

# Promotion of Least Cost Renewables in Indonesia (LCORE-Indo)



## Overview of the Waste-to-Energy Potential for Grid-connected Electricity Generation (Solid Biomass and Biogas) in Indonesia

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## LIST OF ABBREVIATIONS

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<b>BOE</b>	Billion Oil Equivalent
<b>BPS</b>	Central Statistics Agency
<b>CDM</b>	Clean Development Mechanism
<b>CHP</b>	Combined Heat and Power
<b>COD</b>	Chemical Oxygen Demand
<b>CPO</b>	Crude Palm Oil
<b>EFB</b>	Empty Fruit Bunches
<b>FFB</b>	Fresh Fruit Bunches
<b>IGCC</b>	Integrated Gasification Combined Cycle
<b>LHV</b>	Lower Heating Value
<b>NREL</b>	National Renewable Energy Laboratory
<b>POME</b>	Palm Oil Mill Effluent
<b>PLN</b>	PT Perusahaan Listrik Negara (Indonesia's state-own electricity company)
<b>RHA</b>	Rice Husk Ash
<b>UASB</b>	Up-flow Anaerobic Sludge Blanket
<b>RAN-GRK</b>	National Action Plan for Greenhouse Gasses Reduction

## EXECUTIVE SUMMARY

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The objective of this study is to give an overview of the biomass potential in the Indonesian agroindustry for electricity generation and related CO<sub>2</sub> savings. The study distinguishes between the theoretical and the technical potential; additionally the economic feasible potential is also defined in this study.

The methodological approach is to focus on those residues, which are most dominant in terms of volume in Indonesia. Thus, agro industries in the palm oil sector as well as in rice paddy and sugar cane are considered for further investigation, since they count for 80% of all residues in the Indonesian agro industry. Palm oil crops with 100 mio tons per year are most dominant, followed by rice paddy with 69 mio tons per year and sugar cane with 30 tons per year. In a first step, those three commodities have a theoretical electricity generation potential of total 328 TWh per year with an equivalent power capacity of 46 GWe.

In a second step, the study investigates the technical potential by analyzing the local distribution of the agro industries in relation to the availability of PLN grid. For this regional filtering, it is observed that 70% of all palm oil mills are located in Sumatera where grid availability stands at 75 to 90%, depending on the area. The industries for processing sugar cane (64%) and rice paddy (55%) are both mainly located on Java, where grid availability stands at 80 to 100%. Taking this regional filter into account, the technical potential of electricity production from the three industries is 43 TWh with a CO<sub>2</sub> saving potential of approximately 39 mio tons per year. Here, fibres and shell residues from palm oil mills play the most dominant role in contributing around 66% to the electricity generation potential. Although the theoretical electricity potential of palm oil effluents is only 900 GWh/year, it's CO<sub>2</sub> saving potential is more than 7 mio tons per year due to high impact of methane capture.

In the last step, the evaluation of the economic bioenergy potential in Indonesia is taking also ownership of the industry sector into account, as well as market selling price of the feedstock. But the main driving factor of economic viability is the feed-in tariff. At present, only projects, using biogas from palm oil effluents with very short distance to the grid and high processing capacities might be considered for evaluation of economic potential.

The technical potential of electricity generation of 43 TWh/year from the biomass/biogas power plant could meet the nation's electricity demand of 174 TWh/year by 25%.

The above figure is significantly lower than the theoretical electricity generation potential of 328 TWh/year. Thus the availability of interconnected transmission grid is still a primary barrier to tap the full potential of bioenergy power plants in Indonesia.

Besides supplying electricity generation, the implementation of the biomass/biogas project will also contribute to the National Action Plan for Greenhouse Gas Reduction (RAN-GRK). The target of RAN GRK it to reduce the greenhouse gasses emission by 26%, by the year of 2020; for the energy and transportation sector the target is set to 38 mio tons CO<sub>2</sub>. Thus, the realization of the technical waste-to-energy potential from solid biomass and biogas could fully meet the Indonesian emission reduction target in the energy and transportation sector!

# CHAPTER I: INTRODUCTION

## 1.1. BACKGROUND

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Although Indonesia produces abundant amounts of biomass feedstock which could be used for renewable energy generation, the current electricity production is still mainly based on fossil fuels such as oil, gas and coal.

Apart from the environmental effects of the fossil-fuel consumption of the 4th most populous country in the world, the budgetary effects are pressing. The country shows an increase of energy demand of 7-10% p.a. (PT PLN, 2013) which, in combination with a rising oil price, is a costly issue for the government. To guarantee a minimum degree of energy security (in 2012 about 76% of the population has access to electricity (Resources, 2013)) energy is strongly subsidized. These factors require the Indonesian government to find different sources of electricity that allow a more cost efficient supply of electricity.

The total installed electricity generation capacity by PT PLN (Persero) has been constantly increasing over the last years, but is still not sufficient to meet the full demand. PLN's targets foresee an electrification ratio of 90% by 2020. The electricity demand the calendar year 2012 was 174 TWh (PT PLN, 2013).

Table 1 Total installed capacity by PT PLN (Persero)

YEAR	2007	2008	2009	2010	2011
Total Installed Capacity (MW)	22,153	25,987	25,610	32,850	35,254

Source: (Badan Pusat Statistik, 2013)

PLN total installed capacity stands out more than 35 GW up to year 2012.

The Indonesian Government introduced several policy measures aiming to increase private sector investment into renewable energies to meet the rising demand and increase the electrification of the country. The central instrument in this array of measures is the feed-in tariff paid for electricity from renewable sources sold to PLN. For biomass and biogas plants up to 10 MW installed capacity, Ministerial Regulation No. 4/2012 foresees a price of 975 to 1267.5 IDR/kWh depending on the location of the plant. Apart from this feed-in tariff, renewable energy IPPs can benefit from tax incentives.

In general a biomass power potential of 50 GWe is assumed for Indonesia (Economics, 2012, p. 2). There is however no clear breakdown of the different feedstock and technologies used.

## 1.2. OBJECTIVE

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This study aims to give an overview of the resource; technical and economic potentials from biomass waste available from the Indonesian agroindustry, and the emission reduction potential that would result from using this biomass for **grid-connected** electricity generation.

### 1.3. METHODOLOGY

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Data for this overview report is taken from online publications by relevant government bodies such as Ministry of Energy and Mineral Resources (MEMR) and Ministry of Agriculture. In some cases, data is calculated from Central Statistics Agency (BPS).

The feedstock for biomass based electricity generation mostly stem from the Indonesian agricultural sector. The focus here does not lie on the plantation of energy crops for electricity generation but on the utilization of waste and residues from agricultural productions.

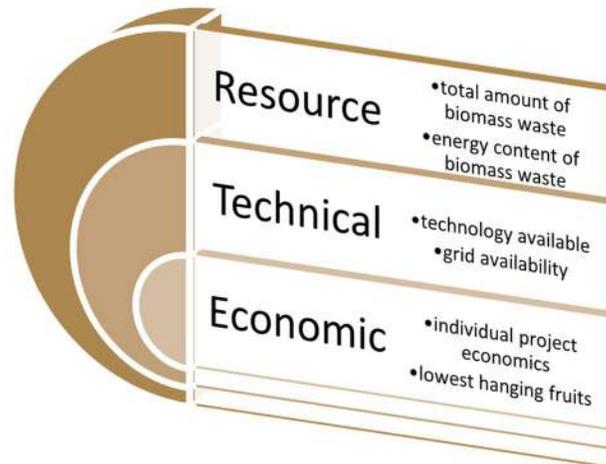


Figure 1: Types of biomass potential (own outline based on (NREL, 2013))

A distinction will be made between the resource potential, the technical potential and the economic potential (NREL, 2013).

The resource potential is classified as the total biomass waste that is available in the Indonesian agro-industry and the energy content of this biomass waste. The technical potential only considers the share of biomass that can be processed by technology currently available in Indonesia. Furthermore, focus is laid on the amount of biomass that is concentrated in easily accessible regions. This concern reflects a certain required concentration of biomass as well as grid availability. The economic potential finally would only take into account the amount of biomass which will be economically attractive for the IPP to be used for electricity generation. At this point, the industry structure, feedstock security and the opportunity cost of the feedstock should be taken into account.

## CHAPTER II: BIOMASS RESOURCE POTENTIAL

The following agricultural commodities are produced in Indonesia:

Commodities:	
Oil palm (CPO)	Cashew nut
Sugar	Corn
Rice	Wood
Rubber	Coffee
Cassava / Tapioca starch	Cocoa
Rubber	Coconut
Tea	Clove

As shown in Table 2 and Figure 2, the largest amounts of agricultural products and potential of solid biomass residues stem from the oil palm, rice and sugar cane industries. Other important agricultural sectors are the corn, rubber and tapioca-starch production.

Table 2 Agricultural commodities (resource potential) produced in Indonesia

No	Crops	Amount (ton/year)	Percentage
1.	Palm Oil (FFB)	100,000,000	41 %
2.	Rice Paddy	69,000,000	28 %
3.	Sugar Cane	30,000,000	12 %
4.	Others (Corn, Rubber, Cassava)	47,000,000	19 %

Source: (Badan Pusat Statistik, 2013)

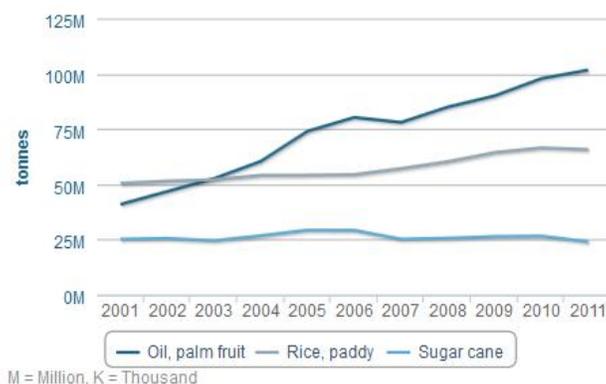


Figure 2 Production of Top 3 Crops in Indonesia (2001-2011) (FAO, 2013)

The reason for the amounts of production of the oil palm sector being higher than that of the rice industry in Figure 2 is due to the fact that the complete fruit is considered while the Central Statistics Agency (Badan Pusat Statistik/BPS) data only includes the amount of crude palm oil produced. As the bioenergy production is supposed to be based on residual materials, the amount of fruit produced is more relevant.

This study will therefore concentrate on the assessment of the biomass / gas and emission reduction potential from the **palm oil, rice and sugar cane industries**.

## CHAPTER III: THEORETICAL POTENTIAL

### 3.1. PALM OIL INDUSTRY

Depending on the units applied, different figures for the amount of available biomass can be found in the literature. Taking the unit of tons of fresh fruit bunches (FFB) produced as a basis, the overview of the shares of the different components that arise during crude palm oil production could be seen on the annex A.

As the only regional data of production amounts of the palm oil industry in Indonesia is available for the crude palm oil (CPO) production, the shares of the different residues will be calculated based on these figures and the mass balance.

The POME potential of a typical Indonesian palm oil mill processing 30 to 90 tons of FFB/hour lies around 0.6 m<sup>3</sup> / ton FFB (Rauch & Schweinfurth, 2013, p. 5). This figure is in line with the 58.3% mentioned in Annex A: Mass Balance of Palm Oil Extracts and Residues. The shares named in Table 3 have also been verified by (Indonesian Oil Palm Research Institute (IOPRI), 2012, p. 24) during an assessment of palm oil mill in North Sumatra done for GIZ. The exact shares that were reported by the mills studied and the resulting amounts of residues produced, assuming a total production of FFB of around 100 million ton in 2012 are outlined in Table 3.

Table 3 Shares and amounts of residues in palm oil mills

Feedstock	% of FFB	Amount (ton/year)
FFB (t)	100%	100,089,664
EFB (t)	21%	21,018,829
Fibre (t)	15%	15,013,450
Shells (t)	6.5%	6,505,828
POME (m <sup>3</sup> )	58%	58,052,005
CPO (ton)	24%	23,521,071

Source: (Badan Pusat Statistik, 2013) (Yusoff, 2006) (ANNIES Export NZ Ltd, 2012)

For the calculation of the electricity generation and emissions reduction potential the following amounts are assumed.

Table 4 Theoretical electricity generation from palm oil residues in Indonesia

Feedstock	Palm Oil mill residues amount <sup>1</sup>		Annual electricity generation (GWhe)
	Solid (ton/year)	Effluent (m <sup>3</sup> /y)	
POME (58%)		58,052,005	1,161 <sup>2</sup>
EFB (fresh) (21%)	21,018,829		25,685 <sup>3</sup>
Shell (6.5%)	6,505,828		115,983 <sup>4</sup>
Fiber (15%)	15,013,450		
<b>Total theoretical annual electricity generation potential from palm oil mill residues (round up)</b>			<b>142,800 GWhe</b>

<sup>1</sup> Figures based on data from Directorate General of Estate for 2012 and the mass balance assumptions

<sup>2</sup> Electricity generation potential by multiplying the amount of POME with 0.02 MWh/m<sup>3</sup> as unit conversion to electricity (refer to CDM PDD for Biogas project)

<sup>3</sup> Electricity generation potential by multiplying the amount of EFB with 1,222 kWh/ton as unit conversion to electricity (Yoon, Tomoko, & Sohei, 2011)

<sup>4</sup> Combined electricity generation potential from shell & fiber with ratio 50:50, by multiplying the shell solid waste with 5,583 kWh/ton and fiber solid waste with 5,305 kWh/ton as unit conversions to electricity (Yoon, Tomoko, & Sohei, 2011)

### HIGHLIGHT

With FFB production amount of 100 million tonnes/year, the total theoretical electricity generation from palm oil mill residue is 142,800 GWh. The highest electricity generation is resulted from combustion of shell and fiber combination which is 115,983 GWh or 82% of the total generation.

## 3.2. RICE PADDY INDUSTRY

With a paddy production of around 69 million tons in 2012, and increasing production over the past years and a share of husk of the total production of 20 %, this results in an overall potential for Indonesia of 13 million tons. This amount can provide a heat value of 45,000 GWh which could translate into 700 to 1,600 MWe depending on the technology applied (Kwintkiewicz, 2013, p. 5).

Apart from the rice husk, rice straw which makes up 50% of the total harvest volume can also be used as fuel (Rauch & Schweinfurth, 2013, p. 8). The Lower Heating Value of rice straw can vary between 12.5 and 16.5 MJ kg<sup>-1</sup> depending on the ash content (Gadde, Menke, & Wassmann, 2009, p. 1538).

Table 5 Theoretical electricity generation from rice industry residues in Indonesia

Feedstock	Rice industry residues amount <sup>5</sup>	Annual electricity generation (GWHe)
Rice husk	13,811,200	45,826 <sup>6</sup>
Rice straw	34,528,063	119,888 <sup>7</sup>
<b>Total theoretical annual electricity generation from rice mill residues (round up)</b>		<b>165,700 GWHe</b>

### HIGHLIGHT

With paddy production amount of 69 million tonnes/year, the total theoretical electricity generation from rice paddy industry residue is 165,700 GWh. The highest electricity generation is resulted from rice straw feedstock which is 119,888 GWh or 72% of the total generation.

## 3.3. SUGAR INDUSTRY

The annual sugar cane production in Indonesia has been fluctuating between 24 and 26 million tons over the past five years (Annex B).

The processing capacity of Indonesian sugar factories ranges between 1,000 to 12,000 tons of sugar cane per day. The amount of residues in these factories sums up to 320-370 kg of bagasse per ton of sugar cane (EKONID, 2011, p. 23) (Winrock International, 1991).

<sup>5</sup> Based on (Badan Pusat Statistik, 2013)

<sup>6</sup> Electricity generation potential by multiplying the amount of rice husk with 3,318 kWh/ton as unit conversion to electricity (Kwintkiewicz, 2013)

<sup>7</sup> Electricity generation potential by multiplying the amount of rice straw with 3,472 kWh/ton as unit conversion to electricity (Gadde, Menke, & Wassmann, 2009)

Table 6 Theoretical power generation from sugar cane factories residues

Feedstock	Sugar cane factories residue amount	Annual electricity generation (GWHe)
Bagasse (32%)	9,752,960 <sup>8</sup>	19,789 <sup>9</sup>
<b>Total theoretical annual electricity generation from rice mill residues (round up)</b>		<b>19,800 GWHe</b>

Source: (Directorate General of Estate, n.d.)

#### HIGHLIGHT

With sugar production amount of 30 million tonnes/year, the total theoretical electricity generation from bagasse as sugar cane factory residue is 19,800 GWhe.

## 3.4 OTHER INDUSTRIES

A brief overview of the biomass potential in other relevant industries will be given in this subsection.

### 3.4.1 RUBBER RESIDUE

As the second-largest rubber producer worldwide, Indonesia supplies a substantial amount of rubber to the international market. About 80% of Indonesia's rubber production is accounted for by small hold farmers and about 85% of total production is exported (Indonesia Investment, n.d.). According to data from the Ministry of Agriculture (Directorate General of Estate, n.d.), the total natural rubber production in 2012 amounted to 3 million tons, which produced from 3.5 million ha plantations scattered all around Indonesia. Due to this lack of concentration of biomass, larger grid-connected biomass plants cannot easily secure their feedstock supply and consequently the technical and economic potential will not be discussed.

Table 7 Theoretical power generation from rubber wood residue

Feedstock	Amount (ton/year)	Annual Electricity Generation (kWh)
Rubber wood residue	41,000,000	33,360 *
<b>Total theoretical annual electricity generation from rubber wood (round up)</b>		<b>33.4 MWh</b>

\*Source: Directorate of Electricity and Electricity Utilization, 2001 ([www.unescap.org\\_esd\\_Energy-Security-and-Water-Resources\\_energy\\_renewable\\_promotion\\_biomass\\_seminar\\_Indonesia](http://www.unescap.org_esd_Energy-Security-and-Water-Resources_energy_renewable_promotion_biomass_seminar_Indonesia))

### 3.4.2 CASSAVA

Cassava is not included as solid biomass because the tube is used for producing liquid fuel (bioethanol) while most of the stem is used for establishing new plantation, and the leaves are used as animal fodder (Prastowo, 2011).

<sup>8</sup> Based on sugarcane production 2012 according to (Badan Pusat Statistik, 2013) \* 0.32 (share of bagasse)

<sup>9</sup> Electricity generation potential by multiplying the amount of bagasse with 2,029 kWh/ton as unit conversion to electricity (ANNIES Export NZ Ltd, 2012)

The cassava processing industry, like the palm oil industry, can however use the wastewater from their processes for biogas generation. The COD level of tapioca starch wastewater is somehow smaller than that of POME, but still there is some potential with so far 18 of the more than 50 listed companies using anaerobic digestion technology. All these tapioca starch wastewater plants currently apply tank based reactors (Up-flow Anaerobic Sludge Blanket: UASB). However the other technology options (covered lagoon or continuous stirred lagoon) which show simpler daily operations and handling might be applied for upcoming reactor designs. (PT. Biogas Program International, 2013)

Table 8 Theoretical power generation from cassava processing industry biogas power plant\*

Feedstock	Amount (m <sup>3</sup> /year)	Annual Power Generation (GWh/year)
Tapioca starch plant waste water (32%)	389,255,700 <sup>10</sup>	6,384 <sup>11</sup>
<b>The theoretical annual electricity generation from cassava processing industry (round up)</b>		<b>6,400 GWh</b>

\*Source: (Badan Pusat Statistik, 2013) (Emission Reduction Calculation for Budi Acid Jaya Tapioca Starch Factory, 2011) (Titiresmi (IFAD, 2010) (NC State University, n.d.)

Due to the relatively small industry size, the technical and economic potential of bioenergy from the tapioca-starch industry are not discussed.

### 3.4.3 CORN RESIDUE

Indonesia accounted for a production of corn of 19 million tons in 2012 (Badan Pusat Statistik, 2013). Solid residue from corn is corncob with 'residue to product ratio' of 0.273 with Calorific Value of 4451 kcal/kg (Sudrajat, 2004 quoted by (Widodo, 2007)). The energy potential from corncob is about 55.75 GJ. This energy potential is equivalent with 15.5 MWh<sup>12</sup>.

Another solid residue from corn is corn stove taken from the plantation. According to Prasetyo (2002) corn stove potential is 3.46 tonnes/ha with Calorific Value of 4,370 kcal/kg (Sudrajat, 2004). The energy potential from corn stove is about 66 GJ. This energy potential is equivalent with 18 MWh.

Although there is a high energy potential from corn cob, the utilization of corn residue for electricity generation would still face some barriers such as the scattered production area and the low bulk density of corn. Therefore the transportation cost to collect the product may be expensive (Widodo, 2007). Based on this, the technical and economic potential will not be further discussed.

<sup>10</sup> Based on cassava production 2012 according to (Badan Pusat Statistik, 2013) \* 16.1 (conversion factor based on data from Budi Acid Jaya PDD : <http://cdm.unfccc.int/filestorage/9/L/6/9L6PQF3YJMB8UVSHCI120AK4ET7OZW/2673%20PDD.pdf?t=MTZ8bjl5M2d4fDDDeQLMldRxWlWGBKbcS14qm>)

<sup>11</sup> Feedstock amount \* 16.4 kWh/m<sup>3</sup> as the electricity generation conversion factor

<sup>12</sup> 1 GJ is equivalent with 278 kWh : Conversion factor for bioenergy, NC Woody Biomass

### 3.5 OVERVIEW OF THE THEORETICAL BIOMASS POTENTIAL

Theoretically, about 328,000 GWh electricity generation which equivalent to 46 GWe power output is calculated from the three largest agroindustry commodities: palm oil; rice paddy and sugar cane industries. With biomass power output potential assumed around 50 GWe from the study (Economics, 2012, p. 2), hence those three commodities has donated about 94% out of the total generation potential.

The Table 9 below will summarize the overall theoretical potential three largest agriculture commodities:

*Table 9 Overview of the theoretical potential from three largest agriculture commodities*

<i>Industry</i>	<i>National commodities (ton/year)</i>	<i>Feedstock</i>	<i>Theoretical Annual Electricity Generation (GWh)</i>
Palm Oil	100,089,664	EFB; Fiber & Shell POME	142,800
Rice Paddy	69,056,126	Rice Straw Husk	165,700
Sugar Cane	30,477,475	Bagasse	19,800
<b><i>Total theoretical annual electricity generation from three commodities</i></b>			<b><i>328,300 GWh</i></b>

## CHAPTER IV: BIOMASS/ BIOGAS TO ELECTRICITY TECHNOLOGIES AND THEIR APPLICATION IN INDONESIA

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Biomass energy is a suitable fossil fuel replacement for electricity power generation. Different technologies which can be applied to produce electricity from biomass energy will be shortly described in this section (IEA, 2007).

1. Biomass co-firing
2. Biomass combined heat and power (CHP)
3. Biomass integrated gasification combined cycle (BIGCC)
4. Anaerobic digestion

Technologies and cost of power and heat generation from biomass depend on feedstock quality, availability and transportation cost, power plant size, conversion into biogas (if any).

### 4.1 BIOMASS CO-FIRING

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Biomass co-firing is the process of replacing part of the fossil fuel supplied to a power station or boiler with a renewable alternative (Biomass Energy Centre, n.d.)

One of the biomass utilization technology applicable in Indonesia is biomass co-firing with coal. In the agroindustry this technology is applied i.e. by wood mills to generate electricity.

The share of biomass should not exceed 10% in co-firing systems, as otherwise changes in mills, burners and dryers are needed. Furthermore, mill owners have to use high-quality biomass to avoid tar production which can cause slagging and fouling that affects plant reliability and raises costs.

Since only a small portion of biomass could be utilized in co-firing technology, this technology is not relevant to our study and will not be discussed further.

### 4.2 BIOMASS COMBINED HEAT AND POWER (CHP)

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The production of electricity from biomass resources is most economic when the resulting waste heat is also captured and used as thermal energy – an approach called combined heat and power or CHP. The least cost forms of biomass for generating electricity are residues such as sawdust, rice husks, wheat straw, corn stalks, and bagasse. CHP is a common technology to produce heat and power especially for palm oil industries in Indonesia.

Biomass can be burned to produce electricity and heat via a steam turbine in dedicated power plants with typical size from 1 to 100 MW. This technology is used to dispose of large amount of residues and wastes (e.g bagasse). Plant efficiency ranges between 30% - 34% depending on plant size and feedstock quality and up to 40% if operated in electricity-only mode.

### 4.3 BIOMASS GASIFICATION

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This technology converts biomass into biogas by using fast thermo-chemical processes (e.g. pyrolysis) or slow anaerobic fermentation. The biogas can be used in combustion engines (10 kW to 10 MW) with efficiency of some 30%-35%; in gas turbine at higher efficiencies or in highly-efficient combined cycles.

Biomass integrated gasification gas turbines are not yet in commercial use, but their economics is expected to improve. The first IGCC running on 100% biomass (straw) is operating successfully in Sweden.

Gasification technology could become the state-of-the art technology to utilize the abundant EFB potential from palm oil industry. By using this technology, palm oil mills could optimize their biogas production from both POME and EFB feedstock and generate additional income by supplying electricity to the grid. However, gasification technology has not yet been applied in Indonesia.

### 4.4 BIOGAS AN-AEROBIC DIGESTION

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Agroindustry wastes such as animal manure and liquid waste are usually treated in a set of open lagoons before discharged into rivers. This wastewater can be used to produce methane by applying an-aerobic digestion technology in the lagoons.

Biogas can be utilized for power and heat generation. After purification and upgrading, biogas can be used in heat plants, stationary engines, fed into the natural gas grid, or used as a transport fuel (compressed natural gas).

Anaerobic digestion to produce biogas is well-applied in Indonesia proven by 46 CDM biogas projects under the UNFCCC. Biogas plants usually treat Palm Oil Mill Effluent (POME) and tapioca starch waste water. The most common technology used is the covered lagoon for POME and UASB for tapioca-starch wastewater.

## CHAPTER V: TECHNICAL POTENTIAL AND CO<sub>2</sub> REDUCTION POTENTIAL

Even though large potential of biomass is available in Indonesia theoretically, biomass and biogas power plant application is still limited to some industries so far. Biogas technology is applied in the palm oil and tapioca starch industry to treat the wastewater under the CDM-framework and the palm oil, rice and sugar industry use solid biomass as feedstock to generate steam and electricity for their own production. The map below shows the location of the main transmission grids by PLN and the concentration of the different agricultural products, which are important criteria for the calculation of the technical potential.

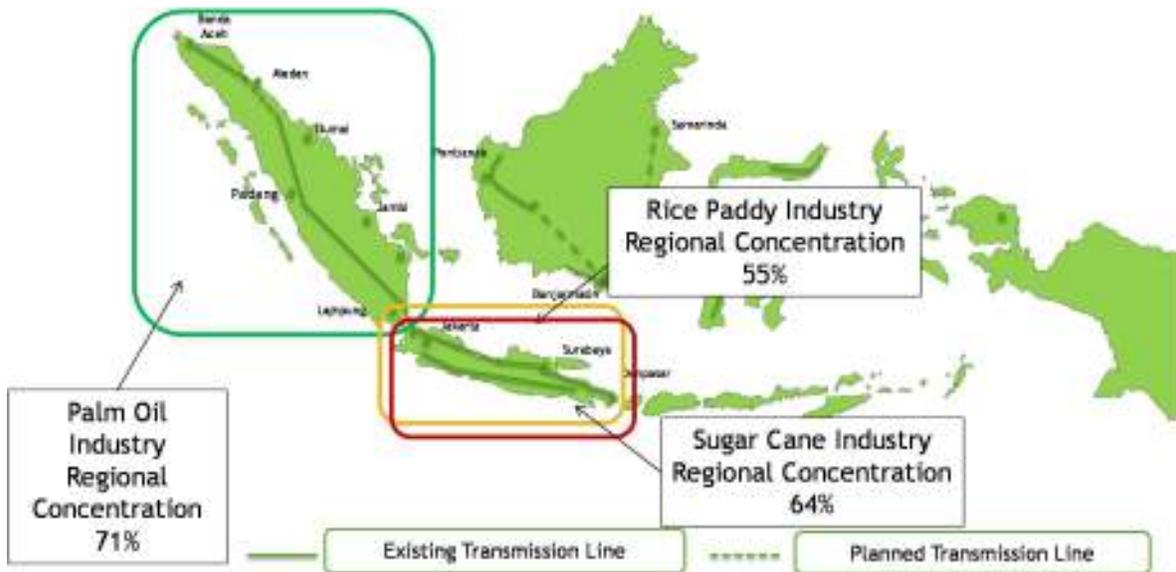


Figure 3 PLN Transmission Grids and Biomass Concentration Map

As mentioned above, **the location of the main transmission grids by PLN and the concentration of the different agricultural products** are important criteria to narrow-down the theoretical electricity generation potential into technical electricity generation potential. For further calculation, the biomass feedstock available on the region with highest concentration of selected biomass type will be used for the calculation.

The selection of technology will define the efficiency of electricity generation from each of feedstock type. Some feedstock is difficult to develop due to lack information on the applicable technology. Thus, **the electricity generation efficiency of selected technology** will also be an important criteria for technical calculation. The Figure 4 shows the screening process to calculate the technical electricity generation potential by considering three (3) important criteria as explained above.

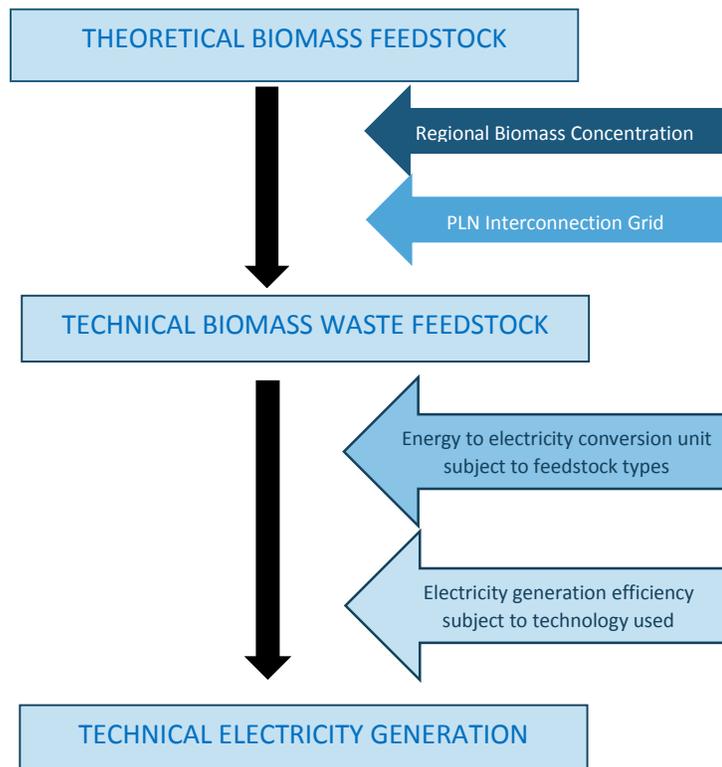


Figure 4 Screening process to calculate the technical electricity generation

## 5.1 PALM OIL INDUSTRY

Palm oil mills already use the solid residues, mainly fibers and fruit kernel shells, for heat and electricity generation for their own processes. This means most of them are already energy-self-sufficient. The empty fruit bunches (EFB), which amount to 21 % of the fresh fruit bunches, as well as the POME are only to a small extent used as fertilizer in the plantations.

Emission reduction potential in CDM projects in Indonesia ranges from 0.06 to 0.12 ton CO<sub>2</sub> per ton FFB (PT. Biogas Program International, 2013). However, these reductions are achieved by methane capture and subsequent flaring of the biogas. Hence, additional emission reductions can be achieved by generating electricity from the biogas which can substitute PLN grid-electricity. Emission reduction potential from electricity production however varies depending on the technology applied.

The map of Palm Oil Mills in Indonesia (ANNIES Export NZ Ltd, 2012) (see Annex D) underlines the concentration of palm oil mills in Sumatra and Kalimantan. More than 70% of the CPO production is located in Sumatra, and as there is also an interconnected grid available, the share of CPO production in Sumatra is used as a basis for the calculation of the technical potential.

### 5.1.1 EFB: FUEL FOR MEDIUM PRESSURE STEAM TURBINE – CHP TECHNOLOGY

Medium Pressure Steam boiler is a closed tank in which water is converted into steam under medium pressure (40 bar) (ANNIES Export NZ Ltd, 2012). Currently, fiber and shell are combusted to produce steam for heat and electricity power. The application of EFB for steam boiler will replace utilization of shell. The excess shell then available to be sold as feedstock or it can be used to generate electricity which will give additional economic revenue when fed into the grid.

Assuming a power generation potential from EFB of 1,222 kWh/ton and an amount of EFB of 21% of overall FFB production, the table below outlines the technical potential for electricity generation and emission reduction potential from applying 100% EFB in a medium pressure steam boiler. The application of 100% EFB is for modelling purpose only since EFB will need to be combusted with other POM residues on a certain percentage to avoid corrosion of the furnace steel (ANNIES Export NZ Ltd, 2012).

Table 10 Technical power generation potential of EFB feedstock

Parameter	Value	Unit
FFB (Theoretical Biomass Feedstock)	100,089,664*	Ton/year
EFB (Technical Biomass Waste Feedstock)	15,004,158 <sup>13</sup>	Ton/year
<b>Technical Electricity Generation from EFB</b>	<b>4,401<sup>14</sup></b>	<b>GWh/year</b>

\*Source: Ministry of Agriculture, 2013

Table 11 CO<sub>2</sub> Emission Reduction potential of EFB feedstock

Parameter	Value	Unit
Technical Electricity Generation from EFB	4,401	GWh/year
Emission Factor for Sumatera Grid in 2010*	0.748	tCO <sub>2</sub> /MWh
<b>CO<sub>2</sub> Emission Reduction (round-up)</b>	<b>3,300,000</b>	<b>tCO<sub>2</sub>e/year</b>

\*Source: <http://pasarkarbon.dnpi.go.id/web/index.php/dnacdm/read/23/pembaruan-faktor-emisi-sistem-interkoneksi-tenaga-listrik-2011.html>

#### HIGHLIGHT

With technical EFB production of 15 million tonnes/year from palm oil industry, the total technical electricity generation from EFB feedstock is 4,401 GWh/year or 17% of the theoretical generation potential. The Emission Reduction from EFB feedstock is 3,300,000 tCO<sub>2</sub>e/year.

### 5.1.2 SHELL AND FIBER USED IN OPTIMIZED HIGH PRESSURE STEAM TURBINE

With 71 million ton/year of FFB technically available for biomass on-grid plant, the potential electricity generation is 14,748 GWh/year. The table below outlines the electricity generation and emission reduction potential from combined shell and fiber co-firing.

<sup>13</sup> FFB regional potential from Sumatera Islands (71.38% of National FFB production) \* 21% as share of EFB

<sup>14</sup> EFB potential \* 1,222 kWh/ton EFB as energy to electricity conversion unit \* 24% as electricity generation efficiency for MP steam turbine

Table 12 Technical power generation potential of Shell & Fiber feedstock

Parameter	Value	Unit
FFB (Theoretical Biomass Feedstock)*	100,089,664*	Ton/year
Shell (Technical Biomass Waste Feedstock)	2,322,072 <sup>15</sup>	Ton/year
Fiber (Technical Biomass Waste Feedstock)	5,358,628 <sup>16</sup>	Ton/year
<b>Technical Electricity Generation from shell and fiber</b>	<b>29,475<sup>17</sup></b>	<b>GWh/year</b>

\*Source: Ministry of Agriculture, 2013

Table 13 CO<sub>2</sub> Emission Reduction potential of Shell & Fiber feedstock

Parameter	Value	Unit
Technical Electricity Generation from Shell & Fiber	29,475	GWh/year
Emission Factor for Sumatera Grid in 2010*	0.748	tCO <sub>2</sub> /MWh
<b>CO<sub>2</sub> Emission Reduction (round-up)</b>	<b>22,050,000</b>	<b>tCO<sub>2</sub>e/year</b>

\*Source: <http://pasarkarbon.dnpi.go.id/web/index.php/dnacdm/read/23/pembaruan-faktor-emisi-sistem-interkoneksi-tenaga-listrik-2011.html>

### HIGHLIGHT

With technical Shell & Fiber production of 15 million tonnes/year from palm oil industry, the total technical electricity generation from Shell & Fiber feedstock is 29,475 GWh/year or 25% of the theoretical generation potential. The Emission Reduction from EFB feedstock is 22,050,000 tCO<sub>2</sub>e/year.

### 5.1.3 BIOGAS POWER PLANT USING POME

There are 646 POMs in Indonesia of which less than 10% applies biogas technology for treating the POME (PT. Biogas Program International, 2013). The potential of all palm oil mills in Sumatra is calculated below.

Table 14 Technical power generation potential of POME

Parameter	Value	Unit
FFB (Theoretical Biomass Feedstock)*	100,089,664*	Ton/year
POME (Technical Waste water Feedstock)	41,440,055 <sup>18</sup>	m <sup>3</sup> /year
Biogas (Technical biogas feedstock)	1,160,321,532 <sup>19</sup>	m <sup>3</sup> /year
<b>Technical Electricity Generation from biogas</b>	<b>939</b>	<b>GWh/year</b>

\*Source: Ministry of Agriculture, 2013

<sup>15</sup> FFB regional potential from Sumatera Islands (71.38% of National FFB production) \* 6.5% as share of Shell

<sup>16</sup> FFB regional potential from Sumatera Islands (71.38% of National FFB production) \* 15% as share of Fiber

<sup>17</sup> EFB potential \* 5,583 kWh/ton shell (or 5,306 kWh/ton fiber) as energy to electricity conversion unit \* 35.6% as electricity generation efficiency for HP steam turbine

<sup>18</sup> POME regional potential from Sumatera Islands (71.38% of National FFB production) \* 0.58 m<sup>3</sup>/t FFB as share of POME

<sup>19</sup> POME technical potential \* 28 m<sup>3</sup>/m<sup>3</sup> POME as conversion unit from POME to biogas production (Annie's Waste to Energy Identification study, 2012)

Table 15 CO<sub>2</sub> Emission Reduction potential from methane capture & electricity generation of POME feedstock

Parameter	Value	Unit
CO <sub>2</sub> Emission Reduction from methane capture (round-up)*	6,580,000 <sup>20</sup>	tCO <sub>2</sub> e/year
CO <sub>2</sub> Emission Reduction from electricity generation (round-up)**	703,000 <sup>21</sup>	tCO <sub>2</sub> e/year
Emission Factor for Sumatera Grid in 2010*	0.748	tCO <sub>2</sub> /MWh
<b>Total CO<sub>2</sub> Emission Reduction (round-up)</b>	<b>7,283,000</b>	<b>tCO<sub>2</sub>e/year</b>

\*Source: UNFCCC methodology for small-scale project (AMS-III.H) & IPCC

\*\*Source: <http://pasarkarbon.dnpi.go.id/web/index.php/dnacdm/read/23/pembaruan-faktor-emisi-sistem-interkoneksi-tenaga-listrik-2011.html>

#### 5.1.4 OVERALL TECHNICAL POTENTIAL PALM OIL INDUSTRY

The section 5.1.1 to 5.1.3 above give detailed calculation on the technical potential from each of palm oil biomass feedstock. The Table 16 below will summarize the overall technical potential from palm oil industry:

Table 16 Overall technical potential from palm oil industry

Feedstock	Technical Electricity Generation		CO <sub>2</sub> Emission Reduction	
EFB	4,401	GWh/year	3,300,000	tCO <sub>2</sub> e/year
Shell & Fiber	29,475	GWh/year	22,050,000	tCO <sub>2</sub> e/year
POME	939	GWh/year	7,283,000	tCO <sub>2</sub> e/year
<b>Total</b>	<b>34,815</b>	<b>GWh/year</b>	<b>32,633,000</b>	<b>tCO<sub>2</sub>e/year</b>

#### HIGHLIGHT

The highest electricity generation potential is resulted from combustion of fiber and shell, due to their high calorific values. This combustion model has been implemented by all palm oil mills in Indonesia. While the power generation potential from POME is considerably lower than that of shell and fiber, this option shows the highest emission reduction potential which is due to methane emission capture. In general, the electricity generation potential from palm oil industry is higher than other agroindustry. Hence, the economic potential of palm oil biomass power generation will be discussed further.

## 5.2 RICE INDUSTRY

Assuming an off-site 2.5 MW medium pressure steam turbine plant as the technology to be applied, a rice husk input of 3.5 tons per hour or 29,000 tons per year would be needed. If this feedstock demand is to be supplied by smallholders processing 50-60 tons of paddy/day, around 12 mills need to be contracted (Kwintkiewicz, 2013).

The rice industry in Indonesia is mostly located in the islands Java, Sumatra, Sulawesi, Kalimantan and Bali/West Nusa Tenggara (Hasan, Mahlia, & Nur, 2012).

<sup>20</sup> POME amount \* COD Removal \* Methane Production capacity of the waste water \* Methane Correction Factor \* Global Warming Potential (GWP) of Methane = 41 mio m<sup>3</sup> \* 0.045 \* 0.21 \* 0.8 \* 21

<sup>21</sup> Technical electricity generation from biogas \* 0.748 tCO<sub>2</sub>/MWh as Emission Factor for Sumatera Grid

More than 50% of the national paddy production is harvested in Java and Bali. These islands have an integrated grid connection, which is known as JAMALI Grid. With a demand growth of about 9.1% p.a., the electricity demand for this grid is relatively high (PT PLN, 2013). Hence, the share of biomass produced in Java and Bali is taken as the basis for the calculation of the technical potential.

Table 17 Technical electricity generation potential from rice industry

Parameter	Value	Unit
Rice Paddy (Theoretical Biomass Feedstock)*	69,056,000	Ton/year
Rice Straw (Technical Biomass Feedstock)	19,127,500 <sup>22</sup>	Ton/year
Rice Husk (Technical Biomass Feedstock)	7,651,000 <sup>23</sup>	Ton/year
<b>Technical electricity generation from rice husk (round-up)</b>	<b>5,362<sup>24</sup></b>	<b>GWh/year</b>

Source: BPS Statistic Data, 2012

Rice straw is not concentrated in the mills hence no study on rice straw potential as biomass power plant feedstock is available for Indonesia. Hence, this overview study only considered electricity generation from rice husk.

Table 18 CO<sub>2</sub> emission reduction potential from rice husk

Parameter	Value	Unit
Technical Electricity Generation from Rice Husk	5,362	GWh/year
Emission Factor for JAMALI Grid in 2010*	0.741	tCO <sub>2</sub> /MWh
<b>CO<sub>2</sub> Emission Reduction (round-up)</b>	<b>3,973,000</b>	<b>tCO<sub>2</sub>e/year</b>

\*Source: <http://pasarkarbon.dnpi.go.id/web/index.php/dnacdm/read/23/pembaruan-faktor-emisi-sistem-interkoneksi-tenaga-listrik-2011.html>

### HIGHLIGHT

The total technical electricity generation potential from rice husk is 5,362 GWh/year or 3.2% from the theoretical potential. Although the technical potential is lower than potential from palm oil industry, rice mill owner might get additional income from selling of Rice Husk Ash (RHA) to other industries. Hence the economic potential from rice industry will be discussed further.

## 5.3 SUGAR INDUSTRY

The majority of sugar mills is located in Java. This location of mills is in line with the amounts of production per region. With a sugar production of 1,557,624 tons in 2012 milled from an equivalent of 19.4 million tons of sugar cane, Java accounts for the main share of 64 % (Directorate General of Estate, n.d.). Consequently this share will be the basis for the calculation of the technical electricity and emission reduction potential.

<sup>22</sup> Rice Straw regional potential from Java-Bali regions (55.40% of National Rice production) \* 50% as share of RS

<sup>23</sup> Rice Husk (RH) regional potential from Java – Bali regions (55.40% of National Rice production) \* 20% as share of RH

<sup>24</sup> RH potential \* 3,318 kWh/ton as the conversion unit for Rice Husk

Table 19 Technical electricity generation potential from sugar industry

Parameter	Value	Unit
Sugar cane (Theoretical Biomass Feedstock)*	30,478,000	Ton/year
Bagasse (Technical Biomass Feedstock)	6,230,603 <sup>25</sup>	Ton/year
<b>Technical electricity generation from bagasse (round-up)</b>	<b>3,034<sup>26</sup></b>	<b>GWh/year</b>

\*Source: Ministry of Agriculture, 2013

Table 20 CO<sub>2</sub> Emission Reduction potential from bagasse

Parameter	Value	Unit
<b>3.1 Technical Electricity Generation from bagasse</b>	<b>3,034</b>	<b>GWh/year</b>
Emission Factor for JAMALI Grid in 2010*	0.741	tCO <sub>2</sub> /MWh
<b>CO<sub>2</sub> Emission Reduction (round-up)</b>	<b>2,250,000</b>	<b>tCO<sub>2</sub>e/year</b>

\*Source: <http://pasarkarbon.dnpi.go.id/web/index.php/dnacdm/read/23/pembaruan-faktor-emisi-sistem-interkoneksi-tenaga-listrik-2011.html>

### HIGHLIGHT

Even though more than 60% of the sugar cane production is located in Java, the productivity of the industry is higher in Sumatra (Guerin, 2002) the 61 sugar mills identified in Indonesia in 2005, only 10% are privately owned, which however show a much higher productivity than the state-owned mills, contributing 35% of the total sugar production (Guerin, 2002). This ownership structure makes the sugar industry less suitable for biomass power investments than the palm oil and rice industry. Therefore, the sugar industry will not be further discussed in the next section.

<sup>25</sup> Bagasse regional potential from Java – Bali regions (64% of National Sugar Cane production) \* 32% as share of RH

<sup>26</sup> Bagasse potential \* 2,029 kWh/ton as the conversion unit for Bagasse \* 0.24 as efficiency of MP Steam Turbine

## 5.4 OVERVIEW OF THE TECHNICAL BIOMASS POTENTIAL

The section 5.1 to 5.4 above give detailed technical potential from palm oil; rice paddy and sugar cane industries. Table 21 below summarizes the total technical potential from each industry as below:

Table 21 Overview of the technical potential from three agro-industries:

Industry	Feedstock	Technical Annual Electricity generation		CO2 Emission Reduction	
	EFB	4,401	GWh/year	3,300,000	tCO <sub>2</sub> e/year
<b>Palm Oil</b>	Fiber & Shell	29,475	GWh/year	22,050,000	tCO <sub>2</sub> e/year
	POME	939	GWh/year	7,283,000	tCO <sub>2</sub> e/year
<b>TOTAL PALM OIL</b>		<b>34,815</b>	<b>GWh/year</b>	<b>32,633,000</b>	<b>tCO<sub>2</sub>e/year</b>
<b>Rice Paddy</b>	Rice Husk	5,362	GWh/year	3,973,000	tCO <sub>2</sub> e/year
<b>Sugar Cane</b>	Bagasse	3,034	GWh/year	2,250,000	tCO <sub>2</sub> e/year
<b>TOTAL FROM ALL INDUSTRIES</b>		<b>43,211</b>	<b>GWh/year</b>	<b>38,856,000</b>	<b>tCO<sub>2</sub>e/year</b>

### HIGHLIGHT

Although rice paddy industry has higher theoretical electricity generation potential than the palm oil industry, due to the technology constraint to utilize the risk straw feedstock now the palm oil industry has the highest technical electricity generation potential than the rice paddy industry. The private ownership structure of the palm oil industry and the interconnected Grid availability strengthened the technical potential from this industry.

## CHAPTER VI: OVERVIEW OF BIOMASS POTENTIAL AND EMISSION REDUCTION POTENTIAL

The Chapter III and Chapter V above describe the theoretical and technical potentials of biomass feedstock. The theoretical potential of biomass feedstock is assumed based on the national production data in 2012 available on Central Statistics Agency and Ministry of Agriculture websites.

The technical potential is calculated by considering the location of the main transmission grid by PLN; the concentration of the different agricultural products; and the electricity generation efficiency of the selected technology.

The Table 22 below summarize the biomass and Emission Reduction potentials:

Table 22 Overview of Biomass Potential and Emission Reduction Potential

Industry	Theoretical Biomass Waste Potential			Technical Potential		CO <sub>2</sub> Emission Reduction (ER) Potential		
	Feedstock	Type	Electricity Generation (GWh)	Technology use	Net Electricity Generation (GWh/year)	Methane Avoidance	Electricity Generation	Total ER (thousand tCO <sub>2</sub> e/year)
Palm Oil	EFB	Solid	25,685	Medium Pressure Steam Turbine	4,401	-	3,300	3,300
	Fiber & Shell	Solid	115,983	High Pressure Steam Turbine	29,475	-	22,050	22,050
	POME	Effluent	1,161	Anaerobic digester	939	6,580	703	7,283
	<b>Total</b>		<b>142,829</b>		<b>34,815</b>	<b>6,580</b>	<b>26,053</b>	<b>32,633</b>
Rice Paddy	Rice Husk	Solid	165,714	Medium Pressure Steam Turbine	5,362	-	3,973	3,973
Sugar	Bagasse	Solid	19,789	Medium Pressure Steam Turbine	3,034	-	2,250	2,250
<i>Total theoretical electricity generation output</i>			<b>328,332 GWh/year</b> = <b>328 TWh/year</b>	<i>Total technical electricity generation output</i>	<b>43,211 GWh/year</b> = <b>43 TWh/year</b>	<i>Total CO<sub>2</sub> Emission Reduction (ER) Potential</i>		<b>38,856,000 tCO<sub>2</sub>e/year</b> = <b>0.039 Giga tCO<sub>2</sub>e/year</b>

## CHAPTER VII: ECONOMIC POTENTIAL

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The economic potential will be evaluated for POME, EFB/Shell/fiber co-firing and rice husk power plants. This overview study will concentrate on the lowest hanging fruits, therefore this section will evaluate the immediate economic potential and the repeatability of pilot projects. The sugar industry will not be covered in this section as first, the electricity generation potential is much lower than in the other industries and second, the industry structure being predominantly government-owned does not favor private investment into energy projects.

### 7.1 RICE INDUSTRY

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Rice mill owner could utilize their production residue to supply electricity to PLN under the feed-in tariff scheme. Rice straw is not yet considered economically attractive due to its emergence in the rice fields and not concentrated in the mills. Hence, only solid biomass from rice husk should be taken into account for economic consideration of biomass power plant from rice industry.

Currently the feed-in tariff for biomass plants selling their electricity to PLN is 975 IDR/kWh in Java and Bali (ESDM, 2012), the islands the technical potential is based on.

Beside income from electricity generation, rice mill owners could generate additional income from selling Rice Husk Ash (RHA). The combustion of rice husks will afford RHA or Silica which is a valuable resource that can be marketed as a filler for the concrete industry, for heat insulation in the steel industry or as filter material in other industries (Kwintkiewicz, 2013, p. 10). The sales of RHA can strongly improve project economics. Rice husk that is not used internally reached a market price of around 130-150 IDR/kg in November 2012 (Kwintkiewicz, 2013, p. 7)

The capacity of rice mills in Indonesia is very diverse. It ranges from 4 to 100 tons of paddy/day in small family owned mills, up to more than 1,000 tonnes of paddy/day in corporate mills. The smaller mills are in many cases not connected to the grid and feed their power demand with diesel generator, using 400-450 litres of diesel/day. In these mills the application of rice husk for power generation could reduce diesel consumption (Kwintkiewicz, 2013, p. 5ff). The only possibility for grid connection, is by in an external plant buying the rice husk from surrounding mills and generating electricity which will be sold to PLN (Abinanto, 2013) (Kwintkiewicz, 2013).

The main barrier faced by project developers is the low bulk density of rice husk of 70-110 kg/m<sup>3</sup>. As the feedstock needs to be transported, project economics will not only depend on the price of the feedstock but also on the cost for diesel for transport (ANNIES Export NZ Ltd, 2012).

Therefore, rice husk power plants are considered a valuable opportunity for power generation but considering the difficulty of securing sufficient feedstock supply, this industry is not considered the best option.

## 7.2 PALM OIL INDUSTRY

As most POMs are already using parts of their biomass for captive power and heat generation, the economic potential is based on the possibility to feed the generated electricity into the grid and generate revenues from the sales to PLN. This option is determined by the distance of the mill from the medium voltage grid<sup>27</sup>. In a study of the POMs located in North Sumatra (Indonesian Oil Palm Research Institute (IOPRI), 2012), 21 POMs were assessed in detail<sup>28</sup>, of which 9 were located closer than 1 km to the medium voltage grid, 1 is still located closer than 5 km to the grid and 8 POMs did not or could not provide any information on this. 3 POMs are located more than 5 km away from the medium voltage grid. As became apparent during interviews with different stakeholders of the IPP sector in Indonesia<sup>29</sup>, PLN might be open for negotiations to bear the cost of grid connection of IPPs up to 3-5 km. Any plant that is located further from the grid would need to provide the connection to the grid at own expenses which decreases project economics drastically.

Another point of concern for the economics of using POM biomass for electricity generation is the size of the mill. Assuming an on-site power plant that is only supplied by the biomass of the “parental” POM, this POM should process at least 30 tons FFB/hour (Heidrich, 2013). The study in North Sumatra found out that only 3 or 14% of the POMs have a capacity lower than 30 tons FFB/hour (Indonesian Oil Palm Research Institute (IOPRI), 2012).

Shells, fibers and parts of EFB are already used for captive power generation (EKONID, 2011, p. 65). The feedstock that is not used for this purpose is sold due to the high market prices especially for shells. These opportunity cost have to be taken into account when assuming the economic potential. High demand from other industries (domestic and international) caused rising prices from around 24 to 25 \$ per ton in 2006 to around 50 to 60 \$ per ton in 2011 for shells (German-Indonesian Chamber of Industry and Commerce (EKONID), 2011, p. 65). 84% of the POMs in North Sumatra use 50% or more (each group 9 mills) of their shells for captive power generation and only 16 % (3 mills) use less than 50% of shells for captive power (Indonesian Oil Palm Research Institute (IOPRI), 2012).

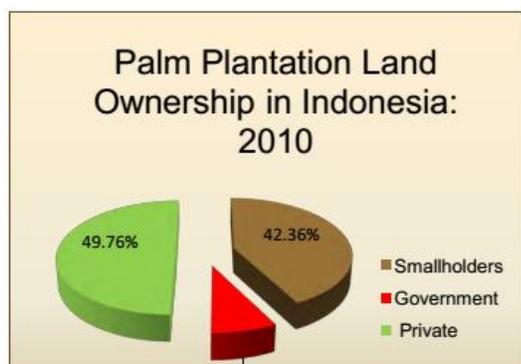


Figure 5: Shares of land ownership of palm plantation (EKONID, 2011)

<sup>27</sup> The low voltage grid is not relevant for feeding in electricity as soon as the plant is bigger than 100kW?! The electricity losses will be too high to be economically feasible. (Personal communication with Thomas Strobel & Alin Pratidina, GIZ, 2013)

<sup>28</sup> In total GIZ found 107 POMs located in North Sumatra

<sup>29</sup> RE Guidelines Peer Review Summary

Irrespective of the demand for shells from outside the industry, using the full amount for electricity generation could still be a more valuable option when the electricity is sold to PLN for the fixed FiT. An assessment based on a GIZ site visit of a POM showed that under a system efficiency of 25% and a FiT of 975 IDR/kWh the economic value of shells would amount to 907 IDR/kg which is higher than the market value of 700 IDR/kg at that time (Eichelbröner, 2013)

Due to the large number of POM in Indonesia, which are predominantly privately owned, this industry offers good opportunities for waste-to-energy project development. Furthermore, due to the location of the majority of the POM in Sumatra, grid connection is relatively easy. A third factor, underlining the suitability of the palm oil industry for grid-connected electricity generation is the security of feedstock supply which is available as residue in the mills.

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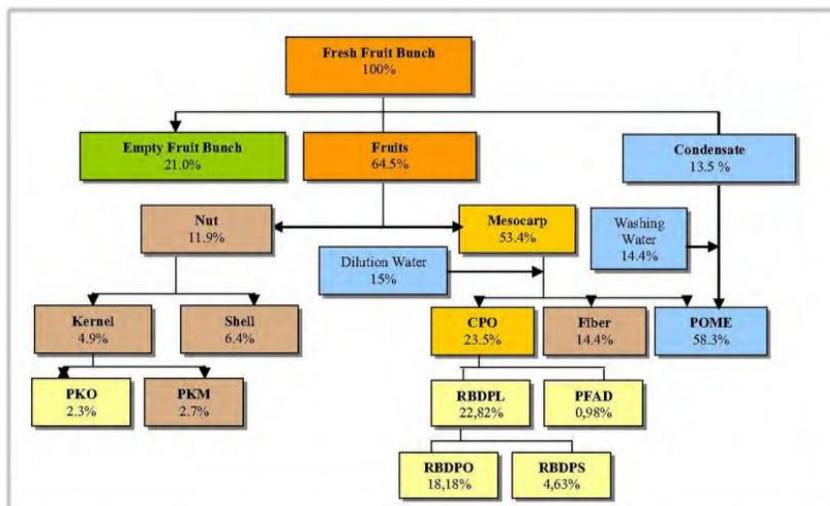
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## ANNEX

### ANNEX A: MASS BALANCE OF PALM OIL EXTRACTS AND RESIDUES



Source: (Hambali, Thahar, & Komarudin, 2010)

### ANNEX B: INDONESIA SUGAR CANE PRODUCTION IN THE PAST FIVE YEARS

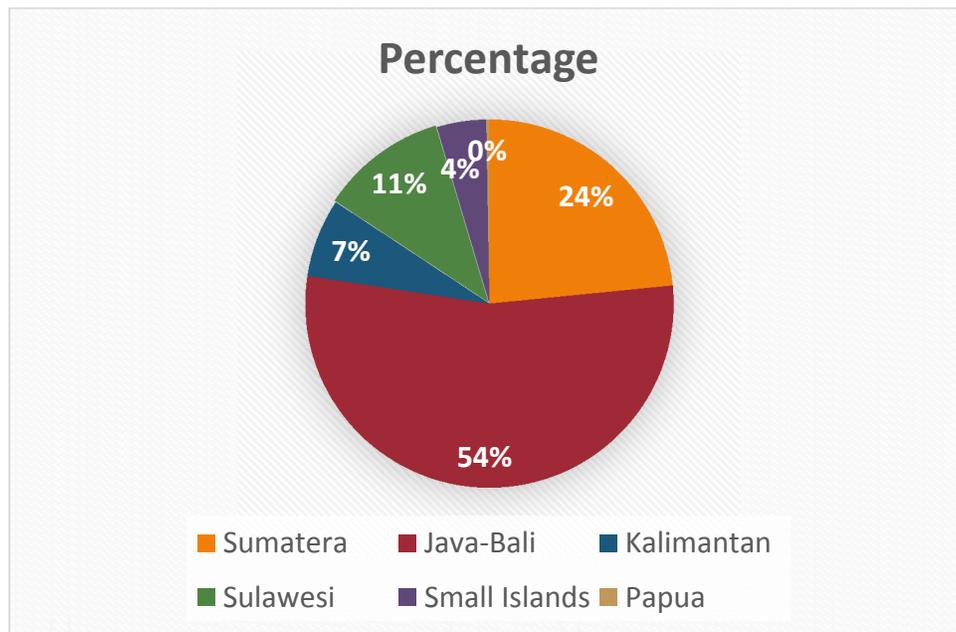
Sugar cane production per calendar year  
(ton/year)

2003	2008	2009	2010	2011	2012
24,500,000	25,600,000	26,400,000	26,600,000	24,000,000	26,341,600

Source: (FAOSTAT, 2013)

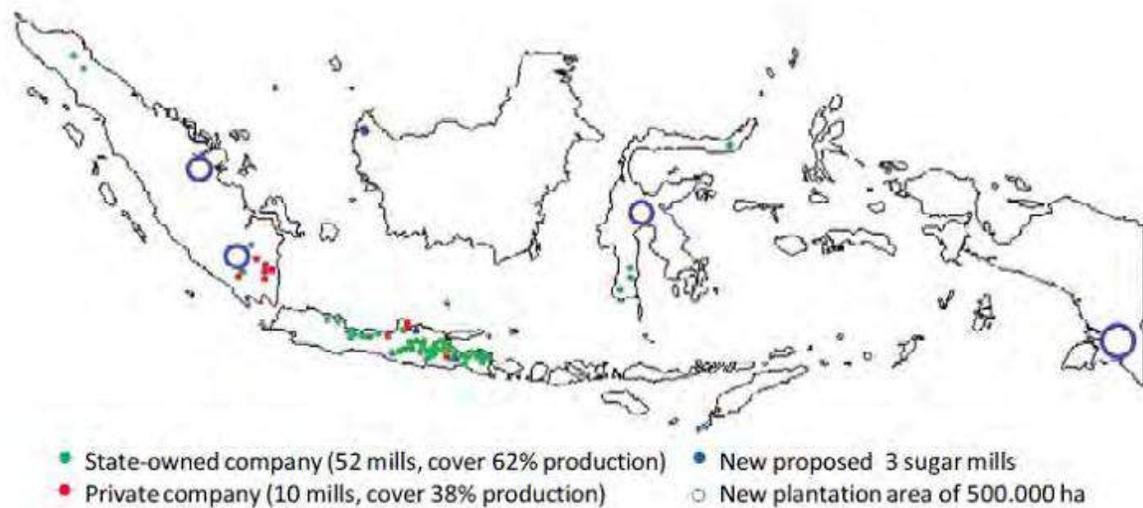


## ANNEX E: PERCENTAGE OF PADDY PRODUCTION PER ISLANDS



Source: Ministry of Agriculture, 2013

## ANNEX F: MAP OF SUGAR CANE MILLS IN INDONESIA



Source: (ANNIES Export NZ Ltd, 2012)



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