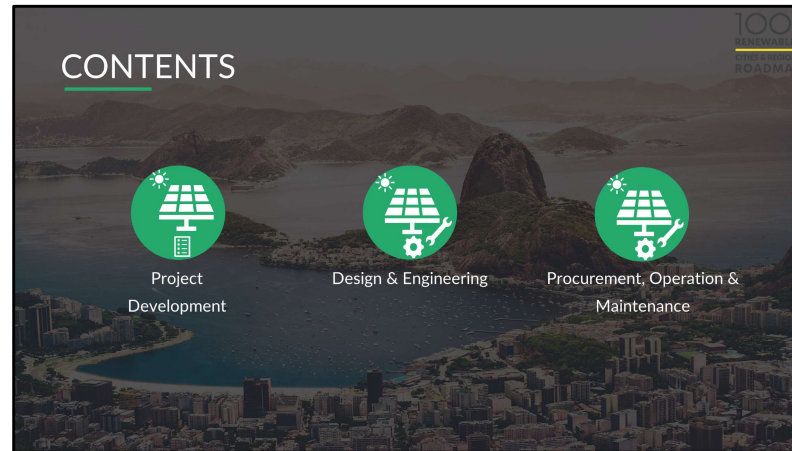


CHAPTER 3:

Solar PV Project Development





Introduction to 100 % Renewables Cities & Regions, ICLEI's Sustainable energy position
Why renewables, Global status of renewables in power capacity growth & power capacity expansion

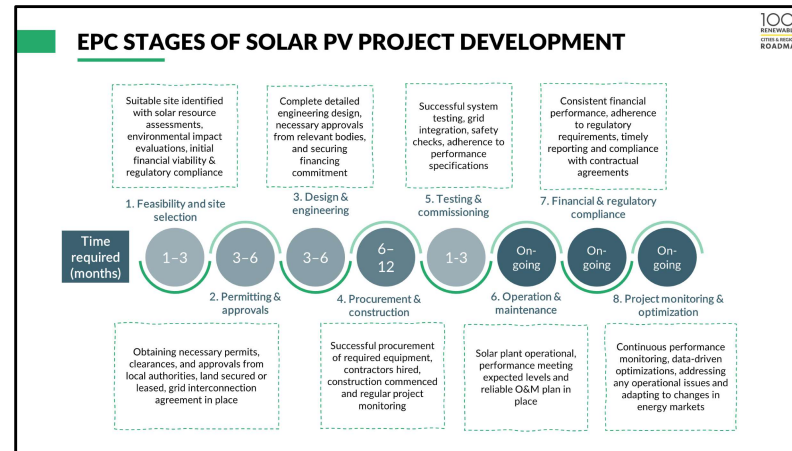
Introduction to the solar energy:

Energy from the sun, Solar energy received on earth, sun path geometry, radiation distribution on earth surface, peak sun hours, global horizontal irradiation

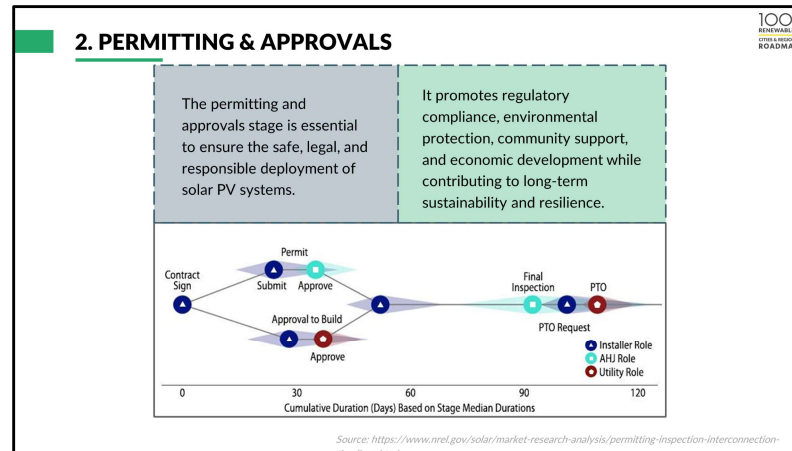
Introduction to solar photovoltaic (PV) systems: Solar PV cell operation, key milestones in history of PV technology, Solar PV cell current voltage characteristics, solar cell parameters, solar cell – module – PV panel – PV array, available technologies, linear vs non-linear PV module, area required by technology, technical specifications of PV module, standard test conditions and normal operating cell temperature, working of PV module with varied radiation and temperature.

STAGES OF PV PROJECT DEVELOPMENT





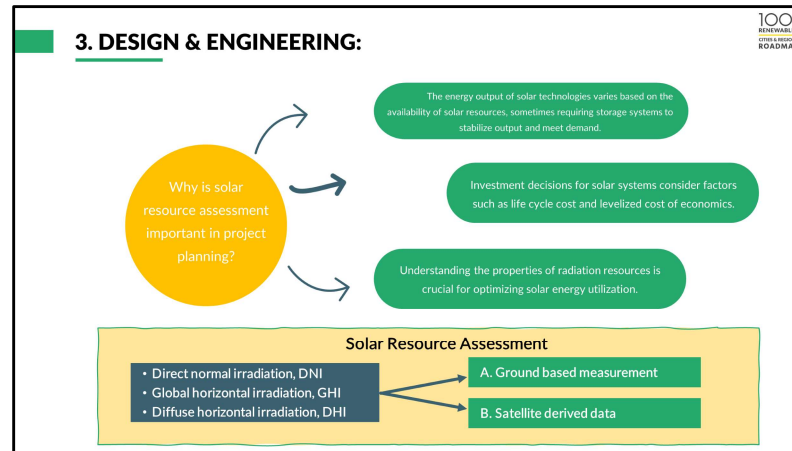
The key stages of solar PV project development involve a comprehensive series of steps aimed at harnessing solar energy efficiently and sustainably. It all starts with the crucial solar resource assessment, where the sunlight potential of the project site is evaluated using various measurement methods such as ground-based and satellite-based techniques. A meticulous site survey is then carried out, taking into account critical factors such as topography and environmental conditions, followed by a shading analysis to optimise solar panel placement and maximise energy production. Once the feasibility of the project has been established, the critical phase of procurement and logistics takes centre stage to ensure the timely acquisition of the necessary materials and equipment for the construction of the PV power plant. The actual construction of the power plant is a complex process involving detailed engineering, structural work and electrical installations and is a key stage in the project. Once constructed, rigorous testing and certification procedures are implemented to ensure the plant's safety, performance and compliance with industry standards. This comprehensive process ensures that the solar PV project is not only designed for optimal energy output, but also built to last, enabling sustainable clean energy generation and contributing to a greener future. Successfully navigating these key stages is essential for a solar PV project to reach its full potential and make a significant impact on the renewable energy landscape.



A thorough solar site survey is essential when designing solar energy systems for homeowners. This process involves several critical steps to ensure that the solar installation meets the customer's needs and maximises energy production, taking into account various technical aspects. Here's why each step is important:

1. **Gather customer information:** Understanding the homeowner's property, energy consumption and system preferences is fundamental. This data drives the design to meet their specific requirements.
2. **Utilising satellite data and imagery:** Satellite imagery and aerial photography provide vital insight into the solar potential of the property. They help to assess roof orientation, tilt and shading, and guide optimal panel placement. Images provided by the customer further assist the installation team.
3. **Taking Roof Measurements:** Accurate roof measurements are essential for accurate panel placement. This step ensures the panels fit perfectly, using software tools to streamline the process.
4. **Performing a shade analysis:** Assessing shading is critical, as obstructions affect energy output. Tools such as solar pathfinders or software simulate shading effects to ensure maximum solar potential.
5. **Electrical system assessment:** A proper electrical assessment is required to ensure compatibility with the solar system. This step may require system upgrades to meet the necessary requirements.
6. **Determine Solar Panel Location and Layout:** Using the data collected, determine the optimal location and layout of the solar panels. This includes the best angle and orientation to maximise energy production while avoiding shading.
7. **System Design and Proposal:** A detailed proposal is essential for transparency. It includes system size, components, estimated energy output, installation costs and payback period, giving homeowners a clear understanding of the benefits of the solar system.

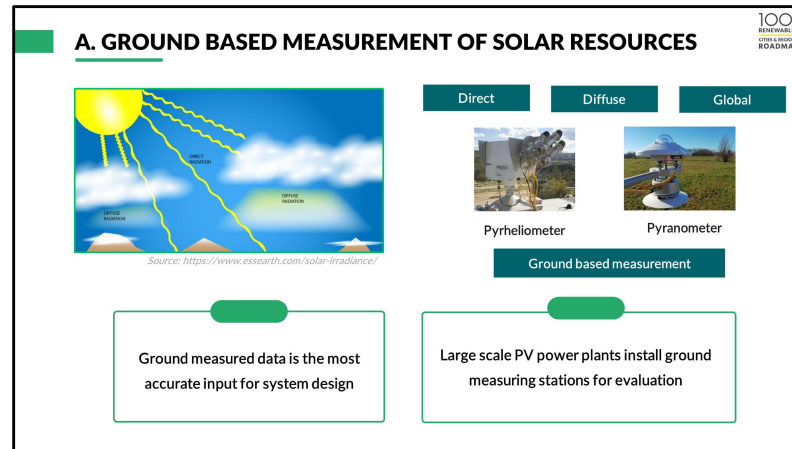
A robust solar site survey ensures that the solar energy system is tailored to the customer's needs, maximising efficiency and reducing energy costs. It's a crucial step in the transition to sustainable, renewable energy solutions.



Solar resource assessment is crucial for determining the feasibility and profitability of solar energy projects. It helps in identifying the potential of a site in terms of solar irradiation and shading analysis. This information is then used to design an optimal solar PV system that can generate maximum power output with minimum losses.

Moreover, solar resource assessment also plays a key role in predicting the performance and reliability of solar modules. By analyzing the historical weather data and simulating the solar radiation on the surface of a module, we can estimate the energy yield and degradation rate of a solar panel over its lifetime. This allows us to select the most suitable solar panels for a specific application and ensure that they meet the desired performance standards.

The data is derived from both ground measurements and satellite observations, ensuring comprehensive coverage. The properties of irradiation data are vital for project planning and system design. Firstly, spatial variability highlights differences in solar energy across geographical regions, impacting the efficiency of solar installations. Secondly, inter-annual variability captures year-to-year fluctuations in solar irradiance due to atmospheric and climatic conditions. This knowledge aids in system optimization and risk assessment. Lastly, long-term drifts refer to gradual changes in solar irradiance patterns over extended periods, necessitating adaptability in solar projects. Understanding these properties enables informed decision-making in harnessing solar energy, optimizing resource utilization, and ensuring the resilience and sustainability of solar PV projects.



Global radiation calculation: Global radiation includes both direct and diffuse solar radiation. It's the total amount of solar energy received on a horizontal surface and is critical for sizing and evaluating the performance of solar energy systems.

Ground-based solar resource measurement: Pyranometers measure global solar radiation (direct + diffuse). Pyrheliometers specifically measure direct solar radiation. Reference photovoltaic cells calibrate solar instruments, ensuring accurate data. Sunshine recorders track the total duration of sunshine, providing insight into available sunlight. These measurements are essential for assessing the solar potential of a site.

B. SATELLITE-DERIVED SOLAR RESOURCE DATA



Global insights:

- Satellite data provides global solar information, allowing assessments of remote regions.



Timely updates:

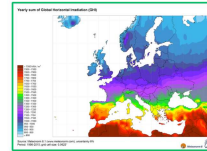
- Regular updates provide current solar potential, which is crucial for dynamic energy markets and decision-making.



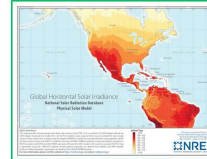
Software integration:

- Satellite data blends with simulation software (PVGIS, NREL, Meteornorm, PV*sol, Pvsyst), helping streamline solar project design, operation, and assessments.

Meteornorm – Annual data



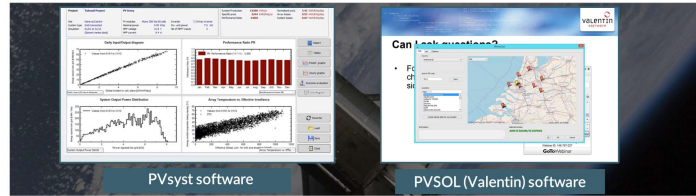
NREL – Solar radiation database

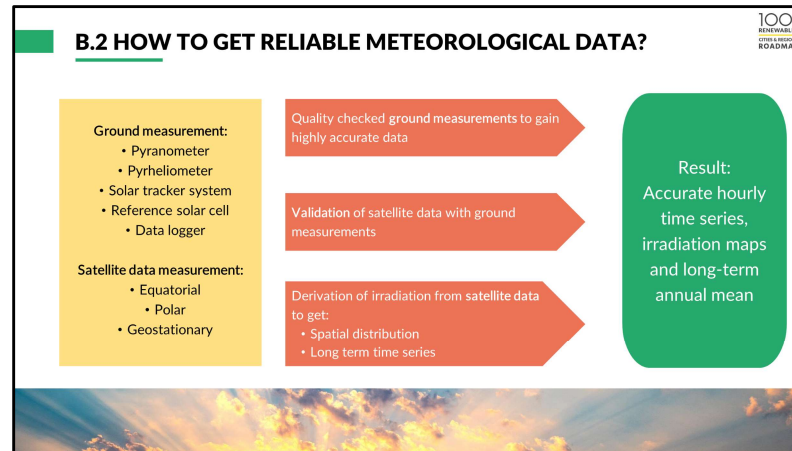


<https://www.nrel.gov/gis/solar-resource-maps.html>

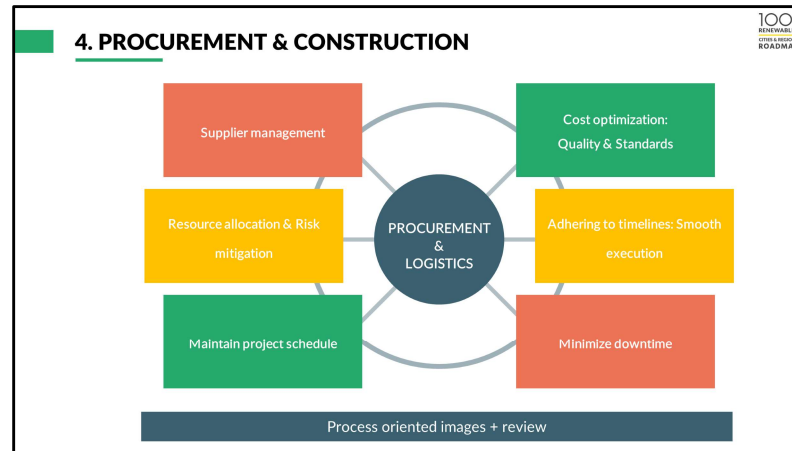
B.1 SOURCES OF SATELLITE-DERIVED DATA

- PVGIS – https://re.jrc.ec.europa.eu/pvg_tools/en/
- National Renewable Energy Laboratory, USA – <https://www.nrel.gov/gis/solar.html>
- NASA - Horizontal data only – <https://asdc.larc.nasa.gov/project/SSE>
- Meteonorm (digital database) – <https://meteonorm.com/en/buy#datasets-maps>
- Simulation software
- PVsol – <https://valentin-software.com/>
- Pvsyst – <https://www.pvsyst.com/>





In the field of solar energy analysis, ensuring accurate and reliable data is paramount. We start with quality-assured ground measurements, a critical foundation for achieving the highest levels of accuracy. However, to gain a broader perspective, we harness the power of satellite-derived irradiance data. This approach allows us not only to see the spatial distribution of solar energy, but also to construct long-term time series, allowing us to examine trends over longer periods of time. To confirm the reliability of our satellite-derived information, we meticulously validate it against rigorously scrutinised ground measurements. The culmination of this comprehensive process produces exceptional results: accurate, granular hourly time series, detailed irradiation maps showing solar potential across regions, and a robust long-term annual average that provides a holistic view of solar resource availability. This combination of validated data ensures that we can make informed decisions, drive efficient solar projects and contribute to a sustainable energy future.



Procurement and logistics are critical pillars in the construction of a PV power plant. Supplier selection is the foundation, as choosing reliable suppliers ensures quality and timely delivery of materials. This in turn minimizes downtime, keeps the project on schedule and reduces risk. Cost optimization balances quality and cost, while efficient logistics ensure smooth execution and adherence to strict schedules. Appropriate resource allocation increases efficiency, ensuring that project objectives are met while minimizing waste. In summary, procurement and logistics are critical to a successful PV power plant project, ensuring quality, cost effectiveness and timely completion.

PROCUREMENT & LOGISTICS FOR PV

100%
RENEWABLES
2025-2030
ROADMAP

Procurement required for:

- Road building
- Foundation
- Transport and installation
- PV power plant (PV modules, inverters, cables, etc.)
- Grid-connection
- Compensatory measures
- Remote monitoring system
- Others (construction management, etc.)

Question: One EPC contractor or different partners?

Logistical aspects:

- **Transport:** PV is modular, therefore special transport is not required (standard trucks can be used.) Largest items are transformers, standard housing for inverters, DC cable drums.
- **Roads:** Since no very large items are being transported, no special preparation of the roads is needed



Inverter housing : Source: SMA

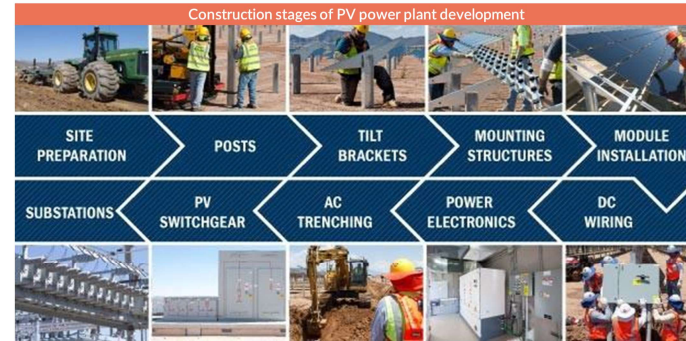


Wooden cable drum

Procurement involves the strategic acquisition of key elements for various aspects of the project, such as road construction, foundations, transportation, installation, PV power plant components (including modules, inverters and cables), grid connection elements, offsets and remote monitoring systems, as well as various ancillary requirements such as construction management. The question of whether these procurements should be managed by a single EPC contractor or distributed among different partners is one that requires consideration based on expertise and efficiency. In terms of logistics, the modular nature of PV allows for simplified transport, usually using standard trucks without the need for special road preparation due to the absence of oversized items. The largest items typically transported include transformers, standard inverter housings and DC cable drums. This logistical framework ensures efficient transport and installation, enabling a streamlined construction process for PV power plants.

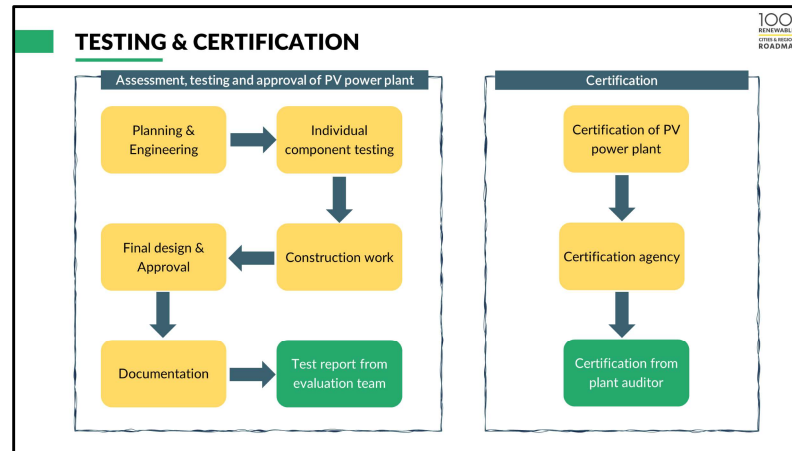
PV POWER PLANT CONSTRUCTION

100%
RENEWABLES
GRID VISION
ROADMAP



Source: <https://www.linkedin.com/pulse/your-complete-guide-pv-plant-construction-eslam-allam>

The construction of a power plant involves several crucial stages, each integral to the successful realization of the project. It begins with meticulous site preparation, ensuring the land is ready for the installation of the solar array. This is followed by the establishment of posts and the installation of tilt brackets, which lay the foundation for the mounting structures that support the solar panels. The module installation process carefully places the panels, while DC wiring ensures efficient energy flow. Power electronics are integrated to manage the energy conversion process, and AC trenching is carried out to accommodate the electrical infrastructure, including cables and conduits. The installation of PV switchgear further streamlines the energy distribution, preparing the power plant for its connection to the grid via the substation. This final step ensures that the energy generated by the solar panels can be effectively delivered to the larger electrical network, facilitating the provision of clean, sustainable energy to the end-users.



The testing and certification of a photovoltaic (PV) power plant is critical to its reliability, safety and performance. The process includes planning, engineering, component testing, construction supervision, final design approval, comprehensive documentation and a detailed test report from an evaluation team. Certification, conducted by an authorized agency and a plant auditor, further validates compliance with industry standards and regulations, providing confidence in the quality, safety and sustainability of the plant.

OPERATIONS & MAINTENANCE

The operation and maintenance of solar PV systems generally involves the following components:

- General safety
- Safety instructions
- Maintenance
- SPV technology & components
- Preventive maintenance
- Trouble shooting for PV systems



OPERATIONS & MAINTENANCE

RESPONSIBILITY FOR EQUIPMENT FAILURE

- **Negligence clause:** Negligence or maloperation responsibility lies with the Bidder.
- **Repair/replacement:** Bidder undertakes free repair or replacement if equipment failure is due to negligence/maloperation by their operator.

OPERATION AND MAINTENANCE GUIDELINES

CLEANING ROUTINE

- **Frequency:** Clean solar modules every fortnight or as per site conditions.
- **Responsibility:** Beneficiary to perform the task.
- **Vendor role:** Vendors educate beneficiaries on the importance and proper cleaning techniques.

EQUIPMENT TESTING AND CALIBRATION

- **Maintenance responsibility:** Bidder maintains testing instruments.
- **Calibration Requirement:** Every 2 years from accredited labs.
- **Documentation:** Calibration certificates kept for reference.

COMPLIANCE FOR ENERGY GENERATION

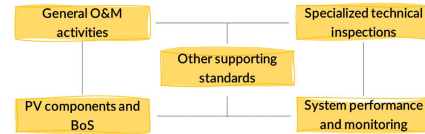
- **O&M Standards:** Compliant with grid requirements.
- **Objective:** Ensure committed energy generation.

ROUTINE CHECKS AND MAINTENANCE

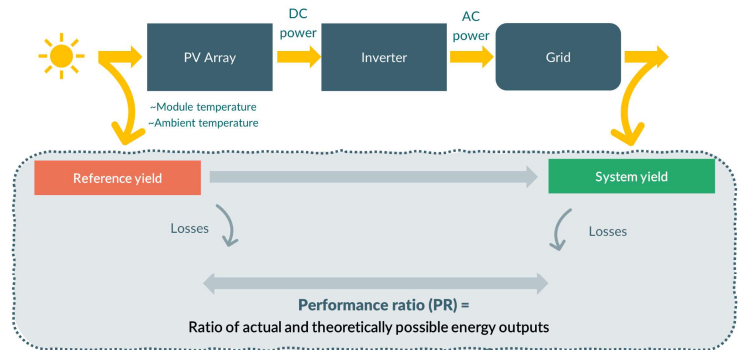
- **Periodic inspections:** Modules, PCUs, and BoS.
- **Prompt action:** Immediate replacement of defective equipment.
- **Supply management:** All necessary spares and consumables supplied as per recommendations.

STANDARDS APPLICABLE IN OPERATION & MAINTENANCE

General O&M activities	Specialized technical inspections	PV components and BoS	System performance and monitoring	Other supporting standards
<ul style="list-style-type: none"> • EN 13306 • IEC 62446 - 1: 2016 • IEC 62446 - 2 • IEC 63049: 2017 • IEC 60364 - 7 - 712: 2017 • IEC 62548 	<ul style="list-style-type: none"> • IEC TS 62446 - 3: 2017 • IEC 61829: 2015 • IEC TS 60904 - 13: 2018 	<ul style="list-style-type: none"> • EN 50380 • IEC 61215 (all parts) • IEC 61439 • IEC 61557 (all parts) • IEC 61730 (all parts) • IEC 62093 • IEC 62109 (all parts) • IEC TS 62804 (all parts) • IEC TS 62915 • IEC TS 63126 	<ul style="list-style-type: none"> • IEC 61724 - 1: 2017 • IEC 61724 - 2: 2016 • IEC 61724 - 3: 2016 • IEC 61724 - 4 • IEC 63019: 2019 • ISO 6847: 1992 	<ul style="list-style-type: none"> • IEC TS 61836 • IEC TS 62738: 2018 • IEC TR 63149: 2018 • IEC TS 62540 • IEC 60891: 2009 • IEC 61853 - 1: 2011 • IEC 61853 - 2: 2016 • IEC 61853 - 3: 2018 • IEC 61853 - 4: 2018 • IEC 60904 - 5: 2011 • IEC 60904 - 4



MONITORING & EVALUATION



Derived from sources: Anwar Rashid & Gulala Safar, 2021, Technical performance evaluation of solar photovoltaic systems. A case study of eight PV systems on the Swedish market installed at RISE research facilities

FACTORS TO MONITOR

Production quality: cell
process, materials, etc.

Energy yield
1) Reference
2) System

- Dirt/soiling
- Location/surrounding
- Seasonal behavior: snow, rain, temperature, etc.
- Shadows
- Etc.

- Long term behavior of system components: PV module, inverter
- Radiation measurement: Sensor quality
- Different spectrum: Direct/diffuse irradiation
- Low light behavior
- Measurement uncertainty
- Temperature behavior

- Maximum power point tracking of inverter
- Efficiency of inverter
- Design of overall PV power plant

