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Local Governments for Sustainability

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CITIES & REGIONS ROADMAP

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Federal Ministry for Economic Affairs and Climate Action

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on the basis of a decision by the German Bundestag

Capacity Building Module: Solar Energy Basics & Solar Photovoltaic Systems

CHAPTER 4:

(Pre-)Feasibility Studies for Rooftop PV

CONTENTS

INTRODUCTION

SOLAR PV PROJECT PHASES

ROOFTOP SOLAR PV PROJECT PHASE

1. Pre-feasibility Study

Building owner

1 month

Objective:
To assess the initial viability of a proposed project before committing significant resources to a feasibility study

2. Feasibility Study

EPC / Developer

1 month

Output:
1. FS report
2. Detailed Engineering Design
3. Financial Assessment

3. Administration

EPC / Developer

1 - 6 months

Planning Phase and Design

4. Construction and Installation

1 - 6 months (depending on the project's size and complexity)

5. Operation and maintenance

Building owner/ Developer/EPC

25 years or depending on the O&M contract

Source: C40. 2024. Project Development and Planning

PRE-FEASIBILITY AND FEASIBILITY STUDIES

	Prefeasibility study vs Feasibility study
Scope	A prefeasibility study scans a series of options and determines the best one in the set. The feasibility study analyzes in depth the best solution from the prefeasibility phase.
Uncertainty	Uncertainty in the prefeasibility study is often much higher than for the feasibility study, e.g., -35% to +65% for PFS, and -22% to +35% for FS for Capital Cost.
Financing	Financial security is usually not mandatory for a PFS (though a preliminary assessment is generally made), whereas financial bankability must be ensured at the end of the FS.

Source: Danish Energy Agency. 2021. Pre-FS Guidelines.

PART 1

SITE SELECTION

SITE SELECTION

The most important thing is to check the readiness of the site for installing solar panels on a house or building.

In accordance with the regulation concerning solar PV installations, it is essential to evaluate whether a house or building has suitable areas, such as roofs, walls or other spaces (such as parking lots), that can support the placement of solar panels.

This assessment ensures that installations are efficient, safe and align with local guidelines for renewable energy systems.

ANALYSIS OF ROOF AREA AND ORIENTATION

Generally, the available roof area can be used for rooftop solar PV installations. However, not all roof areas can be utilized effectively. This is because certain roof orientations may create shading effects (for example, on pitched roofs), which can reduce the performance efficiency of solar panels. Additionally, roofs that are already occupied by building equipment, such as cooling towers, water tanks, etc.) are less suitable for rooftop solar PV installations.

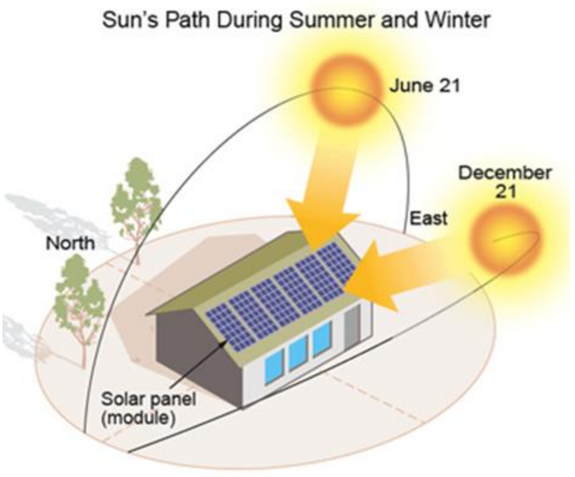
Pitched roof with shading effect

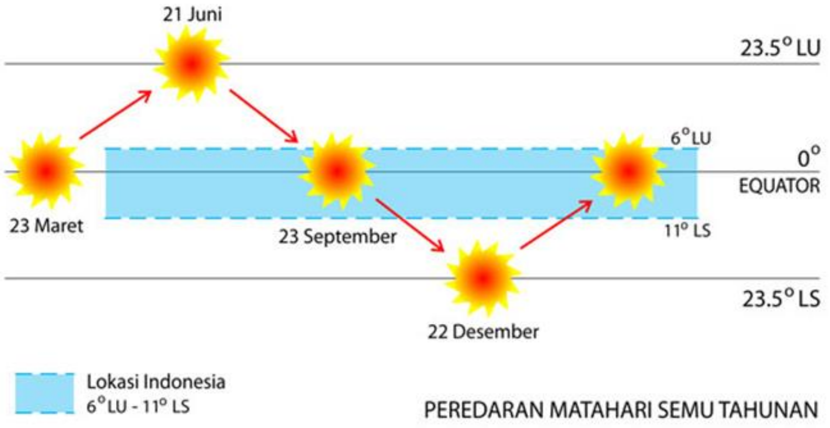
Flat roof occupied by building equipment

Source: USAID. 2020. Panduan Perencanaan dan Pemanfaatan PLTS Atap di Indonesia.

ANALYSIS OF ROOF AREA AND ORIENTATION

The position of the sun's path changes throughout the year, shifting slightly north of the equator during certain periods and slightly south during others. As a result, buildings located north of the equator should ideally face their solar panels to face south. Conversely, buildings located south of the equator should face their solar panels to face north.

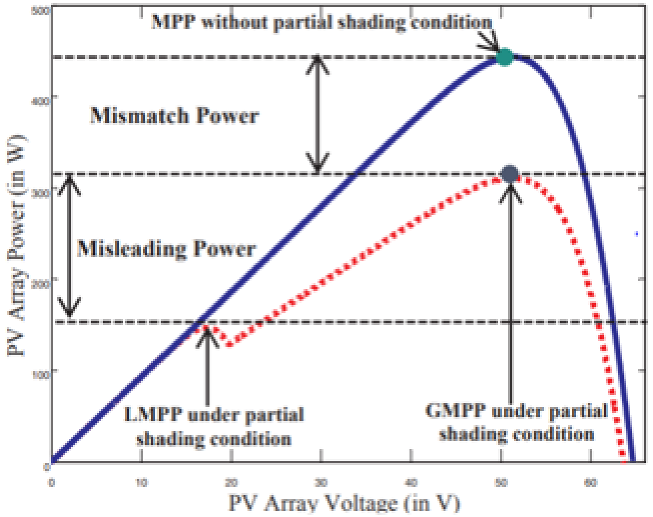


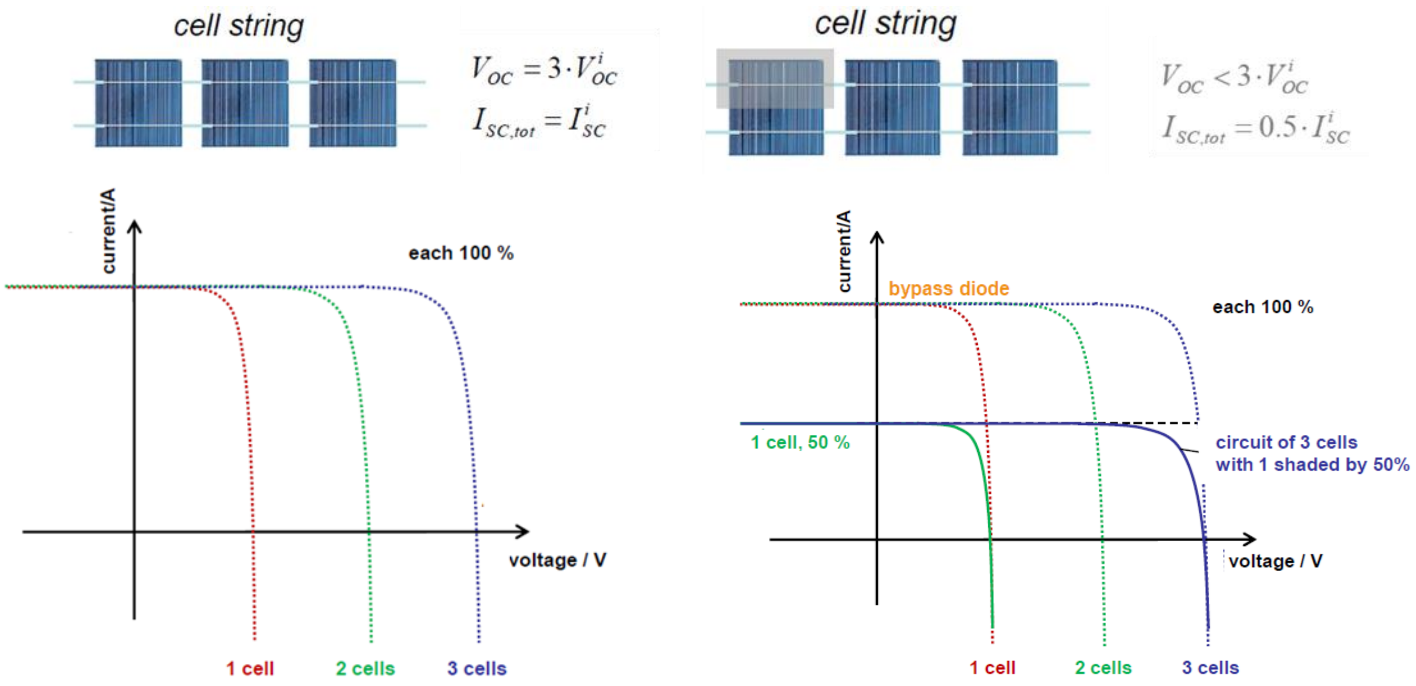


Source: USAID. 2020. Panduan Perencanaan dan Pemanfaatan PLTS Atap di Indonesia.

SHADING ANALYSIS

Shadows on solar panels significantly reduce system performance, energy production, and module condition, leading to higher heat dissipation and reduced module lifetime.





Source: Mansur, A et al. 2019. Performance Investigation of Different PV Array Configurations at Partial Shading Condition for Maximum Power Output.

STRUCTURAL STRENGTH ASSESSMENT

A structural analysis of the roof, wall, or area designated for solar panel installation is also necessary to determine whether the location is adequate or suitable to support the weight of the solar module system.

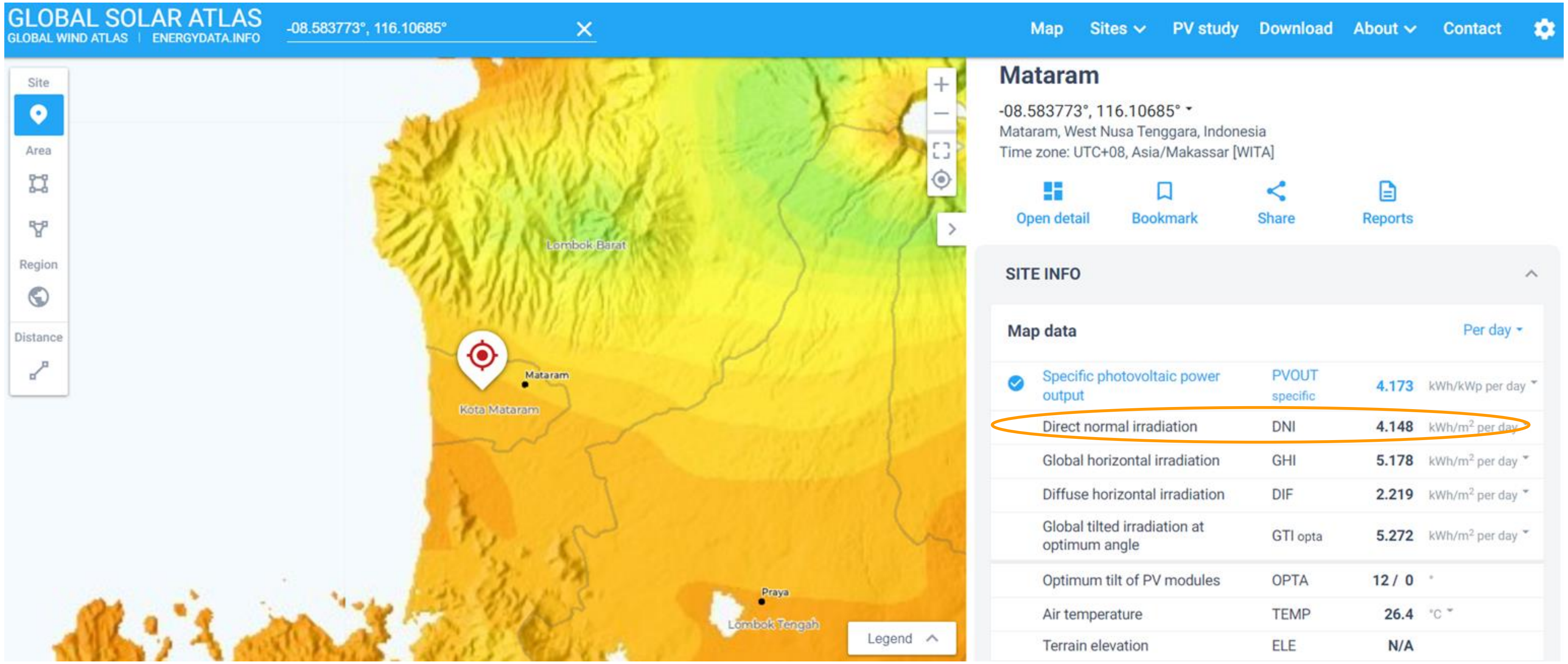
For flat roofs made of concrete structures, installing rooftop solar PV systems may not have any issues. However, for installations on government offices, residential buildings, and other structures that use wooden frames or steel frames to support the roof, it's important to consider the roof's structural strength. This includes the ability to bear the load from the roofing materials used as well as the weight of the solar PV module system.

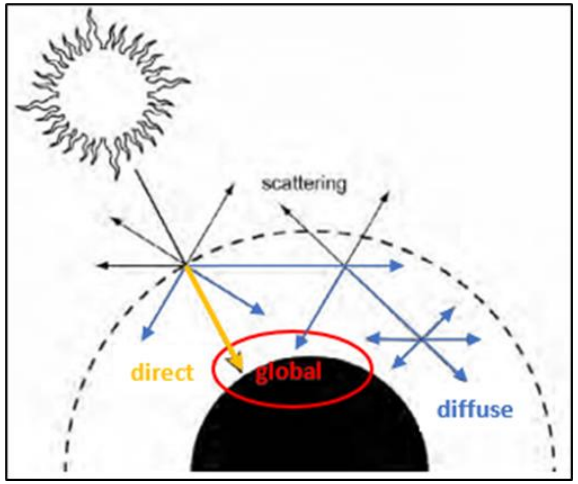
If the installation of rooftop solar PV systems requires roof repairs or structural renovations before the installation, it will result in additional costs.

PART 2

INITIAL SOLAR RESOURCE ASSESSMENT

INITIAL SOLAR RESOURCE ASSESSMENT

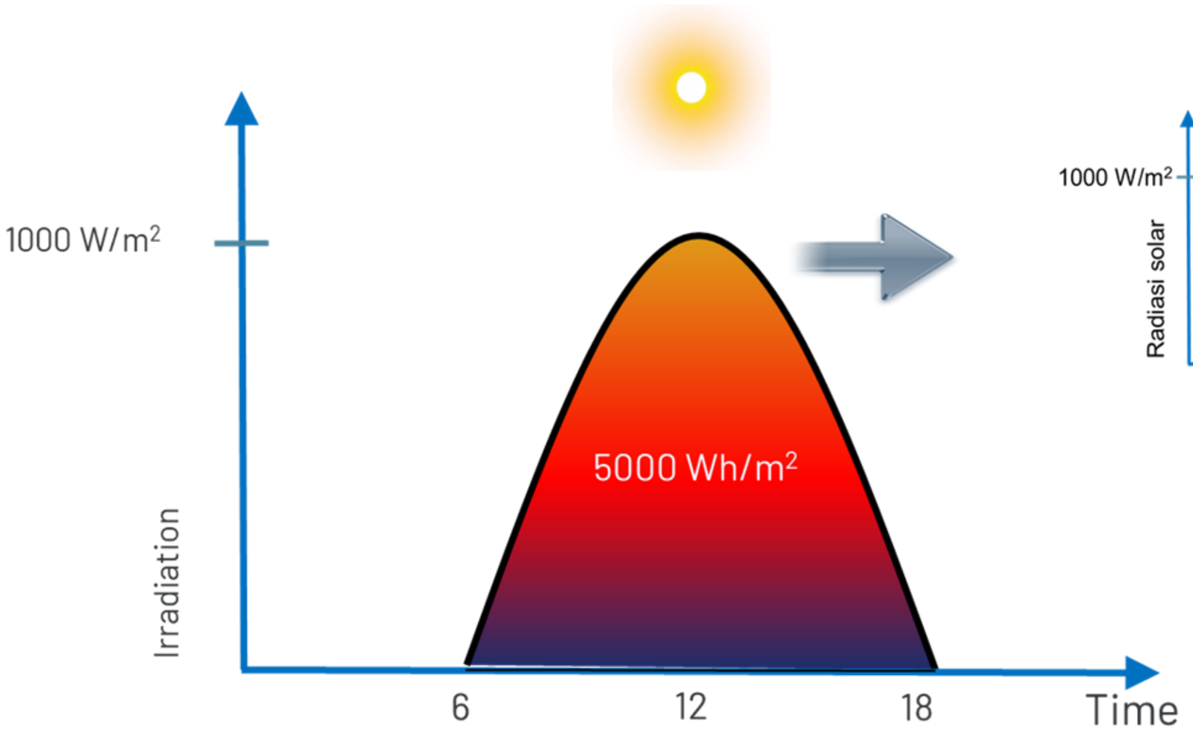


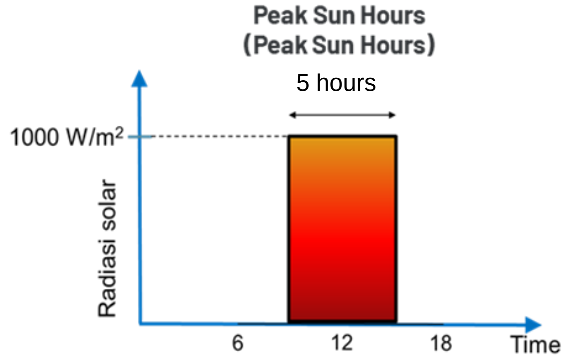


Global Horizontal Irradiance (GHI): the sum of direct and diffuse solar radiation received on a horizontal surface. GHI is used as a reference value for comparing the solar potential related to PV electricity systems, as it eliminates variations that could arise from the selection of technical components and the design of the PV system.

Source: https://globalsolaratlas.info/map

INITIAL SOLAR RESOURCE ASSESSMENT





$$\text{Peak Sun Hour} = \frac{\sum G_{hourly} \left[\frac{wh}{m^2}\right]}{1000 \left[\frac{W}{m^2}\right]}$$

This curve is called the irradiation flux or solar radiation wave in units of watts per square meter (W/m^2).
The area inside the curve is called the irradiation in units of $Wh/m^2/day$

PART 3

PRELIMINARY ASSESSMENT

PRELIMINARY ASSESSMENT

- Data Collection
  - Electricity bill analysis
  - Roof plan (roof size, roof slope angle, and orientation)
  - Building Location

- Initial Planning and Simulation
  - Determining the purpose of rooftop solar PV installation (bill savings or achieving 100% RE from solar PV)
  - EPC/Developer research
  - Financing scheme research

PRELIMINARY ASSESSMENT

- Electricity Bill Analysis
  - Monthly electricity bill
  - Electricity tariff

Prioritize buildings with high monthly electricity consumption so that the use of rooftop solar PV can significantly reduce operational costs from electricity bills.

PRELIMINARY ASSESSMENT

▪ Roof Plan

When selecting a building for a rooftop solar PV installation, consider the following criteria for roof plan to ensure optimal performance:

- A larger roof area allows for more solar panels, which can increase the potential energy generation. Additionally, the roof should be accessible for installation and maintenance.
- Choose a roof area that is free from obstructions such as trees, neighbouring buildings, or other structures that can cast shadows on the panels.
- In the southern hemisphere, such as Mataram north-facing roofs capture more direct sunlight. This orientation helps maximize the solar energy captured by the solar panels.
- Ensure that the roof structure can support the additional weight of the solar panels and mounting equipment.
- Ensure that the roof is in good condition before installation. Any necessary repairs or upgrades should be completed to avoid complications later.

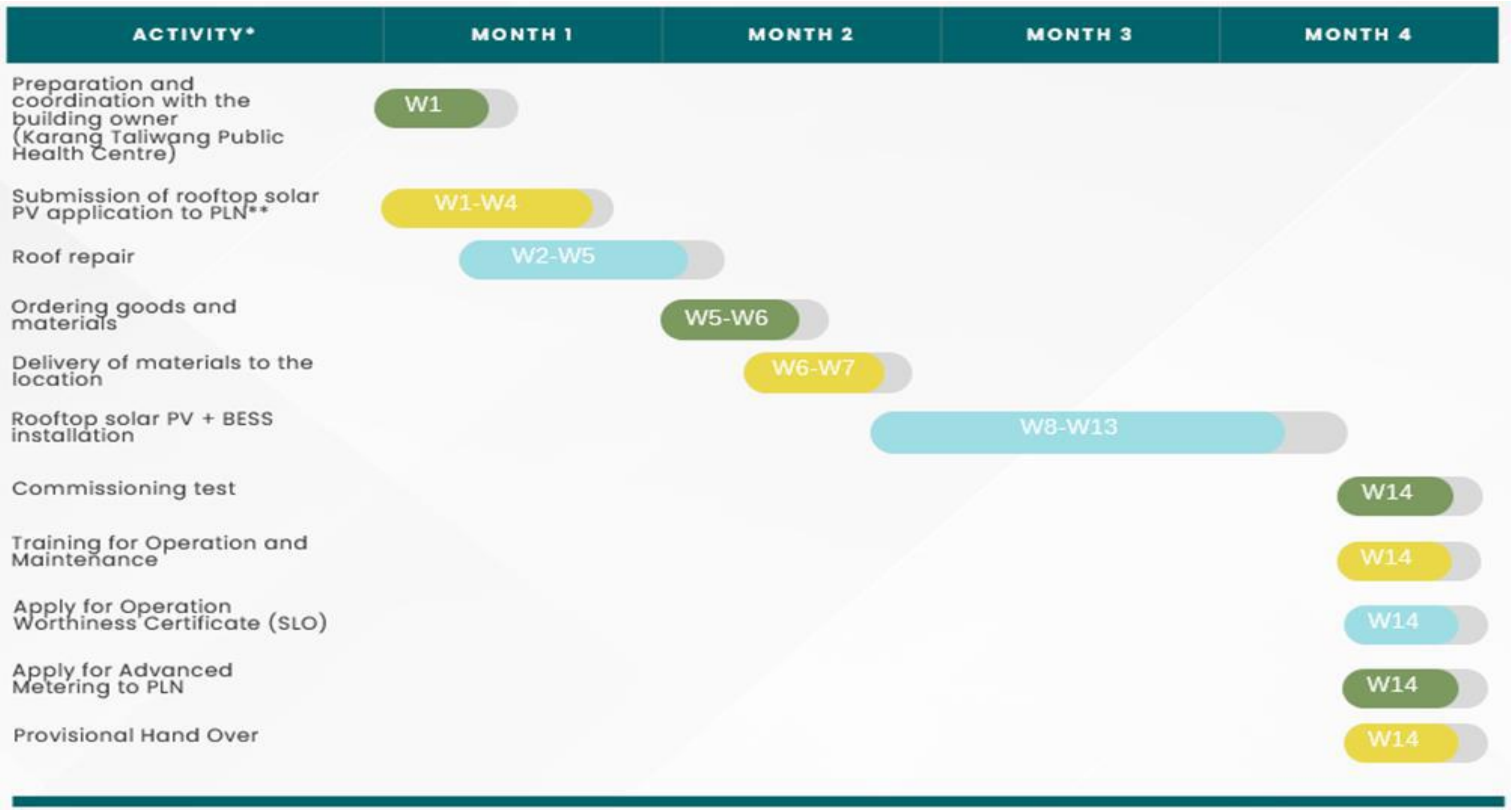
PRELIMINARY ASSESSMENT

- Determining the purpose of rooftop solar PV installation
  - **Bill savings (on-grid)**: By producing your own electricity from rooftop solar PV, you reduce your reliance on the utility company and lower your monthly electricity bill.
  - **Achieving 100% RE (hybrid)**: Design the solar PV system with battery storage to match the total energy consumption. This involves calculating the PV capacity required to generate enough electricity to cover 100% of the building's energy needs, based on the average solar irradiance in the area and the building's load profile. Energy storage, such as batteries, is necessary to store excess solar energy generated during the day for use during periods of low sunlight, such as at night or on cloudy days. This ensures a continuous supply of renewable energy and maximizes the use of solar power.

- EPC/Developer research

It is essential to research certified solar EPCs. This can be through relevant government or industry certification database, which provides list of accredited companies qualified to handle solar installations.

TENTATIVE PROJECT TIMELINE



Projected tentative timelines include key phases such as coordination with the building owner, ensuring compliance with regulatory and utility company procedures, to provisional handover of the project.

IMPORTANCE OF INVOLVING KEY STAKEHOLDERS IN PRE-FS

Ensures Support

- Engaging stakeholders (local government and building owner) early helps secure their support for the project.
- Involvement can lead to stronger commitment and willingness to contribute.

Identifies Potential Challenges

- Stakeholders can provide insights into local challenges and constraints.
- Early identification of issues helps in developing effective mitigation strategies.

Enhances Project Alignment

- Helps in tailoring the project to better fit community expectations.

Improves Communication and Transparency

- Regular engagement builds trust and keeps stakeholders informed about project progress.
- Transparency in decision-making fosters a positive project environment.

QUIZ

Let's discuss which building is the best option for installing rooftop solar PV

A

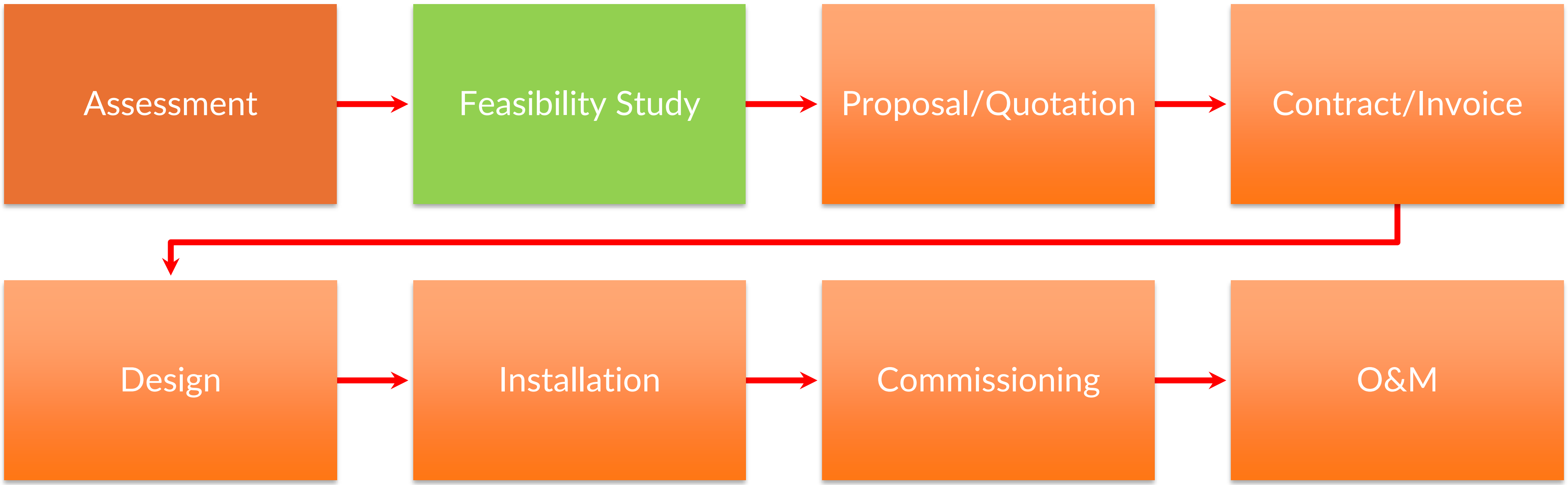
B

C

PART 4

FEASIBILITY STUDIES

ROOFTOP SOLAR PC PROJECT DEVELOPMENT PHASES



OVERVIEW

Conducting feasibility study (FS) for a rooftop solar PV project is essential for several important reasons:

- The project requires a significant investment, so it's crucial to thoroughly assess its potential before moving forward.
- Not all locations are suitable for solar PV installation due to factors like shading, roof orientation, and structural strength, making careful site selection is vital.
- There is also a considerable risk of project failure or abandonment, which highlights the need for detailed planning and risk management.
- The project must comply with local regulations, building codes, and energy policies, which can vary widely.

A **feasibility study (FS)** aims to determine whether the development of a solar PV system is viable from technical, financial, environmental, social, and other perspectives.

OVERVIEW

Main Benefits of FS:

- A tool for making investment decisions
- Identifying risks and developing mitigation strategies
- Securing funding
- Ensuring compliance with government licensing/regulatory requirements.

CONTENT OF FEASIBILITY STUDIES

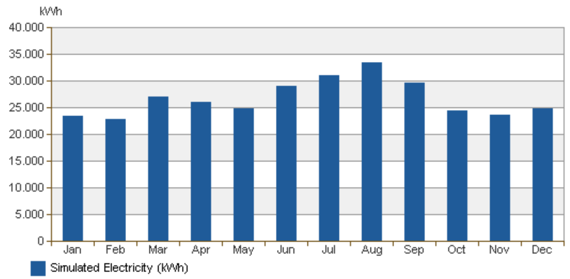
FS report consists of:

1. Overview of Project and Objectives
2. Site Assessment
3. Solar Resource Assessment
4. Shading Analysis
5. System Design and Selection of Components
6. Grid Integration
7. Energy Yield Estimation
8. Losses and Performance Ratio
9. Capital expenditure, operating expenditure
10. Revenue streams
11. Financial modelling - NPV, IRR, LCOE, etc
12. Environmental Impact Assessment
13. Social Impact Assessment
14. Permitting Requirements
15. Regulatory Compliances
16. Risk Identification and Mitigation Strategies
17. Project Timeline and Implementation Plan
18. Operation and Maintenance Schedule
19. Performance Monitoring
20. Conclusion and Recommendations with Key Findings

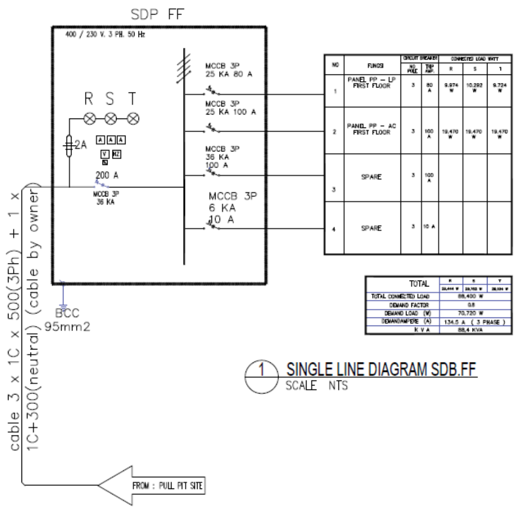
SITE ASSESSMENTS

SITE ASSESSMENT

Electrical System Survey



Electricity bill or load profile measurement



Check existing electrical panel distribution lines and interconnection location points

G. Electrical System Assessment		
1	Type of usage [zero feed-in, export excess]	
2	Source of electricity [utility grid, own power plant]	
3	Service connection [kVA]	
4	Distance to point of interconnection POI or panel distribution [m]	
5	Incoming supply [single/three phase]	
6	Grid voltage at POI [V]	
7	Main transformer capacity [kVA]	
8	Electricity price [IDR]	
9	Average monthly electricity consumption [kWh]	
10	Average monthly fuel consumption [liter]	
11	Approximate daytime (08 - 16) consumption [kWh]	
12	Daily base load [kW]	
13	Daytime peak load day time [kW]	
14	No. of non-operational days in a week	
15	Daytime peak load on non-operational day [kW]	
16	Base load on non-operational day [kW]	
17	Backup power source [kVA]	
18	Type of load [PF]	
19	Monthly reactive energy [kvarh]	
20	Lightning protection system [yes/no]	
21	Grounding system [yes/no]	

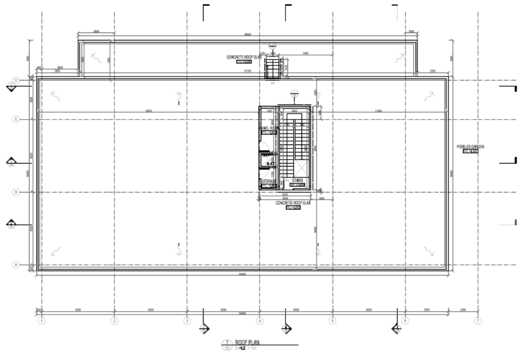
SITE ASSESSMENT

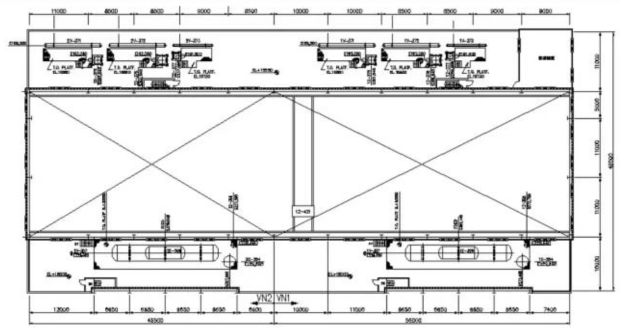
Roof Condition Check

C. Roof Assessment							
No	Parameter	Roof 1	Roof 2	Roof 3	Roof 4	Roof 5	Roof 6
1	Building height [m]						
2	Style of roof [flat/inclined]						
3	Type of roof cover [concrete tiles, small tiles, gravel, metal corrugation, metal seams, galvalum]						
5	Orientation of the roof [deg]						
6	Tilt angle [deg]						
7	Available roof area [m2]						
8	Possible shading [yes/no]						
9	Height of other objects surrounding [m]						
10	Other objects on the roof [chimney, vent, tower, etc]						
11	Height of other objects on the roof [m]						
12	Shadow free area [m2]						
13	Maximum load capacity of the roof [kg/m2]						
14	Available space for inverter [yes/no]						
15	Access to roof						

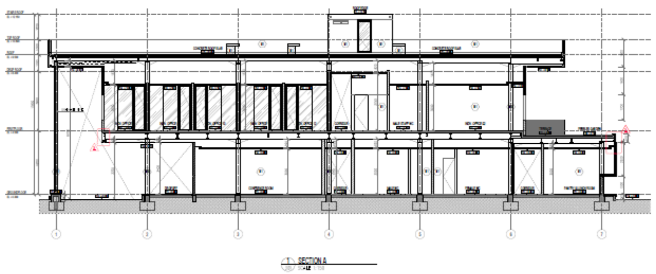
Ask the owner for all relevant technical drawings (at least):

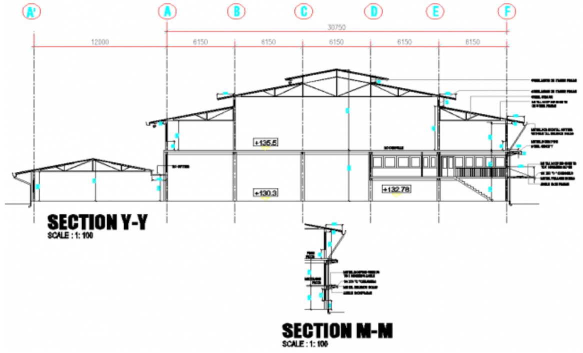
Roof plan





Side view





Get the right dimensions, tilt angle, orientation, and material!

SITE ASSESSMENT

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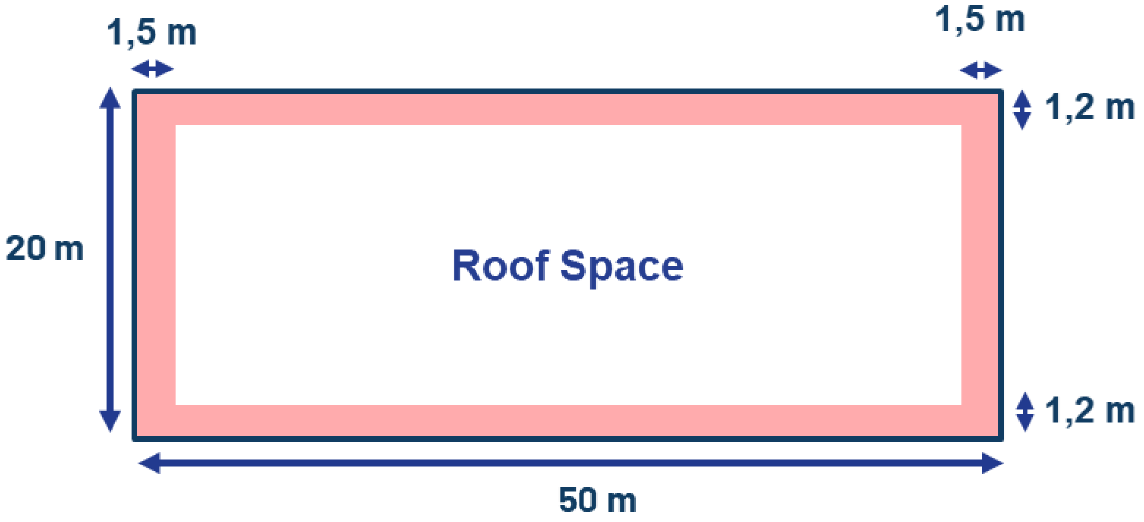
Roof Inspection and Measurement

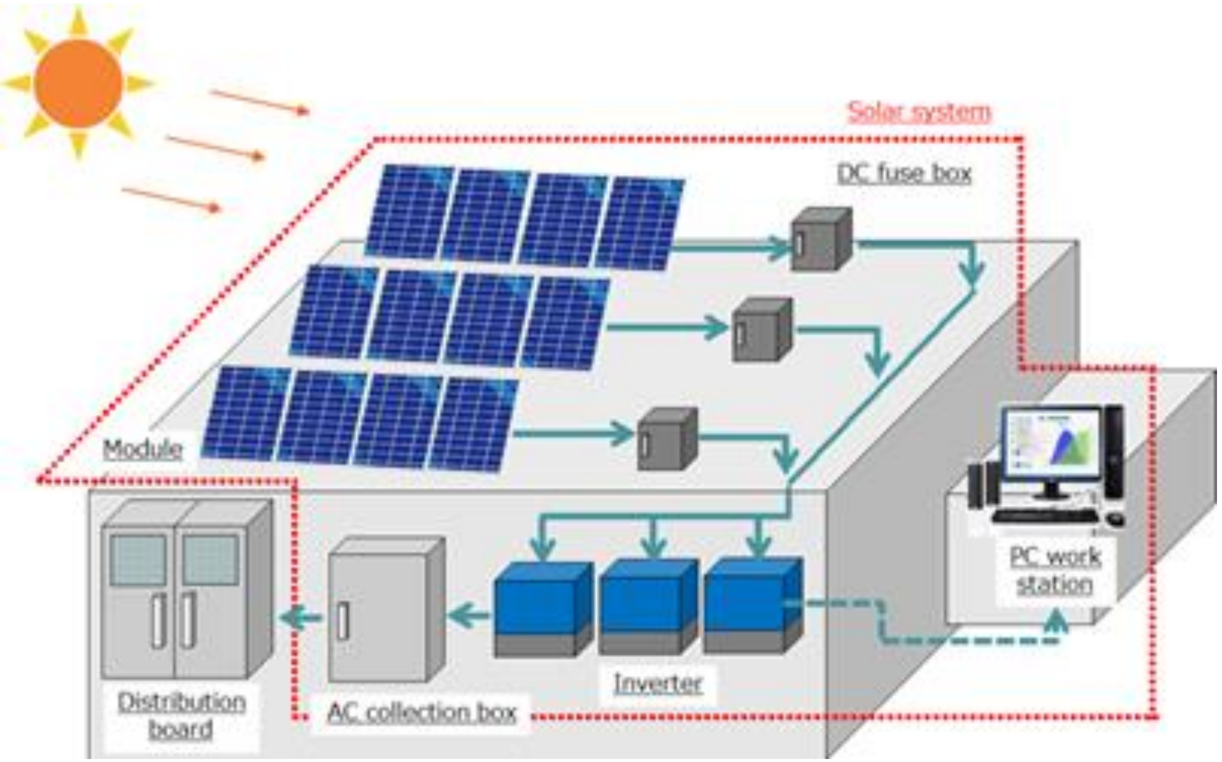
- Ensure roof slope and roof dimensions
- Site survey used to verify roof plan drawings
- Consider all objects on the roof, such as lightning protection



LAYOUT DESIGN

Determining the location for installing inverters and distribution panels:

- Distance from solar module to control room
- Calculation of optimal cable length and size
- Easily accessible inverter location
- Access to rooftop



TECHNICAL DESIGN

PROJECT OBJECTIVE IDENTIFICATION

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- Calculate daily electricity needs in kWh/MWh
- Perform a load analysis over a period of 1 week to 1 month
- Evaluate topology and grid interconnection
- Assess environmental impact
- For public buildings, the procurement of infrastructure should meet local content requirements (Indonesia: TKDN)

SOLAR RESOURCE ASSESSMENT

Main Indicators:

GHI (Global Horizontal Irradiance)
Energy Yield (kWh/year)

Other Indicators:

DNI (Direct Normal Irradiance)
DIF (Diffused Irradiance)
Average Temperature

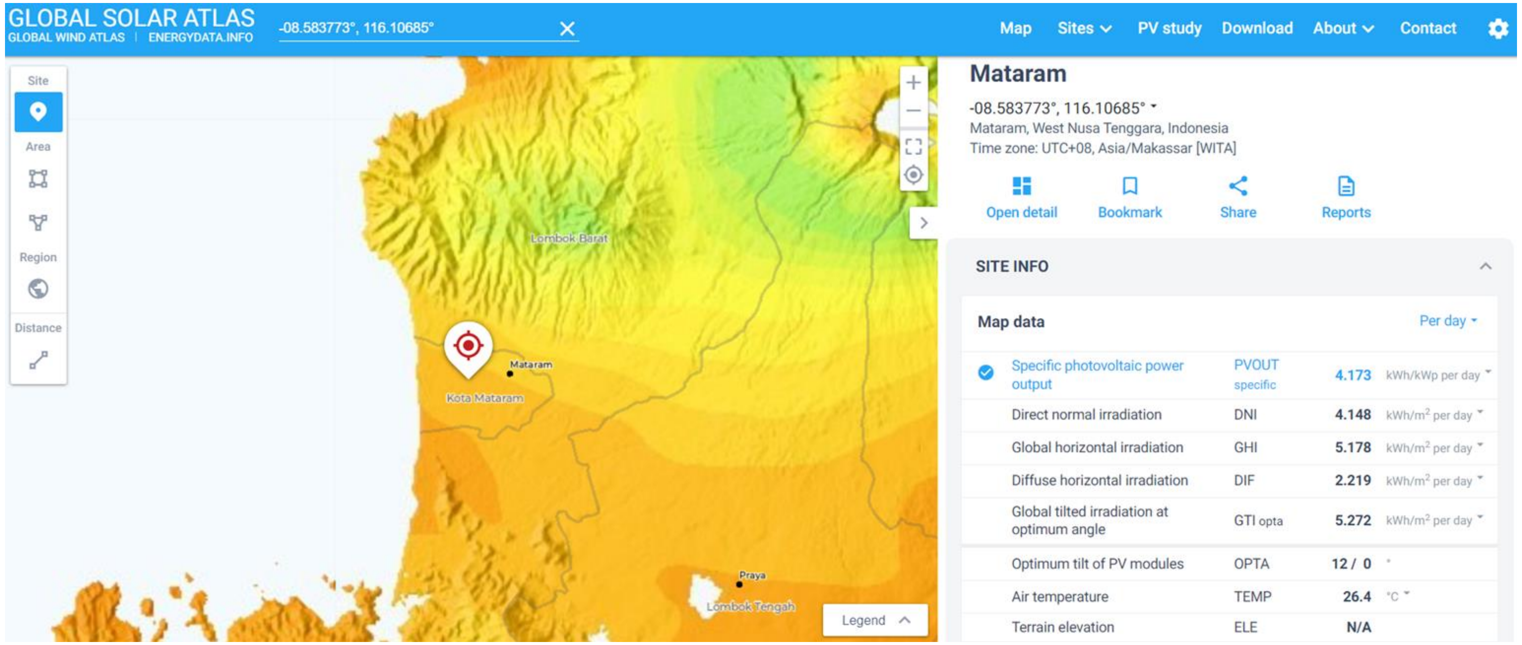
SOLAR RESOURCE ASSESSMENT

Tools

Free: Global Solar Atlas

Paid License: Pvsyst,

Helioscope, etc



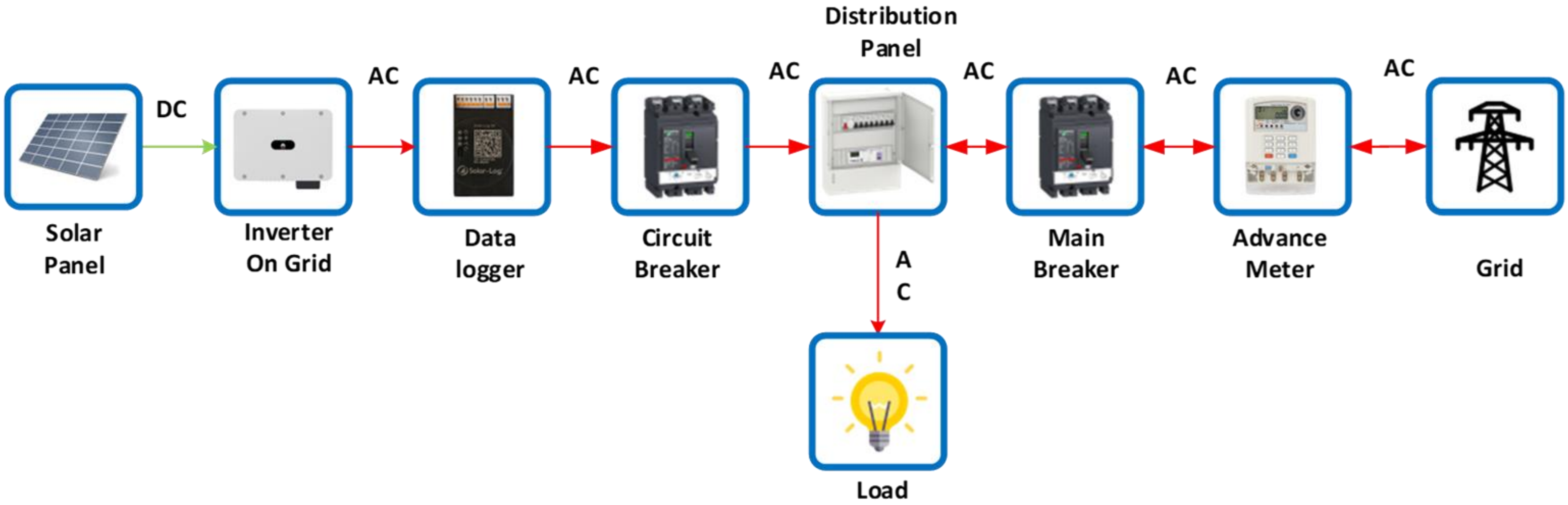
BASIC DESIGN – SPECIFICATION SYSTEM

- Total System Capacity (AC, DC): The overall power capacity of the system in both alternating current (AC) and direct current (DC).
- Inverter Capacity (kW/kVA): The power rating of the inverter in kilowatts (kW) or kilovolt-amperes (kVA).
- Solar Panel Capacity (kWp): The power rating of the solar panels in kilowatts peak (kWp), which indicates their maximum output under optimal conditions.
- Battery Capacity (kWh/MWh): The energy storage capacity of the batteries, measured in kilowatt-hours (kWh) or megawatt-hours (MWh).
- Balance of System: Includes all components of the system other than the solar panels and inverter, such as wiring, mounting hardware, and safety equipment.
- Azimuth, Tilt Angle, Structure: The orientation (azimuth) and angle (tilt) of the solar panels relative to the ground, and the structural support system used for mounting the panels.

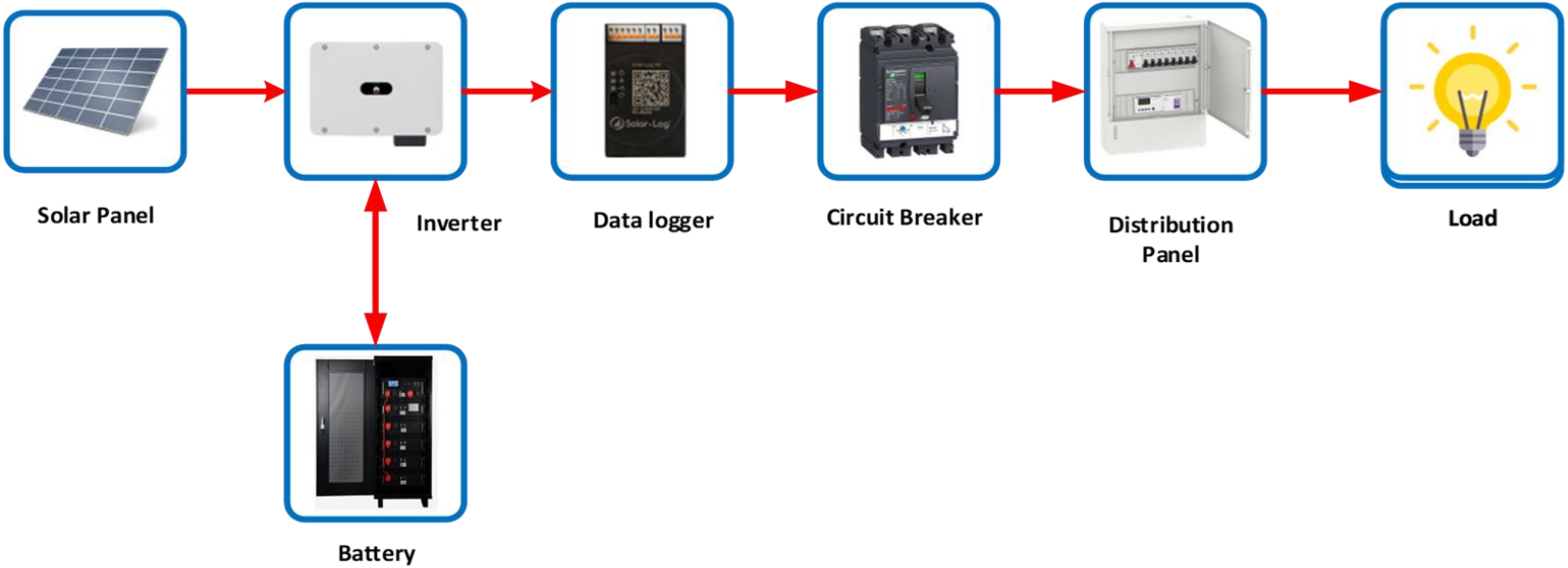
DOMESTIC COMPONENT LEVELS REQUIREMENTS

For public buildings, the procurement of materials and services must comply with domestic component regulations, which are often established by local/national government authorities. These guidelines typically mandate minimum levels of locally produced goods and services to be used in the development of infrastructure, including energy projects.

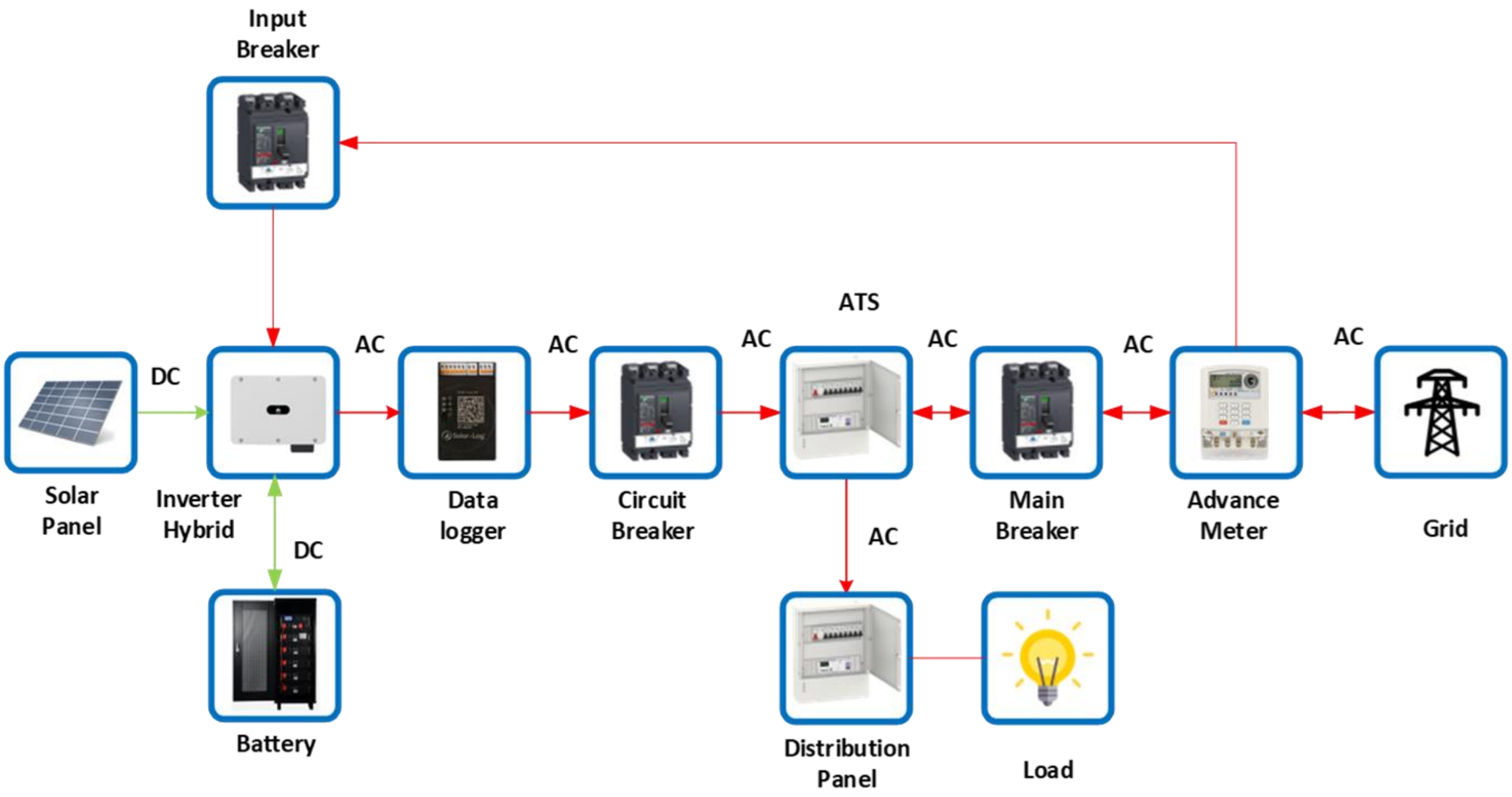
ON-GRID TOPOLOGY



OFF-GRID TOPOLOGY



HYBRID TOPOLOGY



TECHNICAL DESIGN

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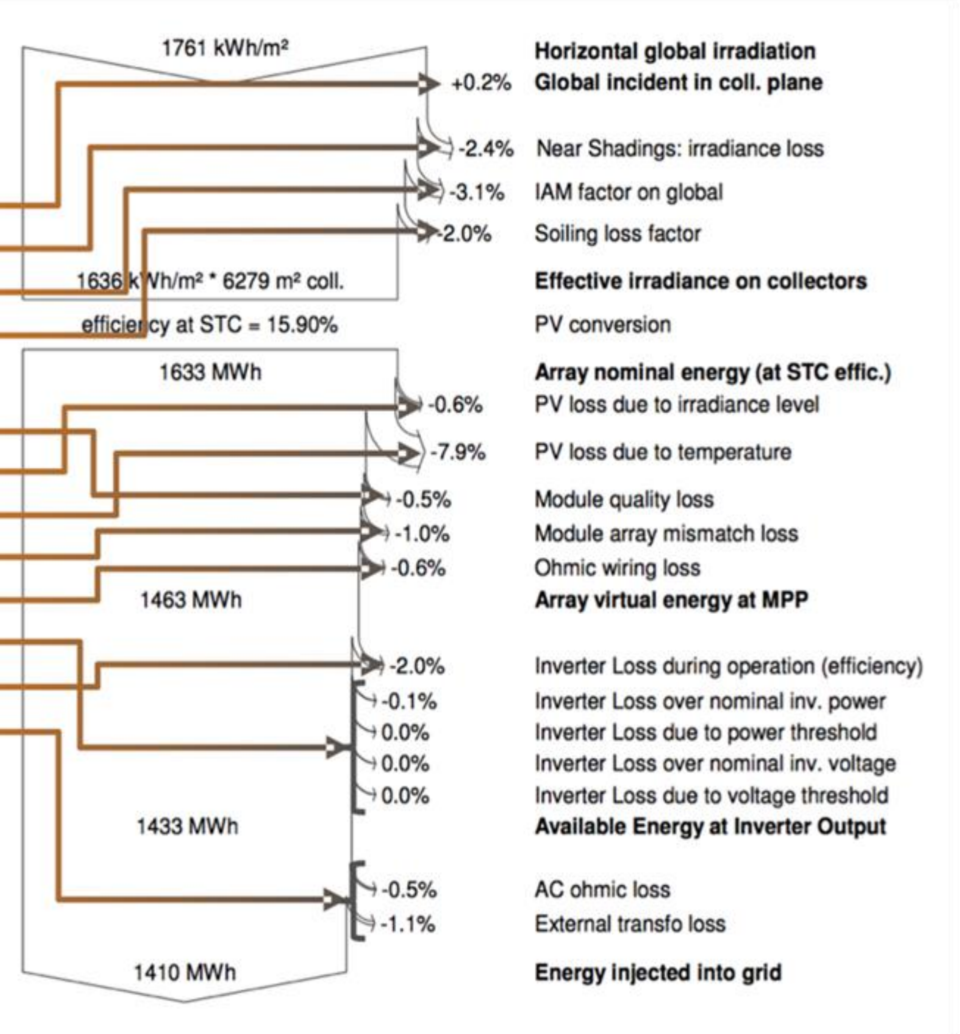
Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,984.1	
	POA Irradiance	2,188.9	10.3%
	Shaded Irradiance	2,142.6	-2.1%
	Irradiance after Reflection	2,082.0	-2.8%
	Irradiance after Soiling	2,019.6	-3.0%
	Total Collector Irradiance	**2,019.6**	**0.0%**
Energy (kWh)	Nameplate	757,675.2	
	Output at Irradiance Levels	761,967.1	0.6%
	Output at Cell Temperature Derate	711,697.4	-6.6%
	Output After Mismatch	680,222.2	-4.4%
	Optimal DC Output	657,832.3	-3.3%
	Constrained DC Output	657,278.7	-0.1%
	Inverter Output	640,646.0	-2.5%
	Energy to Grid	**627,833.0**	**-2.0%**
Temperature Metrics			
	Avg. Operating Ambient Temp		20.5 °C
	Avg. Operating Cell Temp		31.0 °C
Simulation Metrics			
	Operating Hours		4368
	Solved Hours		4368



REGULATORY COMPLIANCE

List of permits required to install rooftop solar PV:

PV capacity > 500 kWp:

1. Operation Eligibility Certificate (SLO)
2. Operation Permit (Izin Operasi)
3. Business License for Self-Used Electricity Supply (IUPTLS)

PV capacity < 500 kWp:

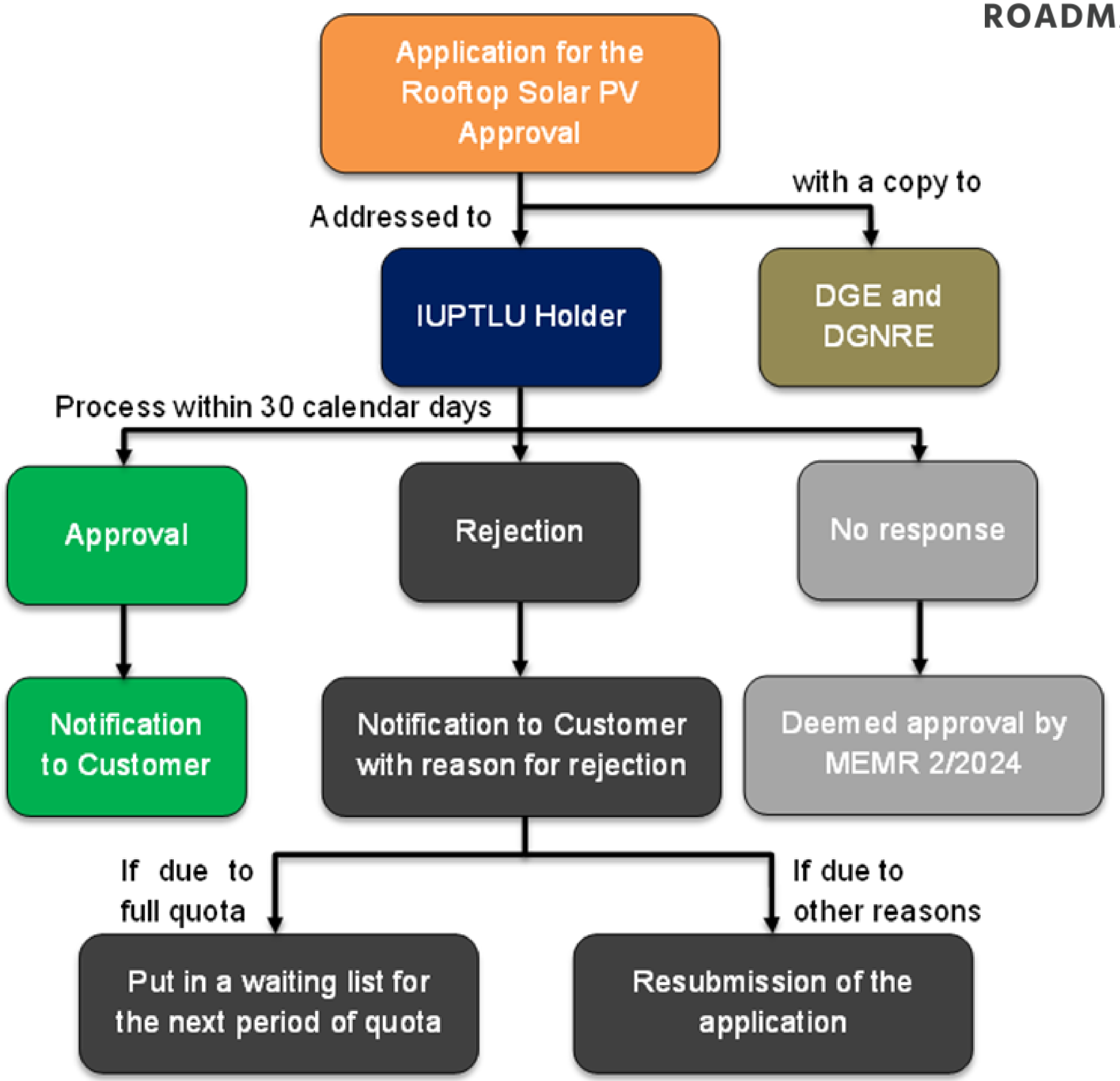
1. Operation Worthiness Certificate (SLO)

REGULATORY COMPLIANCE

This flow chart presents the rooftop PV application flow based on the newest regulation, MEMR Regulation No. 2/2024.

Key points in this latest regulation:

1. Implementation of Quota for Rooftop PV development
2. Elimination of net metering scheme
3. The window for submitting applications to procure and install Rooftop Solar Systems is now limited to twice a year, specifically in January and July.



FINANCIAL ASSESSMENT

FINANCIAL ASSESSMENT

- Calculating Investment Costs (CAPEX)

  Determine the initial capital expenditure for the project, including all costs related to purchasing and installing the solar PV system.

- Calculating Operational Costs (OPEX)

  Assess the ongoing operational expenses, such as maintenance, insurance, and other recurring costs.

- Calculating Energy Yield

  Estimate the amount of energy the solar PV system will produce over time.

- Conducting Financial Modeling

  Use financial models to simulate Net Present Value (NPV), Internal Rate of Return (IRR), and other financial feasibility indicators to evaluate the project's profitability and financial viability.

FINANCIAL FEASIBILITY INDICATOR

- **NPV (Net Present Value)**
  NPV is the difference between the present value of all cash inflows and cash outflows associated with an investment project.
  NPV > 0 means project is financially acceptable.
- **Internal Rate of Return (IRR)**
  IRR is a concept based on the return on invested capital in terms of a project investment.
  Companies use the **WACC (Weighted Average Cost of Capital)** as a minimum rate for consideration when analyzing projects since it is the base rate of return needed for the firm.
  IRR > WACC means project is financially acceptable.
- **Payback period**
  The payback period determines when the project will break even, i.e. how long it takes for revenues to pay investment outlays.
  Payback period < project duration means project is financially acceptable.
- **Levelized Cost of Electricity (LCOE)**
  The levelized cost of electricity (LCOE) is a measure of the average net present cost of electricity generation for a power plant over its lifetime. The LCOE is also the minimum price at which energy must be sold for an energy project to break even (NPV = 0).
  LCOE < electricity tariff means project is financially acceptable.

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END OF CHAPTER 4 OF 7

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