CDM POTENTIAL IN PALM SOLID WASTE COGENERATION AS AN ALTERNATIVE ENERGY IN ACEH PROVINCE

Mahidin[1,2*)], Izarul Machdar[1,2], Muhammad Faisal[1,2], and Muhammad Nizar[2]

1. Department of Chemical Engineering, Faculty of Engineering, University of Syiah Kuala, Darussalam, Banda Aceh 23111, Indonesia
2. Chemical Engineering Postgraduate Program, University of Syiah Kuala, Darussalam, Banda Aceh 23111, Indonesia

[*)]*E-mail: mahidin@unsyiah.ac.id*

Abstract

Empty Fruit Bunch (EFB) as a solid waste in Crude Palm Oil (CPO) industry does not utilized yet as an alternative energy source to generate electricity. It is well known that use of solid wate (biomass) as an energy source is part of the Clean Development Mechanism (CDM) scheme due to direct reduction of Green House Gases (GHGs) emission and provide a direct contribution to sustainable development. Utilization of EFB as a source of energy is very potential to be implemented in Aceh since this province has 25 CPO Mills at the moment which actively produce about 870,000 ton EFB per year. This study is subjected to evaluate the potency of electricity from EFB theoretically by using primary data (survey data) and secondary data. Potency of EFB and number of electricity produced from that EFB are estimated using primary data and direct combustion scenario, respectively. Calculation methods for emission reduction acieved are done by AMS-I.D: Renewable electricity generation to the grid and AMS-III.E: Methane emissions avoided from dumping at a solid waste disposal site. The result of this investigation shows that energy consumption in 25 CPO Mills is 45 GW(e)h per year. Evidently, the number of energy/electricity which is potential to be produced by using 75% EFB is 1,047 GWh per year; so that the GHGs emission reduction up to 171,232.21 tCO_2e per year.

Abstrak

Potensi MPB dalam Co-Generasi Limbah Padat Kelapa Sawit sebagai Energi Alternatif di Provinsi Aceh. Tandan Kosong Kelapa Sawit (TKKS) sebagai limbah padat di industri minyak kelapa sawit belum dimanfaatkan sebagai sumber energi alternatif untuk membangkitkan listrik. Sudah sangat dimaklumi bahwa pemakaian limbah padat (biomassa) sebagai sumber energi adalah bagian dari skema Mekanisme Pembangunan Bersih (MPB) karena dapat mereduksi emisi Gas Rumah Kaca (GRK) secara langsung dan dapat memberikan kontribusi langsung terhadap pembangunan berkelanjutan. Pemanfaatan TKKS sebagai sumber energi sangat potensial untuk diimplementasikan di Aceh karena provinsi ini memiliki 25 Pabrik Kelapa Sawit (PKS) saat sekarang yang aktif memproduksi sekitar 870.000 ton TKKS per tahun. Studi ini diarahkan untuk mengevaluasi potensi listrik dari TKKS secara teoritik dengan menggunakan data primer (data survei) dan data sekunder. Potensi TKKS dan jumlah listrik yang dapat diproduksi dari TKKS tersebut masing-masing diestimasi menggunakan data primer dan skenario pembakaran langsung. Metode perhitungan untuk reduksi emisi yang diperoleh dilakukan dengan AMS-I.D: Pembangkitan listrik dari energi terbarukan untuk dimasukkan ke *grid* dan AMS-III.E: Pencegahan emisi metana dari penumpukan biomassa di tempat pembuangan limbah padat. Hasil dari investigasi ini menunjukkan bahwa konsumsi energi untuk 25 PKS adalah sebesar 45 GW(e)h per tahun. Jumlah energi/listrik yang mungkin diproduksi dengan memanfaatkan 75% potensi TKKS adalah 1,047 GWh per tahun; sehingga reduksi emisi GRK mencapai 171,232.21 tCO_2e per tahun.

Keywords: empty fruit bunch, clean development mechanism, GHGs emission, renewable energy

1. Introduction

In order to promote the economic growth in Aceh, one of the important factors, that should be taken into consideration is the available of energy. Actually, Aceh has abundant of renewable energy (RE) resources, such as: hydropower, geothermal, biomass, windpower, solar, etc. However, development on those energy resources run slowly because of lack in technology, invesment and support from local goverment. Biomass (solid waste) from palm oil industry is one of the interesting RE resources to discus.

Nowadays, there are 25 Crude Palm Oil (CPO) Mills actively operate in Aceh, located in 8 districts with actual capacity of 725 ton Fresh Fruit Bunch (FFB) per hour [1]. In general, CPO Mill is operated for 20 hours/day, sometimes when FFB available abundanly, mill can be operated for 24 hours/day. Based on this data, the amount of solid waste discharged is predicted about 2,900 tons per day (by assumption that solid waste is about 20% of FFB). If this waste is not utilized, it will reflect a serious problem for the environment such methane release.

Generally, CPO Mill waste is classified as solid and waste water (palm oil mil effluent/POME). Usually, waste water contains highly organic material which tends to pollute the environment. Number of water used and volume of waste water produced by CPO Mill depend on control mechanism of water consumption in whole processing steps. For one ton of FFB processed in CPO Mill, the water used is 1-2 tons [2].

Solid waste in CPO industry is classified in two types, those are: solid waste from FFB processing and solid waste from wastewater. Among the solid waste from FFB processing are EFB, palm kernel shell (PKS) and fibre. Meanwhile, the solid waste from wastewater is active sludge. Table 1 shows the fraction of some solid wastes to FFB. In addition, palm trunk is also available in each period range of 20-25 years in plantation area when replanting activity is done, and stem which is available periodically at least at harvesting times.

In fact, EFB has not been utilized yet as an energy source recently. More than 75% of EFB are piled up in plantation area and the rest are fired in incenerator. Whereas, the other solid waste such as fibre and PKS have been fully used as boiler fuel. At the moment, PKS are also used as a raw material of active carbon.

Energy use from solid waste in CPO Mill. It is clear that all solid wastes in CPO mill can be used to fulfil the need of energy in the mill such as boiler fuel for steam and electricity generating. Fiber and PKS can directly be burned as a fuel. Depend on design, boiler can be operated by using 100% of PKS or 100% of fibre or combined fuel of PKS and fibre. Opposite to fibre and PKS, due to big in size and high in moisture content (between 65-70%), EFB at first has to be passed to a muncher and drier before burned in boiler to reach of the moisture contains under the 50%.

Table 1. Fraction of Solid Waste to FFB

Type of waste	Fraction to FFB (%)
EFB	20-25
Fibre	11.3-15
PKS	5-7

Source: Survey data

This kind of technology has been established in Sabah Malaysia by TSH Bio Energy in 14 MWe cogeneration system fueled by EFB, fiber and PKS [3]. In Aceh, PTPN I and Gistek Prima Lestarindo will use the same technology to build 10 MWe Power Station in CPO Mill Tanjong Seumantoh, Aceh Tamiang using EFB as a fuel. It is should note that energy from EFB can be converted to a significant number of electricity. As an illustration, a CPO Mill with capacity of 100,000 tons of FFB per year will produced about 20,000 tons of EFB which is possible to generate energy up to 30 GW(e)h at 25% conversion efficiency.

Clean Development Mechanism (CDM). CDM is one of the *flexibility mechanisms* that are defined in the Kyoto Protocol. The flexibility mechanisms are designed to allow Annex B countries to meet their emission reduction commitments with reduced impact on their economies [4]. The flexibility mechanisms were introduced to the Kyoto Protocol by the US government. Developing countries were highly skeptical and fiercely opposed to the flexibility mechanisms [5]. However, in the international negotiations over the follow-up to the Kyoto Protocol, it has been agreed that the mechanisms will continue.

The purpose of CDM is to promote clean development in developing countries, i.e., the non-Annex 1 countries (countries that are not listed in Annex 1 of the United Nations Framework Convention on Climate Change [UNFCCC]). CDM is one of the Protocol's "project-based" mechanisms; in that CDM is designed to promote projects that reduce emissions. CDM is based on the idea of emission reduction "production" [6]. These reductions are "produced" and then subtracted against a hypothetical "baseline" of emissions. The emissions baseline is the emissions that are predicted to occur in the absence of a particular CDM project. CDM projects are "credited" against this baseline, in the sense that developing countries gain credit for producing these emission cuts.

The economic basis for including developing countries in efforts to reduce emissions is that emission cuts are thought to be less expensive in developing countries than developed countries [7-8]. For example, in developing countries, environmental regulation is generally weaker than it is in developed countries [9]. Thus, it is widely thought that there is greater potential for developing countries to reduce their emissions than developed countries.

From the view point of bringing about a global reduction in emissions, emissions from developing countries are projected to increase substantially over this century [7]. Infrastructure decisions made in developing countries could therefore have a very large influence on future efforts to limit total global emissions

[10]. CDM is designed to start off developing countries on a path towards less pollution, with industrialized (Annex B) countries paying for these reductions.

Parallel with the reduction of greenhouse gas (GHG) emission, projects taking place in CDM scheme will bring profit the developing countries which are on achieving the sustainable development throught the financial and technology supports. The supports, generally called emission credit, are provided from the CDM Project via Certified Emission Reductions (CERs). These certificates can be redeemed on an open carbon market. GHGs emission are varies with industries. Table 2 shows the type of GHG and its source category.

The Kyoto Protocol has opened the market for trading in GHG emission credits. CDM has been set up to assist non-Annex-I countries in achieving sustainable development objectives by promoting GHG reduction projects that generate emission credits (CERs) for Annex-I countries [11]. There is tremendous interest among palm oil industries, project promoters, financing institutions, and other stakeholders in the opportunities emerging out of the CDM. So far carbon certificates from CDM are mainly being generated from voluntary projects on an experimental basis.

Kyoto Protocol consists of 28 Chapters and 2 Annex: 1) Annex A: Sector/source category of GHG; 2) Annex B: Quantity of obligation to reduce the emission as agreed for stake holders.

As has been mentioned above, EFB produce from CPO Mills in Aceh are normally spread on the plantation, incinerated or dumped in unmanaged sites. Therefore, CDM project for the utilization of EFB is relatively new in Aceh. To date, in Indonesia only 5 companies have already built the composting plants from EFB for their CDM project.

Table 2. Type of GHG and its Source Category

Kind of GHG	Source
Carbon dioxide (CO_2)	Combustion of fossil fuel, deforestation, agriculture, plantation
Methane (CH_4)	Agriculture, plantation, changing of area, combustion of biomass, landfills
Nitrogen oxide (N_2O)	Combustion of fossil fuel, industry, agriculture, plantation
Hydrofluorcarbon (HFCs)	Industry, manufacture
Perfluorocarbon (PFCs)	Industry, manufacture
Sulphur hexafluoride (SF_6)	Electrical transmission, manufacture

Source: Ref. [4]

Recently, EFB has been utilized for fertilizer or soil conditioner since EFB contains certain macro and micronutrients that are required for plant growth. In fact, incinerating EFB to obtain its ash is currently the common practice in many CPO Mills as this can offset the increasing cost of inorganic fertilizers. In some oil palm mills, EFB is not incinerated, but mulch and directly thrown back to oil palm plantations [12]. Since EFB belongs to the category of fibrous crop residues or also known as lignocellulosic residues, therefore EFB can also be converted into pulp [13-14].

EFB can also be a cheap carbon source for bioplastic industry, such as polyhydroxyalkanoates (PHAs) or polylactate (PLA), thus reduce total manufacturing cost [14]. The utilization of EFB has been applied for CDM project in some CPO Mills in Malaysia, however the utilization of EFB for RE less implemented in Indonesia. Base on the fact, this research will be focused on the potential of EFB for energy sources in order to solve the problem on crisis of energy and reduce GHGs emission.

In CPO mill itself, main GHG are CO_2, CH_4 and N_2O. From several of GHG, each gas has potential value of different Global Potential Warming (GWP) between one and another. Global potential measurement measure the relative effect of radiation effected by GHG comparing with CO_2. For instance, 1 tons of methane has global potential heat equal to 21 tons CO_2, as shown in Table 3.

CDM requirement project in Indonesia are: 1) project must support continuous development in Indonesia, 2) project must produce the real GHG emission reduction and can be calculated, and 3) produce emission reduction which is not done without CDM.

CDM project can be classified into two main categories: (1) GHG emission reduction and (2) Sequestration (sink, carbon adsorption). In those two categories, there are some sub-categories classified based on how big the project is, as shown in Figure 1.

Table 3. Type of GHG and its GWP

Kind of GRK	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrogen oxide (N_2O)	310
Hydrofluorcarbon (HFCs)	140–11.700
Perfluorocarbon (PFCs)	6.500–9.200
Sulphur hexafluoride (SF_6)	23.900

Source: Ref. [15]

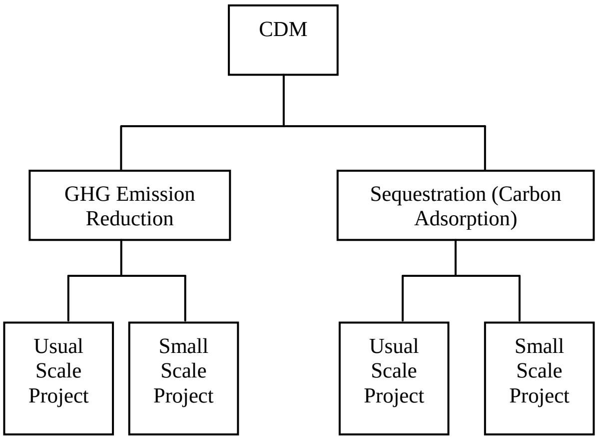

Figure 1. Classification of CDM Project Activity [15]

For CDM project of CPO plant in Aceh, project clarification is assumedcorresponding in small scale project. This is due to potential CDM in Aceh fulfil one of the criteria from three type of which below [15]: (1) Type I: project on renewable energy with output capacity ≤ 15 MW (or equivalent); (2) Type II: project on improvement of energy efficiency, that is possible to reduce energy consumption, whichever in supply side and/or demand size up to 15GWh per year; (3) Type III: other project which is pontential to reduce the emission from people activity (anthropogenic) wherein the emission reducing < 15 ktCO_2 equivalent (CO_2e) per year.

Even though CDM project is aimed to realize the continuous development in home-grown country, those small scale projects are hard to developed due to their characteristic in highly cost but producing low credit. Actually those small scale projects on contrary are more useful and continuous to local people. As a result, the UNFCCC try to solve this problem by making fast-way of regulations and requirements (modalities and procedures) in order to minimize the cost.

CDM small scale project is given some eases enabling acceleration of registration process. The only description which can be applied to CDM small scale project is bundling and debundling.

Bundling is a classification/integration of smallest project which cannot attract investor even having additional CERs. Nowadays, there are so many projects based on people (e.g. small hydro power project), UKM projects, in which they give significant contribution to continuous development, having resistant due to investors not to interested in helping them except the existence of public pressure. Those projects can be caused into one so that they can be a proper project based on financial side.

As for the amount of projects united cannot be limited by regulation maintained by UNFCCC, as long as the amount do not pass the criteria of limitation of CDM small scale project. However, large projects cannot debundle the projects into some small projects. This situation is to prevent misusing fast-way of facilities to CDM small scale project [15].

Nevertheless, UNFCC is still allowing a small project taken from fraction of large scale project if it has been registered or will be registered as CDM small scale project, if: (1) subject of the project is still the same; (2) project category, technology and its measurement are still the same; (3) have been registered two years before, and (4) project boundary is in 1 km radius from the small scale project boundary (in the closest point).

Thus, CDM has a role in the context of sustainable development, formation of carbon markets, and promotion of bioenergy options. Besides contributing to mitigate climate change, CDM can be used to demonstrate and disseminate new technologies, reduce investment risks and enhance the cost efficiency of projects, while also creating jobs and improving environmental condition [16].

Oil palm biomass such as EFB, fiber and PKS can be used to produce steam for processing FFB and for generating electricity, which can be directly used in the mill. However, due to their characteristics, some of these fuel sources have to be pretreated before they can be burned in the boiler [14]. Therefore, basic pretreatment process is required for effective use of biomass includes shedding to reduce the size and drying to reduce moisture content. Hopefully, future technologies might overcome these problems, so that the CDM Project by the use of EFB for an alternative RE seems to be promising in the future.

Apart from that, the utilization of EFB as a source of energy will bring other environmental benefit like reduction in GHGs emission. In case of Aceh, the used of EFB as a source of energy received much attention and promising since the regions now face the problem with energy and electricity.

Indonesian Policy. Share of RE in total energy supply in Indonesia is poised to rise in the future. To achieve this goal, the country has instituted a number of policies to promote RE and CDM which is providing benefits to the RE projects that have feeble project finance and are additional to business as usual scenario. In order to increase use of RE, Indonesia is taking a number of actions including formulating a directive policy on investment and financing. The Indonesian Blueprint for National Energy Management 2006-2025 has put RE to supply 17% the country's energy primary by 2025 [17].

This study is aimed to investigate the potency of EFB as an energy source in Aceh, as a CDM project by predicting how much the GHG emission reduction per year and the possiblity of applying CDM in Aceh. The study is focused from the view of point technical aspecs, not from economical aspecs. The economic potential of biomass cogeneration as CDM projects in Indonesia has been studied previously even if for different biomass, i.e. bagasse [18].

2. Methods

This research is carried out by using the approaces below: a) Quantitative Method: to calculate how much CO_2 and CH_4 obtained from baseline scenario and calculate how much CO_2 and CH_4 emission reduction happened if CDM project is applied in CPO Mill. Baseline method used is Approved Methodology for Small Scale (AMS) as agreed by UNFCCC, that is: AMS-I.D: Renewable electricity power to the network and AMS-III.E: The prevention of methane production from the biomass degradation via combustion controlling; b) Qualitative Method: this method carried out to more investigate about various issues relating to the CDM application in CPO Mill via interview to mill management.

AMS-I.D Methods: Renewable Electricity Power to The Network. This method is used to RE such as fotovoltaik, microhydro, low tide of sea water, wind, geothermal and biomass substituing electricity from fossil fuel distribution system.

If there is an additional unit of machine not only in renewable component but also not renewable component, the limitation feasibility of 15 MW for CDM small scale project only be treated to renewable component. If the unit add co-fired fossil fuel, the whole capacity must not exceed 15 MW.

Baseline emission calculation. Baseline emission is result of baseline energy ($EG_{BL,y}$), expressed in kWh of electricity produced by RE power multiplied by an emission factor, as defined below:

$$BE_y = EG_{BL,y} * EF_{CO_2} \quad (1)$$

where:
BE_y = baseline emission in y year (t CO_2)
$EG_{BL,y}$ = baseline energy in the year of y (kWh)
EF_{CO2} = emission factor of CO_2 in the year of y (t CO_2e /kWh).

Emission factor calculated transparency and conservatively by using method below: a) Using Combination Margin (CM), consisting of combination of Operation Margin (OM) and Build Margin (BM) or b) Average emission (in kgCO_2e/kWh) from combination generator available. Data for years in location before project carried out must be used and must be based on formal sources.

Project emission. For some large RE project, project emission (PE_y) is equal to zero. This means CDM Project activity of RE does not use facility to produce significant emission.

Leakage project emission. If the component of energy generating is a used component from another project, the leakage emission (LE_y) must be considered. But, if the component used in project is new component, LE_y is equal to zero.

Calculating emission reduction. Emission reduction is calculated with the equation below:

$$ER_y = BE_y - PE_y - LE_y \quad (2)$$

where:
ER_y = emission reduction in y year (t CO_2e/y)
BE_y = baseline emission in y year (t CO_2e/y)
PE_y = emission project in y year (t CO_2/y)
LE_y = emission leakage in y year (t CO_2/y).

AMS-III.E Method: Prevention of Methane Production from the Biomass Degradation via Combustion Controlling. This method is used to CDM project preventing methane production from biomass or other organic material. Usually, before that, biomass is left to be degrading in anaerobic condition or store in location of solid waste disposal without methane recovery.

With the existence of the project, waste degradation can be prevented by one of the action such as controlling combustion, gasification to produce synthesis/producer gas, mechanical/thermal treatment to produce refuse-derived fuel (RDF) or stabilize biomass (SB). For instance RDF/SB is pelletisation/densification of solid waste.

Baseline calculation. Amount of methane that would in the absence of the project activity be generated from disposal of waste at the solid waste disposal site ($BE_{CH4,SWDS,y}$) is calculated with a multi-phase model. The calculation is based on First Order Decay (FOD) model. The model differentiates between the different types of waste j with respectively different decay rates k_j and different fractions of Degradable Organic Carbon (DOC_j).

Calculation for methane release is based on actual waste streams $W_{j,x}$ disposed in each year x, starting with the first year after the start of the project activity until the end of year *y*, for which baseline emissions are calculated (years *x* with *x* = 1 until *x* = *y*). The amount of methane produced in year *y* ($BE_{CH4,\ SWDS,\ y}$) is calculated as follows:

$$BE_{CH4,SWD,y} = \varphi(1-f)GWP_{CH4}(1-OX)\frac{16}{12}F.DOC_f.MCF.$$
$$.\sum_{x=1}^{y}\sum_{j}W_{j,x}.DOC_j.e^{-k_j(y-x)}(1-e^{-k_j}) \quad (3)$$

where:

$BE_{CH4,\ SWDS,\ y}$ = methane emission avoided during year *y* from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year *y* (tCO_2e)

φ = model correction factor to account for model uncertainties

f = fraction of methane captured at the SWDS and flared, combusted or used in another manner

GWP_{CH4} = Global Warming Potential of methane, valid for the relevant commitment period

OX = oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)

F = fraction of methane in the SWDS (volume fraction)

DOC_f = fraction of DOC that can decompose

MCF = methane correction factor

$W_{j,\ x}$ = amount of organic waste type *j* prevented from disposal in the SWDS in the year *x* (tons)

DOC_j = fraction of DOC in the waste type *j*

k_j = decay rate for the waste type *j*

j = waste type category (index)

x = year during the crediting period: x runs from the first year of the first crediting (*x* = 1) to the year *y* for which avoided emissions are calculated (*x* = *y*)

y = year for which methane emissions are calculated.

3. Results and Discussion

Survey data from some CPO Mills in Aceh are shown in Table 4. The data present the condition which is not too different between one mill and another. This is due to the technology for FFB processing is similar in each CPO Mill. Samples taken in those three CPO Mills are assumed can represent the conditions of all CPO Mills located in Aceh.

Characteristic of the EFB analyzed are calorific value, water, nitrogen and organic carbon contents. Parameters examined are main source components for GHGs such as CO_2, CH_4 and N_2O. All the calculations in this research were based on the EFB characteristics taken from three CPO Mills: Patisari Trenggulun, Aceh Tamiang (20 tons per hour), PTPN I Cot Girek, North Aceh (45 tons per hour) and PTPN I Tanjong Seumantoh, Aceh Tamiang (60 tons per hour). The characteristics of some EFBs are shown in Table 5.

From the analysis data as shown in Table 5, it is seen that calorific value of EFB are up to calorific value of brown coal i.e. 5,904 kcal/kg [19]. If the energy of EFB from those mills is converted into kWh, the mill will produce the energy up to 6.9 KWh/kg. This means there is a large potency to be used as electricity source.

Moisture in EFB of the three CPO plant are relatively low (<55%) comparing to the research report done by Yusoff [12] that is 65%. EFB need to be cut in order to minimize the size and dried until the moisture content under 50% so that become easier to be burned.

Table 4. Profile of Some CPO Mills in Aceh

	Unit	Patisari CPO Mill	PTPN I CPO Mill	PTPN I CPO Mill
Actual capacity	t/h	20	45	60
Working capacity	% of act. cap.	75	75	77
Number of working hour	h/d	18	20	19.11
Number of working day	d/y	300	300	300
Fraction of EFB	% of FFB	22	22	23
Existing EFB used:	t/d			
- burned in incinerator		107 (25%)	128.2 (20%)	171 (20%)
- other application		321 (75%)	512.8 (80%)	684 (80%)
Source of electricity	-	Steam turbine (fuel: PKS)	PLN	PLN
Energy consumpt.	KWh/ton FFB	n.a.*	13.26	13.26

Source: Survey data; * data is not available

Table 5. Characteristics of EFB

Parameters	Unit	Patisari CPO Mill	PTPN I CPO Mill	PTPN I CPO Mill
Calorific Value	kcal/kg	6,098	6,013	5,688.4
Moisture	%	51.07	47.81	47.69
Nitrogen	%	0.48	0.41	0.51
Organic Carbon	%	52.88	51.56	48.97

1 kcal = 4187 Joule = 1.163 Wh

Carbons contents in those EFB are also not quite different to carbon in brown coal i.e. 60.65% [19], however, much higher to EFB reported in previous publication that is 43.5% [20]. Carbon in EFB will form the CO_2 as GHG emission in combustion process, therefore in the estimation of total emission reduction; this gas must be taken into consideration.

Potency of Energy in CPO Mill. Based on survey data, Aceh produce more than 4,350,000 tons FFB every year from 15 districts/cities with more than 290,000 hectare of plantation area. This big amount of palm production surely will produce EFB approximately 870,000 ton EFB per year by assumption EFB is 20-25% of FFB processed in CPO Mill.

Base on observation, it is seen that 75-80% of EFB is collected in mill area and used as a fertilizer (as has been cited above) not only in plantation itself but also for people nearby. The rest of 20-25% is fired in on-site incinerator at temperature of 300°C. If 75% of EFB potency is utilized as source of energy, it will produce about 1,047 GW(e)h per year at conversion efficiency of 25%. While the energy consumption in all CPO Mills in Aceh is only 45 GW(e)h per year.

The estimation result for the power consumption, potency of energy from EFB and total emission reduction per district are tabulated in Table 6. The data in the table show that the electricity consumption in CPO Mills can be fulfilled by using EFB and this fact prove that the use of EFB to substitute fossil fuel is very advantageous.

Calculation procedure of emission factor (*EF*) for the electricity network of Sumatera is done by ACM0002 new version (Version 07): "Approved consolidated baseline and monitoring methodology ACM0002, Consolidated baseline methodology for grid-connected electricity generation from renewable sources". In addition, the other guidance is Annex 12, Complement of method (Version 01): "Complement for calculation of emission factor for electricity system".

The electricity network in Aceh is a network which has been connected to the Sumatera interconnection system. Thus, in calculating *EF*, it was included all power plants located in Sumatera such as Diesel Power Plant, Steam Turbine Power Plant, Gas Turbine Power Plant and Hydro Power Plant. The evaluating procedure for EF required a comprehensive data on electricity system in Sumatera and for this calculation; it has been done by Directorate of Electricity and Energy Utilization in 2006. The calculated value by taking into consideration all input data is EF_{2006} = 0.743 tCO2e/MWh.

Emission Reduction. The use of biomass fuel such as EFB as energy/electricity source in CPO Mill gives the emission reduction. The emission reduction is provided by the combustion of EFB since this combustion process produce less emission compare to the use of fossil fuel. Moreover, in addition to the emission reduction in biomass combustion, the emission reduction is also come from the avoiding of methane release from dumping of EFB. The calculation of baseline emission in CPO Mill is conducted by following equation:

Baseline emission = Baseline emission of electricity + Baseline emission from dumping of EFB (4)

GHGs emission in steam generator and mill's generator itself is excluded in this project scenario. The source of emission for baseline calculation is limited to only on electricity from the PLN network and GHGs emission is only predicted from CO_2 and CH_4. Thereafter, the emission reduction is the difference between the emission of fossil fuel-based electricity and the EFB-based one.

Table 6. Power Consumption, Potency of Energy from EFB and Total of Emission Reduction by District

CPO Plant	Capacity (t/y)	EFB (t/y)	Power Consumption (KWh/y)	Potency of Energy from EFB (KWh/y)**	CO_2 Emission in Power Generation Fuelled by EFB (t/y)	Total of Emission Reduction (t/y)
North Aceh, 3 CPO Mills	449,100	98,802	5,955,066	127,825,087.5	2,045.19	20,904.80
East Aceh, 1 CPO Mill	128,400	28,248	1,702,584	36,545,850.0	584.73	5,976.79
Aceh Tamiang, 10 CPO Mills	1,411,500	310,530	18,716,490	401,7481,87.5	6,427.96	65,702.78
West Aceh, 2 CPO Mills	256,800	56,496	3,405,168	73,091,700.0	1,169.46	11,953.58
Nagan Raya, 4 CPO Mills	641,700	141,174	8,508,942	182,643,862.5	2,922.29	29,869.98
Aceh Singkil, 4 CPO Mills	684,300	150,546	9,073,818	194,768,887.5	3,116.29	31,852.93
Subulussalam, 1 CPO Mill	106,800	23,496	1,416,168	30,397,950.0	486.37	4,971.35
Total	3,678,600	809,292	48,778,236	1,047,021,525	16,752.29	171,232.21

**Assumption of conversion efficiency in boiler is 25%

The leakages of equipment which is possible to occur and caused the increase in emission when the EFB are being used in this project are neglected, with the assumption that the equipment used is new. Hence, the emission reduction becomes:

Emission reduction = Baseline emission – (Project emission + Leakage emission) (5)

When the leakage emission equal to zero, thus:

Emission reduction = Baseline emission – Project emission (6)

Project itself is assumed not to produce emission (zero emission), therefore the emission reduction is equal to baseline emission:

Emission reduction = Baseline emission (7)

If it is assumed that energy consumption in CPO Mills (45 GW(e)h per year) is generated from fossil fuel and substituted with biomass, it is clear that the carbon emission reduction equal to 36,226 tons per year. The carbon emission is the difference between the use of fossil fuel and biomass. According to Chan [21] carbon emission from the use of EFB is lowest one i.e. 16 gCO_2/KWh.

Methane (CH_4) produced is caused from the reaction of the anaerobic bacteria in heaping of empty bunch that is GHG which effect the environment so that it has to be avoided. The avoidance of methane is carried out by calculating using determined method of methane emission avoidance from waste disposal located in solid waste disposal as similar in Annex UNFCCC attachment. The calculation is used based on Eq.(3) mentioned above. Based on data from UNFCCC, the parameters used for EFB and its values are shown in the following table. These values have been widely used and validated by many investigator, for example the φ value validated by Oonk et al. in 1994 [22].

Table 7. Parameters Used for EFB

Variable	Value	Unit
φ	0.9	-
OX	0	-
F	0.5	-
DOC_f	0.5	-
DOC_j	0.15	-
k_j	0.4	-
MCF	0.8	-
F	0	-
GWP_{CH4}	21	tCO_2e/tCH_4
$W_{j,x}$	466,077.6	tons/year

Source: Ref. [22]

Finally, by using the value of the parameters tabulated in Table 7, hence the methane avoided is 151,758 tCO_2e per year. If this result is added by carbon emission from fossil fuel and minus by carbon emission formed in combustion of EFB, total emissions can be avoided is (as shown in last column Table 6):

$$36{,}226 - 16{,}752 + 151{,}758 = 171{,}232 \ tCO_2e/year$$

This emission reduction in the next years will increase due to the accumulation of methane avoidance because of the increase of EFB.

4. Conclusions

The application of CDM Project in Aceh is possible to reduce the GHGs emission. From the view point of sustainable development, the use of EFB as energy source potentially solves the energy and environment problems in Aceh Province. The GHG emission reduction evaluated based on the difference of fossil fuel electricity emission to EFB one. Every year, 25 of CPO Mills in Aceh produce about 870,000 tons of EFB which is possible to generate electricity as much as 1,047 GW(e)h with consumption energy about 45 GW(e)h. Avoidance of methane from EFB dumping is up to 151,758 tCO_2e per year. Total emission reduction from utilization of EFB and methane avoidance is 171,232 tCO_2e in the first year.

Acknowledgements

This study was funded by Directorate General of Higher Education, Ministry of National Education through the Hibah Pascasarjana with the contract number of 285/SP2H/PL/Dit.Litabmas/IV/2011.

References

[1] Anon., Data Perusahaan Perkebunan Kelapa Sawit yang Memiliki Unit Pabrik Kelapa Sawit di Provinsi Aceh, Dinas Kehutanan dan Perkebunan Provinsi Aceh, Banda Aceh, 2012, p.25.

[2] B. Loebis, P.L. Tobing, Buletin Perkebunan BPP Medan. 19/20 (1989) 49.

[3] A.D.C. Gonzales, International Development in Biomass Utilization, Presented in the Renewable Energy Asia 2008, Bangkok, Thailand, 2008, *http://www.thai-exhibition.com/entech/conference/rne/pdf/S2/13.30-14.pdf*.

[4] A. Verbruggen, In: B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (Eds.), Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report: Climate Change 2007, Cambridge University Press, Cambridge, U.K., 2007, p.809.

[5] Anon., Global Carbon Mechanisms: Emerging lessons and implications (CTC748), Carbon Trust, 2010, p.60.
[6] F.L. Toth, M. Mwandosya, In: B. Metz, O. Davidson, R. Swart, J. Pan (Eds.), IPCC Third Assessment Report: Climate Change 2001, Cambridge University Press, Cambridge, U.K., 2001, p.601.
[7] J. Goldemberg, R. Squitieri, J. Stiglitz, A. Amano, X. Shaoxiong, R. Saha, In: J.P. Bruce, H. Lee, E.F. Haites, (Eds.), IPCC Second Assessment Report: Climate Change 1995, Cambridge University Press, Cambridge, U.K., 1996, p.29.
[8] M. Grubb, World Economics 4/3 (2010) 143.
[9] J. Sathaye, D. Bouille, In: B. Metz, O. Davidson, R. Swart, J. Pan, (Eds.), IPCC Third Assessment Report: Climate Change 2001, Cambridge University Press, Cambridge, U.K., 2001, p.345.
[10] B.S. Fisher, N. Nakicenovic, In: B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (Eds.), IPCC Fourth Assessment Report: Climate Change 2007, Cambridge University Press, Cambridge, U.K., 2007, p.176.
[11] P. Purohit, Energy 34 (2009) 1014.
[12] S. Yusoff, J. Cleaner Production 14 (2004) 87.
[13] W.D. Wanrosli, Z. Zainuddin, K.N. Lawb, R. Asro, Ind Crops Prod 25 (2006) 89.
[14] S.H. Shuit, K.T. Tan, K.T. Lee, A.H. Kamaruddin, Energy 34 (2009) 1225.
[15] Anon., Panduan Kegiatan MPB di Indonesia, Institute for Global Environmental Strategies, Edisi Kedua, Jakarta, 2006, p.23.
[16] S. Silveira, Biomass and Bioenergy 28 (2005) 107.
[17] Anon., *Blueprint* Pengelolaan Energi Nasional 2006-2025, Departemen Energi dan Sumber Daya Mineral, Jakarta, 2006, p.58.
[18] D. Restuti, A. Michaelowa, Energy Policy 35 (2007) 3952.
[19] Mahidin, A. Gani, Khairil, Makara Seri Teknol. 15 (2011) 178.
[20] A.B. Nasrin, A.N. Ma, M.C. Chow, H. Hamdan, Y.M. Choo, J. Oil Palm Ind. Eco. 6 (2006) 31.
[21] K. W. Chan, Biomass Production in the Palm Oil Industry, Palm Oil and Environment, Malaysian Palm Oil Association, Malaysia, 1999.
[22] CDM Executive Board, Annex 10 Methodological Tool: Tool to determine Methane Emissions Avoided from Dumping Waste at Solid Waste Disposal Site, United Nations Framework Convention on Climate Change (UNFCCC), 2005.