesel. Comprehensive energy balance and GHG emission assessments were carried out that reveal that exploitation of palm biodiesel could generate an energy yield ratio of 3.53 (output energy/input energy) showing a net positive energy generation that ensures its sustainability. The combustion of palm biodiesel compared to petroleum-derived-diesel cut down the emission of CO_2 by a factor of 38%.

The extraction of palm oil produces a huge amount of biomass from its plantation and milling activities which is much larger compared to other types of biomass in Malaysia. This biomass has a great potential to be converted to either commercial products like animal food, fertilizer or to biofuel and to generate electricity. Shuit et al. [45] studied oil palm biomass as a sustainable energy source for Malaysia and discussed the use of oil palm biomass to bio-based commercial products, synthetic biofuels and for power generation. The researchers highlighted that all conversion technologies discussed in their research are either being used by the commercial sector are still under research and development (R & D). They concluded that with the use of palm biomass Malaysia can become a major renewable energy contributor in the world and become a role model to other countries having huge biomass feedstock.

The Government introduced the "National Biofuel Policy" in 2006 to reduce the huge demand for transport fuel that concentrates on five strategic thrusts: biofuel for transport, biofuel for industry, biofuel technologies, biofuel export and biofuel for a cleaner environment. Early 2006 saw the launch of B5 (Envodiesel) blended diesel with 5% locally refined, bleached and deodorized (RBD) palm olein however this product was abandoned in 2008 when engine manufacturers decided to stop the use of Envodiesel as it clogs the engine in the long run. Therefore, B5 (Envodiesel) palm oil methyl esters with 5% blend of diesel that meets the European Union (EU) standards was targeted for export. For marketing any biodiesel requires certification from the engine manufacturers as fuel as was done in Brazil that uses vast agricultural resources and opted for a different fuel system known as flex-fuel engine to adapt to biothanol (E85). The flex-fuel engines can burn any proportion of blend in the combustion chamber through electronic sensors which sense as soon as fuel is injected and adjust ignition time. However, for biodiesel not a single modified vehicle patent has been developed so far. The researchers suggested that Malaysian car manufacturers look into the improvement in a diesel engine that includes modifications on fuel supply system so that biodiesel developed in Malaysia can also be used in the country [46]. Goh and Lee [47] stated that a palm based biofuel refinery could provide an alternative for Malaysia as a reliable energy supply. With the full use of palm biomass 35.5% of national energy consumption can be secured using a land area of only 8% of current palm cultivation.

A renewable energy feed-in-tariffs (FiT) to support generation of green electricity in the country was introduced by the Malaysian Government under the 10th Malaysian plan which includes all renewable energy technologies, differentiates tariffs by technology, and drives the tariffs based cost of the generation. In the proposal it is also suggested that the FiT programme would add 2% to the average electricity price in the country. Under such a system, electricity generated from renewable energy resources is paid a premium price for delivery to the grid and an exemption for a rise in electricity costs in available for low-income consumers [48]. Chua et al. [49] reported on the feed-in-tariff (FiT) outlook in Malaysia and claimed that this process can lead to a stable investment environment that can generate the development of renewable energy deployment in the country. They quoted the examples of Germany, Spain and Thailand who adopted this process successfully and created more employment, a great investment market and security as it is renewable and helps in reduction of GHG emission. Biomass and biogas including solid waste are expected to be continued as the main sources of renewable energy for the next 20 years. A Municipal solid waste (MSW) of approximately 17,000 tonnes per day throughout the country has been handled by the local authorities and waste management consortia. The largest source of MSW are domestic waste (49%) followed by industrial waste(24%), commercial/institutional (16%), construction (9%) and municipal (2%). It is expected that approximately 9 mil tonnes of MSW will be produced a year by 2020 and the potential of renewable energy generation through waste disposal in Malaysia is extremely high. There are 150 landfill sites in operation that are contributing to the immense potential of land fill gas formation. The Jana landfill Gas power generation plant is connected to the national grid and has a capacity of 2.096 MW using two gas engines rated at capacity of 1048 kW, the landfill receives 3000 tonnes of garbage daily. Malaysia also uses the incineration method for solid waste disposal and has one unit that utilizes 1500 tonnes of MSW per day with an average calorific value of 2200 kcal/kg and daily generates 640 kW of electricity.

The authors claimed that a total of about 2500 MW capacity is estimated from *25 mil tonnes* of palm oil residues and 39 $mil\ m^3$ of POME which are used for power generation and cogeneration. In addition to that there is also a substantial amount of unexploited biomass waste from logging, padi, sugar and other residues. It was concluded that the potential cumulative installed capacity of biomass will reach to 1340 MW in 2050 from 110 MW in 2010. Two demonstration projects under BioGen of total capacity 13.5 MW are under construction and on completion could deliver *10.5 MW* to the national grid. The Biogen project reported that the total potential for biomass and biogas mill waste was *2600 MW per annum* in 2005.

There are three generation of biodiesel feedstock: the first generation is due to food crops (FGC); the second generation deals with non-food crops (SGC); and the third generation extracts it from microalagae and palm oil. Algae are grown in open ponds or photo-bioreactors and can produce in areas unsuitable for agriculture. Due to their high productivity, current yields of algae fuels in test facilities lie well above those of FGC [48, 50]. Goh and Lee [51] reported that total energy potential available from the third generation biodiesel (TGB) is $6.50 \times 10^6\ GJ$ while the energy consumption in transportation section for the year 2007 in the State of Sabah was $7.41 \times 10^6\ GJ$ which is equivalent to 88% of the energy demand of the State. Ahmad et al. [52] presented a comparison of microalgae with other biodiesel feedstocks and concluded that microalgae that grow rapidly with high oil contents have the potential to produce an oil yield that is up to 25 times higher than the yield of traditional biodiesel crops, such as oil palm. The authors recommended that two national car manufacturers: Proton and Perodua should concentrate on the development of flexible fuel vehicles to promote TGB.

ASEAN countries have abundant sources of agro-industrial residues that can serve as feedstocks for production of SGB. Goh et al. [53] studied the potential of SGF in Malaysia and reported that the total capacity and domestic demand of SGB are26, 161 $ton\ day^{-1}$ and 6677 $ton\ day^{-1}$, respectively. This indicates that SGB is capable of providing energy to the country provided that lignocellulosic biomass are fully converted into bioethanol and it can reduce 19% of the total CO_2 emissions in Malaysia. The data for the year 2007 on SGB reveal a production of *9549 ktonnes* with predicted increasing waste generation trends in future, the estimated potential of bioethanol is $2.58 \times 10^8\ GJ$ using a net calorific value of 27 GJ per ton. The transport sector of Malaysia consumed total amount of energy equivalent to $6.58 \times 10^7\ GJ$ in the year 2007. The authors determined that if lignocellulosic biomass were fully utilized to produce second-generation bioethanol it would fullfill 35.5% of the country's energy demand. Due to a lack of awareness by the policy makers and other related issues this potential could not be harnessed.

http://dx.doi.org/10.5772/51917

It is noted that future trends of biofuel usage are expected to show an increase in demand, ergo necessitating significant and sustainable sources. Pam Oil may not be able to meet such future production scales as it limits the availability of land for food production, fodder and other crops. Ahmad et al. [54] proposed microgales as a sustainable energy source for biodiesel production and reported that these are more sustainable source of biofuels in terms of food security and environmental impact compared to palm oil. Micralgae are photosynthetic microorganisms that convert sunlight, water and CO_2 to algal biomass and its total world commercial production is about 10,000 tonnes per year [55] while in a tropical zone its natural production is reported as$1.535\, kg\, m^{-3} day^{-1}$.

Singh et al. [56] and Singh et al. [57] discuss the management of biomass residues and urban solid waste respectively. They propose vermicomposing solid organic waste of industrial and municipal origin as a viable alternative technology based on a decomposition process involving the joint action of earthworms and microorganisms, as the end product is pathogen free, odourless, and nutrient rich compared to conventional compost. The application of vermicomposing to agriculture could lead to plant nutrient recycling and the facilitation of soil degradation monitoring. It could also reduce dependency on inorganic fertilizer which is more conducive to a sustainable ecosystem.

There are the technical obstacles related to the development of biofuel in ASEAN countries which are highlighted by Goh and Lee [58]. The feasibility studies should base on fundamental technology and practicalities rather than unrealistic assumptions. It is noted that some countries in this region do not follow pubic tendering for awarding biofuel project and introduced non-professionals in this field creating a fledgling industry which collapse due to deceitful activities. In order to overcome these flaws the policies should be transparent and carefully planned by considering all possible aspects which could be arise in the future. Projects under development should follow up with strict monitoring and the capability of companies involved in biofuel projects should be thoroughly investigated and evaluated prior to issuing licences.

Banana is one of other important crops that are cultivated in Malaysia and the Malaysian climate is most suitable for it. Banana takes almost 10-12 months from planting to harvesting and gives its fruit only once indicating that the crop is to dispose of as soon as fruit-producing period is over leading to a huge source of biomass. However, biomass can directly be converted into energy with direct combustion but the relatively high moisture contents of banana residues suggests that supercritical water gasification and anaerobic conversion would be a better choice and these can give higher conversion efficiency. India is the leading country in this field which converts banana residues into methane using Compact Biogas Plant (CBP) [59]. Tock et al [60] studied the production of banana for the years 2003-2008; and its energy and power potential for Malaysia. They claimed that a total power of 949.65 MW comprising of 80.52 MW from direct combustion and 869.13 MW from anaerobic could be obtained from banana residues which are 5% of the total energy consumption of energy.

8. Myanmar

Energy utilization in Myanmar mainly depends upon traditional energy; 64% from fuel wood, charcoal and biomass; and 35% from crude oil and petroleum, natural gas, coal and lignite and hydropower. 52.5% of the total land area is covered with forest and potential available annual yield of wood-fuel is 19.12 million cubic tons. The cultivation of Jetropha was initiated in 2006 as a national project on 3.15 million acres that will increase to *6 million ha* by 2015, and expected biodiesel production would be 20 million tonnes. Two small scale biodiesel plants were established in Northern Shan State and MICDE (Myanmar Industrial Crops Development) respectively. There are four plants under Government of Myanmar (Ethanol Distillery No. 2 Sugar Mill, Kan-ba-lu Distillery, Taung-sin-aye Distillery and Mat-ta-ya Distillery) in the country producing 667 *tons per day* of 99.5% Ethanol. There are three projects for biodiesel production by the private sector: Technology Company Limited managing 10,000 acres of land at Ayeyarwaddy Division, Ngapudaw TS to cultivate mainly jatropha and later cassava and sugarcane; MICDE is preparing an MOU to carry out biodiesel production with a Korean Company (Hae Joyub Bio Energy Myanmar Corporation) to cultivate 150,000 ha of land provided by MICDE to produce biofuel crops; and Great Wall company is cultivating 1000,000 acres of sugarcane in Northern Shan State to produce bioethanol. There are also Government plans to develop large scale production of bioethanol from cassava and sweet sorghum [61].

The Government of Myanmar is planning to establish biofuel villages at some townships states and divisions where potential biofuel crops can be cultivated. A community-based biodiesel demonstration project is being carried out to educate and introduce the community to the importance of biofuels, their impact on our environment and their economical impacts on the country as a whole and on individuals in particular [61].

The Ministry of Science and Technology is providing services for installing biogas plants designed for small village electrification. There are 105 biogas plants installed generating 945 kW of electricity. There is an estimated paddy production of 22,000,000 tons per year; estimated husk volume 4,392,000 tons per year; and 11,695 (small, medium and large) rice mills. Small and medium scale rice mills use rice husk as fuel to generate steam for steam engines. The rice mills using rice husks for gasification are becoming popular among people. 352,000 tons of husk per year is used to generate electricity [61].

9. Philippines

The Philippines is an agricultural country which generates an average of *36,172.50 tons* of waste annually and the waste generation rate is reported as $0.52\,kg\,cap^{-1}\,day^{-1}$ in urban areas and $0.30\,kg\,cap^{-1}\,day^{-1}$ in rural areas that can significantly contribute the country's energy supply. Apart from agricultural residues woodfuels including woodwastes and fuelwood from forested lands are extensively used. The estimated bioenergy resources from non-plantation biomass consisting of agricultural residues, animal manure, fuelwood released through efficiency improvement of current/base energy systems, fuelwood released through substitution by other fuels, municipal solid waste and back liquor are to be 969 PJ in the year 2010. However, the total bioenergy potential is expected to be rise in future but the consumption of fossil fuel is projected to grow at a faster rate. Literature states that in order to fully utilize the potential of non-plantation biomass concentration should be focus on their development and efficient use [62].

Elauria et al. [63] discussed the total annual biomass production potential from forest in the Philippines is in the range of $3.7-20.37\,Mt$ that can generate an energy of *55.5* to *305.6 million GJ* assuming that energy content of wood is $15\,GJ\,t^{-1}$ and if $1\,Mt$ of woody biomass can generate $1\,TWh$ of electrical power, then the annual electricity generation potential ranges from *3.7* to *20.37 TWh*. It could be concluded that the potential of electricity generated trough bioenergy plantation would lie in the range of 3% to 22% of the country's projected electricity demand for the year 2008 and it can reduce a significant amount of GHG emission. The reported results are based on the theoretical model consisting of three possible schemes: incremental biomass demand (IBD), sustainable biomass demand (SBD), and full biomass demand (FBD).

In February 2004, the Government of Philippines through a Department of Energy Circular made it compulsory for the incorporation of one per cent of coconut biodiesel blend in diesel fuel for use in all government vehicles. The president of Philippines in January 2006 introduced a law "The Biofuels Act 2006" that focused on the future development and use of this fuel in the country initially consisting of 5 per cent proportions for bioehtanol and one per cent for diesel blend with provisions for increasing their blend as recommended by the National Biofuels Board (NBB). The Philippines National Oil Company-Alternative Fuels Corporation (PNOC-AFC) was given a task for "identification and development of low-cost biofuel feedstock: jatropha for biodiesel and sweet sorghum and cellulosic for bioehtanol" and identified the following targets to achieve by 2012: 1,500 hectares of jatropha mega-nurseries cum pilot plantations; 700,000 hectares of biofuel crop plantations; and one million MT biodiesel refineries. Later a special clause in the biofuels act was introduced stating that this act shall not be interpreted as prejudicial to the clean development mechanisms (CDM) projects that cause carbon dioxide and greenhouse gas emission reduction by means of fuel use which encouraged and engaged the interests of biofuel producers to introduce biofuels-CDM projects in country [64].

Coconut is one of the three major agricultural by-products of the Philippines and the feasibility study for coconut as a biodiesil was conducted that concentrate on economics, social, political and environmental issues concludes that coconut has a potential for biodiesel production and the energy required for biodiesel processing (thermal energy and electricity requirement) can be met with its residue consisting of husk (*4.1 million tons per year*), frond (*1.8 million tons per year*) and shell (*4.5 million tons per year*). The reduction in the CO_2 emission was estimated to be in the range $3.70-5.01\times10^6$ of tons per year which is $2.85-3.85\%$ of the Philippines' total CO_2 emission in 2010. The authors claimed that the production of biodiesel could further be increased by improving agricultural yields for coconut through improved irrigation; genetic engineering and other technological advances; conversion of additional non-agricultural land into sustainable energy farms; and utilization of alternative feedstocks such as waste grease [65-66]. The other biomass resources in Philippines include residues from rice, maize and sugarcane which are abundantly grown in the country. An assessment of biomass resources conducted by Asia-Pacific Economic Cooperation based on marginal lands (6, 357 km^2 *equivalent to* 2.3% *of area*) reported that the Philippines has a potential of 1, 793, 000 *tonnes per year* and ethanol potential from marginal lands (0.7 hm^3) is equivalent to 13% of current gasoline consumption [67].

Literature reports an average quantity of rice production per annum in Philippines calculated over a five year period (2002 – 2006) is 14,239 Gg that generates 10,680 Gg of rice straw; 95% of the rice straw is burned in the field and only 5% used for other activities. The rice straw burnt in the field could be used to generate electricity. There are 62 countries in the world currently generating electricity using biomass and this production has steadily increased by an avaeage of 13 TWh per year between 2000 and 2008 [68].

The Philippines currently produces biodiesel from coconut oil and is expanding jatropha production. Ethanol feedstocks used or being considered include sugarcane, corn, cassava, and nipa [69]. Biodiesel production in the year 2007 is reported as 35 ML [70].

10. Singapore

It is reported that total organic waste resources of Singapore in 2006 was 1.91 M tonnes which is 74.4% of the total waste [71]. Singapore uses incineration (waste-to-energy) technology to dispose MSW that involves the combustion and conversion of this waste into energy. This technology reduces the volume of solid wastes by 80-90% making it popular in countries having limited territory for landfills. Four incineration plants in Singapore are Ulu Pandan, Tuas, Senoko and Tuas South with turbine capacity of 16 MW, 46 MW, 56 MW and 80 MW, respectively; these plants generates 980 *million kWh* of electricity per year which is 2-3% of total electricity demand of the country; and 22, 800 $tonnes\ year^{-1}$ of scrap metal is recovered for recycling. The proportions of food waste input treated by the four plants are reported as 12.88%, 16.52%, 34.66% and 39.95%, respectively. A typical incineration plant requires the energy input 70 $kWh\ ton^{-1}$ of waste and generates around 20% ash [72-73].

Neste Oil announced in November 2007 the construction of a biorefinery capable of producing NExBTL renewable fuel with a capacity of *800,000 metric tonnes per annum* and the proposed plant would be the largest renewable fuel refinery in the world. Nexsol (joint venture between Peter Cremer and Kulim group) in joining with Continental Bioenergy and Natural fuels invest in Singapore for biofuels production. There will be a capacity of *1,650,000 metric tonnes per annum* of biofuels in the country with the completion of these two projects [70].

11. Thailand

Thailand is abundant in agricultural residues: rice husk, sugar cane bagasse, wood, cassava, maize, cotton, soyabean, sorghum, caster and palm oil; and the country has a potential of $11.2 TW\ h\ yr^{-1}$ or $2.98\, GW$ of power generation capacity. Sajjakulnukit et al. [74] studied the sustainable energy potential of following biomass resources in Thailand: agricultural residues, animal manure, fuelwood saving potential through improvement of efficiency, flelwood saving potential through substitution by other fuels, municipal waste and industrial waste water. A comprehensive estimation on individual resources was conducted using data of harvested land and production statistics from the Centre for Agriculture Information (CAI). They claimed that the total energy potential of these sources is expected to be *821 PJ* for the year 2010 that corresponds to 14% of the total primary energy consumption in the same year [74].

The biomass is processed to generate either electricity or heat using conventional power plants. For successful utilization of biomass for energy production a continuous and secure supply of it to the power plants is the fundamental requirement. Sometimes biomass projects could face difficulties due to limited accessibility, logistical problems, seasonal availability, variation in biomass prices and increased utilization for other applications. Junginger et al. [75] described a methodology to set up fuel supply strategies for large-scale biomass conversion units (between *10* and $40\ MW_e$). The proposed methodology was demonstrated on a case study in an agricultural region in Northeastern Thailand. The study examined variations in residue quantities produced, limited accessibility of residues, utilization by other competitors and logistical risks. Four expected major risks in near future were considered. The first is an increased demand for residues as fuel, especially rice husk; the second risk is the possibility of a bad harvest; the third is the possibly increased demand of rice straw and sugarcane tops and leaves as a raw material for the pulp and paper industry; and the fourth concerns transportation and logistics. To overcome these risks different fuel supply scenarios were incorporated to show how biomass quantities and prices may vary under different conditions. It was noted that both residue quantities and prices can vary strongly which are dependent on fluctuating harvests, increased utilization by competitors and varying transportation costs. The researchers concluded that the combustion biomass plant is economical for agricultural residues.

The amount of agricultural residues (paddy, sugarcane and oil palm) estimated in the year 1997 was about *61 million ton*, of which *41 million ton* equivalent to about *426 PJ* of energy, was unused. The potential of biogas resources due to industrial waterwaste and live stock manure is 7800 and $13,000 TJ\ yr^{-1}$, respectively. Prasertsan and Sajjakulnukit [76] identified that one of the barriers to promote biomass energy production projects in Thailand is the lack of awareness and confidence that created misconceptions in the Thai people on the use of renewable energy in general and biomass energy in particular. This is because of the fact that education on acid rain that can destroy crops produced a negative impact on the common man and they consider a biomass power plant as a monster. They stressed the need of a new policy approach to overcome the barriers for utilization of biomass energy in Thailand.

Krukanont and Prasertsan [77] used Geographic Information System (GIS) to compute the potential of rubber for power generation in the rubber dominated growing area of south Thailand. The authors identified the location of eight potential rubber-fired power plants along *700 km* of the highway in this region which are economically feasible with a total capacity of 186.5 *MWe* having the fuel procurement area in the range of less than *35 km*.

The Government of Thailand encourages the production of bioethanol from local energy crops like cassava and sugarcane to prevent energy risks when crude oil prices fluctuate greatly or increase rapidly. This fuel has been used for vehicle in various types of ethanol blend with gasoline (known as gasohol) i.e. E10, E20 and E85. E10, a 10% blend of bioethanol with 90% gasoline, was introduced in the market in 2004. E20, a 20% ethanol blend, was introduced in 2008 after E10 had penetrated the market. Later, E85 gasohol was launched in 2008 [78]. Due to Government promotion strategies, the total gasohol consumption in Thailand has increased from $0.61 Mlday^{-1}$ in 2004 to $10.48 Mlday^{-1}$in 2008 [79]. The Thai renewable energy policy has set the target to increase the use of ethanol up to $3\,Mlday^{-1}$by 2011. The growing demand for biofuels increases the demand for feedstocks that in turn is anticipated to increase the land for agriculture requirements. To cope with the target for 2011 about $6.36 M\ ton\ yr^{-1}$of cassava are needed with an assumption of *133.21* ethanol produced per ton of cassava roots. This demand will change the cropping system and land requirement which contribute approximately 58-60% of the net green house gas (GHG) emissions. GHG emission can be reduced by increasing productivity rather than cultivating land [78]. Silalertruksa and Gheewala [80] stated that feedstock efficiency would be increased and hence GHG emission be reduced by improving soil quality with organic fertilizers, preventing the sugarcane leaves burning during harvesting, enhancing the waste recycling program from ethanol plants such as biogas recovery, organic fertilizer and DDG or DDGS production. They recommended that the use of renewable fuels in ethanol plants, implementing energy conservation measures and providing technical knowledge associated with cassava ethanol production to the industry also need to be encouraged.

Fluidized bed technology is used to convert agricultural and wood residues into energy and emission of various pollutants from this process depends on fuel analysis, combustor design and operating conditions. It is reported that unburned pollutants are expected at insignificant levels with supply of sufficient combustion air. Permchart and Kouprianov [81] studied combustion of three different biomass fuels: sawdust, rice husk and pre-dried sugarcane bagasse in a single fluidized combustor (FBC) with a conical bed using silica sand as the inert bed material and fairly uniform axial temperature. They reported that emission of CO for rice husk was much greater than those for sawdust and bagasse for similar operating conditions due to the presence of coarser particles and higher ash concentration. They noted that the emission of CO can be rapidly diminished with an increase in excess air of up to 50—60% but has a weak dependence with excess air in the range of 60—100%. The emission of NO strongly depends on the fuel-nitrogen contents rather than operating conditions. They concluded that sawdust is the most environmentally friendly biomass whereas rice husk produce noticeable environmental impact. A maximum efficiency of 99% was obtained for sawdust and bagasse at the maximum combustor load with an excess air of 50-100%. The maximum combustion efficiency for rice husk with excess air of about 60% was 86%. A further increase in excess air for rice husk decreases combustion efficiency rather than an increase compared with those of sawdust and bagasse.

Janvijitsakul and Kuprianov [82] investigated the emission of CO and NO_x in a newly-built, $400\,kW$ conical fluidized-bed combustor for firing $80\,kg\,h^{-1}$ rice husk with medium-ash contents and high-calorific value $(LHV = 15.7\,MJ\,kg^{-1})$ for wide range of excess air, 3-59%. They reported the emission of NO_x as 75-143 ppm (corrected to 7% O_2 dry flue gas) at elevated bed temperature of $900-950\,^oC$. The emission of CO was 128-716 ppm (7% O_2 dry flue gas) which shows an inverse correlation with excess air. The total Polycyclic Aromatic Hydrocarbons (PAHs) emission was found to predominate for the coarse ash particles due to the effects of a highly developed internal surface in a particle volume. The highest emission was noted for acenaphthylene, $4.1\,\mu g\,kW^{-1}h^{-1}$ at the total yield of PAHs due to fly ash was $10\,\mu g\,kW^{-1}h^{-1}$.

Shrestha et al. [83] examined the development of energy system during 2000-2050 and its environmental implications in Thailand. The energy system was ranked into two components: energy supply and conversion (energy extraction, imports and conversion of primary energy to secondary energy i.e. power generation), and service demand. New as well as twenty existing technologies were considered for power generation in four different scenarios: *global market integration* (TA1); *dual track* (TA2); *sufficiency economy* (TB1); and *local stewardship* (TB2). They concluded that industry and commercial sectors remain the most intensive user of electricity throughout the study period. The share of coal and natural gas for power generation would account for almost 85% while 15% was from renewable energies like biomass and hydro. Energy used by road transportation considerably increased during this period. In the last two decades of study period clean fuels based vehicles become important and play a dominant role. Thailand imports energy which would increase from 50% in 2000 to 89% in 2050 and this could impose energy security issue for the country. A considerable increase in emission of SO_2 and NO_x was estimated with reference to that of the emission in 2000. In all four scenarios, SO_2 emission would be much faster that the NO_x emission which is due to the substantial use of coal for electricity generation.

The utilization of rice straw residues for power production can improve the renewable energy development plan in Thailand. The major goal for biomass-fuelled power plants is to deliver energy at a reasonable cost. Delivand et al. [84] conducted economic feasibility assessment of rice straw utilization for electricity generation through combustion in Thailand and concluded that to ensure a secure fuel supply smaller scale power plants with capacities $5-10\,MW_e$ are more practicable. Literature reports the production of biofuels in the year 2008 of 822 ML [70].

The Ministry of Energy (MOE) of Thailand stated three main sources of biomass namely agricultural residues, forest industry and the residential sector. The potential and targeted capacity of biomass is *1751 MW* corresponding to *623 MW* from rice husk, *106 MW* from bagasse and *32 MW* from wood residue. The Energy Policy and Planning Office (EPPO) disclosed in March 2010 the existence of *76* biomass power plants generating *673 MW* of electrical power, negotiation with the Metropolitan Electrical Authority (MEA) and the Provincial Electrical Authority (PEA) for *30* plants of capacity of *290 MW* are under way, *40* approved plants with a capacity of *290 MW* are waiting for signing Power Purchase Agreement (PPA) contracts and *211* power plants of capacity *1585 MW* are under construction and waiting for Commercial Operation Date (COD) [85]. The Government of Thailand under the 15 years of the Alternative Energy Development Plan (AEDP) lay down targets to generate electricity utilising biomass in 2022 in three phases: short term (*2008-2011*) to achieve generation of power at *2800 MW*, mid-term (*2012-2016*) to attain a power at *3220 MW*, and long-term (*2017-2020*) to reach the objective of generation of electricity at *3700 MW*, respectively [85]. The 15 years of the Alternative Energy Development Plan (AEDP) presents electricity generation utilising biogas in 2022 in three phases: short term (*2008-2011*) to achieve generation of power at 6*0 MW*, mid-term (*2012-2016*) to attain a power at 9*0 MW*, and long-term (*2017-2020*) to reach the objective of generation of electricity at 12*0 MW*, respectively [85]. Similarly for MSW: short term (*2008-2011*) to achieve generation of power at 78 *MW*, mid-term (*2012-2016*) to attain a power at 13*0 MW*, and long-term (*2017-2020*) to reach the objective of generation of electricity at 16*0 MW*, respectively [85]. It is reported that to date 1,610 MW, 46 MW and 5 MW of electricity generation has been obtained using biomass, biogas and MSW.

Literature reports industrial wastewater and livestock manure are the major resources of biogas in Thailand that have a potential of *7800* and *13,000 TJ per year*, respectively. This amount of waste can produce *620 million* m^3 of biogas. The installed capacity of biogas power is *146 MW*. The Energy Policy and Planning Office (EPPO) highlighted in March 2010 the working of *41* biogas power plants feeding *43 MW* of power to the grid, negotiations are in progress with the Metropolitan Electrical Authority (MEA) and the Provincial Electrical Authority (PEA) for 15 plants with a capacity of *41 MW*, *31* approved plants with a capacity of *44 MW* are waiting for signing Power Purchase Agreement (PPA) contracts and *33* power plants with a capacity of *72 MW* are under construction and waiting for COD [85]. The Government of Thailand under the 15 years of Alternatives Energy Development Plan (AEDP) lay down targets to generate electricity utilising biogas in 2022 in three phases: short term (*2008-2011*) to achieve generation of power at *60 MW*, mid-term (*2012-2016*) to attain a power at *90 MW*, and long-term (*2017-2020*) to reach the objective of generation of electricity at *120 MW*, respectively [85].

Thailand generates approximately *14.5 million tonnes* of MSW annually consisting of food waste (*41-61%*), paper (*4-25%*) and plastic (*3.6-28%*) which is decomposed to produce landfill gas comprised of *60%* methane and *40%* CO_2 using 90 landfills and three incinerators. The installed capacity of generating electricity from MSW is *13 MW*. The Energy Policy and Planning Office (EPPO) declared in March 2010 that 8 MSW power plants are in operation generating 11 MW of electricity which is fed to the grid, negotiations with Metropolitan Electrical Authority (MEA) and Provincial Electrical Authority (PEA) are being held for *10* plants with a capacity of *305 MW*, *15* approved plants with a capacity of *68 MW* are waiting for signing PPA contract and *14* plants with of capacity *96 MW* are under construction and waiting for COD [85]. The Government of Thailand under the 15 years of AEDP lay down targets to generate electricity utilising biogas in 2022 in three phases: short term (*2008-2011*) to achieve generation of power at *78 MW*, mid-term (*2012-2016*) to attain a power at *130 MW*, and long-term (*2017-2020*) to reach the objective of generation of electricity at *160 MW*, respectively [85].

The contribution of Stainable Development (SD) of a CDM project is interpreted by the host country, which develop their own SD criteria for assessing CDM projects. There are no common international standards for the host country approval processes and the development of SD criteria. Stakeholder preferences towards the SD of CDM projects are not explicit and are left to the host countries to interpret. Kerr and Parnphumeesup [2] carried out research using quantitative and qualitative methods to investigate stakeholder preferences towards SD priorities in CDM projects. This study investigate CDM's contribution to SD in the context of biomass by taking a rice husk project as a case study conducted in Thailand. Their quantitative analysis demonstrated the use of renewable energy as a highest priority followed by employment and technology transfer. Qualitative results obtained from this project revealed that rice husk CDM projects could contribute a lot to SD towards generation of employment, increase in the usage of renewable energy and transfer of knowledge but it definitely produces a potential negative impact on air quality. Stakeholders advised that in order to ensure the environmental sustainability of CDM projects Thailand should cancel an Environmental Impact Assessment (EIA) exemption for CDM projects with an installed capacity below 10 *MW* and apply it to all CDM projects. They recommended that the Government of Thailand develop a biomass commodity market to highlight the importance of rice husks for the country's renewable energy plan. Alternatively, farmers form cooperatives that could enforce mills to buy paddy rice at higher price making sure that the true value of the rice husk is paid.

12. Vietnam

Biomass resource potential on marginal lands which is 6.5% of the total area of the country is reported to be 11, 281, 000 $tonnes\ year^{-1}$ and ethanol potential from this land at a rate of 4.4 $h\ m^3$ is *79%* of the current gasoline consumption [86]. Biofuels development in Vietnam is in its early stages compared with other ASEAN community, biofuels plants are in process of cultivation, potential feedstock are cassava, sugarcane, rubber seeds, jathropa and catfish oil. The country has a strong national target for biofules as alternative to fossil fuel and woking on ethanol and vegitable oil to replace 1% of country's petroleum demand by 2015, and 5% in 2025.

The biomass resources in Vietnam are: agricultural (paddy, maize, cassava, sweet potato), forest (natural, planted, wood, dispersed), industrial crops (sugarcane, peanut, coconut, cotton, jute, sedge, elephant grass) and other waste (industrial residues consisting of sawdust and molasses, livestock residues and solid waste) which accounts for 60-65% of the primary energy consumption and is being used for cooking fuel, organic fertilizer, biogas for domestic cooking, electricity production (in paper mills) and bioethanol production. The Government of Vietnam introduced a state biofuel development program in November 2007 aiming to develop renewable biofuels from biologically derived organic resources to replace a part of fossil fuels for future State energy security and environmental protection. The targets for these programs are: to develop *100 thousand tons* of E5 and *50 thousand tons* of B5 (0.4% of mass fuel consumption of the country) by the year of 2010; 250,000 tons of ethanol and vegetable oils equivalent 5 *mill tons* of E5 and B5 by the year 2015; and the production of ethanol and vegetable oil will reach 1.8 *mill tons* by the year 2020. A joint project between Petrosetco Vietnam and Itochu Company Japan is constructing a bioethanol factory that would be on completion capable of producing 100 *mill liters per year* using cassava starch. The country is in the process of developing new types of biomass as raw materials for biofuels from sea known as “Kappaphycus alvarezii (Green and Brown), Gracilaria tenuistipitata”. The literature does not report any production current activities of vegitable oil in Veitnam. Projects are largely still in the developing stage under the government, save for B5 production levels sourced from fish operating at 50,000 tonnes per year [86A, 86B].

The main feedstocks for biodiesel production in Vietnam are “Basa” fish oil, used cooking oil and rubber seed oil. The potential of “Basa” for the year 2005 was estimated to be of *60,000 tones* that could produce *48,000 tons* of biodiesel. Saigon Petro and Agifish are in the processing of developing a project with a capacity of producing 10, 000 *tons per year* biodisel. There is *73,800 tons* of used oil with a potential of producing 33,000 tons of biodiesel. Saigon Petro is developing a facility to extract 2 *tons per day* biodiesel using $4-5$ *tons per day* of used cooking oil. Rubber trees are planted on more than 500, 000 *ha* in 2006 and it is planned to rise to 1, 000, 000 *ha* that can produce $200,000-300,000$ *tons* rubber fruits every year, equivalent to $17,600-330,000$ *tons* of rubber oil which is not edible and one of important bio-resource to biodiesel production. It can either be used directly by thermal cracking to hydrocarbon or in form of ethyl ester, blended with petroleum diesel. Biodiesel from ethyl ester of Vietnamese rubber seed oil according to the European standard for determination of biodiesel (E.DIN 51606), blended from 5% to 20% with petroleum diesel, can be used as a fuel for electric generators and car diesel motors [87].

Many projects have been carried out to develop cultivation of jatropha in different providences of Vietnam and some of these projects are in pilot scale for production of biodiesel [87]. Nguyen [88] studied the rice husk potential of Vietnam (1995 – 2002) and noted a rise in the planted area (6,766,000 to 7,485,000 hectors); rice husk output which was assumed to be 20% of paddy increased from 4,993,000 tons to 6,813,000 tons; 30% of the rice husk was assumed to be used to generate electricity and with this assumption a rise in the supply of rice husk for generating power was increased from 923,000 tons to 1,249,000 tons. This study reports that there are 615 rice mills in the country and each mill collects rice within a radius of 20 km. The electricity generated using rice husk that feeds power to a grid can reduce the emission by $0.615\, kg\ of\ CO_2\ per\ kWh$ compared with the conventional fossil fuel. Off grid can reduce $0.8\, kg\ of\ CO_2\ per\ kWh$ [89].

Rice husk and straw are the most available biomass for energy production in the Mekong Delta. Dang et al. [90] studied energy needs for this region by estimating the current and future energy demands of rural industries; identifying the type and quantity of most availa-

http://dx.doi.org/10.5772/51917

ble source of energy production; and developing and assessing biomass utilization scenarios assuming various system scales and conversion technologies. Their findings reveal three important facts. Firstly, electricity and heat energy obtained from rice husk burning furnaces, kilns, or stoves are the energy sources highly in demand by Mekong Delta's rural industries in both the present and the future. Secondly, the biomass based power plants use rice husk and straw as a fuel for generating power which accounts for 73-87% and 8-10%, respectively, of total unused agricultural residues in 2007-2030. Thirdly, the use of biomass power plant due in 2007-2030 could potentially reduce emission by $163-871\, kTCO_{2-eq}$, equivalent to $21-109\%$ of GHG emission in the study area over the same period of time.

Literature reports that a 4.4 GW of renewable energy moderate capacity potential exists in Vietnam that could be utilised to replace conventional fuel-generating capacities to produce electricity in the country. Among other renewables like hydro energy and geothermal energy, biomass resources consisting of rice husk, paddy straw, bagasse (sugarcane, coffee husk and coconut shells), wood and plant residues have a potential of $1000-1600\, MW$ generating electricity equivalent to 22.7% of the total expected potential of renewable energy for the country that accounts for $4.4\, GW$ [91].

The largest obstacle to implementation of CDM projects is lack of technical knowhow, difficulties calculating emission reductions and submitting the requisite evidence of 'additionality' as compared with the business-as-usual scenario. The energy sector is also faced with a lack of reliable official data on the Vietnamese power grid, making it more difficult to calculate viable emission factors and baselines for ascertaining CO_2 savings.

13. Unified ASEAN bioenergy outlook

ASAEN countries are the main producers of palm oil and rubber with substantial plantations of coconut and paddy fields and they have started cultivation of jatropha on large areas. ASEAN countries are located in the equatorial region of the globe that provides a constant warm temperature and humid conditions throughout the year and makes this region suitable for a variety of large areas of plantation. The region has a potential of unwanted biomass (wastes from only palm oil, sugarcane and rice excluding all others) of up to $208.68\, \textit{million tonnes per annum}$ that is generated from the by-products after the milling process. This unwanted biomass has a potential of generating electricity up to $71.47\, TWh$ which was 14.37% of total residential electricity usage for all ASEAN countries in 2006; with a conversion efficiency of 30% and $10\, MJ\, kg^{-1}$ biomass energy yield. There is a huge agricultural land available in Mynmar, Vietnam, Cambodia and Lao that is still unused due to lack of sufficient funding, infrastructure and a skilled workforce. At the moment these countries are considered as undeveloped and use traditional agricultural methods for cultivation. Under the ASEAN cooperation framework, these countries can take help from other members through technology transfer and skilled manpower to modernise their agricultural sector and increase agricultural revenues. It is expected that with this cooperation the total land area of $10.74\, \textit{million hectares}$, after deducting the area of plantations from total agricultural land for Myanmar, Vietnam, Cambodia and Lao, can be increased. If oil palm which is one of the highest yield crops is cultivated, assuming that this land is suitable for it, 664.40 *million tonnes* of extra biomass residues can be produced annually which would generate electrical power of 220.68 *TWh* with the same assumptions as stated above. 58.74% of residential electricity usage including the earlier estimate can be generated from biomass leading to a huge reduction in carbon emission [74]. The global contribution of Asia in biofuel production is 4.6% and the ASEAN share lies in the range of less than 2% [74A].

It is noted that highly urbanized cities in ASEAN countries generate a high percentage of organic and mixed inorganic waste (55-77%), with about 10-16% made of plastic, approximately 4-10% of glass and about 4-12% of metal. The largest fraction of MSW in ASEAN countries is paper and cardboards constituting 28% of the waste. There is about 529, 500 *tons per day* urban MSW in ASEAN countries. Out of which approximately 50-80% is collected each day and then disposed in landfills or dumpsites. The capacity of landfills is mostly exceeded due to lack of waste management planning. In countryside waste is either thrown directly into rivers, dumped at the road side or burned in the open because of a lack of finance, land acquisition problems, lack of awareness of the environment, inadequate solid waste management, and lack of enforcement that could impose serious environmental pollution problems [74]. The amount of MSW dumped openly and/or burn is not known.

At the same time one of the most sophisticated waste treatment systems, "incineration" has successfully been used in Singapore. Malaysia has one municipal incinerator and planning for another one, Indonesia and Thailand also have one in their capital cities. Recycling is also becoming popular in this part of the world. In high income countries like Singapore approximately 44.4% of solid waste is recycled. In the middle income countries, the percentage of waste recycled is about 12%, and it is approximately 8-11% for the rest of ASEAN [74]. If 529, 500 *tons per day* urban MSW in ASEAN countries is wisely and professionally treated as Singapore does, it has a potential of generating 271 *GWh per day* of electricity. Research and development (R &D) projects in Malaysia, Thailand and Indonesia are investigate vermicomposing of solid organic waste from industrial as well as municipal origin [56].

Shi et al. [92] estimated the global potential of cellulosic ethanol from waste paper and cardboard to be *82.9 billion litres* and reported that the substitution of gasoline use with waste paper-derived cellulosic ethanol could offer GHG saving of between 29.2% to 86.1% [92]. The introduction of a proper MSW management system in the ASEAN community could lead to a clean environment and it is this area where CDM projects can play a prominent role for sustainable development by reducing the emission of GHG of this region.

A study conducted on construction waste generation and management in Thailand claimed that on average 1.1 million tons of construction waste is generated per year and if the management of this waste material is given attention by prompting recycling an average saving of 3.0×10^5 *GJ per year* could be made [93]. Researchers focused on the introduction of proper MSW management and disposal systems along with strong Government commitment in ASEAN countries which has a high potential of generating electricity from this unavoidable and ever increasing source.

http://dx.doi.org/10.5772/51917

It is desirable that in ASEAN countries waste treatment facilities should be strictly regulated and protected regarding licensing, authorization and compliance with the country's law. Enforcement of law to ensure the regulatory framework must be applied strictly and if necessary existing law on waste management be amended or new laws introduced to protect and minimise environmental pollution through open burning of any type of waste including agricultural, forest, MSW, industrial liquid waste discharges and gas exhaust. The region should concentrate on and opt for available "waste to energy" technologies to deal with all types of these wastes like agro-based industrial systems, recycling, bio-digestion, bio refineries, bio-extraction etc. Developed countries like Malaysia and Singapore help other developed and developing countries of this community to enhance and introduce sustainable waste management system through joint R & D projects and sharing their resources [74].

Effective utilization of biomass as an energy resource is based on biomass availability, transportation distances, and the scales and locations of power mills/factories within a region. Palm oil mills use small boilers for both electricity generation and palm oil extraction processes. The most common type of power plant used in ASEAN countries consists of a small tube boiler capable of processing 30-60 tonnes of full fruit bunches (FFB) per hour that can produce an excess heat and electricity of $23.8\,MJ\ per\ ton\ FFB$ and $22.4\,MJ\ per\ ton\ FFB$, respectively. These conventional boilers should be replaced with high pressure boilers such as dual fire boilers capable of burning palm oil waste as well as use of use of POME derived biogas as a supplementary fuel for efficient production of power and heat from biomass. Energy efficiency could also be improved by the adoption of high efficiency motors, high efficiency transformers and variable-speed controls in power plants. Literature states that $2-8\,MW$ or $12\,MW$ combined heat and power (CHP) plants are most appropriate and can generate the largest profits in Malaysia as well as throughout the ASEAN countries. Installation of large plants requires Empty Fruit Bunches (EFB) transportation over longer distances and couples with low stability of EFB supply particularly in low season. It is recommended that small power plants are installed in such a way that each power plant has a collection area for FEB within approximately a radius of 40-50 kilometres which will ensure the supply of FEB to plants and protect it if left to decay on-site due to limitations of either a plant capacity or difficulties on transportation over long distances for large plants [43, 56]. Malaysia, Indonesia and Thailand among the ASEAN countries have huge resources of biomass from the palm oil industries and these countries can help developing countries of this community to build up biomass conversion technologies by providing expertise as well as skilled manpower. With the close cooperation within the ASEAN community bioenergy technologies are able to penetrate resulting in production of biofuels, generation of electricity using wasted agricultural and other types of residues in the region that can compete with conventional fossil fuels more economically that could lead to sustainable energy development [94].

Forests in ASEAN are an important source of timer and other forest products, of energy for cooking and space heating for the rural population and a potential source of bioenergy. Literature reports that these forests produce about $563.8\,million\ tons\ per\ year$ ($11.3\,EJ$)of woody biomass for the period 1990-2020 and a decrease of 1.5% in annual woody biomass was noted for this period. It was highlighted that if this trend is continued then this region of the world could face a shortage of woody biomass as well as its ecosystem functioning can be adversely affected leading to the risk of its sustainable development. The region has strongly reacted and enforced laws against deforestation and forest degradation. Rehabilitation and plantation programs have been initiated resulting in the recovery of about 0.1% of the 2.4 million ha deforested land. It is claimed that use of woody biomass to replace fossil fuel for energy generation could prevent carbon emission of about $169.0-281.7\,TgC\ per\ year$, where one tetragram carbon (TgC) is one million tons of carbon, between 1990 and 2020 [95]. A case study of household energy demand of a rural community and its electrification in Lao People's Democratic Republic was conducted. Prior to electrification 99% of the primary energy demand was met with firewood. Only 75% of villages used commercial lighting fuels while 25% have no access to this fuel and therefore are not engaged with entrepreneurial activities. These families were wasting thousands of hours of productive time each year which could be used to improve their families' living conditions through education and safer time-saving work if they could have access of about three hours of lighting per day indicating the importance of energy and its impact on the lives of rural people. A proper management of forests could solve these very simple problems of the rural communities and enhance their productivity [96].

Biofuels are growing steadily in ASEAN countries which are extracted from sugarcane and cassava; 75% of the current biethanol production in Thailand is from cassava. Thailand is the largest producer of bioethanol with$517\,Ml\ per\ year$, followed by Philippines ($116\,Ml\ per\ year$) Indonesia ($77\,Ml\ per\ year$) and Singapore ($34\,Ml\ per\ year$). The international energy agency (IEA) stated that Thailand will continue to lead ethanol production in ASEAN countries for the next three years to achieve an expected annual production of $1276\,Ml$ in 2012 while Indonesia and Philippines production will further increase to $355\,Ml$ and $332\,Ml$, respectively in 2012. Malaysia and Vietnam do not produce ethanol for use in the transport sector [48 & 97]. Palm oil is the main feedstock for biodiesel production in this region of the world with an average biodiesel yield in the range of $4,\ 000-4,\ 700\,l\ per\ ha$ (FAO 2008). Literature states that Thailand led in the production of biodiesel in the year 2009 with a quantity of $625\,Ml$ while Indonesia, Malaysia and the Philippines produced $243\,Ml$, $203\,Ml$ and $96\,Ml$ respectively, whereas Singapore had a comparatively small output of $48\,Ml$. A steady increase in the production of biodiesel for the next three years is predicted led by Thailand with an annual output of $955\,Ml$ in 2012, followed by Singapore with an expected increase in production by almost twentyfold to $946\,Ml\ per\ year$. This increase is due to a large plant which is currently under construction capable of increasing the country's capacity by$900\,Ml\ per\ year$. The expected increase of biodiesel in Malaysia, Indonesia and Philippines lies in the range of *25-60%* [49, 97].

There is a huge potential for increasing the power efficiency of energy plants. This can be done by increasing steam parameters and installed power in cogeneration plants and reducing consumption in process. Biogas can be generated from the anaerobic treatment of the liquid effluents of the process and its conversion into electricity using internal combustion engines or micro-turbines. The extraction methodologies used to extract cooking oil and biofuels from biomass could be modified to increase the efficiency [98]. This can be done with use of suitable catalysts to catalyze the transesterification reaction for extraction of cooking oil/biofuels from biomass. Edric et al. [99-100] claimed that conversion of biomass into biofuel/cooking oil and apparent bulk reaction rate are insensitive to temperature but dependent on mass transfer rate and their results reveal that overall reactor performance may be further improved by increasing the porosity of the biomass. It is desirable to investigate further how to improve the catalyst and elucidate the reaction mechanism to increase the quality of biofuels extracted from biomass.

A lot of interest in investing in biomass power in ASEAN countries especially in Malaysia and Thailand has been reported under carbon finance opportunities through CDM projects. It has been reported that among the registered CDM projects for ASEAN countries 41% are on biomass power generation. The majority of the registered CDM projects are small scale under 10MW that are often located in remote, off-grid areas in countries with relatively low electrification rates. A number projects under carbon finance are being planned in different ASEAN countries and feasibility studies are underway to investigate how much reduction in GHG could be made with the proposed projects [48, 101-103].

14. Conclusion

The results presented in the literature on the development of bioenegy in ASEAN and development of CDM projects in this part of the world reveal that this region of the globe could lead the world in bioenergy with a unified community where all member countries concentrate on collective resources of biomass; member countries (Malaysia, Indonesia, Thailand and The Philippines) share technological expertise with developing member countries (Cambodia, Lao PDR, Myanmar, Vietnam). Developed countries could provide training to cater a skilled workforce for the developing community and centralized research and development centres for biomass and bioenergy technologies. Singapore, and Malaysia could initiate in setting up bio-refineries and MSW treatment (waster-to-energy) plants; and regional collaboration on development and utilization of unified bioenergy resources. With these collective and integrated efforts this region would not only become energy sufficient using bioenergy resources but lead the world in this area. Lim and Lee [94] proposed a diamond framework for ASEAN biomass bioenergy cooperation that provides an ideal unified framework for this community to work together and this would lead the ASEAN countries towards leadership in bioenergy where the developing members as well as developed ones are to play their roles to achieve energy as well as social sustainability.

Acknowledgements

The author acknowledge the useful discussion with Dr. Lim Chee Ming and grateful to Dr. M. G. Blundell, Faculty of Science, University of Brunei Darussalam for providing valuable comments on the manuscript.

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