Proceedings

The 5th Environmental Technology and Management Conference

Green Technology towards Sustainable Environment

23 - 24 November 2015, Bandung, Indonesia

Editor in Chief

Prof. Dr. Ir. Enri Damanhuri

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Green Technology that provides the basic needs of society in sustainable environment is essential for the survival, health and well-being of a society in developing countries. The engineers, scientists, policy makers, academics, environmental consultants, environmental contractors, industrial practitioners, businessmen, politicians, NGOs are at the epicenter in seeking means to enhance human life through modernization of technology and infrastructure. The current rate of urbanization, industrialization and environment mismanagement rise environmental issues. The problems are further aggravated with environmental degradation such as soil erosion, depletion of water resources, climate changes, and others. In order to seek answers for these multifaceted challenges, proper planning, implementation and verification exercises are required, via an integrated, multidisciplinary and holistic approach especially in the area of green infrastructure and green cities, development of eco-industry, environmental health and risk assessment, air quality, advanced technology, natural resources and mitigation of climate change. This international conference shall become a momentum for development of sustainable environment through green technology.

The 5th Environmental Technology and Management Conference (ETMC) was held on 23-24th November 2015, at Sasana Budaya Ganesha, Institut Teknologi Bandung (ITB). The ITB is located in Bandung, West Java. Bandung is the center of Sundanese culture and volcanoes surrounds city which make Bandung to be a delightful place to host this conference. More than 300 scientific participants (researcher, students, government officers and industries) had many fruitful discussions and exchange ideas that contribute to the success of the conference. Participants of the conference are coming from US, Australia, Nederland, Japan, Malaysia, Singapore and Indonesia, made the conference truly worthwhile globally. There are 4 speakers in plenary sessions covering different areas, and all the keynote speakers are well known and competent speakers; They are Ir. Mochamad Basoeki Hadimoeljono, M.Sc., Ph.D (Ministry of Public Works and Housing, Republic of Indonesia), Prof. Dr. AJM Smits (Director of Institute for Science, Innovation & Society, Radboud University Nijmegen), Albert Simanjuntak (President Director of Chevron Pacific Indonesia) and Ir. Edwan Kardena, PhD (Environmental Engineering, Institut Teknologi Bandung). There were also 5 parallel sessions with eight invited speakers : Prof. Satoshi Okabe; Prof. Ir. Mindriany Syafila, MS; Prof. Ir. Iwan Kridasanta Hadihardaja, MSc, PhD; Prof. Dr. Takeshi Fujiwara; Rene van Berkel, PhD; Prof. dr. A.M.J. Ragas; Dr. Budi Haryanto, SKM, MKM, MSc; Dr. rer.nat Armil Susandi,MT.

This volume of proceedings from the conference provides an opportunity for readers to engage with a selection of refereed papers that were presented during the conference. These proceedings divided into 6 sections of 110 abstracts as oral presentation and 23 abstracts as poster session with such topics as follows: Air Quality & Climate Change, Green Cities & Infrastructures, Eco-Industries, Appropriate & Advanced Environmental Technology, Natural Resource Management, and Environmental Health and Risk Assessment. Selected papers will be republished in the special issues of Journal of Technological and Engineering Sciences.
Generous support for the conference was provided by Chevron Pacific Indonesia, JICA, BNI, Vale, Sari Husada, Indocement, Holcim, Sabuga and Faculty of Civil and Environmental Engineering, ITB. The funds were sizeable, timely, and greatly appreciated, and allowed us to support a significant number of young scientists (students) and delegates from developing countries.

Finally, the 5th ETMC was a very successful conference. The plenary lectures, parallels session and special reports bridged the gap between the different fields of green technology, making it possible for non-experts in a given area to gain insight into new areas. Also, included among the speakers were several young scientists and students, who brought new perspectives to their fields. Given the rapid advancement of science in all areas that covered by ETMC, we expect that this ETMC was as stimulating as the previous one, as indicated by the papers contributions presented in this proceeding volume.

Bandung, 24 November 2015

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LIFE CYCLE ASSESSMENT OF INTEGRATED PALM OIL INDUSTRY WITH SCENARIOS OF LIQUID AND SOLID WASTES UTILIZATION AND INTEGRATION WITH CATTLE FARM

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Abstract: This research work used Life Cycle Assessment (LCA) as a tool for identification possibilities for improvement of crude palm oil (CPO) production, focusing on energy efficiency and greenhouse gas emission aspects. The research was conducted with two cases of palm oil mill (POM). Results showed that energy consumption for production of one ton CPO was 6313 MJ in POM 1, with a Net Energy Ratio (NER) of 6.2 and a Net Energy Value (NEV) of 33.03 GJ/ton CPO, while energy consumption in POM 2 was 7270 MJ/ton CPO with NER of 5.4 and NEV of 32.08 GJ/ton CPO. The GHG emissions in the case POM 1 and the case POM 2 were 1463 and 624 kg CO₂–eq/ton CPO, respectively. The identified most potential opportunity to improve energy efficiency and reduce emission is the utilization of biogas from anaerobic decomposition process of wastewater as an energy source of power plant. The scenario can reduce emission of approx. 970 kg CO₂–eq/ton CPO (POM 2) resulting in NER and NEV increases of up to 5.7 and NEV of up to 33.83 GJ/ton CPO. A further significant improvement of CPO production process can be achieved through the integration of the oil palm plantation with cattle farm and the utilization of solid waste as an organic fertilizer.

Keywords: Crude palm oil, greenhouse gas emission, integrated oil palm plantation, Life Cycle Assessment, net energy efficiency

1. Introduction

Indonesia is the biggest Crude Palm Oil POM 1(CPO) producer in the world with a production of 27 million tons CPO in 2013 (Ditjenbun 2014). The development of palm oil industry will increase further as the Government of Indonesia targeted to produce 40 million tons CPO per year by 2020. To support the achieving of the target, the government will allocate some forest area for oil palm plantation in according to the National Forestry Plan 2011-2030 (Kemenhut 2011).

The rapid growth of the oil palm industry had caused the environmental impacts. Palm oil industry activities from nursery, planting, fertilizing, energy use, and management of the wastes are considered as sources of greenhouse gas (GHG) emission. The GHGs absorb and
reflect infrared radiation resulting in an increase in temperature of the earth (Cicerone 1987). The environmental issues are becoming more serious attentions from international communities leading to the decrease of the competitiveness of Indonesian CPO in the international market.

In order to improve the international competitiveness of Indonesian oil palm products, the government of Indonesia implements regulations arranged in the Indonesian Sustainable Palm Oil (ISPO) consisting of seven principles: licensing system and plantation management, application of technical guidelines for the cultivation and processing of palm oil, environmental management, responsibility to workers, social responsibility, empowerment of economic activities, and increased efforts for sustainability. According to the criteria, the corporate environmental management needs to identify and manage the source of GHG emissions (Ditjenbun 2014). Life cycle assessment (LCA) can be applied to in-depth environmental evaluation process of CPO production. The methodology enables a holistic life cycle thinking, comprehensive identification of potentials and opportunities for improvement of the CPO production process.

This research work aimed to develop an inventory of environmental burdens by identifying and quantifying energy and materials used and wastes released by palm oil production process. The results are expected to provide can benchmark for assessment and improvement of CPO production processes covering resource use, energy efficiency, and the impact on the environment.

2. Research Methodology

The LCA is realized by the quantitative identification of all material and energy input-output flow at the CPO production system, with attention focused on the energy efficiency and the environmental impact. The analysis of environmental impact of CPO production process is given at all stages of its life cycle, starting from the nursery, oil palm plantation, FFB transportation, and FFB processing (or CPO extraction), including scenarios of the capturing and utilization of methane from anaerobic degradation of wastewater, integration of oil palm plantation with cattle farm, and utilization of solid waste as an organic fertilizer.

This study was conducted with two cases, namely palm oil mill (POM) 1 (case 1) and POM 2 (case 2). The POMs are owned by the State-Owned Enterprises. The POMs are different in many aspects; including distance between plantation area and POM, POM production capacity, type of product, ISPO certification, and biogas electric generation plant (Table 1).

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<th>POM 1 (Case 1)</th>
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<tr>
<td>Plantation area</td>
<td>5870 ha</td>
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<tr>
<td>Production capacity</td>
<td>40 ton FFB/h</td>
</tr>
<tr>
<td>Main product</td>
<td>CPO &amp; PKO</td>
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<tr>
<td>ISPO certification</td>
<td>No</td>
</tr>
<tr>
<td>Biogas electric generation</td>
<td>No</td>
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Inventory analysis was undertaken by analyzing the mass and energy flows at the CPO production process life cycle. The materials and energy flows are standardized in the unit per ton CPO produced. Inventory data are collected from field observation, in-depth interviews, corporate documents, and relevant scientific publications. The impacts of the CPO production are evaluated based on the results of the inventory analysis referring to the net energy and the GHG emissions in the CPO production process.

The CO$_2$ emission (E) per ton CPO is estimated by referring to the equation in the IPCC (2006):

$$E = A \cdot EF$$

(1)

where A is inventory volume, and EF is emission factor (kg CO$_2$–eq/A).

Energy consumption is converted in a standardized energy unit (Joule) to estimate the net energy ratio (NER) and the net energy value (NEV). The energy consumption ($E_n$) for production of one ton CPO is estimated by using Eq. 2:

$$E_n = n \cdot CV$$

(2)

where n is inventory volume, CV is calorific value of each inventory.

Energy efficiency is expressed in NER and NEV that are calculated by using Eq. 3 and 4, respectively:

$$NEV = \sum E_{n0} - \sum E_{ni}$$

$$NER = \frac{\sum E_{n0}}{\sum E_{ni}}$$

(3)

(4)

where NEV is net energy value, NER is net energy ratio, $\sum E_{n0}$ is total energy earned, and $\sum E_{ni}$ is total energy used.

The net energy is used as indicator of the process performance. For a good process performance, NEV should be positive and NER should be more than 1. The higher the value of NER and NEV, the better is the performance of the CPO production process, in the context of energy consumption and energy recovery.

3. Results and Discussion

3.1 Inventory of CPO Production

CPO production process life cycle is started with nursery and plantation. At these stages, impacts on the environment are caused by the use of synthetic fertilizers, pesticides, herbicides, and diesel (RSPO 2012). Fertilizer is one of the major emitters in agriculture, so that its use should receive special attention (Vijaya et al 2008b).
Both synthetic and organic fertilizers can be applied in palm oil plantations. The synthetic fertilizers include urea, NPK fertilizer, Kieserite, MOP (Muriate of Potash), dolomite, and TSP/RP. The application of the fertilizers causes emission from the fertilizer production itself (use of fossil energy during the production production), transportation, direct emissions from the field both physically and biologically by soil microbes, and indirect emissions due to re-deposition (RSPO 2012). The oil palm plantations also use organic fertilizers derived from solid wastes such as empty fruit bunches and wastewater sludge, but the applied organic fertilizers are still relatively small in quantity, so that the emissions by organic fertilizer are not taken into account in the emission calculation.

Pesticides and herbicides also have an impact on the environment because it can produce emissions. Pesticides and herbicides have substantial emissions as stated by ISCC (2011). The pesticides are applied only if the plantation is attacked by pests such as caterpillars and beetle horns. Herbicides are used to control weeds around the oil palm trees.

The next inventory analysis is the transportation of FFB from the field to the palm oil mills. FFB transportation is done by using diesel-fueled trucks. Diesel consumption is taken into account in the analysis of usage due to the use of direct impact on the environment (IPCC 2006). FFB is transported from the field to the POMs by using trucks with an average capacity of 9 tons. Diesel consumption for the transportation is estimated based on consumption of diesel trucks per km distance. Empty trucks require diesel of 0.25 liters / km, while loaded trucks (10 ton FFB/truck) require diesel of 0.49 liters / km (ISCC 2011). The map of plantation area is used to estimate the distance of FFB transportation.

The final stage of the oil palm life cycle is the FFB processing to extract CPO. FFB is going through a series of processes: weighing, sorting, boiling, pressing, and oil refining. Inventory at the FFB processing consist of the utilization of electric, diesel and steam (ISCC 2011, RSPO 2012). Electricity from steam turbine is used to run various processing machines. Diesel is used as fuel for electric generator when the electricity from boiler have not been adequat for covering the electricity demand. Steam obtained from the boiler is used in the boiling FFB process.

Table 2 shows the results of the analysis of inventory based on operation data of the studied POMs during 2013. Energy consumption and earning, as well as GHG emissions at every stage of the life cycle are also presented in Table 2, which will be discussed later in the subchapter 3.2.

The use of the inventory at the nursery and plantations stages for POM 2 is greater than it is for POM 1. This is because of the lower crop productivity for POM 2 in the time. Palm oil plantation of POM 2 experienced rejuvenation of plantation crops and many plantation areas did not produce FFB optimally yet, while utilities such as fertilizers were needed for the young crops. The differences in inventory of both cases as presented in Table 2 are caused mainly by the condition of the plantation (crop productivity), distance of plantation and POM location, the capacity of POM, and operational practices in both plantation and the palm oil mills.
3.2 Energy Efficiency and GHG Emission

Each identified inventory has a specific calorific value as presented in Table 3, representing the energy value of each inventory volume. Results of energy calculations according to the Eq. 2 are presented in Table 2. Table 4 shows the NEV and NER calculated using the Eq. 3 and 4. The specific energy consumptions for CPO production are 6330 MJ for POM 1 and 7270 MJ for POM 2. Differences in energy efficiency represented by NER and NEV are resulted from differences in conditions of the oil palm plantation (crop productivity), the distance between the plantation and POM location, the use of agricultural inputs (fertilizers, pesticides, and herbicides), the capacity and efficiency of the FFB processing mills. The most important factor of the CPO proses performance is the efficiency of palm oil extraction. The CPO yields were 23.46% (1 ton CPO/4.26 ton FFB) for POM 2 and 20.71% (1 ton CPO/4.83 ton FFB) for POM 1.

Utilization of the methane gas from the anaerobic decomposition of wastewater as an energy source for electricity generation will improve energy efficiency that is indicated by the increase of the NER and NEV. The generated methane gas is about 12.36 kg CH₄/ton palm oil mill effluent (Yacob et al 2006). One kg of methane gas is equivalent to 45.1 MJ (JRC 2011). POM 2 has been equipped with the installation of a biogas power plant that generates electrical energy of 1750 MJ/ton CPO. By taking into account of the generated as the energy output in the life cycle assessment, the NER and NEV in POM 2 will increase to 5.7 and 33.83 GJ/ton CPO, respectively.

### Table 2 Inventories, energy consumption, and GHG emission of POM 1 and POM 2

<table>
<thead>
<tr>
<th>Stage of the life cycle, and the inventories</th>
<th>Unit</th>
<th>Quantity (per ton CPO)</th>
<th>Energy (MJ/ton CPO)</th>
<th>Emission (kg CO₂–eq/ton CPO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursery and Plantation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFB</td>
<td>ton</td>
<td>4.83</td>
<td>4.26</td>
<td></td>
</tr>
<tr>
<td>N Fertilizer</td>
<td>kg</td>
<td>2.57</td>
<td>0.33</td>
<td>360.86</td>
</tr>
<tr>
<td>P Fertilizer</td>
<td>kg</td>
<td>4.80</td>
<td>10.71</td>
<td>51.79</td>
</tr>
<tr>
<td>K Fertilizer</td>
<td>kg</td>
<td>8.96</td>
<td>31.47</td>
<td>44.80</td>
</tr>
<tr>
<td>Urea</td>
<td>kg</td>
<td>11.29</td>
<td>23.04</td>
<td>37.35</td>
</tr>
<tr>
<td>Kieserit</td>
<td>kg</td>
<td>0.26</td>
<td>0.66</td>
<td>0.05</td>
</tr>
<tr>
<td>Dolomit</td>
<td>kg</td>
<td>26.29</td>
<td>28.03</td>
<td>3.42</td>
</tr>
<tr>
<td>Herbicides</td>
<td>liter</td>
<td>0.05</td>
<td>0.27</td>
<td>0.54</td>
</tr>
<tr>
<td>Pesticides</td>
<td>liter</td>
<td>0.02</td>
<td>-</td>
<td>0.16</td>
</tr>
<tr>
<td>FFB Transportation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>liter</td>
<td>3.25</td>
<td>3.76</td>
<td>116.86</td>
</tr>
<tr>
<td>FFB Processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>kWh</td>
<td>58.35</td>
<td>67.60</td>
<td>210.06</td>
</tr>
<tr>
<td>Diesel</td>
<td>liter</td>
<td>0.79</td>
<td>0.91</td>
<td>28.31</td>
</tr>
<tr>
<td>Stream</td>
<td>kg</td>
<td>2360.49</td>
<td>2360.01</td>
<td>5499.94</td>
</tr>
</tbody>
</table>
The GHG emissions are affected by the materials and energy uses in the life cycle. The GHG emissions from production processes of 1 ton CPO at each stages of life cycle was calculated using Eq. 1 are presented in Table 2. The greatest GHG emissions is identified came from the CPO extraction. Total emissions released from two cases differ greatly, where case 1 and case 2 emit 1463 and 624 CO$_2$–eq/ton CPO, respectively. The great difference is mainly due to the emission from wastewater. POM 2 applied methane capture and utilization technology
resulting in energy substitution and GHG emission reduction. In opposite, POM 1 treated the wastewater without methane emission control. Methane is 25 times harmful than carbon dioxide in term of the GHG effect (IPCC 2007). During the year 2013, POM 1 produced around 157 thousand m$^3$ of wastewater which is equivalent to 895 kg of CO$_2$-eq/ ton CPO.

According to Hutzler (2004), one kg COD (chemical oxygen demand) in wastewater can be converted to 0.6 m$^3$ of biogas. The calorific value of biogas is approx. 6 kWh/m$^3$, which is equivalent to 0.5 liter of diesel. Each kg of CH$_4$ produced is equivalent to 45.1 MJ (JRC 2011). POM 2 has a biogas power plant with a capacity of 1 MWh. The electricity generated is used for the purposes of the plant (in this case, used for PKO production process). The average electricity generated is 900 kWh which is equivalent to about 70 liters of diesel per hour. With the methane capture and utilization as electric generation, POM 2 can reduce CO$_2$ emissions by 970 kg CO$_2$-eq/ton CPO or approximately 60%.

3.3 Other Potential Opportunities

Some oil palm plantations have been implementing the integration of the management of oil palm plantation with cattle business. As the form of integration, cattle obtains feed in the form of the stem of oil palm tree, grass, and POM solid waste. One adult cattle produces about 4 ton dung per year that can be used as compost or additional substrate for biogas production. Furthermore, the utilization of forage growth among the oil palm trees as cattle feed will reduce the use of herbicides as a weed killer. Thus, the integration of cattle farm into the management of oil palm will be able to save both the use of inorganic fertilizers and herbicides. Research of the Animal Husbandry Office of Jambi Province (2003) showed that a hectare of oil palm plantations could meet about 80% of the one cattle feed.

The palm oil industry generates solid waste such as empty fruit bunches (EFB), stem, shell, and fibers. Management of the solid wastes is until now still not optimum yet. So far, the wastes are just burned and a part is scattered on the field as mulch. In other side, the solid waste is potentially a source of nutrients that can replace synthetic fertilizers (Urea, TSP, etc.). EFB contains nutrients such as N, P, K and Mg; 1 ton EFB is equivalent to 3 kg of urea; 0.6 kg CIRP (P= 30-35%); 12 kg MOP; and 2 kg Kieserite (Lubis and Tobing, 1989). About 5 thousand tons EFB is produced in POM 1 and POM 2 in 2013. If all the generated EFB is used as organic fertilizer, organic fertilizer it will produce fertilizers that are equivalent to 15 ton urea, 3 ton CIRP, 60 ton MOP, and 10 ton Kieserite. The use of organic fertilizer will reduce the use of synthetic fertilizers that result in reduction of CO$_2$ emissions. Based on the equivalence of each fertilizer, the use of organic fertilizer as substitution of synthetic fertilizer would reduce emissions by 75 tons of CO$_2$-eq/ year, or about 1.5 kg CO$_2$-eq / ton CPO.

4. Conclusions

The amount of resources (inventories) to produce CPO is influenced by various factors at each stage of the life cycle, covering the FFB production activities in the plantation, FFB transportation and CPO extraction. The energy consumption for production of 1 ton CPO is 6313 MJ for POM 1 and 7270 MJ for POM 2, respectively. The most energy consumption is for the extraction of palm oil, which is about 80-90 percent. With NER of 5.4-6.2 and NEV of 32-34 GJ/ton CPO, energy earning through the production of CPO is relatively high. The GHG emission from CPO production is estimated around 1,500 CO$_2$-eq / ton CPO, where the
greatest emission is coming from wastewater treatment and disposal. With the application of
technology for methane capture and utilization of methane from anaerobic decomposition
process of wastewater as renewable energy source for generating electricity, for example in
the case of POM 2, NER and NEV value can be increased, respectively from 5.4 to 5.7 and
from 32 to almost 34 GJ/ton CPO, and GHG emission reduction can be up to 970 kg CO2-
eq/ton CPO. A further significant improvement of CPO production process performance can
be achieved through the integration of the oil palm plantation with cattle farm and the
utilization of solid waste as an organic fertilizer.

References