Lifecycle Quality

Best Practice Guidelines

Version 1.0

SolarPower Europe

Foreword

Welcome to the first version of SolarPower Europe's Lifecycle Quality Guidelines, produced by SolarPower Europe's Lifecycle Quality Workstream, which is chaired by Lightsource bp. Since its launch in 2015, the Workstream has been raising the bar for quality assurance, firstly for Operation & Maintenance (O&M), and subsequently for Engineering, Procurement, and Construction (EPC) and Asset Management. As the European solar PV industry develops, so too do the links between the phases of a solar project's lifecycle, resulting in substantial overlaps between the roles of EPC and O&M service providers, and Asset Managers. This new document seeks to draw together the shared elements of these roles and of quality assurance in general. It can be seen as providing the core concepts that underpin SolarPower Europe's other Best Practice Guidelines and should be used as an accompaniment to them.

Quality management is crucial at all stages of a project. Europe currently has one of the largest and oldest fleet of solar power plants in the world. According to SolarPower Europe's estimates, based on the *100% Renewable Europe* study, the EU's ambition for a 55% reduction in its greenhouse gas emissions from 1990 levels by 2030, requires a 45% renewable energy share in the final energy demand. In other words, Europe needs an additional 870 GW of solar capacity by 2030 to meet the continent's climate commitments. Quality installation and long-term care will be key to guaranteeing the continued technical and economic performance of solar systems and power plants. This is the first version of the Lifecycle Quality guidelines, and it aims to act as an umbrella document for the EPC, O&M and Asset Management Best Practice guidelines. This is a living document, powered by an active community of experts.

This document focuses on quality assurance throughout an asset's lifecycle, and the importance of due diligence and risk management at all stages of a project. It also seeks to standardise definitions of common key terms and stakeholders that appear across SolarPower Europe's suite of Best Practice Guidelines. We thank our members for their extraordinary level of engagement, which reflects the importance of quality management for our sector. We will continue the work in 2022 and invite interested stakeholders to join our Workstream activities and help us further improve our contribution to higher performing lifecycle quality services.

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Please note that this Version 1.0 may be subject to future changes, updates, and improvements.

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1 Introduction

As the solar PV industry in Europe has matured, quality assurance throughout their lifecycle has helped power plants perform more efficiently and for longer. Although advances in technology have helped this process, doing the basics right has underpinned the consistent decrease in the levelised cost of electricity (LCOE) that has made solar PV competitive against conventional fossil fuels and other renewables. This will continue to be the case in the future as well.

To improve and standardise the levels of quality assurance in Europe, SolarPower Europe has produced a suite of guidelines that cover Engineering, Procurement, and Construction (EPC), Operation & Maintenance (O&M), and Asset Management (AM). However, the lines that mark the difference between these services and the people who provide them are becoming increasingly blurred. This document seeks to capture the elements of quality assurance that are common to all lifecycle phases. It explains the core concepts that underpin the best practice recommendations in the rest of SolarPower Europe's guidelines and should be read in conjunction with them.

These guidelines include definitions of the key terms in quality assurance and detail the roles of the principal stakeholders involved in a power plant's operation. In a new approach, it groups together the four key pillars of lifecycle project management: risk management, health, safety, security and environment, due diligence, and quality management, explaining them and advising how to apply them at each stage of a project. It also includes guidance on potential pitfalls as projects move from one stage of their lifecycle to another. This is treated separately to lifecycle project management as the transitions between stages can pose continuity problems for a project. Finally, these guidelines provide a comprehensive overview of the skills required to successfully manage a solar PV project throughout its life.


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2 Definitions

This section introduces a set of definitions for important terms that are widely used in the Lifecycle Quality field. It is extremely important that all stakeholders have a common understanding of these terms when working together as they will clarify expectations and responsibilities issuing from a contract.

This chapter has been partly compiled from the definition sections in SolarPower Europe's EPC, O&M and Asset Management Best Practice Guidelines, and additional definitions have come from the electrotechnical dictionary, Electropedia. It is designed to serve as a useful accompaniment to understanding the terms in SolarPower Europe's suite of guidelines.

Additional Services	Actions and/or works performed, managed, or overseen by an O&M service provider, which are not (but can be if agreed) part of the regular services and normally charged "as-you-go" (e.g., ground maintenance, module cleaning, security services etc.). Some of the additional services can be part of Preventive Maintenance, depending on the contractual agreement.
Advanced Data Analysis	The autonomous or semi-autonomous analysis of data, using specifically developed algorithms and techniques, which delve deeper than standard monitoring capabilities, and enable access to deeper insights. This can help make predictions more accurate and generate recommendations.
Asset management platform	A software package or suite of tools that is used by the Asset Manager to store and manage technical, and non-technical data and information collected from and relating to the solar asset, portfolio or Special Purpose Vehicle (SPV). It combines the abilities of a Computerised Maintenance Management System (CMMS) and an Enterprise Resource Planning System (ERP).
Asset management (AM)	The commercial and financial management of a solar investment and the supervision and control of technical activities. This involves management of a company or a portfolio operating across several sites, dealing with a variety of regulatory frameworks and business models. AM is also defined as the coordinated activities of an organisation to generate value from its assets (ISO 55000).
Asset portfolio	A group of assets that are governed by the same regulations and obligations. A portfolio is typically established and assigned for managerial control purposes and is usually defined by country, monitoring service provider, Operation & Maintenance (O&M) service provider or another category.

Commissioning	System commissioning closes the construction phase of the solar power plant and begins the commercial operation period. Commissioning includes performance and reliability tests to make sure that the solar power plant is built according to international standards, best industry practice, and complies with the Owner's requirements and grid specifications.
Computerised Maintenance Management System (CMMS)	Software designed to measure and record various O&M Key Performance Indicators (KPIs), such as Acknowledgement Time, Intervention Time, Reaction Time, Resolution Time, and equipment performance, including Mean Time Between Failures, to optimise maintenance activities.
Contract management	Managing the rights and obligations of contracts to ensure they are fulfilled. For Asset Managers this involves building, developing, and maintaining business relationships with counterparties of different contracts. This includes selecting service providers, negotiating with banks, landowners, and operations providers, managing insurance and warranty claims, as well as ensuring compliance of the contractual obligations, such as notifying, filing, and reporting. For service providers this involves fulfilling their agreed contractual obligations.
Contractual framework	An agreement with specific terms between an Asset Owner and a service provider. This agreement defines the scope of the services to be provided, the management and interfaces of those services, and the responsibilities of each party. Liquidated damages and bonus schemes are also part of the contractual commitments.
Control Room Services (also known as Operations Centre Services or Remote Operations Centre)	Comprehensive actions like PV plant monitoring, performance analysis, supervision, remote controls, management of maintenance activities, interaction with grid operators, regulators, Asset Managers and Asset Owners, and the preparation and provision of regular reporting, performed by experienced and qualified staff in a control room, during operational hours for 365 days/year.
Corrective maintenance	Measures (immediate or deferred) taken to correct failures, breakdowns, malfunctions, anomalies, or damages detected during inspections, or through monitoring, alarming, or reporting or any other source. These measures are designed to restore a PV system to regular operating status.
Data & monitoring requirements	Technical and functional specifications for both software and hardware systems used to collect, transmit and store production, performance, and environmental data for power plant management.
DC box	A DC box (or Generator Connection Box) is used in PV power plants to connect the individual solar module strands of a photovoltaic array in parallel, and to connect larger wire cross sections to the inverter.
Degradation	Decrease in the efficiency of a solar plant with the passage of time. Usually, at least 80% of the original output is expected within a 20-year period. Most financial assessments assume a 0.3-0.5% yearly ageing factor.
Development (project development)	Phase in the lifecycle of a project that includes its initiation, site selection, customer identification, preliminary studies, applications for permits, securing financing and selecting the Engineering, Procurement, and Construction (EPC) service provider. Project developers may own the project in the early development stages or even longer. The term "Project development" sometimes includes elements of Engineering and Procurement. However, this is not the case in SolarPower Europe's suite of guidelines.

Digital Twin	A digital incarnation of the entire solar plant which delivers both the geospatial and electrical context of individual components and allows the recording and display of data and files against these components.
Distribution station	A Distribution Station is the final stage in the delivery of electric power. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers.
Document management system (DMS)	A management system that records, manages, and stores documents required for O&M and AM. These include previous and current versions of technical plant and equipment documentation and drawings, maintenance manuals, photos, reports, reviews, and approvals. DMS also define proper document formats and the processes for information exchange. Due to the increasing complexity of documents and to enable advanced analytics, electronic DMS with the ability to handle meta-tags and searchable, editable documentation are becoming best practice.
Engineering, procurement & construction (EPC)	EPC refers to companies that deal with the Engineering, Procurement, Construction and Commissioning of solar systems. The EPC service provider is responsible for delivering a complete Photovoltaic (PV) power plant to the Asset Owner, handling all aspects from seeking authorisation for the construction to commissioning and securing a grid connection. For more information, see SolarPower Europe's EPC Best Practice Guidelines.
Enterprise Resource Planning System (ERP)	Business management software that allows a company (such as an O&M service provider or an Asset Manager) to gather, store, manage and analyse all types of data relevant to their operations.
Extraordinary Maintenance	Actions and/or works performed in case of major unpredictable faults, such as serial defects, force majeure events etc, that are generally considered outside of the ordinary course of business.
Final Acceptance Certificate (FAC)	An official acknowledgement that the minimum Performance Ratio (PR), guaranteed by the EPC service provider, has been met over a two-year period since the issuance of a Provisional Acceptance Certificate (PAC). The acknowledgement also confirms that the power plant has no defects. Once delivered, the Owner takes over full responsibility for the plant.
Feed-in tariff (FiT)	A policy mechanism, designed to accelerate investment in renewable energy technologies, through which power producers enter into a long-term contract where they receive a fixed rate payment for each unit of energy they produce and inject into the electricity grid.
Good industry practice	A legal term, often used in contracts, good industry practice is synonymous with best practice throughout SolarPower Europe's suite of guidelines. The term refers to practices, methods, techniques, standards, codes, specifications, acts, skills, and equipment that go beyond the established minimum acceptable baseline in the international solar power industry (including in the construction and installation of solar power facilities). They are adhered to by high-quality service providers and are designed to help accomplish the desired result of a decision or action (or lack thereof), in line with applicable laws and permits. Good industry practices are reliable and safe, economically efficient, protect the environment and are done with the degree of skill, diligence and prudence that would ordinarily be expected.
Grid code compliance requirements	Equipment, procedures, and actions required by a grid operator to comply with grid safety, power quality and operating specifications.

Health, Safety, Security & Environment (HSSE)	HSSE are the policies and guidelines in place to ensure occupational health, and safety at work, the security of a site and environmental protection. They are applicable to staff and visitors and are designed in accordance with European and national laws and regulations.
Insurance claim	An application to an insurer, from a customer, for reimbursement based on their insurance policy terms.
Inverter	An Inverter is a type of electrical converter which converts the variable direct current (DC) output of a photovoltaic power plant into a utility frequency alternating current (AC). Afterwards it feeds into a commercial electrical grid or is used by a local, off-grid electrical network.
Irradiation	The solar radiation incident on a solar panel over time, relative to its area. It is usually expressed in watt-hours per m^2. It plays an important role in the determination of the optimal inclination angle of PV modules and the profitability of a PV system.
Key performance indicators (KPIs)	SMART (specific, measurable, achievable, relevant, time-bound) parameters used to evaluate relative performance against a set of fixed objectives.
Management of change	Management of change defines the way to handle necessary adjustments of the design of a PV power plant after the Commercial Operation Date (COD). Changes require a close cooperation between the Asset Owner and the O&M service provider.
Monitoring system	The digital platform used for the overall management of PV plants or a PV plant portfolio. It allows for centralised monitoring of the functioning, energy generation and reference data of a PV plant and its components. Ideally, this would be performed through a real-time monitoring module that retrieved data from local Supervisory Control & Data Acquisition (SCADA) systems. It also includes operational modules such as ticket dispatching, analytics, and reporting. The centralised monitoring module receives data for 24 hours a day, all year from in-plant SCADA systems, purpose-built sensors for measuring irradiation and temperature and other sources such as meteorological information.
Operation & Maintenance (O&M)	O&M includes all the services that ensure maximum efficiency and the smooth running of a PV plant. The services include monitoring and supervision, predictive, preventive, and corrective maintenance, performance analysis and improvement, power generation forecasting, and site security management.
Performance analysis & improvement	Measurements, calculations, trends, comparisons, inspections, etc. performed to evaluate a PV plant, segments and/or single component performance, site conditions, equipment behaviour, etc., and to provide reports and assessment studies to interested parties (customer, public authority, etc).
Performance Ratio (PR)	PR is a quality indicator of the PV plant. As the ratio between the actual Specific Yield and the theoretically possible Reference Yield, PR captures the overall effect of losses of the PV system when converting from nameplate DC rating to AC output. Typically, losses result from factors such as module degradation, temperature, soiling, inverter losses, transformer losses, and system and network downtime. The higher the PR is, the more energy efficient the plant is.
Personnel & training	Operators, technicians, engineers, and managers employed for the execution of the O&M activities and training plans/programmes to train them on relevant PV plant related aspects and to keep them continuously updated on their respective roles.

Power Purchase Agreement (PPA)	Contract of electricity supply between a party generating and selling electricity, and a party purchasing electricity. The PPA defines the conditions of the agreement, such as the amount of electricity to be supplied, point of interconnection, applicable rate schedule, production guarantees and penalties for non-compliance.
Power plant controls	Actions required by the grid operator, for controlling active and/or reactive power being fed into the grid, other power quality factors that are subject to adjustments and/or (emergency) shut down (if applicable).
Power plant supervision	The supervision and analysis of data from a monitoring system, by experienced personnel. This takes place during daylight hours and managed by one or more control rooms (365 days/year). The reception and qualification of the alarms from the monitoring tool is also considered to be part of the supervision.
Power Generation Forecasting	Adoption of forecasting tools calculating expected power production for a certain timeframe from weather forecasts to supply the expected power production to Owner, grid operator, energy traders or others. This is normally country and plant dependent.
Predictive Maintenance	Actions and/or techniques that are performed to help assess the condition of a PV system and its components, predict/forecast and recommend when maintenance actions should be performed. The prediction is derived from the analysis and evaluation of significant parameters of the component (e.g., parameters related to degradation). Monitoring systems and expert knowledge are used to identify the appropriate actions, based on a cost benefit analysis.
Preventive Maintenance	Actions, testing or measurements to ensure optimal operating conditions of equipment and the entire PV plant, preventing defects and failures before they arise. Preventive maintenance takes place periodically, and according to a specific maintenance plan and schedule.
Provisional Acceptance Certificate (PAC)	A preliminary acknowledgement that the minimum Performance Ratio (PR), guaranteed by the EPC service provider, has been met after an initial testing period, following completion of the power plant's construction. The issuance of the PAC launches the two-year warranty period, after which, provided the PR guaranteed by the EPC service provider has been met, a FAC is issued.
PV Power plant	An independent electricity generating entity (PV panels and Balance of System), with its own set of operational and financial contracts.
Quality	Quality is a perceptual, conditional, and somewhat subjective attribute and may be understood differently by different people. It is a commitment to customers in the market. It can also be defined as fitness for intended use. Quality also takes into account the reduction of harm that a product may cause to the environment or human society.
Quality Management (QM)	Quality Management is the process through which an organisation ensures Quality. Its four pillars are Quality Control & Assurance, Quality Review, Quality Improvement and Quality Planning.
Reference yield	The Reference yield represents the energy obtainable under standard conditions, with no losses, over a certain period.
Regulatory & statutory compliance	Compliance with any law, statute, directive, bylaw, regulation, rule, order, delegated legislation, or subordinate legislation directly applicable in the country where a service is provided or an SPV and PV power plant are located. This also includes respecting any mandatory guidelines and measures issued by a utility or any other competent public authority.

Reporting & other deliverables	Obligations to provide updates, or deliver results and products, to the relevant stakeholders, issuing from a contract or as best practice.
Risk	The effect of uncertainty on objectives. The major categories of PV risk include, but are not limited to, financial risks, country and regulatory risks, contractual risks, commercial risks, technical risks, and reputational risk.
Risk Management	The practice of identifying and analysing the risks around solar power systems and operations and taking steps to mitigate them. The four areas of Risk Management in this document are Risk Analysis, HSSE, Due Diligence and Quality Management.
Security	Actions, procedures, equipment and/or techniques that are adopted on site and remotely to protect the plant from theft, vandalism, fire, and unauthorised entry. Security services are to be provided be specialised security service providers.
Spare parts management	Ensuring that the right amounts and types of components and equipment are available to carry out prompt maintenance and minimise the downtime of a PV plant. They can be stored in warehouses or in the O&M service provider's stocks.
Special Purpose Vehicle (SPV)	A company with its own rights, assets, and liabilities, created for building, owning, and operating one or more solar power plants. An SPV can also be referred to as an SPE (special purpose entity) or as a project company.
Specific yield	Specific yield is the measure of the total energy generated per kWp installed over a certain period of time. This measure is generally calculated at plant AC energy metered. In both cases it indicates the number of full equivalent hours a plant produced during a specific time frame.
Substation	Substations transform voltage from high to low or the reverse. A substation is a part of an electrical generation, transmission, and distribution system. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages or at the interconnection of two different transmission voltages.
Supervisory Control & Data Acquisition (SCADA)	A data acquisition system that connects various hardware and software components in a given site and is used to monitor and control the solar power plant remotely. SCADA systems are typically employed to send data to a centralised monitoring system for monitoring and analytical purposes (see definition for "Monitoring System").
Transmission System Operator (TSO)	Entity responsible for controlling and operating the transmission grid, which usually comprises the voltage levels of 220 kV and 380 kV in Europe. The operations include monitoring and controlling the current grid topology (position of breakers and switches within the grid), as well as the voltage, in all parts of the transmission grid. Any planned PV plant outages need to be communicated to the TSO.
Turnkey EPC contract	A turnkey EPC contract is a contract in which the EPC contractor service provider delivers the entire solar power plant to the investor so that construction and commissioning are completed, and the solar power plant is ready, available to operate and feed the generated electricity to the grid distribution system.
Warranty management	Warranty management usually aggregates activities of a diverse nature which are linked to areas such as supply of equipment and services, and project construction. All these responsibilities (warranties) are usually materialised when a PAC is issued by the EPC service provider. Warranty Management is the activity that manages these warranties with the objective of reducing the costs and response times after warranty claims for repair or replacement of certain PV system components (under the warranty of the EPC service provider and/or the components manufacturer).

3 Stakeholders

There are several stakeholders involved at various stages in the lifecycle of a solar power plant. Having a common understanding of each one's role will help ensure clear lines of responsibility and accountability throughout a project. Whilst separate definitions are given for all these terms, that is not to say that a single entity cannot perform multiple functions. For example, an EPC service provider can also be an Independent Power Producer, and an O&M service provider at the same time, throughout the lifecycle of one project.

Aggregator	An entity that combines multiple customer loads or generated electricity for sale, purchase, or auction in any electricity market. This is useful for Asset Managers and O&M service providers as aggregators can provide them access to electricity markets, balancing markets, and other future flexibility markets, helping them to sell power produced by distributed assets or stockpiled in storage assets and unlock new revenue streams from providing flexibility services.
Asset Manager	The service provider responsible for the overall management of the SPV, from a technical, financial, and administrative point of view. The Asset Manager ensures that SPV and service providers fulfil their contractual obligations. Asset Managers also manages the site to ensure optimal profitability of the PV power plant (or portfolio of plants) by supervising energy sales, energy production, and O&M activities. Asset Managers furthermore ensure the fulfilment of all administrative, fiscal, insurance and financial obligations of the SPVs. Asset Managers review the performance of the sites regularly and report to Asset Owners and seek to balance cost, risk, and performance to maximise value for stakeholders. In some cases, when the SPV belongs to large Asset Owners, such as utilities or Independent Power Producers (IPPs), the AM activity is done in-house. For more information, see SolarPower Europe's Asset Management Best Practice Guidelines (available at www.solarpowereurope.org).
Asset Owner	Asset Owners are the stakeholders that finance the EPC phase, and the overall operation of a PV power plant. They can be a single investor or part of a group and can be classified as either private individuals, investment funds, IPPs, or utilities. The preferred model for asset ownership is an SPV, i.e., limited liability companies, specifically incorporated for building, owning, and operating one or more PV plants. In some cases, when the SPV belongs to large Asset Owners, such as utilities or IPPs, some, or all, of the roles of Asset Owners, Asset Managers, project developers, O&M and EPC service providers may be done in-house.

Authorities	Local (e.g., the municipality), regional (e.g., the provincial or regional authorities supervising environmental constraints), national (e.g., the national grid operator) or international (e.g., the authors of a European grid code) bodies with competence in areas that relate to stages of a project's lifecycle.
Data-related service providers	Companies that provide hardware and software solutions such as monitoring systems, asset management platforms, CMMS, or ERP. Other players in this segment provide advanced data analysis by using site data to calculate KPIs (analytical tools) or provide a repository for key site information whilst facilitating some administrative workflows. Data is crucial to ensuring that Owners, Asset Managers and O&M service providers are aware of on-site conditions, including equipment behaviour. It is vital for ensuring that prompt action is taken once a fault has been identified and providing important information on potential areas of underperformance. There is a tendency in the industry to opt for solutions that integrate all the above-mentioned systems and platforms into one software. There are several advantages to this approach, and it can be considered a recommendation.
Distribution System Operator (DSO)	Entity responsible for distributing the electricity from the transmission grid to end users (households/businesses) and maintaining the distribution networks.
EPC service provider	The entity in charge of the engineering, procurement, and construction of a solar power plant. An EPC service provider is responsible for delivering a complete PV power plant to the Asset Owner, handling all aspects from seeking authorisation for the construction to commissioning and securing a grid connection. Their role is very important in procuring quality components and ensuring quality installation, which have a large impact on the long-term performance of solar power plants. Many EPC service providers also offer O&M services to the solar power plants they develop. They often provide a 2-year performance warranty period lasting from the COD until the delivery of an FAC. In certain mature markets the role of the EPC service provider is increasingly split between different entities. For more information, see SolarPower Europe's EPC Best Practice Guidelines.
Independent Power Producer (IPP)	A producer whose principal activity is to generate electric energy with the sole intention of its sale to distribution business entities, or, via a third-party electric power system, to customers.
Lender	The lender or debt provider (financing bank) is not considered as an Asset Owner even if the loans are backed up by securities (collateral). The lender normally measures the risk of providing debt service based on the debt service coverage ratio (DSCR) of an Asset Owner. The role of the lender is evolving, with enhanced considerations and involvement regarding the requirements for the debt provision. Some projects also have a mezzanine lender providing junior debt services, where another layer of debt is provided at a higher risk than in the original lender's case.
Off-taker	The entity that pays for the electricity produced. This role is still evolving and is often subdivided according to national renewable power support schemes: ▪ The state or national grid operator / electricity seller(s), or specific authorities for renewable energy (e.g., GSE in Italy) in an FiT scheme. ▪ Energy traders or direct sellers in a direct marketing scheme ▪ End customers in schemes that support autonomy in energy supply

O&M service provider	The entity that responsible for the O&M activities as defined in the O&M contract. In some cases, this role can be subdivided into: ▪ Technical Asset Manager, serving as an interface between some of the technical O&M activities and the Asset Owner. This person is responsible for providing high-level services such as performance reporting to the Asset Owner, managing contracts, and managing invoicing and the warranty agreement. ▪ Operations service provider is responsible for the monitoring, supervision, and control of a PV power plant alongside maintenance coordination. ▪ Maintenance service provider carries out maintenance. A comprehensive set of O&M activities (technical and non-technical) is presented in SolarPower Europe's O&M Best Practice Guidelines (available at www.solarpowereurope.org).
Project developer	The Project Developer is the entity responsible for carrying out the actions described under "development (project development)" in Chapter 2 of these guidelines.
Specialised suppliers	Providers of specialised services (e.g., technical, or operational systems consulting) or hardware (e.g., electricity generating components or security systems).
Technical advisors and Engineers	Individuals or teams of experts that provide specialised services (e.g., detailed information, advice, technical consulting). Their role is important as they ensure that procedures and practices are robust enough – according to standards and best practices – to maintain high performance levels from a PV plant. Technical advisors can represent different stakeholders (e.g., investors and lenders) but often an independent engineer is employed in an attempt to minimise the risk of bias towards any party.

4 Fundamentals of Lifecycle Project Management

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Effective Lifecycle Project Management (LPM) ensures that all the necessary actions throughout the development, EPC, O&M, and decommissioning/disposal phases are performed. Therefore, LPM has two different focuses: on the one hand, it has to ensure the timely and cost-effective progress of the project through each of the lifecycle phases; on the other hand, it has to ensure that this progress is not impeded by avoidable problems that could affect the profitability of the project.

While there are other definitions for risk and risk management, in these guidelines we see Risk Management (RM) as the overarching management system which ensures that project progress, throughout its lifecycle, is timely and cost-effective, with a reasonable trade-off between risk and cost. To achieve this, RM includes the following areas:

- Risk Analysis
- Health, Safety, Security & Environment (HSSE)
- Due Diligence
- Quality Management

The four areas can each be divided into four sub-areas. These will be explained below on the following page.

FIGURE 1 THE 20 SQUARES OF RISK MANAGEMENT

4.1. Risk Analysis

RM starts with the Risk Analysis (RA), for which we define the following steps:

- Risk Identification (RI)
- Risk Assessment (RAss)
- Risk Prevention & Mitigation (RP)
- Risk Plan Communication & Implementation (RC)

a) Risk Identification

RI is the beginning of RM. As a minimum, it is important to identify and define all major risks with a significant chance of occurrence. If this does not happen or happens too late, the whole project could be jeopardised.

b) Risk Assessment

Once a risk is identified, an assessment must take place to determine how likely it is to occur, what the impact would be, and estimate the costs of eliminating or reducing the risk.

c) Risk Prevention & Mitigation

Once the RAss has been conducted a decision must be made on the best way to prevent (by establishing barriers) or mitigate the risk and/or its consequences.

d) Risk Plan Communication & Implementation

Once a decision has been made on how to prevent or mitigate the risk, a plan on how to do so must be communicated.

4.2. Health, Safety, Security & Environment (HSSE)

HSSE are priorities throughout an asset's lifecycle. There are legal requirements in most countries, and internationally accepted standards, such as the IFC Performance Standards and the Equator Principles, to ensure that solar projects do not negatively impact the environment and guarantee a healthy and safe workplace. Furthermore, international financial institutions also use HSSE, and social requirements when assessing projects. Security is often a requirement in insurance policies, otherwise claims can be void.

Good HSSE coordination is fundamental to achieving all HSSE objectives, which can be summarised as follows:

- Establish an HSSE culture within the organisation and the relevant project team
- Establish, implement, and maintain an effective integrated HSSE management system
- Ensure compliance with applicable health, safety, and environmental legislation, codes, and standards and, whenever possible, with higher standards and best practices
- Ensure surveillance of the project site, especially of high-value products, as well as components which are difficult to replace quickly
- Ensure that intrinsically safe design is achieved by monitoring progress and preparation of results and systematically reviewing the design process, if necessary
- Manage risks in the design, procurement, construction, installation, commissioning, operation, and maintenance activities
- Ensure appropriate levels of skills for all staff engaged in carrying out critical HSSE activities and provide training where necessary
- Check for any potential HSSE impacts in the project area and ensure that these are minimised
- Make sure that the site surveillance is in line with the insurance requirements
- Ensure that a complete inventory of all waste and discharges is maintained and that all waste is disposed of in an environmentally acceptable way, in compliance with the relevant regulations
- Review lessons learned, performance and any opportunities to continuously improve, to update safe design

For this purpose, it is important that Asset Owner, the EPC, and other service providers meet to align on procedures to follow to avoid risks, especially when different service providers are working on the site simultaneously.

4.3. Due Diligence

Over the lifetime of a project, the asset, and its operating company – typically a special purpose vehicle (SPV) – move through a number of defined stages.

These stages are typically marked by changes in contractual liability and obligation, and the transitions or 'stage-gates' between phases are usually accompanied by contractual documentation. This could be in the form of a new contract starting with a different service provider, or third-party certification, with supporting documents, as defined in an ongoing contract.

A very important step of each due diligence assessment is the collection of the relevant documentation. An advisor should have comprehensive documentation check lists and conduct a "gap analysis" in the data-room. Within this context, the role of the Asset Manager (AM) is also very important as they can ensure that a structured data-room is properly built at all stages of a project.

The Due Diligence (DD) process can be divides into four sub-areas:

- Legal DD
- Technical DD
- Financial DD
- Political DD

Financial DD consists of the Insurance DD, Accounting DD, and Taxation DD.

4.3.1. Challenges and opportunities in the due diligence process

An effective due diligence process requires a structured methodology to assess key elements of risks and communicate the related outcomes to decision-makers, in a timely manner. This can result in changes to the structure of a project or the way that investments are monitored.

Relying on a weak methodology, unqualified or inexperienced assessors, or a poorly defined project plan to conduct due diligence, results in a cumbersome and ineffective process that does not produce the key information needed for effective decision-making.

There are numerous challenges in the due diligence process:

- The scope of work may not be well-defined, leaving key questions unanswered.
- Information requested may be poorly communicated, leading to more time spent gathering new or different data.
- Transaction responsibilities and timelines may not be well-understood; critical matters uncovered during due diligence may not be communicated to the appropriate counterparty.

At the same time, there are many benefits to conducting effective due diligence as it can help stakeholders:

- Objectively understand the assets and their underlying historical performance, including deviations from historical and recent trends.
- Identify key risks faced by the lender/investors and establish a communication framework to address these risks, including potential mitigation efforts. This could also result in deal-structuring alternatives such as pricing considerations, collateral requirements, or enhancements to required periodic reporting.
- Develop an understanding of critical policies and procedures used to prepare information used for decision-making and identify potential areas of information weakness.

Market confidence relies on and will improve with more effective and frequent due diligence. Increasing the cost-competitiveness of solar PV in the future will rely heavily on quality due diligence services which can help avoid asset underperformance, or non-performance.

TABLE 1 DUE DILIGENCE THROUGH THE STAGES OF A PROJECT'S LIFECYCLE

TYPE OF DUE DILIGENCE	PERTINENT PHASE	MAIN ASPECTS ANALYSED	NOTES
a) Legal DD (consisting of Legal, Environmental, and Compliance DD)			
Legal DD	Development and operation	Development: i. Respect of the relevant constraints ii. Respect of the key legal requirements within authorisation processes Operation: iii. Corporate aspects iv. Legal terms of the key contracts v. Correctness of the authorisation process	
Environmental DD	Development, construction, operation, and decommissioning	Verification of the compliance with environmental regulation and safeguarding against environmental accidents such as soil and/or groundwater contamination.	
Compliance/ reputational DD	Development, procurement, construction, and operation	Verification of the reliability, honesty, and legal compliance of the relevant counterparties. This should include technical, financial, legal, and social dimensions.	There is a serious risk of reputational damage linked to a lack of supply chain transparency. For more information on building sustainable and transparent supply chains, please refer to SolarPower Europe's *Sustainability Best Practices Benchmark*. In addition, SolarPower Europe is currently (as of December 2021) developing a supply chain monitoring programme that will further this effort.
b) Technical DD			
Technical DD	Development, construction, operation, and decommissioning	Development: i. Yield forecasts ii. Correctness of the layout of the site iii. Respect of site constraints iv. Land /rooftop rights v. Verification of grid connection solutions vi. Key terms of PPAs vii. Quality assessment of key components viii. Assessment of the EPC service providers' creditworthiness Construction: ix. Installation quality x. Compliance of as-built design with the approved layout Operation: xi. Production forecasts based on historical data xii. Warranty management xiii. Quality of components xiv. Compliance with key regulatory requirements	A technical advisor or "Owner's engineer" should be involved during the construction phase.

TABLE 1 DUE DILIGENCE THROUGH THE STAGES OF A PROJECT'S LIFECYCLE - *CONTINUED*

TYPE OF DUE DILIGENCE	PERTINENT PHASE	MAIN ASPECTS ANALYSED	NOTES
c) Financial DD (consisting of Insurance, Accounting, and Tax DD)			
Insurance DD	Construction and operation	i. Extent of coverage of risks insured ii. Adequate levels of insurance iii. Adequate deductibles	The insurance due diligence should cover both the erection policies, civil responsibility, Directors' & Officers' liability and "all risks" during operation.
Accounting DD	Operation	i. Verification of the credits and debits in the balance sheet (to quantify the working capital) ii. Verification of operating costs and key occupational assumptions iii. Verification of Profit & Loss and Cash Flow Statement to facilitate onboarding during operations	When a locked box mechanism is applied, due diligence processes should also include the verification of permitted leakages.
Tax DD	Operation	i. Verification of the timely and correct submission of tax returns ii. Verification of the effective entitlement to tax benefits requested (if any) iii. Verification of the correct management of VAT credits	
d) Political DD			
Political DD	Development, Construction	i. Change of political support for (ground-mount) solar systems ii. Risk of retroactive changes in support schemes iii. Instability of government	

4.4. Quality Management

Quality – if not set by clear criteria and measurements – is a perceptual, conditional, and somewhat subjective attribute and may be understood differently by different people. In general, it can be defined as a commitment to customers in the market or as fitness for intended use, in other words, how well the product performs its intended function. Quality also encompasses the reduction of harm that a product may cause to the environment or human society.

Quality management is key in all phases of LPM, from development to decommissioning. When done robustly, it ensures that a PV power plant works at its maximum efficiency for longer, lowering the levelized cost of electricity (LCOE) and making PPAs cheaper and more competitive. This is crucial to maintaining the growth of solar PV and attracting the necessary commitments and investments to support this. Taking a strong approach to QM will enable the industry to move on from past mistakes and confidently deliver solar plants as part of Europe's critical energy infrastructure.

Key to effective QM is a strong Quality Management System (QMS). Like QM, a QMS must always be present in LPM, from site selection to the end-of-Life phase and actions should always be flanked by good documentation. A sound QMS can form an important prerequisite for accessing project financing from banks and investors as it minimises the risks of a project. To further boost access to project finance, it is also important to ensure the power plants conform, and are certified to, international standards throughout their lifecycle. There a several international certification schemes and conformity assessment systems available for this. For more information see the *Risk management in the operational phase* chapter of the *Asset Management Best Practice*

4 Fundamentals of Lifecycle Project Management

/ continued

FIGURE 2 QUALITY MANAGEMENT THROUGHOUT THE LIFECYCLE OF A PROJECT

ENGINEERING PHASE

- Basic design
- Preliminary design
- Execution design
- As-built

Quality planning

PROCUREMENT PHASE

Supply control

Shortlisting of suppliers

- Selection of suppliers
- Qualification of suppliers

Factory Audit

- Pre-production control

Quality review: Audit

Supplier selection

- Agreeing on fixing the findings from the Factory Audit
- Agreeing on specs
- Agreeing on special quality requirements
- Defining criteria for Quality Monitoring

Quality improvement

Supply

- During production inspections
- Post-production control
- Pre-shipment inspection
- Pre-shipment inspection
- Pre-shipment testing
- Post- shipment inspection

Quality review: Monitoring

CONSTRUCTION PHASE

Preparatory phase

- Site survey
- Stakeholder management
- Construction Plan Preparation
- Work permits

Quality control

Implementation

- EH&S coordination
- Site organisation
- Civil works
- Electro-mechanical works
- Ancillary works
- Grid connection
- Checks and functional tests
- Mechanical completion
- Delivery of "As-built" docs
- Set up of strategic spare parts warehouse
- Training of owner and O&M service provider

Quality control

COMMISSIONING

Pre-commissioning and mechanical completion

Commissioning

- Off-grid testing
- On-grid testing

PAC tests

- PR test
- Other tests
- Start of plant operation

Intermediate and FAC

- PR test
- Other tests
- Handover to O&M service provider

Quality control

OPERATIONAL PHASE

Power Plant Operation

Power Plant Maintenance

(See also the O&M Best Practice Guidelines.)

Technical Asset Management

Commercial and Financial Asset Management

Lifecycle lessons learnt and feedback loop opportunity to previous lifecycle phases

(See also the Asset Management Best Practice Guidelines.)

Quality control

DOCUMENTATION

PRODUCT LIFETIME

Guidelines and the *Risk management* in the EPC phase of the *EPC Best Practice Guidelines* (available at www.solarpowereurope.org).

The four pillars of the **QMS** as defined in these guidelines are:

- Quality Review (QR)
- Quality Control & Assurance (QC)
- Quality Planning (QP)
- Quality Improvement (QI)

a) Quality Review

QR consists of a Quality Audit (QAu) and Quality Monitoring (QMo) of component and equipment suppliers. As a recommendation, this pillar should be supported by third-party audit/test firms. The QAu shall take place before a contract is signed. It should ensure that a supplier is capable of delivering on the terms of a contract. The QMo takes place once a contract has been signed and provides an ongoing review of a supplier's quality management processes. This might be in the form of pre-shipment testing, the commissioning (of parts) of the power plant, or the analysis of the plant performance. The QMo is necessary because an EPC service provider is not in control of a supplier's quality management processes. It is limited to reviewing the quality performance of the supplier and rejecting or accepting their components based on whether they conform to quality standards within the contract between the two parties.

b) Quality Control & Assurance

Another pillar of the QSM is the Quality Control & Assurance (QC). This applies more to suppliers as they need sound QC to avoid financial losses from rejections, or claims, and to fulfill their duties towards banks and insurers. It must be ensured that all standards and agreed criteria in a contract are met.

c) Quality Improvement

Using the QAu and drawing on their own experience can help service providers identify possible problems. These issues need to be addressed and actions must be agreed with the supplier, such as implementing better processes, and giving improved (narrower, clearer, more detailed) specifications. This is another pillar of the QSM, QI. This pillar has large cost saving potential, as it helps avoid quality issues.

d) Quality Planning

While QI starts with the supplier selection process, QP will have already started before. While QI is designed to help a supplier improve their processes, QP is designed to help select the right component type. For example, it might be possible to improve the service promise from the supplier for central inverters in remote areas during the QI process. However, it might be a better decision, to design the project with string inverters, as they can be easily replaced with locally stored spare inverters. This shows that an optimised design is of utmost importance. QP begins with site selection, since they can impose significant limitations on project designers' choices, either through natural or regulatory environments.

4.5. Lifecyle lessons learnt and feedback loop

Projects that have reached the operational stages of the lifecycle represent a significant learning opportunity from a technical, contractual, and financial perspective.

The experience and available operational data available can help stakeholders improve their services in two ways:

- Providing realistic, tested, and proven assumptions (both from a technical-operational perspective and from a financial-commercial one).
- Identifying areas of improvement that have created a positive impact on the overall return on investment and plant performance.

Carrying out lessons learned from the operational phases is a key tool in identifying ways of improving the efficiency of PV plants. More specifically the feedback loop has proven effective in identifying added value opportunities such as:

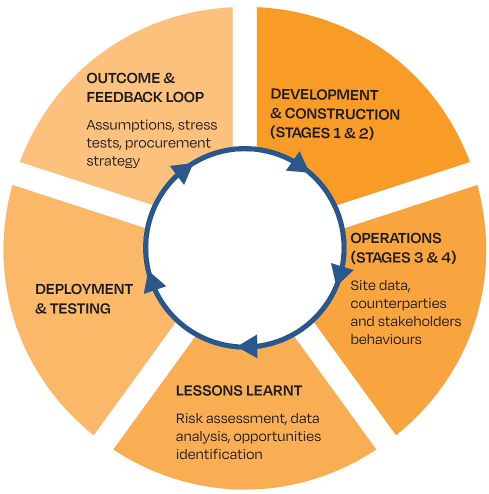
- Repeating the yield assessment based on reliable site data, aimed at improving the overall production expectations.
- Fine tuning the contracting strategy (simplification of complex or redundant processes set forth in

complex contracts, for instance the final acceptable processes).

- Re-defining the scope of work of the main service providers, rebalancing pricing, and risk allocation between stakeholders.
- Strengthen the criteria for the selection of key component suppliers and manufacturers.
- Increasing the sophistication and appropriateness of the spare parts strategy on a site- and portfolio-basis.

To take full advantage of the knowledge created by the operational phases of the lifecycle, a data driven, and analytical approach must be used from the very early stages of operation of the PV plants. This data is vital to establishing and carrying out a meaningful risk assessment and overall review of the PV plant as an investment. This risk driven approach is the foundation of stable operations and reduces the overall volatility of investments in PV plants.

FIGURE 3 LESSON LEARNT AND FEEDBACK LOOP PROCESS



5 Stage-Gates and Due Diligence

5.1. Introduction: discontinuity points across the lifecycle of solar assets

In the lifecycle of a PV plant, there are specific events that represent discontinuity points. They should be handled carefully to keep risks under control, ensure that the appropriate stakeholders and skillsets are involved, and avoid "gaps" in the transition phase.

In particular, the most relevant discontinuity events can be summarised as follows:

- Change of phase of a project:
  - Development, engineering, procurement
  - Construction
  - Operation under EPC warranty
  - Operation under ownership
  - Decommissioning & disposal
- Change of ownership between Asset Owners
- Change of financing structure, such as closing new financing or refinancing

The fundamentals of LPM are described under Chapter 4 of these guidelines. The present chapter focuses on the relevance of due diligence to ensuring continuity as a project transitions through the phases of its lifecycle.

5.2. Change of phase

When transitioning between project phases, it is crucial to conduct appropriate assessments to ensure the quality of a project, identify potential issues that could impact a project in the medium- and long-term, and ensure that the forecasted financial returns can be achieved.

A thorough assessment of solar assets typically requires a multi-disciplinary and holistic approach, as shown in Table 1 in Chapter 4. The relevant assessments can be conducted by in-house teams if the right expertise is available. However, using an external advisor is recommended (especially for technical and legal due diligence assessments) to ensure a fully impartial view. In addition, an external advisor can provide a wealth of benchmarking experience from other projects or assets they have analysed. Information obtained via objective and independent due diligence is a critical component of the investment and lending process, and such efforts directly affect the confidence that key parties, in particular service providers, lenders, and investors, have in the solar markets.

Depending on the size of the PV portfolio involved, the standardisation level of some contracts (e.g., insurance policies) and the geographical focus, some due diligence tasks can be skipped.

The results of the various assessments provide the rate and reliability in terms of performances for the lifetime of a PV plant.

5.2.1. Development, engineering, procurement

This phase covers all the tasks undertaken to get the project 'shovel-ready' or 'ready to build'. Usually, this is focused on the technical and financial development of the project, with a series of transactional milestones, such as investment committee approval, execution of EPC contracts and financial close.

It is important to assess the quality of the developed project to reach a final decision to build the project and sign the relevant contracts. In particular, the following aspects need to be analysed and it is recommended that they are properly investigated with legal and technical due diligence:

i. Yield estimates

To estimate the energy yield potential of a PV plant, technical advisers typically use simulation software based on models that use the best available data and methods. The result of the modelling is the P50 estimate, or in other words, the "best estimate". P50 is essentially a statistical level of confidence suggesting that the predicted solar resource/energy yield may be exceeded with 50% probability. P50 level of confidence may represent too high a risk for some investors. Therefore, other probabilities such as P90 (estimate exceeded with 90% probability) or P75 (estimate exceeded 75% of the time) might be considered. Lenders and investors might use P90 estimates in uncertain, or high-risk profile projects to be confident that sufficient energy is generated to comfortably repay the debt.

ii. Land rights

Ideally, the site on which the project is located should be free of obstacles. If these do exist, they must be considered during the design phase and the relevant consents or permits for the works must be obtained then (if required). If the site is affected by restrictive covenants which preclude solar PV (limitation to solely agricultural use can sometimes affect rural properties), then a release needs to be negotiated with the beneficiary of the covenant. Alternatively, defective title insurance can be put in place. This must be at a level which would fully compensate the project company for wasted capital costs, and loss of future income, arising from the project being decommissioned earlier than anticipated. Lenders will also want to see that insurance is in place where a site is affected by rights to run service media in unidentified locations, or where mineral rights are excepted from the title.

iii. Consistency of the authorisation process:

a) Planning permission in respect of the PV plant which is clear from the risk of judicial review.

b) Planning permission for cable route works which is clear from the risk of judicial review.

c) All relevant conditions imposed on the permissions (in particular those required to be discharged prior to commencing works on site) to have been discharged.

iv. Quality of the layout

A review of conceptual design is required in relation to the selected components, as well as infrastructures to ensure the plant design is in line with market standard and respect relevant constraints / prescription of the relevant permits.

v. Verification of the key terms of the PPAs

Including, when applicable, the creditworthiness of the counterparty.

vi. Connection to the grid

In most cases, solar PV projects require the right to connect to the grid. Therefore, a key part of the property due diligence is to check that both the site and project company have the rights to lay a cable to the point of connection to the grid.

5.2.2. Construction and operation under EPC warranty

If technical problems are not detected early during the construction of the plant, or at least within the two-year acceptance period, they can affect future performance and long-term operation. An Asset Owner/project developer will need the professional view of a technical advisor to check the overall quality of the plant. This will include a detailed review of components used on site, future yield estimations and site visits during and after construction. From the Owner's perspective, it is crucial for the technical advisor to identify any major issues prior to the acceptance period commencing, or at the latest, before the acceptance period is complete. Some crucial steps in the operation of the plants are the acceptance. The role of technical advisor becomes crucial during the PAC and FAC tests (whose recommended protocol has been described under Chapter 9 of the EPC guidelines).

5 Stage-Gates and Due Diligence

/ continued

5.2.3. Operation under ownership

In addition to periodic technical verifications, other important areas of evaluation for plants in operation are accounting and tax matters. It is the responsibility of SPV directors to verify all relevant documentation, especially when dedicated tax benefits have been obtained, to ensure legal compliance and avoid significant penalties. It is best practice to include a third-party auditor in this process to ensure transparency.

Effective tax and accounting due diligence may also reveal key indicators of potentially fraudulent activity. These can range from unusual transactions, discrepancies in accounting records, activities/transactions outside the normal course of business, and changes in important credit and underwriting policies and procedures.

5.2.4. Decommissioning

During the decommissioning phase, the role of technical advisor is to confirm that the components of the plant have been dismissed/recycled according to the relevant regulatory framework and that the land/roof has been restored to its original conditions. This work is particularly relevant for local authorities, landlords, and building owners.

5.2.5. Change of ownership

If ownership of a PV plant or portfolio changes hands, it is very important for the potential buyer to collect the relevant information and to learn as much as possible about the "history" of a plant and the SPV. In addition, due diligence may also benefit the seller as a rigorous assessment and examination may reveal market value that is higher than expected. Hence why it is not uncommon to also have a "vendor due diligence", commissioned by the Seller prior to starting a selling process.

5.2.6. Financing or Refinancing

The introduction of debt financing within a project's capital structure or refinancing at any phase of the lifecycle of a PV plant, typically requires detailed verification. To satisfy lenders' requirements for approving initial or further financing, all aspects of the project must be aligned and quality assured. Ensuring sufficient protection of an investor's capital requires a fully functioning, and revenue-generating project, with all the required permits.

Accordingly, a solar project finance transaction is not a mere negotiation of financial structuring but also involves an analysis of real property rights, construction and development contracts, equipment warranties, power purchase and interconnection agreements, PV power plant performance, cash management, environmental permitting, energy regulatory matters, and, of course, tax analysis.

The key rule for project finance is risk mitigation: the transaction structure must allocate risks that could affect the project's cash flow to a creditworthy party, with the ability to mitigate them . Much of the tension in negotiating solar project financing derives from each participant's efforts to properly identify risks and shift them to others while retaining the benefits from the transaction. For example, the project sponsor usually seeks to shift technology risks to the equipment manufacturer and EPC service provider, while preserving as much of the cash flow and appreciation in project value as possible for itself. The lender will usually seek to shift risk to the Owner by taking paramount positions in the project revenues and assets. They will also seek to guarantee the loan repayment schedule by placing contractual obligations and risks related to warranties onto third parties, such as equipment manufacturers and EPC service providers.

Risk shifting can be done through various legal procedures, including (i) grants of liens on the project assets, revenues, and key project agreements; (ii) warranties and contractual requirements for the equipment and for the maintenance services performed; (iii) requirements for various types of insurance products to cover certain adverse events; (iv) and guaranties of each participant's obligations from creditworthy entities. During a project financing transaction, the relevant advisor focuses on the calculation of risk magnitude, and the negotiation of risk-shifting devices. This normally results in substantial and complex documentation that must be effectively stored and closely evaluated.

6 Personnel & training

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Any project needs to have the right mix of skills amongst its personnel to carry out the required work at every stage. The solar industry benefits from a wide range of skills and experience. Team members with electrical, mechanical, financial, business and communications skills are required to handle different tasks and all of them strengthen the positive impact of the service provision.

These guidelines propose two skills matrices that can be found in the annexes. The first (annex a) maps the necessary skills through the different phases of a project's lifecycle and encompasses the skills needed by EPC, O&M, and any other sub-contracted service providers. The second matrix (annex b) focuses on the Asset Manager's role as they are present throughout the lifecycle and have different responsibilities to other service providers. This does not exclude AM, EPC, and O&M activities being done by the same, vertically integrated company and the two matrices can be used alongside each other.

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A Annex

A. Lifecycle phases skills matrix. (Download it from www.solarpowereurope.org)

LIFECYCLE PHASE	TASK CATEGORY	TASK	REQUIRED CERTIFICATION	REQUIRED SKILLS	SKILLED PERSONNEL AVAILABLE?	NAME	SURNAME	CONTACT
Development, engineering, and procurement	Site assesment	Risk Assesement - health and occupational	Certification (postgrad) of Occupational Health & Safety					
		Risk Assesement - mechanical	Static engineer					
		Related partly solar specific regulations (heritage protection, building authority)	Engineer / Architect					
	Authorisation	Communication with Electricity Provider	Certified electric engineer	Knowledge about actual standards and regulation, managerial and communication skills				
		Create and submit authorisation documentation	Country related licence for designing renewable energy structures					
	Procurement	Purchasing PV modules, Frames, Inverters, electrical materials etc. Manage Supplier Relationships.						
	Logistics, organisation	Managing transportation of personnel, materials and tools						
		Organization planning on site						
Construction and operation under EPC warranty	Construction & installation	PV Module	Certified electrician	Basic knowledge about the intalled product (e.g., handling, general safety guidelines, installation, etc.). See also recommendations by module manufacturer/installation manual, thermography and power measurements				
		Inverter	Certified electrician	Power Electronics (e.g. experience with specific product and type of inverter), Learning Tools Interoperability (LTI)				
		Electric - General	Certified electrician with MV certification (MV in case of plants with HV connection)	Other relevant skills (e.g. Specific Inspection & Test training, relevant accredited courses etc.)				
		Data & Comms	Certified electrician	Termination of specific communication cabling, monitoring/SCADA, and satelite/broadband systems				
		Security Systems	Certified electrician	Specific experience with security systems for site protection				
		Mounting	Company or country relevant requirements (e.g. working at height, Certified industrial alpinist, asbestos awareness, use of specific equipment, construction/installation certificate etc.)	Basic knowlege about the installed product (e.g. handling, general sefety guidlines, installation etc.; see also recommendations by supplier/installation manual), technical experience				
		Preparatory works if needed (e.g., earthwork, roof works, etc.)	Specific job-related certification	Specific job-related skills				
		Technical Lead - Electrical (resonsible for all electrical works and guides electric installers)	Electric engineer or certified electrician with country-related licence and certification	Advanced knowledge and experience in solar system's electric works. Managerial skills, experience in supervision and coordination of teams				
		Technical Lead - Mechanical (responsible for all mechanical works, such as mouning, and guides installers)	Country-related licence and certification	Advanced knowledge and experience in mounting solar systems. Managerial skills, experience in supervision and coordination of teams				
		Mechanical - Structural						

A. Lifecycle phases skills matrix - *continued.* (Download it from www.solarpowereurope.org)

LIFECYCLE PHASE	TASK CATEGORY	TASK	REQUIRED CERTIFICATION	REQUIRED SKILLS	SKILLED PERSONNEL AVAILABLE?	NAME	SURNAME	CONTACT
Construction and operation under EPC warranty	Health & Safety	High Voltage (HV) Substation Access						
		Inspection - electrical work (Touch protection, tests etc)	Certified electrician. Country-related licence and certification for touch protection control	Accuracy, advanced knowledge about related standards. Experience in measuring process				
		Risk Assessment	Certification of Occupational Health & Safety					
		Occupational Health & Safety training course	First Aid at Work					
		(Sub)contractors' assessment and control						
		Company's Services Introduction						
		Health & Safety assessment test						
		Manual handling						
		Display Screen Equipment						
		Other task, company or country relevant requirements (e.g. working at height, asbestos awareness, use of specific equipment,						
	Environment	Training course and/or certificate	Certificate of Environmental Management					
		Any further, relevant training in environmental and waste management	Waste disposal and handling authorisation					
	Monitoring & metering	Installing monitoring system (WIFI, SCADA, Connection, Settings)	Monitoring tool training. Other relevant skills (e.g. data handling tool)	Knowledge of using monitoring tools				
		Meter accreditation and calibration	Only personnel authorised by electricity provider					
	Warranty services	Handling during construction as well as ensure warranty conditions are kept.						

A. Lifecycle phases skills matrix - *continued*. (Download it from www.solarpowereurope.org)

LIFECYCLE PHASE	TASK CATEGORY	TASK	REQUIRED CERTIFICATION	REQUIRED SKILLS	SKILLED PERSONNEL AVAILABLE?	NAME	SURNAME	CONTACT
Operation under ownership	Health & Safety	Company's Services Introduction						
		Health & Safety assessment test						
		Manual handling						
		Display Screen Equipment						
		Risk assessment	Certification of Occupational Health & Safety					
		Occupational Health & Safety training course						
		Training to handle Health & Safety in a team						
		First Aid at Work						
		MV/HV Substation Access						
		(Sub)contractors' assessment and control						
		Other task, company or country relevant requirements (e.g. working at height, asbestos awareness, use of specific equipment, construction/installation certificate etc)						
	Environment	Training course and/or certificate	Certificate of Environmental Management and Assessment					
		Any further, relevant training in environmental and waste management	Waste disposal and handling authorisation					
	Operation & Maintenance	Operating and maintaining monitoring system (WIFI, SCADA, Connection, Settings)	Monitoring tool training. Other relevant skills (e.g. data handling tool)					
		Meter operation, maintenance, accreditation, and calibration						
		Operating and maintaining PV Modules	Basic knowledge about the installed product (e.g., handling, general safety guidelines, installation, etc.). See also recommendations by module manufacturer/installation manual, thermography and power measurements					
		Operating and maintaining the inverter	Power electronics, learning tools interoperability (LTI)	Experience with the specific product and type of inverter used				
		Operating and maintaining the electrical systems in a PV plant	Certified electrician	Other relevant skills (e.g. Specific Inspection & Test training, relevant accredited courses etc.)				
		Operating and maintaining the data & comms infrastructure	Certified electrician	Termination of specific communication cabling, monitoring/SCADA, and satelite/broadband systems				
		Operating and maintaining the security system	Certified electrician	Experience with the specific product and type of system installed				

B Annex

A. Skills matrix for Asset Managers. (Download it from www.solarpowereurope.org)

Category	Function	Leadership	Leadership	Leadership	Leadership	Managerial	Managerial	Managerial	Managerial	Administration	Administration	Administration	Administration	Data &	Data &	Data &	Data &
	First name																
	Surname																
Technical	Certain monitoring tool training for portfolio overview and analysis of production losses																
	Training on KPIs																
	Training on benchmarking for costs of key components and servicies (inverter, modules, meter calibration, main protection calibration, etc.)																
	Training on insurance claim management																
	Training on warranties management																
	Training on key terms of EPC contracts																
	Training on key terms of O&M contracts																
	Training on production forecasts																
	Specific inspection and on site test training																
Health & Safety	Company's Services introduction																
	Health & Safety assessment test																
	Manual Handling																
	Display Screen Equipment																
	Risk Assessment																
	Occupational Health & Safety training course																
	Training to handle Health & Safety in a team																
	Certification of Occupational Health & Safety																
	First Aid at Work																
	HV Substation Access																
	Managing Contractors																
	Other task, company or country relevant requirements (e.g. working at height, asbestos awareness, use of specific equipment, construction/installation certificate																
Administrative /Commercial	Training on contract management and related																
	Training on key regulatory obligations in a specific																
	Training about permitting processes in a specific																
	Training on software to manage the revenue cycle																
	Training on grid operator web site																
	Training on feed-in tariff portal and related applications																
Financial	Training on financial modelling																
	Training on main obligations from loan agreements																
	Certain ERP training																
	Training on budgeting and reporting models																
	Training on main accounting principles for the renewable energy sector in a specific country																
	Training on main tax obligations in a specific country																
Portfolio Management	Project Management training																
	Training on management of multi-disciplinary																

Planned

Not required

Required

Update required

SolarPower Europe

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