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)

SOLAR IRRADIANCE MAPPING

Prepared by : Consortium lead by Trama TecnoAmbiental

tta · SOLARGIS · ERM · QUADRAN SOLUSI ENGINEERING · INOVASI DINAMIKA PRATAMA

DECEMBER 2024

UNOPS · AFD Agence Française de Développement · Federal Ministry for Economic Affairs and Climate Action · Department for Energy Security & Net Zero · Environment and Climate Change Canada / Environnement et Changement climatique Canada · Australian Government Department of Climate Change, Energy, the Environment and Water · CIFF Children's Investment Fund Foundation · Sequoia Climate Foundation

Solar Irradiance and Potential Area for Solar PV Development Mapping

December 18, 2024

Prepared by:

Trama TecnoAmbiental, S.L. (TTA) and The Consortiums

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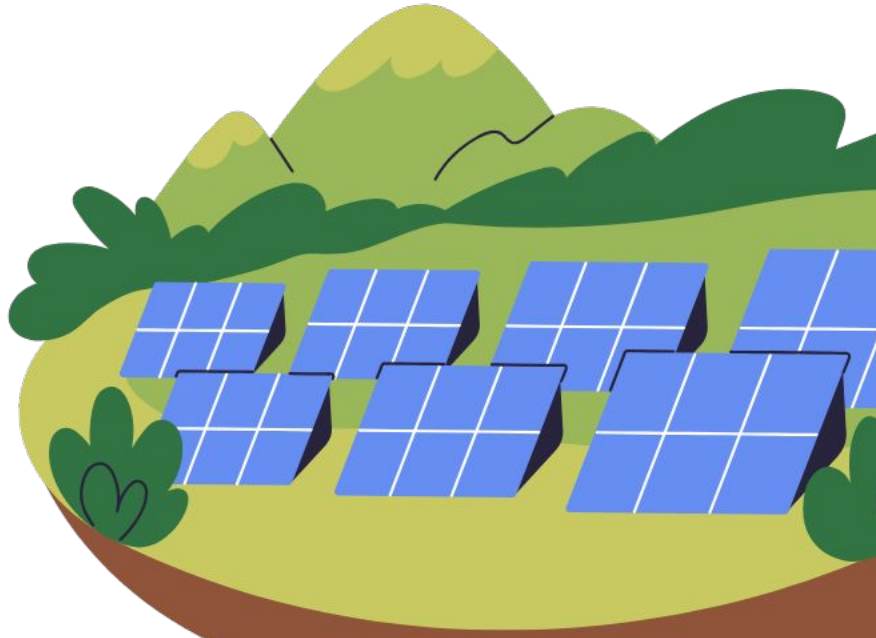


1. PROJECT AND REPORT OBJECTIVES

1.1 PROJECT OBJECTIVES

14.11 % Current Renewable Energy shared

8.8 GW New additional RE installed capacity by 2030

$8 B Annual investment in RE 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 2050.

Key Project Outputs:

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

1.2 WORKPLAN

M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15

Deliverable 2

Report on Solar Irradiance Mapping and accessible database

What are the optimal placements for solar PV installations in Jamali Indonesia?

Irradiation data and potential locations will be selected based strictly on high irradiation locations and proximity to PLN substations.

A Multi Criteria Decision Matrix will be developed to further refine and prioritize the locations.

Deliverable 3

Report on Grid Integration Assessment

- **What would be the impact of the solar PV installations on the existing grid if located if the sites identified in deliverable 2?**
- **What is the effective capacity planning of the existing grid systems ? What is the ability of the current infrastructure to handle current and future energy demands including the integration of renewable energy sources?**
- **If validated on a technical point of view, are the selected viable to be implemented on a economic and environmental factor?**

The grid assessment aims at addressing/identifying technical, economical and environmental challenges of the existing power systems and in. It aims also to estimate the integration of renewable energy and assess if any of the sites initially selected would affect it negatively.

Deliverable 4

Review and Recommended solutions on the impediments of Solar PV development

- **To what extend the sites selected would be viable?**
- **Would private sector actors be able to implement the solar PV installation in the sites located?**

What are the challenges and opportunities for the solar PV development in Indonesia?

Who are the relevant stakeholders involved in the solar PV development in Indonesia and what are their roles and responsibilities?

What are the impediments that holding the solar PV projects development in Indonesia? How to overcome those barriers?

What kind of actions that can accelerate the solar PV projects development in Indonesia? When should these actions be done?

How can the relevant stakeholders be involved in overcoming the impediments or in solving the challenges and accelerating the solar PV development in Indonesia?

Deliverable 5

Pre-Feasibility Study with Regulatory and non-Regulatory Analysis

- **How can the relevant stakeholders be involved to address the challenges and accelerate the development?**
- **What are the recommendations to make the solar PV projects in Indonesia attractive to the investor and bankable?**
- **What kind of financing and investment mechanism is best for the selected solar PV project?**

1.3 OBJECTIVES AND OUTPUT OF THE REPORT

M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15

Deliverable 2

Deliverable 2 entails a comprehensive assessment of solar irradiance data and site suitability within the JAMALI regions

The deliverable provides answers to the following :

1. Define the optimal placements for solar PV installations in JAMALI, Indonesia, to reach the development generation of 1 GW of solar energy infrastructure.
2. Provide solar irradiance data mapping, which will serve as the project's fundamental basis, strengthen the MEMR database, and make it accessible to the public.
3. Develop a Multi-Criteria Decision Matrix (MCDM), including GIS and non-GIS data layers, to prioritize sites according to potential solar radiation, environmental and social criteria, land availability, and regulations.

Notes :

The report includes the methodology of the selection, the types of data utilized for the output, and the final visual map of the potential sites for distributed solar PV installations across the JAMALI region.

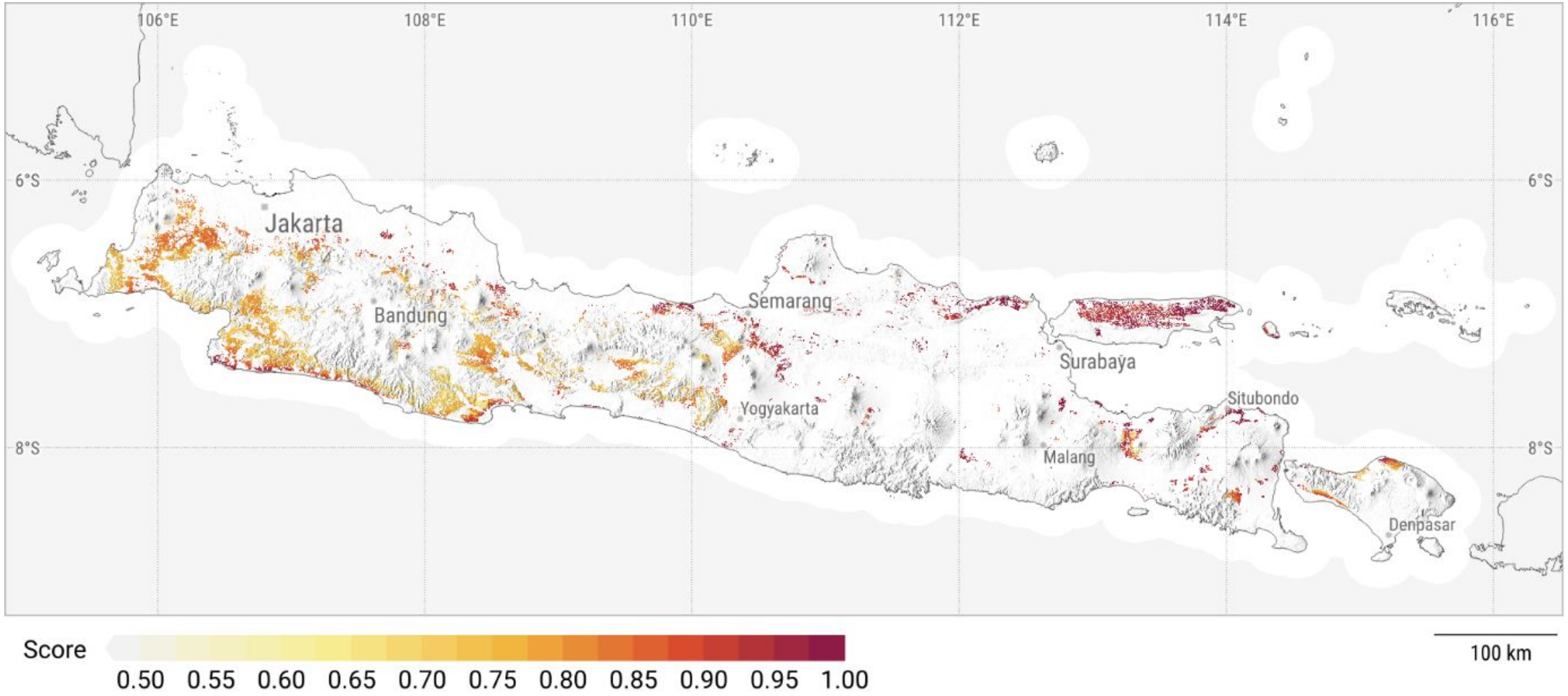
The final location selection is available, and the GIS data provided can be added to Indonesia's MEMR One Map. The Indonesian government counterpart can use this to develop a 1 GW solar PV roadmap and procurement strategy for private sector project developers.

The outputs of this report are as follows:

1. Solar Irradiance Mapping in the JAMALI region
2. Regulatory, social, and environmental suitability analysis
3. Multi-Criteria Decision Matrix for the selection of the most suitable distributed solar PV installation
4. Optimal sites for distributed Solar PV installation across the JAMALI region

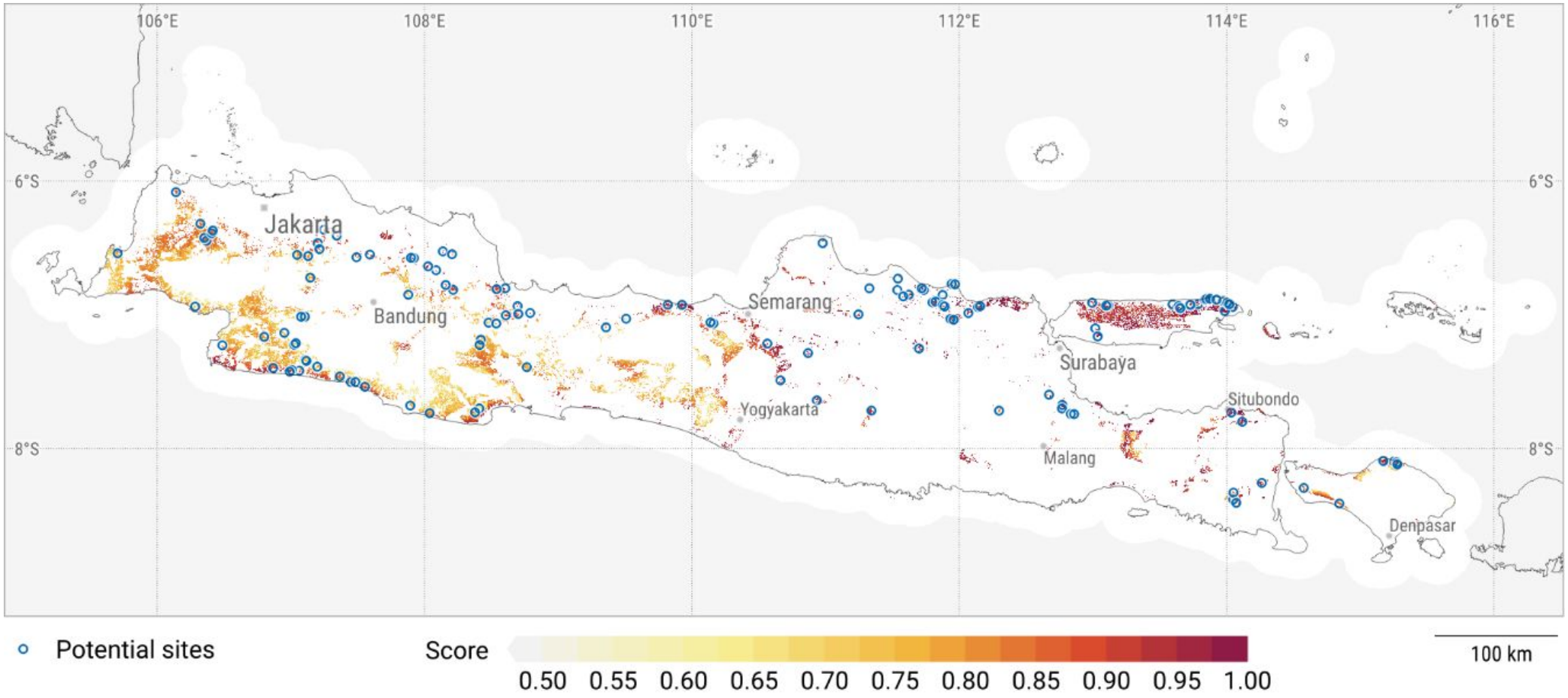
GEOSPATIAL ANALYSIS RESULT

Geospatial analysis result, the composite of binary and range layers



GEOSPATIAL ANALYSIS RESULT

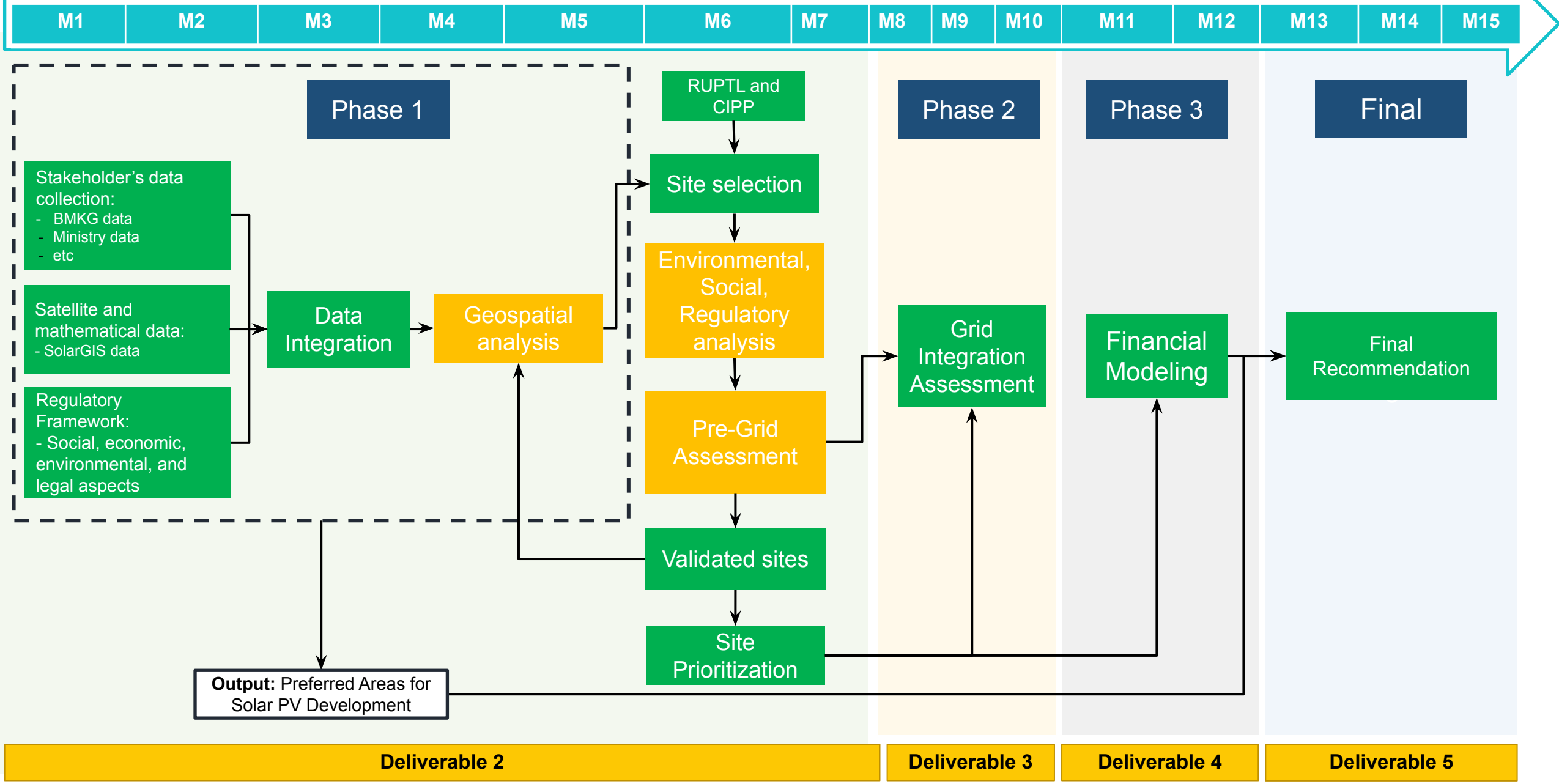
140 Pre-selected Sites



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

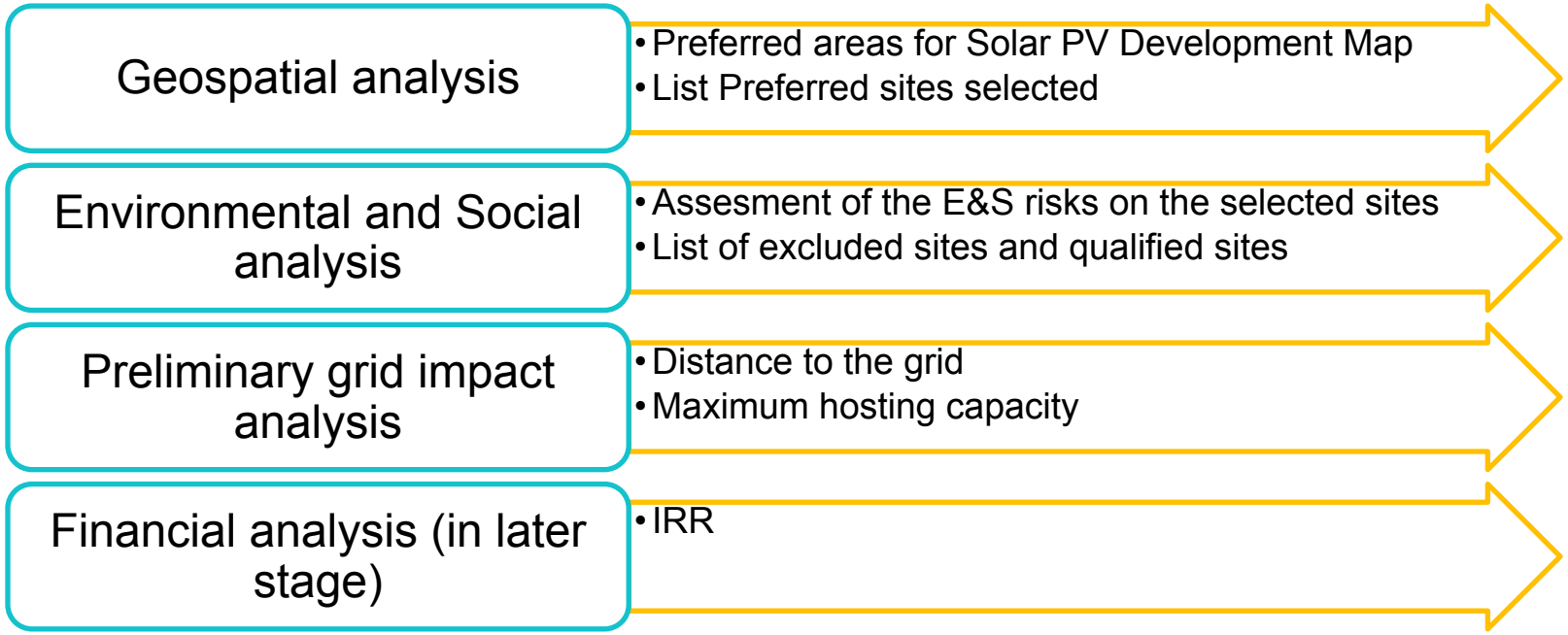
2. METHODOLOGY

2.1 METHODOLOGY OF THE PROJECT



2.2 ABOUT THE METHODOLOGY

A Multi-Criteria Decision Matrix (MCDM) assessment was built collaboratively to identify the preferred locations for PV development in JAMALI. The process consisted of:

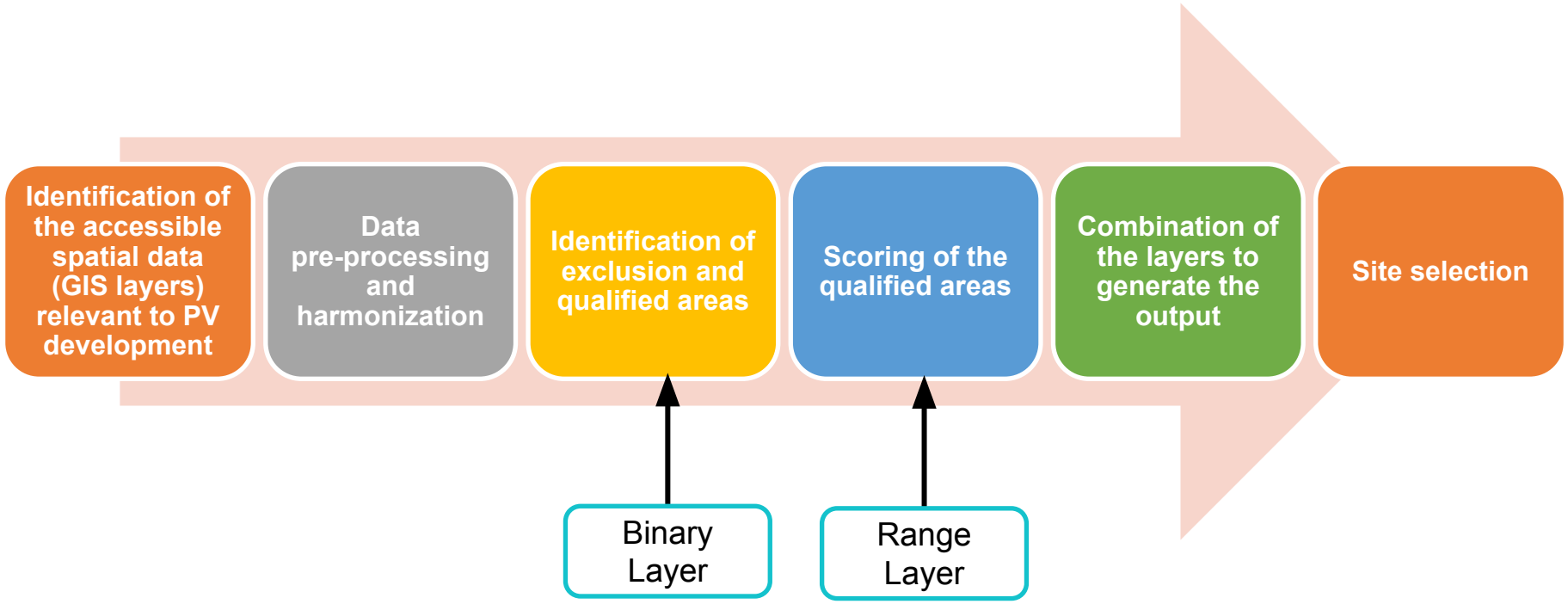


2.2.1 GEOSPATIAL ANALYSIS

OBJECTIVES :

to identify the preferred areas for utility-scale PV development in the JAMALI region from the point of technical and social constraints

APPROACH :



2.2.1 GEOSPATIAL ANALYSIS

Binary Layer

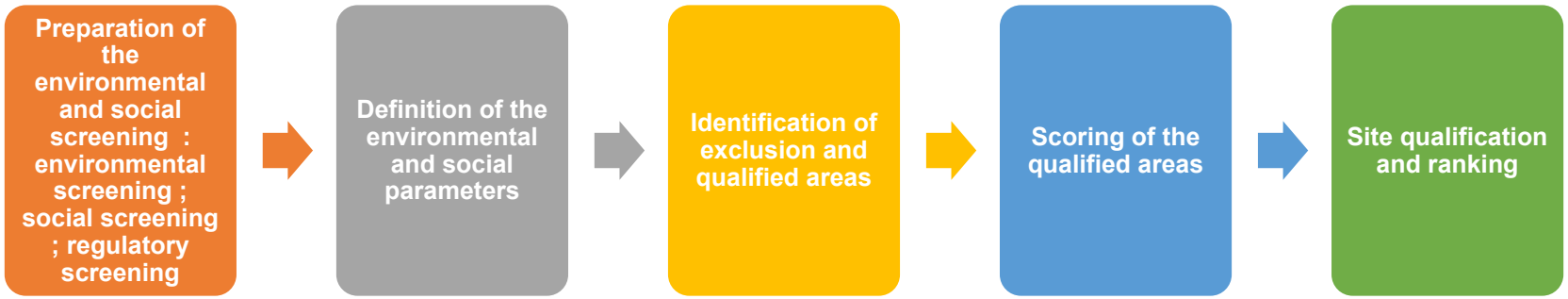
Range Layer

2.2.2 ENVIRONMENTAL AND SOCIAL ANALYSIS

OBJECTIVES

This assessment is conducted as a confirmatory step to the relevant spatial plan regulations related to protected areas that need to be reviewed after the sites are selected due to the limited database provided by Indonesia's government. The purpose of E&S analysis is ultimately to rank the pre-selected sites and exclude unsuitable sites.

APPROACH :



2.2.2 ENVIRONMENTAL AND SOCIAL ANALYSIS

SCORING PARAMETERS – BINARY LAYER

- Forest moratorium
- The presence of mangrove areas
- Forestry status
- Regional spatial planning category

SCORING PARAMETERS – RANGE LAYER

- Water risk
- Presence of social forests
- Population density, and potential for physical and economic displacement
- Regional spatial planning category

2.2.3 PRE-GRID ANALYSIS

OBJECTIVES AND APPROACH

This study focuses on the preliminary grid assessment to evaluate the system's capacity to absorb 1 GW of solar PV into the JAMALI Grid and analyze the maximum hosting capacity at each substation

APPROACH :

Preliminary Grid Systems analysis

Distance to the nearest substation

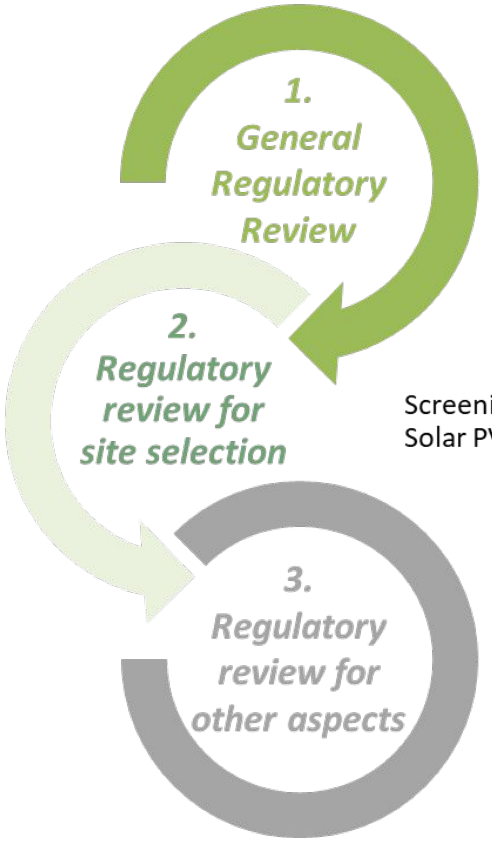
Maximum hosting capacity

2.3 REGULATORY ANALYSIS

OBJECTIVES AND APPROACH

Reviewing the relevant regulations establishes the context and landscape of the 1GW solar PV development.

APPROACH :



Identifying Laws, Government Regulations, Presidential Regulations, and Ministerial Regulations that overseen Solar PV development in Indonesia

Screening relevant regulations for site selection of Solar PV development as input for MCDM criteria

Compile findings from identified regulations that will be useful in the next stage of analysis i.e financial assessment, business development, etc

3. RESULTS AND ANALYSIS

RESULTS

GEOSPATIAL ANALYSIS

- 140 sites

E&S ANALYSIS

- 137 sites qualified
- 41 high-risk
- 96 medium risk
- 3 excluded

PRE-GRID ASSESSMENT

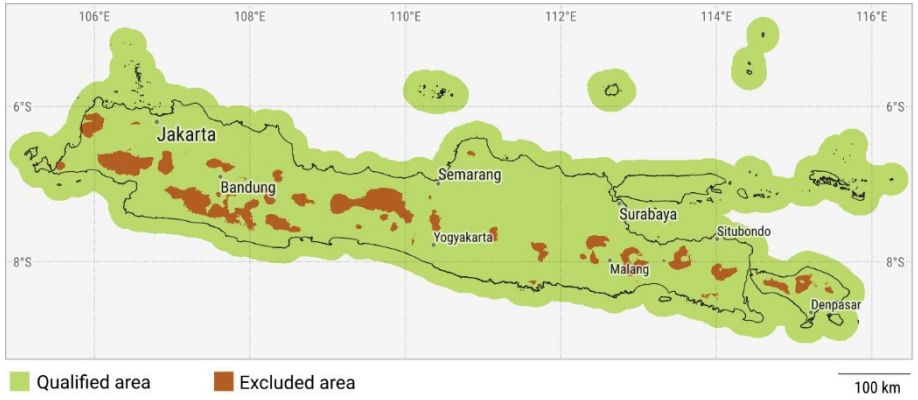
- Maximum Hosting Capacity for relevant substations
- Potential Solar PV Capacity

SITE PRIORITIZATION

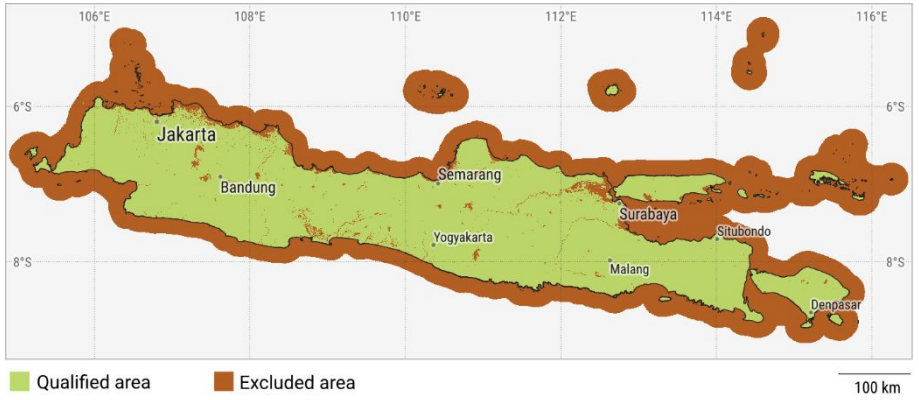
- Final list of sites

3.1 GEOSPATIAL ANALYSIS RESULT

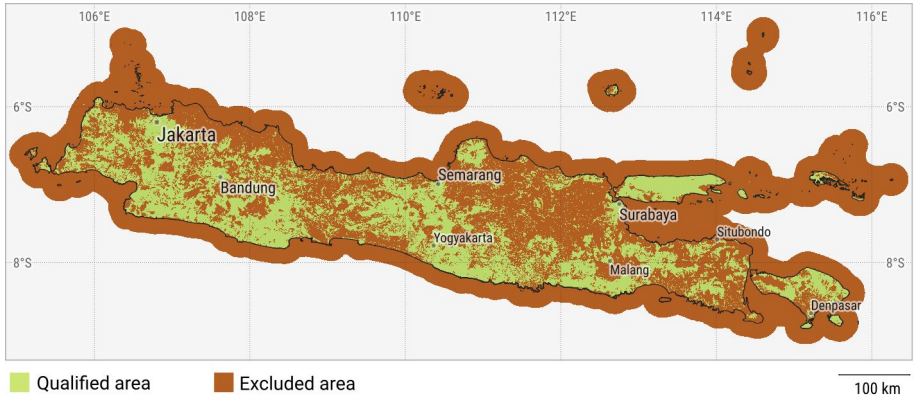
BINARY LAYER



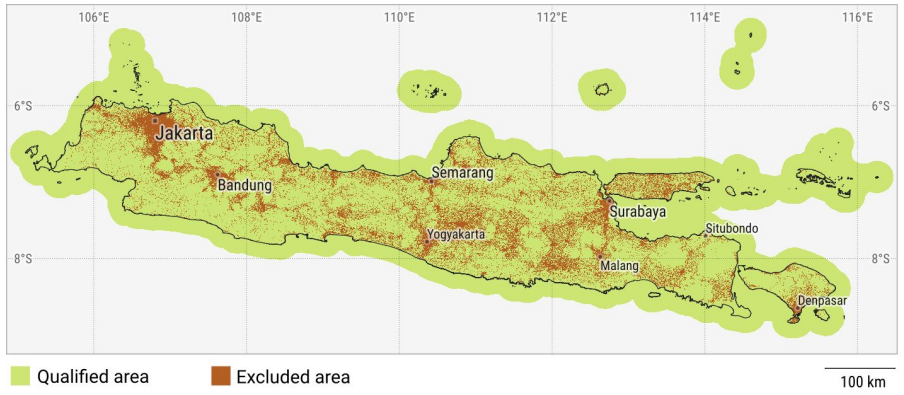
PV power production potential



Water bodies



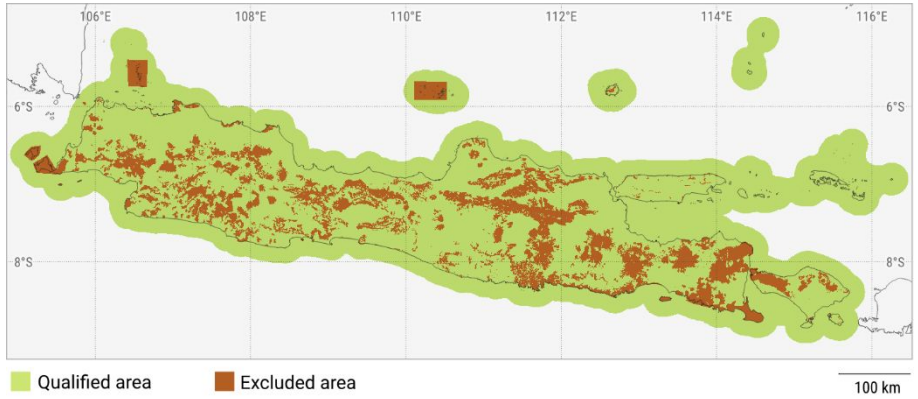
Land cover classes



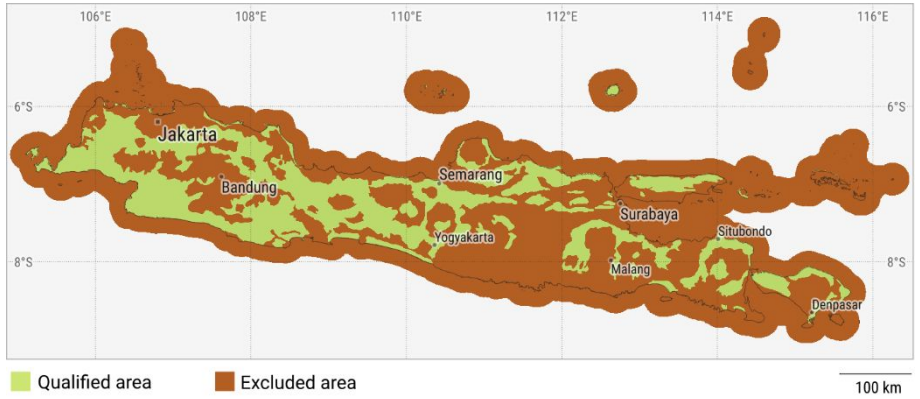
Built-up areas

3.1 GEOSPATIAL ANALYSIS RESULT

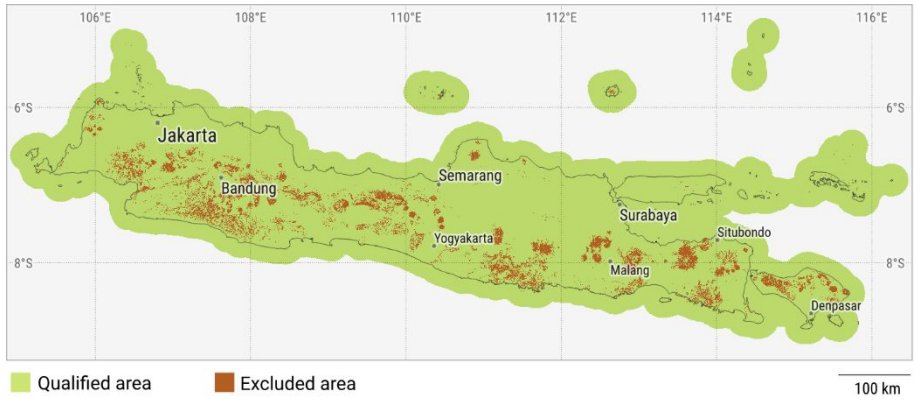
BINARY LAYER



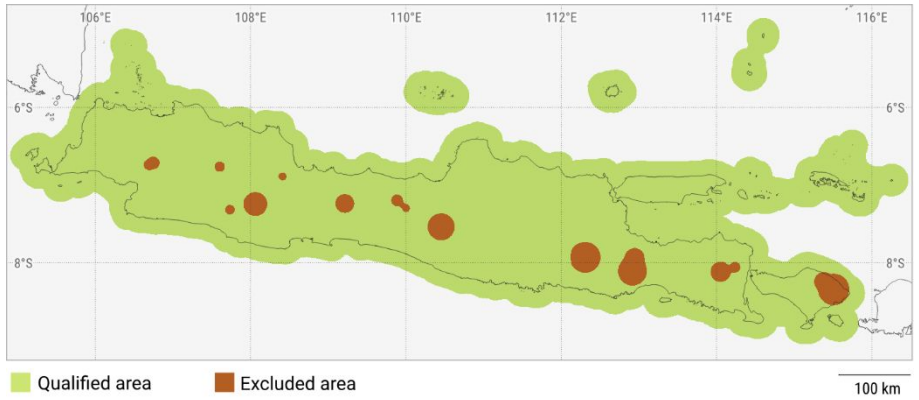
Additional forestry data



Soil types and the agricultural value



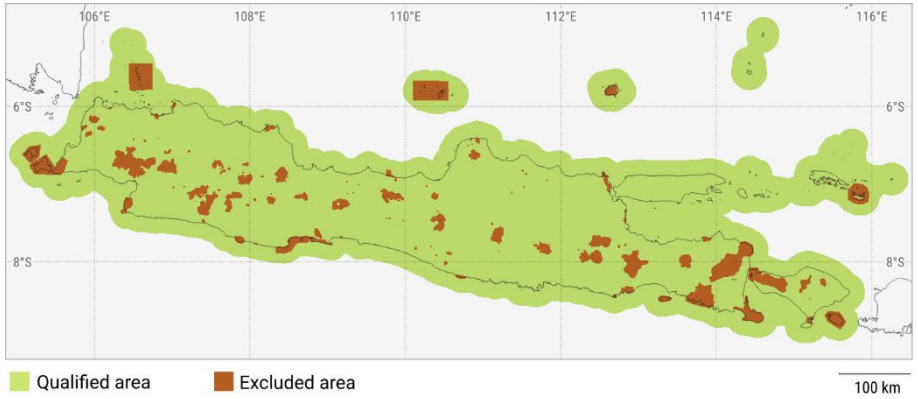
Terrain slope



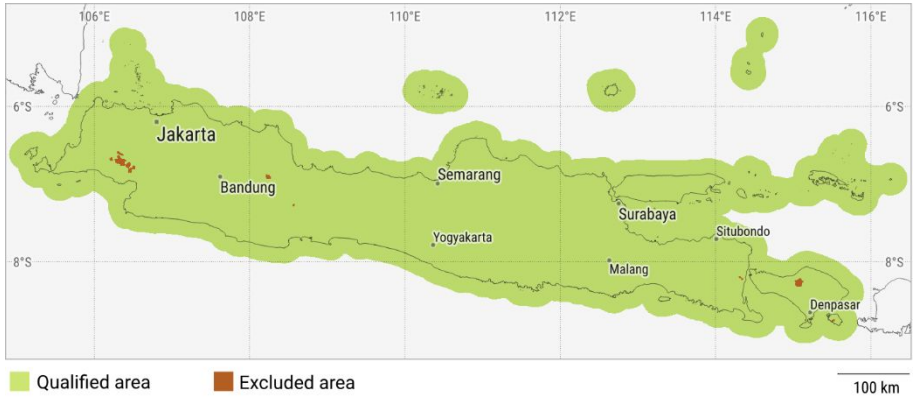
Vulcanic activity

3.1 GEOSPATIAL ANALYSIS RESULT

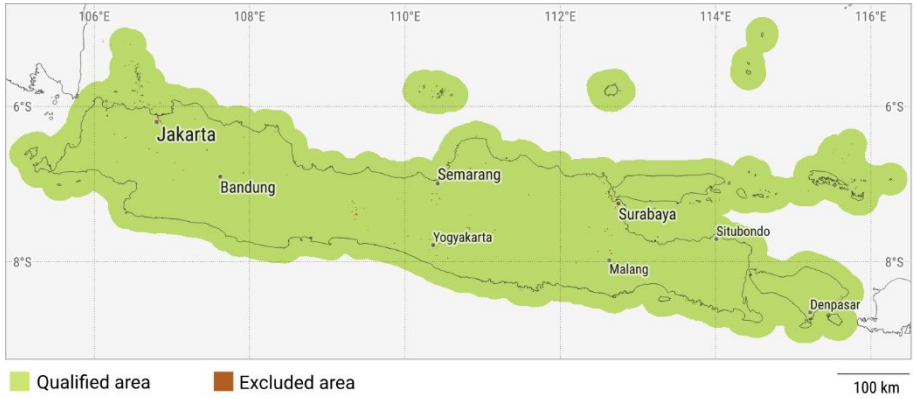
BINARY LAYER



Natural reserves, protected areas, and key biodiversity areas



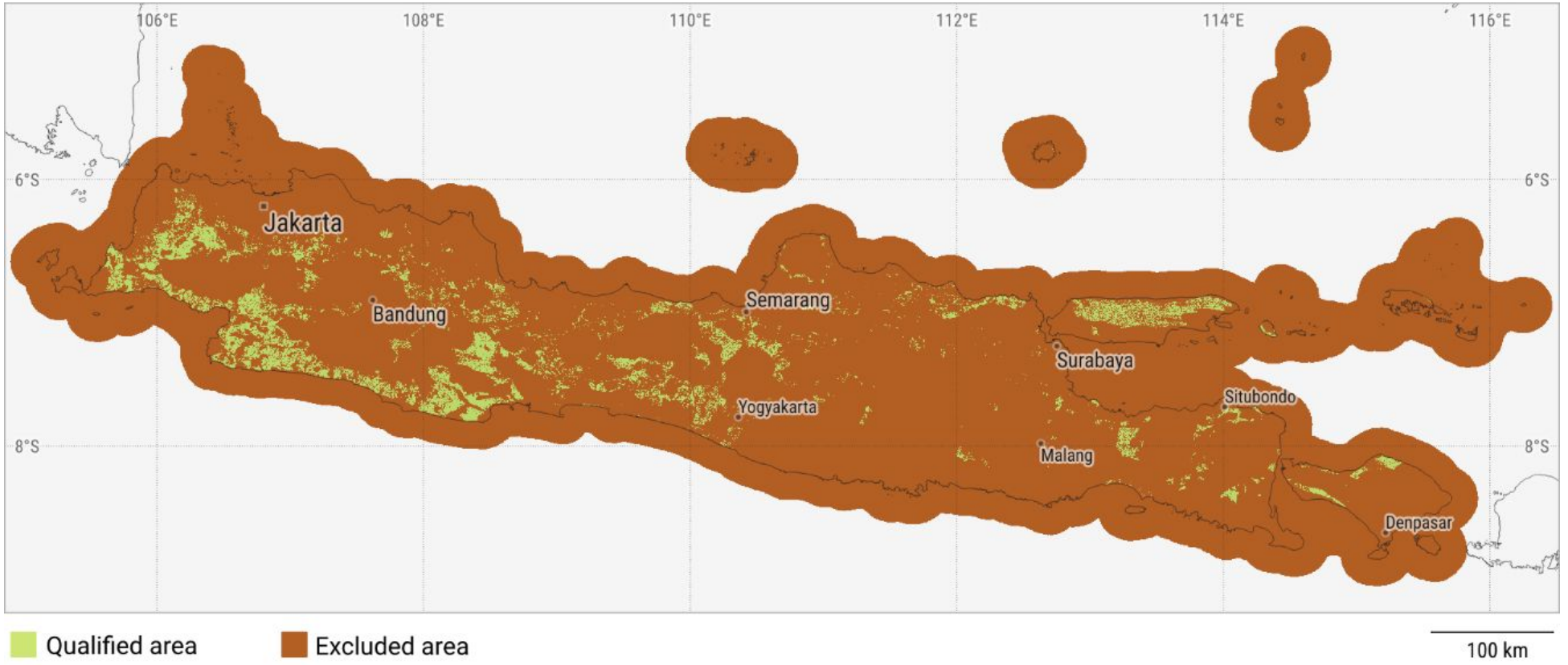
Indigenous peoples' territories



Cultural heritage sites

3.1 GEOSPATIAL ANALYSIS RESULT

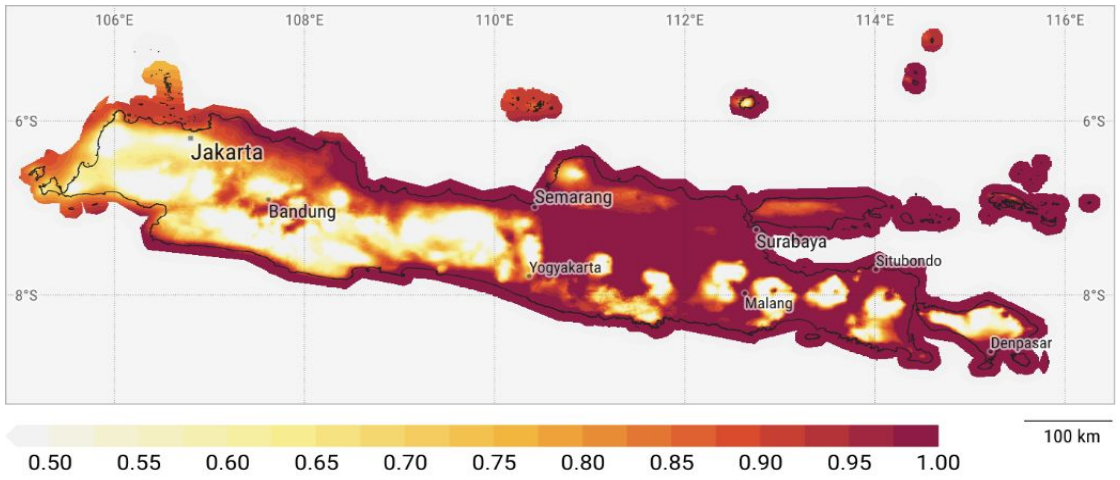
RESULTS OF THE SPATIAL ANALYSIS – BINARY LAYER



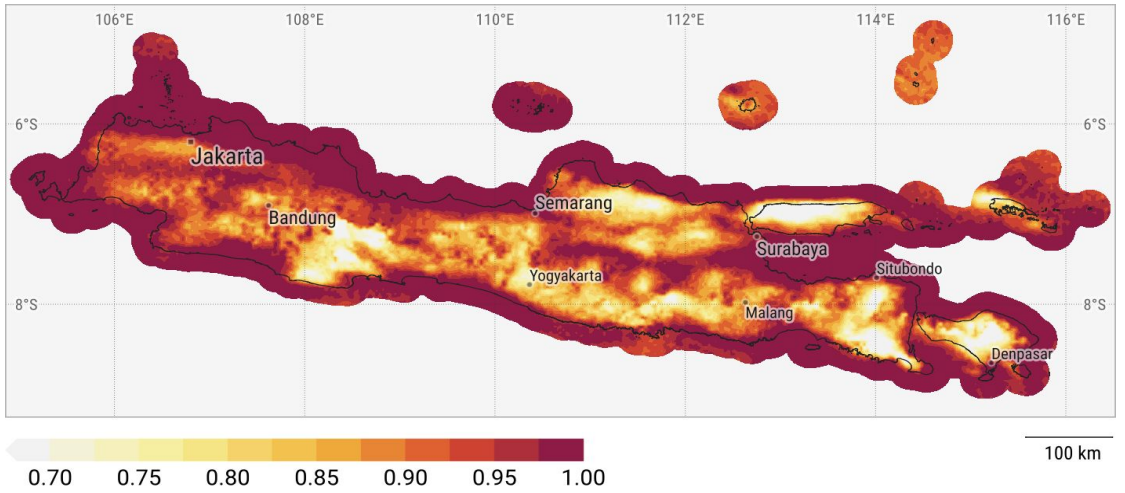
The qualified areas is approximately 9% of the land area of the JAMALI region

3.1 GEOSPATIAL ANALYSIS RESULT

RANGE LAYER



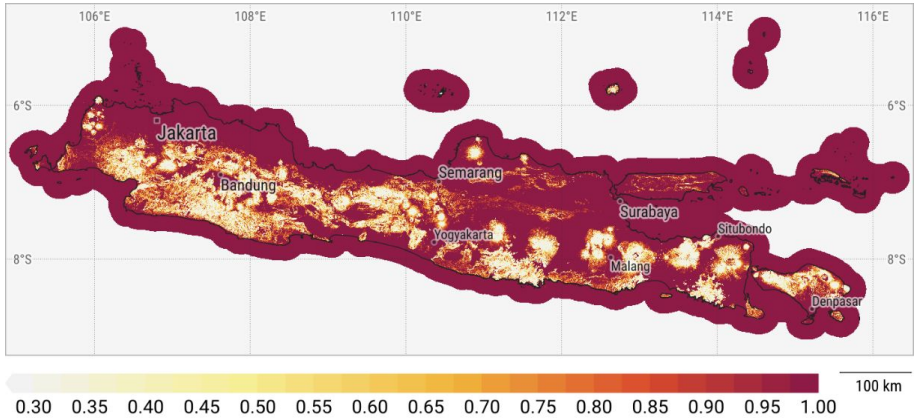
PV power production potential



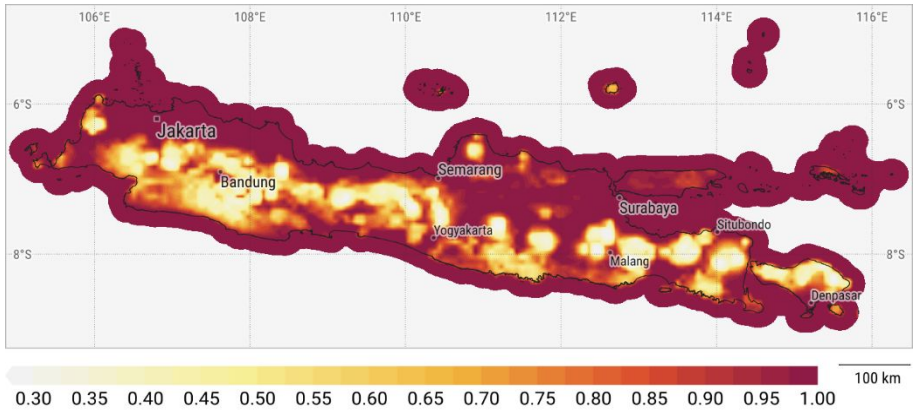
Short-term variability of solar resource

3.1 GEOSPATIAL ANALYSIS RESULT

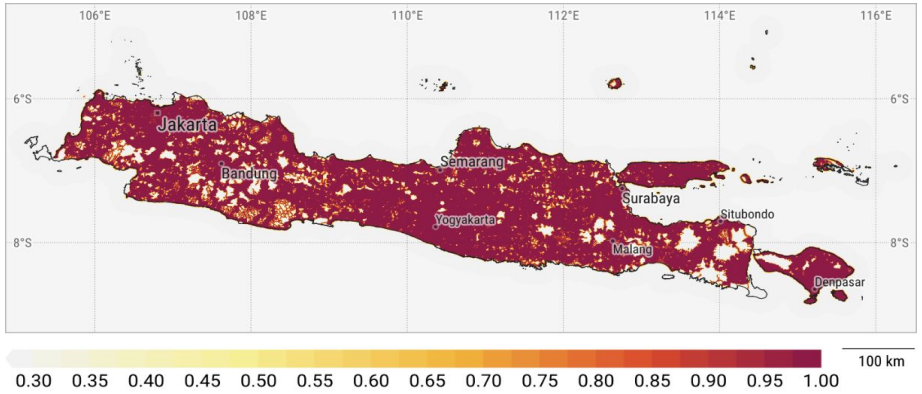
RANGE LAYER



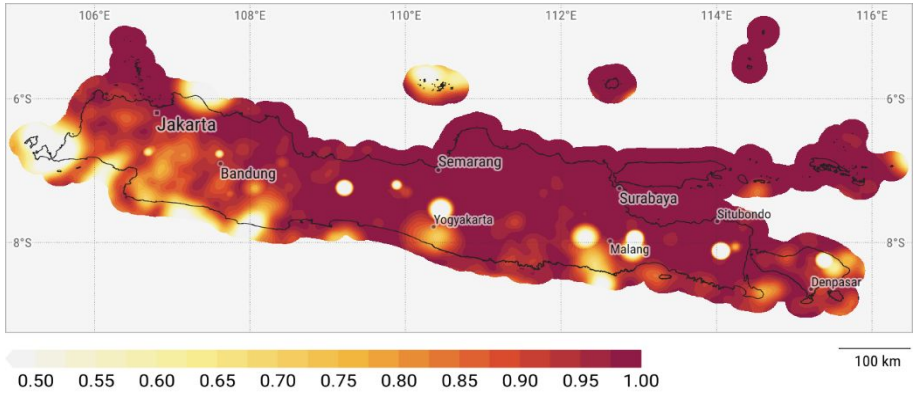
Terrain slope



Terrain complexity



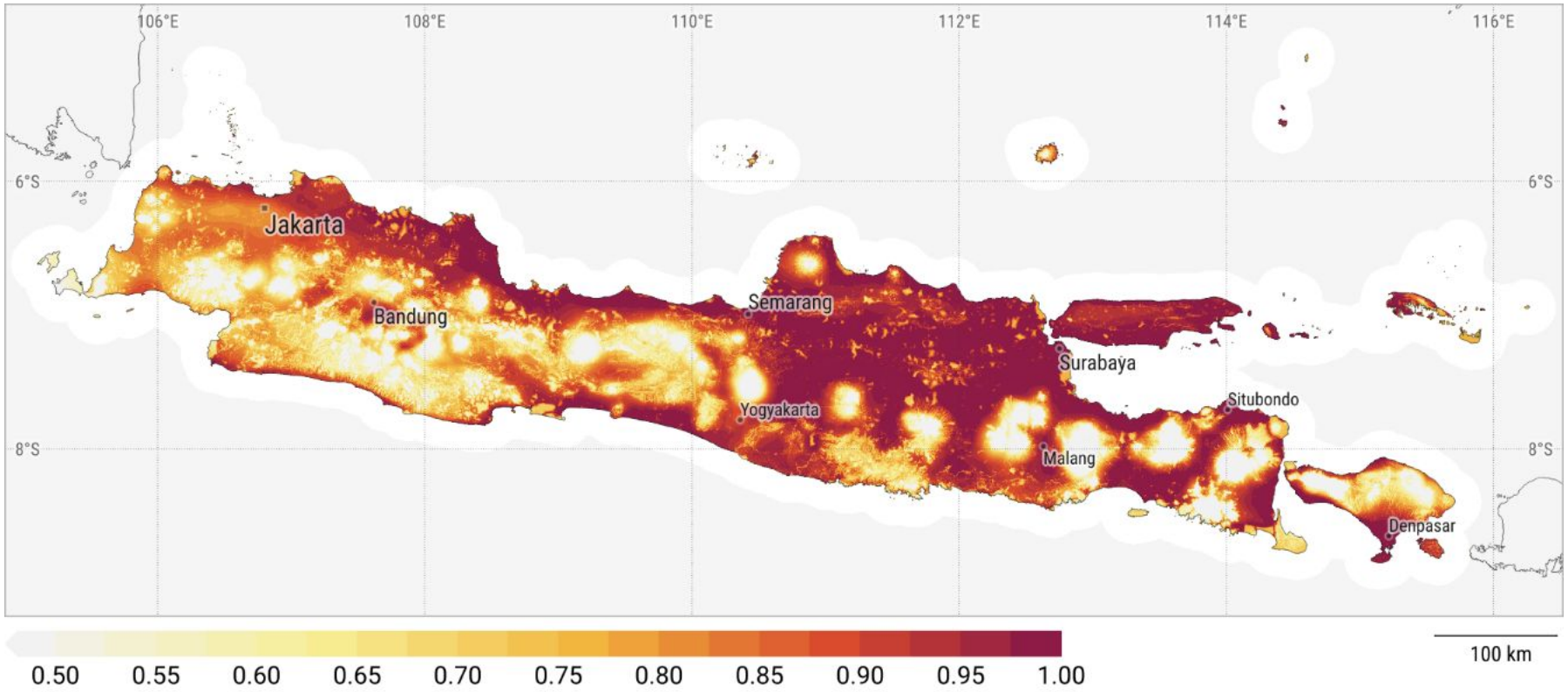
Accessibility by road



Seismic and volcanic activity

3.1 GEOSPATIAL ANALYSIS RESULT

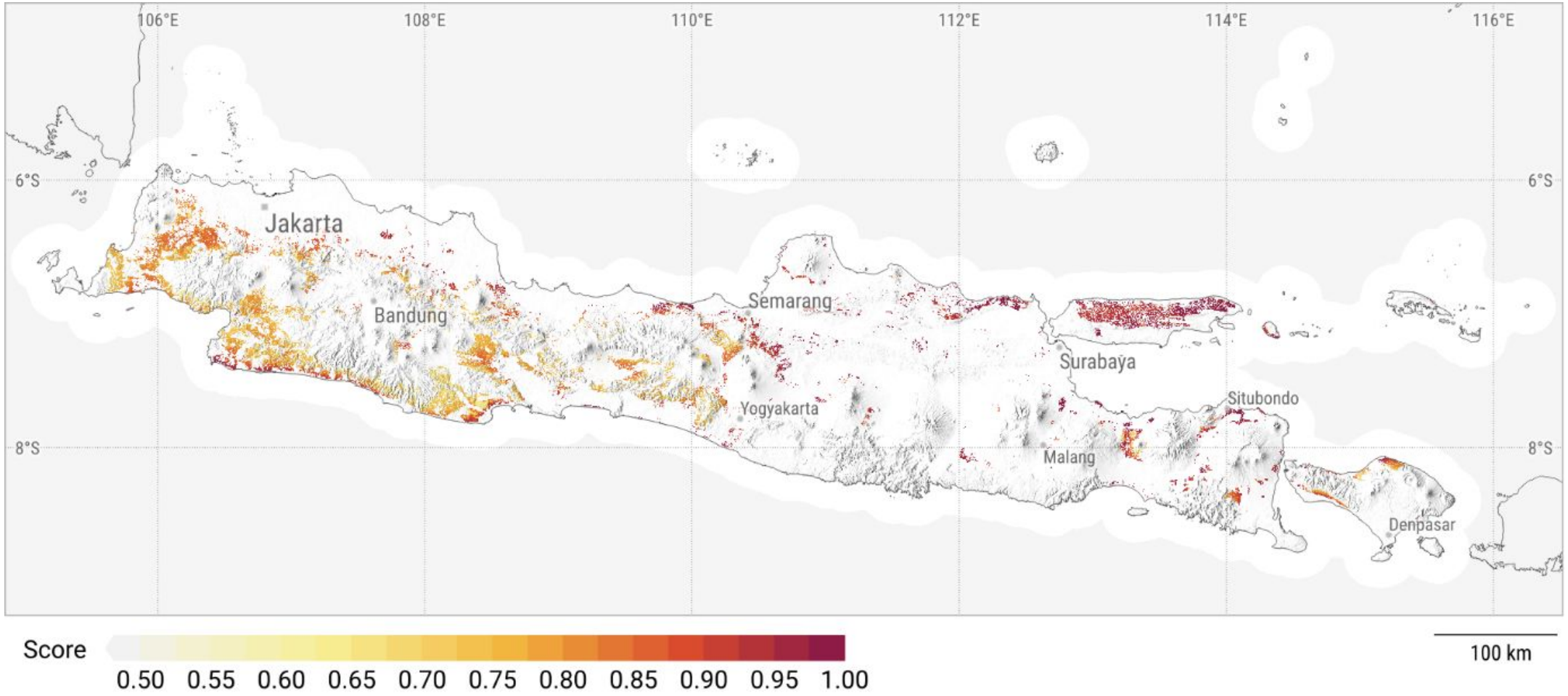
RESULTS OF THE SPATIAL ANALYSIS AND THE PRE-SELECTION POTENTIAL SITES



Lower scores are typical for mountainous regions, which are often characterized by lower PVOUT yields and complex terrain features.

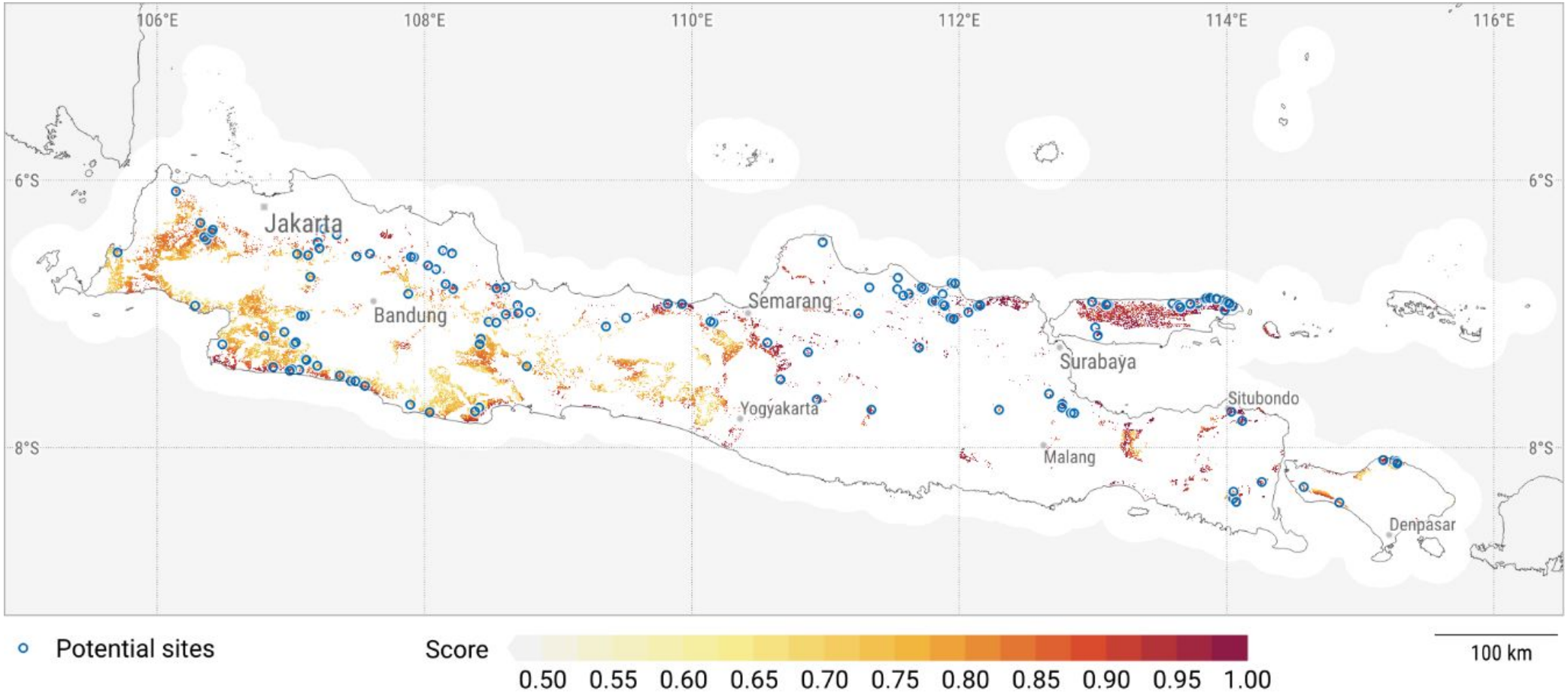
3.1 GEOSPATIAL ANALYSIS RESULT

Geospatial analysis result, the composite of binary and range layers



3.1 GEOSPATIAL ANALYSIS RESULT

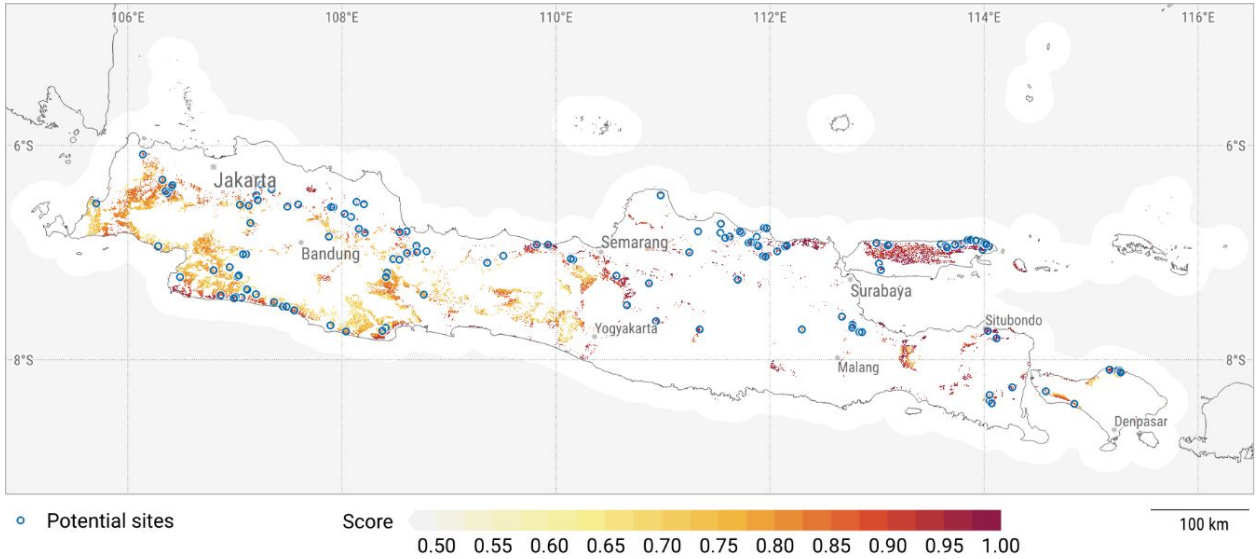
140 Pre-selected Sites



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

3.1 GEOSPATIAL ANALYSIS RESULT

Land Availability



Land availability for each site was analyzed

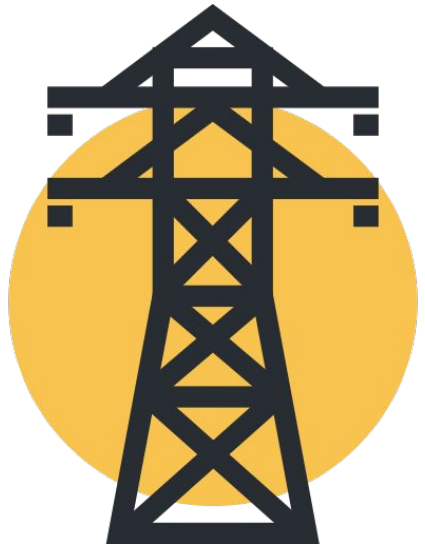
3.2 E&S ANALYSIS RESULTS

Excluded	• 3 sites	No Go site
Critical High Risk	• 0 site	Requires initial environmental and social risk screening for site selection. Requires Due Diligence, including Site visits and development of Mitigation action (ESMP) should the site be selected.
High Risk	• 41 sites	Requires Due Diligence, including Site Visit and development of Mitigation action (ESMP)
Medium	• 96 sites	Requires Due Diligence with potential site visit and development of Mitigation action (ESMP)

3.3 PRE-GRID ANALYSIS RESULTS

PRELIMINARY GRID INTEGRATION ASSESSMENT

To calculate potential capacity for each site



Land Availability

Maximum hosting capacity

Potential capacity

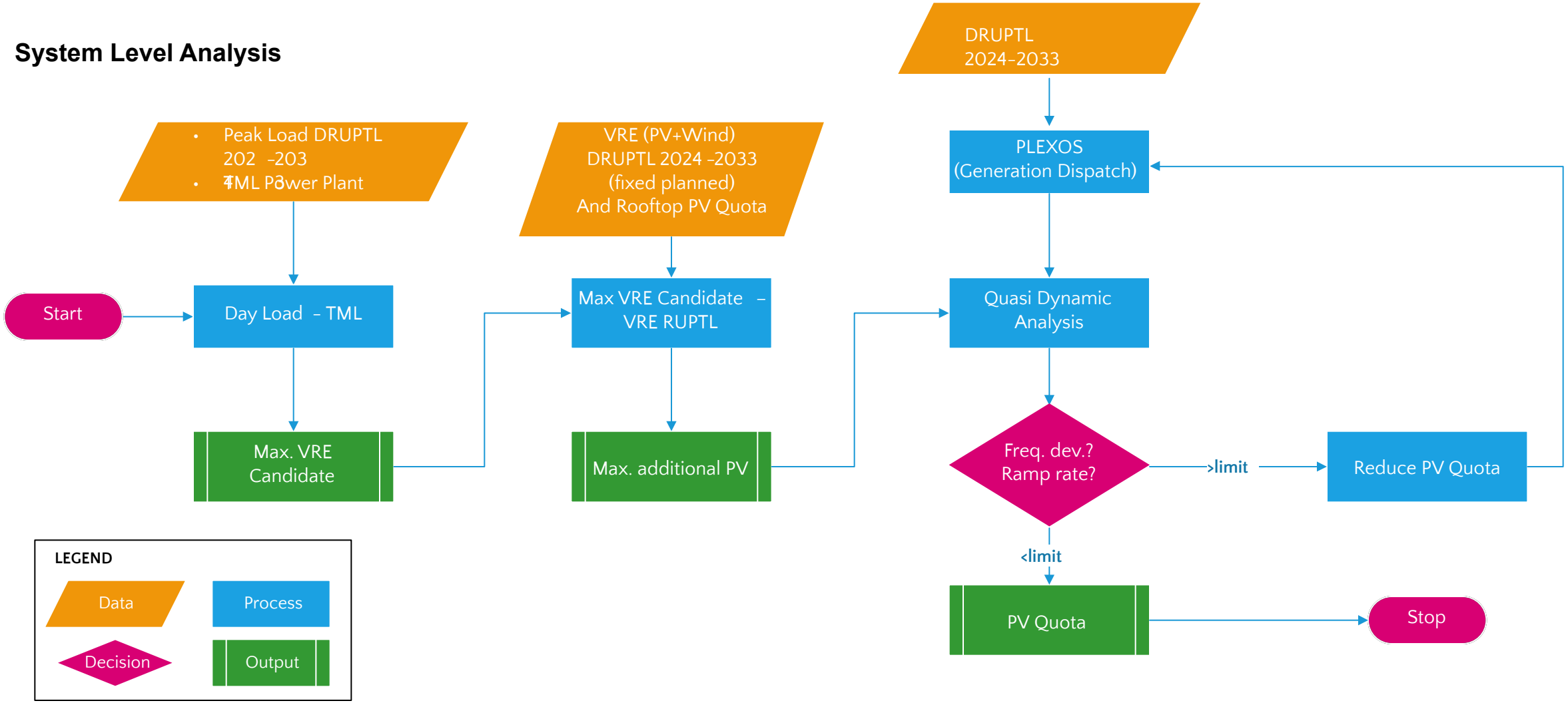
3.3 PRE-GRID ANALYSIS RESULTS

PRELIMINARY GRID INTEGRATION ASSESSMENT

- Hypothesis: Integrating 1 GW PV into a 30 GW+ system such as Java-Bali which is only around 3% of its size will not cause any significant impact
- A detailed grid impact assessment to analyze the integration of 1 GW PV to Java-Bali system will be conducted in the next deliverable

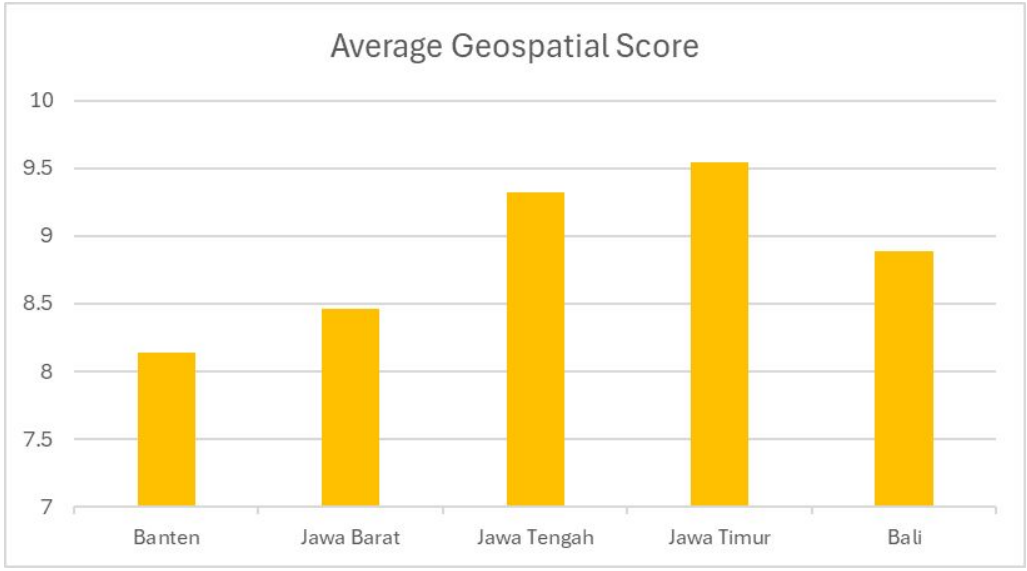
4.3 SYSTEM LEVEL GRID ASSESSMENT METHODOLOGY

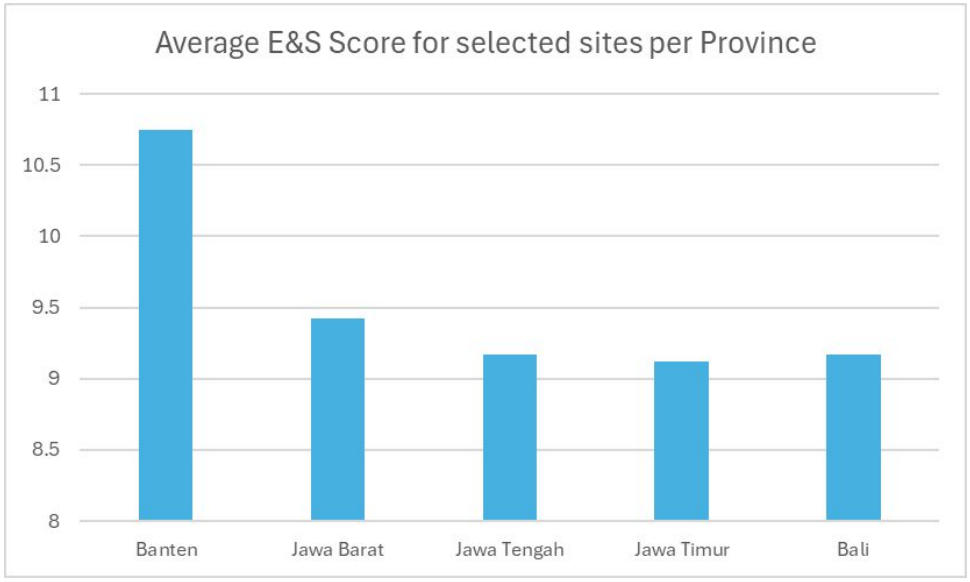
System Level Analysis

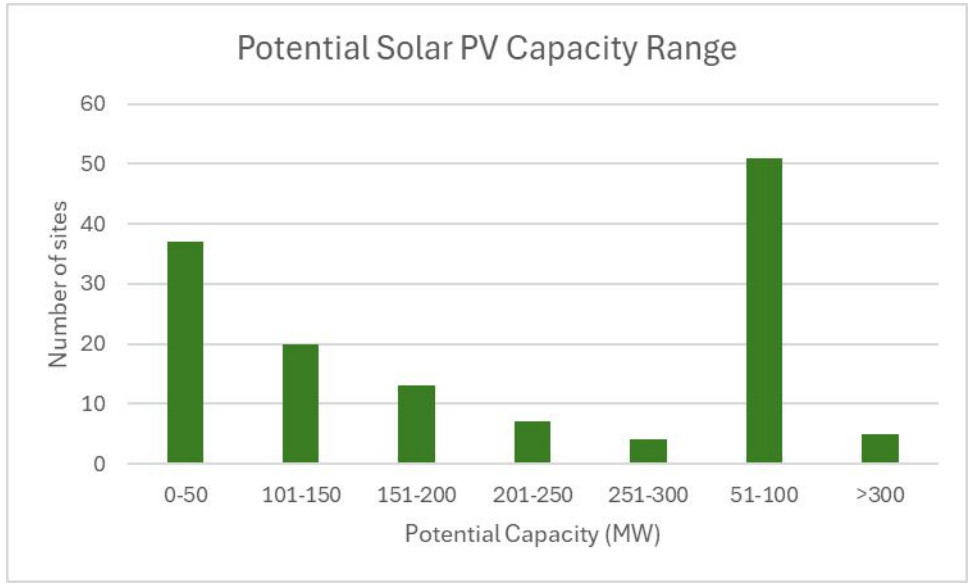


TML = technical minimum loading

3.4 SITE PRIORITIZATION RESULTS







3.4 SITE PRIORITIZATION RESULTS

TOP 20 SITES

Rank	Latitude	Longitude	ADM1	ADM2	ADM3	ADM4	Geospatial Score	ESIA Score	RISK	HubName	Hub Distance (kmr)	Solar PV Potential (MW) - Individual
1	-6.463676	110.978186	Jawa Tengah	Pati	Dukuhseti	Wedusan	0.973	10	High	GITET 500 kV Tanjung Jati	26	110
2	-6.81405	111.536483	Jawa Tengah	Rembang	Sale	Tengger	0.928	9	Medium	GI 150 kV Semen Indonesia	10	121
3	-6.800867	111.719162	Jawa Timur	Tuban	Bancar	Siding	0.999	9	Medium	GI 150 kV Mliwang	19	103
4	-6.888254	113.858622	Jawa Timur	Sumenep	Dasuk	Dasuk Timur	0.986	10	High	GI 150 kV Sumenep	13	190
5	-7.638159	110.934651	Jawa Tengah	Sukoharjo	Polokarto	Genengsari	0.977	10	High	GI 150 kV Palur	10	332
6	-6.940136	114.045873	Jawa Timur	Sumenep	Batang Batang	Bilangan	1	9	Medium	GI 150 kV Sumenep	24	105
7	-7.251292	111.699117	Jawa Timur	Bojonegoro	Tambakrejo	Dolokgede	0.997	10	High	GI 150 kV Cepu	18	157
8	-7.79798	114.117181	Jawa Timur	Situbondo	Arjasa	Bayeman	0.98	9	Medium	GI 150 kV Situbondo	14	82
9	-7.416727	107.063116	Jawa Barat	Cianjur	Sindangbarang	Kertasari	0.895	9	Medium	GI 150 kV Patuha	47	76
10	-7.729317	114.03488	Jawa Timur	Situbondo	Panji	Panji Kidul	0.983	9	Medium	GI 150 kV Situbondo	2	230
11	-7.056141	110.13914	Jawa Tengah	Kendal	Patean	Sidodadi	0.935	10	High	GI 150 kV Weleri	11	111
12	-6.924807	113.728822	Jawa Timur	Sumenep	Ambunten	Tambaagung Barat	0.965	9	Medium	GI 150 kV Sumenep	15	87
13	-6.985719	108.790202	Jawa Tengah	Brebes	Banjarharjo	Cikakak	0.961	9	Medium	GI 70 kV Babakan	13	80
14	-6.861324	111.581306	Jawa Tengah	Rembang	Sale	Joho	0.956	9	Medium	GI 150 kV Semen Indonesia	13	91
15	-6.901331	111.823752	Jawa Timur	Tuban	Kerek	Trantang	0.95	9	Medium	GI 150 kV Sementuban	10	84
16	-6.728982	111.541064	Jawa Tengah	Rembang	Sedan	Sambong	0.864	9	Medium	GI 150 kV PLTU Rembang	12	101
17	-6.540033	105.703628	Banten	Pandeglang	Panimbang	Citeureup	0.781	9	Medium	GIS 150 kV PLTU Labuan	1	382
18	-8.379733	114.049428	Jawa Timur	Banyuwangi	Glenmore	Karangharjo	0.853	9	Medium	GI 150 kV Genteng	13	206
19	-6.906619	111.79984	Jawa Timur	Tuban	Kerek	Gemulung	0.89	10	High	GI 150 kV Sementuban	13	151
20	-6.525476	108.137335	Jawa Barat	Indramayu	Cikedung	Loyang	0.965	10	High	GI 150 kV Haurgeulis	23	106

ENERGY TRANSITION PARTNERSHIP

Powering Prosperity and Enabling Sustainability in South East Asia

THANK YOU

tta Trama TecnoAmbiental

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Department of Climate Change, Energy, the Environment and Water

CIFF CHILDREN'S INVESTMENT FUND FOUNDATION

SEQUOIA CLIMATE FOUNDATION

Annex

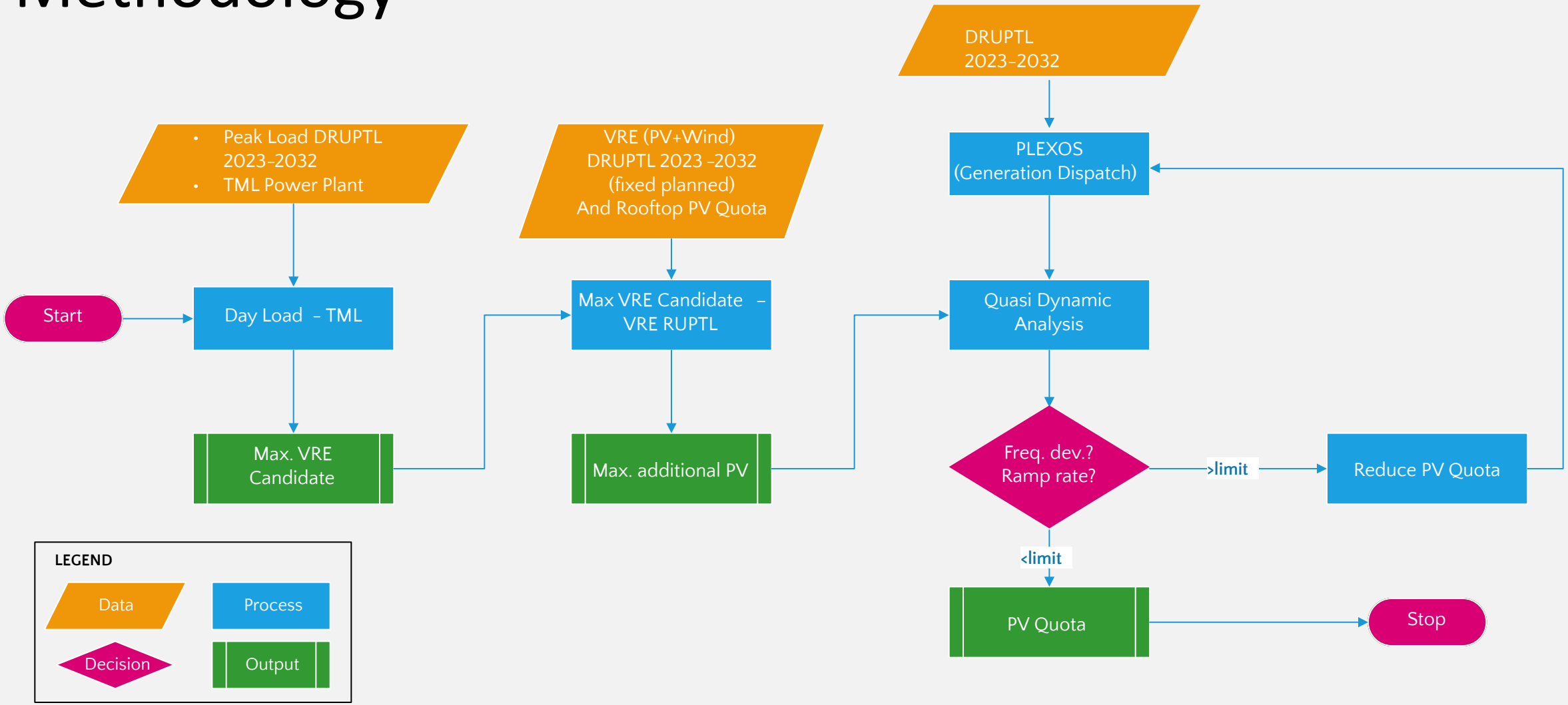
5.1 Next Step

Grid Integration Assessment

Economic and Regulatory Analysis

Stakeholders Engagement

Methodology



TML = technical minimum loading

3.1 GEOSPATIAL ANALYSIS RESULT

BINARY LAYER

Exclusion	Description	Justification for exclusion/qualification
Excluded	Primary Dry Forest	PV power development must not encourage deforestation, forests are protected under Indonesian government regulations
Excluded	Secondary Dry Forest	PV power development must not encourage deforestation, forests are protected under Indonesian government regulations
Excluded	Primary Mangrove Forest	Mangroves are protected under various Indonesian national regulations
Excluded	Secondary Mangrove Forest	Mangroves are protected under various Indonesian national regulations
Excluded	Secondary Swamp Forest	PV power development must not encourage deforestation, forests are protected under Indonesian government regulations
Excluded	Plantation Forest	PV power development must not encourage deforestation, forests are protected under Indonesian government regulations
Qualified	Bushes	Often indicates abandoned agriculture land, pastures, or waste land.
Excluded	Swamp Mix Bushes	Unsuitable for PV power development due to swampy terrain
Qualified	Dryland Agriculture	Only areas with soil types with low agricultural value are considered (the filtering based on soil type is performed in the next step).

3.1 GEOSPATIAL ANALYSIS RESULT

BINARY LAYER

Exclusion	Description	Justification for exclusion/qualification
Qualified	Dryland Agriculture Mix Plantation	Only areas with soil types with low agricultural value are considered (the filtering based on soil type is performed in the next step).
Excluded	Paddy Field	Unsuitable for PV power development by administrative regulations
Excluded	Aquaculture / Fishpond	Unsuitable for PV power development
Qualified	Farm/Plantation	Only areas with soil types with low agricultural value are considered (the filtering based on soil type is performed in the next step).
Excluded	Settlement/Developed Area	This land areas are better treated in the GHS Built-up dataset, described in the next steps. Therefore areas with this class were excluded.
Excluded	Port / Airport	Unsuitable for PV power development
Excluded	Open Area	In JAMALI region, areas are localized only in high altitudes, unsuitable for PV power development
Excluded	Mining Area	Unsuitable for PV power development due to industrial activity and air pollution
Excluded	Savanna	In JAMALI region, areas are localized only in high altitudes, unsuitable for PV power development
Excluded	Waterbody	Unsuitable for PV power development
Excluded	Swamp	Unsuitable for PV power development