



Ministry of National
Development Planning/Bappenas
Republic of Indonesia



ENERGY
TRANSITION
PARTNERSHIP

Powering Prosperity and Enabling Sustainability in South East Asia

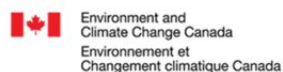
SOLAR PV MAPPING AND DEVELOPMENT PLAN (INDONESIA)

FLOATING PV POTENTIAL IN JAMALI

Prepared by : Consortium lead by Trama TecnoAmbiental



AUGUST 2025



FLOATING PV POTENTIAL IN JAMALI REPORT DISSEMINATION

August 22th, 2025

Prepared by:

Consortium lead by Trama TecnoAmbiental, S.L. (TTA)

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INTRODUCTION

1.1 BACKGROUND

The Southeast Asia Energy Transition Partnership brings together governments and philanthropies to work with partner countries in the region. ETP supports the transition towards modern energy systems that can simultaneously ensure economic growth, energy security, and environmental sustainability.

ETP priority countries:



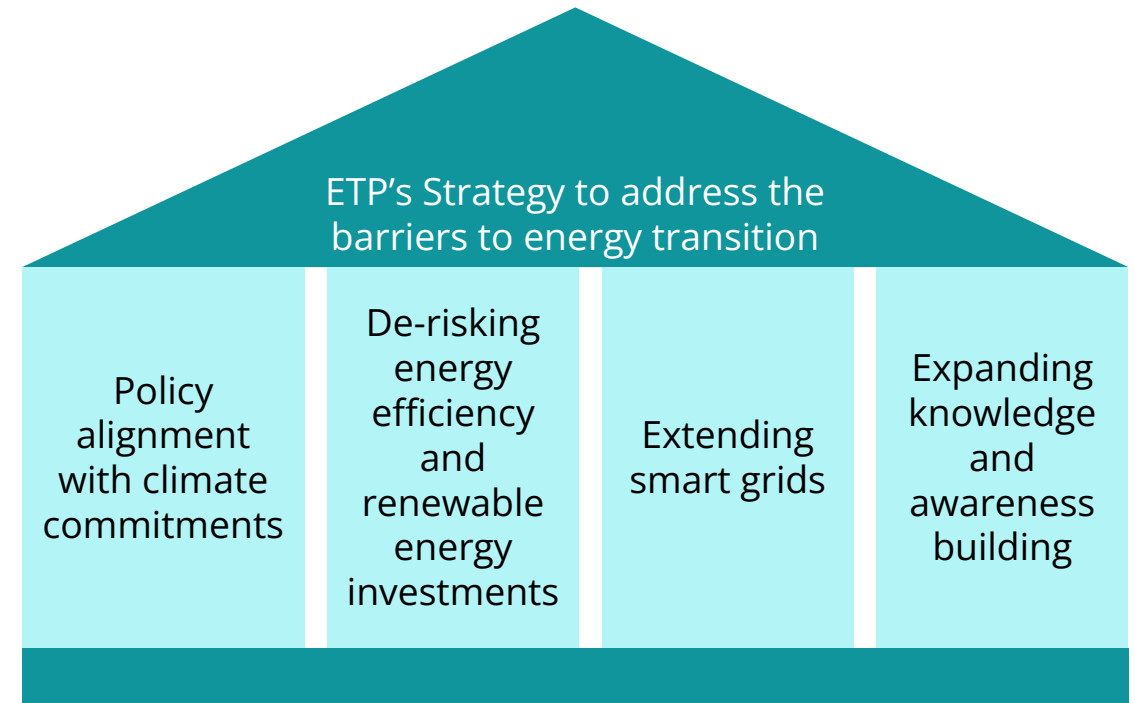
Indonesia



The Philippines



Vietnam

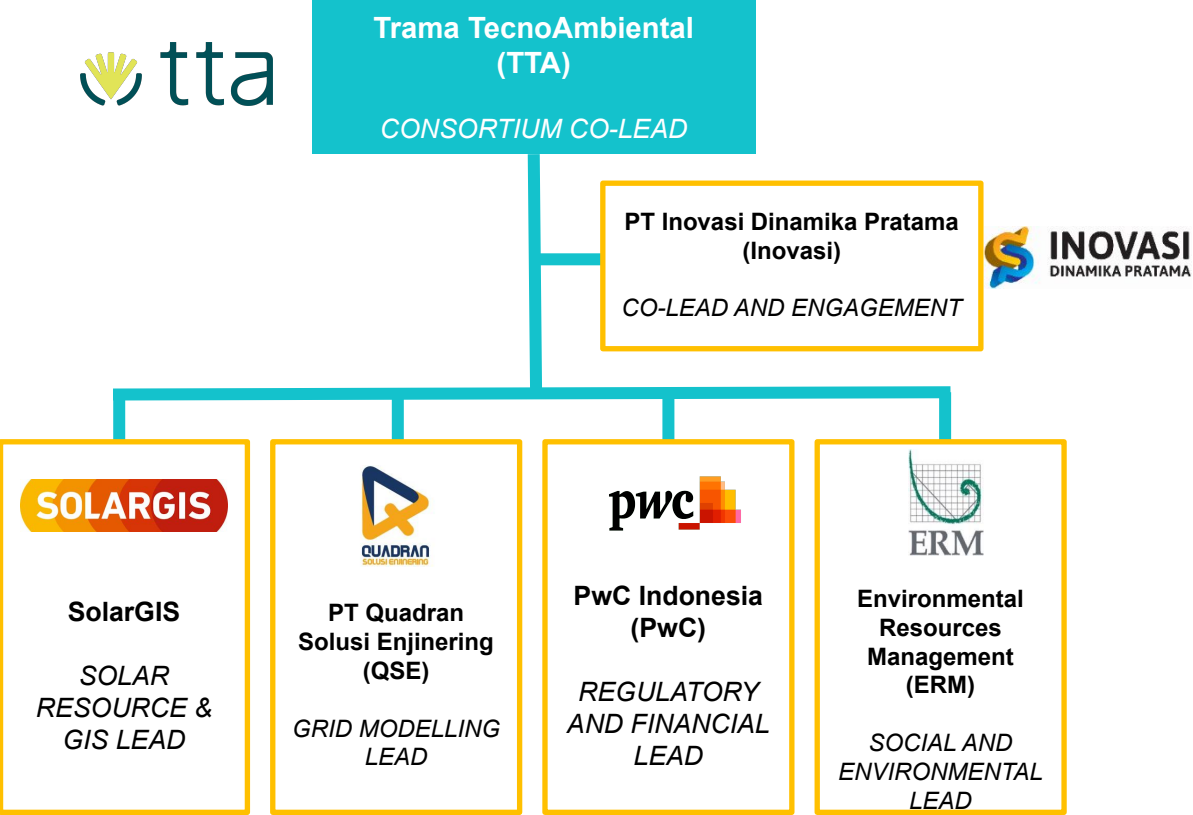


For this project, **ETP is working with the Ministry of National Development Planning (BAPPENAS) to support Indonesia's renewable energy transition planning.**

Project Objectives:

- Strengthen the enabling environment for renewable energy (RE) policies
- Increase the flow of public and private investments to RE projects
- Improve the development and accessibility of RE knowledge

1.2 THE CONSULTANT TEAM



1.3 PROJECT OBJECTIVES

±1GW

Renewable Energy shared in 2024

443
GW

New additional RE installed capacity by 2060

~ 1T
USD

Investment required

This project aims to increase the use of solar photovoltaic (PV) technology in Indonesia to reduce emissions and meet the country's goal of achieving net-zero emissions in the power sector by 2060.

Key Project Outputs:

- Solar Irradiance Data Mapping and accessible database
- Grid assessment and Impact evaluation
- Environmental and Social Impact Assessment
- A solar PV development and investment plan for 1 GW of the JAMALI power grid
- Pre-feasibility document of the 1GW Solar PV mapping and development in JAMALI systems

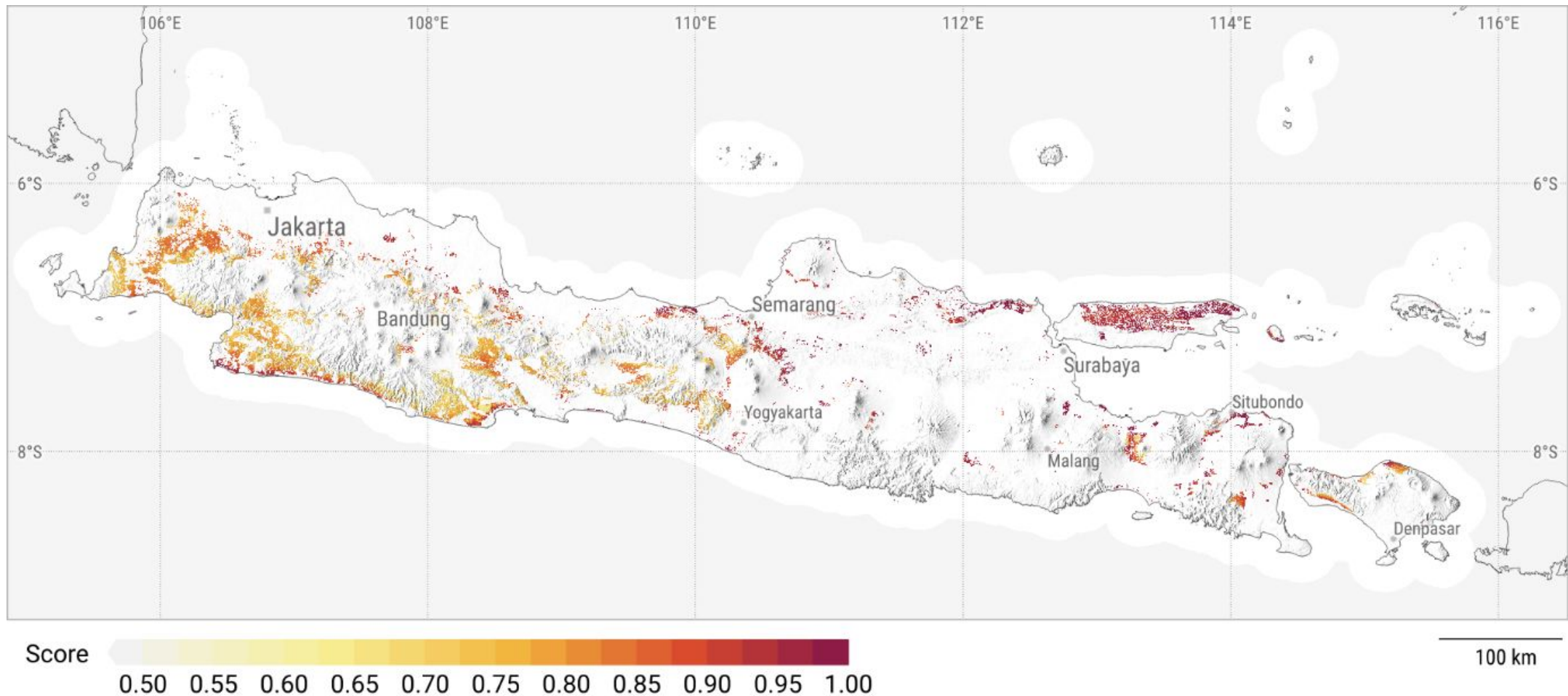
Additional Outputs:

- Floating PV Potential in JAMALI**

1.4 PREVIOUS STUDY

GROUND-MOUNTED GEOSPATIAL ANALYSIS RESULT

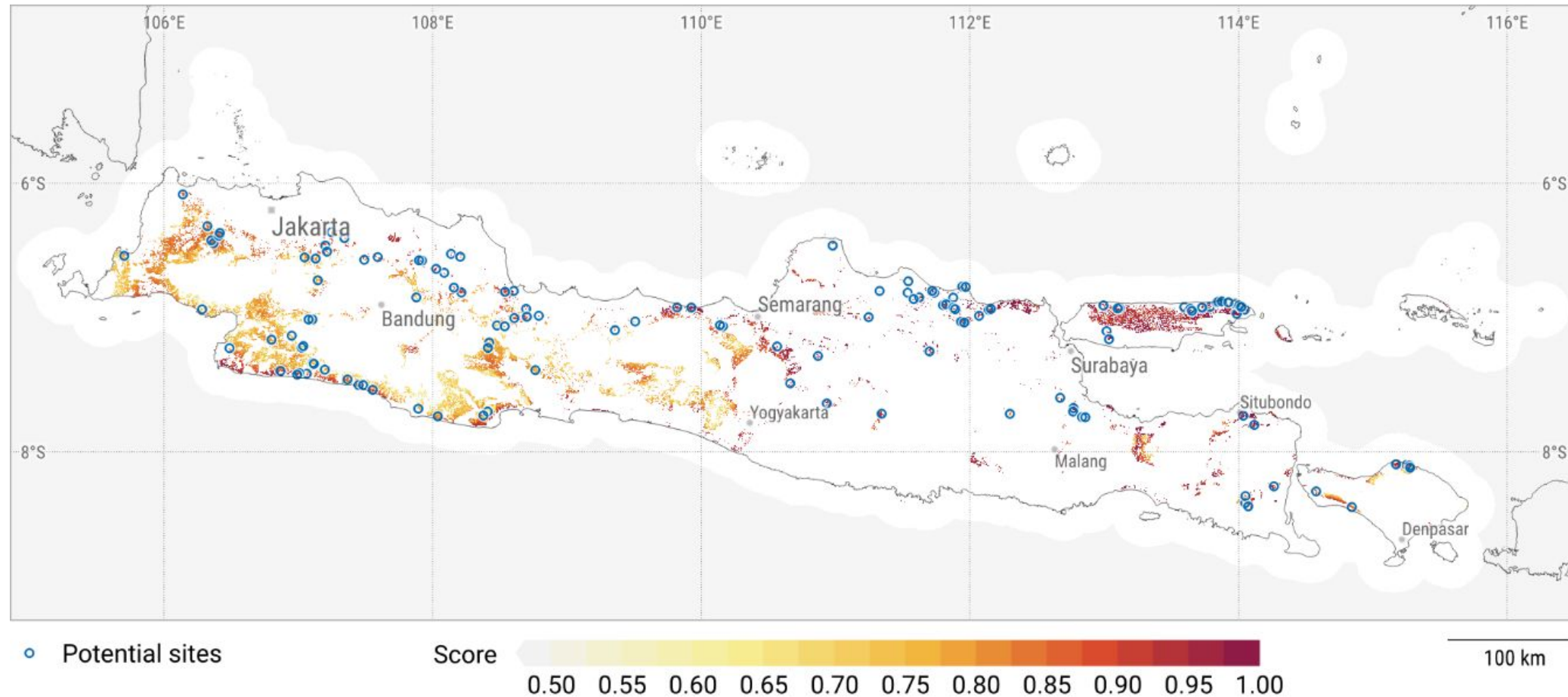
Geospatial analysis result, the composite of binary and range layers



1.4 PREVIOUS STUDY

GROUND-MOUNTED GEOSPATIAL ANALYSIS RESULT

140 Pre-selected Sites



Calculated score for the classified areas and 140 pre-selected potential locations for utility-scale PV development. Higher scores present more favorable areas

1.5 KEY INSIGHTS

The key insights of the report are:

Based on the compiled dataset of water reservoirs in the JAMALI region, 51 distinct water bodies with a surface area exceeding 100 hectares were identified. 21 reservoirs were selected for further analysis

1. Geospatial Analysis

- Technical scoring based on PVOUT, shading, wind, water level fluctuation, reservoir shape, infrastructure proximity, aquaculture/vegetation coverage.
- Scores <0.5 indicate higher technical challenges but not infeasibility; require advanced engineering/O&M.
- Site-specific feasibility studies essential to address bathymetry, anchoring, water level, and soil conditions.

2. Environmental & Social (E&S) Assessment

- No sites excluded; 11 medium-risk and 7 high-risk sites require ESIA & mitigation plans.
- Key challenge: high Floating Net Cage (FNC) aquaculture density causing environmental impacts & social tensions, high presence of cultural heritage in some locations.
- Apply international E&S standards to ensure sustainability & stakeholder acceptance.

3. Grid Integration

- Technical potential often exceeds grid hosting capacity for 2030.
- Grid upgrades & expansion essential to fully utilize FPV potential.

4. Financial Analysis

- Most sites deliver moderate returns under some condition; FPV not inherently unviable.
- Some sites show promising IRRs but below 12% equity IRR threshold without policy/tariff support.
- Excluding evacuation line costs improves viability; supportive mechanisms needed for bankability.

1.5 KEY INSIGHTS

FLOATING PV POTENTIAL

21 Site Selected



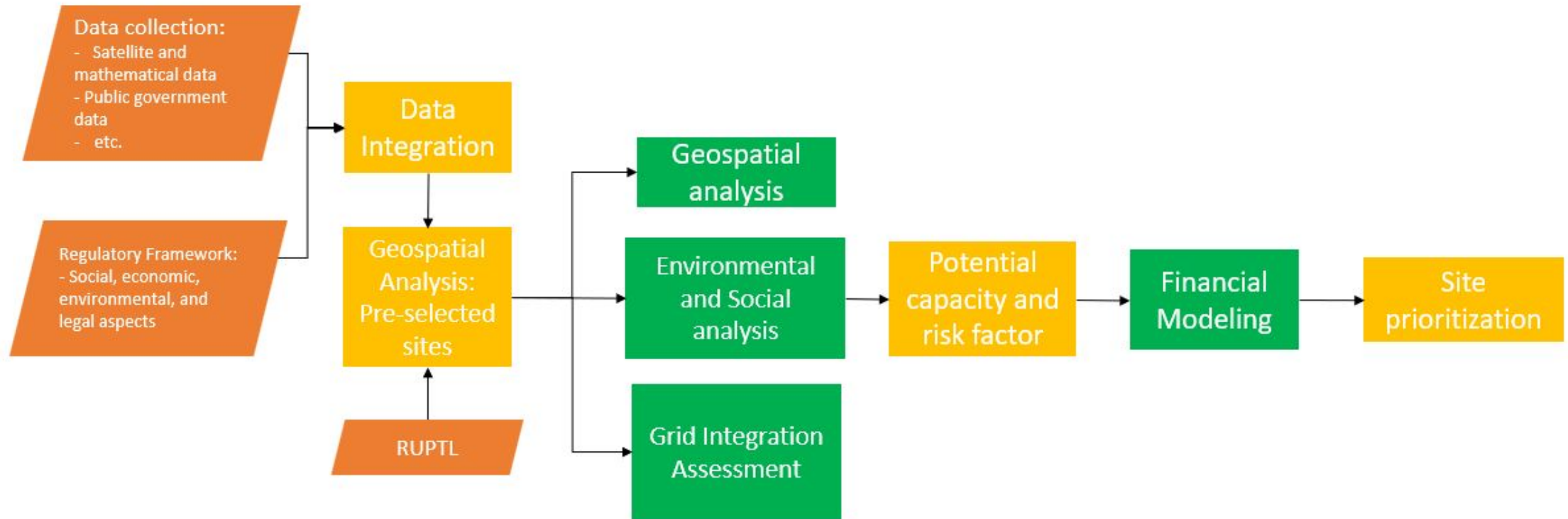
1.5 KEY INSIGHTS

The key insights of the report are:
Below is the result of site prioritization for the top ten sites.

Rank	Reservoir name	Geospatial score	E&S score	Risk rating	Potential capacity (MWp)	Capex (USD/M Wp)	Project IRR (Base Case)	Total score
1	Waduk Kedung Ombo	1.00	17	High	411	554,400	8.97%	8.628
2	Waduk Gajah Mungkur	0.89	14	Medium	340	580,815	8.19%	8.206
3	Waduk Karangates	0.78	14	Medium	257	554,741	8.69%	8.088
4	Waduk Jatigede	0.79	16	High	662	545,444	7.86%	7.708
5	Waduk Cirata	0.63	15	Medium	1146	542,713	7.85%	7.512
6	Waduk Jatiluhur	0.63	16	High	651	542,217	7.72%	7.153
7	Waduk Wadaslintang	0.64	14	Medium	261	555,693	6.34%	6.596
8	Waduk Mrica	0.76	14	Medium	97	623,81	5.10%	6.329
9	Waduk Cengklik	0.60	15	Medium	58	619,201	6.08%	6.152
10	Waduk Saguling	0.29	16	High	310	566,787	7.43%	5.844

METHODOLOGY

2.0 METHODOLOGY OF THE STUDY



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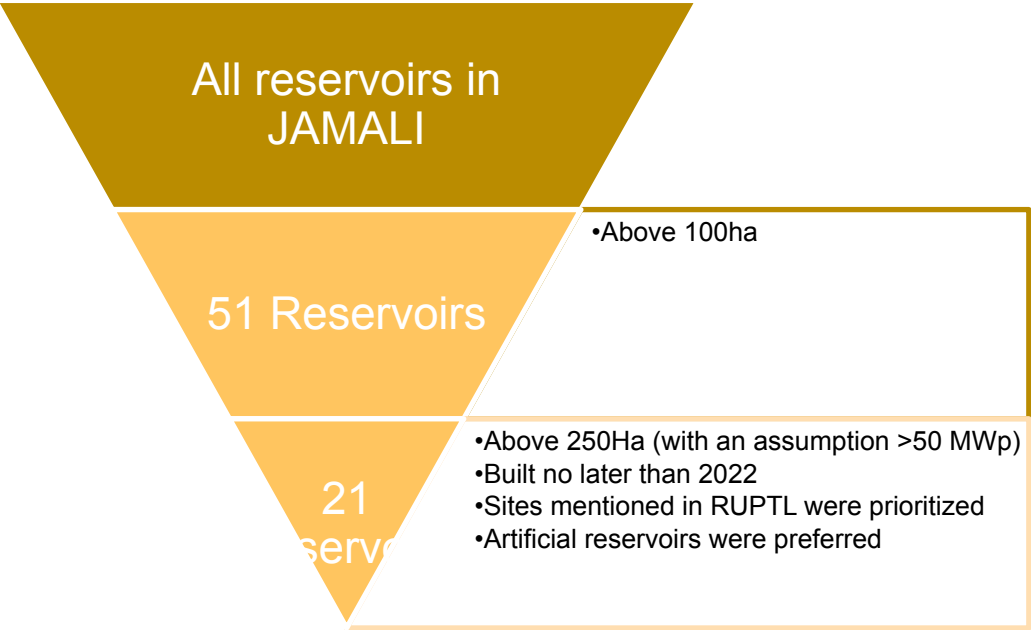
This methodology consisted of four key activities:

- 1. Geospatial analysis:** To identify technically feasible locations for floating PV deployment across the JAMALI region.
- 2. Environmental and social analysis:** To validate the technical findings and assess potential risks related to environmental, social, and regulatory factors.
- 3. Preliminary grid integration assessment:** To estimate the maximum hosting capacity of solar PV at the substation level for each shortlisted site.
- 4. Financial modelling:** To analyse the financial viability and bankability of each floating PV site.

GEOSPATIAL ANALYSIS

2.1 Geospatial Analysis

Selected Sites



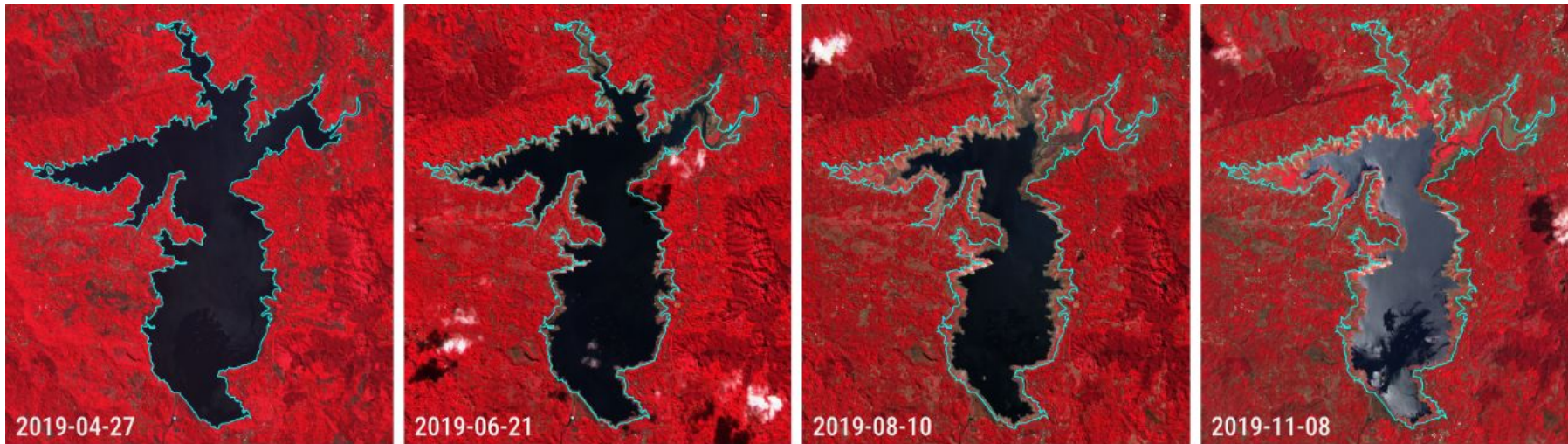
		Geometry		
No	Reservoir name	Area MWL – satellite data [ha]	Perimeter [km]	Estimated Capacity based on total Areas 20% [MWp] – satellite data
1	Waduk Jatiluhur	7091.4	220.1	1418
2	Waduk Cirata	5729.6	190.7	1146
3	Waduk Gajah Mungkur	4849.3	208.8	970
4	Waduk Kedung Ombo	3838.6	210.3	768
5	Waduk Saguling	3515.6	399.4	703
6	Waduk Jatigede	3392.0	127.2	678
7	Waduk Karangates	1283.0	71.5	257
8	Waduk Wadaslintang	1141.8	55.4	228
9	Waduk Cacaban	642.6	49.1	129
10	Waduk Malahayu	538.4	35.2	108
11	Waduk Mrica	487.0	34.1	97
12	Waduk Gondang	484.6	33.2	97
13	Waduk Widas	437.7	52.2	88
14	Danau Beratan	383.4	8.1	77
15	Waduk Darma	382.1	16.3	76
16	Waduk Wonorejo	362.1	21.0	72
17	Waduk Pondok	332.1	49.5	66
18	Waduk Cipancuh	329.0	23.0	66
19	Waduk Pacal	317.3	33.2	63
20	Waduk Lahor	315.1	34.4	63
21	Waduk Cengklik	288.7	11.0	58

2.1 Geospatial Analysis

Mean Water Level Area

The Mean Water Level (MWL) area is used as a representative value for the typical reservoir area and serves as the basis for some of the subsequent calculations. Reservoir water levels naturally fluctuate across seasons and years, influenced by inflow and outflow dynamics. The MWL area reflects the typical reservoir extent observed in time-series satellite imagery

The magnitude of seasonal change differs significantly, some reservoirs are more stable, some variable



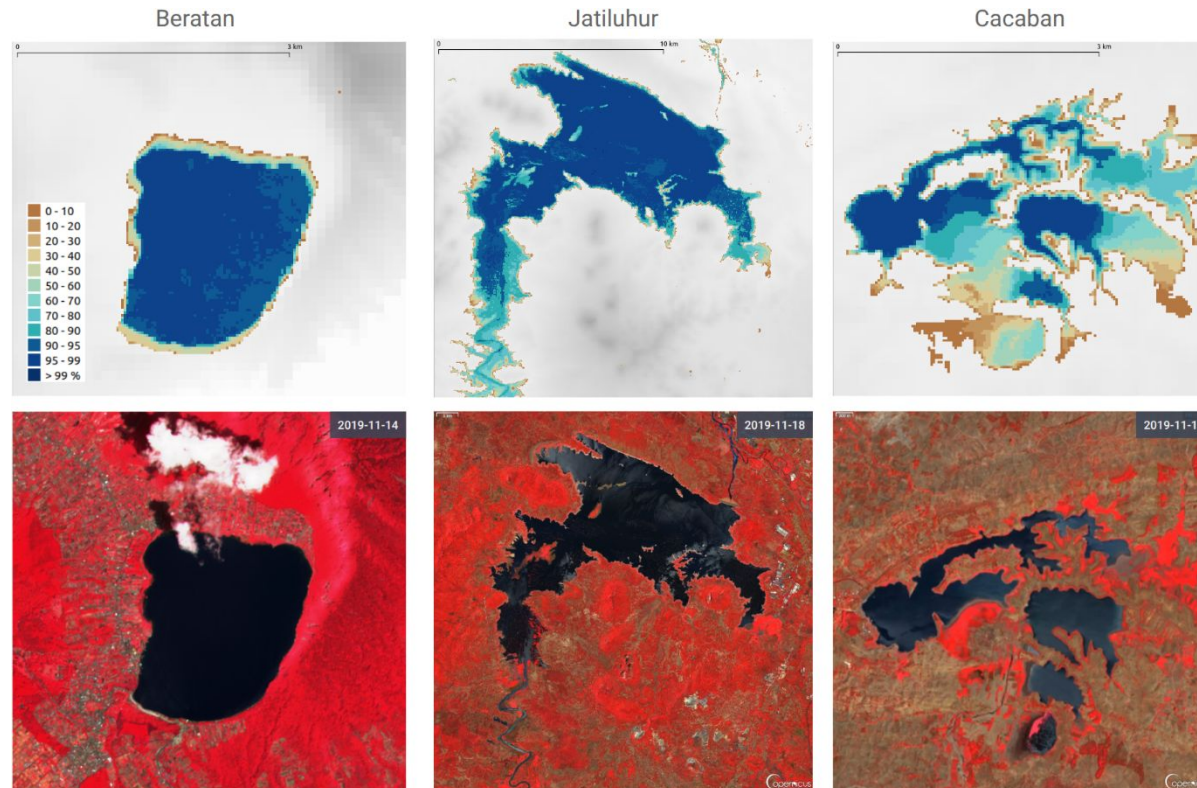
Satellite imagery visualised in false color, based on modified Copernicus Sentinel-2 data

2 km

2.1 Geospatial Analysis

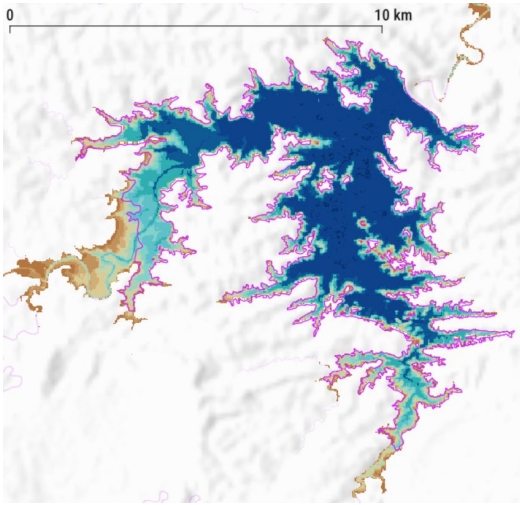
Effective Area

Effective Area is the portion of the reservoir that consistently holds water. The effective was estimated based on analysis of satellite images over the last 10 years. The effective area indicates the risk of water extent changes due to seasonal and yearly cycles.

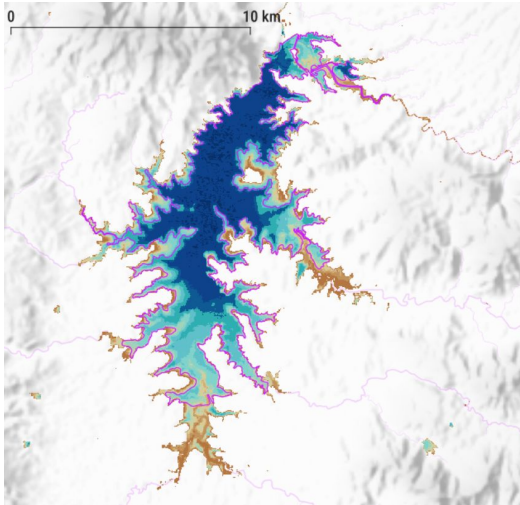


2.1 Geospatial Analysis

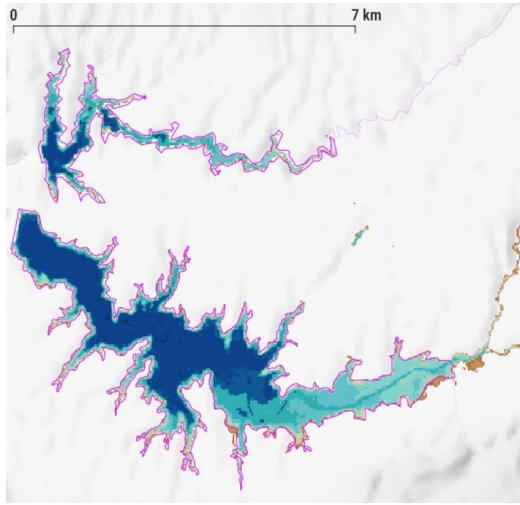
Effective Area



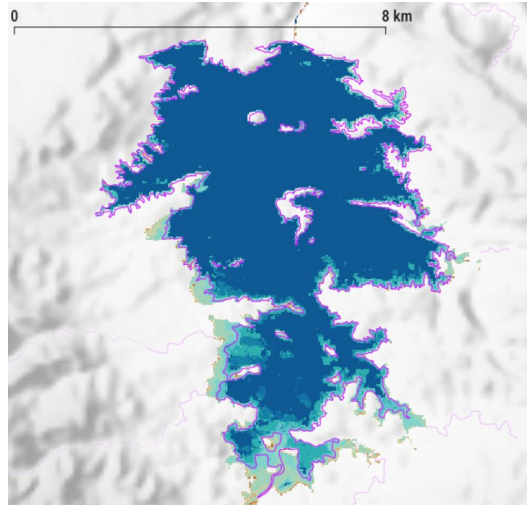
Kedung ombo



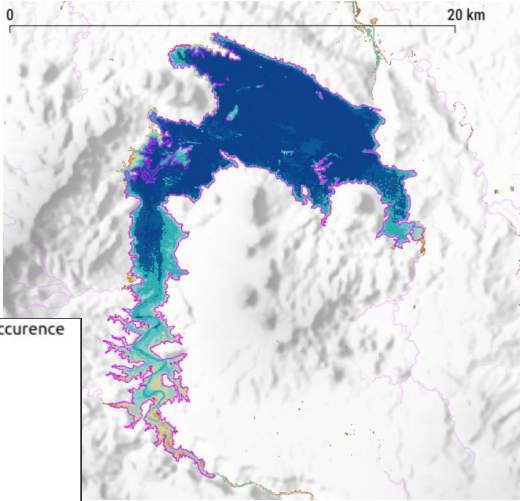
Gajah Mungkur



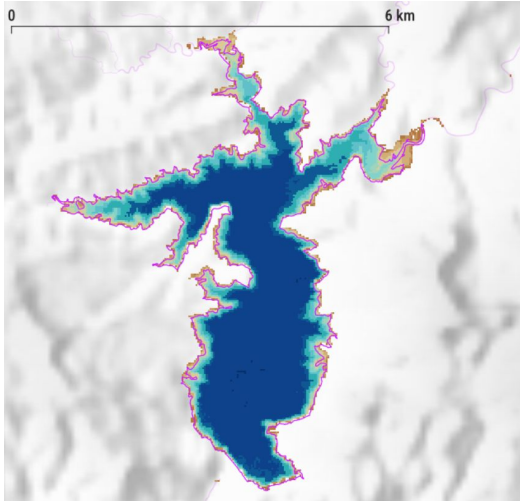
Karang Rates



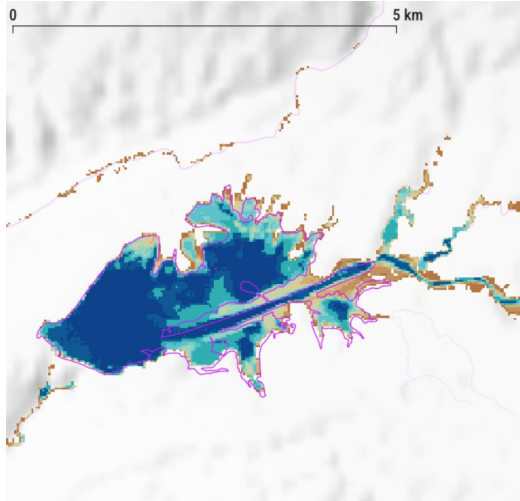
Jatigede



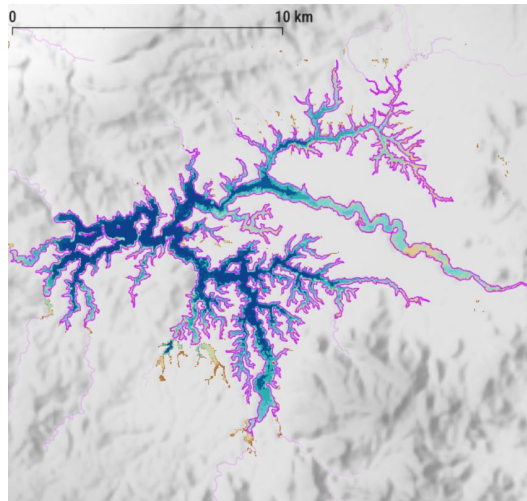
Jatiluhur



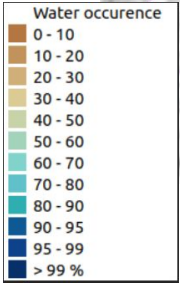
Wadaslintang



Mrica



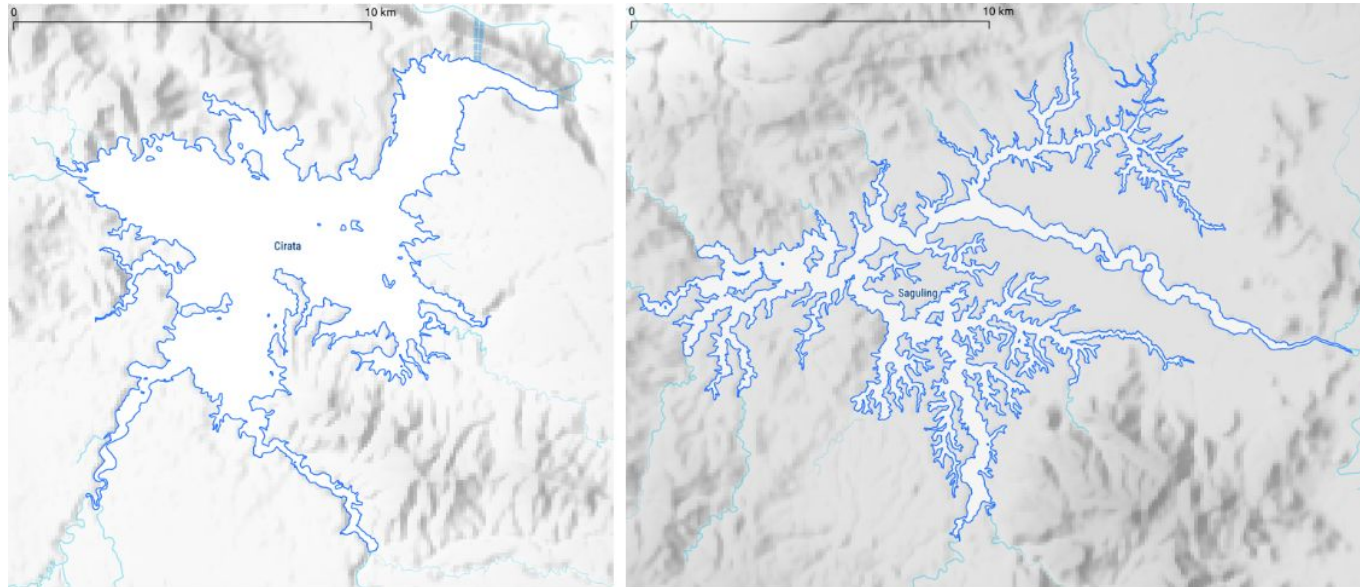
Saguling



2.1 Geospatial Analysis

Reservoir Shape Complexity

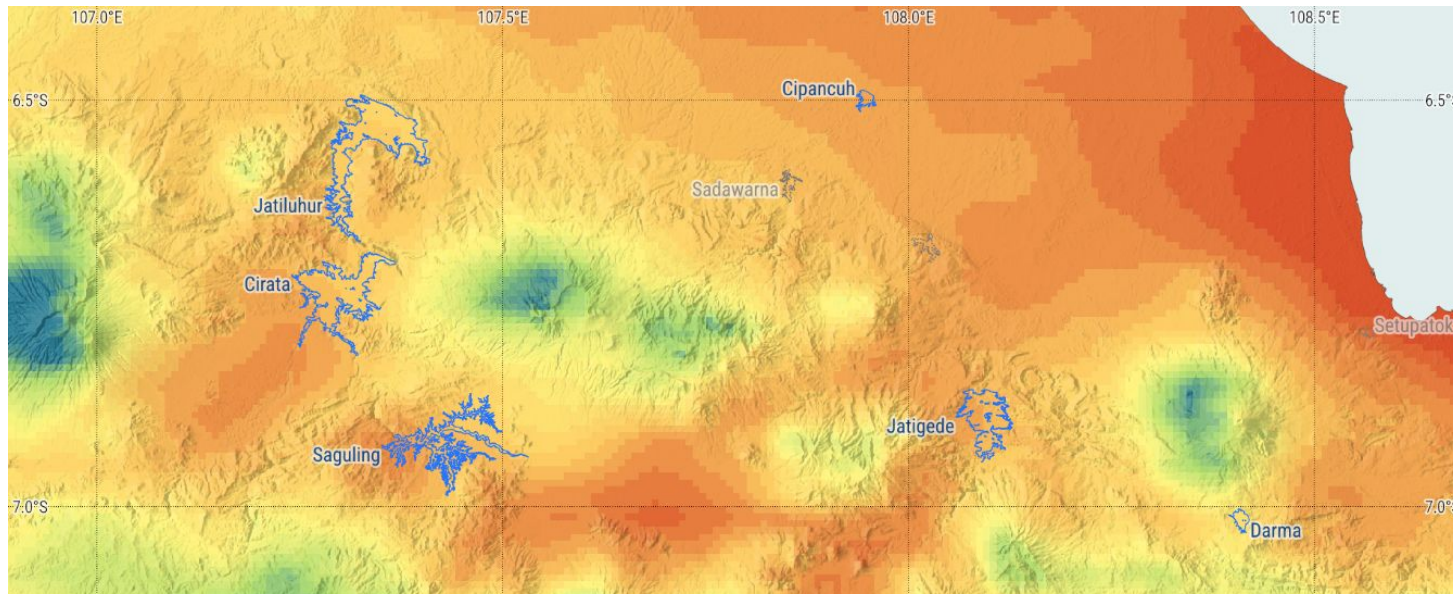
The reservoir shape complexity, expressed as kilometres of shoreline per hectare of area, is a measure of the fragmentation of the reservoir area. This is illustrated in Figure below, showing the Cirata and Saguling reservoirs. The shape complexity of Cirata is 0.03 km/ha, while Saguling's is 0.11 km/ha. The Saguling reservoir is characterised by long and narrow corridors or water, small bays, and no large open water area.



2.1 Geospatial Analysis

Mean PVOUT

PV power output (PVOUT) is the main performance characteristic of any PV power plant, regardless of whether it is mounted on water or land. The mean PVOUT parameter describes the expected power production of the FPV on the reservoir. It is calculated based on Solargis data and the PV simulation algorithm as the yearly average of PV power generation potential in the last 18 years (period 2007-2024). The calculation is performed with a spatial resolution of 30 arcsec resolution (approx. 1 km).



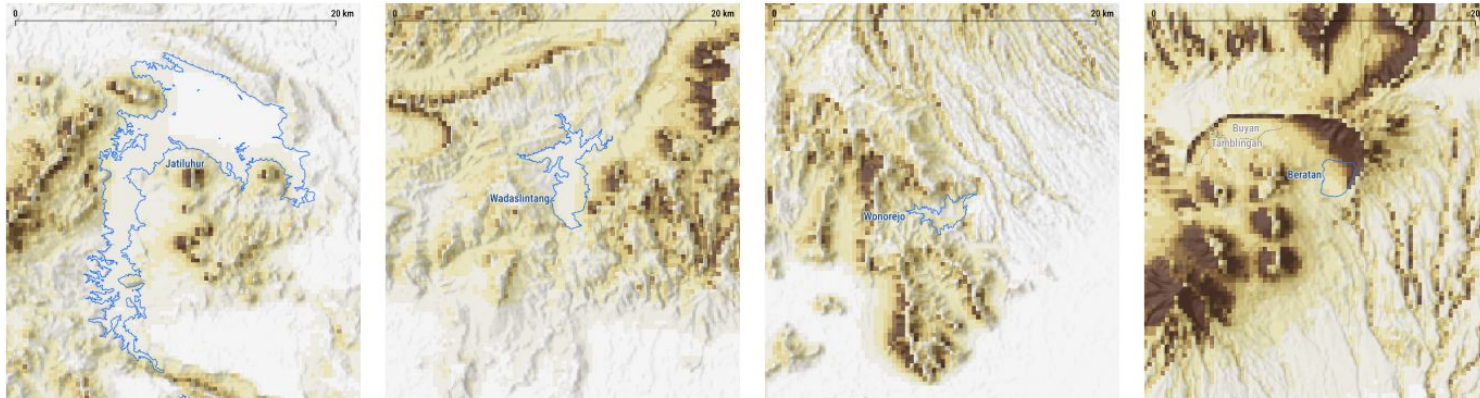
PVOUT: Long-term average of potential PV power production, period 2007-2024, calculated by Solargis data and software



2.1 Geospatial Analysis

Terrain Shading

Shading from terrain, either nearby or far horizon, is an important factor to consider when localising the PV power plant, as it leads to losses in the PV power production. The mean shading is calculated as the mean reduction in Global Horizontal Irradiation (GHI) over the MWL area of the reservoir due to the surrounding terrain and far horizon.



GHI losses due to shading from terrain, calculated for the period 2007-2024



2.1 Geospatial Analysis

Wind Speed

For FPVs wind speed is especially important, as wind causes waves to arise on the water body, which the FPV must be designed to withstand. In practice, structures, including FPVs are designed to basic wind speeds. Basic wind speed (also known as fundamental wind speed) is generally defined as the peak gust wind speed (usually over a 3-second or 10-minute average period) measured at 10 meters above ground level in open terrain, with a specified return period (often e.g. 50 years), and adjusted for mean recurrence interval, topography, and exposure conditions.

The basic wind speeds are also typically aggregated over a wider area, and a safety factor may be applied. This may lead to an overestimation of the typical wind speeds at a particular location. For the analysed water bodies in JAMALI, the basic wind speeds are defined by range from SNI 1727:2020 — Minimum Loads for the Design of Buildings and Other Structures

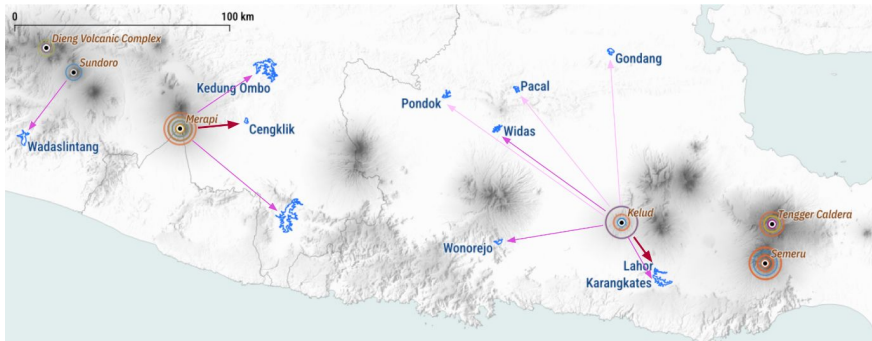
Basic Wind Speed Value

Reservoir name	Basic Wind Speed (V) [m/s]
Waduk Pacal	27–30
Waduk Gondang	27–30
Waduk Cirata	30–33
Waduk Jatiluhur	30–33
Waduk Saguling	30–33
Waduk Widas	27–30
Waduk Lahor	28–31
Waduk Karangates (Sutami)	28–31
Waduk Wadaslintang	28–31
Waduk Wonorejo	28–31
Waduk Mrica	28–31
Waduk Cengklik	28–31
Waduk Malahayu	28–32
Waduk Cipancuh	28–32
Waduk Darma	30–32
Waduk Pondok	28–31
Danau Beratan	30–33
Waduk Jatigede	30–32
Waduk Cacaban	28–32
Waduk Gajah Mungkur	27–30
Waduk Kedung Ombo	27–30

2.1 Geospatial Analysis

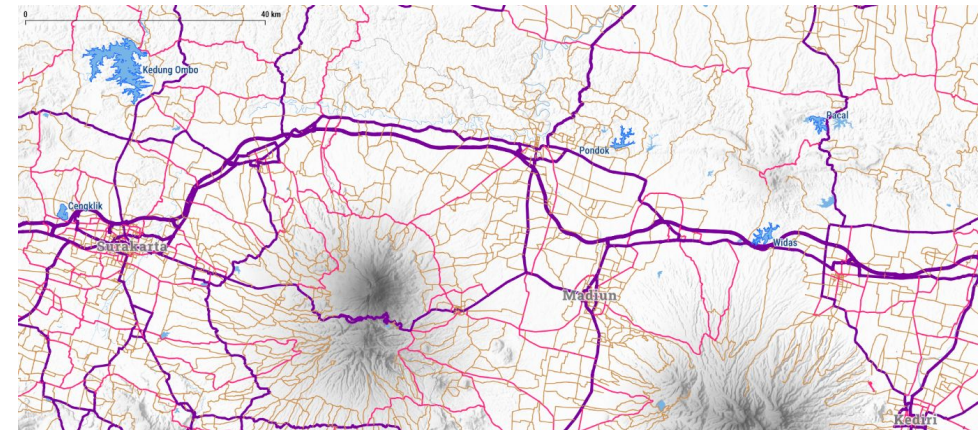
Closest Volcano

The closer the volcano, the higher the risk of an eruption damaging the power plant.



Road Access

Road access to the reservoir is crucial during the construction of the FPV and maintenance activities. While not a blocking parameter, poor road access will increase the development cost



2.1 Geospatial Analysis

Hydropower on the Same Reservoir

Presence of a hydro power plant on the same reservoir as a potential FPV offers synergic effects. The reservoirs are categorised based on the size of the hydro power plant at the reservoir. The values for the parameter were assigned within the following categories:

- Value 0 for no installed hydropower capacity
- Value 1 for installed hydropower capacity ≤ 100 MWp (small)
- Value 2 for installed hydropower capacity 100 – 200 MWp (medium)
- Value 3 for installed hydropower capacity > 200 MWp (large)

Electrical Substation Proximity

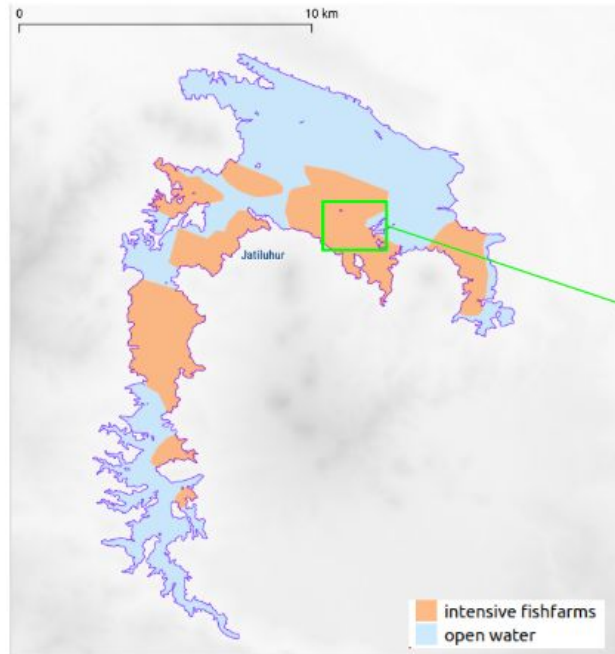
Available electrical infrastructure for power export means the total costs of FPV development are lower.



2.1 Geospatial Analysis

Floating Net Cages

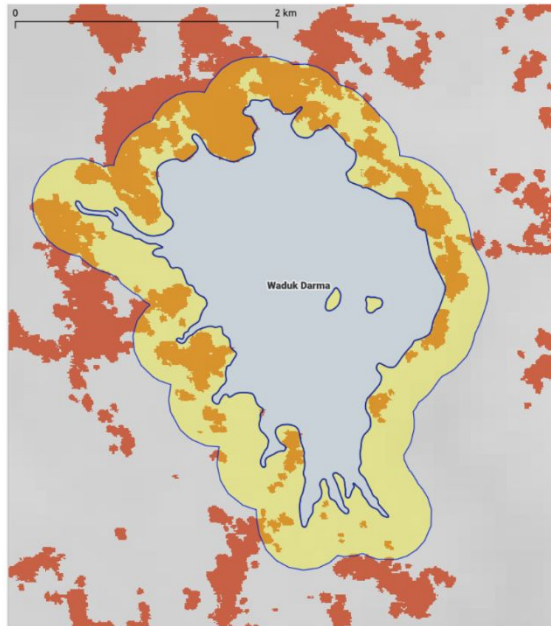
Many reservoirs in the JAMALI region are being actively used for aquatic farming. Even though the floating net cages could be displaced to make space for the FPV, this will present additional requirements and hence should be considered as a risk for the FPV development



2.1 Geospatial Analysis

Built-up Area on the Shore

Some reservoirs are highly utilised, either as urban spaces, agricultural facilities, or leisure areas, so their shorelines are heavily developed. FPV requires onshore infrastructure such as inverters, transformer stations, maintenance stores, and lay-down areas. Even more land on the shore is required during the construction, when the equipment must be laid down as close as possible to the water to simplify the installation

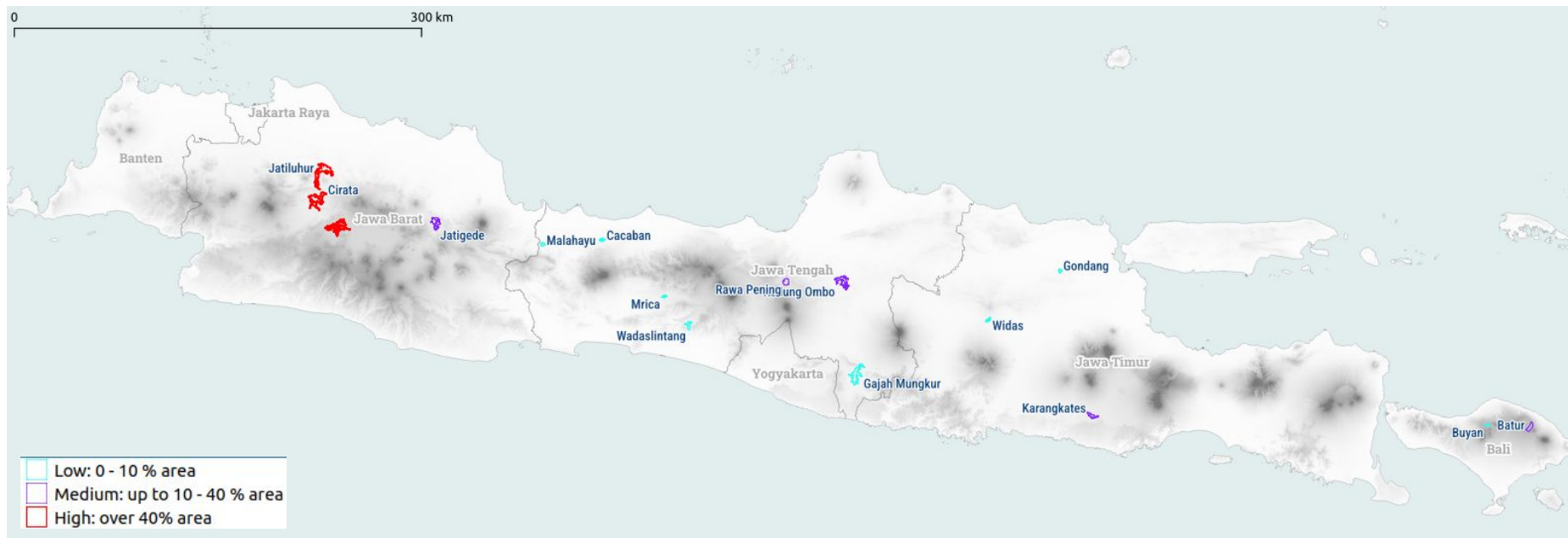


2.1 Geospatial Analysis

Water Hyacinth Coverage

Water hyacinths (*Eichhornia crassipes*) are an invasive species in Indonesia, growing abundantly on the surface of water reservoirs. They pose a risk to any structure on the surface of the water, especially FPV, where they can damage cables and electrical connections and accelerate the degradation of PV modules, floats, and support structures. Although they can be removed and effectively controlled, this requires additional O&M costs.

- Value 0 for no water hyacinth on the surface of the reservoir
- Value 1 for ≤ 10 % coverage of the surface of the reservoir (low)
- Value 2 for 10-40 % coverage of the surface of the reservoir (medium)
- Value 3 for >40 % coverage of the surface of the reservoir (high)



ENVIRONMENTAL AND SOCIAL ANALYSIS

2.2 Environmental and Social Analysis

The E&S analysis aims to achieve the following objectives:

- **Outline the E&S Framework:** Describe the E&S framework, including the International Finance Corporation (IFC) Performance Standards (PSs) requirements.
- **Review Local Regulation:** Summarise the Indonesian environmental and social requirements relevant to FPV projects, highlighting key regulations and relevant E&S considerations.
- **Conduct E&S Analysis:** Using land-use maps, provide a desktop assessment of the socio-environmental conditions at the proposed project sites, including a high-level risk evaluation and recommendation of mitigation measures.

2.2 Environmental and Social Analysis

Environmental and Social Screening

- IFC Standards

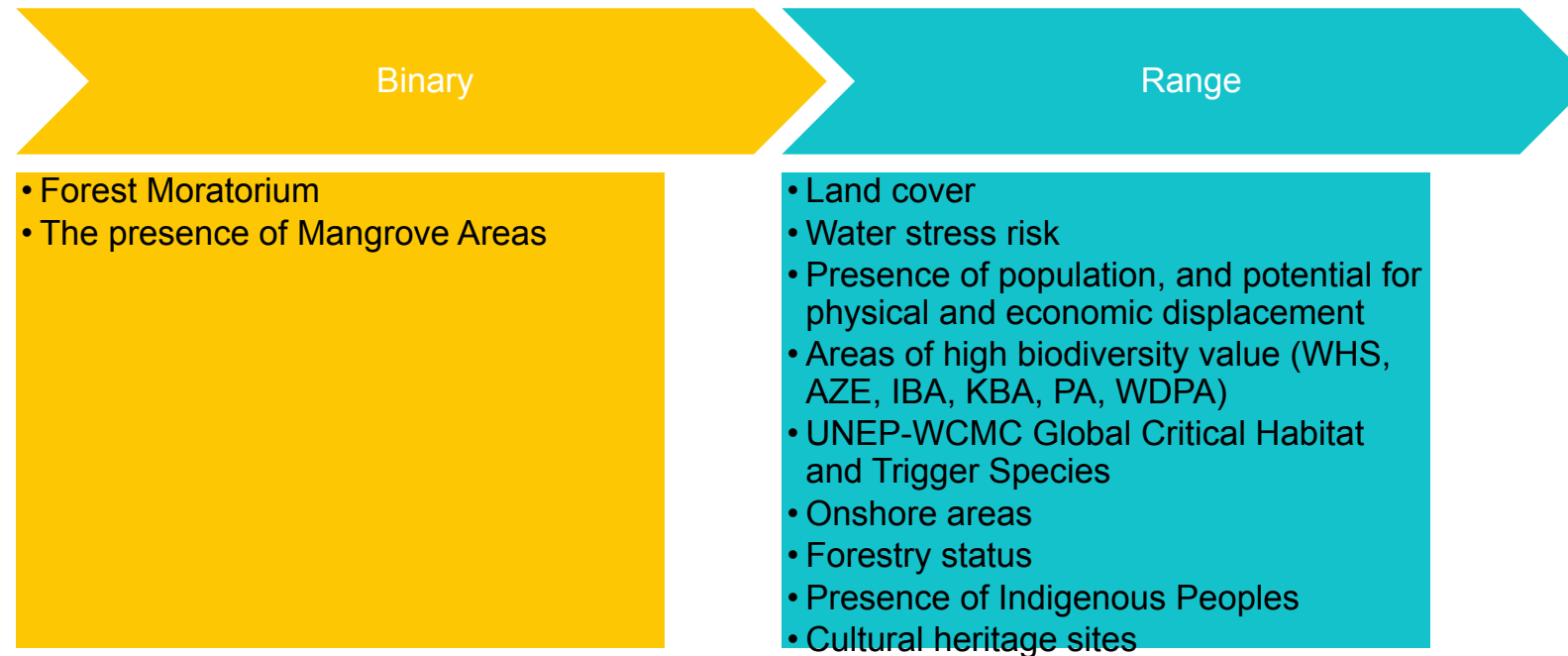
Performance standards (PS)	Key Requirements
PS 5: Land Acquisition and Involuntary Resettlement	The IFC PS 5 requirements include compensation and benefits for displaced persons, community engagement, resettlement and livelihood restoration planning and implementation, and a grievance mechanism for physical and economic displacement.
PS 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources	The IFC PS 6 ensure that biodiversity is protected and conserved, sustainable management and use of natural resources is used wherever feasible throughout the project lifecycle. The key concerns required by the IFC PS6 include protecting and conserving biodiversity by assessing and managing modified and natural habitats, critical habitats, legally protected and internationally recognised areas, and invasive alien species; managing ecosystem services; managing living natural resources; and managing supply chains.
PS 7: Indigenous People	The IFC PS 7 require the Project to anticipate and avoid adverse impacts on the Indigenous People, including People screening and impact assessment, maintain relationships based on Informed Consultation and Participation (ICP), obtain FPIC if the project significantly affects the Indigenous People, and promote sustainable development benefits and opportunities.
PS 8: Cultural Heritage	The IFC PS8 requires sites to protect cultural heritage from any adverse impacts of Project activities and support its preservation. In this case, the implications of IPs are being assessed.

- E&S Parameters and Criteria

Parameters	Criteria
Environment (Aligned With Ps5)	1. Land Cover 2. Water Stress Risk
Social (Aligned With Ps5)	3. Presence Of Population, And Potential For Physical And Economic Displacement
Parameters: Biodiversity (Aligned With Ps6)	4. Areas Of High Biodiversity Value (WHS, AZE, IBA, KBA, PA, WDPA) 5. UNEP-WCMC Global Critical Habitat And Trigger Species 6. Onshore Area 7. Forestry Status
Parameters: Indigenous People (Aligned With Ps7)	8. Presence Of Indigenous Peoples
Parameters: Cultural Heritage (Aligned With Ps8)	9. Cultural Heritage Sites

2.2 Environmental and Social Analysis

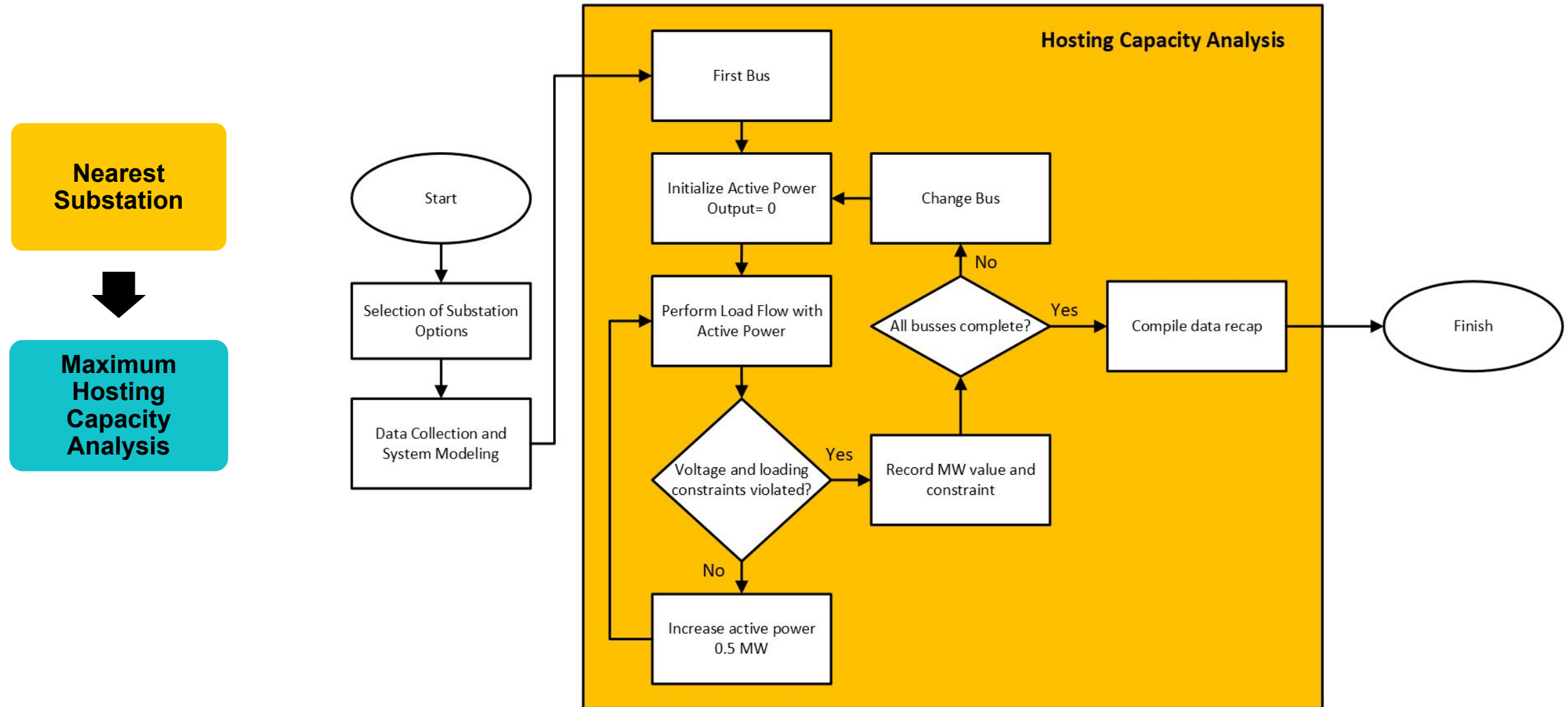
Approach to E&S Analysis



PRE-GRID INTEGRATION ANALYSIS

2.3 Pre-grid Integration Analysis

Approach:

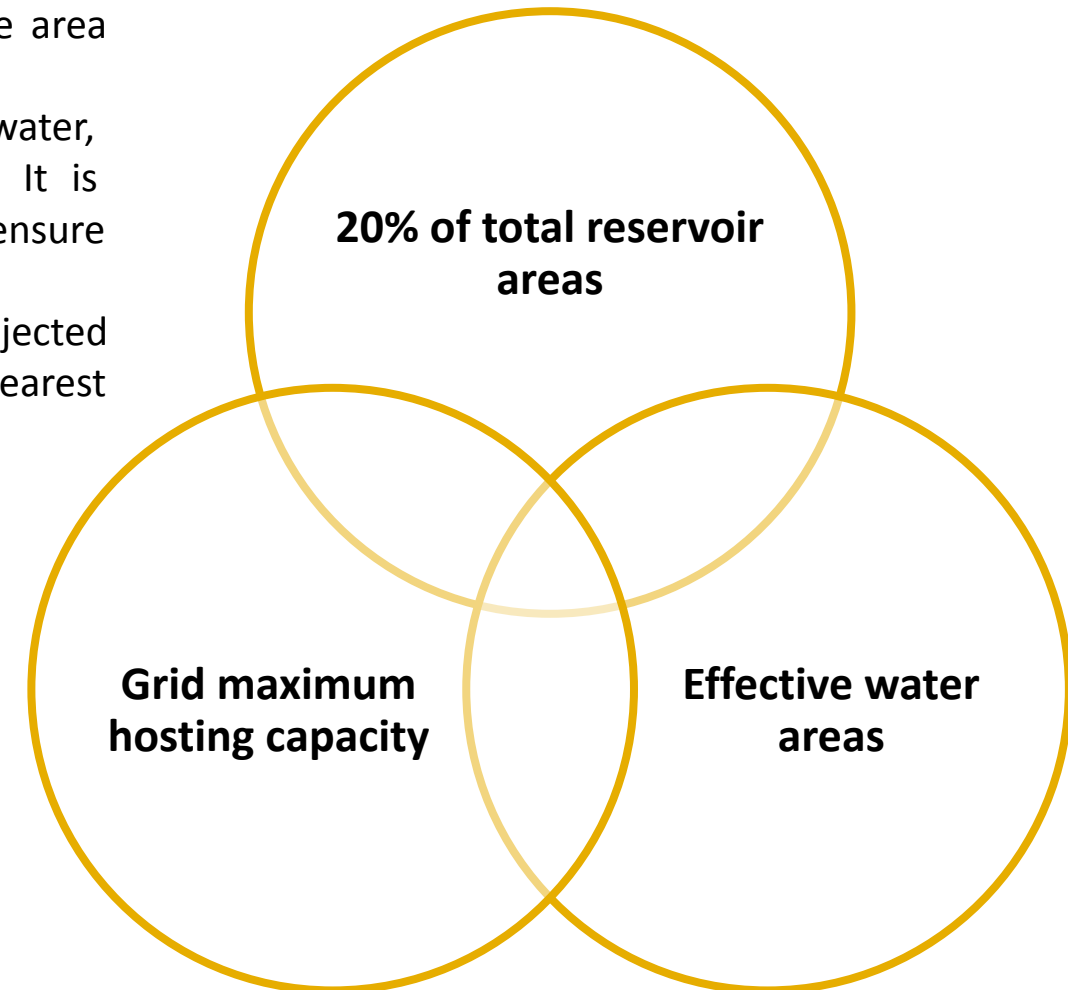


POTENTIAL CAPACITY

2.4 Potential Capacity

Approach:

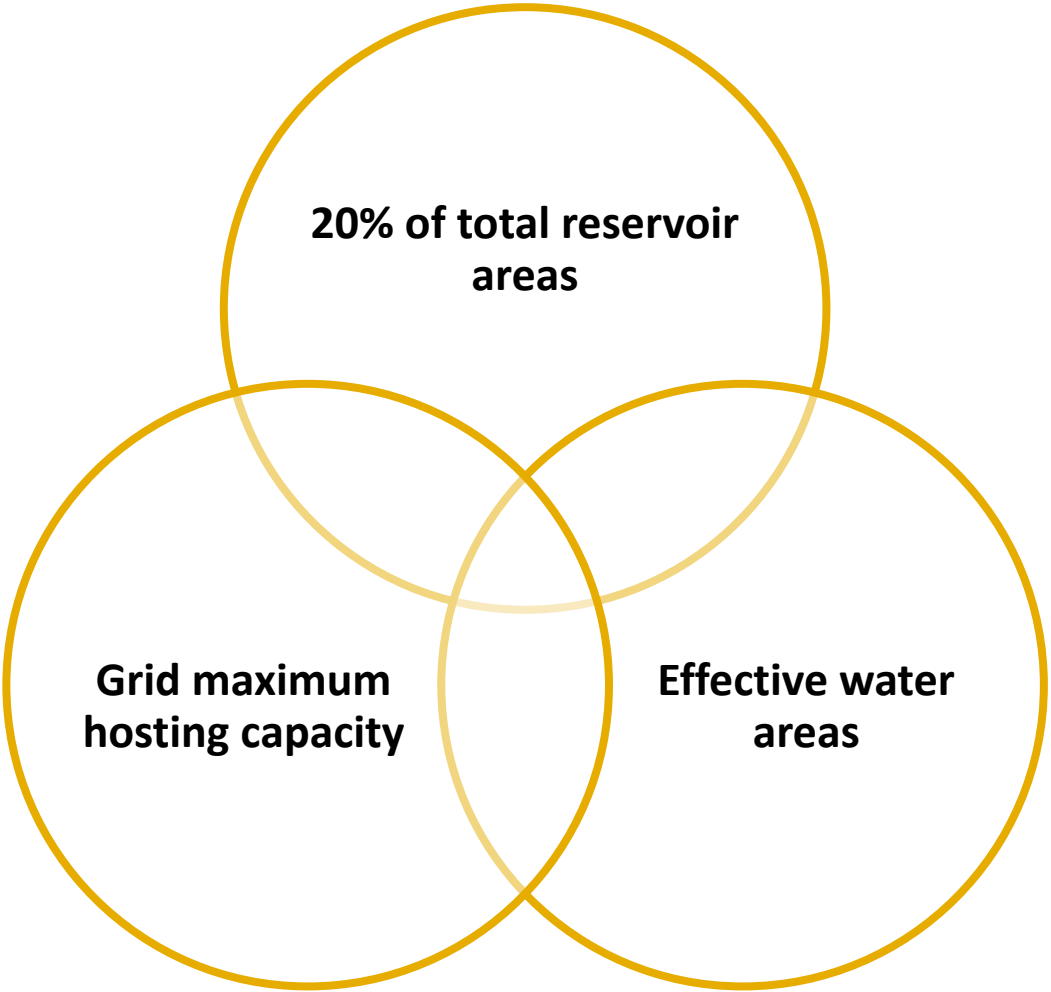
- **20% of the total reservoir area:** Based on the Ministry of Public Works and Housing Regulation Number 27/PRT/M/2015 on Dams, as amended by Regulation Number 7 of 2023, limits the maximum reservoir surface area that can be utilised for floating PV installations to 20%.
- **Effective area:** a portion of the reservoir that consistently holds water, representing the effective water surface available for floating PV. It is assumed that FPV systems will be installed within this MWL area to ensure that the floaters do not come into contact with the reservoir bed.
- **Grid maximum hosting capacity:** The maximum capacity that can be injected into the grid is limited by the technical hosting capacity of the nearest substations.



2.4 Potential Capacity

List of Sites

Geometry					
No	Reservoir name	Area by PUPR /other sources (ha)	Area MWL [ha]	Perimeter [km]	Estimated Capacity based on total Areas 20% [MWp]
1	Waduk Jatiluhur	7780	7091.4	220.1	1418
2	Waduk Cirata	6200	5729.6	190.7	1146
3	Waduk Gajah Mungkur	8800	4849.3	208.8	970
4	Waduk Kedung Ombo	4600	3838.6	210.3	768
5	Waduk Saguling	5600	3515.6	399.4	703
6	Waduk Jatigede	4946	3392.0	127.2	678
7	Waduk Karangates	1500	1283.0	71.5	257
8	Waduk Wadaslintang	1320	1141.8	55.4	228
9	Waduk Cacaban	790	642.6	49.1	129
10	Waduk Malahayu	540	538.4	35.2	108
11	Waduk Mrica	1250	487.0	34.1	97
12	Waduk Gondang	544	484.6	33.2	97
13	Waduk Widas	560	437.7	52.2	88
14	Danau Beratan	375	383.4	8.1	75
15	Waduk Darma	397	382.1	16.3	76
16	Waduk Wonorejo	380	362.1	21.0	72
17	Waduk Pondok	380	332.1	49.5	66
18	Waduk Cipancuh	387	329.0	23.0	66
19	Waduk Pacal	520	317.3	33.2	63
20	Waduk Lahor	263	315.1	34.4	53
21	Waduk Cengklik	253	288.7	11.0	51



FINANCIAL ANALYSIS

2.5 Financial Analysis

ASSUMPTION

- Inflation:**

	2025	2026	2027	2028+
Indonesia's Inflation Rate	2.80%	3.10%	3.10%	3.00%

- Currency exchange:**

1 USD = 16,209 (Middle rate data from the BI as of July 4th, 2025)

- Loan Interest rate:**

Interest Rate = 8%

- Ceiling price:**

Year 1-10: 6.95 cent USD/kWh

Year 11-30: 4.17 cent USD/kWh

- CAPEX:**

No	Capacity (MWp)	Price (USD/kWp)
1	Between 0 and 50	624
2	Between 50 and 75	612
3	Between 75 and 100	600
4	Between 100 and 250	582
5	Between 250 and 500	552
6	More than 500	540

- OPEX:**

Fixed cost for OM: 12.36 USD/kWh/year

Variable cost for OM: 0.0005 USD/kWh/year

RESULT

3.1 Sites Prioritization Result

Rank	Reservoir Name	Geospatial Score	E&S Score	Risk Rating	Potential Capacity (MWp)	Project IRR (Base case)	Total score
1	Waduk Kedung Ombo	1.00	17	High	411	8.97%	8.628
2	Waduk Gajah Mungkur	0.89	14	Medium	340	8.19%	8.206
3	Waduk Karangates	0.78	14	Medium	257	8.69%	8.088
4	Waduk Jatigede	0.79	16	High	662	7.86%	7.708
5	Waduk Cirata	0.63	15	Medium	1146	7.85%	7.512
6	Waduk Jatiluhur	0.63	16	High	651	7.72%	7.153
7	Waduk Wadaslintang	0.64	14	Medium	261	6.34%	6.596
8	Waduk Mrica	0.76	14	Medium	97	5.10%	6.329
9	Waduk Cengklik	0.60	15	Medium	51	6.08%	6.152
10	Waduk Saguling	0.29	16	High	310	7.43%	5.844
11	Waduk Lahor	0.44	15	Medium	53	5.90%	5.583
12	Waduk Widas	0.62	13	Low	88	3.88%	5.487
13	Waduk Pondok	0.39	15	Medium	66	4.04%	4.623
14	Waduk Cacaban	0.23	13	Low	129	4.42%	4.595
15	Waduk Gondang	0.51	15	Medium	68	3.18%	4.594
16	Waduk Wonorejo	0.51	12	Low	72	2.19%	4.551
17	Waduk Darma	0.35	16	High	76	3.51%	4.158
18	Waduk Malahayu	0.28	17	High	108	1.97%	3.177
19	Waduk Pacal	0.45	14	Medium	54	0.03%	3.093
20	Danau Beratan	0.20	18	High	75	-1.48%	1.300
21	Waduk Cipancuh	0.37	14	Medium	0	NA	0.000

3.2 Geospatial Analysis Result

Rank	Reservoir	Advantages	Disadvantages
1	Waduk Kedung Ombo	Good performance across almost all parameters. Very good PVOU potential with low shading, low basic wind speed, available existing infrastructure (both hydropower and substation)	Medium-scale changes in water extend (effective area). Partially covered by floating net cages, moderately complex shape of the reservoir.
2	Waduk Gajah Mungkur	Good PVOU potential, low shading, small water extent changes, and good reservoir shape. It is far away from volcanoes, but the existing substation is relatively close by. Floating net cages cover almost nothing. Basic wind speed is low.	No existing hydropower. Low-medium coverage by water hyacinth.
3	Waduk Jatigede	Very low fluctuation of the water extent. Very good reservoir shape. Existing infrastructure (both hydropower and substation). Low coverage by floating net cages, low overage by water hyacinth.	Medium-high basic wind speed, relatively close to a volcano.
4	Waduk Karangates	Good PVOU potential, low shading, moderate water extent changes, medium-low basic wind speed, existing hydropower, and very close to a substation.	Very close to a volcano. High coverage by floating net cages, and medium-high coverage by water hyacinth.
5	Waduk Mrica	Very low fluctuation of the water extent. Existing infrastructure (both hydropower and substation). Medium-low basic wind speed, low shading risk, and no presence of water hyacinth.	Low PVOU potential and relatively complex reservoir shape. Moderate built-up of the shore.
6	Waduk Wadaslintang	Very low fluctuation of the water extent. Existing infrastructure (both hydropower and substation). Medium-low basic wind speed. Low coverage by floating net cages and water hyacinth.	Low PVOU potential with moderate to strong shading potential, and relatively complex reservoir shape. Relatively close to a volcano.
7	Waduk Jatiluhur	Very low fluctuation of the water extent. Existing infrastructure (both hydropower and substation).	High coverage by floating net cages and water hyacinth. High basic wind speed. Relatively close to a volcano.

3.2 Geospatial Analysis Result

Rank	Reservoir	Advantages	Disadvantages
8	Waduk Cirata	Good performance across almost all critical parameters. Existing infrastructure (hydropower and substation), low coverage of the shore by existing buildings, advantageous reservoir shape and only moderate changes in water extent.	Very high coverage by floating net cages and water hyacinth. Moderate PVOU and potential from terrain shading. Relatively close to a volcano. High basic wind speed.
9	Waduk Widas	Very good PVOU potential with very low shading. Low basic wind speed. No presence of floating net cages, low built-up of the shoreline, and far from a volcano.	Very severe water extent changes and very complex reservoir shape. No hydropower present and relative far from a substation. Low-medium coverage by water hyacinth.
10	Waduk Cengklik	Very good PVOU potential with very low shading. Medium-low basic wind speed. Close to an existing substation. Very good reservoir shape.	No existing hydropower, relatively large changes in water extent. High built-up of the shore and very high coverage by water hyacinth. Relatively close to a volcano.
11	Waduk Gondang	Moderately good PVOU potential, very low shading. Far away from volcanoes. Low basic wind speed. Almost no coverage by floating net cages.	Very severe water extent changes. No existing hydropower and relatively far from a substation. Low-medium coverage by water hyacinth.
12	Waduk Wonorejo	Small water extent changes, and good reservoir shape. Far away from volcanoes. Medium-low basic wind speed. No coverage by floating net cages or water hyacinth.	Relatively far from an existing substation, no existing hydropower. Very strong shading.
13	Waduk Pacal	Good PVOU potential, low shading. Low basic wind speed. No coverage by floating net cages. Almost no built-up of shore. Far from volcanoes.	Severe water extent changes. Extremely complex reservoir shape. No existing hydropower, substation far away. Low-medium coverage by water hyacinth.
14	Waduk Lahor	Good PVOU potential, low shading. Very close to a substation. Medium-low basic wind speed. Low coverage by water hyacinth.	Severe water extent changes, and the reservoir shape is extremely complex. Close to a volcano. No existing hydropower. High coverage by floating net cages.

3.2 Geospatial Analysis Result

Rank	Reservoir	Advantages	Disadvantages
15	Pondok	Good PVOUT potential, low shading. Far away from volcanoes. Medium-low basic wind speed. Almost no coverage by floating net cages, low coverage by water hyacinth.	Severe water extent changes. Extremely complex reservoir shape. No existing hydropower. Unfavourable road access. High built-up of the shore.
16	Waduk Cipancuh	Existing substation close by. Far away from volcanoes. No coverage by floating net cages or water hyacinth.	Extreme water extent changes (up to complete dry-out of the reservoir), water management must be addressed in more detail. No existing hydropower. Medium-high basic wind speed.
17	Waduk Darma	Very low fluctuation of the water extent. Good shape of reservoir. Relatively close to a substation. Low coverage by water hyacinth.	Low PVOUT potential. Medium-high basic wind speed. Very close to a volcano. No existing hydropower. High coverage by floating net cages. High built-up of the shore.
18	Waduk Saguling	Existing infrastructure (both hydropower and substation).	Severe water changes and complex reservoir shape. High basic wind speed. Close to a volcano. High coverage by floating net cages and water hyacinth. High built-up of the shore.
19	Waduk Malahayu	Relatively far from a volcano. No coverage by floating net cages or water hyacinth. Almost no built-up of shore.	Moderate water extent changes. Medium-high basic wind speed. No existing hydropower, very far away from a substation.
20	Waduk Cacaban	No coverage by floating net cages or water hyacinth. Almost no built-up of shore.	Large water extent changes. Medium-high basic wind speed. Close to a volcano. No existing hydropower, and the substation is relatively far away. Only moderate PVOUT potential.
21	Danau Beratan	Very little fluctuation in the water extent, low shape complexity. Very close to an existing substation. Very low coverage by floating net cages and water hyacinth.	Poor PVOUT potential, very strong terrain shading potential. High basic wind speed. No existing hydropower. Highly built-up shore.

3.3 E&S Analysis Result

No	Site	Land cover accumulated score	Environmental	PS 5	PS 6				PS 7	PS 8	Total score	Site Rating
			Water Stress Risk	Presence of Population, physical and economical displace	High biodiversity value area (WHS, AZE, IBA, KBA, PA, WDPA)	UNEP WCMC Global Critical Habitat, triggers critical habitat	Onshore Area	Forestry Status	Presence of Indigenous People	Cultural Heritage Site		
14	Danau Berantan	Low	High	Medium	Medium	Medium	High	Low	Low	High	18	High
4	Waduk Kedungombo	Low	High	Medium	Low	Medium	High	Low	Low	High	17	High
10	Waduk Malahayu	Medium	High	Medium	Low	Medium	High	Low	Low	Medium	17	High
5	Waduk Saguling	Low	High	High	Low	Medium	Low	Low	Low	Low	16	High
6	Waduk Jatigede	Medium	High	Medium	Low	Medium	Low	Low	Low	High	16	High
1	Waduk Jatiluhur	Low	High	High	Low	Medium	High	Low	Low	High	16	High
15	Waduk Darma	Low	High	High	Low	Medium	High	Low	Low	Low	16	High
2	Waduk Cirata	Low	High	High	Low	Medium	Low	Low	Low	Medium	15	Medium
12	Waduk Gondang	High	High	Low	Low	Medium	Low	Low	Low	Medium	15	Medium
17	Waduk Pondok	High	High	Medium	Low	Medium	Low	Low	Low	Low	15	Medium
20	Waduk Lahor	High	Medium	High	Low	Medium	Low	Low	Low	Low	15	Medium
21	Waduk Cengklik	High	High	Medium	Low	Medium	Low	Low	Low	Low	15	Medium
3	Waduk Gajahmungkur	Low	High	Low	Low	Medium	Low	Low	Low	High	14	Medium
7	Waduk Karangates	Medium	Medium	High	Low	Medium	Low	Low	Low	Low	14	Medium
8	Waduk Wadaslintang	Medium	High	Low	Low	Medium	Low	Low	Low	Medium	14	Medium
11	Waduk Mrica	High	High	Low	Low	Medium	Low	Low	Low	Low	14	Medium
18	Waduk Cipancuh	High	High	Low	Low	Medium	Low	Low	Low	Low	14	Medium
19	Waduk Pacal	Medium	High	Low	Low	Medium	Low	Medium	Low	Low	14	Medium
9	Waduk Cacaban	Low	High	Medium	Low	Medium	Low	Low	Low	Low	13	Low
13	Waduk Widas	Medium	Medium	Low	Low	Medium	Low	Medium	Low	Low	13	Low
16	Waduk Wonorejo	Medium	Medium	Low	Low	Medium	Low	Low	Low	Low	12	Low

3.3 E&S Analysis Result

Key Highlights for HIGH-RISK sites

Site	Social Risk	Cultural Heritage	Environmental/Natural Habitat	Key Notes
Danau Beratan	Medium (tourism, restaurants, hotels, viewpoints)	High – Adjacent to Pura Ulun Danu Batur (UNESCO World Heritage)	Dryland forest within 5 km; endemic species: <i>Rasbora baliensis</i> (VU), <i>Lentipes whittenorum</i> (DD)	Floating structures: 1.04%
Waduk Kedungombo	Medium (moderate population, floating net cages 13.85%)	High – Floating tomb of Nyi Ageng Serang (sacred site & religious tourism)	Limited info	Strong community significance
Waduk Malahayu	Medium (low population, small islands as tourism spots)	None in reservoir; near Dutch colonial ruins	Dryland forest within 5 km	Photo tourism attraction
Waduk Saguling	High (dense population, floating net cages 68%)	Medium – Sirtwo Island with prehistoric fossils	Severe environmental stress (overcapacity, pollution)	35,000–37,000 Floating Net Cages (above limit)
Waduk Jatigede	Medium (low population, floating net cages 12.29%)	High – Submerged historical graveyard (Makam Keramat Prabu Guru Aji Putih)	Small island photo spots	Community access by boat
Waduk Jatiluhur	High (dense population, floating net cages 41.83%)	None reported	Dryland forest within 5 km	Intensive aquaculture
Waduk Darma	High (dense population, floating net cages 52.34%)	None reported	Dryland forest within 5 km	Hotspots: Cipasung & Jagara Villages

3.4 Grid Maximal Hosting Capacity

No	Name	Substation	Distance (km)	Maximum hosting capacity (MW)
1	Waduk Jatiluhur	Jatiluhur Baru 150 kV	1.17	521
2	Waduk Cirata	Cirata 150 kV	2.52	1853
3	Waduk Gajah Mungkur	Wonogiri 150kV	7.94	272
4	Waduk Kedung Ombo	Kedungombo 150 kV	0.8	329
5	Waduk Saguling	Rajamandala 150 kV	6.73	248
6	Waduk Jatigede	Jatigede 150kV	2.92	529.5
7	Waduk Karangates	Sutami 150kV	0.57	487.5
8	Waduk Wadaslintang	Wadaslintang 150 kV	0.78	208.5
9	Waduk Cacaban	Kebasen 150kV	13.5	599
10	Waduk Malahayu	Brebes 150 kV	26.87	406
11	Waduk Mrica	Mrica 150kV	1.88	450.5
12	Waduk Gondang	Ngimbang 150 kV	13.06	1073
13	Waduk Widas	New Nganjuk 150 kV	13.31	731
14	Danau Beratan	Baturiti 150 kV	2.13	413
15	Waduk Darma	Kuningan Baru 150kV	7.64	826
16	Waduk Wonorejo	Tulungagung 150kV	13.22	1113
17	Waduk Pondok	Ngawi 150kV	11.74	1071
18	Waduk Cipancuh	Haurgeulis 150 kV	6.12	97
19	Waduk Pacal	Bojonegoro 150kV	20.72	418
20	Waduk Lahor	Sutami 150kV	1.91	487.5
21	Waduk Cengklik	Banyudono 150kV	3.68	1069

3.5 Potential Capacity Result

No	Reservoir name	Area (ha)	Capacity_20 % areas (MWp)	Capacity eff_water area (MWp)	Maximum Hosting Capacity (MWp)	Distance to Substation (km)	PV Capacity (MWp)
1	Waduk Jatiluhur	7091.4	1418	5248	651	1.17	651
2	Waduk Cirata	5729.6	1146	3953	2316	2.52	1146
3	Waduk Gajah Mungkur	4849.3	970	2716	340	7.94	340
4	Waduk Kedung Ombo	3838.6	768	2034	411	0.8	411
5	Waduk Saguling	3515.6	703	1477	310	6.73	310
6	Waduk Jatigede	3392.0	678	2646	662	2.92	662
7	Waduk Karangkates	1283.0	257	616	609	0.57	257
8	Waduk Wadaslintang	1141.8	228	948	261	0.78	261
9	Waduk Cacaban	642.6	129	238	749	13.5	129
10	Waduk Malahayu	538.4	108	226	508	26.87	108
11	Waduk Mrica	487.0	97	365	563	1.88	97
12	Waduk Gondang	484.6	97	68	1341	13.06	68
13	Waduk Widas	437.7	88	105	914	13.31	88
14	Danau Beratan	375.0	75	376	516	2.13	75
15	Waduk Darma	382.1	76	290	1033	7.64	76
16	Waduk Wonorejo	362.1	72	239	1391	13.22	72
17	Pondok	332.1	66	96	1339	11.74	66
18	Waduk Cipancuh	329.0	66	0	121	6.12	0
19	Waduk Pacal	317.3	63	54	523	20.72	54
20	Waduk Lahor	263.0	53	101	609	1.91	53
21	Waduk Cengklik	253.0	51	107	1336	3.68	51

3.6 Financial Analysis Result

Base case Scenario (with evacuation line)

No	Reservoir name	Capacity (MWp)	With Evacuation Line		Without Evacuation Line	
			Project IRR	Equity IRR	Project IRR	Equity IRR
1	Waduk Jatiluhur	651	7.72%	7.51%	7.77%	7.60%
2	Waduk Cirata	1146	7.85%	7.73%	7.91%	7.85%
3	Waduk Gajah Mungkur	340	8.19%	8.34%	8.88%	9.61%
4	Waduk Kedung Ombo	411	8.97%	9.78%	9.03%	9.90%
5	Waduk Saguling	310	7.43%	7.00%	8.06%	8.12%
6	Waduk Jatigede	662	7.86%	7.76%	7.99%	8.00%
7	Waduk Karangates	257	8.69%	9.26%	8.76%	9.38%
8	Waduk Wadaslintang	261	6.34%	5.15%	6.42%	5.28%
9	Waduk Cacaban	129	4.42%	2.26%	6.73%	5.82%
10	Waduk Malahayu	108	1.97%	-1.26%	6.65%	5.63%
11	Waduk Mrica	97	5.10%	3.20%	5.56%	3.89%
12	Waduk Gondang	68	3.18%	0.53%	6.80%	5.94%
13	Waduk Widas	88	3.88%	1.27%	7.17%	6.50%
14	Danau Beratan	75	-1.48%	-	-0.65%	-
15	Waduk Darma	76	3.51%	0.84%	5.60%	3.94%
16	Waduk Wonorejo	72	2.19%	-1.00%	5.58%	3.89%
17	Waduk Pondok	66	4.04%	1.80%	7.51%	7.15%
19	Waduk Pacal	54	0.03%	-3.93%	6.21%	4.84%
20	Waduk Lahor	53	5.90%	4.45%	6.77%	5.85%
21	Waduk Cengklik	51	6.08%	4.82%	8.15%	8.28%

3.6 Financial Analysis Result

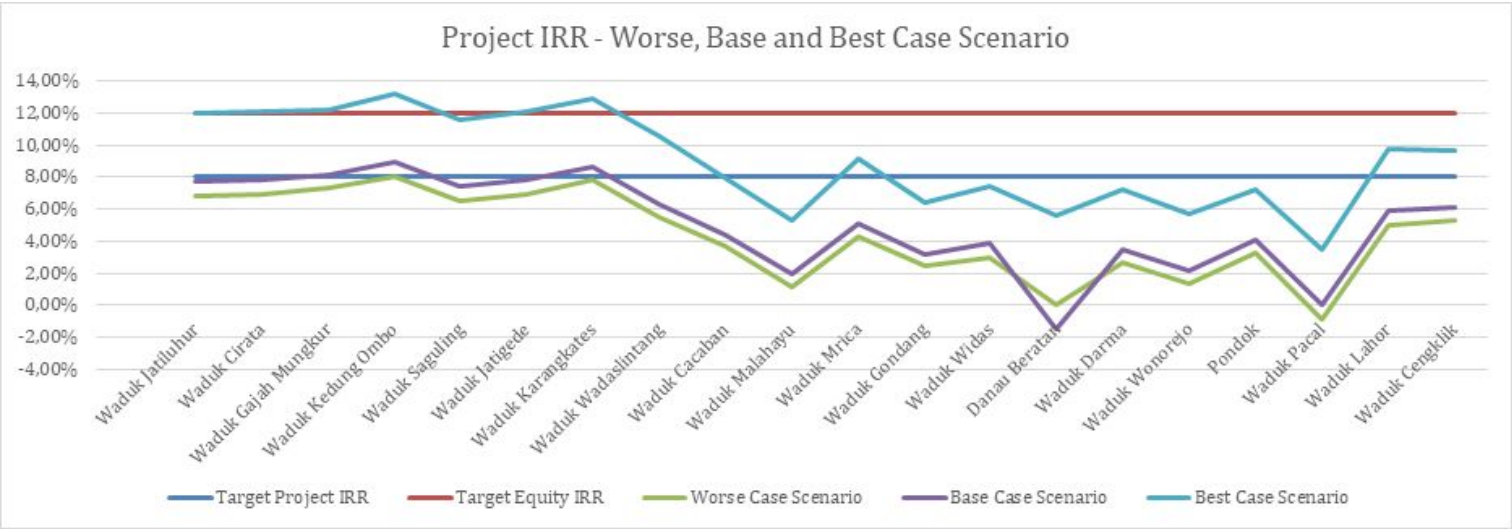
Comparison to best case scenario

Assumptions	Worse Scenario	Base Scenario	Best Case Scenario
Energy generation	-5% Annual Energy Generation	100 % Annual Energy Generation	+5% Annual Energy Generation
Fixed OPEX	USD 12.36 per kW per year (10.30 USD per kW per year based on International Renewable Energy Agency (IRENA), 2024, multiplied by 1.2)	USD 12.36 per kW per year (10.30 USD per kW per year based on International Renewable Energy Agency (IRENA), 2024, multiplied by 1.2)	4.80* USD per kW per year
Main power plant CAPEX and OPEX	Ground Mounted CAPEX multiplied by 1.2.	Ground Mounted CAPEX multiplied by 1.2.	Ground Mounted CAPEX multiplied by 1.1.

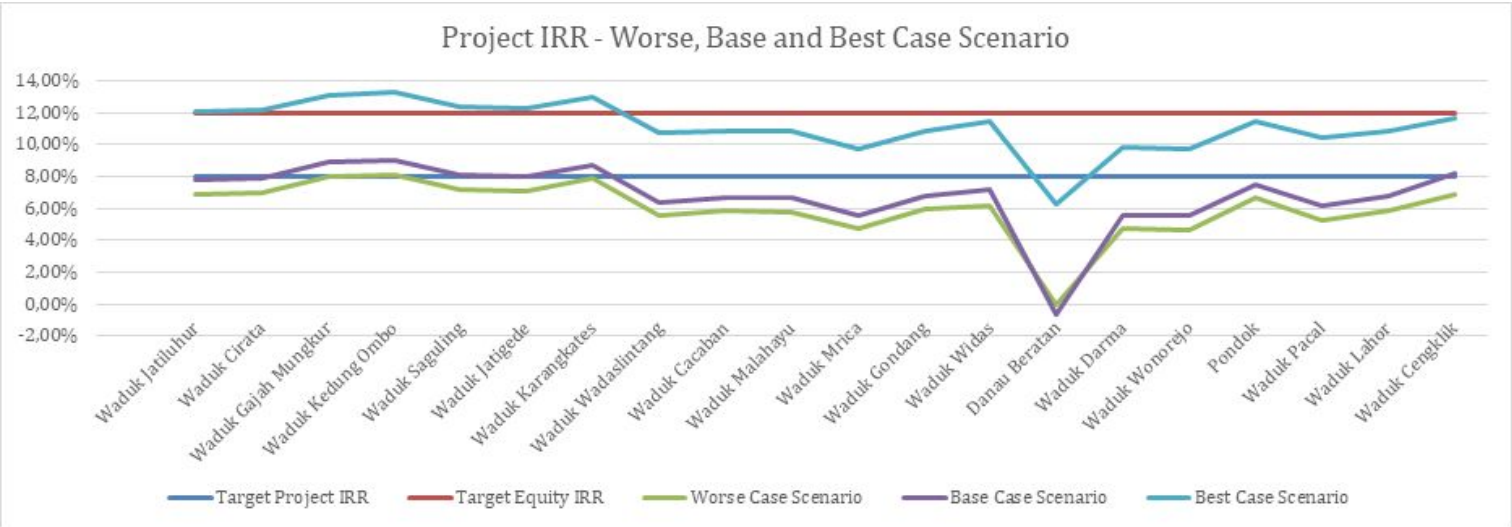
3.6 Financial Analysis Result

Project IRR Range

With Evacuation Line



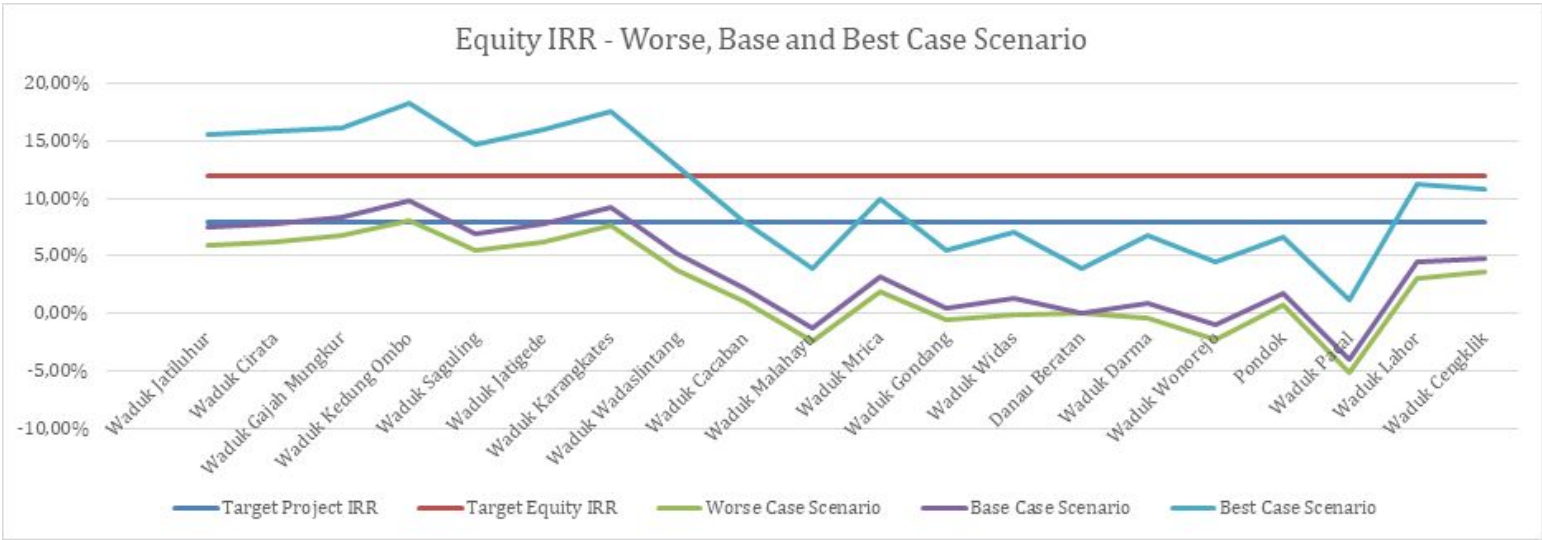
Without Evacuation Line



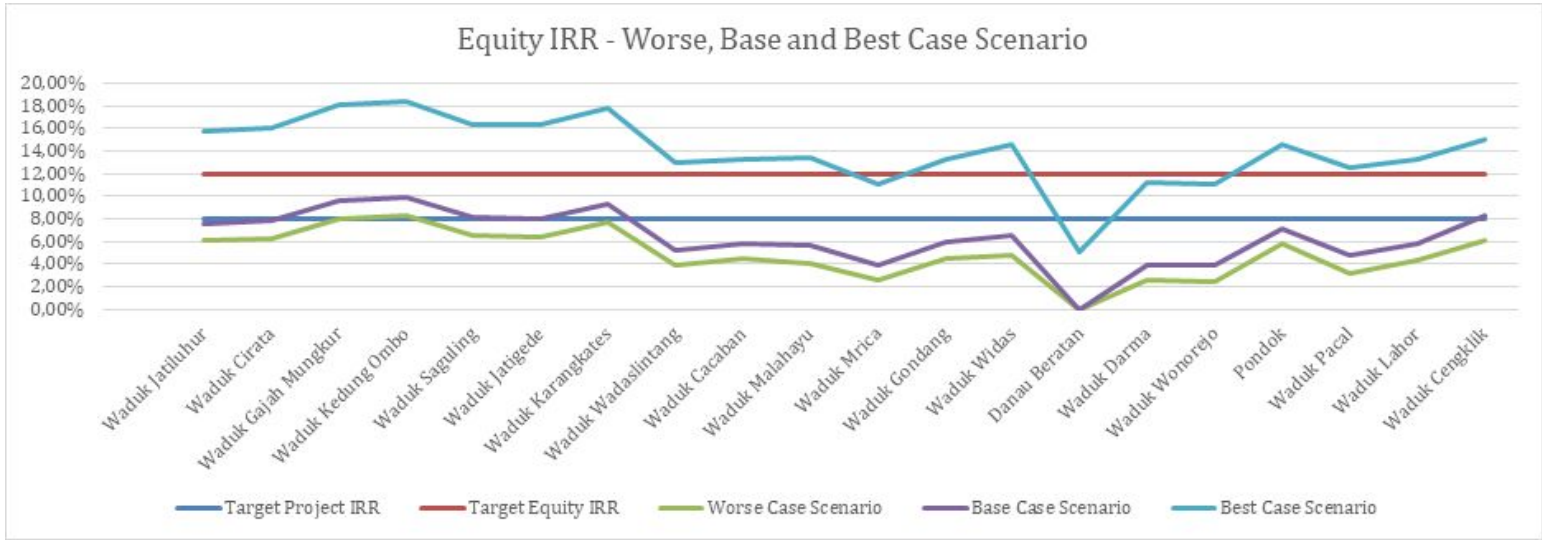
3.6 Financial Analysis Result

Equity IRR Range

With Evacuation Line



Without Evacuation Line



RESULT ANALYSIS

4.0 Result Analysis

Key Highlights

Analysis Component	Key Findings	Implications
Geospatial Analysis	- 21 reservoirs ranked by solar potential, shading, wind, water level, shape, infrastructure, aquaculture. - Sites <0.5 score = more technical challenges but feasible.	Prioritize high-score sites; low-score sites need advanced engineering & higher costs.
Environmental & Social (E&S)	- No sites excluded. - 18 sites have medium/high E&S risks, mainly due to dense aquaculture (FNC) & related social tensions.	Conduct ESIA; follow international standards; early stakeholder engagement critical.
Grid Integration	- Strong technical potential often limited by 2030 grid hosting capacity.	Grid upgrades/expansion required to unlock full FPV capacity.
Financial Analysis	- Moderate returns; none reach 12% equity IRR base case. - Higher tariffs or no evacuation cost improve viability.	Focus on tariff negotiation & cost-sharing for transmission.
Site Prioritization	- High priority: Kedung Ombo, Gajah Mungkur, Karangates, Jatigede. - Medium: Potential with risk mitigation. - Low: Low IRR/high E&S risk.	Advance top sites first; address risks for medium-tier; defer low-tier.

4.0 Result Analysis

Sites Rank Sumamry

Priority Tier	Sites	Key Characteristics
 High	Waduk Kedung Ombo, Gajah Mungkur, Karangates, Jatigede	Strong technical potential and good financial returns
 Medium	Cirata, Jatiluhur, Wadaslintang, Mrica, Saguling	Good technical capacity; moderate E&S or financial constraints
 Low	Lahor, Widas, Pondok, Cacaban, Gondang, Wonorejo	Moderate feasibility; low returns or higher development effort
 Least Suitable	Darma, Malahayu, Pacal, dan Danau Beratan	Very low IRR, high E&S risk, and cultural/environmental sensitivities

Notes:

- Priority for near-term FPV: sites with **balanced technical, E&S (with some notes), and financial profiles**.
- Medium-tier sites viable with **strong risk mitigation**.
- Low-return/high-risk sites should be **deprioritized**.
- Detailed site-specific feasibility studies remain essential before development.

4.1 CRITICAL NOTES

It is important to emphasise that this high-level assessment serves only as an initial screening **and does not replace the need for a detailed, site-specific feasibility study**. Any future FPV project at these reservoirs **must be preceded by a comprehensive feasibility study considering each site's unique technical, environmental, social, regulatory, and financial circumstances**. This should include acquiring site-specific bathymetric data, identifying the exact placement for the FPV installation, and conducting real-time water level and weather measurements. In addition, detailed grid connection studies, stakeholder engagement, and a thorough evaluation of commercial viability and bankability, aligned with the requirements of potential investors and lenders, are all essential to ensure successful implementation.



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