

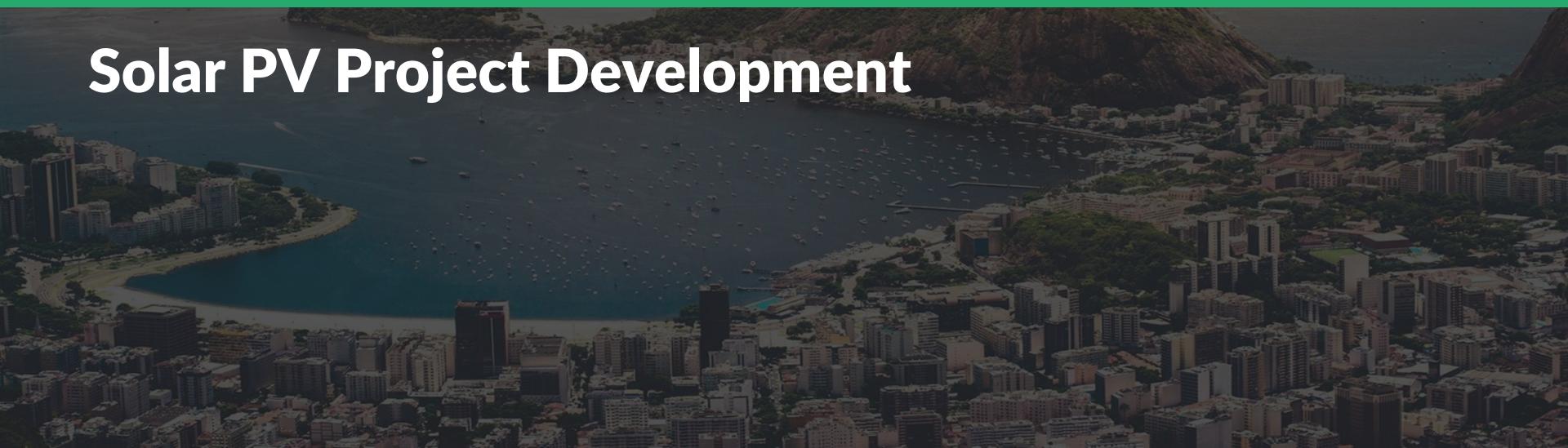




on the basis of a decision by the German Bundestag



CHAPTER 3:





STAGES OF PV PROJECT DEVELOPMENT



2. EXPERT ENGAGEMENT

Engage the right experts to assess

options

4. EARLY PROJECT FINANCE

Secure financial support from LRG and National Government. Engage with other development partners.

6. SECURE FUNDING

Formalize funding commitments
with legal contracts or via LRG/NG
budgets

8. MONITORING

Monitor performance of private sector against contractual obligations. Report on KPIs.



3. ASSESS OPTIONS Quantify the benefits of each option

1. IDENTIFICATION and assess which options are Identify projects based on affordable. Identity a preferred option.



5. DEMONSTRATE FEASIBILITY

Conduct detailed technical and financial studies to conclude on affordability



7. PROCUREMENT

Appoint private sector partner (if PPP)

via tender process. Procure EPC

contractor if public owned, and SLA

partner if operated by the private

sector.

Engineering, procurement, and construction (EPC) stages >

EPC STAGES OF SOLAR PV PROJECT DEVELOPMENT



Suitable site identified with solar resource assessments, environmental impact evaluations, initial financial viability & regulatory compliance

Complete detailed engineering design, necessary approvals from relevant bodies, and securing financing commitment

Successful system testing, grid integration, safety checks, adherence to performance specifications Consistent financial performance, adherence to regulatory requirements, timely reporting and compliance with contractual agreements

1. Feasibility and site selection

3. Design & engineering

3-6

5. Testing & commissioning

1-3

7. Financial & regulatory compliance

On-

going

Time required (months)



4. Procurement & construction

6-

12

6. Operation & maintenance

On-

going

8. Project monitoring & optimization

On-

going

Obtaining necessary permits, clearances, and approvals from local authorities, land secured or leased, grid interconnection agreement in place

Successful procurement of required equipment, contractors hired, construction commenced and regular project monitoring

Solar plant operational, performance meeting expected levels and reliable O&M plan in place

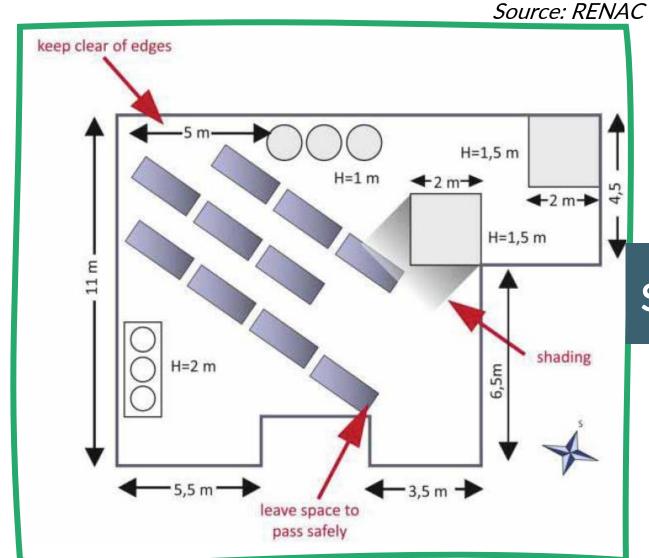
Continuous performance monitoring, data-driven optimizations, addressing any operational issues and adapting to changes in energy markets

1. FEASIBILITY & SITE SELECTION



Key steps involved in a site survey:

- Gather customer information
- Use satellite or aerial data
- Take roof measurements
- Perform a shade analysis
- Evaluate the electrical system
- Determine solar panel location & layout
- Create a system design
- Creating proposal



Shading analysis

Possibility for rooftop installation

Possibility for ground mounted PV installation



Possible installation sites for rooftop and ground mounted PV

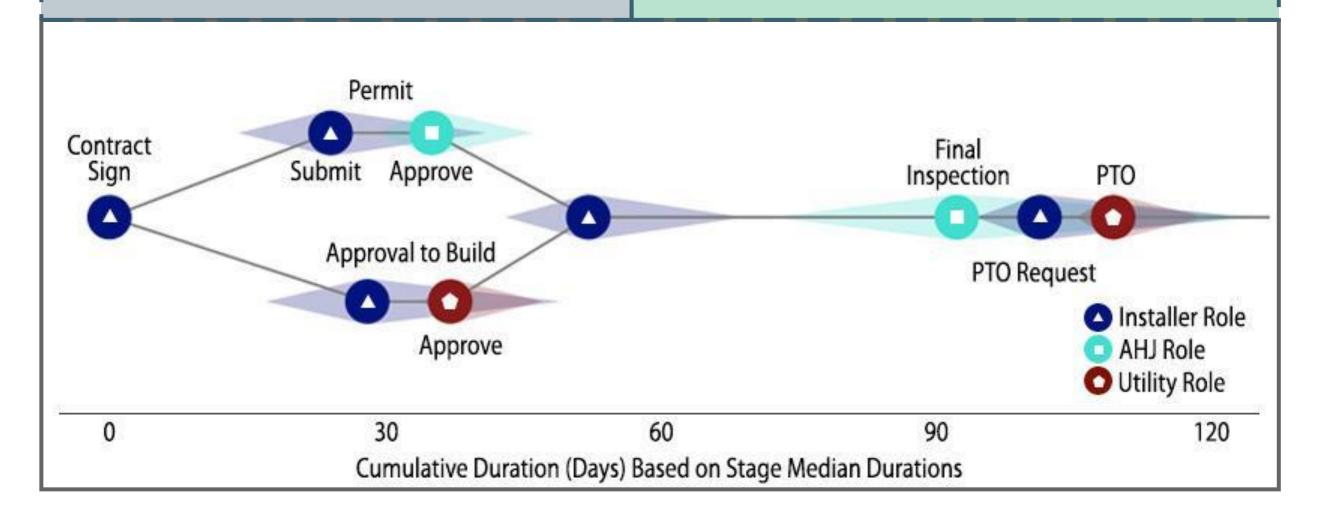
Source: Google maps - Germany 2023

2. PERMITTING & APPROVALS



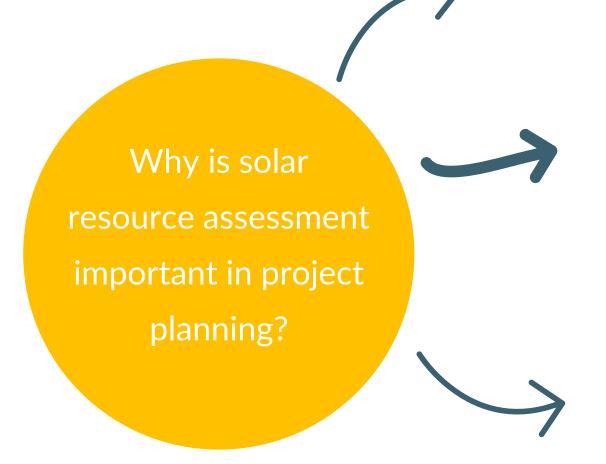
The permitting and approvals stage is essential to ensure the safe, legal, and responsible deployment of solar PV systems.

It promotes regulatory compliance, environmental protection, community support, and economic development while contributing to long-term sustainability and resilience.



3. DESIGN & ENGINEERING:





The energy output of solar technologies varies based on the availability of solar resources, sometimes requiring storage systems to stabilize output and meet demand.

Investment decisions for solar systems consider factors such as life cycle cost and levelized cost of economics.

Understanding the properties of radiation resources is crucial for optimizing solar energy utilization.

Solar Resource Assessment

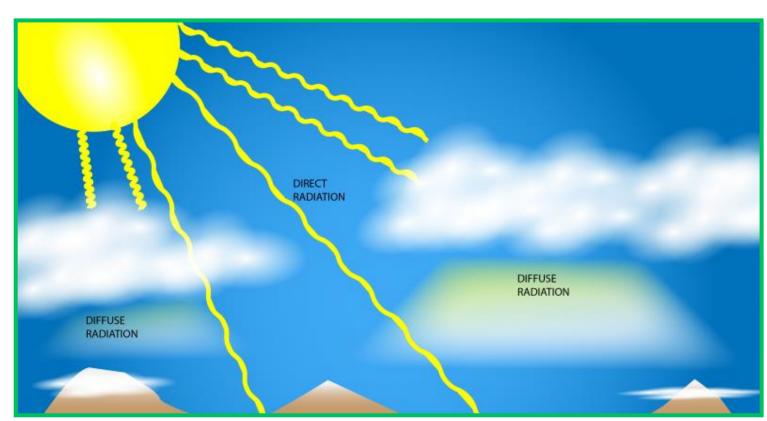
- Direct normal irradiation, DNI
- Global horizontal irradiation, GHI
- Diffuse horizontal irradiation, DHI

A. Ground based measurement

B. Satellite derived data

A. GROUND BASED MEASUREMENT OF SOLAR RESOURCES





Source: https://www.essearth.com/solar-irradiance/

Direct

Diffuse

Global



Pyrheliometer



Pyranometer

Ground based measurement

Ground measured data is the most accurate input for system design

Large scale PV power plants install ground measuring stations for evaluation

B. SATELLITE-DERIVED SOLAR RESOURCE DATA





Global insights:

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



Timely updates:

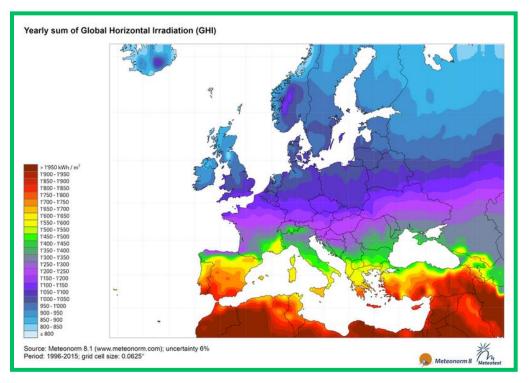
• Regular updates provide current solar potential, which is crucial for dynamic energy markets and decision-making.



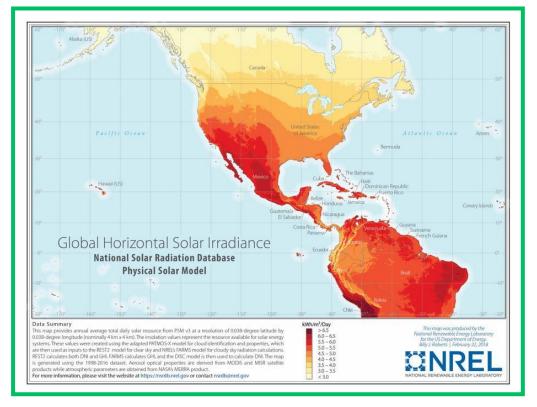
Software integration:

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

Meteonorm - Annual data



NREL - Solar radiation database

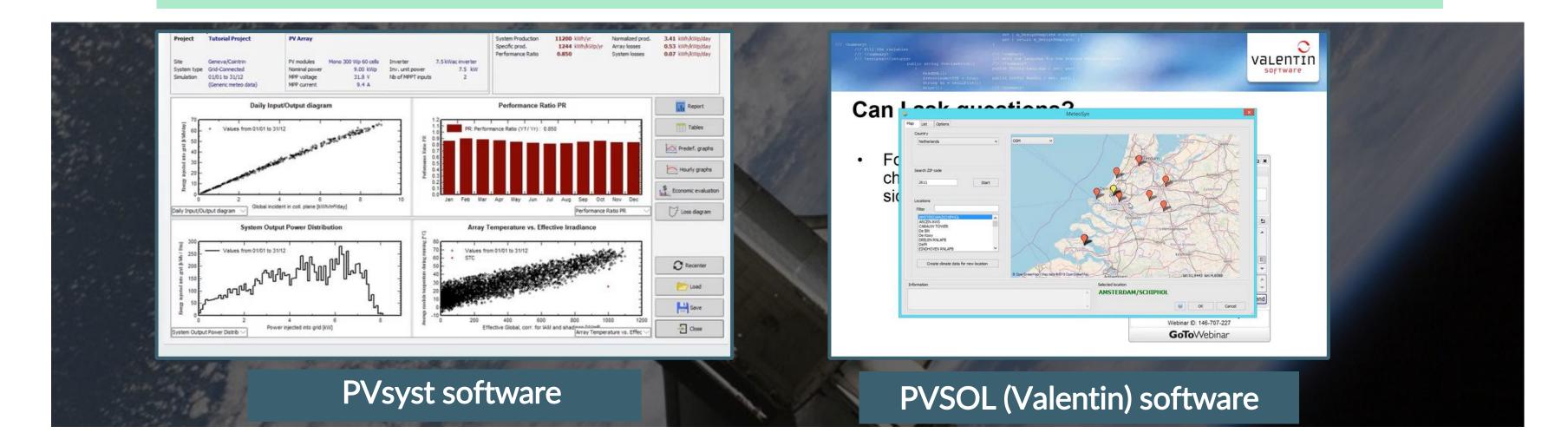


https://www.nrel.gov/gis/solar-resource-maps.html

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
- PV*sol https://valentin-software.com/
- Pvsyst https://www.pvsyst.com/



B.2 HOW TO GET RELIABLE METEOROLOGICAL DATA?



Ground measurement:

- Pyranometer
- Pyrheliometer
- Solar tracker system
- Reference solar cell
 - Data logger

Satellite data measurement:

- Equatorial
 - Polar
- Geostationary

Quality checked **ground measurements** to gain highly accurate data

Validation of satellite data with ground measurements

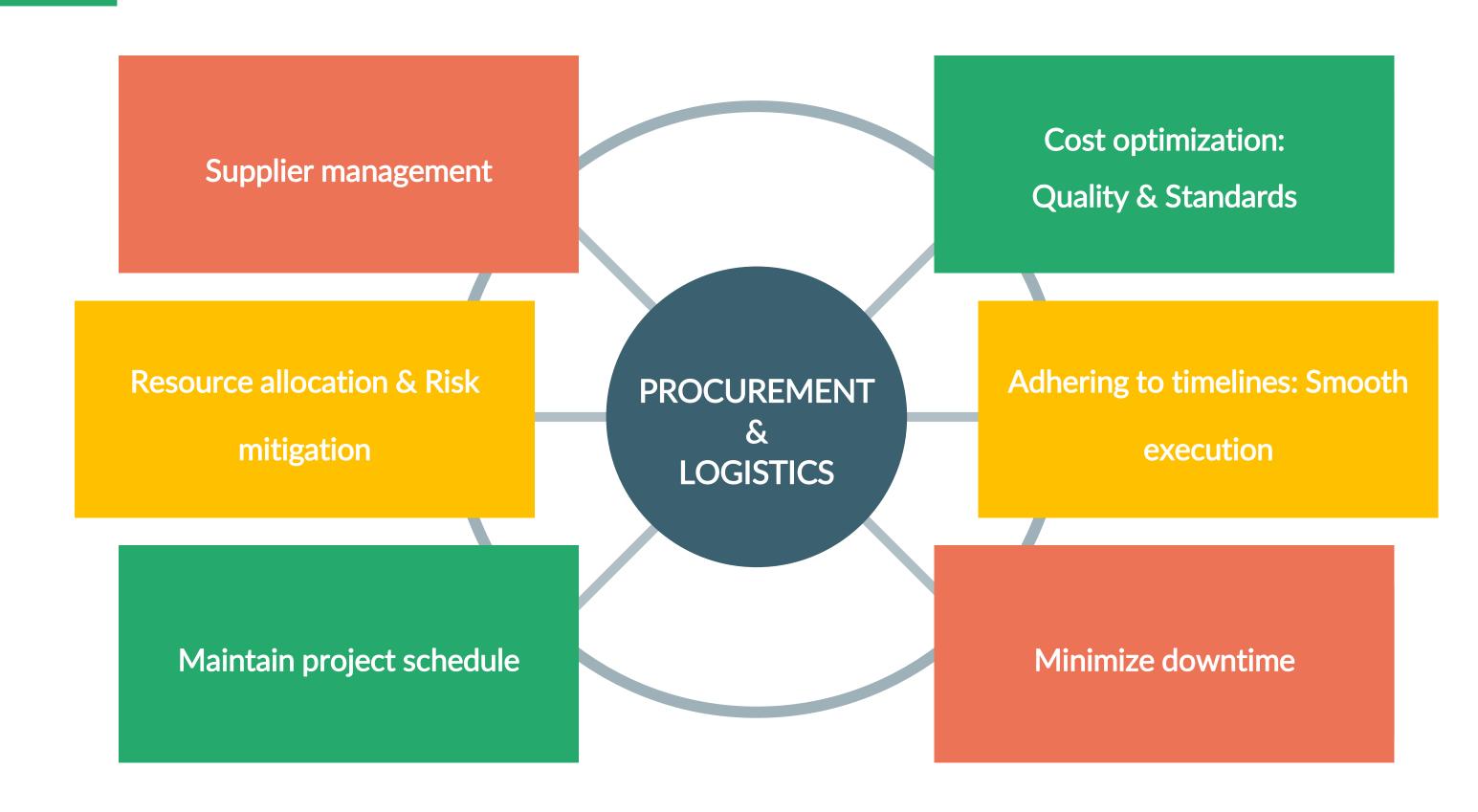
Derivation of irradiation from satellite data to get:

- Spatial distribution
- Long term time series

Result:
Accurate hourly
time series,
irradiation maps
and long-term
annual mean

4. PROCUREMENT & CONSTRUCTION





PROCUREMENT & LOGISTICS FOR PV



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



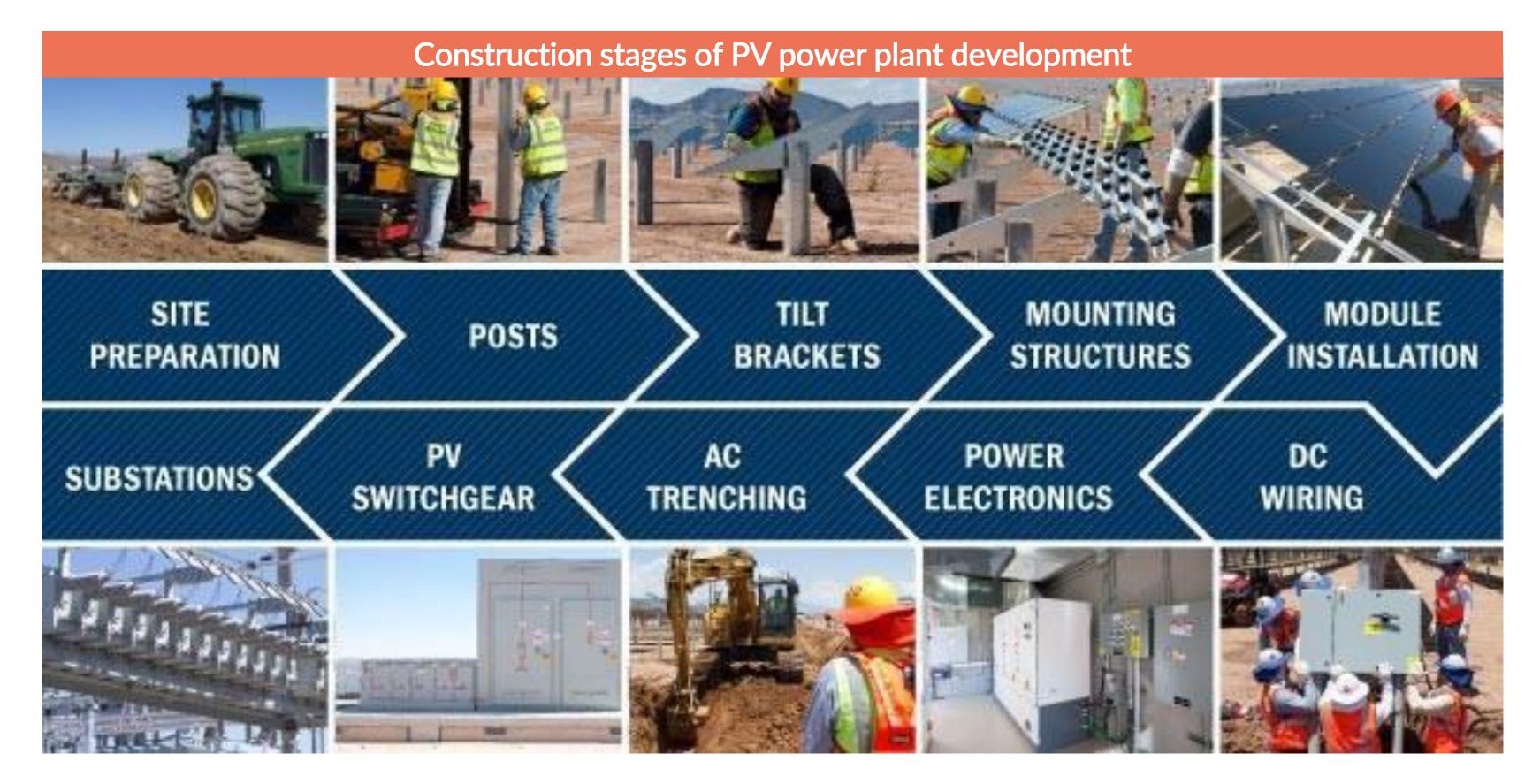
Inverter housing; Source: SMA



Wooden cable drum

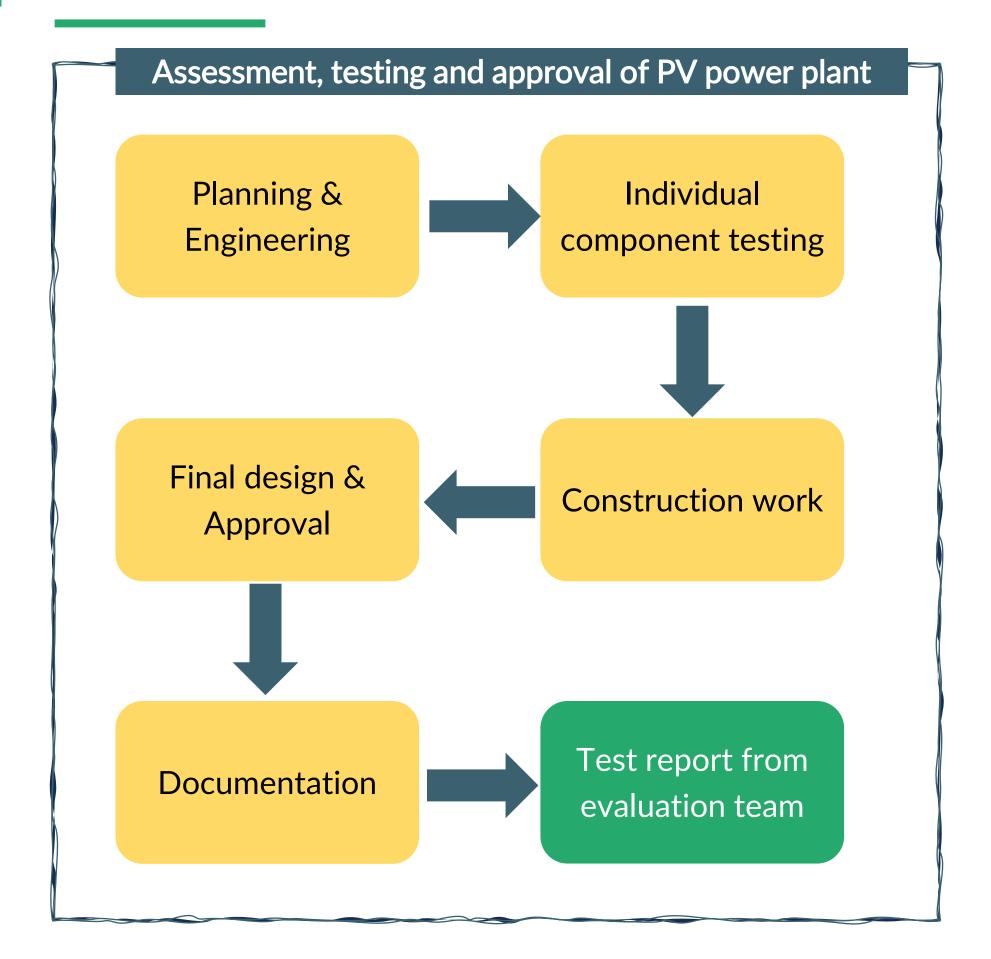
PV POWER PLANT CONSTRUCTION

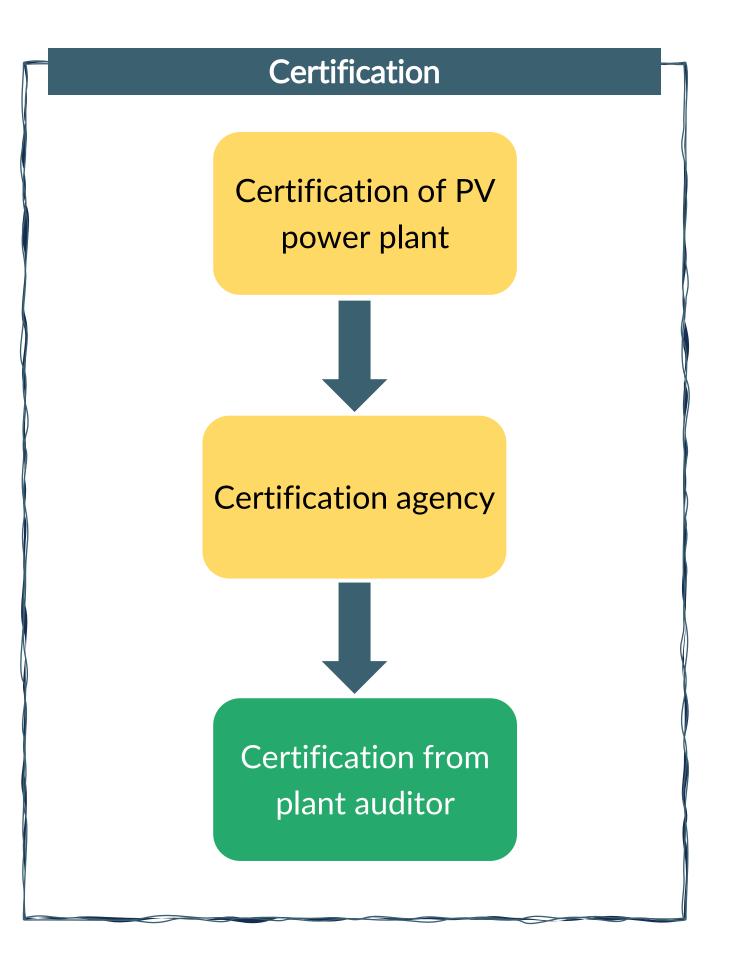




TESTING & CERTIFICATION







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



- **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.



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



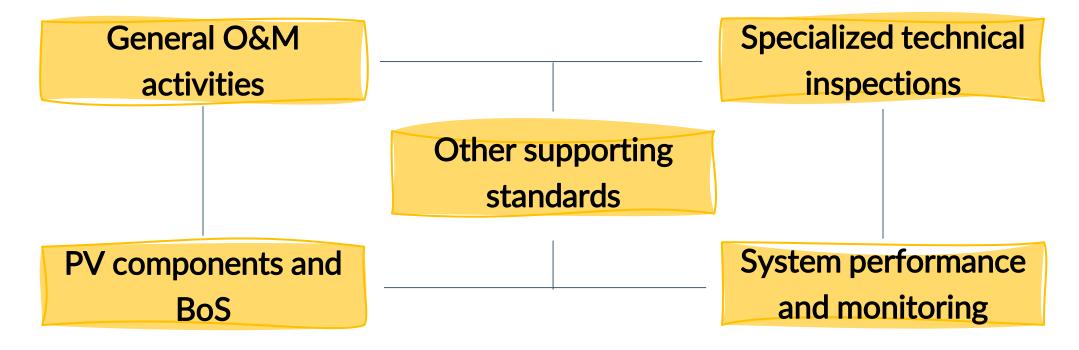
ROUTINE CHECKS AND MAINTENANCE

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



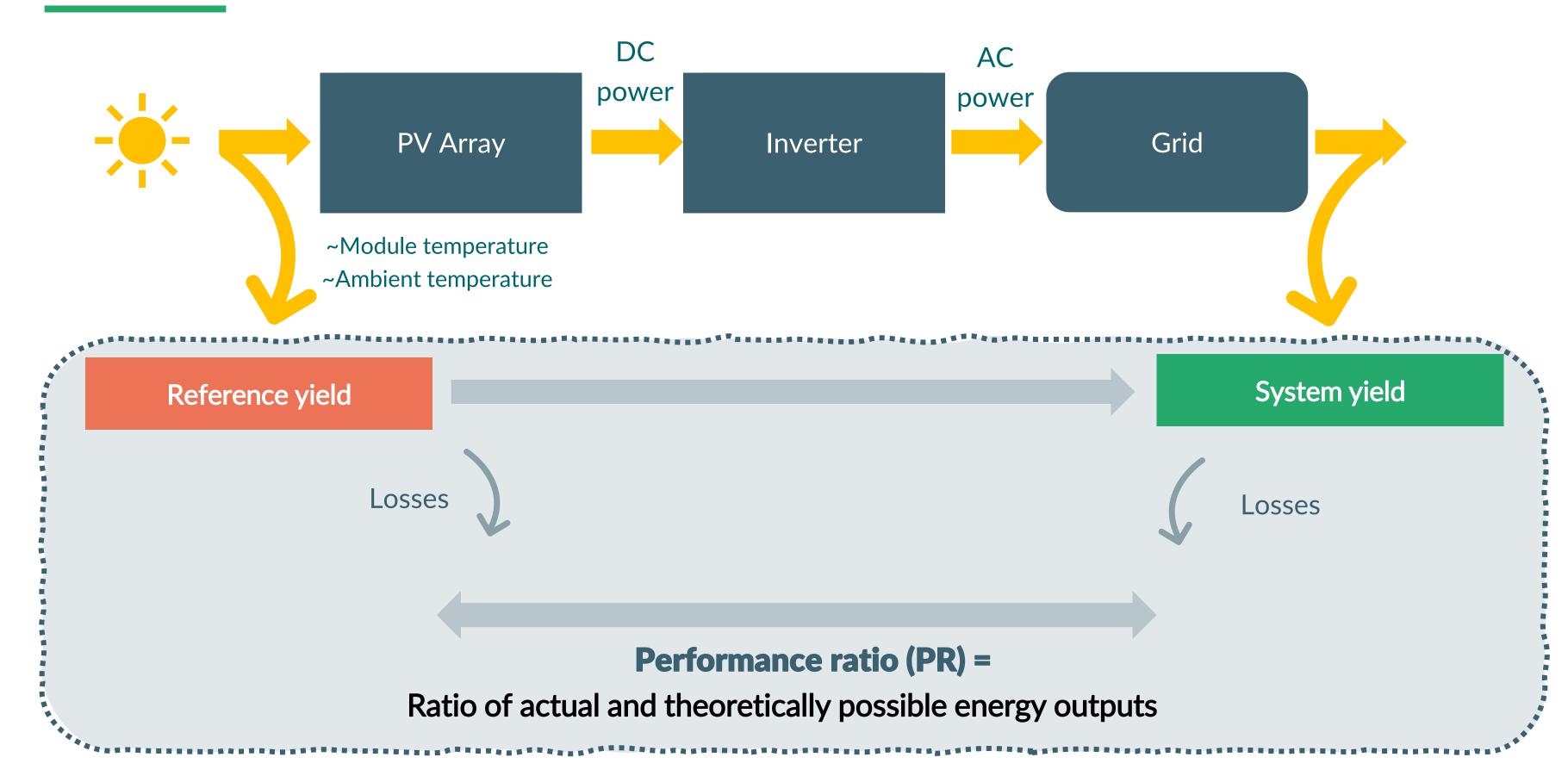


General O&M activities	Specialized technical inspections	PV components and BoS	System performance and monitoring	Other supporting standards
• EN 13306 • IEC 62446 - 1: 2016 • IEC 62446 - 2 • IEC 63049: 2017 • IEC 60364 - 7 - 712: 2017 • IEC 62548	• IEC TS 62446 - 3: 2017 • IEC 61829: 2015 • IEC TS 60904 - 13: 2018	 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 63126 	• IEC 61724 - 1: 2017 • IEC 61724 - 2: 2016 • IEC 61724 - 3: 2016 • IEC 61724 - 4 • IEC 63019: 2019 • ISO 6847: 1992	 IEC TS 61836 IEC TS 62738: 2018 IEC TR 63149: 2018 IEC TS 62548 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





FACTORS TO MONITOR

RENEWABLES
CITIES & REGIONS
ROADMAP

Production quality: cell process, materials, etc.

Energy yield

- 1) Reference
- 2) System

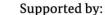
- Dirt/soiling
- Location/surrounding
- Seasonal behavior: snow, rain, temperature, etc.
- Shadows
- Etc.

- 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











on the basis of a decision by the German Bundestag

