IRENA PROJECT NAVIGATOR

IRENA
International Renewable Energy Agency

Technical Concept Guidelines
Utility-Scale Solar PV

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Authors: Fabian Kuhn[a], Roland Roesch[b], Carlos Ruiz[b], Simon Benmarraze[b]

[a] Fichtner GmbH & Co KG

[b] International Renewable Energy Agency

For further information please contact IRENA: navigator@irena.org or info@irena.org. This report is available for download from www.irena.org/Publications.

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AC	Alternating current
ADFD	Abu Dhabi Fund for Development
AM	Air mass
a-Si	Amorphous silicon
BOS	Balance of system
C	Celsius
CAPEX	Capital expenditure
CCTV	Closed-circuit television
CdTe	Cadmium telluride
CE	Communauté Européenne
CF	Capacity factor
CIS, CIGS	Copper indium gallium (di)selenide
COB	Clean on board
COD date	Commercial operation
CPV	Concentrated photovoltaic
c-Si	Crystalline silicon
DC	Direct current
DCS	Distributed control systems
DHI	Diffuse horizontal irradiation
DNI	Direct normal irradiation
DSCR	Debt service coverage ratio
EBRD	European Bank for Reconstruction and Development
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EMP	Environmental Management Plan
EPC	Engineering, procurement and construction
ESIA	Environmental and Social Impact Assessment
EU	European Union
EUR	Euro
EVA	Ethylene vinyl acetate
FAC Certificate	Final Acceptance
FiT	Feed-in tariff
GaAs	Gallium arsenide
GHI	Global horizontal irradiation
GIS	Geographic information system
GW	Gigawatt
H&S	Health and safety
ha	Hectare
HIT	Heterojunction with intrinsic thin layer
HSE	Health, safety and environment
HVS	High-voltage stress
IEA-PVPS	International Energy Agency Photovoltaic Power Systems Programme
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
INSPIRE	IRENA International Standards and Patents in Renewable Energy platform
IP	Ingress protection
IRENA	International Renewable Energy Agency
IRR	Internal rate of return
IV-curve	Current-voltage curve
km	Kilometre
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
kWp	Kilowatt peak

LCOE	Levelised cost of electricity
LD	Liquidated damages
LID	Light-induced degradation
LLA	Land lease agreement
LTSA agreement	Long term service
MENA Africa	Middle East and North
mm	millimetre
mono-Si	Monocrystalline silicon
MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
MRA Account	Maintenance Reserve
m	Metre
m/s	Metres per second
MW	Megawatt
MWh	Megawatt-hour
MWp	Megawatt peak
NASA	National Aeronautics and Space Administration
NGO	Non-governmental organisation
NOCT	Nominal operating cell temperature
O&M maintenance	Operation and
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturer
OPEX	Operational expenditure
PAC	Provisional Acceptance Certificate
PID degradation	Potential induced
POA	Plane of array
poly-Si	Polycrystalline silicon
PPA	Power purchase agreement
PR	Performance ratio
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
QA	Quality Assurance
QC	Quality Control
REC certificate	Renewable energy
RFP	Request for proposal
SCADA	Supervisory Control and Data Acquisition
Si	(Crystalline) silicon
SPV	Special Purpose/Project Vehicle
STC	Standard test conditions
TMY	Typical Meteorological Year
TÜV	Technischer Überwachungsverein (Technical Inspection Association)
TWh	Terawatt-hour
UK	United Kingdom of Great Britain and Northern Ireland
UL	Underwriters Laboratories
UPS Supply	Uninterruptible Power
USD	United States dollars
V	Volt
VAT	Value-added tax
W	Watt

I. INTRODUCTION

The Paris Agreement adopted at the United Nations Climate Change Conference in December 2015 puts renewables at the forefront of the required energy transformation towards a low-carbon future. Among all renewable energy technologies, solar photovoltaic (solar PV) is a commercially available and reliable technology with a total installed capacity of 222 GW worldwide in 2015 and more than 47 GW added in 2015 alone (IRENA, 2016a).

Even though solar PV is a mainstream renewable energy technology, many projects face obstacles during their development due to the unavailability of transparent guidelines, complicating the path of many project developers towards financial close and commercial operations.

In its mission to promote the widespread adoption and sustainable use of solar PV energy technology in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity, the International Renewable Energy Agency (IRENA) is providing *Technical Concept Guidelines* for utility-scale PV plants in order to support the development of bankable utility-scale PV projects.

These guidelines are meant to support developers throughout the project development process by providing knowledge, tools and best practices to develop a successful utility-scale solar PV project, which generally can be identified by its size and equipment – typically starting at 5 megawatts (MW) with large inverters and a connection to a high- or medium-voltage grid.

The project development process outlined in the *IRENA Project Navigator Technical Concept Guidelines* is composed of nine phases which range from the identification of a business opportunity to the execution of a given solar PV project:

1. Identification: Analysis of local constraints by evaluating potential issues, opportunities and needs as a basis for project development kick-off.
2. Screening: Systematic protocol used to identify characteristics of various alternatives within a defined project scope.
3. Assessment: Determination of the value of a given project and analysis of activities required to implement it.
4. Selection: Decision-support process that benchmarks project ideas and selects the project configuration with the highest potential or priority.
5. Pre-development: Establishment of project requirements and concept documentation, providing the basis for design and evaluation of the final project configuration.
6. Development: Critical phase where requirements and activities are finalised in order to approach financial close with investors and lenders.
7. Construction: On-site equipment and systems design, procurement and installation with qualified contractors. This phase demands high quality standards and extensive expertise in order to meet project performance targets.
8. Operation and maintenance: After commissioning, the plant is operated and managed to maintain the highest level of availability. Preventive and correction maintenance protocols are applied in a quality environment to prevent any outages or failures.
9. Decommissioning: At the plant's end-of-life, equipment is dismantled and eventually prepared for removal and recycling.

The main aspects of each phase are described in detail, along with the minimum requirements for the development of a bankable project. In addition, practical frameworks, checklists, forms, models and various templates are provided. Each section provides insights on the key conditions and requirements to be fulfiled, mainly in terms of the technical suitability and bankability of the project to achieve financial close.

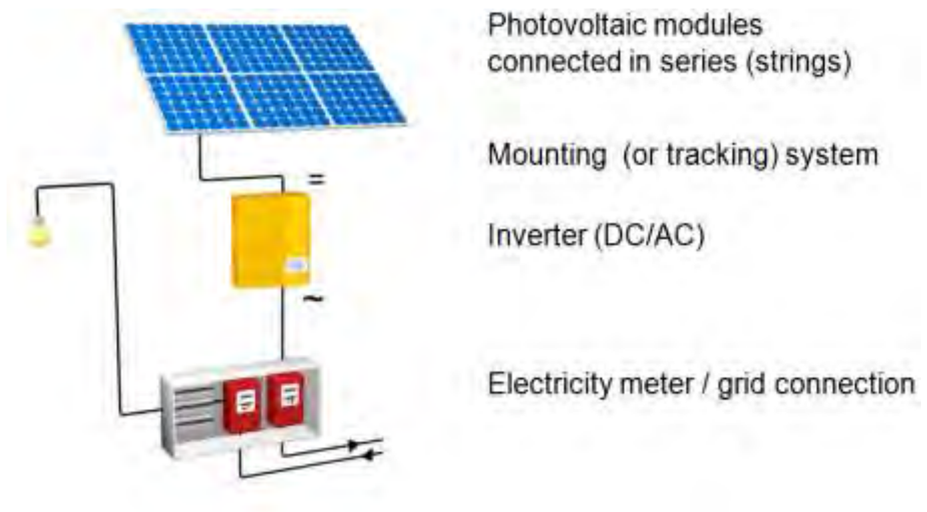
I.1 Solar photovoltaic technology

Solar PV technology converts solar irradiation into electricity based on the so-called photovoltaic effect, according to which light striking a surface frees electrons from their bound position. In the case of semiconductor materials such as silicon with a pn-junction, when light strikes the space charge region, electron-hole pairs can be generated and separated so that current can flow through plus and minus electrodes of a solar cell. Once an electric load is applied, a flow of electric current is created. Several cells connected in series and in parallel create a solar module with the desired voltage and current characteristics.

Solar PV module arrays generate direct current (DC). For grid applications, solar inverters are required to convert the DC of the solar PV array into alternating current (AC) at the utility frequency. The AC power then can be fed into the grid or used by an isolated local network. In order to achieve higher yields, solar PV modules are oriented to the sun with different mounting concepts, which may vary from fixed structures to continuous tracking mounting systems.

The basic components of a solar PV system are shown in Figure I-1.

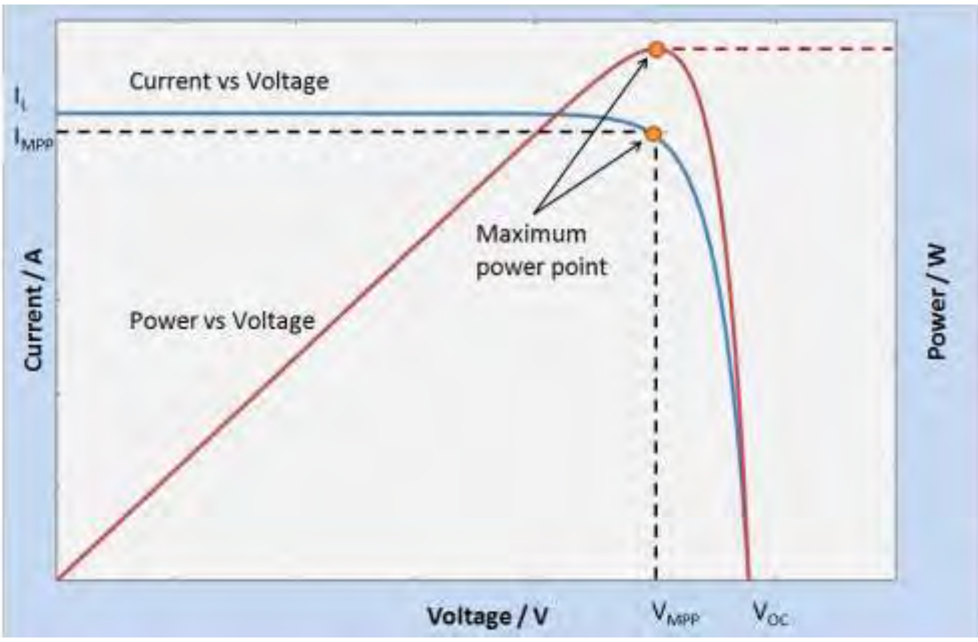
Figure I-1: General drawing of the main components of solar PV systems



Credits: Fichtner, 2015.

Other components of a solar PV system that are not depicted in this figure are the mounting structure for the modules, power transformer, DC and AC cables, storage system, monitoring system, weather station and protection devices.

Figure I-2: Current-voltage and power-voltage curves of a solar cell



PV modules have a characteristic current-voltage curve (IV-curve) and power-voltage curve. The IV-curve is described by the diode equation:

$$I = I_0 \left[exp\left(\frac{qV}{nkT}\right) - 1 \right] - I_L$$

I_0 is the reverse bias saturation current, n the diode ideality factor, k the Boltzmann constant, T the temperature, q the elementary charge and I_L the light-generated current. I_0 is much smaller than I_L. The output power of a PV module is given by the product of current times voltage P = I x V (blue line).

PV module manufacturers provide certain characteristic values to rate a PV module:

- Open-circuit voltage V_{OC} – infinite load applied to the module
- Short-circuit current I_{SC} – no load applied to the module
- Maximum power point (MPP) – maximum output power of PV module.

Inverters have an MPP controller to hold the module at MPP.

The voltage V_{MPP} and current I_{MPP} at MPP are always lower than V_{OC} and I_{SC}.

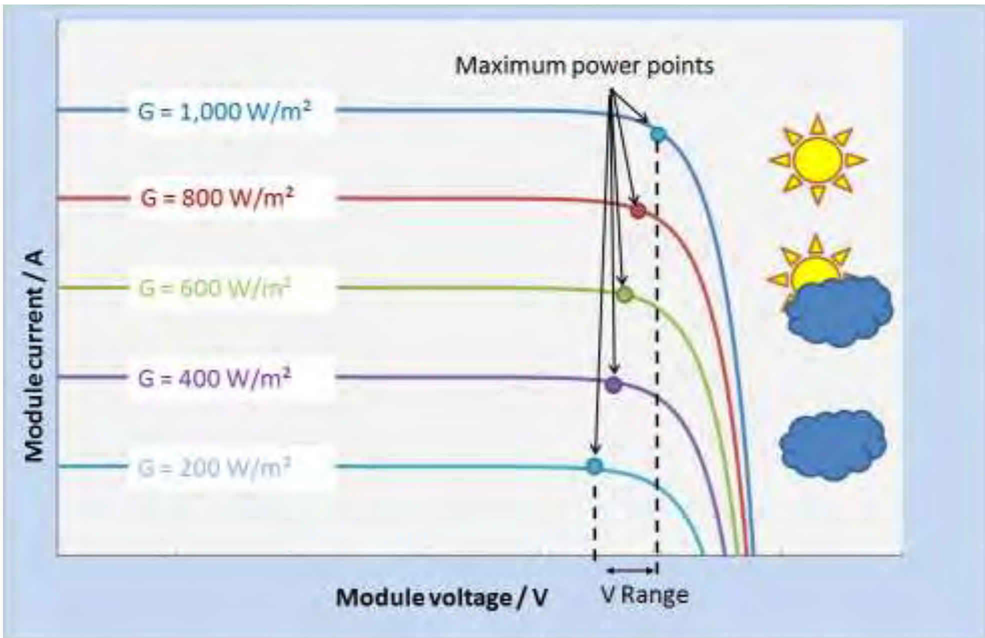
The actual power, voltage and current of a PV module depend on the solar irradiation. According to the diode equation the short-circuit current is

$$I_{SC} = I(V = 0) = -I_L$$

The short-circuit current depends linearly on the light-generated current I_L and therefore on the sun's irradiation intensity in watts per square metre (W/m^2). The open-circuit voltage depends logarithmically on the sun's irradiation intensity in W/m^2:

$$V_{OC} = \frac{nkT}{q} \ln\left(\frac{I_L}{I_0} + 1\right)$$

Figure I-3: Solar module current voltage dependence on irradiation



Standard test conditions / Nominal operating cell temperature

In order to compare PV modules with different designs, standard test conditions (STC) are defined:

- Ambient temperature = 25 °C
- Irradiation = 1 000 W/m²
- Irradiation spectrum = air mass (AM) 1.5.

These conditions will seldom occur, as the module temperature increases with irradiation and depends on several other factors such as the ambient temperature, wind velocity and albedo of the ground. To determine the output power of the solar cell under real-life conditions, PV module manufacturers determine the nominal operating cell temperature (NOCT), which is defined as the temperature reached by open-circuited cells in a module under the following conditions:

- Irradiance on cell surface = 800 W/m²
- Ambient temperature = 20 °C
- Wind velocity = 1 metre per second (m/s)
- Mounting = open back side.

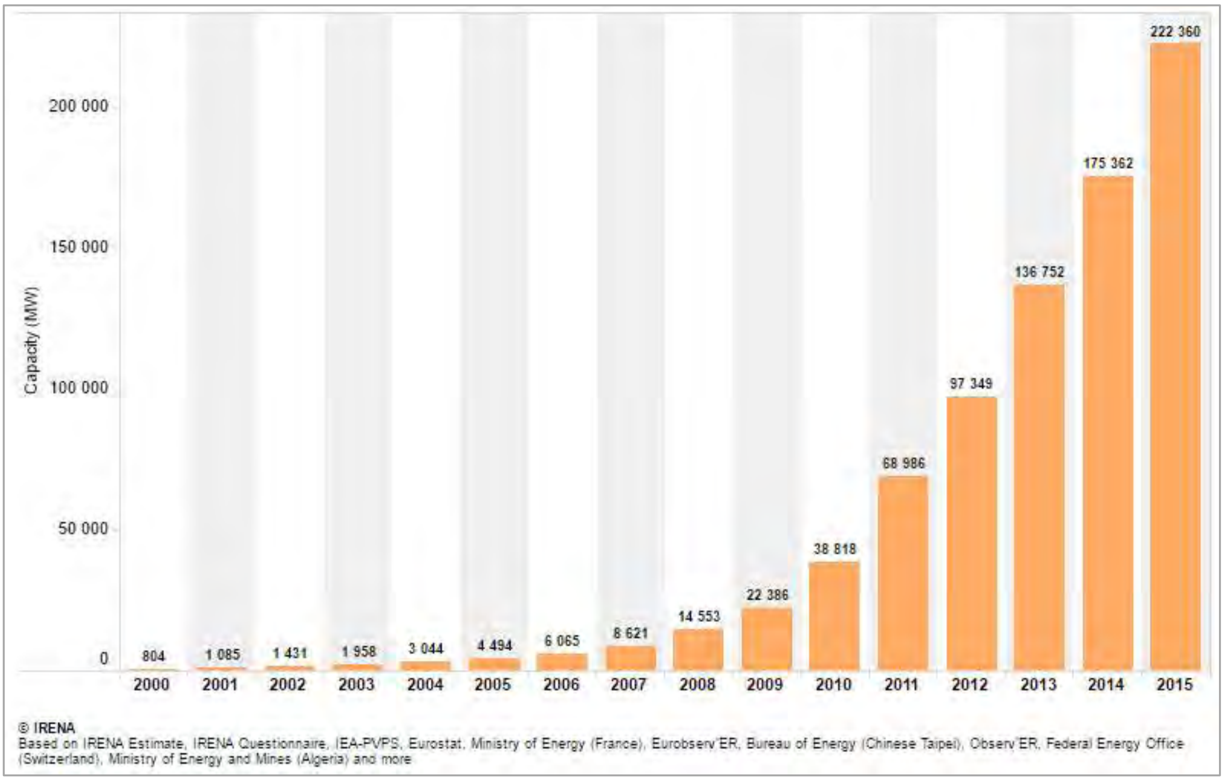
The cell temperature T_{cell} for different ambient conditions (air temperature T_{air} and irradiation S) can be calculated according to Ross *et al.* (1980):

$$T_{Cell} = T_{Air} + \frac{NOCT - 20}{80} S$$

I.2 Solar photovoltaic market

Crystalline silicon-based (c-Si) PV modules currently dominate the solar PV market (around 90% of new installations by capacity), as their mature nature, relatively high efficiency and low cost make them a very attractive commercial choice. The thin-film solar PV sector has undergone significant consolidation in recent years, and deployment appears to be stabilising at around 4 gigawatts (GW), with 4.1 GW and 3.9 GW deployed in 2012 and 2013, respectively. Thin-film technologies have some advantages under specific operating conditions, so they are likely to continue to play an important role in the suite of technology options in order to maximise yield and minimise the levelised cost of electricity (LCOE) of solar PV, despite the fact that they have struggled to displace c-Si modules to date.

Figure I-4: Cumulative installed solar PV capacity, 2000-2015



Source: IRENA, 2016a.

The most competitive utility-scale solar PV projects are now regularly delivering electricity for just USD 0.05 per kilowatt-hour (kWh) without any subsidies. Even lower costs are being realised, down to USD 0.03/kWh, for utility-scale solar PV where excellent resources and low-cost finance are available.

Since 2013, the leading countries for PV deployment have shifted from Europe to Asia due to the rapidly rising installation rates in both China and Japan. India also is one of the faster growing markets, with a total of 1 GW of new capacity in 2013. China is now the largest market in the world for new solar PV, surpassing Germany, although Germany still has the largest cumulative installed capacity, at 38 GW. The Japanese solar PV market grew quickly following the introduction of feed-in tariffs (FiTs) in July 2012. Japan installed 7 GW of solar capacity in 2013 alone (IRENA, 2016a).

I.3 Solar photovoltaic system configurations

Solar PV modules convert solar irradiation into electricity and generate a direct current when sunlight is available. A certain number of PV modules are connected in a series configuration to form strings that are connected in parallel to the DC/AC inverters. Solar PV systems can be divided into four main categories, as follows:

- Grid-connected centralised solar PV power plants – generating electricity which can be fed into the commercial high-voltage electrical grid on a utility scale.
- Grid-connected distributed solar PV systems – generating electricity which normally is fed into the low- and medium-voltage electrical grid to be used by a local customer in the community. This customer could be a single house or an industrial facility.
- Off-grid domestic solar PV systems – generating electricity for houses or small villages which are not connected to the grid.
- Off-grid non-domestic solar PV power plants – providing electricity for large-scale industrial applications, *e.g.*, for industrial and commercial consumers, water pumping facilities, etc.

There are different types of solar PV modules which have their own specific characteristics. Therefore, different types of modules could be suitable for a single given project. The main solar PV module technologies are:

- Solar photovoltaic (PV)
    - Crystalline silicon (c-Si):
    - Monocrystalline cells (mono-Si)
    - Polycrystalline cells (poly-Si or multi-Si)
- Thin film:
    - Amorphous silicon (a-Si) and micromorph silicon (μ-cSi)
    - Copper indium gallium (di)selenide (CIS, CIGS).
    - Cadmium telluride (CdTe)
- Concentrating photovoltaic (CPV).

The major characteristics of solar PV modules technologies are listed in table I-1.

Table I-1: Summary of solar PV technologies

Solar cell type	Material properties	Module efficiency (laboratory)	Module efficiency (market)	Technology readiness
Monocrystalline silicon (mono-Si)	homogeneous crystalline structure	25.6%[1]	15%-22%	industrial production
Polycrystalline silicon (poly-Si)	multi-crystalline structure	21.3%[1]	15%-17.5%	industrial production
Hybrid heterojunction with intrinsic thin layer (HIT) cell	combination of crystalline and amorphous	25.6%[1]	≥19.5%[2]	industrial production
Amorphous silicon (a-Si)	atoms irregularly arranged, thin-film technology	13.6%[1]	5%-8%	industrial production
Micromorph silicon (a-Si/µc-Si)	atoms irregularly arranged, thin-film technology	12.5%[1]	7.5%-10%	industrial production
Gallium arsenide (GaAs)	multi-junction, crystalline	46%[1]	25%	first production lines / no commercial production in 2016
Copper indium gallium (di)selenide (CIGS, CIS)	thin-film, polycrystalline	22.3%	≥13.8%[3]	industrial production
Cadmium telluride (CdTe)	thin-film, polycrystalline	22.1%	≥16.4%[4]	industrial production
Organic cells	thin-film, crystalline	5.4%	n/a	research and development stage, not commercially available
Dye sensitised	thin-film, nano-crystalline	10.4%	n/a	research and development stage, not commercially available

[1] Green *et al.* (2016) [2] Panasonic [3] Solar Frontier [4] First Solar

Source: Fichtner, 2016.

Inverters

Inverters convert DC into AC in order to provide the right output for the utility grid. Normally, inverters are classified into two main types: central inverters and string inverters. When a central inverter is used, a certain number of parallel strings are directly connected to it. With string inverters, one or more series of strings are connected to these. Inverters have the following key functions:

- Converting DC power to AC power, allowing power evacuation to the grid
- Maximum Power Point Tracking (MPPT): to operate the inverter at the best operating point, the maximum power point (MPP) in the current-voltage (I-V) curve depending on solar irradiation
- Galvanic isolation: an internal transformer provides isolation from the grid to meet safety requirements
- Inverters usually have their own monitoring tool with remote Internet access.

A technical assessment also is required to decide on the final solution for the inverters.

Mounting systems

The mounting system fixes the solar PV modules to the ground, giving them the correct tilt angle or the possibility to be installed in a tracking system configuration. The mounting structure may be a "fixed system" or a "tracking system" which follows the path of the sun. As with solar PV modules and inverters, the mounting structure requires a technical assessment in order to select the optimal solution in terms of cost, performance, and installation and maintenance requirements.

Step-up transformers

Depending on the final AC voltage level, a step-up transformer is required to increase the low voltage from the power plant to the required AC voltage level of the grid. Step-up transformers and grid connection interfaces normally have more constraints than the other components due to the specific requirements they need to meet.

Grid connection

The grid connection represents the physical connection between the solar PV power plant and the electricity grid. To fulfil the requirements of the grid, several protection devices as well as meters are required. These normally are installed in a cabinet or in the grid operator building. The connection to the grid normally follows specific codes defined by local or regional authorities.

II. PROJECT DEVELOPMENT PROCESS

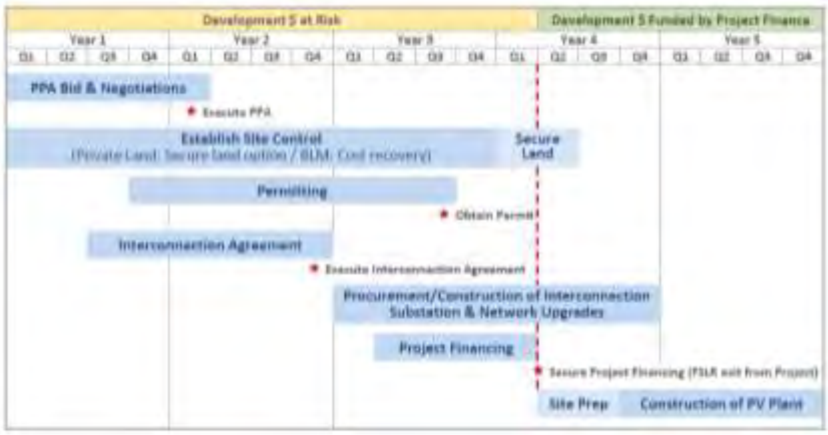
II.1 Project development general criteria

At the start of any project development activity, the project developer should be able to draft a basic business plan and identify funding sources in order to provide sufficient seed capital for the activities of project development (*i.e.*, studies, surveys, reports, employees and visits to various public authorities). In addition, the project developer should reflect on the general criteria to implement a solar PV plant:

- Is the region suitable for solar PV project development (*i.e.*, political and economic stability, large solar resource potential, availability of land with adequate grid connection capacity)?
- How will the project generate revenue, and who are the stakeholders?
- What is the regulatory basis for project implementation?

Figure II-1 shows a typical project development timeline indicating the non-technical milestones up to the construction of the plant and the allocation of the development costs. Depending on the plant size and plant location, the overall timeline of the "Development $ at Risk" phase can be much shorter.

Figure II-1: Typical solar PV project development timeline



Source: Hansen, 2011.

When starting a project, the actions, questions and deliverables of the kick-off of the project should be:

Key actions

- Determination of the general potential for project development and solar PV power plant operation.

Control questions

- Is the basis given for project development in the region/country (*e.g.*, political and economic stability, grid connection, land, regulatory basis)?
- Do you have internal and external resources and enough experience for the development?
- Do you have the required time and money?
- Are you aware of potential land for the solar PV power plant?

Key deliverables

- Business plan with a rough idea of the project (*e.g.*, project size, time schedule, parties involved, expenses).

II.2 Identification

II.2.1 Identification criteria

The first step in the development of a solar PV power plant project is the identification phase. In this phase, potential locations are identified for the installation of the plant in a certain region or country.

Project developers will need to identify different sites and check their availability and suitability against a set of constraints, from the local up to the national level, including sensitive installations (*e.g.,* environmental constraints, archaeological restrictions, military installations, etc.), which includes identifying the best site from both regulatory and socio-economic standpoints. As outlined in this section, the following actions, questions and deliverables should be the focus of this phase:

Key actions

- Identification of a portfolio of potential sites.

Control questions

- Are you aware of the potential restrictions for the pre-selected sites (governmental, environmental and regulatory)?
- Do the sites generally look suitable from a technical point of view (*e.g.*, size, topography, slope, ground conditions)?
- Do you know the land owners and are they willing to lease/sell their land?
- Have you identified all relevant stakeholders for each project opportunity?

Key deliverables

- List of potential project sites including location/co-ordinates, size, contact information of land owner as compiled in the Site Identification Template in Appendix IV.1.

II.2.2 Identification methodology

To assess the suitability of a specific site for a particular industrial or power application, and to compare different potential sites with each other, a comprehensive and transparent set of assessment and selection criteria is required. These criteria are defined at an early stage of site investigations and are used as a guideline for screening of sites, *e.g.*, during site visits. Later on, the criteria are refined and used for detailed assessment, comparison of sites, and finally ranking and site selection.

The result of this step is a shortlist of the technically most favourable projects which qualify for further analysis of the demand and supply situation as well as with regard to financial, economic and legal aspects. After passing these steps in the evaluation, the result later build the project pipeline for subsequent phases, from development through construction and up to operation.

The methodology for identifying suitable sites proceeds under general criteria, such as:

- Governmental guidelines of the specific region or country have to be considered.
- General identification and selection of sites for the implementation of large-scale solar PV power plants should be closely co-ordinated with the regulatory authorities and grid operator.
- Agricultural and former agricultural areas typically are suitable for solar PV power plants as these require substantially less preparation works. Nevertheless, other categories are possible (former industrial land, depolluted land, etc.) provided that no permit restrictions are in place. Unprotected forests also can be considered as potential locations for PV plants, notwithstanding the need of additional work for site preparation.

- Horizontal and level terrain is most suitable for solar PV installations, as uneven terrain is more prone to shading effects. Furthermore, uneven terrain requires more extensive consolidation and structure installation works. The slope profile of the terrain must not exceed 10%, and often a maximum of 6% is specified as an identifier for suitable areas.

In subsequent phases, the depth of detail is increased, and after passing through the screening and assessment steps, a reduced number of sites will be deemed suitable and then selected.

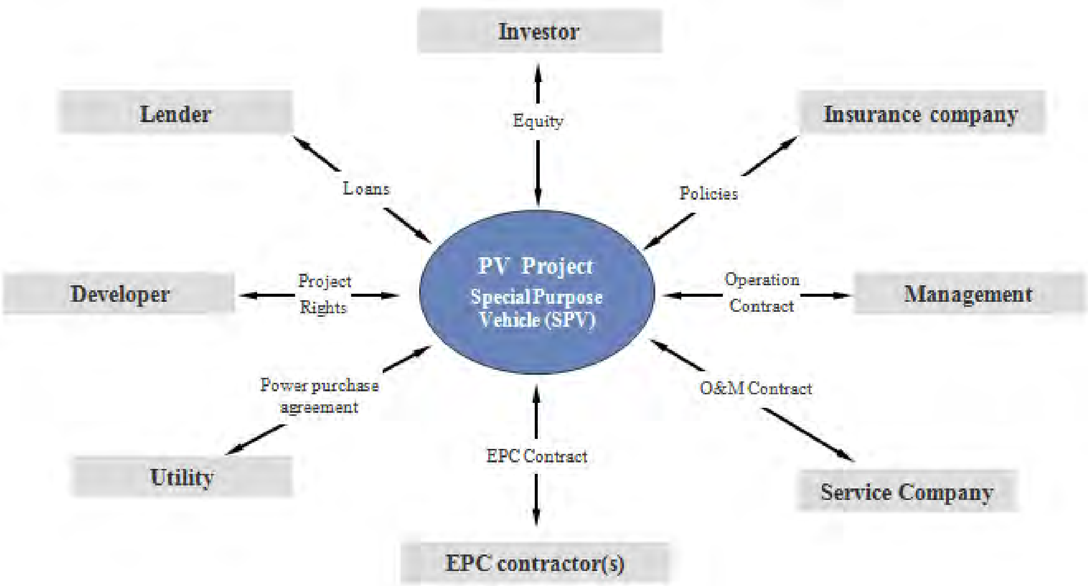
On this basis, useful criteria for identifying potential sites could include:

- government guidelines
- permit restrictions
- land use (former agricultural areas are preferable)
- availability of land
- co-ordination with authorities
- terrain (horizontal and level terrain are preferable).

II.2.3 Key stakeholders in a solar PV project

Project developers must be aware of and have a clear overview of the different key stakeholders involved in a typical solar PV project. The key stakeholders that take part in a large-scale solar PV project under a power purchase agreement (PPA) business model are represented in figure II-2.

Figure II-2: Key actors in a typical utility-scale and project-financed solar PV power plant under a PPA business model



An overview of these entities is shown in table II-1, with a description of the relationships among these parties and the time or phase during which they are involved.

Table II-1: Summary of entities involved in a solar PV project

Entity	Description	Relationship	Involvement
SPV (or project company)	A Special Purpose/Project Vehicle (SPV) is a legal entity that is responsible for undertaking a project. It generally is established as a commercial company with shares owned by the investors. It acts as the owner (or "project owner") of the plant and negotiates all contractual agreements with other stakeholders. In the case of non-recourse financing, its cash flow is the only source of debt repayment.	Owns project	Entire life of the solar PV project Objective: Owns and operates the plant
Project developer	The developer is responsible for the "greenfield" project development of the solar PV power plant or for sizeable solar PV plant portfolios. During project development, it interacts with all actors to ensure a successful outcome. Usually after the start of operation, the developer is not involved anymore in the project. It can be that the developer intends to supply the solar PV modules to the SPV or the project company directly to make a profit equivalent to the margin of the associated project investment cost items. In such a case, the solar PV modules will not be supplied by the construction contractor.	Project rights	From the beginning of the project up to its authorisation Objective: Project development
Investor	The investor normally is a private or public investment firm guided by operational and industry experience with the aim of attaining long-term investment objectives. A portion of the total required funds is provided by the investor.	Equity	Entire life of the solar PV project Objective: Capital investment
Lender	The lender may be a public or private entity and is responsible for the required loan. The latest trends show a typical gearing (ratio between equity and debt portions) of close to 20:80, meaning that 80% of the total investment comes from the lender. Depending on the financial model, usual payback periods (without refinancing) are between 12 and 18 years for a 25-year plant operational lifetime.	Loan	From authorisation up to the end of the loan period Objective: Capital investment
Utility	The utility is the local or national grid operator which owns the substation and the transmission or distribution lines at the point where the solar PV power plant is connected to inject the generated electricity. In countries where transmission and distribution is not under the responsibility of the utility, the transmission and distribution operator(s) also may be involved in this.	Power purchase agreement	Entire life of the project Objective: Purchase of electricity

Entity	Description	Relationship	Involvement
EPC contractor	The engineering, procurement and construction (EPC) contractor is in charge of turnkey implementation of the solar PV project, including mainly engineering, design, procurement, provision of security, installation, testing and commissioning of the solar PV power plant in accordance with the EPC contract. The EPC contractor is the single point-of-contact for any issues related to construction. This contract includes duties of the EPC contractor and charges against the contractor's services (EPC price). This contract allocates construction risk to the EPC contractor, which then interacts with project stakeholders (lenders, offtaker, insurance company, developer, etc.).	EPC contract	From authorisation up to the end of EPC warranties (usually at least two years after provisional acceptance) Objective: Construction of the plant
O&M contractor	The service company (or O&M operator) is the party that takes care of the solar PV power plant during the operation phase formally starting at the end of the warranty period, which ends with the receipt of the Final Acceptance Certificate (FAC). During the period between the Provisional Acceptance and Final Acceptance where both parties are responsible for smooth operation and immediate rectification of any plant malfunction, the O&M operator interacts closely with the EPC contractor. In some cases, the EPC contractor also plays the role of the O&M operator.	O&M contract	From provisional acceptance up to the end of operation Objective: Operation of the plant
Manager	The manager is responsible, on behalf of the investor and/or the project company, for handling all stages of project development as well as for the construction and, at times, also the operation phases. The manager interacts with all other actors that are involved in the project. Usually, the manager comes from the developer side and thus will be very familiar with the history of the project; the manager also exchanges information and agreements with other parties.	Management contract	From provisional acceptance up to the end of operation Objective: Management of the plant
Insurance company	Insurance companies take care of the policies for the solar PV power plant during both the construction and the operation phases with regard to any events, such as damage or theft of equipment, which might occur during the asset life cycle.	Insurance policies	From start of construction up to the end of operation Objective: Provision of policies

Other regional stakeholders could come from the area directly surrounding the project site. Although their direct involvement may not be required for project implementation, their contribution could be beneficial, for example to avoid a bad atmosphere or opposition to the project. Possible stakeholders are:

- Local forms of government (city, council, assemblies, etc.)
- Local skilled and unskilled workers
- Local companies
- Farmers, herders
- Neighbours, residents

Their involvement also can be related to different local services, such as the supply of:

- food and water for the workers
- labour for civil, electrical, mechanical work
- labour for operation and maintenance (O&M) of the plant
- security during construction and plant operation.

II.2.4 Third-party engagement

The objective in engaging a third-party advisor is to rapidly acquire and apply knowledge and experience in a specialised area (*e.g.*, environmental impact assessment (EIA), technical review, due diligence, etc.) in order to bridge the skill gap or accelerate the implementation of an activity during a given project development phase. The project developer should define in advance what scope of work the advisor will engage in, initiate a robust selection process and negotiate adequate contractual terms before kicking off the mission.

It is helpful that the project developer gain knowledge of how consultancies have tackled similar projects in the past and how they have added value. This can be achieved through direct contact or by sending a request for information to a selection of firms. In order to select an adequate advisor, the project developer should develop clear guidelines for bid submission and draft a request for proposals (RFP) that should include a detailed approach for the project, the proposed scope of work, the estimated budget, a draft project plan with transparent milestones, and preliminary terms and conditions. For this selection process, the project developer also can rely on existing guidelines for project procurement established by several international financing institutions (*see*, for example, EIB, 2011; ADB, 2013; KfW, 2013).

Example of activities potentially supported by third parties:

During the development of a given project, areas where third-party advice could add value include:

Yield studies

- Financing parties will rely on the final yield simulation results provided by a technical advisor. The advisor will use the data and preliminary yield analysis from the developer as a starting point but will perform its own independent solar resource and yield studies with different P-cases (probability cases).

Environmental and social impact assessment (ESIA)

- Should project development be subject to an international financing application, an experienced international environmental advisor can be part of the project development team and provide extensive expertise regarding international environmental guidelines. Besides checking relevant environmental legislation, the advisor can check the applicability of a specific EIA law or decree that would have to be considered in close conjunction with the environmental legislation.

- The contribution and support of an environmental advisor can be helpful for EIA scoping. The EIA scoping document generally consists of a technical project description, a detailed description of the project location, an initial assessment of potential impacts, a description of applicable mitigation and monitoring measures together with a suggestion for the scope of work for the subsequent EIA. It also features the participation and announcement process for people affected by the project, relevant non-governmental organisations (NGOs) and other authorities on a national, regional or local level.
- The requirement for site-specific EIA screening can be reviewed by an experienced environmental advisor.
- Support by an experienced and certified national environmental advisor will be of advantage when attending official authority meetings and by providing a second opinion with respect to environmental conditions imposed on the ESIA by the competent authority for the further project implementation process.
- In addition to co-ordination with the relevant authorities, provision of legal assistance is suggested, especially if the applicable environmental legislation is only available in the official local language.
- In some cases, the EIA has to be undertaken by a registered and certified environmental advisor, and there also may be a requirement that specific studies have to be prepared by specialised advisors, *e.g.*, archaeological studies or a noise assessment.
- In specific cases, the project approval process and the studies carried out for the EIA may require a statement of compliance with the Equator Principles or an environmental due diligence audit, both of which are to be prepared by an independent advisor. It is recommended that project developers familiarise themselves with the requirements to provide pertinent and reliable documentation that enables the environmental advisor to prepare the compliance statement or undertake the due diligence review without interruption or delay.

Contracts

- Technical and legal advisors can review contract drafts to support negotiations with contractors to maintain the general viability for the project.
- A technical advisor can support the project developer during contract negotiation to verify that the amount of the bonds covers the related liquidated damages.
- An insurance advisor can confirm the project-specific insurance requirements before financial close.
- Acceptance is carried out in two stages: provisional acceptance and final acceptance. Both are defined in the EPC contract, including the related technical requirements, testing equipment and measurement methods, and should be carried out under the supervision of an independent technical advisor. Successful acceptance needs to be documented by respective certificates (the Provisional Acceptance Certificate, PAC, and the Final Acceptance Certificate, FAC).

Project risk analysis and mitigation

- A advisor can be engaged to produce a detailed risk assessment analysis that will be part of the final project documentation. Typical analyses include general political risks, financial risks and regulatory/ legal framework risks.

Technical due diligence

- Before financial close, independent advisors shall prepare legal and technical due diligence reviews.

II.3 Screening

II.3.1 Screening criteria

In the second phase, all potential sites selected during the identification phase will be broadly examined with the objective of discarding options which are unlikely to be successful due to practical limitations. For this phase, the project developer can use the Site Screening Template available in Appendix IV.2.

As outlined in this section, the following actions, questions and deliverables should be the focus of this phase:

Key actions

- Screening of the identified sites in more detail.

Control questions

- Did you identify potential "showstoppers" and do they need to be resolved or do you have enough alternative sites in the portfolio?

Key deliverables

- Site Screening Template completed for each site (see Appendix IV.2).

II.3.2 Potential showstoppers

There are certain situations, known as "showstoppers", that can lead to a stop in the development of a project once they are identified. These can happen throughout the entire development process, including the early stages. Potential showstoppers include the following:

- The land owner changes his or her mind and is no longer willing to sign an agreement for the land that was pre-selected for the solar PV project.
- The land which was initially identified turns out to be unsuitable for the selected technology or planned capacity (*e.g.*, due to site complexity, slope, soil conditions, access to the site, etc.).
- The land initially identified has new large "exclusion areas" that the developer was not aware of at the beginning of the project. This can include archaeological discoveries, protected species on the site, protected areas in the vicinity, or other developments such as residential houses, streets or airports, from which a minimum distance is prescribed.
- The local authority does not approve the site for "industrial use" when it was classified previously as agriculture land.
- The geotechnical desk study shows that the site is located within a flood-prone area with periodical flooding.
- The cost of grid connection is prohibitive due to lack of planning (*e.g.*, the need to cross streets, rivers or other obstacles, and/or long lead times for relevant permits), or lack of available capacity at the nearest substation (the cost of a new build and/or extending an existing substation could be high).
- The government changes the regulatory framework (*e.g.*, lowering the feed-in tariff, new application requirements such as for expensive bank guarantees, tax, self-consumption).
- Unforeseen political instability in the region/country.

II.4 Assessment

II.4.1 Assessment criteria

In the third step, the assessment phase, the various areas or sites are compared and evaluated under technical and socio-environmental aspects. The outcome will be as objective as possible. One matrix is used for technical site assessment and one matrix for socio-environmental impact.

Accordingly, all sites identified and selected under the preceding criteria will be assessed by applying the appropriate tools which are provided, among other places, in the Appendix section.

The site assessment focuses on technical assessment and does not consider economic or financial aspects, which would be assessed separately.

Technical and socio-environmental evaluation criteria can be defined for each site and weighted differently as shown in Appendix IV.3. The criteria can be graded from 0 to 4 with 4 being the most suitable result.

Based on the region and specific location, the criteria, weight and points can be adjusted to properly reflect local conditions. As outlined in this section, the following actions, questions and deliverables should be the focus of this phase:

Key actions

- Assessment, comparison and ranking of the screened project sites based on different evaluation criteria.

Control questions

- Does the site pass the technical criteria?
- Does the site pass the socio-environmental criteria?
- Do you have all the information required for the evaluation of the sites? If not, how can you obtain it?
- Do you have preferred sites due to personal/private reasons and is the ranking independent of these?

Key deliverables

- Matrix of technical and socio-environmental site assessment for each site (Table IV-1 and Table IV-5 in Appendix IV.3).
- Updated list of project sites and ranking of projects (see Appendix) considering the results of the technical and socio-environmental screening.

II.4.2 Solar resource assessment

Reliable solar resource data are the basis for the development of solar PV power plants. The irradiation reaching the earth's surface can normally be described by the global horizontal irradiation (GHI), which accounts for the total irradiation impinging on a horizontal plane. The GHI is the sum of direct normal irradiation (DNI) and diffuse horizontal irradiation (DHI).

These two last parameters depend on the geographical characteristics of the site of interest and on other meteorological conditions. For example, on a cloudy day, most of the solar irradiation impinging on a horizontal surface will be DHI.

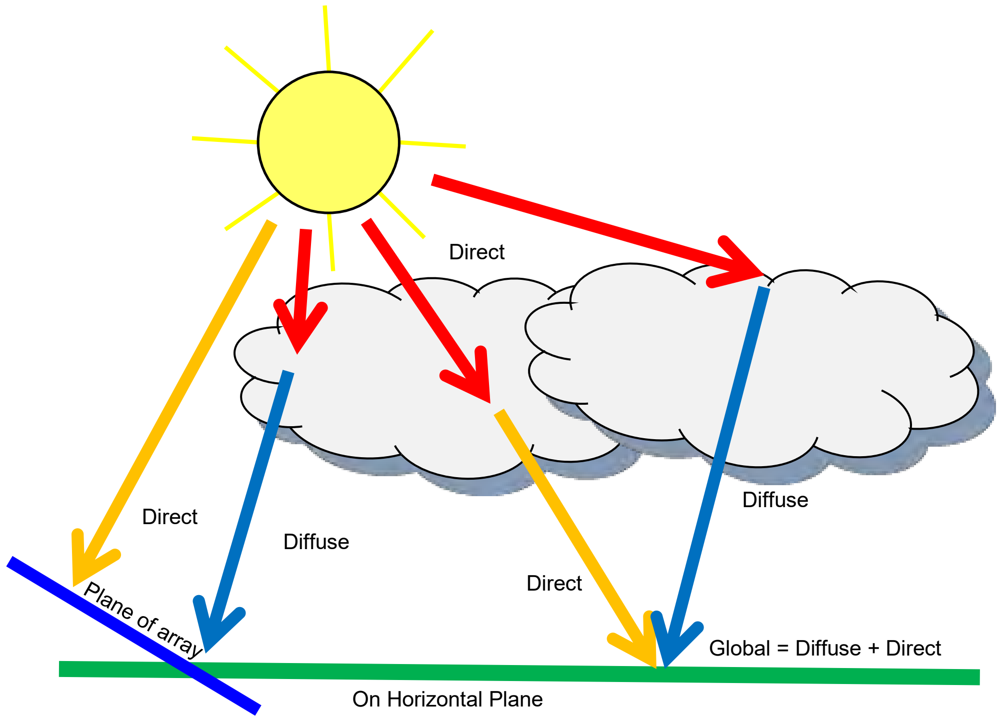
GHI is the parameter of interest when assessing the solar resource of a potential location for the implementation of a solar PV power plant.

Plane of array (POA) irradiation represents the total amount of solar energy available to a tilted module array, based on the location of the array and the direction of the modules. POA irradiation is calculated at the module level and averaged across modules to generate system-level values.

POA irradiation typically is computed from GHI values when simulating a solar PV power plant in preliminary stages as well as measured and used for performance verification and testing in operating a solar PV power plant.

The relationship between direct, diffuse and global horizontal irradiation as well as the POA irradiation is shown in figure II-3.

Figure II-3: Irradiation characteristics



Irradiation is measured in kWh/m² and values are often given for a period of a day, a month or a year.

The long-term average annual GHI is of most interest to solar PV project developers as they indicate the expected future solar irradiation at a site. Average monthly values are important when assessing the proportion of energy generated in each month and the distribution over one year.

With regard to the solar resource assessment, several tools and data available on the Internet can be applied in a first step. The following sources are free of cost and give an impression of the solar irradiation at site level:

- IRENA Global Atlas for Renewable Energy (http://globalatlas.irena.org/)
- US National Aeronautics and Space Administration (NASA) solar database (https://eosweb.larc.nasa.gov/sse/)
- Solar PVGIS: Photovoltaic Geographical Information System for Africa, Asia and Europe (http://re.jrc.ec.europa.eu/pvgis/)
- Solar Atlas published by several countries.

The level of detail and availability of datasets may vary depending on the location of the project. The datasets should be used mostly for assessing the suitability of the site.

II.4.2.1.1 Meteorological data providers

As a general approach, the solar resource at a specific site can be evaluated through different types and sources of data, listed as follows together with their main features:

- Data from national meteorological stations or institutes
- Interpolation of data due to different project location, long-term data
- Programmes available with worldwide databases like Meteonorm (possibly with high uncertainties, depending on the region; sometimes correlated with satellite data)
- Can be applied for energy yield simulations (yield study).

II.4.2.1.2 Satellite data

Satellite data have the following advantages:

- Exact project location (co-ordinates); 10 years-plus of data available, making it suitable for assessing long-term averages
- No maintenance and calibration required
- Accuracy of high-quality data depends on the location and in most cases is in the range of ±4-8%
- Can be applied for energy yield simulations (yield study).

Different sources of varying quality, for example:

- SolarGIS (http://solargis.info/)
- Vaisala 3TIER (http://www.vaisala.com/en/Pages/default.aspx)
- Meteocontrol (http://www.meteocontrol.com/en/)
- NASA (https://eosweb.larc.nasa.gov/sse/)
- Solar PVGIS (http://re.jrc.ec.europa.eu/pvgis/).

Note that with the tool Solar PVGIS (free of cost) it also is possible to determine the solar irradiation at the inclined module surface, in addition to the GHI.

II.4.2.1.3 Map-based analysis using IRENA Global Atlas

IRENA's Global Atlas for Renewable Energy is a collaborative, Internet-based geographic information system (GIS) relevant for solar GHI resource and can support decision making during the assessment phase, especially in areas where existing information is insufficient. Featuring data from a consortium of 67 countries and 50 data providers, the Global Atlas is the world's largest collection of the most recent and most accurate public maps of renewable energy resources.

Figure II-4: Example of map-based solar PV regional analysis using IRENA Global Atlas

Source: IRENA, 2016b.

The Global Atlas supports project developers in the assessment phase with map-based analyses. Maps are particularly well suited to complete high-level evaluations of projects, and help project developers understand the potential resource impacts in their projects.

The Global Atlas, despite its high resolution, remains sensitive to the selection and ranges of input data. The maps provide a valid overview at the continental and regional levels but may not be relevant in local contexts. The primary reason is that as the area under study decreases in size there should be an accompanying increase in detail, including more information about local conditions.

The value proposition of the Global Atlas is therefore not to deliver a final map or assessment but instead to introduce a consistent and replicable methodology for evaluating renewable energy potential using a peer-reviewed opportunity-based approach, which is a more detailed option in contrast with more common exclusion-based approaches. This new approach can generate maps that can be used to identify ideal sites for projects and to initiate a dialogue with regional and local entities and communities.

II.4.2.1.4 On-site ground measurement

The combination of satellite data with a campaign of on-site ground measurement provides the following benefits:

- High accuracy with high-quality equipment possible if well maintained
- Well-maintained sensors can measure the solar resource with an accuracy of ±3-5%
- Usually for performance control during operation (performance ratio).

Sensor technologies with differing accuracy are available, with two main technology classes:

- Pyranometers – high precision can be achieved with regular cleaning and recalibration

- Silicon sensors (solar PV cells) – cheaper than pyranometers but their scope is limited by the spectral sensitivity of the cell.

II.4.3 Site technical assessment

When performing a site visit of a potential site for project development it is useful to have an overview of the points that need to be reviewed and assessed during the inspection. A template is attached in Appendix IV.3 with the complete set of items to be taken into consideration for assessing the site suitability for a solar PV power plant. Appendix IV.3 provides a table with the following technical evaluation criteria:

- Meteorology:
  - solar resource on annual basis
  - annual mean ambient temperature and maximum temperature
  - annual mean wind speed and maximum wind speed
  - extreme conditions, *e.g.*, storms, advanced soiling, hailing, severe salinity
- Land characteristics:
  - land cover
  - land use
  - geotechnics
  - external shading
  - slope and topography
  - profile
  - area of available plot
  - potential seismic and flooding risks
- Infrastructure:
  - availability of substation
  - distance to grid/substation
  - road available to access site
  - water intake
  - distance from closest port
  - availability of telecommunications.

These criteria are weighted differently from 0 to 4 with 4 being the best result. The awarded grades are multiplied by the weighting, with a maximum value of 400 achievable.

The acceptable minimum is 200; the higher the score, the fewer impacts are anticipated from solar PV power plant construction and operation on the site.

Land characteristics

The typical approach to land considerations is to acquire or lease the specific area of land that will be used for the project. The objective of the developer should be to identify a land area that has the minimal conflict of use in order to reduce the risk of rejection of the building permit.

In the case that the land required for the project is subject to certain land-use restrictions, it often is required to obtain an authorisation from local regulatory authorities to change the type of use of the land. Evaluation of the future land use of the area also must be taken into account, assuming that the plant will be in operation for at least 20 years.

Agricultural activities on a neighbouring site, ongoing construction works or industry can lead to dust generation that could implicate additional cleaning requirements of the solar PV modules. For projects in dry areas such as desert regions or savannah, the higher soiling losses in general have to be carefully assessed.

Locations in environmentally sensitive areas should be critically studied due to the potential issues related to the permitting process as well as high associated costs of environmental remediations. In addition, a certificate of non-objection from the military is needed when the land is located within or near a sensitive area.

The topographical configuration of the selected land has a direct effect on the design of the plant. It will affect civil work and mounting structure designs. In general, mounting structures are flexible, and design and installation can be done for almost any kind of terrain. If a particular mounting structure is needed due to the special land conditions (*e.g.*, complex, uneven), the additional cost of the new design and installation must be compared with the land cost. It is recommended selecting pre-designed and tested types of mounting structures from experienced suppliers. The trade-off between a specific land configuration and the required civil work adaptation and mounting structure design therefore should be assessed during this phase.

Table II-2 indicates different site characteristics that have to be assessed.

Table II-2: Different site characteristics

Characteristic	Technical category
Slopes	<10% preferred
Depressions	Limited, or backfill may be required
Hills and washes	Limited, assessment of flash flood risk may be required
Homogeneity/complexity	Trackers require plane areas (sometime with slope <1°)
Soil type and depths	No rocky or sandy soil preferred
Groundwater level	Should not be within the depth of the foundations

A complex terrain can have a high impact on required earthworks for site levelling and foundation works which would need to be considered in the construction schedule.

Geotechnical desk study

To improve knowledge of the geological conditions of the project area, a desk study should be prepared by an expert. This should include a review of available relevant data for the proposed area, including the immediate surrounding area. Reference should be made to all available sources, including:

- published maps and charts
- geological survey maps, reports and borehole data
- meteorological office data
- aerial and satellite photos and surveys
- government mine and geology departments
- geography/geology departments at local universities
- other sources such as local libraries, local stakeholders/geologists, Internet, etc.

The desk study report should include an appraisal of the geological nature of the area and potential risks for project development, *e.g.*, events of heavy rain, flooding, seismic activity and landslides.

In general, the geotechnical surveys of a project site can be split into the following phases as further described in the pre-development section:

- desk study (screening phase during the early development stage)
- preliminary geotechnical site investigation (development phase)
- detailed geotechnical site investigation (detailed design, after financial close).

Slope and orientation

The slope is a key factor for the technical site selection since it defines a physical limit to the ramming machines constructing the mounting structures. For the technical limit, the orientation of the slope does not matter. A slope in direction to the sun is preferred and can be used to optimise the spacing between module rows (in the northern hemisphere this would mean a slope in a southern direction).

For solar PV plants, the slope and orientation can be categorised into ranges as shown in table II-3.

Table II-3: Slope and orientation classified by technical suitability

Slope	Orientation	Technical category
below 7%	<4°	technical standard
8%-10%	4.5°-6°	advised technical limit
11%-35%	6°-19°	above advised limit
35%-50%	19°-27°	extreme technical conditions
above 50%	>27°	off technical limits

Source: Fichtner, 2014.

Infrastructure

Depending on the project location, the distance to the grid or the next substation varies. Only in exceptional cases (for example, very large plant capacity, very high solar irradiation or no land cost) the distance to the grid should be more than some kilometres (approximately 1-4 km). Note that easement rights usually are required for the land between the project site and the grid. The site should be accessible for heavy trucks, and a port for the shipment of components should be at a reasonable distance.

II.4.4 Energy yield estimation

It is possible to estimate the predicted yield using high-level solar resource data and the typical performance ratio for similar plants in order to discuss with potential partners and start subsequent activities with a *pro forma* evaluation of yield and generation figures.

Another rough yield prediction can be done by applying to the given GHI a certain increase in irradiation to estimate the irradiation in the module plane and assuming a value for the plant performance ratio (PR) (*e.g.*, 78% in a moderate climate).

II.4.5 Environmental and social impact assessment

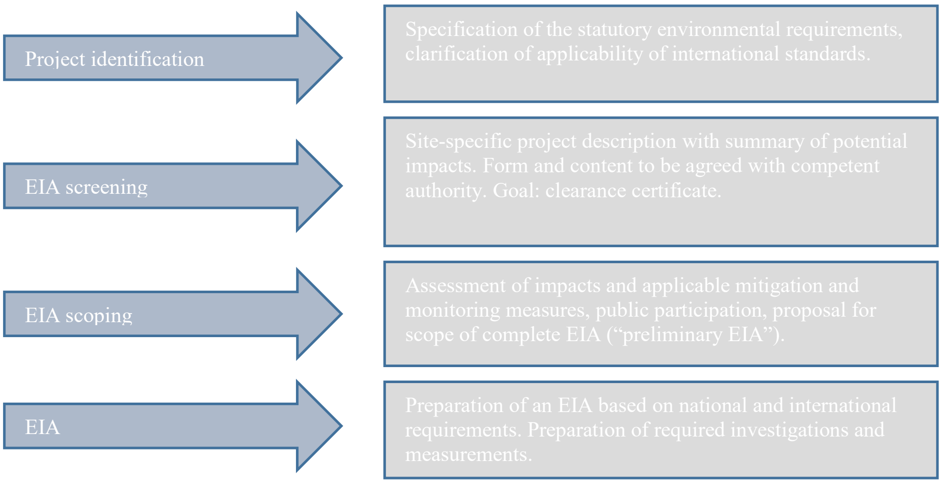
In addition to the technical suitability of the different sites, environmental and social issues should be considered. One goal during the construction of solar PV power plants is to have minimal impact on the natural, physical and human environment. Therefore, some aspects have to be considered in order to detect "red flag" issues that could put project implementation at risk or require stringent mitigation measures. Not only should environmental impacts at the site be investigated, but also impacts due to grid connection and transportation. Environmental and social criteria and potential restrictions comprise the following points to be considered in the assessment stage:

- Natural
    - flora/fauna habitats
    - protected areas and species
- Physical
    - geology and soil conditions
    - surface and groundwater
- Social
    - residents living on site
    - residential housing nearby
    - current land use
    - neighbouring land use
    - recreation areas nearby
    - indigenous people
    - cultural, religious and archaeological heritage
    - visual character of landscape
- Additional infrastructure works:
    - impacts from site access works
    - impacts through grid connection.

The development of a solar PV project requires the consideration of environmental aspects in each project step and during the entire project life cycle. A pending or outstanding environmental permit or, as a worst-case scenario, a rejected permit application could lead to a complete project stop.

The steps, tasks and activities outlined in figure II-5 are recommended according to the frequently applicable environmental legislation and/or international environmental guidelines with regard to the EIA.

Figure II-5: Different tasks of an EIA process



Project identification

The suitability of a proposed project area must be assessed at an early project development stage with respect to environmental constraints and requirements specific to a particular location. It may be the case that environmental site conditions are such that:

- they generally do not allow project development because of environmental restrictions, such as the presence of a natural park
- they are of an ecologically sensitive nature, allowing project approval but resulting in:
  - a large number of expensive mitigation measures, or
  - extensive compensation measures with a possibly negative impact on economic feasibility due to land acquisition for compensation measures and the costs of their implementation.

During the project identification phase, *i.e.*, the early development stage, the specific statutory environmental requirements should be verified together with the specific conditions required to obtain the necessary environmental construction and operation permit.

It is recommended that consultations on the environmental approval process be undertaken in close co-operation with the competent environmental authority on a national or even regional or local level. Comparable projects undertaken in the past have shown that close co-operation with relevant agencies is important.

II.4.5.1 *Socio-environmental assessment*

In parallel to the technical assessment and the technical evaluation criteria, the socio-environmental aspects also need to be considered and assessed.

The evaluation of potential impacts that might arise from implementing a solar PV power plant project can be based on a five-scale approach:

Scale 1 – negligible impact

- No or only negligible impacts are expected for the physical, biological and human environment under consideration of mitigation and compensation measures.

Scale 2 – low impact

- Impacts will or may occur that are regarded as "low" because, due to their intensity, duration or magnitude, they are regarded as worth mentioning but not significant; usually no measures have to be applied to mitigate or compensate most of these negative effects.

Scale 3 – medium impact

- Impacts will or may occur that are regarded as "medium" because, due to their intensity, duration or magnitude, they are regarded as significant; however, mitigation or compensation measures can be applied for most of these negative effects to reduce them to a scale 1 or scale 2 level, *e.g.*, resettlement of a few people within an existing settlement, etc.

Scale 4 – high impact

- Serious and lasting impacts are expected which significantly impair the present situation in the project area and which can be neither fully mitigated nor fully compensated, *e.g.*, resettlement of people to a distant location, loss of cultural heritage, decimation of endemic species or valuable habitats, etc.

Scale 5 – very high impact

- Large-scale and lasting impacts are expected which significantly impair the present situation in the project area and which can be neither mitigated nor compensated, *e.g.*, resettlement of a village, loss of their way of life, loss of cultural heritage, extinction of endemic species or loss of valuable habitats, etc.

Table IV-5 in the Appendix provides an environmental and social evaluation matrix. It shows the different impacts on the natural, physical and human environment and the additional works required.

II.4.5.2 Environmental impact assessment screening

Environmental impact assessment screening determines if an EIA is needed for the project, depending on national legislative requirements and/or considering international or bank-specific environmental guidelines.

The screening process consists mainly of a site-specific technical project description, a description of the chosen location and a summary of site-specific impacts during construction and operation of the solar PV power plant.

The form and content of the screening document has to be discussed with the competent authority in advance to adapt it to potential country-specific requirements.

The screening process, in some country-specific cases described as a "Basic Assessment", should enable the competent authority to verify if:

- the project is generally compliant with national environmental legislation
- the environmental site conditions possibly may not allow granting of an environmental permit
- the further project application process will require site-specific specialised studies together with the environmental permit application or the EIA study.

Specialised studies on environmental aspects could be:

- fauna and flora investigations in general or with respect to endangered or protected species
- baseline noise measurements for a subsequent noise assessment
- groundwater quality analysis, etc.

The EIA screening process is finalised by 1) receipt of an environmental clearance certificate by the competent authority confirming that the project is not subject to an EIA, or 2) by a request for an EIA, in which case this will occur most likely together with initial recommendations for the content of the ensuing environmental scoping process.

However, the project developer must consider the need for an environmental permit application document even if an EIA is not officially required, and the need for mitigation measures to be implemented before or during the construction phase. It is not unlikely that an issued environmental permit will be limited to the construction phase and that a permit application for the operation phase must be developed separately. This process should be discussed with the competent authority during the project identification phase or, at the latest, during the EIA screening process. Should an EIA study be required, it is likely that an additional phase – the scoping phase – will be needed during the pre-development phase.

II.4.6 Assessment example

In order to enable a clear and better comprehension of all steps to be followed during this phase, a potential site with all assessments is shown in the following to provide an example of a real application of all of the above-mentioned criteria. It may offer a helpful guideline for developing a solar PV power plant.

II.4.6.1 Systems and configuration assessment

Solar PV module technology

To evaluate the solar PV energy potential of the selected site, based on the analysis of the solar resource set out in the previous section, the following solar PV module technologies can be selected for a simulation with the software PVsyst:

- Monocrystalline silicon (mono-Si)
- Polycrystalline silicon (poly-Si)
- Cadmium telluride (CdTe).

Mounting system

Two types of mounting systems have been compared in this analysis:

- Fixed mounting system
- Single-axis (E-W) tracking system

The application of tracking alternatives depends highly on the latitude of the planned solar PV power plant. Double-axis tracking is employed more often in latitudes between 30° and 60° (*e.g.*, North Africa – Northern Europe). Between these, the angular variation is greater throughout the year, hence the need for continuous adjustment of the solar PV arrays' inclination to the sun, as well as greater adjustment to track the sun's path through the sky.

In case of single-axis tracking, for latitudes above 60°, there is less variation in solar altitude during the year. This means that the sun remains at lower apparent angles. That is why the use of a constant inclination combined with azimuth tracking to follow the sun's daily path is a more suitable option than double-axis tracking.

At latitudes closer to the equator, which is this case in this example, the sun remains relatively "high" in the sky. In these cases, the use of a horizontal tracker normally is more suitable, and double-axis tracking will not be considered in this study.

II.4.6.2 Geographical location

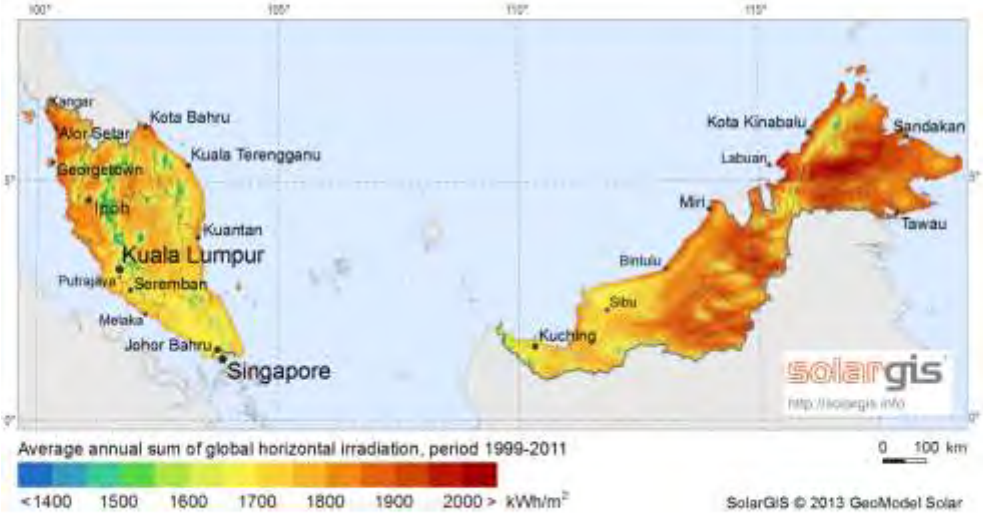
The site is located about 80 km south of Kuala Lumpur in Malaysia, some 25 km away from Malacca City, the capital of the Malaysian state of Malacca, situated on the coast. The geographical co-ordinates are available.

II.4.6.3 Meteorological data

The solar irradiation at the site is one of the highest among the proposed sites, reaching an annual mean irradiation of 1 814 kWh/m². In this sense, the site is one of the most attractive and suitable sites for the generation of PV energy.

Figure II-6 presents the solar resource in terms of the average annual sum of GHI for the period 1999-2011 in kWh/m². Each colour on the GHI map indicates a different level of GHI across the country, ranging between 1 400 and 2 000 kWh/m² per year.

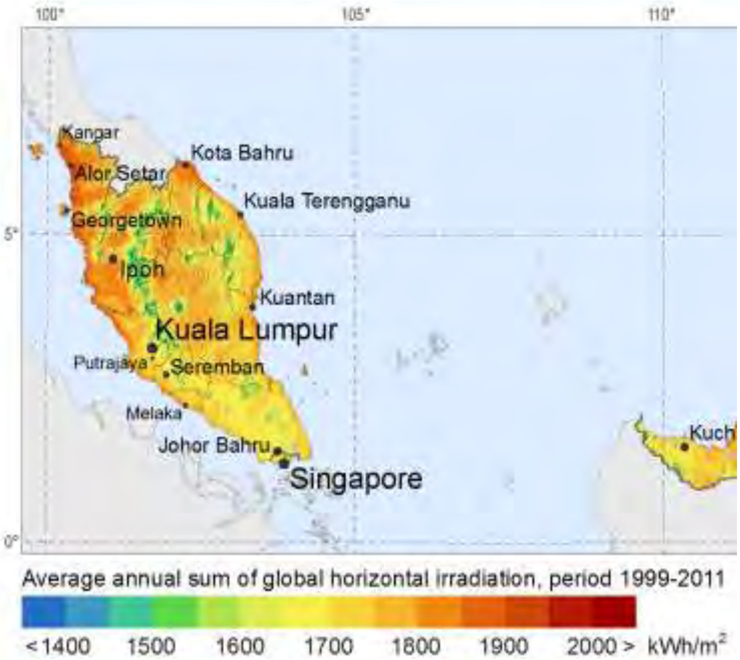
Figure II-6: Solar resource in Malaysia



Source: SolarGIS, 2014.

Since the focus of this study is on West Malaysia (Peninsular Malaysia), the annual GHI map of this region can be seen in more detail in figure II-7, which illustrates GHI levels in the range of 1 600-1 850 kWh/m^2 per year.

Figure II-7: Solar resource in Peninsular Malaysia

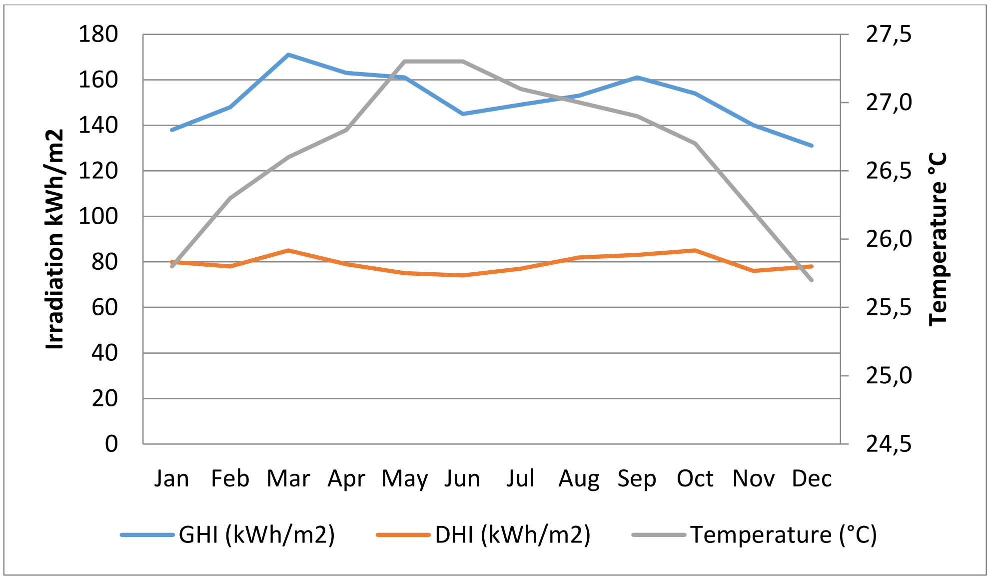


Source: SolarGIS, 2014.

II.4.6.4 Solar resource assessment

The irradiation and other relevant meteorological conditions are evaluated for the selected site in detail. The acquired data are presented in the following sections. Figure II-8 presents the monthly values of GHI, DHI and ambient temperature from the SolarGIS database.

Figure II-8: Monthly trend of GHI, DHI and ambient temperature for site



Source: SolarGIS, 2014.

Ambient temperature

The annual mean ambient temperature is 26.6 °C, among the highest of the proposed sites and therefore not very suitable compared with other sites.

Extreme/special climatic conditions

The site is directly on the coast, with the west side of the site located on the waterfront. Coastal zones have a considerable corrosion effect on metallic parts in the long term because of the high ambient salinity from seawater. The corrosion effect is enhanced by high temperatures. In this sense, the site has a considerable risk of corrosion of metallic parts of the solar PV power plant in the long term.

Wind speed

High wind speeds mitigate the decreasing effect of high temperature on module performance. The annual mean wind speed of the site is 2.25 m/s, one of the highest wind speeds in this area.

II.4.6.5 Site characteristics

General situation and surroundings

The proposed area is adjacent to a power plant. With a total available area of approximately 103 hectares, the site offers a PV capacity of around 55-122 MW.

Internally, the site presents some water channels, which should be duly considered in the further steps of project development.

A religious temple also is present towards the centre of the area, and a water reservoir is present on a hill in the south-east, which should be taken into account during the further development steps.

In the surroundings there are plots similar to the considered one, as well as some small settlements and a combined-cycle power plant.

Figure II-9: Site southern and northern view

Credits: Fichtner, 2014.

Topography and soil conditions

The site has some hills (maximum height around 60 m) between the centre of the plot and the sea. The remaining part is generally flat or with slight slopes.

Further soil investigations are required to establish the most suitable foundations (generally micropiles, vibro-embedded poles, screw or cement foundations) to be used for each kind of soil and the possibility of some ground movement.

The required works and resulting costs depend on the necessary rock and soil works. These may include light to heavy excavation works, crushing of excavated rocks and back-filling by suitable soils obtained from sources situated near the site.

Land use and land cover

The site is located in an irregularly used area, partly free from vegetation, partly used for grass cultivation and partly former palm oil production. At the northern and western borders of the area there are also residential areas.

The soil on the site varies according to actual land use. Some parts were free of vegetation and partly rocky, some parts were grass cultivated, and the former plantation presents old palm trees apparently not used by any company and spontaneous vegetation on the soil.

Flooding potential

The area may be mostly dry, but some watercourses and presence of water can be found close to the eastern border. The site also is close to the mouth of an important river, presenting a potential flooding risk. The flooding risk should be further investigated by an in-depth hydrological study to properly define the flooding risk for the area and measures to be taken to avoid it.

II.4.6.6 Site infrastructure

Electrical grid

An electrical substation is present nearby. According to the substation signs, this is operated at 275/132 kilovolts (kV) and is basically suitable for the connection of capacities of around 100 MW. Further investigation is suggested to verify the overall capacity of both the substation and high-voltage line as input to a grid study for estimating the maximum connectable power at this point and the possible works required for the task.

Site access and transport infrastructure

There is direct road access to the site, as the site is crossed by several main roads. The general transport accessibility of the site can be considered acceptable. The nearest seaport is only 12 km away and the nearest airport around 56 km away, allowing rapid transport to the site for international deliveries.

Since a power plant is next to the site, the availability of telecommunication infrastructure, such as landline telephone, is assumed.

Water supply

No detailed investigation has been performed to date regarding the availability of water at the site or the relevant quality and composition. Nevertheless, due to the presence of a power station and small villages in the surroundings, it is assumed that water supply for the proposed project will not be an issue. The selection of a water source, quantity requirement and storage requirement at the site will be finalised during subsequent project stages.

II.4.6.7 Yield assessment methodology

For evaluation of the specific energy potential (kWh of energy produced per nominal installed kWp (*i.e.*, kWh/kWp) and produced energy of various solar PV technologies and different mounting configurations of equivalent installed power, several simulations with PVsyst software have been performed to model the system behaviour of a solar PV power plant based on climatological data of the site under consideration.

As explained previously, three different PV systems have been considered for this study, as follows:

- fixed mounting system with poly-Si technology
- fixed mounting system with thin-film (CdTe) technology
- single-axis tracking system with poly-Si technology.

Estimation of solar power generation is done in several steps:

1) In a first step, the solar climatic conditions, mainly the GHI and the DHI, are determined from the SolarGIS database. The global irradiation is the integrated electromagnetic radiated power from the sun over a specified time interval on a horizontal surface (unit: kWh/m²/year). Ambient temperature also is taken into consideration in the simulations.

2) GHI and DHI data are used to calculate the irradiation in the tilted plane of the PV array (POA) of the fixed or tracked system by means of the Perez transposition model.

3) With a tentative layout of the solar PV power plant (dimensions and geometrical arrangement of the modules), the irradiation losses due to optical effects (*e.g.*, deviations from the sun's perpendicularity with the modules' arrays) and thus the usable irradiation can be calculated.

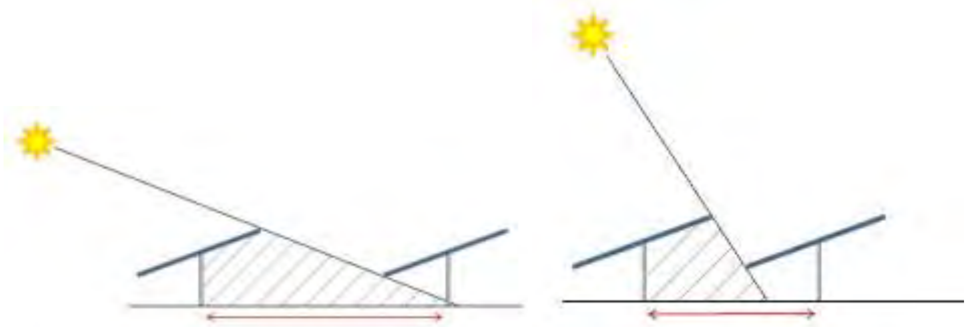
4) The electrical simulation takes into account the properties of the solar PV modules and the inverters as well as losses in the electrical cabling to calculate the energy available at the low-voltage/medium-voltage transformer.

The yield potential of various technologies and different mounting alternatives has been determined at the considered site using the following assumptions:

- The same installed power was used for each mounting alternative by considering blocks of 10 MW (AC) in each simulation performed.
- A tilt angle of 10° and a limit shading angle of 22.4° were set for all fixed installations (tilt angles lower than 10° may lead to additional module soiling, and the yield differences for module tilts between, *e.g.*, 7° and 10° are not significant).
- The parameters of single-axis trackers were defined based on experience and on single-axis tracking systems used in the industry.
- The horizon or interference by high elevations of each site was accounted for and, if applicable, was imported to PVsyst from the Meteonorm software. Therefore, far shading effects were considered in the simulations.
- The losses caused internally by the solar PV module rows (self-shading) have been set to a constant value of approximately 1% shading losses (with the exception of single-axis tracking that uses backtracking), which is within the standard for well-designed solar PV power plants.
- This study does not account for additional losses, such as initial degradation of the modules, or the plant's own consumption and availability.
- A DC/AC power ratio of 1:1 was assumed for all scenarios.

The region of the site is located closer to the equator than other countries where solar PV has been largely implemented, so the sun is at higher altitudes and the solar PV module rows can be closer to each other with a lower shadowing influence.

Figure II-10: General comparison of shadow behaviour between solar PV module rows in Europe and in locations close to the equator



The following three modules have been chosen as representative solar PV components:

Table II-4: Selected solar PV modules

Technology	Solar PV module	Efficiency
Monocrystalline silicon (mono-Si)	SunPower SPR-300NE-BLK-D (300 Wp)	18.40%
Polycrystalline silicon (poly-Si)	SunEdison SE-300YPC (300 Wp)	15.43%
Cadmium telluride (CdTe)	First Solar FS-392 (92.5 Wp)	12.84%

To perform each simulation under the same electrical conditions, an inverter from the company SMA (Sunny Central 500 CP) has been chosen in a central inverter configuration with a power rating of 500 kilowatts (kW) and a European Efficiency of 98.5%[1].

500 kW inverters are widely established in the market for large solar PV power plants. Because modular design of the solar PV power plants is intended, 500 kW units are more suitable for this concept.

II.4.6.8 Results

The parameters of interest for the comparative assessment are the following:

- specific yield (kWh/kWp)
- produced energy (megawatt-hour, MWh)
- performance ratio, PR (%)
- specific land requirement (ha/MWp)
- density of production (MWh/ha)
- capacity factor, CF (%)

This last co-efficient was included as a general reference, even though it is rarely used to assess solar PV technology. It is useful to make comparisons with other generation technologies. As it evaluates the operational hours at nominal power with respect to the whole year, it reflects the technical impossibility to operate solar PV power plants during the night (*i.e.*, approximately half the year), leading to low values for this co-efficient when compared to other energy sources.

For the yield projection process, a global estimated uncertainty of +/-10% has been applied. It includes the uncertainties for the simulation, accuracy of irradiation data and processing, as well as the long-term consideration of irradiation data.

The specific yield is the annual energy produced in kWh per nominal installed kWp (kWh/kWp). The produced energy in MWh is simply the specific yield times the installed nominal power of the plant and accounts for the annual plant production delivered at the grid connection.

[1] The European Efficiency is an averaged operating efficiency for a European climate. It is obtained by assigning percentages to different operating ranges.

II.4.6.9 Performance ratio

The performance ratio (PR) is defined as the ratio of total AC energy to the theoretically available energy and gives an indication of the quality of the installation. The PR can be considered as the relationship between the effective and the theoretical production of a PV system measured at the AC outlet of the inverter.

The PR is defined as:

$$\boxed{PR = Y_{AC} / G_{TILT} A_{1kW} \eta_{STC}}$$

where

Y_{AC} = specific AC electricity yield

G_{TILT} = total global solar irradiation sum in the tilted module plane

A_{1kW} = area of a 1 kWp solar PV module array and

η_{STC} = solar PV module efficiency at standard test conditions (STC).

As can be observed from the above equation, the PR is directly related to the specific yield of the plant and inversely related to the irradiation on the plane of array and the efficiency of the module.

The specific land requirement is the amount of land used for one MW of installed nominal power. It is a measure of the land requirement for the given technology. The density of production is the amount of energy produced in a year per hectare of land.

The yield projection results for the 10 MW block of this site are presented in table II-5 and in figures II-11 to II-13.

Table II-5: Yield projection results for 10 MW block at site

10 MW block (Site 1)	Specific production (kWh/kWp)	Annual production (MWh)	Performance ratio (%)	Specific land requirements (ha/MW)	Density of production (MWh/ha)	Capacity factor (%)
Fixed poly-Si	1 419	15 663	78.7	1.00	1 560	16.2
Fixed CdTe	1 497	16 480	83.1	1.20	1 375	17.1
Single-axis mono-Si	1 764	19 409	81.8	1.54	1 258	20.1

Figure II-11: Specific production for the different plant configurations at site

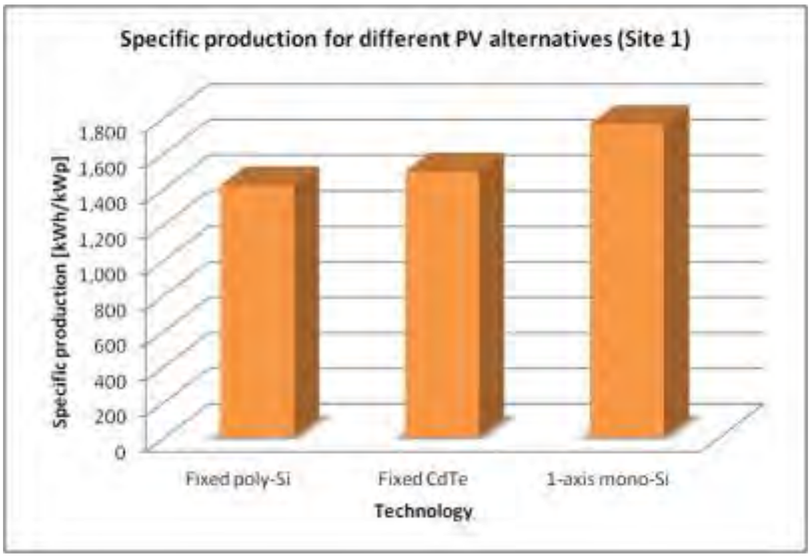


Figure II-12: Annual production for the different plant configurations at site

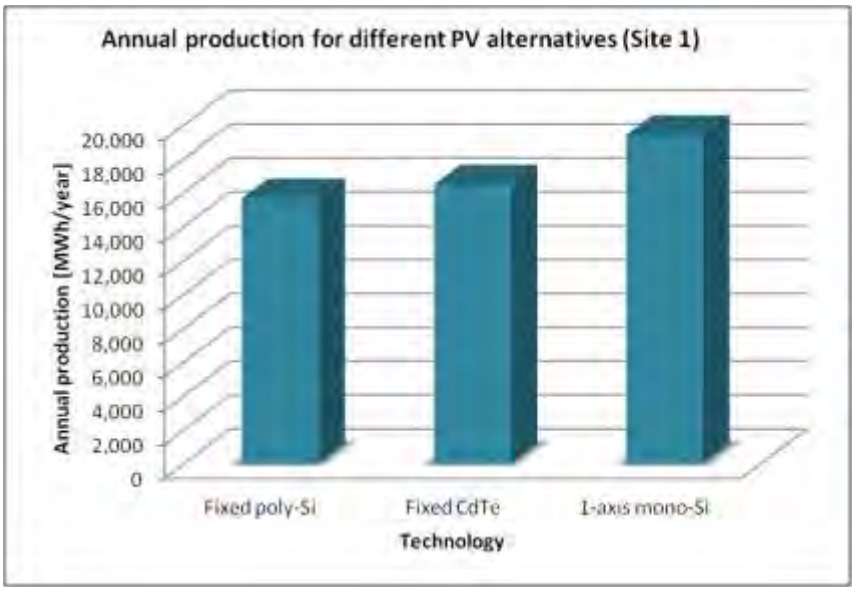
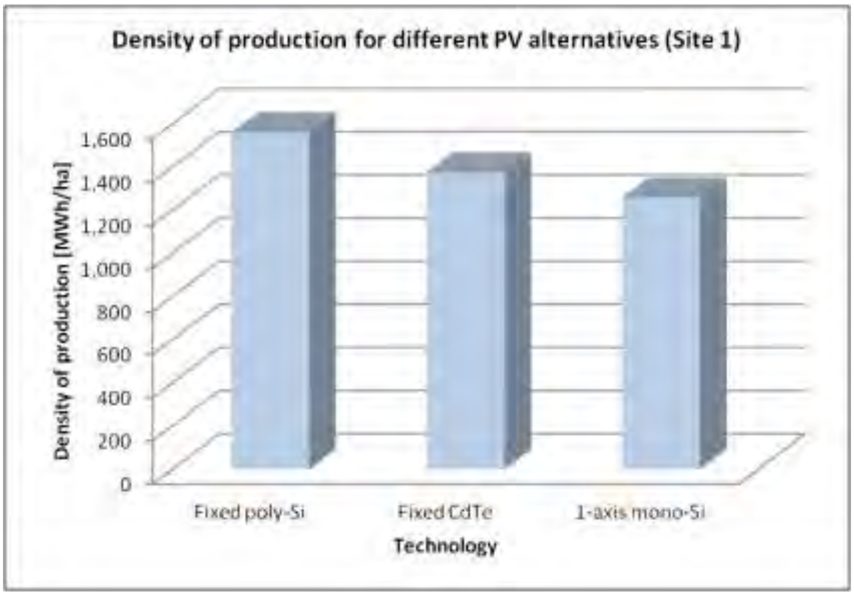


Figure II-13: Density of production of different plant configurations at site



From above it can be seen that the single-axis tracking configuration with mono-Si modules has the highest yield potential of all three scenarios. The simulation results show that the specific yield and annual production for this configuration are about 18% and 24% higher than the fixed mounting solutions with CdTe and poly-Si modules, respectively. In terms of land requirements, it becomes apparent that fixed mounting solutions require less area than single-axis tracking systems. Therefore, the density of production in MWh/ha shows that, in a given area of one hectare, the fixed mounting configuration with poly-Si technology produces 13% and 24% more than CdTe technology (fixed mounting) and mono-Si technology (single-axis tracking), respectively, on site.

II.5 Selection

II.5.1 Selection criteria

At this stage, the usual objective of site selection is oriented towards maximum output of the power plant at minimal cost and minimum socio-environmental impact.

After assessing all the potential areas and sites for the solar PV project, the developer has to make a decision. Based on the results from the assessment phase, the pros and cons of each area have to be examined and ultimately the area or site with the lowest social environmental impact and the best technical viability should be preferred. As previously mentioned, close co-ordination with regulatory authorities and the grid operator is crucial.

It also is possible that the objective is not the highest output (electricity generation in MWh) but the highest installed capacity. This depends on the business model and is project-specific. It can be, for example, that an investor is paying the developer for a certain installed capacity and not for a maximised plant performance. With more installed capacity at a given site, the overall MWh produced per year will be higher, but the specific yield (kWh/kWp) will be lower. As outlined in this section, the following actions, questions and deliverables should be the focus of this phase:

Key actions

- Selection of the preferred sites for further project development.

Control questions

- Is the site selection objective and independent?
- Do you know what the final selection criteria should be for the different sites (*e.g.*, maximum yield vs. maximum capacity)?
- Are you aware of any potential former or new showstoppers? (see examples below)
- Do you have the required resources for further development?

Key deliverables

- Table with sites for final project development based on lists available in Appendix.

II.6 Pre-development

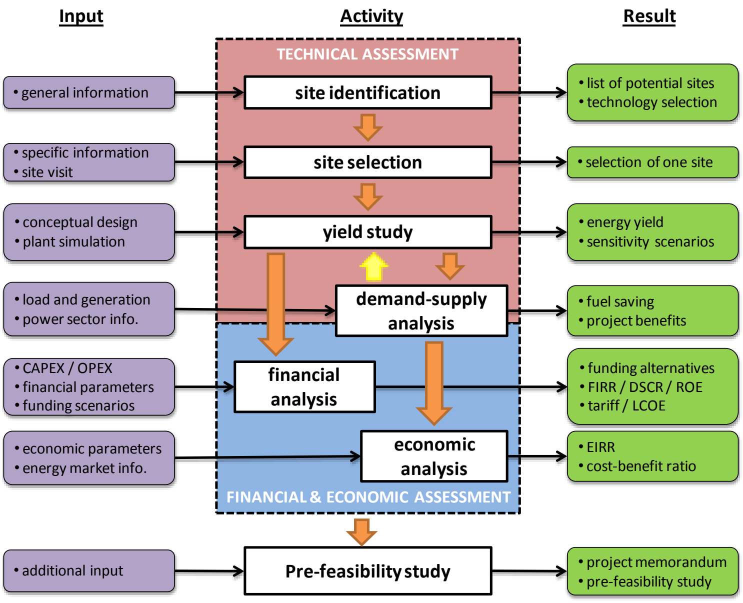
II.6.1 Pre-development criteria

During this phase, major engineering studies are performed, including the basic design of the solar PV power plant. These design activities form the basis to prepare applications for permits, licences and authorisations. A typical scope for the pre-development phase includes the following tasks:

- Technology evaluation and preliminary selection of solar PV modules and balance of system (BOS) equipment
- Preliminary conceptual design of the solar PV power plant
- Evaluation of the project site and its boundaries in accordance with the previous assessments
- Preliminary performance estimation (*i.e.*, hourly electricity generation values based on P50 resource analysis) as well as estimates of performance ratio and capacity factor
- Implementation of environmental studies
- Preparation of all permit applications including construction permit and grid connection
- Preliminary estimate of the total investment cost including grid connection.
- Early financial model with estimate of total revenues on a monthly and an annual basis

Figure II-14 provides a flow diagram as an example of technical and financial assessment during pre-development.

Figure II-14: Example of a flow diagram for project development



There are many trade-offs that need to be made to achieve the optimum balance between performance and cost. Solar PV module technologies, technical design and factors, as well as degradation and warranty-related aspects are described in this section in order to highlight some of the key issues to be considered during the pre-development phase of a solar PV project. As outlined in this section, the following actions, questions and deliverables should be the concern of the project developer during the pre-development phase:

Technology evaluation

Key actions

- Evaluation of technology costs per module type and per supplier.
- Analysis of suitability of primary components with regard to site-specific climatic and environmental conditions.
- Analysis of certificates provided by suppliers.
- Visit to existing solar PV facilities to verify supplier track record.

Control questions

- Have you obtained datasheets for module, inverter and other balance of system (BOS) equipment? Are power ratings, efficiencies and losses in line with industry standards? Are you comfortable with the general commercial terms (guarantees, warrantees)?
- Have you obtained confirmation about solar PV module characteristics with key suppliers (performance, voltage control, tolerance, temperature co-efficients, degradation, low-light profiles)?
- Have you obtained confirmation of characteristics with key suppliers (MPPT, voltage efficiencies)?
- Is all selected equipment suitable for your project site's climatic conditions?

Key deliverables

- List of selected equipment including datasheets, certifications and commercial terms.
- Compatibility report of all BOS equipment regarding site-specific conditions.

Technical design

Key actions

- Preparation of grid connection assessment study.
- Preparation of solar resource and yield study.
- Execution of geotechnical and topographic surveys.
- Evaluation of grid connection constraints (total substation capacity, direct and travel proximity, road crossing, local area stability and remaining substation availability).
- Preparation of plant technical design report.

Control questions

- Is your technical design in line with best practices for tilt angle, orientation, inter-row distance, shading, string optimisation, and civil works and security?
- Have you properly sized all plant equipment?
- Have you discussed your design with an independent engineer, public authorities and potential insurance providers?
- Did you take into account possible requirements from the grid code for the inverter selection and sizing?
- Did you consider horizon and near-shading obstacles for the plant layout?
- Have you identified potential restrictions on land availability and use together with local authorities?

- Do you have a clear picture on the availability of water supply and the associated regulatory requirements and costs?
- Does the geotechnical study cover all relevant aspects related to foundations and soil compaction?

Key deliverables

- Topographical study
- Geotechnical study
- Civil engineering study (including recommendation on foundations)
- Basic Engineering Technical Dossier
- Basic plant layout
- Grid connection layout
- Plant design criteria

Performance evaluation

Key actions

- Production of verified location-specific solar resource files (P50/P75/P90) with calibration of satellite-derived meteorological data interpolated with ground-based measurements of at least one year and thorough uncertainty analysis
- Production of P50/P75/P90 hourly electricity generation values and detailed yield study highlighting assumptions and uncertainties with a clear yield loss Sankey diagram
- Calculation of performance ratio
- Calculation of capacity factor
- Drafting of preliminary financial model
- Evaluation of all costs associated with development, construction and operation.

Control questions

- Do you know the quality and accuracy of the meteorological data? Does it cover the long-term weather at the site?
- Did you use industry-standard algorithms to convert GHI values to tilted values at the surface of the solar PV modules?
- Are the components and the system layout properly inputted in performance model?
- Did you consider all losses and uncertainties in the performance model including cable, soiling, auxiliary and grid availability losses?
- Are the prices in the cost estimation realistic and complete?
- Have you evaluated all relevant investment and operations costs associated with the performance level?
- Do the key parameters in the financial model reflect local market price and best practices?
- Does your financial model cover the full life cycle of the project?

Key deliverables

- Solar resource assessment study and associated files
- Detailed yield study with ratios and performance metrics
- Preliminary costing report
- Draft financial model

Permits, licenses and authorisations

Key actions

- Preparation of a list with the required permits
- Implementation of local consultations with community stakeholders
- Follow up, tendering and execution of EIA
- Completion of environmental studies
- Building permit application submission
- Grid connection authorisation submission
- Operation licence submission

Control questions

- Are you aware of the requirements of an EIA?
- Has the local authority given confirmation of the land use (*i.e.*, agricultural/industrial/landfill)?
- Do you have a clear and documented overview of land ownership?
- Have you prepared all relevant supporting files for permit applications (including environmental studies, layout and preliminary drawings)?

Key deliverables

- Completion of all environmental studies including addendum requests by regulatory authorities
- Building permit application
- Grid connection authorisation application
- Operation licence application

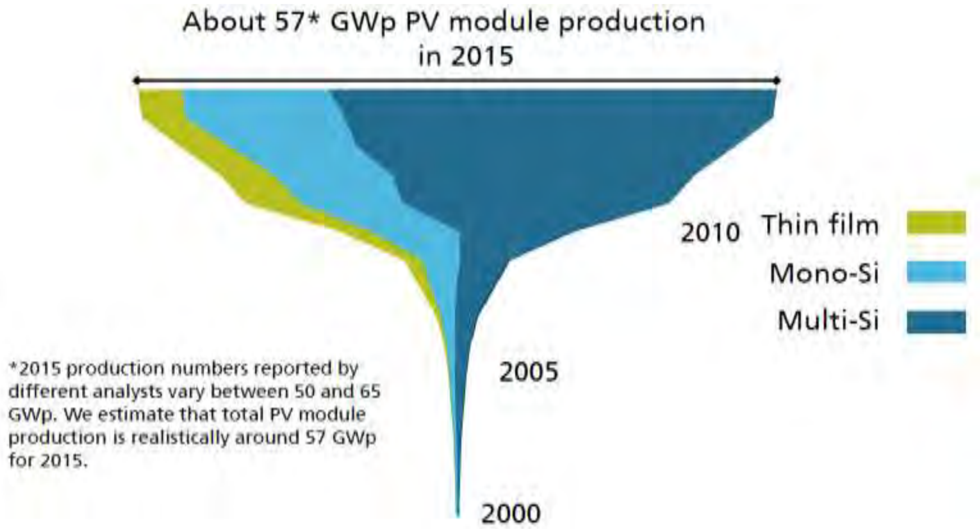
II.6.2 Technology evaluation

II.6.2.1 Solar PV modules

Solar PV modules represent the main component of a solar PV system and occupy the largest area of the plant. These modules convert solar irradiation into electric current, causing it to flow due to the voltage difference set up in the module.

For non-concentrating solar PV module technology, the market is dominated by c-Si cell (mono- and polycrystalline) technologies. Thin-film modules encompassing single- or multi-junction a-Si and µc-Si, CdTe, CIGS and other technologies currently stand at around 10%.

Figure II-15: Global annual PV installation by technology, 2000, 2005, 2010 and 2015



Source: Fraunhofer ISE, 2016.

II.6.2.1.1 Crystalline silicon

II.6.2.1.1.1 Crystalline silicon module types

The modules with blue-colored cells are poly-Si modules, and the modules with dark blue or black cells are mono-Si modules, as depicted in figure II-16.

Figure II-16: Examples of polycrystalline and monocrystalline solar PV modules

Source: Solarworld, 2015.

Poly-Si solar cells generally attain lower efficiencies in comparison to mono-Si cells. Mono-Si cells reach up to 25.6% conversion efficiencies, whereas poly-Si cells achieve 21.3% efficiencies on a laboratory scale. Typically, poly-Si and mono-Si modules are fabricated with a rated power of 210-345 W, and their dimensions vary between 0.7 m² and 1.6 m².

II.6.2.1.1.2 Crystalline silicon module degradation

Solar PV modules suffer power losses because of different ageing processes occurring over time, such as delamination of layers, failures in cell interconnections and water intrusion.

A degradation effect which is particular to crystalline modules occurs after several hours of sun exposure. This effect is called light-induced degradation (LID). For poly-Si, the power losses related to this effect are usually around 1% of the nominal power, while typical LID losses for mono-Si are around 2%.

In addition, the following degradation effects have been observed:

- yellowing of laminating material (*e.g.*, ethylene vinyl acetate, EVA)
- glass soiling and corrosion
- glass breakage
- front-grid and anti-reflection-layer oxidation
- busbar corrosion
- cell cracks
- backsheet polymer cracks
- delamination and bubble formation in the encapsulant
- backsheet delamination
- frame and junction box defects
- hot spots.

Modules manufactured in recent years demonstrate improved stability due to several changes in design, material selection and manufacturing controls.

Recently, a new kind of degradation has been seen, referred to as "potential induced degradation" (PID). PID is caused by leakage current in the solar PV module and also is known as high-voltage stress (HVS). This is a loss of up to 80% of the nominal module power caused by leakage current at high voltages. In case the modules are not PID-free, it is highly recommended to adopt the use of inverters that allow (solid) grounding of the negative pole of the DC system to avoid or minimise the effect of PID.

Estimates for degradation figures found in the market for installation at moderate climatic conditions for c-Si modules are 0.25% to 0.8% per year after LID. On average, for current industry practice, annual degradation of the nominal power of crystalline solar PV modules is accepted as 0.5%, or 12.5% over the 25 years of the expected lifetime of solar PV systems. In a financial model, an average yearly power degradation of 0.5% is recommended for the lifetime of the solar PV power plant.

II.6.2.1.1.3 Crystalline silicon module standard warranties

There are two types of warranties: the product and the power warranty. Typical product warranties for fabrication or materials are for five years. Some manufacturers offer product warranties up to 10 years or even more. Figure II-17 shows the typical performance (or power) warranties found on the market for mono-Si modules. The power warranty is usually for a period of 25 years. The current market standard is a linear power warranty:

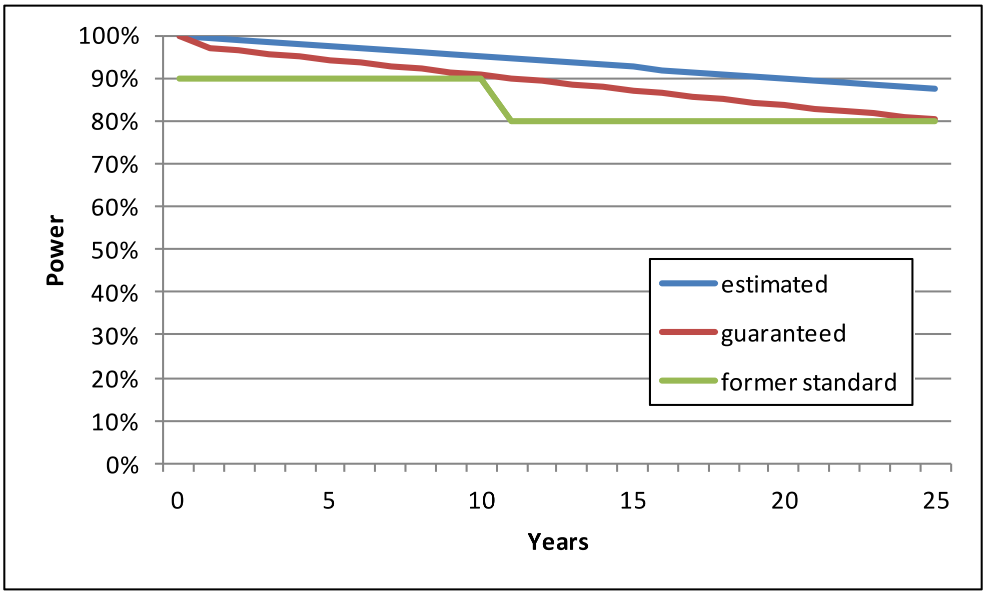
- 97-98% of the nominal peak power after the first year, and
- 0.7% degradation of the nominal peak power per year thereafter (red line in the figure).

The estimated trend of the actual power degradation is 1% in the first year, followed by 0.5% in the following years (blue line in the figure).

The formerly applied "stepwise" power warranty of 90% in the first 10 years and then 80% of the nominal power for years 11-25 is no longer a market standard. The green line in the figure illustrates this two-step warranty ("former standard").

The warranties apply under the provision that modules are used under normal installation, application and service conditions as described in typical installation and operation manuals provided by original equipment manufacturers (OEM).

Figure II-17: Typical degradation curve for monocrystalline modules



Source: Fichtner, 2015.

II.6.2.1.2 Thin film

While silicon is an indirect-band gap semiconductor, thin-film PV materials are direct-band semiconductors and as a consequence have 100 times higher light absorption. Therefore, 100 times thinner layers are sufficient to convert the incoming solar irradiation.

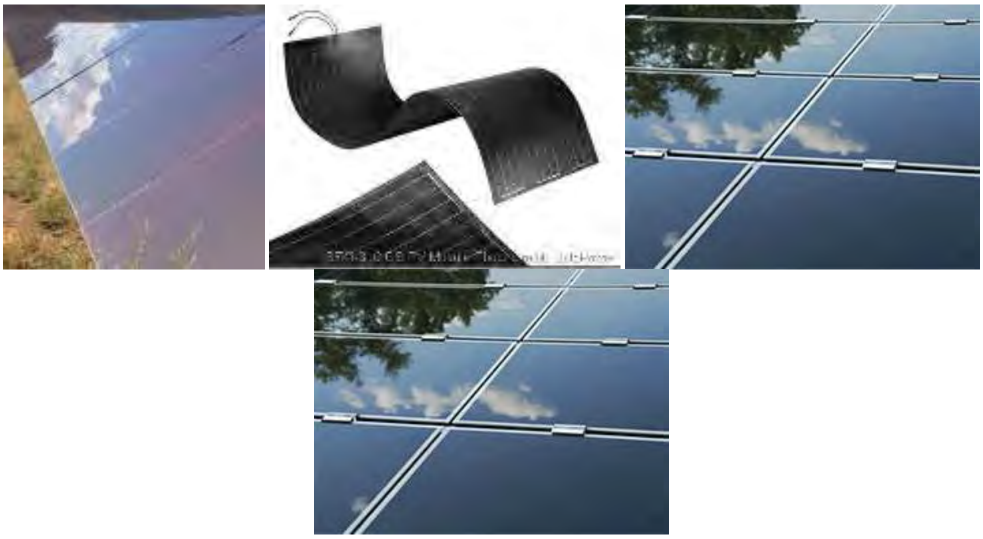
Thin-film technologies might have cost advantages over wafer-based c-Si solar cells, as they use less material and require fewer processing steps at lower temperature. In general, the energy payback time for thin-film-based PV modules is lower. One disadvantage when compared to mono-Si is the lower efficiency of thin-film modules. Nevertheless, the utilisation of diffuse light and low irradiation is better with thin-film cells, and they generally have a more favourable temperature co-efficient than c-Si, so the influence of higher ambient and operating temperatures is lower than for c-Si, making thin-film cells favourable for use in hot desert regions like the Middle East and North Africa (MENA) region.

II.6.2.1.2.1 Thin-film module types

The most common semiconductor materials for thin-film PV technologies are:

- Cadmium telluride (CdTe)
- Amorphous silicon (a-Si)
- Copper indium gallium (di)selenide (CIS, CIGS)
- Gallium arsenide (GaAs).

Figure II-18: Different types of thin-film modules (a-Si, CIGS, CdTe)



Credits: Fichtner 2015; Gunther 2010

Thin-film cells are not restricted in their format to standard wafer sizes as is the case with c-Si cells. Thin-film-based modules consist of up to several hundred solar cells. These are monolithically integrated, meaning that they are *in situ* separated and connected in series to a neighbouring cell. The glass substrate with the cells is encapsulated with a laminating material (*e.g.*, EVA) and supported by a second glass sheet. Some thin-film modules can be produced as flexible material, opening up the possibility of other designs and applications (*e.g.*, façades). Typically, thin-film modules are fabricated with a rated power of 70-120 W and their dimensions vary between 0.9 m² and 1.6 m².

The most relevant thin-film technologies are described in the following paragraphs:

Amorphous silicon (a-Si)

- Amorphous silicon does not form a regular crystalline structure as in c-Si but an irregular network. This results in flexible solar modules that can be created on non-transparent and lightweight substrates such as metal or plastic sheets.
- The a-Si technology has the advantage that it does not contain heavy metals like copper, cadmium or indium, unlike other thin-film technologies. The disadvantage of amorphous cells is their low efficiency which diminishes even during the first 6 to 12 months of operation due to LID ("Staebler-Wronski effect") before levelling off at a stable value, the nominal power rating.
- The efficiency of commercially available modules is between 5% and 10% after the initial LID and stabilisation.

CIS/CIGS

- The active semiconductor material in CIS (also called CIGS) solar cells is copper indium gallium (di)selenide. CIS solar cells, with a record conversion efficiency of 22.3%, are currently the most efficient of all thin-film based solar cell technologies.
- A disadvantage of CIS modules is the toxicity of selenium. Furthermore, indium is a rare earth metal, and CIGS module manufacturers have to compete with the television and flat screen industries which use the same material.
- The efficiency of commercially available modules is between 10% and 13.8%.

Cadmium telluride (CdTe)

- CdTe is a semiconductor compound which has good solar irradiation absorption. CdTe has one main disadvantage: the toxicity of the heavy metal cadmium. Special recycling procedures are required at the end of life of the PV systems. CdTe solar panels have been commercially available since 2002 and represent the most widespread thin-film technology.
- CdTe-based solar modules offer the highest efficiency of all commercial available thin-film-based PV modules, at 16.4%, and production costs which are similar or even lower than for c-Si-based technologies seem to be possible.

GaAs

- GaAs is a semiconductor compound with good solar irradiation absorption. GaAs cells can reach high efficiencies. Still, due to the relatively high production costs, GaAs modules are so far not used in utility-scale PV power plants.

II.6.2.1.2.2 Thin-film module degradation

Due to the different substrates and semiconductors, the degradation behaviour for thin-film technologies varies. Like c-Si, thin-film modules experience power degradation during their operation in a power plant. In the case of CdTe technology, manufacturers have estimated that the modules undergo a degradation of approximately 0.6% to 0.8% per year.

In the case of a-Si technology, the modules undergo an initial degradation between approximately 14% and 20%. This initial degradation is normally considered when rating the modules. Once the modules stabilise, a stable degradation between 0.3% and 0.4% per year is expected.

II.6.2.1.2.3 Thin-film module standard warranties

As with the c-Si technology, there are two types of warranties: the product and the power warranty.

For commercial thin-film technologies, the product warranty is typically two to five years after module purchase for CdTe and a-Si. Alongside similar validity provisions, the following additional provisions apply for some thin-film technologies:

- Installation must be done by contractors authorised by the module manufacturer.
- Specific mounting structures and concepts accepted by the module manufacturer must be used.
- After installation of solar PV modules, the plant must be energised within specific periods of time.

The power (or performance) warranty is usually for a period of 25 years. Both the stepwise warranty of 90% (for the first 10 years) and 80% (until the 25th year) as well as the linear power warranty have been seen on the market.

II.6.2.1.3 Solar PV technology benchmark

II.6.2.1.3.1 Efficiency and area requirements

The efficiency has a direct influence on the area requirements and the construction costs. Crystalline technologies usually have a higher efficiency and have a smaller footprint, resulting in lower land costs for the installation of an equivalent power rating with thin-film modules. This depends on the thin-film technology with which they are compared. Taking the poly-Si area requirement as a basis, the proportional area requirements for the same installed capacity would be approximately as depicted in table II-6.

Table II-6: Area requirements for solar PV installation

Solar PV technology	Surface requirement
mono-Si	80%-100%
poly-Si	100%
CdTe	100%-125%
a-Si	180%-200%
CIS	130%-140%

Source: Fichtner, 2015.

The area requirements of CIS and CdTe are up to 60% higher for a comparable mono-Si solar PV power plant. In the case of a-Si, a solar PV power plant would require more than twice the area of a mono-Si solar PV power plant with an equivalent power rating.

Considering only land use, it can be concluded that in regions with substantial area restrictions or high specific land costs, mono-Si technology could possess an advantage over thin-film technologies.

It is worth pointing out that the optimisation of the configuration (*e.g.*, distance and tilt when applicable) is important for maximising energy production and minimising energy costs, given the area restrictions.

II.6.2.1.3.2 Thermal behaviour

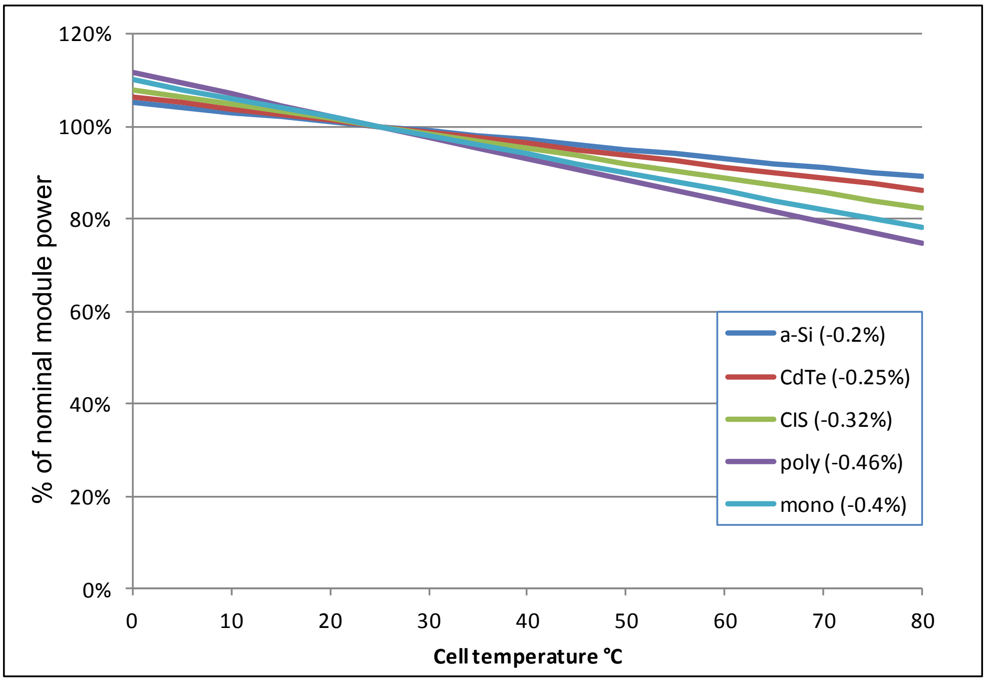
The actual power of the solar PV modules installed depends on the ambient temperature at the specific site. This influence is characterised by the temperature co-efficient. For all technologies, the temperature co-efficient is negative. Figure II-19 shows the temperature behaviour of the power output for the main module technologies. At 25 °C the power output is 100% of the nominal power.

To give an example: with a cell temperature of 60 °C (poly-Si), the actual power output is approximately 16% lower compared to the output at standard conditions of 25 °C. Thus higher temperatures negatively affect the conversion efficiency of solar PV modules.

The temperature co-efficients of thin-film technology vary considerably. The most established technologies a-Si and CdTe have co-efficients between -0.2% and -0.25% per °C in comparison to values of -0.4% and -0.46% per °C of c-Si technologies. This means that thin-film modules are more efficient than c-Si modules at higher temperatures.

The thin-film technologies a-Si and CdTe have the most favourable temperature co-efficients with the exception of the heterojunction c-Si technology, which displays the same temperature co-efficient as the a-Si technology.

Figure II-19: Typical change of output power at different cell temperatures



Source: Fichtner, 2014.

For sunny regions with high temperatures, thin-film technologies can have a better performance than c-Si technologies as the temperature effect on module efficiency is lower.

II.6.2.1.4 Solar PV module quality and standards

It is critical for developers to consider aspects such as standards and product and power warranties when selecting the solar PV modules. These ensure the integrity of the modules and the bankability of the project, since all solar PV modules suffer power losses due to different types of degradation.

When selecting solar PV modules, the following key aspects should be considered, also with regard to potential bankability requirements defined by the lender:

- Appropriate performance objective of solar PV modules in terms of efficiency and supply cost with regard to land and associated BOS equipment requirements.
- Module power tolerance should be quoted "positive only", for example 0/+5 W and no longer the former market standard of +/-3%.
- The power warranty quoted by manufacturers should be linear over 25 years and not a stepwise guarantee.
- Product warranties of at least 5, 10 or even 12 years must be given by the manufacturer to cover product failures.
- Modules should be PID-free.
- If installed near the sea, the modules should have a salt mist corrosion test certificate (IEC 61701).
- Evaluation of the actual performance of a sample solar PV module should be performed by a third-party accredited laboratory.

Solar PV modules are tested to evaluate their safety and performance under test conditions that simulate outdoor temperatures and climate. No modules without at least these certificates are considered reliable or bankable. Tests are carried out according to the following international standards:

IEC 61215: Design qualification and type approval for crystalline silicon solar PV modules

- The IEC standard relates to an evaluation of ageing and performance of the panel by submitting the modules to several tests and measurements. It describes the various qualification tests on the basis of artificial loading of the materials.

IEC 61646: Design qualification and type approval for thin-film solar PV modules

- The IEC standard is related to several tests and measurements, and this IEC describes the various qualification tests for this kind of module.

IEC 61730: Safety qualification and mechanical operation

- IEC 61730 comprises the requirements for the design and testing of solar PV modules regarding the qualification for safe electrical and mechanical operation throughout their expected lifetime.
- IEC 61730 comprises all tests that are part of the Safety Class II qualification. Safety Class II is an electrical safety certification for electric plants with nominal voltages below 1 000 V AC and 1 500 V DC. Devices gaining this certification are built with double insulation to prevent user electrocution, should the normal insulation fail.

Table II-7 gives an overview of further tests and certificates.

Table II-7: Typical module and manufacturer tests and certificates

Optional certifications/tests	Reference
Compliance with EU legislation	CE
Standard for flat-plate PV modules and panels	UL 1703
Ammonia corrosion testing	IEC 62716
Salt mist corrosion testing	IEC 61701
Blowing sand test	IEC 60068-2-68 method Lc2
System voltage durability test for c-Si modules – qualification and type approval (PID test)	IEC/TS 62804
Module manufacturers:	
Quality management systems	ISO 9001:2008
General requirements for the competence of testing and calibration laboratories	ISO 17025:2005
Environmental management systems	ISO 14001:2004
Design and manufacturing of solar modules	BS OHSAS 18001:2007
Manufacturing of solar power devices for the automotive industry – with product design and development	ISO 16949:2009

II.6.2.1.4.1 *Identifying solar PV module standards using IRENA's INSPIRE platform*

Project developers need easy access to renewable energy technology standards, which typically are spread among difficult-to-find databases that are not user friendly. IRENA's International Standards and Patents in Renewable Energy (INSPIRE) platform is the first and most complete solution of its kind, allowing users to find the most relevant international standards and patents for renewable energy at no cost.

INSPIRE's standards database provides a comprehensive one-stop-shop of information on renewable energy standards consolidated from scattered sources. INSPIRE guides users through a vast repository of international renewable energy standards information to raise awareness of the subject and its usage.

Figure II-20: IRENA's INSPIRE platform

Credits: IRENA.

The platform provides a direct contact point with renewable energy standards developers and mechanisms to support developing country engagement in the international standards process.

II.6.2.2 Balance of system

The balance of system (BOS) typically refers to all equipment other than solar PV modules that transmits and regulates DC electricity produced in the array and converts it to AC electricity to be offtaken to the grid. Each aspect of the BOS scope should be evaluated for optimisation with reference to the aspects of energy production, net present value, LCOE, etc. It is important to obtain a balance between cost savings and quality; a BOS design with the only aim of reducing present costs is likely to lead to increased future costs and lost revenues due to high maintenance requirements and low performance.

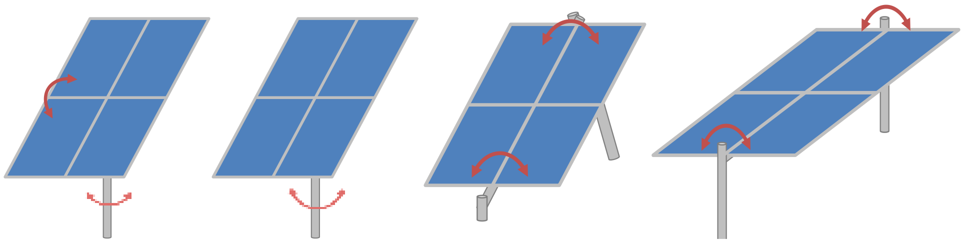
II.6.2.2.1 Structural BOS

II.6.2.2.1.1 Mounting systems

The mounting system is crucial for optimising the orientation of the modules, as higher energy yields can be generated by pointing the modules directly towards the sun. For example, in the northern hemisphere, solar PV modules are tilted to the south in order to maximise the energy output. It could be suitable in some cases to tilt them differently to change the distribution of the produced energy over the course of a day.

Besides the fixed mounting installation, various kinds of tracking systems are available on the market that exhibit differing advantages depending on location. Figure II-21 shows commonly used orientation and tracking systems.

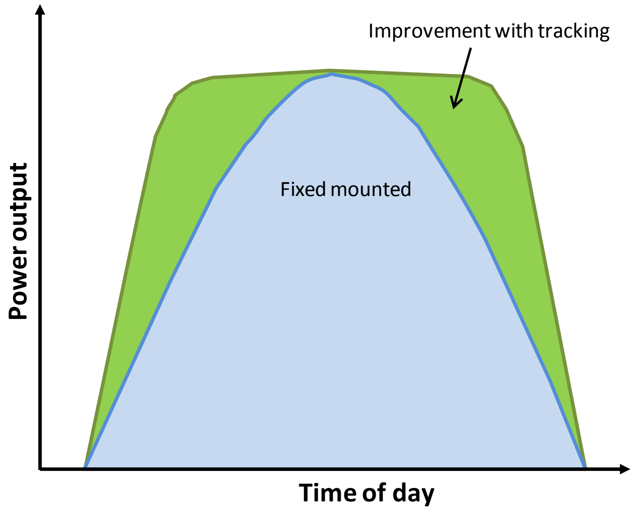
Figure II-21: Different tracking systems for solar PV power plants (double- and single-axis)



In areas where the component of direct irradiation is high, the solution with single- or double-axis tracking systems may be considered. Depending on the site and on the precise characteristics of the solar irradiation, trackers may increase the annual energy yield by up to 27% for single-axis and 37% for double-axis trackers (Aditya and Ramsankar, 2014). Figure II-22 shows the general improvement of the power output with tracking technology compared to a fixed mounting system.

The orientation of solar PV modules also can be influenced by contractual requirements related to the electricity offtake with an utility. In some cases, the developer might want to maximise electricity generation during the summer, which will result in a different optimisation than the maximum yearly electricity generation profile.

Figure II-22: General benefit of a tracking system



Note that the capital expenditure as well as the O&M costs for tracking systems – especially for double-axis tracking systems – are considerably higher than for a fixed mounting system. Furthermore, the potential vulnerability of the tracking algorithm and motor accuracy are a risk to be taken into account in the selection of the technology. Careful consideration is needed between the higher yield (at higher costs) of a tracking system and the lower yield (with lower O&M risk) of a fixed mounting solar PV system.

II.6.2.2.1.1.1 Technical evaluation of support structures

The topographical site conditions and information obtained during the geotechnical survey will influence selection of the foundation type, which, in turn, will affect the choice of mounting structures (steel- or aluminium-based). The project developer shall procure such structures from established manufacturers because mounting systems are an important part of the technical design viability of the solar PV plant and will be scrutinised by financing parties during technical due diligence. In some cases, manufacturers provide soil testing and qualification services in order to certify a design for a specific project configuration (IFC, 2012).

The warranty supplied with support structures varies but may include a limited product warranty of 10 years, even if, depending on adequate maintenance and corrosion protection, the useful life of support structures is expected to be beyond 25 years.

Solar PV plants equipped with tracking systems usually have a better yield than solar PV plants based on fixed mounting systems. However, solar PV arrays with tracking systems require a larger and even land area, whereas fixed mounting arrays are more suitable for complex terrain and have easier O&M procedures since there are no moving parts.

Tracking system life expectancy is quite specific and depends greatly on adequate maintenance. Components of the actuation system, such as bearings and motors, can be serviced or replaced within the planned project life, and steel driven piles should be hot-dip galvanised to reduce corrosion. In environments close to the sea, additional corrosion protection or coating of the structures may be required.

Tracker warranties vary among technologies and manufacturers. However, a 10-year guarantee on components or parts could be considered typical.

Usual bankability criteria regarding the selection of the support structures are given below:

- Sufficient track record and realised projects
- Installation and operation in similar climatic conditions
- Service agreements for maintenance and spare parts

- Warranty conditions at least according to market standard (see above).

II.6.2.2.1.1.2 Fixed systems

Solar PV modules with a fixed orientation require an optimal installation angle, which is calculated as an average over the course of the day and throughout the year. To convert a maximum of energy over the entire year, the modules commonly have a tilt (to the south in the northern hemisphere and to the north in the southern hemisphere) similar to the latitude.

Figure II-23 illustrates why the inclination of the modules is important for maximising solar irradiation on the module plane. At the optimum angle (image in the middle) the solar irradiation reaching the module surface is maximised.

Figure II-23: Effect of different inclinations on solar irradiation

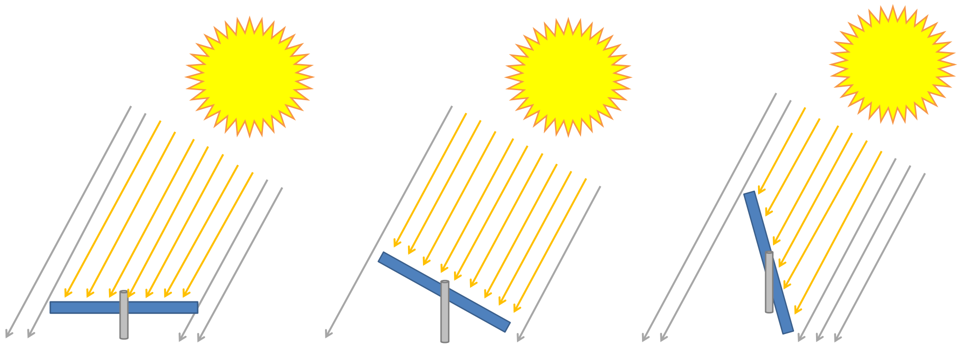


Figure II-24 shows an example of a fixed mounting solar PV power plant.

Figure II-24: Example of a fixed mounting solar PV power plant

Credits: Fichtner, 2015.

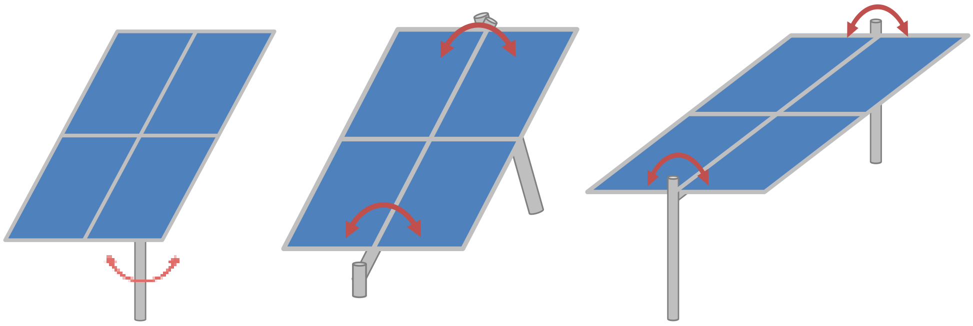
Since fixed mounting systems have no moving parts, their main advantages are lower installation costs and lower O&M costs, often referred to as capital expenditure (CAPEX) and operating expenditure (OPEX), respectively. Their specific yield, however, is rather low compared to tracking systems. Due to significantly reduced module costs, fixed systems directed to different angles are now an economic option in order to optimise yield and avoid higher investments for tracking systems at the same time. Fixed systems find application for all types of non-concentrating solar PV modules.

The optimum angle of the modules depends on the latitude of the plant location and usually varies between 10° and 35°. Module suppliers recommend a module angle of not less than 5° to 7° to reduce module soiling. In order to maximise the installable capacity at a given site it might be appropriate to install the modules with a lower inclination and lesser module row distance. The azimuth of a solar PV system is normally 0° (facing south) for systems in the northern hemisphere and 180° (facing north) for systems in the southern hemisphere.

II.6.2.2.1.1.3 Single-axis tracking systems

As depicted in figure II-25, there are different kinds of single-axis tracking systems. In general, the electricity generation of the first two configurations is higher compared to the horizontal single-axis system due to the module tilt. Near the equator, the horizontal single-axis system is advantageous.

Figure II-25: *Vertical, polar tilted and horizontal single-axis trackers*



The two photographs in figure II-26 show two types of single-axis tracking systems.

Figure II-26: *Example of single-axis trackers*

Credits: Fichtner, 2015.

These tracking systems originally were considered only for c-Si PV modules because of their higher efficiency and reduced specific investment and operating costs per installed kWp. Recently, the systems also have found application for thin-film modules.

II.6.2.2.1.1.4 Double-axis tracking systems

Solar PV modules installed on double-axis tracking systems face the incoming solar irradiation perpendicularly as they precisely track the sun's diurnal path. These systems have the greatest energy yields, but their construction and operation costs are highest. Figure II-27 shows an example of a double-axis tracker.

Figure II-27: Example of double-axis trackers in Spain

Credits: Fichtner, 2015.

These tracking systems traditionally have been considered only for c-Si solar PV modules and CPV modules.

II.6.2.2.1.1.5 Comparative yield analysis of mounting systems

In general, the energy gain of c-Si modules mounted on single-axis trackers can be estimated to be about 20% to 34% higher compared to fixed mounting systems. This estimation assumes optimum tilt of fixed mounting systems and no appreciable shading effects between tracking rows.

When comparing single-axis trackers with double-axis trackers, it is noted that at higher latitudes the gain of single- and double-axis tracking systems exhibits a wider spread between these two alternatives compared with locations close to the equator, due to the variation in sun height throughout the year. Table II-8 shows estimated figures for the typical energy yield increase of solar radiation for single- and double-axis systems for c-Si technology.

Table II-8: Energy gain of tracking systems

Tracking system	Typical yield increase compared to a fixed structure
Single-axis	10-25 %
Double-axis	25%-45%

Source: Lave (2011)

These figures must be compared with the final LCOE. Tracking systems are profitable if the gain in energy revenues (which occasionally might be impacted by time-based pricing negotiated with an utility) exceeds their marginal cost for procurement, installation and operation.

II.6.2.2.2 Electrical BOS

II.6.2.2.2.1 Distributed control system

It is standard in utility-scale solar PV power plants to monitor the production of the inverters or correct operation of strings and, generally, the overall plant performance. The concept comprises equipment and systems for the basic functions of a monitoring and performance control system:

- meteorological data (irradiation, ambient temperature, module temperature, wind speed)
- supervisory control and data acquisition systems (SCADA) for electrical production data (energy, capacity, performance)
- data logging and visualisation on-site and remotely (via Internet)
- automatic error detection and notification
- uninterrupted power supply (UPS).

II.6.2.2.2.2 Array combiner boxes

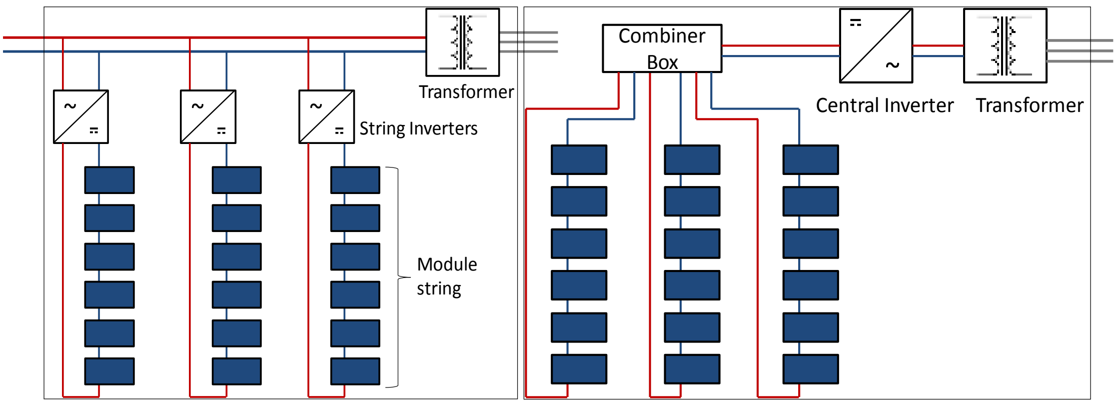
A solar PV array combiner box is a string combiner box installed between the solar PV array and the inverter, providing protection and performance monitoring. Depending on the solar PV plant design, multiple sets of boxes can be used.

II.6.2.2.2.3 Inverters

II.6.2.2.2.3.1 Inverter types

Two main inverter concepts are applied in solar PV power plants: the central inverter and the string inverter. There is no single inverter concept suitable for all situations. In practice, local conditions and the system components have to be taken into consideration for the specific application. Different solar PV module technologies and layouts may suit different inverter types; the integration of modules and inverters to ensure optimum performance and lifetime needs to be carefully evaluated and is subject to the experience and track record of the designer (IFC, 2012).

Figure II-28: Comparison between string and central inverters



Central inverters: Central inverters are used for large power plants in the multi-MW range and where the modules are the same and the ground is homogeneous. In this configuration many modules are connected in a series in one string, and these strings subsequently are connected in parallel to the inverter.

Figure II-29: Example of a central inverter

Credits: Bonfiglioli, 2014.

Advantages	Disadvantages
Shared load during high-irradiation hours	Correction maintenance lead time for repair or replacement in the event of a failure
Capacity to switch off some inverters during low-irradiation hours	

String inverters: The string inverter concept uses several inverters for multiple strings of modules, and the devices are suited for medium-scale solar PV power plants with a capacity of usually not more than a few MW.

Advantages	Disadvantages
Applicable for small-scale installation and/or hybrid systems	Not favoured for large-scale solar PV installations
Can be installed outdoors directly at the solar PV modules under the substructure	
Applicable for sites with heterogeneous slope profiles	
Applicable for installation with different module types, orientation	
Ability to achieve local MPPT on a string level	
Easier preventive maintenance operations by local personnel	
Modular addition of equipment in case of plant extension	

Figure II-30: String inverter mounted under solar PV modules

Credits: Fichtner, 2015.

In general, inverters may be transformer-less or include a transformer to step up the voltage. Inverters with transformers are galvanically isolated and can be used for grounding of certain solar PV modules that require such grounding, for example thin-film modules. Where transformer-less string inverters are installed, the efficiency is higher and the size and weight are reduced as well as cost, even if this is partially offset by the need for additional protective equipment.

When operating in hot climates, inverters suffer de-rating at temperatures above 45-55 °C. As the temperature rises further, power output drops, for instance at 2% per °C. This means that the inverter temperature must be monitored and cooling might be required.

A project-specific case-by-case evaluation is required to decide whether from an economic viewpoint central inverters are better compared to string inverters.

As a general rule it can be said that for large utility-scale solar PV power plants it usually is advantageous to use central inverters if there are no criteria that argue against central inverters. These criteria could be:

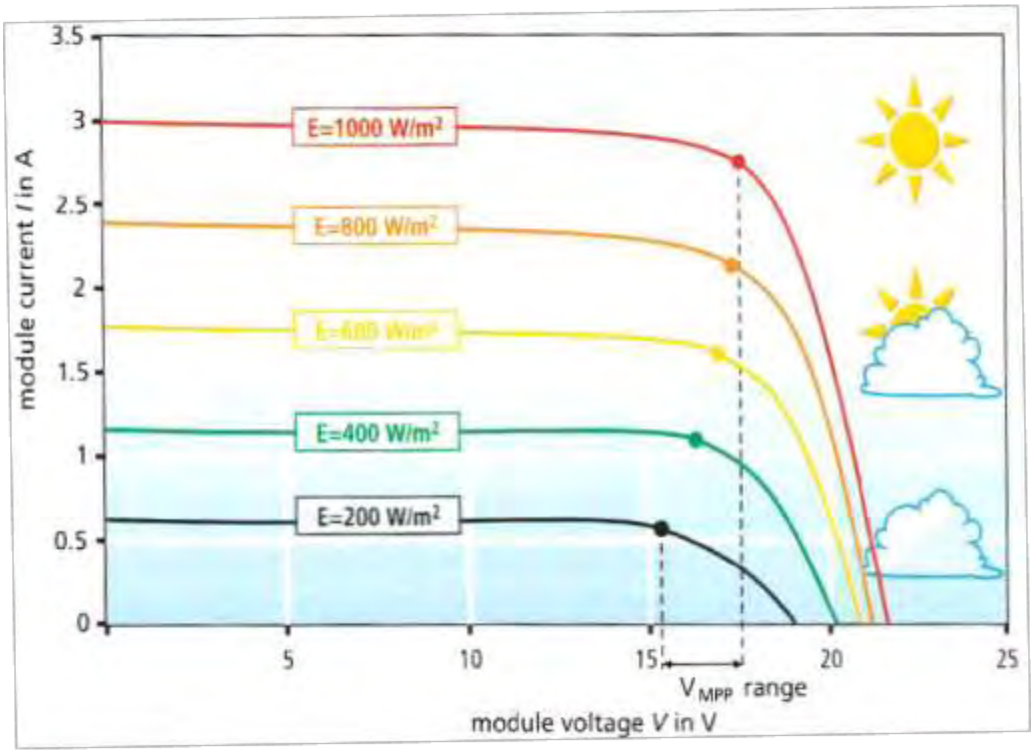
- remote or mountainous area without proper access, no harbour
- developing country without proper infrastructure
- no trained personnel at the site
- high import taxes on solar components in the project country.

The pure inverter lifetime is lower than that of solar PV modules. Therefore, it is recommended to make use of the services offered by inverter suppliers through service and maintenance contracts for proper maintenance of the central inverters. Local technicians are trained to qualify for performance of basic corrective maintenance of central inverters. For string inverters, it is important to implement a proper management of strategic spare parts, which usually includes a local stock kept in a warehouse to replace defective devices that are completely removed and sent back to the supplier.

II.6.2.2.2.3.2 Inverter efficiency

Efficiency varies depending on a number of factors, with DC input voltage and percentage load being the main ones.

Figure II-31: Module I-V curve and MPP behaviour with varying irradiation



Source: DGS, 2013.

Several other factors should be evaluated for inverter selection, including site temperature, product reliability, maintainability, serviceability and total cost. Usual bankability criteria regarding the inverter selection are given below. It is highlighted that there is no bankability standard and the criteria may differ for different lenders and investors:

- Compliance with all required standards and the grid code
- Sufficient track record and realised projects
- Installation and operation in similar climatic conditions
- Long term service agreements (LTSA) covering, *e.g.*, maintenance, spare parts, inverter availability
- Warranty conditions at least according to market standard (see below).

The guarantee offered for inverters varies between manufacturers. A minimum guarantee of 2 to 5 years is typical, with optional extensions of up to 25 years.

II.6.2.2.2.4 Substation

The design of the substation or the switchyard to connect the solar PV power plant to the local or national grid is usually provided by a national company accredited by the utility/grid operator for the substation design. Normally, the substation comprises medium-voltage switchgear, low-/medium-voltage auxiliary transformers, medium-/high-voltage power transformer, SCADA system and grid interface devices for protection and metering systems.

A typical medium-/high-voltage transformer can be, for example, 22/220 kV, 120 mega volt amps (MVA) for a 100 MW power plant.

II.6.2.2.2.5 Medium-voltage switchgear

Medium-voltage switchgear and protection systems should be provided throughout the electrical system to provide disconnection, isolation, grounding and protection for the solar PV power plant. On the output side of the inverters, provision of a switch disconnector is recommended as a means to isolate the solar PV array.

II.6.2.2.2.6 Transformer

Normally, inverters supply power at low-voltage level, and transformers are needed to provide a voltage level suitable for the grid. A low-/medium-voltage transformer is basically necessary to step up the voltage between the inverter and the grid, for example a 0.400/22 kV transformer.

II.6.2.2.2.7 Batteries

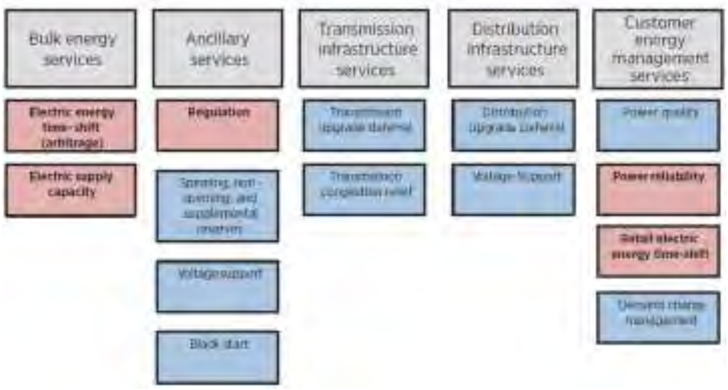
The intermittent nature and wide fluctuations in the availability of solar irradiation mean that provision has to be made to secure a continuous electricity supply, especially in remote and off-grid areas. Especially for distributed generators and consumers, energy storage is mostly more cost-effective than the alternative of grid extension and is indispensable for a power supply system. The need for storage and grid extension increases with the expansion of renewable energy use. The driving force here is not only to provide power back-up when renewable energy is not available, but also to use surplus power to meet the immediate demand rather than letting it go to waste.

Especially for off-grid applications, electrical storage can be applied for the following tasks:

- power shifting from fluctuating renewable energy sources to match the daily load profile
- smoothing out short-term fluctuations of demand
- reduction of operation of peak-load power plants
- back-up system and supply of spinning reserve capacity
- frequency and voltage regulation
- provision of an electrical consumer to prevent reverse current flow into other generation systems
- evening out short-term fluctuations of solar PV supply due to, *e.g.*, passing clouds
- providing short-circuit current
- black start capability
- reactive power compensation.

The IRENA *Battery Storage* report (IRENA, 2015) gives a relevant overview of the current market status and the storage technology. Figure II-32 shows the services that can be provided by energy storage.

Figure II-32: Services provided by energy storage



Source: IRENA, 2015.

There are many storage technologies available. Some are already on the market while others are still undergoing research and development. The most appropriate storage technology depends on various factors and must be investigated for each energy system and application case. A distinction is made between short- and long-term storage. Whereas short-term storage can bridge transitory energy shortfalls of seconds to hours, long-term storage can balance seasonal fluctuations from days to weeks. The variety of storage technologies with all their substantive combinations is almost infinite.

II.6.3 Technical design

The design of a solar PV power plant is the result of a thorough analysis of several technical alternatives. Due to the technology's modularity, project developers have a high degree of freedom to obtain the required voltage and current levels of an array, with various configurations of modules connected in series, parallel or mixed configurations. In almost all cases, solar PV modules occupy the largest area of the plant.

Given the broad variety of module technologies, a thorough technical design is required to determine how many solar PV modules the project requires to match the peak power output, how many solar PV modules shall be connected in strings and how many strings shall be connected to one inverter.

II.6.3.1 Solar PV plant arrangement

Solar PV plants shall be designed according to specific site conditions. Therefore, project developers shall identify at an early stage geological or topographical constraints which might limit the optimal design of the plant. In addition, the plant design must consider infrastructure requirements in terms of roads for construction and maintenance activities and account for an appropriate distance between the solar PV array and the site fence. The design typically should take into account the following aspects:

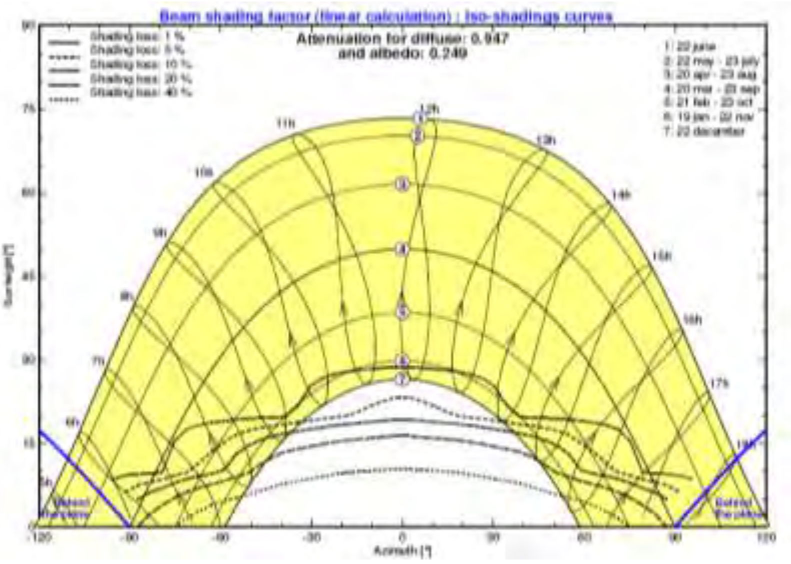
- row distance to minimise internal shading and shading losses
- optimised low- and medium-voltage cable runs to minimise electrical losses
- internal access roads within the plant to assure efficient movement of vehicles for maintenance
- module inclination to optimise energy generation for the specific site by minimising shading and optimising area usage (in some projects the aim also can be to maximise the installed capacity, accepting somewhat more shading in this specific case)
- module orientation to maximise energy generation. Usually, this is to the south (azimuth = 0) in the northern hemisphere and to the north in the southern hemisphere.
- inverter voltage limits, MPPT range as well as safety and grid requirements.

Solar PV plant optimisation

Design software tools usually include algorithms that describe the path of the sun, as shown in figure II-33. This, along with information on module row spacing, can be used to:

- calculate the degree of shading
- simulate the annual energy losses associated with various configurations of tilt angle, orientation and row spacing.

Figure II-33: Sun-path diagram (example for Apulia, Italy)



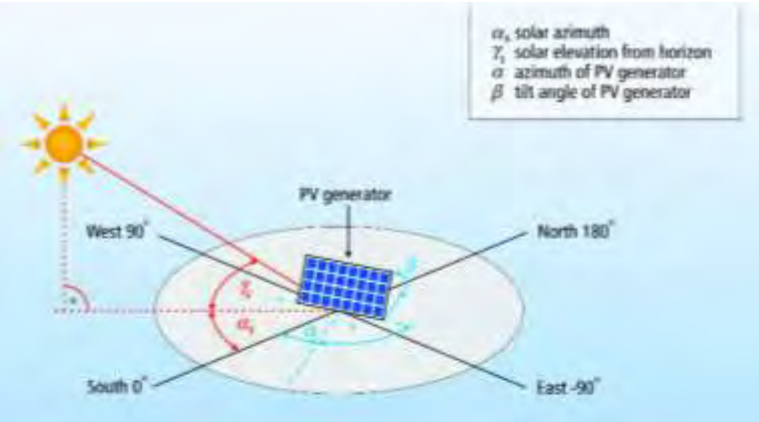
Credits: PVsyst, 2014.

Amongst others, the following software tools are available for simulating solar PV power plants:

- PVsyst, http://www.pvsyst.com/
- Solar PV*Sol, http://www.valentin-software.com/
- INSEL, http://www.insel.eu/
- Greenius, http://freegreenius.dlr.de/index.php.

The orientation of a solar PV system is defined by the azimuth, which is the deviation from south direction: an azimuth of 0° represents south direction (90° west, -90° east).

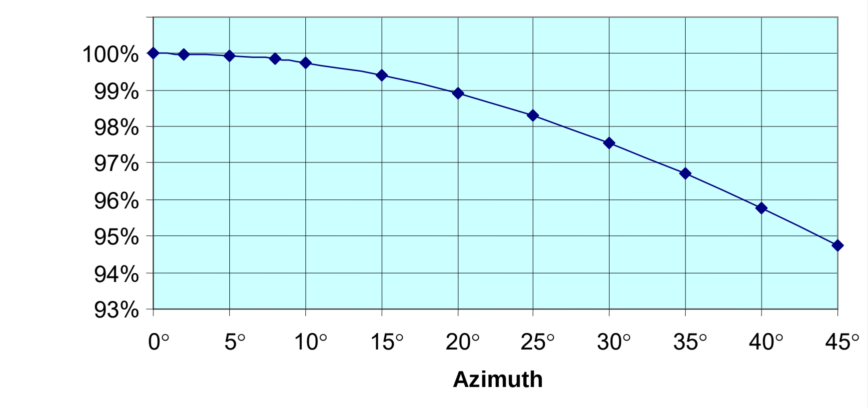
Figure II-34: Different angles used in the solar PV sector



Credits: DGS, 2013.

Figure II-35 shows the losses due to azimuth angles below 20° (east or west) remaining below 1%. Generally in order to minimise losses, solar PV power plants should have an azimuth close to zero.

Figure II-35: Influence of azimuth on energy yield



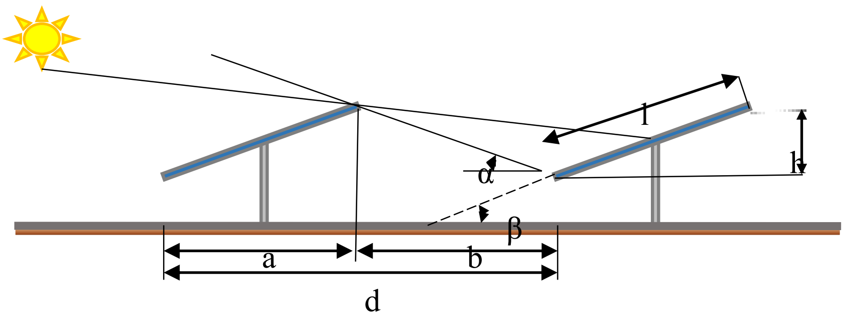
Source: Fichtner, 2014.

Every location has an optimal tilt angle that maximises annual irradiation on the module surface, although other considerations may play a role, such as (IFC, 2012):

- *Soiling* – higher tilt angles have lower soiling losses. The natural flow of rainwater cleans such modules more effectively, and snow slides off more easily at greater angles.
- *Shading* – tilted modules result in more shading on modules to the rear, and a good option is to reduce tilt angle. It usually is better to have a lower tilt angle as a trade-off for loss in energy yield due to inter-row shading.
- *Capacity* – the installable capacity in a solar PV power plant can be maximised, if needed, with lower module tilt angle.

The spacing between module rows is a compromise to reduce inter-row shading while keeping the required area of the solar PV power plant within reasonable limits. Inter-row shading can practically never be reduced to zero: in the morning and in the afternoon, the shadows are very long. Figure II-36 illustrates the different angles that must be considered in the design process.

Figure II-36: Shading angle diagram



The shading limit angle α is the solar elevation angle beyond which there is no inter-row shading on the modules. If the elevation of the sun is lower than α, then a part of the module will be shaded with an associated yield loss. Detailed energy yield simulations can be carried out to assess losses due to shading and to obtain an economic optimisation.

Minimising cable runs and associated electrical losses may suggest positioning a low-/medium-voltage transformer station centrally within the plant while avoiding shading for the modules behind it.

II.6.3.2 Inverter design

The DC/AC ratio (the installed module DC power divided by the AC power of the inverters) is the major criterion for inverter selection. With increasing DC/AC ratio, the potential clipping losses also increase due to undersized inverter power, *e.g.*, at high solar irradiation and low ambient temperature.

DC/AC ratio values of between 1.1 and 1.5 have been seen in the market. A value of 1.1 means that there are enough inverters installed in the plant to convert all the DC energy to AC energy. A comparison is required between the capped (clipped) energy and the investment for additional inverters to avoid clipping losses. Future module degradation also has to be considered, as this reduces the DC/AC ratio over the years.

Other factors for inverter selection are:

- capability to safely withstand the maximum array current
- grid code requirements (supply of reactive power)
- grounding capability
- site temperature and irradiation.

Table II-9 summarises the major criteria to prepare inverter technical specifications:

Table II-9: Inverter selection criteria

Criteria	Description
Project size	Size of the solar PV power plant influences the inverter concept. Central inverters are commonly used in utility-scale solar PV power plants.
Performance	High-efficiency inverters should be sought: the additional yield usually offsets the higher initial cost.
MPP range	A wide MPP range allows flexibility and facilitates design.
Grid code	The grid code affects inverter sizing and technology. The national grid code might require the inverters to be capable of reactive power control or supply. The final inverter sizing depends on it.
Product reliability	High inverter reliability ensures low downtime as well as maintenance and repair costs.
Module supply	Solar PV module specifications have an impact on the inverter concept, *e.g.*, if modules of differing specifications are to be used, then string or multi-string inverters are recommended to minimise mismatch losses.
Maintainability and serviceability	Ease of access to qualified service and availability of parts is an important item to be considered during inverter selection. String inverters do not need access by heavy trucks for transportation and also can be maintained by local personnel.
System availability	The impact on plant operation has to be evaluated during selection: if a fault arises in a string inverter, only a small proportion of the plant output is lost (*i.e.*, from the defective inverter); spare inverters may be kept locally and replacement may be faster. With central inverters, a large proportion of the plant output would be lost until replacement.
Modularity	The possibility of expanding system capacity and flexibility of design should be considered.
Shading conditions	For sites at which shading conditions or orientations vary, string inverters may be more suitable.
Installation location	Outdoor or indoor placement and site ambient conditions like temperature influence the requirements, *e.g.*, ingress protection (IP) rating and cooling system.
Monitoring	Plant monitoring, data logging and remote control requirements define a set of criteria that must be taken into account when choosing an inverter.
Grounding	In some cases, the poles of the solar PV modules need to be grounded to avoid the PID effect. This can be done on the inverter side, so it must allow such grounding.

Source: Adapted from IFC, 2012.

II.6.3.2.1 *Inverter adaptation for desert conditions*

Due to the harsh conditions, with high temperatures, humidity, sand and dust, special measures have to be taken at the inverters for desert regions, mainly:

- Thermal insulation
- Protection against dust, sand and saline air (corrosion).

Regarding thermal protection, the inverters should be capable of working under ambient conditions nearing (or surpassing) 50 °C. This should be verified in the datasheet of the inverter. Additionally, the thermal analysis for the inverter should be reviewed to verify the suitability of the inverter components and their overall integration. Two options are on the market: outdoor inverters and indoor inverters.

Outdoor inverters should be able to operate without any substantial de-rating at high temperatures. Their temperature is regulated by means of passive or forced ventilation. An inverter's ingress protection (IP) rating should be sufficient to avoid direct air flow on sensitive components. IP 54 is commonly applied, although the specification of the IP rating should be investigated in-depth on a case-by-case basis (including IP 65/66 for harsh environment). The IP rating should be sufficient to prevent sand and dust build-up on inverter components.

In the case of desert conditions, indoor inverters are commonly placed inside a transformation centre in a container together with the medium-voltage transformer, switchgear, auxiliary transformers and monitoring system.

For indoor inverters, besides the inverter characteristics, the centre as a whole should be checked regarding integration of its various components.

If a transformation centre is set up, a thermal analysis should be provided by the EPC contractor (or when applicable the equipment supplier) or the container manufacturer confirming that the technical characteristics of the components have been investigated and considered for the design, including air flow requirements, *i.e.*, heat dissipation from inverter and container components; pressure drop; and protection against sand and dust.

For indoor inverters, closed-circuit systems with air conditioning are also on the market. Such systems prevent ingress of dust, sand and moisture. Maintenance of the air conditioning systems and additional electrical load has to be factored in to the cost estimate for design and operation.

Incorrect dimensioning, poor operation or inappropriate selection of components may lead to inverter failure due to excessive temperature or a danger of malfunction through electrical arcing and a fire hazard from dust build-up within the inverter. Various inverters are available on the market suitable for operation in desert-like conditions. However, an in-depth investigation is required on a case-by-case basis for each project.

II.6.3.3 Siting studies

The specific area requirement (m^2/kWp) depends on the module technology and structure selection (fixed mounting vs. tracking).Only sites with sufficient space should be chosen. This would allow the required or expected plant capacity to be installed within an optimised layout without compromising plant performance due to suboptimal row-to-row distance or module inclination.

Depending on the site location and the module type, a solar PV power plant with a capacity of 1 MWp requires between one and two and a half hectares of land (10 000 to 25 000 m^2).

II.6.3.3.1 Local climate

The site should be located in a region with limited extreme weather conditions which could increase the risk of severe damage. In general, a moderate climate with low seasonal variations is preferred. Weather events that may need consideration include:

- *Flooding* – Flooding risk has to be considered in the layout by means of adequate drainage systems. Without drainage, mounting structure and foundations may be prone to erosion and local settlement.
- *High wind speed* – The performance of a solar PV power plant is influenced by wind; wind direction and speed are relevant for annual plant performance and design loads, respectively. Wind gusts are relevant for structural design, *i.e.*, the panel support structure and foundation loads. The likelihood of extreme wind events such as hurricanes or cyclones may require high-strength structural design, which would increase the capital costs. For tracking systems, extreme wind loads (above approximately 40 m/s) may require temporary shutdown for safety reasons, depending on the product specification of the manufacturer.

  Generally, fixed mounting systems are less vulnerable to wind loads in comparison to tracking systems. At high wind speeds, the plant is more vulnerable to mechanical incidents; therefore the tracking systems must adopt safety positions, temporarily reducing the energy production capacity associated with the use of tracking systems. On the other hand, with regard to the impact on module performance, the effect of wind also is advantageous, as wind dissipates high temperatures of the module surface, resulting in higher efficiency of the module.
- *Snow* – In certain regions, snowfall can have a significant impact on the performance of a solar PV power plant. The structural analysis also has to consider additional snow load in the design. Manual removal of snow from the module surface has a cost impact and should be weighed against the lower performance of the plant that is covered with snow. The design of the mounting structure also should consider the typical snow level in the region. Finally, a higher module tilt will result in earlier slipping of melting snow.
- *High temperature* – The efficiency of a solar PV power plant is reduced with increasing temperature, which means that lower temperatures are preferred. Likewise, ambient temperatures and their seasonal and daily profiles are a major influence for annual plant performance. The rated (peak) module output is based on 25 °C as a standard test module temperature, whereas module output rises slightly with reducing temperatures. Solar PV modules can, however, be operated under all ambient temperatures without further operational limitations. Temperature extremes may require technical measures which could make a plant more economic or expensive at one site compared to another site. Examples may be requirements for freeze protection or design temperatures for electrical and instrumentation and control field equipment, for both cold and hot temperatures.
- *Extreme weather conditions* and *special climate* – Some other critical conditions may be taken into consideration and accordingly mitigated; for example, at a site near to the coast, saline air must be taken into account, considering the corrosion risk on metallic parts.

II.6.3.3.2 *External shading*

Shading always leads to irradiation losses on the module surface and thus to yield losses, which negatively impacts the economy of the project.

Besides the internal (or near) shading of the solar PV power plant caused by shading between module rows (which generally is accepted in the economical plant design up to a certain extent), external shading also has an influence on the performance. For this reason, sufficient distances should be kept from shading objects such as trees or buildings. In addition, potential energy losses due to horizon shading such as hills should be considered in the site assessment.

As far as possible the site should be free of major obstacles. Site clearance and removal of trees, bushes or other plants is possible but would mean additional work during site preparation.

II.6.3.3.3 *Topography*

The ideal site for a solar PV power plant is flat. If the site topography is not complex, terrain preparation and civil works can be minimised, leading to lower construction costs.

In the development phase the site is already selected and the topography is known to the developer. The plant layout and the type of mounting structure will consider the site topography

II.6.3.3.4 Geotechnical

The purpose of the geotechnical survey is to analyse the subsoil for proper design of the foundation and the mounting structure.

Generally, it is possible to install solar PV modules on many different types of soils, depending on the correct sizing of the structural elements and on the selection of an appropriate fixing technique. For this reason, prior to the design of the PV plant, it is necessary to carry out a geotechnical survey to clarify the physicochemical properties of the soil and its strata.

The geotechnical survey of the site can be split into the following phases:

- desk study (pre-development)
- geotechnical site investigation for basic design or tendering (development phase)
- geotechnical site investigation and assessment of local pile tests (if required) by the contractor (detailed design phase).

The required level of the geotechnical survey will depend on the structure and planned foundation design for solar PV structures as well as for buildings and equipment, and the calculated loadings.

Table II-10: Common foundation types for solar PV structures

Type	Comment
Rammed/vibrated micro-piles made of steel	Pre-drilling may be required
Ground screws	Pre-drilling may be required
Small diameter drilled and concreted piles	Permit for use of concrete required
Block foundations or strip foundations	Possibly with anchorage in the ground or ballasting

As a minimum, the following site characteristics should be investigated and described by the geotechnical expert:

- groundwater level and its variation over the year and/or influencing by rainfall
- soil properties and geological texture of the site such as soil layers, density, inner friction angles, soil and groundwater aggressiveness to concrete and steel, settlement behaviour, drainage and erosion of the surface.

Based on the results of the local investigations and findings, a report should be prepared. It should express its recommendation for foundation works regarding loads and structure design.

The detailed design of the solar PV structures, buildings and equipment foundations, roads and infrastructure works requires in-depth geotechnical assessment by a specialised consulting firm. The detailed site investigation is usually done by the EPC contractor during the detailed design phase after financial close.

In particular, the foundations for the solar PV racks should be optimised in terms of material use, construction time and machinery required. Depending on the location and site conditions, site access, and the available construction machinery as well as skilled personnel, the foundation type should be chosen and designed in accordance with the loading conditions to be considered.

The required investigation works during the detailed design can be defined after the basic design phase depending on structure design and site conditions.

II.6.3.3.5 Lightning protection

Lightning protection should be applied to all major equipment according to local regulations. Sites with a high solar radiation and air humidity are susceptible to frequent lightning strikes. Therefore, solar PV power plants can be exposed over their lifetime to damage caused by thunderstorms. Plant equipment should be shielded from the destructive effects of a direct lightning strike and inductive/capacitive voltage coupling caused by lightning electromagnetic fields.

Such protection equipment is relevant to protect project workers from any electric shock, fire hazard and lightning damages. For example, charge accumulation during a lightning strike is prevented by linking equipment to the earth.

It should be noted that banks and insurance companies frequently analyse lightning protection measures during due diligence.

II.6.3.4 Site security and fencing

A solar PV power plant is a financial investment with a certain value, and measures to minimise the risk of theft must be taken. Intrusion protection options to take into consideration include:

- fence along the perimeter of the solar PV power plant (*e.g.*, two metres high)
- microphonic cable or optical fibre along the fence
- closed-circuit television (CCTV) security cameras with night and day function and/or microwave barriers
- communication of alarm signal to local police
- anti-theft module mounting bolts or synthetic resin
- alarm system for solar PV power plant gate, low-/medium-voltage cabinets, medium-/high-voltage substation and metering station.

The bankability of a security system depends on the country, the specific location and the requirements from the insurance provider.

II.6.3.5 Cabling

Usually, standard cross-sections of 4 mm^2 or 6 mm^2 are used for the DC string copper cables in solar PV power plants. Besides the requirement for transmitting the maximum current from the solar PV power plant, cable losses should be limited to 1.5% on the DC side and 1% on the AC side. Aluminium is an alternative and more economic material for cables, but some additional measures are required when using aluminium instead of copper cables.

Relevant standards for DC and AC cabling include:

- above 30 kV and up to 150 kV: IEC 60840
- between 1 kV and 36 kV: IEC 60502
- low voltage: IEC 60364.

II.6.3.6 Technical design changes

It is not unusual that, at a later stage, the EPC contractor changes the concept design and components within the allowed framework in order to optimise the layout and the components and to make it bankable, if needed. This also may be a requirement of the lenders after reviewing the Technical and Legal Due Diligences.

Sometimes these changes can have an impact on the overall contract price and the financial model.

Design or component changes can be, for example:

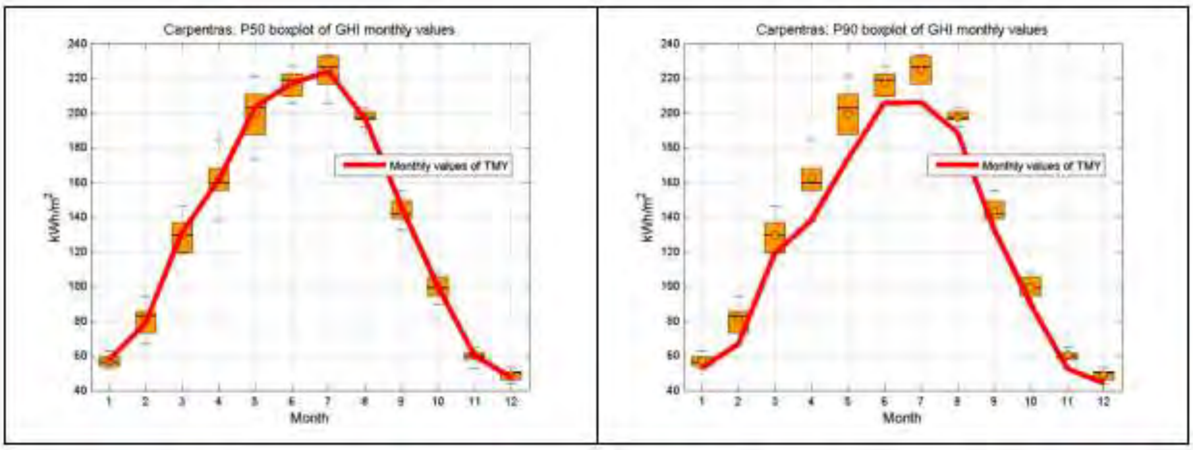
- Problems with the inverter warranties in a developing country require the substitution of the inverter supplier.
- The EPC contractor intends to use similar solar PV modules but with higher power class. This leads to a change of the module-string-inverter configuration.
- A financing party requests a better security system for a certain region; not only a fence but also cameras are now required.
- A minimum distance to a nearby road was not considered, and the EPC contractor has to adjust the layout of the module rows accordingly.

II.6.4 Performance evaluation

II.6.4.1 Solar resource evaluation

Ground-based solar radiation measurement is important for the development of solar PV projects because solar radiation data generated only by satellite sources introduce a bias in the estimation of the site-specific solar resource in terms of instantaneous, average, frequency distribution and statistical representability of solar radiation values. Depending on the approach, the uncertainty of long-term averages can be reduced below 5% for GHI using ground-measured data coupled with satellite data.

Figure II-37: Example of monthly average GHI values



Source: Transvalor, 2015

The objective of the project developer should be the production of a proven site-specific solar resource typical meteorological year (TMY) dataset with low uncertainty in order to align with conservative approaches from lenders.

This TMY file should be a realistic frequency distribution of solar hourly values of solar radiation and meteorological parameters for a one-year period. It should be generated from a dataset longer than a year in duration so that it still provides annual averages that are aligned with long-term averages provided by satellite data. In addition, the project developer also should be able to generate P75, P90 and P99 datasets in which solar radiation values would be exceeded in 75%, 90% and 99%, respectively, of all years to prepare financial model stress cases.

II.6.4.2 Energy yield evaluation

II.6.4.2.1 Yield evaluation methodology

An important step in assessing PV solar projects is to determine the expected amount of energy (kWh) generated by the solar PV power plant.

For a higher level of accuracy in yield estimations, special simulation tools are available and can be applied to specify the design of the plant. To increase the accuracy of the calculation, other information and parameters are needed, such as:

- long-term weather data with GHI and ambient temperature: TMY
- technical datasheets of main components: solar PV module, inverter, transformer, tracking system (if applicable)
- system layout and design
- loss factors: *e.g.*, degradation, shading losses, cable losses, transformer losses, soiling losses, own / auxiliary consumption.

Usually, the procedure to simulate a PV power plant with this software consists of the steps outlined in figure II-38.

Figure II-38: General procedure for energy yield prediction

Sourcing climate weather data, mainly ambient temperature and solar irradiation, which are satellite-based or from a meteorological station in the area of the site

⇩

Calculating the POA irradiation

⇩

Simulation of the energy production for each time stamp for a given irradiation and temperature

⇩

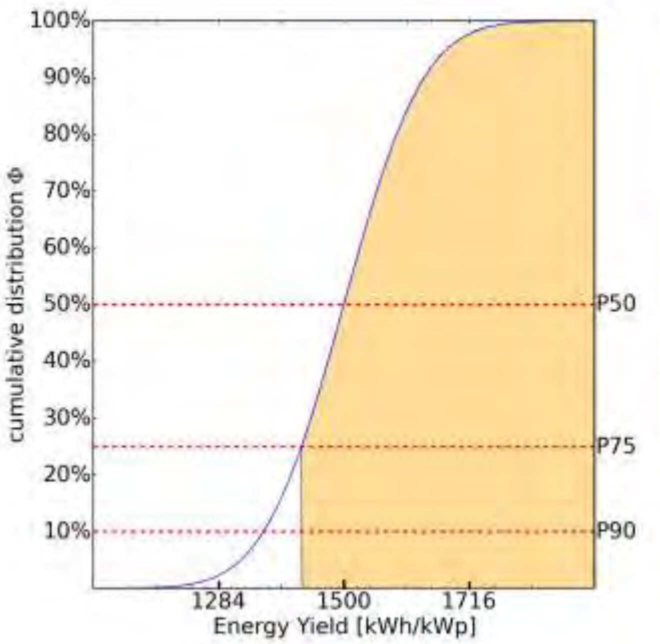
Applying the uncertainty of the input values to determine the final value of the energy production estimation

As per the first point in figure II-38, it is necessary to have a clear picture of the expected solar irradiation at the site, as it is the key driver for the operation of the plant. For this, long-term historical and site-specific solar data will be reviewed. Usually this is the GHI.

Together with the simulation results, assumptions for module degradation, and uncertainty analyses, a final energy yield prediction is obtained with an appropriate level of uncertainty. The results of the statistical analysis are the so-called P-cases (probability cases).

The P50 value is the yield without considering and deducting any uncertainty. In this case the likelihood is 50% that the expected value will be exceeded, as shown in figure II-39 (1 500 kWh/kWp). In the P75 case it is 75% probable that the value will be reached (and only 25% that it will not be reached). Consequently, the P75 value is lower than the P50 value. The usual P-cases considered by lenders are P50, P75, P90 and P99. In addition to these P-cases, lenders also apply so-called downside scenarios to consider potential overestimation of solar irradiation and electricity generation.

Figure II-39: Cumulative distribution of the probabilities



There are no general requirements for a minimum energy yield from lenders, but their minimum expectations for a return must be at least met or exceeded.

II.6.4.2.2 Performance ratio

The key parameter for evaluating the performance and quality of a solar PV power plant is the performance ratio (PR). The PR is the ratio of total energy yield to the theoretically available energy, and it gives an indication of the quality of the installation and the weather conditions. It can be considered as the relationship between the effective and the theoretical electricity generation of a solar PV power plant. The PR may be calculated as follows:

$$PR = \frac{AC\ Yield\ [kWh]}{Installed\ Capacity[kWp]x\dfrac{Irradiance\ on\ module\ plane\ \left[\frac{kWh}{m^2}\right]}{STC\ Irradiance\ \left[\frac{kW}{m^2}\right]}}$$

This parameter identifies the overall impact of losses on the rated output. As it is normalised with respect to irradiation, this allows comparison of solar PV power plants in different locations.

The higher the PR, the more efficient the solar PV power plant is, which means basically that more energy is obtained from solar irradiation.

The PR is determined by measuring the solar irradiation on the module plane and the AC energy yield. Usually the ambient and module temperature also are logged to allow temperature adjustment of the PR calculation. During project development the PR is predicted using different modelling software. Usual PR values for new solar PV systems vary from less than 75% in summer to more than 82% in winter.

Performing the energy yield analysis allows evaluating the average annual energy output for the entire lifetime of the solar PV power plant in order to predict revenues for input to the financial model:

INPUT:

GHI = 1 300 $\frac{kWh}{m^2}$, increase of irradiation in module plane: 10%, PR = 78%

OUTPUT:

Yield = $PR\ \times\ Irradiance = 78\%\ \times\ 1\,300\ \times 1.1 = 1\,115\frac{kWh}{kWp}$.

II.6.4.2.3 Capacity factor

Another important key parameter is the capacity factor (CF), which is the ratio of the yearly energy generation and the theoretical generation if it had operated at rated power the whole year:

$$CF = \frac{Energy\ generated\ per\ year\ [kWh]}{8\,760\ [hours]\ x\ Installed\ Capacity[kW_p]}$$

Capacity factors for a fixed solar PV power plant are in a range of 10% to 20% depending on the location of the plant.

To give an example: in northern Europe a solar PV power plant with a capacity of 1 kWp could generate 1 000 kWh per year, so its CF works out to 1 000 / 8 760 = 11.4%. In the regions with higher solar irradiation, this value could be almost twice as high.

The specific yield is the annual energy divided by the installed capacity: in this example 1 000 kWh/kWp.

II.6.5 Permits, licences and authorisations

II.6.5.1 Environmental studies

A thorough environmental study is required to obtain almost all authorisations for the development of a solar PV power plant. A distinction has to be made between the need for an Environmental Impact Assessment (EIA) or an Environmental and Social Impact Assessment (ESIA), according to the applicable national environmental legislation of the project country and the requirements of the international financing institutions, which may differ from the legislative requirements.

II.6.5.1.1 Environmental guidelines

Applicable environmental guidelines are established, for example, by the World Bank or the International Finance Corporation (IFC), or by specific banks themselves, for example the European Investment Bank (EIB) or the European Bank for Reconstruction and Development (EBRD). The Equator Principles[2], adopted by several international financing institutions, should be taken into account.

Table II-11: Environmental and social standards

Standard	Source
IFC – International Finance Corporation	http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/our+approach/risk+management/performance+standards/environmental+and+social+performance+standards+and+guidance+notes
World Bank	http://documents.worldbank.org/curated/en/2014/07/19898916/environmental-social-framework-setting-standards-sustainable-development
EIB – European Investment Bank	http://www.eib.org/infocentre/publications/all/environmental-and-social-standards-overview.htm?lang=en
EBRD – European Bank for Reconstruction and Development	http://www.ebrd.com/what-we-do/strategies-and-policies/approval-of-new-governance-policies.html
Equator Principles (EP III)	http://www.equator-principles.com/

[2] The Equator Principles is a risk management framework, adopted by financial institutions, for determining, assessing and managing environmental and social risk in projects and is intended primarily to provide a minimum standard for due diligence to support responsible risk decision making (Equator Principles, 2015).

II.6.5.1.2 *EIA scoping*

Most commonly, an EIA study will be preceded by environmental, or EIA, scoping. The scoping process has two objectives:

- to inform stakeholders about the proposed project, whether potential site-specific impacts are expected to be of minor, moderate or high significance, and the scope of work required for the EIA study
- to inform the project developer:
  - of possible environmental or social objections to the planned project
  - of previously unknown significant site conditions and the resulting adjustments of the proposed scope of work for the EIA.

Preparation of the scoping document, as the basis for the scoping session, involves meetings with stakeholders, people affected by the project, NGOs, etc. This must be undertaken by the project developer.

In many cases, the entire scoping process and environmental impact study application process together with their time frames is laid down in the environmental legislation.

An appropriate result of a scoping session and process is mutual agreement on and understanding of the EIA content and the corresponding scope of work between all involved parties.

In some cases, the scoping document is called "Preliminary Environmental Impact Assessment" with a similar content. However, as already noted, it is essential to discuss the entire environmental permit approval and EIA implementation process with the competent authority during the project identification process.

II.6.5.1.3 *Environmental Impact Assessment*

The following section addresses primarily international EIA requirements as implemented by the World Bank and the IFC. Specific national requirements vary from country to country and therefore should be investigated specifically.

The extent, duration and scale of an EIA depend on:

- the ecological value and importance of the chosen project location
- the size of the proposed project and resulting need for additional infrastructure, such as transmission lines, access roads, etc.
- the requirements under environmental legislation
- how EIA execution fits in the overall project schedule.

The final item – how EIA execution fits in the overall project schedule – may be of major importance. Should specific ecological investigations be required and the start of the EIA is scheduled to occur during the winter, EIA execution overall will delay project development. Additionally, it may be the case that, under authority requirements, the ecological investigations have to consider a full vegetation period. This aspect supports the recommendation to co-ordinate the environmental and EIA requirements in close consultation with the competent authority and to consider the need for environmental and/or EIA approval right from the start in the project development schedule. It also may be required that, for example, a noise assessment must use specific calculation software approved by the competent authority.

Such specific requirements entail a risk of project interruptions or delays, and they should be taken into account during the project development steps, at least as possible worst-case scenarios.

EIA of Category A according on World Bank standards

These EIA requirements set out the content and scope of work applicable to Category A projects. The definitions for Category A, B, C and D projects may be obtained from *World Bank Operational Manual 4.01*. Should a project be categorised as B or C, the required content and scope of work may differ from the below. In this case, the scope will be jointly agreed between the project developer, the competent national authority and, if financiers are involved, the requirements of the financing institutions.

Close co-ordination with the competent authority is recommended. Generally, an EIA of Category A must contain the following content based on *World Bank Operational Manual 4.01* – Appendix B (World Bank, 2015):

- *Executive summary:* Provides a concise description of significant findings and recommended actions.
- *Policy, legal and administrative framework:* Discusses the framework within which the EIA is carried out; explains the environmental requirements of any co-financiers; identifies relevant international environmental agreements to which the country is a party.
- *Project description:* Provides a concise description of the project and its geographical, ecological, social and temporal context, including any offsite investments that may be required; indicates the need for a resettlement plan or indigenous peoples development plan; normally includes a map showing the project site and the project's area of influence.
- *Baseline data:* Assesses the extent of the study area and describes relevant physical, biological and socio-economic conditions, including any anticipated changes before the project commences; takes into account current and proposed development activities within the project area but not directly connected to the project; data should be relevant to taking decisions on project location, design, operation or mitigation measures; indication of accuracy, reliability and sources of data.
- *Environmental impacts:* Predicts and assesses the project's likely positive and negative impacts in quantitative terms as far as possible; identifies mitigation measures and any residual negative impacts that cannot be addressed; explores opportunities for environmental enhancement; identifies and estimates the extent and quality of available data, key data gaps and uncertainties associated with predictions as well as specific topics that do not require further attention.
- *Analysis of alternatives:* Systematically compares feasible alternatives to the proposed project site, technology, design and operation – including the "without project" situation – in terms of their potential environmental impacts; the feasibility of mitigating these impacts; their capital and recurrent costs; their suitability under local conditions; and their institutional, training and monitoring requirements; for each alternative, quantifies environmental impacts as far as possible and attaches economic values where feasible; states the basis for selecting the particular project design and justifies recommended emission levels and approaches to pollution prevention and abatement.
- *Environmental Management Plan (EMP):* Covers mitigation measures, monitoring and institutional strengthening measures (for detailed EMP requirements, see *World Bank Operational Manual 4.01* – Appendix B).

II.6.5.1.4 Public consultation

Financing institutions as well as national legislation frequently introduce a public consultation process in the permitting process. Therefore, attention has to be paid to project-affected people, and their objections and concerns have to be considered. If public participation is mandatory, various consultation steps are initiated throughout the project implementation process, most commonly during the project scoping process and after completion of the draft EIA. The specific requirements can be obtained from the competent authority for further consideration. It should be borne in mind that the entire public consultation process and its extent could be time-consuming and have a major impact, depending on the project location and the number of affected people.

II.6.5.1.5 Equator Principles compliance statement and environmental due diligence

The compliance statement is based on the Equator Principles together with IFC performance standards.

II.6.5.2 Land-use change authorisation

At this stage the land is already selected, and it is necessary to obtain as soon as possible final confirmation from the local authority for the expected land use, if required. The project developer should prioritise the use of land with the lowest value possible, such as landfills or polluted lands or equivalent. When this is not possible, an agricultural site could be considered with regard to previously mentioned criteria such as solar resource potential or infrastructure availability. The project developer therefore should obtain from the local authority a permit to be authorised to change the land use at the specific location. This land-use change often is a time-consuming process because of cadastral requirements within municipalities.

Close collaboration with local authorities is required to obtain the most favourable permit process and to avoid a specific project from being side-tracked due to long administrative procedures. In addition, the land owner has to decide if he/she will sell or lease the land.

II.6.5.3 Building permit

Building permits are a key authorisation to obtain during the development phase. The project developer should outline in an extensive manner the foreseen technical, environmental and social impacts of the solar PV project to enable the authorities to evaluate the relevance of the project in light of existing regulations.

Supporting documentation can include a detailed solar PV plant layout with clear indication of the total occupied area, local land zoning, environmental protected zones, site access protocols, distance to grid connection point, etc. Local authorities are likely to assess structural designs, including mounting structures if concrete reinforcement is required to accommodate the additional weight of solar PV module structures.

Construction activities and site access impacts also should be assessed. Some restrictions may apply within specific locations including historic districts to preserve aesthetic harmony or sites in close proximity to airports. Before a building permit is obtained, the project developer should have obtained all pre-requisite licences/permits including land-use change when applicable.

Early-stage consultation with the relevant authority is recommended to evaluate permit requirements.

II.6.5.4 Grid connection authorisation

The following items should be investigated regarding the grid connection point due to the impact on the overall costs:

- requirements of the grid operator and compliance with the national grid code
- available capacity at the grid connection point
- available voltage level at the grid connection point
- route and distance between the nearest suitable grid connection point and the solar PV power plant
- equipment available at the grid connection point.

The responsible grid operator (utility) defines the requirements for the solar PV power plant's grid connection. Depending on the size of the solar PV power plant, a separate substation for grid connection may be required and should be provided by the solar PV power plant: due to the impact on the costs of the project, these requirements have to be evaluated during the development phase.

The grid code compliance study should be studied by the grid operator or solar PV power plant. Therefore, the selection of the grid connection point can be defined only jointly with the grid operator.

Depending on the available route and considering the local requirements, the solar PV power plant can be connected via an overhead line or an underground cable. Additionally, the social impacts on routing through different areas may have an impact on site selection; this should be investigated in more detail during line routing survey at the site.

The preferred connection point is in the substation behind the medium-/high-voltage power transformer.

II.6.5.5 Operation licence

In some countries, the need to obtain an operation permit might arise due to existing regulations imposed on the operation of the solar PV power plant in specific grid configurations. The purpose of the operation permit is to provide local authorities the assurance that the overall solar PV power plant complies with all local requirements that the utility may impose on power generation stations to operate the grid network in a proper way and deliver electricity to its customer.

Therefore, the operating permit shall be planned at an earlier stage, but some administrative processes may require that the actual plant has been built and commissioned and verify by public technical offices with regard to compliance to electrical codes.

II.6.6 Preliminary economic and financial evaluation

II.6.6.1 Project cost estimation

The project developer should be able, with studies and documentation prepared during the pre-development phase, to prepare a cost estimate report for the total plant. Typical costs include, among others:

- cost of plant equipment
- on-site facilities and infrastructure costs (workshops, temporary and permanent offices, access roads)
- direct and indirect labour costs required for development, design, procurement, construction and operation activities
- detailed design, contractor permitting, and construction management costs
- owner's costs
- interest during construction.

The project developer also should discuss with stakeholders about project contingencies that are unknown during pre-development due to a lack of complete project definition and engineering. Estimating these contingencies relies on developers' and contractors' experience because they cannot be determined at the time the cost estimates are prepared. They typically include:

- Change in scope (*i.e*., adding more modules or change in foundation type)
- Labour productivity (*i.e*., accounting for seasonal effects or contracting approach)
- Procurement delays due to design changes or shipping issues
- Unforeseen cost escalation.

II.6.6.2 Preliminary financial modelling

Once design and cost estimates have been prepared, the project developer should prepare a draft financial model to initiate early discussions with potential investors and lenders even though not all parameters have been secured.

The project developer should include key assumptions including development, construction and operation cost estimates (with *pro forma* payment schedule), energy yield values including performance ratio, PPA price and escalation, and preliminary financing terms. The draft financial model should be able to calculate cash flows and main indicators such as project internal rate of return (IRR), equity IRR and debt service coverage ratio (DSCR) and provide an early sensitivity analysis for the main parameters.

II.7 Development

II.7.1 Development criteria

During the final project development phase, all activities previously performed under multiple tasks and in different steps will be finalised with the aim of reaching financial close. The main tasks are:

- Completion of detailed engineering and technical dossier documentation
- Completion of EIA report
- Co-ordination of final permit application steps with regulatory authorities
- Decision on approach to contract strategy, *e.g.*, EPC turnkey contract
- Benchmarking all main equipment, suppliers and contractors
- Co-ordination of EPC and O&M tendering processes
- Contract negotiations with OEM suppliers and/or EPC and O&M contractor, etc.
- Finalisation of financial model, including final evaluation of energy yield and project returns
- Evaluation and mitigation of major project risks
- Co-ordination of lender's technical and legal due diligence.

In addition, with these main tasks and with the same importance, the following agreements must be finalised:

- land lease agreement (LLA)
- power purchase agreement (PPA)
- grid connection agreement.

The development phase, as analysed in detail in the previous sections and provided as a guide, is the crucial part of the whole process during which final decisions are taken affecting the solar PV power plant performance. The following actions, questions and deliverables should be the focus of this stage, as outlined in this section:

Bankability guidelines for financial close

Key actions

- Finalisation and execution of pending studies
- Submission of final permit applications to the authorities
- Completion of bankability checklist (see Appendix IV.4)
- Co-ordination of technical and legal due diligence with independent advisors representing the financing parties.

Control questions

- Are there any new requirements (permits, environmental, grid) to be considered?
- Have you identified potential financial or economic incentives with relevant community stakeholders?
- Have you agreed with the lender's advisors on the final yield report and addressed all potential issues?
- Is the project bankable (feedback from technical and legal due diligence), and, if not, what needs to be done and will it affect the financial model?

Key deliverables

- Final version of all engineering studies
- Finalisation of all permitting, authorisation and licensing processes
- Bankability report
- Input report for technical and legal due diligence
- Data room with all required information from lenders.

Contracting approaches

Key actions

- Analysis of contracting terms with regard to project structure (*i.e.*, performance guarantee requirements imposed by lenders)

Control questions

- Have you identified all risks and rewards of each contracting alternative?
- Are you comfortable with the complexity of the chosen contracting approach?
- Is the contracting approach in line with your partners' expectations?

Key deliverables

- Report on contract approach recommending the best approach to work with contractors

Contractual agreements

Key actions

- Preparation and negotiation of all contracts (EPC, O&M, LLA, grid connection, PPA)

Control questions

- Have you issued full tender documentation to potential contractors with clear technical definitions?
- Have all contracts' scope of work been clarified with your contractors?
- Have you agreed on the level of performance bonds or guarantees in your term sheets?
- Are project milestones (commissioning, Provisional Acceptance Certificate (PAC), Final Acceptance Certificate (FAC), etc.) well-defined and understood by the contractors?
- Are all test protocols well-defined and reflecting industry best practices including performance ratio (PR) test protocols at different project milestones?
- Have you agreed on liquidated damages with all contractors, satisfying financial partners' expectations in case of non-performance?
- Have you agreed on a defects warranty period covering at least the time between provisional and final acceptance?
- Have you considered potential consequences of delays in the project and are you prepared to cope with/manage them if necessary?
- Are the PPA terms of payment in line with the level of debt service required by lenders?
- Are you comfortable with the provisions included in the PPA regarding minimum annual electricity generation?
- Are you comfortable with the provisions included in the PPA regarding payment schedule?

- Are you comfortable with the provisions included in the PPA regarding penalties in case of unavailability of the grid and subsequent curtailment?
- Did you prepare an adequate management contract for your development fees?
- Did you align contractual terms across all agreements (loan, equity, debt, offtake)?

Key deliverables

- Signed LLA
- Signed or pre-agreed PPA
- EPC term sheet signed and all terms and conditions agreed
- O&M term sheet signed and all terms and conditions agreed

Detailed financial model

Key actions

- Alignment of detailed financial model with stakeholders' financial model
- Validation of detailed financial model with financing parties

Control questions

- Have you finalised the financing structure of the project?
- Have you had advanced discussions with investors and lenders regarding the financial model?
- Are all models converging to the same values?
- Did you prepare a clear sensitivity analysis for key parameters and perform stress tests with P90/P99 profiles?

Key deliverables

- Detailed financial model

Project risk identification and mitigation

Key actions

- Review of project risks during technical due diligence with financing parties
- Finalisation of insurance policies for construction and operation

Control questions

- Have you issued and discussed with stakeholders a detailed risk register with quantification (probability, severity) and associated risk mitigation?

Key deliverables

- Risk register detailing all potential risks and any mitigation measures in place
- Signed insurance policies

II.7.2 Bankability and financial close guidelines

Bankability is formally achieved when the project IRR is higher than the cost of capital. However, each lender and investor has its own criteria to judge a project as bankable or not with general and specific bankability requirements. During the development phase, bankability aspects concentrate mainly on general bankability requirements. The final bankability comes along with the specific bankability requirements and the results of the financial model that must be in line with the expectations of investors and lenders:

- General bankability requirements that are taken into account during project development include project risk assessment and mitigation, and completeness of documentation.

- Specific bankability requirements that are closely evaluated relate to the different project agreements, including, among others, land lease agreement, PPA, EPC contract (including module supply agreement), O&M contract, etc.

The main general information requirements for the bankability of a typical solar PV project are shown in the checklist in Appendix IV.4. The developer can use this list as a guideline for the different phases of a project. It includes an overview, as follows:

- Project description with general information
- Technology
- Plant location
- Project contracts
- Permits including grid connection
- Investment and financing
- Technical and legal due diligence.

The following are examples of the usual "specific" bankability criteria for solar PV modules:

- Successful references of realised projects all over the world (track record)
- All certificates are in place and valid
- Solar PV modules have experienced no PID and are independently tested and certified
- Warranty conditions are at least market standard.

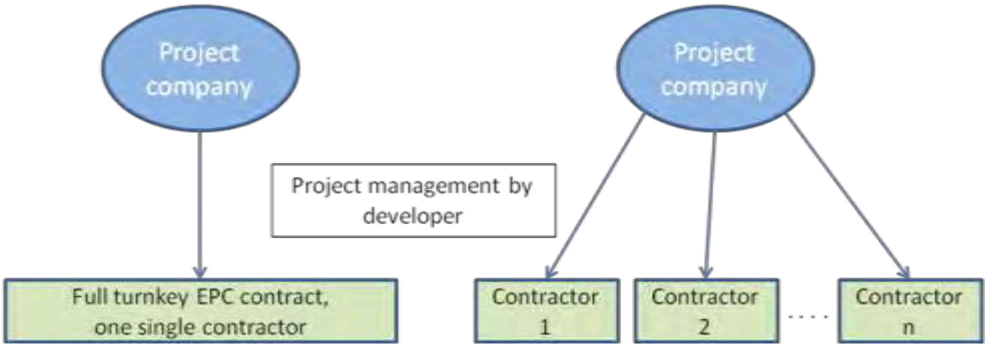
Similar criteria apply for inverters and other components. With regard to the EPC contractor, the main bankability criterion is the availability of a strong track record with successful references of similar size and in a similar region/climate, experience in the sector with appropriate financial strength and company size. At that stage, the EPC contractor is usually selected and potential changes proposed by the EPC contractor are considered in the project, for example changes in the plant layout, components, guarantees or test procedures.

Investors and lenders typically require a technical and legal due diligence before the start of the construction. They are the final steps towards the confirmation of the bankability of a project.

II.7.3 Contracting approaches

From a project developer's perspective, construction project management for a full turnkey EPC contract will significantly reduce project risk implementation, although a multi-contract approach gives the developer greater control over the final plant configuration. Figure II-40 shows two possible contracting alternatives. However, financing institutions usually prefer one turnkey EPC contract, as the overall responsibility lies with the EPC contractor and there are no interfaces that could lead to additional problems.

Figure II-40: Management in single- vs. multi-contract approach



Contractor 1 could be for the supply and installation of modules, Contractor 2 electrical cabling, Contractor 3 civil works, etc.

II.7.4 Contractual agreement guidelines

This section focuses on the five main agreements that need to be negotiated and closed in a utility-scale solar PV power plant project.

Table II-12: Main contractual agreements in a solar PV project

Type of agreement	Parties	Duration
Land lease agreement	Land owner and project owner to secure the land	Project lifetime (usually 20-30 years)
PPA	Project owner and utility to sell the energy	Project lifetime (usually 20 years)
EPC contract	Project owner and contractor for plant construction	Until final acceptance (usually 2-5 years)
O&M contract	Project owner and operator for plant operation	Project lifetime, with termination clauses
Module supply agreement	Project owner/contractor and module supplier	Guarantees should extend to the project lifetime (usually 20-30 years)

II.7.4.1 Land lease agreement (LLA)

The land lease agreement should be closed at an early stage of the project development. Without the secured land the project development risk remains very high. The agreement should contain an optional contract termination in case the project cannot be realised as planned. Sometimes the land owner prefers to sell the land by means of a land purchase agreement instead of leasing it to the developer. In the case of private owners, it is common practice to secure the land with an option-to-buy/lease contract, before the authorisation process. This secures the land for the project with an option to terminate if authorisation is refused or in case of other impediment.

Typically, the land is secured by means of a lease contract, the duration of which is normally bound to that of the feed-in tariff and/or PPA. It is possible that the lease fee for the entire estimated lifetime of the plant will be higher than the sales price. In such a case, the land also can be secured by means of a sales contract. In this case, additional taxes may be applied and these should be taken into account in the business model, together with the resale fee to be recovered upon expiration of the FiT and/or PPA. For plants to be realised on public land, the land securing process can vary depending on national laws and local regulations. It also may vary depending on who the applicant is, *i.e.*, a private individual or public authority.

Table II-13 summarises key criteria that have to be taken into account when finalising a lease agreement for a ground-mounted solar PV power plant.

Table II-13: Key terms and conditions guidelines in a land lease agreement

LLA item	Description
Parties	Detailed description of all parties involved (all owners, etc.).
Property	Detailed description of each owner of the real property (previously verified by legal due diligence) with all references (cadastral identification).
Land identification	Identification and specification of the only part of the property (or the entire property if this is the case) involved in the solar PV solar project, including the connection run (evacuation line) to link to the grid connection point.
Term of agreement	Detailed description of the purpose of the agreement, which means, by definition, detailing all the activities the developer/project company (SPV) intends to carry out on the property: • site access • site and land facilities (*e.g.*, water) • construction activities, installing some equipment on the ground (*e.g.*, solar PV modules, inverter cabinets) and other equipment underground (*e.g.*, conduits, cables) • maintenance activities during operation.
Duration	Basically, the agreement lasts 20-30 years or more depending on the regulations in force country by country.
Termination clause	• Initial conditions under which the developer/project company (SPV) may terminate the agreement without any liquidated damages (*e.g.*, failure to obtain permits or authorisations). • Final conditions under which the developer/project company (SPV) may terminate the agreement by paying liquidated damages (*e.g.*, failure to obtain financial close).
Liquidated damages	Fixed amount usually based on the yearly fee plus removing all equipment installed on-site up to that moment and leaving the land in its original condition.
Fees	One-off or on a yearly/monthly basis.
Milestone payments	• Down-payment upon signature (usually corresponding to a few monthly fees) • Yearly or monthly basis.
Deposit	Normally fixed as one or two years′ fee, or secured by "bank guarantee".

II.7.4.2 Power purchase agreement (PPA)

A PPA is a contractual agreement that secures the revenue generation of the project's business plan by defining the terms and conditions of the selling of a specific amount of electricity generated by the solar PV plant. The PPA governs the relationship between the offtaker and the project company in defining important parameters such as main milestones (*i.e.*, commercial operation date or COD), schedule for delivery, payment terms, liquidated damages, termination. The seller is the project company and the buyer is typically a utility.

PPAs are appropriate when a project developer is looking to:

- guarantee the projected revenues of the project, agree on purchased quantities and price paid required to make the project viable
- shield the project from cheaper or subsidised domestic or international competition (*e.g.*, a neighbouring power plant is producing power at a lower price)
- reduce the volatility of energy costs of a given offtaker by providing a fixed price during a determined period (World Bank Group, 2016).

Below are stated key items (terms, milestones, activities) to be addressed in a PPA for a solar PV plant:

Table II-14: Key terms and conditions defined in a PPA

PPA item	Description
Scope	Delivery and sale of the energy as well as the takeover and purchase of the energy output by an offtaker.
Term	A PPA enters into force on the effective date and remains in place for a given period to be decided between the purchaser and the project company starting from the COD of the plant. In the case of *force majeure* events, an extension may be considered; by consequence the tariff on calculations must be adjusted accordingly.
Conditions precedent	"Conditions precedent" are conditions that must be satisfied before the commencement of the PPA, providing a common understanding of the project requirements before the commissioning. These conditions include the granting of all necessary project permits (IFC, 2015), receipt of all necessary governmental authorisations, the entry into force of an O&M agreement, a secured grid connection agreement, and the issuance of a Provisional Acceptance Certificate (PAC) by relevant authorities. In the case that these conditions are not met, the offtaker has the right to terminate the agreement without liability.
Electricity tariff	Certain mechanisms can be used to calculate the tariff, a FiT regime where a flat-fixed rate price is agreed for the life of the project. Alternatively, the tariff also may be set through a reverse auction, negotiated on power market parameters (*e.g.*, marginal cost of power supply), or it can be adjusted based on an index that reflects annual inflation and foreign exchange fluctuations. The methodology for calculating the electricity price should depend on the market within which the project is operating and the prevailing regulatory regime (IFC, 2015). It is recommended to perform a preliminary market assessment considering: • Market-based instruments which could contribute to the developer's revenue (*i.e.*, renewable energy credits (RECs)). • Potential for revision of negotiated tariffs, such as if the government decides to revise the tariffs retroactively (uncommon but has occurred) or the offtaker asks for re-negotiation.

PPA item	Description
Third-party sales	A third party can be included as a purchaser in the presence of excess capacity which is not being consumed by the offtaker. Then the power can be sold to a third party under a negotiated agreement.
Obligations to provide contract capacity and electrical output	The project company should commit to provide the offtaker the agreed power capacity at the negotiated price not later than the specified COD under the terms of the PPA.
Obligations to pay for available capacity and electrical output	The method of payment, currency, tariff and inflation adjustment have to be agreed by the PPA parties. Any late payments can come along with an interest rate; this can be based on the inter-bank rate for the monetary market published by the central bank of the country (CLDP and ALSF, 2014).
Obligations of the project company for maintenance and repair	The project company should, throughout the term, maintain and repair the facility according to the initial performance specifications as described in the operating characteristics. These characteristics can be adjusted depending on each site climatic conditions.
Liquidated damages	The PPA provides a compensation mechanism for the damages suffered by the offtaker if the benchmarks set forth are not satisfied. The parties agree on a shortfall in the output taking as a basis the expected performance, this shortfall shall be multiplied by a price (per MWh or otherwise) leading to an agreed index for the monetary value of the required compensation defined as "liquidated damages". Additionally the PPA may account for an assumed value of the environmental attributes. Normally the amount of liquidated damages is estimated once per year; the project company should pay or also can credit the damages against amounts owed by the offtaker (Stoel Rives LLP, n.d.). *Damages for delay*: The project company may be required to pay the offtaker liquidated damages when a date deadline is not accomplished; a negotiated amount shall be given per day up to a cap. The payable amount can increase after a specified number of days on the delay. If the delay causes are not in the project company's control, then it should not be required to pay liquidated damages (Kerf, 1998). *Damages for underperformance*: If the project company fails to meet the performance agreed, underperformance damages are payable to the offtaker. Minimum availability thresholds are agreed between the parties; in the case of a failure the offtaker shall not pay for capacity that is not available, accounting for the liquidated damages for this event (CLDP and ALSF, 2014).
Performance security	The project company shall furnish to the offtaker a monetary performance security in the form of an irrevocable and unconditional letter of credit from a reasonably acceptable bank to the offtaker. The quantum of the performance security shall remain fixed until the COD and shall be reduced on the COD and thereafter be maintained at such value until the expiry of the term.
Decommissioning security	The project company shall submit to the offtaker a decommissioning plan with an estimate of the decommissioning costs. The decommissioning security shall be an irrevocable letter of credit from a bank reasonably acceptable to the offtaker. All costs, fees, expenses or other disbursements relating to the decommissioning security shall be borne by the project company. The decommissioning security shall be returned to the project company upon satisfactory decommissioning of the facility.
Termination	In the case that the PPA is terminated, or otherwise becomes unenforceable, the project company shall cease to have a reliable source of revenues.

PPA item	Description
	The agreement can be terminated by several events such as *force majeure*, failure to fulfil conditions precedent, failure to meet payment obligations, failure to achieve financial close or commercial operation dates, project foreclosure, etc. (World Bank, 2008). The rights and obligations governing the relationship between an offtaker and the project company during termination can be defined as put and call options (CLDP and ALSF, 2014): • *Put option* is a right held by the project company to require the offtaker to purchase either the power plant or the outstanding shares in the project company at a pre-agreed purchase price. • *Call option* is a right held by the offtaker to require the project company to sell either the power plant or the outstanding shares in the project company to the offtaker at a pre-agreed purchase price.

Table II-15: Key activities defined in a PPA

PPA item	Description
Performance tests	Performance testing of the solar PV plant is required in order to verify the proper operation of the plant according to its design and contractually agreed performance values. A notice in advance shall be given to the offtaker so nominated experts can participate and witness the tests performed with transparent standards and suitable testing equipment. Certificates should be issued with the test results and be presented as one of the requirements for the plant completion milestone. Thereafter, if the plant performance is lower than the measured output, the project company could be liable for the resulting losses (CLDP and ALSF, 2014).
Operation activities	In addition to obligations related to the sale and purchase of the power generated, the PPA also shall set out the output and O&M specifications for the power plant. The project company and the offtaker shall, during the term, operate the facility and the electrical grid in a manner that complies with the laws of the country, the system grid code, all government authorisations, the operating procedures and prudent offtaker practice. *Notification*: The project company shall keep the offtaker informed by prompt notification of any event that could reasonably be expected to materially and adversely affect the availability of energy output, and of any material change to the operating characteristics of the substation or the facility. *Reporting*: The project company shall provide the offtaker with a monthly report containing information regarding the operation of the facility by no later than, for example, seven days from the end of a billing month. Each monthly report shall include a summary of abnormal conditions or events, data concerning solar irradiation and module temperature during the billing month and detailed information relating to units in operation, air and module temperature, and power generation. This should be compared to the information stipulated in the operating protocol. *Communication protocol*: The operating protocol shall be based on the plant O&M procedures. The operating protocol can be prepared by the project company and then amended by the offtaker. In the event that the parties are unable to agree on such an operating protocol within a certain period of time, any disputed issues shall be referred to the expert for final determination and then incorporated into the final form of the operating protocol.

PPA item	Description
Maintenance activities	The project company shall be entitled to withdraw the units from operation for major maintenance activities planned in advance. The project company shall, for example, at least 180 days prior to the proposed commencement date of such work, submit to the offtaker the proposed maintenance programme and schedule. In the occurrence of an emergency, the project company shall forthwith notify the offtaker thereof and provide reasonable details of the event along with appropriate measures to be taken. The offtaker may, for example, within 30 days after receiving the project company's maintenance programme and schedule of activities, notify the project company with feedback, in which case the parties shall consult and the project company shall use reasonable endeavours to accommodate the offtaker proposals. *Equipment connected to facilities operated by the offtaker*: Any planned maintenance that the project company wishes to undertake relating to the equipment connected to the interconnection facilities (*i.e.*, substation) requires prior approval by the offtaker. This shall use reasonable endeavours to accommodate the project company's request, but under no circumstances shall the offtaker be liable in any manner whatsoever for its inability to make such accommodation. *Outages*: The project company may take the facility or any part thereof out of operation, without prejudice to obligations of the project company and subject to applicable notification requirements under the plant O&M operating procedures and pending offtaker's approval.
Metering	The project company is responsible for acquiring, installing and maintaining the meters that shall measure the power plant output. Both parties shall agree on the type of meters and the measurement points; communication equipment should be in place allowing the offtaker to read the meters from a remote location at any moment. The net electrical output is measured commonly based on a metering code stated by the country regulator. All meter units must be regularly tested and inspected by the project company or contractors specialised for this task. All meters must be sealed; the seal can only be broken with consent of both parties when an inspection, test or adjustment is required. *Net metering*: Net metering is a policy that enables a project company to receive credit on the electricity bill due to a surplus of electricity sent back to the utility. Its regulations are dependent on the project company's location; these commonly include electricity excess specifications, the rate at which the utility can take the electricity excess and the rate at which the utility can produce the credit (NREL, 2009).

Table II-16: Key dates defined in a PPA

PPA item	Description
Commercial operation date	COD is a project milestone by which all electrical equipment required to operate the plant, including interconnection and transmission facilities, have been tested and commissioned. In some cases, the project developer also shall obtain a certificate from a certified engineering body stating that the project company is authorised to operate and deliver energy to the transmission system in accordance with local regulations.
Longstop date	The longstop date is an extension to the COD, usually three months after the COD. The offtaker might terminate the agreement if the COD does not occur by the longstop date.
Deemed completion	Deemed completion occurs when the construction completion is not achieved (CLDP and ALSF, 2014). In such circumstances, the offtaker shall receive capacity payments (or deemed energy payments) calculated on the basis of the contracted capacity of the plant.
Deemed commissioning	Deemed commissioning occurs when the offtaker fails to install required interconnection or transmission facilities (Kerf, 1998; CLDP and ALSF, 2014). In such circumstances, the project company shall receive capacity payments (or deemed energy payments) calculated on the basis of the contracted capacity of the plant.
Pre-operation period	During the pre-operation period, the project company shall acquire the permits required by relevant authorities (Kerf, 1998). The project company also shall pass inspections needed in order to obtain operations licences, as well as to comply with local regulations related to power plant operations. Other obligations in this period are related to the securing of all operational agreements including the O&M agreement.

II.7.4.3 Engineering, procurement and construction (EPC) contract

An EPC contract is normally used as a legal arrangement for complex power plant projects in the private sector. In this regard, a contractor is committed to finalise the project (scope of work) for an owner on a "turnkey" basis. The contractor is responsible for the full project, including the design, engineering, purchase of technical components, as well as construction and commissioning of the plant.

The selected contractor should have sufficient expertise in the solar PV sector. He/she should have installed reference solar PV plants of similar size and in similar conditions with regard to climate and terrain. Usually, several years of experience are a must for employees that occupy key positions such as construction site manager, health and safety manager, and quality manager. When local (national) labour is temporarily employed for the construction, it is important that the supervisors (*e.g.*, civil, electrical, mechanical) can communicate with the workforce in their language or at least in English.

II.7.4.3.1 EPC contract general structure

The EPC contract structure should be checked for the items described in table II-17:

Table II-17: Description of EPC contract structure

Item	Description
General structure of the contract	• Version available for review (draft, initialised or executed version) • Structured in a comprehensive manner • Contract language • Structured in articles, appendixes, schedules • Correctness and completeness of definitions and terminology
Contract parties	• Clear definition of contract parties • Definition of responsible contact person • Subcontractors (list of approved sub-contractors or at least owner's discretion to approve them) • Further contract parties (*e.g.*, module procurement by the owner)
Duration of contract	• Contract duration defined in contract • Guaranteed completion (or "taking over" date) is defined • Deadline for start of construction • Maximum allowed delays to complete before project rejection and contract termination • Notice to proceed and/or condition precedent for the EPC contractor to start the works/enter the site • Exceptional termination of contract possible (*force majeure*) • Transfer of title/risk

II.7.4.3.2 EPC contract scope of work guidelines

In any EPC contract, the scope of work of the contractor should be clearly defined. Usually, a list of key activities should outline what the contractor has to do in order to fulfil the contract. The activities of the contractor should cover at least the items described in table II-18.

Table II-18: Description of EPC typical scope of work

Item	Description
Engineering	• Basic design • Detailed engineering / executive design / as-built design • (If necessary, acquisition of approvals from authorities or the public utility for construction and operation of the plant) • (If necessary, acquisition of approvals from grid operator or local distributor for connection of the plant to the grid)
Procurement	• Solar PV Module Supply Agreement • Procurement of all necessary equipment (long-lead items procurement to be managed in a way to assure their availability for the project) • Procurement of warranty certificates and manuals • Procurement of factory flash reports of the solar modules
Civil works	Site preparation: • ground levelling • internal and external access roads • drainage system, cable ducts, trenches • buildings • perimeter fence The responsibilities for landscape works have to be clarified. Likewise, the effects and related responsibilities of exceptional soil conditions (de-mining or archaeological findings, etc.) have to be considered.
Mechanical works	• Supply of support structure • Foundations and erection of support structure
Electrical works	• Module assembly and connection to inverter (DC works) • String (combiner) boxes • Low-voltage AC system, Underwriters Laboratories (UL) power supply • Auxiliary supply system • Medium-voltage (or high-voltage) grid connection • Medium-voltage evacuation line (if included in scope of work) • Metering system • Grounding, earthing • Communication (internal and for remote control)
Installation of auxiliary components	• Monitoring system • Meteo/weather station

Item	Description
	• Surveillance/plant security system
Testing and commissioning	• Factory acceptance tests • Testing of plant before grid connection ("cold tests") • Commissioning and start-up • Testing of plant after grid connection and compliance with requirements to obtain FiT • Carry out performance tests for Provisional Acceptance Certificate (PAC) • Carry out performance tests for Final Acceptance Certificate (FAC) (usually after one and two years from PAC)
Documentation	• Progress reports during construction • Provide test reports / certificates / commissioning protocols to project company • Quality Assurance (QA) / Quality Control (QC) protocols • As-built documentation • O&M manual • Technical assistance in diligent and timely manner providing the documents needed for administrative purposes (utility, fiscal, agency, government authorities, etc.)
Hand-over	• Training of O&M and owner's personnel • Supply of initial spare part stock
Health and safety	Safety and health of the workers at the worksites according to the applicable laws

It should be mentioned that there also are obligations on the owner, such as providing the contractor with:

- the authorisation titles obtained
- specifications of the authorised area
- authorised design
- soil conditions and access to the site.

These items must be clearly defined in the contract in order to avoid conflicts over responsibilities.

II.7.4.3.3 *EPC contract solar PV module supply guidelines*

Table II-19 shows key criteria that must be considered as part of a Module Supply Agreement for a Solar PV power plant. A carefully drafted agreement will avoid later discussions and disputes with the module supplier in the event of a claim. Rejection criteria must be properly defined as well as the guarantees, delivery, payment conditions, etc.

Table II-19: Description of main module supply terms and conditions

Item	Description
Parties	• Detailed description of all parties involved, such as the buyer and the seller
Product and quality specification	• Technical specification of the product (generally integrated by technical datasheet in a specific appendix) • Product compliance with TÜV, CE, IEC certification standards • No change of technical specs is acceptable without written information received in advance (*e.g.*, one month) • Module shall be produced exclusively on the seller's own production line • Products delivered by the seller shall be new and free from any visible and hidden defects • Total power delivered shall not be less the total power as stipulated in the agreement
Price, delivery and delivery schedule	• Definition of price (normally cost/Wp) • Definition of quantity • Definition of place of delivery • Definition of delivery schedule
Payment	Definition of payment conditions and payment milestones
Documents	Definition of documents to be provided by the seller, such as: • Full sets of clean on board (COB) bills of lading • Original commercial invoice • Packing declaration of treated pallets • Insurance letter • Flash list • Certificate of origin
Packaging	Transportation packaging: • The seller shall be responsible for the packaging of the modules at the seller's expense • Packaging in accordance with international packaging standards, good commercial practice and applicable laws and regulations • The buyer may request inspection/testing of the goods by its own employees or by a third party at the seller's factory • Definition of the percentage (*e.g.*, 5%) of modules ready for delivery to be tested • The buyer has the right to refuse those goods that do not meet the specifications, and the seller shall replace the refused goods

Item	Description
	• Costs in connection with such inspection at the seller's factory shall be borne by the buyer Supply packaging: • Labelling with the main technical data of each solar PV module on the back and a bar code with the serial number visible from the front inside the glass
Defects	Timing of inspection (*e.g.*, within 60 days from first delivery). Identifiable and hidden defects shall be notified to the seller within a certain time (*e.g.*, within 45 days). Rejection criteria shall be properly defined in the document.
Delayed delivery and late payment	Early or late deliveries are permitted only with the buyer's consent. Acceptance of delayed delivery by the buyer shall not be considered a waiver of any claims to damages. In case of delay, the buyer shall be entitled to liquidated damages for a fixed percentage of the contract price (*e.g.*, 0.1%) of the delayed modules per day, with a fixed cap on a yearly basis (*e.g.*, 15%). Title of the products shall be transferred to the buyer upon full payment. In case of late payment, the buyer shall pay liquidated damages for a fixed percentage of the delayed payment (*e.g.*, 0.1%) for each day of delay with a fixed cap on a yearly basis (*e.g.*, 15%).
Quality guarantee	The quality of the delivered products shall be guaranteed by the seller (normally reported in a separate appendix). Limited warranty must be provided, including Limited Product Warranty and Limited Power Warranty.
Claim and liability	The seller shall compensate the buyer according to the seller's Limited Warranty if modules supplied are defective or damaged in whole or in part.
Force majeure	The seller will not be responsible for failure to perform or delay in performing all or any part of the contract due to natural disasters (*e.g.*, flood, fire, earthquake, etc.) if notification of this event is given within a defined time (*e.g.*, one week) to the buyer.
Quality control	In-process quality control and inspection before loading will be done by the buyer's employees or by a third party (first-class laboratory). Normally, quality control measures are set forth in a specific appendix and are generally in line with applicable standards.
Insurance	Insurance from a first-class insurance company must be provided by the seller to the buyer under terms and conditions that are normally set out in a separate appendix.

II.7.4.3.4 EPC contract technical specifications guidelines

Technical specifications are an important part of the contract and can be seen as a complement to the scope of work. They provide detailed information on how the contractor must carry out the works. Technical specifications on the works can be provided as described in table II-20:

Table II-20: Examples of EPC technical specifications

Type	Description
Functional requirements (or "Minimum" or "Owner" requirements)	These consist of functional specifications containing solar PV plant descriptions and functional requirements for the main items, in agreement with the usual practice for turnkey contracts.
Design documents agreed by the parties prior to contract signature	The technical specifications should contain data sheets for all relevant components as well as the related warranty certificates.

In the first case (functional requirements), special care has to be taken when reviewing the functional specifications. It is important that at least the key components, such as solar PV panels, inverters, transformers and structures, be named/short-listed or anyway subject to the owner's approval.

The technical specifications also should state that the works must be carried out according to all relevant electrical standards and applicable laws of the country of installation. This applies also with regard to the respective health and safety (H&S) requirements.

Other important tasks are the authorisation requirements to be undertaken by the EPC contractor when performing their design activities.

Because component datasheets do not always report 100% exhaustive specifications of the components, it also is important that the equipment be supplied according to "Best Industry Practice" and "Market Standard" to avoid disputes arising from equipment malfunction or deterioration.

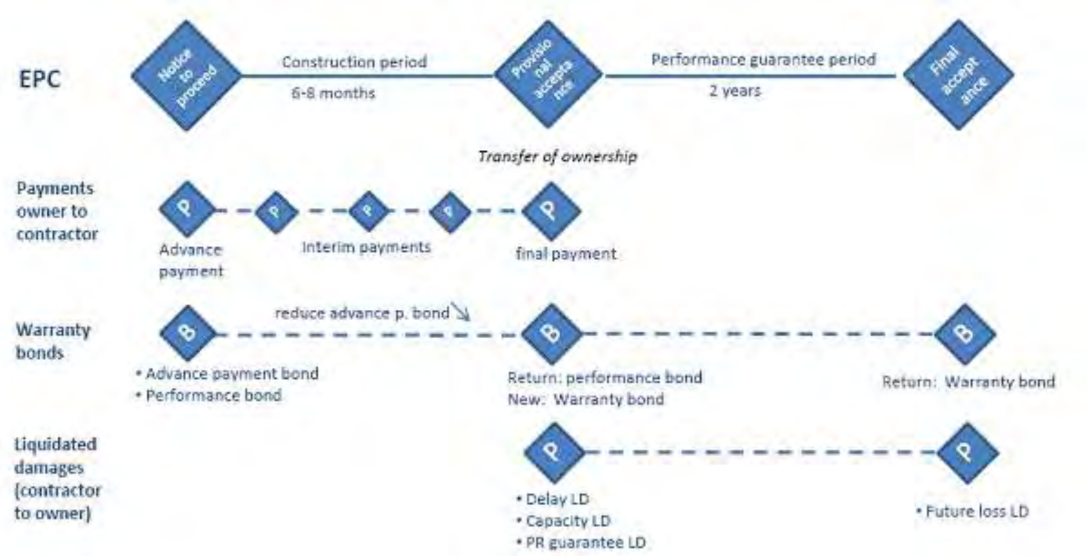
The technical specifications also should contain detailed requirements for data processing (structure of irradiation and yield data, at least hourly data and temperature).

II.7.4.3.5 EPC contract milestones and completion guidelines

The definition of the project milestones and the completion deadline is a crucial part of the EPC contract. Project milestones usually are linked with interim payments that the plant owner has to pay to the contractor during the construction phase. Upon milestone payment, the property of the corresponding part of the works is transferred to the owner, while the risk usually remains with the contractor until provisional acceptance of the plant.

Figure II-41 indicates the typical duration, milestones and guarantees of an EPC contract.

Figure II-41: EPC contract milestones and completion dates



In detail, the EPC contract structure should be checked for the items described in table II-21:

Table II-21: EPC milestones checklist

Item	Description
Start of work	From which event is the contract effective (signature, notice to proceed, etc.)? Is the commencement of works date defined? Once this date is expired, is the owner free from their obligations? Which conditions precedent make the owner obliged to perform payments and fulfil their obligations? Which conditions precedent make the EPC contractor obliged to perform their scope of work?

Item	Description
Time schedule and completion deadlines	Is the time schedule defined? Are there completion deadlines? Penalties for delays? What is agreed in case of *force majeure* events, *e.g.*, adverse weather conditions? Are there any allowed delays and how are they managed (deadline postponement, cost reimbursement)? Is the guaranteed taking over date properly defined? Is the substantial (or "mechanical") completion date defined in order to allow utility standard to connect the plant? Is the deadline/termination date properly defined?
Milestones	Have you agreed on the definition of milestones? • Notice to proceed works • Purchase order for major components • Completion of site preparation and civil works • Delivery of components to site • Installation of modules and electrical equipment "mechanical" or substantial" completion • Commissioning and start of provisional acceptance tests • Provisional acceptance • Final acceptance

II.7.4.3.6 EPC contract price/remuneration guidelines

The EPC contract price as well as payment issues are the points to which financing institutions will pay the most attention. Therefore, special emphasis should be put on this section:

Table II-22: Description of EPC price and payment schedule

Item	Description
Contract price	Contract price is defined per installed capacity (EUR/MWp). If, at the end of construction, the capacity is different, the contract price has to be adjusted accordingly.
Payment schedule	Typically, milestone payments are shown as percentage values of the total contract price. An adequate payment schedule reflects the value of the performed works at the specific milestone. The percentage values below are tentative numbers. • Notice to proceed works: 10% • Purchase order for the plant hardware: 5% • Completion of site preparation and civil works: 5% • Delivery of components to site: 55% • Installation of modules and electrical equipment /"mechanical" or substantial" completion: 10% • Commissioning and start of the provisional acceptance tests: 5% • Provisional acceptance: 10%

II.7.4.3.7 EPC contract acceptance guidelines

Acceptance is carried out in two stages: provisional acceptance and final acceptance. Both are defined in the EPC contract, including the related technical requirements, testing equipment and measurement methods. Successful acceptance needs to be documented by respective certificates (PAC and FAC).

Table II-23: Description of EPC acceptance tests

Item	Description
General checklist for both acceptance types	• Is there provision for partial acceptance[1]? If so, is this acceptable to the lender? • Acceptance conditions defined in an unambiguous manner? • Date and time frame defined? • Favourable weather conditions for tests? • Is there provision for supervision of technical advisor? • Is there provision for acceptance certificates? • Suitable basis is the standard IEC 62446 which defines the tests and documentation
Provisional acceptance	The purpose of provisional acceptance is to prove that: • All civil, electrical and mechanical works have been carried out properly according to the stipulations of the contract and prevailing norms and standards

Item	Description
	• The plant is functionally operational and capable of converting solar irradiation into electricity and feeding power into the medium-voltage or high-voltage network in a safe and reliable manner • The plant is able to reach a minimum performance ratio (PR) level. Furthermore, it must be checked at provisional acceptance that: • The contractor has transferred to the owner the titles, documents and manuals to operate the solar PV plant (also through the appointed O&M contractor) • The punch lists work is completed • The warranty bond is released to the owner. The EPC contract should explain in detail how the three above-mentioned acceptance criteria will be checked. The EPC contract should contain procedures that have to be followed if acceptance criteria are not reached. Usually, for minor corrections, a so-called punch list will be established, giving the contractor the possibility to remedy the defaults within a pre-defined deadline, *e.g.*, 30 days. For cases where the faults are more severe, *e.g.*, health and safety is not guaranteed or the plant does not operate properly (or cannot be remedied by the contractor), the contract should make provision for special stipulations. These may be, for example, penalty payments or stipulations that the plant owner has the right to remedy the defaults on their own, with costs to be incurred by the contractor. As a last resort, extraordinary termination of the contract should be possible. In case of termination (exceptional or not), it must be clarified that surviving component warranties will be transferred to the owner.
Final acceptance	The final acceptance should ensure that the solar PV plant has continued to function in accordance with the technical standards for a relatively long time period (two years). It basically consists of two acceptance requirements: • Visual and functional check of the plant components; check of wear on components; detection of possible warranty cases • Long-run performance of the plant has been proven over the two-year period.

[1] Partial acceptance can apply, for example, if the plant is composed of several, independently operating sub-plants or power blocks.

II.7.4.3.8 *EPC contract guarantees guidelines*

EPC contracts show a wide range of guarantee provisions. The guarantee provisions described in table II-24 are considered indispensable and market standard.

Table II-24: Description of EPC guarantees

Type	Description
Defect/workmanship warranty	Contractor guarantees that the plant is free from defects. This guarantee is usually given for the first two years starting from the provisional acceptance.
Completion guarantee	This guarantee ensures that the plant has been completed in a timely manner before the provisional acceptance deadline and must be linked to delay liquidated damages.
Capacity guarantee at provisional acceptance	This guarantee ensures that the actual installed plant capacity is not too different from the planned nominal plant capacity. Generally, there is a contract price adjustment mechanism, which provides monetary compensation if the plant's capacity is lower than the planned capacity. There should be provision for a threshold of a minimum acceptable capacity (MWp) under which the plant can be rejected by the owner.
Performance guarantee at provisional acceptance	This guarantee refers to the minimum guaranteed performance ratio (PR) of the provisional acceptance. The guaranteed PR at provisional acceptance should be defined in the contract (*e.g.*, by means of a table of monthly PRs). If the actual PR is below the guaranteed level, liquidated damages apply.
Performance guarantee at final acceptance	The purpose of the performance guarantee is to give the plant owner security with regard to the future yield of the plant. The best way to ensure this is by setting a minimum guaranteed PR that has to be achieved during the 24-month testing period. The contract should provide the following stipulations: • compensation payments in case of non-achievement of the guarantee values • plant rejection for severe underperformance.
Other guarantees	Product warranties for the main components (against defects and wear): • 10 years for the support structure of the modules • 2 years for civil works • 5 years for inverters and other electrical equipment • 5 years for the modules. • Further balance of plant installations: 2 years Module degradation warranty: • The manufacturer's degradation warranties (*e.g.*, 90% of initial power after 10 years; 80% after 20 years) need to be transferred to the plant owner. Parent company guarantee
Limitations of liability	Limitations of liability should be clarified in the EPC contract. A usual cap for the overall liability is the EPC contract price.

II.7.4.3.9 EPC contract liquidated damages guidelines

Liquidated damages (LD) are payments by the contractor to the owner for non-achievement of guarantee values or other shortcomings during contract execution, such as delays. The guiding principle for these checks should be that the monetary value of the liquidated damages is able to cover the potential losses related to the shortcomings.

Table II-25: Description of EPC liquidated damages

Type	Description
Delay LD	If taking over of the works is not achieved on the date of takeover, liquidated damages have to be paid by the contractor. The amount and also how the LD are calculated (per day or per week of delay) are a matter of individual contractual arrangements between the owner and the contractor. Particularly if feed-in legislation changes are on the horizon (*e.g.*, at year's end), delay LD can become a very important tool to shield the owner from future losses. There should be an upper limit for the LD above which the owner has the right to withdraw from the contract or draw the contractor's bank guarantee (performance bond).
LD at provisional acceptance	If the guaranteed performance ratio (PR) at provisional acceptance is not reached, the contractor must pay LD to the owner. Usually, these payments are set out as a certain amount of the contract price, which is calculated *pro rata* for each percent of PR shortcoming. There should be an upper limit for the LD above which the owner has the right to withdraw from the contract or draw the contractor's bank guarantee (performance bond). The upper limit should fit with the corresponding bond/payment retention and, to the extent possible, with the maximum amount of LD payable as a consequence of underperformance.
LD at final acceptance (= future loss LD)	If the actual PR measured during the 12- or 24-month warranty period is lower than the guaranteed PR, the contractor must pay the owner LD to indemnify for the future losses that will occur by running the plant with the lower PR. As with LD at provisional acceptance, the LD can be calculated as *pro rata* payments of parts of the total contract price for each percent of PR shortcoming. There should be an upper limit for the LD above which the owner has the right to withdraw from the contract or draw the contractor's bank guarantee (warranty bond).

II.7.4.3.10 EPC contract bonds guidelines

Bank guarantees (or bonds) provide additional security for the plant owner. In cases of severe default (*e.g.*, inability or unwillingness of the contractor to pay the agreed liquidated damages), the owner has the right to ask the contractor's bank to pay out the bond. All three bonds listed in table II-26 are typical requirements.

Table II-26: Description of EPC bank guarantees (bonds)

Item	Description
Advance payment bond	This can be seen as a guarantee that the contractor actually undertakes the works. The bond is equivalent to the initial down-payment and can be reduced with the progress of the works. In some cases, the EPC contract can require a remainder of the advance payment bond to be withheld until provisional acceptance. *Usual value: 10-20% of the EPC contract price.*
Performance bond	This is an indispensable guarantee element in EPC contracts. It warrants that the contractor delivers a functional plant at the date of acceptance. The performance bond is set out as a percentage value of the full contract price and should be released only after successful provisional acceptance. *Usual values: 10-15%*
Warranty bond	This serves as a guarantee that the plant is still functional and performing after the one- or two-year (12- or 24-month) warranty period. The warranty bond should be established at the day of taking over of the plant. It will be returned upon successful final acceptance. *Usual value: 10%*

II.7.4.3.11 EPC contract insurance policies guidelines

The types of insurances that should be contracted are described in table II-27.

Table II-27: Description of EPC insurance policies

Item	Description
Insurance of the owner	Builders risk insurance Commercial general liability insurance
Insurance of the contractor	Public/product liability Employers liability / workers compensation Contractor's plant and equipment Automobiles, motor and mobile equipment Professional indemnity (in respect to design services)
Further issues	The scope of the insurance policy should include theft and vandalism during the construction period. As a precondition for payout of the first down-payment at notice to proceed, copies of the insurance policies should be submitted by the contractor to the owner. In case of plant operation interruption, loss of revenues and cost of re-installation has to be covered by the insurance.

II.7.4.4 Operation and maintenance contract (O&M)

O&M services should start at the takeover of the plant. The O&M contract should be checked for the following key elements:

II.7.4.4.1 O&M contract general structure

The O&M contract structure should be checked for the items described in table II-28.

Table II-28: Description of O&M contract structure

Item	Description
General structure of the contract	Structured in a comprehensive manner Contract language Structured in articles, appendixes, schedules Correctness of definitions and terminology
Contract parties	Clear definition of contract parties Definition of responsible contact person Subcontractors Contractor identical with EPC contractor
Duration of contract	Start of the services and contract duration defined in contract Exceptional termination of contract possible

II.7.4.4.2 O&M contract preventive maintenance guidelines

Preventive maintenance covers the services that the O&M contractor has to carry out on a regular basis in order to ensure the operation of the plant.

Table II-29: Description of O&M preventive maintenance

Item	Description
Scope of preventive maintenance	The following tasks are considered market standard: • Daily: remote monitoring/check/control of plant status, irradiation and produced energy • Monthly: sending O&M reports, cleaning of irradiation measurement instruments (meteorological station) • Quarterly: checking and greasing of mechanical parts of trackers (if available) • Semi-annual: visual plant check, module cleaning, grass cutting and removal of vegetation, checking and fastening of electrical interconnectors and cables • Annual: infrared camera check for hot spots, inverter, transformer, electrical measurements, check and maintenance of security system (*e.g.*, surveillance cameras, intrusion sensors, fences).
Reporting and communication with the client	The contractor has to prove that he/she has carried out the services by submitting monthly maintenance and plant status reports to the owner. The reports should include daily electricity generation data and irradiation information in order to allow the calculation of the performance ratio (PR).
Other services	Other services can include: • Administrative work • Communication with authorities and electric utility • Co-ordination with security company • Communication with insurance companies.

II.7.4.4.3 O&M contract corrective maintenance guidelines

Corrective maintenance covers the necessary services that the O&M contractor has to carry out when failures occur in order to keep the plant operational.

Table II-30: Description of O&M corrective maintenance

Item	Description
Scope of corrective maintenance	The scope of O&M corrective maintenance has to cover all components of the plant. The critical components are those responsible for power production and electricity feed-in: • Within 12 hours: all operations that can be performed by remote control (software resetting of inverters, trackers) • Within 72 hours: inverter, transformer and medium-voltage electrical components • Within one week: repair of module strings, tracking systems.
Additional service contract with inverter manufacturer	In addition to the contractual services, the O&M contractor can be obliged to enter into a special service agreement with the inverter manufacturer.
Reporting and communication with the client	All corrective maintenance interventions have to be mentioned in the regular maintenance reports. Major repairs, in particular those requiring replacement of expensive spare parts, have to be notified in advance to the client. This also includes repairs that exceed correction cost limits.

II.7.4.4.4 O&M contract price and remuneration guidelines

The contract price is set out as an annual lump sum, which usually covers all services and repair materials, except for expensive repairs and replacement of expensive spare parts. Other concepts do not cover the corrective maintenance works and materials but only the preventive maintenance. In doing so the contract price can be reduced but a reserve account should be built in order to cover unscheduled maintenance work and especially also the required material and components. Different options and the impact on the O&M cost are shown in table II-31.

Table II-31: Different O&M concepts and related costs

Item	Lowest O&M cost	Medium O&M cost	Highest O&M cost
Preventive O&M	x	x	x
Corrective O&M no spares	-	x	
Corrective O&M with spares	-		x
Availability guarantee	-	-	x
Inverter service agreement	-	-	x

Table II-32: Description of O&M contract price

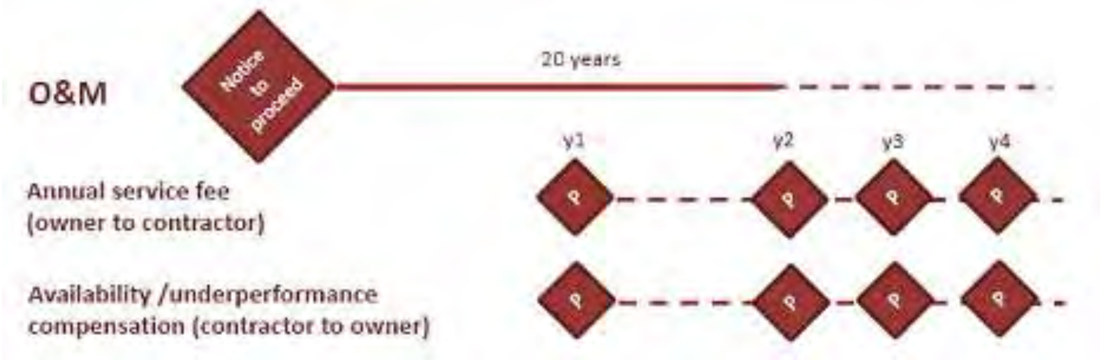
Item	Description
Contract price	The contract price should be negotiated between the parties. Industry best practices indicate that the contract price shall be set out as a EUR/MWh value. This would provide additional incentive for the contractor to provide proper maintenance services. Some contracts also include a "bonus-penalty arrangement" for the availability or the performance of the power plant. In case of high availability and/or performance, the contractor receives an additional payment. In case of underperformance, the contractor has to pay a fee.
Cost limitations, restriction	In certain cases, the contract may provide for certain cost limitations, such as if repair works exceed a certain limit.
Payment terms	Generally, contracts provide that payment is made as a lump sum at the end of every service year. In case of unsuccessful achievement of services and plant performance, a certain percentage of the payment can be retained by the owner as liquidated damages for the incurred losses.

II.7.4.4.5 O&M contract milestones and completion guidelines

The definition of the project milestones and the completion deadline is a crucial part of the O&M contract. Project milestones usually are linked with interim payments that the plant owner has to pay to the contractor during the O&M phase. Upon milestone payment, the property of the corresponding part of the works is transferred to the owner, while the risk usually remains with the contractor until provisional acceptance of the plant.

Figure II-42 indicates the typical duration, milestones and guarantees of an O&M contract.

Figure II-42: O&M contract milestones and completion dates



II.7.4.4.6 O&M contract guarantees and liquidated damages guidelines

O&M contracts should provide for guarantees and liquidated damages, as described in table II-33:

Table II-33: Description of O&M guarantees and liquidated damages

Item	Description
Guarantee parameters	There are principally two possibilities for guarantee parameters: • *Availability guarantee*: contractor has to ensure a minimum technical availability of the plant. The guarantee value for availability should be at least 98%. • *PR guarantee*: contractor has to maintain a certain level of the initial performance ratio of the plant.
Penalties/ liquidated damages	Calculation of the penalties should be based on the PR shortfall between the measured and guaranteed PR.

II.7.4.4.7 *O&M contract spare parts guidelines*

The items that should be considered are described in table II-34:

Table II-34: Description of O&M spare parts

Item	Description
Initial provision of spare parts	Initial spare part stock has to be provided by the EPC contractor.
Costs of initial spare part stock	These have to be paid by the EPC contractor.
Costs of spare part stock refill	Contract has to define which spare parts have to be refilled at the expense of the owner and which spare parts have to be refilled at the expense of the O&M contractor.
Spare part list	A spare part list should be provided in the O&M contract. Generally, it should contain those components that need to be replaced quickly in order to reduce plant off-times after failure (*e.g.*, inverters and circuit breakers).

II.7.4.4.8 *O&M contract plant security guidelines*

Plant security during the construction time has to be ensured. The items described in table II-35 should be included in the O&M contract.

Table II-35: Description of O&M plant security

Item	Description
Plant security firm	The contract should provide for the provision of plant security through a plant security company for a price te be determined in the contractual agreement.
Co-ordination with O&M contractor	The O&M contractor should have clear communication protocols in place with the plant security company in case of intrusion events detected by the surveillance system.

II.7.4.4.9 *O&M contract insurance policies guidelines*

The items described in table II-36 should be addressed:

Table II-36: Description of O&M insurance

Type	Description
Insurance of the owner	Builders risk insurance Commercial general liability insurance
Insurance of the contractor	Public/products liability Employers liability / workers compensation Contractor's plant and equipment Automobiles, motor and mobile equipment Professional indemnity (related to design services)
Further issues	The scope of the insurance policy should include theft and vandalism during the operations period.

II.7.5 Financial modelling guidelines

A financial model represents the financial performance of a project and is necessary to determine its financial viability. The underlying criteria for this decision are usually set by the equity investor and the lenders based on market conditions and perceived risks, among others. Usually, both parties require a certain return on their investment and have expectations regarding financial indicators.

II.7.5.1 Financial model performance indicators

Two important indicators of a financial analysis are the debt service coverage ratio (DSCR) and the internal rate of return (IRR):

- The DSCR is the ratio of cash available for debt servicing to interest and principal payments. For typical project financing, the DSCR is usually required to be at least between 1.1 and 1.45. For example, if the yearly income of a project is USD 500 000 and the mortgage debt service is USD 400 000, the DSCR works out to 1.25.
- The IRR represents the average annual return earned throughout the life of an investment and is used to determine the profitability of and return on an investment. IRR expectations depend on the investor and usually vary depending on factors such as perceived risk and market conditions. To give an example: formerly, in 2010, the usual IRR expectation for solar PV plants in Italy was between 14% and 16%. At that time, the feed-in tariff was quite high at over 30 Eurocents/kWh. Nowadays, a typical IRR is in the range of 10%.

II.7.5.2 Financial model input parameters

The two main economical figures are CAPEX and OPEX. Table II-37 gives an overview of their typical values.

Table II-37: Typical financial parameters in a financial model

Item	Typical value	Comment
CAPEX	EUR 1 000 - 3 000/kWp	Depends, among others, on project size, country, location, technology, final negotiation
OPEX	EUR 10 - 30/kWp	Depends on the scope of work and responsibility of the operator. If all activities are included in the contract, such as unscheduled maintenance and replacement of major equipment (transformers), the figure can be higher. If unscheduled maintenance is not included, the figure is lower.

Source: Fichtner, 2015.

Another important project-specific input is the maintenance reserve account (MRA) which is set up to cover unplanned maintenance expenses such as inverter replacement costs. These costs may not be covered by a service agreement during the operation period. This can be, for example, expenses for inverter refurbishment, which is usually necessary after 10 to 14 years of operations. Usually approximately two-thirds of the inverter CAPEX is allocated in the MRA.

An example of typical technical input data is included in table II-38.

Table II-38: Example of technical input in a financial model

Input	Typical value	Comment
Installed power	110 MWp	Based on project characteristics In accordance with design/EPC contract
Plant availability	99.5%	In line with yield estimate (contract-specific 98%-99.5%)
Grid availability	99%	In line with recommendation from utility (country-specific 97%-99.9%)
POA irradiation	2 500 kWh/m²	Based on satellite data (country-specific 1 200 - 2 800 kWh/m²)
Yield	2 100 kWh/kWp	Based on yield estimate (values between 1 100 and 3 000 kWh/kWp.
PR	84%	Based on yield estimate and expected irradiation (usual values vary between approximately 75% and 85%)
Initial degradation	0.25%	In line with recommendation
Ongoing degradation	0.5%	In line with recommendation

Source: Fichtner, 2015.

II.7.5.3 Financial model stress scenarios

Sensitivity or stress scenarios (upside and downside) indicate the effect of extreme conditions and occurrences on the financial model, for example very high degradation, low solar irradiation or high grid unavailability. As stress (downside) scenarios, the inputs described in table II-39 could be applied:

Table II-39: Typical stress scenarios for a financial model

Item	Typical value	Comment
Module initial degradation	3%	Corresponds to the manufacturer's guarantees. Any value below that would result in a warranty claim.
Module annual degradation	0.7%	Corresponds to the manufacturer's guarantees. Any value below that would result in a warranty claim.
Production	P90 10 years or P90 for the duration of the loan	90% probability that at least this value is obtained over the given period.
Solar irradiation	-10% to -20%	General consideration of lower solar irradiation than expected.
Availability	98%	Corresponds to 7 days unavailability of the grid or the power plant
OPEX	+25%	Price adjustment which may need to be paid in addition in case of change of O&M contractor.
CAPEX	+10%	General contingency.
Construction delay	3 months with and without delay LDs	In some cases, delay LDs may not be applicable because of events beyond the EPC contractor's control. Delays of more than 3 months are possible but with low probability.

Source: Fichtner, 2015.

II.7.5.4 Financial model return optimisation

In order to maximise the future positive cash flow of a project, the developer should consider as early as in the development phase relevant criteria that will have an effect on the project return. These have to be balanced against potential higher costs to see if it would be worthwhile to consider them in the project. Key criteria are summarised in table II-40.

Table II-40: Criteria to maximise the return of a project

Criterion	Comment
System design	The layout has to be optimised so as to minimise system losses. Criteria are, for example: • module inclination and row spacing (shading) • string length • DC/AC ratio (inverter sizing), • DC and AC cabling
Component selection	Criteria for selection of the components are: • proven high quality and efficiency, track record • market standard warranties and certificates • lifetime and durability • adequacy for the location (*e.g.*, hot climate, saline air, sand storms)
EPC contract	Consideration of, for example: • workmanship guarantee • proper monitoring system for failure detection • proper security concept against theft/intrusion • (PR guarantee*)
PV module supply agreement	The warranty conditions in general and specifically the rejection criteria for modules need proper definition in the module purchase agreement.
O&M contract	Consideration of: • Corrective and preventive maintenance • Permanent team on site (for larger plants) • Short reaction time in case of a failure • Adequate stock of spare parts • Availability guarantee
Insurance	• Business interruption insurance to protect against loss of revenue • General liability, property risk

* Note that a PR guarantee is no warrantor for high yields in a system, as it depends directly on incoming solar irradiation. In other words, a 100% cloudy year can result in very high PR values, but the energy generation for such a year will be low.

II.7.6 Project risks mitigation

The following sections show an assessment of different kind of risks that may occur during all phases of project development. Most of these may affect the bankability of the project, making it necessary to put in place mitigation action plans to address them and to reduce their impacts on project finalisation. The overall objective for a project developer is to produce a robust risk register highlighting all mitigation approaches developed during the development of the project.

II.7.6.1 Development risks

Development risks arise during the development phase of a project. The developer should be aware of the potential risks and undertake an assessment to finally decide whether to continue with the project opportunity or not.

Table II-41: Development risk analysis

Type of risk	Identification	Mitigation
General political risks	Risks or events related to political instability or social policies	Project country should be politically stable
Financial risks	Risks that may have an influence on the economic and financial structure and project outcome. This means for a project developer that the expected project costs that are applied in the financial model (CAPEX and OPEX) should be as accurate as possible.	Realistic or conservative approach for project costs Proper arrangement of funds, currency exchange and interest rates, and other variables that can affect cash flow
Regulatory/legal framework risks	Regulatory/legal framework conditions are not transparent and may be subject to changes, *e.g.*, the ultimate FiT system is not yet fixed or in place	Discussion and tracking of trends in framework conditions
Local protest	Local groups and stakeholders may intervene in the project	Meetings with these groups for discussion and information Integrate local population by offering project benefits through employment, purchasing materials and goods, etc. Offering participation in planning process
Site specific risks	Permit requirements: not all required permits have been considered or are available, *e.g.*, EIA	Legal due diligence
	Permit requirements: the required permits are not available in time	Amicable agreement with permitting authority on a realistic and guaranteed timeline
	Land securing: not all of the relevant land is secured for the project since owners may speculate with their land	Flexibility in designing the project layout and/or consider an alternative area for another plant size/ capacity
	Critical grid connection: this task is often non-contestable and thus reliant on the works of a third-party grid operator or its subcontractor	Amicable agreement with grid operator on a realistic and guaranteed timeline
Production estimation	Yield analysis prediction	Acceptable and valid sources and comparison between three or more different sources
Suppliers	Selected suppliers might not be bankable	Bankability list of financing banks

II.7.6.2 Construction risks

Construction risks occur during the construction phase of a project. Most of the risks or their likelihood can be minimised through proper contract preparation and studies undertaken during the development phase. Nevertheless, the developer should be aware of any risks and obtain advice from an insurance broker with regard to adequate insurance cover for the construction phase. Required insurance policies also must be defined in the EPC contract.

Table II-42: Construction risk analysis

Type of risk	Identification	Mitigation
Site-specific risks	Bad long-term weather conditions	Conservative approach for financial model
	Soil findings: unexploded ordinance, archaeological relics	Geological study and soil investigation Discussion with local authorities on potential relics
	Theft or vandalism	Insurance Integrate local population into benefits of project
EPC contractor	Underperformance	Adding performance clauses to the EPC contract based on the availability of the solar PV plant and targets for energy yield or PR
	Accidents, breakdown, collapse	Obligation to comply with health, safety and environment (HSE) plan/regulations
	Pollution	Obligation to comply with HSE plan/regulations
	Damage to the equipment of the grid operator due to failure or alteration of the supply of electrical energy	Electrical installations should be provided with protection for such events.
	Additional expenses, *e.g.*, additional overtime cost, additional subcontractors, urgent transportation of spares, etc.	Insurance
Third-party liability	Damage to or injury of third parties or employees	Compliance with all legal requirements regarding HSE Insurance and/or transfer of responsibility to EPC contractor
Supplier of components	Delay in supply	Track record of supplier Satisfaction certificates Adding clauses in the purchase order on timely delivery of components
Project company	Mismanagement by the director of the project company may give rise to substantial impairment to the cash flow of the borrower	Sufficient oversight by owner

II.7.6.3 *Operational risks*

Operation risks occur during operation of a solar PV plant. As with construction risks, many operation risks and their likelihood can be minimised through proper contract preparation, *e.g.*, for the O&M and main components like module supply agreement, and studies during the development phase. Insurance cover also must be in place for the operation of a solar PV plant.

Table II-43: Operation risk analysis

Type of Risk	Identification	Mitigation
Operating permit	Delay in obtaining operating permit: in some jurisdictions the relevant authorities must determine whether the construction of the plant conforms with the approved design	Amicable agreement with permitting authority on a realistic and guaranteed timeline
Site-specific risks	Unexpected climate change / meteorological events, *e.g.*, less than expected solar radiation due to more rain. Increase of *force majeure* events through thunderstorms and outages.	Conservative approach for financial model
	Increased shading through change of land use in neighbouring areas, *e.g.*, dust through cement plants, agricultural filling facilities, gravel roads, plantations for fast-growing trees like willow and poplar	Careful and comprehensive site discussion and selection Remedial measures through buffer zones / sufficient distance to plant site in case of vegetation cover or increase of module cleaning
	Erosion in sloping terrain	Careful and comprehensive site discussion and selection Countermeasures through, *e.g.*, coverage of soil by vegetation, gabions, comprehensive drainage study and system
	Earthquakes	Earthquake study and risk map Insurance due diligence
	Flood	Careful and comprehensive site discussion and selection Exclude zones of inundation Heightening of components, *e.g.*, solar PV modules, inverter and transformer stations, combiner boxes, etc.
	Lightning	Lightning study and risk map Overvoltage protection concept
	Theft or vandalism	Insurance Integrate local population by offering project benefits through employment, purchasing materials and goods, etc.
Solar PV plant-specific	Malfunction, plant does not work according to the contractual specifications/ obligations	EPC contractor warranty Compensation payments and liquidated damages under the EPC contract
	Problems in statics, *e.g.*, structural analysis for support structure was not adequately addressed in detailed design	EPC contractor warranty Reinforcement of substructures
	Solar PV module degradation through defects like PID, delamination	Product and power warranties of solar PV module supplier Check of financial strength and backing of solar PV module supplier

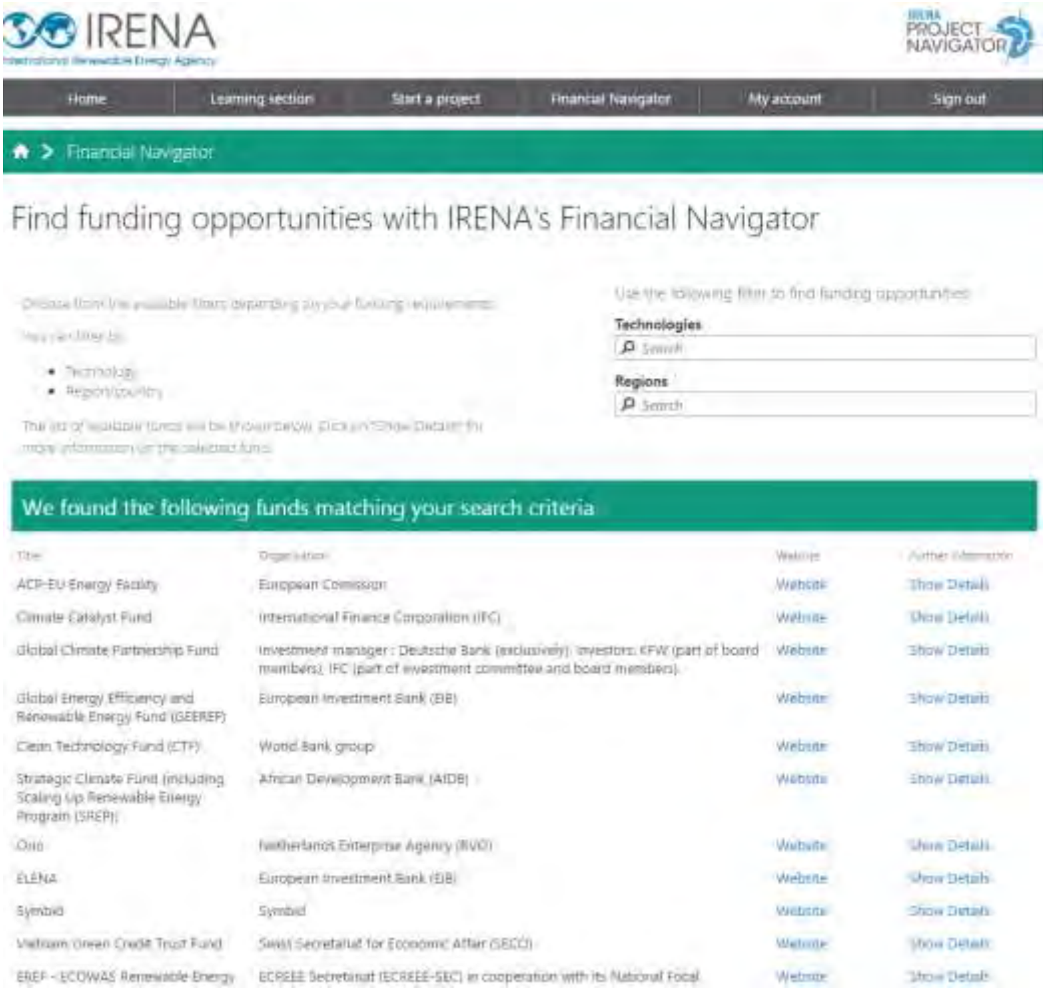
Type of Risk	Identification	Mitigation
	Manufacturing or material defects	EPC contractor warranty and supplier warranties
Pollution	Unexpectedly high noise emissions	Remedy through insulation measures
	Mirroring effect through solar PV modules	Remedy through corresponding measures, *e.g.*, screen
Supplier of components	Bankruptcy of major suppliers (*e.g.*, solar PV modules, inverter, etc.) and therefore worthless warranties	Check of financial strength and backing of suppliers in feasibility study phase Track record of suppliers
O&M contractor	Inefficient performance of O&M contractor, *e.g.*, reaction time or unavailability of spare parts reduce energy output	Track record of O&M contractor Satisfaction certificates Adding performance clauses to the O&M contract based on the availability of the solar PV plant and targets for energy yield or PR
Grid operator	Loss of profit due to a failure in grid operator's installations	PPA Terms and conditions
	Solar PV plants switched off more frequently by the grid operator to secure grid stability	PPA Terms and conditions
	Higher grid unavailability than expected	PPA Terms and conditions
Project company	Mismanagement by the directors of the project company may give rise to substantial impairment to the cash flow of the borrowers which would, consequently, expose to risk the debt granted under the finance documents	Sufficient oversight by owner
Regulatory/legal framework risks	Risks resulting from decisions by legislative or administrative authorities of a country or a region which could result in changes of the FiT or the application of new taxes retroactively	Discussion and tracking of trends in framework conditions
Insurance	Invalid/wrong backup policies	Insurance due diligence
Local protest	Local groups and stakeholders may intervene in the project	Meetings with these groups for discussion and information Offering benefits by employment, purchasing materials and goods, etc.

II.7.7 Project development support through the use of IRENA platforms

II.7.7.1 Identifying financial instruments using IRENA Project Navigator's Financial Navigator

IRENA Project Navigator provides a regularly updated online search engine on financial Institutions that provide financial instruments for renewable energy projects, including solar PV projects, and that help project developers identify financing opportunities by listing all major requirements to access such instruments (location, size, technology, etc.).

Figure II-43: Financial Navigator on the IRENA Project Navigator platform



II.7.7.2 Obtaining debt financing using ADFD/IRENA Financing Facility

IRENA and the Abu Dhabi Fund for Development (ADFD) have collaborated to offer concessional loans worth USD 350 million over seven annual funding cycles to promising renewable energy projects in developing countries. These projects are recommended by IRENA to ADFD for final selection. The ADFD loans cover up to 50% of the projects' costs and help leverage additional funding. Since 2012, USD 144 million of ADFD loans has already been allocated to 15 renewable energy projects recommended by IRENA. Over USD 189 million has been leveraged through other funding sources to cover the rest of the project costs.

Figure II-44: IRENA ADFD Financing facility platform

Projects should be submitted by Members of IRENA, Signatories of the IRENA Statute or States in Accession which are included as developing countries in the "DAC List of ODA Recipients" from the Organisation for Economic Co-operation and Development (OECD). Preference will be given to project proposals submitted by IRENA Members. Each project selection cycle opens in November of each year. Selected projects are announced at the annual IRENA Assembly session in January of each year.

Loans are provided to finance up to 50% of each project, attracting co-financing from banks, international financial institutions and other development partners. This mobilises enough funds to more than double the original investment and helps build local financial markets to create valuable know-how for the future.

II.7.7.3 Connecting with potential investors using IRENA's Sustainable Energy Marketplace

IRENA's Sustainable Energy Marketplace is a virtual platform that gathers all renewable energy actors and IRENA's expertise and work to pursue together the deployment of renewable energy in developing countries. The Marketplace aims to scale up the existing global investment and support the channelling of public and private finance to meet the demand in the market. Project developers, financiers, service and technology suppliers can register and work together to realise projects and bring energy where it is still needed.

Figure II-45: IRENA Sustainable Energy Marketplace platform

Credits: IRENA.

The platform brings together renewable energy project owners, governments, financiers and service/technology providers to:

- enhance the understanding of the market and the capabilities of project owners
- create a transparent and structured framework for entities to operate
- increase project success rates
- increase sustainable development and energy access in the Caribbean, Latin America and Africa regions.

II.8 Construction

II.8.1 Construction criteria

The construction phase demands high quality standards and extensive expertise in order to meet the main targets. The following actions, questions and deliverables should be the focus during this phase:

Key actions

- Finalisation of detailed technical documentation
- Completion of master project planning
- Production of project quality plan
- Production of project health, safety and environment (HSE) plan
- Setting up of project management structure
- Application for any temporary permitting
- Preparation of all procurement and shipping documentation
- Clearance of all access and internal roads
- Execution of project implementation plan
- Commissioning of project plant

Control questions

- Have you obtained all required technical documentation for the installation of the solar PV plant project?
- Do you regularly supervise the construction schedule with contractors?
- Did you plan sufficiently in advance the final activities of the construction phase, *i.e.*, tests and commissioning?

Key deliverables

- Project master plan
- Project implementation report
- Monthly project progress report
- Commissioning report
- Receipt of provisional and final acceptance certificates

II.8.2 Construction planning

Developing an appropriate time schedule to properly manage the construction phase is the first step to be assessed. In this time schedule, all the tasks should follow a certain sequence in order to optimise the time and cost and where milestones and overlapping between companies should be clearly defined.

The Gantt chart in Table II- shows the typical process that is followed during the construction of a solar PV power plant.

Table II-44: Example of a high-level Gantt chart of solar PV power plant construction

ID	Task	Duration (weeks)	Start	Finish	Months											
					1	2	3	4	5	6	7	8	9	10	11	12
	TOTAL CONSTRUCTION PHASE															
1	Detailed Engineering	4	01.02.14	01.03.14												
2	Civil Works	17	22.02.14	01.07.14												
3	Mechanical Works	20	01.05.14	01.10.14												
4	Electrical Works	25	01.07.15	01.12.14												
5	Commissioning Tests	4	01.01.00	31.12.14												

The most important activities for building a solar PV power plant are detailed here as best practice and may be used as a guideline. The main risk during the construction phase is an unforeseen delay that has a negative impact on the expected commissioning date and the cash flow.

The typical main works are as follows:

- Site preparation and site access
- Civil works
- Mechanical works
- Electrical works
- Grid connection
- Testing
- Commissioning.

A useful and complete time schedule should include all the resources needed to execute the construction activities as well as the equipment delivery schedule (*e.g.*, for transformers, central inverters and modules). Following this approach, continuous monitoring should be ensured for all phases with an opportunity to put in place an action plan to recover from any unexpected delays.

II.8.3 Construction breakdown

During the construction phase of a solar PV power plant, the main activities can be broken down as follows:

- Detailed engineering
- Civil works
    - o site access
    - o site preparation / grading / backfill
    - o roads (internal and external)
    - o drainage system
    - o fence

  - trenches (for DC and AC cables)
  - foundations
  - inverter cabinets
  - substation
  - camera poles
- Mechanical works
  - mounting structure of solar PV modules
  - installing solar PV modules
  - substation
- Electrical works
  - DC and AC cables
  - communication system cables
  - lightning protection
  - combiner boxes
  - inverters
  - transformers
  - security system
  - monitoring system
  - weather stations
  - grid connection
- Commissioning and tests.

II.8.4 Construction activities

The main installation activities for solar PV power plants are described below:

Civil works

The civil works consist mainly of activities related to preparation of the terrain, such as levelling and soil compaction, for the erection of structures and inverters as well as excavation of trenches and inverter basements. Examples of trenching and basement excavation for central inverters are shown in figure II-44.

Figure II-44: Civil works for solar PV power plants

Credits: Fichtner, 2014.

Mechanical works

The mechanical works comprise mainly the following steps:

- embedding of structure piers/poles with or without concreting
- assembly of metallic support structure (structures for quick assembly and specialised for solar PV modules with different technologies are offered on the market)
- mounting of solar PV modules.

Figure II-45: Examples of mechanical installation of solar PV power plants

Credits: Fichtner, 2014.

Electrical

For the electrical works, higher-qualified contractors are required:

- pulling of low-voltage and medium-voltage cables in trenches to electrical equipment, *i.e.*, inverters, switchgears
- installation of electrical boxes and inverters with corresponding electrical protection and installation of SCADA (Supervisory Control and Data Acquisition) and security systems.

Figure II-46*:* Electrical routing of cables and installation of electrical boxes

Credits: Fichtner, 2014,

After completion of construction and pre-commissioning, grid connection and testing of the electrical installations and components are conducted.

II.8.5 Accessibility and logistics

Large-scale solar PV power plants require heavy and fragile load transports (*e.g.*, modules, central inverters, transformers) with a high number of workers on site every day during construction. This means that the plant should be easily accessible during the construction phase. During construction, a high number of activities take place on site. A certain number of companies and subcontractors are normally involved as well as vehicles and equipment. In this regard, site infrastructure and facilities should be carefully considered, such as required access, space for temporary storage of materials or temporary offices.

The equipment and materials for solar PV power plants – solar PV modules, inverters, mounting structure – can be transported in conventional heavy goods trucks, and no special vehicles are required, except for transformers for the substation. The cost of transportation is included in the contracts with the suppliers or subcontractors. Good access roads are required to avoid damage mainly to inverters and solar PV modules, so it is common for contractors to upgrade roads to facilitate and speed up transport.

Figure II-47*:* Examples of activities for transport of metallic structures & unloading of PV modules

Credits: Fichtner, 2014.

II.8.6 Grid connection

The grid connection is normally executed by an accredited third party selected by the grid operator. The physical grid connection is done once all the equipment of the solar PV power plant and substation has been installed. Generally, the grid operator attends as a witness to the connection of the grid and finally signs off on the execution of the activity. The grid connection agreement defines the parameters that the interface devices with the grid must have, such as frequency current, disconnection time or specific electrical protection.

II.8.7 Commissioning and testing

The last phase of construction is identified by commissioning and testing, which basically certifies that the solar PV power plant installation has been completed and the project and grid requirements have been met. The completion of all commissioning activities can be identified as provisional or final acceptance of the solar PV power plant. Normally, commissioning is carried out by a third party appointed by the owner or the utility (for the substation components).

There are always two types of tests: The first test takes place before energising and connecting the solar PV power plant to the grid and consists, among others, of visual inspection and testing of the main solar PV power plant components. The second test takes place after grid connection in order to prepare the solar PV power plant for provisional acceptance:

- Cold commissioning tests (pre-connection tests) – before connection to the grid and energisation of the solar PV power plant, some tests must be executed. This requires a visual inspection and specific tests on the main components.
- Hot commissioning tests (post-connection tests) – after connection of the solar PV power plant to the grid and once the solar PV power plant is energised, other tests will be executed, including the performance (PR) tests.

Table II-45 summarises the main cold and hot commissioning tests. The bases for the hot commissioning tests are IEC standards 62446 and 60364, explaining in detail the measurement requirements.

Table II-45: Cold and hot commissioning tests in a solar PV power plant

Cold tests	Verification
As-built documents / drawings	Comparison with actual installation
Modules and strings	Visual inspection of correct installation, string connectors, anomalies on module surface
Mounting structure and foundations	Visual inspection of correct installation, corrosion
Combiner boxes	Visual inspection of protection devices, lightning protection, connection of clamps, IP rating, labels
Inverter, transformer	Installation according to manual, dust/sand protection, ventilation, warning lights, labels and tags
Monitoring / security / weather station	Check of installation and functionality
Hot tests	**Verification**
DC system inspection	Polarity
Protection against overvoltage/shock	Solar PV string IV-curve
AC system	Functional test
Labelling	Solar PV array insulation resistance test
Plant Performance	PR test

The hot commissioning tests will then be followed by:

- Provisional acceptance – based on the results of all the hot commissioning tests, preliminary acceptance can be assessed.
- Final acceptance – this usually takes place after two years and after a successfully repeated performance test, even if the period of operation between the two acceptances depends on the EPC contract.

II.8.8 Warranties

Warranties within the EPC contract may include:

- Defect warranty / workmanship warranty – the contractor warrants that the plant will be free from defects and will be in line with the technical specifications document and good industry practice.
- Module capacity warranty – the contractor warrants the total peak capacity of the solar PV power plant.
- Performance ratio warranty – the contractor warrants a certain value of PR, which will not be less than an agreed value.
- Structure warranty – the contractor warrants the integrity and durability of the mounting structure.

II.9 Operation and maintenance

II.9.1 Operation and maintenance criteria

It is important to define the conditions and parameters for O&M of a solar PV power plant during its service life. Proper maintenance of the solar PV power plant is essential for safe, efficient and reliable long-term operation. Consequently, a yearly O&M fee is to be considered in the financial model. There are two kinds of maintenance: preventive (or scheduled) maintenance and corrective (or unscheduled) maintenance. Preventive maintenance usually adheres to the requirements and recommendations of the component suppliers, whereas corrective maintenance is done in case of an unexpected failure in the solar PV power plant:

- Preventive maintenance – this is the result of activities scheduled before starting operation with the purpose of preventing faults or underperformance.
- Corrective maintenance – this is the result of activities performed during operation of the solar PV power plant due to unexpected failures.

Under the O&M contract, an "availability warranty" should be given by the O&M contractor in order to assure the performance of the solar PV power plant above an agreed value.

In some cases, if the O&M contractor is also the EPC contractor, it is possible for the warranty to include targets for the PR or energy yield. The agreed availability limits often are based on the independently verified energy yield report, including a defined safety margin. The following actions, questions and deliverables should be the focus of this phase:

Key actions

- Development of operation procedures
- Development of maintenance procedures
- Monthly supervision report

Control questions

- Did you agreed on sufficient liquidated damages to overcome any significant outage period?
- Did you agreed with the O&M contractor on an optimised approach to spare parts stock and replacement?
- Did you agree on clear maintenance procedures following industry standard practices (ISO, VDI etc.)?
- Do you feel comfortable with the preventive maintenance activities to optimise the availability period of the plant?

Key deliverables

- Operation report
- Maintenance report

II.9.2 Maintenance protocol

The maintenance protocol must, as a minimum, cover the maintenance requirements to ensure compliance with the individual component warranties and EPC contract warranties. If an O&M contractor is being employed to undertake these tasks it is important that the requirements are clearly stated in the contract along with when and how often the tasks need to be conducted. A sample of maintenance protocol is provided in table II-46.

Table II-46: Sample solar PV plant maintenance protocol

PV plant maintenance protocol

project:	**date:**	**time (arrival / departure):**
expert:	**Client:**	**weather conditions:**

maintenance / inspection		**checked** ↓	**defect / to verify** ↓	
component	*description: visual control / conditions of …*			*result / comments*
access, terrain	roads, drainage, vegetation, erosion, waste			
perimeter fence, poles, gate	foundations, stability, wire mesh, corrosion, sensor cable, lock			
security system	cameras, lights, motion detection, microwave, siren, microphonic cable, transmission to security company			
monitoring system	alarms, connectivity			
sensors, weather station	fixation, position, inclination, soiling, recalibration			
UPS, battery, diesel gen	functionality			
buildings (inverter, transformer, etc.)	cleanliness, dryness of cable chamber, cooling and ventilation, manuals			
stock of spare parts	inventory protocol			
inverters	visual check, maintenance according to manual			
solar module	soiling, scratches, glass breakage, cell colour, back side, fixation, snail trails			
string cabling	module-module, module-string box, fixation			
string boxes	visual check, maintenance according to manual			
mounting structure, tracking system	corrosion, coating, mounting, alignment, electrical bonding between tables, earthing			
foundation	corrosion, stability			
protection against lightning	visual check, fixation			
cable ducts	visual check, dirt			
others:				

II.9.3 Preventive maintenance

Preventive maintenance is executed as scheduled and in accordance with the manufacturers' recommendations (*i.e.*, as per equipment warranties). It should be carried out during non-peak production periods, in the morning or evening hours to avoid loss of energy when parts of the system must be disconnected. In special cases, maintenance also is performed at night, when the whole plant must be switched off.

The aim of preventive maintenance is optimised, reliable and safe operation of the solar PV power plant. The correct choice of scheduled activities is a balance between costs and benefits in maintaining a high yield during the life of the system.

Major preventive maintenance activities include:

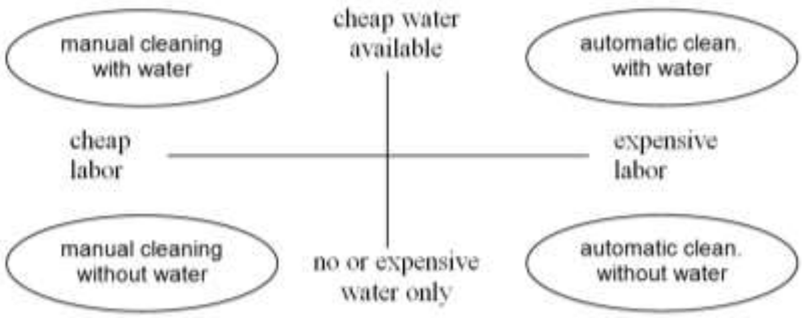
- Module cleaning – the frequency depends on local site conditions (*e.g.*, dust) and time of year.

- Module connection/junction or string combiner box integrity – these connections or integrity must be checked periodically (*e.g.*, check for presence of dust or water).
- Inverter checks in accordance with the manufacturer's specifications (*e.g.*, visual inspection, analysis and diagnostics, etc.).
- Hot spot checks – annual random checks through thermography on major equipment (*e.g.*, connections in junction boxes or along strings).
- Integrity of mounting structure (*e.g.*, for corrosion).
- Tracker system – in accordance with manufacturer's requirements.

II.9.3.1 Module cleaning

PV plants require water primarily for module cleaning, if the cleaning strategy is based on water. The frequency of washing and, therefore, water consumption depends on the site conditions. At sites with frequent rainfall, the washing frequency usually will be lower than at sites in arid and dusty climates where several cleanings per year or even permanent cleaning is needed. Depending on the technology and cleaning method, the water consumption can be up to one litre per solar PV module or even more. Figure II- shows different module cleaning methods depending on the availability and cost of water and manpower in the region.

Figure II-48: Possible module cleaning methods



Raw water has to be extracted from a reliable source, such as a major river, a large dam reservoir or, if environmentally acceptable, a high-capacity well. Water availability is an important criterion to optimise O&M processes. The logistics of water supply have to be taken into account during the early phases of development.

Moreover, the quality of raw water will determine the required processing steps, with impacts on plant complexity and the cost of water treatment. Generally, a water source within a few kilometres is preferable, which reduces the costs of pipeline construction, land rights and permitting. If water is scarce or far away, module cleaning without water is recommended.

II.9.4 Corrective maintenance

Corrective maintenance is carried out when unexpected failures happen during operation of the solar PV power plant. The most important parameters are time-response and repair time, which normally are defined in the O&M contract.

Major corrective maintenance issues can be:

- replace broken modules.
- repair inverter failures
- replace defective fuses
- repair equipment damaged by intruders, such as cameras or other security equipment
- solve any issues related to distributed control systems (DCS) / SCADA systems.

Usually, the O&M contract defines also how often the different activities for preventive maintenance have to be performed: daily, weekly, monthly, every six months or yearly.

Maintenance is required for all system components. The following protocol gives an example of some typical scheduled maintenance activities.

II.9.5 Spare parts

To facilitate a rapid response during corrective maintenance, a spare parts list must be defined in advance. A suitable spare parts list should include:

- mounting structure parts
- combiner/junction boxes
- fuses
- DC and AC components
- communications equipment
- solar PV modules
- spare inverters
- spare motors, actuators and sensors also should be kept where tracking systems are used.

These spare parts should be located on site.

II.10 Decommissioning

II.10.1 Decommissioning criteria

End-of-life disposal of solar PV modules is a serious environmental issue. Because of the very long life span of solar PV modules (25-30 years), most modules installed today have not yet reached the disposal stage. Therefore, little experience with knowledge of solar PV waste management and recycling is available. In general, decommissioning involves three activities. The first is planning of the general dismantling and removal process, which covers the two other activities of waste management and recycling.

A conservative approach to take into account the cost of decommissioning would be to set aside a part of the revenue of the last months of plant operation before decommissioning starts. Some developers have a more risky approach and do not explicitly require this in the financial model. They rely on the expected high value of the material on the ground that can be recycled and sold, mainly glass, aluminium, copper and steel.

The following actions, questions and deliverables should be the focus of this phase:

Key actions

- Phased dismantlement of the plant

Control questions

- Did you allocate an accrued reserve account for decommissioning?
- Are you aware of all regulations in place regarding the dismantlement and recycling of each equipment of the plant?
- Did you inform all relevant authorities of the works?
- Have you established transparent procedures for the dismantlement and removal of waste?
- Have you agreed on who will earn the proceeds of any sale of materials or equipment?

Key deliverables

- Decommissioning report

II.10.2 Waste

The greatest environmental impact of solar PV power plants evaluated on a full life-cycle basis is due to decommissioning waste. A major share of decommissioning waste is made up of balance of system (BOS) components like inverters. These components may contain hazardous materials such as lead, brominated flame retardants and hexavalent chromium. Heavy metals and organic substances found in capsule materials may exceed environmental limits and need special handling.

Another important issue is to prevent solar modules or components of solar modules ending up in municipal waste incinerators, as heavy metals within the solar modules would be gassified and released into the atmosphere.

Especially CdTe, CIS and CIGS solar PV modules have to be handled carefully, because these all contain cadmium compounds, which are considered toxic to the environment and to human health.

II.10.3 Recycling

Solar PV module recycling has been receiving worldwide attention in recent years and is the approach that is most advisable for end-of-life management of modules. Reclamation of rare and valuable materials processed in the solar cells is especially important to avoid resource depletion. Some module suppliers have implemented a take-back policy to ensure that all modules will be recycled.

Up to 90% of solar module materials could be recovered in this recycling process.

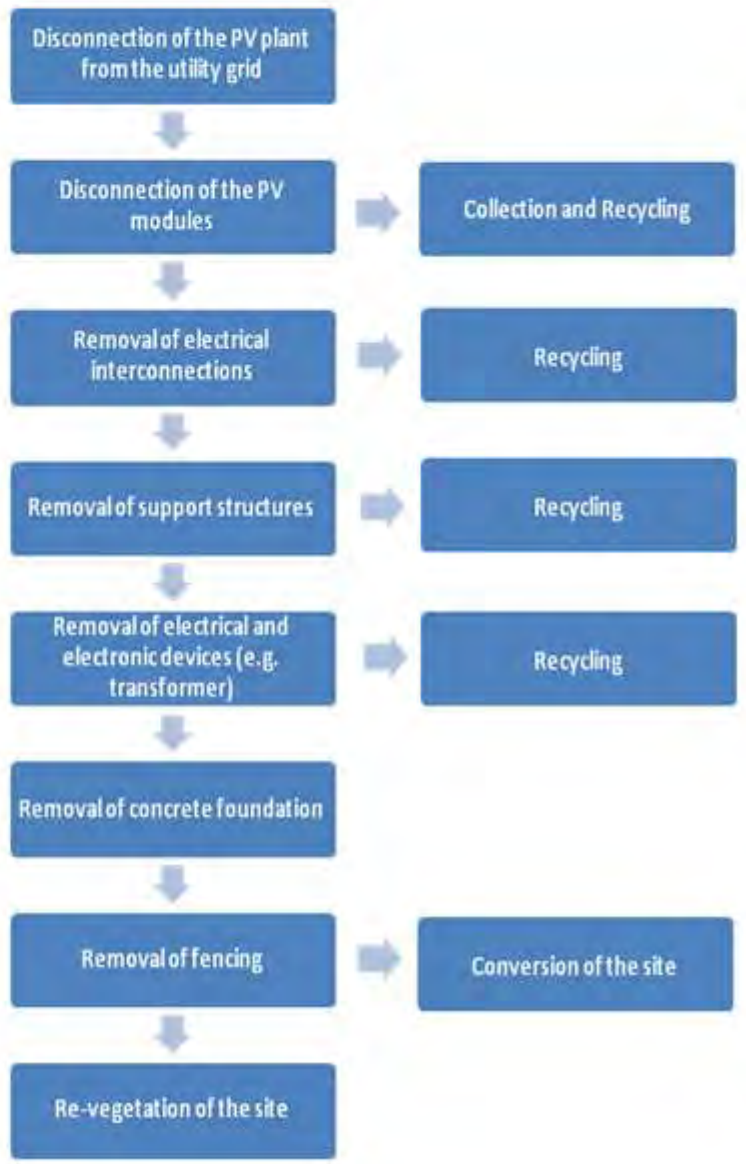
However, recycling of CdTe solar cells has been a major focus of the solar PV industry, and recycling facilities are operating in different locations as well for c-Si cells.

A report titled *End-of-Life Management: Solar Photovoltaic Panels* prepared jointly by IRENA and the International Energy Agency Photovoltaic Power Systems Programme (IEA-PVPS) presents the impact of recycling and repurposing solar PV panels at the end of their lifetime by unlocking raw materials and other valuable components (IRENA and IEA-PVPS, 2016).

II.10.4 Dismantling

Before starting the decommissioning process, the general approach that will be followed has to be scheduled. It is important to recycle as many of the used components as possible. An overview of the process is given in Figure II-48 to give an impression of the general removal process.

Figure II-48: Typical dismantling process



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IV. APPENDIX

IV.1 Site identification template

	Name of the site	Location	Size	Land owner
1				
2				
3				
4				
5				
...				

IV.2 Site screening template

Name of the site:	Date of site visit:	Time:
1. Geographical position: Size:		
2. Meteorology a) Annual solar irradiation: ....kWh/m² b) Source of data: .... c) Annual mean ambient temperature: ....°C d) Extreme conditions:		
3. Topography – Site inclination: - North ☐ - North-East ☐ - North-West ☐ - South ☐ - South-East ☐ - South-West ☐ - No Inclination ☐ Remarks: ....:..............................		
4. Site Surface - Flat ☐ - Hilly/Undulating ☐ Remarks:		

5. Shading objects:

Type	Location	Approx. height
Within the plot		
a)		
b)	....	.... m
c)		
At the plot border	....	.... m
d)		
e)		
f)	....	.... m
No shading objects ☐		
	....	.... m
	....	.... m

6. Description of the site / land use

a) Site is covered by ruderal flora / bushes (Y/N): ....

b) Currently used as agricultural area (Y/N): ....

c) Are there stones/rocks, is there ponding on the site? (Y/N): ....

d) Water supply for construction and operation phase? ....

e) Power supply for construction and operation phase? ....

f) Former use of the site? ....

g) Other (flooding potential, telecommunication): ....

Remarks: ....:......................................

7. Use of neighbouring areas

a) North = ...

b) East = ...

c) South = ...

d) West = ...

e) Activities with dust emissions? ....

8. Accessibility

a) Name of the next rural road leading to the project site: ....

b) Distance to the project site: .... km

c) Is the road condition adequate for construction traffic? (Y/N) ....

d) Name of the nearest highway/road leading to the project site: .... e) Distance to the project site: .... km f) Is the highway condition adequate for construction traffic? (Y/N) .... g) Distance to closest seaport: .... km h) Distance to airport: .... km
9. Grid connection point a) Location of nearest grid connection (distance/orientation): .... b) Connection to the low-voltage or medium-voltage grid? .... c) Connection by transmission line or underground cable? ....
10. Environmental and social a) Natural restrictions: .... b) Physical restrictions: .... c) Social/human restrictions: .... d) Infrastructure works: ....
11. Site evaluation ....

IV.3 Technical and socio-environmental assessment matrices

Table IV-1: Technical and socio-environmental assessment matrix

Category	Criteria	Weight	Mark
		100	0-4
A: Meteorology	A: Meteorology	30	
	A.1 Solar resource	20	
	A.2 Annual mean ambient temperature	7	
	A.3 Extreme conditions	3	
B: Land characteristics	B: Land characteristics	40	
	B.1 External shading	10	
	B.2 Slope	10	
	B.3 Profile	5	
	B.4 Land cover	5	
	B.5 Use of land, ownership	4	
	B.6 Size of available plot	3	
	B.7 Flooding potential	3	
C: Infrastructure	C: Infrastructure	30	
	C.1 Availability of substation	10	
	C.2 Distance to grid/substation	10	
	C.3 Road available for site access	5	
	C.4 Potable water available	1	
	C.5 Distance to closest seaport	1	
	C.6 Distance to closest airport	1	
	C.7 Telecommunications available	2	

Table IV-2: Meteorological criteria (A)

Part A	Meteorological criteria	Mark
Annual solar irradiation	GHI < 1 650 kWh/m^2	0
	GHI: 1 650 - 1 700 kWh/m^2	1
	GHI: 1 700 - 1 750 kWh/m^2	2
	GHI: 1 750 - 1 800 kWh/m^2	3
	GHI > 1 800 kWh/m^2	4
Annual mean ambient temperature	> 26 °C	0
	25 °C - 26 °C	1
	24 °C - 24.9 °C	2
	23 °C - 23.9 °C	3
	< 23 °C	4
Extreme conditions	Corrosive atmosphere due to proximity to the sea (≤ 10 km) or prone to cyclones/hurricanes	0
	No corrosive atmosphere and no cyclones/hurricanes	4

Table IV-3: Criteria for land characteristics (B)

Part B	Criteria for land characteristics	Mark
External shading	Hills above horizon > 4°	0
	Hills above horizon 3°- 4°	0.5
	Hills above horizon 2°- 3°	1
	Near shading objects (buildings, trees)	2
	No external shading	4
Slope	> 10%	0
	8% - 10%	1
	6% - 7.9%	2
	4% - 5.9%	3
	< 4%	4
Profile	Very hilly, up to 5 m	0
	Hilly, up to 2 m	1
	Moderate, up to 1 m	2
	Nearly flat, below 1 m	3
	Flat	4
Land cover	High forest (> 6 m)	0
	Medium-high forest (2 m - 6 m)	1
	Low forest, shrubs (< 2 m)	2
	Pasture, agricultural	3
	No cover	4
Land use	Buildings in use on site	0
	Plantations in use on site	1
	Buildings not in use on site	2
	Plantations not in use on site	3
	No use	4

Part B	Criteria for land characteristics	Mark
Area of available plot	< 100 ha	0
	100 - 299 ha	1
	300 - 499 ha	2
	500 - 699 ha	3
	> 700 ha	4
Flooding potential	High flooding risk	0
	Medium-low flooding risk	1
	No flooding risk	4

Table IV-4: Criteria for infrastructure (C)

Part C	Criteria for infrastructure	Mark
Availability of substation	No substation	0
	Substation in the vicinity	4
Distance to high-voltage grid/substation	> 25 km	0
	20 - 25 km	1
	15 - 20 km	2
	10 - 15 km	3
	< 10 km	4
Road available to access site	> 6 km	0
	4 - 6 km	1
	2 - 4 km	2
	1 - 2 km	3
	< 1 km	4
Potable water available	Not available within 5 km	0
	Water well < 5 km	1
	Piped water < 5 km	2
	Water well on site	3
	Piped water on site	4
Distance from closest seaport	> 100 km	0
	50 - 100 km	1
	20 - 49 km	2
	10 - 19 km	3
	< 10 km	4
Distance from closest airport	> 100 km	0
	50 - 100 km	1
	20 - 49 km	2

Part C	Criteria for infrastructure	Mark
	10 - 19 km	3
	< 10 km	4
Telecommunications available	No telecommunications available	0
	Mobile	1
	Landline, 15 - 20 km	2
	Landline, 10 - 14 km	3
	Landline < 10 km	4

Table IV-5: Environmental and social evaluation matrix

Criteria		Mark 0 - 5
Impact on …		
A: Natural environment		
Natural environment	Flora/fauna habitats	
	Protected areas and species / environmentally sensitive areas	
B: Physical environment		
Physical environment	Climate, air	
	Geology and soil	
	Surface and ground water	
C: Human environment		
Human environment	Residents living on site (*e.g.*, resettlement)	
	Residential housing nearby (impacts from traffic, dust, noise)	
	Existing land use on site	
	Neighboring land use	
	Recreation areas nearby	

Criteria		Mark
		0 - 5
	Indigenous people	
	Cultural/religious heritage	
	Archaeological heritage	
	Visual character of landscape	
D: Additional infrastructure works necessary		
Additional infrastructure works necessary to build the plant	Impacts from site access works	
	Impacts through grid connection of plant	
Total		

IV.4 Bankability checklist

Table IV-6: Checklist for bankability of a solar PV power plant

Requirements for bankability and financing of a solar PV power plant			
	For the purpose of:		
	Indicative term sheet	Update	Final approval
General project description			
Location			
Capacity			
Project company (name, existing activity, ownership structure)			
Investor (name, activity, experience with solar projects)			
Project team			
Technology			
Contractual relationship among the suppliers/sub-suppliers including description of responsibility of each party			
EPC contractor (if any)			
Activity, financial statements, references in solar projects, company size, liability insurance, etc.			
EPC contract (final / before signing)			
Solar modules			
Supplier (activity, financial statements, references)			
Technology (technical parameters, references, guarantees, certification)			
Supply contract / guarantee agreement (final / before signing)			
Other key suppliers (inverters, transformers, mounting systems, project design)			

Requirements for bankability and financing of a solar PV power plant			
	For the purpose of:		
	Indicative term sheet	Update	Final approval
Activity, references			
Supply contract / guarantee agreement (final / before signing)			
Location			
Land lease contract / Purchase contract (final / before signing)			
Purpose of land / changes for the purposes of constructing the specific solar PV power plant			
Site specification (extract from cadastral register, current shape, required works, distance from grid, ownership issues, access)			
Environmental Impact Assessment (or statement from competent government authority)			
Solar irradiation – report from expert acceptable to the Bank			
Construction permit (if final agreement for connection to the grid in place to be presented for the indicative term sheet)			
Grid connection			
License for planned capacity			
Capacity reservation (preliminary or final agreement for connection to the grid)			
Grid study			
Operation and maintenance			
Activities and their securing (in-house / outsource)			
Site security			
O&M contractor (activity, references)			

Requirements for bankability and financing of a solar PV power plant			
	For the purpose of:		
	Indicative term sheet	Update	Final approval
O&M contract (final / before signing)			
Investment budget			
Modules (fixed price necessary)			
Other key technology parts (fixed price necessary)			
Land (fixed price necessary)			
Other investment costs (including operating costs until commissioning)			
Reserve			
Payment schedule			
Financing structure			
Equity (amount, form, investor) – min. 20% of Total Project Costs injected upfront (prior to bank financing)			
Bank loan (assumed amount)			
Time schedule			
Project Planning			
Financial plan			
Key assumptions			
Revenues			
Solar irradiation analysis			
Performance parameters			
Feed-in tariff			
Volatility during the year			
Operating costs			

Requirements for bankability and financing of a solar PV power plant			
	For the purpose of:		
	Indicative term sheet	Update	Final approval
Capital expenditures (initial, continuous)			
VAT during construction			
Financial statements			
Income statement			
Balance sheet			
Cash flow			
Due diligence			
Technical			
Technical feasibility (assessment of the technology, suitability of the design and overall technical solution, location, permits for construction and operation)			
Additional environmental review included in the Technical Review (if deficiencies are expected from EIA or are expected from the location)			
Assessment of suppliers' suitability			
Review of project documents and contracts			
Financial plan assessment (key assumptions, solar radiation, capacity of generated energy, revenues, operating costs, capital expenditures)			
Investment budget (completeness, adequacy)			
Time schedule			
Legal review			
Review of project contracts (especially supply of modules, land lease / land purchase, EPC, O&M, connection agreement, licences if applicable)			

Requirements for bankability and financing of a solar PV power plant			
	For the purpose of:		
	Indicative term sheet	Update	Final approval
Site issues (ownership title, legal issues/encumbrances, access availability, encumbrances on the surrounding land plots that are necessary for grid connection)			

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