Solar Bankability Final Workshop

8th February 2017 – Session 3

Best Practices Guidelines for EPC and O&M

Caroline Tjengdrawira (3E)

Funded by the Horizon 2020 Framework Programme of the European Union

www.solarbankability.eu

Presentation Outline

I. Lifecycle costs and related risks in PV investment financial model

II. Gaps in EPC and O&M technical aspects

III. Best-practice guidelines for EPC and O&M contracting

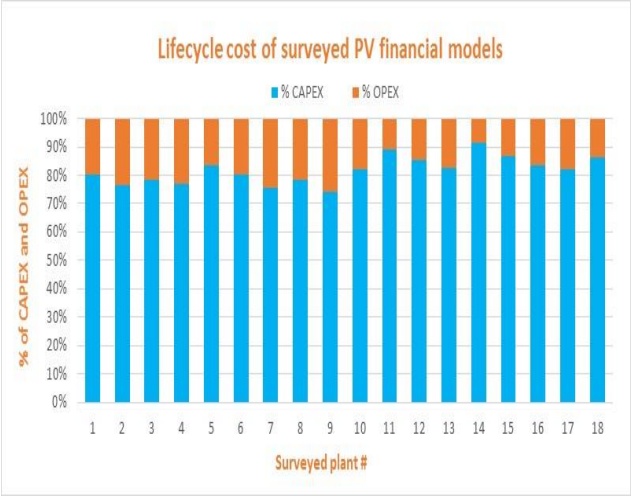
Lifecycle Costs in PV Investment Financial Model

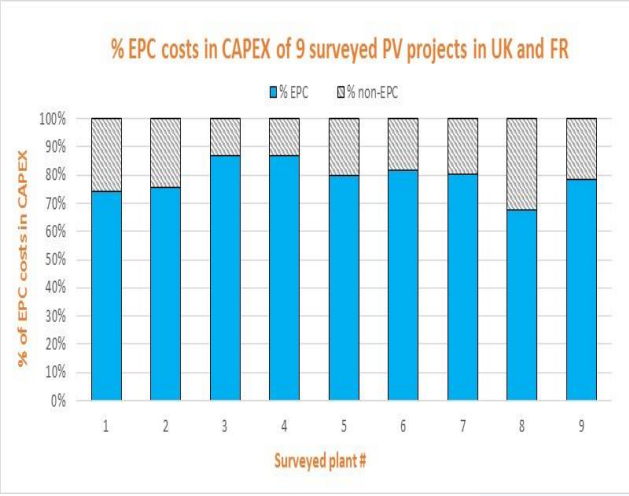
EPC and O&M are Influential to CAPEX and OPEX

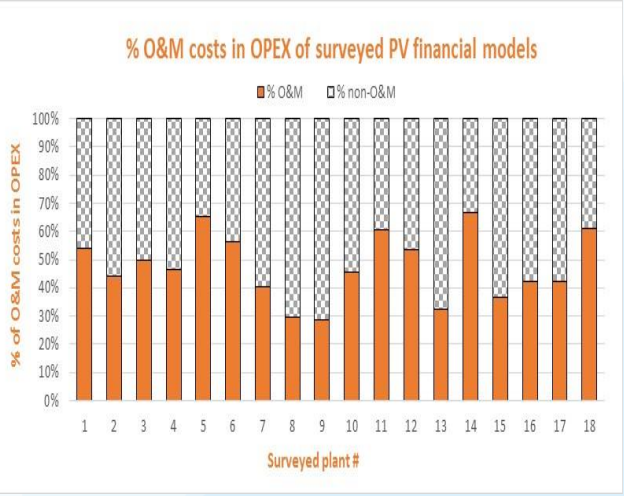
» CAPEX is dominant in lifecycle costs (75-90%)

» Majority of CAPEX is EPC (70-90%)

» Wide O&M range in OPEX (30-70%)







Data from surveys of

- *18 PV financial models (ground-mounted plants, FR-UK-DE-IT, 2011-2015)*
- *8 EPC and O&M contracts (ground-mounted and rooftop plants, FR-UK-IT-NL, 2014-2016)*
- *7 yield reports and scientific literature*

Technical Inputs in EPC, O&M and Yield Estimation

Gaps Analysis in Technical Assumptions

Risk	Phase/field	Identified critical technical gaps
Year-0	Procurement/ product selection and testing	1. Insufficient EPC technical specifications to ensure that selected components are suitable for use in the specific PV plant environment of application. 2. Inadequate component testing to check for product manufacturing deviations. 3. Absence of adequate independent product delivery acceptance test and criteria.
	Planning/ lifetime energy yield estimation	4. The effect of long-term trends in the solar resource is not fully accounted for. 5. Exceedance probabilities (e.g. P90) are often calculated for risk assessment assuming a normal distribution for all elements contributing to the overall uncertainty. 6. Incorrect degradation rate and behavior over time assumed in the yield estimation. 7. Incorrect availability assumption to calculate the initial yield for project investment financial model (vs O&M plant availability guarantee).
	Transportation	8. Absence of standardized transportation and handling protocol.
	Installation/ construction	9. Inadequate quality procedures in component un-packaging and handling during construction by workers. 10. Missing intermediate construction monitoring.
	Installation/ provisional and final acceptance	11. Inadequate protocol or equipment for plant acceptance visual inspection. 12. Missing short-term performance (e.g. PR) check at provisional acceptance test, including proper correction for temperature and other losses. 13. Missing final performance check and guaranteed performance. 14. Incorrect or missing specification for collecting data for PR or availability evaluations: incorrect measurement sensor specification, incorrect irradiance threshold to define time window of PV operation for PR/availability calculation.
Risks during operation	Operation	15. Selected monitoring system is not capable of advanced fault detection and identification. 16. Inadequate or absence of devices for visual inspection to catch invisible defects/faults. 17. Missing guaranteed key performance indicators (PR, availability or energy yield). 18. Incorrect or missing specification for collecting data for PR or availability evaluations: incorrect measurement sensor specification, incorrect irradiance threshold to define time window of PV operation for PR/availability calculation.
	Maintenance	19. Missing or inadequate maintenance of the monitoring system. 20. Module cleaning missing or frequency too low.

» Gaps exist across all project phases

Data from surveys of

- *18 PV financial models (ground-mounted plants, FR-UK-DE-IT, 2011-2015)*
- *8 EPC and O&M contracts (ground-mounted and rooftop plants, FR-UK-IT-NL, 2014-2016)*
- *7 yield reports and scientific literature*

Gaps in EPC Contracting

Year-0 Risks

Procurement, Product Selection and Testing

- Insufficient EPC technical specifications for major plant components
- Inadequate component testing
- Absence of product acceptance

Transportation

- Absent standard protocol for transport and handling

Construction

- Inadequate protocol for component handling by workers
- Missing construction monitoring

Gaps in EPC Contracting

Year-0 Risks

Provisional and final acceptance

- Inadequate visual inspection protocol
- Missing/incorrect short-term performance check at provisional acceptance
- Missing/incorrect final performance check
- Absence of guaranteed performance
- Missing/incorrect:
  - Assumptions in performance calculation
  - Measurement sensor specification
  - Irradiance threshold

Gaps in O&M Contracting

Risks During Operation

Operation

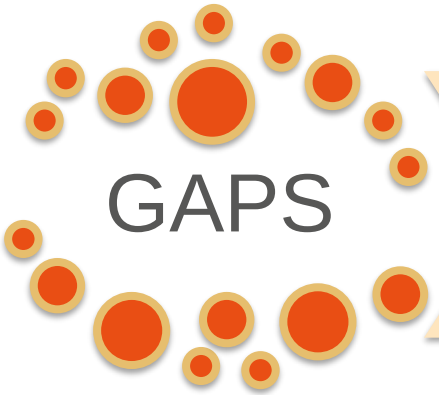
- Inadequate monitoring system for advanced fault detection and identification
- Inadequate visual inspection protocol
- Absence of guaranteed performance
- Missing/incorrect:
  - Assumptions in performance calculation
  - Measurement sensor specification
  - Irradiance threshold

Maintenance

- Missing/inadequate monitoring system maintenance
- Module cleaning missing or frequency too low

PV Financial Model – Technical Risks

Gaps in Technical Assumptions Leading to Technical Risks Impacting PV Investment Costs



- Incorrect set-ups of EPC and O&M
- Incorrect yield estimation

RISKS

- Type 1 risks influence plant performance and yield
- Type 2 risks cause partial or overall plant outage → lowering plant availability and yield

LCOE

- Increase costs (CAPEX or OPEX)
- Over- or under-estimation of yield

Managing PV Technical Risks

Technical Aspects in EPC and O&M Contracts

» Are important since they affect CAPEX, OPEX or yield.
» Need to be set up properly to minimize technical risks.

EPC

Scope of works
- Engineering & design
- Component procurement
- Construction & installation
- Test & commissioning
- Decommissioning
- Site/structural study
- Weather station
- Surveillance/security
- Site preparation
- Access roads/paths
- O&M manual provision
- Initial spare parts

Technical specifications
- Design & technology
- Component brand & quality
- Component warranties

Testing & acceptance
- Construction monitoring
- Completion test
- Provisional commissioning
- Final commissioning

Performance & guarantees
- Performance measurement & calculation
- Guaranteed performance
- Guaranteed availability
- Defect liability period / EPC warranty

O&M

Scope of works
- Monitoring
- Preventive maintenance
- Predictive maintenance
- Corrective maintenance
- Reporting
- Spare part management
- Warranty claim management
- Site security & maintenance
- Cleaning of PV modules

Performance & guarantees
- Test protocol
- Performance measurement & calculation
- Guaranteed performance
- Guaranteed availability

Best Practice Checklists

Tools to Minimize Technical Risks by Proper EPC and O&M Contracting and Yield Estimation

Three main checklists are:

1. Best Practice Checklist for EPC Technical Aspects
2. Best Practice Checklist for O&M Technical Aspects
3. Best Practice Checklist for Long-Term Yield Assessment

Three supplementary checklists are:

4. Checklist for As-Build Documents – Type and Details
5. Checklist for Record Control
6. Checklist for Reporting Indicators

Best-Practice for EPC and O&M Contracting

Technical Aspects & What to Look for in The Contracts

EPC contract	
A	Definitions, interpretation
B	Contractual commitments
C	Scope of works – engineering
D	Scope of works – procurement
E	Scope of works – construction
F	Scope of works – administrative and others
G	Manufacturer warranties
H	EPC warranty and Defect Liability Period (DLP)
I	Key performance indicators (KPIs) and guarantees
J	Commissioning and acceptance

O&M contract	
A	Definitions, interpretation
B	Purpose and responsibilities
C	Scope of works – environmental, health and safety
D	Scope of works – operations
E	Scope of works – maintenance
F	Scope of works – data and monitoring
G	Scope of works – spare parts management
H	Scope of works – plant security
I	Key performance indicators (KPIs)
J	Contractual commitments

BestPracticeChecklists PDF

Best Practice Checklists

Online at www.solarbankability.eu

SOLAR BANKABILITY

Best Practice Guidelines for PV Cost Calculation

Accounting for Technical Risks and Assumptions in PV LCOE

Deliverable D3.2
13/12/2016

Funded by the Horizon 2020 Framework Programme of the European Union

www.solarbankability.eu

Annex C – Best Practice Checklists

This annex presents 6 checklists which are aimed for use for utility-scale (ground-mounted) and commercial rooftop PV installations. The checklists for residential systems are presented in the report *Technical Bankability Guidelines - Recommendations to Enhance Technical Quality of PV Investments* [3].

C.1. Best Practice Checklist for EPC Technical Aspects

☑/☒	Technical aspect & what to look for in the EPC contract
A	**Definitions, interpretation**
☐	1. Is there a set of definitions of important terms provided and are those clear and understood by all stakeholders?
B	**Contractual commitments**
☐	2. EPC contractor qualification
☐	3. Responsibility and accountability
☐	4. Date of ownership and risk transfer are defined and acceptable
☐	5. Construction start date and end date are defined and acceptable
☐	6. Plant Commercial Operation Date (COD) is defined and in line with FiT or PPA commencement dates
☐	7. The EPC works should be carried in compliance with (non-exhaustive list) • Grid code compliance; plant controls (e.g. ability for emergency shut-downs or curtailment according to grid regulations) • PPA compliance • Building permits (if applicable) • Environmental permits • Specific regulation for the site (e.g. vegetation management, disposal of green waste)
C	**Scope of work – engineering**
☐	8. Overall the scope of works for the EPC should be clearly defined. Which activities are included in the EPC services (is it a turnkey EPC)? Are they clearly defined?
☐	9. The EPC should include Technical Specifications consisting of • [Best practice] The operating environment is defined for: ○ Minimum and maximum ambient temperature ○ Maximum relative humidity ○ Maximum altitude ○ Local climate

Best Practice Guidelines for PV Cost Calculation 50

C.2. Best Practice Checklist for O&M Technical Aspects

☑/☒	Technical aspect & what to look for in the O&M contract
A	**Definitions, interpretation**
☐	1. Is there a set of definitions of important terms provided and are those clear and understood by all stakeholders?
B	**Purpose and responsibilities**
☐	2. Is the fundamental purpose (goals) of the contract clearly defined?
☐	3. Are the roles and responsibilities (and boundary conditions) of the multiple stakeholders within the contract clear and understood?
C	**Scope of works – environmental, health and safety** Note: The Asset Owner has the ultimate legal and moral responsibility to ensure the health and safety of people in and around the solar plant and for the protection of the environment around it. This practice implementation is normaly subcontracted to the O&M contractor.
☐	4. Environment • Regular inspection of transformers and bunds for leaks (according to the annual maintenance plan) • Recycling of broken panels and electric waste • Sensible water usage for module cleaning • Proper environmental management plan in place
☐	5. Health and safety (H&S) • Properly controlled access and supervision in the solar plant – necessary boundaries and site restrictions • Proper induction to ensure awareness of risks and hazards • Proper training and certification on the specifics of a PV plant and voltage level • Hazard identification/marking • Wiring sequence marking • H&S legislation available • Established personal protective equipment (PPE) (not exhaustive list): safety shoes, high visibility clothing, helmet, gloves (and/or insulated gloves), slash masks and glasses (depending on the site), fire retardant and/or arc flash rated PPE where necessary • Calibrated and certified equipment (full documentation available)
D	**Scope of works – operations**
☐	6. Documentation Management System (DSM) • As-built documentation / IEC82446 (see Annex C.4) ○ Site information ○ Project drawings ○ Project studies

Best Practice Guidelines for PV Cost Calculation 58

C.3. Best Practice Checklist for Long-Term Yield Assessment

☑/☒	Technical aspect & what to look for in the LTYA
A	**Solar resource assessment**
☐	1. Only reliable solar irradiation data sources should be used and the name(s) and version(s) must be clearly stated. Data source(s) used must be able to provide uncertainty estimations and ideally have been extensively validated
☐	2. The period covered by the solar irradiation data source(s) used must be reported. Only data sources with more than 10-year recent data should be used for LTYA calculations
	3. The effect of long-term trends in the solar resource should be analyzed. In the presence of such trends, the long-term solar resource estimation should be adjusted to account for this effect
☐	4. The use of site adaptation techniques is recommended to reduce the uncertainty. A measurement campaign of at least 8 months and ideally one full year is recommended
B	**PV yield modeling**
☐	5. The PV modeling software and the specific version used must be clearly stated in the report
☐	6. If in-house software is used, the name(s) and version(s) must also be stated
☐	7. All assumptions (e.g. soiling losses, availability, etc.) and sub-models used (e.g. transposition model) must be clearly stated
C	**Degradation rate and behavior**
☐	8. The degradation rate(s) used for the calculations must be clearly stated in the report. It is recommended to differentiate between first year effects and yearly behavior over project lifetime
☐	9. Degradation behavior assumption (e.g. linear, stepwise, etc.) over time should be clearly stated and ideally backed up with manufacturer warranties
☐	10. If specific manufacturer warranties are available (e.g. module warranty document or sales agreement), these can be used to fine tune the lifetime degradation calculation
D	**Uncertainty calculation**
☐	11. All steps in the long-term yield calculation are subject to uncertainties. All uncertainties should be clearly stated and references must be provided in the report
☐	12. Special attention must be paid to the solar resource related uncertainties as these are among the most important elements in the contribution to the overall uncertainty
☐	13. If special methods are used to reduce some uncertainties e.g. site adaptation techniques, these should be clearly documented and ideally backed up with scientific validation
☐	14. Special care must be taken when classifying each uncertainty as either systematic or variable (stochastic) since these are treated differently in overall lifetime uncertainty calculations
☐	15. When possible, exceedance probabilities (e.g. P90) for each uncertainty must be calculated using empirical methods based on available data instead of assuming normal distribution for all elements

Best Practice Guidelines for PV Cost Calculation 64

C.4. Checklist for As-Build Documents – Type and Details

Information type and depth of detail / as-built documents		
No.	Minimum Requirements	Description
1	Site information	• Location / map / GPS Coordinates • Plant access / keys • Access roads • O&M building • Spare parts storage / warehouse • Site security information • Rooftop condition and load requirements / restrictions (rooftop system only) • Stakeholder list and contact information (for example, owner of the site, administration contacts, firefighters, sub-contractors / service providers, ...)
2	Project drawings	• Plant layout and general arrangement • Cable routing drawings • Cable list • Cable schedule/ cable interconnection document • Single line diagram • Configuration of strings (string numbers, in order to identify where the strings are in relation to each connection box and inverter) • Earthing / grounding system layout drawing • Lightning protection system layout drawing (optional) • Lighting system layout drawing (optional) • Topographic drawing • Grid access point schematic
3	Project studies	• Shading study / simulation • Energy yield study / simulation • Inverter sizing study
4	Studies according to national regulation requirements	• Voltage drop calculations • Protection coordination study • Short circuit study • Grounding study • Cable sizing calculations • Lightning protection study
5	PV modules	• Datasheets • Flash list with PV modules positioning on the field (reference to string numbers and positioning in the string) • Warranties and certificates
6	Inverters	• O&M manual • Commissioning report • Warranties and certificates • Factory Acceptance Test • Inverter settings

Best Practice Guidelines for PV Cost Calculation 65

C.5. Checklist for Record Control

Record control			
No.	Activity Type	Information Type	Input Record
1	Alarms / operation incidents	Alarms description	Date and time, affected power, equipment code / name, error messages / codes, severity classification, curtailment period, external visits / inspections from third parties
2	Contract management	Contract general description	Project name / code, client name, peak power (kWp)
3	Contract management	Asset description	Structure type, installation type
4	Contract management	Contract period	Contract start and end date
5	Contract management	Contractual clauses	Contract value, availability (%), PR (%), materials / spare parts, corrective work labor
6	Corrective maintenance	Activity description	Detailed failure typification, failure, fault status, problem resolution description, problem cause (*)
7	Corrective maintenance	Corrective maintenance event	Associated alarms (with date), event status (*)
8	Corrective maintenance	Corrective maintenance event log	Date and time of corrective maintenance creation (or work order), date and time status change (pending, open, recovered, close), end date and time of the intervention, start date and time of the intervention, technicians and responsible names and function (*)
9	Corrective maintenance	Intervention equipment / element name	Affected power and affected production, equipment code / name
10	Inventory management	Warehouse management	Inventory stock count and movement, equipment code / name
11	Monitoring and supervision	Equipment status	Date, status log (protection devices, inverters, monitoring systems, surveillance systems)
12	Monitoring and supervision	Meteo data	Irradiation, module temperature, other meteo variables (ambient temperature, air humidity, wind velocity and direction, ...) (**)
13	Monitoring and supervision	Production / consumption data	AC active and reactive power at PV plant injection point and other subsystems or equipment, consumption from auxiliary systems, other variables (DC/AC voltages and currents, frequency), power from DC field (**)
14	Monitoring and supervision	Performance data	PV plant energy production; PR; expected vs real
15	Preventative maintenance	Intervention equipment / element name	Affected power and affected production, equipment code / name, intervention start and end date
16	Preventative maintenance	Maintenance description	Measurements, preventative maintenance tasks performed, problems not solved during activity and its

Best Practice Guidelines for PV Cost Calculation 68

C.6. Checklist for Reporting Indicators

Reporting Indicators				
No.	Proposed Indicator	Predicted	Measured	Estimated
1	Insolation	•	•	
2	Active energy produced	•	•	✓
3	Active energy consumed		✓	
4	Reactive energy produced		✓	
5	Reactive energy consumed		✓	
6	Peak power achieved		✓	
7	Performance Ratio	•	•	✓
8	Energy Performance Index			✓
9	Balance of system efficiency			✓
10	Plant external energy losses			✓
11	Plant internal energy losses			✓
12	Energy-based availability			✓
13	Time-based availability			✓
14	Inverter specific energy losses			✓
15	Inverter specific efficiency			✓
16	Module soiling losses		✓	
17	Module degradation			✓

Note: • Minimum Requirement, ✓ Best Practice

Best Practice Guidelines for PV Cost Calculation 70

Technical Risk Flash Cards

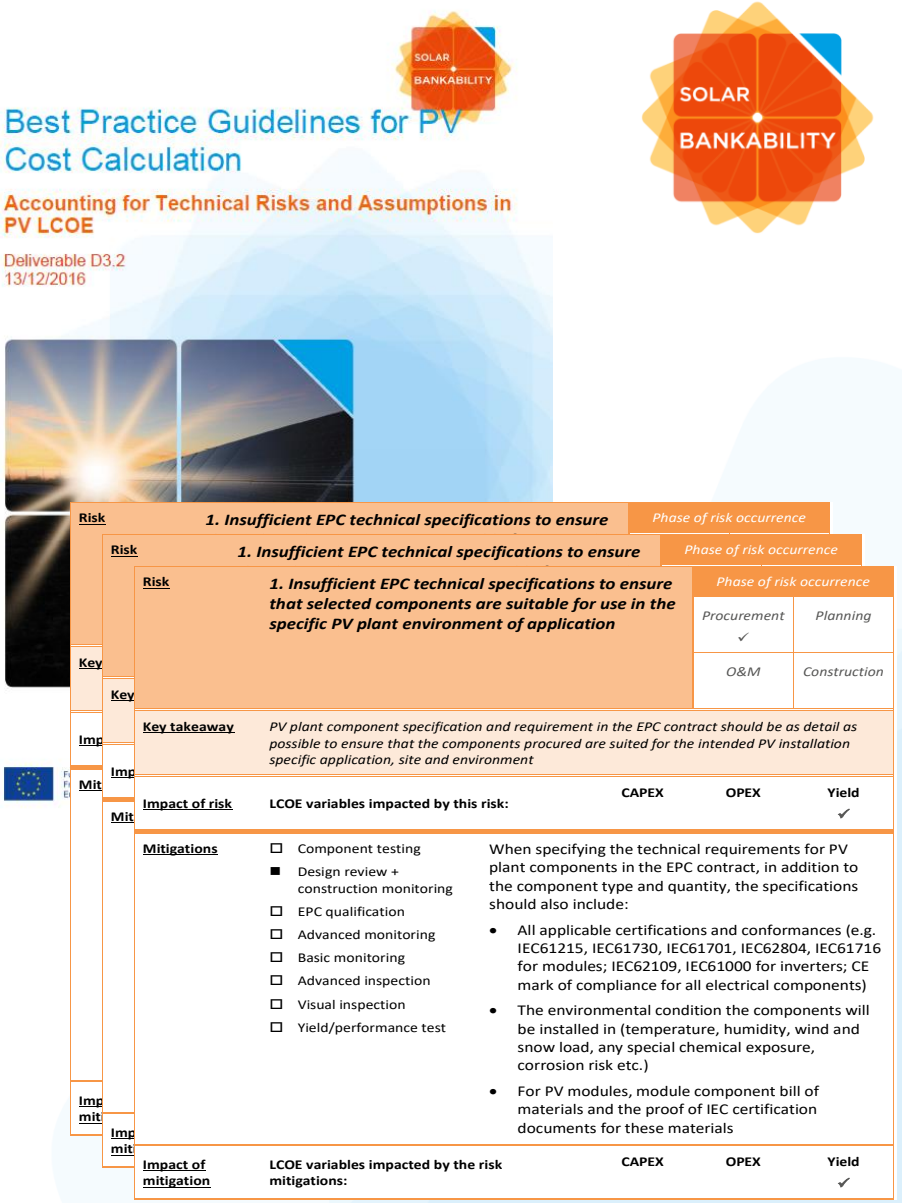
Online at www.solarbankability.eu

Categorization based on:

- Risk impacts CAPEX/OPEX/yield
- Risk mitigation impacts on CAPEX/OPEX/yield

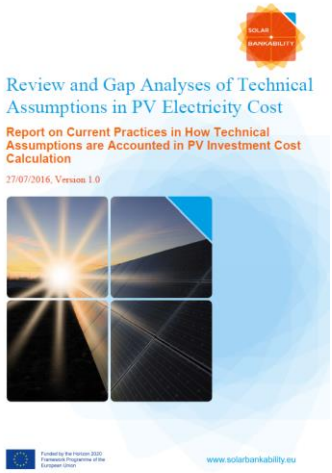
Risk flash cards with following info:

- Description of the risk,
- Phase at which the risk occurs,
- Key takeaway of the risk,
- Mitigations,
- Risk and mitigation impacts on LCOE



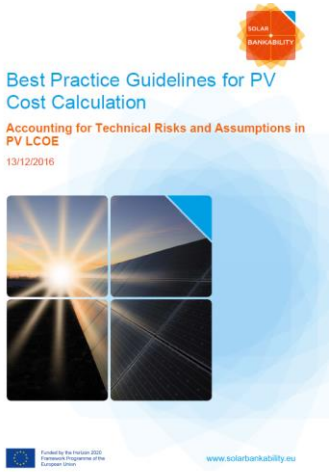
Reports

Online at www.solarbankability.eu



Deliverable D3.1 report

- "Review and Gap Analyses of Technical Assumptions in PV Electricity Cost – Report on Current Practices in How Technical Assumptions are Accounted in PV Investment Cost Calculation"



Deliverable D3.2 report

- "Best Practice Guidelines for PV Cost Calculation – Accounting for Technical Risks and Assumptions in PV LCOE"

Thank you

PRESENTED BY
Caroline Tjengdrawira
ctj@3e.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649997.
The content of this report reflects only the author's view and the Commission is not responsible for any use that may be made of the information it contains

Funded by the Horizon 2020
Framework Programme of the
European Union

www.solarbankability.eu