Resource Assessment for Livestock and Agro-Industrial Wastes—Indonesia

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Global Methane Initiative

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EXECUTIVE SUMMARY

The Global Methane Initiative (GMI) aims to reduce global methane emissions while enhancing economic growth, promoting energy security, improving the environment, and reducing greenhouse gases. The initiative focuses on cost-effective, near-term recovery and use of methane as a clean energy source. GMI collaborates internationally with developed and developing countries, countries with economies in transition, and with strong participation from the private sector.

The initiative works in five main sectors: agriculture, municipal solid waste, municipal wastewater, oil and gas, and coal mines. The GMI agricultural sector strategy focuses on developing and/or enhancing fully functioning, robust, and competitive agricultural anaerobic digestion (AD) technologies in energy markets in GMI countries. AD provides significant methane reduction potential and other environmental and energy-related benefits. Understanding the potential for emission reductions is a key foundation for developing a strategy to reduce methane from AD installations. This *resource assessment* (RA) characterizes management processes, industry conditions, and markets for various agricultural sectors, and estimates the potential emission reductions in these sectors.

This analytical approach has resulted in increasing market penetration rates and expanded scales of operation in numerous countries. RAs help to identify many of the obstacles—technical, economic, market- and knowledge-based—that may impede the successful and widespread deployment of AD. For this reason, the U.S. Environmental Protection Agency (U.S. EPA) conducted a livestock and agro-industry RA in Indonesia to identify and evaluate the potential for incorporating AD into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy. The key findings of the RA are summarized below.

Sector characterizations. This RA evaluates three sectors—palm oil processing, cassava processing, and swine farms—which were chosen due to their potential for emission reductions from AD projects. The supply and demand markets for the swine sector can be summarized as technically and financially weak; the cassava and palm oil sectors appear stronger technically and somewhat stronger financially. Of the three sectors, palm oil can be characterized as having the most advanced supply and demand markets. All three sectors have high emission profiles; these can be reduced within a program that merges finance and technology, allowing users to choose and install appropriate AD technologies.

This RA also summarizes each sector's geographic distribution, the size of their markets, scale of operations, and current waste management practices. Figure E-1 presents the geographic concentrations of each sector, based on the percent of production from each sector. Table E-1 presents the size distribution of production in each sector.

Figure E-1. Percent of Production by Sector and Region

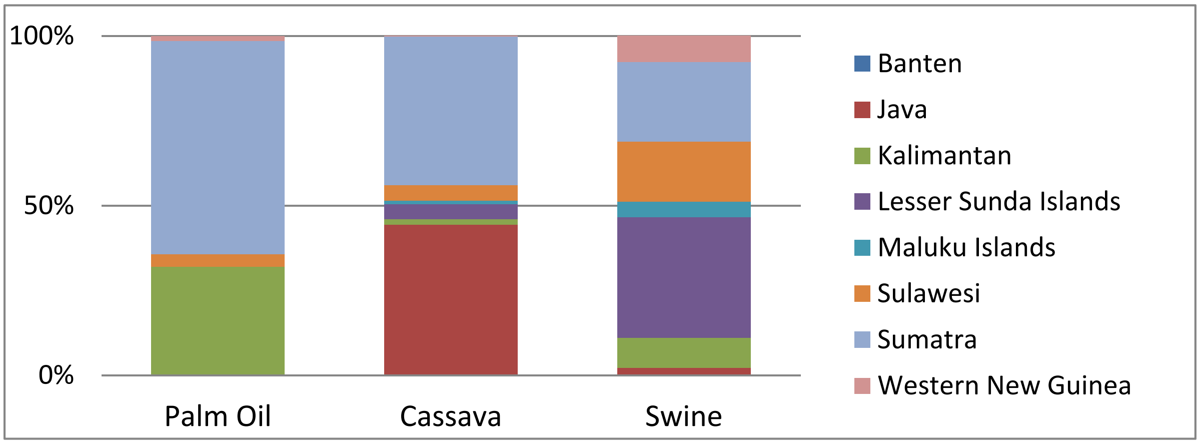


Table E-1. Sector Production Distribution by Size of Operation

Sector	Size Category	Size Category Description	Percent of Production
Palm oil	Large	>70 tons of fresh fruit bunches per hour	33%
	Medium	45–70 tons of fresh fruit bunches per hour	52%
	Small	<45 tons of fresh fruit bunches per hour	16%
Cassava	Large	>200 tons per day	36%
	Medium	100 to 200 tons per day	36%
	Small	<100 tons per day	29%
Swine	Large	>6,000 head	20%
	Medium	1,000–6,000 head	40%
	Small	<1,000 head	40%

Emission profiles: Table E-2 illustrates the baseline (current) emission profiles of the main agricultural emission sectors, based on the RA sector characterizations and Intergovernmental Panel on Climate Change methodology. The potential emission reductions, also shown in Table E-2, are estimates of the reductions that could be achieved if significant numbers of AD systems were installed in these sectors due to a fully functional market or other mechanism. The sector with the highest potential for methane reduction and carbon offsets is the palm oil sector, followed by the cassava and swine sectors.

Table E-2. Baseline Methane Emissions and Potential GHG Emission Reductions

Sector	Baseline Methane Emissions by Waste Management ($MTCO_2e/yr$)				Total Baseline Emissions ($MTCO_2e/yr$)	Potential GHG Emission Reductions ($MTCO_2e/yr$)		Total Potential Emission Reductions ($MTCO_2e/yr$)
	AD*	Lagoons	Direct Discharge	Pasture		Direct Emission Reductions*	Indirect Fuel Replacement Offsets	
Palm oil	321,750	40,326,000			40,647,750	36,293,400	1,432,010	37,725,410
Cassava	113,690	5,998,290	34,540		6,146,520	5,396,390	212,920	5,609,310
Swine	58,030	1,554,120		16,820	1,612,140	1,392,650	54,950	1,447,600
TOTAL	**493,470**	**47,878,410**	**34,540**	**16,820**	**48,406,410**	**43,082,440**	**1,699,880**	**44,782,320**

* Emissions were estimated assuming a 10 percent leakage rate from AD systems, based on default leakage rate from UNFCCC CDM 2008.

AD supply and demand market: The Indonesian AD supply market can be characterized as young and growing, consisting mostly of a contingent of international AD developers with a market focus on the larger-scale palm oil facilities and growing interest in large cassava processing plants. The technical focus appears to be on inflated-type covered anaerobic lagoons and large (>250 kW) high-quality imported reciprocating engines. There are limitations in equipment, particularly access to reliable, lower cost, medium BTU reciprocating engines.

While covered anaerobic lagoons are recognized as an applicable AD technology for medium to large scales, the current market would benefit by transferring other proven technologies for medium-to-small-scale facilities, such as tube anaerobic digesters and various types of fixed dome digesters, applicable for swine and small cassava facility conditions.

In Indonesia, there are limited drivers to develop and sustain a demand market that can deliver a large number of operating AD systems. There are financing opportunities from energy programs operated in Indonesia by the United States Agency for International Development (USAID) and Capacity for Indonesian Reduction of Carbon in Land Use and Energy (CIRCLE). Both of these focus primarily on the palm oil sector.

1.0 INTRODUCTION

The Global Methane Initiative (GMI) is a collaborative effort between national governments and others to capture methane emissions and use them as a clean energy source. It was founded in 2004 as the Methane to Markets Partnership. Its Partners make formal declarations to minimize methane emissions from key sources, stressing the importance of implementing methane capture-and-use projects in developing countries and countries with economies in transition. The initiative focuses on five key sources of methane, including agriculture, coal mines, municipal solid waste, municipal wastewater, and oil and gas systems.

GMI's objective is to bring diverse organizations together with national governments to catalyze the development of methane projects. Organizations include the private sector, the research community, development banks, and other governmental and non-governmental organizations. Facilitating the development of methane projects will decrease greenhouse gas (GHG) emissions, increase energy security, enhance economic growth, improve local air quality, and improve industrial safety.

GMI has conducted *resource assessments* (RAs) in twelve GMI participating countries to identify the types of livestock and agro-industrial subsectors with the greatest opportunities for cost-effective implementation of methane recovery systems. The objectives of this RA are to:

- Characterize waste management to identify baseline waste management systems that emit methane.
- Identify the largest emission sectors and develop an emissions profile for each one.
- Identify the potential for incorporating anaerobic digestion (AD) into livestock manure and agro-industrial (agricultural commodity processing) waste management systems.
- Assess supply and demand markets that can lead to emission reductions.

Anaerobic digestion (AD) reduces methane emissions and provides a renewable source of energy. This RA presents priority sectors and regions for implementing AD technologies, based on potential methane emission reductions. In Indonesia, the agricultural sectors with the greatest emission reduction potential are palm oil processing, cassava processing, and swine farms.

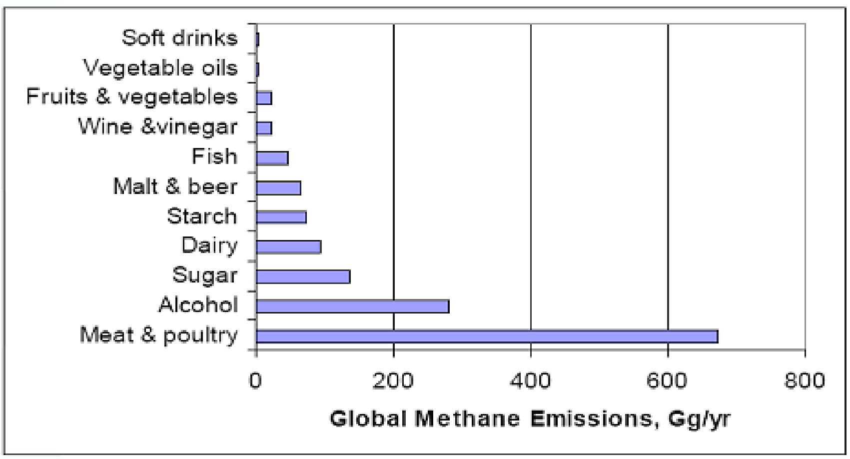
While there are other studies showing methane emissions from these sectors, the studies usually take total population or production levels as the baseline for calculating the emissions. This RA, however, uses a bottom-up approach that uses the best available data to estimate the percentage of waste management operations that generate methane. Using the most accurate and validated data available for each sector, emission reduction estimates are considered for industries that generate methane via their waste management systems (e.g., lagoons). The estimates are based on population, scales of operation, and number of facilities. For example, methane emission reduction estimates from the swine sector only take into account a reasonable fraction of the total number of animals and number of operations in the country. This fraction represents the number of animals whose waste is assumed to be managed through practices that generate methane. Estimating emissions and emission reductions using these assumptions provides a sound basis for policy development and capital investments, and provides conservative estimates of emission reductions.

1.1 Global Methane Emissions from Manure and Agro-Industrial Wastes

In 2010, livestock manure management contributed more than 237 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) of global methane emissions, which is approximately 4 percent of total anthropogenic (human-induced) methane emissions. Three groups of animals account for more than 80 percent of total emissions: swine (40 percent), non-dairy cattle (20 percent), and dairy cattle (20 percent). In some countries, poultry was also a significant source of methane emissions.

Waste from agro-industrial activities is an important source of methane emissions. The organic fraction of agro-industrial wastes typically is more readily biodegradable than the organic fraction of manure. Thus, greater reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), and volatile solids (VS) during AD can be realized. In addition, the higher readily biodegradable fraction of agro-industrial wastes translates directly into higher methane production potential than from manure. Figure 1-1 shows global estimates of methane emissions from agro-industrial wastes.

Figure 1-1. Global Methane Emissions from Agro-Industrial Wastes



Source: Doorn et al., 1997. Estimate of Global Greenhouse Gas Emissions from Industrial and Domestic Wastewater Treatment. EPA-600/R-97-091.

As shown in Table 1-1, the majority of agro-industrial wastewater in developing countries are not treated before discharge; wastewater that is treated is generally treated anaerobically. As a result, agro-industrial wastewater represents a significant opportunity for methane emission reduction through the addition of appropriate AD systems.

Table 1-1. Disposal Practices for Livestock and Agro-Industry Wastewater

Sector	Region	Wastewater	
		Percent Discharged without Treatment	Percent Managed Anaerobically
Meat, poultry, dairy, and fish processing	Africa	60	34
	Asia (except Japan)	70	22
	Eastern Europe	50	23
	Latin America	50	32

Table 1-1. Disposal Practices for Livestock and Agro-Industry Wastewater

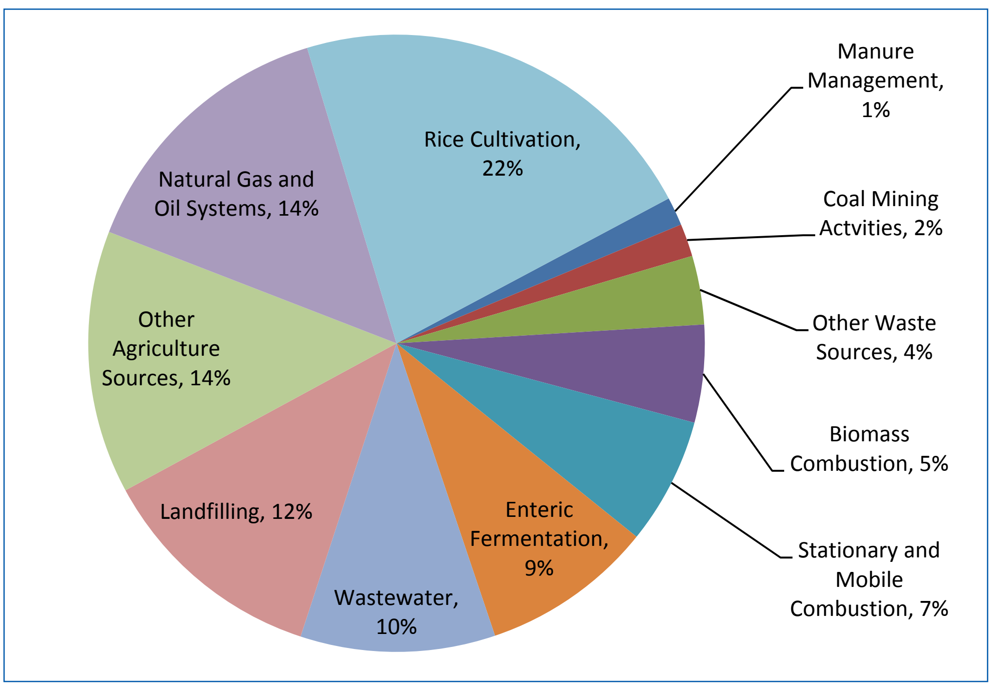
Sector	Region	Wastewater	
		Percent Discharged without Treatment	Percent Managed Anaerobically
Fruit and vegetable processing	Africa	70	6
	Asia (except Japan)	70	5
	Eastern Europe	50	1
	Latin America	60	5
Alcohol, beer, wine, vegetable oil, sugar, and starch	Africa	60	17
	Asia (except Japan)	60	11
	Eastern Europe	20	8
	Latin America	20	13

Source: Doorn et al., 1997. Estimate of Global Greenhouse Gas Emissions from Industrial and Domestic Wastewater Treatment. EPA-600/R-97-091**.**

1.2 Methane Emissions In Indonesia

The most recent estimate of methane emissions from Indonesia were presented in the U.S. EPA's *Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gas Emissions* report. In 2010, Indonesia ranked as the 6th highest methane emitter, behind China, the U.S., Russia, India, and Brazil, with estimated total anthropogenic methane emissions of 234.6 $MTCO_2e$. As shown in Figure 1-2, methane from rice is the principal source of anthropogenic methane emissions. Wastewater, which includes both municipal and industrial wastewater, accounts for 10 percent of the emissions, other waste sources account for 4 percent of the emissions, and manure management for 1 percent.

Figure 1-2. Indonesia's 2010 Estimated Anthropogenic Methane Emissions by Source



Source: U.S. EPA, 2011. Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions. EPA 430-R-12-006.

1.3 Resource Assessment Methodology

Before beginning work on this RA, GMI developed a preliminary assessment for Indonesia that provided information on multiple industries. This RA focuses on the three sectors identified in the preliminary assessment with the highest potential for methane emission reductions. The RA uses a variety of data sources, including:

- **Published data**, including national and international data (e.g., United Nations Food and Agriculture Organization [FAO] production datasets); specific subsector information from business and technical journals; and other documents, reports, and statistics.
- **Interviews** with local experts from pertinent ministries (e.g., ministries of agriculture, environment, and energy), local non-government organizations, and engineering/consulting companies working in agriculture and rural development; current users of AD; and other stakeholders.
- **Field visits** to sites of various sizes in the different sectors to characterize the waste management systems used and to verify the information collected through other sources.

The team took the following approach, which has been used in other RAs in this series:

1. The first step in the development of the Indonesia livestock and agro-industry RA involved constructing general profiles of the individual sectors (or commodity groups), such as palm oil or swine production. Each sector profile includes a list of all operations and the distribution of facilities by size and geographical location. For the various livestock commodity sectors, , the appropriate metric for delineating distribution by size is the average annual standing population (e.g., number of lactating dairy cows or swine). For the various agro-industry commodity sectors, the metric is the mass or volume of annual processing capacity, or the mass or volume of the commodity processed annually.
2. Based on available data, the team then approximated the composition of the livestock production and agro-industry sectors at the national level, as well as the relative significance of each geographically.
3. With this information, the team focused on identifying the sectors with the greatest potential to emit methane from waste management activities. Using the best available information, such as statistical information published by a government agency, the team identified sectors with higher emissions and, if possible, assembled profiles of these livestock production and agro-industry sectors. If such information was unavailable or inadequate, the team used a credible secondary source, such as FAO. Most of the production data used in this RA is from primary data sources.
4. The team characterized the waste management practices used by each sector. Typically, only a small percentage of the total number of operations in sector will be responsible for the majority of production, and thus the majority of the methane emissions. Additionally, the waste management practices employed by the largest producers in each sector should be relatively uniform. When information about waste management practices was incomplete or not readily accessible—which was often the case for the livestock industry in Indonesia—the team identified and directly contacted producer associations and local consultants and visited individual operations to obtain this information.

5. The team then assessed the magnitude of current methane emissions to identify those commodity groups that should receive further analysis. For example, large operations in the livestock production sector that rely primarily on a pasture-based production system will have only nominal methane emissions (because manure decomposition will be primarily aerobic). Similarly, an agro-industry subsector with large operations that directly discharge untreated wastewater to a river, lake, or ocean will not be a source of significant methane emissions. In estimating current methane emissions, therefore, the team focused on sectors that could most effectively use available resources. This profiling exercise helps identify the more promising candidate sectors and/or operations for technology demonstration. To expand on Step 5, the specific criteria to determine methane emission reduction potential and feasibility of AD systems included the following:

    - **Sector size:** The sector is one of the major livestock production or agro-industries in the country. The distribution of waste production across facility sizes within the sector is a key element, as the waste management systems (which impact methane generation) may be different depending on facility size.
    - **Methane conversion factor (MCF):** The amount of methane generated depends on the method of waste management, as reflected by the MCF. Anaerobic systems will produce more methane than other waste management systems, and therefore have a higher MCF.
    - **Waste volume:** The livestock production or agro-industry generates a high volume of waste that is currently managed anaerobically.
    - **Waste strength:** The wastewater generated has a high concentration of organic compounds as measured in terms of its BOD, COD, or both. These high strength wastes will have high maximum methane generating capacity (B_0) values.
    - **Geographic distribution:** Of secondary importance, priority sectors may concentrate in specific regions of the country, making centralized or commingling projects potentially feasible.

The top sectors that meet all of the above criteria in Indonesia are palm oil processing, cassava processing, and swine farms. Sugar cane processing, slaughterhouses, dairy production, and beverage production (both non-alcoholic and beer) were also reviewed during the preliminary assessment as possible sources of methane emissions, but were determined to have less emission reduction potential than the three priority sectors. Therefore, these other sectors are not included as part of the main report.

2.0 SECTOR CHARACTERIZATION

The important sectors of the livestock production and agricultural commodity processing industries in Indonesia are palm oil processing, cassava processing, swine farms, sugar cane processing, slaughterhouses, dairy production, and beverage production (both non-alcoholic and beer). This resource assessment focuses on the three sectors estimated to have the greatest potential for AD projects: palm oil processing, cassava processing, and swine farms. These sectors are discussed in detail in Sections 2.1 through 2.3.

2.1 Palm Oil Processing Plants

2.1.1 Description of Size, Scale of Operations, and Geographic Location

Palm oil is widely used in various foods, cosmetics, and biofuels. Over the past three decades, its versatility and low cost have resulted in increased demand. Worldwide palm oil production in 1980 was 4.6 million tons; it reached 53.7 million tons in 2012. Over that period, palm oil increased from 8 percent of world vegetable oils and fats to 30 percent.[1] As the leading producer of palm oil, the Indonesian palm oil sector has been developing significantly over the past two decades. The Indonesia Palm Oil Board reported that there are approximately 608 palm oil mills (POMs) in Indonesia, with capacities ranging from 30 to 90 tons per hour.[2] The Ministry of Agriculture's statistics show that Indonesian total crude palm oil production was 26 million metric tons in 2012, nearly 50 percent of world production.[3, 4] Indonesia plans to increase production to 40 million tons by 2020.[5] Over the past 5 years, crude palm oil production has increased steadily, with an average growth rate of 10.2 percent per year.[6]

There are palm oil plantations in much of Indonesia, including Sumatra, Kalimantan, Sulawesi, and Papua, as shown in Figure 2-1. The largest cultivation area is in Riau Province, followed by North Sumatra, South Sumatra, and West and Central Kalimantan. The first commercial-scale palm oil plantations in Indonesia were planted in Aceh and North Sumatra in 1911; the development of smallholders began in the late of 1970s with a World Bank loan. Since the beginning of the 1980s, the palm oil industry has grown rapidly. Figure 2-2 illustrates the growth of the industry from 2000 to 2011. In 2011, the total area of palm oil plantations reached 8.91 million hectares, consisting of 4.65 million hectares (52.2 percent) of large private plantations; 3.62 million hectares (40.64 percent) of smallholder plantations, which were owned by 1.8 million farmers; and 0.64 million hectares (7.15 percent) of state-owned large plantations.[7] The Ministry of Agriculture reported that the total area reached 9.1 million hectares in 2012 and 9.2 million hectares in 2013, producing roughly 155 million tons of fresh fruit bunches (FFB) .[8,9]

[1] Palm Oil the Leader in Global Oils and Fat Supply, June 2013, www.oilworld.de

[2] Facts of Indonesian Oil Palm, Ministry of Agriculture

[3] Statistik Pertanian 2013 Kementerian Pertanian Republik Indonesia

[4] FAOSTAT3.fao.org, accessed August 2015

[5] http://blog.cifor.org/17798/fact-file-indonesia-world-leader-in-palm-oil-production#.VBmTSxbYrFk

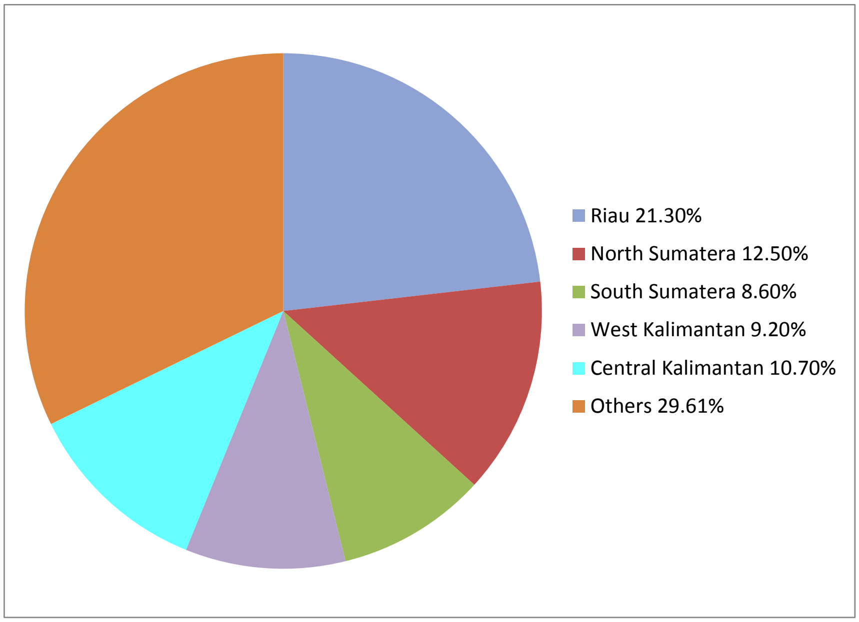
[6] Ministry of Agriculture, Directorate General of Data and Agriculture Information System Centre, January 2013

[7] "Informasi Ringkas Komoditas Perkebunan Kelapa Sawit," January 2012, Ministry of Agriculture: Secretary General of Data and Information System Center (pusdation.setjen.pertanian.go.id)

[8] Agriculture Statistics 2013, Ministry Agriculture Republic of Indonesia.

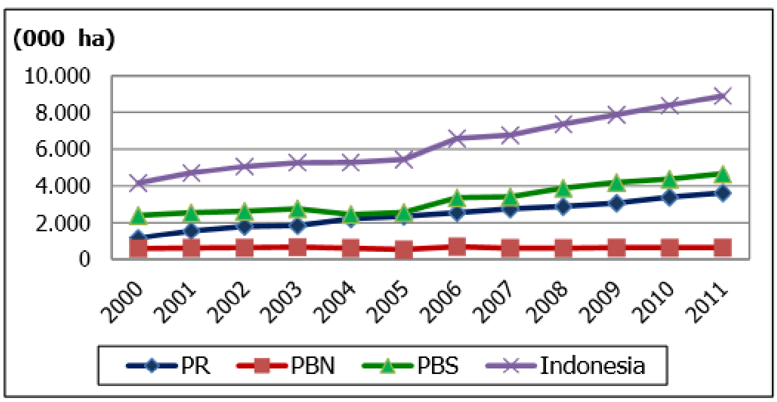
[9] FAOSTAT3.fao.org, accessed August 2015

Figure 2-1. Five Provinces with the Highest Palm Oil Production in Indonesia



Source: Ministry of Agriculture, Directorate General of Data and Agriculture Information System Centre, January 2013

Figure 2-2. Development of Palm Oil Plantation Area



PR: perkebunan rakyat (smallholder plantations), PBN: perkebunan besar negara (state-owned large plantations), PBS: perkebunan besar swasta (private large plantations)
Source: Ministry of Agriculture, Directorate General of Data and Agriculture Information System Centre, January 2013

Palm oil mill (POM) size is typically defined by production rate, which is the amount of FFB processed per hour. Generally, POMs in Indonesia range between 30 and 90 metric tons per hour, with a total capacity of 34,280 tons of FFB per hour, as presented in Table 2-1. Based on this information, GMI grouped Indonesian palm oil mills into three size categories: less than 45 tons FFB per hour, 45 to 70 tons FFB per hour, and more than 70 tons FFB per hour. Using the information in Table 2-1, GMI estimates that 22 percent of POMs (representing 16 percent of production) process less than 45 tons FFB per hour, 55 percent of POMs (representing 52 percent of production) process 45 to 70 tons FFB per hour, and 23 percent of POMs (representing 33 percent of production) process more than 70 tons FFB per hour.

Table 2-1. Palm Oil Mills and Production Capacities per Province

No	Provinces	Total Number of POMs (Unit)	Total Production Capacity (Tons FFB/hour)
1	Nangroe Aceh Darussalam	25	980
2	North Sumatra	92	3,815
3	West Sumatra	26	1,645
4	Riau & Riau Islands	141	6,700
5	Jambi	42	2,245
6	South Sumatra	58	3,555
7	Bangka Belitung	16	1,235
8	Bengkulu	19	990
9	Lampung	10	375
10	West Java	1	30
11	Banten	1	60
12	West Kalimantan	65	5,475
13	Central Kalimantan	43	3,100
14	South Kalimantan	15	770
15	East Kalimantan	29	1,545
16	Central Sulawesi	7	590
17	South Sulawesi	2	150
18	West Sulawesi	6	260
19	South-East Sulawesi	3	260
20	Papua	3	140
21	West Papua	4	360
Total		**608**	**34,280**

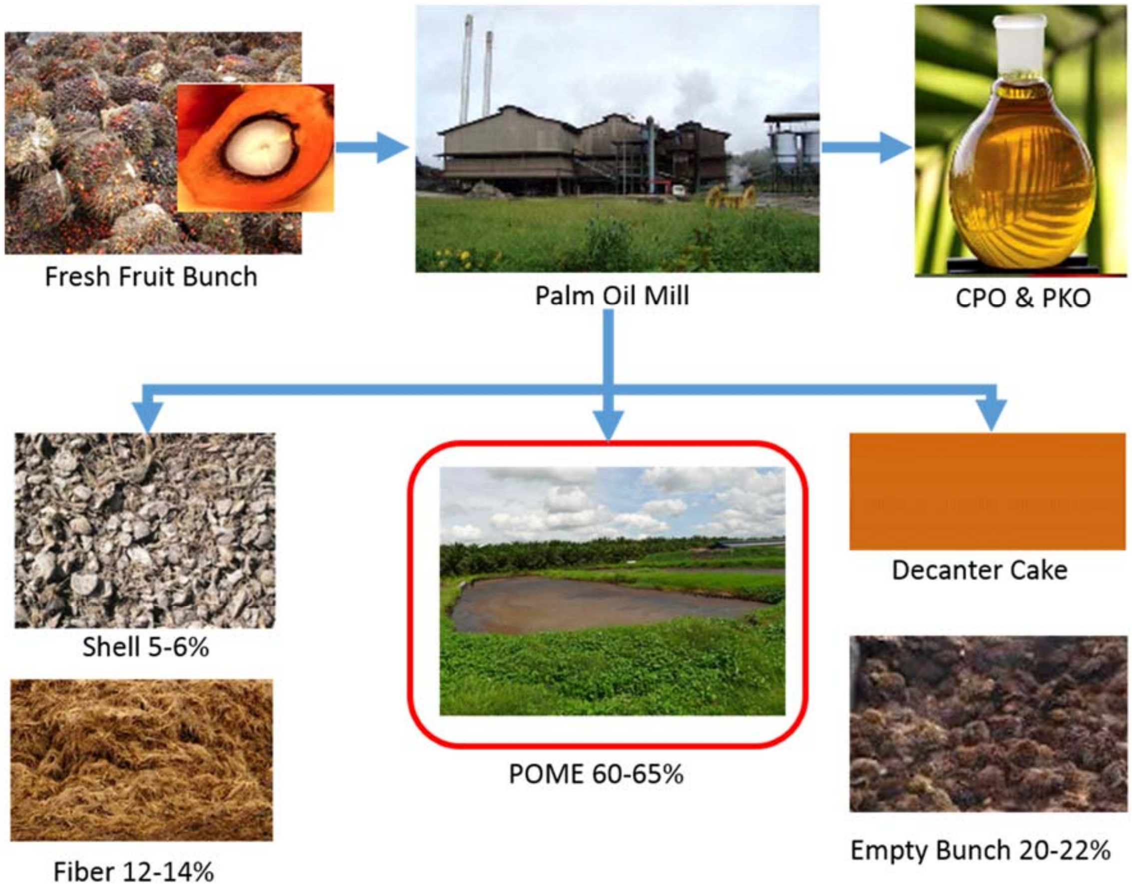
Source: Facts of Indonesian Oil Palm, Ministry of Agriculture

2.1.2 Description of Waste Characteristics, Handling, and Management

Palm oil mills mainly produce crude palm oil and palm kernel oil. The process produces two types of waste: palm oil mill effluent (POME), with waste effluent of 0.7 m^3 per ton of FFB processed. and solid waste in the form of shell, fiber, decanter cake, and empty fruit bunches. [10] Palm oil mills generally cite an effluent rate of 65 percent, but the Capacity for Indonesian Reduction of Carbon in Land Use and Energy (CIRCLE) project studies have found that effluent rates in the Indonesian palm oil sector could exceed 80 percent. Most of mills apply the final treated effluent from the last lagoon for fertilizer in their plantation. Figure 2-3 depicts the production flow at palm oil mills.

[10] CIRCLE (Capacity for Indonesian Reduction for Carbon in Land Use and Energy) Project and "Biodegradable of Palm Oil Mill Effluent (POME) by Bacteria," Jeremiah David Bala, et al., *International Journal of Scientific and Research Publications*, Volume 4, Issue 3, March 2014.

Figure 2-3. Palm Oil Production Process



Source: CIRCLE Project

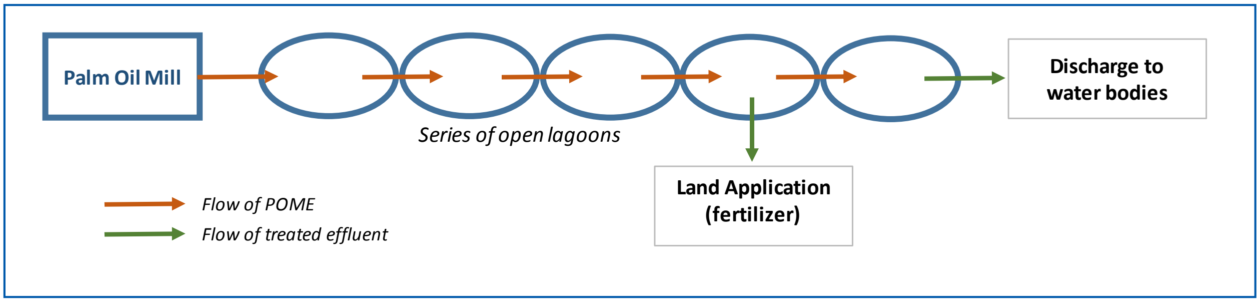
Palm oil mills use the solid waste as a feedstock for a combined heat and power production facility to generate steam and power for the production process, and to supply power for the office facilities and workers' housing.

In the palm oil industry, the amount of waste produced will depend on the volume of feedstock processed, which can be driven by crop seasonality. Generally, palm oil plantations have a low season from January to April and a peak season from August to November.

2.1.3 Description of Common Waste Treatment Technologies

POME is typically treated using a series of 6 to 10 aerobic and anaerobic open lagoons that reduce the COD level to meet the environmental standards set by the Ministry of Environment. During the process, methane is released to the atmosphere. A schematic diagram of palm oil mill effluent is depicted in Figure 2-4.

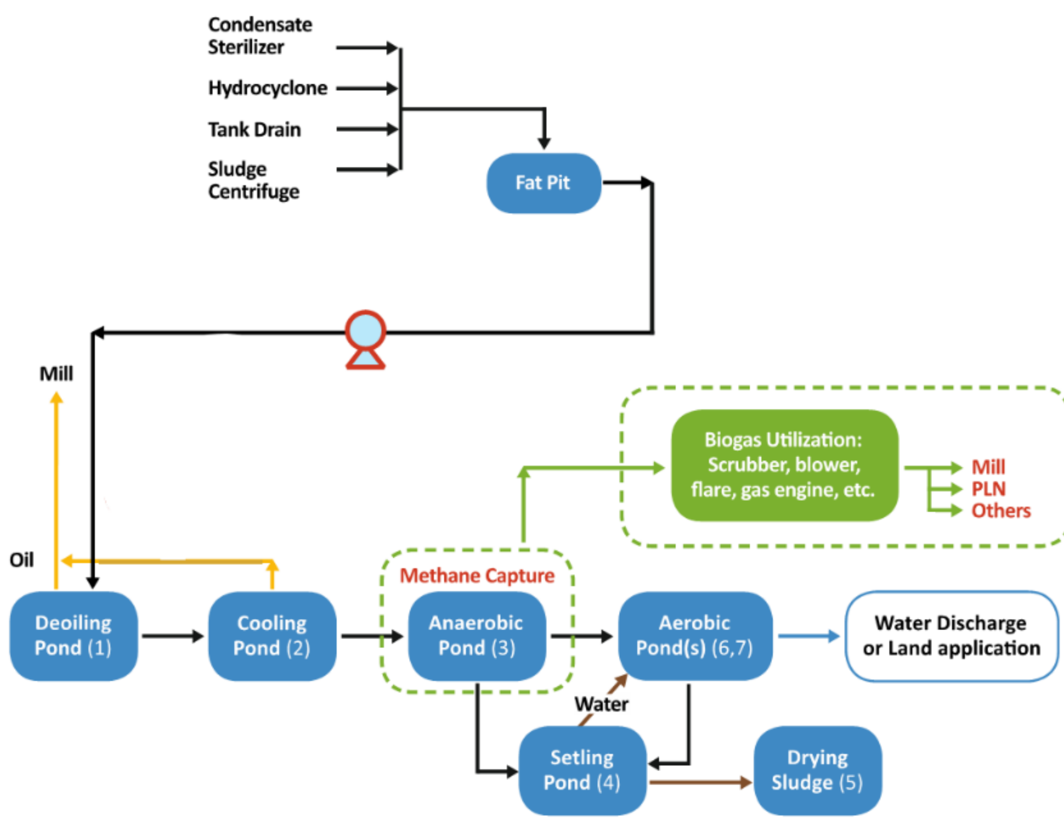
Figure 2-4. Palm Oil Mill Effluent (POME) Treatment Process



Source: CIRCLE Project

The level of COD varies from one mill to another, since it depends on the fruit's quality and the production process. CIRCLE studies have found COD levels typically range between 38,000 and 83,000 mg/L. The average COD level at the fat pit outlet (factory effluent) is 80,000 mg/L, while the level at the cooling pond outlet released into the AD process is 60,000 mg/L. **Error! Reference source not found.** Figure 2-5 shows a typical palm oil mill process flow diagram, including the fat pit and cooling ponds.

Figure 2-5. Typical Palm Oil Mill Process Flow Diagram



Source: Biogas Handbook, CIRCLE Project

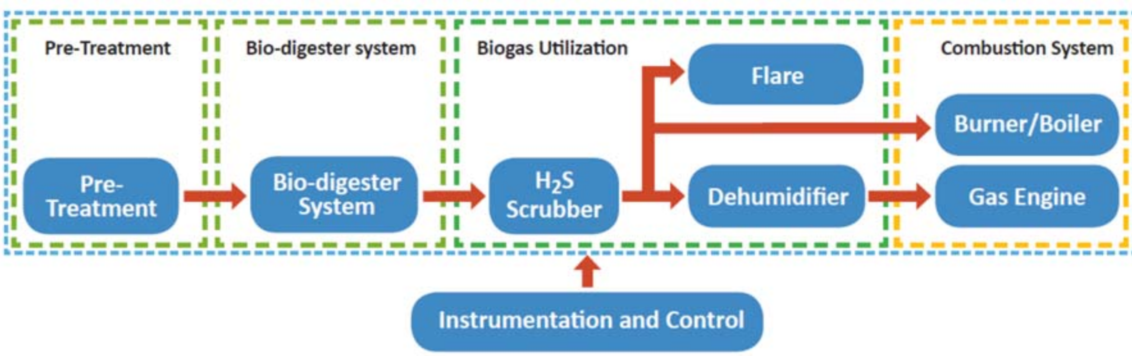
The treated POME has value as organic fertilizer at the plantation because it contains a considerable amounts of nitrogen, phosphate, potassium, calcium, and magnesium. Untreated POME is not allowed to be discharged directly due to its potential effect on the environment. Table 2-2 shows the typical characteristics of untreated POME and Indonesian discharge standards.

Table 2-2. POME Parameters and Discharge Standard

Parameter	Unit	Untreated POME[11]		Regulatory Discharge Limits	
		Range	Average	Water Bodies[12]	Land Application[13]
BOD	mg/L	8,200–35,000	21,280	100	5,000
COD	mg/L	15,103–65,100	34,740	350	
Total suspended solids	mg/L	1,330–50,700	31,170	250	
Ammonia (NH_3-N)	mg/L	12–126	41	50	
Oil and fat	mg/L	190–14,720	3,075	25	
pH		3.3–4.6	4	6–9	6–9

Indonesian palm oil mills are beginning to adopt AD technologies to treat waste. As noted in Section 2.1.4, approximately 6 percent of palm oil mills currently have AD. To date, two major technologies have been used for anaerobic digestion in the Indonesian palm oil sector: covered lagoons and continuous stirred tank reactors. While both systems use anaerobic bacteria to degrade organic wastes, covered lagoons have longer retention times and require more land area than tank systems. A schematic diagram of a methane capture project is presented in Figure 2-6.

Figure 2-6. Palm Oil Mill Biogas Process



Source: Biogas Handbook, CIRCLE Project

POME is channeled to a pre-treatment system, which could be a cooling pond, cooling tower, or heat exchanger, with the purpose of lowering the effluent temperature. Then the effluent is pumped to the AD system (covered lagoon or tank system), where the bacteria digest the organic content. The biogas produced in the AD system, with 50 to 75 percent methane content, is pumped to a biogas utilization system, which consists of a hydrogen sulfide (H_2S) scrubber and dehumidifier, prior to being injected to a gas engine or burner/boiler. Excess biogas is pumped to a flare system to destroy the methane.

The AD system can remove at least 80 percent of the COD and the treated effluent can be used multiple ways. The treated effluent could be used as fertilizer for the plantation. Alternatively, the final

[11] "Waste Management Guideline of Palm Oil Industry," Agriculture Department 2006, Permen LH No.3/2010

[12] Environment Minister Decree No. 51/1995 (Appendix B.IV)

[13] Environment Minister Decree No. 28/2003

effluent can be discharged to water bodies; in this case, the treated effluent from the AD system is typically pumped to sedimentation ponds prior to discharge.

2.1.4 Current Status of Anaerobic Digestion

In Indonesia, 38 methane capture projects at palm oil mills were registered as Clean Development Mechanism (CDM) projects. Many of these were probably initiated and developed in part based on the incentive of carbon revenues.[14] Note that not all projects registered are confirmed to be operating—some may be in planning, some in development, and others shut down. Due to a lack of available comprehensive data on operational projects, the registered CDM project data were used as a proxy. The projects are listed in mills ranging from 35 to 90 tons per hour, with a total of 2,110 tons per hour. The installed projects are estimated to reduce greenhouse gas emissions by more than 1.2 $MTCO_2e$ per year as shown in Table 2-3.

Although the majority of the listed projects flare the generated biogas, a few use it for power generation. Only one of these projects is reported to be connected to the electricity grid, while the rest use it for captive power generation. Recently, the Indonesian Ministry of Energy and Mineral Resources developed a methane capture facility at Rokan Hulu, Riau.[15] In this project, biogas is converted to electricity for the local community that was previously without a reliable electricity source.

Assuming all the registered projects are operating, approximately 6 percent of Indonesia's total palm oil mill effluent is currently treated in AD systems while the remaining 94 percent are treating POME in open lagoons based on 2013 sector data. The majority of AD projects are located in the Sumatra region.

Table 2-3. Facilities with Methane Capture Registered as CDM Projects

No	Project Ref.	Palm Oil Mill/Company	Province	Capacity (tph)	Estimated Reductions (tCO2e/year)
1	1735	PT Pelita Agung Agriindustri	Riau	35	42,301
2	1899	PT Milano Pinang Awan	Sumatra Utara	30	33,390
3	2130	PT Victorindo Alam Lestari	Sumatra Utara	60	39,218
4	2421	PT Nubika Jaya	Sumatra Utara	30	44,181
5	2612	PT Sahabat Mewah Makmur	Bangka – Belitung	30	19,718
6	2621	PT Tolan Tiga Indonesia	Sumatra Utara	35	31,757
7	2633	PT Permata Hijau Sawit	Sumatra Utara	60	38,424
8	2622	PT Sago Nauli	Sumatra Utara	30	19,723
9	2643	PT Bakrie Pasaman	Sumatra Barat	60	21,980
10	2663	PT Sisirau	Nanggroe Aceh Darussalam	30	16,470
11	2634	Bukit Maradha	Sumatra Utara	30	10,094
12	2664	PKS Nilo & Mandau	Riau	120	47,655
13	2662	PT Sumbertama Nusapertiwi	Jambi	60	15,743

[14] www.unfccc.int

[15] http://www.esdm.go.id/siaran-pers/55-siaran-pers/6921-peresmian-pilot-project-pemanfaatan-limbah-cair-sawit-pome-untuk-pembangkit-listrik-perdesaan-1-mw.html

Table 2-3. Facilities with Methane Capture Registered as CDM Projects

No	Project Ref.	Palm Oil Mill/Company	Province	Capacity (tph)	Estimated Reductions (tCO2e/year)
14	3702	PT Pinago Utama Sugihwaras	Sumatra Selatan	75	54,312
15	4394	PT Harapan Sawit Lestari	Kalimantan Barat	80	19,919
16	4480	PT Musim Mas	Riau	45	52,397
17	6258	PT Mitra Aneka Rezeki	Kalimantan Barat	45	35,190
18	6632	PT Berkat Sawit Sejati	Sumatra Selatan	90	54,108
19	6256	PT Rea Kaltim Plantations - Cakra	Kalimantan Timur	60	55,118
20	6227	PT Rea Kaltim Plantations - Perdana	Kalimantan Timur	60	48,886
21	6737	PT Maju Aneka Sawit	Kalimantan Tengah	45	43,877
22	6725	PT Sukajadi Sawit Mekar #1	Kalimantan Tengah	90	52,125
23	6889	PKS Batang Kulim	Riau	90	48,845
24	6872	PT Agrowiratama	Sumatra Barat	45	37,565
25	6756	PT Sukajadi Sawit Mekar #2	Kalimantan Tengah	45	50,974
26	7652	PTPN VI - PKS Bunut	Jambi	60	31,337
27	6728	PT Unggul Lestari	Kalimantan Tengah	45	52,781
28	7429	PT Golden Blossom Sumatra	Sumatra Selatan	75	21,675
29	7423	PT Suryabumi Agrolanggeng	Sumatra Selatan	75	21,675
30	8944	Tandun Mill (PTPN V)	Riau	40	30,443
31	9233	Sei Galuh Mill	Riau	60	45,986
32	9234	Sei Rokan Mill	Riau	35	38,936
33	9826	PT Swastisiddhi Amagra	Riau	35	512
34	7031	Sei Pelakar Mill	Jambi	60	13,446
35	6749	PT Bahari Dwikencana Amagra	Nanggroe Aceh Darussalam	60	13,602
36	6209	Negeri Lama I & II (PT Hari Sawit Jaya)	Sumatra Utara	90	51,947
37	9090	PTPN VII	Lampung	35	19,844
38	8389	PTPN VI – PKS Pinang Tinggi	Jambi	60	15,773
Total				**2,110**	**1,291,927**

Source: UNFCCC CDM website
Note that not all projects are confirmed to be operating; some may be in the planning or development stages or shut down.

2.2 Cassava Processing

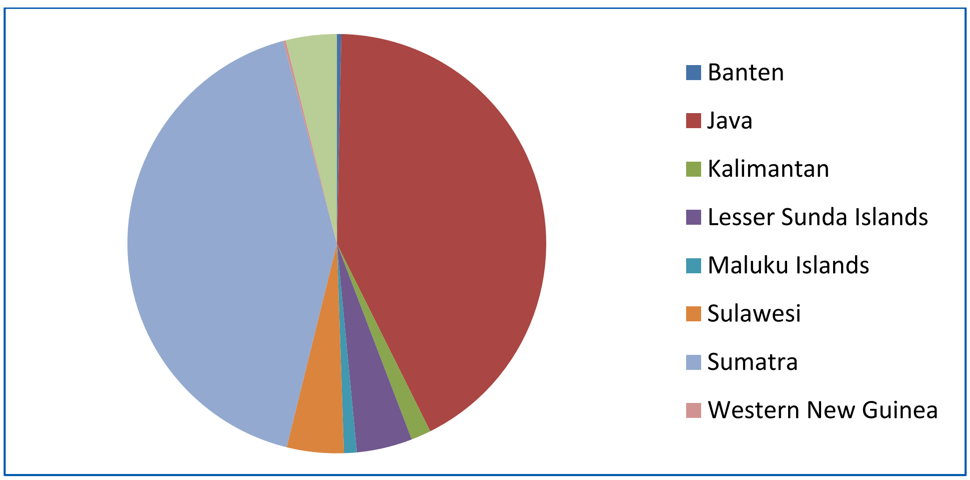
2.2.1 Description of Size, Scale of Operations, and Geographic Location

Indonesia's production of cassava—24,177,372 metric tons in 2012[16]—ranks third in the world. In Indonesia, cassava root is processed from its raw state for use in bio-ethanol, food additives, pharmaceuticals, and textiles, but it is primarily used to make tapioca starch.[17] The conversion rate for cassava root to tapioca starch is typically 25 percent by weight.

Cassava starch processing facilities are typically categorized by the amount of starch produced daily: "large" for more than 200 tons per day, "medium" for 100 to 200, and "small" for less than 100. In 2010, the Indonesian Ministry of Industry identified 139 registered medium and large facilities throughout Indonesia.[18] Interviews with industry representatives in 2014 indicate that there are roughly 200 medium and large facilities and 100 to 150 small facilities.[19] Small facilities in Indonesia typically do not prioritize the treatment of wastewater. Instead, small facilities generally release wastewater directly to open waterways due to resource constraints and the lack of regulation. Therefore, small facilities are not a focus of this report because they are not likely to invest in AD.

Seventy percent of Indonesia's cassava starch processing facilities (and 35 percent of the production),[20] are in the Lampung province on the southern end of the island of Sumatra. Most of the remaining production occurs in Java.[21] (These concentrations are driven primarily by historical and cultural farming traditions and decisions, rather than growing conditions; cassava grows well throughout most of Indonesia.[22]) Figure 2-7 presents cassava production by region.

Figure 2-7. Cassava Production by Region



[16] Statistik Pertanian 2013 Kementerian Pertanian Republik Indonesia

[17] Ditrektorat Pengolahan Dan Pemasaran Hasil Pertanian, Direktorat Jenderal Bina Pengolahan Dan Pemasaran Hasil Pertanian, Departemen Pertanian (Agriculture Department) -Jakarta, 2005

[18] Perkembangan Jumlah Unit Usaha Industri Besar dan Sedang Indonesia—tapioca/pati ubi kayu, Ministry of the Industry, Indonesia, 2010. http://kemenperin.go.id/statistik/ibs_indikator.php?indikator=1

[19] Interview with Pt. Asindo Tech staff, 27 June 2014.

[20] Indonesian Agriculture Department, 2005

[21] Interview with *Pak* Fidrianto (Abo), Director, Pt. Asindo Tech, 22 July 2014.

[22] Interview with *Pak* Fidrianto (Abo), Director, Pt. Asindo Tech, 22 July 2014.

Lampung has 20 to 30 large facilities and 40 to 50 medium-sized facilities.[23] A typical facility operates for 20 hours per day and 330 days per year, with the remaining 35 days dedicated to maintenance and holidays.[24] Depending on the season, the local industry operates at varying capacity that fluctuated by a factor of about 15.[25]

2.2.2 Description of Waste Characteristics, Handling, and Management

Cassava is primarily processed into tapioca starch using one of two methods: a traditional method that relies on sunlight to dry cassava, and a method that uses machinery for both drying and starch production. Medium and large facilities typically use the fully mechanized method.

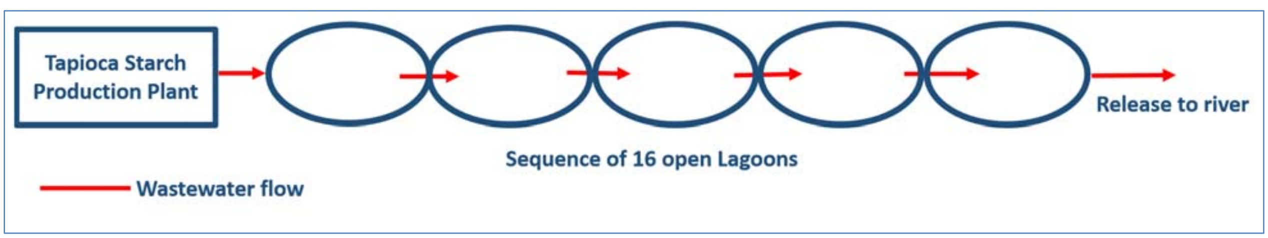
Starch production generates both solid and liquid wastes. The solid waste consists of cassava peelings and residues from the starch extraction process (known as "grout" or "lees"). Cassava peels are normally collected and used as animal feed and fertilizer, while grout is used in the food industry to make sauces and crackers, or to make mosquito coils and animal feed.

In the cassava industry, the amount of waste produced will depend on the volume of feedstock processed, which can be driven by crop seasonality. In many locations in Indonesia, cassava can be harvested throughout the year so supply tends to be constant. However, mills that rely on external suppliers or individual farmers with seasonal patterns may see feedstock supply fluctuations. Some cassava mills in Solo, Central Java, stop operating several months each year due to lack of cassava supply.

2.2.3 Description of Common Waste Treatment Technologies

In medium and large facilities, liquid waste is produced during cassava washing and tapioca production. The wastewater may be recycled back into the washing step, but it is eventually pumped either to cascading open lagoons or to an AD system. In open lagoon systems, as depicted in Figure 2-8, wastewater is pumped into a series of ponds that overflow from one to the next. These ponds are designed to hold the wastewater long enough to reduce COD to the desired level before releasing the treated water to open waterways. Sludge is typically collected from the lagoons, dried, and used as fertilizer.

Figure 2-8. Cascading Lagoon Wastewater Treatment System



Source: BAJ Tulang Bawang Factory tapioca starch CDM project design document[26]

[23] Interview with Pt. Asindo Tech staff, 27 June 2014.

[24] Interview with TedCoAgri and Pt. Asindo Tech staff, 27 June 2014.

[25] Interview with TedCoAgri and Pt. Asindo Tech staff, 27 June 2014.

[26] Available online at: http://cdm.unfccc.int/filestorage/K/U/3/KU3XVOLWYZ7INHCFJ09ABP4MGDQS15/4265_PDD_rev.pdf?t=ZHR8bjl6ZTI2fDDtlHWYYWnAbynhEffJD9Ea

In AD systems, wastewater is pre-treated using a sand trap to remove sand and dirt. The wastewater is then pumped to an equalization pond to adjust the pH to neutral, as required by anaerobic bacteria. The pre-treated wastewater is then pumped to the AD system, which typically consists of an upflow anaerobic sludge blanket (UASB) or a covered lagoon system. Collected methane gas is used to generate electricity or heat, which may be used for tapioca production or sold to other users. As with open treatment ponds, sludge is collected and used as fertilizer.

Wastewater discharge standards for the Indonesian tapioca industry require treatment to 300 mg/l for COD; however, facility and government monitoring records are not kept consistently. There is a lack of available data to allow estimates of the amount of COD in cassava wastewater prior to treatment, so the RA team attempted to collect this information during field interviews. One facility found the COD of the wastewater flowing into its cascading open lagoons to be 10,000 – 11,000 mg/l, and its typical final discharge levels to be 150 mg/l.[27] Another cassava facility with an anaerobic treatment and biogas collection system did not monitor COD at either the plant or treatment system outlets.[28] Table 2-4 below highlights key tapioca starch processing and waste characteristics collected during field interviews.

Table 2-4. Key Tapioca Starch Processing and Wastewater Characteristics

Characteristic	Value
COD, prior to treatment	10,000-11,000 mg/l
COD, post treatment (by regulation)	300 mg/l, max. 9 kg/ton tapioca produced, max.
Wastewater produced	4-5 m^3 per ton of cassava processed (typical) 30 m^3 per ton of tapioca starch produced (max., by regulation)
Tapioca starch produced	25% (by weight) of cassava processed

2.2.4 Current Status of Anaerobic Digestion

In Lampung, field interviews with personnel at three mills and at an engineering and construction company operating extensively in the cassava industry, indicated that 50 percent of the medium-sized and 25 percent of the large facilities in the area employ anaerobic treatment with biogas collection. Many of these facilities are not designed or operated for optimal efficiency, as indicated by low biogas output and a lack of measurement equipment and operating plans at several visited facilities. This indicates that emissions from existing facilities with biogas capture could be further reduced by improving operational efficiencies. Field interviews noted that none of the small facilities in Lampung and almost no facilities of any size in other locations throughout Indonesia use anaerobic treatment with biogas collection. All small operations throughout Indonesia are assumed to discharge wastewater directly to open waterways without treatment. Medium and large facilities outside of Lampung are assumed to use cascading open lagoons.

Based on these figures and on the industry-wide facility numbers highlighted in the previous section, approximately 100 medium facilities and 70 large facilities could potentially add biogas collection systems to their operations. Assuming an average capacity of 150 tons per day at medium

[27] Interview with TedCoAgri staff, 27 June 2014.

[28] Interview with Guning Sugi staff, 27 June 2014.

facilities and 250 tons per day at large facilities, approximately 62 percent of tapioca starch production capacity is in facilities that do not currently do biogas collection, but are appropriately sized to do so.

The assumptions regarding the potential for AD are supported by the facts surrounding 18 tapioca starch CDM projects registered in Indonesia. A substantial majority (15 out of the 18) of the projects are at medium facilities (between 100 and 200 tons per day), while the remaining three are at large facilities. All but one of the projects are in Lampung. (See Table 2-5.) Note that not all projects registered are confirmed to be operating—some may be in development, in the planning stage, or shut down. However, due to a lack of available comprehensive data on operational projects, these data were used as a proxy.

Table 2-5. Tapioca Starch CDM Projects in Indonesia

Company	Province	Technology	Biogas Use	Capacity
BAJ Way Abung	Lampung	UASB (upflow anaerobic sludge blanket)	Internal electricity (replace grid and diesel backup)	450 t/d
BAJ Unit 6	Lampung	UASB	Internal electricity (replace grid and diesel backup)	200 t/d
BAJ Way Jepara	Lampung	UASB	Internal electricity (replace grid and diesel backup)	200 t/d
BAJ Gunung Agung	Lampung	UASB	Internal electricity (replace grid and diesel backup)	200 t/d
BAJ Terbanggi	Lampung	UASB	Internal electricity (replace grid and diesel backup)	200 t/d
BAJ Pakuan Agung	Lampung	UASB	Internal electricity (replace grid and diesel backup); donate excess to community	200 t/d
BAJ Ketapang	Lampung	UASB	Internal electricity	200 t/d
BAJ Tulang Bawang	Lampung	UASB	Internal electricity (replace grid and diesel backup)	450 t/d
PT Florindo Makmu—Tulung Buyut	Lampung	Covered lagoon	Internal electricity (replace grid and diesel backup)	200 t/d
BAJ Buyut Ilir	Lampung	UASB	Internal electricity (replace grid and diesel backup)	100 t/d
BAJ Menggala	Lampung	UASB	Internal electricity (replace grid and diesel backup)	100 t/d
PT Florindo Makmur SB7	Lampung	Undecided	Internal electricity (replace grid and diesel backup)	100 t/d
PT Florindo Makmur Sukaraja	Lampung	Covered lagoon	Internal electricity (replace grid and diesel backup)	100 t/d
PT Gunung Sewa Kenchan	Lampung	UASB	Supplement internal electricity and power	200 t/d
PT Budi Lumbung Cipta Tani	Central Java	Undecided	Internal electricity (replace grid and diesel backup)	100 t/d

Table 2-5. Tapioca Starch CDM Projects in Indonesia

Company	Province	Technology	Biogas Use	Capacity
PT Florindo Makmur Rumbia	Lampung	Undecided	Internal electricity (replace grid and diesel backup)	100 t/d
PT Florindo Makmur Tanjung Bintang	Lampung	Undecided	Internal electricity (replace grid and diesel backup)	100 t/d
Hutama Global Energy/ PT Sinar Pematang Mulia 2	Lampung	Covered lagoon (CIGAR)	Internal electricity (in place of diesel generator)	350 t/d

BAJ = Pt. Budi Acid Jaya

Source: UNFCC CDM website (note that not all projects are confirmed to be operating; some may be in the planning or development stages or shut down)

2.3 Swine Farming Industry

2.3.1 Description of Size, Scale of Operations, and Geographic Location

Although regional considerations may suggest variations in how swine farms are categorized by size, small farms generally have fewer than 1,000 swine; in fact, small swine farms are nearly all backyard operations with less than 10 swine. Medium-sized farms have 1,000 to 6,000 swine and are managed by individual owners. A small number of large farms have more than 6,000 swine, with the largest facility managing 230,000 swine.[29] This RA focuses on the facilities that are assumed to manage enough manure and waste to be viable for collection in lagoons.

The population of swine in Indonesia was estimated at 7.9 million head in 2013.[30] Large intensive operations control 20 percent of this total; medium-sized farms have 40 percent of the swine population, and the remaining 40 percent are managed in backyard operations.[31]

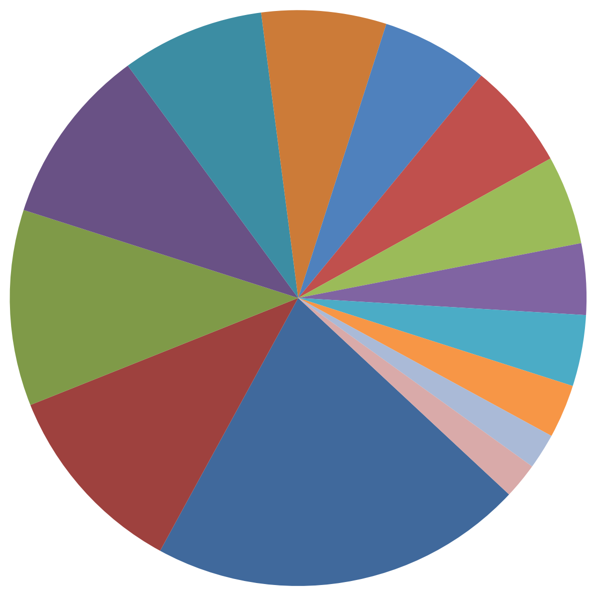
Swine farming is carried on throughout Indonesia (see Figure 2-9); farms in each size category are also widely dispersed. Because there are no centralized sources of data for swine farms in Indonesia, the RA team focused on collecting data from a cross-section of farm sizes in three geographic areas, described below:

[29] "Project 0450: Methane Capture and Combustion from Swine Manure Treatment Project at PT Indotirta Suaka Bulan Farm in Indonesia"

[30] "Livestock and Animal Health Statistics 2013," Directorat Jenderal Peternakan dan Kesehatan Hewan—Kementerian Pertanian, September 2013.

[31] "Swine production: a global perspective," Pig Industry (online), by J. Moore, Feb 7, 2007. http://en.engormix.com/MA-pig-industry/management/articles/swine-production-global-perspective-t336/124-p0.htm

Figure 2-9. Swine Population in Indonesia by Province (2012)



- **Central Java.** In this province, there are approximately 35 medium-sized swine farms, most with 1,000 to 2,000 swine per farm. There is a particularly high concentration of swine farms and a close-knit farming community in Sroyo village, which also hosts the largest farm in the province (with 6,000 swine). Central Java also is home to numerous smaller pig farms, with 50 to 100 swine per farm; inadequate data make it problematic to estimate the number of small farms.
- **Bali.** In Bali, the swine farms are mostly smaller than in other parts of Indonesia. Locally, farms with up to 100 swine are classified as small, and medium when they have 100 to 500 swine. Large swine farms in Bali have more than 500 swine, with the largest holding approximately 3,000. Many of the larger farms are in the Bangli region.[32]

  The farms in Bali tend to be smaller because of a 2012 agreement between local swine farmers, the provincial government's agriculture department, industrial farmers, and animal feed factories. The 2012 agreement allows industrial-scale farmers to develop large-scale swine farms in Bali, but requires them to market their swine outside Bali to protect the smaller local farmers.[33] The total swine population in Bali is 890,598 head. Of these, 12 percent are on small farms, 25 percent on medium farms, and 63 percent on large farms. For the purposes of this RA, these farms fall into the small and medium categories (the RA categorizes small farms as having less than 1,000 head and medium farms as having 1,000 to 6,000 head).
- **East Nusa Tenggara.** The total swine population in this province in 2014 was approximately 1,739,000, which was approximately 22 percent of the total swine population of Indonesia.[34]

[32] Interview with Chief of local NGO Yayasan Timur Sejahtera, Mr. Irianto, September 2014.

[33] Online media Trobos Livestock Magazine, 1 November 2012

[34] http://kupang.tribunnews.com/2014/02/25/babi-dominasi-peternakan-di-ntt

Of that population, 45 percent are in four regions: Timor Tengah Selatan (19 percent), Manggarai (10 percent), Flores Timur (9 percent), and Kupang (7 percent).[35] Swine farms in the province are classified as small when they have less than 50 swine and medium when they have 50 to 100. Large intensive farms have up to 3,000 swine per farm.

Although Riau and the Riau Islands are not an area of focus, it is worth noting that PT Indotitra Suaka is a large private company that operates a swine farm on Pulau Bulan in the Riau Islands. The farm has a capacity of more than 300,000 swine and a regular operating population of about 230,000.[36, 37] The facility is the largest swine farm in Indonesia and hosts the only CDM manure-based biogas project in Indonesia.[38] Most of these swine are exported to Singapore.

2.3.2 Description of Waste Characteristics, Handling, and Management

Waste handling practices at swine facilities in Indonesia vary based on the size of the facility and the common practices within the given geographic region. Generally, medium-sized and large operations use covered pens, concrete or slatted flooring, and gutter systems to collect and convey animal waste.[39] Smaller backyard operations are typically open-air and bare-ground, with liquid and solid wastes running off when it rains and discharging directly to open waterways. Solid waste is periodically manually removed for processing in small AD system or for use as fertilizer.[40]

Although swine populations do not tend to fluctuate seasonally, certain farms may experience risks associated with population fluctuations when their swine come from external suppliers. In particular, fattening farms that receive adolescent swine into their operations depend on their suppliers to maintain constant pig numbers, while "all-in/all-out" farms have much more control over population changes.

2.3.3 Description of Common Wastewater Treatment Technologies

In Solo, 27 (77 percent) of the medium-sized facilities, which house an average of 1,500 swine each, use open lagoons.[41] The remaining eight (23 percent) use fixed-dome AD systems to treat the pig waste.[42] At these eight facilities, the swine are housed in covered areas with solid or slatted floors which are regularly cleaned. The waste slurry is channeled to open holding tanks where the liquid waste overflows to subsequent holding tanks, while the solid waste/sludge settles to the bottom. The solid waste is manually fed to the fixed dome reactor, from which biogas is captured and piped for use in heating or cooking. The liquid is treated in the open holding tanks and released to open waterways.

The facilities and processes at these farms in Solo are managed to varying levels of success. At any time, several of the facilities may bypass the anaerobic digester because it is undergoing maintenance, there is insufficient labor to transfer sludge, or other operating issues. During a site visit to

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[35] Badan Pusat Statistik, Animal husbandry statistics tab year 2006.

[36] Interview with Pak Handiman via telephone, 25 April 2014.

[37] "Project 0450: Methane Capture and Combustion from Swine Manure Treatment Project at PT Indotirta Suaka Bulan Farm in Indonesia" http://cdm.unfccc.int/Projects/DB/DNV-CUK1149685494.73/view

[38] "Project 0450: Methane Capture and Combustion from Swine Manure Treatment Project at PT Indotirta Suaka Bulan Farm in Indonesia" http://cdm.unfccc.int/Projects/DB/DNV-CUK1149685494.73/view

[39] Based on site visits and field interviews conducted by project team 28 June 2014.

[40] Based on site visits and field interviews conducted by project team 28 June and 19 November 2014.

[41] Based on site visits and field interviews conducted by project team 28 June 2014.

[42] Based on site visits and field interviews conducted by project team 28 June 2014.

the area, several of the observed AD systems were not operating.[43] It was evident that some systems were not appropriately designed or managed to optimize biogas production or wastewater treatment before release.

The 27 farms in Solo that do not have AD systems treat the mixture of liquid and solid waste in open cascading tanks or lagoons. Liquid waste overflows through a series of tanks and is discharged to open waterways; solid waste settles at the bottom of the tanks and is manually removed to be dried for use as fertilizer. The tanks are often insufficiently designed, in number and size, to provide the optimal retention time for proper treatment.

In Bali, due to community pressures and a relatively strict regulatory regime, most swine farmers are highly aware of good waste treatment management practices. In addition, a Dutch nongovernmental organization called Hivos International, in cooperation with the Ministry of Energy and Mineral Resources (MEMR), is operating its Indonesia Domestic Biogas Program ("BIRU" in Indonesian) in Bali and other provinces. This program subsidizes equipment and technical assistance for the installation of AD systems on small pig, cow, and poultry farms. As a result of incentives provided by MEMR and Hivos International under BIRU, many small and medium-sized swine farms in Bali have AD systems to treat their swine waste.[44] Approximately 20 percent of the farms in Bali province have AD systems, while the other 80 percent use the pig waste directly for fertilizer. Between 2009 and 2013, 631 digesters were installed, most of them between 4 and 6 cubic meters.

Small farms with AD typically have one fixed dome reactor of 4 to 6 cubic meters; medium-sized farms have one reactor of 8 cubic meters; and large farms have two reactors of 8 cubic meters, or one of 10 cubic meters. These digesters are not designed to maximize the amount of biogas produced, but sized to produce enough biogas to offset liquid petroleum gas (LPG) purchased for heating piglets and household cooking, and to allow for excess manure to be used or sold as fertilizer.[45] The liquid and solid waste is either collected in an open tank or channeled directly to the anaerobic digester. The slurry, generated as a co-product of the AD system, and solid waste are used as fertilizer. Some small farmers discharge waste directly to rivers.[46]

One large PT Indotirta Suaka facility in Pulau Bulan converted a series of existing waste treatment lagoons to a covered lagoon AD system to generate carbon credits.[47] Swine are kept in covered areas with slatted floors and a waste conveyance channel below. Waste is channeled to the anaerobic digester for treatment. Biogas generated by the system is flared to destroy the methane. Wastewater is further processed in an aerobic lagoon before release to open waterways. Sludge from the lagoons is used as fertilizer.[48]

Table 2-6 and Table 2-7 present information for swine farms in Solo. Based on the data in Table 2-6, the average weight per head of swine in Solo is 74 kilograms. The data presented for Solo are

[43] Based on site visits and field interviews conducted by project team 28 June 2014.

[44] Stakeholder interviews during site visits, 19 November 2014.

[45] Stakeholder interviews during site visits, 19 November 2014.

[46] Interview with chief of local nongovernmental organization Yayasan Timur Sejahtera, Mr. Irianto, September 2014.

[47] "Project 0450: Methane Capture and Combustion from Swine Manure Treatment Project at PT Indotirta Suaka Bulan Farm in Indonesia" http://www.trobos.com/show_article.php?rid=8&aid=3615

[48] "Project 0450: Methane Capture and Combustion from Swine Manure Treatment Project at PT Indotirta Suaka Bulan Farm in Indonesia"

applied nationally in Table 2-7 to produce the national estimates of average swine weight and average daily volatile solids produced per head.

Table 2-6. Livestock Population at Swine Farms in Solo[49]

Type of Swine	Average number	Average weight (kg)
Total sows	430	200
Gestating sows	260	200
Lactating sows	60	200
Open sows	40	200
Gilts	70	90
Boars	13	200
Nursery swine	480	2–12
Starters	1,677	30
Growers		60
Finishing swine	400	85–90
Total	**3,000**	**74**

Table 2-7. Key Swine Waste Statistics

Key Statistic	Value
Head of swine in Indonesia	7,900,000
Average swine weight (est.)	74 kg per head
Volatile daily solids per swine	0.3 kg per head per day

2.3.4 Current Status of Anaerobic Digestion

Although numerous small farms in Bali (and others scattered throughout Indonesia) employ AD systems, the majority of small farms have a pasture-based system, which does not produce a significant amount of methane. Therefore, small farms are not ideal candidates for methane reduction because their emissions are already low. There are, however, other benefits to households and local areas from installing small systems, such as rural development, offsetting fuel use, replacing fertilizer, etc.

Medium-sized and large farms offer the best opportunity to reduce emissions from the swine sector in Indonesia. As noted, approximatelyly 40 percent of Indonesia's 7.9 million swine are on medium-sized facilities and roughly 20 percent in large facilities. Applying nationally the data obtained from interviews with farmers in Solo, 77 percent of large and medium farms in Indonesia (housing roughly 46 percent of the country's swine) do not already have AD systems and hence are candidates for implementing AD.

In addition to the potential for new AD systems, many existing AD systems are not operating well and could be improved. Assuming that 50 percent of the large farms and 30 percent of the medium farms have AD systems that could be improved, wastes from another 9 percent of the swine in Indonesia could be covered by improved AD.

[49] Based on site visits and field interviews conducted by the project team, 28 June 2014.

3.0 SECTOR METHANE EMISSIONS AND METHANE REDUCTION POTENTIAL

This section presents an estimate of methane emissions and the potential for reducing GHGs from livestock manure and agricultural commodity processing wastes though anaerobic digestion. Anaerobic digestion reduces GHG emissions in two ways. First, it directly reduces methane emissions by capturing and burning biogas that otherwise would escape from the waste management system into the atmosphere. Second, it indirectly reduces carbon dioxide and methane by using biogas to displace fossil fuels that would otherwise be used to provide thermal energy or electricity. Section 3.2 explains the potential methane emission reductions from manure management systems and agricultural commodity processing wastes.

The feasibility of modifying existing livestock manure and agricultural commodity processing waste management systems with AD will depend on the ability to invest the necessary capital and generate adequate revenue to offset (at least) operating and management costs, as well as provide a reasonable return on the invested capital.

There are several options for anaerobically digesting wastes and using the captured methane. For a specific enterprise, waste characteristics will determine which digestion technology options are applicable. Of the technically feasible options, the optimal approach will be determined by financial feasibility, subject to possible physical and regulatory constraints. For example, the optimal approach may not be physically feasible due to the lack of necessary land. Section 3.1 briefly describes the types of AD technology, methane use options, and costs and benefits.

3.1 Baseline Methane Emissions

Based on the information presented in Section 2.0, GMI developed estimates of the baseline (current) waste management systems in place for each sector, as shown in Table 3-1. These estimates are important because methane emissions are dependent on the type of waste management system. Anaerobic management systems (AD and lagoons) produce more methane than aerobic management systems (direct discharge and pasture).

Table 3-1. Baseline Distribution of Waste Management Treatment Technologies

Sector	Waste Management Systems (Percent of Production)			
	AD	Lagoons	Direct Discharge	Pasture
Palm oil	6%	94%	0%	0%
Cassava	9%	62%	29%	0%
Swine	14%	46%	0%	40%

Next, the baseline methane emissions were estimated using Intergovernmental Panel on Climate Change (IPCC) methods, based on the waste management system distributions and other information presented in Section 2.0. The IPCC methodologies are presented in Appendix A. Each type of waste management system is associated with a methane conversion factor (MCF) (see Appendix A). There are several parameters needed to estimate emissions for palm oil, cassava, and swine. Table 3-2 through Table 3-4 present the parameters used in the calculations; Table 3-5 presents the resulting baseline methane emissions.

Table 3-2. Summary of Parameters Used to Calculate Emissions for the Palm Oil Sector

Parameter	Unit	Palm Oil
Production	MT/yr	26,000,000
Wastewater generation	m^3/MT	5.5
Chemical oxygen demand (COD)	kg/m^3	60
Maximum methane producing capacity (B_0)	m^3 CH_4/kg VS	0.25

Table 3-3. Summary of Parameters Used to Calculate Emissions for the Cassava Sector

Parameter	Unit	Cassava
Production	MT/yr	24,177,372
Wastewater generation	m^3/MT	8.0
COD	kg/m^3	10
Maximum methane producing capacity (B_0)	m^3 CH_4/kg VS	0.25

Table 3-4. Summary of Parameters Used to Calculate Emissions for the Swine Sector

Parameter	Unit	Swine
Swine population	Number of head	7,900,000
Volatile solids (VS) excretion rate	kg/head/day	0.3
Maximum methane producing capacity (B_0)	m^3 CH_4/kg VS	0.29

Table 3-5. Baseline Methane Emissions

Sector	Methane Emissions by Waste Management System ($MTCO_2e/yr$)[a]				Total Methane Emissions ($MTCO_2e/yr$)
	AD[b]	Lagoons	Direct Discharge	Pasture	
Palm oil	321,750	40,326,000			40,647,750
Cassava	113,690	5,998,290	34,540		6,146,520
Swine	58,030	1,554,120		16,820	1,612,140

a - A global warming potential value of 25 was applied to the estimated methane emissions (IPCC 2007).
b - Estimated assuming a 10 percent leakage rate from existing AD systems (UNFCCC CDM 2008).

3.2 Greenhouse Gas Emission Reductions

Anaerobic digestion projects for both manure and agricultural commodity processing wastes may produce more methane than the existing waste management systems, because anaerobic digesters are designed to optimize methane production. For example, adding AD to a manure management operation where manure is applied daily to cropland or pasture would produce significantly more methane than the baseline system. For this reason, the direct methane emission reductions from a digester correspond not to the total methane generated, but rather the baseline methane emissions from the waste management system before installation of the digester. The indirect emission reductions, as explained in Section 3.2.3, are based on the maximum methane production potential of the digester and how the biogas is used.

3.2.1 Direct Emission Reductions in Palm Oil and Cassava Processing Sectors

The method used to estimate GHG emission reduction potential for palm oil and cassava processing in Indonesia is presented in Appendix A. Table 3-6 presents the results of these calculations.

Table 3-6. Methane Emission Reductions from Agro-Industrial Waste, Palm Oil and Cassava Sectors

Parameter	Palm Oil Processing	Cassava Processing
Production (MT/yr)	26,000,000	24,177,372
% Waste management system[a]	94%	62%
Wastewater generation (m^3/MT)	5.50	8
COD (kg/m^3)	60	10
B_0 (kg CH_4/kg COD)	0.25	0.25
MCF	0.80	0.80
Methane Emission Reductions ($MTCO_2e$/yr)[b]	**36,293,400**	**5,396,390**

a - Assumed 94% of palm oil processing waste and 62% of cassava processing waste is managed using lagoons that could be converted to AD systems.

b - A global warming potential value of 25 was applied to the estimated methane emissions (IPCC 2007), and a leakage rate of 10 percent was assumed from the AD systems (UNFCCC CDM 2008).

3.2.2 Direct Emission Reductions in the Swine Sector

The method used to estimate the methane emission reduction potential for swine is presented in Appendix A. Table 3-7 presents the results of these calculations. In addition to the conversion of lagoon systems to AD systems, there are AD systems which are currently not maximized for methane reduction. GMI estimates that 9 percent of existing swine AD systems could be improved and an improvement in these systems could increase the methane emission reductions by 56,770 $MTCO_2e$/yr (2,270 MT CH_4/yr).

Table 3-7. Methane Emission Reduction Potential, Swine Farming

Parameter	Value
Head (#)	7,900,000
% Waste management system[a]	46%
Volatile solids (kg/head/day)[b]	0.3
B_0 (m^3 CH_4/kg VS)[b]	0.29
MCF	0.8
Methane Emission Reductions ($MTCO_2e$/yr)[c]	**1,392,650**

a - Assumed 46% of swine are using lagoons that could be converted to AD systems.

b - Used IPCC default values of VS and B_0 for swine in Asia.

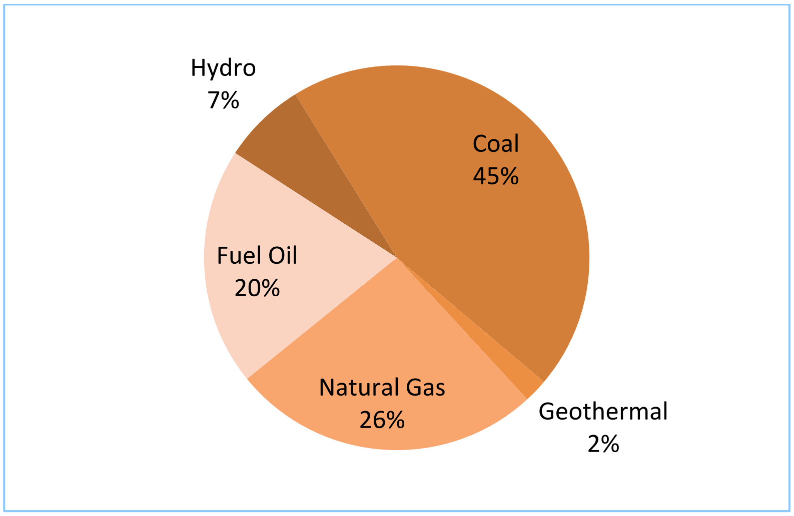
c - A global warming potential value of 25 was applied to the estimated methane emissions (IPCC 2007) and a leakage rate of 10 percent was assumed from the AD systems (UNFCCC CDM 2008).

3.2.3 Indirect GHG Emission Reductions

The use of AD systems has the financial advantage of offsetting energy costs at the production facility. Biogas can be used to generate electricity or to replace the use of other fuels. Using biogas for energy also reduces emissions from the fossil fuels being displaced. The degree of emission reduction depends on how the biogas is used.

When biogas is used to generate electricity, the emission reductions depend on the energy sources used by the central power company to power the generators. In Indonesia, fuel consumption generated a total of 200,320 GWh of energy in 2012. The type of fuel consumed consisted of coal (45 percent), natural gas (26 percent), and fuel oil (20 percent), as illustrated in Figure 3-1.

Figure 3-1. Distribution of Energy Consumption in Indonesia



Source: PLN Statistics, 2012[50] and PT PLN Investor Presentation, September 2014[51]

Using the energy consumption distribution in Figure 3-1 and the method described in Appendix A, GMI estimated the indirect emission reductions presented in Table 3-8.

Table 3-8. Indirect GHG Emission Reduction Potential

Sector	Indirect Emission Reductions ($MTCO_2e$/yr)
Palm oil	1,432,010
Cassava	212,920
Swine	54,950
Total	**1,699,880**

[50] Available online at: http://www.pln.co.id/dataweb/STAT/STAT2012ENG.pdf

[51] Available online at: http://www.pln.co.id/dataweb/NDR/NDR%201H2013%20September%202013.pdf

3.3 Summary

The principal factor determining the magnitude of methane emissions from livestock manure and agricultural commodity processing wastes is the waste management practice employed, which determines the MCF. As shown in Table 3-5, anaerobic lagoons generate higher baseline emissions than any other waste management scheme, emitting almost 48 million $MTCO_2e$ annually for the palm oil, cassava, and swine sectors combined. Replacing lagoons with AD has the greatest potential to reduce methane emissions. The methane captured will be a source of renewable energy, potentially reducing fossil fuel consumption and the associated GHG emissions from sequestered carbon.

Table 3-9 summarizes the findings of this RA regarding potential methane emission reductions and carbon offsets in Indonesia. The sector with the highest potential for methane reduction and carbon offsets is palm oil, followed by cassava and swine.

Table 3-9. Potential GHG Emission Reductions for Indonesia

Sector	Potential Direct Methane Emission Reductions ($MTCO_2e$/yr)	Potential Fuel Replacement Offsets ($MTCO_2e$/yr)	Total Potential Emission Reductions ($MTCO_2e$/yr)
Palm oil processing	36,293,400	1,432,010	37,725,410
Cassava processing	5,396,390	212,920	5,609,310
Swine farms	1,392,650	54,950	1,447,600
Total	**43,082,440**	**1,699,880**	**44,782,320**

4.0 TECHNOLOGY POTENTIAL AND BARRIER ASSESSMENT

This section provides further detail on the operational characteristics of anaerobic digestion (AD) technologies and barriers to their implementation in the palm oil, cassava and swine industries in Indonesia. It includes information on the potential amount of power that can be generated, the amount of energy used in operations, the industries' understanding and experience with biogas recovery technologies such as AD, and the ownership structures within these industries. It also details barriers to adoption at the sector and facility levels, and recommends projects that could be pursued to help overcome those barriers.

4.1 Technology Potential

As noted earlier in the RA, AD systems have proven promising in the palm oil, cassava, and swine farming sectors in Indonesia, but they are not the current standard for these industries.

- In the palm oil industry, 39 registered clean development mechanism (CDM) projects (of 608 total POMs) report using methane capture, primarily for flaring to destroy methane. Note that not all projects registered are confirmed to be operating—some may be in various stages of planning and development, or shut down. The driver for many of these projects was the potential for revenue from carbon credits, but carbon prices have declined significantly, reducing that incentive. Renewed interest in installing AD systems has been spurred by sustainable palm oil certification, such as the Indonesian Sustainable Palm Oil (ISPO) mechanism, and savings or revenues from power and electricity production. Based on the data presented in Section 2.1, approximately 570 palm oil mills, representing approximately 94 percent of the total production capacity, do not use AD, and so offer an opportunity for further methane emission reductions.
- In the cassava industry, there are 18 registered CDM projects that capture biogas to power their facility operations. There are an additional 12 facilities with AD systems. The remaining 170 large and medium-sized facilities represent more than 60 percent of the production capacity in the country, and offer a significant opportunity for reducing methane emissions.
- In the swine industry, an estimated 23 percent of the 1,100 medium and 150 large farms use AD. Taking into account the number of swine in each size farm, this means that roughly 46 percent of the swine population are on farms that offer an opportunity to implement AD to reduce methane emissions. In addition, not all of the current AD systems are operating properly, so another 9 percent of the swine population are on farms whose systems could be improved for additional methane reductions.

4.1.1 Potential Power Generation and Current Energy Usage

Typical potential power generation for waste effluent from palm oil mills, cassava processing facilities, and swine farms is presented in Table 4-1 below. The table presents average values based on common industry assumptions for effluent volumes, COD concentrations, and conversion rates. However, actual generation potential varies from one facility to another, depending on site-specific operational characteristics and system efficiencies.

Information gathered during site visits and interviews regarding energy usage and monthly electricity costs within the three industries are also highlighted in Table 4-1. The table shows costs for monthly electricity purchases from PLN in addition to other fuels used. For the cassava and swine industries, the costs and amounts of other fuels used were not available.

Table 4-1. Power Generation Potential and Energy Usage Information

	Sector		
	Palm oil	**Cassava**	**Swine**
Effluent Ratio	0.7 m^3/ton FFB[a]	2.1 m^3/ton cassava[b]	0.3 kg/per head/per day, volatile solids[c]
COD Concentration (kg/m^3)	60	10	No data available[d]
Electricity Generation Potential per Unit	40.6–48.2 kWh/ton FFB	200–375 kWh/ton cassava	0.01 kWh/head swine
Energy Use per Unit Processed	18 kWh/ton FFB	200 kWh/ton cassava	3.75 kWh/head
Monthly Grid Electricity Cost[d]	NA	8,000,000 IDR[e]	5,000,000 IDR
Monthly Captive Power Cost	850,000,000 IDR[f]	NA	NA
Additional Fuel Used	Diesel fuel for backup and startup	Coal, rice husk, and or coconut shell	Diesel for backup

a - Source: CIRCLE Handbook POME-to-Energy Development in Indonesia, 2014.
b- Source: UN CDM PDD: “BAJ Tulang Bawang Factory tapioca starch wastewater biogas extraction and utilization project, Lampung Province, Indonesia” 16 May 2013.
c- Source: CDM design document for swine farming at PT Indotirta, Pulau Bulan—Riau Province
d -Methane production = 0.45 m^3 CH^4/kg dry matter
e- Electricity purchased from PLN, in addition to purchases of “additional fuel used.”
f -Calculated based on average monthly shell consumption For a 200 ton/day cassava starch facility of 2,425 ton per month (combusted for process heat) and shell price of IDR 350,000/ton

4.1.2 Experience with Anaerobic Digestion

The development of methane capture projects in Indonesia started in 2008 through CDM. Of the three sectors being assessed, the palm oil industry has the most experience with large-scale technologies and related supply markets, followed by the cassava industry, and then the swine farming industry.

4.1.2.1 Biogas Recovery in the Palm Oil Sector

Through CDM projects, owners of medium and large scale palm oil mills have gained experience in acquiring and installing the AD equipment as integrated components of mill operations. Medium and large scale mills are better situated to install new equipment because they can make the necessary capital investment and are better positioned to manage the risk associated with implementing “new” technologies.

As a result, the demand for supplies and services related to designing, installing, and operating AD technologies has matured beyond the initial stages. However, many of the necessary supplies and services are imported because the local capacity has not yet developed sufficiently, as noted in Section 6.0. Although the CDM market has declined, there are other drivers of sustainable palm oil production, such as European Union import requirements and impending Indonesian government production standards. These drivers will continue to encourage growth in the use of methane capture technologies within the palm oil sector. Indonesia has about 10 POME-to-energy projects under construction at this time.

4.1.2.2 Biogas Recovery in the Cassava Sector

The use of AD and other biogas capture technologies is not prevalent in the cassava starch industry. Through the CDM, 18 projects have been approved at medium-sized tapioca facilities, presumably with extensive technical assessments and expert design to ensure optimal methane recovery.

Beyond these projects, about 12 other facilities have implemented biogas projects, but direct observation and field interviews indicate that many of these projects were designed and installed by relatively inexperienced people, relying on incomplete knowledge of the technologies involved. As a result, even facilities that have AD systems are not operated as efficiently as they could be. Some owners of tapioca starch facilities who would consider adding biogas capabilities may be discouraged after learning of lower-than-expected biogas production within the industry.

4.1.2.3 Biogas Recovery in the Swine Sector

Methane capture technology exists within the swine industry, specifically at larger farms with access to capital and international supplies. For example, the largest facility in Indonesia—a farm on Riau Province's Bulan Island with a capacity of 304,000 swine—has developed methane capture using an anaerobic covered lagoon and registered its project for CDM.

Methane capture technology is limited at medium-scale swine farms in Indonesia. Small-scale and many backyard swine farms have gained experience with methane capture technologies through assistance activities, such as BIRU. These "household" methane capture operations use fixed dome or tank digesters designed and constructed by local contractors with some technical and financial assistance from governments or nongovernmental organizations. However, these systems are typically designed to produce only a small amount of gas for cooking, and frequently are not built or operated for optimal methane capture.

4.1.3 Ownership Structures

This section summarizes ownership structures in each of the three sectors. Industry ownership structure impacts how new technologies are adopted; thus, AD adoption strategies may vary based on the ownership structure.

4.1.3.1 Palm Oil Ownership Structures

Privately-owned palm oil facilities hold the majority of the market and national production. Several groups of companies, with many mills, contribute to more than 80 percent of national crude palm oil production. There are also state-owned (badan usaha milik negara, or BUMN) companies, but these represent a minority of the market share. Palm oil companies usually source fresh fruit from their own plantations. They are also supplied by nucleus farmers, external suppliers, or independent growers. If not sourcing from company-owned plantations, large companies prefer to procure fruit from nucleus farmers to maintain its traceability.

Many palm oil facilities implemented methane capture projects seeking carbon credits. Some were developed by external parties in revenue sharing arrangements with mill owners. Third party independent power producers were attracted to the market after successful demonstration projects in Thailand and Malaysia, and the establishment of feed-in-tariff in Indonesia. Third party developers usually have "build, operate, and transfer" agreements with the mill owners, where ownership transfer typically occurs after 10 to 15 years, at the end of the power purchase agreement.

4.1.3.2 Cassava Ownership Structures

Most tapioca starch facilities are privately owned and are typically operated separately from the farms that grow the cassava crop. Anaerobic digester systems are generally constructed under a build-own-operate model because the energy produced by biogas collection and conversion systems is only sufficient to supplement or fulfill plants' internal energy requirements. They lack the potential to provide a significant source of revenue from the sale of heat or electricity. While several CDM projects aimed at generating carbon credits have been established, unstable carbon prices limit the use of carbon credits as a source of long-term revenue.

4.1.3.3 Swine Ownership Structures

Large swine farms are typically owned by private companies, whereas most of the small and medium-scale farms are owned by individual farmers. The farmers usually organize in cooperatives or groups, which have several functions, such as providing feedstock and loans to its members. Some breeding farmer groups cooperate with PT Charoen Pokphand Indonesia, a large feed and processed meat producer, which provides feed and agrees to purchase livestock at a negotiated price. AD projects at these farms are typically built and operated by the farms themselves.

4.1.4 Policy and Regulatory Framework

Since the early 1990s, the government of Indonesia has proposed and implemented policies and regulations that encourage investment and build capacity for low-carbon and other environmental technologies. These policies and regulations, listed in Table 4-2, include:

- Eliminating energy-market-distorting subsidies.
- Promoting use and development of renewable energy.
- Encouraging public adoption of energy efficiency.
- Spurring the use of clean and efficient energy in industry and commerce.
- Restructuring the prices of various energy sources.
- Providing for private sector involvement through IPPs.
- Establishing feed-in tariffs, created initially for renewables as a broad source, and more recently specifically for biomass/biogas, geothermal, municipal waste sources, and solar.
- Providing facility and tax incentives for renewable energy development.
- Setting nationwide renewable energy goals and GHG reduction targets
- National and international palm oil sustainability standards.

Table 4-2. Policies and Regulations Related to the Renewable Energy Market

Regulation Number	Topic	Relevance to Renewable Energy Technology
Renewable Energy		
Ministry of Environment Regulation No. 17/2001	Private energy production	Institutes requirements for business licenses for electricity production companies; exempts producers of renewables under 10 MW for own-use from full environmental impact review process.
Presidential Regulation No. 5/2006	Energy policy	Targets energy balance in energy mix; sets goal of at least 5% new renewable energy by 2020.
Law No. 30/2007	Energy	Prioritizes locally available energy sources and renewable energy generation, and provided for incentives to support the economic viability of new renewables. Obliges government to provide funding for electricity development for low-income, underdeveloped, isolated, and rural areas.

Table 4-2. Policies and Regulations Related to the Renewable Energy Market

Regulation Number	Topic	Relevance to Renewable Energy Technology
Law No. 30/2009	Electricity	Prioritizes the use of locally available energy resources for electricity generation. Allows independent power producers (IPPs) to generate and sell electricity to end users in the Indonesian market.
Energy Minister Regulation No. 31/2009	PLN purchase of renewable energy	Obligates PLN to purchase renewable energy at fixed rates from <10MW plants or excess power: 656 IDR/kWh (medium voltage) or 1,004 IDR/kWh (low voltage) plus an applied location factor.
MOF Regulation No. 21/PMK.011/2010	Tax incentives for renewable energy	Implements a range of financial instruments to support renewable energy development: reduces income tax, accelerates depreciation, and exempts some value-added taxes and import duties for motors and other equipment.
Agriculture Minister Regulation No. 19/2011	Guidance on ISPO	Requires palm oil plantation companies to be ISPO compliant by 31 December 2014. The ISPO, implemented by the Ministry of Agriculture, mandates palm oil plantations to register an emissions reduction plan, including methane capture for treatment of POME.
Presidential Regulation No. 61/2011	Greenhouse gas emission reduction	Commits government to reducing greenhouse gas emissions by 26% through its own effort and by 41% with international support by 2020; includes activities in agriculture, forestry and peat land, energy and transportation, industry, waste management, and other supporting activities.
Energy Minister Regulation No. 4/2012	PLN purchase of renewable energy	Modifies PLN renewable/excess power purchase prices for <10 MW plants: 656 to 1,398 IDR/kWh, depending on technology and voltage (plus an applied location factor).
Energy Minister Regulation No. 19/2013	PLN purchase of waste-based energy	Sets PLN waste-based power purchase prices for <10 MW plants at 1,250–1,798 IDR/kWh depending on technology and voltage.
Energy Minister Regulation No. 27/2014	PLN purchase of biomass- and biogas-based energy	Sets PLN waste-based power purchase prices for <10 MW biogas and biomass power plants at 1,050–2,400 IDR/kWh depending on project location and connection voltage.

Although these policies and regulations help to support the development of renewable energy, a range of other factors continue to limit development and investment:

- Power purchase agreements for small scale facilities are usually one-size-fits-all and do not account for differences in technologies and project location.[52]
- Feed-in tariffs for electricity from biomass and biogas power plants (which include incentives for specific locations) do not include provisions for escalation in response to shifts in fuel prices or other market fluctuations.

[52] "Integration of Renewable Energy in Indonesia—Challenges and Opportunities for PLN," Presented by Milosz Mogilnicki, PLN Resident Advisor, at the 8th Asia Clean Energy Forum, Manila, June 2013.

- Tax and customs exemption regulations are unclear about how businesses can implement them, and are otherwise difficult to navigate.
- The license and permit process is not streamlined—different project types require coordination with multiple offices at multiple levels of government.

4.2 Assessment of Barriers

This subsection discusses industry- and facility-level barriers which hinder widespread adoption of AD in the palm oil, swine, and cassava sectors. Facilities have implemented AD projects at various scales and to varying degrees of success. Focused efforts to address existing barriers could improve the viability of biogas generation projects in the future.

The market for biogas recovery technologies and supporting services in Indonesia is immature but growing. Key considerations in assessing the market are the availability of human and technical resources, access to proven technologies, and national economic issues. These are discussed in the following subsections.

4.2.1 Human Resources

There are human resource challenges in the financial, technical, and government sectors. In the finance sector, there is limited lender experience with relevant financing mechanisms, technologies, and industry financial performance. This results in a perception of higher risk than is often appropriate, a lack of standardized procedures, and higher loan rates.

In the technical sector, there are not enough personnel with the technical background to perform high-quality, bankable feasibility studies. There is limited access to employees capable of supervising and monitoring AD operations, or able to train others. This is particularly problematic for small household digester systems. There is also a shortage of people with technical skills necessary for design, construction, operation and maintenance, upgrades, and equipment replacement. This increases project costs due to stationing or shuttling qualified personnel to remote locations, particularly for simple but technical tasks.

In the government sector, there is a lack of coordination among government organizations for approvals and support to investors. A primary example is the lack of standardized procedures for obtaining import tax exemptions from the Ministry of Finance. Also, high turnover rates in local governments and companies make it difficult to maintain or expand human resources and skills capacity.

4.2.2 Technical Resources

Technical considerations that hinder AD adoption include a lack of relevant technical expertise for AD design, operation, safety, and interconnection standards and procedures. There is a lack of proven AD implementation within Indonesia, in which inhibits the trust of potential owners and investors in the effectiveness of the technologies. Immature markets with limited technical depth often lead to substandard design and poor operation of facilities. Costly and inefficient operations are apt to discourage other facility owners from investing in AD.

There is also a lack of technical expertise from energy suppliers to provide solutions that respond to market needs and support AD development.

4.2.3 Access to Technology

Because the AD industry in Indonesia is relatively new, there is no robust industrial base to produce high-quality system components. A shortage of local technology providers limits knowledge transfer and implementation, resulting in higher costs. In addition, there are logistical challenges related to moving large or sensitive pieces of equipment to remote locations via sea transport o on degraded roadways. There may be limited access to construction materials and equipment in remote areas.

Due to the lack of local suppliers (especially for more complex technologies), certain components that can improve operational performance and system lifespans must be imported, which increases costs and complicates planning timelines. In addition, imported components are typically priced in foreign currencies, introducing the risk of exchange rate fluctuations. However, the increased costs associated with importing components are partially offset by policies that eliminate importation taxes for renewable energy equipment. Components for household biogas recovery technologies are available locally.

An experience during field visits highlighted these issues with equipment availability. The Gunung Sugih cassava mill has been operating an AD system for approximately two years, using the biogas to fuel the starch drying system. The mill owner has ready access to inexpensive biomass (rice husks) that could be used for the starch drying system, which should allow for more efficient use of the biogas to generate electricity. However, the scrubber that would be needed to provide quality biogas for a gas engine is not available from an Indonesian manufacturer; it must be imported at a cost that is prohibitive for the mill owner.

4.2.4 Economic

Key investment considerations include currency exchange risk, feedstock supply, return on investment, primary product price, and financing options. This section summarizes these considerations.

Major equipment for methane capture for palm oil and cassava is imported from overseas and paid for in foreign denominations. Loans and revenues are denoted in rupiah, exposing project owners to currency risk.

Most palm oil companies rely on FFB supply from their own plantations, while some source from external suppliers or independent growers. The same practice applies to cassava starch mills. Companies with their own and nucleus plantations can secure supply for the long term. They also tend to be more confident in developing methane capture facilities than those that rely on externally sourced supplies for production.

There is a lack of reliable data regarding return on investment due to the low number of biogas recovery projects in Indonesia. The payback period for each project ranges from approximately three years (or fewer) to seven years, depending on the technology and project location. The rate of return on investment has averaged 10 to 22 percent in the palm oil sector, which is much lower than the rate of return for the company’s primary product (CPO). Higher expected return on investment would provide necessary motivation to initiate more AD projects. In general, biogas used to generate electricity for the grid provides higher revenues and a shorter payback period than household methane capture. Household methane capture by small swine farms does not typically generate revenue, but offsets operational or household costs.

The price of primary products may serve as a proxy for an investment decision. Higher revenues (due to higher prices for the primary product or reduced prices for feedstock) often enable owners to expand their business or make additional investments in their business.

Palm oil and cassava companies can access loans through corporate financing, but financing specifically for biogas recovery projects in Indonesia is not common. There is no specific concessional loan available for biogas recovery projects. Companies that have implemented biogas recovery projects usually have strong internal financing and access to corporate financing. Lack of financial assistance hinders small and medium-sized companies, as they need to target their expenditures on the primary business of the mill and plantation (i.e., mill's expansion, replanting).

The government of Indonesia provides loans to farmers through the Ministry of Agriculture, administered by conventional banks. Interest rates are slightly lower for animal farmers. Farmers can access these loans from conventional banks using assets, such as their houses, as collateral. (Farmers consider the interest on these loans to be too high and unreflective of genuine government support.)

BIRU, implemented by Hivos, provides technical and financing help for farmers seeking to develop household digesters. Hivos works closely with the MEMR and SNV Netherlands Development Organization to administer subsidies for biogas installation, as much as U.S. $220 per digester. Farmers can also access biogas credit through farmers' cooperatives; the credit fund itself is provided by Nestlé, Bank Syariah Mandiri, and the Rabobank Foundation.

5.0 ANAEROBIC DIGESTION TECHNOLOGY OPTIONS AND FINANCIAL PERFORMANCE

This section presents AD options for the palm oil, cassava, and swine sectors in Indonesia. It also summarizes the financial performance of existing systems.

5.1 Technology Options

While AD reduces GHG emissions, it is also a common waste management practice for other reasons. For example, AD requires low-energy input as no aeration process is involved. AD achieves low COD effluent and can produce methane gas for power. Additionally, treated effluent and generated sludge can be used for land application as a fertilizer.

AD methods have been used for more than a century and applied in various sectors, including palm oil waste, cassava waste, and swine manure treatment. Globally, the technology applications for those three sectors adopt similar processes, yet may vary in scale and specific components or equipment. The methods and application of AD are presented in Table 5-1. Note that wastewater with high concentrations of solids and high oil content requires pre-treatment before entering an anaerobic filtration system, fluidized bed, or UASB.[53]

Table 5-1. Anaerobic Digestion Technology Options

Method	COD Removal Rate	Sectors Used
Anaerobic filter	Minimum 70%	Slaughterhouses, soybean processing, palm oil, municipal wastewater, municipal landfill, alcohol brewing, pharmaceutical, etc.
Fluidized bed reactor	Minimum 65% (often more than 90%)	Sunflower milling, palm oil, dairy, alcohol distilling and brewing, textile, etc.
UASB reactor	More than 60%	Palm oil, cassava starch, domestic sewage, dairy, sugar-beet, pharmaceutical, slaughterhouse, confectionery, etc.
Low-rate anaerobic digester (e.g., covered lagoon, fixed domes, tube digesters)	Minimum 80%	Palm oil, swine, sugar, citric acid, yeast, cassava starch, meat, dairy, alcohol distilling, olive oil, etc.
Continuous stirred tank reactor (CSTR)	Minimum 60%	Palm oil, dairy, swine, cassava starch, etc.
Membrane separation anaerobic treatment process	~ 94%	*New technology; being tested in pilot projects in various industries*

Low-rate anaerobic digesters have lower design, operation, and maintenance costs than other options, and they have proven effective in warm climates. These types of anaerobic digesters include covered anaerobic lagoons, fixed domes, and tube digesters.

5.2 Anaerobic Digestion System Configurations

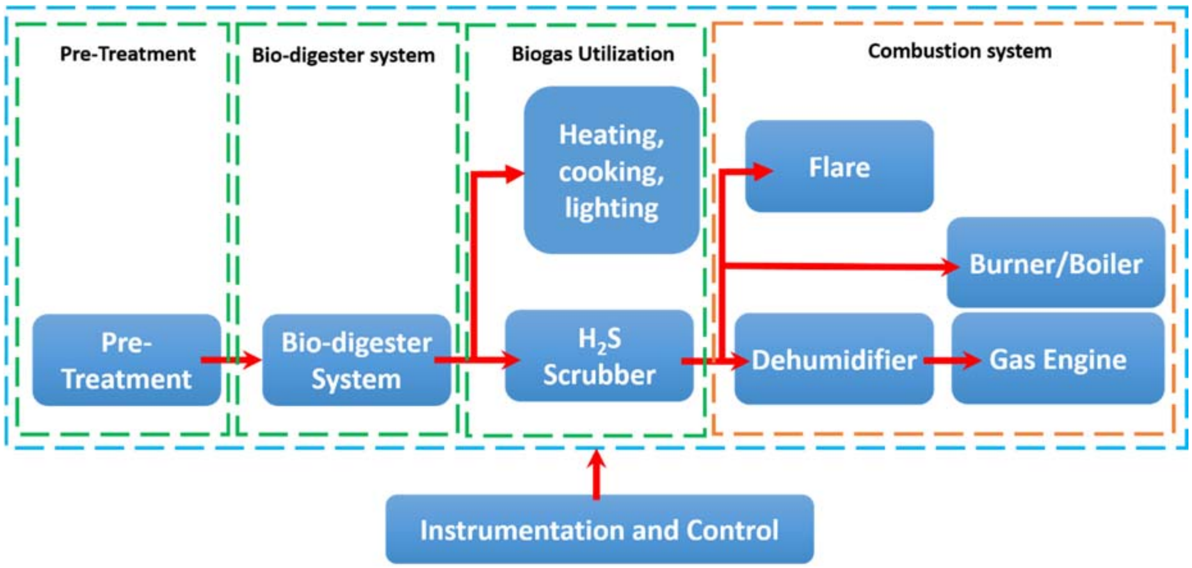
5.2.1 General AD Systems

An AD system generally consists of a pre-treatment process, a digester, a scrubber, a combustion system, and an instrumentation and control system, as shown in Figure 5-1 below. While

[53] CIRCLE Handbook POME-to-Energy Development in Indonesia, 2014

large-scale projects often use all of these components, smaller-scale systems may only consist of a digester and biogas use option.

Figure 5-1. General Biogas Treatment System Process



Source: CIRCLE Biogas Handbook, 2014.

Table 5-2 provides a detailed list of the system components and, where applicable, describes various technology options that can be used to perform the functions of those components.

Table 5-2. General AD System Components and Their Functions

Component	Technology Option	Function
Digester		
Pre-treatment	Multiple (screen, filter, oil and grease removal, chemical addition, equalization, etc.)	Screens, removes fat, oil, and grease, mixes to neutralize pH, and cools to reduce the temperature of wastewater.
Digester	Covered lagoon (including geo-membrane, piping)	Reacts anaerobically to degrade COD content and produce methane using a lagoon covered by a geo-membrane.
	UASB	Treats wastewater anaerobically and generates methane; uses pumped water to mix the material and improve microorganism contact with the wastewater passing through the sludge blanket.
	CSTR	Treats wastewater anaerobically and produces methane with continuous mixing mechanisms (mechanical, hydraulic, or gas injection) to improve contact.
Biogas Treatment System		
H_2S scrubber	Biological scrubber	Removes H_2S content in the biogas using sulfur bacteria (biological process).
	Chemical scrubber	Removes H_2S content in the biogas using, e.g., caustic soda (chemical process).

Table 5-2. General AD System Components and Their Functions

Component	Technology Option	Function
	Water scrubber	Removes H_2S content in the biogas using water.
Flare	Open or closed flame	Burns off excess biogas for safety and/or to destroy methane.
Dehumidifier	Biogas dryer/chiller/cyclone	Removes moisture to optimize the combustion process in the engine, prevent condensation, and help protect the engine from acid.
Biogas storage system	Biogas holder	Stores biogas (not common in Indonesia, where price is high).
Biogas Conversion System		
Thermal energy	Burner/boiler	Combusts biogas directly to generate heat or steam for use in internal processes; can replace biomass fuel usage such as shell and fiber in the palm oil sector.
Electricity	Generator	Generates electricity via internal combustion using biogas that has been cleaned to remove impurities to specified levels.
	Turbine	Generates electricity by combusting biogas to turn a turbine with pressure from fast-moving water, gas, or steam.
	Grid (internal/external transmission)	Delivers electricity from producers to private consumers, government grids (external), or internal transmission for captive power; consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers.
Transportation fuel	Purification and compression systems	Cleans biogas to remove impurities and increase methane content; compresses biogas to be used as transportation fuel for farm or facility vehicles.
Heating	NA	Burns raw biogas as heating fuel.
Lighting	NA	Burns raw biogas as fuel for lanterns, particularly in the swine sector.
Cooking	NA	Burns raw biogas for cooking.
Controls and Instrumentation		
Electrical works and system controls	Standard component	Components in this category monitor and control electrical systems and motor operations; various types of instrumentation may be used to monitor operational parameters, such as temperature, pH, liquid and gas flows, and gas pressure; instrumentation allows for manual and automatic shutdown of the system during unsafe conditions.
Motor control center and panel	Standard component	
Instrumentation	Flow meter, pH and temperature transmitter, level meter, biogas analyzer, etc.	

Many technology options for methane capture are available in the market; to choose among them for a project (particularly a large-scale one) requires detailed knowledge of project-specific considerations. Such considerations should be explored in a feasibility study. However, technology options for the various palm oil, cassava, and swine facility sizes explored in this report can be generally described, as in Table 5-3.

Table 5-3. Anaerobic Digestion Technology Selection Based on Best Practices

Component	Palm Oil		Cassava		Swine		
	Medium	Large	Medium	Large	Small	Medium	Large
AD system	Tank/enclosed container or covered lagoon		Tank, enclosed container, or covered lagoon		Tube digester or fixed dome, fiber or plastic tank	Fixed dome, fiber or plastic tank	Tank or covered lagoon
Biogas treatment	Scrubber, chiller		Scrubber, chiller		None	Scrubber, chiller	
Electrical/ instrumentation	Automatic or semi-automatic		Automatic or semi-automatic		None		Automatic or semi-automatic
Energy conversion	Biogas engine, boiler	Biogas engine, boiler, transporta-tion	Biogas engine, boiler	Biogas engine, boiler, transporta-tion	Heating, lighting, cooking	Heating, lighting, cooking, power	Biogas engine, heating, lighting

5.3 Anaerobic Digestion in Indonesia

The biogas captured in the AD system can be used as a source of heat or electricity, or destroyed using a flare system. Palm oil and cassava operations typically use Biogas for heat and electricity, whereas swine farms commonly use biogas for lighting, cooking, or heating.

The choice of AD type is influenced by factors such as investment costs, area requirements, intended use of the biogas, and project location. Covered anaerobic lagoons are common in Indonesia because they have lower investment costs than continuous stirred tank reactors (CSTRs). However, covered anaerobic digesters might not be viable if land area is limited, in which case tank systems may be a better solution. Although CSTRs are generally more efficient at converting organic material into methane than covered anaerobic lagoons, a well-designed lagoon can also be quite efficient.

There are 56 registered CDM projects in the palm oil and cassava sectors in Indonesia. However, as mentioned previously, not all registered projects are confirmed to be operating—some may be in development, and some may be shut down. If every registered CDM project were operational, the current distribution of AD systems in Indonesia would include:

- Thirty-eight POME-to-energy registered CDM projects. Most of the projects use covered lagoon systems; three use tank systems.[54] One project has used the generated biogas for

[54] http://cdm.unfccc.int/Projects/projsearch.html

electricity and sell it to the national grid; others use it to produce heat through boilers or electricity for captive usage, or they destroy it using flaring systems.

- Eighteen biogas-from-cassava-starch registered CDM projects. These projects use covered anaerobic lagoons and UASB and are estimated to generate 1 megawatt of electricity, which they use as captive power.
- Several UASBs and expanded granular sludge bed reactors. In Indonesia, this technology has been applied in the pulp and paper, petrochemical, and gum and candy industries.
- One large swine methane capture project in the Bulan Islands, using covered lagoons with a bank-to-bank cover type.
- Many fixed-dome and tube digesters at household farms. BIRU has constructed more than 11,000 fixed-dome digesters on small, household-size livestock farms. Research reports suggest that at least 1,000 tube digesters have been installed at other farms. These facilities convert the generated biogas into heat for cooking, or use it for lighting.[55]

Revenue streams generated in Indonesia by AD for biogas production include avoided costs for fuel purchases, revenue from electricity sales, and carbon credit sales on the voluntary market. Such revenue streams would typically be realized in nearly every country. Benefits that are particularly important in Indonesia include increased access to markets for sustainable products (especially for palm oil in the EU market) and a reliable, uninterrupted power supply (compared to the national grid, which frequently fails in remote parts of the country).

5.3.1 Biogas Uses

The way biogas will be used determines the equipment to be installed in the system. Electricity export to the grid would need an accessible grid connection and a more robust control system than captive power usage. Use in a boiler would need less equipment and more limited control systems than use in gas engines; and household uses such as for cooking have even fewer requirements in the way of electronics and control systems.

There are a range of potential uses for biogas produced by palm oil mills, cassava plants, and swine farms. The choice of end use is largely driven by industry-specific conditions and can include:

- ***Own-Use Electricity.*** Combustion to produce electricity for internal operations is largely done to displace diesel fuel purchases by the facility. This is a common choice for palm oil mills that can produce large quantities of electricity and have extensive operations that demand electricity, such as onsite housing complexes.
- ***Own-Use Thermal Energy.*** Combustion to produce thermal energy for internal operations is a common choice for facilities that need heat, but do not have access to inexpensive fuel sources. This is typical for the cassava and swine industries. Cassava facilities require significant amounts of heat for drying during starch production. If they do not use biogas for this purpose, they often purchase fuel, such as rice husks or coal. Swine farms will use biogas for heat when incubating newborn swine; those that do not recover biogas often buy LPG for the purpose. Some farms also use biogas in lanterns and cook stoves. Biogas can thus substitute for fuels that would otherwise need to be purchased. .

[55] BIRU Interim Report Indonesia Domestic Biogas Program, January–June 2014.

- ***Grid-Connected Electricity.*** Biogas combustion in a generator to create electricity for sale to the PLN public grid is a viable choice for facilities with excess power and relatively easy access to the grid. In Indonesia, this is more likely for the palm oil industry than the cassava or swine industries. As noted above, many palm mills meet their internal energy needs with waste palm biomass and can sell surplus electricity to the grid (where connectivity is accessible).
- ***Flaring.*** Biogas production for flaring is done to obtain and sell carbon credits. The UN's CDM offers a mechanism for generating carbon credits through the destruction of methane. Over the past 15 years, this has been a common driver at palm oil mills. Facilities with minimal external power needs can establish a revenue stream without having to purchase engines, boilers, or extensive system controls.
- ***Transportation.*** Although not typical in Indonesia, biogas can be processed for use as a transportation fuel, which could be used to displace vehicle fuel used in facility equipment. For this application, vehicle fleets must be appropriately equipped.

The following section provides a general guide to the procurement costs and the system characteristics that can drive the ongoing operational costs of various biogas conversation systems.

5.3.2 Financial and Operational Performance

The general drivers of cost for the design and implementation and ongoing operation of biogas projects come from those related to engineering, procurement and construction (EPC); biogas operation and maintenance; and overhauls. Table 5-4 highlights AD system components and their estimated costs as a percentage of EPC costs.

Table 5-4. AD System Costs

Component	Sub-components		Cost (% of EPC Cost)
AD and Biogas System			
Digester	For covered lagoon: • Cooling system • Civil works: earthworks, cut and fill land, AD construction • Geo-membrane • HDPE membrane • Hydraulic works • Piping system • Equipment	For tank reactor (UASB and CSTR): • Cooling, hydrolysis, and acidification ponds • Civil and foundation works • Pumping system and pump-house • Fabrication and installation of anaerobic digester tank • Digester continuous mixing system • Feed tank and piping system	~ 25%
Biogas treatment system	For covered lagoon: • Civil works: earthworks, foundation, concrete works • Hydraulic works • Equipment (chiller, scrubber, blower, flaring system)	For tank reactor: • Civil and foundation works • Equipment (scrubber, blower, flaring system)	~ 16%

Table 5-4. AD System Costs

Component	Sub-components	Cost (% of EPC Cost)
Electrical and instrumentation system	• Electrical works and system • Motor control center panel, control panel • Instrumentation • Integration of SCADA system	~ 10%
Logistics		~ 20–25%
Shipping and insurance		
Installation, commissioning, and startup (including biomass seeding)		
Biogas Conversion System		
Biogas to energy conversion	For biogas to electricity: • Biogas engines and installation • Shipping and insurance • Equipment and instrumentation system For biogas to thermal energy: • Boiler modification	~ 20–30% for biogas to electricity; less than 10% for thermal energy
Other		
Grid installation	For biogas-to-electricity: • Grid within mill • Grid connection to PLN's grid	~ IDR 280–420 million per km
Project contingency	Established to address risks and unforeseen events (e.g., price escalation, exchange rate, design growth, change in scope, and inaccurate estimates); this is not a budget allowance, so the balance should be reviewed and adjusted along the project duration	~ 5–10%

Source: CIRCLE Handbook POME-to-Energy Development in Indonesia, 2014

5.3.2.1 Greenfields vs. Retrofits

AD systems can be installed at existing facilities or built as part of new construction projects (greenfields). The investment costs for building in greenfields and existing facilities are similar, because retrofitting requires significant civil works, such as emptying and modifying existing effluent ponds.

5.3.2.2 Operation and Maintenance Costs

The annual operation and maintenance costs for palm oil and cassava methane capture facilities are estimated to be 5 percent to 10 percent of investment costs. The maintenance costs cover routine and major (overhaul) maintenance for the AD and biogas utilization system. The project owner can engage a service contract with the technology provider for a minimum of one year.

For swine waste methane capture projects, operation and maintenance activities are relatively simple and can be performed by farmers or the farm's staff. For household methane capture, operation and maintenance consists of regular cleaning of the dome, main gas faucet, water drain, etc.

5.3.2.3 Overhauls

The cover material for a covered lagoon has a lifetime of more than 10 years, so it incurs no overhaul cost during that period. If the biogas is utilized for power production using a gas engine, the engine will need to be overhauled after operating for a certain numbers of hours (about 60,000 hours, depending on the brand).

There is no major overhaul for a household swine methane capture facility; medium and large facilities may use the same routines as palm oil and cassava facilities.

5.3.3 Industry-Specific Cost Estimates

The current investment cost for methane capture in palm oil and cassava mills in Indonesia is in the range of U.S. $2–3.5 million per megawatt electricity, including biogas engine units and installation. Table 5-5 shows a cost estimate from a cassava mill point of contact (demonstrating that these costs do not demonstrate a linear increase based on size, but employ economies of scale). Note that Table 5-4 reflects that costs for AD systems in the sector do not increase linearly with size, but employ economies of scale.

Table 5-5. Cassava Facility AD System

Size (ton/d)	Size (MW)	Cost (Without Gas Engine)	Cost (Gas Engine Only)
300	3.5	$2.5–2.6M	$750K/MW
200–250	2.5	$2M	$1.5M
100	1	$1.5–1.6M	$750K

Source: Interview with Pak Abo

Cost components for large swine farms' methane capture are shown in Table 5-6.

Table 5-6. Components and Cost of a Large Swine Farm Methane Capture System

Components	Sub-components	Costs
AD System	Covered lagoon	U.S. $1,200,000 for 500,000 m^3 of AD system, equipment, and installation
	Piping system	
	Civil works	
Biogas Flare		

Source: PDD of Batu Bulan project, UNFCCC website

A household methane system would include an inlet mixing tank, water pipes and drains, a digester, gas pipes and valves, gas pressure meter, and a slurry pit. These systems may also include cooking stoves, lamps, or heaters for biogas use. The investment costs for a 4 m^3 digester is IDR 9 million or approximately USD 750 (exchange rate IDR 12,000/USD). [56]

5.4 Summary

Anaerobic digestion for methane capture is not broadly used in the palm oil, cassava, or swine sectors in Indonesia, but the technology is used by a handful of actors in each sector. Palm oil mills and cassava processing facilities saw expanded use of AD under the CDM program when carbon prices were relatively high. Medium and large sized facilities typically used UASB technologies for flaring, but largely relied on international suppliers and service providers for project implementation. The prevalence of international actors was driven by a lack of technical capacity within Indonesia and by the external market growing from the demand for carbon credits.

With a depressed carbon market, interest in CDM projects began to wane a decade ago. However, in the palm oil industry, a combination of Indonesian government standards and the demands

[56] http://www.biru.or.id/index.php/digester/

of external consumers for CSPs is driving greater interest in AD among palm oil operations. As a result, the desire for projects is being driven internally, and the local service and supply market is beginning to respond.

The cassava industry, with thin operating margins, has not seen the same resurgence in interest for AD implementation. Similarly, the swine industry is largely dispersed in Indonesia, making financing for AD projects less attractive. Small farmers are quite familiar with AD technologies, but they largely utilize tank systems that are often inappropriately sized and designed.

6.0 ASSESSMENT OF SUPPLY AND SERVICE MARKETS

This section summarizes the availability of AD system components and supporting services in Indonesia. There are approximately 30 AD service and equipment providers either operating in Indonesia or with experience in Indonesia. Appendix B presents the full list of service and equipment providers that operate at various levels within the biogas industry, with capabilities relevant to either palm oil, cassava, or swine AD system implementation in Indonesia.

AD system components not produced in Indonesia must be procured internationally and shipped to the project site, or procured through equipment manufacturers' distributors within Indonesia. AD system components include combinations of the following:

- The digester
  - Pre-treatment
  - Covered lagoon
  - UASB
  - CSTR
- Gas treatment
- Chiller
- H2S scrubber
- Flare
- Biogas conversion system
  - Burner
  - Boiler
  - Electrical/transmission/other
  - Generator
  - Turbine
  - Biogas upgrading to transportation fuel
- Instrumentation and controls
  - Electrical system
  - Motor system
  - Instrumentation

Of the listed AD system components, CSTRs, chillers, burners, generators, turbines, biogas upgrading, and instrumentation are not yet available from Indonesian companies.

Table 6-1 indicates which implementation-related services are conducted by Indonesian providers and the general level of experience those providers have in the palm oil mil, cassava processing, and swine industries. This information is based on direct industry knowledge of Winrock International staff and field interviews of industry personnel.

Table 6-1. Service Capabilities of Indonesian Companies

Service	Indonesian Provider			Provider Experience		
	Palm Oil	Cassava	Swine	Palm Oil	Cassava	Swine
Design	No	Yes	Yes	None	Minimum	Minimum
Engineering	Yes	Yes	Yes	Moderate	Minimum	Minimum
Electrical works	Yes	Yes	No	Significant	Significant	None
Mechanical works	Yes	Yes	Yes	Significant	Significant	Significant
Civil works	Yes	Yes	Yes	Significant	Significant	Significant
Financing*	Yes	Yes	Yes	Minimum	Minimum	Minimum
Turnkey	Yes	Yes	Yes	Minimum	Minimum	Minimum

*Financing by Indonesian firms is largely project-level, not corporate-level.

7.0 SUMMARY

As noted in Section 1, Indonesia ranked as the 6th highest methane emitter with anthropogenic methane emissions of 234.6 $MTCO_2e$ in 2010. Wastewater, which includes both municipal and industrial wastewater, accounts for 10 percent of the emissions, other waste sources account for 4 percent of the emissions, and manure management for 1 percent.

GMI determined the agro-industrial sectors with the greatest potential for methane emission reductions are palm oil processing, cassava processing, and swine farms (as described in Section 2). There are only a small number of AD systems currently in place at palm oil processing facilities, cassava processing facilities, and swine farms:

- There are 608 palm oil mills in Indonesia and only 38 of them have registered CDM AD projects.
- There are approximately 300 to 350 cassava processing plants and only 18 of them (primarily in Lampung) have registered CDM AD projects.
- There are 7.9 million swine in Indonesia and only approximately 14 percent of the swine are housed on farms with AD systems. These systems are primarily present on small farms as a result of the efforts by MEMR and Hivos International under BIRU. BIRU has constructed more than 11,000 fixed-dome digesters on small, household-size livestock farms.

Through the installation of additional AD systems, these sectors could achieve direct and indirect methane reductions totaling almost 45 million $MTCO_2e$ per year, as shown in Table 7-1 (and estimated in Section 3.0).

Table 7-1. Potential Greenhouse Gas Emission Reductions for Indonesia

Sector	Potential Direct Methane Emission Reductions ($MTCO_2e$/yr)	Potential Fuel Replacement Offsets ($MTCO_2e$/yr)	Total Potential Emission Reductions ($MTCO_2e$/yr)
Palm oil processing	36,293,400	1,432,010	37,725,410
Cassava processing	5,396,390	212,920	5,609,310
Swine farms	1,392,650	54,950	1,447,600
Total	43,082,440	1,699,880	44,782,320

Although the government has policies in place to encourage renewable energy use, there are still barriers to AD deployment, as described in Section 4. Section 5 summarizes the appropriate technologies which include tube digesters for small swine farms, fixed domes for medium swine farms, and tank/enclosed systems or covered lagoons for large swine farms, palm mill processing, and cassava processing. There are a limited number of technology providers available in Indonesia for AD systems and AD system components (as presented in Section 6.0).

APPENDIX A. METHANE CALCULATIONS

APPENDIX A. METHANE CALCULATIONS

This appendix describes the generally accepted methods for estimating methane emissions from livestock manures and agricultural commodity processing wastes. It also describes the way to modify these methods to estimate the methane production potential of adding AD as a waste management system component.

Direct Emissions from Manure

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Tier 2 methodologies were used for estimating methane emissions from each commodity group in the livestock production sector. Using the Tier 2 methods, methane emissions for each livestock commodity group (M) and existing manure management system (S) and climate (k) combination are estimated as follows using Equation A-1:

$$CH_{4(M)} = \left(VS_{(M)} \times H_{(M)} \times 365\ \text{days/yr}\right) \times \left[B_{o(M)} \times 0.67\ \text{kg}\ CH_4/m^3\ CH_4 \times MCF_{S,k}\right] \quad \text{(A-1)}$$

where:

- $CH_{4\,(M)}$ = Estimated methane emissions from manure for livestock category *M* (kg CH_4 per year)
- $VS_{(M)}$ = Average daily volatile solids excretion rate for livestock category *M* (kg volatile solids per animal-day)
- $H_{(M)}$ = Average number of animals in livestock category *M*
- $B_{o(M)}$ = Maximum methane production capacity for manure produced by livestock category *M* (m^3 CH_4 per kg volatile solids excreted)
- $MCF_{(S,k)}$ = Methane conversion factor for manure management system *S* for climate *k* (decimal)

As shown, Equation A-1 requires an estimate of the average daily VS excretion rate for the livestock category under consideration. The default values for dairy cows, breeding swine, and market swine are listed in Table A-1. Default values for other types of livestock can be found in Tables 10A-4 through 10A-9 in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Table A-1. 2006 IPCC Volatile Solids Excretion Rate Default Values for Dairy Cows, Breeding Swine, and Market Swine (kg/head-day)

Region	Dairy Cows	Breeding Swine	Market Swine
North America	5.4	0.5	0.27
Western Europe	5.1	0.46	0.3
Eastern Europe	4.5	0.5	0.3
Oceania	3.5	0.5	0.28
Latin America	2.9	0.3	0.3
Middle East	1.9	0.3	0.3
Asia	2.8	0.3	0.3
Indian Subcontinent	2.6	0.3	0.3

Realistic estimates of methane emissions using Equation A-1 also require identification of the appropriate MCF, which is a function of the current manure management system and climate. MCFs for various types of manure management systems for average annual ambient temperatures ranging from greater than or equal to 10°C to less than or equal to 28°C are summarized in Table A-2, and can be found in Table 10-17 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Table A-2. Default MCF Values for Various Livestock Manure Management Systems

Climate	Manure Management System Default Methane Emission Factor (%)								
	Lagoons	Storage Tanks and Ponds	Solid Storage	Dry Lots	Pit <1 Month	Pit >1 Month	Daily Spreading	AD	Pasture
Cool	66–73	17–25	2	1	3	17–25	0.1	0–100	1
Temperate	74–79	27–65	4	1.5	3	27–65	0.5	0–100	1.5
Warm	79–80	71–80	6	5	30	71–80	1	0–100	2

There is very little information on methane leakage from AD systems, but some leakage probably occurs from all systems and should be incorporated into estimates of net methane emission reductions. The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* provide no guidance, with an MCF default value of 0 to 100 percent. Thus, the use of the 2008 California Climate Action Registry (CCAR) default collection efficiency value of 85 percent is recommended unless a higher value can be justified by supporting documentation

Finally, use of Equation A-1 requires specification of the methane production potential (B_o) for the type of manure under consideration. Default values listed in Tables 10A-4 through 10A-9 of the *2006 IPCC Guidelines* can be used. The default values for dairy cows, breeding swine, and market swine are listed in Table A-3.

Table A-3. 2006 IPCC Methane Production Potential Default Values for Dairy Cows, Breeding Swine, and Market Swine (m^3 CH_4/kg VS)

Region	Dairy Cows	Breeding Swine	Market Swine
North America	0.24	0.48	0.48
Western Europe	0.24	0.45	0.45
Eastern Europe	0.24	0.45	0.45
Oceania	0.24	0.45	0.45
Latin America	0.13	0.29	0.29
Middle East	0.13	0.29	0.29
Asia	0.13	0.29	0.29
Indian Subcontinent	0.13	0.29	0.29

Direct Emissions Related to Agricultural Commodity Processing Waste

Agricultural commodity processing can generate two sources of methane emissions: wastewater and solid organic wastes. The latter can include unprocessed raw material or material discarded after processing due to spoilage, poor quality, or other reasons. One example is the combination of wastewater and the solids removed by screening before wastewater treatment or direct disposal. The methods for estimating methane emissions from wastewater are presented below.

Wastewater

For agricultural commodity processing wastewaters, such as meat and poultry processing wastewaters from slaughterhouses, the *2006 IPCC Guidelines'* Tier 2 methods (Section 6.2.3.1) are acceptable for estimating methane emissions. They use COD and wastewater flow data. Using the Tier 2 methods, the gross methane emissions for each waste category *(W)* and prior treatment system and discharge pathway *(S)* combination should be estimated using Equation A-2:

$$CH_{4\,(W)} = [(TOW_{(W)} - S_{(W)}) \times EF_{(W,S)}] - R_{(W)})] \quad \text{(A-2)}$$

where:

$CH_{4\,(W)}$ = Annual methane emissions from agricultural commodity processing waste *W* (kg CH_4 per year)

$TOW_{(W)}$ = Annual mass of waste *W* COD generated (kg per year)

$S_{(W)}$ = Annual mass of waste *W* COD removed as settled solids (sludge) (kg per year)

$EF_{(W,\,S)}$ = Emission factor for waste *W* and existing treatment system and discharge pathway *S* (kg CH_4 per kg COD)

$R_{(W)}$ = Mass of CH_4 recovered (kg per year)

As indicated above, the methane emission factor in Equation A-2 is a function of the type of waste and existing treatment system and discharge pathway and is estimated using Equation A-3:

$$EF_{(W,S)} = B_{o\,(W)} \times MCF_{(S)} \quad \text{(A-3)}$$

where:

$B_{0\,(W)}$ = Maximum CH_4 production capacity (kg CH_4 per kg COD)

$MCF_{(S)}$ = Methane conversion factor for the existing treatment system and discharge pathway (decimal)

If country- and waste-sector-specific values for B_o are not available, the *2006 IPCC Guidelines'* default value of 0.25 kg CH_4 per kg COD should be used. In the absence of more specific information, the appropriate MCF default value selected from Table A-4 also should be used.

Table A-4. Default MCF Values for Industrial Wastewaters, Decimal

Existing Treatment System and Discharge Pathway	Comments	MCF*	Range
Untreated			
Sea, river, or lake discharge	Rivers with high organic loadings may turn anaerobic, which is not considered here	0.1	0–0.2
Treated			
Aerobic treatment plant	Well managed	0	0–0.1
Aerobic treatment plant	Not well managed or overloaded	0.3	0.2–0.4
Anaerobic reactor (e.g., UASB, fixed film)	No methane capture and combustion	0.8	0.8–1.0

Table A-4. Default MCF Values for Industrial Wastewaters, Decimal

Existing Treatment System and Discharge Pathway	Comments	MCF*	Range
Shallow anaerobic lagoon	Less than 2 meters deep	0.2	0–0.3
Deep anaerobic lagoon	More than 2 meters deep	0.8	0.8–1.0

*Based on IPCC expert judgment.

If the annual mass of COD generated per year (TOW) is not known and the needed data cannot be collected, the remaining option is estimation using Equation A-4, with country-specific wastewater generation rate and COD concentration data obtained from the literature. In the absence of country-specific data, values listed in Table A-5 can be used as defaults to obtain first order estimates of methane emissions.

$$TOW_{(w)} = P_{(w)} \times W_{(w)} \times COD_{(w)} \qquad \text{(A-4)}$$

where:

$P_{(W)}$ = Product production rate (metric tons per year)

$W_{(W)}$ = Wastewater generation rate (m^3 per metric ton of product)

$COD_{(W)}$ = Wastewater COD concentration (kg per m^3)

Table A-5. Examples of Industrial Wastewater Data

Industry	Typical Wastewater Generation Rate (m^3/MT)	Range of Wastewater Generation Rates (m^3/MT)	Typical COD Concentration (kg/m^3)	Range of COD Concentrations (kg/m^3)
Alcohol	24	16–32	11	5–22
Beer	6.3	5.0–9.0	2.9	2–7
Coffee	NA	NA	9	3–15
Dairy products	7	3–10	2.7	1.5–5.2
Fish processing	NA	8–18	2.5	NA
Meat and poultry processing	13	8–18	4.1	2–7
Starch production	9	4–18	10	1.5–42
Sugar refining	NA	4–18	3.2	1–6
Vegetable oils	3.1	1.0–5.0	NA	0.5–1.2
Vegetables, fruits, and juices	20	7–35	5.0	2–10
Wine and vinegar	23	11–46	1.5	0.7–3.0

Source: Doorn et al., 1997. Estimate of Global Greenhouse Gas Emissions from Industrial and Domestic Wastewater Treatment. EPA-600/R-97-091.

Indirect Emissions

To estimate indirect emissions, GMI determined the emissions associated with the energy that was offset from biogas use. GMI assumed that the collected biogas would be used to generate electricity, replacing the fuels shown in Figure 3-1. Table A-6 shows carbon dioxide emission coefficients associated with various types of fuel.

Table A-6. Emissions by Type of Fuel

Fuel Replaced	CO_2 Emission Factors (kg CO_2 per million BTU)
100% coal	95.3
100% hydro or nuclear	0
Natural gas	53.1
Distillate fuel oil	76.0

Source: U.S. Energy Information Administration, http://www.eia.gov/environment/emissions/co2_vol_mass.cfm

GMI calculated a weighted average CO_2 emission factor for Indonesia, using the percent of fuels consumed in Figure 3-1. To determine a CO_2 reduction emission factor, GMI subtracted the natural gas CO_2 emission factor (assumed to be similar to the CO2 emission factor from biogas consumption) from the weighted average emission factor. This value (in metric tons of CO_2 reductions per million BTU) was used to calculate the indirect emissions, as shown in Equation A-5:

$$CH_4\ Reductions_{indirect} = REF \times CH_4\ Reductions_{direct} \times 52{,}493{,}731 \qquad (A\text{-}5)$$

where:

CH_4 Reductions $_{indirect}$	=	Indirect CH_4 reductions (metric tons CO_2e per year)
REF	=	Reduction emission factor (kg CO_2 reduced per million BTU)
CH_4 Reductions $_{direct}$	=	Direct CH_4 reductions (metric tons CH_4 per year)
52,493,731	=	CH_4 net heating value (BTU/ metric ton methane)

APPENDIX B. TECHNOLOGY SUPPLIERS IN INDONESIA

APPENDIX B. TECHNOLOGY SUPPLIERS IN INDONESIA

Table B-1 highlights service and equipment providers that operate at various levels within the biogas industry, with capabilities relevant to either palm oil, cassava, or swine AD systems implementation in Indonesia.

Table B-1. International and Indonesian Technology Suppliers for Biogas Production and Utilization

Company	Industry	Relevant Product	Country of Origin	Indonesia (P)resence/ (E)xperience	Website/ Contact
ABB/PT. PAL	Power/ electrical	Boiler	Australia/ Indonesia	P: yes E: yes	budi.supomo@id.abb. com
ADI Systems	Palm oil	Turnkey Covered lagoon (CIGAR)	Canada	P: no E: yes	asiapacific@adi.ca
Asia Biogas	Palm oil	Turnkey	Thailand	P: yes E: yes	joice.caroline@ asiabiogas.com
Babcock & Wilcox Volund A/S	Biomass	Boiler	Denmark	P: yes E: yes	bwv@volund.dk
Biomass Technology Group BV (BTG)	Biogas	Consulting	Netherlands	P: no E: yes	btgworld.com; knoef@btgworld.com
Biotec	Palm oil	Turnkey and financing for covered lagoons	Belgium	P: yes E: yes	asia@bio-tec.net
Biothane Asia Pacific—Veolia Water Solutions and Technologies SEA	Palm oil	Turnkey double-stage CSTR + lamella clarifier	Holland/ France	P: yes E: yes	michel.otten@ veolia.com
Dresser-Rand/Guascor	Power	Generator	U.S./ Indonesia	P: yes E: yes	dresser-rand.com
Euro Asiatic	Power	Generator	Germany	P: yes E: yes	euroasiatic.com
GE's Jenbacher Gas Engines	Power	Generator	U.S./ Indonesia	P: yes E: yes	GE.com
Global Water Engineering (GWE)	Palm oil	Turnkey CSTR + dissolved air flotation unit	Belgium	P: no E: yes	mail@globalwe.com
KIS Group	Palm oil and swine	Turnkey CSTR + lamella clarifier	India	P: no E: yes	contac@kisgroup.net
KPSR	Palm oil and cassava	Design and engineering for covered lagoons	Thailand	P: no E: yes	biogas.kpsr@gmail.com
Merapi Solutions	Engineerin g services	Turnkey	Indonesia	P: yes E: yes	merapi.co.id; info@merapi.co.id
MTU Onsite Energy	Power	Generator	Germany	P: no E: yes	mtu-online.co.; henry.tio@mtu-online.co.id; dun@centrin.net.id; epj@epj.co.id
Novaviro/Oiltek Nova	Palm oil	Turnkey CSTR + settling tank	Malaysia	P: no E: yes	http://www.novaviro.com. my/aboutus.htm
Pak Irianto	Swine	Turnkey	Indonesia (Bali)	P: yes E: yes	+62.812.394.6374
Pak Sarimo	Swine	Turnkey	Indonesia (Solo)	P: yes E: yes	+62.813.933.37434

Table B-1. International and Indonesian Technology Suppliers for Biogas Production and Utilization

Company	Industry	Relevant Product	Country of Origin	Indonesia (P)resence/ (E)xperience	Website/ Contact
PT. AES Agriverde	Palm oil	Turnkey covered lagoons	Indonesia	P: yes E: yes	altencos.com
PT. Asindo Tech	Cassava	Turnkey	Indonesia	P: yes E: yes	Mr. Abo: fidrianto.amt@ gmail.com
PT. Barata	Palm oil	EPC	Indonesia	P: yes E: yes	info@barata.co.id
PT Gikoko Kogyo Indonesia	Power	Turnkey	Indonesia	P: yes E: yes	gikoko@gikoko.co.id; gikoko@aol.com
PT Indonesia Power	Power	Engineering	Indonesia	P: yes E: yes	kontak-ip@ indonesiapower.co.id
PT Spektra Matrika Indah	Biogas (manure)	Design and construction	Indonesia	P: yes E: yes	+62.21.765.3180
Shengdong	Power	Generator	China	P: no E: yes	shengdong.en. gongchang.com
Stork Indonesia	Power	Boiler	Indonesia	P: yes E: yes	storkjkt@cbn.net.id
TEDOM	Biogas	Turnkey	Czech Republic/ China	P: no E: yes	tedom.com; petr.dolezal@ tedom.com
Wartsila	Power/ electrical	Engineering/ generator	Finland	P: yes E: yes	wartsila.com