Methane for Power Generation in Muaro Jambi: A Green Prosperity Model Project

K. Moriarty, M. Elchinger, G. Hill, J. Katz, and J. Barnett

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Abbreviations and Acronyms

AD	anaerobic digestion
AMDAL	full environmental assessment
BBIP	PT. Bukit Barisan Indah Prima
BOD	biological oxygen demand
CDM	clean development mechanism
CER	Certified Emission Reduction
CF	counterfactual
CIRCLE	Capacity for Indonesian Reduction of Carbon in Land Use and Energy
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COD	chemical oxygen demand
CPKO	crude palm kernel oil
CPO	crude palm oil
EFB	empty fruit bunch
EPA	U.S. Environmental Protection Agency
ERR	economic rate of return
ESMS	Environmental and Social Management System
FAS	Foreign Agriculture Services
FiT	feed-in tariff
FFB	fresh fruit bunches
GHG	greenhouse gas
GOI	Government of Indonesia
GWh	gigawatt-hours
H_2S	hydrogen sulfide

IPB	Bogor Agricultural University
ICED	Indonesia Clean Energy Development (USAID Program)
IDR	Indonesia rupiah
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
IRR	internal rate of return
kg	kilograms
km	kilometers
kV	kilovolts
kWh	kilowatt-hours
m	meters
L	liters
MCA-I	Millennium Challenge Account – Indonesia
MCC	Millennium Challenge Corporation
MEMR	Ministry of Energy and Mineral Resources
mg/L	milligrams per liter
MJ	megajoule
MW	megawatts
MWh	megawatt-hours
Nm3	Normal standard temperature and pressure meters squared of methane production
NPV	net present value
NREL	National Renewable Energy Lab
OLR	organic loading rate
O&M	operation and maintenance

PLN	Perusahaan Listrik Negara (National Electricity Corporation of Indonesia)
PPA	power purchase agreement
POME	palm oil mill effluent
RFP	request for proposal
SPPL	letter of commitment to manage the environment
UKL-UPL	environmental management and monitoring plan
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
W	Watt
WP	with-project

Preface

This study supports the Millennium Challenge Corporation's (MCC) Compact with Indonesia.[1] NREL has contributed to the Compact in many areas, including by formulating project evaluation guidance, participating in stakeholder forums, and developing studies of illustrative projects meeting Indonesian and MCC requirements and aspirations.

Green Prosperity, the largest project of the Compact, seeks to address critical constraints to economic growth while supporting the Government of Indonesia's commitment to a more sustainable, less carbon-intensive future. An ambitious project, Green Prosperity seeks to contribute to some of Indonesia's most prominent development priorities, including increased access to clean and reliable energy in rural areas, and improving stewardship of natural resources.

This report is one of a series evaluating eight model Green Prosperity projects on behalf of MCC and the Indonesian implementing organization, Millennium Challenge Account-Indonesia (MCA-I). Each report reviews the potential of a project centered on a defined geographic area, or landscape. Ideal Green Prosperity projects will be designed to improve the economic conditions of the people living in the identified landscape, integrating some combination of renewable energy, natural resources management, and sustainable land use activities. The eight studies are identified in the table below.

Note that two studies, centered on Rantau Suli village and Berbak National Park, are examples of integrated projects strongly linking renewable energy production, natural resources management and sustainable land use. The other six studies are also defined in a landscape context, but focus more on particular project types identified in the Compact. All of the project types explored in the series of eight model studies can be considered by project developers and sponsors for any landscape, and in any combination that makes sense in local context.

Each study includes a project description; technical analysis; economic assessment; environmental and land use impacts; and social implications. Other potential energy or land use activities are also often noted. The studies are intended to serve as examples for potential project sponsors, who may choose to propose something similar, or who may be inspired to propose some other innovative project. Further, the technical, economic, environmental/land use, and social discussions and analyses in these studies are intended to help guide the assessment of proposals submitted to MCA-I for Green Prosperity funding.

This report does not constitute an endorsement of the identified projects by anyone, and does not give the identified projects preferential status for funding. Additional detailed analysis of formal proposals would be needed prior to any investment decision.

[1] Additional information about the Millennium Challenge Corporation's Indonesia Compact is available at http://www.mcc.gov/pages/countries/program/indonesia-compact.

Table P-1. The Eight Model Green Prosperity Projects

Model Project	Kabupaten/Province	Emphasis
Rantau Suli Integrated Project	Merangin, Jambi	Mini-hydropower, with protection of forested catchment area
Berbak National Park Integrated Project	Muaro Jambi, Jambi	Forest protection and restoration, with off-grid solar photovoltaic power production
Methane Capture for Power Generation	Muaro Jambi, Jambi	Power production from methane captured from palm oil mill effluent
Cacao Intensification	Mamuju and Mamasa, Sulawesi Barat	Training to improve cacao yields, as an example of agricultural intensification
Karampuang Island Solar Photovoltaic Electricity	Mamuju, Sulawesi Barat	Solar photovoltaic power for an island, with project options including connection to the mainland grid
Grid-tied Mini-hydropower	Mamasa, Sulawesi Barat	Assessment of a larger mini-hydropower project
Community Agroforestry	Mamuju, Sulawesi Barat	Forest boundary protection through community-based peripheral agroforestry
Aggregated Micro-hydropower	Mamasa, Sulawesi Barat	Transaction/implementation cost reduction through aggregation of small projects

Executive Summary

This study evaluates electricity generation from the organic content of wastewater at a palm oil mill in Muaro Jambi, Sumatra. Green Prosperity has numerous criteria for projects including rural renewable energy generation and low carbon intensity. Electricity generation from palm oil mill effluent (POME) would provide grid-tied renewable electricity to nearby villages that currently depend on expensive diesel generation, and reduce greenhouse gas (GHG) emissions by converting a problematic waste into energy. It would indirectly meet Green Prosperity's goal of increasing Indonesians' incomes because this project would be expected to result in higher prices paid to local oil palm smallholders and lower electricity costs for area villagers.

Muaro Jambi is one of four Green Prosperity starter districts selected based on the potential to achieve significant reductions in poverty based on economic development opportunities, renewable energy potential, and environmental factors such as peat land degradation. The mill is located in rural northwest Muaro Jambi in the village of Bukit Baling where more than half of villagers are either oil palm or rubber smallholders. Bukit Baling has a population of approximately 8,000. Electricity supply in both the Bukit Baling settlements and all of Muaro Jambi is estimated at 70% grid and 30% diesel generation. The population living on diesel generation pays considerably more for electricity, negatively impacting monthly household income. The diesel generators could be replaced with renewable electricity if all three palm oil mills in the village captured methane and generated electricity.

Sumatra and the Muaro Jambi district dedicate significant land and labor to the production of palm oil. Smallholders have long supplied palm oil mills, and many obtained land through a Government of Indonesia (GOI) Transmigration project. This project provided two hectares each to families moving from overpopulated areas to more rural areas of Sumatra and other islands. Over the past 10 years, smallholders' contribution to oil palm land area and supply to mills has grown significantly compared to plantations. This is likely due to a change in GOI regulations that ended the requirement for mills to source fresh fruit bunches (FFB) from plantations, resulting in more mills and increased sales opportunities for smallholders. The mill evaluated in this study is interested in additional revenue from electricity sales to pay a premium to smallholders to encourage supply of FFB to their Muaro Jambi mills.

Many past studies have found positive economic impacts of electricity generation at palm oil mills, yet the income from electricity sales at palm oil mills is estimated to be only a tiny fraction compared to their crude palm oil (CPO) revenue. Mills tend to view grid-connected electricity sales as less risky than other alternatives, such as selling directly to villages, due to both the redundancy of power available on transmission lines and because they receive payment from Perusahaan Listrik Negara (PLN), the National Electricity Corporation of Indonesia. This allows mills to focus on food production and markets. Very few mills have invested in POME electricity due to a lack of familiarity with electricity sales compared with known rapid return of investment in palm plantations and mills, which is the business they know.

Who benefits from this project depends on what indicators are evaluated. If economics alone are considered, PLN would achieve the greatest benefit due to the avoidance of high generation costs while obtaining inexpensive renewable electricity. If only environmental benefits are evaluated, both the palm mill and the local communities would benefit from reductions of emissions and stabilization of POME, a problematic waste that negatively impacts land and downstream activities in its current state. The social assessment indicates the greatest benefits are afforded to villagers with the opportunity to access power more often for a lower price, which will enable them to consider developing small businesses near their homes.

Project Overview

This project evaluates the feasibility of generating electricity from POME at an average Indonesian palm oil mill. The data used in this study to determine costs and estimated electricity generation was based on average statistics from the evaluation of POME to electricity at numerous palm mills by the United States Agency for International Development (USAID) Capacity for Indonesian Reduction of Carbon in Land Use and Energy (CIRCLE) and Indonesia Clean Energy Programs Development (ICED) projects.

The CIRCLE program evaluated the feasibility of POME electricity at the PT. Bukit Barisan Indah Prima (BBIP) mill. The BBIP mill was used in this study as an illustration of a particular location, and to explore the economics associated with a mill's decision to generate electricity. None of BBIP mill's operational or financial data were used in this study; instead, representative Sumatra mill data were used in order to protect BBIP's proprietary information.

BBIP owns a plantation but relies on smallholders to supply FFB to both their Bukit Baling and nearby Batanghari Sawit Sejahtera mills. The mill is located in Bukit Baling, a village in an agricultural area of northwest Muaro Jambi. BBIP mill is interested in using electricity profits to pay a modest premium to independent smallholders to ensure their mills continue to operate at capacity. Villages surrounding the mill rely on diesel generation for electricity, and many of the population grow oil palm. Connecting nearby villages to the grid would reduce monthly household expenses.

For this type of project, in many instances a mill would enter into a special-purpose vehicle contractual agreement with an independent power producer (IPP) who would develop, own, and operate the POME electricity generation plant. The IPP would enter into a power purchase agreement with PLN at the biomass power rate for Sumatra, as specified in the Ministry of Energy and Mineral Resources (MEMR) Regulation No. 4/2012. An alternate business arrangement is for a mill to issue a request for proposal for a design, build, and construction and own the resulting electricity generation equipment. The example mill is located approximately 5 kilometers (km) from PLN's nearest transmission lines. In most instances, the project will pay for transmission line; in certain instances it is possible PLN could pay for the transmission line. This study assumes the project pays for transmission lines for grid connection. Several villages are along nearby paved roads and are in PLN's long-term plan for electrification.

To pursue this project type, palm oil mills would require technical assistance to determine the feasibility of electricity sales at their mills. It is important that mills work with contractors and IPPs, and purchase equipment with past successful experience converting POME into electricity. A project of this type will require several permits and licenses and must adhere to regulations. USAID estimates this project will take between 3 and 5 years to complete from the start of an initial assessment.

Technical Assessment

Palm oil is a significant economic driver in Indonesia providing income opportunities in rural areas. It is the world's leading vegetable oil in production and trade, and Indonesia is the top producer. Worldwide demand for vegetable oils has led to a continuous increase in oil palm plantation land area and palm oil production in Indonesia. The supply of FFB comes from large private plantations, smallholders, and state-owned plantations. Palm oil mills typically operate 6 days per week for 20 hours/day, and totaling 300 days/year. The CPO production process is water-intensive, resulting in large volumes of POME, a wastewater rich in organic content that can be converted to electricity.

POME is currently processed through a series of ponds to reduce environmental toxins and stabilize it prior to final release to land or water. This project would use a flexible membrane to cover an existing anaerobic pond to collect biogas—a combination of methane, carbon dioxide (CO_2), and trace amounts of other gases. The biogas will be cleaned up to remove impurities for use in a reciprocating gas engine to produce electricity and deliver it to the grid.

Methane capture for electricity generation is a result of a controlled biological process called anaerobic digestion (AD). AD is the natural biological degradation of organic matter without oxygen, resulting in biogas. Biogas from POME ranges from 56% to 64% methane and 35% to 41% CO_2, whereas natural gas typically contains more than 90% methane. Biogas is capable of operating in nearly all devices intended for natural gas with minimal adjustments to account for lower energy content. In western nations, AD is a mature technology with 30 years of experience in wastewater treatment plants. It is imperative to control AD process parameters to ensure optimal biogas production and electricity generation. The most important of these parameters are temperature, acidity, and organic loading rate (i.e., the rate at which POME enters the covered anaerobic pond). The benefits of AD include generation of revenue from a waste by-product, renewable energy generation, GHG emission reductions, and reduced water pollution.

Before biogas can be used to generate electricity, moisture and hydrogen sulfide (H_2S) must be removed. Then biogas enters gas engines to generate electricity. There are a few existing examples of this technology type in Indonesia. USAID's ICED organization reports that of more than 600 palm oil mills in the country, 25 are capturing methane and flaring for carbon credits in voluntary markets, but less than 10 are capturing biogas and generating electricity.[2]

Economic Assessment

For project funding or financing, the MCC Compact in Indonesia requires projects to demonstrate an increased income for Indonesians and an economic rate of return (ERR) of 10%. This project performs very well economically primarily because of PLN's avoided cost of generation, which is roughly three times what it would pay for electricity generated by the project. This means that the majority of the benefit is captured by PLN. Under reference case assumptions, the project ERR is 40.5% with a net present value (NPV) of Indonesia rupiah (IDR) 123 billion ($12.7 million USD).[3] This analysis is conducted assuming a loan is offered at 50% of total capital costs at a 4.5% nominal interest rate. The main economic risk for this project is that there is a relatively low return for all other stakeholders beside PLN. Because the IPP returns

[2] Data provided by ICED's Chief of Party.

[3] Conversion rate of IDR 9,700 per $1 (October 2012 rate).

are low, there is concern that there will be tight cash flow and exposure to external risk such as construction delays. The IPP's internal rate of return (IRR) is 3.9% real (8.1% nominal) under reference case assumptions, which is relatively low, even to incentivize a non-governmental organization or non-profit to participate in this project as designed.[4] The small return to the IPP also limits the amount that it can pay to the mill owner: 10% of revenue (NPV) of IDR 4.2 billion ($434,000 USD) in the reference case. Consequently, there is only a small share of the project's total NPV available to the mill's FFB suppliers, a target beneficiary of the project. Local electricity consumers are the other local beneficiaries of the project. These consumers benefit from avoided diesel cost and increased consumption, which total IDR 17 billion ($1.75 million USD) in NPV.

Table ES-1. Economic results

Economic Results	
Economic Rate of Return	40.50%
Net Present Value ($)	12,700,000
Net Present Value (IDR million)	123,000

The project's ERR is most sensitive to projections of PLN's avoided cost over the project lifetime because PLN's cost savings are the primary economic benefit. The reference assumption is that PLN's generation cost grows at a rate comparable to recent experience: 8.3% per year in nominal terms. Although the NPV is sensitive to that assumption, a nominal growth rate of 1.5% per year—less than inflation—still leads to a project ERR of 43.1%.

Alternative project design options could make this project more viable for the IPP and mill, and provide more benefit to smallholders. Offering a grant of 50% of capital costs has no impact on project ERR but increases the IPP's IRR to 13% (17% nominal), which could be distributed to the mill through lease payments and on to smallholders through FFB price premiums. A change to electricity policy that would allow an escalator to be negotiated in power purchase agreements (PPAs) would shelter the IPP's revenue from long-term inflation, reducing the IPP's exposure and the overall project risk. Including an escalator to the feed-in tariff (FiT) at the projected rate of long-term inflation would provide an IRR to the IPP of 15% (20% nominal).

With the exception of changing the loan to a grant, these changes are unlikely; therefore, the project reference case is designed to reflect the mostly likely conditions an IPP would face in this situation. Note also that if the price of Certified Emission Reduction (CER) credits rebounded in world markets, it could provide an additional source of revenue for the operator. Because forward prices of CER credits are very difficult to predict, they were excluded from this analysis. Assuming CER credit prices rebound to IDR 97,000 ($10 USD) per ton of carbon dioxide equivalent (CO_2e) and IDR 9.7 billion ($1,000,000 USD) certification and compliance costs, revenue for the IPP would significantly increase by approximately IDR 4.85 billion ($500,000 USD) per year and improve its real IRR.

[4] Unless otherwise noted, all percent returns are expressed in real terms. Real returns are adjusted for inflation while nominal returns are quoted in a given year's dollars.

Environmental and Spatial Land Use Assessment

This project poses more environmental risk by not doing it than by building it because POME electricity generation significantly reduces methane emissions at a palm mill. USAID estimates that methane emissions from POME in Indonesia are 16 million tons of CO_2e/year [1].

The potential GHG emissions reductions from this project are 39,006 tons of CO_2e. Methane emissions from POME can be reduced to nearly zero by covering the pond, capturing biogas, and converting it to electricity. The BBIP mill burns shells and fiber to supply steam and electricity needs, as do most mills in Indonesia, when the plant is operating. This is considered a carbon-neutral activity because both the shells and fiber are waste products from an FFB of oil palm and are continuously harvested.

This project is proposed at an existing palm oil mill and does not require any land acquisition. Land area for oil palm cultivation is expected to continue its upward trend in Jambi and throughout Indonesia due to world market demand for vegetable oils. Renewable electricity from POME is not expected to increase demand for oil palm land area because electricity generation equipment would be sized for the current capacity of a mill. If a mill with electricity generation from POME did expand, it would need significant capital to purchase additional biogas collection and electricity generation equipment, which would also result in significant downtime for the mill and the electricity generation plant.

The proposed project is less than 10 megawatts (MW) at an existing manufacturing facility with expectations of low environmental impacts. It is expected that an environmental management plan and an environmental monitoring plan (UKL-UPL) are required for this type of project to identify potential environmental risks and methods to mitigate and monitor them. The acceptance of a project's UKL-UPL coincides with receipt of an environmental license. Both of these are required prior to obtaining a business license.

Social Assessment

The Bukit Baling is populated by approximately 70% smallholders. The community is 75% migrants from Java and 25% local ethnic Melayu Jambi. Initially, migrant farmers planted rubber but over time, most of the settlements in the area of palm mills converted to oil palm to increase their household incomes. Division of labor on oil palm farms is fairly even between men and women. In addition to smallholders, the four palm oil companies operating in Bukit Baling are large employers with permanent and temporary positions at plantations and mills with daily pay IDR 57,000 for men and women. Other area income activities include rice paddy, duku, durian, and fishing/fish processing.

Bukit Baling is approximately 70% grid-connected; however, villages near the palm mill are on individual- or community-based diesel generator systems. Diesel systems are typically used from 6:00 a.m. to 6:00 p.m., limiting when women can perform household activities. The introduction of lower-cost PLN power in the area will provide electricity throughout the day, which will allow household activities to occur at various times of the day. The availability of PLN power will also enable local entrepreneurs to open businesses such as shops, restaurants, salons, and mechanic repair. These villages are unable to support roadside businesses with current diesel generation due to availability and cost and an inability to compete with grid-tied businesses within 15 km. A potential risk is the recent introduction of community diesel generator power in nearby settlements. Each household made a significant investment and may be reluctant to pay for a connection to PLN even though monthly electricity costs are expected to be significantly lower.

Palm mill premium payments to oil palm smallholders may lead to a slight increase in production of FFB. It is not clear how households may use this additional income because it is modest and will not enable a smallholder to purchase more land. This is expected on existing smallholder land as they typically harvest twice a month rather than three times a month, which is more common on plantations. This will further increase smallholders' yield and income. This project is not expected to increase FFB production because demand is driven by markets for the primary products crude palm oil and palm kernel oil and not far less profitable by-products of kernel shells and POME based electricity.

Project Risks

This project has two technical risks: limited past experience with this project type in Indonesia and risk of system shutdown due to operational issues. There are only ten POME-based electricity projects in Indonesia and none are connected to PLN, although several grid-connection projects were in development at the time of this report. This risk can be mitigated by using contractors and equipment who built existing facilities and visiting those sites to ensure there are no major operational issues. The more significant technical risk is system shutdown, which causes biogas production to stop. This is a known issue and can be mitigated by carefully controlling the flow of POME into the anaerobic pond and monitoring process parameters.

A potential financial risk to the project is that most of the value is captured by PLN while there are slim margins for other stakeholders. Both the mill and smallholders benefit from the project, but only marginally. Similarly, the IPP only receives a small financial benefit.

Some specific risks that are less likely but worth noting include policy or regulation risk that might impact IPP revenue. Also, changes to the mill production from changes to world market demand for palm oil may impact the IPP's methane supply from POME, thus impacting the IPP's ability to reliably meet its off-take obligations. Lastly, any one of the project proponents could opt out of the arrangement and thereby undermine the intended flow of benefit.

An additional risk is smallholders not receiving a premium. Independent smallholders do not enter into contractual arrangements with plantations or mills, allowing them flexibility to sell wherever they choose. Presumably, smallholders would sell through a local collector to an area mill able to offer a premium as a result of revenue from electricity sales. The payment of premiums to smallholders would need to be monitored regularly.

POME is a significant source of emissions in the palm oil process. Environmental risk is higher if nothing is done, because this project would significantly improve wastewater environmental issues at a palm oil mill.

Conclusions

Ideal biomass energy projects are those that generate a waste product onsite with energy potential, such as is the case with this proposed project. There are numerous benefits from POME electricity at palm mills, including electrification of rural areas, renewable electricity entering the grid, and reductions in emissions and POME processing wastes. Economics in this study indicate a modest return for an IPP, which may not achieve their corporate hurdle for investing in a project. However, geography may positively influence economic returns and investments in this type of electricity generation because PLN biogas rates for PPAs are higher on other provinces—such as Kalimantan, Maluku, West Nusa Tenggara, Papua, or Sulawesi—than on Sumatra. The projected revenues the mills receive would be small but would allow them to pay a premium to smallholders, whose income would increase a small amount. There is no guarantee that smallholders will receive higher prices as they are independent and have no formal agreements with mills, however, the BBIP mill profiled in this study currently pays a premium. Compared to the specific mill project studied in Mauro Jambi, the economics of other similar projects may be more attractive if the POME is richer in organic content, leading to greater electricity potential and/or if they are located where PLN biogas rates are higher.

This project type is more likely to benefit older or inefficiently run mills than new or efficient mills. A poorly operated or old mill is capable of producing more than the 1.25 MW used in the model; up to 2.5 MW is possible, resulting in economies of scale for the project. If a mill is new or highly efficient, it may produce less than 1.25 MW, making the project less feasible.

This project meets several of Green Prosperity's target goals by increasing income through modest FFB price premiums to smallholders, lower monthly energy costs for villagers, low-carbon project development, and renewable electricity generation in a rural area.

Table of Contents

List of Figures

List of Tables

1 Project Overview

1.1 Project Location and Natural Features

The project area is located by the northern boundary of Muaro Jambi approximately 40 kilometers (km) from Jambi City. The PT. Bukit Barisan Indah Prima (BBIP) mill is located at kilometer 46 on Jl. Lintas Timur in Bukit Baling village, Sekernan subdistrict, Muaro Jambi. The area is characterized by concentrated agricultural production of oil palm and rubber. There are many small settlements within the village boundaries, and the majority of the population is smallholders. The Batanghari River is to the south of the palm oil mill, and water used at the mill comes from a creek nearby. There are many paved roads in the area; however, the roads leading to the mill and within the plantation are unpaved. Figure 1 shows the area is agricultural with no natural or timber forests nearby.

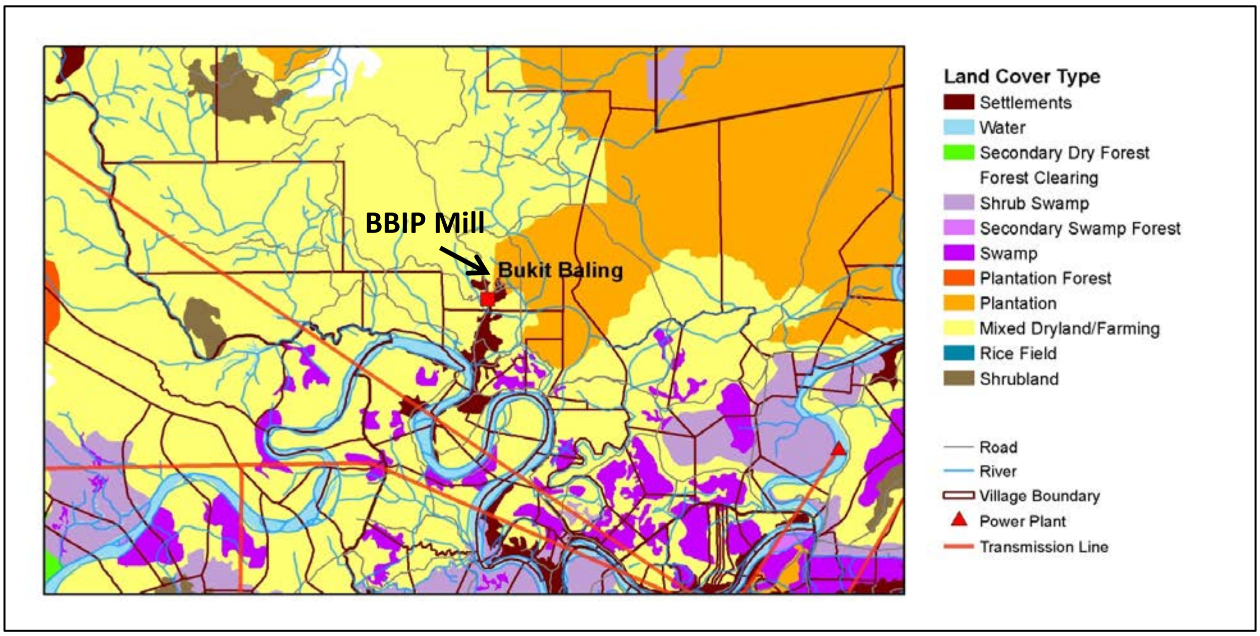


Figure 1. Muaro Jambi land type map

1.2 Current Population and Economic Activities

Bukit Baling has a population of 6,800 people living in 1,900 households across four subvillages and many settlements. In an interview in February 2013, the Village Chief, Mr. Saeroni, estimates that 50% to 70% of the population works in either palm or rubber, and the remainder works in other agricultural activities. He stated that they are trying to introduce cow husbandry into oil palm land to diversify income. There are plantations of 100–150 hectares in the area, but the owners tend to live in Medan or Jakarta. The local government sets the wage for day laborers in the village at IDR 1.3 million/month for 25 days of work. The rate is the same for men and women. BBIP mill stated that the average revenues for an oil palm smallholders are IDR 300 million/year, on which they pay no or minimal taxes.

Mr. Saeroni stated that approximately 3,000 people are not connected to the grid as well as several schools (see Appendix D). There are three palm oil mills located in the village and if all of them captured methane and generated electricity, they could displace diesel generators. PLN is also interested in replacing a Pusat Listrik Tenaga Diesel plant nearby in Tajung Jabung Timur.

There are four settlements surrounding the mill that use diesel generators. The Bukit Baling settlements closest to the BBIP mill include Awin Jaya (Sekernan), Bukit Aempurung, Simpang Kiri, and Jungai Toman. Additionally, Bukit Baling is nearby with both diesel based and PLN power depending on the location. PLN plans to bring transmission lines to the latter three, but the timeline is unknown. A typical household uses electricity for refrigeration, cooking rice, running fans, watching television, charging phones, and lighting. The Muaro Jambi district government office of energy stated that a 900-Watt (W) connection to the grid costs households IDR 75,000/month, whereas households relying on diesel generators pay an average of IDR 400,000/month. There is a one-time fee of IDR 970,000 to connect a household to PLN transmission lines. Households, both on- and off-grid, use liquefied petroleum gas for cooking purposes at a cost of IDR 20,000 for 3 kilograms.

The village chief stated that land values increase when a property is connected to the grid, which is important to villagers. He also said that many small businesses—such as beauty salons, mechanic shops, and restaurants—would open as a result of grid connection. Bukit Baling has not yet succeeded in attracting potential large new businesses that have been interested in the area, including a rubber plant and large-scale chicken farms, due to a lack of grid-connected power.

The BBIP mill employs 105 staff, all of which live onsite. Of these staff, 11 are women who manage and run the laboratory and work in the front office.

1.3 Project Description and Rationale

This report evaluates the feasibility of generating electricity from wastes at an existing palm oil mill. According to the United States Agency for International Development (USAID), there are 686 licensed palm oil mills in Indonesia, each of which emits biogas, a mix of methane and carbon dioxide (CO_2), both potent greenhouse gases (GHGs) and other trace gases including hydrogen sulfide which must be removed prior to electricity generation.[5,6] POME is moved through a series of open-air ponds to reduce its organic content prior to being applied to land or water. The emissions coming off these open ponds are significant, and there are strong odors in this area of the mill. The biogas can be captured by covering an existing POME pond with a flexible membrane cover. Then the biogas is cleaned up to remove impurities and combusted to create renewable electricity. Converting POME into electricity reduces odor and results in less solids and liquids (digestate) than the current POME process because covering the pond accelerates the conversion of solids and liquids into biogas resulting in less digestate. The stabilized remaining liquids and solids after biogas capture result in fewer risks to land and water contamination than the current process.

[5] Methane is more efficient at trapping radiation than carbon dioxide. Pound for pound, the comparative impact of CH_4 on climate change is over 20 times greater than CO_2 over a 100-year period. (http://epa.gov/climatechange/ghgemissions/gases/ch4.html)

[6] Personal communication from Bill Meade Chief of Party for the USAID Indonesia Clean Energy Development (ICED) project on 6/21/2013.

This study is based on BBIP's mill in Bukit Baling but uses published statistics for electricity generation estimates rather than confidential mill data. A previous assessment by Winrock International under USAID's Capacity for Indonesian Reduction of Carbon in Land Use and Energy (CIRCLE) program established that BBIP mill met a long list of sustainability criteria, which is why this mill was selected for this study.

Since representatives of NREL visited in February 2013, the mill has entered into a special purpose vehicle with an IPP for development of electricity generation from POME. BBIP intends to use additional revenue from electricity sales to pay a premium to smallholders because the majority of FFB at their two Muaro Jambi mills are sourced from smallholders. This would increase the incomes of area smallholders who sell to the plant. These farmers are not expected to enter into a formal agreement with the plant because they have expressed the desire to remain independent, allowing them the flexibility to sell to whichever mill they prefer. However, a price premium at a nearby mill would certainly be considered.

BBIP and other mills evaluated under the CIRCLE program have only expressed interest in grid-connected projects as opposed to providing electricity to others through an isolated grid. The mill is focused on crude palm oil production, and there may be times when a mill needs to stop operations to replace machinery or for other routine maintenance. Mills prefer the redundancy of the grid and do not want to be the sole suppliers of electricity generation in an area. It was suggested during various meetings in Jambi that palm oil mills do not have the legal authority to accept payments from area villages for power if they were to set up an isolated grid. However, the establishment of a license to deliver electricity for public use states that an IPP may sell to PLN or use electricity onsite. An IPP in areas not served by PLN can sell to the regional government, to local government if the government is licensed for electricity sales, or to end users at government feed-in tariff (FiT) rates where the IPP builds transmission and distribution lines. BBIP's mill is in an area where PLN is expanding and plans to grid-connect villages nearby. Government regulation states that PLN has first-right-of-refusal for IPPs operating in PLN territory. Therefore, BBIP may only use the electricity at the mill or sell it to PLN.

An alternative option for this project—evaluated by numerous past studies—is where a mill uses the captured biogas in its existing biomass boilers to power the mill and then sell off the shells that are currently used to generated process steam and electricity. While this may financially benefit the mill, it does not meet the goals of Green Prosperity because it would do little to nothing to increase incomes of area villagers.

Communities, on average, pay approximately five times more for diesel-generator-based power than grid electricity. Grid connection also increases the value of land along a paved road. Muaro Jambi's grid power is almost entirely supplied by natural gas with a new 104-megawatts (MW) plant under construction.

1.4 Project Logic

In an international development context, a project logic visually displays an impact analysis. It is designed to link project interventions with intermediate outputs, longer-term outcomes and overall project goals. In this project logic, we examine the impacts the project will have on Green Prosperity goals of poverty and GHG emission reduction through rural electrification of households and avoided POME emissions. At the prefeasibility stage of project assessment, the project logic is less detailed than a fully-developed project logic. As the project is developed further and becomes more defined, additional information that characterizes individual relationships in a quantitative and qualitative way can be added and serve as a guide for monitoring and evaluation activities. Where assumptions and risks deserve mention or require explanation, notes have been added as clarification (see list below). The project logic for this project is shown in Figure 2.

1. **Assumption:** Generating system built according to design plans and is able to secure all relevant approvals and permits to operate
2. **Risk:** Project performance and return depends on the generating system IPP's ability to negotiate an offtake agreement with PLN
3. **Assumption/Risk:** Mill is paid site lease and transfers this payment through to smallholders in the form of price premiums
4. **Assumption:** PLN displaces costly and carbon intensive generating assets
5. **Assumption:** Incremental electricity supply enables increased consumption which increases consumer surplus
6. **Assumption:** As a result of additional power supply, consumers no longer consume diesel power
7. **Assumption:** There is sufficient new power supply to avoid kerosene lighting and enable new household activities at night, including additional studying for children
8. **Assumption**: Improved lighting in the home facilitates additional studying after dark for students
9. **Assumption**: Improved access to cheaper electricity will facilitate economic activity for households and small businesses (needs further research)

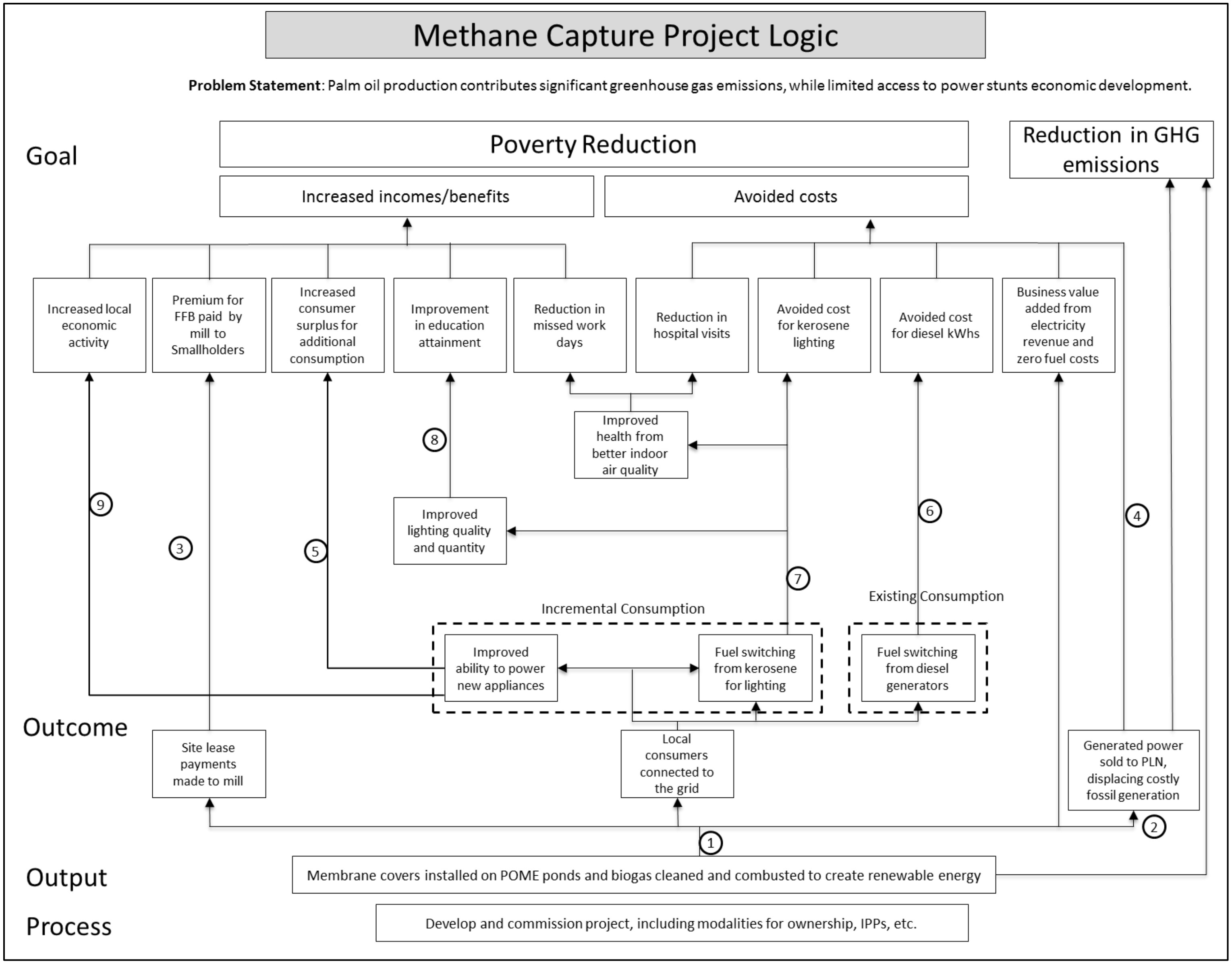


Figure 2. Methane capture project logic

1.5 Offtake or Market Plan

Depending on the business structure, either the mill or an IPP would enter into a PPA with PLN. Indonesia's Ministry of Energy and Mineral Resources (MEMR) allows an IPP to enter directly into a PPA with PLN through a defined process under Regulation No. 14/2012. Power purchase prices are determined on FiTs based on location and type of energy generation as defined in MEMR Regulation No. 4/2012. It is possible to negotiate a higher price at the start of the project to levelize costs; however, overall payments cannot exceed the FiT rates over the life of the project. The process involves multiple reviews and due diligence by a PLN Unit, Central PLN, and MEMR with the maximum time to obtain a PPA set at 240 days. The PPA would establish payment and period of performance between 15 and 30 years. A USAID diagram on the PPA process for plants under 10 MW is available in Appendix A.

The PPA would include an agreement to construct a power plant at a specific capacity and to maintain availability of the power. There is no penalty if these specific requirements are not met. A PPA would be established prior to financing the power plant. PLN will not sign a PPA until 10% of projects costs are in a bank account and a letter is received stating capability to provide equity; a project has 1 year to obtain financing after the PPA is signed. The project must obtain all permits and licenses within 1 year after establishing the PPA. A PPA requires that construction of the plant be completed within 2 years of obtaining financing. The project must have an insurer approved by PLN to cover equipment, construction, as well as construction and operational staff.

PLN's responsibilities under a PPA include reliability of the grid network and purchase of the electricity generated at the palm oil mill. The transaction point is where the project ties into the grid, at approximately 5 km. A meter would be installed to measure electricity delivered.

1.6 Business Case and Financial Structure

Biomass energy projects generally experience greater financial stability when the feedstock is generated onsite. There is a long history of lumber mills successfully using wood wastes in biomass boilers to provide energy for processing. With POME generated at the mill, the supply of feedstock will be available throughout the year. The electricity generation potential of a specific palm oil mill will be determined based on POME samples taken at the specific mill. It is imperative to select contractors and equipment with experience on biogas collection and electricity generation at palm oil mills. Some manufacturers specifically design equipment capable of operating with biogas, which has lower energy content than natural gas. Project risk is reduced when using experienced contractors and equipment for a specific project type.

There are several potential business arrangements for POME-based electricity:

1. The mill could issue a request for proposal (RFP) for a design/build firm to construct the electricity project and take ownership of the project after construction.
2. The mill could enter into a special purpose vehicle with an IPP who will develop, own, and operate the methane capture and electricity generation. This includes the potential for the IPP to transfer/sell ownership to the plant after 10–15 years.

3. A combination of the first two options is possible. The mill could enter into a special purpose vehicle with an IPP where each party owns and operates portions of the project and generates income from different revenue streams:
    - The mill would own the electricity genset and generate income from the sale of electricity.
    - The IPP would build and operate the biogas-capture portion of the project and derive income through a clean development mechanism by offsetting emissions and selling Certified Emission Reduction (CER) credits on voluntary exchanges.[7]
4. Bundled projects where an IPP combines several projects together or a joint venture with companies owning several palm oil mills.

The BBIP mill has entered into a special purpose vehicle with an IPP to develop, own, and operate the entire electricity generation project. The IPP, typically a for-profit company, will share profits of electricity sales with the mill. NREL met with a private third-party engaged in this business who stated that the profit-sharing arrangement between an IPP and mill varies with each project. The special purpose vehicle will guarantee supply of POME (volume for a specific period of performance), allow the third-party to lease land at the mill (there may be no cost), and establish profit sharing.

BBIP intends to use its share of profits from electricity sales to pay a premium to smallholders to ensure supply of FFB to its Muaro Jambi mills. BBIP obtains well over half of its FFBs from smallholders and wants to encourage smallholders to sell to their mills with the price premium. Carbon credits sold to voluntary markets are a potential additional revenue stream. They were not included in the financial analysis because the price is currently too low to warrant costs to establish compliance. USAID's Indonesia Renewable Energy Toolkit suggests it takes 3–5 years from the start of a biomass energy project until commissioning. Electricity generation is expected to last at least 20 years, which is achievable with periodic maintenance of both the palm oil mill and electricity genset.

1.7 Project Team

At least 80 palm oil mills have had a pre-feasibility study on POME electricity generation and therefore have some familiarity with this project type. It is anticipated that most mills would require technical assistance to develop a project through an RFP and selection of a contractor and/or IPP owner operator. A palm oil mill would need to decide if it wants an IPP to own and operate the electricity generation or if it wants a company to build the system and transfer ownership to the mill.

For technical assistance, the palm oil mill should select an entity, such as a consulting firm with strong experience in biogas projects, particularly a business that has brought biogas projects to completion. Experience in other renewable energy technologies is not considered sufficient due to the complex nature of bioenergy projects. The mill should work with the technical assistance provider to develop a clear statement of work and assign tasks and staff as well as a timetable. This will help minimize time requirements of mill staff. It is important that the selected business

[7] CERs are currently too low to overcome establishment and transaction costs.

have sufficient staff with relevant experience and time available to complete the project. Indonesian businesses or those with long-term established offices in Indonesia are more likely to have deeper knowledge of environmental and social issues.

If a mill decides to engage an IPP as BBIP mill has, there are a limited number of corporations offering this service. The mill should select an IPP with operational biogas plants, and mill staff members should visit at least one of their existing sites. The IPP will likely have suppliers that it uses for the flexible membrane cover, genset, and contractors to build the system. The mill should evaluate the financial health of the IPP as well as its timeline and other projects under development to ensure that staff is capable of delivering the project on time. The staff will likely include a main office with engineers, financial analysts, and project managers. The IPP will employ and train local staff to operate the electricity generation plant.

If the palm oil mill decides to own and operate the plant, it would issue an RFP for a construction contract. The proposals should include all costs for equipment and building the project. The mill should focus on proposals from qualified contractors that have previous experience building operational biogas plants. It is anticipated that there are few businesses with this type of experience. If the project is financed with a bank, there would likely be requirements for the selection of an experienced contractor and quarterly reviews of construction progress. The mill should evaluate the proposer's past projects and its ability to build projects on time and on budget. A mill should carefully consider generation engines and only consider those commercially used with biogas and warrantied for its use. Some engines may cost more initially but last longer and require less maintenance.

It is typical to engage a lawyer to ensure all codes and regulations are being followed. Most mill companies would have a lawyer; however, they might consider engaging a lawyer with specific experience in palm oil mill methane capture projects.

The team should also include an organization to train smallholders in sustainable oil palm production which can improve yield and increase income. BBIP owns two mills in Muaro Jambi, and the BBIP and BSS mills currently obtain 50% and 80% respectively of their FFB from smallholders. Smallholder training on optimal harvesting techniques would be a helpful complement to the energy generation component of this project.

1.8 Project Site

The area is an industrial mill site located on a large site with excess land. BBIP's small palm plantation is adjacent to the mill. The facility is surrounded by a fence, and a security team controls access to the mill. Nearly all steam and power for the palm oil mill and employees living onsite is generated by biomass boilers from shells and fiber left over from the production of crude palm oil (CPO) and crude palm kernel oil (CPKO). Since the mill does not operate on Sundays, a diesel generator is used to supply electricity to the palm oil mill office and employee housing.

The road leading up to the mill is not paved and passes through smallholder lands and the mill-owned plantation. It is a short distance to a paved road, which links the mill with Jambi city. The mill obtains process water from a nearby creek. The POME is currently treated through a series of large ponds (also known as lagoons), including two each of cooling ponds, anaerobic ponds, and aerobic ponds. The ponds take up considerably more space than the CPO processing area.

It is anticipated that the electricity genset will be installed in the palm oil mill's existing engine rooms adjacent to existing biomass boilers. At mills where there is not space in the engine room, a small building would be built nearby to house the genset.

PLN's nearest grid line is approximately 5 km away across the palm oil mill's plantation. The grid is 20 km away if traveling out of the mill and onto paved roads. The grid line looks like it was recently built and is a 20-kilovolt (kV) line.[8] The plantation road may require a bit of upgrading prior to adding utility poles and transmission lines.

1.9 Permits and Licenses

Permits and licenses needed to install electricity generation equipment at an existing palm oil mill are expected to be less of a barrier than for stand-alone renewable energy generation plants. The palm oil mill would already have an existing license from the Indonesia Ministry of Agriculture. The water needed for the electricity generation process is minimal, and the mill or IPP should determine whether or not there are any issues with water permits. No additional land would be needed for this project because it would involve using an existing pond and installing equipment in the mill's engine room. However, at other mills, it may be necessary to build a small enclosure on mill land to house the equipment. This project would not be subject to any forestry regulations because it is entirely within an agricultural area.

An environment review will be required per Upaya Pengelolaan Lingkungan / Upaya Pemantauan Lingkungan, UKL/UPL under Law No. 23/1997, Government Regulation No. 27/212, and Ministry of Environment Decrees No. 40/200, No. 17/2001, and No. 86/2002. The project must apply to MEMR for an electricity supply business permit, which is required for electricity generation for public use. It is possible the regional government would require permits or licenses.

1.10 Project Implementation Plan

Pre-construction activities would include development of process design, electrical and civil engineering plans, financing, and establishing a PPA with PLN. The first stage of the construction process will likely involve upgrading the existing anaerobic pond to prepare for attachment of the flexible membrane cover. It may be necessary to construct a small room to house the scrubber and genset if the palm oil mill does not have space in its existing engine room. Major equipment required for the project includes:

- Flexible membrane cover (for existing anaerobic pond)
- Scrubber (to remove hydrogen sulfide and other impurities in biogas)
- Chiller (to remove water/moisture from biogas)
- Flare (to release any excess biogas)

[8] Winrock International and NREL staff observed the transmission line nearest the mill. The poles appeared new with no weathering.

- Genset (engines and associated equipment to generate electricity)
- System control equipment (to monitor all process parameters)
- Clean Development Mechanism (CDM) instrumentation (if selling carbon credits)
- Transmission lines (to connect to grid)
- Miscellaneous equipment including pipes, pumps, electrical wiring

There are a multitude of tasks from an initial assessment of an IPP until it is in operation. USAID suggests it can take 3–5 years from the start of a project until commercial operations begin. A project may include a pre-feasibility study or some type of initial assessment. If it is decided to proceed with a project, it is usually necessary to conduct a full feasibility study to determine the likely success of a project and to meet requirements for permits and licenses. Palm oil mill owners and operators are not typically familiar with biogas and electricity generation. If they intend to own the genset, they would engage a technical assistance consultant to bring them to a point of requesting bids for construction. Otherwise they will enter into a special purpose vehicle with an IPP to develop and own the project. The timeline for selecting a technical assistance company or third party can take a few months or more than a year based on conversations with companies providing these services in Indonesia. Some activities, such as the PPA and funding/financing, may occur simultaneously. Construction timelines will vary widely depending on upgrades needed to the existing anaerobic pond and if any new buildings are necessary. After construction, there is a minimal amount of time for startup, testing, and commissioning prior to selling electricity to PLN.

Table 1. Estimated Timeline to Develop a Biogas Project at a Palm Oil Mill

Activity	Estimated Timeline
Pre-Feasibility Study	6 months
Full Feasibility Study and Engineering Design	6 months to 1 year
Selection of Technical Assistance to Develop a RFP *or* Selection of a Third Party	3 months to 1 year
PPA with PLN	7–8 months
Funding and Financing	Indeterminate (must be done within 1 year of PPA)
Construction	9 months to 1.5 years (must be done within 2 years of PPA)
Testing and Commissioning	1 month
Commercial Operation Date	3–5 years from start of project

Source: NREL meetings with Indonesian biogas technical assistance providers and "Renewable Energy Toolkit." Second Edition. USAID ICED Project. November 27, 2012.

2 Technical Assessment

2.1 Technical Approach

This study reviews the process of generating electricity from POME-wastewater generated by the production of CPO. The project will attach a flexible membrane cover over an existing anaerobic pond to collect biogas (a combination of methane, carbon dioxide and trace amounts of other gasses including hydrogen sulfide). The biogas will be cleaned up to remove impurities for use in a reciprocating gas engine to produce electricity to supply PLN's grid (Figure 3).

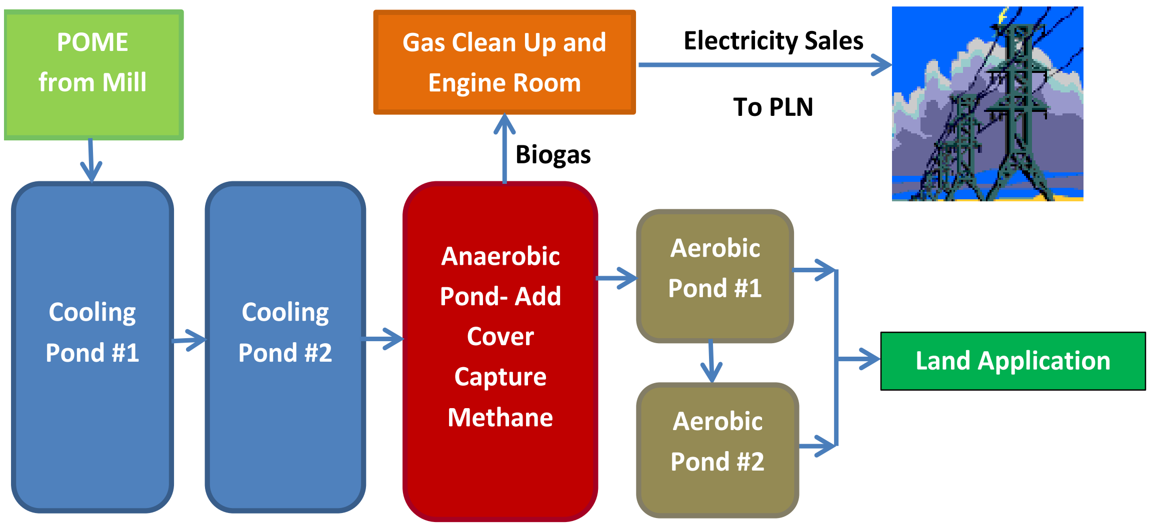


Figure 3. Project schematic

Source: Illustration by Kristi Moriarty, NREL

Methane is a potent GHG that traps radiation at a greater rate than CO_2. Indonesia is the seventh largest emitter of methane in the world, with 85 million tons of CO_2e emitted in 2010 [2]. Indonesia is a member of The Global Methane Initiative, a voluntary partnership led by the U.S. Environmental Protection Agency (EPA) to reduce global methane emissions. While rice is the largest source of methane emissions in Indonesia, POME is also a major source [2].

Methane capture for electricity generation is a result of a controlled biological process called anaerobic digestion (AD). AD is the natural biological degradation of organic matter without oxygen resulting in biogas. Biogas from POME ranges from 56%–64% methane and 35%–41% CO_2 and other trace gasses including hydrogen sulfide [3]. Biogas is capable of operating in nearly all devices intended for natural gas with minimal adjustments to account for lower energy content. In western nations, AD is a mature technology with 30 years of experience in wastewater treatment plants. It is also used as a method for livestock manure treatment. The benefits of AD combined with capturing the biogas include revenue from a waste by-product, renewable energy generation, GHG emission reductions, and reduced water pollution.

There are several potential usage options for biogas (Figure 4). Common applications include heat, power, or combined heat and power. In some instances, biogas is upgraded and compressed for use as a transportation fuel in medium and heavy-duty vehicles. Biogas is typically used to power a microturbine or reciprocating engine. Combustion and steam turbines are only used in very large multi-MW systems. A small portion of generated biogas is required to provide energy to the AD process and machinery associated with generating electricity.

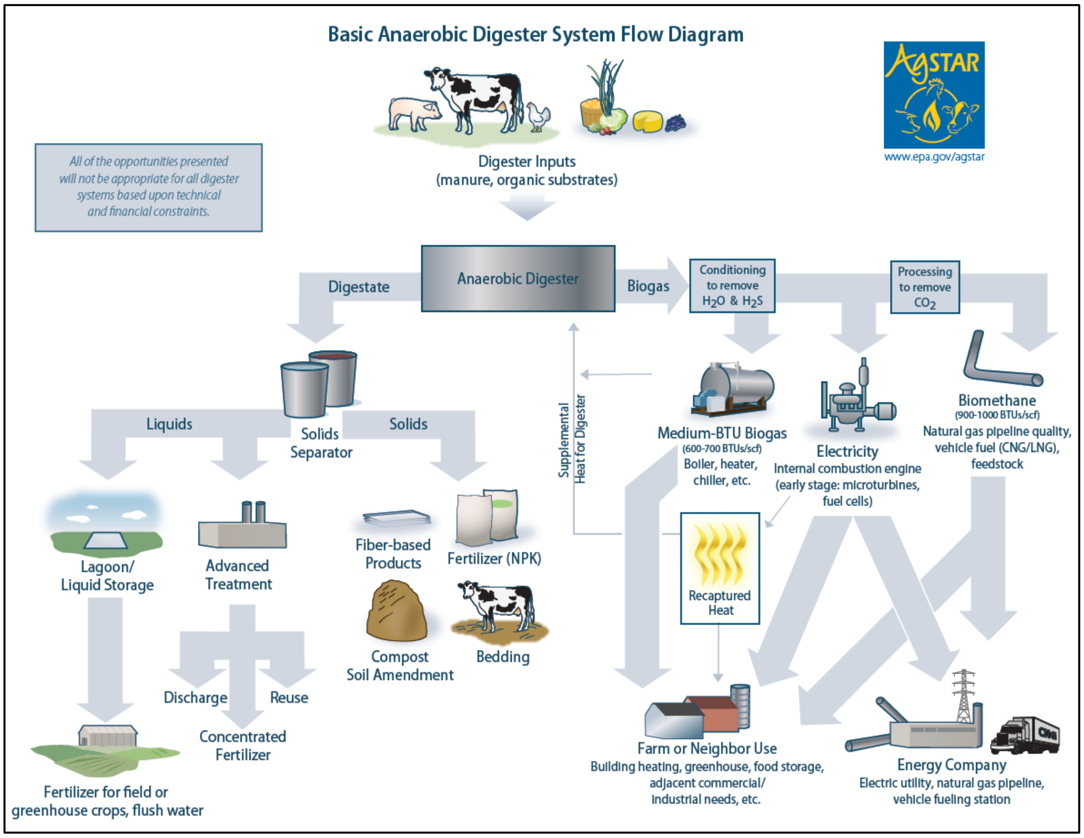


Figure 4. EPA AgSTAR anaerobic digestion uses diagram

Source: Illustration from EPA AgSTAR Program

2.1.1 Technical Information

The AD degradation and conversion process occurs in four stages with different classes of bacteria responsible for each step. Figure 5 illustrates the bacterial process where the first two stages are facultative (operational with and without oxygen) and the latter two are strictly anaerobic. It is essential to operate within defined parameters to optimize biogas production.

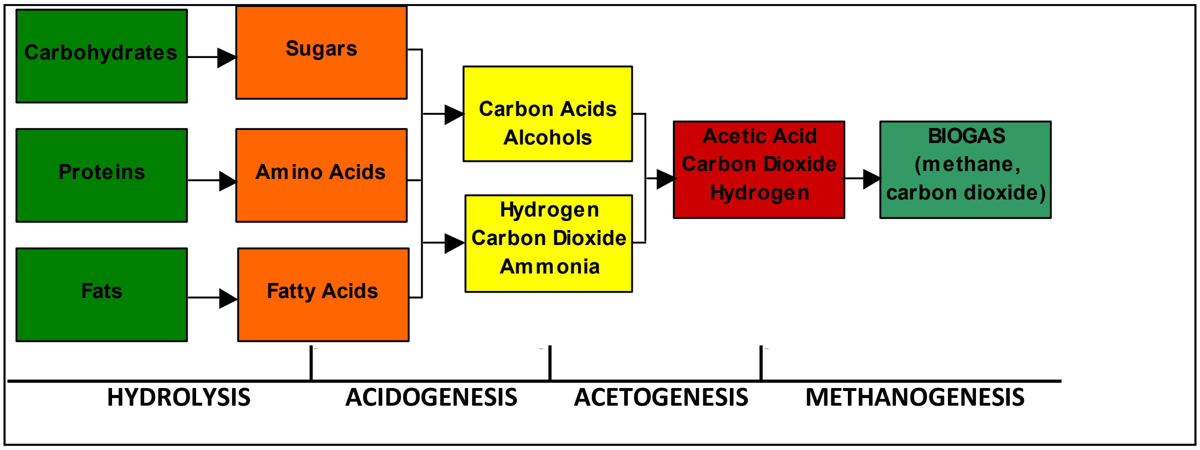


Figure 5. Anaerobic digestion process

Source: Illustration by Kristi Moriarty, NREL

AD technologies are optimized for either low solids or high solids content and an operational temperature range. Indonesia's warm climate, combined with existing anaerobic ponds at palm oil mills, provides an opportunity for a low-cost technology option of covering the pond with a flexible membrane cover to capture biogas. The flare allows combusted biogas to be released to the atmosphere if the genset is down for maintenance or if biogas production exceeds capacity of the genset. It is expected that the generation equipment will be co-located with the palm oil mill's existing biomass boilers if space permits; otherwise, it would be housed nearby in a small, dedicated building.

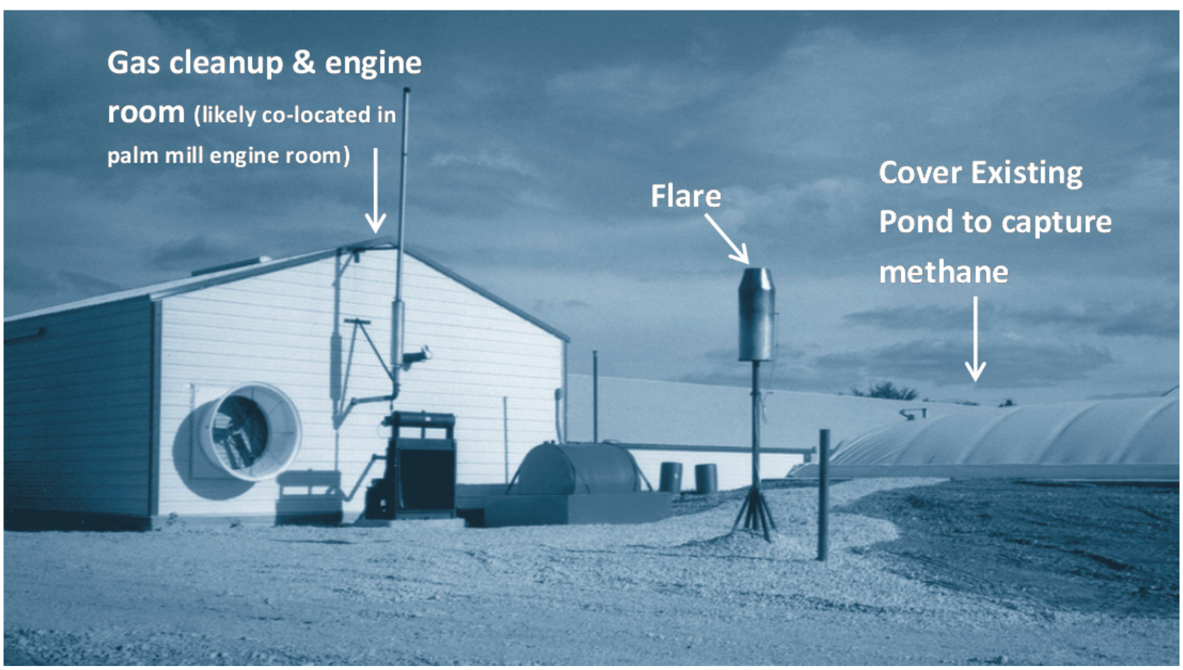


Figure 6. Example of covered pond methane capture

Source: "Managing Manure with Biogas Recovery System." EPA AgStar Program. Winter 2002.

Figure 7. Anaerobic pond at a palm oil mill

Source: Photo by Kristi Moriarty, NREL

Another option deployed at some palm oil mills are complete-mix digesters consisting of a large above-ground steel or concrete reactor. They are a very common type of AD system often used in waste-water treatment facilities in western nations (Figure 8). Waste is mechanically mixed, keeping microbes and volatile solids in suspension and providing good contact and efficient biogas production. Complete mix AD systems are far more costly to build but generally result in more biogas and therefore more electricity generation. A private owner/operator of biogas plants at palm oil mills in Indonesia stated that concrete reactors are rarely used due to rural location of mills and believes it is more difficult to operate this type of system remotely.

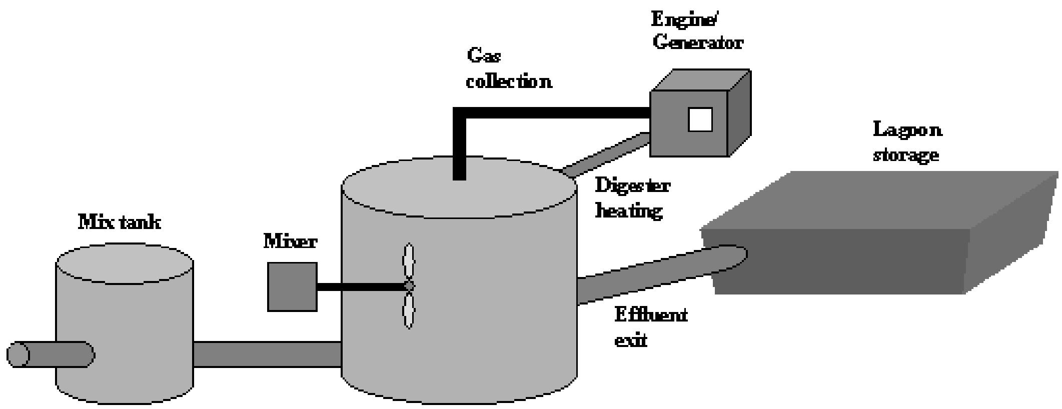


Figure 8. Complete mix AD schematic

Source: Illustration from EPA AgSTAR [4]

2.1.2 Digester Parameters

Temperature is essential to maintaining a steady state for continuous biogas production. Temperatures must be maintained in order for microbes to operate and convert the POME into biogas. The covered pond AD system will operate in the mesophilic temperature range between 35°C and 41°C. Temperature must be constantly monitored as a temperature reading outside the operational range will reduce or stop biogas and electricity production. A temperature falling outside the acceptable range will indicate that the IPP or mill needs to conduct immediate maintenance to determine and fix the problem.

Residence time is the length of time for complete degradation of POME in the AD system. It is a function of POME characteristics, temperature, process system, and pond size. Residence time for a membrane-covered pond ranges from 15–30 days. Engineering design will determine the optimal residence time based on POME sampling and volume of the anaerobic pond.

Organic loading rate (OLR) is the rate at which volatile solids are added to an AD system. It is calculated by dividing pounds of volatile solids added to the anaerobic pond daily by the pond volume. It is essential to standardize the OLR of volatile solids (approximately 84% of total solids, an average of 31,170 milligrams per liter [mg/L]) into a digester to optimize methane production and minimize risk of a system shutdown. This is the most important parameter to control because it most often leads to AD system failure. Overloading the anaerobic pond with POME will send the AD system into shock and lead to reduced or discontinued biogas production. The flow rate of POME from the cooling pond into the anaerobic pond would be regulated by a control system.

Retention time refers to the average time microbes are in the digester. Methanogens grow slower than other bacteria in an AD system. Operating parameters must be changed slowly to maintain methanogen populations and continue biogas production. Overloading volatile solids may result in high levels of ammonia, which are toxic to methanogens.

Table 2. Anaerobic Digestion Operating Parameters

Parameter	Range	Information
Temperature	35–41°Celsius	The higher end of the range is ideal for maximum biogas production
pH	6.5–7.5 pH	Ideal pH is natural at 7.0. Self-regulating by anaerobic microbes; methanogens unlikely to grow with a pH less than 6.5
Alkalinity	1,092 mg/L	Alkalinity is self-regulating by hydrogen in waste converting to bicarbonate
Acidity to Alkalinity Ratio	0.3 to 0.5	This ratio is easier to measure than volatile fatty acids or alkalinity
Volatile Fatty Acids	<106.81mg/L	Higher concentrations will inhibit acetate and biogas production
Carbon to Nitrogen Ratio	20 to 30	Higher carbon to nitrogen ratios result in methanogens consuming nitrogen, which lowers biogas production
Organic Loading Rate	3–5 kg of volatile solids/m^3 of digester volume per day	Microbes are generally inhibited if loading rate exceeds 6.4 kg/m^3 day
Residence Time	9–95 days	Varies widely based on feedstock, temperature, and system design

Source: Loughborough University Biomass Course [5] and EPA Region 2 NorthEast Biogas Presentation [6]

2.1.3 AD Process Co-Products

The AD process reduces biological oxygen demand (BOD) and chemical oxygen demand (COD) by 90%.[9] This will help a palm oil mill to meet government regulations to apply the liquids and solids remaining after biogas capture to the land or water. The AD process produces a by-product commonly referred to as digestate. Digestate consists of biosolids (30%) and liquids (70%) and is usually applied to agricultural lands as a low-grade fertilizer [7]. The digestate will enter the palm oil mill's existing aerobic ponds for further processing before it is applied to land as a soil conditioner or released water. Typical properties of digestate are shown in Table 3.

[9] BOD refers to how quickly a substance uses up oxygen in a body of water. COD is a measure of organic compounds in a substance. Both BOD and COD are very high in POME, which is why they must be treated before they are land- or water-applied. The AD process significantly reduces oxygen demand of POME, which makes it less toxic to apply to land or water after it has been processed.

Table 3. Digestate Characteristics

Parameter	Digestate Content
Total Solids	6%
Volatile Solids	69%
pH	7.6–8.8
Carbon to Nitrogen Ratio	1.5:1
Nitrogen	15%
Potassium	4.70%
Phosphorus	0.70%
Calcium	0.34%
Sulfur	0.30%
Magnesium	0.19%

Source: "New Markets for Digestate from Anaerobic Digestion." WRAP. ISS001-001. August 2011.

2.1.4 Processing Biogas and Generating Electricity

Before biogas can be used to generate electricity, moisture and hydrogen sulfide (H_2S) must be removed. These contaminants are corrosive to equipment, and electricity generation engines operate within defined parameters that require cleanup of biogas. H_2S is removed by either precipitation, adsorption of activated carbon, biological treatment, or chemical absorption. If sulfur content is high, iron may be added to the anaerobic pond to remove sulfur with the digestate. Moisture can be removed by several methods including cooling, pressure, absorption, and adsorption. If water and H_2S are not properly removed, they combine to form sulfuric acid, which is highly corrosive. The biogas then enters a reciprocating gas engine where it burns in the engine cylinders and drives a crank shaft that propels an alternator resulting in electricity. Heat from combustion is either recovered and used or released through radiators. It is important to only use equipment designed for use with biogas since it has less methane than natural gas.

There are several manufacturers offering products designed to operate with biogas. GE Energy's Jenbacher genset appears to be the leader in Indonesia with 28 engines operating at biogas plants with 30 MW of capacity (Figure 9) [8]. Other companies offering biogas gensets include Caterpillar, Guascor, MAN, and MWM. All of these companies are known to have experience in landfill gas, which is similar to biogas. There are likely other manufacturers offering gensets for use with biogas.

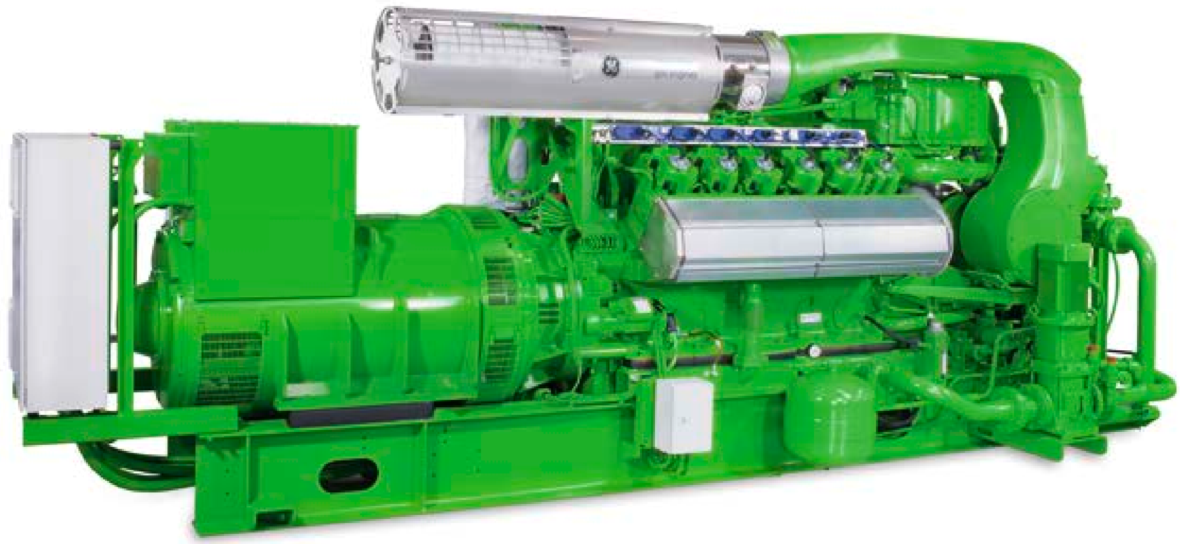


Figure 9. Photo of biogas genset

Source: Photo provided by GE Energy

2.1.5 Existing Systems and Costs

USAID's Indonesia Clean Energy Development (ICED) organization reports that there are currently 686 palm oil mills licensed by the Indonesia Ministry of Agriculture.[10] Less than 25 are capturing and flaring biogas as a clean development mechanism. These systems are paid for by sales of CERs in voluntary markets. Fewer than ten mills are capturing biogas and generating electricity. These mills are using the electricity for internal consumption at the palm oil mill. No mills are selling electricity to PLN; however, several grid-tied projects are under development.

ICED reports the cost of a biogas system to be IDR 24,153/W installed [9]. This cost includes engineering, construction, equipment, and contingency costs. This is an average cost and project bids may be higher or lower based on equipment and contractor selected for the project. The most expensive equipment is usually the electricity genset followed by the upgrading of the anaerobic pond, and the flexible membrane cover. Other costs are incurred for a scrubber and dewater unit to prepare biogas for electricity generation as well as a flare to release biogas during maintenance time for the genset. There are also costs for transmission lines as well as electrical and civil work. Genset engines typically require an overhaul every 8 years. The IDR 24,153 figure is higher than some information discussed by NREL with technology providers, but this allows for a conservative estimate in the economic model.

2.2 Resource Assessment

2.2.1 Palm Oil Statistics

Palm oil is an important economic driver in Indonesia that provides income opportunities in rural areas. Worldwide demand for vegetable oils and fats has grown with the world population. Palm oil is the world's leading vegetable oil in production and trade. According to United States

[10] Data provided by ICED's Chief of Party.

Department of Agriculture (USDA) Foreign Agriculture Service (FAS), Indonesia is the leading producer with 52% of the world's palm oil production, and CPO exports are the third largest export earner in Indonesia [10]. Indonesia and Malaysia combined production of palm oil accounted for 86% of the 2012 world total [11]. Most palm oil is used in food products, and a small portion is converted to biodiesel, a renewable transportation fuel. Land area planted in palm and CPO production has steadily increased, and FAS anticipates more land area in future years (Figure 10). Approximately 400,000 new hectares of oil palm plantation land were added per year between 1997 and 2006 [12]. This declined to 350,000 new hectares/year for 2007 through 2010 because less land was available for plantations, although growth will continue in areas that were already permitted for oil palm.

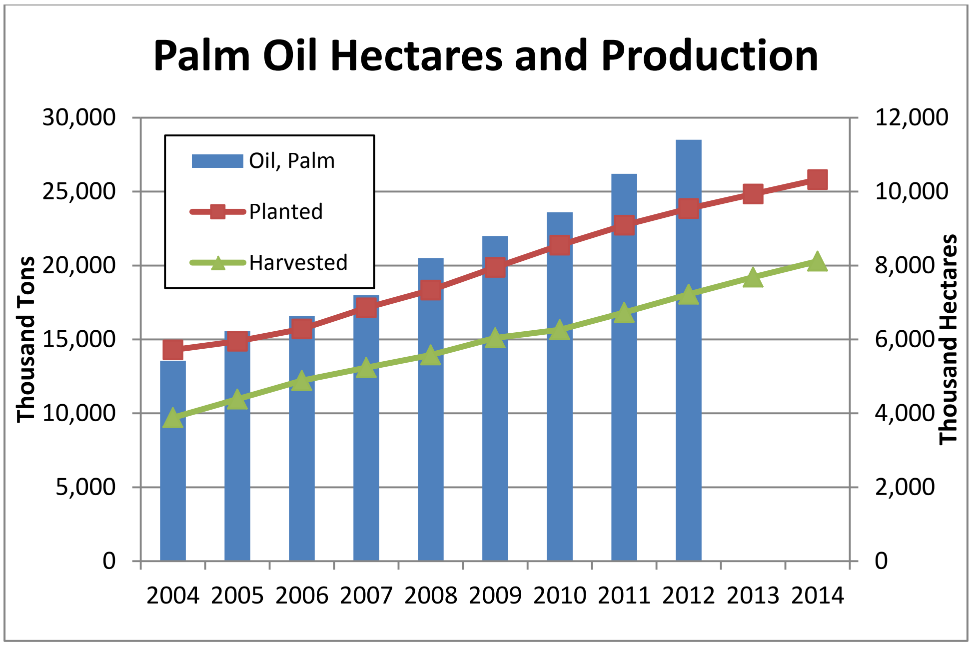


Figure 10. Indonesia palm oil statistics

Source: USDA FAS Production, Supply, Distribution Database; Winyono, I. Slette, J. "Indonesia Oilseeds and Products Annual," March 28, 2013. Gain Report Number: ID1316. USDA FAS, 3 pp.

The premium for certified palm oil is nearly non-existent because its sales only represent 15% of the market and nearly 50% of certified palm oil in 2012 failed to find a buyer and was sold to conventional markets [13]. CPO does not meet the criteria to be used as a biofuel feedstock for the United States Renewable Fuel Standard.

Smallholders and large-scale plantations see oil palm as an easy-to-grow, profitable crop. Seedlings are planted at a density of 110–150/hectare with 2–3 years before the first harvest [14]. Top productivity tends to occur between 9 and 15 years, and an economic lifetime span for an oil palm is 20–25 years. The FFB yield ranges from 15 to 30 tons/hectare, and Indonesian CPO yield averages 2–4 tons/hectare [14]. The FAS is projecting 2013 Indonesia CPO yields of 3.7–3.8 tons/hectare. Oil palm is approximately 10 times more productive on a land-use basis than soybeans. Additionally, oil palm is not a genetically modified organism, which makes it suitable for use in natural food products, a growing market in Europe and North America. Table 4 shows the average breakout of CPO, POME, and other components for each 100 kilograms (kg) of FFB.

Table 4. FFB Material Balance[11]

FFB Material Balance (kg/100 kg of FFB)	
Crude Palm Oil	21
Empty Fruit Bunch	23
Kernel	6
Fiber	13
Shell	7
POME	50

Source: "Preliminary Feasibility Study on the Palm Oil Waste-Fired Power Generation Systems and CDM Project for Rural Electrification in Sumatra, Indonesia". Engineering and Consulting Firms Association, Japan. March 2009; Table 2–3. Accessed June 25, 2013: http://www.ecfa.or.jp/japanese/act-pf_jka/H21/ntt-gp.pdf

Palm oil mills typically operate 6 days per week for 20 hours/day and 300 days/year. FFB are delivered by trucks with 10 tons capacity, although plasmas tend to deliver on flatbed trucks. FFB are continuously processed with shells and fiber burned in biomass boilers to provide energy to the mill with an average requirement of 0.42 tons of steam and 17 kilowatt-hours (kWh)/ton of CPO [15]. Table 5 shows the energy and moisture contents of fibers and shells used to supply energy to a palm oil mill. At most mills, there is an excess of shells beyond what is needed for energy, and they are sold for feed and other purposes at a rate of approximately IDR 388,000/ton.[12] Empty fruit bunches (EFBs) are rarely used to generate energy due to high moisture content, low energy value, and high ash content. EFBs are collected in piles and returned to oil palm land as a form of fertilizer. The POME is processed through a series of ponds and applied to land or water after it is stable.

Table 5. Energy Content of Oil Palm By-Products

Component	Lower Heating Value (kilojoules/kg)	Moisture Content
EFB	5,000	63%
Fiber	11,000	40%
Shells	15,000	15%

Source: Chavananand, K. "Palm Oil Industry Potential for CDM project in Thailand," Palm Oil Crushing Association. Bangkok Thailand. February 19, 2010.

As of 2010, Jambi accounted for 494,000 hectares of oil palm and 1.3 million tons of CPO production ranking fifth behind other areas of Sumatra and one province in Borneo [16]. There are approximately 28 palm oil mills in Muaro Jambi. Of these, six do not own any plantation land and purchase all FFB from plasmas and smallholders. This increases competition for FFB in the area.

There are three categories of oil palm suppliers: state-owned plantations, private plantations, and smallholders. Some smallholders form cooperative agreements known as plasmas with plantations and/or palm oil mills. Land area for oil palm has continued to expand, but ownership

[11] The data in the table exceeds 100 because water is added in the process.
[12] Shell price based on NREL site visits.

has changed over the past 10 years. Smallholders have gained market share while private and state-owned lands have declined proportionately (Table 6). Some of the growth in smallholder contribution is likely due to the arrival of more mills as a result of the government lifting regulations requiring mills to own plantation land. A company can own up to 100,000 throughout Indonesia but only 20,000 in a single province (those limits are increased to 200,000 and 40,000 hectares for Papua).[13]

Table 6. Oil Palm Land Area Ownership

Ownership	2000		2010	
	Hectares[a]	%	Hectares[a]	%
Private Enterprise	2,400,000	58%	4,400,000	54%
Smallholder	1,100,000	28%	3,100,000	38%
State	600,000	14%	600,000	8%
a-hectares are approximate based on source graph; % are real.				

Source: "Palm Oil Plantation Industry Landscape, Regulatory, and Financial Overview 2012 Update." PwC Indonesia

The key environmental issues for oil palm are deforestation, biodiversity loss, peat degradation, climate change, and land conflicts. Of particular concern is the expansion of oil palm into peat lands, which results in fires and water issues; this is occurring in Muaro Jambi based on NREL site visits. It is not clear if improving yield on existing land leads leading to better incomes makes it more or less likely for smallholders to expand into peat lands.

2.2.2 Smallholders

Smallholders typically sell their FFBs to local collectors who tend to deliver to mills nearby due to the time-sensitive quality of palm oil. FFB must be used with 24 hours of harvest because quality deteriorates quickly. The speed with which FFB must be delivered and used may impact smallholders' competitiveness in obtaining the highest price. The condition of the roads where smallholders are working may also impact the ability to deliver FFB to the highest paying mill. The roads in the area of the BBIP mill and surrounding villages are upgraded and, in many areas, paved. There are three privately owned mills in the Bukit Baling village.

Smallholders are either independent or part of a plasma, an organized group of oil palm farmers. A plasma is a group of organized small oil palm land owners who collect and sell FFB to a specific mill or it is an agreement with a mill where the company plants on smallholder land and the smallholder later harvests and supplies FFB to the mill company for a contractual price. This arrangement can be problematic since it obligates smallholders to grow oil palm and may prevent them from growing other crops on their lands. Many farmers own two hectares as a result of the GOI Transmigration program that moved poor families from densely populated areas to rural areas. Other smallholders have five hectares and tend to grow oil palm and rubber on two hectares each while their home and subsistence garden are on the remaining hectare.

There is a significant gap between smallholder yields and those of large private plantations and state-owned plantations. In 2008, smallholder yields were 35% and 40% lower than private and

[13] The Ministry of Agriculture Regulation No. 26/Permentan/OT.140/2/2007 and State Minister of Agriculture/National Land Agency, No. 2/1999.

state-owned plantations, respectively [17]. Yayasan Setara, a Jambi-based, non-governmental organization working with oil palm smallholders, stated that smallholders typically harvest two times per month, which leads to lower yields than plasmas or large plantations that harvest three times per month. Oil palms harvested three times per month produce better quality CPO. It is possible that low yields are also due to expansion into land with low soil fertility. Other factors leading to low yields include lack of adequate labor, limited or inaccurate application of fertilizer, and low-quality planting materials. The yield issue must be addressed in order to increase smallholder income and reduce expansion into peat lands and other environmentally sensitive areas.

Challenges for smallholders include access to credit for establishing the crop and ongoing costs for planting materials and inputs. Oil palm smallholders are not provided with subsidized fertilizer. Smallholders of all crop types in Indonesia rarely have a certificate of land ownership that could be used to guarantee a loan. While CPO prices have been depressed recently, production costs have increased, particularly fertilizer.

The International Finance Corporation (IFC) of the World Bank Group has developed a Strategy for Engagement in the Oil Palm Sector. This effort included a study on Indonesia oil palm smallholders seeking to engage private industry, improve benefits of smallholder communities, and grow the adoption of sustainable practices. The study involved 641 farmers in Riau, South Sumatra, and West Sumatra; of these, 413 farmers were independent smallholders [18]. Findings of the study include the following:

- Issues with harvesting, which typically occurs at a rate lower than private- or state-owned plantations
- Issues with planting materials, including a lack of knowledge of high-yield seedlings
- Good access to inputs, including fertilizer, but insufficient funds to purchase them
- Approximately 27% of farmers have had training/extension advice
- Many farmers have land certificates
- Few farmers were aware of certification or Roundtable for Sustainable Palm Oil
- Approximately 47% of farmers do not have bank accounts
- Few farmers have direct contact with mills; they sell to a local collector
    - Smallholders selling directly to mills generally receive a 20% price premium

Yayasan Setara is a Roundtable on Sustainable Palm Oil member focused on smallholder sustainable oil palm production. It works with smallholders through many types of training and tends to work with the same communities over several years. It also mitigates land disputes between communities, government, and plantations. Yayasan Setara research projects food shortages within 3 years in Jambi as subsistence land area is converted to oil palm or rubber leaving less land for subsistence farming. Jambi's population is growing at a rate of 2.5% per year with Indonesian moving from other provinces and contributes 1.2% to Indonesia's gross domestic product (29% of this is from agriculture). Smallholders in the area surrounding the BBIP mill would benefit from the type of training Yayasan Setara provides.

2.2.3 POME

The milling process to extract palm oil and palm kernel oil generates a significant amount of wastewater. This waste is referred to as POME. Palm oil mills use 5–7.5 tons of water to produce 1 ton of palm oil [18]. Steps in the milling process resulting in POME include sterilization of FFBs (36% of POME), separation of wastewater and crude palm oil (60%), and hydrocyclone wastes from separating out palm kernel and shells (4%) [19]. All these wastes are delivered to a series of ponds. The first two ponds are cooling ponds to reduce the temperature of the POME to begin the stabilization process. These ponds also have oil recovery systems to capture some of the palm oil lost in the process. The POME then enters anaerobic ponds where the AD process occurs and emits methane and CO_2 to the atmosphere. After AD, the POME enters aerobic ponds for the final stages before applying the remaining solids and liquids to land or, in some instances, water.

The potential for electricity from AD of organic matter is a function of BOD, COD, and total suspended solids. All three measure biodegradable pollutants in wastewater. A higher BOD and COD will result in more biogas and electricity. The BOD and COD range is large among palm oil mills depending on the efficiency of their CPO extraction process. A new palm oil mill with high-efficiency extraction equipment will result in a lower-than-average COD, which will result in low electricity potential. In contrast, an inefficiently run or older mill may result in a higher COD and higher electricity potential. The AD process reduces BOD, COD, and total suspended solids up to 95%. Table 7 shows ranges and averages for POME components and the Indonesian standard for release after processing in ponds.

Table 7. POME Characteristics

Parameter	Range	Average	Standard
All units are milligrams/litre except pH			
BOD	8,200–35,000	21,280	50
COD	15,103–65,100	34,740	100
Total Suspended Solids	1,330–50,700	31,170	150
Ammonia (NH_3-N)	12–126	41	20
Oil and Fat	190–14,270	3,075	15
pH	3.3–4.6	4.0	6-9

Source: "Renewable Energy Toolkit." Second Edition. USAID ICED Project. November 27, 2012.

The volume of POME produced for each ton of FFB varies for each mill based on the efficiency of CPO extraction and amount of water used. USAID's CIRCLE program conducted many feasibility studies of electricity generation from POME at palm oil mills. Based on its experience, USAID developed averages for several palm oil mill capacities (30, 45, and 60 tons/hour). The BBIP mill has a capacity for 45 tons/hour. This study uses averages shown in Table 8 rather than BBIP's confidential operational data. The assumption based on average data is that a 45-ton/day palm oil mill is capable of producing 1.25 MW or approximately 9,000 megawatt-hours (MWh)/year. A project should collect POME samples over several days and times and measure characteristics (see Table) in order to calculate and size energy generation equipment for a particular mill.

Table 8. Project Parameters

Measure	Units	Average for 45 ton/day Palm Mill
Annual FFB	tons/year	270,000
Daily throughput	tons/day	900
Effluent rate	%	65
Daily water flow	m^3	585
COD (average)	mg/L	55,000
Conversion to methane	Nm^3 CH4/kg COD	0.3
COD conversion	%	84
Methane production (estimate)	Nm^3 CH4/day	8,108
Methane content (estimate)	%	56
Biogas flow hourly	m^3/h	603
Methane energy value	MJ/m^3	35
Average generation efficiency	%	38
Generation capacity	MW	1.25
Availability factor	%	90
Electricity sold to grid	MWh/year	9,137

Source: "Renewable Energy Toolkit." Second Edition. USAID ICED Project. November 27, 2012.

Sumatra has great electricity and emissions reductions potential from converting POME into electricity. ICED estimates 420 mills in Sumatra could produce 470 MW of electricity and avoid emissions of 9.1 million tons of CO_2e [20]. This would require an investment of more than IDR 9.7 trillion.

2.2.4 Impacts of Project on Palm Oil Production

POME electricity is an unlikely driver for more FFB production. Oil palm land area and crude palm oil production are expected to rise in Indonesia as a result of growing world populations and economies. Additionally, oil palm is not a genetically modified organism, making it more desirable in certain areas of the world. FFB demand is driven by economics of primary products CPO and CPKO. The profits from POME electricity are considered very modest and simply an improvement to overall economics of a mill. The reasons this project is not expected to impact demand for FFB are as follows:

1. Increased demand for FFB is a result of increased demand for palm oil, not increased demand for far-less-profitable, low-volume by-products.
2. Oil palm land area and palm oil production are a function of world demand.
3. Premium payments to smallholders from palm mill electricity profits are modest.
4. POME electricity system is sized for current palm mill size and capacity.
5. This project is proposed at an existing palm oil mill and does not require any land acquisition.

2.3 Current Baseline

The baseline case assumes that the mill continues business as usual and area villages use diesel generators for electricity. This means continuous production of CPO and POME, emitting methane and CO_2 to the atmosphere in the current open pond configuration. This is a loss of benefit because the POME waste stream can be converted into renewable electricity. The settlements surrounding the palm oil mill will continue to spend more per month on electricity than other villages in Muaro Jambi connected to the grid. The PLN long-term plan intends to bring transmission lines to some settlements near the mill, but the timeline for connection is unknown. It is expected that the area will remain in an agricultural area with oil palm and rubber as the primary crops. Overall, it is anticipated that more land area will be converted to oil palm in Jambi due to increased worldwide demand for vegetable oil.

2.4 Technical Feasibility

Electricity generation equipment would be sized based on POME sampling at each candidate mill. In this project, electricity generation from a 45-ton/hour facility is estimated at 1.25 MW. However, a particular mill's potential may be higher or lower depending on the age of the mill, extraction efficiency of palm oil, and general mill operations. Older or inefficiently run mills inefficient at extracting the maximum amount of palm oil will have POME rich in organic wastes capable of producing more than the 1.25 MW used in the model; up to 2.5 MW is possible, resulting in economies of scale for the project. If a mill is new or highly efficient, it may produce less than 1.25 MW, making the project less feasible.

If a mill continues operation as usual and the flow of POME is carefully controlled into the covered anaerobic pond, it is anticipated that the genset will operate at capacity. If the mill produces more POME or if COD increases, some biogas would be flared because the genset cannot produce more power than it is rated for. If the palm oil mill upgrades extraction equipment, POME COD values may decrease, resulting in less power output than anticipated. The PPA with PLN would state the expected electricity delivery and the mill would need to consider this when making any changes to the CPO extraction process.

2.5 Operational Feasibility

2.5.1 Operation and Maintenance Requirements

Staff would need to be on-site 24 hours a day to operate and monitor equipment, biogas, and electricity production. Continuous monitoring of the anaerobic pond and operational parameters would be required to ensure electricity is generated at capacity. System monitoring requirements include pH, temperature, and organic loading rate, because these parameters can indicate an issue with biogas production. The jobs created by this project would include both operational, maintenance, and laboratory positions. Routine maintenance would include repairing pipes, fittings, valves, electrical wires, and any leaks in the anaerobic pond. Any extensive work required for the membrane cover or electricity genset would need to be serviced by a contractor approved by the vendor. An overhaul of the genset engines is anticipated every eight years and the manufacturer would specify what work is required and who can perform it.

NREL met with an IPP that captures biogas and flares it with profits realized from CER sales in voluntary markets. The IPP remotely controls process parameters and send local staff when there is an issue. Generating electricity is more complex and requires staff on-site. If the mill enters into an agreement with an IPP, it would electronically monitor process parameters remotely as well as employ staff on-site.

2.5.2 Operation and Maintenance Personnel

The work of employees in biomass energy is nearly identical to that required of workers who operate or maintain equipment from other fuel sources such as coal or natural gas. Winrock International suggested this type of project would require 10–12 full-time staff members. There would be at least one manager responsible for overseeing other staff and setting work flow and priorities. Operational staff would be needed to operate the genset and monitor control. Lab personnel would be required to collect and analyze POME samples to identify any potential issues. An electrician would be needed to ensure operation of the genset and other electrical wiring. All staff would be responsible for overall site management.

Bukit Baling's village chief and BBIP's mill manager stated staff for these positions will be filled with local villagers and that these skill sets are available in the local population. Staff will either live onsite or nearby. All BBIP laboratory staff and management personnel are women, and it is expected that laboratory staff for the POME electricity project will also be women.

2.6 Technical Risk Assessment

2.6.1 Mitigation Plan for Identified Risks

There are two technical risks for this project: limited past experience with this project type in Indonesia and risk of system shutdown due to operational issues. There are only ten POME-based electricity projects and none are connected to PLN, although several under development plan to grid-connect. Using contractors and equipment from the previous ten projects and visiting those sites to ensure there are no major operational issues would mitigate this risk.

The most significant technical risk is system shutdown where biogas production stops. This has occurred in AD systems when the organic loading rate (i.e., delivery of POME) to the anaerobic pond is too high. Methanogens, responsible for converting POME into biogas, die off and must be re-established in order to generate biogas and electricity. This is why it would be important for staff to monitor operational parameters for performance because a sudden change can indicate an issue that must be addressed immediately to sustain biogas production.

There is a risk of under- or over-estimating power production potential during project development. Electricity generation is calculated based on organic matter measured in POME samples that must be taken at various days and times to quantify potential. It is also possible that changes in the palm mill process, such as improved extraction equipment or expansion, could result in less or more electricity. If there is less electricity than anticipated, the mill or IPP may need to renegotiate the PPA with PLN and it would negatively impact the economics of the plant and increase the payback period. If more POME and therefore more biogas are produced, the mill would either flare the excess biogas or need to evaluate the economics of expanding the anaerobic digestion pond, cover, and adding more electricity generation engines. Another potential issue is a supply disruption of FFB to a mill leading to lower use of mill capacity (20 hours per day, 6 days per week, or 300 days per year). This would result in lower POME production and therefore lower biogas and electricity production. This is a risk of any energy plant depending on an agricultural commodity.

There are also the impacts of delays in construction and budget issues that can negatively impact a project before it starts generating electricity. This is a potential issue for any large construction project.

2.6.2 Monitoring and Evaluation Plan

The mill and/or IPP have an interest in properly designing, building, and operating the plant because there is a significant capital investment, and profits are only available if electricity is sold to PLN. The mill would need to ensure POME is continuously supplied in order to collect biogas. The operations of the plant are continuously monitored, and both routine and substantial maintenance would be required over the life of the project. The monitoring and evaluation of the energy plant would be established in the contract between an IPP and a palm oil mill.

Ensuring that the palm oil mill uses electricity revenues to provide a premium to smallholders would be more challenging to monitor. Smallholders are not under contract to supply any specific mill. In many instances, smallholders sell to a local collector who delivers FFBs to a mill. It would be necessary to survey area oil palm smallholders on their FFB prices because there are no contracts between smallholders, local collectors, and palm mills. This would determine if smallholders selling to mills with POME electricity generation are receiving a premium over those selling to mills that do not sell electricity. It is recommended to hire a local, non-governmental organization or organization to provide this type of survey on a defined schedule.

3 Economic Assessment

An economic assessment evaluating the outcome of this project was performed and presents both the net present value (NPV) and economic rate of return (ERR) as well as detailed economic figures that highlight relevant elements of the analysis. The method for evaluating the impact of this project proposal involves comparing the cash flows of a counterfactual scenario (also referred to as the "base case" or "business-as-usual") to the cash flows if the project proceeds (the "with-project" or case).[14] Evaluating the project in this way ensures that the project delivers incremental returns that meet the required 10% ERR hurdle rate.

This economic assessment considers the project's impact on the local economy instead of considering its impact only on the generating system owner (i.e., the mill or an IPP). Expanding the project boundary allows a better understanding of how the value created by the project is distributed among stakeholders. This has a dual purpose: to demonstrate that the Green Prosperity goal of poverty alleviation is met and to ensure that funding is provided to projects that otherwise would not attract a private investor.

Cash and value flows for both the counterfactual and with-project (WP) cases are based, wherever possible, on data collected in site visits or on comparable projects in Indonesia if site-specific data are not available. In many cases, the most appropriate benefit stream is cost avoidance. This applies to both grid-connected and off-grid projects. Cost avoidance can refer to a reduction in the cost to generate electricity, reduction in electricity expense to consumers, or a reduction in the cost of a service, such as lighting by fuel-switching. In addition, electricity can enable new value creation by powering small businesses and increasing productivity, improving health conditions, and providing for better education opportunities.

A full explanation of methods for calculating counterfactual and WP benefit streams is forthcoming in a separate comprehensive document detailing the electrification economic model, which would describe methods, model structure, and procedures for its use in evaluating similar projects.

3.1 Overview of Results

This project performs well economically, primarily because of PLN's avoided cost of generation, which is roughly three times what it would pay for electricity generated by the project. This means that the majority of the benefit is captured by PLN. Under reference case assumptions, the project ERR is 40.5% with an NPV of IDR 123 billion. This analysis is conducted assuming a loan is offered at 50% of total capital costs at a 4.5% nominal interest rate. The main economic risk for this project is that there is relatively low return for all other stakeholders beside PLN. Because the IPP returns are low, there is concern that there will be tight cash flow and exposure to external risk such as construction delays. The IPP's internal rate of return (IRR) is 3.9% real (8.1% nominal) under reference case assumptions, which is relatively low even to incentivize a non-governmental organization or non-profit to participate in this project as designed.[15] The small return to the IPP also limits the amount that it can pay to the mill owner: 10% of revenue

[14] The counterfactual is what would happen in the project area if the project was not built.
[15] Unless otherwise noted, all percent returns are expressed in real terms. Real returns are adjusted for inflation, while nominal returns are quoted in a given year's dollars.

(NPV of IDR 4.2 billion) in the reference case. Consequently, there is only a small share of the project's total NPV available to the mill's FFB suppliers, a target beneficiary of the project. Local electricity consumers are the other local beneficiaries of the project. These consumers benefit from avoided diesel cost and increased consumption, which total IDR 17 billion in NPV.

The project's ERR is most sensitive to projections of PLN's avoided cost over the project lifetime because PLN's cost savings are the primary economic benefit. The reference assumption is that PLN's generation cost grows at a rate comparable to recent experience: 8.3% per year in nominal terms. Historical data were used to calculate this growth rate, though data about future operating costs would be better for estimating future changes in generation cost. These data were not readily available, and although the NPV is sensitive to that assumption, a nominal growth rate of 1.5% per year—less than inflation—still leads to a project ERR of 31%.

Alternative project design options could make this project more viable for the IPP and mill, and provide more benefit to smallholders. Offering a grant of 50% of capital costs has no impact on project ERR but increases the IPP's IRR to 13% (17% nominal), which could be distributed to the mill through lease payments and on to smallholders through FFB price premiums. A change to electricity policy that would allow an escalator to be negotiated in PPAs would shelter the IPP's revenue from long-term inflation, reducing the IPP's exposure and the overall project risk. Including an escalator to the FiT at the projected rate of long-term inflation would provide an IRR to the IPP of 15% (20% nominal).

With the exception of changing the loan to a grant, these changes are unlikely, and therefore the project reference case is designed to reflect the mostly likely conditions an IPP would face in this situation. If the price of CER credits rebounded in world markets, it could provide an additional source of revenue for the operator. Because forward prices of CER credits are very difficult to predict, they were excluded from this analysis. Assuming CER credit prices rebound to IDR 97,000 per ton of CO_2e and IDR 9.7 billion certification and compliance costs, revenue for the IPP would significantly increase by about IDR 4.85 billion/year and improve its real IRR.[16]

3.2 Assumptions

3.2.1 Baseline Case

The base case for this project is that POME ponds are uncovered and unutilized for energy production. Therefore, no value is created from the wastewater of palm oil processing. The values derived in the counterfactual case consider the economic impacts of the quantity of electricity that would be produced by the IPP in the WP case, along with the respective stakeholders including local electricity consumers and PLN. For PLN specifically, for all units of electricity that PLN purchases in the WP case, it would have incurred generation costs per unit and in both cases accrues revenue for each unit sold at the retail price of electricity. At a selling price of IDR 614/kWh, PLN accrues an average of IDR 5.044 billion/year in revenue from electricity sales. It would have incurred an average of IDR 19.4 billion/year in generation costs at IDR 2,922/kWh [21]. PLN's generation cost offset is determined by the generation cost of the

[16] By comparison, the U.S. Government's estimates for social cost of carbon range from $12 to $129 (in 2007$), which if included in the project returns would have a significant economic impact. See "Technical Support Document: - Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866" U.S. Government, May 2013, pp 2.

asset displaced. Since a POME electricity generation plant can produce electricity throughout the day, the avoided generation cost will be the weighted average of generation costs for all generating assets. All told, PLN loses an average of IDR 217 million/year in the counterfactual case on the kilowatt-hours produced by the IPP.

Local electricity consumers, by contrast, benefit by saving money on the kilowatt-hours they consume in the counterfactual case and benefit from new connection value and additional electricity consumption. There are five villages near the mill, for which diesel generators supply 60% of citizens. These generators burn 100 liters of diesel/day at IDR 7,000/liter (L), and produce 3 kWh/L for a total annual generation of 550,000 kWh. Consuming this amount of electricity costs these villages IDR 1.28 billion annually. Each of these villages would be connected in the project and would therefore avoid the cost of diesel generation in exchange for grid-connection expense, and benefit from additional incremental consumption.

The economic analysis for the counterfactual case focuses on the economic impacts that the IPP generating system has relative to PLN, the palm mill, local smallholder farmers, and local electricity consumers. The total net present lifecycle costs of the counterfactual are IDR 226 billion.

The prefeasibility study team that performed a site visit did not learn of any planned capacity additions in the area by PLN. Because of relative regional supply constraint, it is likely that PLN would enter into PPAs with IPPs offering power to the grid.

This mill sources the majority of its FFB supply from local smallholders with the balance coming from its own plantation, compared to other mills that can supply their entire feedstock from their own plantations. The current price paid per ton of FFB is IDR 1,420,000.[17] The mill representatives expressed concern that the local smallholders are mobile enough to obtain better prices, so they are interested in this arrangement to ensure their supply of FFB.

3.2.2 Proposed Project

The generation system is sized for biogas production from POME produced by the co-located palm oil mill. The mill has a throughput of 45 tons/hour of FFB, which can support a 1.25 MW capacity generator. A plant size of 1.25 MW and 90% capacity factor was modeled for this project and subjected to a sensitivity analysis to account for possible output variation. Because there is a series of POME ponds and a timing delay for organic decomposition, there is a buffer against volatility of biogas production. Therefore, this plant would have high capacity utilization and can be dispatched to the grid at any time.

The generating system organization was modeled as an IPP operator.[18] This arrangement helps ensure that the FiT revenue is reliably paid to smallholders as a transfer for the life of the project. The mill operates and produces POME in the course of its operations while the IPP generates and sells electricity to PLN in exchange for FiT payments. In total, 10% of IPP FiT revenue is paid

[17] FFBs are a commodity; prices change and are very localized. This price is as of March 2013.
[18] Most projects like these are developed by foreign non-government organizations. A recent Presidential Decree (Nos. 77/2007 and 111/2007) regarding Lines of Business Closed and Open with Requirements for Investment stipulate that foreign investors can have up to a 95% shareholding in a plantation company, including palm plantation companies. The remaining 5% shares must be allocated to an Indonesian shareholder.

annually to the mill, and the mill pays 90% of its lease revenue out to its smallholders to secure access to FFB.[19] The assumption is that 50% of this mill's FFB supply comes from local independent smallholders, so there is an incentivize supply by offering a price premium.

Five local villages near the mill that are currently supplied by diesel will be connected to the PLN grid by extending distribution lines to these villages from the transmission line that connects the IPP to PLN's grid. These villages would then receive electricity all day and would have higher electricity reliability.

3.2.3 Alternatives Considered

There are few possibilities for altering the fundamental structure of this project. Similarly, the organizational design presented here is the most probable arrangement, primarily because palm oil mills are in the very profitable business of processing palm oil. They lack the expertise needed for interconnection with the grid, and the financial incentives associated with electricity generation are insufficient to induce them to get into the business. Furthermore, existing POME electricity projects have a similar organizational structure where an IPP operates the generation system and interacts as an intermediary with PLN and the mill. The structure as designed properly aligns incentives and allocates risk between the appropriate parties.

There are, however, some possibilities for changing the specific financial mechanisms whereby value is transferred between stakeholders, but the flows of money still accrue to the same parties. For example, instead of designing IPP lease payments to the mill as a percentage of revenue, this stream of payments could be a specified dollar amount with a negotiated escalation rate. Similarly, the arrangement between the mill and smallholders could be paid some other way beside through premiums for FFBs. Regardless; value is transferred between the same stakeholders in each possible case. A discussion of alternative financing arrangements and the distributional impacts is presented below.

3.3 Project Benefit Streams

There is one distinct driver of value creation in this project and several transfer payments with beneficial distributional effects. Value in this project comes from the generation of electricity from a freely available fuel source. With that electricity, several stakeholders benefit by avoiding cost (PLN and local diesel electricity consumers) and by creating new economic value from increased electricity consumption. PLN's avoided generation cost for its generation is offset by the POME electricity project, which uses a freely available and renewable fuel source. This value alone is worth IDR 114 billion in NPV. Avoided cost from local diesel generation and the value from additional electricity consumption account for IDR 1.7 billion in NPV. Transfer payments include FiT payments from PLN to the IPP; lease payments from the IPP to the mill; and premium payments for FFB from the mill to smallholders. The economic results for individual beneficiaries closely align with separate benefit streams so each are presented below with full project results to follow.

[19] The 10% is assumed; companies were not willing to discuss confidential business agreements with mills.

3.3.1 IPP Production

Construction for this type and size of plant takes 18 months, so the second year produces only half of a normal year. There is no degradation factor modeled because POME ponds would produce biogas reliably as long as the mill is still operating. Onsite energy use was modeled at 7.7%, a figure that was calculated from comparably sized projects in Indonesia [9]. Electricity generated totals 9.855 gigawatt-hours (GWh) annually, and after factoring in parasitic load and line losses, the annual average electricity sold to the PLN is 9.096 GWh annually. The calculated levelized cost of electricity (LCOE) is well below both PLN's generation cost FiT. Factoring on lease payments, the LCOE is IDR 389 per kWh while the LCOE is IDR 324 per kWh excluding lease payments.

3.3.2 IPP Operating Cash Flows

The only source of revenue for the IPP is from FiT payments for electricity sold to PLN. There is a national policy on FiT amounts per kilowatt-hour for renewable energy technologies and location, which for biogas in Sumatra is IDR 975/kWh.[20] There are no escalation rates built into PPAs with PLN, so the real IPP revenue is adversely affected by high long-term inflation. The NPV of IPP revenue is IDR 42 billion. Operating expenses for the IPP include operation and maintenance costs and lease payments to the mill. There are no fuel costs because the biogas from POME ponds is freely available as part of the lease agreement. Operation and maintenance (O&M) is modeled as 10% of total capital costs annually, or an NPV of IDR 21 billion [22].[21] Lease payments to the mill are modeled as 10% of annual revenues, or an NPV of IDR 4.21 billion. The NPV of cash flows from operations for the IPP is IDR 17 billion. Figure 11 shows the real IPP net cash flows over the life of the project. The negative real IPP operating cash flows for the second year in Figure 11 result from a full year of O&M expenses with only a half-year of revenue.

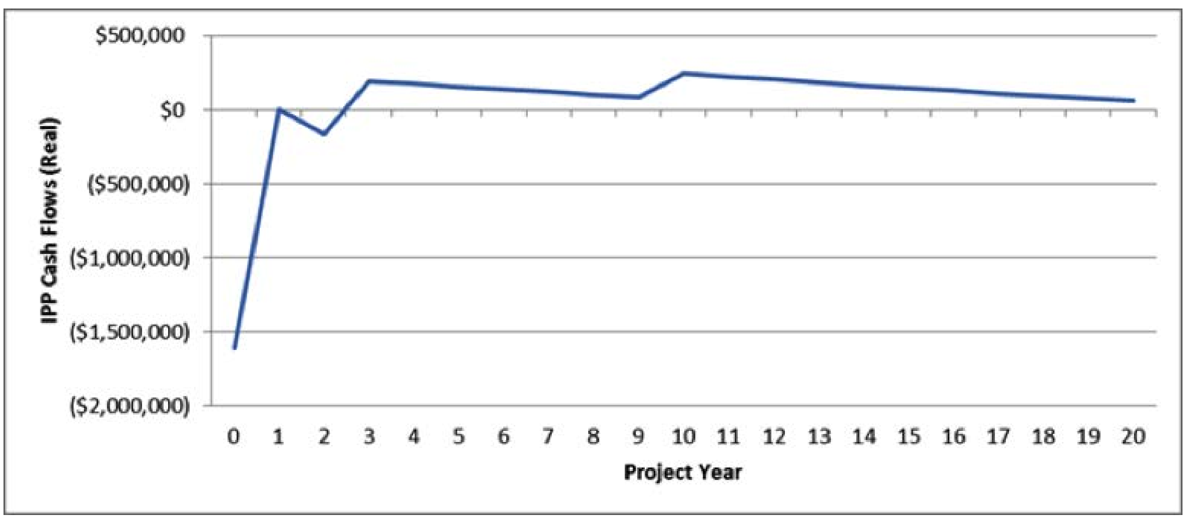


Figure 11. IPP cash flows

[20] 04 Year 2012. About Purchase Price of Electricity by PT PLN (Persero) from Power Plant Using Renewable Energy on Small and Medium Scale or Excess Power. Minister of Energy and Mineral Resources of the Republic of Indonesia, Article 3.

[21] The PFS team found references to projects that use 5% for O&M costs. 10% was used to account for generator overhaul and to add conservatism to the operating expenses.

3.3.3 IPP Investing Cash Flows

Capital costs for a project of this size and configuration are priced at IDR 24,153/W for a total of IDR 31 billion. This model includes the capital costs for extending transmission lines 5 km to connect to the grid at IDR 210 million/km. The analysis assumes that the project would operate for the full life of the equipment (20 years) and that there would be no salvage value remaining at the end of that period.

3.3.4 IPP Financing Cash Flows

The current project design calls for 50% leverage with a loan from the Millennium Challenge Account – Indonesia (MCA-I) lending window at 4.5% nominal interest and a 10-year term from cash disbursement, which gives MCA-I a very small positive real return at an assumed target inflation level of 4%. It also provides low cost of debt for the IPP compared to what it is likely from other lenders.[22] The cash from debt is disbursed before construction, and interest accrues through construction (in this case, 18 months). The IPP capitalizes the interest during construction by beginning payments only when the IPP begins to earn revenue.

The economic results under these assumptions provoke questions about financing terms. The lender would balance the loan amount with the interest rate offered in order to deliver an acceptable return for the IPP along with transfer value for local smallholders through the lease payment. If the IPP were to finance the project entirely with equity and have no transfer payments, it would earn a real return of 5.8%. On the other end of the spectrum, if 90% of project capital costs were grant-funded, the IPP real return would be 62%%. By contrast, with the proposed 10% lease payment, the all-equity return would be 2.8%, while the 90% grant return would be 54%. There is clearly a tradeoff between the loan terms offered (interest rate and amount or leverage) and the IPP return and benefit to smallholders.

Figure 12 shows the tradeoff between interest rate and leverage level to IPP real returns, including the proposed 10% lease transfer payments. At 4% long-term projected inflation and an interest rate of 7%, the IPP is indifferent to any amount of leverage. Whereas at lower interest rates, the IPP would prefer more leverage because it would enable a higher IRR on its investment relative to inflation. This figure has important implications for the MCA-I finance window when setting nominal interest rates. It shows the precise maximum interest rate it could charge before an IPP would seek financing from other sources or fund the project on its own, assuming the IPP holds the same economic assumptions as this analysis. If the IPP developed the project on its own, it would earn a 2.85% IRR; at 50% leverage and 4.5% interest rate (using reference case assumptions), it earns 3.89%.

[22] Meetings with local Indonesian banks and their partners in June 2013 indicated commercial rates are higher.

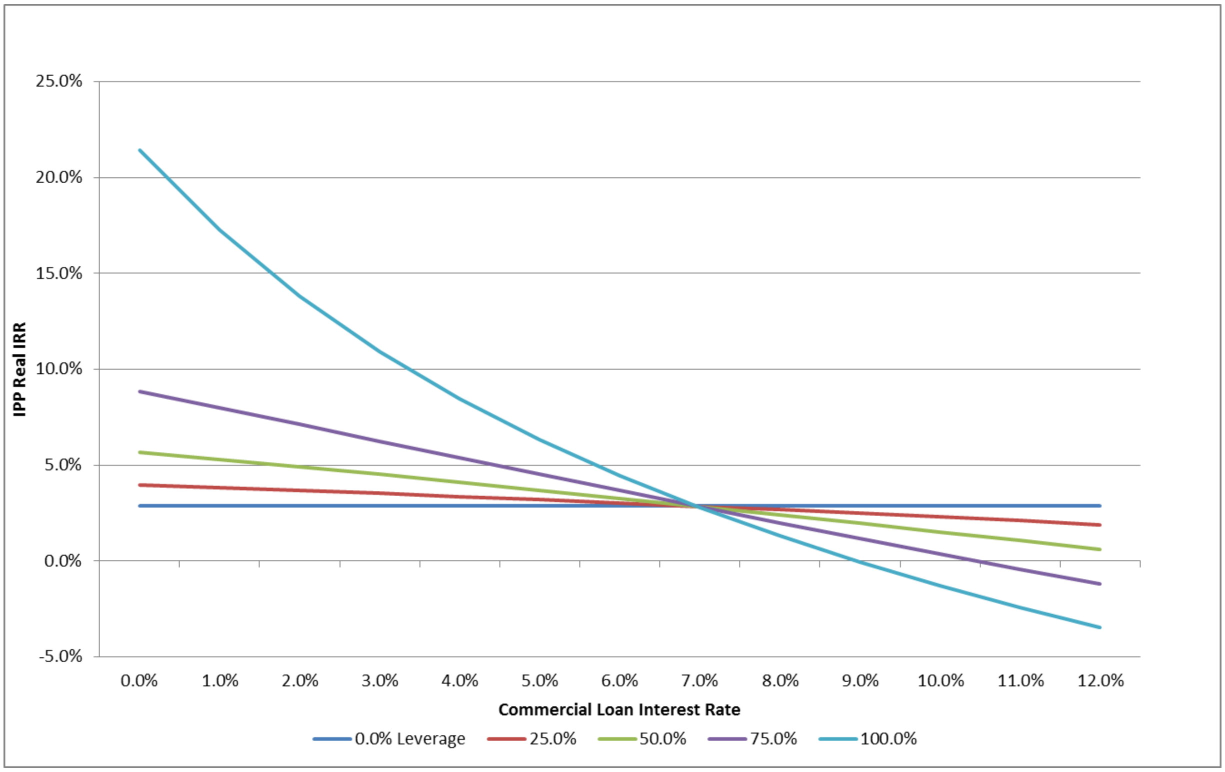


Figure 12. IPP IRR relative to interest rate and leverage ratio (with 10% lease payment)

By contrast, Figure 13 shows the same tradeoffs and returns for the IPP with no lease payments to the mill. In this case, IPP real returns are higher and it would be indifferent to any leverage amount at 10% interest rate. So, even under a project design where all the revenues go to the IPP, the highest reasonable interest rate that can be charged is 10%, which would deliver a 5.8% real return for the IPP. If there is concern over attracting sponsors and the MCA-I finance window wanted to accommodate competitive returns, it would have to offer more debt at lower rates and risk compromising some of the benefit to the local smallholders. For example, assuming that 10% of revenues are paid to the mill as a transfer payment for smallholders, according to Figure 12, to deliver a real return for the IPP above of 10%, MCA-I would have to offer 100% of the capital costs in debt at an interest rate lower than 3.5%. Changing some assumptions about operating costs and unit production of the IPP would impact the returns, but using these reference case assumptions, there are few financing levers available to achieve the desired project outcomes.

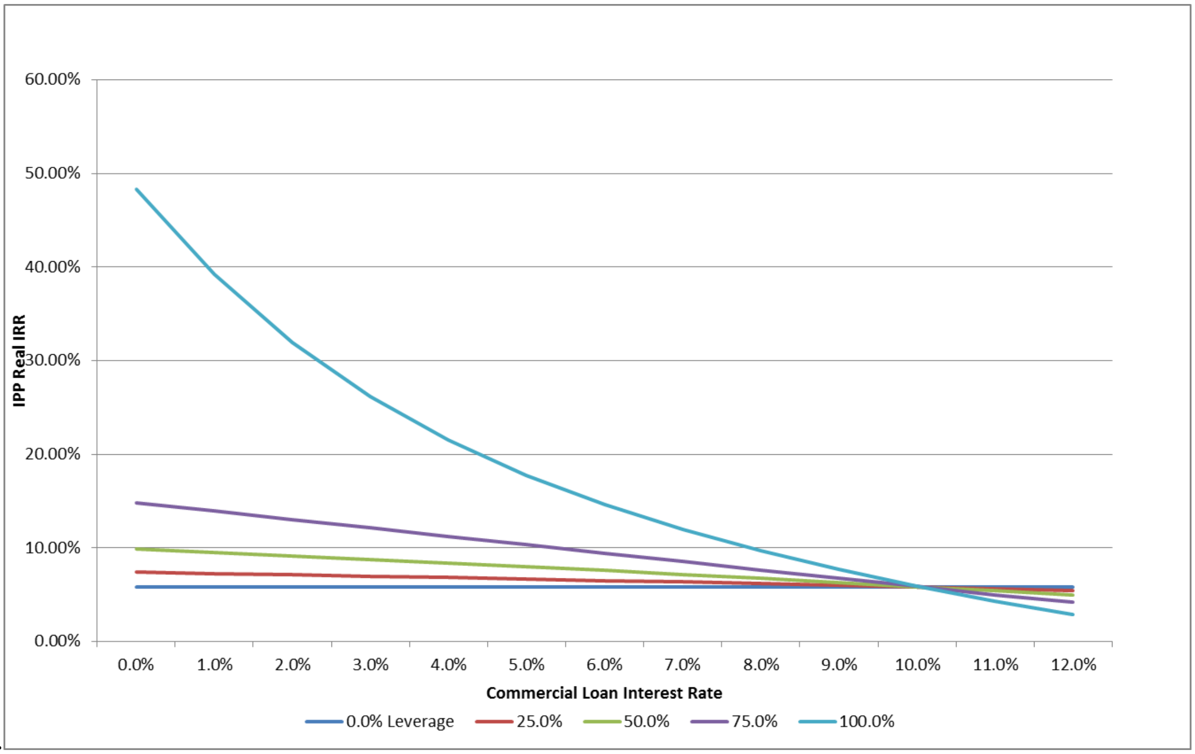


Figure 13. IPP IRR relative to interest rate and leverage ratio (with no lease payment)

3.3.5 PLN Net Benefits

PLN is required to purchase electricity from renewable energy IPPs and to pay a FiT per kilowatt-hour. The FiT paid depends both on technology and location. The FiT for a biogas project connected to the grid through medium voltage lines is IDR 975/kWh. The regional FiT multiplier for Jambi is 1.0, so for each kilowatt-hour sold, the IPP would receive IDR 975.[23]

In Jambi, PLN supplies energy to the grid from various sources including hydro (2.97 GWh), diesel (55.76 GWh), rented diesel (46.75 GWh) and purchased power, which is believed to be entirely natural gas (403.53 GWh) [21]. PLN's generation cost is different for each technology, but since there would be high capacity utilization for this project, which implies that it is baseload power that can be dispatched at any time to the grid. This analysis uses the weighted average of all power generation types IDR 2,922/kWh as a proxy for PLN's avoided cost. The economic model considers only the amount of electricity that would be generated by the POME electricity project. In the counterfactual case, PLN would incur the generation cost per unit for the quantity of that electricity minus any local consumption, which is valued at avoided cost and incremental value per kilowatt-hour; in the WP case, PLN pays the FiT for all unit purchases and avoids the generation cost for all non-local kilowatt-hours. PLN's revenue does not change between the two cases since it would still be selling the kilowatt-hours to other customers. Therefore, the incremental value to PLN is the difference between generation cost and FiT, times the non-local kilowatt-hours purchased by PLN. Separate nominal growth rates for generation

[23] 04 Year 2012. About Purchase Price of Electricity by PT PLN (Persero) from Power Plant Using Renewable Energy on Small and Medium Scale or Excess Power. Minister of Energy and Mineral Resources of the Republic of Indonesia, Article 3.

cost and FiT are applied, which has a significant impact on long-term real values in the analysis. Under reference case assumptions, incremental benefit to PLN of supplying electricity to its grid by purchasing from this IPP is IDR 114 billion in NPV.

3.3.6 Other Beneficiary Net Benefits

Other value flows between stakeholders include lease payments to the mill, premium payments from the mill to smallholders, and financial cash flows between the IPP and the MCA-I finance window. The lease arrangement and finance payments are described above in the IPP cash flows sections.

The price premium paid by the mill to smallholders is designed to secure reliable supply for half of the mill's FFB supply. The FFB premium is calculated by paying 90% of the mill's lease revenue out to local smallholders per unit purchased by the mill; 10% of lease revenue is taken by the mill to cover transaction costs. The NPV of lease revenue is IDR 4.21 billion. An average of 45 tons/hour mill consumes 270,000 tons of FFB/year, which means local smallholders supply 135,000 tons to the mill annually at IDR 1.420 million. The amount available to pay as premium changes over time, depending on revenue growth or decline. The NPV of premium payments to smallholders is IDR 3.79 billion. After collecting lease revenue and paying premiums to smallholders, the net benefit to the mill is IDR 421 million. The benefit available to pay as premiums to smallholders is small, which implies that the premium per FFB is unlikely to achieve the mill's desired impact of securing its FFB supply through price support.

Finally, the five newly grid-connected villages near the mill benefit by offsetting diesel generation costs and by enabling additional incremental consumption. For the 550,000 annual counterfactual kilowatt-hours, local consumers pay a lower retail electricity rate of IDR 614/kWh compared to IDR 2,333/kWh for diesel. For all incremental kilowatt-hours, the local consumers also realize IDR 1,720/kWh (which is the conservative avoided cost estimate of the difference in diesel and grid-based electricity). Since these customers already consume electricity (although it is supply-constrained), they would not realize the World Bank lighting benefit per kilowatt-hour since this is based in part on cost avoidance from switching from kerosene.

3.4 Results

3.4.1 Economic Analysis

This project performs very well economically through its significant reduction of PLN generating costs. This project performs very well economically through its significant reduction of PLN generating costs. Table 9 shows economic results for the project, with reference case assumptions presented in Table 10. Additional economic modeling data are available in Appendix B and C.

Table 9. Economic Results

Economic Results	
ERR (%)	40.5%
NPV (million IDR)	123,000
NPV ($)	$12,700,000

Table 10. Reference Case Assumptions

Descriptor	Value (IDR or %)	Value ($)
Installed Capacity (kW)	1,250	
Capital Cost (IDR/Watt)	24,153	$2.49
Total Installed Capital Cost	31,241,245,900	$3,220,747
Capacity Factor (%)	90%	
Annual O&M Costs (IDR)	3,019,125,000	$311,250
Capital Physical Lifetime (years)	20	
Salvage Value % of Capital Costs	0%	
First Year Production (% of full production)	50%	
Degradation Annual Rate of Production (%)	0%	
PLN FiT Payment (IDR/kWh)	975	$0.101
PLN Sale Price (IDR/kWh)	614	$0.063
PLN Cost of Generation (IDR)	2,922	$0.301
Share of Production Purchased by PLN (%)	100%	

Figure 14 shows the counterfactual and WP annual net benefits with incremental benefits displayed in green bars. The project ERR and NPV are calculated on the incremental net project cash flows. The CF cash flows decline significantly over time because PLN's generation cost increases faster than inflation, exposing it to long-term cost increases. In the WP case, the PPA has a fixed price, which allows PLN to hedge against long-term cost growth.

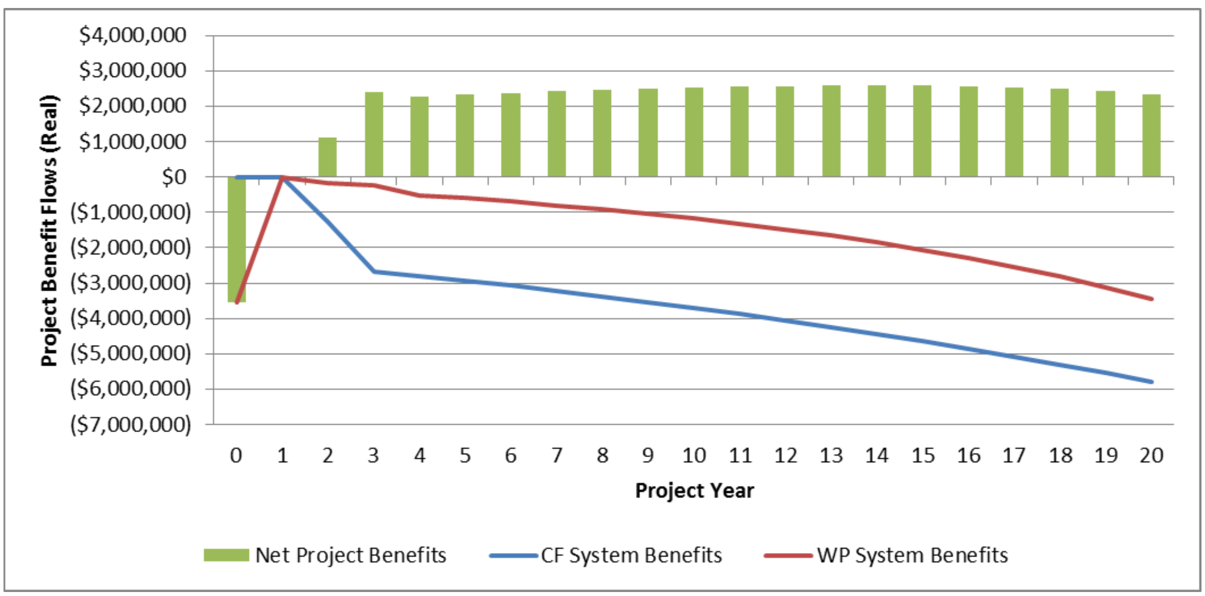


Figure 14. Lifetime net project benefits

Figure 15 shows the project NPV over different time periods. This display is useful for showing when the project pays back on a discounted basis. In this case, the project-discounted payback occurs in the fourth year.

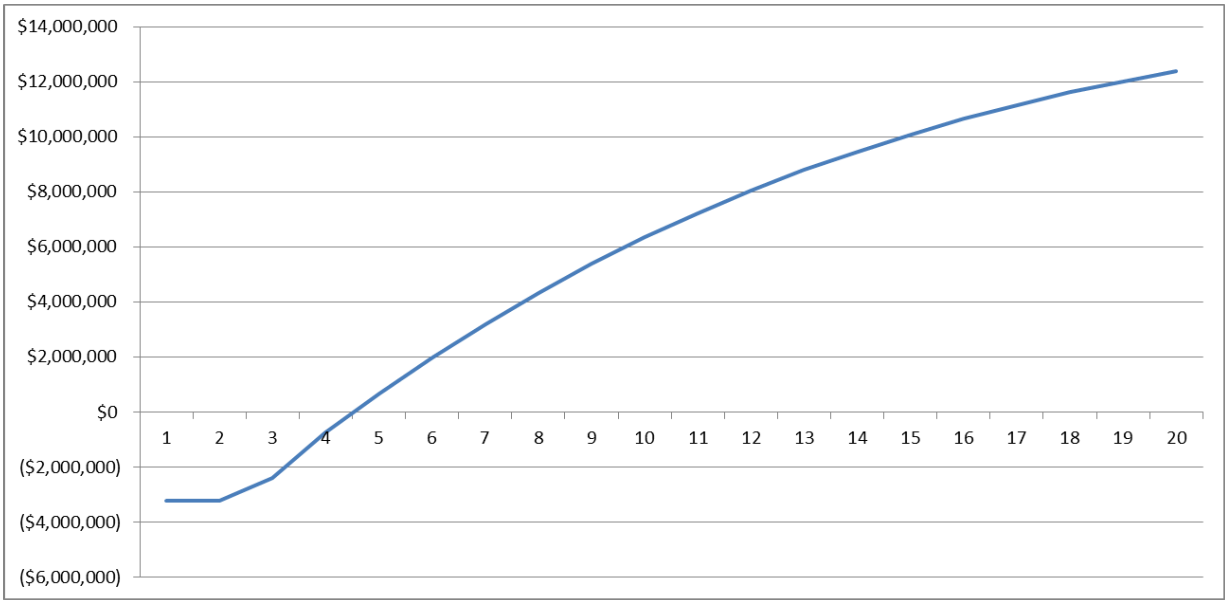


Figure 15. Sensitivity of NPV to time horizon

3.4.2 Beneficiary Analysis

The value from this project is transferred in various ways to the primary stakeholders participating in this project, namely, the IPP, mill, and smallholders. Even after making significant FiT payments for electricity sold to the grid, PLN captures the majority of total benefits.

Table 11 and Figure 16 show the economic impact of this project on various stakeholders. The ERR shown represents the real return to each stakeholder. Likewise, the NPV values are calculated at the social discount rate of 10%. So even though an NPV is negative, it may still perform positively relative to a given stakeholder's specific discount rate (although the real return would be below 10%). No ERR is presented for PLN, the mill, or smallholders because there is no contribution of capital from these stakeholders. The respective NPV values provide a glimpse of how well these beneficiaries fare in this project design.

Table 11. Distribution of Net Benefits

Beneficiary Analysis	Return[24]	NPV (Million IDR)	NPV ($)	% of Project NPV
Operator	3.89%	(6,200)	($641,000)	-5.0%
PLN	154.60%	110,000	$11,700,000	92.3%
MCA-I Finance Window	0.48%	(5,200)	($536,000)	-4.2%
Mill	n/a	420	$43,400	0.3%
Local Electricity Consumers	n/a	17,000	$1,730,000	13.6%
Smallholders	n/a	3,800	$390,000	3.1%

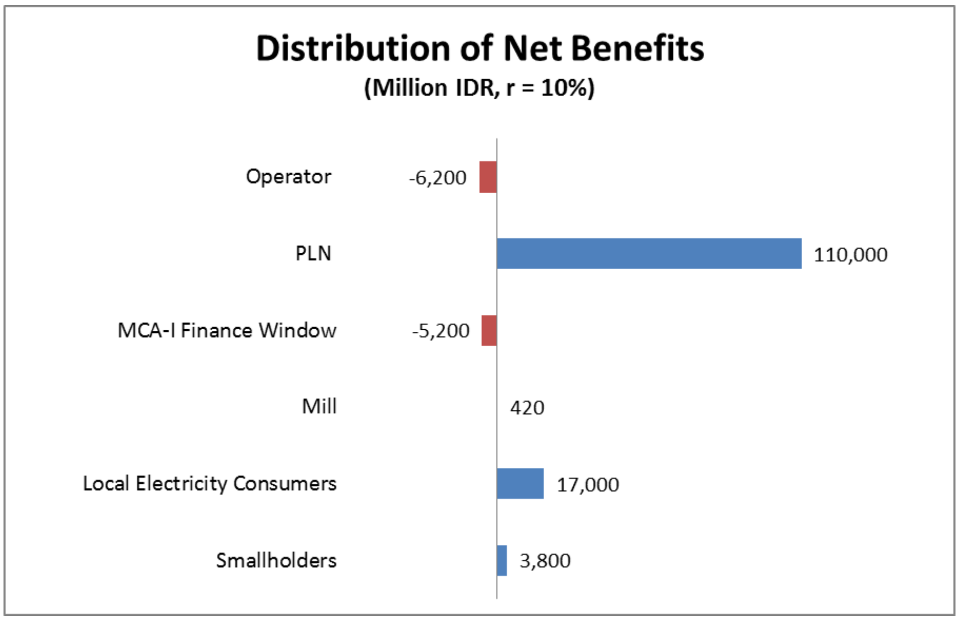


Figure 16. Beneficiary analysis (percent of project NPV)

Figure 17 displays the incremental benefit to each stakeholder over time. The MCA-I finance window and IPP split the capital cost in half, so their first-year cash flows are negative. In years three through ten, the interest and principle payments are positive for the finance window and reduce net income for the IPP. In year ten, however, the IPP's cash flows jump by IDR 1.52 billion.

[24] ERR undefined since all cash flows have the same sign

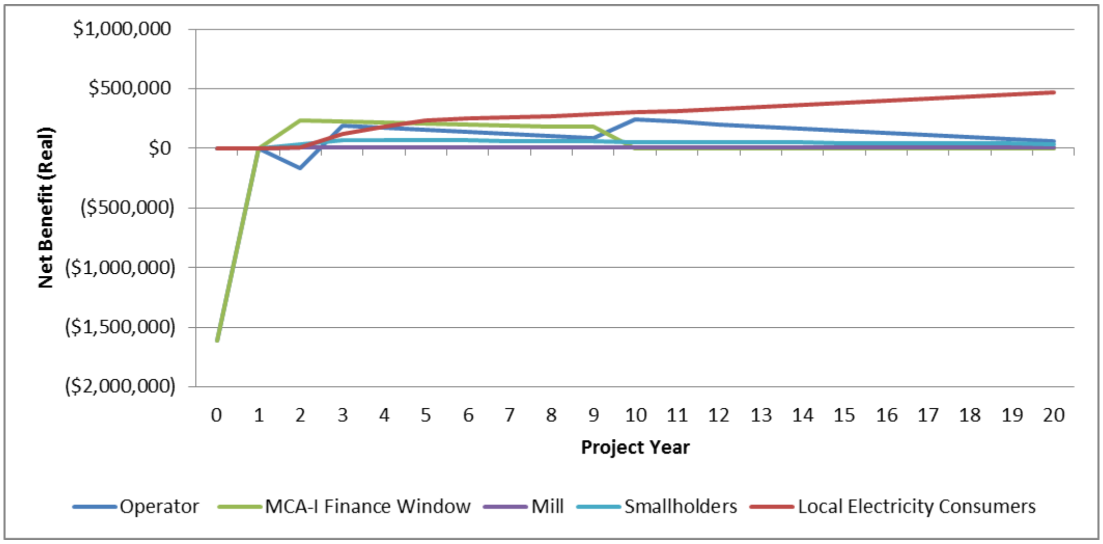


Figure 17. Beneficiary net benefit streams

PLN's value flows include revenue for all of the kilowatt-hours it sells, generation cost avoidance for units it does not have to generate (the difference between the light blue and red line), FiT payments made to the IPP, and connection revenue from new connections in the five villages. PLN's benefit streams are shown in Figure 18.

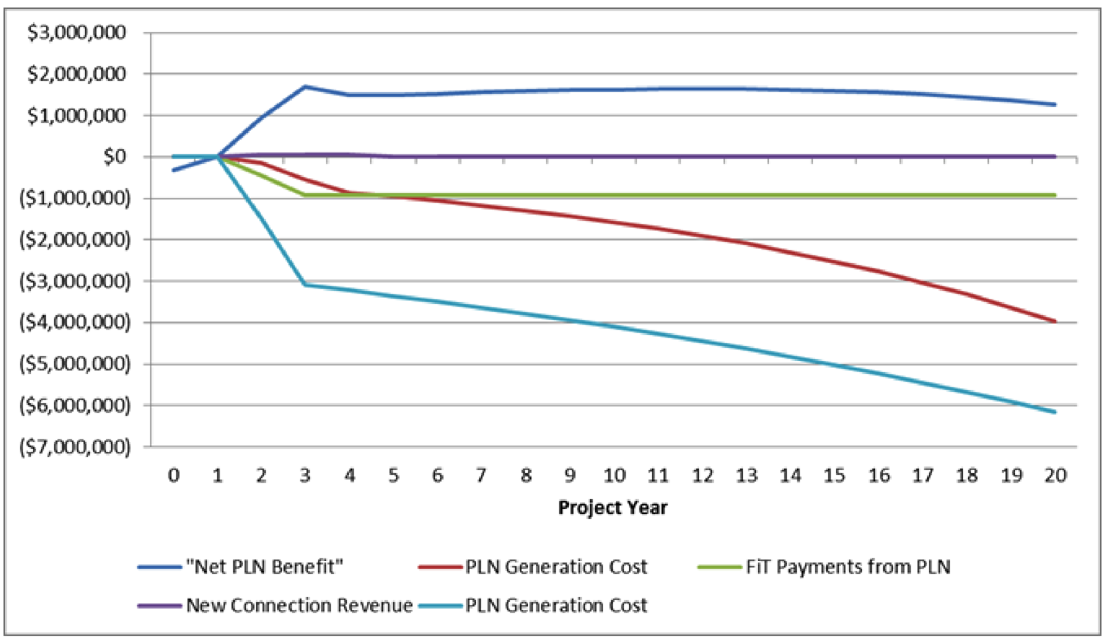


Figure 18. PLN benefit streams

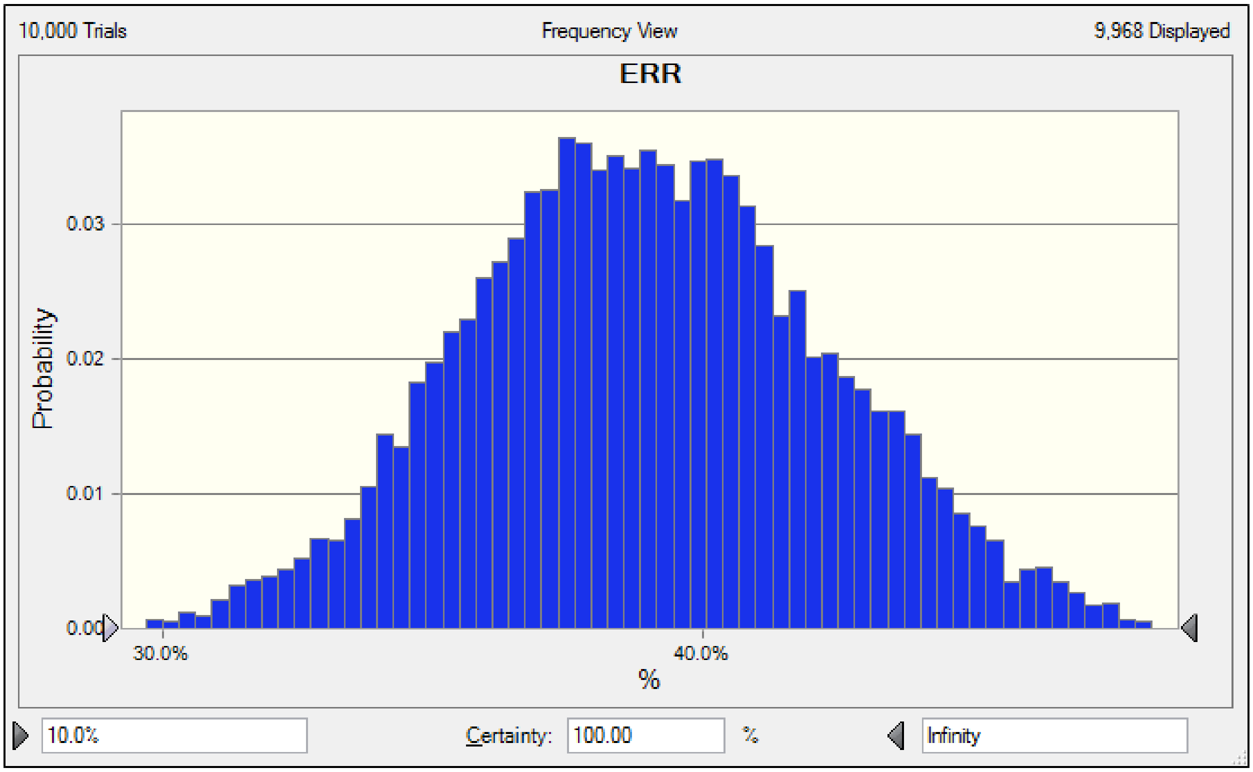
3.4.3 Sensitivity Analysis

The sensitivity analysis revealed that there were a few highly sensitive inputs. Where possible, values were researched and collected in site visits to minimize the uncertainty range or eliminate variables as sensitivity parameters. Table 12 shows the sensitivity analysis parameters, their default values, and their uncertainty distributions. A full discussion of sources and values will be contained in forthcoming electrification model documentation.

Table 12. Sensitivity analysis parameters

Descriptor	Value	IDR	Distribution	Upper	Lower
National Inflation Rate (%)	4.00%		Triangular	5%	3%
Capital Cost per Watt ($/W)	$2.49	24,153	Triangular	$3.00	$2.00
O&M cost (% of installed capital cost)	10%		Triangular	11%	9%
Capacity Factor (%)	90%		Triangular	95%	80%
Parasitic Load (%)	7.7%		Triangular	8%	5%
CF Long Term Consumption Growth Rate (% per year)	0.5%		Triangular	0.75%	0.25%
CF Diesel Electricity Cost ($/kWh)	$0.241	2,333.333	Triangular	$0.400	$0.200
CF Diesel Electricity Nominal Price Growth (% per year)	4.0%		Triangular	4.5%	3.5%
WP Electricity Consumption Growth Rate (% per year)	1.0%		Triangular	1.5%	0.5%
Incremental consumption value per kWh	$0.177	1,719.55	Triangular	$0.200	$0.060
Local HH growth rate (% per year)	2.5%		Triangular	3.0%	2.0%
CF Long Term Consumption Growth Rate (% per year)	0.5%		Triangular	0.75%	0.25%
Percent Purchased from Smallholders (%)	50%		Triangular	60%	40%
Current FFB price ($/ton)	$146.39	1,420,000	Triangular	$160	$130
Nominal FFB Price growth (% per year)	4.00%		Triangular	5.0%	3.0%
Mill share of lease revenue (% per year)	10.00%		Triangular	12.0%	8.0%
Nominal Interest Rate (%)	4.50%		Triangular	6%	3%
Nominal PLN Price Growth (% per year)	3.30%		Triangular	4.00%	3.00%
PLN cost of generation ($/kWh)	$0.301	2,922	Triangular	$0.362	$0.075
Nominal PLN Gen Cost Growth (% per year)	8.3%		Triangular	8.5%	5%

Figure 19 show the results for NPV and ERR of a 10,000-trial Monte Carlo simulation using the sensitivity parameters and uncertainty distributions described above in Table 12 (additional charts in Appendix C). The analysis shows that this project would deliver a positive NPV and an ERR above 10% with 100% certainty. As expected, the highly sensitive variables are capital cost per Watt, the capacity factor, PLN's generation cost per kilowatt-hour, and PLN's generation cost growth.



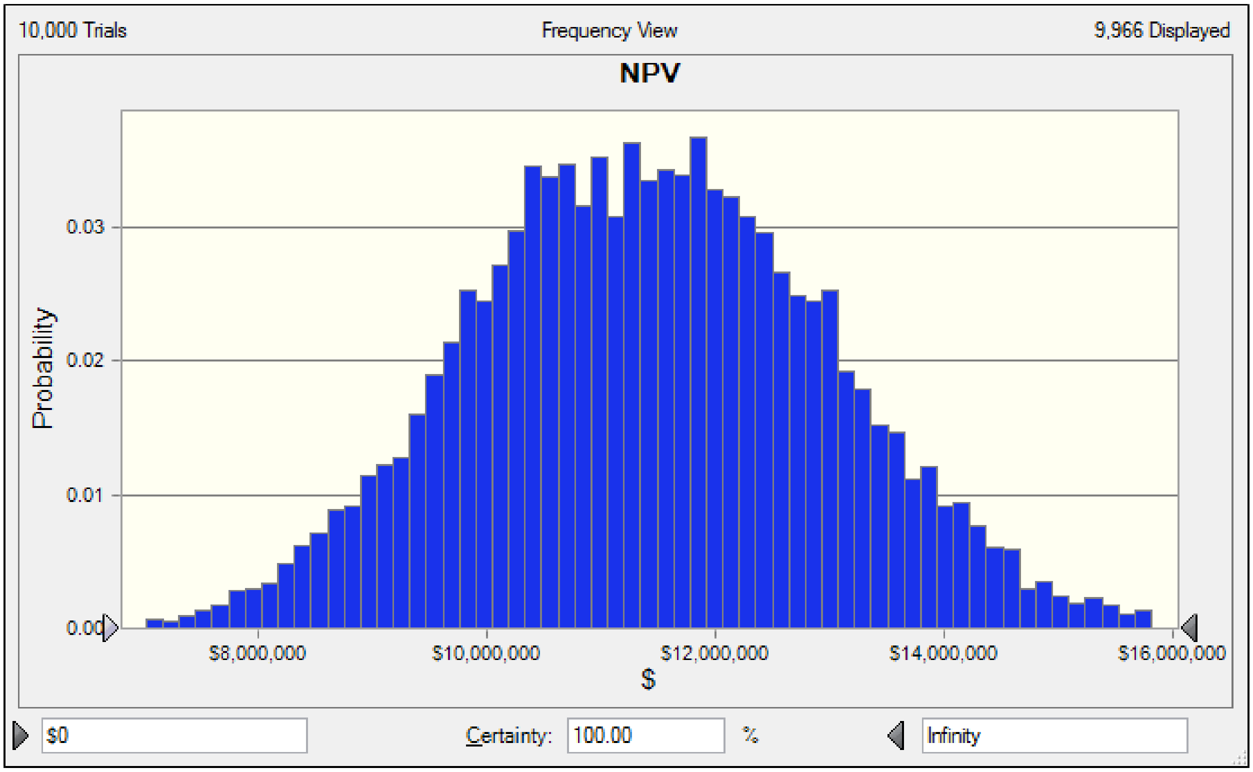


Figure 19. Sensitivity analysis results for NPV and ERR

PLN's generation cost per kilowatt-hour was constrained in the sensitivity analysis because it is a distinct value obtained from PLN reports [21]. Figure 20 shows the sensitivity of the project ERR to only the generation cost per kilowatt-hour with all else equal. This figure shows how important this value is to the economic outcome of the project. However, even at very low values, the project still meets the 10% hurdle. The project return is lower than 10% at generation costs below $0.07 per kWh.

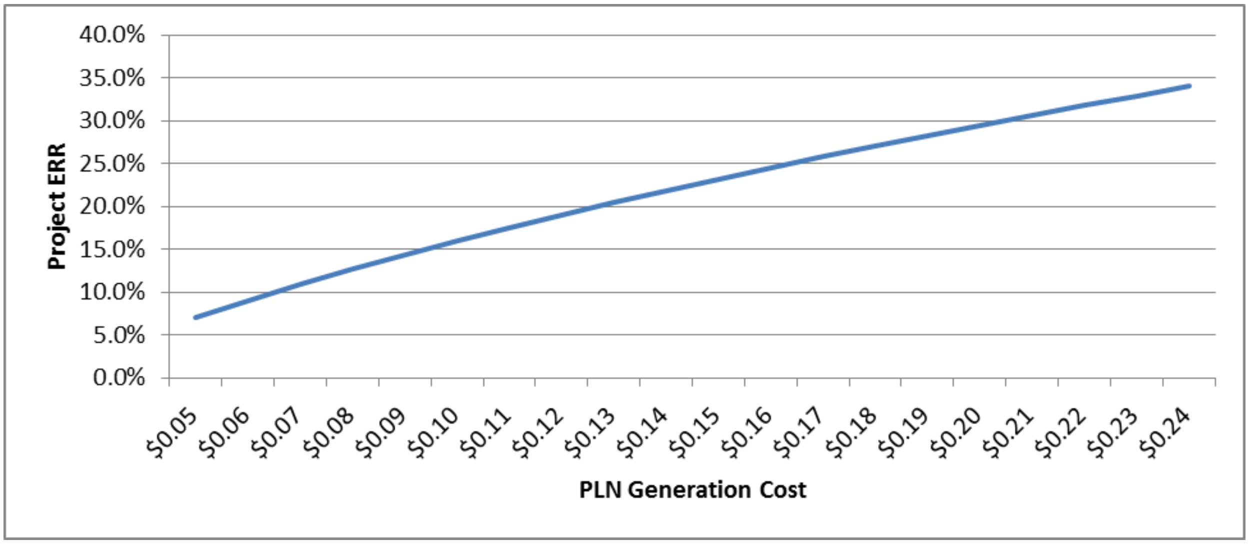


Figure 20. ERR sensitivity to PLN generation cost

Figure 21 through Figure 25 show the sensitivity of project ERR by isolating specific variables (capacity factor, FiT escalation rate if there were a policy change, capital cost per Watt, capacity, and nominal growth rate of PLN's generation cost). It is important to note that even with extremely conservative assumptions for each isolated variable, the project ERR consistently exceeds the 10% hurdle. Isolating these particular variables for single-dimension sensitivity analysis enables the reader to observe how sensitive the project ERR is to a particular variable and over what ranges. For example, the project ERR is highly sensitive to the generating system capacity size at low values, but less so at higher values. The directional impact can also be observed by isolating these variables. The rest of variables have mostly linear relationships with project ERR.

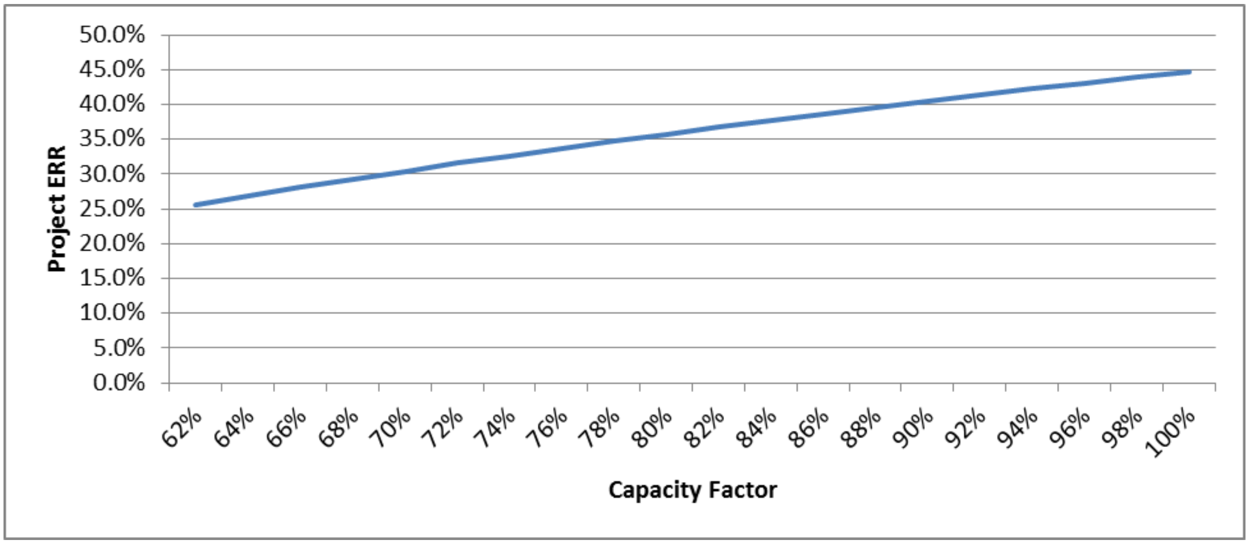


Figure 21. Sensitivity of project ERR to generating system capacity factor

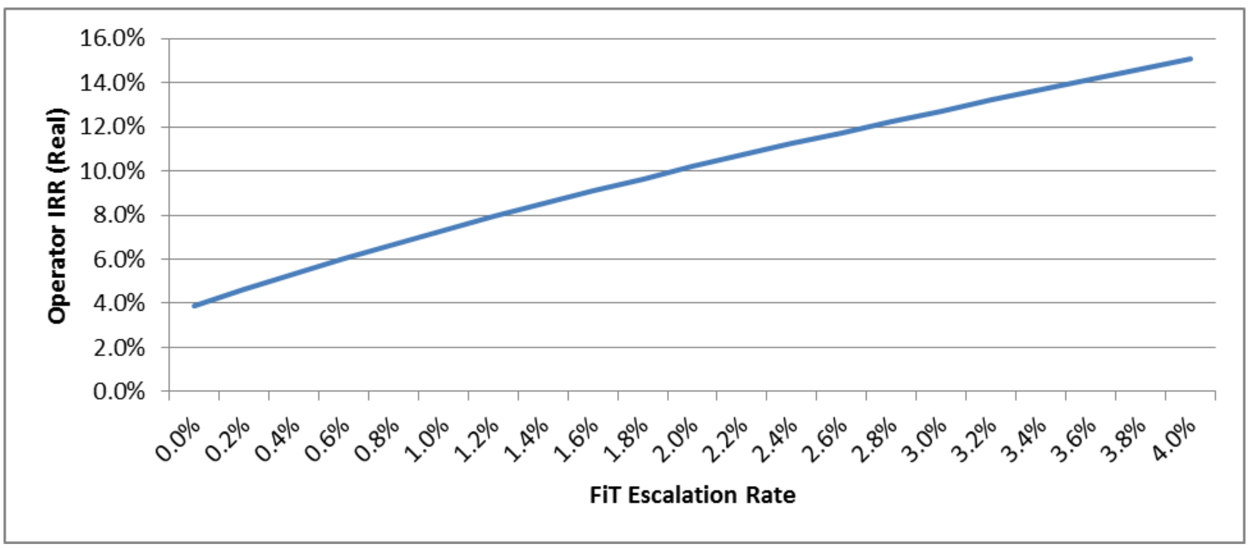


Figure 22. Sensitivity of operator IRR to a hypothetical FiT escalation rate

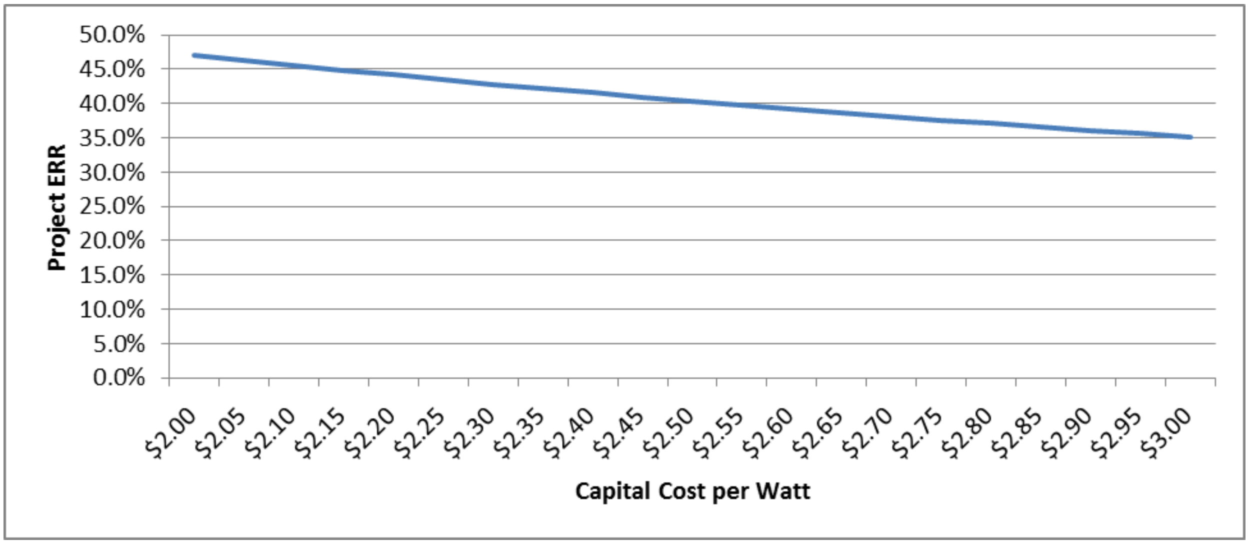


Figure 23. Sensitivity of project ERR to capital cost per Watt

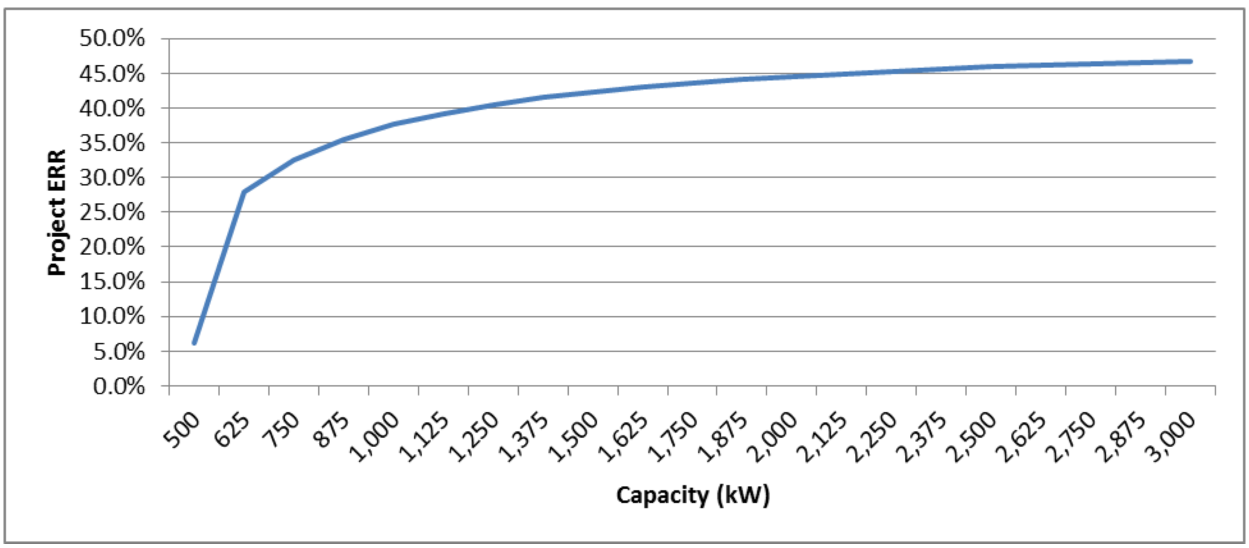


Figure 24. Sensitivity of project ERR to generating system capacity

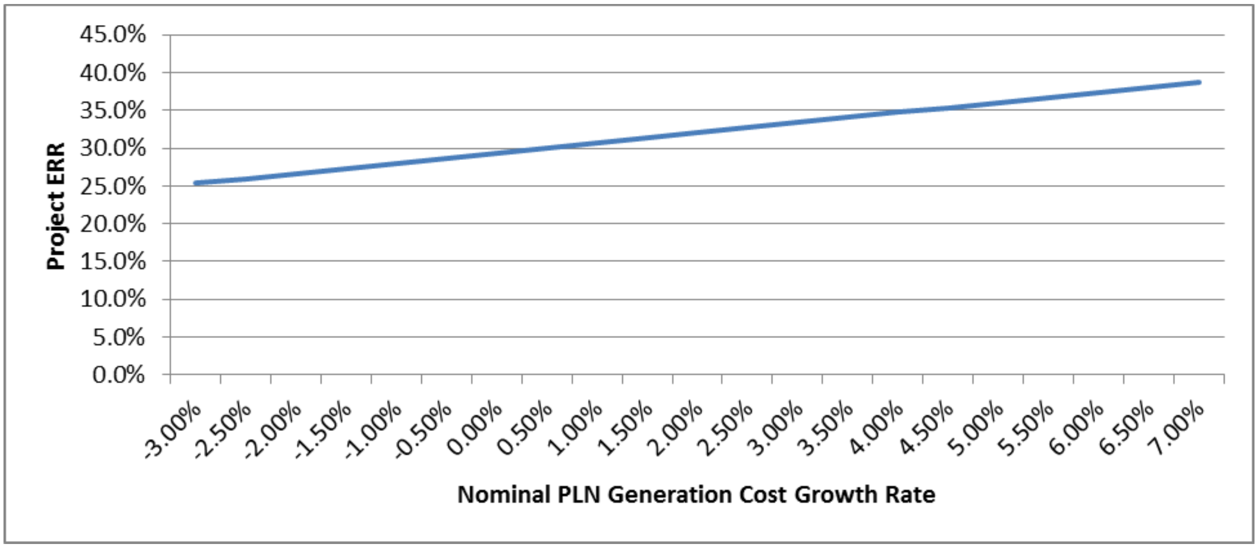


Figure 25. Sensitivity of project ERR to nominal PLN generation cost growth rate

3.5 Economic Risk Assessment

This report presents results for the best estimate of each of the input variables.[25] Changes in these parameters may strongly affect overall economic performance.

The sensitivity analysis presented above reveals the variables that would have significant impact on the economic outcome of the project. Perhaps the biggest risk to the project is that most of the value is captured by PLN while there are slim margins for other stakeholders. Both the mill and smallholders are made better off by the project, but only marginally. Similarly, the IPP does not perform very well (3.89% ERR).

Because two major actors in this project structure have a limited upside determined by the system electricity production and FiT rate, and because the benefit captured is then divided among other beneficiaries, there is little incentive for either proponent to enter into this arrangement from an economic perspective alone. Additionally, tight margins imply insolvency risk for the life of the project, which means that disruptive events like construction delays can inhibit the IPP's ability to meet its obligations.

Some specific risks that are less likely but worth noting include policy or regulation risk that might impact IPP revenue. Changes to the mill production from changes to world market demand for palm oil may impact the IPP's biogas supply from POME, inhibiting the IPP's ability to meet its PPA reliably. Lastly, any one of the project proponents could opt out of the arrangement and thereby undermine the intended flow of benefit.

The most significant changes to the project design would be to negotiate an escalation rate into the PPA with PLN, and increasing generation system output (a possibility as each mill's energy potential varies based on POME characteristics). There would still be a limited upside for the

[25] Please contact the authors for additional information about results for various alternatives or input variable ranges considered.

IPP, but it would provide a much-needed cushion for its obligations. Finally, although it wasn't considered here, if CER credit prices increase in world markets, this project could generate an additional revenue stream.

4 Environmental and Spatial Land Use Assessment

As noted previously, all Green Prosperity program project investments must meet certain technical, economic, environmental, and social expectations expressed in MCC's Compact with Indonesia. Specific to environmental impacts, the Green Prosperity program is focused on promoting the productive use of low-pollution renewable energy, the management of watersheds, forests and other natural resources, and the sustainable use of lands for agriculture and other purposes.

This project focuses on developing a renewable source of power at the BBIP palm oil mill by covering a palm oil pond and collecting methane, which will be combusted to generate electricity. Overall, the project appears to be consistent with the Green Prosperity program's environmental goals. This chapter provides a preliminary assessment of environmental impacts of this project, which would be further detailed in a full feasibility study.

Below, potential environmental impacts of the project are discussed, followed by consideration of applicable Indonesian environmental laws and regulations, the GHG emissions impact of the project, and spatial land use considerations.

4.1 Environmental Impact Assessment

Any project activity in Indonesia requires full disclosure of possible environmental impacts at the earliest stages of project development, and also must ensure that these impacts are addressed by being avoided or mitigated to the greatest extent possible, or that some form of compensation is given to those affected.

In this case, BBIP was selected for evaluation under USDAID's CIRCLE program, which evaluated approximately 100 mills for methane capture. BBIP scored well, meeting environmental standards and promising positive impacts on the environment. The effects could be multiplied if this type of project were replicated throughout Indonesia. Its largest environmental benefit is the reduction of unmitigated methane emissions through the capture and combustion of methane emitted from POME ponds. The current open-air ponds release significant volumes of methane gas, which is pound-for-pound 21 times more impactful as a GHG than CO_2.

A preliminary list of positive environmental impacts of this project are as follows:

- GHG emission reductions, in the form of captured methane (a quantitative estimate of these reductions is given in Section 4.3)
- An increase in renewably generated electricity contributing to Indonesia's 2025 renewable energy target of 15% renewable power, magnified if the project were to be replicated at many other palm oil mills[26]
- A decrease in health issues related to poor air quality from a reduction in diesel power generation in the local villages

[26] http://www.icafrica.org/fileadmin/documents/Knowledge/GIZ/Legal Frameworks for Renewable Energy.pdf

Potential negative environmental impacts are as follows:

- Construction-phase environmental disturbances, which might include heavy construction equipment impacting roads and air quality, and temporary POME wastewater flow disruptions
- Longer-term impacts of added infrastructure (roads, power line connections to PLN, and local villages)

If this project or one similar to it were to move toward a full feasibility study, these impacts would need to be studied, with the likely extent of their impacts explored and mitigations identified where possible.

4.2 Compliance with Legal Requirements and Performance Standards

Initiating any project in Indonesia will require permits and/or licenses from the Government of Indonesia. This includes an environmental permit for projects with potential for environmental impacts. An environmental permit is issued following approval of an Analisis Mengenai Dampak Lingkungan (AMDAL) or Upaya Pengelolaan Lingkungan Hidup dan Upaya Pemantauan Lingkungan Hidup (UKL-UPL) document. An AMDAL is a full environmental assessment, required for projects that are considered to have potentially significant impacts, while a UKL-UPL is an environmental management and monitoring plan for projects that are not expected to cause significant impacts. Small-scale activities may be required to prepare a Surat Pernyataan Kesanggupan Pengelolaan Dan Pemantauan Lingkungan Hidup (SPPL), which acts as a letter of commitment to manage the environment. The type of environmental document required is governed by the Regulation of the Minister for Environment No. 5 Year 2012 on Types of Projects and/or Activities that Require an AMDAL.[27]

The environmental permit and approval of AMDAL or UKL-UPL documents for Green Prosperity projects is likely to be the authority of the provincial or district-level government, depending on the size and location of the project. The national government only issues environmental permits for projects that cross provincial boundaries or are strategic in nature.

MCC also requires that Green Prosperity projects adhere to the IFC Performance Standards. These standards support a process to ensure that any project is exercising due diligence of environmental and social risks from start to finish. Table 13 is a list of the IFC Performance Standards related to environmental impacts.[28]

[27] http://www.lexology.com/library/detail.aspx?g=ef8a4775-49a1-445a-aae3-56c8f759f93c

[28] Other IFC Performance Standards not cited here address: Performance Standard 2: Labor and Working Conditions; Performance Standard 4: Community Health, Safety, and Security; Performance Standard 5: Land Acquisition and Involuntary Resettlement; Performance Standard 7: Indigenous Peoples; and Performance Standard 8: Cultural Heritage.

Table 13. IFC Performance Standards

IFC Performance Standard	Description
Performance Standard 1: Assessment and Management of Environmental and Social Risks	Describes the importance of identifying environmental and social risks and impacts, and managing environmental and social risks throughout the life of a project. This standard applies to all projects.
Performance Standard 3: Resource Efficiency and Pollution Prevention	Recognizes that increased industrial activity and urbanization often generate higher levels of air, water, and land pollution, and that there are efficiency opportunities.
Performance Standard 5: Land Acquisition and Involuntary Resettlement	Recognizes that project-related land acquisition and restrictions on land use can have adverse impacts on communities and persons that use this land. Involuntary resettlement refers both to physical displacement (relocation or loss of shelter) and to economic displacement. For this particular project there will be no land acquisition.
Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	Promotes the protection of biodiversity and the sustainable management and use of natural resources.

4.2.1 Relevant Indonesian Laws

The Government of Indonesia has many laws that could pertain to the proposed project activity. Selected laws are listed Table 14.

Table 14. GOI Laws & Regulations

Green Prosperity Application	GOI Laws & Regulations
Green Prosperity as a whole	Act No. 32, 2004 on Regional Autonomy
	Act No.7, 2004 on Water Resources
	Act No. 32, 2009 on Environmental Protection & Management
	Act No. 14, 2008 on Public Information Disclosure
	Act No.39, 1999 on Human Rights
	Act No.41, 1999 Forestry
	Act No.18, 2004 Plantation
	Act No. 5, 1990 on Conservation of Biological Resources & Ecosystems
	Ministry of Forestry 5-year Strategic Plan (RENSTRA) 2009 – 2014 with a program focus on Community-based Watershed Management
	Ministry of Forestry Decree, P.7/Menhut-II/2011 re Public Information Service of Forestry Sector, 02 February 2011
	Ministry of Forestry Decree on Information Transparency, 27 February 2006
	Government Regulation 6 of 2007 on Forestry
	Ministry of Forestry (2000), General Framework and Criteria & Standards for Forest and Land Rehabilitation. Directorate for Land Rehabilitation and Soil Conservation, Directorate General for Land Rehabilitation and Social Forestry, Jakarta, 2000
	Presidential Instruction (INPRES) No.1 of 2000 on Gender Mainstreaming
Participatory land-use planning	Law 26 of 2007 on Spatial Planning, specifically Article 48, (1), (a), on Empowerment of Local People through Spatial Planning
	Ministry of Home Affairs Guidelines 27 and 28 of 2006 on village boundary-setting
	Spatial Planning Act 26 of 2007 and Spatial Planning Act 27 of 2007 for Coastal Regions and Small Islands
	Government Regulation 15 of 2010 on Spatial Planning Implementation

Green Prosperity Application	GOI Laws & Regulations
Green Prosperity Facility	Act No.30 Year 2009 on Electricity
	Ministerial Regulation of Agrarian Minister / Head of National Land Agency No. 2, 1993 on Procedures to Obtain Location Permit and Land Use Rights for Investing Corporations Investing Ministerial Regulation of Agrarian Minister / Head of National Land Agency No. 2, 1999 on Issuance of Location Permit for National and Foreign Direct Investments
	Presidential Regulation No. 5 Year 2006 on National Energy Policy
	Presidential Regulation No. 61 Year 2011 on National Action Plan on Greenhouse Gas Emission Reduction

Source: Draft Environmental and Social Management System Tier 2, I. Marifa and S. Feld, Aug 2013

As projects of this type move toward implementation, MCA-I's Environmental Social Management System should be consulted to ensure awareness of and adherence to all relevant requirements of Indonesian law and MCC corporate practice.

4.2.2 Application to the Proposed Project

For the project under consideration, since it is an electricity generation project with capacity less than 10 MW, the UKL-UPL is the only required environmental document.[29] The UKL is an environmental management effort, and the UPL is an environmental monitoring effort providing an overview of potential environmental impacts with a focus on management and monitoring efforts by the project owner. The UKL-UPL is provided to the appropriate authority, which may be a Minister of Environmental Affairs, Governor, or Regent, and notice of the application must be announced in the media within five days after submission.

The UKL-UPL is an important milestone in the project's development because when it is approved, the Environmental License is issued. An Environmental License is a new requirement under Indonesian law GR 27/2012 and it restates requirements and obligations for a project as described in the UKL-UPL. The Environmental License will also detail any other Environmental Licenses required by the project. Requirements to maintain the Environmental License include compliance with the terms of the permit, a compliance report twice annually, and a guarantee of funds for environmental mitigation. Approval of the UKL-UPL and issuance of the Environmental License are prerequisites to obtaining a business license.

4.3 Greenhouse Gas Calculations

Electricity generation from POME in Mauro Jambi will affect GHG emissions through two primary mechanisms. First, recovering biogas from lagoons will reduce waste-related emissions (particularly methane). Second, generating electricity from captured biogas will reduce combustion emissions from grid-connected electricity generation. This section provides a preliminary estimation of the GHG emissions reduction associated with each of these impacts.

[29] See Indonesian Law No. 23/1997 on Environmental Management, Government Regulation No. 27/2012, and Ministry of Environment Decrees No. 40/2000, No. 17/2001, and No. 86/2002

4.3.1 Emissions Reduction from Methane Capture

GHG emissions result from numerous points along the palm oil production chain, including oil palm cultivation, FFB processing and transportation, machinery use in palm oil mills, biomass decomposition, POME, and others [23]. Since biogas capture and use will not result in any changes in the capacity of the palm oil mill, the only GHG impacts considered in this analysis are those associated with POME. Similarly, although wastewater treatment involves several components, this analysis considers only the GHG emission impacts associated with recovering biogas from anaerobic lagoons, reflecting the assumption that all other wastewater treatment processes—and their resulting GHG emissions—would be unchanged by the addition of biogas capture and combustion equipment. Additional assumptions applied to this analysis include the following:

- The existing lagoon is anaerobic, has an ambient temperature above 15 degrees Celsius during part of the year, and has an average annual depth greater than 2 m. The depth of the lagoon can be confirmed via engineering design documents or direct measurement.

- The wastewater treatment systems will continue to operate with the same quality of feed inflow, volume (retention time), and temperature in the baseline scenario as in the project scenario. Therefore, the methane generation potential is unaltered by the project.

- The biogas capture and utilization system will have negligible impact on methane emissions associated with sludge treatment, decay of the final sludge generated by the treatment systems, and the quantity of degradable organic carbon in wastewater discharged into the sea/river/lake relative to the baseline scenario. Emissions from these portions of the wastewater treatment process are not quantified in this analysis.

Annual methane emissions from the uncovered lagoon ($BE_{ww,lagoon}$) are quantified using the following equation, which is adapted from the United Nations Framework Convention on Climate Change (UNFCCC) approved small-scale CDM methodology for methane recovery in wastewater treatment (AMS-III.H) [24]:

$$BE_{ww,lagoon} = Q_{ww,lagoon} \times COD_{\text{inflow},lagoon} \times \eta_{COD,BL} \times MCF_{ww,lagoon,BL} \times B_{o,ww} \times UF_{BL} \times GWP_{CH4}$$

Table 15 shows the definition of each parameter in the equation above. Direct measurement of these parameters at the BBIP mill was not possible during the pre-feasibility assessment, so parameter values have been assumed based on the sources indicated in Table 15.

Table 15. Parameters for Estimating GHG Emissions from Baseline POME Treatment (uncovered lagoon)

Parameter	Definition	Value	Unit	**Source [**Error! Bookmark not defined.**]**
$Qww_{,lagoon}$	Volume of wastewater treated in the anaerobic lagoon	213,671.25	m^3/year	ICED Indonesia Renewable Energy Toolkit (estimate for a 45tph mill)
$COD_{inflow,lagoon}$	Chemical oxygen demand of wastewater inflow to the anaerobic lagoon	0.05	tons/m^3	ICED Indonesia Renewable Energy Toolkit
$\eta_{COD,BL,i}$	COD removal efficiency of the anaerobic lagoon	0.98	(unitless)	Assumed efficiency based on values reported in CDM project development documentation for similar systems in Indonesia[30]
$MCF_{ww,lagoon,BL}$	Methane correction factor for the anaerobic lagoon	0.8	(unitless)	IPCC default value for anaerobic deep lagoons (depth greater than 2 m)[31]
$B_{o,ww}$	Methane producing capacity of the wastewater	0.25	kg CH_4/kg COD	IPCC default value[32]
UF_{BL}	Model correction factor to account for model uncertainties	0.89	(unitless)	AMS-III.H default value
GWP_{CH4}	Global warming potential for methane	21	(unitless)	
$\boldsymbol{BE_{ww,lagoon}}$	**Baseline emissions from uncovered anaerobic lagoon**	**39,136**	**tCO_2e/yr**	**Calculated**

The proposed biogas recovery system (i.e., a flexible membrane covering the anaerobic lagoon) will eliminate most of the methane emissions associated with the uncovered lagoon; however, this system is associated with two types of inefficiencies: (1) fugitive methane emissions from biogas release in capture systems ($PE_{fugitive}$); and (2) methane emissions due to incomplete flaring ($PE_{flaring}$). Fugitive emission are estimated using an equation:

$$PE_{fugitive} = (1 - CFE_{ww}) \times Q_{ww} \times B_{o,ww} \times UF_{PJ} \times COD_{removed,PJ} \times MCF_{ww,lagoon,PJ} \times GWP_{CH4}$$

According to AMS-III.H, emissions from incomplete flaring can be calculated using the equation for baseline wastewater emissions ($BE_{ww,lagoon}$, shown above) but without consideration of the

[30] Project development documentation for CDM projects is available at http://cdm.unfccc.int/Projects/projsearch.html.

[31] As reported in UNFCCC. (2010). Indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories. III.H./Version 16, Sectoral Scope: 13. EB 58. Retrieved 4 Sept 2013 from http://cdm.unfccc.int/filestorage/8/R/I/8RIV5MZ4AG7YE9UQJ6HSL3NTFXD1C0/EB58_repan22_AMS-III.H_ver16.pdf?t=Um98bXNvNnBhfDBiKG3LnN-XSiXb2E1TjBld.

[32] *Ibid.*

global warming potential for methane. Using this approach, emissions from incomplete flaring associated with the methane recovery system equal 1,864 tons of CO2e per year.[33]

Table 16. Parameters for Estimating GHG Emissions from POME Biogas Recovery

Parameter	Definition	Value	Unit	Source
CFE_{ww}	Capture efficiency of the biogas recovery equipment in the wastewater treatment system	0.9	(unitless)	AMS-III.H default value
$Q_{ww,lagoon}$	Volume of wastewater treated in the anaerobic lagoon	213,671.25	m^3/year	ICED Indonesia Renewable Energy Toolkit (estimate for a 45tph mill)
$COD_{removed,PJ}$	Chemical oxygen demand removed by the anaerobic lagoon equipped with biogas recovery	0.05	t/m^3	ICED Indonesia Renewable Energy Toolkit (assumes no change from baseline value)
$MCF_{ww,lagoon,PJ}$	Methane correction factor for the anaerobic lagoon equipped with biogas recovery	0.8	(unitless)	IPCC default value for anaerobic deep lagoons (depth greater than 2 m)
$B_{o,ww}$	Methane producing capacity of the wastewater	0.25	kg CH_4/kg COD	IPCC default value
UF_{PJ}	Model correction factor to account for model uncertainties	1.12	(unitless)	AMS-III.H default value
GWP_{CH4}	Global warming potential for methane	21	(unitless)	
$\boldsymbol{PE_{fugitive}}$	**Fugitive emissions from biogas release in capture systems**	**5,026**	**tCO_2e**	**Calculated**
$\boldsymbol{PE_{flaring}}$	**Emissions due to incomplete flaring of captured biogas**	**1,864**	**tCO_2e**	**Calculated**

Based on the above calculation, the total emissions reduction associated with biogas recovery relative to uncovered anaerobic lagoons is approximately 32,247 tons of CO_2e per year. The recovery system reduces emissions relative to uncovered lagoons by 82%.

4.3.2 Emissions Reduction from Grid-Tied Electricity Generation

The electricity generated from the captured POME biogas will be grid-tied; thus, the baseline scenario is that the electricity delivered to the grid by the proposed system would have otherwise been generated by existing grid-connected power plants and by the addition of new generation sources to the grid. According to the UNFCCC, approved small-scale CDM methodology for grid-connected renewable electricity generation (AMS-I.D), baseline emissions are the product of the megawatt-hours of electricity produced by the renewable energy generating unit (i.e., the biogas digester) multiplied by the combined margin emission factor for the grid. The combined

[33] Since anaerobic digestion does not directly involve flaring, this calculation likely overestimates GHG emissions associated with inefficiencies in biogas recovery. However, the calculation is used in this analysis to provide a conservative estimate for GHG emissions that occur from flaring under certain outstanding circumstances, for instance, if a generation unit has been temporarily shut down for maintenance but methane continues to be captured, or if more biogas is produced than the generator can process and the excess is flared.

margin accounts for both the operating margin and build margin [25]. The combined margin for Sumatra is 0.743 tons of CO_2e/MWh [26]. Table 17 summarizes the inputs used to calculate baseline GHG emissions associated with grid-tied electricity generation.

Table 17. Assumptions Underlying Calculations of Baseline GHG Emissions from Grid-Tied Electricity Generation

Measure	Value
Total annual electricity production from biogas (MWh)	9,855,0
Parasitic load/other site uses (MWh)	758.8
Net annual electricity delivered to grid (MWh)	9,096.20
Annual baseline emissions (tCO_2e)	**6,758**

Although the combustion of recovered POME biogas results in CO_2 emissions, these emissions are considered biogenic under Intergovernmental Panel on Climate Change (IPCC) accounting methodologies [27]. The electricity generated from the biogas system is therefore carbon-neutral. Thus, generating electricity from captured methane will reduce combustion emissions associated by the grid by 6,758 tons of CO_2e annually.

4.3.3 Summary

Table 18 summarizes the preliminary estimate of the GHG emissions associated with POME biogas capture and its utilization to generate electricity. This analysis indicates that, relative to the baseline scenario, this system can reduce GHG emissions by approximately 39,000 tons of CO_2e/year.

Table 18. GHG Emissions and Potential Reduction from POME Biogas Capture and Use in Mauro Jambi

Emissions Reductions from Methane Capture	
Annual baseline emissions from POME lagoons (no biogas capture) (tCO_2e)	39,136
Emissions associated with fugitive emissions from biogas capture system (tCO_2e)	5,026
Emissions associated with incomplete flaring of captured biogas (tCO_2e)	1,864
Subtotal: absolute emissions reduction (tCO_2e)	*32,247*
Emissions Reductions from Electricity Generation	
Base case emissions (based combined emission margin for Sumatra grid) (tCO_2e)	6,758
Emissions associated with electricity generation using captured biogas (tCO_2e)	0
Subtotal: absolute emissions reduction (tCO_2e)	*6,758*
Total emissions reduction from methane capture and use (tCO_2e)	**39,006**

These calculations account only for the emissions reductions associated with capturing biogas from the anaerobic lagoons and using that biogas to generate grid-tied electricity. Secondary emissions impacts for this project have not been estimated and might include effects such as a reduction in emissions associated with reduced transportation of diesel fuel to villages that will become grid-connected because of this project; an increase emissions associated with the transportation, construction, and installation of the biogas capture and utilization systems; and an increase in emissions associated with termination of the project at the end of its life (such as waste emissions). These secondary effects are assumed to have relatively small emissions implications relative to the primary impacts.

As a preliminary, high-level analysis, this emission reduction estimate is not appropriate for estimating or verifying officially recognized GHG reduction offsets (or "credits") for use in mandatory or voluntary emission reduction programs, including the Kyoto Protocol's CDM. If the generation of carbon offsets is an objective of this project, a thorough GHG reduction analysis can be performed during the feasibility and project development stages.[34]

4.4 Spatial Land Use Planning

Spatial land use planning refers to the "landscape approach" for planning environments. This means that a combined geographical and socio-economic approach to managing land, water, and forest resources is taken to ensure that the goals of food security and inclusive green growth are met.[35]

Since 2007, spatial land use planning has been required in Indonesia for all terrestrial and coastal resource planning. Any new project activity is required to create a spatial land use plan that considers the social and environmental resources inside and outside the project area.

Spatial land use does not apply to this project because it occurs entirely within agricultural land and consequently, tenure can be assigned as individual titles by BPN.

The question of the impact of the proposed project on oil palm cultivation area is of interest. Land area for oil palm cultivation is generally expected to continue its upward trend in Jambi and throughout Indonesia due to world market demand for vegetable oils. Renewable electricity from POME is not expected to increase demand for oil palm land area because electricity generation equipment will be sized for the current capacity of a mill.[36] If a mill with electricity generation from POME did expand, significant capital would be required to purchase additional biogas collection and electricity generation equipment, which would also result in significant downtime for both the mill and electricity generation plant. Further, the profitability of palm oil manufacture greatly surpasses economic benefits of electricity production from the methane byproduct. This project is therefore not expected to contribute to any significant increase of oil palm cultivation area.

The proposed project does not require any land acquisition and involves minimal land use conversion at the site because BBIP owns the relevant lands. There are land use implications connected with (1) new construction and infrastructure in the form of expanding or building new roads, and (2) connection of transmission lines with PLN.

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[34] Detailed accounting methodologies (including guidance for *ex ante* and *ex post* monitoring) for GHG reduction projects can be found in World Resources Institute and World Business Council for Sustainable Development's GHG Protocol for Project Accounting (http://www.ghgprotocol.org/standards/project-protocol); approved small scale methodologies for Clean Development Mechanism project activities (http://cdm.unfccc.int/methodologies/SSCmethodologies/approved); and the International Organization of Standardization's ISO 14064 (http://www.iso.org/iso/catalogue_detail?csnumber=38381)
[35] http://siteresources.worldbank.org/EXTSDNET/Resources/Landscapes-RIO-FAQ.pdf
[36] BBIP mill has no plans to expand the capacity of this mill.

The proposed project may require proof of Right of Building or Right of Use registered land to build a transmission line connecting with PLN. This type of land acquisition is problematic in many energy projects, but is not expected to be an issue here because there is a mill-owned road surrounded by mill-owned land, connecting to the existing PLN transmission line.

Current land use in Muaro Jambi District is identified in Figure 26 and Table 19.

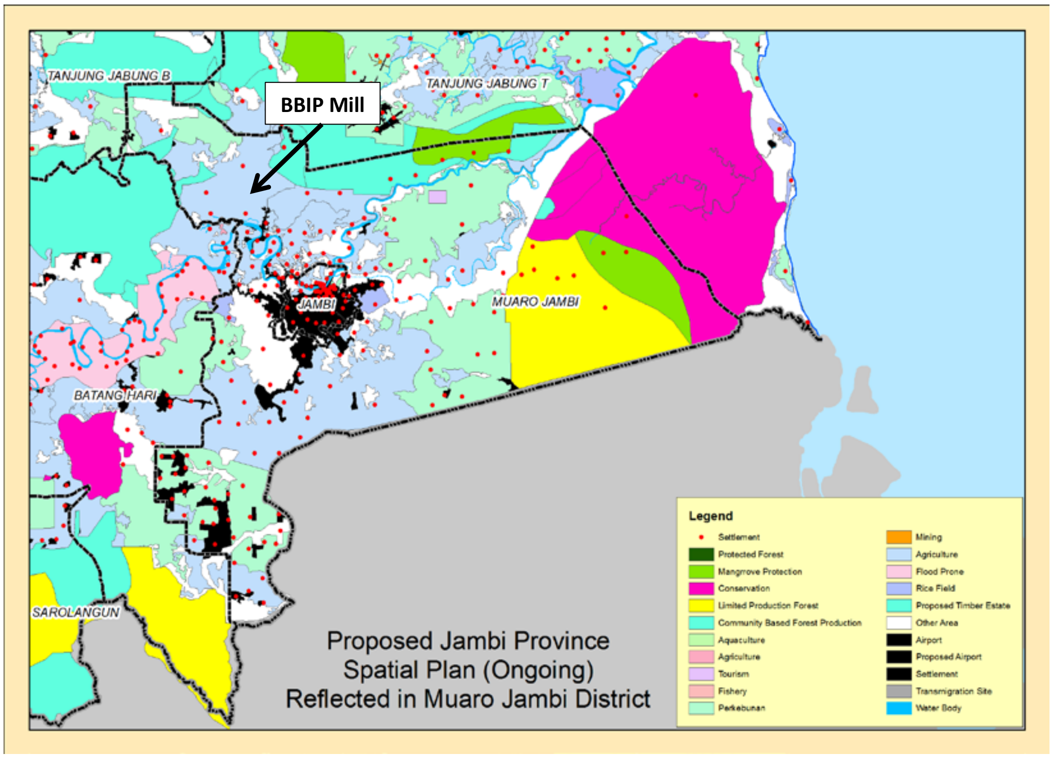


Figure 26. Muaro Jambi land use

Source: Muaro Jambi Government Statistics Department

Table 19. Muaro Jambi Land Use Area

Muaro Jambi Land Type	%
Berbak N.P.	4.4
Peat	4.4
Forest Park	2.8
Limited Production Forest	11.8
Production Forest	6.7
Dry Land (agriculture)	12.39
Settlements	9.72
Palm, Rubber, Coffee, Coconut	41.75
Temple Complex	0.6
Coal	0.2
Other	5.24
Total	100.00

5 Social Assessment

5.1 Community Impacts

A Community Demographic Assessment was conducted with the following results. Bogor Agricultural University (IPB), under subcontract to NREL, visited a village near the BBIP mill to obtain demographic data and assess social implications of this project type. The IPB team visited the Sakernan Sub-District of Bukit Baling, one of five settlements near the mill. Bukit Baling is a village with many settlements. IPB also visited Mekarsari-Kumpeh in another district located among oil palm plantations.

The ethnicity of Bukit Baling is a mix of ethnic migrants from Javanese (Tanjabtim district) (75%) and local ethnic Melayu Jambi (25%). Voluntary Javanese migrants began arriving in 1985 seeking better opportunities as rubber farmers. They initially worked in rubber plantations owned by local residents and saved money to eventually purchase their own land. Marriages between these two ethnic groups led to sharing agricultural experiences and activities. Younger men and married women are more likely to seek work with oil palm companies.

Table 20. Bukit Baling Demographics

Bukit Baling Demographics	
Male Population	3,512
Female Population	3,271
Households	1,926
Farmer Household	70%
Households using PLN	27%
Households with other electricity sources	68%

Java migrants in Bukit Baling initially planted rubber as a means to increase income. They also planted other food crops such as cassava, corn, duku, and durian. It is estimated that oil palm was introduced in that area in 1990s, and large oil palm plantations were established in 2003. As private oil palm companies expanded their lands, many smallholders with lands not susceptible to flooding (both local and migrants) removed rubber trees and planted oil palm because it was thought to have better potential to increase income.

Some smallholders entered into partnerships with oil palm companies while others remain independent. In the past, village land was distributed to the community where it was later taken over by oil palm companies. There are several methods of land use for oil palms including:

1. Independent smallholders growing oil palm on their lands and selling FFB to local traders who hold delivery orders from oil palm companies. Smallholders receive approximately 11,000/kg of FFB from local traders. Local traders typically sell to various palm mills at a rate of 14,000/kg of FFB.
2. Cooperative arrangement of community members who release their land to a palm oil company as a partnership; these lands typically have sporadic documents (lands without certificate).
3. Palm oil companies obtain a community member’s land through a broker based on inventory and categorization of lands with sporadik documents.

In Bukit Baling, PT Bukit Bintang Sari established the Aksobondo Cooperative with village smallholders where the palm oil company manages the lands. In this arrangement, the palm oil mill typically keeps 70% of net profits, and the remaining 30% are paid to the cooperative. In this arrangement, the palm oil company runs all stages of the production process leading to little capacity building among farmers. The Jambi office of the Indonesian Oil Palm Farmers Association suggested that these partnerships were more favorable for farmers when the government was involved in the process; currently smallholders and palm oil companies negotiate directly without government involvement. BBIP mill, the focus of this study, does not have this type of arrangement—it obtains its FFB from independent smallholders, a small BBIP owned plantation, and a minimal amount from plasmas (organized oil palm smallholders).

Land prices in the area range from IDR 40 million/hectare for empty lands to IDR 60–100 million/hectare for productive lands. The system of land inheritance is based on ethnicity of family structure.

Table 21. Bukit Baling Land Inheritance System

Ethnicity	Inheritance System	Land Resource		
		Farm	Unirrigated Land	Home and Vegetable Garden
Melayu Jambi (local)	Matrilineal	Man	Woman	Woman
Java (migrant)	Bilineal	Man and Woman	Man and Woman	Man and Woman
Mixed (marriage of migrant and local)	Matrilineal (tend to follow female)	Man	Woman	Woman

Overall, communities tend to view the development of the palm oil industry positively due to the creation of jobs at plantations and mills as well as increased demand for FFB, which increases income for smallholders when compared with other crops. Typical jobs include fruit pickers, fertilizer application, bedding, foremen, and supervisors. All workers are paid monthly and permanent employees receive insurance. Approximately 40% of the jobs are permanent and include housing. Non-permanent employees make up 60% of palm oil company jobs and are split evenly between men and women with a daily pay of IDR 57,000.[37] In some areas, palm oil companies fund village development programs that assist in infrastructure and training.

Leadership in the village includes the village head, village secretary, religious leader, as well as oil palm managers. Local oil palm traders, who collect and deliver FFB to mills, are also viewed as important in communities. In 2013, Bukit Baling will have elections for the headman and two of three candidates are local oil palm traders.

5.1.1 Role of Gender in Oil Palm Community

Both men and women participate in agricultural activities throughout the year (see Table 22). While oil palm is a primary activity in these communities, fishing and other secondary food

[37] This data is based on Mekarsari Village, which is not in Bukit Baling but is a village in Jambi near palm oil companies.

crops are still important for both subsistence and additional income. Marriages between Melayu Jambi and Javanese migrants have resulted in a fairly equal division of labor and responsibilities in oil palm activities, although men generally have the power to make significant decisions. While women have access to land, men control the land used to grow oil palm and also determine if land will be kept or sold. Men also make decisions on production inputs, such as seedlings and fertilizer, and dominate sales of FFB.

For oil palm specifically, both men and women are involved in all stages of the production process. The following division of labor is common in households with oil palm:

- *Men:* purchasing seeds, land preparation, fertilizing, transportation, selling FFB
- *Women:* seeding, bedding, weeding, household labor
- *Both:* planting, pruning, harvesting (men harvest FFB in trees, women harvest fallen FFB), social activities

Table 22. Bukit Baling Agriculture Division of Labor

Season	Economic Activities	Time of Year	Distribution of Labor
Rainy	Oil palm, Duku, Durian	Oct–Mar	*Men:* planting, fertilizer, spraying, harvesting *Women:* weeding, bedding, drying
	Paddy on unirrigated land	Jan–Feb	*Women:* harvesting
	Fishing, processing salted fish, selling fish; oil palm labor	Feb–Jun	*Men:* fishing, oil palm labor *Women:* processing and selling fish, oil palm labor
Dry	Oil palm, Duku, Durian	Apr–Oct	*Men:* planting, fertilizer, spraying, harvesting *Women:* weeding, bedding, drying

Women are responsible for household activities including cooking, washing, and caring for children. Women typically make all household decisions, including financial management, although men and women together decide on expenditures related to buying a motorcycle or sending children to school. Community activities that include women include religious/traditional ceremonies, births, deaths, and marriages. Men dominate public social activities related to village development, farmer groups, and similar events. Women do not have good access to training programs, and if training is provided, it is only for men. Additionally, only women in farmers groups are widows. Gender and access to resources and community are summarized in Table 23.

Table 23. Bukit Baling Access to Resources

Activity	Access to Resources		
	Men	Women	Both
Land			X
Labor			X
Seed purchasing	X		
Training	X		
Farmer Group	X		
Cooperative	X		
Social Organization			X
Kinship Organization			X
Income		X	
Credit	X		

Prior to 2010, most households in Sakernan (the settlement visited by IPB) used kerosene togok lamps for light in the evenings, and few households had diesel generators for electricity. Over the past 2 years, the community built a diesel power plant with a household fee of IDR 2 million for capital costs. Electricity is available to connected households for 12 hours each day beginning at 6:00 p.m. PLN has built transmission lines up to the village, but power has never been delivered. While the community did not provide a reason, this is would sell to an area mill because the transmission line ends in this town and demand for power exceeds supply in Jambi and there is likely not enough power generated to run to the end of the line. A project developer should further explore this issue with PLN. Monthly fees are IDR 150,000 plus IDR 3,000 for each kilowatt-hour, with an average totally monthly cost per household of IDR 220,000 to 300,000. In total, 93 households are connected to the system, which burns 100 L of diesel/night. Community members manage the diesel power plant and all aspects of operating the plant including purchasing diesel, billing, payment, maintenance, and connections. Operators stay overnight to ensure that community members have electricity supply for the whole night.

5.1.2 Results from Impact Assessment

The availability of electricity during the day may lead to alternative economic activities. A household could decide to start a small business close to home. Currently, these communities cannot open small businesses due to the lack of daytime power. Electricity will be available with a 900-W connection for a rate of IDR 75,000/month. This will reduce electricity costs by IDR 150,000–225,000/month when compared with diesel generation. This money could be used towards transportation and school costs for children. It is possible that some households will be reluctant to pay the household connection fee to PLN because they made a large investment in their community diesel system 2 years ago. The project cannot dictate where or how PLN delivers power; however, it is expected that nearby communities will be connected to the transmission line as it passes from the mill to the tie-in and because PLN's plans to connect this area to its grid.

The mill will pay a modest premium payment to area oil palm smallholders. It is unclear how smallholders will use this small increase in household income. Presumably, a higher price paid for FFB may lead to a short-term or sustained increase of harvesting from existing smallholder land as they typically harvest less often than plantations. The increased income will not be significant enough to allow smallholders to purchase new land or make large purchases. Smallholders would benefit from harvesting and similar farmer training, and it may be possible for the palm oil company to provide this type of training.

5.2 Community Participation Plan

Nearby communities, local governments, and organizations should be engaged early in the project by the mill, PLN, and the IPP in a series of stakeholder meetings to communicate project plans. Project owners should insist on including women and any other minorities or marginalized groups. Such meetings should summarize how electricity is made from POME, emissions benefits of both covering POME ponds and from discontinuing use of diesel generators, as well as job opportunities both temporary and permanent. The mill and IPP should also explain the differences between types of renewable energy and natural gas and coal. A timeline should be provided highlighting construction activities that may impact nearby residents with increased traffic for delivery of equipment to the mill. Engagement meetings should provide all residents of the community the opportunity to ask questions and provide input. This will allow the mill and IPP to understand what aspects of the project are most important to the community as well as identify social risks related to the project. The project will need to provide documented responses to community-identified concerns and issues.

An IPP will need to develop relationships and trust for a successful project. It will need to engage community leadership and ensure that its efforts reach women and other marginalized groups. Any large landowners or other industries in the area should also be informed of the project as they may provide valuable input. Community members should be provided with active roles in public outreach meetings and give input to the project to generate public support.

The mill should work directly with local collectors to engage independent smallholders, both men and women, to identify the best methods to provide a FFB premium with profits from electricity sales. The possibility of oil palm smallholder training should also be discussed since smallholder yields are lower than large plantations and state-owned plantations. PLN should identify which communities will be connected to transmission lines, how much power will be supplied, the average monthly costs, a timeline for connection, and costs for connection paid by the household. PLN should also address the investments already made in community-based diesel generators and be specific in why these communities would benefit from PLN grid power.

Engaging all members of nearby communities early and throughout the project will lead to greater social acceptance for the specific project and renewable energy generation in general. Successful community development with a project may serve as an example for expansion of POME electricity at palm oil mills.

5.3 Impact on Local Labor, Goods, and Services

Major equipment, including the flexible membrane and biogas capable electricity gensets, will be purchased from manufacturers outside of Indonesia. This is because there are few companies providing these products and none are domestic. It is possible that piping, pumps, seals, and an assortment of other equipment necessary for the project will be obtained in Indonesia but not from Bukit Baling since this equipment is not manufactured in the local community.

Construction of the project will result in temporary construction jobs and 10–12 permanent jobs to staff the energy project. Jobs for women will include laboratory and office administration positions. It is expected that many of the construction staff and all the permanent staff will be hired from the local community. Some of the construction jobs and staff from equipment suppliers will visit from out of town, which is likely to result in temporary increases in revenues for community shops, restaurants, and related businesses.

5.4 Social Risks

5.4.1 Mitigation Plan for Identified Social/Gender Risks

The BBIP mill intends to use profits from electricity sales to pay a premium price for FFB to smallholders to ensure their mills are able to continuously run at capacity. The BBIP mill obtains the majority of its FFB from independent smallholders through local collectors and a much smaller portion from plasmas (farmer groups). There is transparency in pricing because all smallholders in the area receive the same price and they are aware of the price the local collector receives from the mill. The economic analysis in the study projects modest payments to the mill for electricity, which will result in an equally modest premium to smallholders. Some mills are expected to produce more electricity, which could result in a higher premium for FFB. This may also result in smallholders competing to sell their FFB to the mills and paying a higher price that could create conflicts between smallholders nearby these mills and those further away, and perhaps conflicts with plasmas that may join into a partnership with mills offering a premium. This may drive up the price paid for FFB at all mills in the area because all mills hope to maintain a constant supply of FFB. The overall costs for palm oil production has increased overtime partly due to GOI allowing palm mills to be built without plantation land, which has led to competition for FFB from smallholders. Pricing must be transparent to all parties to ensure that the financial benefits of the project are reaching the smallholders.

Another potential risk is the recent investment of households in community-owned, diesel-based electricity generators. The IPB study stated that a community near the mill invested in a shared diesel-generating unit in 2011 with 93 households each contributing IDR 2 million, a significant sum for equipment and connections. Additionally, three members of the community are paid to operate the diesel plant; they would be affected if the diesel plant was turned off in favor of using PLN grid power. These employees would be ideal candidates for jobs at the mill's electricity generation plant since they already have experience with generators.

While not an official policy, PLN tends to install transmission lines and tie-ins along paved roads and not provide service to communities on unpaved roads. Of the five communities near the mill, two are on unpaved roads and three are on paved roads. This could lead to some communities getting the benefits of PLN power such as electricity available throughout the day and night and lower monthly costs. Furthermore, these communities would have a competitive advantage in opening businesses and more opportunities to increase income, which could create conflict between nearby settlements. The project may work with PLN during the PPA process to influence and encourage PLN to provide grid transmission to all communities in the immediate area of power generation. In Jambi, road improvements appear to be a priority and some communities near the mill recently had their roads paved. This issue will be reduced as road infrastructure continues to develop in the area.

5.4.2 Monitoring and Evaluation Plan Ensuring Social/Gender Equity

The project owner—either a mill or IPP for this project type—needs to develop an effective Environmental and Social Management System (ESMS) that will establish a process between the project owner, employees, and nearby communities.[38] The project should consider engaging a third-party to establish the equal distribution of FFB price premiums to area smallholders. This will require transparency in prices paid to each local collector delivering to the mill and the smallholders from which they typically obtain FFB. The ESMS will define the relationships and responsibilities of all parties involved in the project. The project owner must establish an official method for communities to communicate issues with the project both as it develops and is operational. The ESMS will also establish an effective way to communicate how these issues are being resolved. Representatives from area communities should be a part of the monitoring and evaluating benefits over the life of the project.

5.4.3 Suggested Next Steps

The next steps toward project implementation could begin with discussion of a path forward involving all stakeholders, including the mill, the IPP, villagers, the utility PLN, technology suppliers, and government offices having jurisdiction. This report may inform discussions leading to such a consensus. The following steps should be considered in moving toward a successful project:

1. Project Identification and Planning:
    a. Develop the full description of the project.
    b. Summarize any issues that could impair the feasibility of the project
    c. Describe the proposed financial structure for the project.
    d. Provide details of the proposed project team, any additional technical assistance that would be needed, and documentation needed to complete the project team (e.g., requests for qualification, solicitation for letters of interest, for a market survey). Form any legal entities needed for the project team.
    e. Document site ownership, land use agreements, or other elements of site control.
    f. Develop documentation required to start the PPA process with PLN.
    g. Document all the permits and licenses needed and the status of securing each.
    h. Develop a full implementation plan. This would include the scope of work, procurement and construction, the required equipment for installation, site access for delivery, staging area for equipment and construction, limits on work times

[38] Project owners should refer to IFC Performance Standard guidance while preparing an ESMS. Last Accessed August 13, 2013: http://www.ifc.org/wps/wcm/connect/c8f524004a73daeca09afdf998895a12/IFC_Performance_Standards.pdf?MOD=AJPERES

due to weather or holidays, milestones and timeline, and a monitoring and evaluation plan with outcomes and indicators.

i. Ensure that all project risks are identified, analyzed in detail, and mitigation plans are developed.

2. Technical Plan:

j. Evaluate technical assistance companies, IPPs, equipment, and construction companies with experience in POME electricity projects.

k. Provide a schematic design of the system, including minimum hardware requirements, and evaluate potential equipment.

l. Develop a site plan to confirm the fit of the system into the existing palm mill site. Determine if space is available to co-locate biogas clean up and electricity generation equipment in palm mill's engine room. If space is unavailable, develop plans for a small building to house this equipment.

m. Prepare a detailed electric production estimate by month for input to the economic model, and review and revise all other economic inputs.

n. Develop a detailed O&M plan, describing the local capabilities that would include scheduled maintenance, warranty management, response time and resources for unscheduled maintenance, site security, spare part inventories, experience of the O&M organization, and a training program for local support.

o. Refine the long-term technical risk assessment with regard to selected equipment, access to parts, and reliability; errors in biogas resource estimates, O&M risks, construction risks.

p. Refine the risk mitigation plan, including a commissioning and system acceptance plan; process it for periodic performance verification, review of equipment quality, O&M response time, and system design.

3. Economic Plan:

q. Update and refine the economic model with new information from the full feasibility study, including proof of proposed costs and revenues and strong evidence (such as local surveys) for benefit streams.

r. Provide separate plans for monitoring and managing variables that affect economic return.

s. Document community surveys that show that benefits are distributed equitably.

t. Document the creditworthiness of the borrower or grantee for the project, through a credit check, and if applicable, collateral for the loan, loan insurance, and a plan for default.

u. Refine the long-term economic risk assessment with updated and more complete data, with a mitigation plan that addresses the economic risks identified.

4. Environmental Plan:

v. Conduct thorough baseline studies with quantitative data for compliance with all identified laws and regulations.

w. Conduct the public consultations and scoping analysis required by IFC and others, if required, or develop the UKL-UPL.

x. Develop Terms of Reference for the environmental and social analyses.

y. Develop the Environmental Monitoring Efforts Reports, Environmental Impact Assessment, and Environmental Assessment Application to ensure compliance with Indonesian government regulations.

z. Complete the environmental license application.

aa. Comply with the requirements of the IFC's Performance Standards.

bb. Provide for a guarantee fund that will be used to rehabilitate the site in the event of environmental damage.

cc. Document that the communities impacted by the project plan support the proposed environmental plans.

dd. Refine the GHG impact analyses with more complete and up-to-date information.

5. Social and Gender Plan:

ee. Provide more quantitative detail for project impacts on women, minorities, and other vulnerable groups; land use and community resources; and the local/community economy in terms of job creation, business development, and new supply chains.

ff. Action plan to engage women in empowerment activities in the project.

gg. Complete stakeholder consultations, and document community engagement, such as who has been engaged; their level of support; plans for further engagement, training, or methods for further behavioral change required; and strategy for continued consultations and community feedback during project implementation.

hh. Develop lists of agreements, contracts, and other details that prove the benefits to local stakeholders.

ii. Refine the long-term social risk assessment with updated and more complete data and mitigation strategies for any negative impacts on the community, such as job training, small business startup funds, etc.

5.4.4 Potential Complementary Activity

As explained in the Resource Assessment section of this study, smallholders FFB yields are lower than plantations or state-owned lands. An additional activity to support this project and improve incomes of smallholders would be to engage Yayasan Setara for training or a similar organization. Yayasan Setara is a local, non-governmental organization based in Jambi and that understands the specific issues oil palm smallholders experience in the local area. Yayasan Setara trains smallholders in techniques to sustainably harvest FFB, which both increases yields and incomes, and training fees are expected to be very low. The training takes place on smallholder land in the surrounding areas. There is a risk that increasing yields, resulting in more income, will cause smallholders to expand their oil palm land at the expense of their own land. They may also be tempted to expand into peat land or other degraded areas, resulting in negative impacts on land. In addition to farmer training to increase yields, Yayasan Setara teaches the importance of farmers using some of their land for a subsistence garden as food shortages are projected in Jambi in the next few years, and the problems that occur if farmers expand into peat land.

6 Conclusions

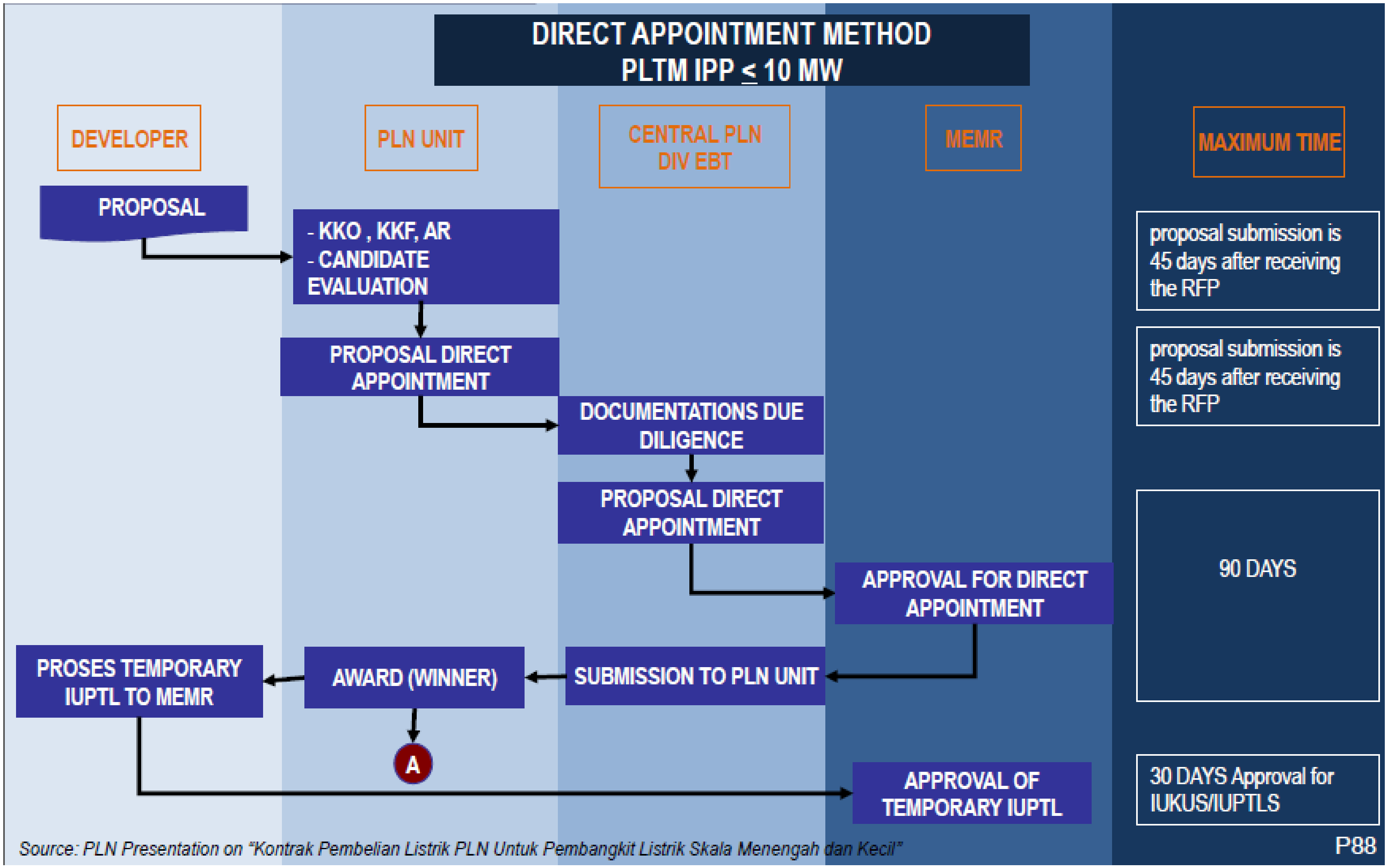
Ideal biomass energy projects are those that generate a waste product onsite with energy potential, which is the case with this proposed project. There are numerous benefits from POME electricity at palm mills, including electrification of rural areas, renewable electricity entering the grid, and reductions in emissions and POME processing wastes. Economics in this study indicate a modest return for an IPP, which may not achieve its corporate hurdle for investing in a project. However, geography may positively influence economic returns and investments in this type of electricity generation because PLN biogas rates for PPAs are higher for other provinces—such as Kalimantan, Maluku, West Nusa Tenggara, Papua, or Sulawesi—than on Sumatra. The projected revenues the mills receive would be small but would allow them to pay a premium to smallholders, thus increasing their income a small amount. There is no guarantee that smallholders will receive higher prices as they are independent and have no formal agreements with mills, however, the BBIP mill profiled in this study currently pays a premium. Compared to the specific mill project studied here in Mauro Jambi, the economics of other similar projects may be more attractive if the POME is richer in organic content, which leads to greater electricity potential and/or if the mills are located where PLN biogas rates are higher.

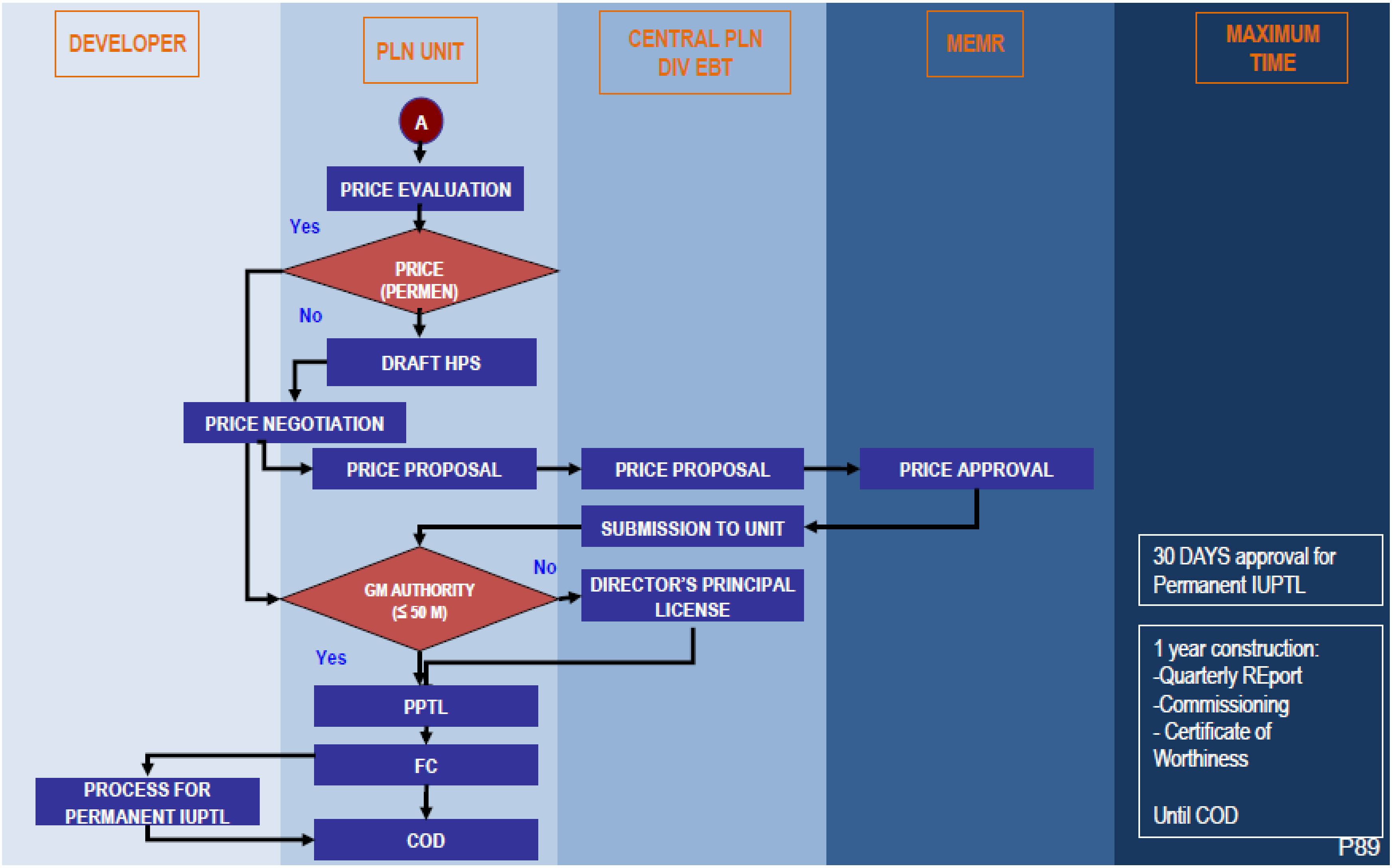
This project type is more likely to benefit older or inefficiently run mills than new or efficient mills. A poorly operated or old mill is capable of producing more than the 1.25 MW used in the model; up to 2.5 MW is possible resulting in economies of scale for the project. If a mill is new or highly efficient, it may produce less than 1.25 MW, making the project less feasible.

This project meets several of Green Prosperity's target goals by increasing income through modest FFB price premiums to smallholders, lower monthly energy costs for villagers, low-carbon project development, and renewable electricity generation in a rural area.

Appendix A: PLN PPA Chart

Source: "Renewable Energy Toolkit." Second Edition. USAID Indonesia Clean Energy Development (ICED) Project. November 27, 2012. pp 88-89.




DEVELOPER
PLN UNIT
CENTRAL PLN DIV EBT
MEMR
MAXIMUM TIME
A
PRICE EVALUATION
Yes
PRICE (PERMEN)
No
DRAFT HPS
PRICE NEGOTIATION
PRICE PROPOSAL
PRICE PROPOSAL
PRICE APPROVAL
SUBMISSION TO UNIT
No
GM AUTHORITY (≤ 50 M)
DIRECTOR'S PRINCIPAL LICENSE
Yes
PPTL
FC
PROCESS FOR PERMANENT IUPTL
COD
30 DAYS approval for Permanent IUPTL
1 year construction:
-Quarterly REport
-Commissioning
- Certificate of Worthiness
Until COD
P89

Appendix B: Details of Economic Calculations and Modeling

General Variables					
Descriptor	Value	IDR	Distribution	Upper	Lower
Start Year	2015				
Start Number	0				
Social Discount Rate (%)	10%				
Number of Periods (years)	20				
National Inflation Rate (%)	4.00%		Triangular	5%	3%
Exchange Rate (IDR/$)	9,700				

Generating System Variables					
	Value	IDR	Distribution	Upper	Lower
Capital/Operating Costs					
Installed Capacity (kW)	1,250				
Capital Cost per Watt ($/W)	$2.49	24,153	Triangular	$3.00	$2.00
Total Installed Capital Cost	$3,220,747	31,241,250,000			
T&D Capital Cost per km ($/km)	$21,649	210,000,000			
T&D length (km)	5				
Total T&D Capital Cost	$108,247				
Fuel Costs ($/kWh)	$0.00	0			
O&M cost (% of installed capital cost)	10%		Triangular	11%	9%
Salvage value % of capital costs	0%				
Mill Lease Payments (% of Revenue)	10%				
Production					
Capacity Factor (%)	90%		Triangular	95%	80%
Degradation Factor (% per year)	0.0%				
Parasitic Load (%)	7.7%		Triangular	8%	5%
Share of production purchased by PLN (%)	100%				
Other					
Capital physical lifetime (years)	20				
Construction Time (months)	18				

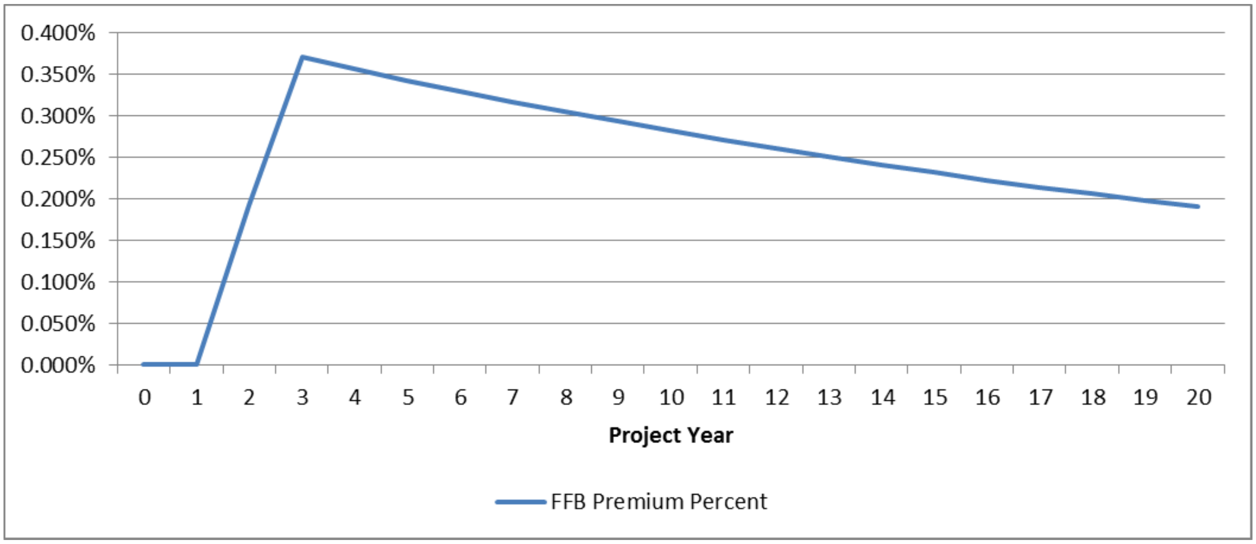
FFB Supply Agreement					
Descriptor	Value	IDR	Distribution	Upper	Lower
Annual Consumption (tonnes per year)	270,000				
Long Term Consumption Growth (% per year)	0%				
Percent Purchased from Smallholders (%)	50%		Triangular	60%	40%
Current FFB price ($/ton)	$146.39	1,420,000	Triangular	$160	$130
Nominal FFB Price growth (% per year)	4.00%		Triangular	5.0%	3.0%
Mill share of lease revenue (% per year)	10.00%		Triangular	12.0%	8.0%

Financial Structure Variables					
Descriptor	Value	IDR	Distribution	Upper	Lower
Grant (0) / Loan (1)/ Combo (2)	1				
WACC (%)	4.7%				
Leverage (% of capital cost)	50%		Triangular	$0.36	$0.24
Grant (% of capital cost)	0%				
Equity (% of capital cost)	10%				
Equity Holder					
Dividend Payout (%)	5%				
Return on Equity (%)	6.07%				
Equity Exit Year	20				
Lender					
Term (years)	10.00				
Debt Payment Start Year (year)	1.50				
Interest Start Year (year)	0				
Nominal Interest Rate (%)	4.50%		Triangular	6%	3%

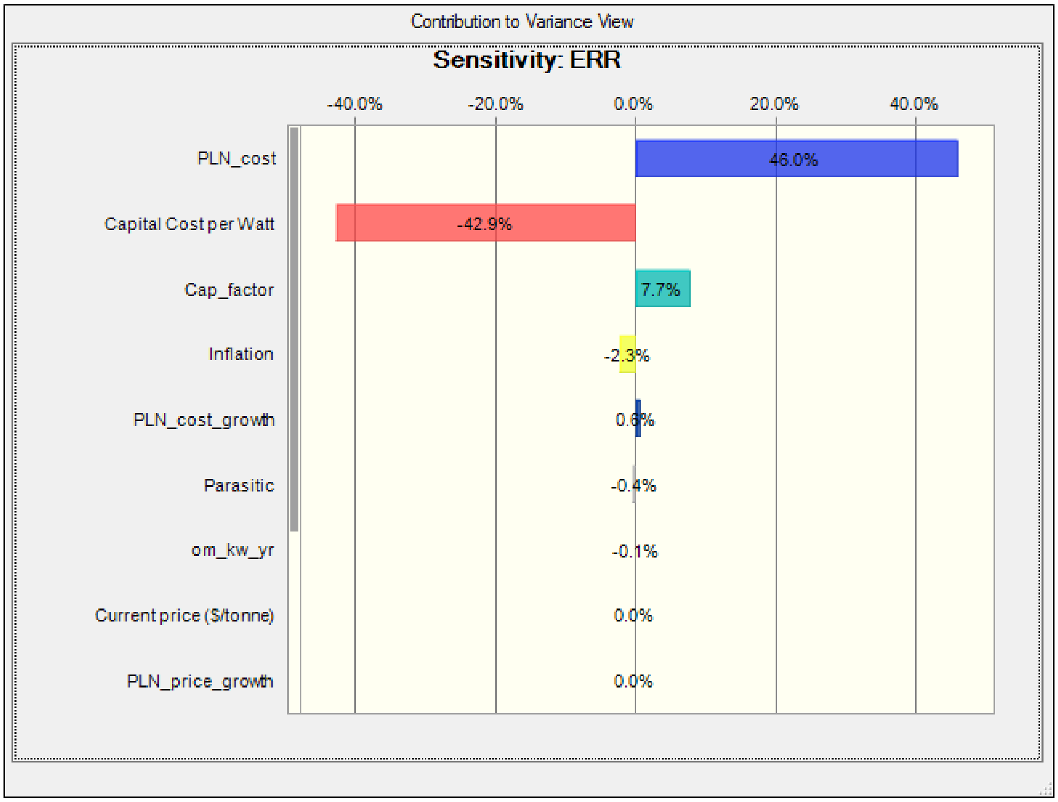
Grid Variables					
Descriptor	Value	IDR	Distribution	Upper	Lower
PLN FiT ($/kWh)	$0.101	975			
Nominal FiT Growth (% per year)	0.0%				
PLN sale price per kWh ($/kWh)	$0.063	614			
Nominal PLN Price Growth (% per year)	3.30%		Triangular	4.00%	3.00%
PLN cost of generation ($/kWh)	$0.301	2,922			
Nominal PLN Gen Cost Growth (% per year)	8.3%		Triangular	8.5%	7.5%

Appendix C: Other Supporting Documentation

FFB Price Premium Paid to Smallholders

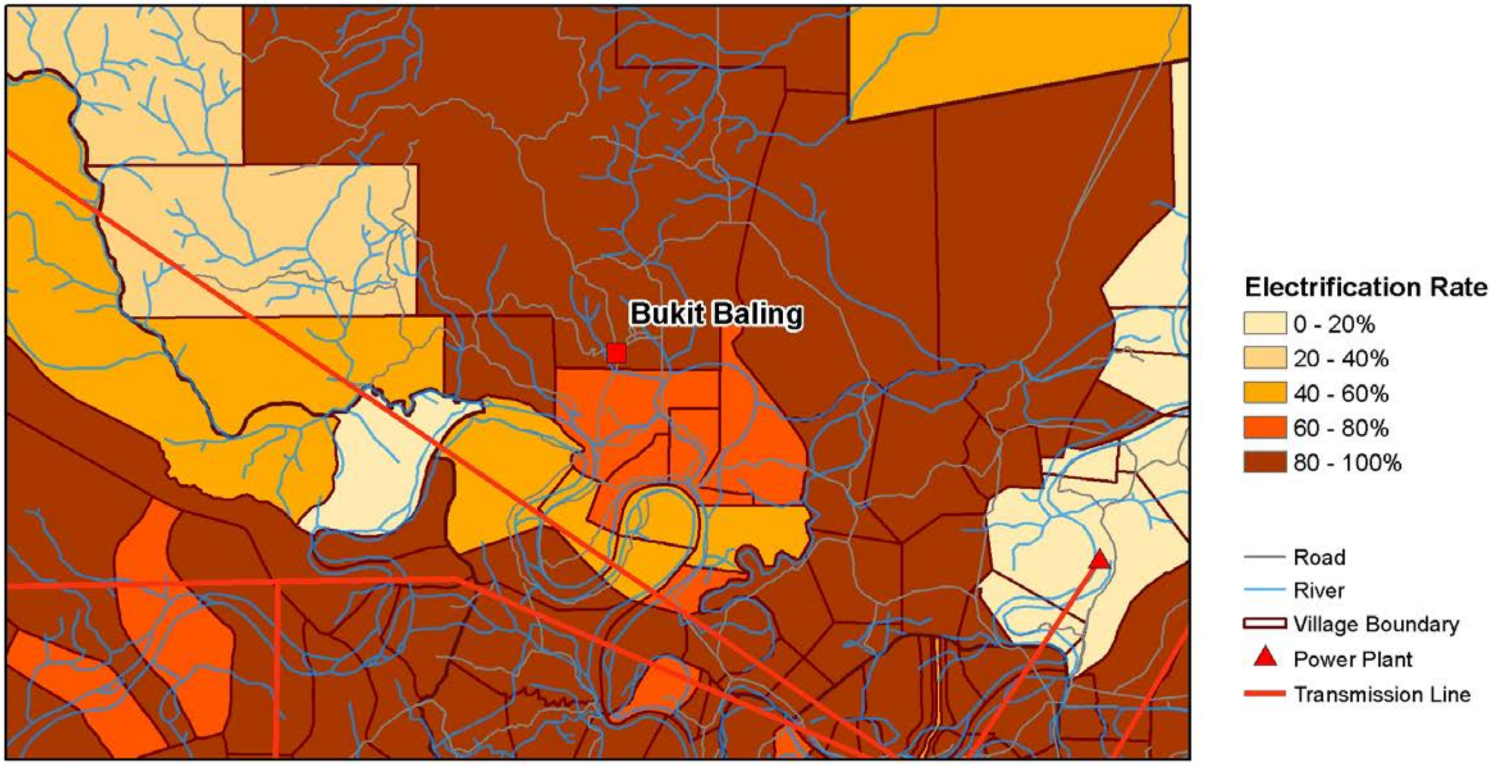


Sensitivity Parameter Contribution to Total Variance



Appendix D: Geospatial Mapping

Bukit Baling Rural Electrification Rate



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