PREFEASIBILITY STUDIES AND SOCIO-ECONOMIC ASSSESSMENTS OF RENEWABLE PROJECTS IN ACEH

Analysis of Solar PV and Onshore Wind

Danish Energy Agency

Viegand Maagøe

Ea Energy Analyses

INOVASI DINAMIKA PRATAMA

COWI

MAY 2025

BACKGROUND

Indonesia and Denmark are collaborating through a **Joint Indonesian-Danish Energy Partnership Programme (INDODEPP)**, which aims to support Indonesia's climate goals of reaching net zero emissions by 2060. The partnership is coordinated by the Danish Energy Agency's Center for Global Cooperation. In Indonesia, key partners include the Ministry of Energy and Mineral Resources (MEMR), the National Energy Council (NEC), the state-owned electricity company (PLN) and the provincial energy agencies (DINAS). Reports and studies produced under INDODEPP are available on the Danish Energy Agency's website[1].

The Sustainable Province Initiative (SPI), running from 2023 to 2026, is a program under INDODEPP that focuses on helping provincial governments identify and evaluate renewable energy potentials. Through SPI, the Danish Energy Agency, with the assistance of international and local consultants, is supporting Aceh with the following activities:

1. Assessment of energy balances
2. Mapping of renewable energy resources
3. Long-term energy planning
4. **Analysis of socioeconomic effects**
5. **Pre-feasibility studies of renewable energy projects**

This report presents the results of the pre-feasibility studies and socioeconomic effects for potential renewable energy projects in Aceh. Following an initial pre-selection process, two projects have been selected for pre-feasibility studies and the socioeconomic analysis:

1. A 170 MW_{ac} Ground Mounted Solar PV plant located in Kuta Cot Glie, Aceh Besar.
2. A 70 MW Onshore wind power plant located in Lhoknga, Aceh Besar.

[1] https://ens.dk/en/our-responsibilities/global-cooperation/country-cooperation/indonesia

The pre-feasibility studies are initiated by the Danish Energy Agency and developed by a consortium consisting of Ea Energy Analyses and Viegand Maagøe. 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. COWI has conducted the analysis of the socioeconomic effects.

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 project has received support from local partners, including DINAS ESDM, Bappeda and PLN. The local partners in Aceh have provided data, and feedback in the selection of technologies and sites, reviewed the results and participated in site visits.

A key priority of the SPI program is to ensure that projects create value for Indonesian partners. Therefore, a range of activities involving our Indonesian partners have been carried out, including the conduction of workshops to gather local insights and perspectives on the findings and criteria used in the analysis.

Physical site visits have been conducted to assess local conditions in terms of resource availability and overall accessibility. These visits included meetings with Heads of Villages and other local community stakeholders to gather their views and perspectives on renewable energy development in their areas.

The project was completed in January 2025. The consortium presented a first draft of the report in November 2024 and the final report was delivered in January 2025.

DISCLAIMER

The report is prepared for partners of the Indonesian-Danish Partnership Program (INDODEPP) and potential investors of renewable technologies in Indonesia. The conclusions of the report reflect the views of the Consortium (Ea Energy Analyses, Viegand Maagøe and COWI). The local partners hold no responsibility with respect to the findings of the report.

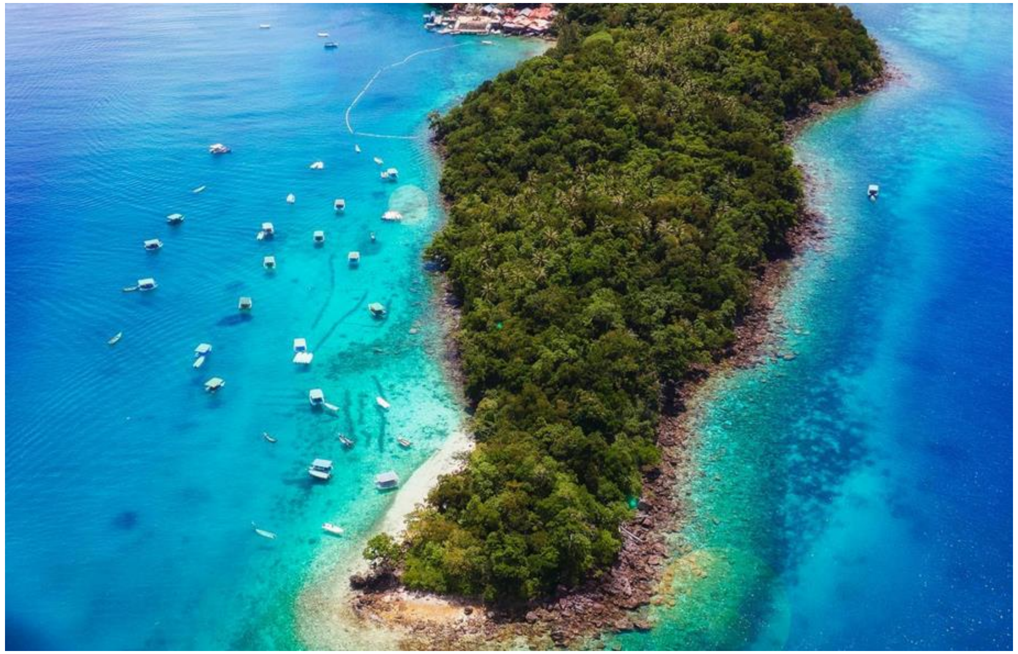
The main source of information used in preparation of this study are PLN, The Danish Energy Agency and the Indonesian Ministry of Energy and Mineral Resources, and provincial agencies, including Dinas ESDM and Bappeda. Economic and technical assumptions used in the business case are primarily based on the Indonesian Technology catalogue from 2024. Assumptions have been validated with local studies and experiences. During the data validation process, several private investors with experience in developing renewable energy projects in Indonesia were consulted.

The Indonesian based consultancy PT Inovasi has provided significant support and local knowledge. They have been particularly active in the engagement of local communities and agencies through site visits and ongoing dialogue.

The sites chosen for the two technologies – utility-scale solar PV and onshore wind – have been identified using satellite imagery, maps, and physical site visits. The selection process considered factors such as available resources, potential for grid connection, proximity to existing power plants, and more. Indications of land costs and current land use were also taken into account; however, a more detailed analysis of the impact of land costs and usage should be included in a future feasibility study.

This study serves as a preliminary screening of projects, intended to assess whether the project holds sufficient potential to warrant a more detailed feasibility study. Prospective investors are advised to seek professional guidance 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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PROJECT SUMMARIES

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Ground Mounted Solar PV in Kuta Cot Glie

Area	
Regency	Aceh Besar
City	Kuta Cot Glie
Type of land	Savannah
Land zoning	Plantation area
Land area	1.71 km^2
Technical details	
Technology	Ground Mounted Solar PV
Solar ressource	1780 kWh/m2/year
Designed Capacity	170 MW_{ac}
Financial details	
CAPEX	131.3 mUSD
OPEX	1.3 mUSD/year
Baseline PPA price (1^{st} 10 years)	7.65 cUSD/kWh
Baseline NPV	-1.2 mUSD
Baseline IRR	8.08%
Key risks	
• Cost escalation and PPA price uncertainty	

Onshore wind power in Lhoknga

Area	
Regency	Aceh Besar
District	Lhoknga
Type of land	Primary Dryland Forest
Land zoning	Protected Forest
Land area	17 km^2
Technical details	
Technology	Onshore wind
Wind ressource	6-8 m/s
Designed Capacity	72 MW
Financial details	
CAPEX	112.2 mUSD
OPEX	2.9 mUSD/year
Baseline PPA price (1^{st} 10 years)	10.5 cUSD/kWh
Baseline NPV	16.3 mUSD
Baseline IRR	10.44%
Key risks	
• Cost escalation and environmental and land use approvals	

CONCLUSIONS AND RECOMMENDATIONS: SOLAR IN KUTA COT GLIE

Business case evaluation:

- The project has a positive socio-economic result with an ENVP of +207.5 mUSD, but a slightly negative project economic result returning an NPV of -1.2 mUSD, performing slightly below “break-even” assuming a WACC of 8.23%.
- A more detailed feasibility study is recommended.

Overall evaluation

- The site has great solar irradiation, which make it attractive from a solar resource perspective
- The land is relatively flat and mostly clear of vegetation. At the same time, it is close to a major toll road, which make access and transport of equipment easier.
- The project returns a negative NPV of -1.2 mUSD, given a WACC of 8.23%, performing slightly below break even.
- Main project risks are PPA price uncertainty and escalated project costs resulting from higher-than expected CAPEX following local content requirements and land costs.
- The site is overall quite attractive, because of great solar irradiation, access and the topography.

Recommendations

- Analyze current market developments in solar panel prices for imports and local sellers. If current price trends translate into lower CAPEX the project could return a positive NPV
- Engage with local suppliers to obtain prices for key services and materials.
- Sign options to lease with landowners to fix land acquisitions costs in the early development phase

CONCLUSIONS AND RECOMMENDATION: WIND IN LHOKNGA

Business case evaluation

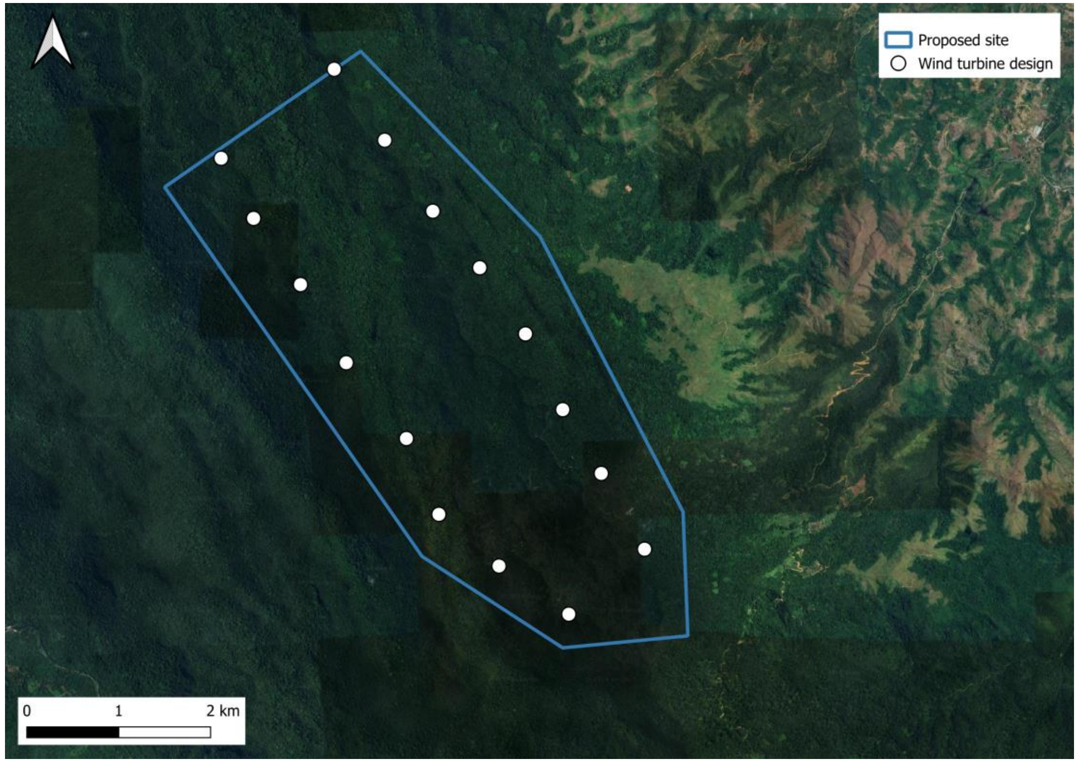
- The project has a positive socio-economic result with an ENVP of +207.5 mUSD, and a positive project economic result returning an NPV of 16.3 mUSD. It is financially attractive under the baseline assumptions.
- The business case is supported by PPA sales, which are derived by multiplication of an assumed PPA price and estimated production volumes. The PPA price follows the regulated ceiling price.
- Installation and equipment costs constitute the majority of total project costs, while operating expenses constitute a small share.

Overall evaluation

- The site is attractive from a wind resource perspective in Aceh, where most of the province has relatively low wind speeds.
- The site is located in a protected forest, which can have severe implications for permitting, and potentially be a showstopper for the project.
- The site is challenging in terms of access and topography. This is a key risk, that could drive up CAPEX costs.

Recommendations

- Before more costs are put into development, discussions with public officials should be initiated to obtain more clarity on the process for environmental and land permits.
- The wind speed estimates are based on desk top research. Onsite wind speed measuring is needed to perform a detailed study of expected production.
- Considering the variability of wind production and the limited experience with integration of wind, early dialogue with PLN is recommended followed by a grid impact study
- Engage with the local officials to obtain information on development activities to explore synergies that could lower the costs of upgrading infrastructure



GPS coordinates:
5.39500; 95.32845

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.

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.

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.

DEA, Ea Energy Analyses & Viegand Maagoe (2020)

Introduction - Socio-economic analysis of renewable energy projects in Aceh Besar

Setting the context and this socio-economic analysis

The Sustainable Province Initiative (SPI), implemented from 2023 to 2026 under the Joint Indonesian-Danish Energy Partnership Programme (INDODEPP), aims to assist provincial governments in identifying and evaluating renewable energy potentials. The SPI is led by the Danish Energy Agency in collaboration with international and local consultants. In Aceh, the initiative focuses on delivering the following key activities and outputs:

1. Assessment of energy balances
2. Mapping of renewable energy resources
3. Long-term energy planning
4. **Analysis of socio-economic effects**
5. Pre-feasibility studies of renewable energy technologies

This report specifically analyzes the socio-economic effects of two renewable energy projects selected for pre-feasibility studies:

1. A 170 MW ground mounted Solar PV plant located in Kuta Cot Glie, Aceh Besar.
2. A 72 MW onshore wind power plant located in Lhoknga, Aceh Besar.

The pre-feasibility studies, titled *"Pre-Feasibility Studies of Renewable Projects in Aceh: Analysis of Solar PV and Onshore Wind,"* were developed by a consortium comprising Ea Energy Analyses and Viegand Maagøe, with local support from PT Innovasi, an Indonesian consultancy. This document on socio-economic analysis was prepared by COWI, with contributions from Lars Grue Jensen and local consultant Nanda Mariska.

The project is coordinated by the Danish Energy Agency (DEA) as part of INDODEPP, with active involvement from the Embassy of Denmark in Indonesia and local Indonesian stakeholders, including the Energy and Mineral Resources Agency (DINAS ESDM), the Regional Development Planning Agency (Bappeda), and the State Electricity Company - Perusahaan Listrik Negara (PLN).

Socio-economic analysis of renewable projects

This report provides a comprehensive socio-economic analysis of two renewable energy projects in Aceh Besar: the 170 MW solar PV project in Kuta Cot Glie and the 70 MW onshore wind project in Lhoknga. The study explores their impacts on job creation, local economic growth, local communities, and environmental sustainability.

Aligned with Indonesia's climate goals of achieving net zero emissions by 2060, these projects aim to foster sustainable energy development while enhancing local livelihoods. Incorporating stakeholder input and adhering to global best practices, this analysis supports strategic decision-making and project implementation.

Geography and Demography:

Aceh Province, located at the westernmost tip of Indonesia, spans an area of 56,839 square kilometers and sits at an average altitude of 125 meters above sea level. Administratively, the province comprises 18 districts and 5 cities, with a total population of 5.4 million as of 2023 and an annual population growth rate of 1.36%. In the same year, Aceh recorded an economic growth rate of 4.23% alongside an inflation rate indicative of regional economic stability.

In the context of a pre-feasibility study, several sub-districts in Aceh have demonstrated potential for renewable energy development, particularly solar photovoltaic (PV) and wind power. GIS-based screenings identified Seulimeum and Kuta Cot Glie sub-districts as promising locations for utility-scale solar PV projects. Additionally, Darussalam and Lhoknga sub-districts exhibit potential for wind power development, highlighting Aceh's prospects for advancing its renewable energy initiatives.

Purpose of Socioeconomic Analysis and Overall Findings

The purpose of a socioeconomic analysis of renewable energy projects is to evaluate their economic feasibility, societal benefits, and environmental impact.

The 170 MW Solar PV project in Kuta Cot Glie is economically viable, yielding positive societal and environmental impacts. It maintains strong performance across varying economic conditions, achieves significant CO_2 reductions, and aligns with Indonesia's renewable energy and climate goals.

The 72 MW wind project in Lhoknga demonstrates economic viability with a positive ENPV and a benefit-cost ratio above 1, even under varying sensitivity assumptions. While it delivers notable socio-economic and environmental benefits, the high PPA rates present challenges for competitive pricing. Situated in a protected forest area, the project must navigate significant regulatory, environmental, and funding constraints.

METHODOLOGY - SOCIO-ECONOMIC ANALYSIS

Introduction to socio-economic or Cost-Benefit Analysis of Energy Projects:

Cost-Benefit Analysis (CBA) is a key tool for assessing the feasibility and value of energy projects, such as power plants, renewable installations, and grid upgrades. These projects require significant investment and have long-term impacts. CBA provides a structured framework to compare costs and benefits, ensuring that resources are directed toward projects with the highest net societal value. The CBA is done according to the standard procedures as outlined in the Asian Development Bank (Asian Development Bank, 2013) and the European Commission. (2014).

CBA translates impacts into monetary terms, addressing economic, environmental, and social dimensions. Economically, it evaluates resource efficiency through metrics such as Economic Net Present Value (ENPV), the Economic Rate of Return (ERR), and the Cost-Benefit Ratio (C/B ratio). These indicators help prioritise projects that deliver the highest returns relative to costs while considering opportunity costs to guide effective allocation of capital.

Environmentally, CBA accounts for externalities like emissions and resource depletion, aligning projects with sustainability goals. Monetising these impacts enables a comprehensive comparison of environmental costs and benefits. Socially, CBA considers implications such as improved access to energy and potential harms like community displacement, supporting equitable decision-making.

As a decision-support tool, CBA enhances transparency and accountability in energy planning. It ensures investments maximise societal value while addressing challenges like climate change and energy poverty, aligning projects with broader policy objectives. The projects support Indonesia's commitment to reaching net-zero emissions by 2060 and contribute to increasing the share of renewable energy in the national energy mix, aligning with Indonesia's energy targets for 2025 and 2050.

Main steps in a socio-economic or cost-benefit analysis:

A socio-economic or CBA analysis is a systematic approach used to evaluate the economic viability of projects or policies. It involves quantifying and comparing the costs and benefits to determine whether a project delivers net benefits to society. The figure below outlines the main steps in conducting a comprehensive CBA, ensuring a robust framework for decision-making.

Qualitative assessment:

Assessing the impact of the two potential renewable energy projects requires considering not only factors that fit into calculations but also gaining a deeper understanding on potential affect on the local community. This includes understanding the social dynamics and local communities, how the community uses the land, and the environmental conditions in the area. To gain deeper qualitative insights, local consultants conducted interviews with relevant stakeholders and experts, such as sub-district chiefs, village heads, and representatives from local organizations. A complete list of interviews conducted in Aceh to support this study can be found in the Appendix.

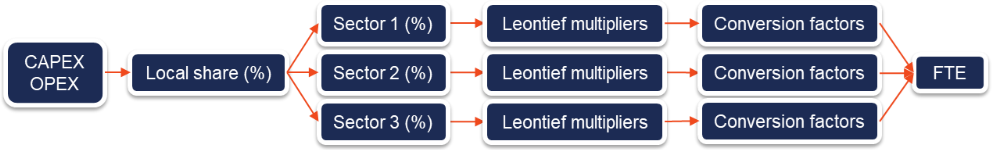
Social economics vs Business economics

Social economics focuses on society as a whole, considering overall welfare, externalities, and societal costs and benefits. Business economics focuses on individual businesses, aiming to maximize profit and financial performance.

1. Define the Project Scope
   - Clearly outline objectives, scale, and components.
2. Identify Costs and Benefits
   - List financial and non-financial costs and benefits.
3. Monetise Costs and Benefits
   - Assign monetary values; use market or shadow pricing.
4. Apply a Social Discount Rate
   - Convert future costs/benefits to present values
5. Calculate Economic Net Present Value (ENPV)
   - Sum discounted benefits and costs; determine viability.
6. Perform Sensitivity and Risk Analysis
   - Assess the impact of assumption changes and risks.
7. Conduct Distributional Analysis
   - Analyse stakeholder impacts, including poverty.
8. Make Recommenda-tions
   - Provide clear feasibility recommendations.

METHODOLOGY - JOB CREATION

The quantification of the social impacts involves estimating the job creation from the construction and subsequent operation of renewable energy sites. The job creation is calculated based on an employment model, that COWI has developed and provided training in during a mission March 2024. This section will briefly highlight the methodology, which is also highlighted in the figure below. The main assumptions for the model are summarized in the table.



Dataf low of the employment model

The main input to the model is the CAPEX and OPEX estimates, which is the direct economic impact to the regional economy. Based on assumptions on the need for import the local share of the investments are split in 3 main sectors. These sector specific investments are multiplied with Leontief multipliers to find the indirect economic impact to the local economy. A Leontief multiplier is a measure in input-output analysis that quantifies the total effect of a change in final demand for one sector on the entire economy. It reflects both the direct and indirect impacts of production in one sector on other sectors, based on inter-industry dependencies. The Leontief multipliers are based on regional input-output tables from the Aceh Provincial Statistical Agency (Aceh Provincial Statistical Agency, 2016).

The direct investment (CAPEX and OPEX) and the indirect economic impact is converted to full time equivalents (FTE), using sector specific conversion factors. A full-time equivalent represents the workload of an individual working full time for one year. This conversion factor is calculated based on production output and employment numbers from the National Account for Indonesia from the Asian Development Bank (Asian Development Bank, 2022).

The direct and indirect employment effects are measured in terms of full-time equivalents. During the construction phase, workers are needed to manufacture the equipment for the electricity generation facilities, transport materials as well as install and construct the facilities. These jobs are the direct effect.

Additionally, the investments will also result in an employment effect related to the extraction of raw materials, manufacturing of tools, provision of support, as well as health and other support to the workforce directly engaged in the construction. This effect is the indirect employment effect. Thus, the investment will directly increase the activity on the main three sectors, which will increase the (indirect) activity in most other sectors in the economy. The calculation does not take into account whether there are sufficient workers to fill the jobs or whether the employment of the workers postpones other construction projects.

As the model estimates the employment based on CAPEX estimates, it considers more jobs for the construction phase than those created directly during the actual construction of the renewable energy power plants. It also includes the jobs created in manufacturing the plant equipment as well as the transport to the construction site. Depending on the scope of other job creation estimates, the estimates might vary.

A benefit of the employment model is that it estimates the local economic impact and translates it to jobs based on Indonesian economic and employment data. However, as the CAPEX/OPEX estimates provided are based on international experience, it is important to consider the contrasting context of Indonesia to other countries with more experience in renewable energy construction. For example, in a European context, productivity is influenced by well established infrastructure, advanced technologies, and a high degree of automation. European countries benefit from economies of scale in the offshore wind industry, enabling efficient production processes and higher productivity levels. This, in turn, affects the number of jobs created.

The local share is based on the updated local content requirements given in this report. However, the local share on the operation and maintenance of the plants are assumed to be able to increase as the jobs created are more permanent, and it is thus realistic to find or train local competencies to solve the tasks. The technical assumptions behind the employment model are provided in the table below.

Table – Main assumptions in the employment model

Sector	Assumed sector split		Local share		Sector specific conversion factor
	Wind	Solar PV	CAPEX (%)	OPEX (%)	(mil. USD/FTE)
YTDL Machinery and Equipment Industry	80%	45%			0.0115
Construction	10%	45%	15%	80%	0.0139
Land Transportation	10%	10%			0.0104

INTRODUCTION TO ACEH AND ITS POWER SYSTEM

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ACEH PROVINCE: DIVERSE GEOGRAPHY, AGRICULTURAL ECONOMY, AND STRATEGIC INVESTMENT IN INFRASTRUCTURE AND SEZS

Population: Aceh is the northern province of Sumatra consisting of 23 districts. The population of Aceh is 5,372 million people with 238,000 people living in Banda Aceh, which is the capital of the province.

Geography: Aceh stretches over 72,034 km2 and 80 % land. The province consists of 119 islands, 119 major rivers and 35 mountains with the highest reaching 3466 meters.

Economy: Aceh’s economy is dominated by agriculture, forestry and fishery (30%), followed by trade (14%), government administration (10%) and construction (9%). Coffee is one of the leading commodities in Aceh. The growth rate of Aceh province reached 4.2% in 2022. Key investment priority sectors include energy, infrastructure, agro-industry—particularly cocoa, coffee, and palm oil—tourism, and the development of special economic zones (SEZ).

Special Economic Zone (SEZ): Located in North Aceh Regency and Lhokseumawe City, this zone was established by Government Regulation No. 5 of 2017. Capitalizing on Aceh's strategic position along the Malacca Strait, it aims to integrate into the global production network.

Focusing on energy, petrochemicals, agro-industry for food security, logistics, and kraft paper production, the zone's projects include LNG regasification, LNG and LPG hubs, a Mini LNG Plant PLTG, and clean energy power plants. These industries are supported by improved logistics infrastructure, including ports and docks meeting international standards.

Indonesia Chamber of Commerce; Aceh Investment Promotion Agency

ACEH'S INFRASTRUCTURE: DEVELOPING ROAD NETWORKS, STRATEGIC PORTS, AND LIMITED INTERNATIONAL AIR LINKS

Roads: Aceh's road network links its major cities, with larger roads primarily located along the coastal areas. In 2018, construction began on a 73 km toll road connecting Banda Aceh and Sigli. By September 2024, half of the road had been inaugurated. This toll road is part of the larger Trans Sumatra Toll Road project, which spans a total length of 1,235 km.

Ports: Aceh has two industrial ports for transport of general cargo and tankers.

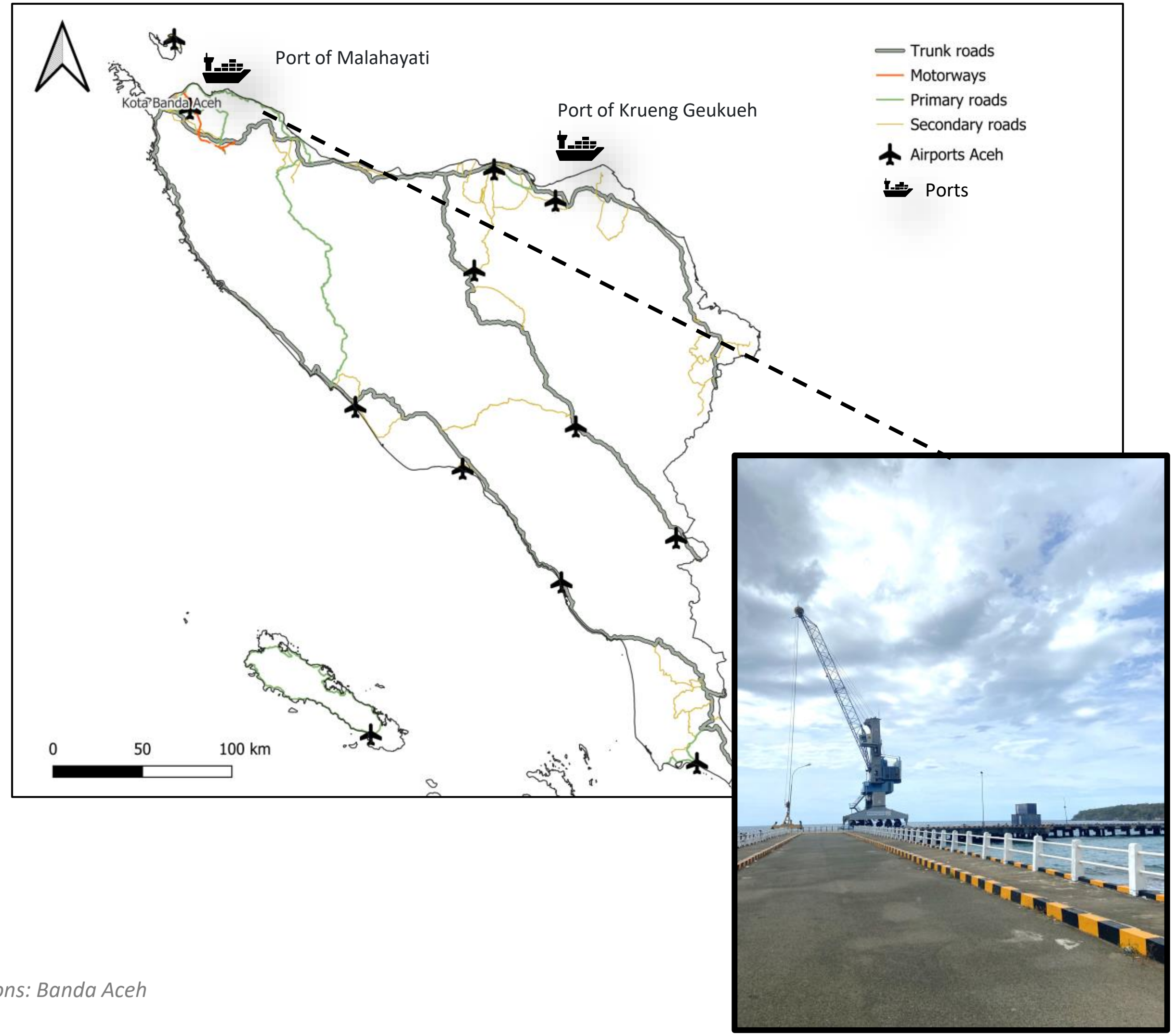
Port of Malahayati

The port of Malahayati, situated in Krueng Raya Bay in the Aceh Besar district, is approximately 35 km from Banda Aceh, the capital of Aceh Province. As the largest port in the province, it is managed by PT. Pelabuhan Indonesia I (Persero), Malahayati Branch. Since the official opening of a new container terminal in 2013, the port has handled over 4,000 containers, with that number increasing to more than 8,000 containers by 2018

Port of Krueng Gekueh

The Port of Krueng Gekueh is situated in Lhokseumawe City, a designated priority area for investment due to its status as a special economic zone. The port is located around 200 km from Banda Aceh.

Airports: Aceh is served by several smaller airports that facilitate connections within the province. The largest airport is Sultan Iskandar Muda International Airport, which is located outside Banda Aceh. Most international flights to Aceh transit through Jakarta, with the exception of flights from Kuala Lumpur (Malaysia), which is the only international destination with direct air links to Aceh.



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

Logistics Cluster; PWC (2024); Cabinet Secretariat of the Republic of Indonesia (2024); Flight Connections: Banda Aceh

ACEH'S POWER SYSTEM: FOSSIL FUEL DOMINANCE, GRID EXPANSION, AND EMERGING RENEWABLE ENERGY POTENTIAL

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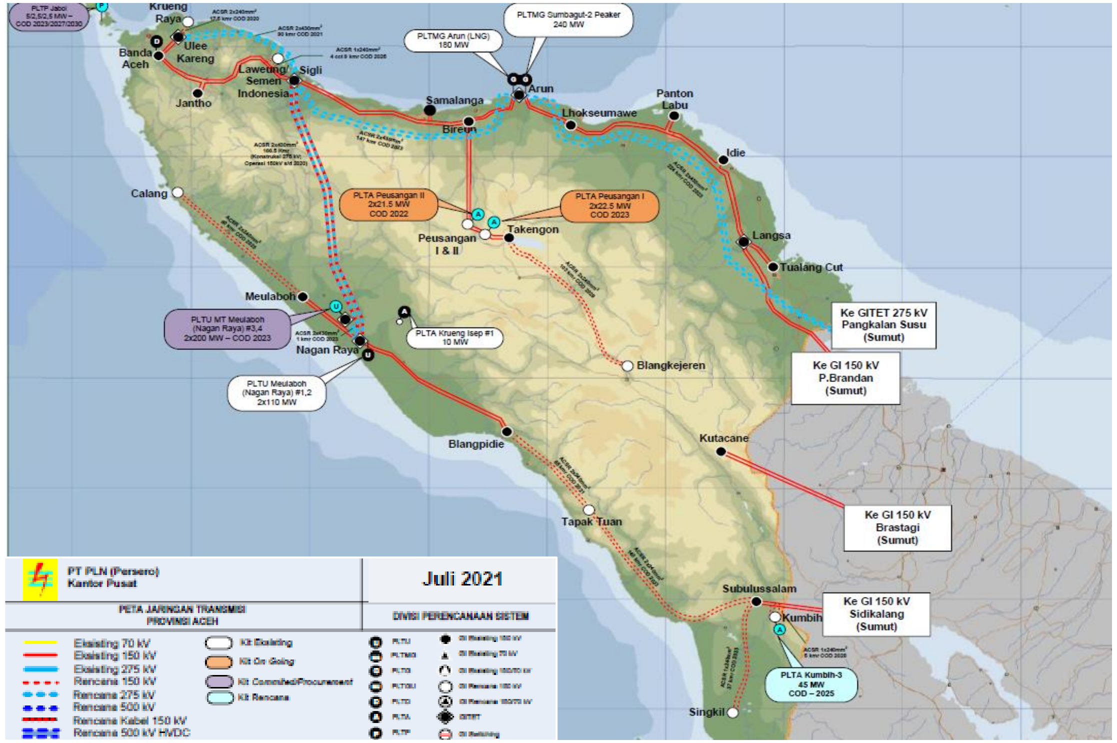
Deployed grid: Aceh's power system is part of the Sumatra grid and is supported by interconnections to other regions as well as its isolated 20 kV systems in remote areas. PLN currently operates 70 kV and 150 kV systems in Aceh, with plans to expand the 150 kV network and develop additional 275 kV and 500 kV systems. The province has 19 substations connected to the 150 kV network with a combined capacity of 1,200 MVA.

Existing generation capacities: Power supply in Aceh is primarily provided by PLN, with some generation owned by independent power producers (IPPs). In 2020, the combined installed capacity totaled 770 MW. After accounting for losses, maintenance, and other operational factors, the net capacity available for grid supply was 628 MW. In comparison, peak load demand reached 615 MW in 2020.

Aceh's power supply is dominated by fossil fuels, which accounted for 99 per cent of the total installed capacity in 2020. Natural gas accounted for 55 percent, followed by coal at 30 percent and diesel at 15 percent. The renewable share of Aceh's power supply came from hydropower, contributing a net generation capacity of 11 MW in 2020.

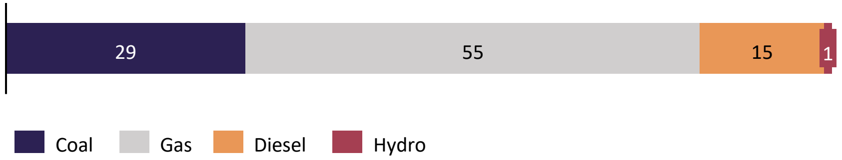
Renewable energy targets: According to the Provincial Energy Plan (RUED), Aceh aims to achieve a renewable energy share of 33.9% by 2025, rising to 43.3% by 2050. With the current share at around 1%, Aceh will need to significantly increase investments in renewable energy in the coming years.

Future generation capacities: Aceh holds significant potential for renewable energy generation, particularly from hydropower, geothermal, and solar PV. The province also has substantial reserves of oil, natural gas, and coal, which could further boost its future power generation capacity. According to the latest Electricity Plan (RUPTL 2021-2030), the total planned capacity, including both existing and new projects, is 1,482 MW, with 400 MW coming from a coal power plant. In June 2024, this coal power plant achieved its commercial operation date (COD).



The map is derived from PT PLN's Electricity Supply Business Plan (RUPTL) for 2021-2030.

Installed capacity, Aceh, 2020 [%], RUPTL 2021-2030



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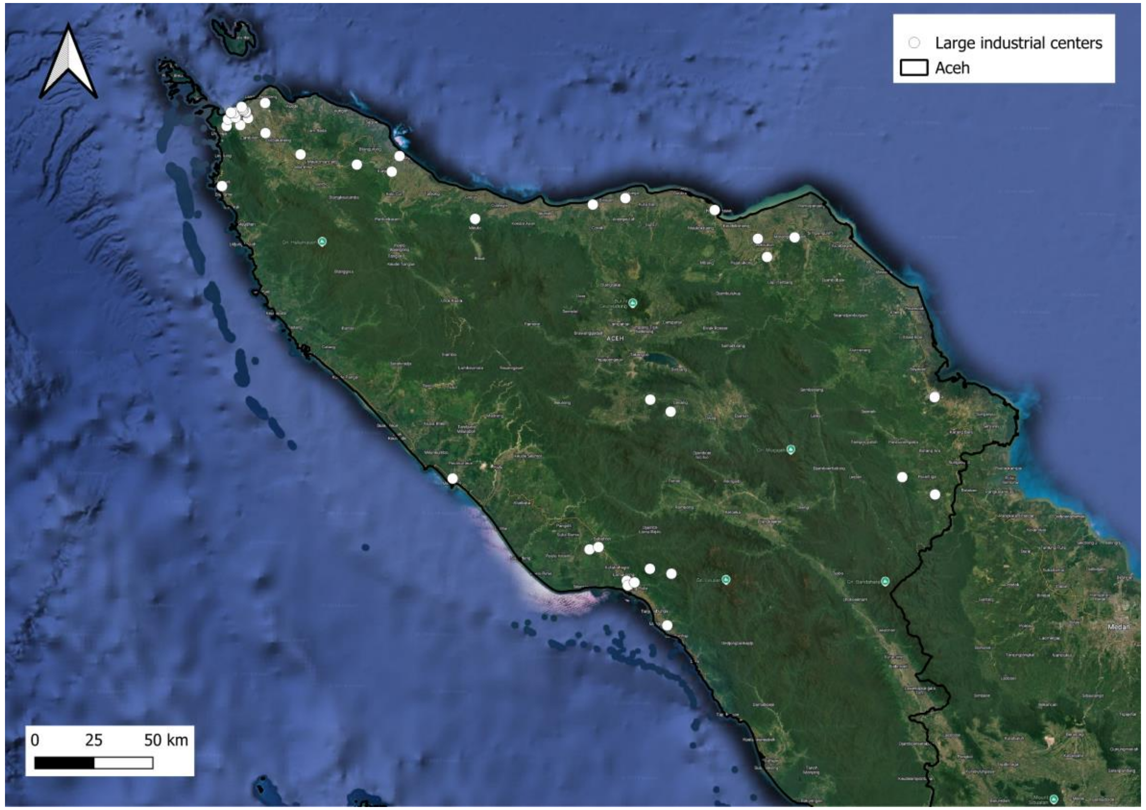
PT PLN – 'RUPTL' (2021); Power Technology (2024); Ministry of Energy and Mineral Resources (2019).

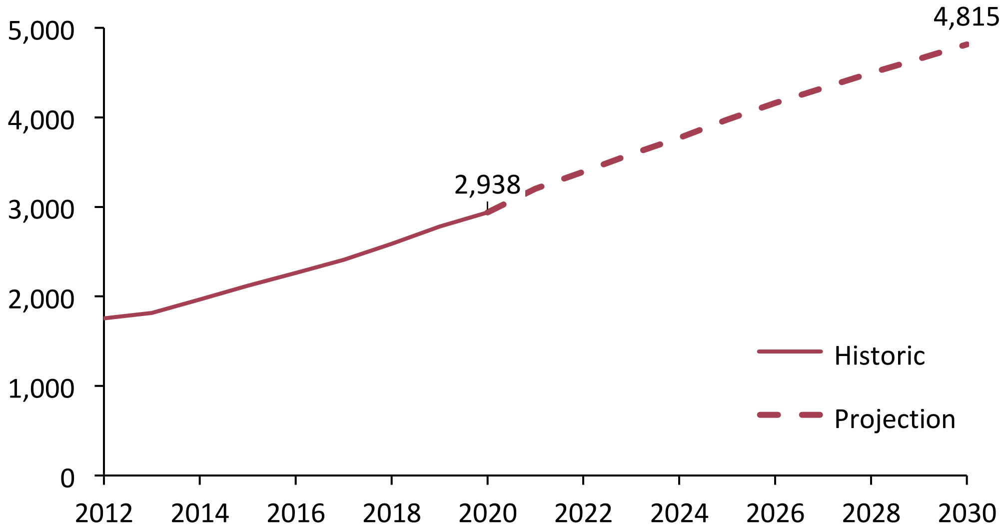
POWER DEMAND IN ACEH: HOUSEHOLD DOMINANCE AND INDUSTRIAL DEMAND CONCENTRATED AROUND BANDA ACEH

Electricity demand: The total electricity demand in Aceh reached approximately 3 TWh in 2020, with 64 percent of the demand coming from households. By 2030, electricity demand is projected to exceed 4.8 TWh.

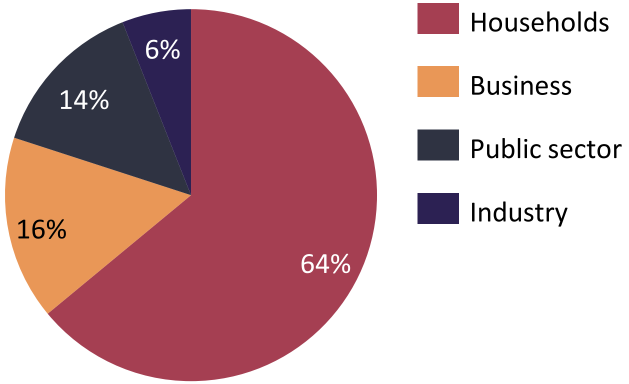
Industrial demand centers are most present around Banda Aceh.



Historic and projected electricity demand in Aceh, 2012-2030 [GWh]



Electricity demand in Aceh by consumer category, 2020 [%]



BPS Statistics Indonesia; DESDM (2024); PLN – RUPTL 2021-2030

ELECTRICITY TARIFFS, GENERATION COSTS, AND RENEWABLE ENERGY PROCUREMENT IN INDONESIA

Electricity tariffs: Electricity tariffs must be approved by Parliament and PLN's financial position is thus affected by the political process. Whenever electricity tariffs are higher than the cost of generation, PLN receives compensation through the Ministry of Finance. Following the Government's decision to revoke subsidies for selected customer groups, average electricity tariffs have increased resulting in a reduction in subsidies to PLN in between 2012 and 2022.

Average generation costs (BPP): The average generation cost (BPP) reflects PLN's expenses for procuring power from various subsystems. Since PLN generates its own power, the BPP is a combination of PLN's internal generation costs and the cost of purchasing power from third-party providers. Given that coal dominates Indonesia's energy mix, the BPP is closely tied to coal production costs. In 2020, the BPP in Aceh was 9.26 cUSD/kWh.

Procurement mechanism: Under Presidential Regulation (Perpres 112/2022), the renewable procurement for solar and wind energy follow the direct selection process, where PLN chooses the IPP offering the most attractive PPA price in a competitive tender process.

Ceiling price: With the introduction of Presidential Regulation (Perpres 112/2022) the government has set a ceiling price for the PPA price where the ceiling price indicates the maximum power price that can be negotiated with PLN. The regulated ceiling price drops significantly from year 11 until the end of the contract term.

RE technology type and capacity influence the PPA ceiling. It follows that the ceiling price for smaller scale projects is higher than for large scale projects. The PPA price also reflects LCOEs for RE technologies, why the ceiling price is higher for wind power projects compared to solar PV projects.

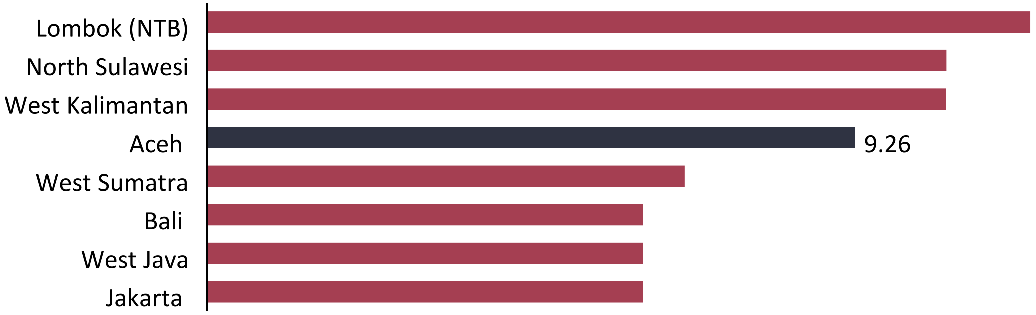
PPA price: The PPA price is a critical component of the overall business case. When submitting a tender for an onshore wind or solar project in Indonesia, the proposed PPA should be competitive however not higher than the ceiling price. Realistically the proposed PPA price should also not exceed the average generation costs (BPP).

MEMR (2021); Baker McKenzie (2021); PwC (2023);

Average cost, average tariff, and subsidies: 2012/2022 [IDR/kWh]

Year	Average cost	Average tariff	Subsidies
2012	1,374	728	103.3
2022	1,473	1,137	58.8

PLN's average generation price (BPP) for selected sub-systems: 2018/2020 [cUSD/kWh]



Calculation method for maximum PPA price according to Perpres 112/2022

Technology	Capacity	Ceiling price (cUSD/kWh)	
		1st to 10th years	11th to 30th years
PLTS (solar)	>20 MW	6.95 x F	4.17
PLTB (wind)	>20 MW	9.54 x F	5.73

The location factor (F) for Aceh is 1.1.

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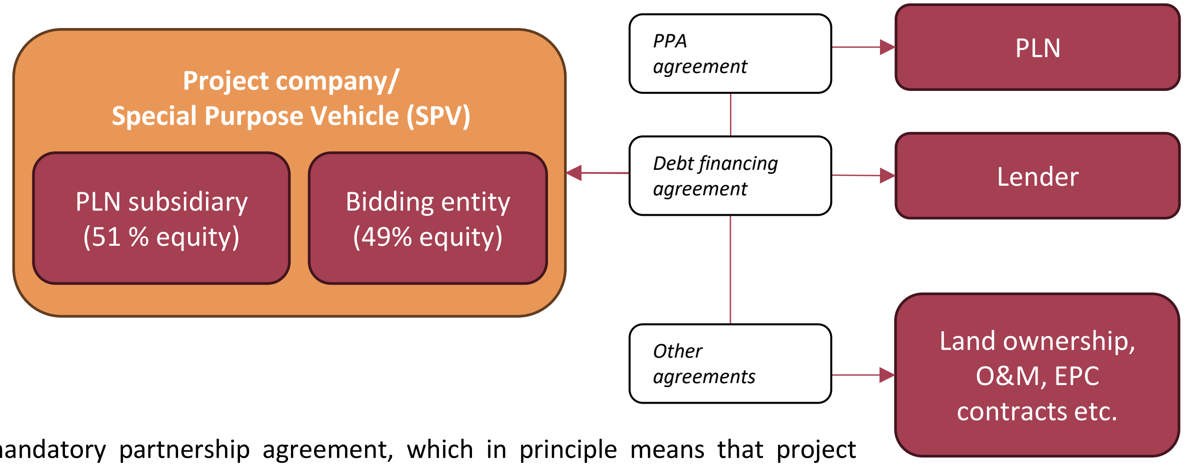
PLN OPERATIONS AND THE MANDATORY PARTNERSHIP SCHEME

PLN: PLN controls the supply of power in Indonesia through a de facto monopoly of the transmission, distribution and supply of power. The private sector may hold a temporary license to operate grids between PLN’s substation and privately owned generation plants, however, the ownership of these grids is normally transferred to PLN following construction. PLN owns its own power generation plants and procure power through independent power producers (IPP) via Power Purchase Agreements (PPA).

Project structure and finance: Large scale renewable energy projects normally follow a project finance structure, whereby a special purpose vehicle (SPV) is formed as a separate legal entity. An SPV is a created to isolate the financial risk of the shareholders. The financing of the SPV normally constitute both equity and debt in a 70/30 or 80/20 split.

Example of project structure where PLN owns 51% of ownership in a project



Mandatory partnership scheme: Since 2017, Indonesia has implemented a mandatory partnership agreement, which in principle means that project developers should pass on up to 51 pct. of the ownership of the project to PLN. However there has been different interpretations of the requirements under the mandatory partnership scheme, and it is uncertain how this will be regulated in the future.

Whether PLN acts as a minority or majority owner, potential conflicts of interest may arise in disputes over power delivery and compensation, as PLN serves both as the off-taker and a (primary) producer of power. Depending on the contractual terms, this ownership structure could introduce risks to the project. Additionally, PLN’s limited cash reserves and reliance on government subsidies make it challenging to raise equity cash. If unable to secure cash equity, PLN would need to provide in-kind contributions, thereby becoming dependent on the IPP partner’s financial strength through loan mechanisms.

PLN’s recent joint investments in renewable projects with IPPs

Project name	Location	Entity	Status	PLN’s ownership	Partner
145 MW Floating Solar plant	West Java	PT Pembangkitan Jawa Bali Masdar Jakarta	In operation since 2023	51%	Masdar or Abu Dhabi Future Energy Company
50 MW Solar PV + 14 MWh storage	East Kalimantan	PT Nusantara Sembcorp Solar Energi	In development/construction stage	51%	Semcorp Industries Ltd.
46 MWp Floating Solar PV	Riau Island	PT Nusantara Tembesi Baru Energi	PPA/financial close	51%	PT TBS Energi Utama Tbk

IEEF (2024)

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REGULATIONS AND PERMITTING FOR RENEWABLE ENERGY PROJECTS

Renewable energy regulation: The legal framework for energy and renewable energy acceleration serves as a natural starting point for assessing the regulatory environment for renewable energy generation in Indonesia. Energy planning begins at the national level, guided by an overarching national energy policy. This policy is translated into a National Energy Plan (RUEN) and renewable energy targets, which are further implemented by provincial governments through Provincial Energy Plans (RUED) and provincial renewable energy targets. However, provincial targets sometimes fail to fully account for the financial capacity and capabilities of provincial governments, leading to significant variations in progress. For example, Aceh, with a renewable energy share of only 1%, lags far behind in meeting its renewable energy targets.

The Ministry of Energy and Mineral Resources oversees the energy planning process, while PPA contract negotiations are conducted directly between Independent Power Producers (IPPs) and PLN.

Table: Selected regulations on energy

Regulation	Description
Law No. 30/2017 on Energy	Establishment of the national energy council (NEC) and the national energy policy
Government Regulation (GR) No. 79/2014 on National Energy Policy	Regulates a national goal of the share of renewable energy of primary demand to 23 % in 2025 and 31 % by 2050
Presidential Regulation No. 11/2022 on the Acceleration of Renewable Energy Development for Electricity Supply	Regulates the renewable energy tariff scheme and the preparation of RUPTL (Electricity Supply Plan)
MEMR Regulation No. 10/2017 jis. MEMR Regulation No. 49/2017 and No. 10/2018 on Principles of Power Purchase Agreements	Regulates the principles of power purchase agreement between PLN as off-taker and business entities as electricity sellers
MEMR Regulation No. 20/2020 on Power System Network Rules (Grid Code)	Regulates network management, connection, planning & execution of operations, power transactions, measurements, and a summary of operational schedules

ETP & UNOPS (2024); IEEFA (2024); MEMER 11/2024 referred to in stakeholder interviews

Local content regulation: The primary goal of local content requirements is to ensure local participation, stimulate job creation, and support economic development. However, these requirements may increase project costs and deter foreign investment. For instance, locally produced materials are typically 35-45% more expensive than imported alternatives due to higher production costs and limited supply.

Indonesia recently introduced MEMR Regulation 11/2024, relaxing local content requirements compared to previously where companies struggled to fulfil the requirements.

According to the updated regulation, at least 20% of the total contract value must come from local content for solar PV projects, while onshore wind projects must meet a 15% local content requirement. Projects must also meet local content requirements for specific parts of the contract value. For instance, 25 pct. of the costs of solar panels must be certified local content.

Planning and permits: A variety of regulations impact project feasibility, with environmental regulations often causing delays and posing challenges to investments. The aim of these regulations is to safeguard the natural environment and ensure industrial development does not harm biodiversity or the surrounding ecosystem. Coordination with the Ministry of Forestry and Natural Resources is essential to gather information on land classification and permissible usage for the proposed project. Additionally, conducting an environmental assessment and obtaining the required permits are critical steps in the planning process.

The spatial planning office can provide crucial insights into existing zoning regulations and the feasibility of converting land into an industrial zone suitable for renewable energy development. Furthermore, development and planning agencies can offer guidance on the regional development plan and identify any other projects planned for the proposed location, ensuring alignment and minimizing potential conflicts.

[1]The 35 pct. represent a weighted average for all materials. In reality, there are specific local content requirements for each material.

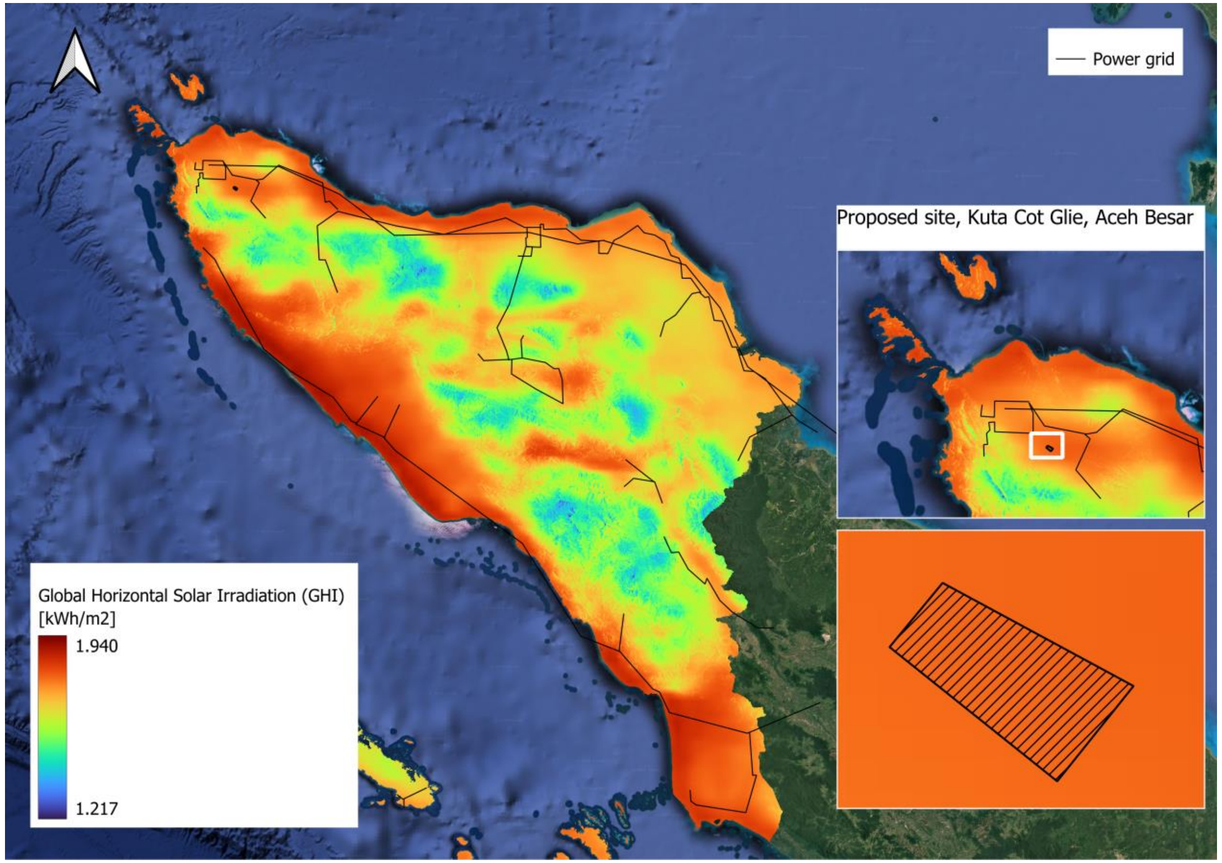
PRE-FEASIBILITY STUDY FOR UTILITY SCALE SOLAR PV

Stock photo ID:1794790762
Location: China

LARGE AREAS WITH GOOD IRRADIATION CONDITIONS IN ACEH, WITH MEAN ANNUAL GHI UP TO 1900 KWH/M2 IN MANY AREAS

Solar irradiation distribution: The daily mean global horizontal irradiation (GHI) observed at ground level across the province is relatively uniform, with the highest values found along the coastline.

Mean annual GHI values range from 1,200 to 1,900 kWh/m².The map below illustrates the GHI distribution across the province. Areas with higher GHI values will experience higher Full Load Hours (FLHs), which follow a similar distribution pattern



Global Solar Atlas (2024)

Location selection: Based on the observed GHI (Global Horizontal Irradiance) patterns, the lowest values are found in the central region of the province and the mountainous areas, while higher values are observed in the northern region and along the coasts.

The site selection process considered several criteria, including road access, terrain topography, proximity to demand centers, and transmission lines. Rather than applying strict cutoffs, an overall evaluation of these criteria was conducted for each potential site.

Aceh offers several areas with excellent solar irradiance. The selected site stands out due to its good road access, proximity to Banda Aceh—a significant consumption center—and close connection to the transmission grid.

The chosen location is in the Kuta Cot Glie district (5.347309; 95.529376). A ground-mounted solar PV plant has been identified as the optimal choice for this area.

Potential production: When evaluating the production of a PV plant, it is crucial to differentiate between AC and DC ratings (refer to the sizing factor description on the next page).

According to the Global Solar Atlas, the GHI of the selected site is 1780 kWh/m2/year.

This equates to a potential production in the selected area of approximately 1,420 kWh/kWdc. Using a sizing factor of 1.2, this translates to 1,704 kWh/kWac, which will be the value applied for the subsequent study.

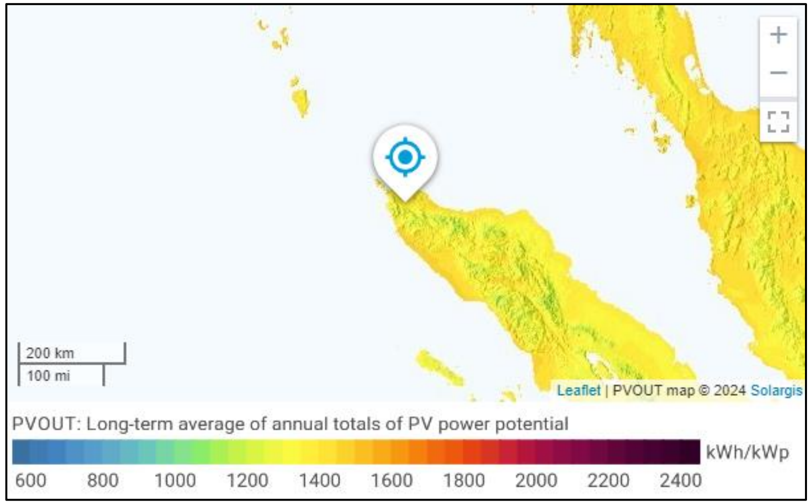
STABLE ANNUAL PRODUCTION WITH 1,704 FLHs (AC) EXPECTED

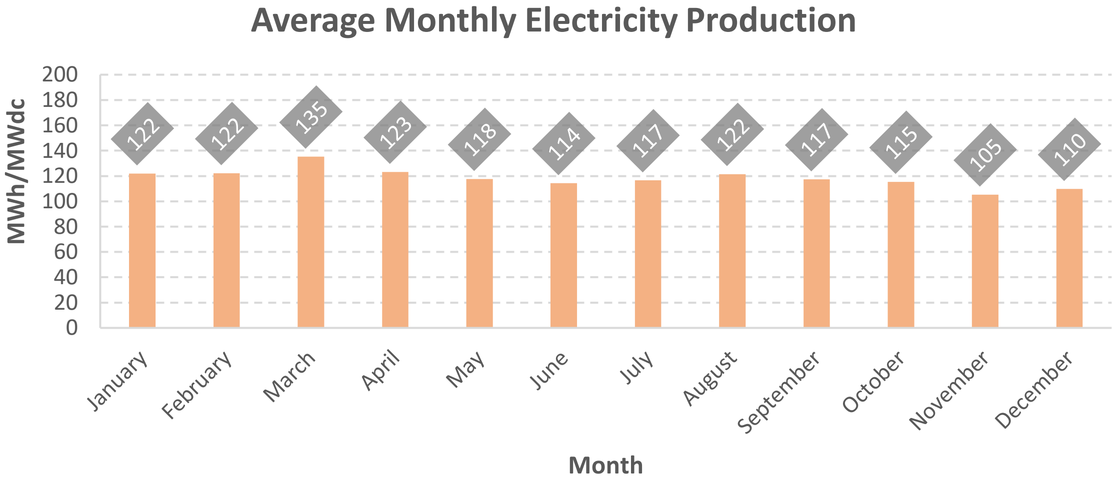
Solar irradiance in Aceh is high and stable throughout the year: Aceh has a high and stable solar irradiance, which makes it a great location for solar PV. The main share of production is between 6 am and 5 pm.

Parameters assumed for the PV:
Tilt: **6º**
Azimuth: **180º**
Losses assumed: **7.2%**

Capacity factors:

AC: **19.5%** (1,704 FLH_{AC})
DC: **16.2%** (1,420 FLH_{DC})





Global Solar Atlas (2024)

Monthly production: The average potential daily unit production (MWh/MW) varies by approximately 7% on a monthly basis throughout the year, indicating relatively stable annual electricity production. This ensures a consistent monthly output, providing a reliable power supply across seasons. This stability is a notable advantage compared to the low wind power potential in most parts of the region. The months with the highest solar production are January to April and August to September.

Annual production: An analysis of daily solar production throughout the year shows that the highest output occurs between 10:00 and 13:00. By 18:00, solar production drops to zero during most months. This timing creates challenges for the power system, as it coincides with the evening peak in power demand, making it difficult to meet the required load ramps.

Hourly electricity production profile

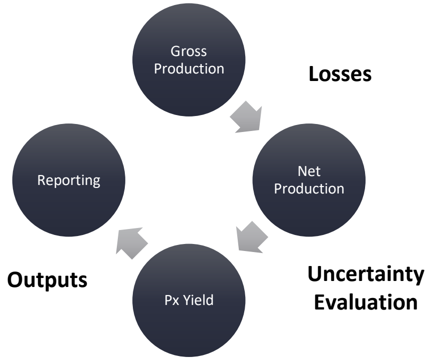
kWh/MWdc Daily Hour	January	February	March	April	May	June	July	August	September	October	November	December
0 - 1	0	0	0	0	0	0	0	0	0	0	0	0
1 - 2	0	0	0	0	0	0	0	0	0	0	0	0
2 - 3	0	0	0	0	0	0	0	0	0	0	0	0
3 - 4	0	0	0	0	0	0	0	0	0	0	0	0
4 - 5	0	0	0	0	0	0	0	0	0	0	0	0
5 - 6	0	0	0	2	3	3	1	1	3	4	3	0.2
6 - 7	46	47	61	92	91	83	71	75	90	107	98	66
7 - 8	201	215	241	254	233	217	201	215	228	253	244	209
8 - 9	359	388	417	446	376	354	332	382	389	393	386	348
9 - 10	491	526	554	563	489	467	445	492	493	500	493	455
10 - 11	575	616	636	616	555	535	515	547	553	546	530	520
11 - 12	588	643	649	618	563	553	539	558	555	531	516	532
12 - 13	545	611	590	547	507	515	509	526	513	474	449	485
13 - 14	467	530	496	428	411	439	447	453	449	398	353	400
14 - 15	346	400	389	292	290	325	345	340	360	293	246	286
15 - 16	216	255	220	165	181	208	225	214	193	161	142	168
16 - 17	94	117	98	73	82	98	108	103	80	58	49	66
17 - 18	8	14	12	10	11	14	19	13	6	1	1	3
18 - 19	0	0	0	0	0	0	0	0	0	0	0	0
19 - 20	0	0	0	0	0	0	0	0	0	0	0	0
20 - 21	0	0	0	0	0	0	0	0	0	0	0	0
21 - 22	0	0	0	0	0	0	0	0	0	0	0	0
22 - 23	0	0	0	0	0	0	0	0	0	0	0	0
23 - 24	0	0	0	0	0	0	0	0	0	0	0	0

SOLAR PRODUCTION UNCERTAINTY CAN BRING THE P90 VALUE TO 1,493 FLHs (AC)

Solar resource assessment: The evaluation of solar resources, including confidence intervals, begins with data from ESMAP and the World Bank's Global Solar Atlas. Additional uncertainty factors, such as the utilized model and expected interannual variability, are incorporated into the following calculations to refine the assessment of irradiation and potential losses.

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 at an ac/dc sizing factor of 1.2
- Net production: assumption of systematic operational losses (7.2%) applied through Global Solar Atlas
- P50, P75, P90: Consideration of uncertainty factors on production and calculation of confidence level on annual energy production



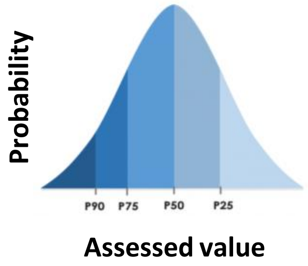
Considered Uncertainty Factors i (On AEP)	
Solar Radiation Model Uncertainty	8.00%
Energy Simulation Model Uncertainty	5.00%
Inter-Annual Variability of Expected Energy	2.00%

**Global Solar Atlas represents 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 net P50 yield for the assessed 140 MWac utility scale solar PV park corresponds to **289.7 GWh/y** (**1,704 FLHac**), consisting the central estimate utilised in the Business Case ahead. Often at a later stage of the project, when financing needs to be secured, a P90 generation level frequently consists the preferred indicator by financial institutions since it entails a significantly higher revenue certainty. The P90 level for the present case corresponds to 253.9 GWh/y (1,493 FLHac).

Value Level	Description	FLH_{AC} Confidence	AEP Confidence [GWh/y]
$P50_{value}$	Value based on the already considered uncertainty within the calculated model	1,704	290
$P75_{value}$	$P50_{value} * (1 - P75_{uncertainty})$	1,593	271
$P90_{value}$	$P50_{value} * (1 – P90_{uncertainty})$	1,493	254



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ESMAP & World Bank (2024); MEASNET (2016)

A 170 MW_{AC} PROJECT IS CONSIDERED, WITH A SIZING FACTOR OF 1.2

DC to AC sizing: When evaluating the cost and production of a PV plant, it is important to differentiate between the capacity and capacity factor for both the DC and AC components. Typically, the AC capacity output is significantly lower than the DC rating. This is due to losses during the conversion process, as well as the higher efficiency of inverters when operating at higher loads. Oversizing the DC side relative to the AC side offers benefits such as cost savings on inverters and grid connections, along with more efficient system operation. A DC/AC ratio, also known as a sizing factor, typically ranges from 1.1 to 1.5 in modern systems. For this assessment, a sizing factor of 1.2 has been chosen. According to the Indonesian Technology Catalogue, a sizing factor between 1.0 and 1.35 is common practice.

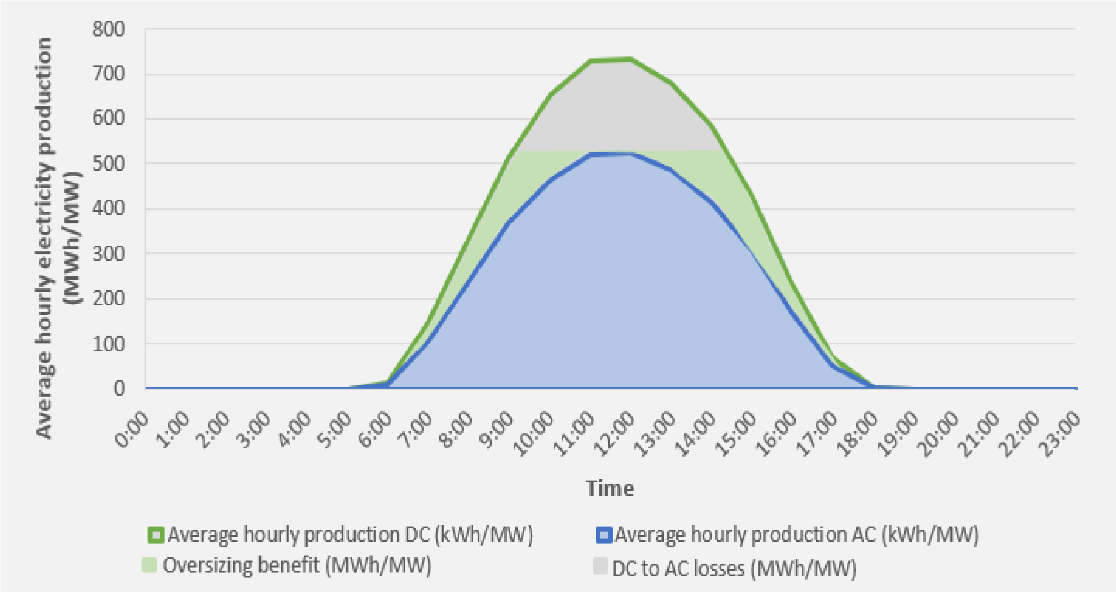


Illustration of average hourly electricity production from solar PV

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

Other large systems have a slightly lover DC/AC sizing factor:

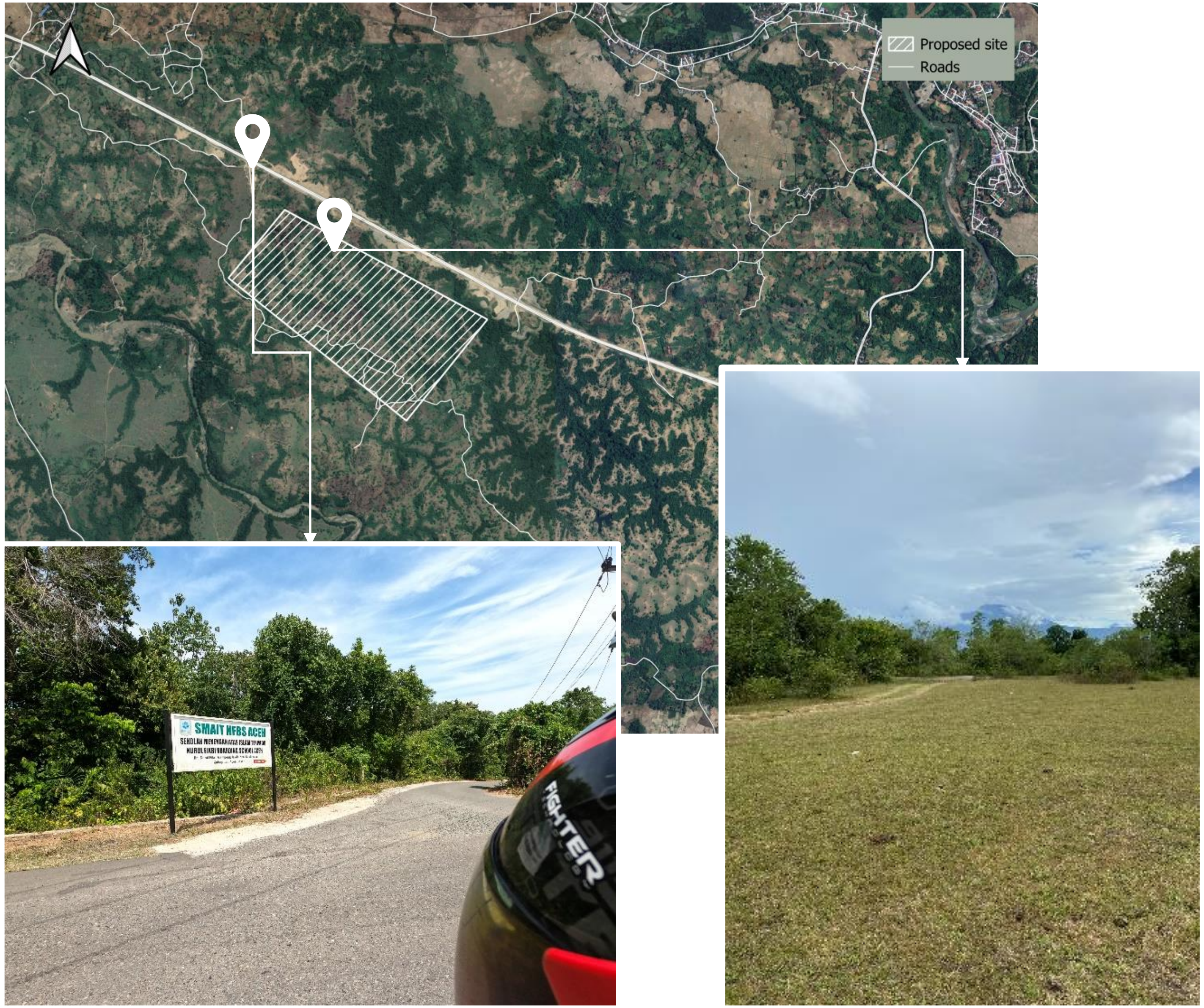
- The floating PV system om the Cirata reservoir in West Java has a capacity of 192 MWdc and 125 MWac. This equals a DC/AC sizing factor of 1.3.

Capacity selection: A **170 MWac PV plant has been chosen as the suitable reference case for the project under examination**, for several reasons:

- Larger solar PV plants generally improve the economic viability of the project
- Larger sizes of PV plants are increasingly common in other markets
- There is limited experience with very large PV plants in Indonesia. Therefore 170 MWac is a relatively large plant, yet still smaller than many projects in other markets.

DEA & Ea Energy Analyses (2024); VENA Energy (2021)

A POTENTIAL LOCATION IN KUTA COT GLIE IS SELECTED



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: The proposed site is situated in the Kuta Cot Glie subdistrict of Aceh Besar regency, with one half located in Bueng Simek village and the other half in Bithak village.

The site's land type is classified as savannah, and according to the Regional Regulation of Aceh Besar No. 04 of 2013, it is zoned as a plantation area. The terrain is relatively flat, with slopes ranging from approximately 1 to 6 degrees. Initial information suggests that the land ownership may belong to either the community or the private sector.

The proposed site is conveniently located near a major provincial road, which helps minimize infrastructure upgrade costs and reduces expenses related to transporting heavy materials and components during the construction phase. As noted by Dinas ESDM, the proximity to the Sigli Banda Aceh Toll Road also positions the site as a potential showcase for utility-scale solar PV in Aceh.

The closest substation is the 150 kV Jantho substation, which is 4.5 km from the site

Spacing requirements: A ground-mounted PV plant of 170 MWac magnitude (204 MWdc with a sizing factor of 1.2) will require ~8,800 m^2/MWdc, according to the latest technological projections, as reported by the Danish Energy Agency in the most recent Technology Data Catalogue for the Indonesian Power Sector (2024). This translates to 1.80 km^2 (180 Ha) of space considerations within the considered area.

TECHNO-ECONOMIC DATA USED FOR THE BUSINESS CASE

Technical features	
Capacity	204 MWdc 170 MWac
Technical lifetime	28 years
Plant availability	99.5%
Space requirements	8,874 m^2/MWdc
Capacity factor	19.5 % (AC) 16.2 % (DC)
Construction time	0.5 years
DC/AC Inverter lifetime	14 years

Economic features	
CAPEX	0.64 mUSD/MWdc 0.77 mUSD/MWac
Fixed OPEX	7.446 USD/MWac-year
DEVEX	3.5%
WACC (real)	8.23%
Expected PPA	Year 1 to 10: 7.65 cUSD/kWh Year 11 to 28: 4.17 cUSD/kWh
Corporate tax rate	22.0%
Depreciation rate	20% declining balance across lifetime
Inflation rate	2.00%

Source	CAPEX[1]	Notes
Technology catalogue for the Indonesian Power Sector	0.73 M$/MWdc 0.88 M$/Mwac	Value for whole Indonesia, based on extrapolation of PPAs and other international sources. Interpolation between 2020, 2030 and 2050. Based on sizing factor of 1.2.
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 projected 2025 data (beginning of construction) in real 2023 price levels, according to the Danish Energy Agency's Technology Catalogue for the Indonesian Power Sector (2024).

PV module price considerations

Decreased component cost trajectories

Solar module procurement has experienced a decrease in costs during 2024 according to the Chinese Module Marker (CMM), which is a benchmark for Chinese solar panel prices. OPIS, A Dow Jones Company has assessed the recent cost of TOPCon panels from China at 0.089 USD/W Free-On-board (FOB). OPIS reports that Q4 2024 deliveries to Southeast Asia at a cost of 0.090 USD/W on a Cost Insurance and Freight (CIF) basis, with indications that prices for the first half of 2025 could be as low as 0.080 USD/W on a CIF basis. (OPIS, 2024)

Current module prices of 0.090 USD/W (CIF) could indicate lower total CAPEX costs than 0.64 M$/MWdc used in this study. The impact of lower CAPEX costs are analyzed in a sensitivity analysis.

FID and COD: The assumed final investment decision (FID) is 2025 and the commercial operation date (COD) is 2026 with construction undertaken between 2025 and 2026.

Comparison of CAPEX sources: Several sources indicate CAPEX estimations for Indonesia. Some of the projects from the table are from 2021. Since 2021 solar PV module prices have fallen, which could indicate lower total CAPEX costs.

Land cost: The ZNT land price for the area is less than 100,000 Rp/m2 (6.3 USD/m2). A general cost of land for Indonesia is included in the CAPEX of the project. A variation in the cost of land is analysed in the sensitivity analysis by changing the CAPEX.

Danish Energy Agency & Ea Energy Analyses (2024)

THE UTILITY SCALE GROUND-MOUNTED PV PROJECT IS ALMOST PROFITABLE WITH AN IRR OF 8.1%

Results: The business case for a 170 MWAC ground-mounted solar plant in Aceh is slightly negative based on baseline assumptions, with a Net Present Value (NPV) of -1.2 mUSD and a real Internal Rate of Return (IRR) of 8.1%, which is very close to the estimated Weighted Average Cost of Capital (WACC) of 8.2%.

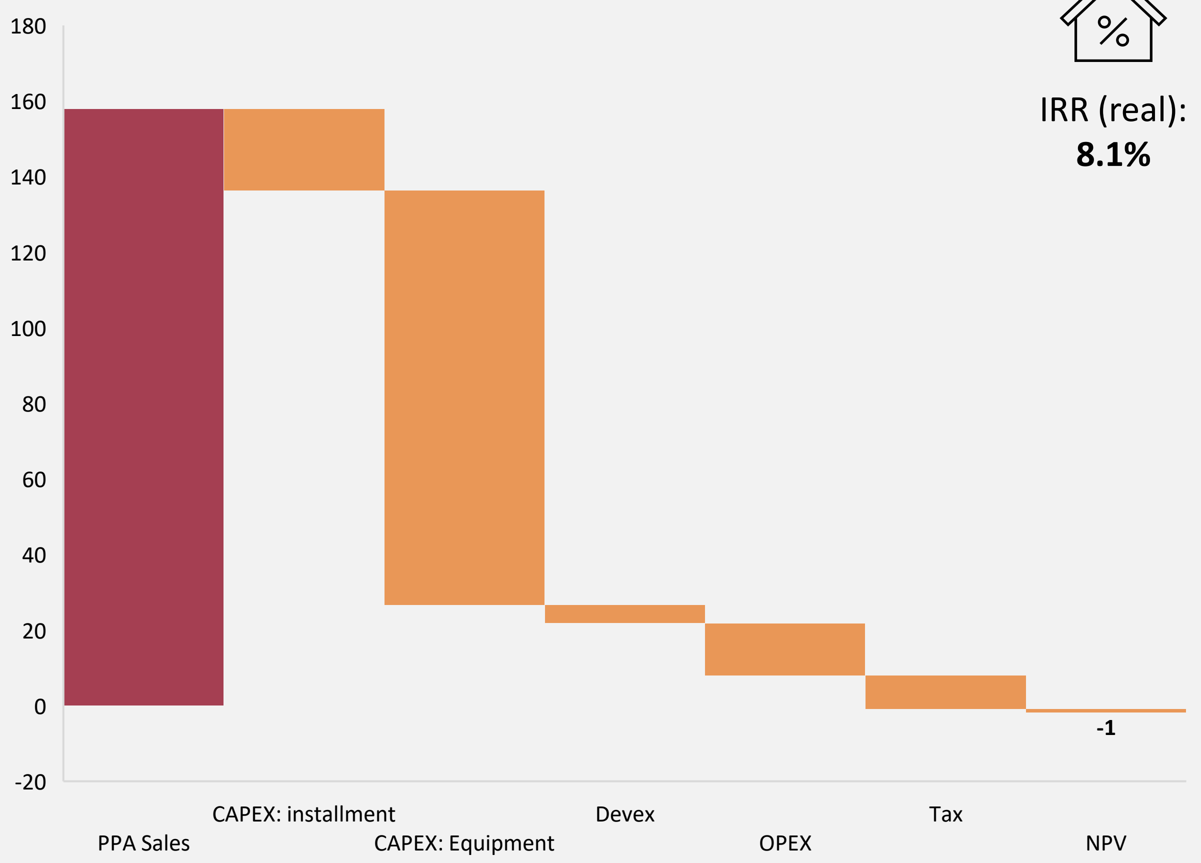
Costs: The cost of equipment constitutes the majority of project costs, meaning even small fluctuations in solar panels or inverters could significantly impact project feasibility. Additionally, stringent local content requirements reduce the available supply of equipment, potentially driving up investment costs.

Other costs include installment costs, development costs, taxes, and operating expenses, though these represent a smaller share of the project's cash flow. Development costs, however, tend to be less predictable, especially in markets with limited experience. Factors such as permitting and land clearing could significantly increase development costs, raising their overall share of total project expenditures.

Revenue: To offset project costs, a stable source of revenue must be secured. For this project, the sale of electricity is assumed to be the sole revenue source why certainty on PPA contract terms and price levels are important.

Following the ceiling price scheme, the net present value of the PPA sales accumulates to 158 mUSD assuming a 28-year contract period.

Breakdown of NPV components



Note: 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 1ST STAGE'S BREAK-EVEN PPA PRICE FOR THE SELECTED PV PROJECT IS 7.76 cUSD/KWH

1st stage PPA price: The first stage of the PPA term is the most critical determinant of project feasibility due to discounting effects. Therefore, the agreed initial PPA price plays a pivotal role in the business case evaluation.

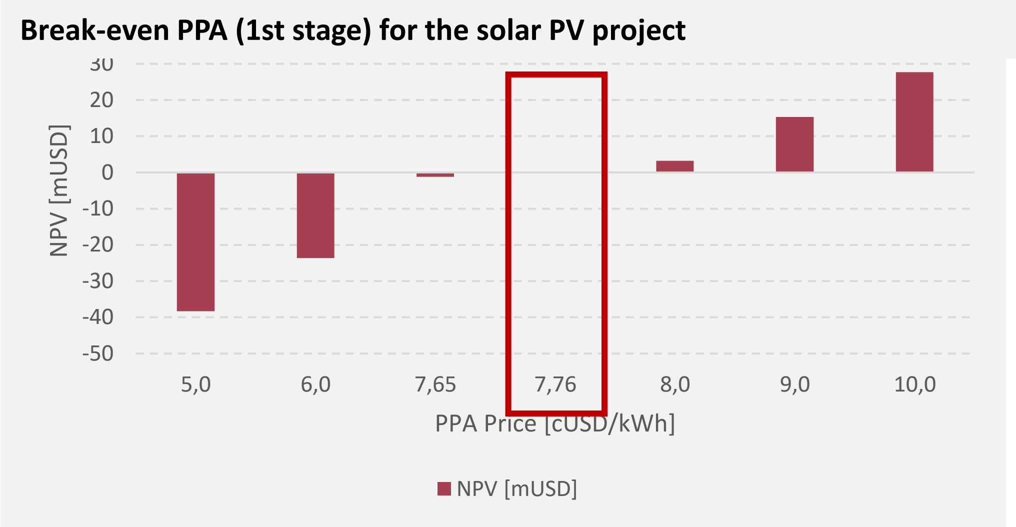
Several factors create uncertainty regarding the potential PPA level expected by investors in a solar project in Aceh, including:

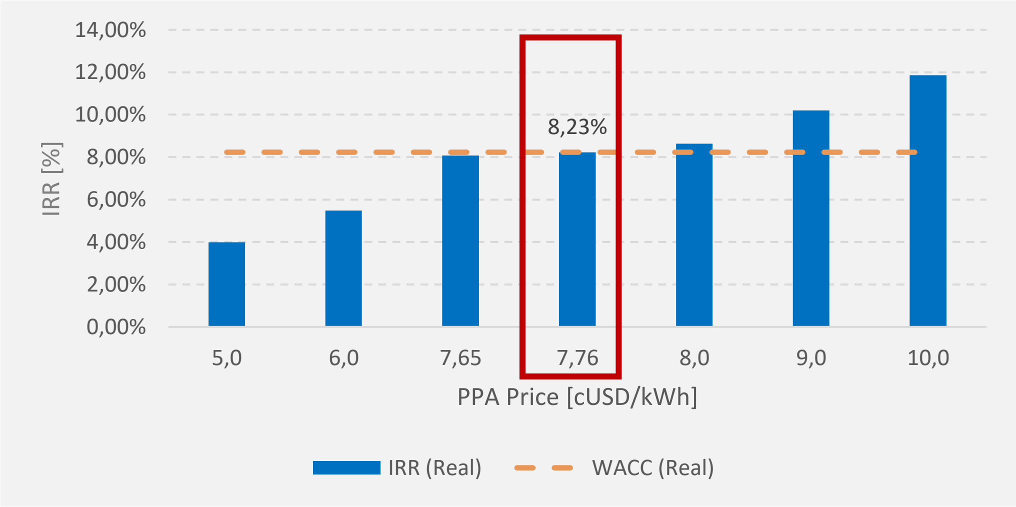
- The regional BPP and how it compares to the ceiling price set by presidential regulation.
- Competitively low bids from other investors, particularly in projects benefiting from financial advantages such as lower financing costs or reduced CAPEX.

Given these factors, it is crucial to determine the minimum first-stage PPA price that enables the project to break even, ensuring an IRR equal to the expected real WACC (8.23%) and an NPV of zero. It effectively represents the bid value an investor might propose in an auction or negotiation to develop the solar project while securing returns in line with the expected WACC.

Break-even PPA price: The break-even PPA price is the PPA price for the first 10 years, which returns an NPV of 0 and an IRR that equals the cost of capital (WACC).

The break-even price for this case in an all-things equal scenario is 7.76 cUSD/kWh, which is slightly higher than the regulated ceiling price assumed in the base case.





1st stage break-even PPA

SENSITIVITY ANALYSIS ON CAPEX, FULL LOAD HOURS, PPA PRICE AND CONTRACT PERIOD

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Scenario analysis : A scenario analysis is conducted to evaluate the impact on Net Present Value (NPV) when key input assumptions deviate from the base case. The results are presented in a matrix format, illustrating the effects of different combinations of input factors on NPV. The key input factors are CAPEX, Full Load Hours and PPA price.

CAPEX: the estimation of the capital costs is based on figures from the Indonesian Technology Catalogue and developer interviews, but actual project costs could vary largely depending on market conditions, supply chain and real project conditions.

CAPEX is varied from **0.6 to 1.4 mUSD/MW$_{AC}$**. The range selected is the cost range of imported panels (IEA WEO23, average of India and China) and the upper bound of the uncertainty range indicated by the Indonesian Technology Catalogue, all projected to 2025 estimations.

Full Load Hours: Irradiance is used to estimate annual production. Since irradiance is based on modelled data, estimated full load hours and annual production levels are subject to some uncertainty. Annual production is varied between **1,565** and **1,843 Full Load Hours.**

PPA Price: The baseline PPA price follows the ceiling price scheme, adjusted for the location factor of 1.1 for Aceh province. Since PPA processes are competitive, the realized PPA price is likely to be lower than the baseline. Additionally, given the low uptake of renewables in Indonesia, regulatory changes could increase the ceiling price. To account for these uncertainties, a ±10% variation in the PPA price has been assumed for the first 10 years of the contract period.

Contract period: Changing the contract period to 25 or 30 years compared to the baseline of 28 years have marginal impact on the overall feasibility of the project. The payback period remains constant at 8.3 years, indicating that variations in project duration do not affect the timeline for recovering the initial investment. This suggests that early-stage cash flows drive the investment recovery, while later years primarily influence overall profitability.

Net Present Value in selected scenarios [mUSD]

Scenario	1st stage PPA (cUSD/kWh)	Capex (m$/MW)	FLHs AC 1.593	FLHs AC 1.704	FLHs AC 1.815
Low	68,81	0,6	-8	-1	5
		0,8	-34	-27	-19
		1,4	-141	-133	-125
Baseline (-1,2)	76,45	0,6	14	21	29
		0,8	-9	-1	7
		1,4	-113	-103	-93
High	84,10	0,6	26	34	42
		0,8	3	12	21
		1,4	-97	-86	-76

Contract period	NPV	IRR	Payback time
Baseline contract period (28 years)	-1.2mUSD	8.08%	8.3
Shorter contract period (25 years)	-2.5mUSD	7.91%	8.3
Longer contract period (30 years)	-0.6mUSD	8.16%	8.3

SOCIO-ECONOMIC ANALYSIS FOR SOLAR PV

Stock photo ID: 699866378
Location: China

Financial assessment input to the socio-economic assessment

Financial analysis of the 170 MW Solar PV Project in Kuta Cot Glie - Aceh Besar:

The Pre-Feasibility Study (PFS) was elaborated by a consortium consisting of Ea Energy Analyses and Viegand Maagøe, with local support from PT Innovasi, an Indonesian consultancy.

The socio-economic analysis in the following sections is based on project specific input from the PFS; see Ea Energy Analyses, Viegand Maagøe and PT Innovasi. (2024a). For easy reference, these inputs are highlighted in the table below. The socio-economic assessment of the project is based on the data provided in the PFS of the 170 MW Solar PV project but adjusted when appropriate; i.e., taxes paid.

Summary Financial Viability Conclusion of the 170 MW Solar PV Project:

- IRR (real): The internal rate of return is 8.08%, slightly below the weighted average cost of capital (WACC) of 8.23%, indicating that the project does not meet its required rate of return.
- NPV (real): The net present value is negative (-1.2 mUSD), suggesting that the project does not create value and may not be financially feasible under the given assumptions.

The project demonstrates strong energy production and relatively low operational costs. However, with a negative NPV and an IRR below the WACC, it faces financial viability challenges under current assumptions. To make the project more attractive, potential adjustments could include increasing PPA rates, optimizing CAPEX/OPEX, or securing subsidies/incentives.

The conclusion above represents the financial evaluation of the project. This financial conclusion will be further refined and adjusted as part of the subsequent economic cost-benefit analysis.

Table – Summary findings of the 170 MW Solar PV project

Solar power, Kuta Cot Glie	Input
Baseline year	2025
IRR (real)	8.08%
NPV (real)	-1.2 mUSD
Size of project in MW	170
Baseline Capex (USD)	131.3 mUSD
Baseline Opex (USD/y)	1.3 mUSD
Price per MW (USD/MW)	0.77
Initial annual production (GWh/y)	288,232
PPA USD/MWh (y 1-10)	76.45
PPA USD/MWh (y 11-28)	41.70
Real SDR	6.23%
Lifetime LCOE (USD/MWh)	48

Summary of quantitative socio-economic assessment

Socio-economic assessment of the solar PV plant of 170 MW in Kuta Cot Glie:
The data provided in the table to the right offers a financial and socio-economic snapshot of the project. Below is an analysis of the key socio-economic indicators (the last five rows) and their implications:

Economic Net Present Value (ENPV): 207.5 USD million

- The ENPV reflects the project's value to society, considering all socio-economic benefits and costs, discounted at a real social discount rate (SDR) of 6.23%. A positive ENPV of 207.5 USD million indicates that the project generates substantial net economic benefits for society, making it economically viable from a public welfare perspective.

Economic Internal Rate of Return (ERR): 19.2%

- The ERR measures the rate of return on the project's socio-economic investment, considering all externalities. An ERR of 19.2% is significantly higher than the real SDR of 6.23%, indicating robust socio-economic viability.

Benefit-Cost Ratio (B/C-Ratio): 2.36

- The B/C-ratio represents the efficiency of the project in converting costs into benefits. A ratio of 2.36 means that for every 1 USD spent, the project generates 2.36 USD in socio-economic benefits. This ratio exceeds the standard threshold of 1.0, confirming the project's strong justification from an economic perspective.

Summary of Socio-Economic Viability

- Positive Outcomes:
  - The project delivers substantial socio-economic benefits, primarily through carbon emission reductions, energy security, and job creation.
  - The high ERR and B/C-ratio demonstrate the efficiency and strong societal value of the investment.
- Considerations:
  - The project's financial NPV is negative (-1.2 USD million), but its socio-economic value compensates for the financial shortfall.
  - Addressing potential land-use and biodiversity impacts effectively will further enhance the project's social acceptability and environmental sustainability

Table – Summary conclusions of the financial and socio-economic assessment

USD	Aceh - Solar
Baseline or evaluation year	2025
IRR (real)	8.08%
NPV (real)	-1.2 mUSD
WACC	8.23%
Size of project in MW	170
Baseline Capex	131.3 mUSD
Baseline Opex	1.3 mUSD
Price per MW	0.77
Initial annual production (GWh/y)	288,232
PPA USD/MWh (y 1-10)	76.45
PPA USD/MWh (y 11-28)	41.70
Real SDR	6.23%
Lifetime LCOE (USD/MWh)	48
ERR	19.22%
ENPV	207.5 mUSD
ENPV of total benefits	360 mUSD
ENPV of total costs	-152.5 mUSD
B/C-ratio	2.36

ECONOMIC ASSESSMENT – JOB CREATION AND LOCAL ECONOMIC IMPACT

Local Economic Impact: The value of the increase in the economic activity in the main sectors of the investments can be summarized as the indirect effect to the economy. This is also known as the multiplier effect of the investment. The local share of this effect is the local economic impact. The increased economic activity occurs throughout the economy, when the investment in the main sectors obtains input from supporting sectors. For the construction, operation and maintenance of a solar PV plant, the main sectors are assumed to be manufacturing of equipment, construction and land transportation. The most important input sectors to the main sectors in Aceh's economy includes production and processing of raw materials, metal and electronics work, transportation and support functions such as financial services, real estate and government administration.

The local economic impact is summarized in table below.

Table – Local economic impact (USD)

Local economic impact	
Construction (Million USD)	6.43
Annual effect from operation and maintenance (Million USD/year)	0.31

Job creation: A new renewable energy plant will generate jobs to the local community and both during the construction phase and the operating and maintenance phase of the process.

As mentioned earlier, during the construction phase of a utility scale solar PV, workers are needed to manufacture equipment for the panels, transport materials, and install and construct the panels. This effect constitutes the direct effect. The employment model bases the calculation of the direct effect on the CAPEX, and it thus accounts for the jobs created not only during the actual construction, but also the production and transport of the solar PV equipment into account. Additionally, the purchase, transport and construction of the panels will lead to jobs related to the extraction of new raw materials, manufacturing of construction tools, provision of administrative, health and other support to the workforce directly engaged in the construction. This is the indirect effect (15% of which is assumed to be local content ref. Table on p31).

The sum of employment effect for a ground mounted solar PV plant of 170 MW in Kuta Cot Glie is summarized in the table below and the effect over time is highlighted in the figure below.

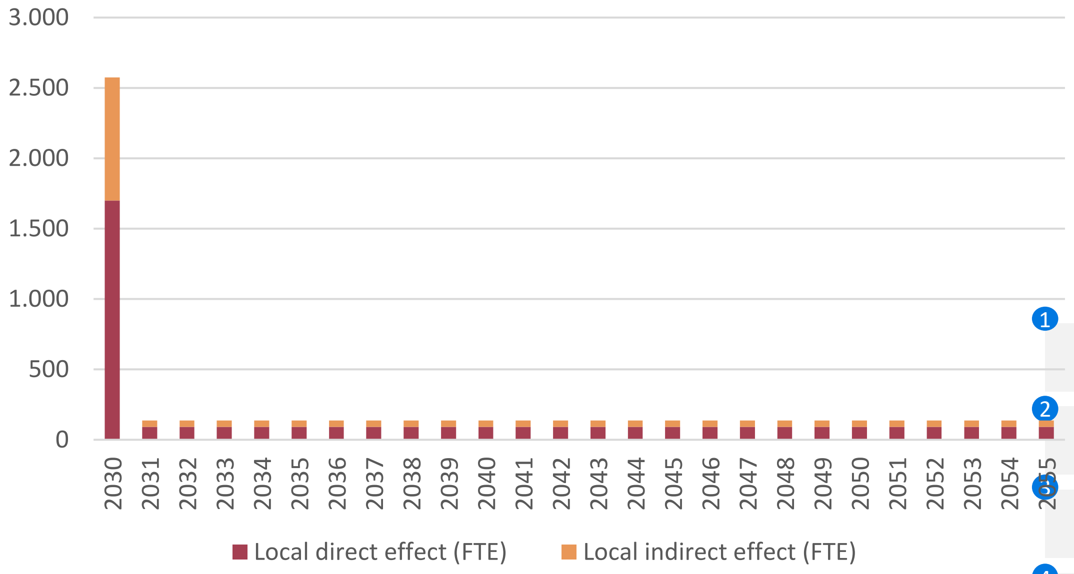

Figure – Local employment effect over time (FTE)

Table – Local direct and indirect employment effect by phase (FTE)

	Local direct effect	Local indirect effect
Construction phase (FTE)	1,700	880
Annual effect from operation and maintenance phase (FTE/year)	90	50

ECONOMIC ASSUMPTIONS UNDERPINNING THE SOCIO-ECONOMIC ASSESSMENT (1)

Assumptions:

Price of CO_2:
It is assumed that the CO_2 tax will start at 4.7 USD per tonne of CO_2 in 2025 and increase annually by 15%, reaching 151 USD per tonne of CO_2 by 2050.

Reduction in CO_2 emissions:
The calculations of CO_2 reductions are based on PLN's documentation, which specifies an emissions factor of 0.817 kg CO_2/kWh in accordance with official figures in State Electricity Company (2019). It is assumed that each kilowatt-hour (kWh) generated by solar PV or wind directly offsets an equivalent kWh that would otherwise be produced by PLN's existing fossil fuel power plants.

In the first year of operation, the solar PV project is projected to generate 288,232 MWh of electricity. Based on PLN's estimated average CO_2 emission factor of 0.817 kg CO2 per kWh for Indonesia, the project will avoid approximately 235,485 tonnes of CO_2 emissions by replacing fossil fuel-based electricity generation. This will contribute to reducing the CO2 intensity of products manufactured in Indonesia, thereby reducing the EU CBAM CO2 tax, and making imports from Indonesia more attractive in Europe.

CO_2 Emissions from Land Clearing in Kuta Cot Glie
The development of the solar PV project in Kuta Cot Glie involves land clearing, contributing to CO_2 emissions due to the removal of vegetation that serves as a natural carbon sink. The land type designated for the solar PV project is savannah, which is zoned as a plantation area under regional spatial planning regulations. Although the site is not a dense forest, the clearing of 170 hectares of vegetation is estimated to release approximately 8,500 tonnes of CO_2, calculated using an emission factor of 50 tonnes of CO_2 per hectare. However, the removal of vegetation also eliminates the annual CO_2 absorption capacity of the area, which are interpreted as a recurring loss of potential sequestration. See Viegand Maagøe and PT Innovasi. (2024a).

Value of Statistical Life (VSL):
In Indonesia, direct estimates of VSL are limited due to the scarcity of comprehensive studies. Various international studies suggest VSL values around 600.000 USD. Data from the Centre for Research on Energy and Clean Air (CREA) and the Institute for Essential Services Reform (IESR) highlight the impact of air pollution in Indonesia.

In 2022, emissions from coal-fired power plants caused 10,500 deaths nationally. The total health cost of these emissions was estimated at USD 7.4 billion; see DataIndonesia. (2023). This implies a VSL value of approximately USD 700,000 which is used in this socio-economic assessment. This value also captures reduced hospital admissions and medical expenses related to air pollution.

Avoided death and health benefits:
The "deaths per MW" metric links energy generation to health impacts. In Aceh, lower population density near coal plants suggests fewer people are exposed to pollutants, warranting an adjusted rate of 0.10 deaths per MW instead of the average for Indonesia of 0.495 deaths per MW. Assuming 50% of the 170 MW capacity replaces coal, while the rest offsets cleaner sources, the calculation is:

Avoided deaths = 0.10 × 85 MW = 8.5 deaths.

Thus, a 170 MW solar PV project in Aceh can prevent approximately 8.5 deaths through partial coal displacement.

Net additional value of increased new employees:
For skilled workers in Aceh, new wages of USD 5,500/year create an additional value of USD 1,500/year compared to previous earnings of USD 4,000/year. For unskilled or semi-skilled labour, the additional value is USD 3,000/year based on previous earnings of USD 2,500/year.

On average, the net additional value of creating one job in Indonesia through renewable energy projects is USD 1,000–5,500/year. Assuming 75% skilled and 25% unskilled workers, the societal value per new employee is approximately USD 1,750/year.

Employment effects:
The 170 MW solar PV project assumes that a total of 2,580 direct and indirect jobs will be created during the construction and preparation phase. This includes direct employment on-site and indirect jobs generated in supporting sectors such as supply chain, transportation, and services. During the operational phase, it is estimated that 140 direct and indirect jobs will be sustained, which include on-site operation and maintenance roles and ongoing support activities in related industries.

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ECONOMIC ASSUMPTIONS UNDERPINNING THE SOCIO-ECONOMIC ASSESSMENT (2)

Assumptions:

Real Social Discount Rate (SDR):

The Social Discount Rate (SDR) is crucial for cost-benefit analyses of public projects, reflecting society's preference for present benefits over future ones. Organisations like the Asian Development Bank and World Bank recommend real SDRs of 6%-9% for developing countries to balance societal preferences and opportunity costs. In Indonesia, the Ministry of Finance estimated a real SDR of 6.19% based on the Social Rate of Time Preference (SRTP) and 6.82% using the Social Opportunity Cost of Capital (SOC).

A midpoint real SDR of 6.23% is deemed appropriate for 2024, aligning with international standards and Indonesia's development goals. This value, 2%-point lower than the WACC used in feasibility studies, ensures public investments are evaluated fairly, prioritising long-term societal benefits.

Fiscal corrections:

Taxes and subsidies are considered transfer payments, meaning they do not represent real economic costs or benefits to society but instead serve to redistribute resources. Therefore, certain adjustments are made to the financial calculations made in the PFS. Value-added tax (VAT) is excluded from input and output prices. Direct and indirect taxes are removed from input prices, and subsidies or public entity transfers, such as tariffs, are excluded from output prices.

Evaluation criteria: ENPV, ERR, and B/C Ratio:

In economic evaluations, particularly within the context of Cost-Benefit Analysis, decision-makers rely on three primary criteria to assess the desirability and feasibility of projects: Economic Net Present Value (ENPV), Economic Rate of Return (ERR), and the Benefit/Cost Ratio (B/C Ratio). Each of these measures provides a distinct perspective on the project's value to society, guiding stakeholders in resource allocation and project prioritisation:

- **1. Economic Net Present Value (ENPV)** measures the net welfare impact of a project by discounting the difference between its total economic benefits and costs. A positive ENPV indicates that the project contributes positively to societal welfare, justifying its implementation.

- **2. Economic Rate of Return (ERR)** evaluates the efficiency of a project by identifying the discount rate at which the project's net benefits (ENPV) become zero. It highlights the project's capacity to generate value relative to its costs.

- **3. Benefit/Cost Ratio (B/C Ratio)** compares the present value of a project's benefits to its costs, offering a straightforward indicator of efficiency. This ratio assists in ranking projects when resources are limited, ensuring that investments yield maximum societal returns.

Summary of Decision Rules for Key Economic Measures:

- The **ENPV** measures the net welfare impact of a project by comparing total discounted social benefits and costs. A positive ENPV indicates societal benefits exceed costs, making the project desirable, while a negative ENPV suggests it should be rejected.

- The **ERR** represents the discount rate at which ENPV equals zero, reflecting the project's efficiency. Projects with an ERR above the social discount rate are considered acceptable.

- The **B/C ratio** compares the present value of benefits to costs. A ratio greater than one indicates economic viability, while a ratio of one or less suggests inefficiency.

Together, these measures evaluate overall welfare (ENPV), efficiency (ERR), and cost-effectiveness (B/C ratio) to assess the project's economic viability.

Sensitivity analysis of socio-economic results (1) - Economic Net Present Value (ENPV)

Overview of Sensitivity Analysis:

The sensitivity analysis evaluates the impact of varying assumptions, such as CO_2 tax, Value of Statistical Life (VSL), emissions intensity, and the real Social Discount Rate (SDR), on key economic metrics. The real Social Discount Rate (SDR) is the rate used to evaluate the present value of future costs and benefits in cost-benefit analysis. It reflects the opportunity cost of capital in society and accounts for the preference for present consumption over future consumption. The real SDR excludes inflation.

ENPV reflects the net societal benefits, while the B/C ratio indicates the project's cost-effectiveness. The analysis helps identify how changes in assumptions influence project viability. The results of the sensitivity tests is presented in the table to the right as well as in the two charts on this and the next slide. Primarily worst-case scenarios have been assessed.

Key findings of sensitivity analysis on the ENPV across scenarios:

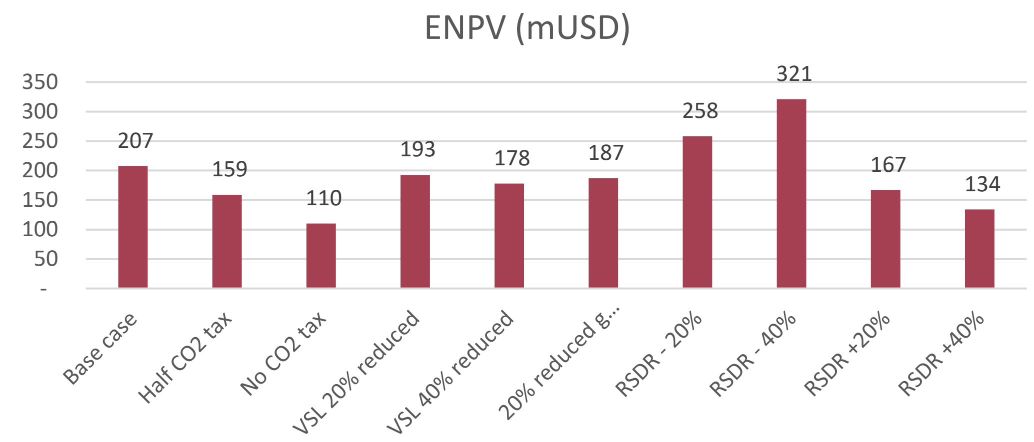

Figure – Sensitivity analysis on the ENPV across scenarios
Note: RSDR in the chart stands for Real Social Discount Rate (SDR)

Table – Summary of sensitivity analyses across scenarios

Scenario	Real SDR (%)	ENPV (million)	B/C Ratio
Base Case	6.23%	207.5	2.36
Half CO2 Tax	6.23%	158.9	2.04
No CO2 Tax	6.23%	110.3	1.72
VSL 20% Reduced	6.23%	192.6	2.26
VSL 40% Reduced	6.23%	177.8	2.17
20% Reduced g CO2/kWh	6.23%	187.3	2.23
Real SDR - 20%	4.99%	257.9	2.67
Real SDR - 40%	3.74%	321.1	3.04
Real SDR + 20%	7.48%	166.8	2.11
Real SDR + 40%	8.72%	133.7	1.90

Sensitivity analysis of socio-economic results (2) – Benefit-Cost Ratio (B/C Ratio)

Key findings of sensitivity analysis:

- **1. CO_2 Tax Variations:** Reducing or removing the CO_2 tax significantly decreases ENPV and B/C ratios, indicating a negative impact on project viability.
- **2. VSL Adjustments:** A 20–40% reduction in VSL moderately lowers ENPV and B/C ratios but retains acceptable viability.
- **3. Reduced Emissions Intensity:** A 20% reduction in g CO_2/kWh shows minimal impact, demonstrating robustness.
- **4. Social Discount Rate (SDR):** Lower SDR values significantly increase ENPV and B/C ratios, while higher SDRs reduce economic desirability.

Overall Conclusion on the Robustness of the Project

The sensitivity analysis demonstrates that the project remains robust under a wide range of assumptions. While variations in CO_2 tax, Value of Statistical Life (VSL), and Social Discount Rate (SDR) impact the Economic Net Present Value (ENPV) and Benefit-Cost Ratio (B/C ratio), the project consistently delivers positive ENPV and a B/C ratio above 1 in most scenarios. This indicates that the project is economically viable and resilient to uncertainties in key parameters.

Lowering or removing the CO_2 tax and increasing the SDR reduces the project's desirability, but the outcomes remain within an acceptable range for decision-making. Additionally, adjustments to VSL and emission factors show minimal effect on the project's economic viability, underscoring its robustness in achieving net societal benefits. Overall, the project is well-positioned to deliver substantial value and remains a strong candidate for investment under varied economic and policy conditions.

Key findings of sensitivity analysis on the B/C ratio across scenarios:

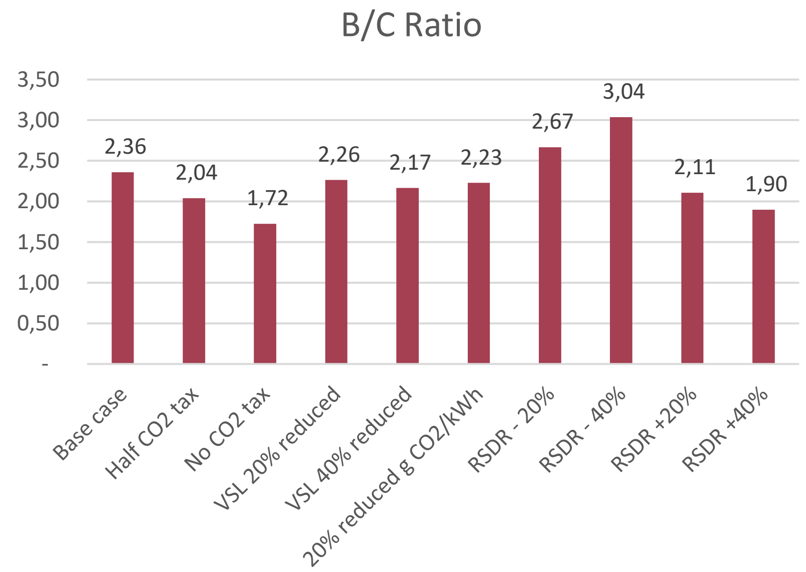

Figure – Sensitivity analysis on the B/C Ratio across scenarios
Note: RSDR in the chart stands for Real Social Discount Rate (SDR)

Social Assessment– Land category, land use and ownership status

Land Category and Land Use*:
The potential Solar PV site is located the Bithatk Village, in the Kuta Cot Glie District. The analysis of land category status shows that in Kuta Cot Glie it is plantation area, dryland- and wetland agriculture, horticulture and production forest, and majority of the area is plantation.

Based of the site visits to the area and interviews with local stakeholders, it is confirmed that most of the areas for solar PV development in Kuta Cot Glie are dry farming areas, plantations and production forests. The agricultural land and plantations in the area are used by the community as rice fields and for ruminant livestock. The designed location for solar power development is privately owned land often used by residents to grow crops as chili, cucumber, and other seasonal vegetables. As majority of local residents are engaged in farming (see also next slide), acquiring this land could affect local livelihoods and it is important to ensure adequate compensation. This would possibly include land for land compensation, or training in alternative livelihoods or employment.

Ownership Status*:
Production forests are managed by companies, but owned by PT Aceh Nusa Indra Puri, and approval for use of the area would need approval from the Ministry of Environment and Forestry.

The different types of horticulture and agriculture in the areas, i.e. plantation, dryland-, wetland agriculture, is managed by the local community, and is either privately owned or owned by the community. Permission to use these areas should be agreed through a sale or rental agreement with the private owners or head of community, as well as address compensation for land and/or livelihoods. Especially because the community in some cases may not have formal ownership, but their livelihoods may depend on using the land for agriculture.

*Table – Land category based on applied regulations in Kuta Cot Glie**

Land Category in RTRW	Actual Land Use	Regency: Kuta Cot Glie	Ownership Status	Notes for RE Development
Plantation Area	Plantation and agriculture	✓	Private or community	Can be used if a sale and purchase or rental agreement is obtained
Dryland Agriculture	Agriculture	✓	Private or community	Can be used if a sale and purchase or rental agreement is obtained
Wetland Agriculture	Agriculture	✓	Private or community	Can be used if a sale and purchase or rental agreement is obtained
Production Forest	Production Forest	✓	All production forest in Aceh belongs to PT Aceh Nusa Indra Puri	It can be used if there is an Approval for Forest Area Use from the Ministry of Environment and Forestry in accordance with Government Regulation No. 23/202
Conversion Production Forest	Production Forest	✓	All production forest in Aceh belongs to PT Aceh Nusa Indra Puri	It can be used if there is an Approval for Forest Area Use from the Ministry of Environment and Forestry in accordance with Government Regulation No. 23/202
Horticulture	Horticulture	✓	Private or community	Can be used if a sale and purchase or rental agreement is obtained

Source: PT Inovasi report

Method:
Initial land analysis was conducted by checking the land zoning status as stated in the published RTRW (Regional Spatial Planning) document for the category of land use. This was validated by checking with the Ministry of Agraria and Land Agency (ATR/BPN) available data at regency level. The land zone can be checked through the website at atr.bpn.go.id that issued by ATR BPN Ministry. The land categories for the regency s showed in the table on the right*. Additionally, field visits and interviews with local stakeholders have been made to check for differences between the real situation and the land use category specified in the RTRW.

*Input from PT Inovasi

SOCIAL ASSESSMENT – COMMUNITY IN THE AREA AND LAND PRICE ESTIMATION

Community in the area:
Kuta Cot Glie is a district located in Aceh Besar Regency with area approximately 332.24 Km2 and includes 32 villages. Some 15,000 people are estimated to live in Kuta Cot Glie. The Kuta Cot Glie district borders Indrapuri District to the north, Aceh Jaya Regency to the south, Indrapuri district and Leupung district to the west, and Seulimuem district and Jantho district to the east. The population is predominantly Acehnese and maintains a blend of traditional and urban lifestyle, with social structure influenced by local customs and Islamic traditions.

A significant portion of the community is young to middle-aged, typically ranging from 15 to 45 years old. Education levels vary, but most residents have completed primary and secondary education, though higher education is pursued by a smaller percentage. Access to higher education is typically through institutions in nearby Banda Aceh.

The economy of Kuta Cot Glie is largely based on agriculture and fishing, small business and trade, as well as construction work in the area. The majority of residents engage in farming, focusing on crops like rice, vegetables, and fruit. Additionally, due to proximity to the coast, fishing remains an important livelihood. Many residents run small shops, food stalls, or engage in local trade, and agro-industry initiatives is growing. Some also travel to construction-related jobs at infrastructural development in the region. Additionally, there is a rising interest in ecotourism and community-based tourism, as Aceh's natural beauty attracts visitors seeking cultural and environmental experiences.

In recent years, there have been government-funded infrastructure projects to improve roads, public facilities, and support economic recovery in Aceh.

Land Price Estimation*:
The land value zone (ZNT) is a standardized land valuation provided by the central government to estimate the market value of land parcels within a defined area. This information is primarily used as a reference for determining non-tax state revenue and is generally lower than the NJOP (Tax Object Sales Value). Based in the value zones provided by the Ministry of Agrarian Affairs and Spatial Planning / National Land Agency /ATR/BPN), the land value in the area is around 200,000-400,000 Rp/m2*.

*Table – Land price estimation**

Regency	Land Value Zone (ZNT) issued by Ministry of ATR/BPN	Interview with local stakeholders
Kuta Cot Glie	Around Rp 200,000 - Rp400,000/m2	Some of the land is owned by communities with non-productive and productive land for dry agriculture

Source: PT Inovasi report

*Input from PT Inovasi

Social assessment– community engagement and indigenous people territory

Community Engagement:

The sub-district head of Kuta Cot Glie and the head village of Bithatk who were interviewed stated that they are aware of renewable energy such as solar panel and generally understand that this is does not harm the environment. They believe this understanding is also shared by the community. However, they lack more detailed knowledge of renewable energy. Basically, the community desires their involvement in the planning to the execution of the development. They believe the development of their area also closely linked to the community development. In general, they are very open and welcome to the development. They believe that any physical development will also support human index development, as long as it is executed with sustainability awareness. Besides, they also ask for information transparency and socialization of the RE development to enhance community understanding on RE and provide adequate support to the development. Additionally, the local organizations in the area Meudaya and WWF Indonesia, emphasized the importance of conducting studies and compiling High Conservation Value, Free, Prior, and Informed Consent documents, as well as documenting the assets of mukim (local people) when moving the project to the next stage. Once the project planning is more mature, it is recommended that an ESIA – Environmental and Social Impact Assessment – is conducted, to ensure that the project risks are managed in alignment with international environmental and social safeguards, such as the IFC Performance Standards for Environmental and Social Sustainability.

Figure – Indigenous People Territory Distribution Map in Aceh Besar (source: PT Inovasi)

Culture and practices:

There is 1 sacred tomb in Bithak Village and a local hero tomb around Kuta Cot Glie. The local community believe this shouldn't be bothered, and the RE development is not expected to have an impact on cultural heritage sites. Other cultural and religious practices (such as kanduri blang, maulid, etc.) are ceremonials and celebrated at a yearly circle, however, will not be affected by local development of renewable energy.

Indigenous People Territory*:

Based on screening of maps from Customary Area Registration Agency (BRWA) of indigenous peoples' areas and the potential locations of the Solar PV site in Kuta Cot Glie, it shows that there are no overlapping areas of classified Indigenous Peoples Territory and the selected site areas (see figure). However, we recommend a throughout analysis of affected communities and livelihoods through an Environmental and Social Impact Assessment (ESIA).

Local institutions and involvement of communities:

As an autonomous region, Aceh has distinct institutions than the rest of Indonesia. Governed under Aceh Provincial Law No. 11 of 2006 and Qanun No. 4 of 2023, there are 68 designated mukim in Aceh Besar, each with defined territorial boundaries under the sub-district level. While mukim structures are adapted from the old sultanate system and play crucial roles in preserving customs, resolving disputes, and managing local resources (e.g., forests, sea, and farming), they are not classified as indigenous people nationally or internationally. However, their involvement is essential in the early stages of development planning, though licensing and land-use authority remain important. For example, there is a position at sub-district level designated as "mukim", and a position at village level called "tuha peut", which would be important to include. These roles act as legislative bodies and assist in resolving conflicts or disputes in the area based on local knowledge. Additionally, there are also individuals entrusted with managing forests (panglima uteun), managing sea-ocean (panglima laot), managing rice farming (kejreun blang), managing land and plantation (peutua seneubok) whose uphold and maintain local rules and mechanisms for each respective fields, which is relevant to include early in the planning process.

ENVIRONMENTAL ASSESSMENT – WILDLIFE, BIODIVERSITY AND NATURAL DISASTER RISK

Wildlife and Biodiversity:

Geographically, the Solar PV site is located in midland area with several uphills. The mountains in this area are part of bukit Barisan mountain range, which stretches along Sumatera Island. interviews with local experts, WWF Indonesia and global mapping data on Protected Areas (WDBA) developed by the Key Biodiversities Area Partnership (KBA), there are no threatened key biodiversity included in the potential locations solar PV in Aceh as shown in the map.

The area of the potential Solar PV site in Aceh is mostly plantations, dry agricultural land, and several production forests. Land acquisition here is not as complex, however, potential environmental impacts must still be considered. Construction of solar PV in this area will require land clearing, which will reduce the area's carbon absorption capabilities and result in the loss of a small part of the working area for farmers and ranchers.

In the area, the Keuliling Reservoir, has been constructed to fulfill the water needs of Banda Aceh and Aceh Besar. It is located in Bak Sukon Village, Cot Glie District, Aceh Besar Regency. The catchment area is 38.20 km², with an average discharge of 1.24 m³/second. Total storage (MAN, EL. + 45.80 m): 18,359,078 m³, Effective storage: 12,992,080 m³.

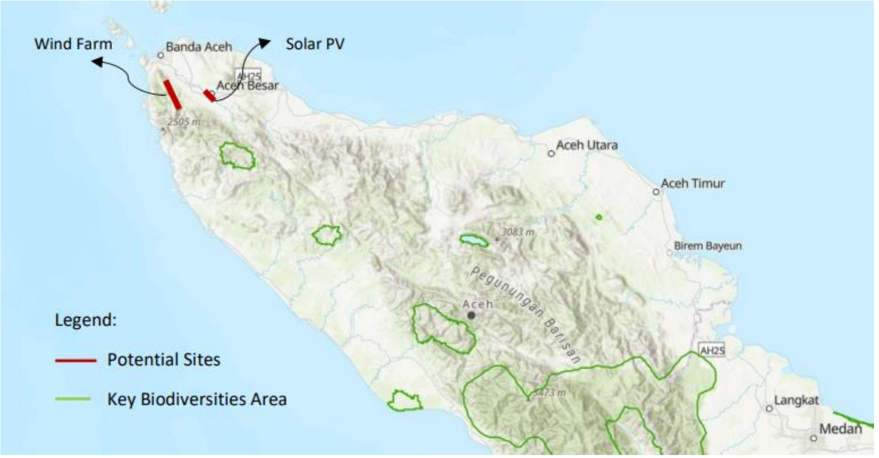

*Figure – Key Biodiversity Areas Map in Aceh Besar**

*Source: https://www.keybiodiversityareas.org**

Natural Disaster Risk:

According to records and data from National Disaster Management Agency (BNPB) Aceh, there is a low risk of natural disasters such as floods, flash floods, extreme waves and tsunamis in the areas. However, there is a moderate risk of drought and the risk for earthquakes is categorized as high.

Of the several potential natural disasters above, the most important to be further identified is the potential for earthquakes. An active fault line is crossing Aceh Besar, and the Solar PV site is approximately 7 km from the active fault. This fault has the potential to provide significant risks to the project, and mitigation measures are relevant to consider, including implementing Earthquake Resistance Planning Procedures for Building Structures. In 2004, Aceh Besar region experiences an earthquake with a magnitude of 9 on the Richter scale and a tsunami that lead to heavy damage.

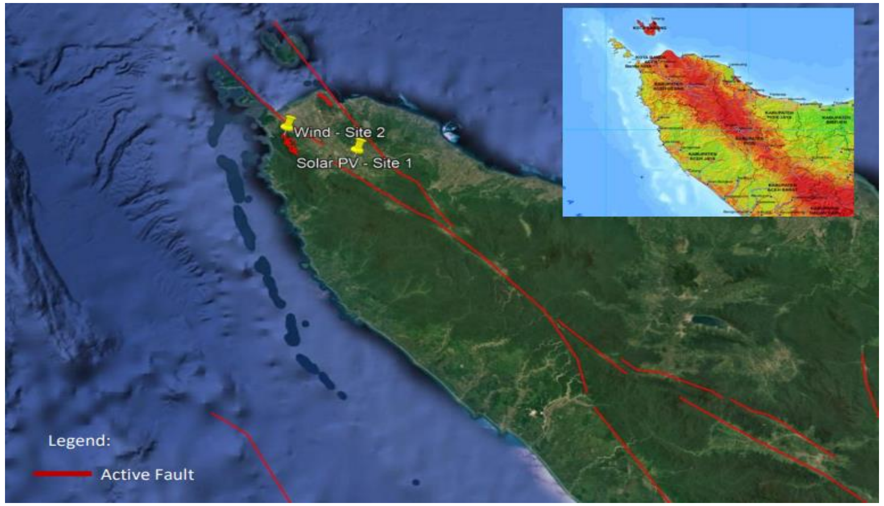

Figure – Identified active fault lines in Aceh Besar

Source: PT Inovasi report / (PUPR)

*Input from PT Inovasi

Environmental assessment- emissions avoided

Emissions avoided:

Reduction in CO_2 Emissions and Land Clearing Impacts

The reduction in CO_2 emissions is calculated using PLN's emissions factor of 0.817 kg CO_2/kWh. Each kWh generated by solar PV offsets the equivalent from fossil fuel power plants. In the first year, the project is expected to generate 288,232 MWh, avoiding approximately 235,485 tonnes of CO_2 emissions.

However, as shown in the figure, power production gradually decreases over time, reducing annual emissions avoided due to the natural degradation of solar PV systems.
The project in Kuta Cot Glie involves clearing 170 hectares of savannah, releasing an estimated 8,500 tonnes of CO_2, based on an emission factor of 50 tonnes per hectare. While these initial emissions partially offset the reductions, the project's long-term environmental benefits remain significant despite the degradation in power production.

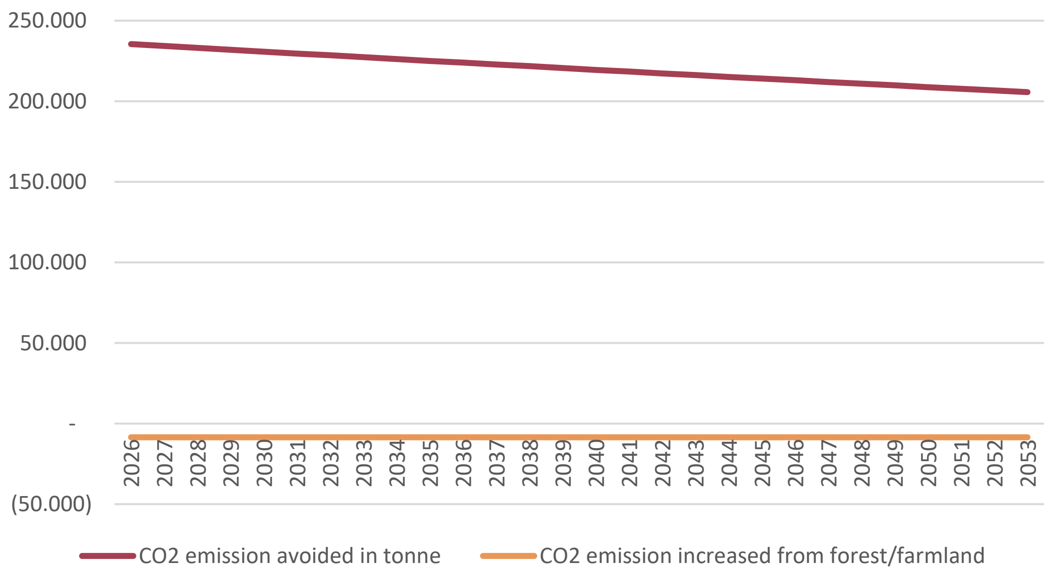

Figure – Emissions avoided tonne CO2 annually

Emissions avoided	Simple sum	NPV
CO_2 emission avoided in tonnes	6,167,217	2,938,606
CO_2 emission increased from forest/farmland	(238,000)	(111,295)
Annual savings in tonnes CO_2 (annuity)		215,933

Table – Sum and NPV of emissions avoided

The table presents a comparison of CO_2 emissions avoided, emissions increased, and annual savings, using both a simple sum and Net Present Value (NPV) approach:

CO_2 Emission Avoided:

The total emissions avoided over the project lifetime amount to 6,167,217 tonnes in the simple sum calculation, but the NPV reduces this figure to 2,938,606 tonnes. The NPV accounts for the time value of reductions, indicating that avoided emissions in later years have less impact in present-value terms.

CO_2 Emission Increased from Land Clearing:

Land clearing contributes to an increase in emissions by 238,000 tonnes (simple sum) or 111,295 tonnes (NPV).

Annual Savings in CO_2 Emissions:

The annual savings in CO_2 emissions are calculated at 215,933 tonnes. This figure highlights the consistent yearly contribution of the project to emissions reduction despite the degradation over time.

Conclusion:

The NPV approach provides a more nuanced view, factoring in the time value of emissions savings, and still demonstrates the project's substantial net environmental benefit.

Summary conclusions and recommendations – 170 MW Solar PV project in Kuta Cot Glie

Summary Conclusions:

1. The 170 MW Solar PV project in Kuta Cot Glie demonstrates strong economic viability, delivering significant positive societal and environmental benefits. The project consistently achieves a positive ENPV and B/C ratio above 1, even under varied sensitivity assumptions.

2. The project is robust, showing resilience to changes in key economic parameters such as CO_2 tax, Value of Statistical Life (VSL), emissions intensity, and the Social Discount Rate (SDR). It offers substantial avoided CO_2 emissions of 235,485 tonnes annually in the first year, making it a critical contributor to Indonesia's renewable energy and climate goals.

3. The project demonstrates strong alignment with Indonesia's long-term energy and climate goals, contributing to the transition away from fossil fuels.

4. Job creation during the construction and operation phases provides direct economic benefits to the local community, fostering regional development:
   - Construction Phase:
     - Local Direct Effect: 1,700 Full-Time Equivalent (FTE) jobs.
     - Local Indirect Effect: 880 FTE jobs.
   - Operation and Maintenance Phase (Annual):
     - Local Direct Effect: 90 FTE jobs per year.
     - Local Indirect Effect: 50 FTE jobs per year.

5. Most of the area is agriculture and plantation used by the community as rice fields and for ruminant livestock. Therefore, usage of the land will likely impact livelihood, and it is important to ensure adequate compensation for the informal and formal usage of the land, to minimize harmful effects.

6. The sub-district head, village head of Bithatk and the community is aware of renewable energy. They are welcoming the development, as long as it's executed with sustainability awareness.

7. The avoided emissions and environmental benefits significantly outweigh the minor CO_2 emissions from initial land clearing, ensuring net positive impacts.

Summary Recommendations:

1. Proceed to detailed feasibility studies to confirm technical and financial assumptions.

2. Once the project is planning to move forward, an Environmental and Social Impact Assessment (ESIA) should be conducted to ensure compliance with international environmental and social safeguards, e.g. IFC Performance Standards for Environmental and Social Sustainability. This is also necessary to secure international funding, which requires justified land acquisition prior to development.

3. Engage with local stakeholders to address land-use considerations and optimize project implementation.

4. Explore policy incentives to secure favourable financial conditions, such as CO_2 pricing mechanisms.

5. Prioritize the project within Aceh's renewable energy development strategy, given its strong socioeconomic impact.

6. Ensure that land clearing and development adhere to environmental best practices to minimize ecological disruption.

7. Develop a robust stakeholder engagement plan to address local concerns, secure community support and locale benefits of the project. Locate and include local stakeholders early in the process, such as the Sub-District level (e.g. Mukim) and village-level (e.g. Tuha Peut).

8. Conduct a comprehensive risk analysis to address uncertainties, particularly around policy changes and CO_2 pricing.

9. Evaluate potential for scaling similar solar projects in other areas of Aceh to maximize renewable energy impact.

10. Prioritize local residents as workers for the project. The community hopes that the construction of the Solar PV will provide significant job opportunities, including the creation of new businesses such as food stalls around the project area to cater to workers.

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Site photos

Drone pictures of potential Solar PV site in Kuta Cot Glie*:






*Input from PT Inovasi

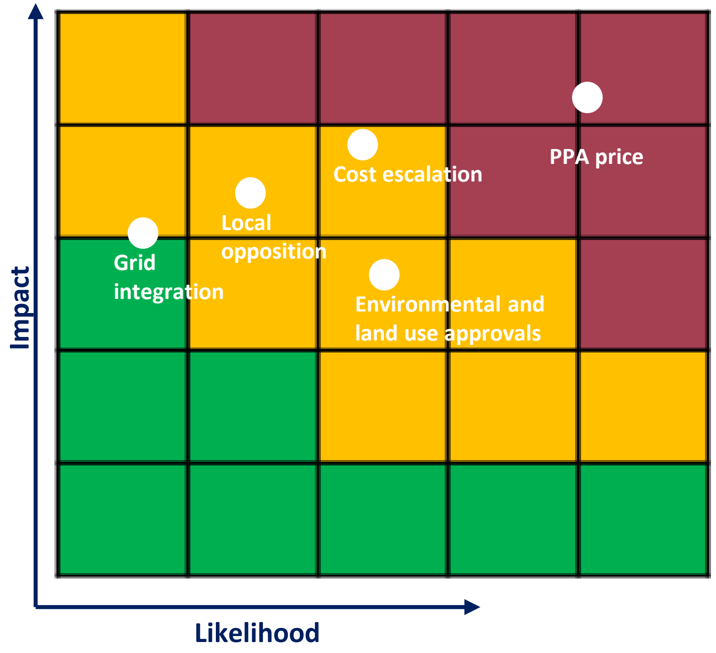
KEY PROJECT RISKS ARE PPA UNCERTAINTY AND COST ESCALATION

Risk log and actions

Risk indicator	Description	Impact	Action
PPA price	Obtaining a PPA price that provides satisfactory returns is subject to high uncertainty, because there is no guaranteed price mechanism as a FiT scheme, why the final PPA price is a result of negotiations with PLN, and PLN is the only offtaker of utility scale PV. Considering previous experience, it is highly unlikely that PLN will accept a price that is higher than the BPP.	PPA price uncertainty have substantial impact on the feasibility of the project, especially since the sale of electricity is the only revenue source of the project.	• Conduct thorough price sensitivity analyses to evaluate the financial impact meeting PLN's acceptable PPA price • Engage in early dialogue with PLN to obtain price indications • Postpone project development until there is more certainty on PPA price settlements. • Abandon the project
Grid integration	The closest substation is the 150 kV Jantho substation around 4.5 km from the site. The availability of the substation is unknown.	Grid integration challenges can result in curtailment and disrupted production, and ultimately it can result in PLN not accepting grid connection at the nearest substation, which could delay or significantly inflate costs.	• Engage with PLN in the early development phase to gain indications of grid availability • Conduct grid impact study • Explore options for adding storage technology
Environmental and land use approvals	The proposed site is classified as production forests, which require forest area approval permits to conduct survey activities. A land use approval and reclassification is also required	There is a risk that approvals for converting production forest land are delayed or cannot be granted for e.g., environmental reasons.	• Engage in early dialogue with the Ministry of Forestry and Environmental planning. • Perform an environmental impact study • Consider alternative locations with good irradiation potentials
Local opposition	Local population might be against the project for reasons related to visual impact, environmental concerns or influence on local economy.	Delayed project development or problems during construction.	• Engage early with the local community • Source local labor in the construction phase • Allocate a share of the budget for local investments in e.g., schools
Costs escalation	Developing renewable energy projects in countries with limited prior experience is subject to costs escalation because there are many unknown factors. For this particular case, there is high uncertainty on local content requirements, which could inflate costs, and the uncertainty on the cost of land.	Costs escalation, particularly if it relates to major budget posts, have a direct impact on the financial feasibility of the project.	• Sign options to lease with landowners to fix land acquisitions costs in the early development phase • Engage with local suppliers to obtain prices for key services and materials, such as clearing of land etc. • Abandon the project

Risk evaluation: The main risk for this project centers on revenue uncertainty, which affects the business case, especially given past challenges in negotiating an acceptable PPA price with PLN. With numerous unknown factors, the likelihood of cost escalations is high. Conducting a thorough cost analysis is essential to developing a realistic PPA proposal and ensuring a financially viable business case.

Risk matrix



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PRE-FEASIBILITY STUDY FOR ONSHORE WIND

Stock photo ID: 699866378
Location: China

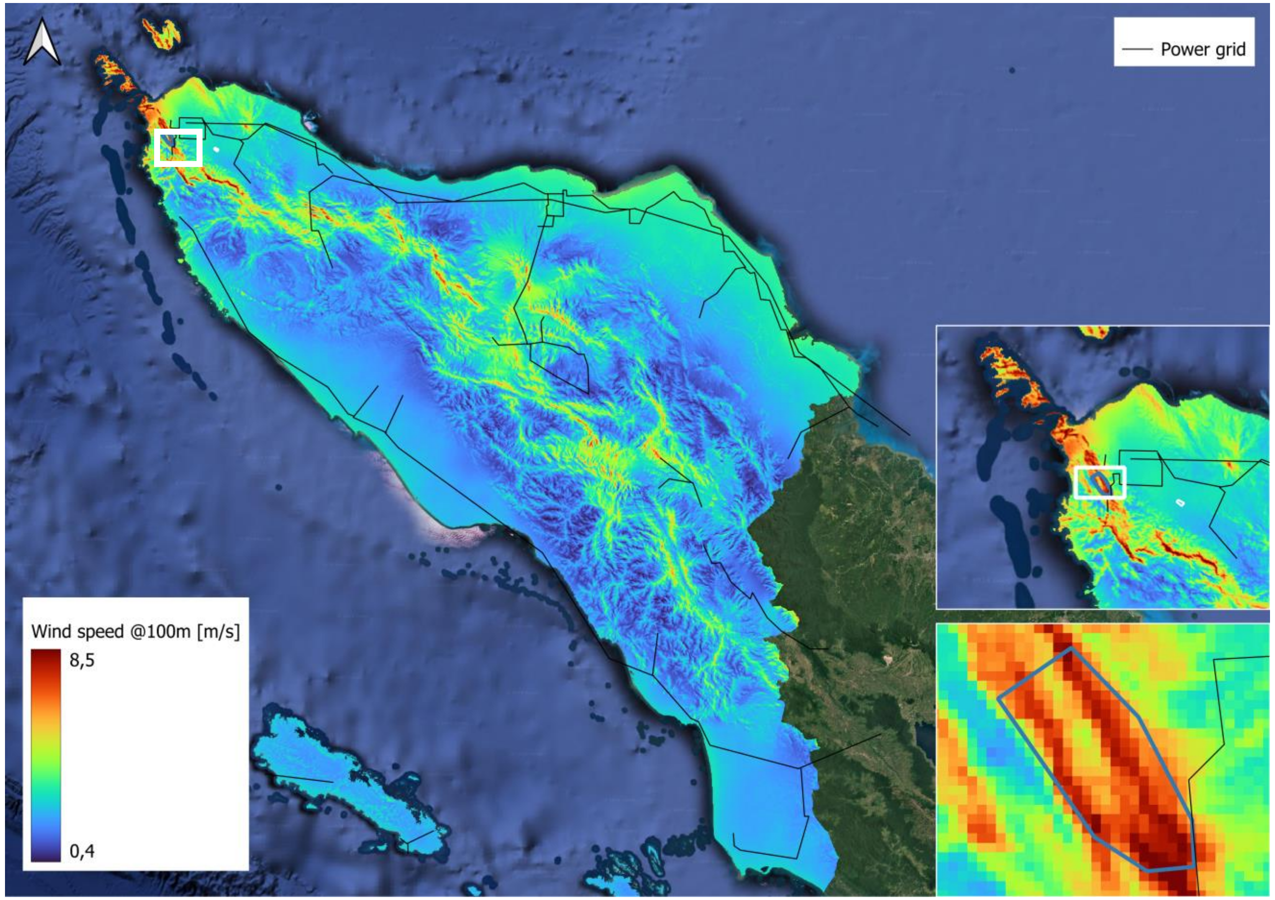
MEAN ANNUAL WIND SPEEDS IN THE PROVINCE ARE BETWEEN >1 AND 8.5 M/S

Wind resource: While the province typically has relatively low average wind speeds, certain locations reach up to 8.5 m/s. The highest wind speeds are found in central Aceh, where elevations can reach 2,500 meters. However, developing wind projects in mountainous areas is often challenging and increases costs. Therefore, onshore wind development is best suited for areas with high wind speeds and closer to ground level. Regions meeting both criteria are located in the northernmost part of Aceh.

Location selection: In the pre-screening of sites, two concrete sites in the Northen part of Aceh where investigated and site visits were conducted. The selected site is split between four districts (Lhoknga, Simpang Tiga, Suka Makmur and Leupung) and was chosen due to the relatively higher wind speed in this area. This site is located approximately 4-5 kilometers from PT Aceh Energi Eoliana, where a planned 60 MW wind turbine project in the nearby Lhoknga area signals favorable wind conditions and opportunities for harvesting synergies. The average mean wind speed of the chosen location is 7 m/s. A 150 KV substation in Banda Aceh is approximately 10 km from the site.

Technology consideration: Given the relatively low nature of wind speeds in the area, a low wind speed turbine technology is considered to maximize the yield from the sites. This type of technology is characterized by larger rotors resulting in low specific power rating, thus producing more power at lower wind speeds. The turbine selected reflects a rotor diameter of 163 m, with a hub height of 150m and a nameplate capacity of 4.5 MW (specific power of 216 W/m^2).

Yield calculations: Using the hourly wind speeds available from Global Wind Atlas and the power curve of the turbine, the calculation of power production results in a FLH value of 3,444 h for the selected area.



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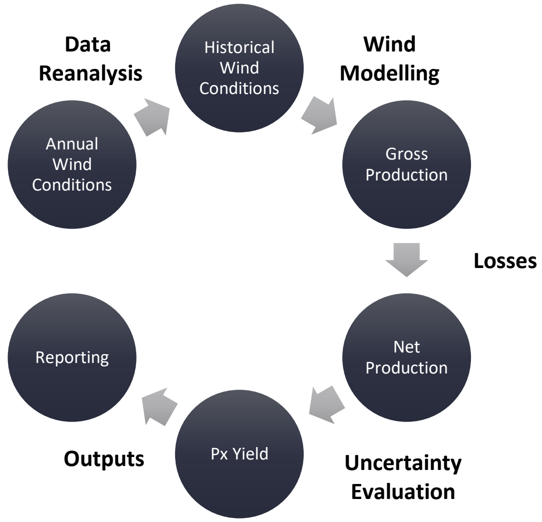
ESMAP & World Bank (2024): Global Wind Atlas

WIND PRODUCTION IS HIGH & UNCERTAIN IN THE AREA: THE P90 VALUE IS 2,910 FLH

Wind resource assessment: Starting from the hourly wind data and the power curve of the turbine deployed (163m rotor diameter, 123m height, 4.5MW), a resource assessment including uncertainty evaluation is carried out to calculate the P50, P75 and P90 values. The assessment is representative for an average weather year in the vicinity of the chosen area and is based on wind resource mapping undertaken by the Technical University of Denmark (DTU) under the umbrella of the Global Wind Atlas.



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

- **Gross production**: assessment of average generation from the wind turbine, based on its power curve, using mesoscale data;
- **Net production**: application of systematic operational losses (standard value of 10% considered);
- **P50, P75, P90**: Consideration of uncertainty factors (table below) on production and calculation of confidence level on annual energy production.

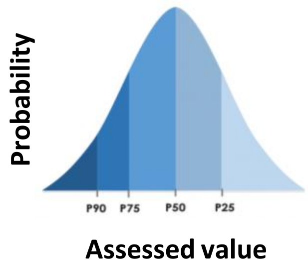
Considered Uncertainty Factors on annual energy production (AEP)			
On Wind Speed → On AEP*		On AEP	
Wind uncertainty (2-5%)	3.50 → 4.55%	Power Curve (5-10%)	7.50%
Long Term Adjustment (1-3%)	2.00 → 2.60%	Metering (0-5%)	2.50%
Vertical Extrapolation (0-5%)	2.50 → 3.25%	Wake Effects (0-5%)	2.50%
Horizontal Extrapolation (0-5%)	2.50 → 3.25%	Technical Losses (0-2%)	1.00%
		Air Density (0-2%)	1.00%

** Sensitivity factor of 1.3 dAEP/dWS assumed for the conversions between wind speed and AEP uncertainties.*

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

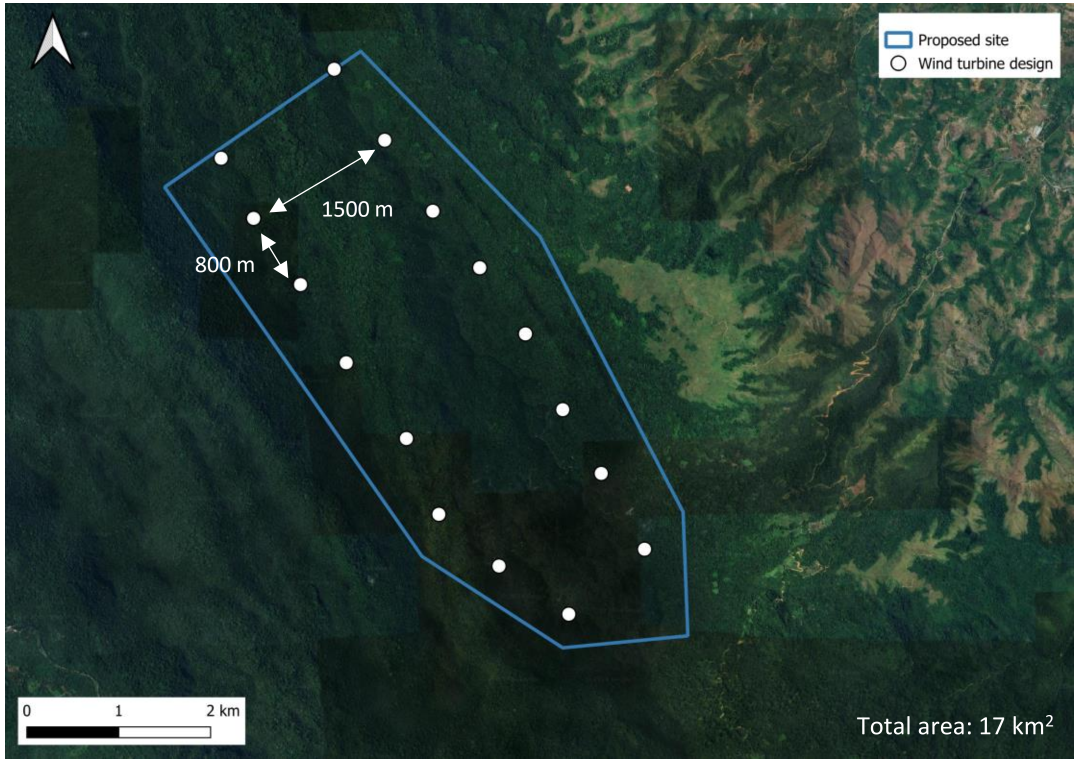
Resulting values: The final net P50 yield for the assessed 72 MW wind farm corresponds to **248 GWh/y** (**3,444 FLH**), consisting the central estimate utilised in the Business Case ahead. At a later stage of the project, when financing needs to be secured, a P90 generation level frequently consists the preferred indicator by financial institutions since it entails a significantly higher revenue certainty. The P90 level for the present case corresponds to 327.4 GWh/y (2,910 FLH).

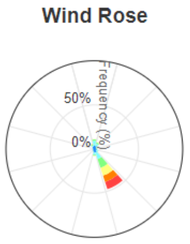
Value Level	Description	FLH Confidence	AEP Confidence [GWh/y]
$P50_{value}$	Value based on the already considered uncertainty within the calculated model	3,444	248
$P75_{value}$	$P50_{value} * (1 - P75_{uncertainty})$	3,163	228
$P90_{value}$	$P50_{value} * (1 – P90_{uncertainty})$	2,910	210

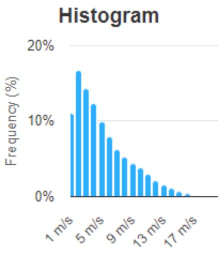


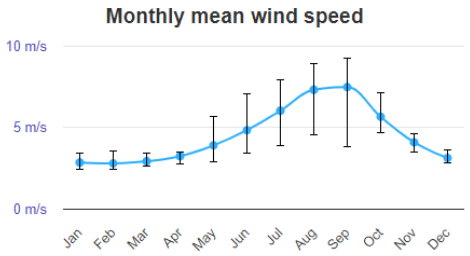
ESMAP & World Bank (2024): Global Wind Atlas, MEASNET (2016)

A POTENTIAL LOCATION IN ACEH BESAR REGENCY IS SELECTED









ESMAP & World Bank (2024): Global Wind Atlas

Siting considerations: Wind resource is a key criterion when selecting sites for onshore wind development, as it forms the foundation of the project's feasibility. Other important considerations include infrastructure conditions, as well as the availability and proximity of grid networks capable of absorbing additional power generation. Lastly, zoning and land ownership can significantly impact permitting processes and project economics.

Location details : The proposed site is located in Aceh Besar regency and spans across four districts: Lhoknga, Simpang Tiga, Suka Makmur and Leupung. The nearest 150 kV sub-station (Banda Aceh) is located 10 km from the site. Most of the site is located on hill tops and the slope of the site is between 15-35 degrees. Elevation ranges between 800 and 1500 meters above ground level. Moreover, the site is situated about 12-16 kilometers from Ulee Lheue Port and approximately 8 kilometers from the Lhoknga import-export port. Though accessible by provincial roads, entry to the site is limited to two- and four-wheeled vehicles due to the rough dirt road, which is only about 4-5 meters wide. This will impact logistics and necessitate road widening and improvements for easier access.

Land zoning and costs: The site is categorized as primary dryland forest, and as outlined in Regional Regulation No. 4 of 2013 concerning the Aceh Besar Regency RTRW, the site is located within a protected forest area. While this land can be utilized for the development of onshore wind (PLTB), it requires approval from the Ministry of Environment and Forestry.

To estimate the initial land price, we can refer to the ZNT (Land Value Zone) data. ZNT is a standardized land valuation provided by the central government to estimate the market value of land parcels within a specific area. Due to its proximity to Banda Aceh city and Lhoknga, land prices in this area are notably high, reaching up to Rp1,000,000 per square meter, which could substantially increase project costs.

Spacing requirements: The spacing requirement depends on the turbine design, defined as the number of turbines, hub height and rotor diameter. In this study it is assumed that the distance between the wind turbines is 5 times the rotor diameter in the dominant wind direction and 9 times the rotor diameter in the non-dominant wind direction. This enable us to locate 16 wind turbines within the proposed area. With a nameplate capacity of 4.5 MW, the total capacity of the site is 72 MW.

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TECHNO-ECONOMIC DATA USED FOR THE BUSINESS CASE

Technical features	
Capacity	72 MWe
Technical lifetime	28 years
Plant availability	99.7%
Space requirements	14,000 m²/MWe
Capacity factor	39% (3,344 FLH)
Construction time	1.5 years

Economic features	
CAPEX	1.56 M$/MWe
Fixed OPEX	40,427 $/MWe-year*
DEVEX	5%
WACC (real)	8.23%
Expected PPA	Year 1 to 10: 10.5 cUSD/kWh Year 11 to 28: 5.73 cUSD/kWh
Corporate tax rate	22.0%
Depreciation rate	20% declining balance across lifetime
Inflation rate (USD)	2.00%

FID and COD: The assumed final investment decision (FID) is 2025 and the commercial operation date (COD) is 2026 with construction undertaken between 2025 and 2026.

Land cost: The fixed O&M costs mostly constitute the cost of land assuming the land is leased.

The land prices in the area could potentially by up to 1,000,000 Rp/m2 (63 USD/m2). But is likely lower in the parts of the area away from Banda Aceh. A general cost of land for Indonesia is included in the CAPEX of the project. A variation in the cost of land is analysed in the sensitivity analysis by changing the CAPEX.

Reference to existing wind power plants

Sidrap Wind Turbine plant (PLTB)
PLTB-Sidrap I, with a **construction year** dating back to **2015** and a COD of 2018, required an **investment of 150 mUSD** for a total capacity of 75MW, bringing the unit cost of investment up to **2.00 mUSD/MW**.

Tolo Wind Turbine plant (PLTB)
PLTB-Tolo I, went public in November 2019, while **construction** works started **in 2018.** A lump sum of **125 mUSD** reflect the **total investment costs**, rising the overall unit cost of investment up to **2.23 mUSD/MW**.

Others
While both of the aforementioned projects consist the 1st phases of each respective plan, second phases are already being planned. The **anticipated future capital costs** for the next phase of the former are **1.8 mUSD/MW**, according to the Ministry of Energy and Mineral Resources. However, this also includes storage technologies, pushing the CAPEX upwards.
Another recent project of 150 MW in Sukabumi, expected for completion in 2024, is anticipated to cost 3.3. trillion IDR (231 mUSD) corresponding to an investment cost of roughly **1.54 mUSD/MW**.

Figures reflect the projected 2025 data (beginning of construction) in real 2023 price levels, according to the Danish Energy Agency's Technology Catalogue for the Indonesian Power Sector (2024).

BASED ON THE BASELINE ESTIMATIONS, THE SELECTED ONSHORE WIND PROJECT IS PROFITABLE, WITH AN IRR OF 10.44%

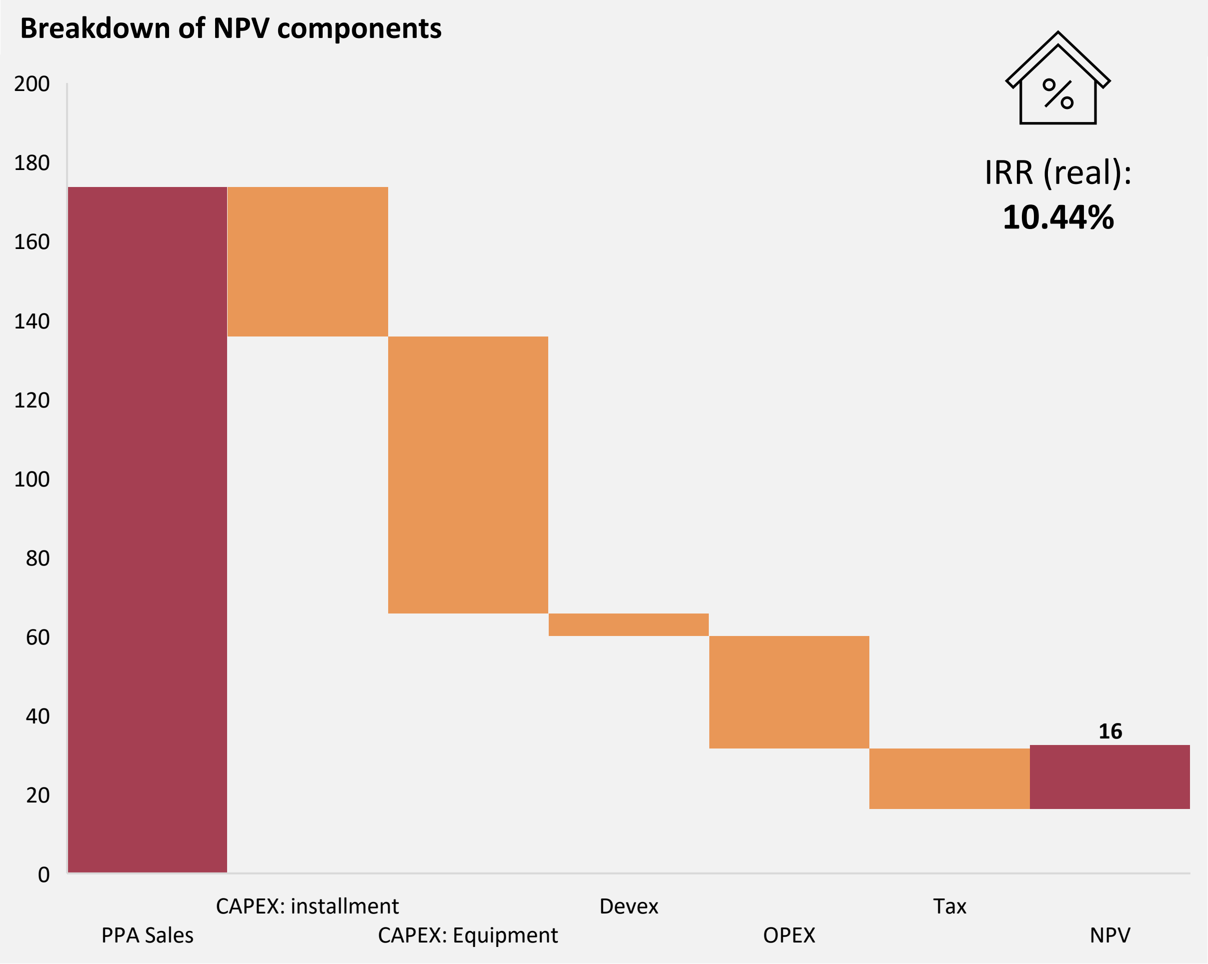
Results: The business case for a 72 MW onshore wind plant in Aceh is positive based on baseline assumptions, with a Net Present Value (NPV) of 16 mUSD and a real Internal Rate of Return (IRR) of 10.44%.

Costs: The cost of equipment and installation constitutes the majority of project costs. Changes in market conditions such as increased local content requirements or supply chain disruptions could drive up project costs and worsen overall project feasibility.

Other costs include development costs, taxes, and operating expenses, though these represent a smaller share of the project's cash flow. Development costs, however, tend to be less predictable, especially in markets with limited experience. Factors such as permitting and land clearing could significantly increase development costs, raising their overall share of total project expenditures.

Revenue: To offset project costs, a stable source of revenue must be secured. For this project, the sale of electricity is assumed to be the sole revenue source why certainty on PPA contract terms and price levels are important.

Following the ceiling price scheme, the net present value of the PPA sales accumulates to 174 mUSD assuming a 28-year contract period.



Note: 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 1ST STAGE'S BREAK-EVEN PPA PRICE FOR THE WIND PROJECT IS 8.8 CUSD/KWH

1st stage PPA price: The first stage of the PPA term is the most critical determinant of project feasibility due to discounting effects. Therefore, the agreed initial PPA price plays a pivotal role in the business case evaluation.

Several factors create uncertainty regarding the potential PPA level expected by investors in an onshore wind project in Aceh, including:

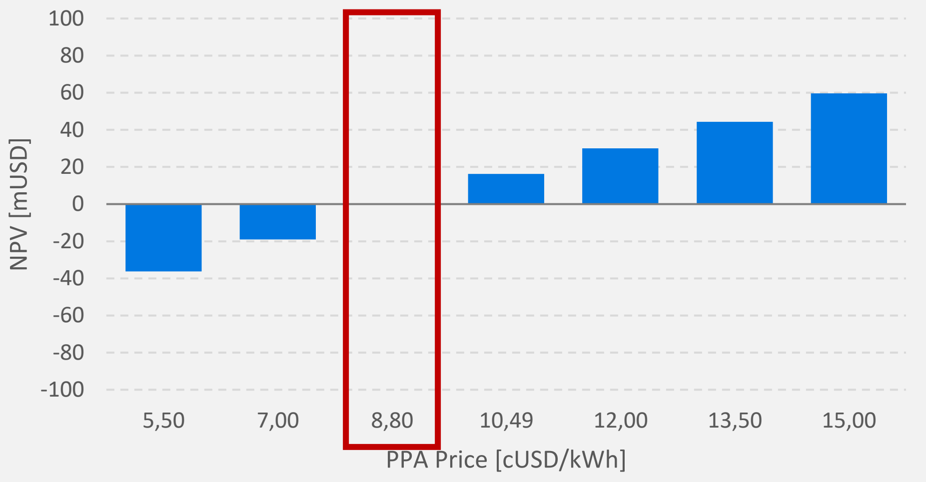
- The regional BPP and how it compares to the ceiling price set by presidential regulation.
- Competitively low bids from other investors, particularly in projects benefiting from financial advantages such as lower financing costs or reduced CAPEX.

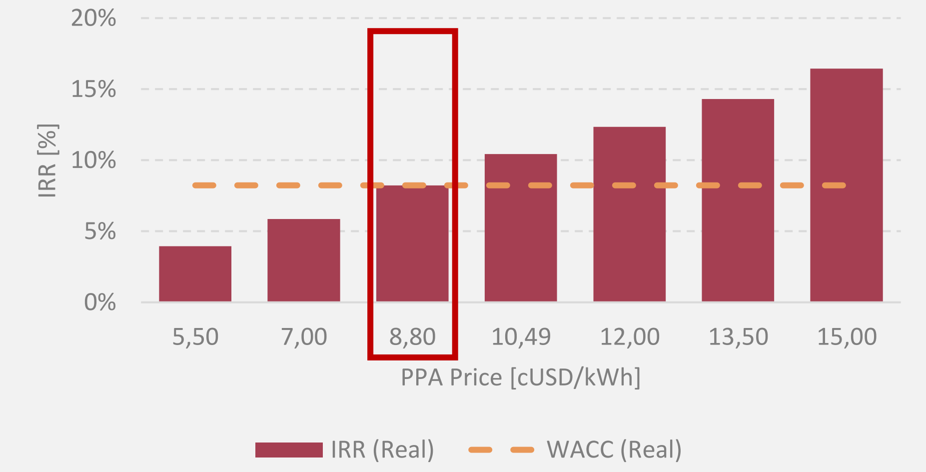
Given these factors, it is crucial to determine the minimum first-stage PPA price that enables the project to break even, ensuring an IRR equal to the expected real WACC (8.23%) and an NPV of zero. It effectively represents the bid value an investor might propose in an auction or negotiation to develop the solar project while securing returns in line with the expected WACC.

Break-even PPA price: The break-even PPA price is the PPA price for the first 10 years, which returns an NPV of 0 and an IRR that equals the cost of capital (WACC).

The break-even price for this case in an all-things equal scenario is 8.8 cUSD/kWh.

Break-even PPA (1st stage) for the wind project





1st stage break-even PPA

SENSITIVITY ANALYSIS ON CAPEX, FULL LOAD HOURS, PPA PRICE AND CONTRACT PERIOD

Scenario analysis : A scenario analysis is conducted to evaluate the impact on Net Present Value (NPV) when key input assumptions deviate from the base case. The results are presented in a matrix format, illustrating the effects of different combinations of input factors on NPV. The key input factors are CAPEX, Full Load Hours and PPA price.

CAPEX: the estimation of the capital costs is based on figures from the Indonesian Technology Catalogue and developer interviews, but actual project costs could vary largely depending on market conditions, supply chain and real project conditions.

CAPEX is varied from 1.1 **to 2.2 mUSD/MW,** corresponding to a range of -31% to +37% of the reference assumption.

Full Load Hours: Irradiance is used to estimate annual production. Since irradiance is based on modelled data, estimated full load hours and annual production levels are subject to some uncertainty. Annual production is varied between **3,163** and **3726 Full Load Hours.**

PPA Price: The baseline PPA price follows the ceiling price scheme, adjusted for the location factor of 1.1 for Aceh province. Since PPA processes are competitive, the realized PPA price is likely to be lower than the baseline. Additionally, given the low uptake of renewables in Indonesia, regulatory changes could increase the ceiling price. To account for these uncertainties, a ±10% variation in the PPA price has been assumed for the first 10 years of the contract period.

Contract period: Changing the contract period to 25 or 30 years compared to the baseline of 28 years have marginal impact on the overall feasibility of the project. The payback period remains constant at 9 years, indicating that variations in project duration do not affect the timeline for recovering the initial investment. This suggests that early-stage cash flows drive the investment recovery, while later years primarily influence overall profitability.

Net Present Value in selected scenarios [mUSD]

Low

1st stage PPA (cUSD/kWh)	Capex (m$/MW)	FLHs AC 3.163	FLHs AC 3.444	FLHs AC 3.726
94,45	1,1	-13	-5	2
	1,6	-43	-35	-27
	2,2	-89	-80	-72

Baseline

1st stage PPA (cUSD/kWh)	Capex (m$/MW)	FLHs AC 3.163	FLHs AC 3.444	FLHs AC 3.726
104,94	1,1	31	42	53
	1,6	-19	16	27
	2,2	-35	-23	-12

High

1st stage PPA (cUSD/kWh)	Capex (m$/MW)	FLHs AC 3.163	FLHs AC 3.444	FLHs AC 3.726
115,43	1,1	41	53	65
	1,6	15	26	37
	2,2	-24	-12	-1

Contract period	NPV	IRR	Payback time
Baseline contract period (28 years)	16.3 mUSD	10.44%	9
Shorter contract period (25 years)	15 mUSD	10.32%	9
Longer contract period (30 years)	16.9 mUSD	10.49%	9

SOCIO-ECONOMIC ANALYSIS FOR ONSHORE WIND

Stock photo ID: 699866378
Location: China

Financial assessment input to the socio-economic assessment

Financial analysis of the 72 MW onshore wind project in Lhoknga - Aceh Besar:
The PFS were elaborated by a consortium consisting of Ea Energy Analyses and Viegand Maagøe, with local support from PT Innovasi, an Indonesian consultancy.

The socio-economic analysis in the following sections is based on project specific input from the PFS. For easy reference, these inputs are highlighted in the table to the right. The socio-economic assessment of the project is based on the data provided in the PFS of the 72 MW onshore wind project but adjusted when appropriate; i.e., taxes paid.

Summary Financial Viability Conclusion of the 72 MW onshore wind project:

- IRR (real): The internal rate of return is 10.44%, above the weighted average cost of capital (WACC) of 8.23%, indicating that the project meet its required rate of return.
- NPV (real): The net present value is positive (16.3 mUSD), suggesting that the project creates value and are financially feasible under the given assumptions.

The project demonstrates strong energy production and relatively low operational costs. However, with a positive NPV and IRR above the WACC, it faces no financial viability challenges under current assumptions. To make the project more attractive, potential adjustments could include increasing PPA rates, optimizing CAPEX/OPEX, or securing subsidies/incentives.

The conclusion above represents the financial evaluation of the project. This financial conclusion will be further refined and adjusted as part of the subsequent economic cost-benefit analysis.

Table – Summary findings of the 72 MW onshore wind project:

Wind power, Lhoknga	Input
Baseline year	2025
IRR (real)	10.44%
NPV (real)	16.3 mUSD
Size of project in MW	72
Baseline Capex (USD)	112.2 mUSD
Baseline Opex (USD/y)	2.9 mUSD
Price per MW (USD/MW)	1.56
Initial annual production (GWh/y)	247,990
PPA USD/MWh (y 1-10)	105
PPA USD/MWh (y 11-28)	57.30
Real SDR	6.23%
Lifetime LCOE (USD/MWh)	52.95

SUMMARY OF QUANTITATIVE SOCIO-ECONOMIC ASSESSMENT

Socio-economic assessment of the 72 MW onshore wind project in Lhoknga:
The data provided in the table to the right offers a financial and socio-economic snapshot of the project. Below is an analysis of the key socio-economic indicators (the last five rows) and their implications:

Economic Net Present Value (ENPV): 144 USD million

- The ENPV reflects the project's value to society, considering all socio-economic benefits and costs, discounted at a real social discount rate (SDR) of 6.23%. A positive ENPV of 144 USD million indicates that the project generates substantial net economic benefits for society, making it economically viable from a public welfare perspective.

Economic Internal Rate of Return (ERR): 18.1%

- The ERR measures the rate of return on the project's socio-economic investment, considering all externalities. An ERR of 18.1% is significantly higher than the real SDR of 6.23%, indicating robust socio-economic viability.

Benefit-Cost Ratio (B/C-Ratio): 2.0

- The B/C-ratio represents the efficiency of the project in converting costs into benefits. A ratio of 2.0 means that for every 1 USD spent, the project generates 2.0 USD in socio-economic benefits. This ratio exceeds the standard threshold of 1.0, confirming the project's strong justification from an economic perspective.

Summary of Socio-Economic Viability

- Positive Outcomes:
    - The project delivers substantial socio-economic benefits, primarily through carbon emission reductions, energy security, and job creation.
    - The high ERR and B/C-ratio demonstrate the efficiency and strong societal value of the investment.
- Considerations:
    - The project's financial real NPV is positive (16.3 USD million), and its socio-economic value increases the financial benefits significantly.
    - Addressing potential land-use and biodiversity impacts effectively will further enhance the project's social acceptability and environmental sustainability.

Table – Summary conclusions of the financial and socio-economic assessment

mUSD	Aceh - Wind
Baseline or evaluation year	2025
IRR (real)	10.44%
NPV (real)	16.3 mUSD
WACC	8.23%
Size of project in MW	72
Baseline Capex	112.2 mUSD
Baseline Opex	2.9 mUSD
Price per MW	1.56
Initial annual production (GWh/y)	247,990
PPA USD/MWh (y 1-10)	105
PPA USD/MWh (y 11-28)	57.30
Real SDR	6.23%
Lifetime LCOE (USD/MWh)	52.95
ERR	18.05%
ENPV	144 mUSD
ENPV of total benefits	293.3 mUSD
ENPV of total costs	-149.3 mUSD
B/C-ratio	1.96

Economic assessment – Job creation and local economic impact

Local Economic Impact: The value of the increase in the economic activity in the main sectors of the investments can be summarized as the indirect effect to the economy. This is also known as the multiplier effect of the investment. The local share of this effect is the local economic impact. The increased economic activity occurs throughout the economy, when the investments in the main sectors obtain input from supporting sectors. For the construction, operation and maintenance of an onshore wind farm, the main sectors are assumed to be manufacturing of equipment, construction and land transportation. The most important input sectors to the main sectors in Aceh's economy includes production and processing of raw materials, metal and electronics work, transportation and support functions such as financial services, real estate and government administration.

The local economic impact is summarized in table below

Table – Local economic impact (USD)

Local economic impact	
Construction (Million USD)	8.15
Annual effect from operation and maintenance (Million USD/year)	0.64

Job creation: A new renewable energy plant will generate jobs to the local community and both during the construction phase and the operating and maintenance phase of the process.

As mentioned earlier, the construction phase of an onshore wind site, workers are needed to manufacture equipment for the turbines and foundation, transport materials, and install and construct the wind farm. This effect constitutes the direct effect. The employment model bases the calculation of the direct effect on the CAPEX, and it thus accounts for the jobs created not only during the actual construction, but also the production and transport of the wind farm equipment. Additionally, the production transport and construction of the plants will lead to jobs related to the extraction of new raw materials, manufacturing of construction tools, provision of administrative, health and other support to the workforce directly engaged in the construction. This is the indirect effect

The following figure highlights the employment effects for an onshore wind power site of 72 MW in Lhoknga over time and the sum of employment effect is summarized in the following table.

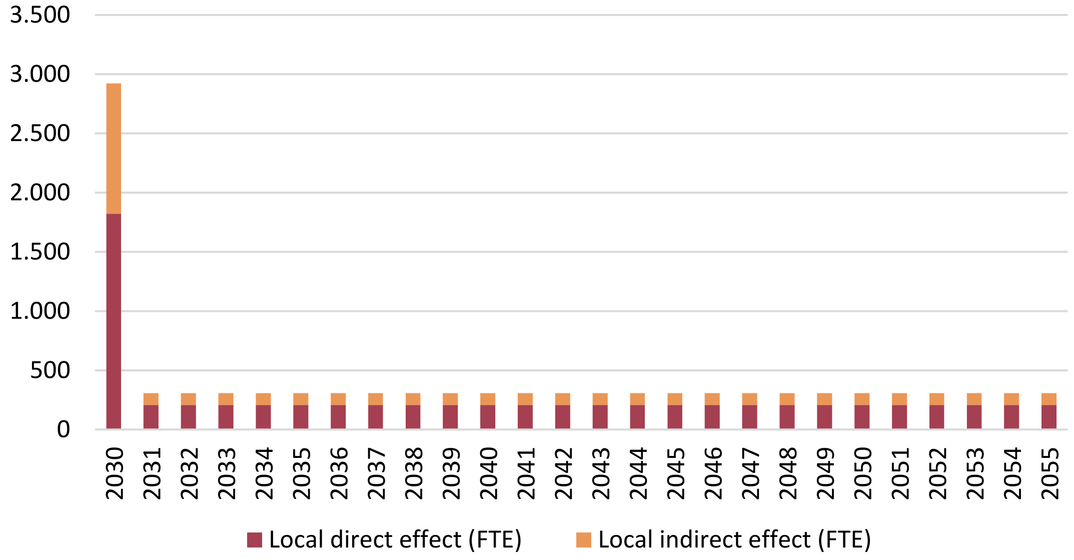


Figure – Local employment effect over time (FTE)

Table – Local direct and indirect employment effect by phase (FTE)

	Local direct effect	Local indirect effect
Construction phase (FTE)	1,820	1,100
Annual effect from operation and maintenance phase (FTE/year)	200	100

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

ECONOMIC ASSUMPTIONS UNDERPINNING THE SOCIO-ECONOMIC ASSESSMENT (1)

Assumptions:

Price of CO_2:

It is assumed that the CO_2 tax will start at 4.7 USD per tonne of CO_2 in 2025 and increase annually by 15%, reaching 151 USD per tonne of CO_2 by 2050.

Reduction in CO_2 emissions:

The calculations of CO_2 reductions are based on PLN's documentation, which specifies an emissions factor of 0.817 kg CO_2/kWh. It is assumed that each kilowatt-hour (kWh) generated by solar PV or wind directly offsets an equivalent kWh that would otherwise be produced by PLN's existing fossil fuel power plants.

In the first year of operation, the wind project is projected to generate 247,990 MWh of electricity. Based on PLN's estimated CO_2 emission factor of 0.817 kg CO2 per kWh for Indonesia, the project will avoid approximately 202,608 tonnes of CO_2 emissions by replacing fossil fuel-based electricity generation.

CO_2 Emissions from Land Clearing in Lhoknga

The development of the onshore wind project in Lhoknga involves land clearing within a protected forest area, contributing to CO_2 emissions due to the removal of vegetation that acts as a natural carbon sink. The site is classified as a protected forest under regional spatial planning regulations, which, although permitted for renewable energy development, poses significant environmental challenges.

The clearing of 1,200 hectares of forest vegetation for the wind farm is estimated to release approximately 60,000 tonnes of CO_2, calculated using an emission factor of 50 tonnes of CO_2 per hectare. These emissions represent a necessary trade-off for the project's renewable energy benefits, but their environmental impact underscores the need for stringent mitigation and reforestation efforts to offset the carbon loss and preserve biodiversity in the area. However, the removal of vegetation also eliminates the annual CO_2 absorption capacity of the area, which are interpreted as a recurring loss of potential sequestration.

Assumptions:

Value of Statistical Life (VSL):

In Indonesia, direct estimates of VSL are limited due to the scarcity of comprehensive studies. Various international studies suggest VSL values around 600.000 USD. Data from the Centre for Research on Energy and Clean Air (CREA) and the Institute for Essential Services Reform (IESR) highlight the impact of air pollution in Indonesia. In 2022, emissions from coal-fired power plants caused 10,500 deaths nationally. The total health cost of these emissions was estimated at USD 7.4 billion. This implies a VSL value of approximately USD 700,000 which is used in this socio-economic assessment. This value captures also reduced hospital admissions and medical expenses related to air pollution.

Avoided death and health benefits:

The "deaths per MW" metric links energy generation to health impacts. In Aceh, lower population density near coal plants suggests fewer people are exposed to pollutants, warranting an adjusted rate of 0.10 deaths per MW instead of the average for Indonesia of 0.495 deaths per MW. Assuming 50% of the MW capacity replaces coal, while the rest offsets cleaner sources, the calculation is:

Avoided deaths = 0.10 × 36 MW = 3.6 deaths.

Thus, a 72 MW onshore wind project in Aceh can prevent approximately 3.6 deaths through partial coal displacement.

Net additional value of increased new employees:

For skilled workers in Aceh, new wages of USD 5,500/year create an additional value of USD 1,500/year compared to previous earnings of USD 4,000/year. For unskilled or semi-skilled labour, the additional value is USD 3,000/year based on previous earnings of USD 2,500/year.

On average, the net additional value of creating one job in Indonesia through renewable energy projects is USD 1,000–5,500/year. Assuming 75% skilled and 25% unskilled workers, the societal value per new employee is approximately USD 1,750/year.

ECONOMIC ASSUMPTIONS UNDERPINNING THE SOCIO-ECONOMIC ASSESSMENT (2)

Assumptions:

Employment effects:

The 72 MW onshore wind project assumes that a total of 2,920 direct and indirect jobs will be created during the construction and preparation phase. This includes direct employment on-site and indirect jobs generated in supporting sectors such as supply chain, transportation, and services. During the operational phase, it is estimated that 300 direct and indirect jobs will be sustained, which include on-site operation and maintenance roles and ongoing support activities in related industries.

Real Social Discount Rate (SDR):

The real Social Discount Rate (SDR) is crucial for cost-benefit analyses of public projects, reflecting society's preference for present benefits over future ones. Organisations like the Asian Development Bank and World Bank recommend real SDRs of 6%-9% for developing countries to balance societal preferences and opportunity costs. In Indonesia, the Ministry of Finance estimated a real SDR of 6.19% based on the Social Rate of Time Preference (SRTP) and 6.82% using the Social Opportunity Cost of Capital (SOC).

A midpoint real SDR of 6.23% is deemed appropriate for 2024, aligning with international standards and Indonesia's development goals. This value, 2%-point lower than the WACC used in feasibility studies, ensures public investments are evaluated fairly, prioritising long-term societal benefits.

Fiscal corrections

Taxes and subsidies are considered transfer payments, meaning they do not represent real economic costs or benefits to society but instead serve to redistribute resources. Therefore, certain adjustments are made to the financial calculations made in the PFS. Value-added tax (VAT) is excluded from input and output prices. Direct and indirect taxes are removed from input prices, and subsidies or public entity transfers, such as tariffs, are excluded from output prices.

The proposed solar PV and wind projects can be seen as pilots for the sector development in Indonesia and their implementation will bring important capacity building and skills development, both for construction and operation phases.

Assumptions:

Evaluation criteria: ENPV, ERR, and B/C Ratio:

In economic evaluations, particularly within the context of Cost-Benefit Analysis, decision-makers rely on three primary criteria to assess the desirability and feasibility of projects: Economic Net Present Value (ENPV), Economic Rate of Return (ERR), and the Benefit/Cost Ratio (B/C Ratio). Each of these measures provides a distinct perspective on the project's value to society, guiding stakeholders in resource allocation and project prioritisation.

- **1. Economic Net Present Value (ENPV)** measures the net welfare impact of a project by discounting the difference between its total economic benefits and costs. A positive ENPV indicates that the project contributes positively to societal welfare, justifying its implementation.

- **2. Economic Rate of Return (ERR)** evaluates the efficiency of a project by identifying the discount rate at which the project's net benefits (ENPV) become zero. It highlights the project's capacity to generate value relative to its costs.

- **3. Benefit/Cost Ratio (B/C Ratio)** compares the present value of a project's benefits to its costs, offering a straightforward indicator of efficiency. This ratio assists in ranking projects when resources are limited, ensuring that investments yield maximum societal returns.

Summary of Decision Rules for Key Economic Measures

- The **ENPV** measures the net welfare impact of a project by comparing total discounted social benefits and costs. A positive ENPV indicates societal benefits exceed costs, making the project desirable, while a negative ENPV suggests it should be rejected.

- The **ERR** represents the discount rate at which ENPV equals zero, reflecting the project's efficiency. Projects with an ERR above the social discount rate are considered acceptable.

- The **B/C ratio** compares the present value of benefits to costs. A ratio greater than one indicates economic viability, while a ratio of one or less suggests inefficiency.

Together, these measures evaluate overall welfare (ENPV), efficiency (ERR), and cost-effectiveness (B/C ratio) to assess the project's economic viability.

Sensitivity analysis of socio-economic results (2) - Economic Net Present Value (ENPV)

Overview of Sensitivity Analysis of the 72 MW onshore wind project in Lhoknga:
The sensitivity analysis evaluates the impact of varying assumptions, such as CO2 tax, Value of Statistical Life (VSL), emissions intensity, and the real Social Discount Rate (SDR), on key economic metrics. The real SDR is the rate used to evaluate the present value of future costs and benefits in cost-benefit analysis. It reflects the opportunity cost of capital in society and accounts for the preference for present consumption over future consumption. The real SDR excludes inflation.

ENPV reflects the net societal benefits, while the B/C ratio indicates the project's cost-effectiveness. The analysis helps identify how changes in assumptions influence project viability. The results of the sensitivity tests is presented in the table to the right as well as in the two charts on this slide and the next. Primarily worst-case scenarios have been assessed.

Key findings of sensitivity analysis on the ENPV across Scenarios:

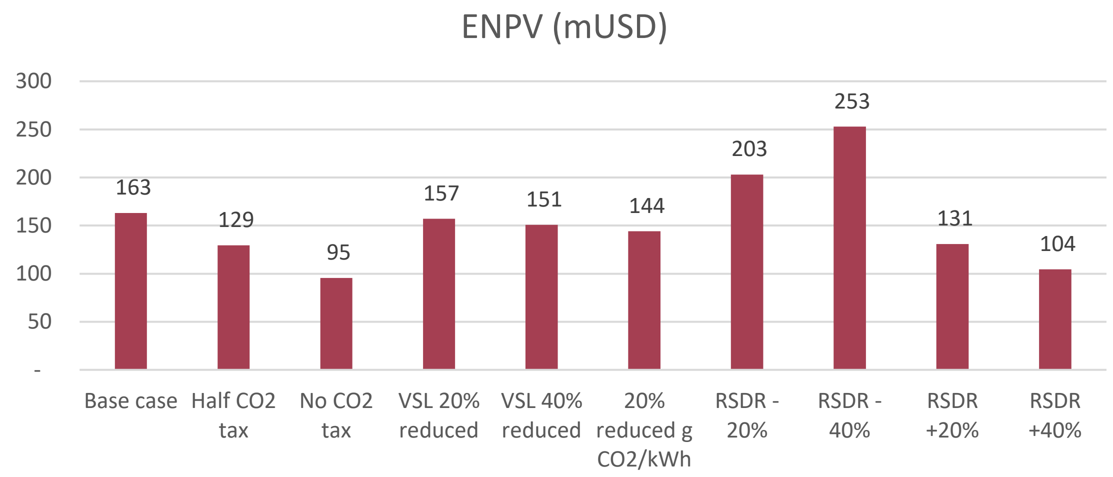


Figure – Sensitivity analysis on the ENPV across scenarios
Note: RSDR in the chart stands for Real Social Discount Rate (SDR)

Table – Summary of sensitivity analyses across scenarios

Scenario	Real SDR (%)	ENPV (million USD)	B/C Ratio
Base Case	6.23%	163.1	2.09
Half CO2 Tax	6.23%	129.3	1.87
No CO2 Tax	6.23%	95.4	1.64
VSL 20% Reduced	6.23%	157.0	2.05
VSL 40% Reduced	6.23%	150.9	2.01
20% Reduced g CO2/kWh	6.23%	144.0	1.96
Real SDR - 20%	4.99%	203.0	2.31
Real SDR - 40%	3.74%	252.7	2.56
Real SDR + 20%	7.48%	130.8	1.91
Real SDR + 40%	8.72%	104.4	1.74

Sensitivity analysis of socio-economic results (2) – Benefit-Cost Ratio (B/C Ratio)

Key findings of sensitivity analysis:

- **1. CO2 Tax Variations:** Reducing or removing the CO_2 tax significantly decreases ENPV and B/C ratios, indicating a negative impact on project viability.
- **2. VSL Adjustments:** A 20–40% reduction in VSL moderately lowers ENPV and B/C ratios but retains acceptable viability.
- **3. Reduced Emissions Intensity:** A 20% reduction in g CO_2/kWh shows minimal impact, demonstrating robustness.
- **4. Real Social Discount Rate (SDR):**
    - Lower real SDR values significantly increase ENPV and B/C ratios, enhancing economic viability
    - Higher real SDR values reduce economic desirability but maintain viability.

Overall Conclusion on the Robustness of the Project

The sensitivity analysis demonstrates that the project remains robust under a wide range of assumptions. While variations in CO_2 tax, the VSL, and the SDR impact the ENPV and the B/C ratio, the project consistently delivers positive ENPV and a B/C ratio above 1 in most scenarios. This indicates that the project is economically viable and resilient to uncertainties in key parameters.

Lowering or removing the CO_2 tax and increasing the real SDR reduces the project's desirability, but the outcomes remain within an acceptable range for decision-making. Additionally, adjustments to VSL and emission factors show minimal effect on the project's economic viability, underscoring its robustness in achieving net societal benefits.

Key findings of sensitivity analysis on the B/C ratio across scenarios:

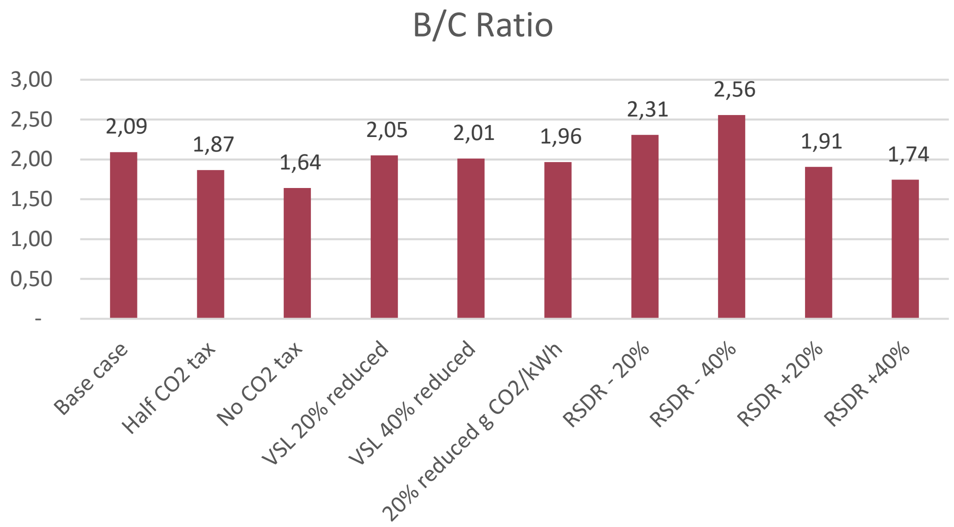


Figure – Sensitivity analysis on the B/C Ratio across scenarios
Note: RSDR in the chart stands for Real Social Discount Rate (SDR)

SOCIAL ASSESSMENT– LAND CATEGORY, LAND USE AND OWNERSHIP STATUS

Land Category and Land Use:

The chosen wind site spans across four districts: Lhoknga, Simpang Tiga, Suka Makmur and Leupung. As shown in the upper right-hand table, the potential area for Onshore Wind Site in Lhoknga is categorized as protected Forest. Interviews with local stakeholders confirm that the area is only forest.

According to Indonesian regulations, development can still be carried out in protected forests, although it will have some complexity in land acquisition, as well as social, economic and environmental impacts must be carefully considered (see also Wildlife and Biodiversity, slide 32). Protected Forest status allows local communities to use the area for plantations and timber collection. In these instances, an assessment of impact on livelihood needs to be conducted. Power generation, transmission and distribution of electricity, and the application of renewable energy technologies are permitted in these areas, when this is 'unavoidable,' under certain conditions.

Ownership Status:

The forest is owned by the Forest Agency or Perhutani, and use of the area needs approval from the Ministry of Environment and Forestry*.

Method:

Initial land analysis was conducted by checking the land zoning status as stated in the published RTRW (Regional Spatial Planning) document for the category of land use. This was validated by checking with the Ministry of Agraria and Land Agency (ATR/BPN) available data at regency level. The land zone can be checked through the website at atr.bpn.go.id that issued by ATR BPN Ministry*. Additionally, field visits and interviews with local stakeholders have been made to check for differences between the real situation and the land use category specified in the RTRW.

*Table – Land category based on applied regulations at the Wind Power site**

Land Category in RTRW	Actual Land Use	Regency: Lhoknga	Ownership Status	Notes for RE Development
Protected Forest	Protected Forest	✓	Forest Agency or Perhutani	It can be used if there is an Approval for Forest Area Use from the Ministry of Environment and Forestry in accordance with Government Regulation No. 23/2021

Source: PT Inovasi report

Land Price Estimation*:

Based on the interview with local stakeholders, data was obtained regarding land market prices in the area around the development as shown in the table below. Based in the value zones provided by the Ministry of Agrarian Affairs and Spatial Planning / National Land Agency /ATR/BPN), the land value in the area is can reach up to 1,000,000 Rp/m2*. Meanwhile in Naga Umbang Village the land value is Rp. 100,000/m2, showing that the price of each location vary depends on its accessibility.

*Table – Land price estimation**

Regency	Land Value Zone (ZNT) issued by Ministry of ATR/BPN	Interview with local stakeholders
Lhokgna	Could reach up till Rp 1,000,000/m	- For areas that are a bit further in, the land price will be cheaper than the price mentioned. - In Naga Umbang Village the land value is Rp. 100,000/m2,

Source: PT Inovasi report

*Input from PT Inovasi

SOCIAL ASSESSMENT – COMMUNITY IN THE AREA AND LAND PRICE ESTIMATION

Community in the area:

Lhoknga and Leupung are located on the coast of Aceh Besar. Employment in these areas spans several sectors. In coastal regions like Lhoknga and Leupung, fishing and aquaculture are primary sources of livelihood. Additionally, these areas have seen growth in tourism and hospitality, driven by interest in surfing, eco-tourism, and natural attractions. The entire coastline is a beach tourism area, with some locations also used for surfing. One village in Lhoknga, Naga Umbang, also utilizes its natural potential in the areas as a tourist destination collectively managed by the village. In the mountainous region of Suka Makmur, there are paragliding and camping areas. Additionally, there is pool area that is often visited by locals during weekends.

In more rural areas like Suka Makmur and Simpang Tiga, agriculture is the dominant sector, with a focus on rice farming, vegetables, and cash crops. Small businesses, local markets, and trade support household incomes across all these regions. In the Lhoknga area, there is also a state-owned cement company, PT. Solusi Bangun Andalas, which are providing jobs in construction and manufacturing for local communities.

The communities in the Lhoknga, Simpang Tiga, Suka Makmur, and Leupung areas of Aceh Besar Regency, Indonesia, reflect a rich blend of tradition and emerging modern opportunities. The population is predominantly Acehnese, with strong family ties and Islamic customs shaping daily life. Residents are generally young to middle-aged, typically ranging between 15 and 50 years old. Educational attainment varies, with most completing primary to secondary education, though access to higher education is improving, particularly near urban centers.

In recent years, significant industrial and infrastructural developments have taken place, including road construction, school improvements, and coastal protection projects. The Leupung District and Lhoknga District was heavily impacted by the 2004 tsunami, leading to rebuilding efforts that reshaped its demographics and economy. Several villages around Lhoknga also receive Corporate Social Responsibility (CSR) funds to support community social activities.

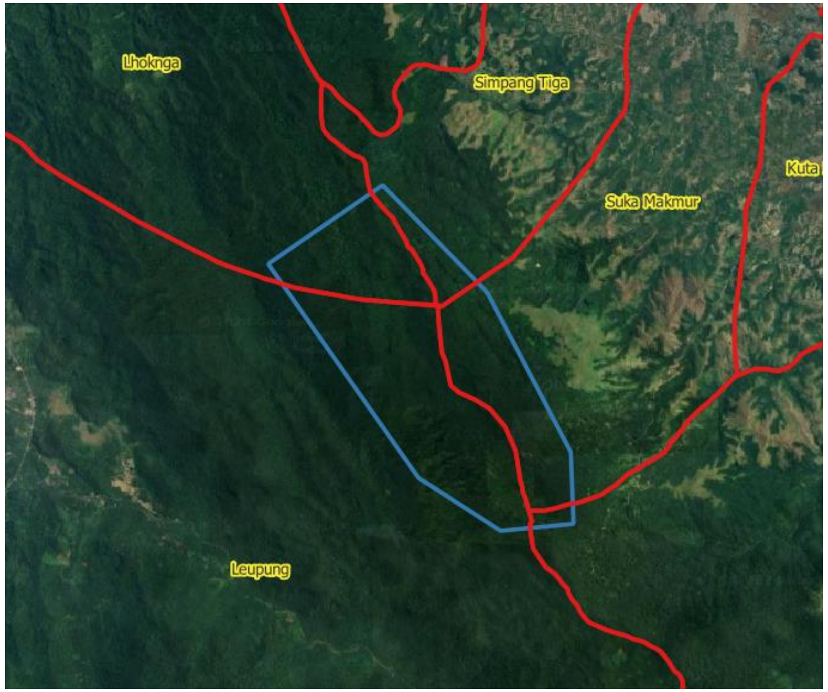


Figure – Onshore Wind site location spanning across four districts

Source: VM / EA Pre-feasibility report

*Input from PT Inovasi

SOCIAL ASSESSMENT– COMMUNITY ENGAGEMENT AND INDIGENOUS PEOPLE TERRITORY

Community Engagement:

According to the interviews conducted with several communities, village governments, and subdistrict governments, they overwhelmingly support, accept and approve of the deployment of wind turbines in their regions. The primary reason for this reaction is because of the potential boost in employment and labor force absorption opportunities. Enhancements to the local economy using local products, labor force, and utilizing local suppliers were also expected. The local organizations in the area Meudaya and WWF Indonesia, emphasized the importance of conducting studies and compiling High Conservation Value, Free, Prior, and Informed Consent documents, as well as documenting the assets of mukim (indigenous people). Once the project planning is more mature, it is recommended that an ESIA – Environmental and Social Impact Assessment – is conducted, to ensure that the project risks are managed in alignment with international environmental and social safeguards, such as the IFC Performance Standards for Environmental and Social Sustainability.

Indigenous People Territory*:

Based on screening of maps from Customary Area Registration Agency (BRWA) of indigenous peoples' areas and the potential locations of the Wind site in Lhoknga, it shows that there are no overlapping areas of classified Indigenous Peoples Territory and the selected site areas (see figure below).

*Figure – Indigenous People Territory Distribution Map in Aceh Besar**

Source: BRWA and PT Inovasi report

*Input from PT Inovasi

Local impacts of Renewable Energy:

Interviews with the Naga Umbang village secretary revealed community expectations for knowledge transfer and job opportunities from potential wind energy projects. Meudaya stakeholders echoed these sentiments, emphasizing the importance of community rights, improved electricity access, and workforce involvement based on Aceh Besar's renewable energy experiences. They also seek better infrastructure and opportunities to develop wind farm-based tourism. The Aceh Department of Energy and Mineral Resources highlighted the potential for wind turbines in Lhoknga, about 20 km from Syiah Kuala University, to attract tourists and boost the local economy. Nearby educational institutions, including Politechnik Aceh, could support workforce development through technical education in engineering, IT, electronics, and mechatronics, aligning with project benefits.

Culture and practices:

In the area there is one mass grave for tsunami victims, one historical mosque tourism site of the tsunami, and several tombs that are considered sacred by the local community. Other cultural and religious activities (such as Kenduri Blang and Maulid) are carried out as ceremonial events at specific times. The development of energy infrastructure appears to not interfere with these practices.

Local institutions and involvement of communities:

As an autonomous region, Aceh has distinct institutions than the rest of Indonesia. Governed under Aceh Provincial Law No. 11 of 2006 and Qanun No. 4 of 2023, there are 68 designated mukim in Aceh Besar, each with defined territorial boundaries under the sub-district level. While mukim structures are adapted from the old sultanate system and play crucial roles in preserving customs, resolving disputes, and managing local resources (e.g., forests, sea, and farming), they are not classified as indigenous people nationally or internationally. However, their involvement is essential in the early stages of development planning, though licensing and land-use authority remain important. For example, there is a position at sub-district level designated as “mukim”, and a position at village level called “tuha peut”, which would be important to include. These roles act as legislative bodies and assist in resolving conflicts or disputes in the area based on local knowledge. Additionally, there are also individuals entrusted with managing forests (panglima uteun), managing sea-ocean (panglima laot), managing rice farming (kejreun blang), managing land and plantation(peutua seneubok) whose uphold and maintain local rules and mechanisms for each respective fields, which is relevant to include early in the planning process.

Environmental assessment – wildlife, biodiversity and natural disaster risk

Wildlife and Biodiversity:

Geographically, mountains in this areas are part of bukit Barisan range and consist of karst formations. Karst mountains are not solid as regular soil. The designated coordinate are located in mountainous area with high tree density which will require land clearing and higher cost to build access road. Therefore, if wind development is pursued, a comprehensive study is necessary to assess the required depth of foundation excavation for wind turbines in the karst area and to evaluate whether the construction costs are justified given the potential risks involved.

Protected Forest Areas are generally designated to protect the condition of the forest, to maintain and protect ecological functions such as watersheds, flood prevention, erosion control, and maintaining soil fertility. At the location of wind farm development in Lhoknga which has land status as Protected Forest, it can have an impact on the environment, flora and fauna and biodiversity in it. From the global mapping data on Protected Areas (WDBA) developed by the Key Biodiversities Area Partnership (KBA), there are no threatened key biodiversity included in the potential locations for wind development. Although Indonesian regulations allow for wind farms in protected forests, the protected status and presence of species of concern can make international funding difficult. International funding for development in protected forests is not given lightly*.

The development of wind projects should ensure that biodiversity is protected, conserved, and that sustainable management and use of natural resources are implemented wherever possible throughout the project lifecycle. In general, the construction of wind farms will have the potential to have direct impacts, such as collisions between animals and birds with wind turbine blades, as well as indirect impacts through habitat disturbance.

Natural Disaster Risk:

Aceh Besar is located on the active Semangko fault which stretches for more than 1.900 km along the island of Sumatra. An active fault line is crossing Aceh Besar, and the Wind site is approximately 7 km from the active fault. The movement of the fault has the potential to cause tsunamis, and Lhoknga and Leupung are vulnerable areas. This fault also has the potential to provide significant risks to the project, and mitigation measures are relevant to consider, including implementing Earthquake Resistance Planning Procedures for Building Structures. There is a moderate risk of drought.

*Input from PT Inovasi

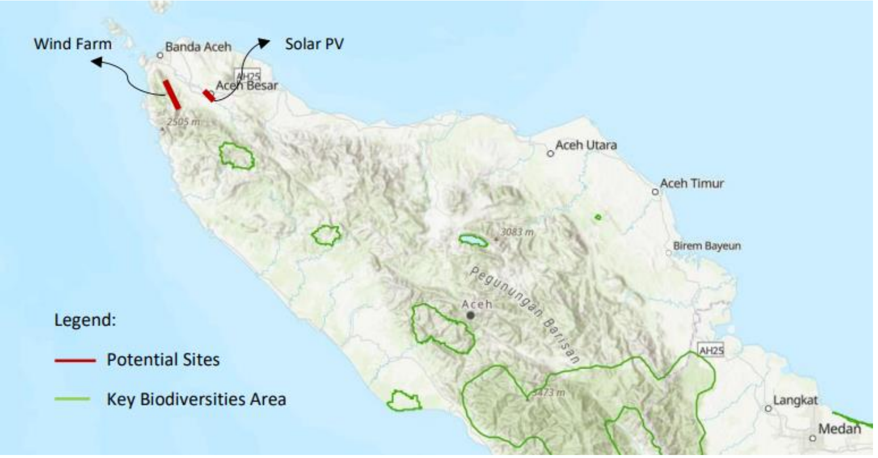


*Figure – Key Biodiversity Areas Map in Aceh Besar**

*Source: https://www.keybiodiversityareas.org**

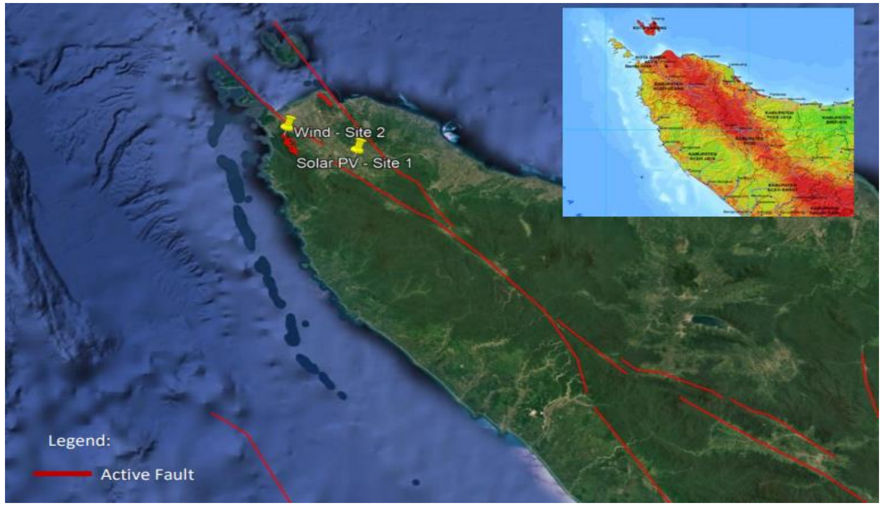


Figure – Identified active fault lines in Aceh Besar

Source: PT Inovasi report / (PUPR)

1 Background & scope
2 Revenue streams
3 Resource evaluation
4 Project size & restrictions
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8 Risk assessment

Environmental assessment- emissions avoided

Emissions avoided:

Reduction in CO_2 Emissions and Land Clearing Impacts

The reduction in CO_2 emissions is calculated using PLN's emissions factor of 0.817 kg CO_2/kWh. Each kWh generated by the wind project offsets the equivalent from fossil fuel power plants. In the first year, the project is expected to generate 247,990 MWh, avoiding approximately 202,608 tonnes of CO_2 emissions.

The project in Lhonknga involves clearing 1,200 hectares of protected forest, releasing an estimated 60,000 tonnes of CO_2, based on an emission factor of 50 tonnes per hectare. While these initial emissions partially offset the reductions, the project's long-term environmental benefits remain significant despite the degradation in power production.

The wind project is expected to produce 247,990 MWh every year.

	Simple sum	NPV
CO_2 emission avoided in tonnes	5,575,773	2,673,123
CO_2 emission increased from forest/farmland	(1,620,000)	(774,569)
Annual savings in tonne CO_2 (annuity)		143,107

Table – Sum and NPV of emissions avoided

Table above presents a comparison of CO_2 emissions avoided, emissions increased, and annual savings, using both a simple sum and Net Present Value (NPV) approach:

CO_2 Emission Avoided:

The total emissions avoided over the project lifetime amount to 5,575,773 tonnes in the simple sum calculation, but the NPV reduces this figure to 2,673,123 tonnes. The NPV accounts for the time value of reductions, indicating that avoided emissions in later years have less impact in present-value terms.

CO_2 Emission Increased from Land Clearing:

Land clearing contributes to an increase in emissions by 1,620,000 tonnes (simple sum) or 774,569 tonnes (NPV).

Annual Savings in CO_2 Emissions:

The annual savings in CO_2 emissions are calculated at 143,107 tonnes. This figure highlights the consistent yearly contribution of the project to emissions reduction despite the degradation over time.

Conclusion:

The NPV approach provides a more nuanced view, factoring in the time value of emissions savings, and still demonstrates the project's substantial net environmental benefit.

Summary conclusions and recommendations – 72 MW wind project in Lhoknga

Summary conclusions:

1. The 72 MW wind project in Lhoknga demonstrates economic viability, achieving very positive ENPV and B/C ratio above 1, even under varied sensitivity assumptions.

2. The project delivers significant socio-economic and environmental benefits, but PPA rates remain relatively high, posing challenges for competitive pricing.

3. Located in a protected forest area, the project faces regulatory, environmental, and funding constraints.

4. Land clearing (1,200 hectares) is expected to release 60,000 tonnes of CO_2, requiring compensatory measures.

5. Potential biodiversity impacts include risks to local flora, fauna, and bird collisions with turbine blades.

6. The project offsets CO_2 emissions by generating renewable energy, avoiding 180,354 tonnes of CO_2 annually.

7. Significant job creation is expected with:
   - Construction Phase: 1,820 direct FTE jobs and 1,100 indirect FTE jobs.
   - Operation Phase (Annual): 200 direct FTE jobs and 100 indirect FTE jobs.

9. Local communities are initially supportive of the project due to its potential to stimulate economic growth, enhance infrastructure and attracts tourism. The site is at a developing area with growing tourism.

9. Regulatory approvals and environmental mitigation measures for development in protected areas are critical.

10. Addressing biodiversity concerns and compensating for ecological losses is essential to ensure compliance.

Summary recommendations:

1. Collaborate with the Ministry of Environment and Forestry to secure necessary approvals and meet compliance standards.
2. Once the project is planning to move forward, an Environmental and Social Impact Assessment (ESIA) should be conducted to ensure compliance with international environmental and social standards regarding livelihood impacts. This is also necessary to secure international funding, which requires a responsible and fair land acquisition process prior to development.
3. Implement biodiversity monitoring and mitigation plans to minimise habitat disruption.
4. Consider reforestation or carbon offset programmes to compensate for land clearing emissions.
5. Engage local communities throughout the project lifecycle to ensure social license for the project, while fostering opportunities in educational, touristic, and industrial development linked to renewable energy.
6. Invest in local infrastructure improvements, such as roads, to support project development and benefit local populations.
7. Highlight the project's CO_2 emission reduction potential in communications with stakeholders.
8. Evaluate potential for scaling similar solar projects in other areas of Aceh to maximize renewable energy impact.
9. Prioritize local residents as workers for the project. The community hopes that the construction of the wind project will provide significant job opportunities, including the creation of new businesses such as food stalls around the project area to cater to workers.

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SITE PHOTOS

Drone pictures of potential Solar PV site in Lhoknga*:




*Input from PT Inovasi

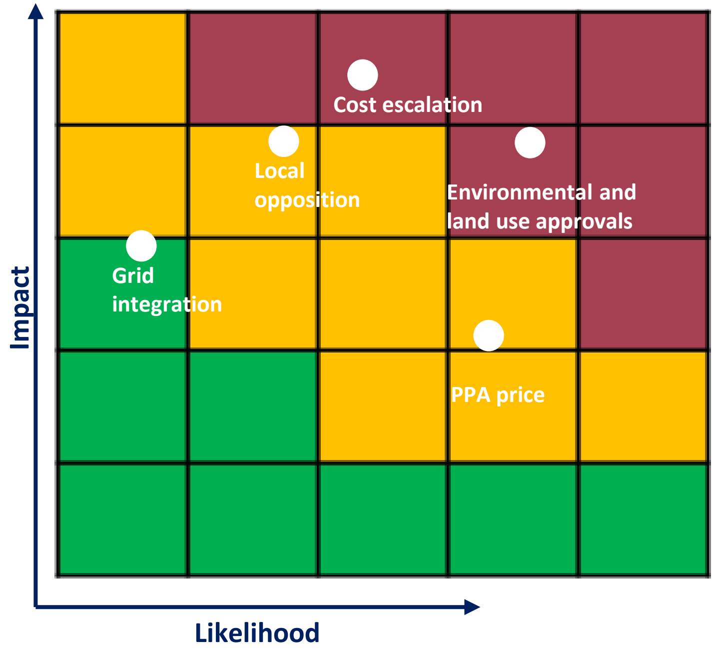
KEY PROJECT RISKS ARE ENVIRONMENTAL AND LAND USE APPROVALS AND COST ESCALATION

Risk log and actions

Risk indicator	Description	Impact	Action
Environmental and land use approvals	The proposed site is classified as protected area, resulting in long and complex permitting processes.	There is a risk that approvals for converting protected forest areas are delayed or cannot be granted for e.g., environmental reasons.	• Engage in early dialogue with the Ministry of Forestry and Environmental planning. • Perform an environmental impact study • Abandon the project
Costs escalation	The proposed site is situated in challenging terrain, with elevations over 1,500 meters and slopes between 15 and 30 degrees. Combined with a high concentration of trees, investments in land leveling and tree trimming are necessary. Additionally, due to limited accessibility, substantial investments in road network upgrades is necessary, potentially driving up costs significantly. Another cost uncertainty relates to land acquisition costs.	Costs escalation, particularly if it relates to major budget posts, such as infrastructure upgrades, have a direct impact on the financial feasibility of the project.	• Sign options to lease with landowners to fix land acquisitions costs in the early development phase • Engage with the local officials to obtain information on development activities to explore synergies that could lower the costs of upgrading infrastructure • Engage with local suppliers to obtain prices for key services, such as clearing of land etc. • Abandon the project
Local opposition	Local population might be against the project for reasons related to visual impact, environmental concerns or influence on local economy.	Delayed project development or problems during construction.	• Engage early with the local community • Source local labor in the construction phase • Allocate a share of the budget for local investments in e.g., schools
Grid integration and power system	The nearest 150 kV sub-station (Banda Aceh) is located 10 km from the site. The availability of the substation is unknown. This risk is compounded by frequent power outages in the area, highlighting limited power system stability. Meanwhile, the delivery or pay mechanism ensures a stable cash flow for the IPP, which lowers the risk.	Grid integration challenges can result in curtailment and disrupted production, and ultimately it can result in PLN not accepting grid connection at the nearest substation, which could delay or significantly inflate costs.	• Engage with PLN in the early development phase to gain indications of grid availability • Conduct grid impact study • Explore options for adding storage technology
PPA price	Obtaining a PPA price that provides satisfactory returns is subject to high uncertainty, because there is no guaranteed price mechanism as a FiT scheme, why the final PPA price is a result of negotiations with PLN, and PLN is the only offtaker of utility scale onshore wind. The risk is compounded by the direct procurement process which increases competition.	PPA price uncertainty is a risk since the sale of electricity is the only revenue source of the project. Meanwhile, the average generation costs (BPP) in Aceh is higher than average, also surpassing the break-even price.	• Conduct thorough price sensitivity analyses to evaluate the financial impact meeting PLN's acceptable PPA price • Engage in early dialogue with PLN to obtain price indications • Postpone project development until there is more certainty on PPA price settlements.

Risk evaluation: The main risk for this project concern environmental and land use approval, since the site is located in a protected forests, which is subject to complex and long permitting processes. With numerous unknown factors, the likelihood of cost escalations is high. Conducting a thorough cost analysis is essential to developing a realistic PPA proposal and ensuring a financially viable business case.

Risk matrix



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LIST OF ACRONYMS

Bappeda	Regional Development Planning Agency
BPP	Average cost of generation
BPS	Central Bureau of Statistics
BRWA	Customary Area Registration Agency
CAPEX	Capital Expenditures
CBA	Cost-Benefit Analysis
CREA	Centre for Research on Energy and Clean Air
COD	Commercial operation date
DEA	Danish Energy Agency
DEVEX	Development expenditures
DCF	Discounted Cash Flow Analysis
DINAS ESDM	Energy and Mineral Resources Agency of Aceh
ENPV	Economic Net Present Value
ERR	Economic Rate of Return
ESIA	Environmental and Social Impact Assessment
FID	Final Investment Decision
FTE	Full Time Equivalent
GHI	Global Horizontal Irradiation
GIS	Geographical Information System
GWh	Gigawatt-hours
IESR	Institute for Essential Services Reform
IFI	International Financing Institution

INDODEPP	Indonesian-Danish Energy Partnership Programme
IRR	Internal Rate of Return
kWh	Kilowatt-hours
LCOE	Levelized Cost of Electricity
MWac	Megawatt Alternating Current
O&M	Operating and Maintenance
OPEX	Operational Expenditures
PLN	Perusahaan Listrik Negara (national electricity company in Indonesia)
PFS	Pre-feasibility Study
PPA	Power Purchase Agreement
PV	Photovoltaics
RECs	Renewable Energy Certificates
RUED	Rencana Umum Keternagalistrikan Provinsi (Regional General Plan for Electricity)
RUPTL	Electricity supply plan
SDR	Social Discount Rate
SOC	Social Opportunity Cost of Capital
SPI	Sustainable Province Initiative
SRTP	Social Rate of Time Preference
USD	United States Dollars
VSL	Value of Statistical Life
WACC	Weighted Average Cost of Capital
ZNT	Land Value Zone

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 project'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).*	$\boldsymbol{FLH}\,[h] = \frac{Annual\ generation\ [MWh]}{Rated\ power\ [MW]}$ $\boldsymbol{CF}[\%] = \frac{FLH}{8760}$

APPENDIX – OVERVIEW OF INTERVIEWS

Name of interviewee	Position of interviewee	Relevant for which site-location	Date of interview	Interview conducted by
Alaidin	Village head of Bithak	Solar PV, Aceh	Conducted (Fri, Nov 8 2024)	Nanda Mariska
Zulkifli, S.Sos	Sub-district head of Kuta Cot Glie	Solar PV, Aceh	Conducted (Fri, Nov 8 2024)	Nanda Mariska
Dr. Puspita Annaba Kamil	Geography Lecturer at Syiah Kuala University, Aceh	Solar PV and Onshore Wind, Aceh	Conducted (Tue, Dec 3 2024)	Nanda Mariska
Fahmi	Meudaya	Solar PV and Onshore Wind, Aceh	Conducted (Sat, Dec 7 2024)	Nanda Mariska
Chik Rini	WWF Indonesia – Aceh Office	Solar PV and Onshore Wind, Aceh	Input via Whatsapp (Dec, 10 & 13, 2024)	Nanda Mariska
Devi Satria	Sekretarit Sub-district	Aceh Besar	N/A	PT Inovasi
Wahyuna	Head of village	Aceh Besar	N/A	PT Inovasi
Masri Fithrian	Head of Sub-district	Aceh Besar	N/A	PT Inovasi
Muhammad Ridha	Head of village	Aceh Besar	N/A	PT Inovasi
Munazar, SE	Head of Sub-district	Aceh Besar	N/A	PT Inovasi
Mukhtar Jakub, S.Sos	Head of Sub-district	Onshore Wind, Aceh	N/A	PT Inovasi
Zulfikar	Sekretarit Village	Onshore Wind, Aceh	N/A	PT Inovasi
Azhari	Head of Sub-district	Solar PV, Aceh	N/A	PT Inovasi

Danish Energy Agency

Viegand Maagøe

Ea Energy Analyses

INOVASI DINAMIKA PRATAMA

COWI