PREFEASIBILITY STUDIES OF RENEWABLE PROJECTS IN RIAU

Analysis of Solar PV, Biogas and Biomass projects

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BACKGROUND

Indonesia and Denmark have for years collaborated through a **Strategic Sector Cooperation** (government-to-government partnership) focused on the green transition of the energy sector. The purpose of the partnership is to bring Denmark's many years of experience with energy efficiency, renewable energy deployment and energy systems to Indonesia in order to assist the Indonesian government and relevant stakeholders in the green transition of the energy sector in Indonesia.

The partnership is anchored within the **Danish Energy Agency's Center for Global Cooperation.** The main partners in Indonesia include the Ministry of Energy and Mineral Resources (MEMR) and the National Energy Council (NEC). Other partners include the state-owned electricity company (PLN) and the regional energy planning office (DINAS).

The latest outcome of the partnership has generated the following outputs[1]:

- Capacity building through various seminars and workshops focused on lessons learned in Denmark on long-term modelling, RE integration and energy efficiency (2016-2020);
- Integration of Balmorel Power sector model in the modelling team at NEC (with inputs to the "Indonesian Energy Outlook"- from 2016 to 2020) and in DG Electricity (support to analyses and RUKN);
- Development of an Indonesian Technology Catalogue on power production technologies (2017, 2020);
- A Regional Outlook to 2030 and prefeasibility studies for the island of Lombok (2018);
- Three Regional Energy Outlook reports for South Kalimantan, Riau[2], North Sulawesi and Gorontalo[3] (2019);
- A Renewable Energy Pipeline for Indonesia to reach their 2025 goal (2021), in collaboration with EBTKE;
- A report with Guidelines for Prefeasibility studies (2021).

The Regional Energy Outlooks of Riau and North Sulawesi, completed in 2019 and constituting the first step of this work, showed significant potential for renewable energy as cost-efficient solutions for the green transition.

As part of the Strategic Sector Cooperation, a consortium consisting of Ea Energy Analyses and Viegand Maagøe, has been appointed to conduct **prefeasibility studies on renewable energy technologies in two provinces in Indonesia: Riau and North Sulawesi**. This report is one of two in total. In this report, the focus is on Riau. Three prefeasibility studies have been completed on the technologies: **biogas, biomass and solar PV**.

The Danish Energy Agency and the Embassy of Denmark in Indonesia have played an active role in developing the scope of the study, reviewing draft reports and planning of site visits. The consortium has received local assistance from PT Innovasi, an Indonesian based consultancy specialized in de-risking energy access investments for rural communities in Indonesia. The National Energy Council (NEC), the regional energy planning office (DINAS) and local PLN offices in Riau and North Sulawesi has helped facilitate contact and retrieve information from local stakeholders.

The study was initiated and completed in 2021. Four missions were carried out throughout the duration of the project; two in Riau and two in North Sulawesi. The missions were completed in April, June and October 2021. The consortium presented a first draft of this report in September 2021. The final report was delivered in November 2021.

Notes:
1. The latest reports and outcomes, as well as a more detailed description of the cooperation can be found at: www.ens.dk/en/our-responsibilities/global-cooperation/country-cooperation/indonesia
2. https://ens.dk/sites/ens.dk/files/Globalcooperation/Publications_reports_papers/riau_reo.pdf
3. https://ens.dk/sites/ens.dk/files/Globalcooperation/Publications_reports_papers/north_sulawesi_and_gorontalo_reo.pdf

DISCLAIMER

The report is prepared for partners of the Strategic Sector Cooperation between Denmark and Indonesia and potential investors of renewable technologies in Indonesia. The conclusions of the report reflect the views of the Consortium (Ea Energy Analyses and Viegand Maagøe). The partners of the strategic cooperation hold no responsibility with respect to the findings of the reports.

Due to COVID-19, it has been a challenge to conduct site visits and collect data from local stakeholders. While the consortium managed to complete three missions, not all data needed for the calculations were obtained. As a result, the study mostly relies on desk top research. In order to validate the data and assumptions from the study, several reports have been reviewed. The local consultancy PT Innovasi has also provided significant support in the validation of assumptions and conclusions of the study. We generally find the results and assumptions to be valuable and we find them to be in line with similar studies.

The main source of information used in preparation of this study are PLN, The Danish Energy Agency and the Ministry of Energy and Mineral Resources.

The sites that have been chosen for the three technologies; biomass, biogas and solar PV have been identified by means of satellite photos and maps taking into consideration the available resources, possibility for grid connection and location of existing power plants. Since this is a pre-feasibility study, we have not studied the costs and possible restrictions on land use at the specific sites.

This study is a high-level screening of three technologies where the aim is to demonstrate if the project has enough potential to proceed with a more detailed feasibility study. Future investors should seek professional support before making any final investment decisions.

The technologies chosen for the study was selected based on input from the local partners, the Danish Energy Agency and the Consortium.

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SUMMARY OF BUSINESS CASES

Biogas power plant

Expected ceiling tariff[1,2]	10.6 cUSD/kWh; 6.35 cUSD/kWh
Resource	260.000 Nm^3 POME (0.12 USD/Nm^3)
Capacity	1.8 MWe
CAPEX/ OPEX	2.8 mUSD/ 170.000 USD

Biomass power plant

Expected ceiling tariff[1]	7.88 cUSD/kWh
Resource	Solid palm oil waste (PKS: 50 USD/t; EFB: 12 USD/t; MF: 7 USD/t)
Capacity	12.5 MWe
CAPEX/ OPEX	24.5 mUSD 1.5 mUSD

Solar PV plant

Expected ceiling tariff[1]	8.25 cUSD/kWh
Resource	1871 FLH_{AC} 21.4% CF_{AC}
Capacity	20 MWac
CAPEX/ OPEX	19.2 mUSD 0.29 mUSD

Notes:
1. Expected ceiling tariff is based on values from Draft of New Perpres with levels for FIT and ceilings for each technologies. Values are not confirmed yet and regulation is not in place. See page 17 for more details.
2. 10.4 cUSD/kWh is the first 12 years of the PPA contract, and 6.35 cUSD/kWh the remaining 18 years of the PPA contract

BREAK-EVEN TARIFFS AND ELABORATION ON PROJECT RISK

Biogas power plant

IRR at ceiling tariff[1,2]	**27%**
IRR sensitivity[3]	**15-40%**
Break even tariff	**1.7 cUSD/kWh**

Elaboration on project risks

- Uncertainty over future PPA prices and contract durations
- Lack of experience with biogas production based on POME can lead to operational downtime low utilization of the capacity of the plant.
- Risk of methane emissions and wastewater leakage from the digester

Biomass power plant

IRR at ceiling tariff[1,2]	**16%**
IRR sensitivity[3]	**3-21%**
Break even tariff	**5.6 cUSD/kWh**

Elaboration on project risks

- The project uses biomasses with a high market value, which poses a risk with respect to the future availability of feedstock
- Limited experience with incineration of solid biomass from palm oil production could result in higher CAPEX and OPEX
- The expected future regulation on PPA price-setting is subject to uncertainty and it may not be possible to negotiate the expected ceiling tariff price.

Solar PV plant

IRR at ceiling tariff[1,2]	**7.9%**
Break even tariff	**8.32 cUSD/kWh**

Elaboration on project risks

- New regulation is under discussion and **no certain levels for potential PPA or FIT** have been published.
- Due to the **variability of solar output** PLN might be concerned about the impact on grid operation and stability of local grids.
- Land acquisition could be a challenge due to **proximity to the capital** of Riau Pekambaru, where land might be more valuable.

Notes:
1. Expected ceiling tariff is based on values from Draft of New Perpres with levels for FIT and ceilings for each technologies. Values are not confirmed yet and regulation is not in place. See pag. 18 for more details.
2. Real IRR shown here, to be compared to the estimated WACC (real) of 8%. An IRR above 8% means a profitable project with positive Net Present Value (NPV).
3. IRR sensitivity shows the IRR as a function of the tariffs.

PROJECTS MATURES OVER FOUR PHASES; FROM IDEA, CONCEPT AND BUSINESS DEVELOPMENT TO EXECUTION

Idea development

The idea development phase consists of brainstorming and idea generation activities to give the project a more rounded shape.

The main purpose of this phase is to flesh out selected business ideas and structure the rest of the project.

Concept development

The concept development phase usually consists of two stages and related studies:

i. a prefeasibility study (PFS)
ii. a feasibility study (FS).

The PSF is a rougher version of a FS. The purpose of a PFS is to discard unattractive ideas and choose the best among many.

Business development

The business development phase usually consists of two stages

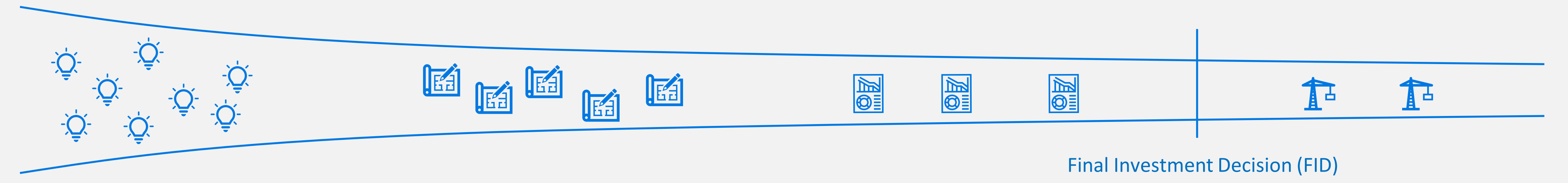
i. a validation stage
ii. a preparation stage

The best feasible idea is validated with detailed analyses of design and operations. Sourcing of permits and licenses follows.

Project execution

The project execution phase entails construction and installation of the plant, plus any other civil work needed for the project operations.

The number of possible projects shrinks during the project development phase, as different options are assessed. One (or a subset) of initial ideas will go to execution.



Sources: DEA, Ea Energy Analyses & Viegand Maagoe (2020)

PREFEASIBILITY STUDIES ARE SCREENINGS THAT IDENTIFY THE MOST FEASIBLE OPTION(S) OUT OF A SET

Prefeasibility study

A prefeasibility study is rough screening aiming at **identifying the most promising idea(s) and discard the unattractive options**. This reduces the number of options that are chosen to proceed with a more detailed feasibility study and eventually with business development, ultimately saving time and money. Often, the pre-feasibility study returns only one most promising option.

The assessment of the business idea has different focuses: technical, regulatory, environmental, economic and financial aspects are analysed. A pre-feasibility study is a **preliminary systematic assessment of all critical elements of the project** – from technologies and costs to environmental and social impacts.

Questions to be answered in a pre-feasibility study include:

- Is the expected revenue enough to proceed with evaluating the project more in depth?
- Are there any regulatory issues of decisive importance for the project?
- Is it economically (and financially) worthwhile to go further with this idea?
- What is the project's expected environmental and social impact?
- What are the risks and uncertainties connected to the idea?

Usually, a prefeasibility study concerns the analysis of an **individual project** only, normally with well-defined boundaries. The whole energy system is usually assumed as given and thus related data can be used as input to the analysis.

Sources: DEA, Ea Energy Analyses & Viegand Maagoe (2020)

THE 8 STEPS OF A PREFEASIBILITY STUDY

The content and topics of a prefeasibility study can be broken down in 8 steps. The last 3 steps build on the project details analysed in the first 5 steps.

1	**Background & scope**	Scope of the study, investment context, case descriptions, power system and stakeholder overview.
2	**Revenue streams**	Revenue sources, markets, support schemes or tariffs, other important regulatory aspects
3	**Resource evaluation**	Sourcing of fuel and fuel price (e.g. biomass), assessment of natural resources and expected energy yield
4	**Project size & restrictions**	Grid and system perspective, physical planning issues, space requirements, other relevant barriers
5	**Financial & technical key figures**	Estimation of CAPEX, OPEX, technical parameters (efficiency, lifetime)

6 **Business case**

Economic attractiveness for the investor (NPV, IRR..), robustness of the case (sensitivity analyses). Rough financial analysis.

7 **Environmental & social aspects**

Evaluation of the potential impacts on the area's environment and other social implications.

8 **Risk assessment**

Assessment of project risks and potential mitigation factors.

Sources: DEA, Ea Energy Analyses & Viegand Maagoe (2020)

Content

1.

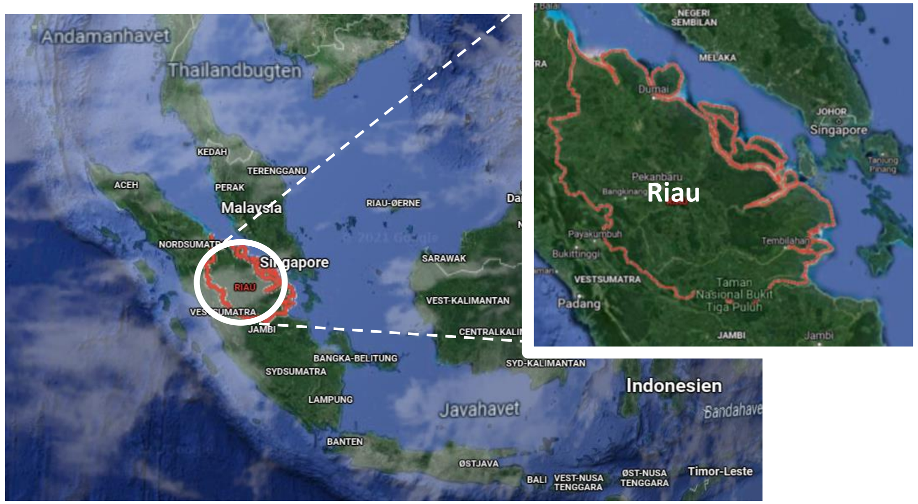
INTRODUCTION TO RIAU AND ITS POWER SYSTEM

RIAU IS A PROVINCE OF 7 MILLION PEOPLE LOCATED IN THE GREATER SUMATRA REGION OF INDONESIA

Riau: As of 2021, Indonesia stands on the 4th tile of the most populated countries around the globe, behind China, India and the United States of America. Indonesia consist of 17,000 different small and large islands. Riau is a province in the Sumatra region.

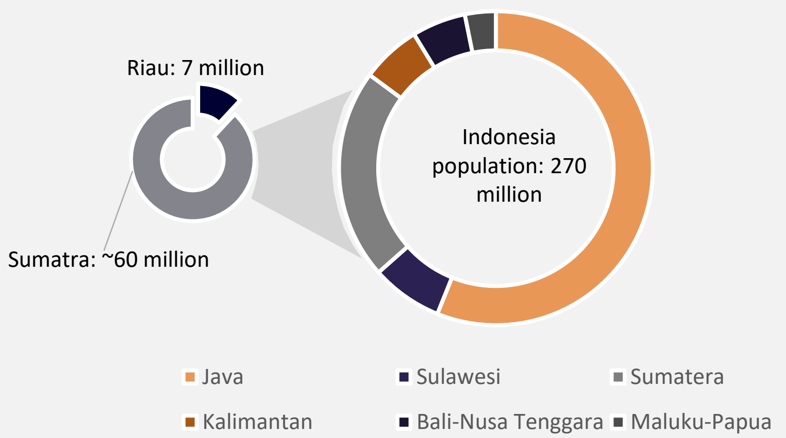
Population: The population of Riau is 7 million, and the greater Sumatra region has a population of ~ 60 million residents, corresponding to 22% of the overall population of Indonesia. According to PLN data, 92 % of households in Riau had access to electricity in 2020.

Power prices: In 2018, The average power generation cost (commonly referred to as BPP) was 11.61 c/kWh in Riau. This is ~50 % times higher than the national average. Natural gas is the dominant power source, yet some areas continues to rely on diesel, which partly explains the moderately-high power prices.

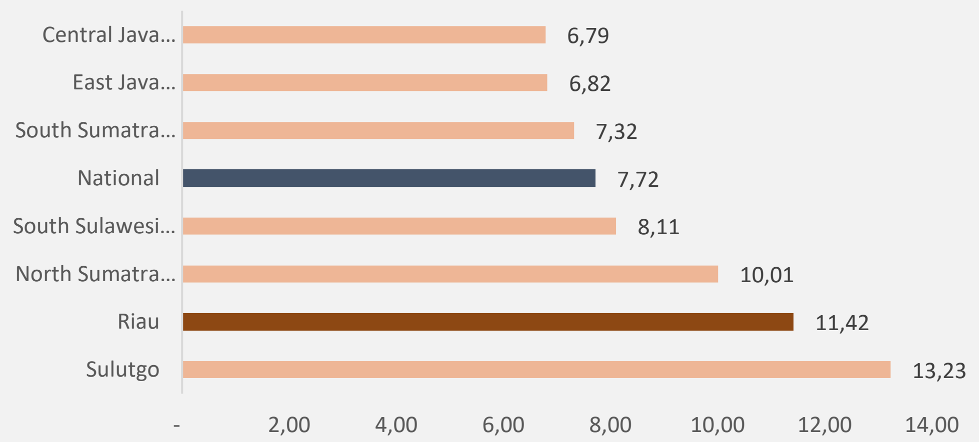


Sources: DEA & Ea (2019); PT PLN Persero (2020).

Indonesian Population (Regional & Provincial Breakdown)



Average power generation cost per region (USc/kWh)



Source: BPS, "Statistik Indonesia" (2020); MEMR, "Nomor K/20/MEM/2019 (2019)" ; Ea Energy Analyses analysis.

POWER INFRASTRUCTURE IS DEVELOPING BUT MORE ADVANCED IN THE NORTHERN PART OF RIAU

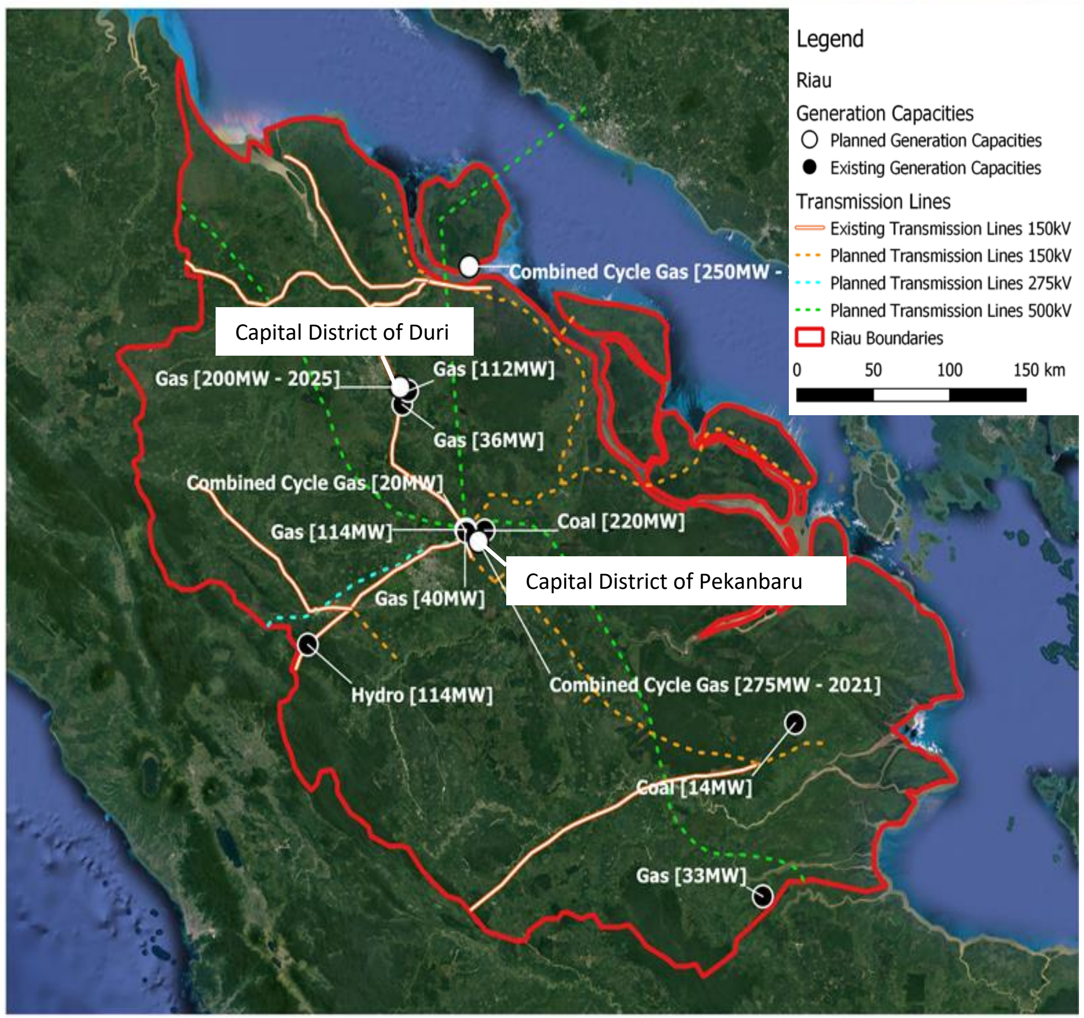
Deployed power grid: The existing power infrastructure (150 KV transmission pipeline) of Riau is mostly developed in the Northern part of Riau province. New transmission lines (both low and medium voltage) are planned from the two largest cities in Riay - Duri and Pekanbaru to neighboring provinces in all directions and coastal cities.

The power system in Riau consists of both isolated grids and a grid, which is coupled to the larger Sumatra power grid.

Existing generation capacities: A total of 818 MW of power plant capacity are connected to the PLN system in Sumatra. More than half relies on natural gas. The remaining conventional assets identify as coal fueled plants . Most of the operational power plants are located close to central cities, such as Pekanbaru and Duri.

Future generation capacities: PLN recently launched a 10- year plan for future capacities in the PLN grid in Riau. Of the total capacity of 489 MW, conventional natural gas constitute the vast majority, whereas solar PV, biogas and biomass represent a minor share. The expected commercial operation date (COD) for the full capacity is 2025.

RUPTL 2021-2030 plant list (RIAU)			
Technology	MW	COD	Phase
Biogas	3 MW	2023	Construction
Gas	100 MW	2025	Construction
Gas	100 MW	2025	Construction
Gas	275 MW	2021	Construction
Biomass	1 MW	2022	Construction
Solar PV	4 MW	2023	Planning
Solar PV	3 MW	2023	Planning
Solar PV	3 MW	2025	Planning
Total	489 MW		



1 Background & scope
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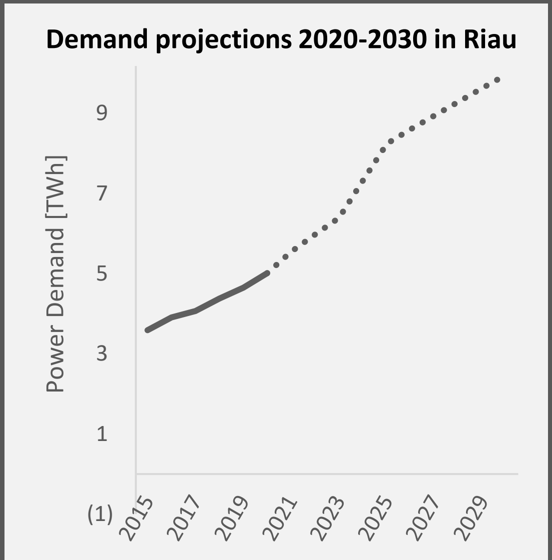
Source: DEA & Ea (2019); PT PLN Persero (2021);

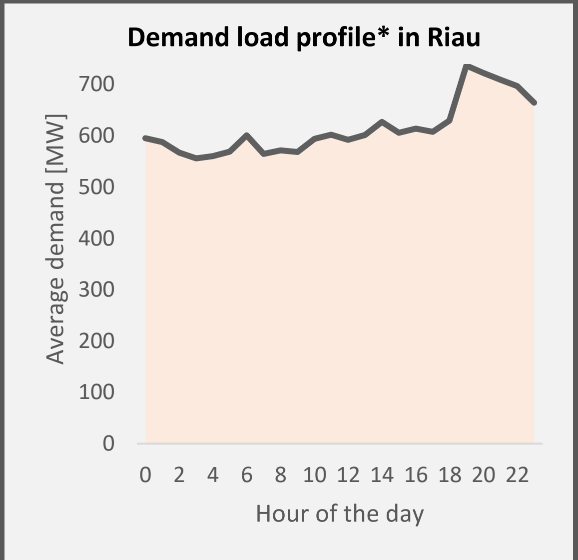
INDUSTRIALIZATION IS EXPECTED TO TRIPLE ELECTRICITY DEMAND IN RIAU THE NEXT 10 YEARS

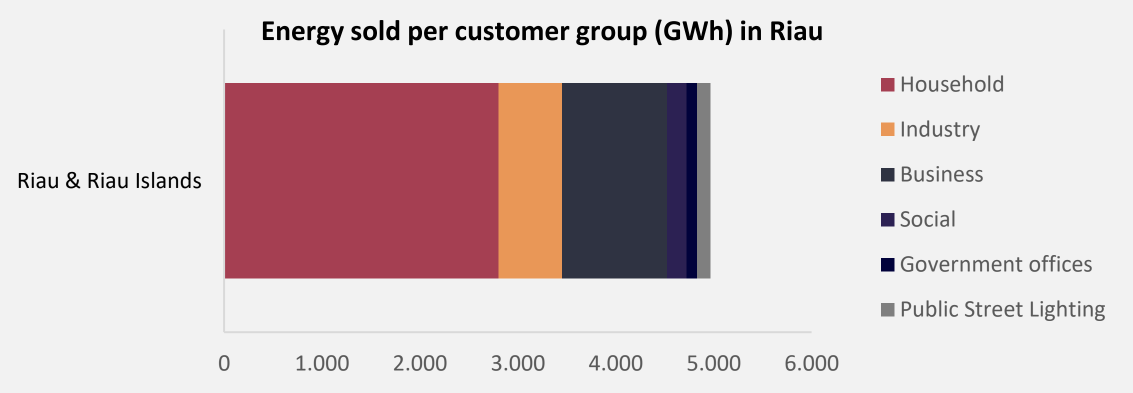
Electricity demand: Being part of a relatively newly industrialized country, Indonesia, electricity demand in Riau is expected to almost triple in size within the next 10 years for the total grid, while almost double for PLN's network. In the past, however, RUPTL has shown to overestimate demand projections. According to the latest statistics from PLN, power demand has declined for all customer groups. It should be noted, however that this is likely due to lower economic activity during COVID-19.

Households constitute over 50 % of total power demand in Riau followed by industry and businesses.

Load profile: The daily load profile is relatively constant except for the small ramp-up in the evening. This could indicate the relative energy consumption across customer groups, whereby the lower demand by households during the day is outweighed by the relatively high demand from other customer groups like industry and businesses. The steepness of the demand curve at night may compromise security of supply, especially in the future where more renewables, such as solar PV, is expected to be added to the system.







Source: DEA & Ea (2019); PT PLN Persero (2021)

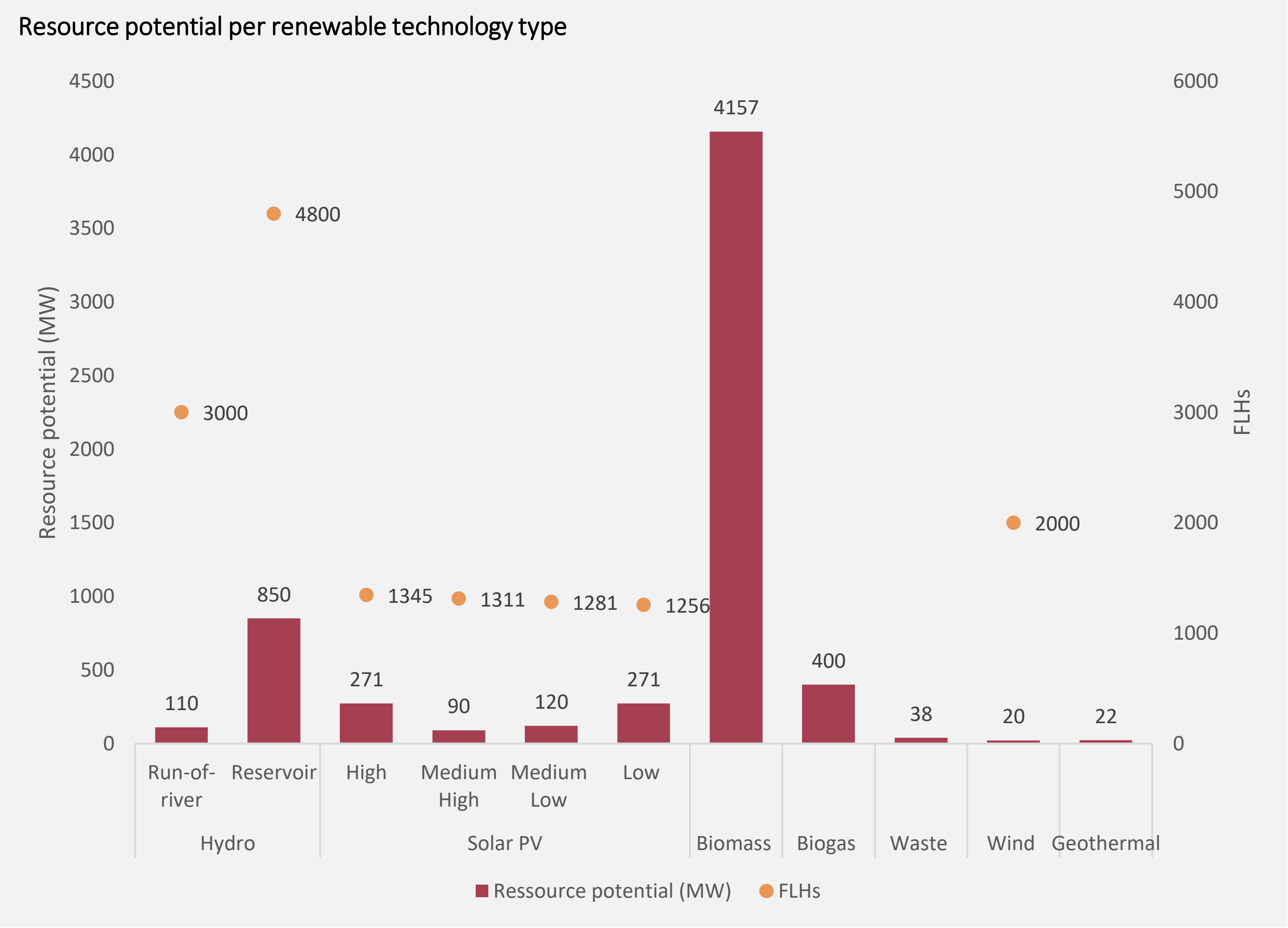
HIGH POTENTIAL RENEWABLES IN RIAU INCLUDES BIOMASS, SOLAR AND HYDRO

Resources in Riau: Riau has various resources for renewable power generation, particularly hydro, bioenergy and solar PV. Other renewable technologies are less attractive due to low resource potentials. This includes wind and geothermal, which are estimated to have a rather insignificant potential of 20 and 22 MW respectively.

Bio-potential: A large potential of biomass is a consequence of the significant palm oil activities' residuals within the province. Both biomass and biogas related installations have promising potential, particularly the former, whereby 4557MW of capacity comprise the cumulative local cap.

Hydro-potential: 960MW of hydro potential has been assessed as the local ceiling, with the reservoir type looking more applicable to the area with a bit more than 50% FLH in comparison with the run-of-river type.

Solar-potential: A wide range of PV installation types bring the total potential local capacity to 753MW with relatively similar FLH.



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Source: DEA & Ea (2019)

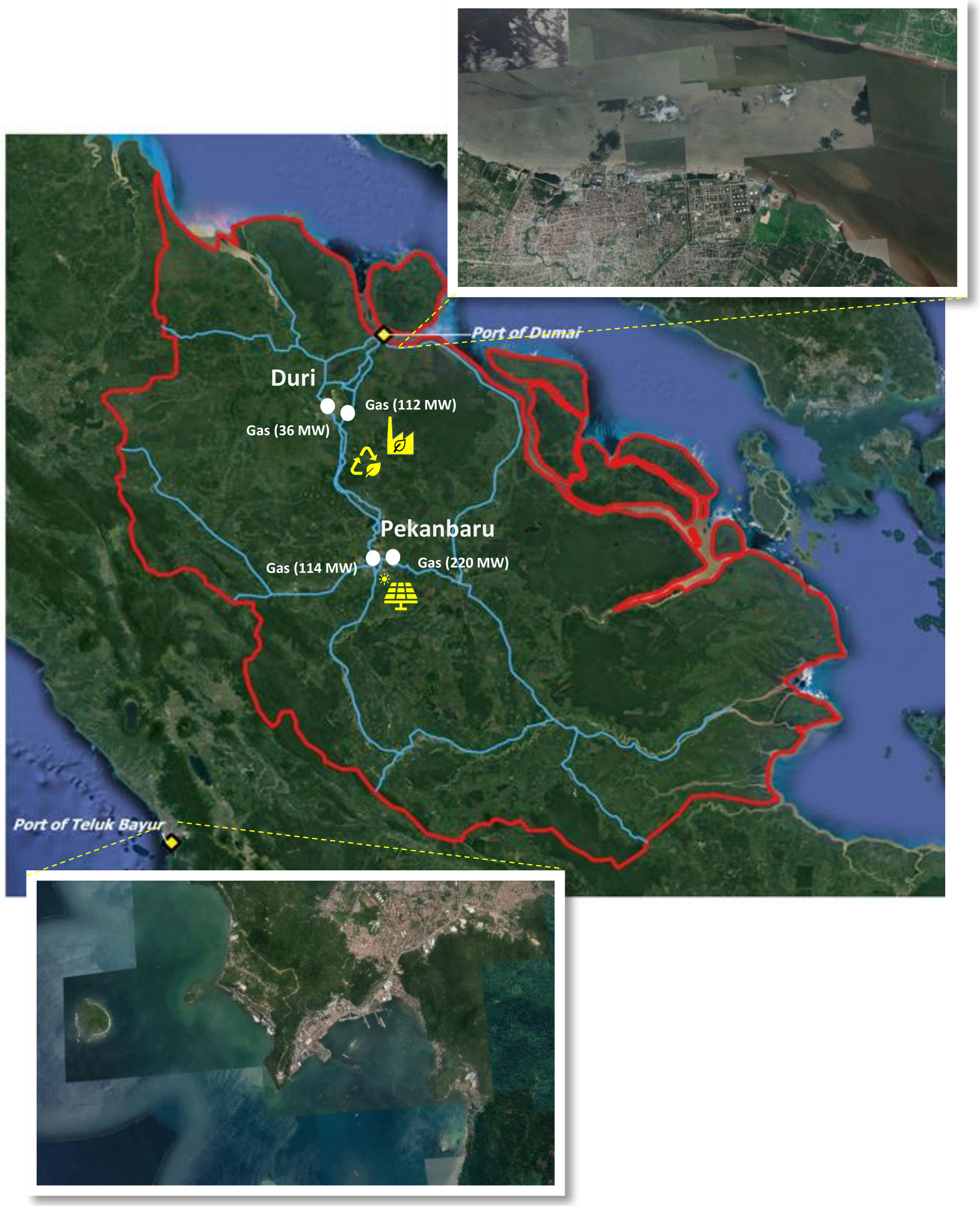
INFRASTRUCTURE IS NOT A SIGNIFICANT BARRIER FOR PROJECT DEVELOPMENT IN RIAU

Roads: Access to roads and port can significantly reduce costs of development. Particularly in places like Riau where some projects require sourcing of components and machinery from overseas. As illustrated in the figure, a plethora of road links are crossing the regional surface, enabling in theory an unhindered deployment of transportation phases within the development of the analyzed projects. Main roads are developed primarily around the Pekanbaru area, situated almost in the center of the region.

Ports: 2 medium size ports are situated anti-diametrically to the regional boundaries, with close proximity to all sides of Riau. Port of Dumai on the NE and Port of Teluk Bayur on the SW side.

Showcasing: Riau has experience with the construction of power plants. To date, 6 power plants are connected to PLN's network (see map). This indicate that it is possible to transport necessary the machinery from within the country and via ports.

Site location: The infrastructure is most developed between the capital district of Duri and Pekanburi. This part of the island is therefore the most suitable for construction of power plants. Since the area around Duri have significant palm oil waste resources for biomass and biogas production, a site ~30 km south of Duri have been chosen for biomass and biogas. A site located close to Pekanabaru has been chosen for the solar PV project.



Source: Google Earth satellite photos; PT PLN Persero (2021)

2.

PREFEASIBILITY STUDIES ON GENERATION TECHNOLOGIES

THE EXPECTED PPA PRICE IS 8.3 CUSD/KWH FOR SOLAR, 7.9 CUSD/KWH FOR BIOMASS AND 10.6 CUSD/KWH FOR BIOGAS

Regulation: The prices for electricity purchased from renewables is set by the national Ministry of Energy and Mineral Resources (MEMR). The most up-to-date regulation, No. 50/2017, sets the pricing regime per power producing technology type. As illustrated in the table to the right, the regional power purchasing price (PPA) of Independent Power Producers (IPP) is benchmarked according to the regional generation costs of renewable technologies also referred to as BPP (Biaya Pokok Pembangkitan). In case a local BPP is higher than the national average, the PPA price between PLN and IPPs for biomass, solar and biogas can maximum be 85% of the local BPP. Following the current regulation, the calculated maximum tariffs for solar PV, biomass and biogas is 9.9 cUSD/kWh. It is derived by multiplying the regional BPP for Sumatra (11.61 c/kWh) with the local cap of 85% for the three technologies.

Upcoming regulation: Following critics on the current PPA regulation, MEMR initiated discussions to revise the current scheme including, among other things, the introduction of Feed-In-Tariffs (FIT) to boost renewable energy technologies, with the aim of to reach the 2025 target of 23% RE. Based on the draft of the regulation, the guaranteed price will depend on generation technology, size of plant, and whether batteries are included, as well as featuring a with a regional correction factor based on the location of the project to account for major costs in more remote systems. Technologies below 5MW would have access to *Direct appointment* and a Fixed FIT, while projects above 5 MW would follow a *Direct selection* mechanism with a price ceiling specified (Highest Benchmark Price or Price Cap), followed by auction/negotiation with PLN to reach the final FIT level.

Expected tariff: The biogas plant envisioned for this study has a capacity of 1.8 MW and would therefore be subject to FiT pricing. Since the location factor of Sumatera, where Riau is located, is 1.1 the expected PPA price during the first 12 years of the contract is 10.6 cUSD/kWh and 6.3 cUSD/kWh the remaining 18 years. The maximum PPA price for the biomass project is 7.9 cUSD/kWh and 8.3 cUSD/kWh for Solar PV. Since these projects follow pricing structures that are subject to negotiation, it is difficult to predict the expected PPA price. For this study, we assume it to be equal to the ceiling tariff times the location factor We also conduct a sensitivity analysis to determine the lowest tariff a developer could accept in order to break even with the project (NPV=0 and IRR=WACC).

Tariffs based on **current** regulation	**Current regulation (No.50/2017 and revisions)**	**BPP Sumatra 2020**	**Expected PPA price (85% BPP)**
	Solar PV, Biogas and Biomass	11.61 cUSD/kWh	9.9 cUSD/kWh

Expected ceiling tariffs based on **upcoming** regulation (BIOGAS)	**Feed-in Tariff (Fit)/ceiling price** (>1 MW & ≤ 3 MW)		**Location factor, F** (Sumatera)	**Expected PPA price (FiT x location factor)**	
	Staging year 1-12	Staging year 13-30	1.1	Staging year 1-12	Staging year 13-30
	9.61 cUSD/kWh	5.77 cUSD/kWh		10.6 cUSD/kWh	6.35 cUSD/kWh

Expected ceiling tariffs based on **upcoming** regulation (BIOMASS)	**Highest Benchmark Price/ceiling price** (>10 MW)	**Location factor, F (Sumatera)**	**Expected PPA price (FiT x location factor)**
	7.16 cUSD/kWh	1.1	7.88 cUSD/kWh

Expected ceiling tariffs based on **upcoming** regulation (SOLAR PV)	**Highest Benchmark price/ceiling price** (>10 MW & ≤ 20 MW)	**Location factor, F (Sumatera)**	**Expected PPA price (FiT x location factor)**
	7.50 cUSD/kWh	1.1	8.25 cUSD/kWh

Source: MEMR (2020); MEMR (2017); CBLJ (2021)

BIOGAS POWER PLANTS

THE POWER GENERATING CAPACITY OF A BIOGAS PLANT BASED ON POME IN RIAU IS ESTIMATED TO BE 1.8 MW

Palm oil mill effluents (POME): POME is generated during the last processes of palm oil production. Before the products can be refined into CPO (crude palm oil), the fruits, nuts and kernels are squeezed and crushed in a palm oil mill (POM). This process generates waste in the form of wastewater and palm oil effluent (POME) and each mill discharges around 0.6-1 m3 of POME. POME has moisture levels of 95 %, is highly acid and has high chemical and biochemical oxygen demands (COD & BOD). POM operators are not allowed to discharge untreated POME into water ways and most operators therefore apply a 4-step treatment process. Although this process is economical, the climate effect in terms of methane emissions is significant. In some cases, treated POME is transported back to the plantations as fertilizers.

Resource potential: Palm oil mill effluent can be used as feedstock to produce electricity thru anaerobic digestion in a biogas plant. Once the POME has been threated in a biogas digester the gas is converted to electricity in a gas engine. According to the Renewable Energy Outlook for Riau, the total biogas potential corresponds to a generating power capacity of 400 MW.

The power generating capacity of a palm oil mill processing 60 tons FFB/hour is estimated to be 1.8 MWe assuming gas engine efficiency (gen_{eff}) of 38%, POME to FFB ratio of 0.65, digester efficiency (COD_{eff}) of 90%, methane energy value of 35.7 MJ/Nm^3 and COD level: 55000 mg/L. With a load factor of 90 %, the power production potential is 14,000 MWh.

Calculation of POME to energy – step-by-step:

(1) Daily throughput = $\frac{Annual\ FFB}{Operating\ days}$

(2) Daily wastewater flow (m^3/day) = $Daily\ throughput * ratio\ POME\ to\ FFB$

(3) COD loading (kg COD/day) = $COD\ level\ *\ daily\ wastewater\ flow\ * \frac{kg}{1{,}000{,}000\ mg} * \frac{1000\ L}{m^3}$

(4) CH_4 production (Nm^3 CH_4/day) = $COD\ loading * CODeff * CH_4/COD$

(5) Generated Power capacity (MWe) = $\frac{CH_4\ production * CH_4ev * Geneff}{24*60*60}$

Off-grid biogas plant in Riau, photo credit: PT Innovasi

As part of this study, a small-scale biogas plant with a capacity of 1 MWe was visited. Since 2017, the plant has processed 200.000 Nm^3 POME. The plant delivers power to community households in a nearby village. The plant currently only operates at 30 % of the capacity returning a yearly production of ~ 2500 MWh. The power production potential of a typical biogas project based on POME from a palm oil mill is much higher (see table below).

One of Asia's largest palm oil producers, Asian Agri, operates 3 POME based biogas plants in Riau. The biogas plants have capacities between 1.2 and 2.2 MWe.

Daily throughput	60	Tons FFB/hour
Daily wastewater flow	650	Nm^3/day
COD loading	35,750	Kg COD/day
CH_4 production	11,262	Nm^3/year
Power capacity	1.8	MWe
Power production	14,000	MWh

1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
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Source: DEA & Ea (2019); DEA (2021); Sung (2016); Windrock International (2016); Asian Agri (2021); PT Innovasi (2021)

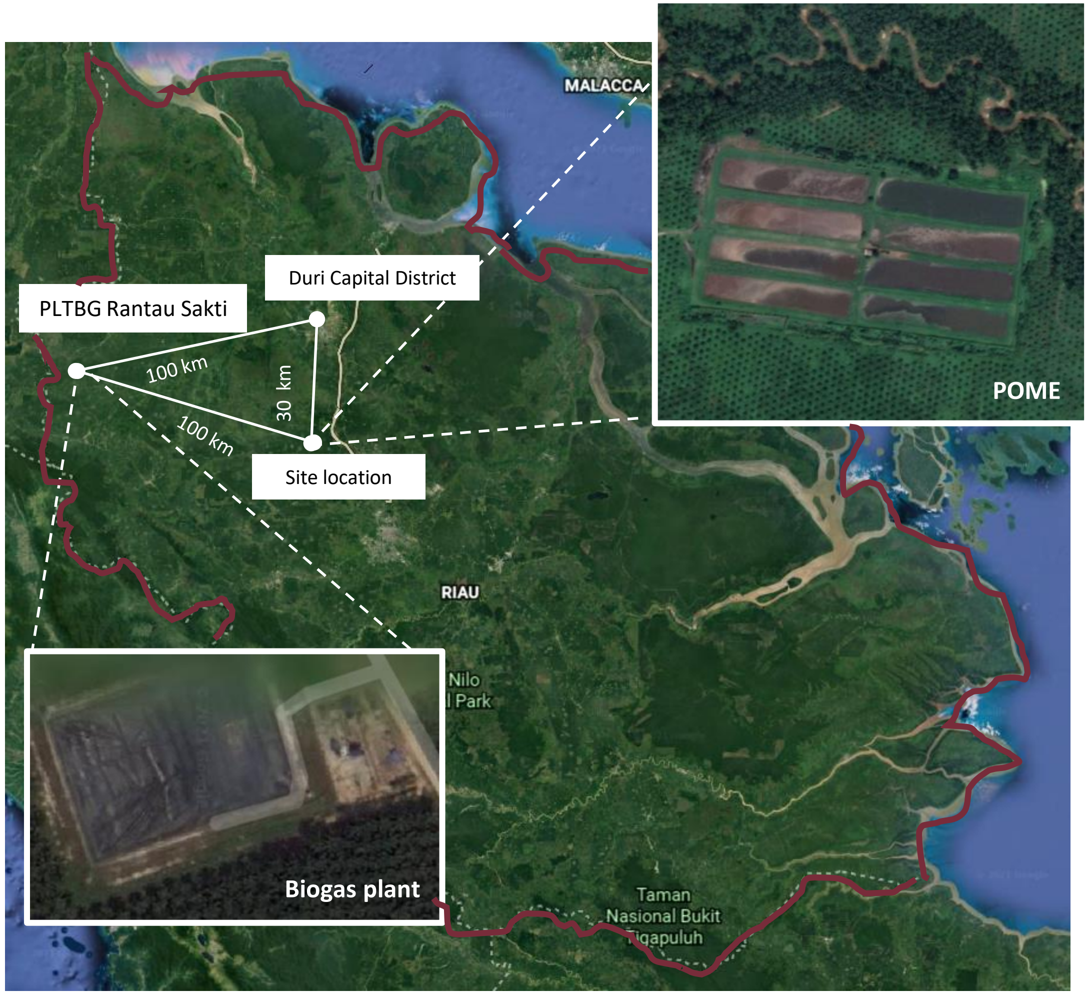
SOUTHEAST OF DURI CAPITAL DISTRICT HAS BEEN CHOSEN AS SITE LOCATION FOR THE STUDY

Location: Access to the power grid is a key driver of the business case in order to monetize the biogas produced by the palm oil mill. Proximity to cities ensures that there is potential off-take if the power is sold to the grid. Lastly, choosing a site close to a central point on the grid lowers the risks of congestion.

Based on the concentration of palm oil mills and proximity to the grid, the northwestern part of Riau – in the regions of Kampar and Rakun Hulu – has been chosen as the site for this study.

Resource and supply: A palm oil mill near the city of Samsam processing 60 tons/FFB per hour has a power potential of 1.8 MWe. Biomasses with a low solid content such as POME are generally expensive and impractical to transport. As a result, small scale biogas plants digesting POME from one palm oil mill is preferable.

Fuel costs: POME is considered a waste product with very small market value; hence fuel costs is assumed to be close to zero. In this study we make a conservative assumption of 0.12 USD/Nm3 POME.



1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
5 Financial & technical key figures
6 Business case
7 Environmental & social aspects
8 Risk assessment

Source: PT PLN Persero (2021); Google Earth satellite photos;

ASSUMPTIONS OF THE FINANCIAL CASH-FLOW MODEL FOR THE 1.8 MW BIOGAS POWER PLANT

Technical features	
Capacity	1.8 MWe
Expected tariff	6.3 c/kWh (first 12 years)- 10.6 c/KWh (last 8 years)
Payment currency	USD
WACC (real)	8.04%
Tax rate	20%
CAPEX	3.8 mUSD
OPEX	173,000 USD (4.5 % of CAPEX)

Economic features	
Fuel costs	0.12 USD/Nm3 POME
Heating value	0.38 GJ/Nm3 POME
Efficiency rate	38%
Availability	100%
Load factor/FLH	90%
Technical lifetime	25

THE CAPEX OF THE BIOGAS POWER PLANT WITH A CAPACITY OF 1.8 MW IS ESTIMATED TO BE 3.8 MUSD

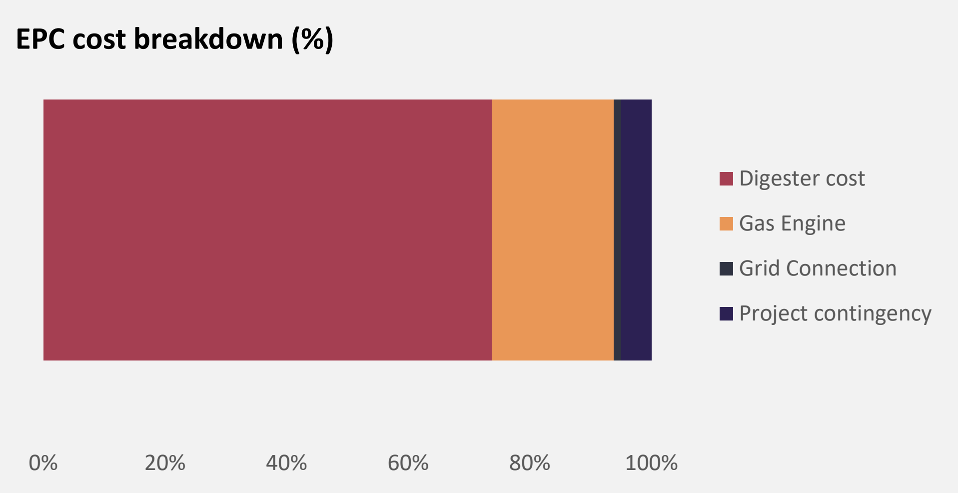
Technology: Covered lagoon digester systems and continuous stirred tank reactors are the most common technology choice for biogas production based on POME from palm oil mills. Covered lagoon digester systems are generally more suitable for highly liquid feedstock compositions and normally handles a solids content of 2 %, whereas CSTR tanks can handle 3-10% solids content. In a covered lagoon digesters, POME that is stored in ponds is covered by an airtight membrane.

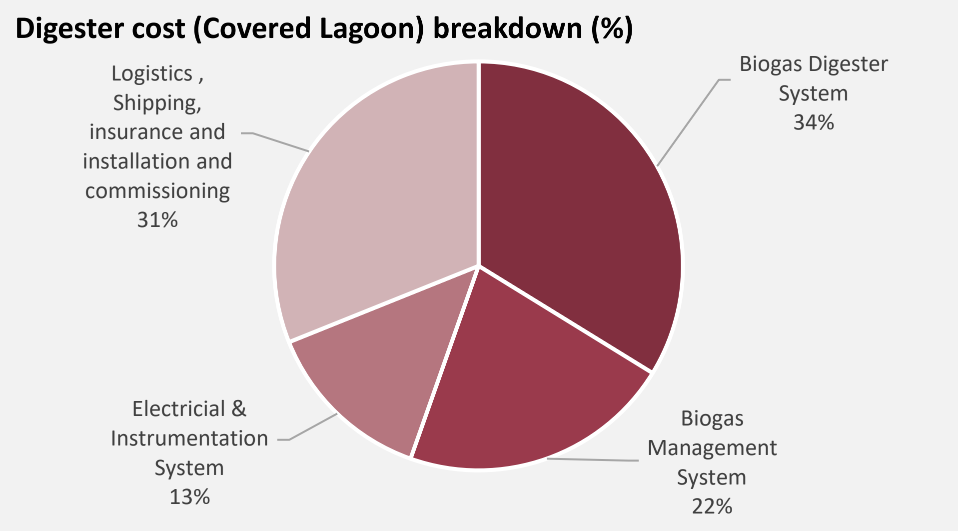
Covered lagoons have simpler design features, partly since the low total solids content means that mechanical stirring mixing can be reduced. The investment costs of covered lagoons is 90% the investment costs of CSTR tanks.

CAPEX: The total CAPEX of a biogas system generating 1.8 MW of electric power is estimated to be 3.8 mUSD, where the digester system makes up 70-75% of the costs. The gas engine is another significant cost factor, representing 20-25% of the costs. The figures to the right show EPC costs, which is CAPEX minus development costs, financial costs and working capital.

According to the Indonesian Technology catalogue, the CAPEX of biogas digester systems is expected to decrease from 2.15m USD/MWe in 2020 to 1.82m USD/MWe in 2030.

OPEX: is estimated to be ~170.000 USD/per year, corresponding to 4.5 % of CAPEX. This is in line with the assumptions made in the Technology catalogue for Indonesia. According to Windrock International, OPEX may constitute 5-9 % of EPC costs.





1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
5 Financial & technical key figures
6 Business case
7 Environmental & social aspects
8 Risk assessment

Source: Windrock International (2016), DEA & Ea (2021).

BIOGAS POWER GENERATION RETURNS AN IRR OF 28% AND NPV OF 8.2 MUSD

Result: The cash flow calculation of the biogas plant with an electric generation capacity of 1.8 MW returns an NPV of 8.2 mUSD and an IRR of 28%.

It is assumed that PPA contract of 30 years is signed with PLN where the PPA price follows the expected Feed-In-Tariffs (FITs) for biogas power plants above 1 MW and below 3 MW. Multiplied with the location factor (1,1) for Sumatera, the resulting PPA price is assumed to be 105.71 USD/MWh the first 12 years and 63.47 USD USD/MWh the remaining 18 years of the 30-year PPA contract.

POME is considered a waste product with very small market value; hence fuel costs is assumed to be close to zero. In this study we make a conservative assumption of 0.12 USD/Nm3.

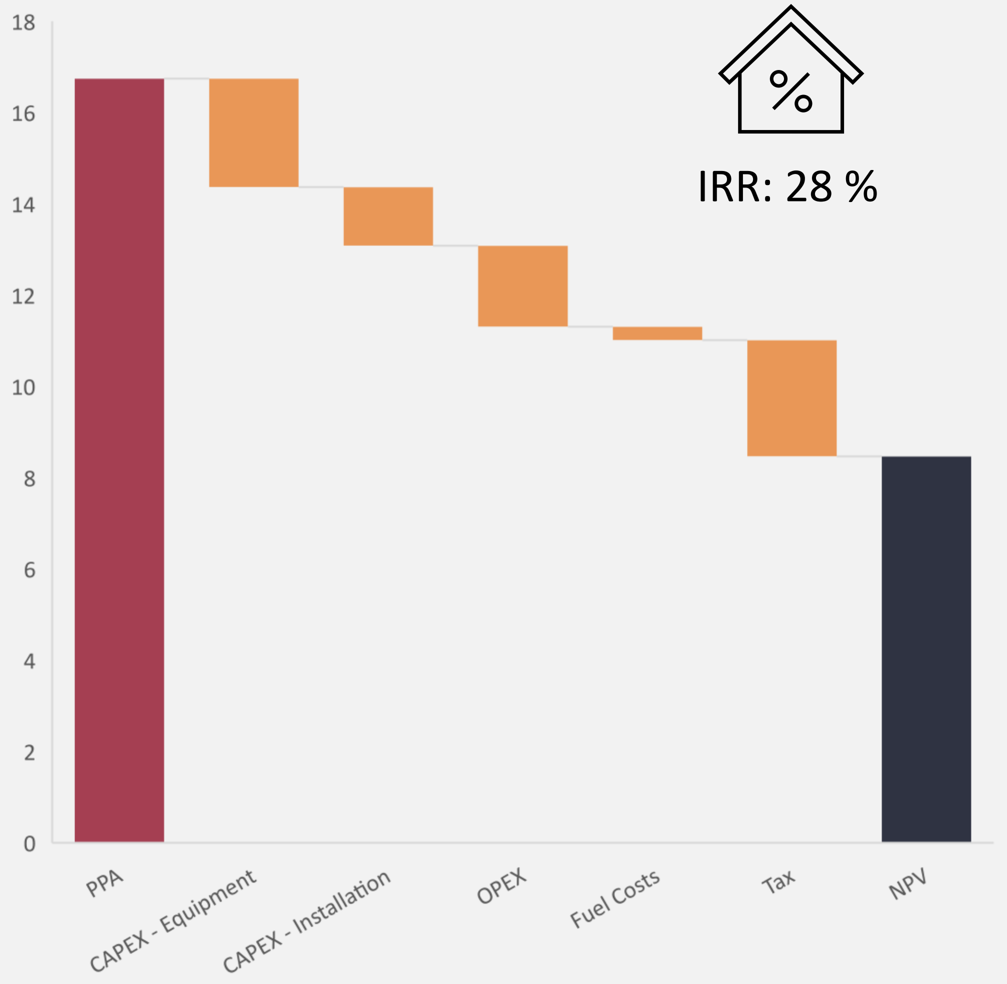
Limitations

There is currently no cases of POME-based biogas plants selling the full capacity to the grid. Some plants sell excess power to the grid and use the majority locally, e.g., to power the electric or thermal energy needs around the palm oil mill. There are also examples of biogas power plants that are 100% off-grid. Whether a off-grid or semi-off grid model is more feasible depends on the potential costs savings from the sourcing of energy for use at the palm oil mill. Such cost savings would improve the economic feasibility of the investment but have not been included in the business case.

In the event, that the investor of the biogas power plant also owns the plantation(s) and the palm oil mill, the costs savings from the purchase of synthetic fertilizers could be added to the positive cash flow, if the by-product from biogas production is used as organic fertilizers.

Sources: MEMR (2020); Nuaini et al. (2018).

NPV Breakdown[1] (mUSD)

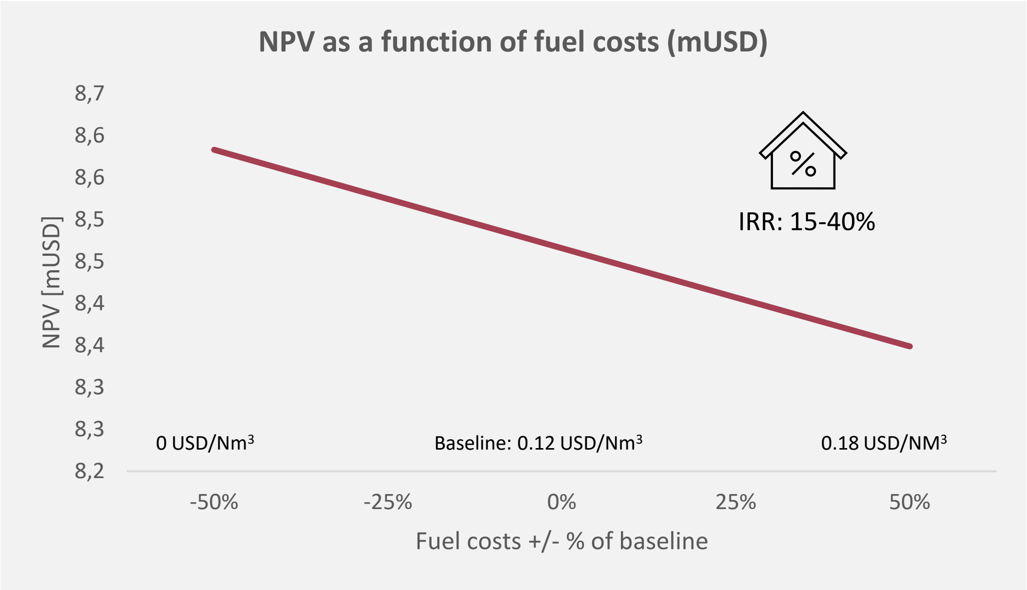


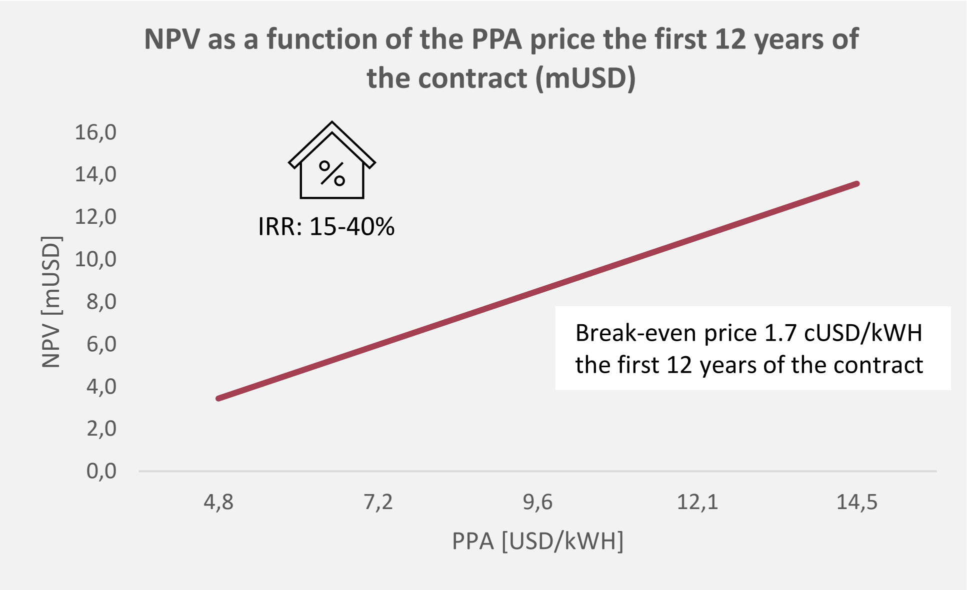
Note: 1. The present value of each cashflow component (revenues and cost) is performed here to break down the contribution to the final NPV value for illustration purposes.

WITH A 50% REDUCTION OF THE PPA PRICE, THE NPV IS STILL POSITIVE; IF THE COSTS OF POME IS ABOVE 4 USD/NM^3, NPV IS NEGATIVE

Fuel costs sensitivity: Generally, POME is not expected to have value of any significance. While POME has other potential end-uses, for instance as fertilizers, the high moisture level makes it expensive and impractical to transport. Therefore, the majority of POME is treated and discharged into water-ways. If anything, using POME for biogas production may generate costs savings to the palm oil mill because it reduces the treatment processes and frees up land space which could be used for other purposes. Below graph shows the effect of higher fuels costs on the NPV and IRR. Fuel costs around 4 yields a negative NPV.

PPA price sensitivity: This study assumes a fixed feed-in tariff (FiT) for biogas starting with a higher PPA price of 10,571 cUSD/kWh the first 12 years of the PPA contract followed by a lower PPA price of 6,3 cUSD/kWh the remaining 18 years of the PPA contract. The PPA price may change depending on how the PPA regulation is implemented. However, even with significantly lower PPA price the first 12 years (-50%), the project still returns a positive NPV. Assuming the PPA price from year 13 to 30 is constant, the PPA break-even price the first 12 years is 1.7 (including location factor) for Sumatra.



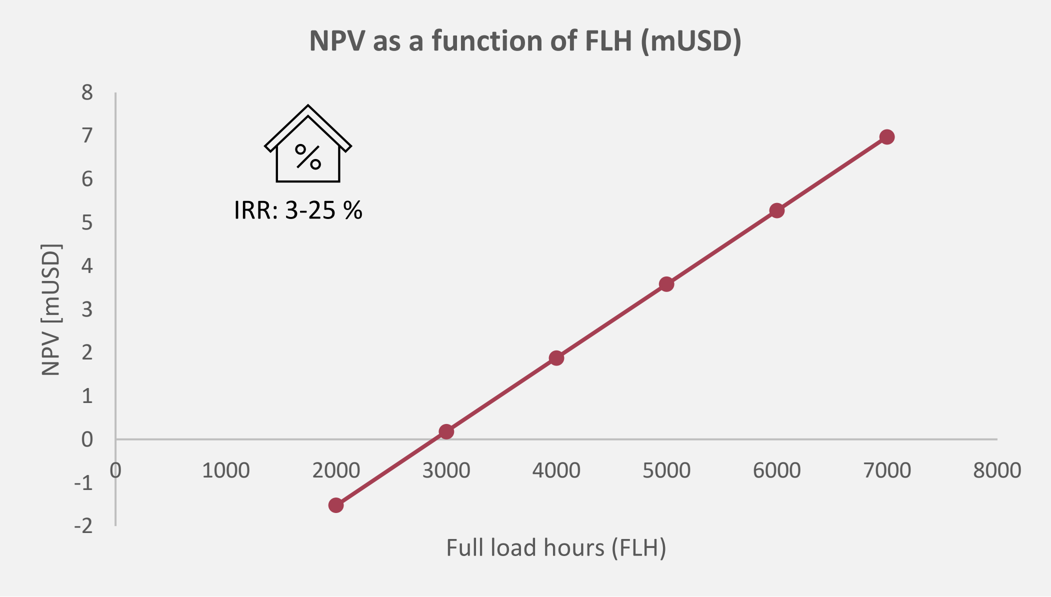


Source: DEA & Ea (2021); MEMR (2020)

THE STUDY IS RELATIVELY ROBUST WITH RESPECT TO CHANGES IN CAPEX AND MORE SENSITIVE TO THE LOAD FACTOR

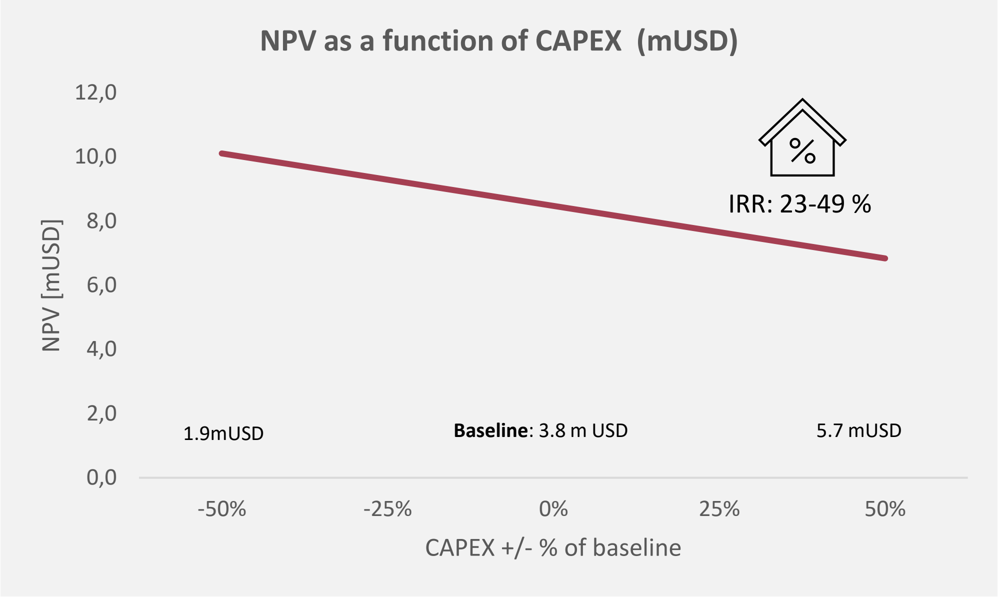
FLH sensitivity: Full load hours gives an indication of the utilization of the capacity in terms of power production. It is also referred to as load factor. Changes in the anaerobic environment, such as temperature, of the plant affect the load factor of the plant. Lagoon digesters are generally less resistant to temperature drops and thereby more likely to experience variation in methane production. However, the climate in Riau is relatively stable throughout the year with a minimum temperature of 22˚C and a maximum of 32˚C.

During a site visit to an off-grid biogas power plant, the load factor was found to be as low as 30 %, corresponding to less than 3000 full load hours. This was explained partly by an explosion of the digester causing operational downtime and customers switching to PLN's grid. As shown on the graph below, FLHs below 3000 yield a negative NPV, which underlines the importance of sizing a project according to demand.



CAPEX sensitivity: CAPEX is costs related to the upfront investment of the digester system, electrical and instrumental equipment among other things.

This study has estimated CAPEX to be 3.8 m USD for a 1.8 MWe biogas plant following the assumption in the Danish Energy Agency's Technology catalogue for Indonesia. Another report on biogas project development from Windrock International estimates that the investment costs of a lagoon digester ranges between 1.5 mUSD and 3mUSD. The sensitivity analysis shows that even if CAPEX increases with 50 %, the business case still returns a positive NPV.



Source: Windrock International (2016); DEA & Ea (2021); Weather and Climate (2021);

THE RISK OF METHANE LEAKAGE CAN BE SIGNIFICANT ALONG WITH THE RISK OF ENVIRONMENTAL DAMAGE FROM A NATURAL DISASTER

Environmental impact: The risk of leakage into the waterways from a lagoon digester can be significant. In the design phase of the digester system, it is important to follow high engineering standard and use high quality materials to reduce leakage of wastewater into the ground and surface water.

Poor operational management or external events such as a natural disasters could cause explosion of the digester. Proper safety measures, such as flood and lighting management systems should be implemented to mitigate the risk of causing environmental damage to the community. Ensuring that all necessary insurances are in place is important to mitigate financial risk.

Social impact: Local opposition of biogas projects has shown to cause significant delays, and in some cases, a full stop of a project. The opposition may relate to the additional transport of materials during the construction phase. It is important to consult the local community in the early phases of the project development to mitigate this risk.

Riau still has households that do not have access to PLN electricity and can be served trough renewable energy utilizing readily available local resources. This was proven by one of the biogas facilities utilizing POME from a nearby palm oil mill providing electricity to the surrounding villages.

Greenhouse gas impact: The palm oil mill effluent from palm oil mills is stored in open lagoons, where the organic materials are degraded in an aerobic environment. This cause the release of methane into the air. Some ponds are covered, and instead of releasing methane, CO_2 is released in the form of flaring. Installing a methane capture system for production of biogas reduces the green house gas emission from the treatment of POME. While flaring must be installed as a safety measure, it is only activated in the event that the production of the plant exceeds demand for power. Since digesters follow a relatively stable production it should be possible to dimension the plant so as to minimize the risk of flaring.

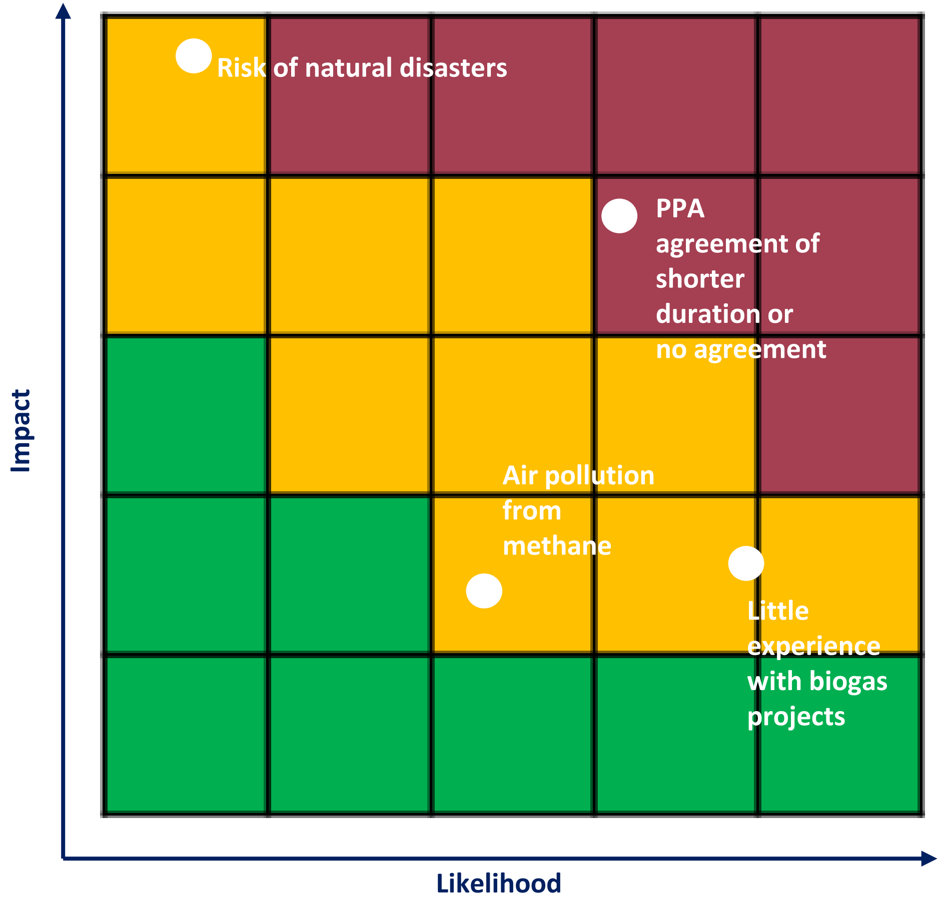
Methane leakage from the biogas plant poses an environmental risk, which can be mitigated by monitoring air pollution and using high quality materials for the lagoon covers.

Photo: Two officers and a local resident cleaning up after a landslide in Rokan Hulu, Riau in 2016. (The Jakarta Post, 2019)

Source: Windrock International (2016); The Jakarta Post (2019); PT Innovasi

THE GREATEST RISK IS LEAKAGE FROM THE PLANT; RISK MITIGATION INVOLVES PROPER PLANNING, SKILLED LABOUR AND CONTINUOUS MONITORING

Risk name	Description	Impact	Action
Little experience with biogas production	Riau has one operating power plant that operates at 30 % of the capacity.	The lack of experience could cause unexpected events, such as disruptions in the operational performance leading to underutilization of the plant and lost revenue.	Hire skilled labour in the construction and development phase to ensure the plant and monitor the operational perfomance of the plant at a continous basis
PPA agreement of shorter duration or no agreement	New regulation is under discussion, hence the expected PPA tariff is subject uncertaintiy	1) Postponement of PPA signature and higher development costs or 2) PPA is only willing to sign the PPA contract significantly below the Highest benchmarking price.	• Ensure dialogue with PLN and ministry on regulation progress. • Prepare for adjustments to the revenue scheme.
Air pollution from methane leakage	Without proper ceiling of the lagoon cover on the digester system, methane can leak.	Leakages of methane poses a climate risk since methane is a potent greenhouse gas. Besides, it lowers production and thereby affects the revenue stream negatively.	Carefully design the plant to minimize the risk of methane leakage and monitor production contiously so repairs on the lagoon cover can be made in due time.
Risk of natual disasters	External events, such as flooding or earthquakes can cause disruption – and in a worst case – explosion of the biogas plant.	Environmental damage in the form of nutrient pollution.	Install safety measures and carefully design the digester to be robust towards external events.



BIOMASS POWER PLANTS

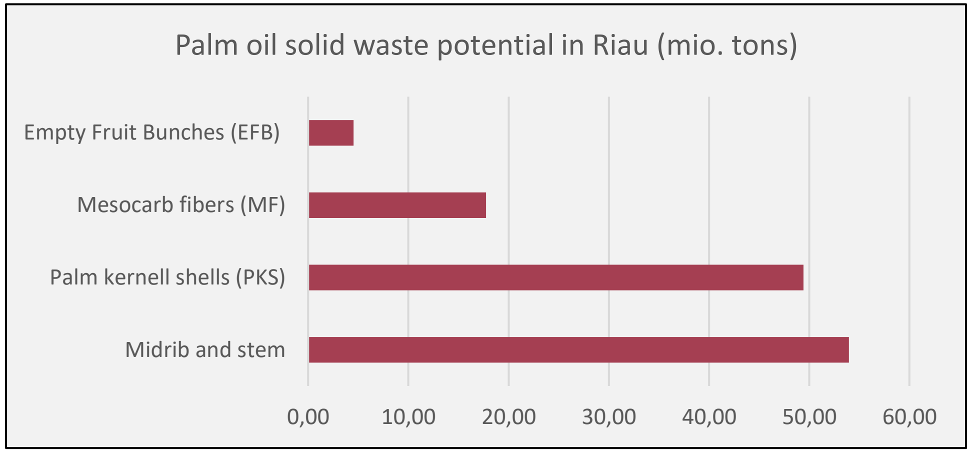
THE POWER GENERATION POTENTIAL OF RIAU BASED ON SOLID WASTE FROM PALM OIL PRODUCTION IS ~4 GW

Palm oil solid waste: The palm oil industry generates a number of solid waste streams, mainly from three processes of palm oil production. 1) During the replanting process in the oil palm plantations, fronds/leaves and trunks (OPT) are produced. 2) during harvest, palm bunches and fronds are cut off. Lastly, 3) the conversion of fresh fruit bunches in the palm oil mill generates a number of solid waste streams, including empty fruit bunches (EFB), Palm kernel shells (PKS) and mesocarb fibers (MF). Today, PF and a portion of the shells are used as boiler fuel either locally in the mill or distributed and sold to factories. Fibers are suitable – and in some cases – used for upholstery. While the decomposition rate is varying, solid biomass from palm oil production is generally feasible for field application and high costs of synthetic fertilizers further increase demand for turning these waste streams into viable agricultural products.

While Indonesia has a wide variety of solid waste biomass, including coconut and rice husk, palm oil mill liquid and solid waste is considered the most suitable for bioenergy generation due to high availability and easy handling.

Resource potential: Biomass with high dry matter content, such as solid biomass from palm oil production is suitable for thermal combustion or gasification for power generation. Riau's total generation of palm oil residues, including PKS, MF and EFB and midrib and stem sum up to 125 mio. ton. The total power generation capacity from palm solid waste streams in Riau is estimated to be ~4 GW, which is half the total potential of Sumatera.

Fuel costs: PKS has, according to several studies, a relative high market value ranging between 30 and 80 USD/ton. This can partly be explained by the demand for PKS from overseas for use in biomass boilers and power plants. In the first quarter of 2020, Indonesia exported 0.5 mio. tons PKS to Japan, a 50 % increase compared to the previous year.



Price of Palm Kernel Shells

Windrock International (2015)	Harap et al. (2019)	Sari (2019)
30-50 USD/ton	70 USD/ton	80 USD/ton

Source: Hamali (2017); Sung (2016); DEA & Ea (2021); PWC (2018); DEA & Ea (2019); Argus (2020); Harahap et al. (2019); Sari (2019).

1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
5 Financial & technical key figures
6 Business case
7 Environmental & social aspects
8 Risk assessment

NORTHWEST OF RIAU IS A SUITABLE LOCATION FOR BIOMASS POWER PRODUCTION

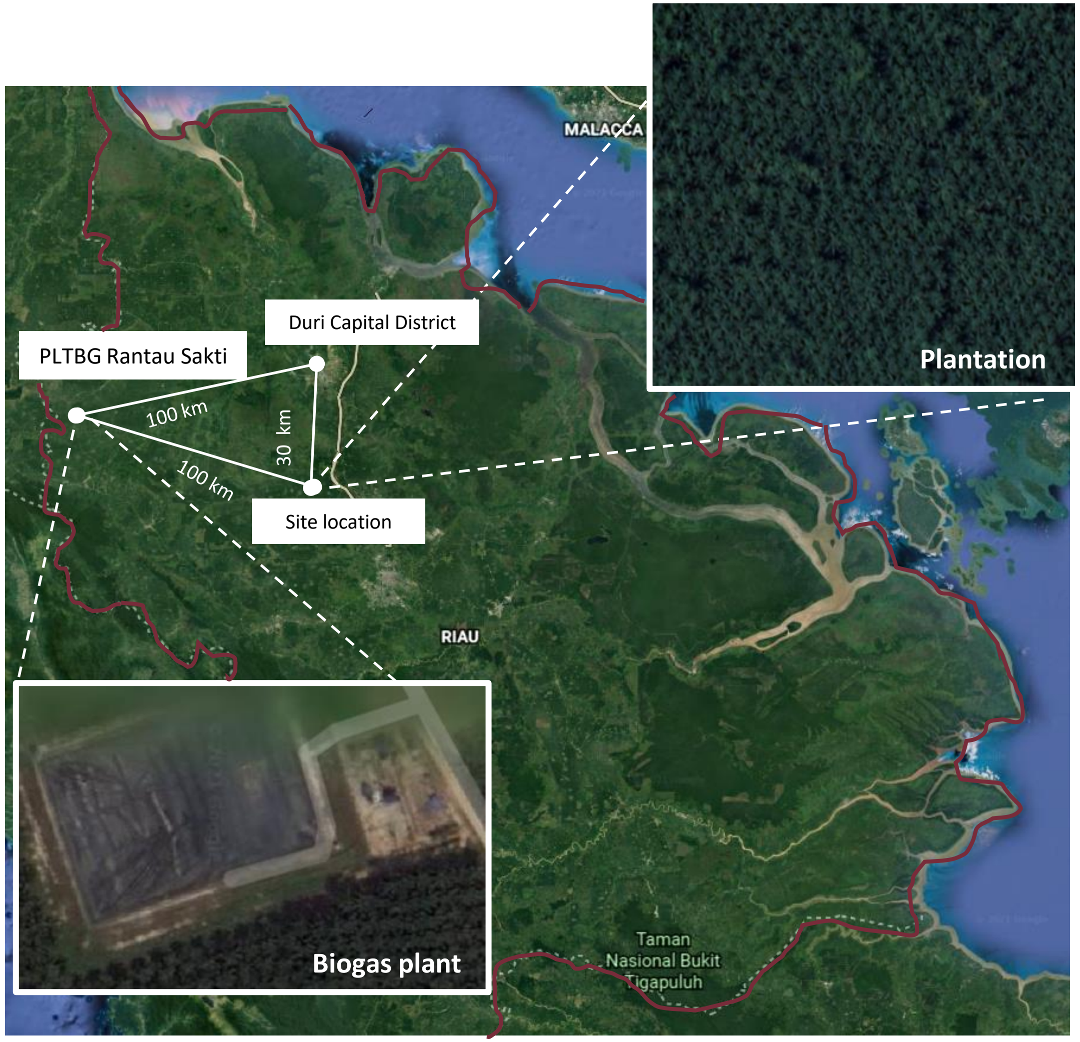
Location: The highest concentration of palm oil mills in Riau is in Kampar and Rakun Hulu in the Northwestern part of Riau. These districts also have the largest concentration of industrial mature palm oil plantations. PLN's grid has connected a number of +100 MW sized (gas-fired) power plants near the Duri Capital district and since a large industrial palm oil plantation is located east of Duri, this location has been chosen for the study.

Resource and supply: The biomass project chosen for this study is assumed to use Empty Fruit Bunches (EFB), Palm Kernel Shells (PKS) and Mesocarb Fiber (MF) as the primary biomass source. MF, PKS and EFB have moisture levels of 15, 40 and 63% respectively, and are therefore deemed feasible for combustion.

The biomass plant is assumed to process biomasses from one palm oil mill, and it is assumed that one palm oil mill process 60 t of fresh fruit bunches (FFB) per hour, corresponding to ~400.000 tons per year. PKS, EFB and MF constitute 5, 20 and 11% of the total FFB dry weight. Assuming calorific values of 5 (EFB), 11 (MF) and 15 (PKS) GJ/ton – and a load factor of 88 %, the fuel power of the plant is estimated to be 38 MW. With an electric efficiency of 32%, the total plant capacity is estimated to be ~12 MWe.

The biomass plant could be scaled up by sourcing additional biomasses in the form of fronds from the plantations or municipal solid waste from the nearby city.

Fuel price: This study estimates fuel costs of 50 USD/ton for PKS, 12 USD/ton for EFB and 7 USD for MF.



1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
5 Financial & technical key figures
6 Business case
7 Environmental & social aspects
8 Risk assessment

Sources: Windrock International (2015); DEA & Ea (2021); PT PLN Persero (2021); Google Earth Satellite photos

THE CAPEX OF THE BIOMASS POWER PLANT IS ESTIMATED AT 10-32 MUSD – OPEX AT 0.8-2.2 MUSD PER YEAR

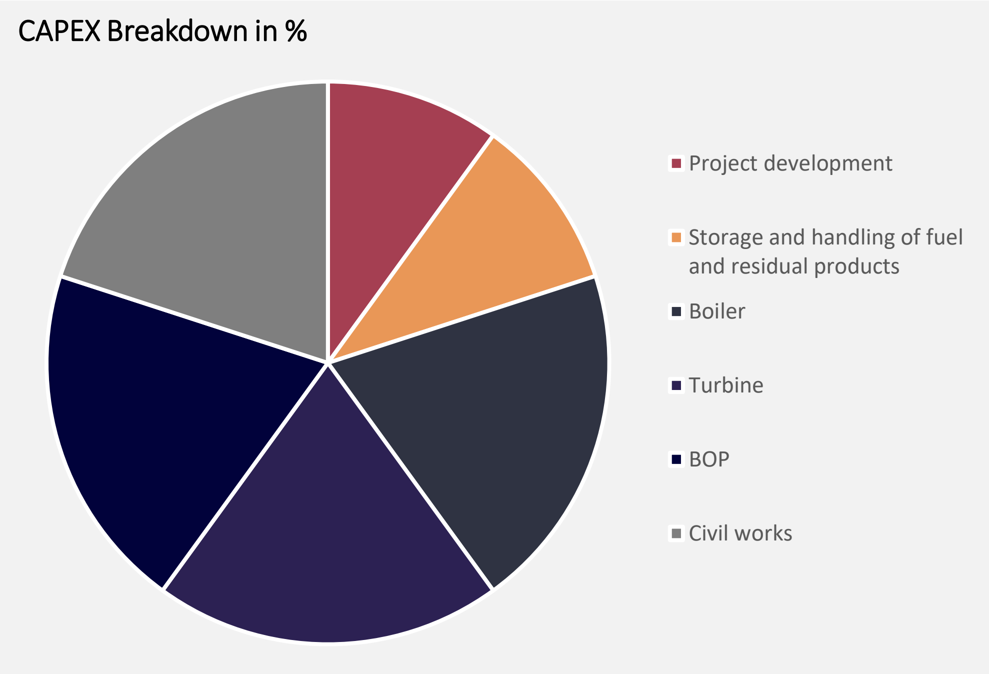
CAPEX: Biomass power plants are considered mature technologies with low potential for development. In Indonesia, however, using biomass for power generation is relatively new.

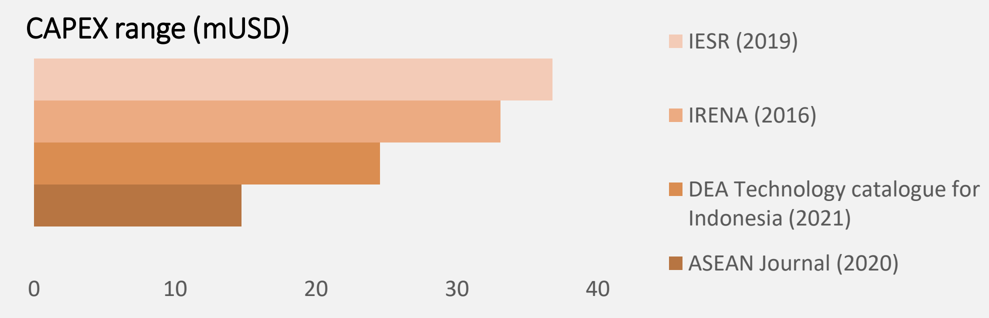
CAPEX for a biomass power plant with steam boiler generation is 2 mUSD/MW according to the Indonesia Technology catalogue. A pre-feasibility study of two 20 MW-sized biomass power plants in Indonesia recorded CAPEX of 1.2 USD/MW.

CAPEX can be divided into development costs, civil works and equipment. Equipment includes boiler, turbine, fuel storage and handling and BOP (Balance of Plant) equipment. Equipment constitute the largest share of CAPEX.

Fuel storage and handling costs are relatively high for greenfield projects. For biomass power plants that are built in existing industrial areas, costs are typically lower, because this equipment is already installed at the site.

OPEX: OPEX is assessed to be 6% of CAPEX in the Danish Technology catalogue, resulting in OPEX for this study at 1.5 mUSD. In comparison, a report on biomass technologies for Malaysia, Thailand and Philippines finds OPEX to range between 3% and 5% of CAPEX.





Source: IESR (2019); IRENA (2016); DEA & Ea (2021); ASEAN (2019); World Bank (2017)

ASSUMPTIONS OF THE FINANCIAL CASHFLOW MODEL FOR THE BIOMASS POWER PROJECT

Technical features	
Capacity	13.5MWe
Expected tariff	7.9 cUSD/kWh
Payment currency	USD
WACC (real)	8.04%
Tax rate	20%
CAPEX	USD 27m
OPEX	USD 1.6m (6% of CAPEX)

Economic features	
Fuel costs	50$/ton (PKS); 7$/ton (MF); EFB
Heating value	8GJ/ton
Efficiency rate	32%
Availability	80%
Load factor	90%
Technical lifetime	25 years

BIOMASS POWER PROVIDES NPV OF 19 MUSD AND IRR OF 16% ASSUMING PALM KERNEL SHELLS COSTS 50 USD/TON

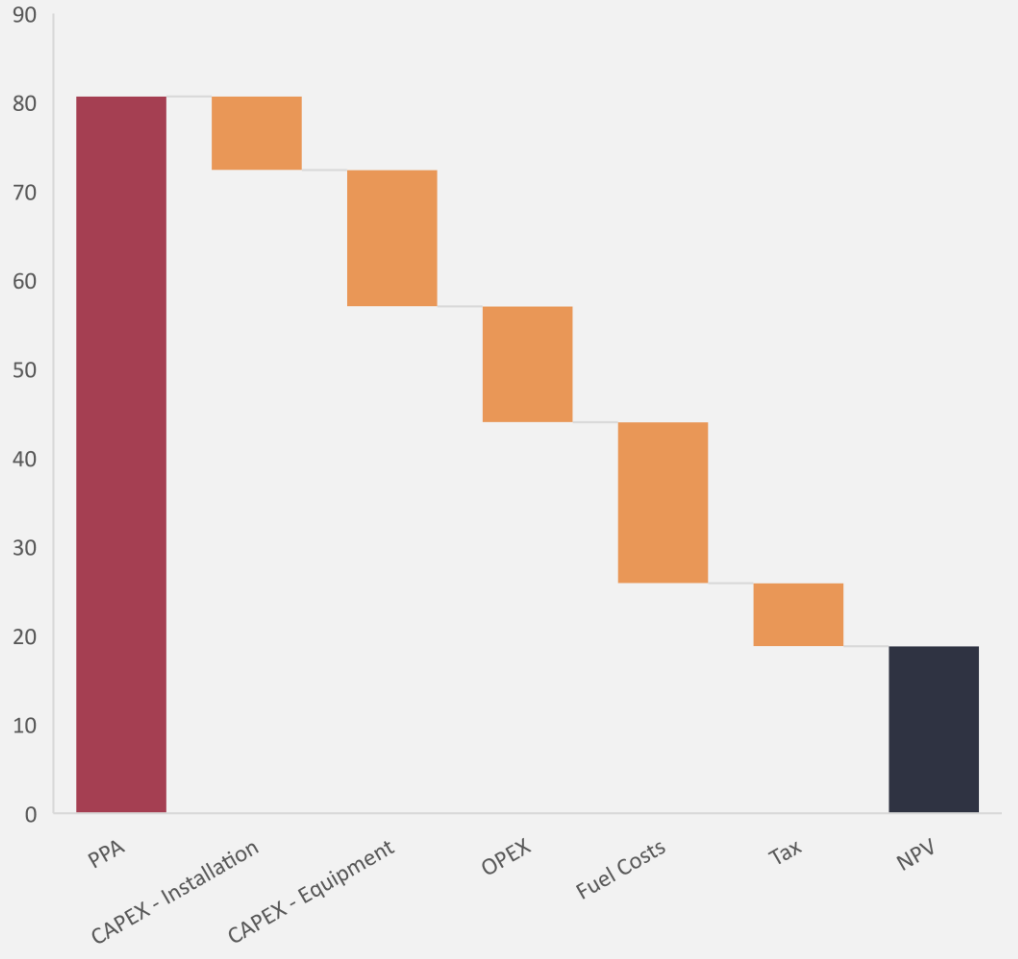
Results: The cash flow analysis for the concerning biomass power project yields a net present value of 19 mUSD and an IRR of 16%. The total generation capacity is estimated to be 12 MWe and the biomass feedstock is a combination of EFB, MF and PKS from a palm oil mill processing 60 t FFB per hour.

The case assumes production of electricity which comes at lower CAPEX and OPEX compared to CHP units. PKS, EFB and MF have been assumed to be 50 USD/ton (110 USD/ton market value minus transportation costs and taxes), 12 USD/t and 7 USD/t, respectively.

A PPA price of 7.9 c/USD is used to calculate the PPA sales. This corresponds to the highest benchmark price according to expected future regulation. However, since the PPA price is a negotiation between PLN and the private developer, the actual PPA price might be lower.

Limitations: In this study it is assumed that the full capacity is sold to the PLN grid. In the meantime, a business model whereby excess power is sold to the grid may be more feasible due to a relatively modest PPA benchmark price. Due to data limitations, it has not been possible to assess this business model.

NPV Breakdown[1] (mUSD)



Note: 1. The present value of each cashflow component (revenues and cost) is performed here to break down the contribution to the final NPV value for illustration purposes.

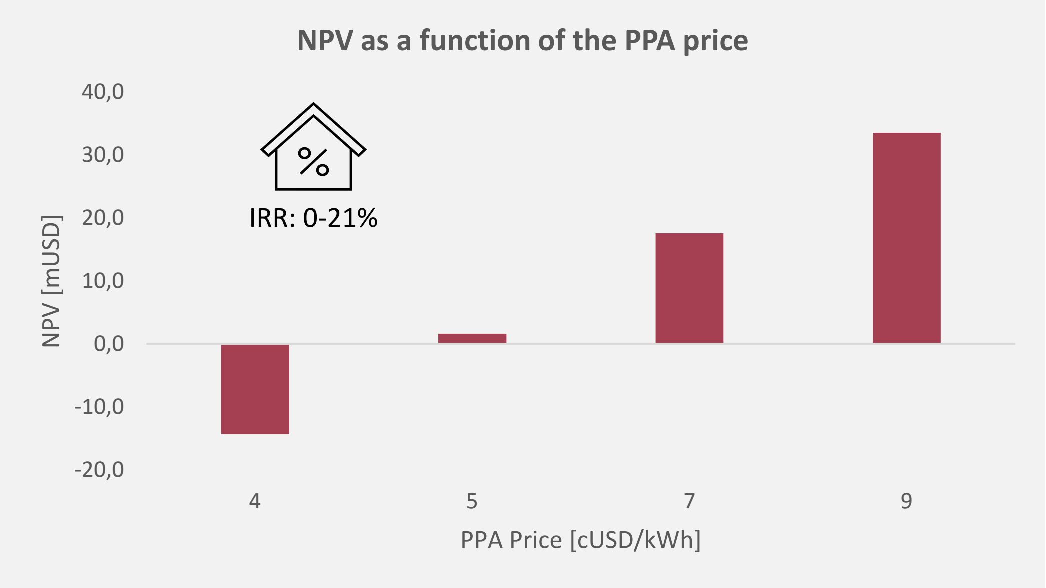
THE PPA BREAK-EVEN PRICE IS 5.7 CUSD/KWH; FUEL COSTS (PKS) BELOW 185 USD/TON RETURNS A POSITIVE NPV

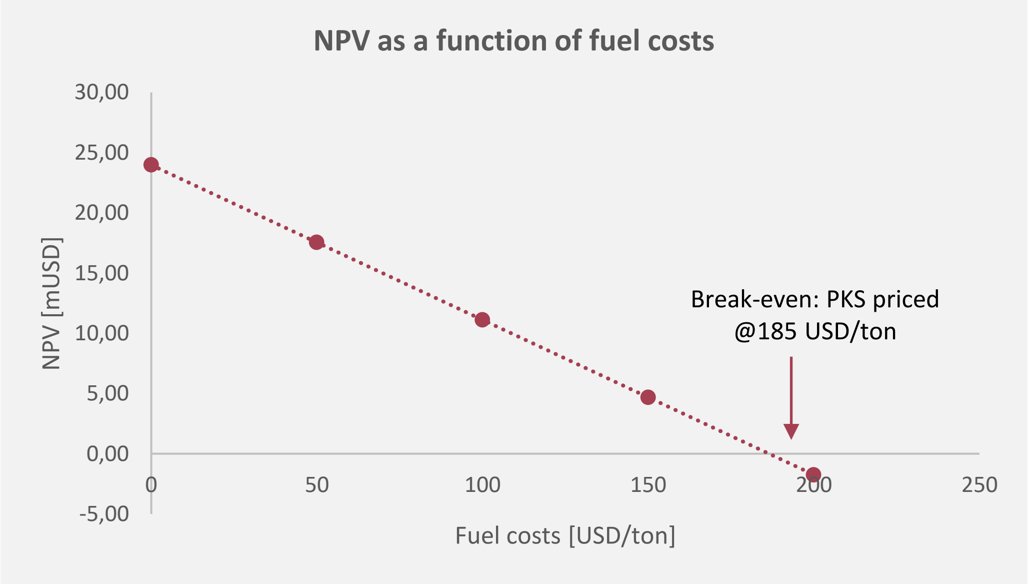
Sensitivity analysis: The upcoming regulation on PPA schemes for renewable energy Indonesia is expected to set a ceiling for biomass power plants. For a power plant with a capacity of 12 MW, the highest benchmark price (HBP) is 7.876 cUSD/kWh (assuming 1.1 location factor for Sumatera). This study uses HBP as a proxy for the PPA sales cash flow. There is however a probability that investors cannot negotiate the highest benchmark price for their PPA contract.

The sensitivity analysis shows that an investment may be attractive even with a PPA price of 5.7 cUSD/kWh, which is the PPA price that returns NPV=0. Since the regulation is not yet implemented, there may be possibility for negotiating even higher PPA prices.

Sensitivity on fuel costs: While solid biomass from the palm oil mills is attractive fuel for thermal and electric energy, it is also an attractive export commodity, specifically PKS. In 2020, PT International Green Energy signed a 15-agreement to ship 150.000 MT of PKS to the Japanese company Erex Co. Ltd. Since 2016, the export of PKS grew with 13.6 % and the Indonesian government continues to support the promotion of PKS as an export commodity and source of renewable energy (BDPD, 2020 - Link). This study assumes PKS is priced at 50 USD/tons. The break-even price where NPV = 0 is 185 USD/tons.

While there seems to be demand for, especially PKS, the process of separating it from the other waste streams may incur additional costs, which would cancel out the potential gain from selling PKS for other usages.





1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
5 Financial & technical key figures
6 Business case
7 Environmental & social aspects
8 Risk assessment

Sources: *MEMR (2021); BPDP (2020)*

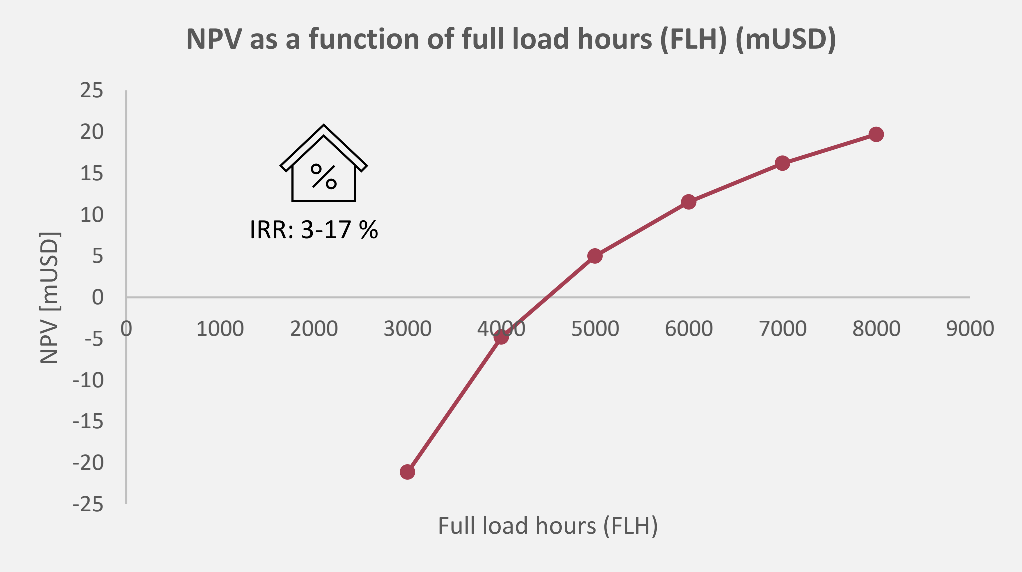
THE LOAD FACTOR HAS GREAT IMPACT ON THE BUSINESS CASE WHERE FULL LOAD HOURS <4500 YIELD A NEGATIVE NPV

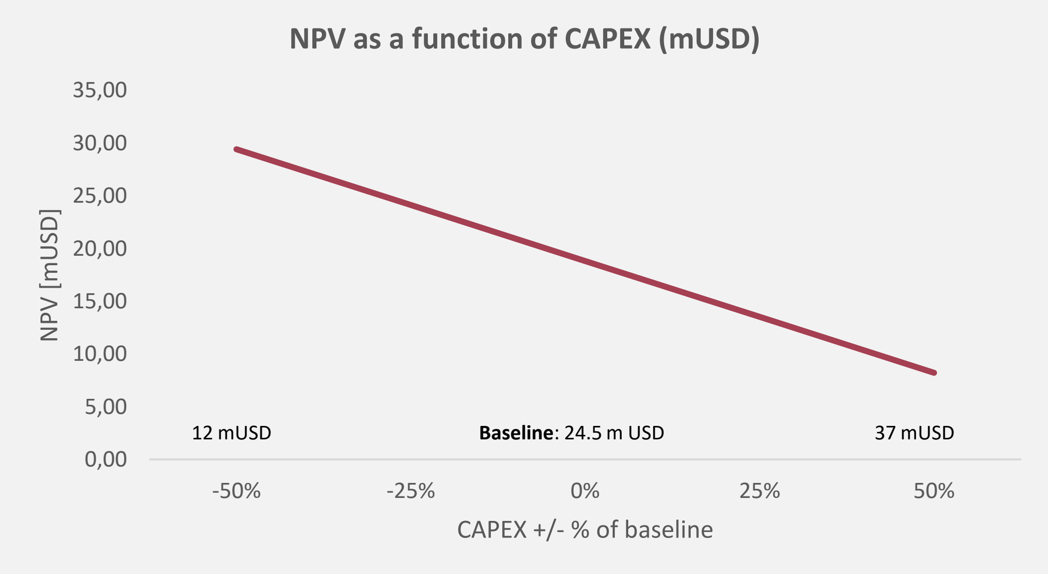
Sensitivity on FLH: Full load hours gives an indication of the utilization of the capacity in terms of power production. It is also referred to as load factor. One of the biomass plants that were visited as part of this pre-feasibility study has a capacity of 1 GW and a power production of 4.7 mio. MWh. Assuming no utilization of heat, the resulting full load hours is only 4700 hours, which is significantly lower than the assumption of this study, which is 7700 hours. However, since processing plants have a high thermal energy load, it is likely that a large majority of the energy is converted into heat.

In some cases, a low load factor can result from a mismatch between the planned and the actual feedstock supply. In this case, full load hours below 4500 hours yield negative NPV. Hence, uncertainty on fuel supply is a critical factor when it comes to project sizing.

Sensitivity on CAPEX: CAPEX for a biomass plant include all costs related to the process equipment, civil works, project development and storage and handling of fuel and residual products. The boiler, balance of plant system (BOP) and the turbine make up half of ~50 % of CAPEX.

This study uses the same assumption on CAPEX as the Danish Energy Agency's Technology catalogue for Indonesia. In the meantime, other studies find CAPEX to be both lower and higher than the assumptions we are making. The sensitivity analysis shows a 50 % increase in CAPEX result in an NPV of 8.3. While NPV is more affected by changes in CAPEX than changes in OPEX, the investment is not significantly impacted, since NPV is still positive.





Source: World Bank (2017); DEA & Ea (2021); PT Innovasi (2021)

THE COMPETITION FROM THE USE OF PALM BASED SOLID BIOMASSES FOR FERTILIZATION AND OTHER USES IS HIGH

Social impact: The project is assumed to located by an industrial site for processing of palm oil, and the public acceptance to the construction of a biomass plant is therefore expected to be relatively moderate. To mitigate public opposition, it is advisable to consult local stakeholders early on in the development process.

The Indonesia government is betting on palm kernel shells as a high value export commodity. This poses a risk on securing biomasses for the biomass project. However, PKS only constitute a fraction of the volumes needed for a project, and so this risk can be mitigated.

Many households in Riau do not have access to electricity. Households that are grid connected could benefit from supply of stable renewable energy in the form of bioenergy. However, most existing biomass plants in Indonesia only sell excess power to the grid. The 1 GW-sized pulp and paper plant, which was visited as part of the study, only sold 0.2 % of the power to PLN in 2017. In this case, the biomass plant has little value to the local community.

Google: Palm oil plantation in Riau

Environmental impact: Since the project is expected to be constructed on an existing industrial site, the risk of harming eco-systems and biodiversity as a result of displacement of forestation areas, is rather insignificant.

There is a growing competition for using biomass as fertilizer on the palm oil field or for fuel, manufacturing products, etc. The latter could result in significant nutrient losses, since plantation owners would need to increase the use of synthetic fertilizers, which is against sustainable farming practices. Besides, fertilizers already make up 50-70 % of the operational costs of the palm oil plantations.

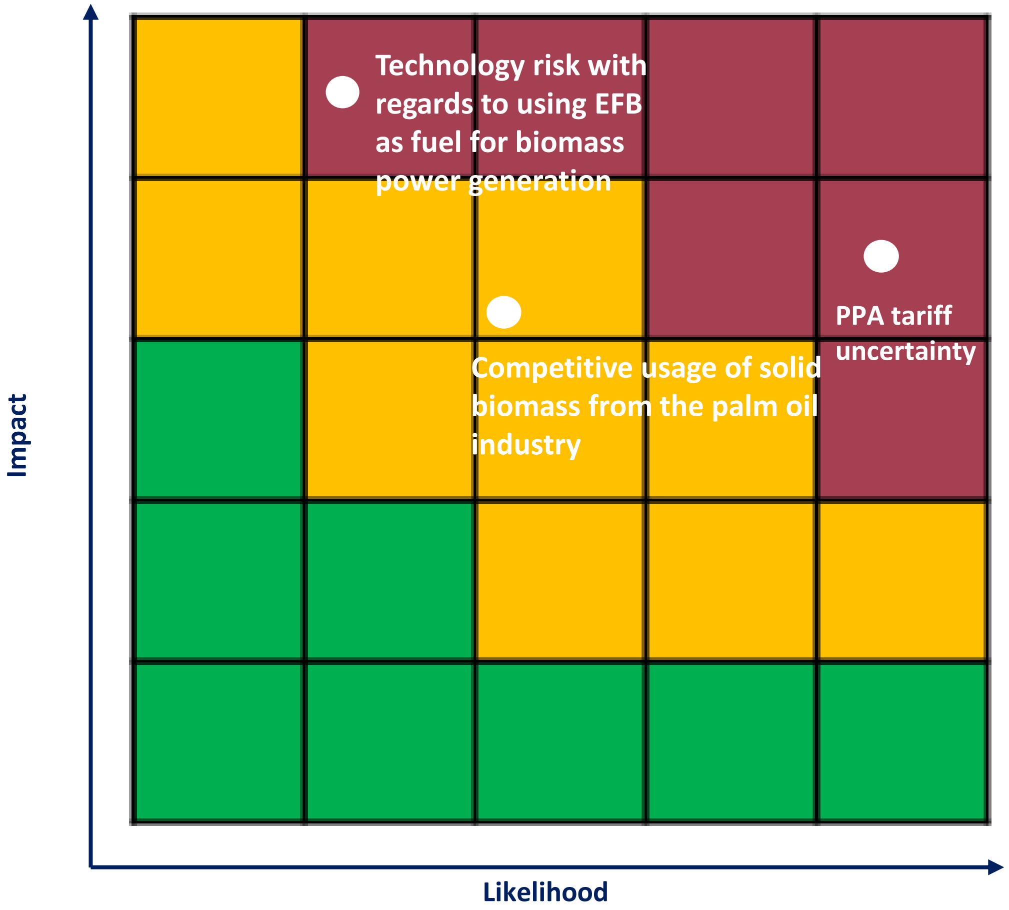
Greenhouse gas impact: Riau is still heavily dependent on fossil sources, particularly natural gas and to some extent coal. The biomass power plant can serve as a substitute or replacement for coal, thereby lowering the green house gas emissions of the region.

The biomass power plant emits particulate matter and chemical air pollutants, which are harmful for the environment. Air pollution can be reduced by reducing the transport of biomasses to and from the plant by focusing on the sourcing of local and adjacent biomasses.

Sources: World Bank, (2017); PT Innovasi; Google Earth Satellite photos

THE EXPECTED COMPETITION ON SOLID PALM OIL WASTE CONSTITUTE A RISK THAT NEEDS TO BE MANAGED CAREFULLY

Risk name	Description	Impact	Action
PPA tariff uncertainty	New regulation is under discussion, hence the expected PPA tariff is subject uncertaintiy	1) Postponement of PPA signature and higher development costs or 2) PPA is only willing to sign the PPA contract significantly below the Highest benchmarking price.	• Ensure dialogue with PLN and ministry on regulation progress. • Prepare for adjustments to the revenue scheme.
Competitive usage of solid biomass from palm oil production	Demand for biomass for agricultural (mulch, fertilizer, animal feed), timber, fuel and manufacturing bio-based products is increasing competition on biomass from palm oil production.	Demand for biomass for other usages could compromise the supply of fuel for the biomass power plant. Unstable supply of biomasses could reduce the load factor and thereby production volume, driving down the revenue sales from electricity. Increase in the market price of PKS would add a higher opportunity costs that stated in the NPV calculation. Prices above 185 $/ton result in a negative NPV.	• The power plant should be designed and planned to handle other biomasses to reduce dependence on PKS and other biomasses that are in high demand • Assuming the investor is not the feedstock suppler, it is important to have the feedstock providers as a close stakeholder to secure stable supply of biomasses
Technology risk with regards to EFB as a fuel for biomass power generation	So far, there is limited experience using empty fruit bunches (EFB) as fuel for biomass power generation. EFB is a relatively bulky fuel and is therefore more difficult to handle. The ash properties of EFB might make it necessary to operate with lower temperature and pressure of the steam to prevent slagging and corrosion of the boilers, which would mean a reduction in the power efficiency	Using EFB for biomass power generation could increase the total project costs, since no biomass technologies are found to be commercially available for this type of fuel.	• Engage in dialogues with existing power producers using EFB, including the owners of the two pulp and paper mills that were visited in Riau as part of the site visits. These plants use EFB in their biomass mix, althoug EFB constituted a small share of the total mix. • Look for alternative and supplementary biomasses that are easier to handle with the current available technology.



1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
5 Financial & technical key figures
6 Business case
7 Environmental & social aspects
8 Risk assessment

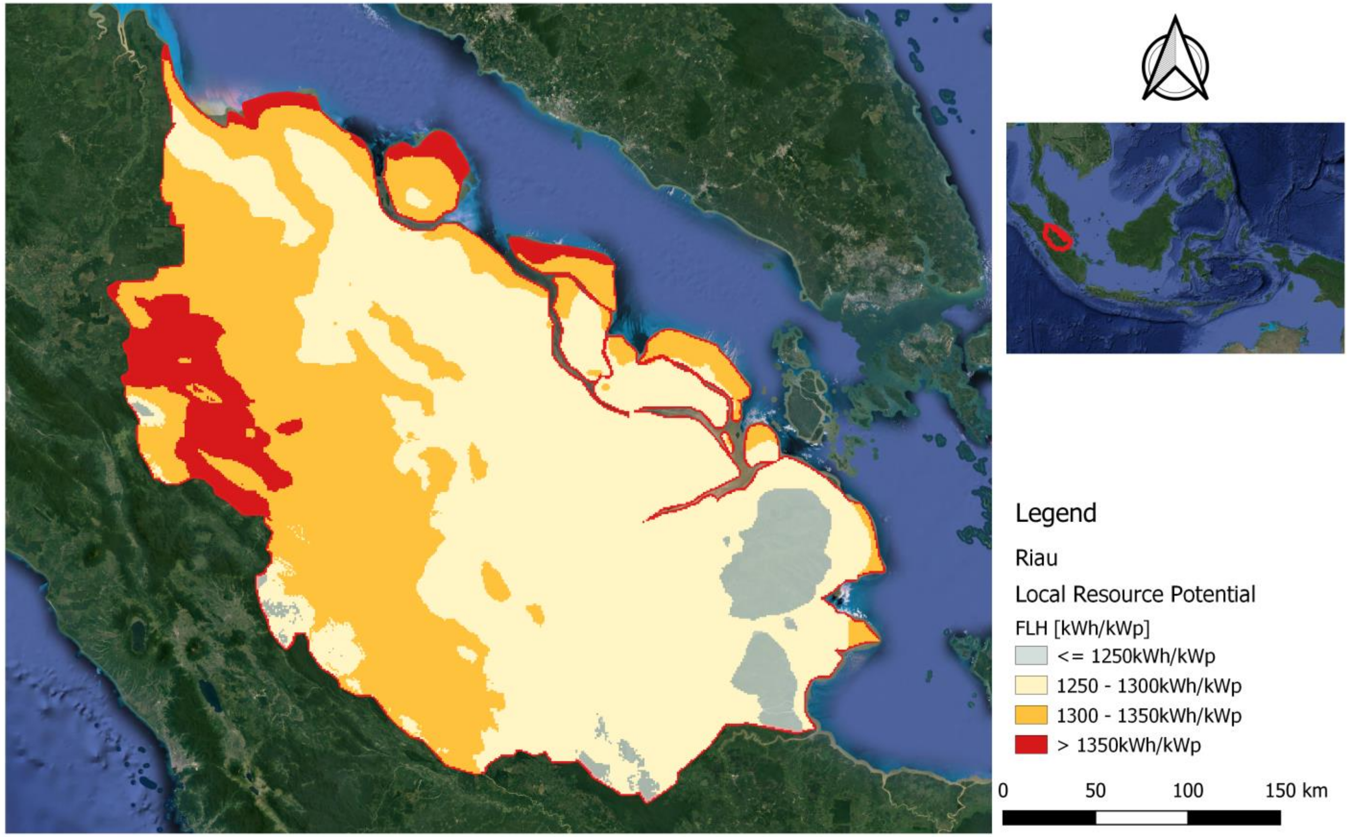
SOLAR PV POWER PLANT – GROUND MOUNTED

Source: VENA Energy (Likupang plant)

SOLAR PRODUCTION IS EXPECTED TO BE 1871 FLH_{AC}

Solar irradiation distribution: The daily mean incoming global horizontal irradiation (GHI) on a flat ground level observed across the province, is roughly similar along the whole local boundaries, with the highest values experienced on the NW side of the province. The GHI illustrated values range between 4.0 and 5.0kWh/m^2.

The experienced FLH, following the above patterns, are distributed in a similar manner and can be seen in the figure below. The maximum provincial potential rises up to approximately 1,350 full load hours (FLH) per year.

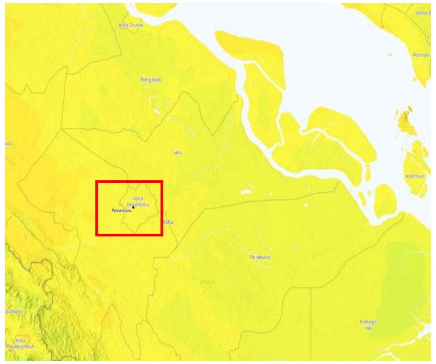


Location selection: Observing the illustrated GHI, the depicted pattern present its lowest values on the SE of Riau, while increases when moving to the NW close to RantaiKasai.
Given the relatively uniform distribution of GHI (and subsequently FLH), the choice of location is not too pivotal. Other factors will play an important role such as proximity to the grid, space availability and presence of substantial load.

Observing that north-western areas experience higher FLH, while accounting for the places closer to highly populated areas within the region, Pekanbaru is chosen as the area for the development of a ground mounted solar PV plant.

Potential production: When assessing the production of a PV plant, it is very important to distinguish between AC and DC rating (see sizing factor description in next page).

The Global Solar Atlas indicates **potential production in the selected area of around 1,337 kWh/kWdc. This corresponds to 1,871 kWh/kWac** which is the value that will be used for the study.



Capacity factors:

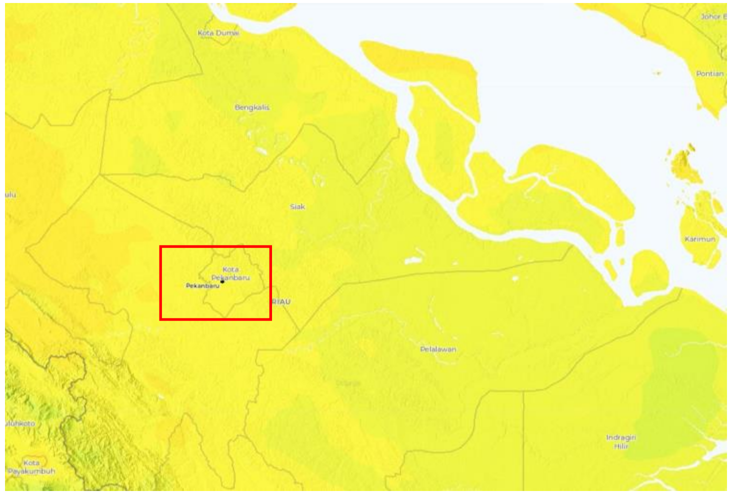
AC: **21.4%** (1,871 FLH_{AC})
DC: **15.3%** (1,337 FLH_{DC})

Sources: ESMAP & World Bank (2021)

DAILY PRODUCTION IS RELATIVELY CONSTANT THROUGHOUT THE YEAR

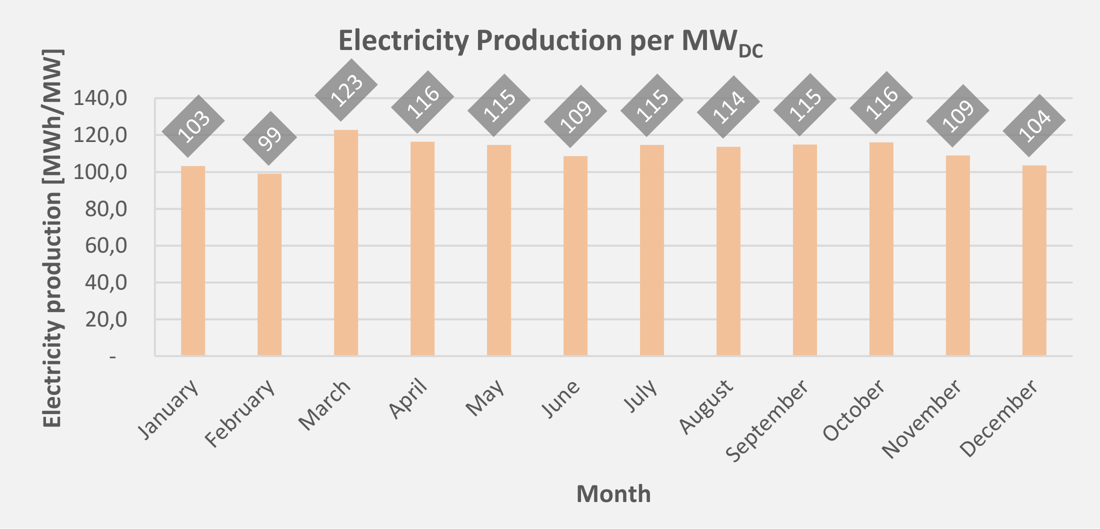
Parameters assumed for the PV:
Tilt: **1º**
Azimuth: **180º**
Losses assumed: **7.2%**

Capacity factors:
AC: **24.2%** (1,871 FLH_{AC})
DC: **15.3%** (1,337 FLH_{DC})



Monthly production: The average potential daily unit production (MWh/MW) deviates on a monthly basis by an average of 19% in the course of a year, signalizing a quite stable electricity production annually. This guarantees a stable monthly output that can supply the load relatively constantly on a seasonal basis. This is an advantage compared to the low wind power potential within the biggest part of the region. Months with the highest solar production are March to May and August to October.

Annual production: When looking at the daily production of solar across the year, one can note that the highest production is observed within the window 10:00 to 13:00 and that by 18:00 the production of solar drops zero within most of the months. This is the time where power is most needed to supply the evening peak of power demand and create challenges in the power system to fulfill the load ramps needed.



Hourly electricity production profile [kWh/MW_{DC}]

Daily Hour	January	February	March	April	May	June	July	August	September	October	November	December
0:00	0	0	0	0	0	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0	0	0	0	0	0
6:00	4	2	4	9	13	10	6	7	15	24	25	12
7:00	86	80	89	110	115	103	99	99	119	131	130	108
8:00	196	198	246	248	240	236	230	227	287	269	258	221
9:00	312	328	404	385	364	363	363	359	411	390	389	343
10:00	418	438	476	487	467	466	471	471	478	492	487	436
11:00	472	496	549	542	529	520	527	524	534	544	529	481
12:00	479	509	555	551	534	527	534	525	536	538	519	480
13:00	448	477	529	521	490	482	495	490	495	493	476	442
14:00	389	417	459	450	418	408	421	423	436	416	394	369
15:00	291	318	374	337	307	294	312	314	329	285	268	265
16:00	174	195	206	186	170	162	179	175	154	132	130	144
17:00	63	73	69	53	49	49	60	56	37	27	25	39
18:00	2	3	3	0	0	0	2	1	0	0	0	0
19:00	0	0	0	0	0	0	0	0	0	0	0	0
20:00	0	0	0	0	0	0	0	0	0	0	0	0
21:00	0	0	0	0	0	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0

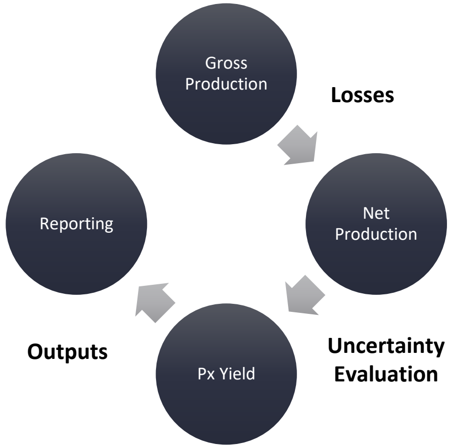
Sources: ESMAP & World Bank (2021)

UNCERTAINTY IN THE PRODUCTION: P90 VALUE IS 1640 FLH_{AC}

Solar resource assessment: To perform a resource assessment, including confidence intervals, the starting point for evaluation of irradiation and losses has been the Global Solar Atlas, while additional uncertainty factors in relation to model used and the interannual variability are considered in the following calculations.

Process: The process to calculate the energy yield at different confidence levels has been the following:

- Gross production: data from Global Solar Atlas for selected location
- Net production: assumption of systematic operational losses (7.1%) applied through Global Solar Atlas
- P50, P75, P90: Consideration of uncertainty factors on production and calculation of confidence level on annual energy production



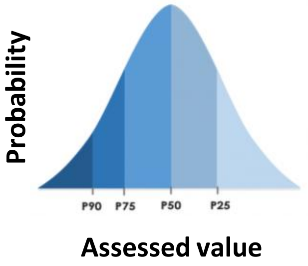
Considered Uncertainty Factors i	
Solar Radiation Model Uncertainty	8.00%
Energy Simulation Model Uncertainty	5.00%
Inter-Annual Variability of Expected Energy	2.00%

**Global Solar Atlas has provided the FLH results as an average of a series of years. DC losses (soiling 3.5%, cables 2.0%, mismatch 0.3%) and AC losses (transformer 0.9%, cables 0.5%) are already considered in the core model.*

Uncertainty Level	Probability of Exceedance vs P50	Formula
$P75_{uncertainty}$	75%	$\sqrt{\sum_i (0.675 * Uncertainty_i)^2}$
$P90_{uncertainty}$	90%	$\sqrt{\sum_i (1.282 * Uncertainty_i)^2}$

Resulting values: The final value for P50 is the central estimate used for the Business Case and corresponds to **37.4 GWh** (**1,871 FLH_{AC}**). Often at a later stage of the project, when financing needs to be secured, P90 is the preferred indicator since it entails a significantly higher certainty. The P90 is here equal to 32.8 GWh (1,640 FLH_{AC})

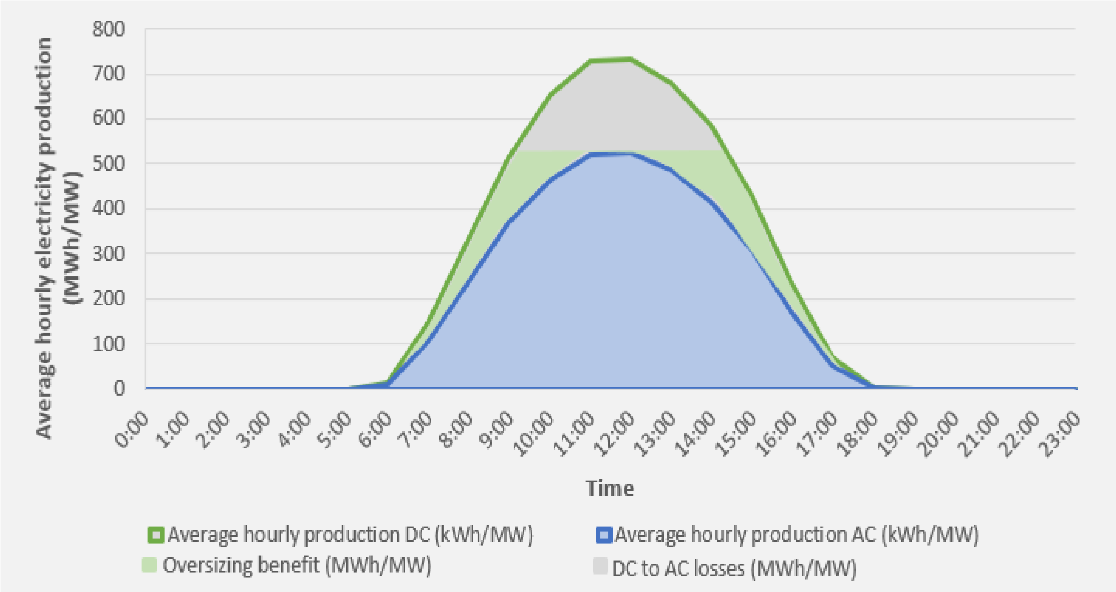
Value Level	Description	FLH_{AC} Confidence	AEP Confidence [GWh/y]
$P50_{value}$	Value based on the already considered uncertainty within the calculated model	1,871	37.42
$P75_{value}$	$P50_{value} * (1 - P75_{uncertainty})$	1,749	34.99
$P90_{value}$	$P50_{value} * (1 – P90_{uncertainty})$	1,640	32.80



Sources: ESMAP & World Bank (2021), MEASNET (2016), SolarGis (2021)

A 20 MW_{AC} PROJECT IS CONSIDERED, WITH A SIZING FACTOR OF 1.4

DC to AC sizing: As mentioned before, when assessing the cost and production of a PV plant, it is very important to distinguish between the capacity and the capacity factor for the DC part and for the AC part. Oftentimes, the AC capacity output is significantly lower than the DC rating. This is done because 1 MW of DC capacity often translate to a lower capacity at the inverter due to losses. The inverter also works at higher efficiency at higher loads. The oversizing of the DC side compared to AC side brings along savings in the inverter and grid connection, as well as more efficient operation. A DC/AC factor, also called sizing factor, of 1.1-1.5 is common nowadays. A **sizing factor of 1.4** is chosen for the present assessment.



Data from existing plants: Examples from the latest large solar projects developed in Indonesia also featured a sizing factor of 1.4:

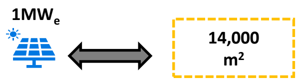
- Likupang solar plant, developed in 2018 in North Sulawesi, with a capacity of 21 MWdc and 15 MWac
- 3 PV projects in Lombok, each with a capacity of 7 MWdc and 5 MWac

Capacity selection: A **20 MWac PV plant has been chosen as the suitable reference case for the project under examination**, for several reasons:

- The grid still faces limitations in terms of absorption of variable renewable energy (e.g. lack of automatic generation controllers, limited spinning reserve available for facing sudden change of generation)
- PLN has a relatively low experience with dispatching solar power plants
- A similar size has been approved for other plants around Indonesia
- Distributing a future higher solar capacity in smaller plants increase the diversification of the solar resource, thus smoothening the output seen from the control center.
- A smaller solar plant would reduce the economy of scale

Sources: DEA (2021), VENA Energy (2021)

A POTENTIAL LOCATION JUST OUT OF PEKANBARU IS SELECTED



Legend

Riau

Riau PV Area

0 1 2 3 4 5 km

Siting considerations: Beside the consideration of irradiation, which is the key factor for the selection of a site, proximity to a suitable grid network and load size, as well as availability of land are important factors.

Location of the ground-mounted PV plant: As mentioned earlier, the selection of the area for the development of a ground-mounted PV plant is the Pekanbaru area.

The chosen location is close to a 150kV substation from PLN named Garuda Sakti. Potentially available solar PV compatible land within 2-5km of the substations were visited and visually surveyed. Most of the soil in the surrounding area is sandy soil, with some clay. The area has been mined for construction sand in the past. Most of the land is available for sale and some has been purchased by speculators and land developers

Surveyed sites in the area around the substation.

Spacing requirements: A ground-mounted PV plant of 20MWac magnitude (28MWdc with a sizing factor of 1.4) will require 14,000m^2/MWdc, according to the latest Indonesian data reported by DEA. This translates to 0.39km^2 (39 Ha) of space considerations within the optimal considered area.

Sources: DEA & Ea (2021); Google Earth Satellite photos.

TECHNO-ECONOMIC DATA USED FOR THE BUSINESS CASE

Technical features	
Capacity	28 MWdc 20 MWac
Technical lifetime	37 years
Plant availability	99.5%
Space requirements	14,000 m^2/MWdc
Capacity factor	21.4 % (AC) 15.3 % (DC)
Construction time	0.5 years
DC/AC Inverter lifetime	15 years

Economic features	
CAPEX	0.69 M$/MWdc 0.96 M$/MWac
Fixed OPEX	10,279 $/MWdc-year 14,391 $/MWac-year
WACC (real)	8.04%
Expected tariff	8.25 cUSD/kWh
Corporate tax rate	20.00%
Depreciation rate	6.25% (16 years of depreciation period)
Inflation rate	2.00%

Figures reflect the estimated 2022 data (beginning of construction) in real 2021 price levels.

Source	CAPEX[1]	Notes
Technology catalogue for Indonesia	0.68 M$/MWdc 0.96 M$/MWac	Value for whole Indonesia, based on extrapolation of PPAs and other international sources. Interpolation between 2020, 2030 and 2050. Sizing factor adjusted upwards to 1.4.
EPC contractors	0.69 M$/MWdc 0.96 M$/MWac	Average value for 2021 based on elicitation of EPC prices, more specifically for North Sulawesi from 4 providers.
Data from small existing PV in Riau	0.75 M$/MWdc	Average value for construction of 2 small size PV in Riau: RAPP (1.35 MWdc) and Pertamina RU II (2 MWdc) constructed in 2021.

Figures reflect the estimated 2022 data (beginning of construction) in real 2021 price levels.

PV module price considerations

Increased component cost trajectories

Solar module procurement has experienced a slight inflation within the past year, mainly due to shortages in polysilicon and glass materials. Bids for module attainment have climbed up by 14% on average within the Chinese market over 2020 pushing the price to 0.28$/W.

Although the material shortage has been expected to be short-term, the ladscape hasn't improved up to date, rather worsened. Domino effects have notably also reached the European market, where since January 2021, all types of crystalline module bids jumped upwards in a range between 6 and 13%.

FID and COD: The assumed final investment decision (FID) is 2022 and the commercial operation date (COD) is 2024 with construction stretching between 2022 and 2023.

Comparison of CAPEX sources: Several sources indicate CAPEX estimations for Indonesia and more specifically Riau. Assuming construction in 2022, the costs in the table applies.

Land cost: Indication from the site surveys shows that most of the land surrounding the substation is available from IDR 250,000 to 850,000 per m2 (17 to 59 USD/m2). Land ownership is still with individual owner with most owning less than 2 hectare.

Sources: DEA & Ea (2021); PV-Tech (2021); PVxChange (2021)

AT CEILING TARIFF, THE GROUND-MOUNTED PV PROJECT IS CLOSE TO PROFITABILITY WITH AN IRR OF 7.9%

Business case at ceiling tariff: The starting point for the economic evaluation is considering the **ceiling tariff of 8.25 cUSD/kWh** for solar projects until up to 20 MW. This is the maximum potential remuneration of a solar project for the chosen size, based on the draft of the current regulation. It therefore represents the best-case scenario in terms of returns for the solar project.

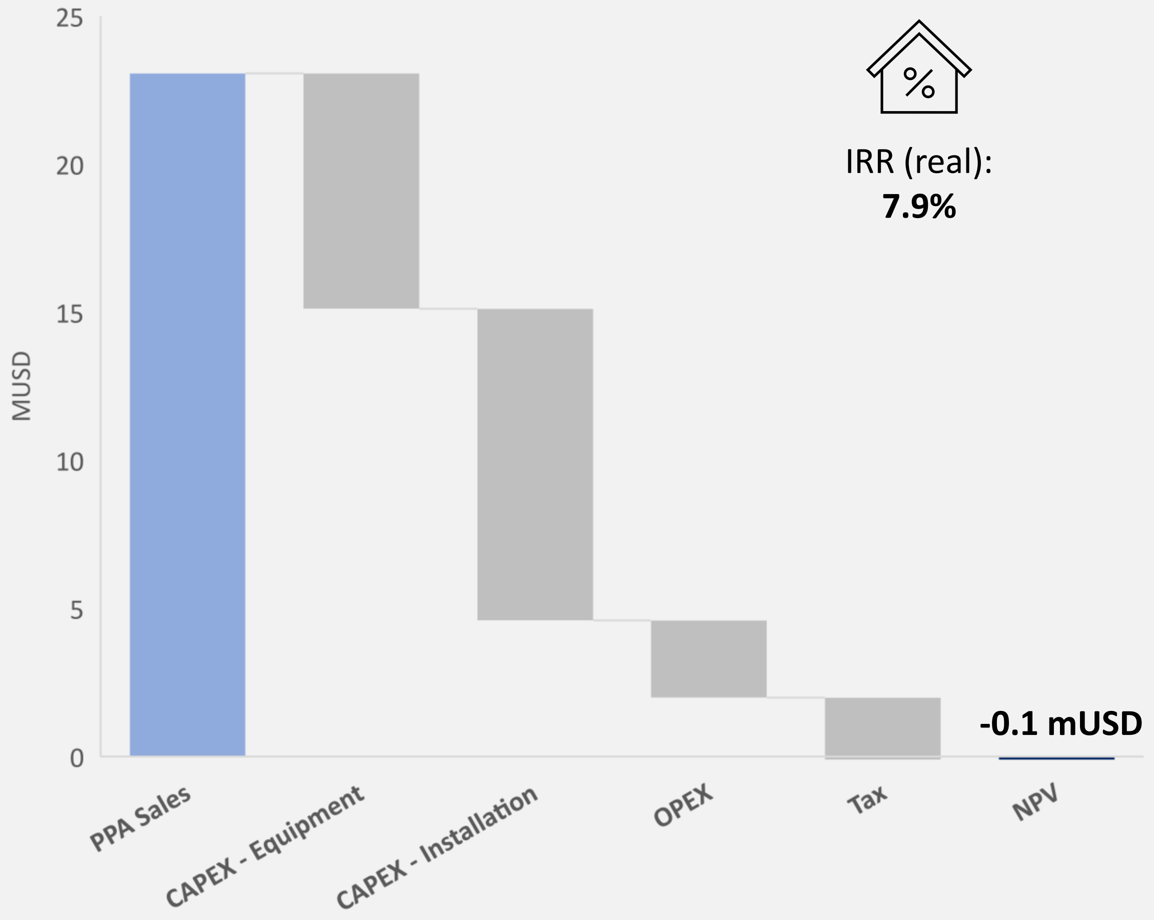
With this level of tariff and an expected annual production (P90) of 1,871 FLH_{AC}, corresponding to a capacity factor of 21.4%, the total annual sales correspond to 3.1 mUSD. Since the PPA is not escalated, this level of annual sales are constant across the project lifetime in nominal terms.

The total CAPEX of 19.2 mUSD is the largest expense to offset, followed by OPEX and taxation at 2.1 and 2.6 mUSD/year respectively.

Results: The resulting business case for a 20 MW ground-mounted solar plant in Riau is close to profitability, with a -0.1 mUSD of Net Present Value and an Internal Rate of Return (real) of 7.9%, very close to the level of the estimated WACC (8%).

NPV at ceiling tariff: **-0.1 mUSD**
IRR at ceiling tariff: **7.9%**

Breakdown of NPV components at ceiling tariff[1] (mUSD)



Note: 1. The present value of each cashflow component (revenues and cost) is performed here to break down the contribution to the final NPV value for illustration purposes.

THE BREAK-EVEN TARIFF FOR THE PV PROJECT IS 8.32 CUSD/KWH

Break Even Tariff: Two key factors are creating uncertainty in the potential tariff level to be expected by an investor in a solar project in Riau, namely:

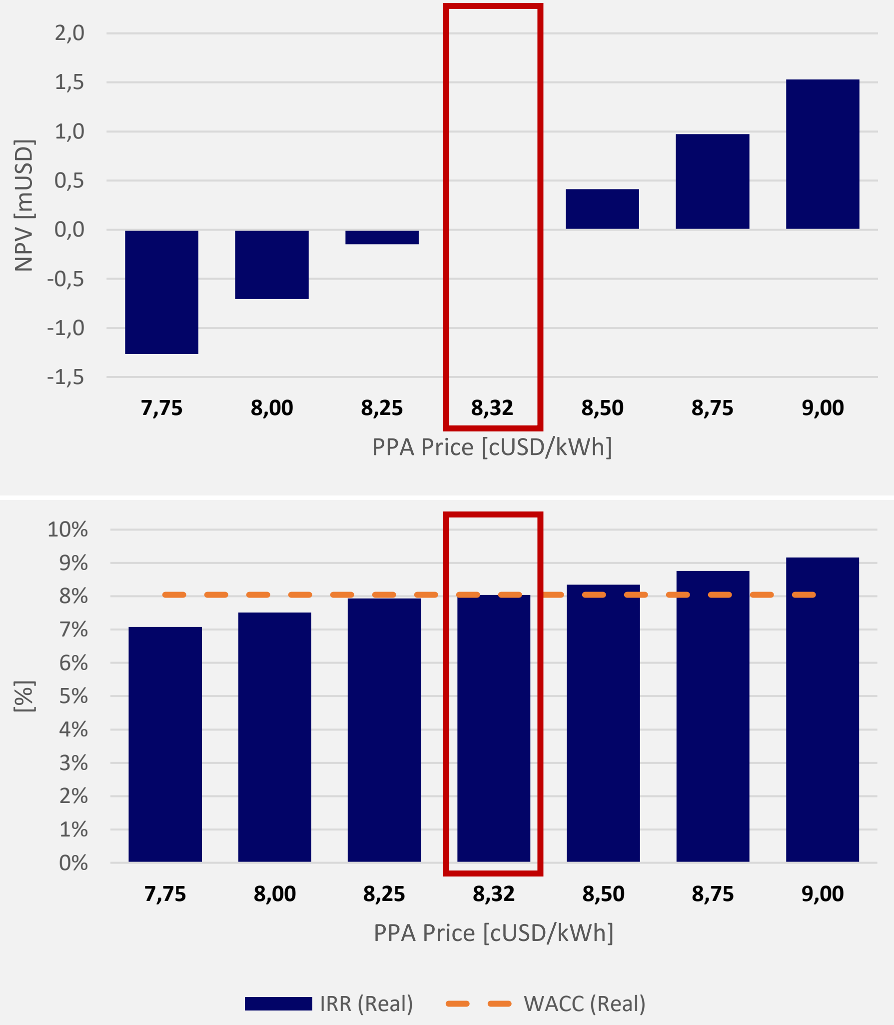
- The **provisional figures of new regulation** are still not confirmed, since the new presidential regulation is only at a draft stage;
- Most likely competition will stem for the development of the project and therefore an **auction/negotiation process would take place**, where competitors will bid the minimum required tariff in order to develop the project.

For these two reasons, it is interesting to assess what would be the minimum tariff at which the project break even, guaranteeing an IRR equal to the expected WACC and a NPV of zero. We call this **Break-even Tariff**, and it virtually could represent the value of the bid to a potential auction/negotiation for an investor that would aim at building the solar project under assessment with return in line with the expected real WACC of 8%.

Results: The resultant break-even tariff for the analysed solar project in Riau is 8.32 cUSD/kWh, with the IRR varying between 7.1% and 9.2% when the tariff goes from 7.75 to 9.00 cUSD/kWh.

Break-even Tariff:
8.32 cUSD/kWh

Break-even tariff for the solar project (cUSD/kWh)



LOWER BOUND OF CAPEX FIGURES LOWERS TARIFF TO 6.7 CUSD/KWH

Key uncertainty factors: When looking at the economic assessment for a solar project in such an early phase, several figures are highly uncertain. It is the case, for example, for the following factors:

- **CAPEX:** the estimation of the capital costs is based on figures from EPC, but actual project costs might largely vary depending on market conditions, supply chain and real project conditions;
- **Capacity factors**: since evaluation of irradiance and potential annual production is based on modelled data at this stage;

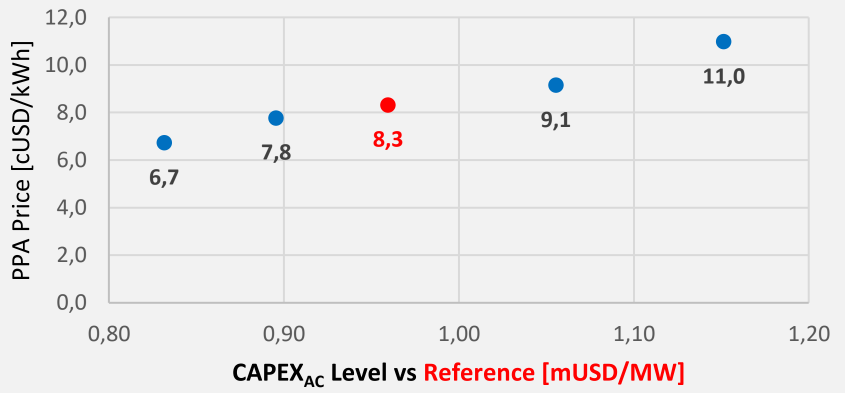
Operational expenditures are another uncertain factor, but the variability and impact on the results is much less significant, therefore it is not assessed in detail here.

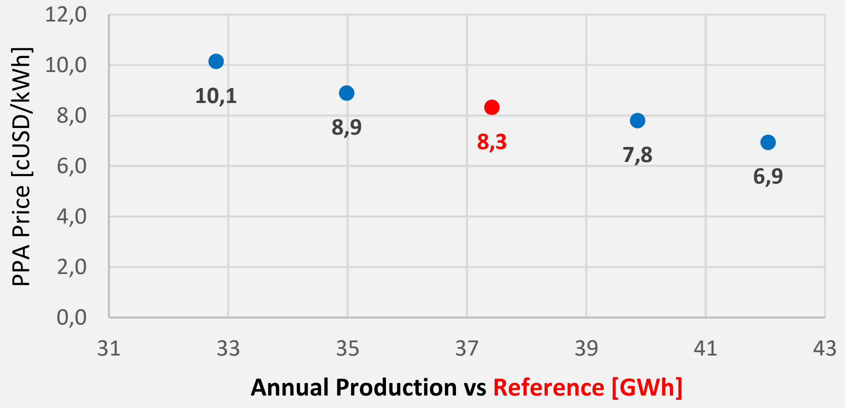
Sensitivity analysis: A sensitivity analysis is carried out on the break-even tariff, to assess the **potential variation of the auction bid if assumptions on key parameters vary** compared to the reference assumption in the study. While one parameter is varying, the other are kept constant, to isolate the impact of the single factor on the final expected tariff. The chosen variation for the key parameters is the following:

- CAPEX is varied from **0.83 to 1.15 mUSD/MW$_{AC}$**, corresponding to a range of -13% to +20% of the reference assumption. The range selected is the cost range indicated by EPC contractors for a project in North Sulawesi.
- Annual production is varied between **32.8** and **42.1 GWh**, based on calculations of P75 & P90 cases versus the base case P50. Lower bound represents the break-even tariff assuming P90.

Results: The results of the sensitivity indicate that the **business case is largely affected by the assumptions on CAPEX and capacity factors/annual production**.
Considering an annual production value equal to P90 (1,640 FLH$_{AC}$) the break-even tariff moves up to 10.1 cUSD/kWh, above the threshold of the ceiling tariff. Similarly, CAPEX plays an important role with the range of bids 6.7-11.0 cUSD/kWh for the variation of the capital expenditures indicated by EPC. OPEX plays a more limited role in the business case but can still impact 3-4% the needed tariff with a change of -20 to +20% OPEX.

Sensitivity on break-even tariff (cUSD/kWh)





Tariff can go as low as **6.7 cUSD/kWh** with lower bound of CAPEX (0.83 mUSD/MW$_{AC}$)
If P90 needs to be considered, the tariff increases to **10.1 cUSD/kWh**.

MINOR NEGATIVE ENVIRONMENTAL IMPACTS ARE EXPECTED, AND LOCAL POPULATION IS POSITIVE TOWARDS A PV PROJECT

Social and economic impacts: The area has been mined for construction sand in the past and there are signs of abandoned rubber plantation and other crops. Use of the surrounding land seems to be for farming that is currently being abandoned in place of employment in nearby city of Pekanbaru.

Having a production cost lower than the current BPP of Riau (8.32 as break-even tariff, versus a BPP of 11.4 cUSD/kWh), the addition of the PV project has the potential to **reduce the cost of generation** in the province, potentially impacting positively local communities and energy tariffs.

The construction and operation phase of the project can bring **local qualified employment**. For a plant of similar size, Likupang Solar PV in North Sulawesi, more than 200 local workforces were employed during construction and during operation 22 employees on site plus 14 employees remotely are needed.

Environmental impact: Among the largest negative impact of a potential PV plant in the area is visual impact and land use. These project impacts appear minor for the selected location, giving the former use of the area for mining of construction sand and the status of abandonment of crops.

On the positive side, a PV project in the area can **reduce the reliance on fossil fuels**, namely natural gas and coal, which still account for the vast majority of power generation in Riau. This translate into a reduction of local pollution (PM2.5, SOx) and a mitigation of greenhouse gas emissions. Considering the CO_2 emission factor of the current fleet, equal to 0.85 ton-CO_2/kWh, the potential **annual CO_2 savings from the project amount to 32 kton**.

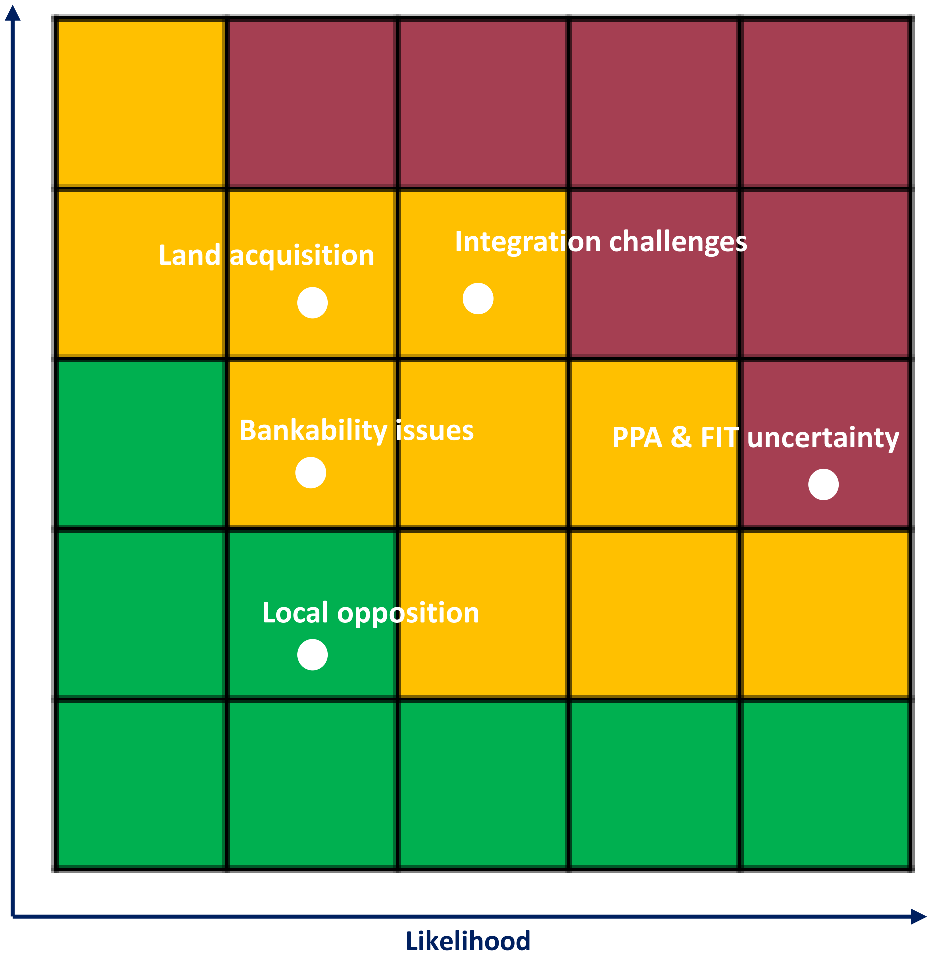
Project acceptance: During the survey to the potential development area outside Pekanbaru, local people were interviewed on their potential views regarding the potential development of a PV farm and the status of the land. Initial elicitation indicate that the attitude of local population towards a solar-PV project is mostly positive and there are no barriers at this point. Most of the locals are familiar with small solar PV systems for households since there are still a few households that do not have access to PLN electricity. They have positive views of solar PV installations in the area and the prospect of their land being purchased for its use, due to the potential impact of economic activity in the area. Some respondent demonstrated interest to work at the solar PV plant during construction or as local technicians.

Sources: Local surveys result, DEA (2021), VENA Energy (2021), PLN Persero (2021)

KEY PROJECT RISKS ARE PPA UNCERTAINTY, GRID INTEGRATION AND LAND ACQUISITION

Based on the site visits conducted during the project, the survey of local stakeholder and population, as well as the results of the economic analysis, the key risk factor for the project are outlined in the risk register and risk matrix below.

Risk name	Description	Impact	Action
PPA & FIT uncertainty	New regulation is under discussion and no certain levels of FIT have been published. Moreover, eventual competition on the bid could result in a tariff that is likely below the ceiling price.	Postponement of PPA signature and higher development costs. Competition can reduce the obtainable tariff.	• Ensure dialogue with PLN and ministry on regulation progress. • Prepare for adjustments to the revenue scheme.
Grid integration challenges	PLN is concerned about the impact on grid operation and stability of local grids. This could lead to curtailment of production or a requirement for inclusion of a battery storage.	No PPA signed with PLN, Curtailment of production.	• Engage with PLN from early on in the process. • Develop proper integration study. • Prepare a plan to potentially add some battery system to project.
Land acquisition issues	Land aquisition problems could be significant due to the proximity to the capital of Riau Pekanbaru, where land might be more valuable. However, first site survey indicate this might not be probelmatic.	Delayed project development or increase project costs due to further location.	• Develop dialogue with PLN in relation to the land around the substation and with local population. • Map land ownership. • Consider alternative locations. Irradiation is distributed quite evenly in the region.
Bankability issues	Lack of final approval from financing institution, potentially due to uncertainty on project return. Banks have in the past expressed concerns regarding the BOOT scheme that PLN preferred before 2020. A new option for BOO has been introduced by new regulation revision.	Challenge to receive financing for the plant.	• Maintain communication with potential financial institutions regarding requirements for bankability, especially in relation to update of current regulation.
Local opposition	Local population migh be against the project for reasons related to visual impact and influence on local economy (e.g. agricolture and forestry). Due to the current lack of large PV and wind projects in Riau province, this could be exhacerbated.	Delayed project development or problems during construction.	• Develop a strategy to involve local population from an early project stage. • Reserve a budget for projects aimed at transferring some of the benefit to local communities in the form of services, infrastructure development or others.



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GLOSSARY AND DEFINITIONS

Net Present Value (NPV)	*Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time.* *Formula notation: CF_0 is the cash flow at year 0 and CF_t is the cash flow at year t, r is the discount rate considered and T the total lifetime of the plant.*	$\boldsymbol{NPV} = -CF_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t}$
Internal Rate of Return (IRR)	*The internal rate of return is a discount rate that makes the net present value (NPV) of all cash flows equal to zero in a discounted cash flow analysis.*	$0 = -CF_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+\boldsymbol{IRR})^t}$
Weighted Average Cost of Capital (WACC)	*The weighted average cost of capital (WACC) is a calculation of a firm's cost of capital in which each category of capital is proportionately weighted.* *Formula notation: E and D are the total Equity and Debt, R_e and R_d the return on equity and debt respectively and T the tax rate in the country.*	$\boldsymbol{WACC} = \frac{E}{E+D} * R_e + \frac{D}{E+D} * R_d * (1-T)$
Levelized Cost of Electricity (LCoE)	*The LCOE can also be regarded as the minimum constant price at which electricity must be sold in order to break even over the lifetime of the project.* *Formula notation: I_t, M_t and F_t are respectively the investment, maintenance and fuel cost at the year t, E_t is the output of the plant at the year t, r is the discount rate considered and T the total lifetime of the plant*	$\boldsymbol{LCOE} = \frac{total\ discounted\ cost\ over\ lifetime}{total\ lifetime\ discounted\ output} = \frac{\sum_{t=1}^{T} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{E_t}{(1+r)^t}}$
Full load hours and Capacity factor	*Full load hours (FLH) is a convenient notion expressing the equivalent number of hours of production at rated capacity that would give the same annual generation. Multiplying the FLH value by the installed capacity gives the production throughout one year.* *The concept is equivalent to that of capacity factor (%); to convert capacity factor to FLH simply multiply the capacity factor by the total number of hours in a year (8760).*	$\boldsymbol{FLH}\ [h] = \frac{Annual\ generation\ [MWh]}{Rated\ power\ [MW]}$ $\boldsymbol{CF}[\%] = \frac{FLH}{8760}$

LIST OF ACRONYMS

CAPEX	*Capital Expenditures*
CHP	*Combined Heat and Power*
DCF	*Discounted Cash Flow*
FID	*Final Investment Decision*
FS	*Feasibility study*
GHI	*Global Horizontal Irradiation*
GIS	*Geographical Information System*
LCOE	Levelized Cost Of Electricity
OEM	Original Equipment Manufacturer
OPEX	*Operational Expenditures*
PBT	*Pay-Back Time*
PFS	*Prefeasibility Study*
PPA	*Power Purchase Agreement*
PV	*Photovoltaics*
USD	*United Stated Dollars*
WACC	*Weighted Average Cost of Capital*

ADDITIONAL MATERIAL

WACC OF 8.04 % IN REAL TERMS ARE ASSUMED FOR THE CALCULATIONS

The weighted cost of capital (WACC): WACC is the expected costs of an investment under a given capital structure. The capital structure is composed of the costs of debt and the cost of equity. For a project to be financially feasible, the internal rate of return (IRR) must be greater than WACC.

This study applies the same assumptions for calculation of WACC as a similar pre-feasibility study on Lombok in Indonesia prepared by KPMG. The break-down of the WACC calculation from the Lombok study is illustrated in the figure to the right. Opposed to the Lombok study, the NPV calculations of this study are based on real prices, hence a real WACC of 8.04 % is applied for the three technologies in this study.

In comparison, the Renewable Energy Outlook for Riau assumes WACC to be 8 % in the Green Transition scenario. Since this WACC is assumes to be nominal, our assumption may be a conservative.

Changes in WACC generally have a greater impact on the business cases of technologies, which are relatively capital intensive. This would be the case for solar, wind and biogas. For biomass technologies, O&M and fuel costs constitutive a relatively high percentage of the total project costs. The business case for biomass technologies is therefore expected to be less affected by changes in WACC.

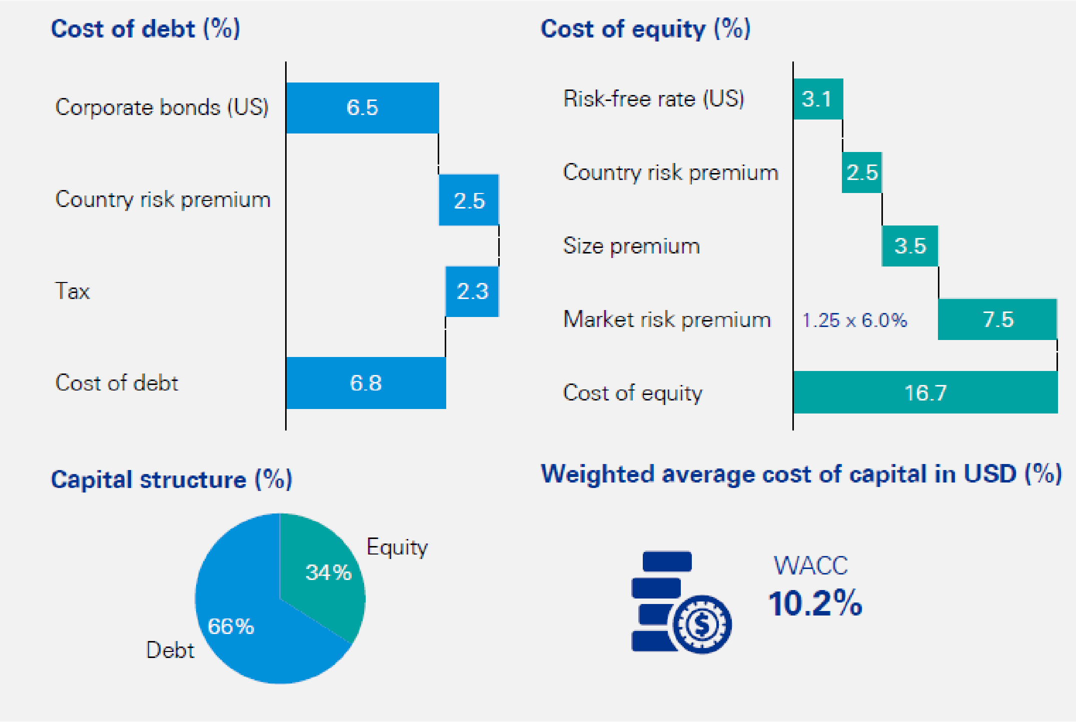

Illustration: DEA & KPMG (2019).

Sources: DEA & KPMG (2019); DEA & Ea (2019).

SITE ASSESSMENT IN PEKANBARU

Site assessment: A survey for the evaluation of a potential site for PV plant have been conducted in November 2021, just outside Pekanbaru.

A PLN sub-station near Pekanbaru city was selected for the potential solar PV system to be connected. The Garuda Sakti 150kV substations is large enough to accommodate utility scale solar PV installation larger than 10MW (https://goo.gl/maps/FTSKMzJ1bGTt21Dz9).

Potentially available land compatible with solar PV within 2-5km of the substations were visited and visually surveyed. Most of the soil in the surrounding area is sandy soil, with some clay. The area has been mined for construction sand in the past. Most of the land is available for sale and some has been purchased by speculators and land developers. Use of the surrounding land seems to be for farming that is currently being abandoned in place of employment in nearby city of Pekanbaru. There are signs of abandoned rubber plantation and other crops.

Most of the available land are available from IDR 250,000 to 850,000 per m2 (USD 17 to 59 per m2). Land ownership is still with individual owner with most owning less than 2 hectare.

One of the potential areas with suitable land and accepting local communities is in the area indicated in the pictures (https://maps.app.goo.gl/fLQr4Smqt31jsRJT9).

Interviews: During the survey, local people were interviewed on their potential views regarding the PV project development.

Most of the locals are familiar with small solar PV systems for households since there are still a few households that do not have access to PLN electricity. They have positive views of solar PV installations in the area and the prospect of their land being purchased for its use. Some expect and interested to work at the solar PV plant as local technicians.