The potency of implementation resource efficient and cleaner production in a Palm Oil Mill with capacity 30 ton per hour

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Abstract. Indonesia is known as the biggest crude palm oil (CPO) producer in the world. The fresh fruit bunches (FFB) are processed in the mill to produce CPO and Palm Kernel as the main products. The process consumes significant amount of energy, water and raw materials and also produces many wastes and emissions. In this study the potency of implementation cleaner production to a Palm Oil Mill is explored. The objectives are to increase efficiency and to reduce risks to humans and environment. As a case study, a Palm Oil Mill with capacity of 30 ton per hour is used. The results show that many potencies of improvement are found. Some of the potential improvements such as electricity intensity reduction from 20.56 to 17 kWh/ton FFB, and the reuse of turbine cooling water. It is shown that implementation of cleaner production to the Palm Oil Mill will improve the efficiency of the mill significantly.

1. Introduction

Crude Palm Oil (CPO) is the main agro-industry in Indonesia. Indonesia is the main producer of CPO in world. In 2015, Indonesia produced 33 million tons CPO which is 26.4 million ton was exported. Indonesia produces 53% of global production of CPO followed by Malaysia and Thailand with production of 20.5 million tons and 2 million tons, respectively. CPO is produced from Fresh Fruit Bunches (FFB) in a Palm Oil Mill. The process of producing CPO in the Palm Oil Mill consists of mechanical, thermal, and chemical processes. Development of Palm oil industry has a long story in Indonesia. It was started in the beginning of 1900 years. Since then there is no significant improvement on the CPO production process. These processes use a huge amount of crude material, water and energy and result in huge amount of solid waste, liquid waste, and emissions. These wastes relate to several environment issues. In particular, Indonesia Greenhouses Gas (GHG) emissions target affected by CPO. Recently, there several issues related to CPO production such as GHG emission, energy efficiency, sustainability, environmental hazards, etc.

Several studies related to environmental issues of Palm Oil Mill have been found in literature. Boons and Mendoza [1] reported the study on constructing sustainable palm oil which focuses on how actors define sustainability. It was analyzed the strategies and value definitions actors involved in the production and consumption of biofuels lead to specific definition sustainability. The empirical material concerns the chain of palm oil production in Colombia and electricity generation in the Netherlands. Chiew and Shimada [2] reported the current state and environmental impact assessment for utilizing oil
palm empty fruit bunches for fuel, fiber and fertilizer. The study was focused in Malaysia Palm Oil industry as the case. The environmental performance of recycling technologies for fuel, fiber and fertilizer was discussed. The results showed that methane recovery and composting were more environmentally friendly than other technologies, as measured by reduction of greenhouse gas emissions. Wicke et. al. [3] analyzed the greenhouse gas emissions of crude palm oil and palm fatty acid distillate production in northern Borneo of Malaysia, their transport to the Netherlands and their co-firing with natural gas for electricity production. It was shown that land use change is the most decisive factor in overall greenhouse gas emissions. Umar et al. [4] examined and identified the areas that require more attention to ensure that renewable energy framework in Malaysia is socio-economically sustainable and reliable to drive industry forward.

The issues of waste to energy in a Palm Oil Mill is reported by Chiew et al. [5]. The study is to develop a method of effective using of empty fruit bunches as fuel for Combine Heat and Power (CHP) plants within a local area, reducing cost and environmental impact while increasing energy production. Umar et al. [6] reported a survey on a sustainable electricity generation from oil palm biomass wastes in Malaysia. It is suggested that government intervention to attract active participation of major developers into the industry would accelerate the future growth of the market. Jekayinfa and Bamgboye [7] reported a study on determination of energy consumption in palm-kernel oil (PKO) processing operations by using data from nine PKO mills in Nigeria. Mathematical models of energy consumption in seven readily defined unit operations of the mill were developed. The equations were analyzed to estimate energy use in the mill. The results showed that averaged energy to process fresh fruit bunches varies from 177 MJ/ton to 352 MJ/ton. Ambarita [8,9] proposed the biogas produced by the Palm Oil Mill to power diesel engine in dual-fuel mode.

The above studies reveal that researchers are focusing on the development of Palm Oil Mill that meet the environment need. Rincon et al. [10] reported an analysis of potential technological schemes for the development of oil palm industry in Colombia. A biorefinery concept was used. The concept is a concept that similar to oil refinery. In this study, the potency of improvement in a Palm Oil Mill will be analyzed. The using a cleaner production point of view will be used. The results are expected to supply the necessary information in development of sustainable palm oil industry.

2. Method
In this study Cleaner Production method will be used to examined the potency of improvements in a Palm Oil Mill. A Palm Oil Mill belongs to Indonesian Government is selected as a case study. The capacity of the mill is 30 ton of empty fruit bunches per hour. As a note, in Indonesia about 600 Palm Oil Mills are being operated. The present selected mill is categorized small.

A concept of Resource Efficient and Cleaner Production (RECP) [11] has been implemented to the selected mill. The RECP consists of twofold terminology resource efficient and cleaner production. Resource efficient or eco-efficient is a management strategy that creates more value with less impact, through delinking goods and services from the use of nature. Cleaner Production is an operational strategy that reduces impacts, cost, risk & liabilities by avoiding the generation of waste & emissions. RECP applies preventive environmental techniques and practices and total productivity management to achieve the triple aims of improving resource productivity, reducing environmental impacts and fostering human health and well-being.

RECP refers to the continuous application of preventive environmental strategies and total productivity method to processes, products and services to increase efficiency and reduce risks to humans and environment. It becomes stepping stone towards sustainable innovation. RECP addresses three sustainability dimensions individually and synergistically. They are: (1) Production efficiency through improved productive use of natural resources (materials, energy, and water) by enterprises, (2) Environmental management: through minimization of the impact on environment and nature by enterprises through reduction of waste and emissions, and (3) Human development: through reduction of risks to people and communities from enterprises and supporting their development.
The RECP practices comprise 8 steps, ranging from low or even no cost solutions to high investment, as follows: (1) Good house-keeping, (2) Input material change, (3) Better process control, (4) Equipment modification, (5) Technology change, (6) Onsite reuse & recycling, (7) Production of useful by-product, and (8) Product modification. In addition, RECP engages several consecutive steps as its method, as follows: (1) Raise motivation, gain commitment and setup team from the company, (2) Building RECP Profile, (3) Develop process flow chart & factory layout, (4) Conducting walk through plant audit, (5) Analysis of materials, energy, and water balances, (6) Option Generation, (7) Technical Evaluation, (8) Economic Evaluation, (9) Project implementation & investment, (10) Ongoing monitoring and evaluation. By doing these steps, there are several RECP indicators must be provided. In area of production, the RECP indicators are productive output per unit of resource consumption; such as: (a) total energy use, (b) total water use, and (c) total material use. While in area of pollution, the indicators are pollution Intensity such as (d) waste and (e) emission generation per total production, and in term of air emissions, (f) waste water volume, and (g) waste quantity.

3. Results
The method and steps that are briefly explained in the above sections have been implemented to the selected mill. The results are explained and discussed below.

3.1. Baseline situation
The Palm Oil Mill was built established in 1995, it belongs to Indonesian Government owned company. The mill is categorized as a small-scale palm oil mill. The mill area was originally designed for a capacity of 60 ton/hour but the present equipment is being operated for a capacity of 30 ton/hour. The mill is categorized as Agribusiness and Agro-industry of palms. The main material for this mill is Palm Fresh Fruit Bunches (FFB). The main products are Crude Palm Oil (CPO) and Palm Kernel (PK).

The mill is operated by a total of 140 employers consists of 5 staff leader and 135 workers. It is operated in two shifts per day, but it depends on availability of Palm (Empty Fruit Bunches) EFB from the plantation field. The mill nearby consists of residential (about 20 m), Palm plantation area, and a river (about 100 m). As a note the fresh water for process used in this factory are drawn from the river. Before it is used, a water treatment is used. The baseline situation of the mill is presented in Table 1. The calculation of the baseline profile is made in one year operation of the mill.

| No | Indicators                        | Value       | Note                                                                 |
|----|-----------------------------------|-------------|----------------------------------------------------------------------|
| 1  | Total production                  | 30,759 ton  | There are two main products: CPO: 26,313 ton Palm Kernel: 4,446 ton |
| 2  | Total material used               | 125,145 ton |                                                                      |
| 3  | Total water used                  | 313,197 m³  |                                                                      |
| 4  | Total energy use                  | 2,573,040 kWh|                                                                      |
| 5  | Total waste generation            | 23,092 ton  | This includes EFB, Shell, Fiber and B3 solid waste                   |
| 6  | Total waste water generation      | 100,606 m³  |                                                                      |
| 7  | Total GHGs emission (CO₂eq)       | 2,293 ton   | GHGs: Green House Gases emission                                      |
| 8  | Material productivity             | 0.246 ton/ton| Total production/total material use                                  |
| 9  | Water productivity                | 0.098 ton/ m³| Total production/total water use                                     |
| 10 | Energy productivity               | 0.012 kg/kWh| Total production/total energy consumption                            |
| 11 | Waste intensity                   | 0.75 ton/    | Total waste generation/total production                             |
| 12 | Waste water intensity             | 3.27 m³/ton  | Total waste water generation/total production                        |
| 13 | Emission intensity                | 0.074 ton/   | Total GHGs emission/total production                                |

Table 1 RECP baseline profile of the Palm Oil Mill
3.2. Findings
Before entering the factory, the members were briefed about safety wear, evacuation procedure, safety, potentially dangerous emission, etc. From the observation, in general, the factory is working well. All of the processes are running perfectly. All of the staff practices all standard operation procedure perfectly. However, some are priorities for improvement areas were found and explained in the below paragraph.

In term of good housekeeping, standard operation and maintenance procedures and practices are very good. This conclusion was based on the clear SOP (Standard Operating Procedure) and maintenance boards were found in the very perfect place. However, in term of leaks and spill of steam and water were found in several stations such as in sterilization station and steam generation station, as shown in Fig 1(a). In addition, many leaks and spill of water caused by broken valve were also found. These leaks and spill of water and steam were one of the priority improvements. The raw material (palm bunches) were also found scattered in several areas such as shown in Fig 1(b). Another priority of improvement also for removing all of the unused equipment to the storage, as shown in Fig 1(c).

As a note, the main input materials in term of mass and volume to the mill are Palm EFB and water, and the other input materials with a very small volume are clay, oil, lubricant, and some chemicals. Based on assessment, there is no improvement in this area. Improvement is also needed in the process control. Many of machine and mechanical equipment were operated with constant speed, even though the load was changing. This leads to waste of energy and resource or inefficiency and generates emissions. Equipment modification is also found as a priority improvement in this factory. The systems of covering holes in many of tanks are not standard equipment. The transfer and piping system of CPO as product are also not standard as shown in Fig 1(d). This equipment needs to be modified in order to the process can be operated efficiently and lower the waste in term of crude oil.
3.3. Technology change

In term of technology change, the blown process can be considered as one of the priority improvements. The process of releasing the steam from sterilization vessel to air is loss of significant of energy. This process can be modified by recovery it in order to heat another stream for instance for hot air drying. The loss in blow down system is shown in Fig 2(a).

The present Palm Oil Mill has been practicing onsite reuse & recycling of the waste material for fuel. There are three types of solid waste with big volume here. They are shell, fiber, and EFB. Shell and fiber are mixed with ratio of 1:3, respectively and it is used as fuel for boiler. Only a small amount of fossil fuel is used to operate this mill, it is for starting up the mill by using generator. The solid waste has been reused as fuel to produce electricity and heat (steam) for process. In other word, this Palm Oil Mill has been practicing onsite reuse & recycling perfectly. However, based on observation, the efficiency of using energy is a priority for improvement. Because many of heat loses were found in the mill, such as the un-perfect insulation for hot vessel and the heat exchanger are not insulated as shown in Fig 2(b) and Fig 2(c), respectively. These losses will degrade the thermal efficiency of thermal system. Thus they need improvement.

![Image](a)

![Image](b)

![Image](c)

Fig 2 Heat losses in the Palm Oil Mill

As mentioned in the previous section, there is one solid waste that is discharged out of the mill, it is Empty Fruit Bunches. This is a biomass material, but has relatively high water content. The Empty Fruit Bunches can be modified as a useful by product. This is a priority area that can be improved. In addition, the other useful by product that can be improved is biogas production from waste water treatment system. In recently, the Indonesia Government is introducing a policy to blend the diesel in the market.
with biodiesel. The diesel oil of B20 (20% of volume is Biodiesel) in Indonesian market is now mandatory. Biodiesel can be produced by CPO which is the main product of this mill. Thus, modification of CPO into Biodiesel can be considered of improvement in the area of Product of modification.

3.4. Detailed Assessment
Detailed assessment has been performed to all of the generated options. There are three options to be considered here. The first option is water recovery unit, energy recovery and kernel loss. The detailed assessment to the water recovery unit results in water saving of 49,666 m$^3$ per year. The second one is energy saving. The energy consumption for the POM is 24.37 kWh/ton EFB. This is far above the standard 17 kWh/ton FFB. This is the second candidate to generate option. However, the measurements are difficult to be performed due to the lack of measurement apparatus in the factory. Based on the discussions with the staff, some of the electricity went to the other utilities. This option was not considered to be evaluated. The third option is high kernel loss, it is 0.6%. This is above the standard 0.4% - 0.5%. There are some possible root causes for this loss. They are leak in clay bath and some kernel mixed with shell and go to solid fuel and burnt in the boiler. Based on the discussion with the staff this problem can be fixed by improved the ability of the operator to follow the SOP. Thus, this is not considered as an option to be evaluated. The feasibility study has been performed to the first option. It needs investment cost of IDR 100 M and will generate revenue of IDR 140 M per year. The Pay Back Period is 0.7 year.

4. Conclusion and Recommendations
In this study, Resource Efficient and Cleaner Production has been implemented to a Palm Oil Mill. A case study to a mill with capacity 30 tons Fresh Fruit Bunches has been carried out. The recommendations are summarized in Table 2.

### Table 2 Summary of the problems and recommendations

| No | Problems                        | Effects to the system                                      | Recommendations                                      |
|----|---------------------------------|-----------------------------------------------------------|-----------------------------------------------------|
| 1  | Decreased FFB as raw material   | Raw material doesn’t meet the factory capacity and production cost will be high | Acceleration for replanting                           |
| 2  | Loses of water in several stations | Low water productivity                                      | Replace all of the broken valves                    |
|    |                                 |                                                           | Recycle the water cooling of turbine                 |
| 3  | Leak of steam in Kernel drier   | • Low water and energy productivity                        | Fix all the leaks                                    |
|    |                                 | • Higher moisture content in kernel                         | Replace the broken Elbow                             |
| 4  | Spill the oil underneath the screw press (the source is from Oil drain) | • Low material productivity                                | Install oil trap in the perimeter of the screw press |
|    |                                 | • Bad aesthetic                                             | Close the leak                                        |
|    |                                 |                                                           | Decrease the flowrate of the oil to fat pit           |
| 5  | Re-use solid waste              | • Additional by product                                     | Convert into biofuel by using pyrolysis              |
| 6  | Re-use Mill Effluent            | • GHGs emissions is high                                    | Biogas Power plant                                   |
|    |                                 |                                                           | Note: Biogas Power Plant investment estimation is USD 5 Million per 2 MW |
| 7  | Constant operation of electric motors | • High energy intensity                                   | Install inverter in fibre cyclone and screw press    |
| 8  | Heat loss from Blowdown silencer | • High energy intensity                                    | Recycling the heat using Heat Exchanger               |
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