



Solar Bankability

Mitigating Technical Risks in PV Investment through Quality Infrastructure



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Funded by the Horizon 2020
Framework Programme of the
European Union

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Together with our clients it's our mission to shape the world of tomorrow. Backed by 150 years of experience in energy, water and infra, we can provide you **engineering, consultancy and project management services** and be your partner in innovative solutions, the energy transition & digital transformation.

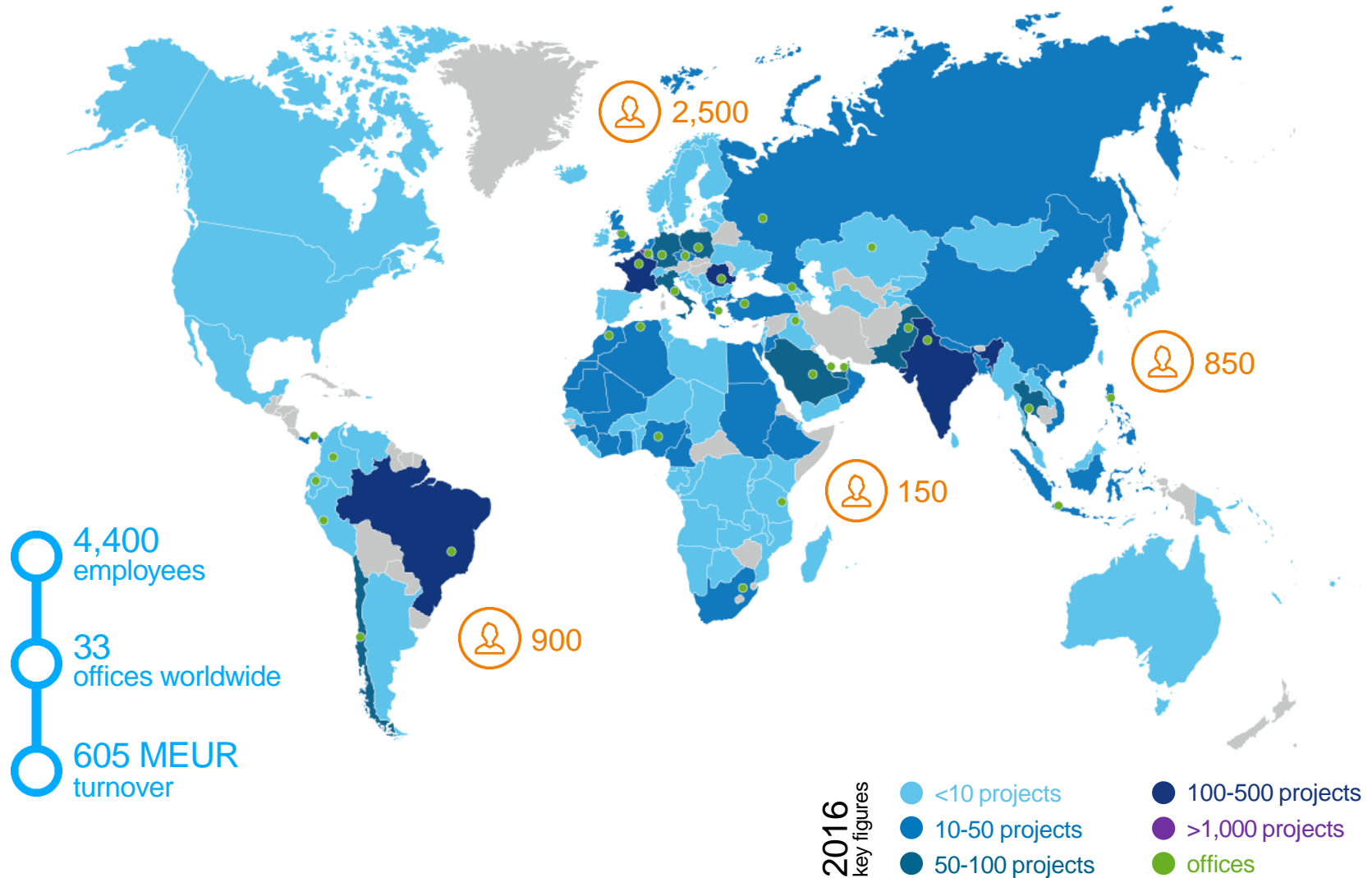
Daniel Develay, CEO



TRACTEBEL

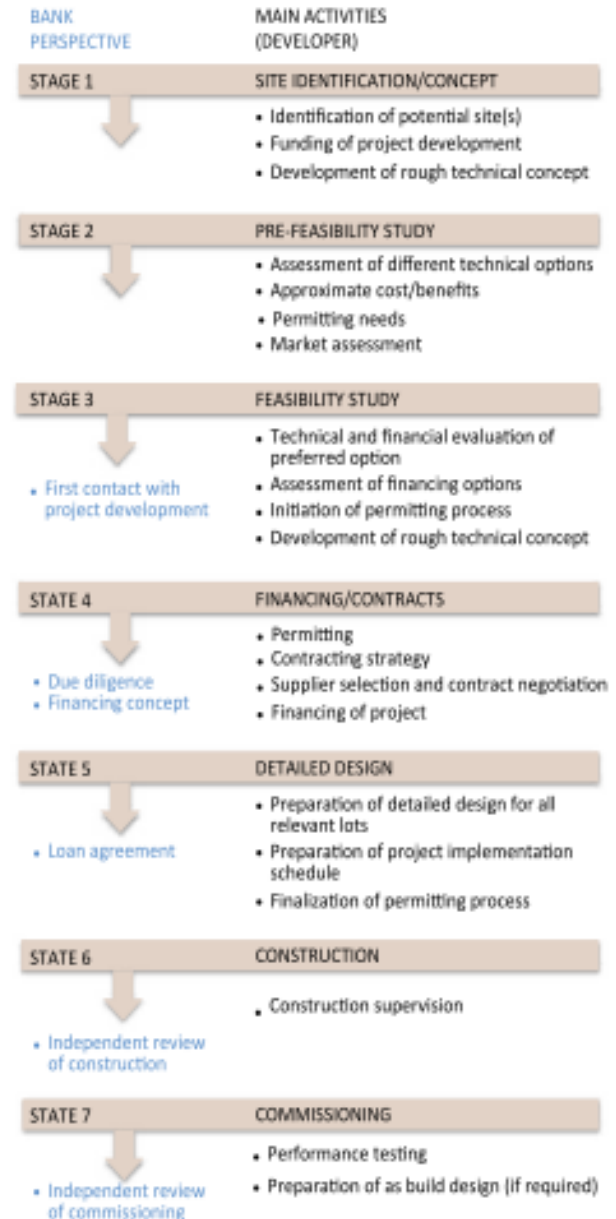


Wherever you are located



Solar PV – Scope of services

- Tractebel can provide Technical Advisory & Owner’s Engineer services at all stages of project development covering
 - Concept / basic / detailed design
 - Solar Resource Assessment & Energy Yield Assessment
 - Grid connection, grid impact and grid code compliance studies
 - Permitting assistance, ESIA
 - Tendering and contracting
 - Construction & commissioning follow-up
- Tractebel can team-up with legal and financial advisors where required



Solar Bankability Project Overview



- Objective:

Improving the **finance-ability** and **attractiveness** of PV investments through common **tools and best-practice guidelines** for **professional risk assessment** which will serve to reduce the technical risks associated with investments in PV projects

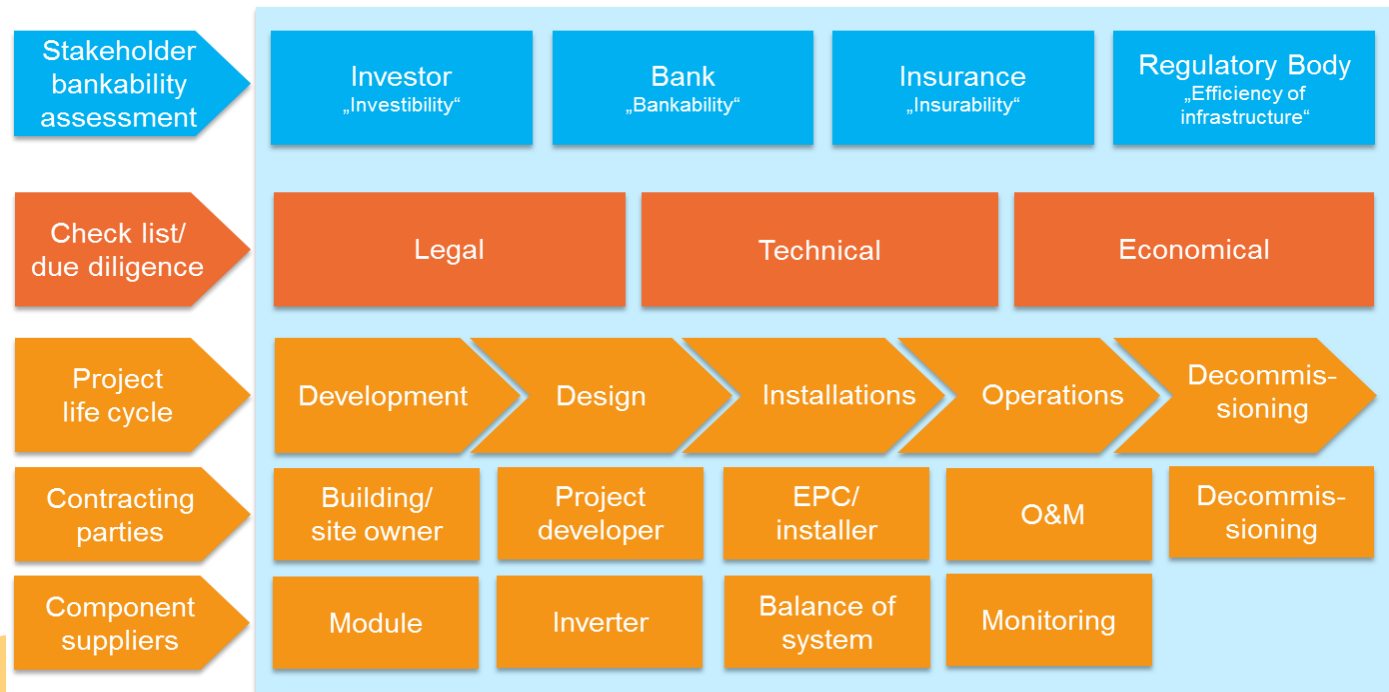
- Funded by European Union Horizon 2020 Work Programme
- March 2015 – February 2017
- 5 consortium partners: 3E (BE), Accelios Solar (DE), EURAC Research (IT), SolarPower Europe (BE), TUV Rheinland (DE)

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Bankability of PV Project



- Solar bankability: active quality management process where all stakeholders in PV project approval process attempt to identify, manage and control potential risks (technical, legal & economical) through entire project lifecycle
- Different stakeholders → different focus



Risk Management Framework



- Solar Bankability has developed a set of **useful tools and best-practice guidelines** for professional risk assessment and management in PV investment:
 - De-risking tools to reduce technical risks
 - Standardization tools as common approach for risk assessment



(I) Risk Identification



**Risk
identification**



Risk
assessment



Risk
management



Risk
controlling

Two tools to help identify PV investment technical risks:

1. Top 20 LCOE technical risks

- most common 20 incorrect technical assumptions in calculating PV LCOE

2. Technical risk matrix

- database of PV plant failures

(I) Risk Identification – Common LCOE Technical Risks



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Risk	Phase/field	Identified critical technical gaps		
Year-0	Procurement/ product selection and testing	<ol style="list-style-type: none"> Insufficient EPC technical specifications to ensure that selected components are suitable for use in the specific PV plant environment of application. Inadequate component testing to check for product manufacturing deviations. Absence of adequate independent product delivery acceptance test and criteria. 		
	Planning/ lifetime energy yield estimation	<ol style="list-style-type: none"> The effect of long-term trends in the solar resource is not fully accounted for. Exceedance probabilities (e.g. P90) are often calculated for risk assessment assuming a normal distribution for all elements contributing to the overall uncertainty. Incorrect degradation rate and behavior over time assumed in the yield estimation. Incorrect availability assumption to calculate the initial yield for project investment financial model (vs O&M plant availability guarantee). 		
		Transportation	<ol style="list-style-type: none"> Absence of standardized transportation and handling protocol. 	
		Installation/ construction	<ol style="list-style-type: none"> Inadequate quality procedures in component un-packaging and handling during construction by workers. Missing intermediate construction monitoring. 	
		Installation/ provisional and final acceptance	<ol style="list-style-type: none"> Inadequate protocol or equipment for plant acceptance visual inspection. Missing short-term performance (e.g. PR) check at provisional acceptance test, including proper correction for temperature and other losses. Missing final performance check and guaranteed performance. 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	<ol style="list-style-type: none"> Selected monitoring system is not capable of advanced fault detection and identification. Inadequate or absence of devices for visual inspection to catch invisible defects/faults. Missing guaranteed key performance indicators (PR, availability or energy yield). 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	<ol style="list-style-type: none"> Missing or inadequate maintenance of the monitoring system. Module cleaning missing or frequency too low.



Impact on installation quality



Impact on cash flow model



Impact on installation quality



Impact on risk/cost ownership



Impact on risk/cost ownership & O&M strategy



(I) Risk Identification – Database of PV Plant Failures

- Tickets from O&M operators from preventive and corrective maintenance
- Visual and detailed PV plant inspections

	Total number of plants	Total power [kWp]	Average number of years
TOTAL	772	441,676	2.7
Components	No. of tickets	No. cases	No. of components
Modules	473	678,801	2,058,721
Inverters	501	2,583	11,967
Mounting structures	420	16,147	43,916
Connection & distribution boxes	256	12,387	25,305
Cabling	682	384,600	246,084
Transformer station & MV/HV	57	224	759
TOTAL	2,379	1,094,742	2,386,742

(I) Risk Identification – Technical Risk Matrix



Modules
<ul style="list-style-type: none"> • Insulation test • Incorrect cell soldering • Undersized bypass diode • Junction box adhesion • Delamination at the edges • Arcing spots on the module • Visually detectable hot spots • Incorrect power rating (flash test issue) • Uncertified components or production line 	<ul style="list-style-type: none"> • Soiling • Shadow diagram • Modules mismatch • Modules not certified • Flash report not available or incorrect • Special climatic conditions not considered (salt corrosion, ammonia, ...) • Incorrect assumptions of module degradation, light induced degradation unclear • Module quality unclear (lamination, soldering) • Simulation parameters (low irradiance, temperature....) unclear, missing PAN files 	<ul style="list-style-type: none"> • Module mishandling (glass breakage) • Module mishandling (cell breakage) • Module mishandling (defective backsheets) • Incorrect connection of modules • Bad wiring without fasteners 	<ul style="list-style-type: none"> • Hotspot • Delamination • Glass breakage • Soiling • Shading • Snail tracks • Cell cracks • PID • Failure bypass diode and junction box • Corrosion in the junction box • Theft of modules • Module degradation • Slow reaction time for warranty claims, vague or inappropriate definition of procedure for warranty claims • Spare modules no longer available, costly string reconfiguration 	<ul style="list-style-type: none"> • Undefined product recycling procedure 	

(II) Risk Assessment



Risk
identification



**Risk
assessment**



Risk
management



Risk
controlling

Three tools to assess technical risk impacts:

1. CPN methodology

- assess economic impacts of technical risks on PV plant operation

2. LCOE sensitivity analysis excel tool

- assess impacts of technical risks on PV LCOE

3. Cash flow risk categorization

- assess impacts of technical risks on PV business models

(II) Risk Assessment – Quantifying Economic Impacts

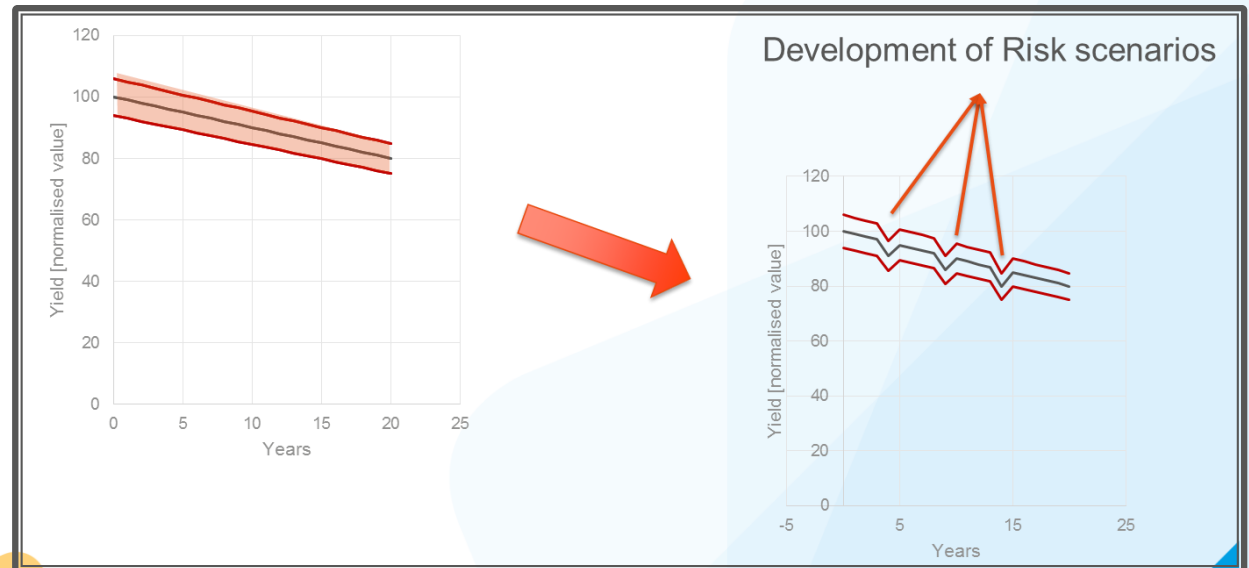


Planning during development phase

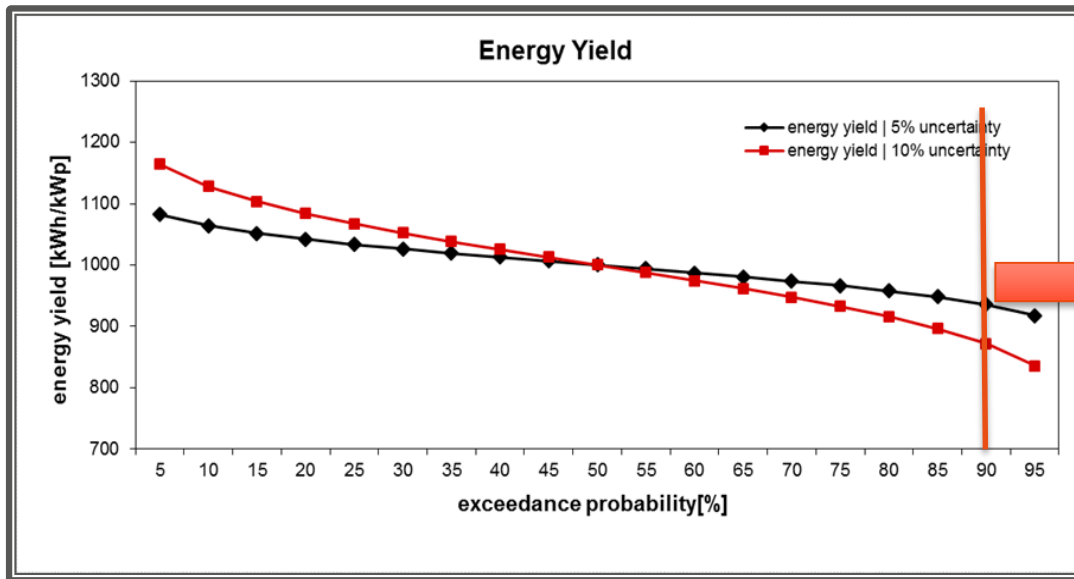
Risks to which we assign uncertainty
→ Impact on financial exceedance probability parameters

O&M phase

Risks to which we assign economic value (€/kWp/yr)
→ Impact on cash flow



(II) Risk Assessment – Uncertainties during Planning



Utilization rate @P90
positively affected by
reduction in uncertainty

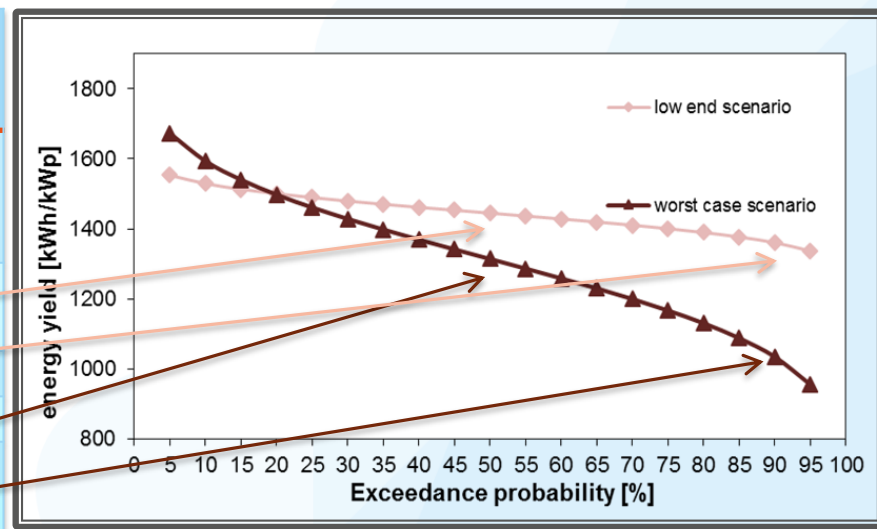
Link with business models
and LCOE calculation

Typical uncertainty values (irradiance, temperature, soiling, shading, etc.) = 5-10%

(II) Risk Assessment – Improving Uncertainties

- Exceedance probabilities obtained by assuming normal distribution when calculating different uncertainties from dataset
- More precise estimation of uncertainty in yield estimation to reduce uncertainties
 - **Using empirically established probability distribution instead**
 - Challenge: need sufficiently large dataset!

	σ (k=1)	P50 (kWh/kWp)	P90 (kWh/kWp)	P90/P50 (P50 ref. case)
Reference case (PVSYST, not all contributions included)	4.3%	1440	1360	94%
Ref. case (sum of squares)	8.7%	1445	1283	89%
Low end scenario	4.6%	1445	1365	94%
High end scenario	9.3%	1445	1273	88%
Worst case scenario	16.6%	1445	1138	79%
Worst case scenario (different mean value)	16.6%	1314	1034	72%

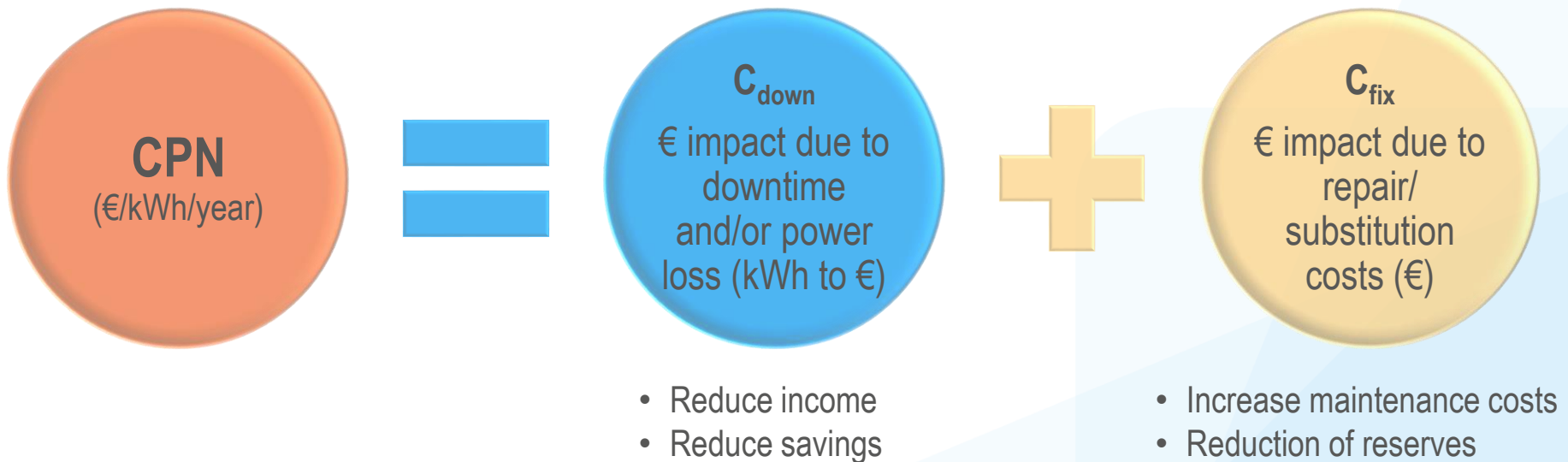


22% difference in yield used in the business model !

(II) Risk Assessment – Quantifying Economic Impacts during Plant Operation

Cost Priority Number – new methodology!

- gives an indication of economic impacts of a failure due to **downtime** and **fixing cost**



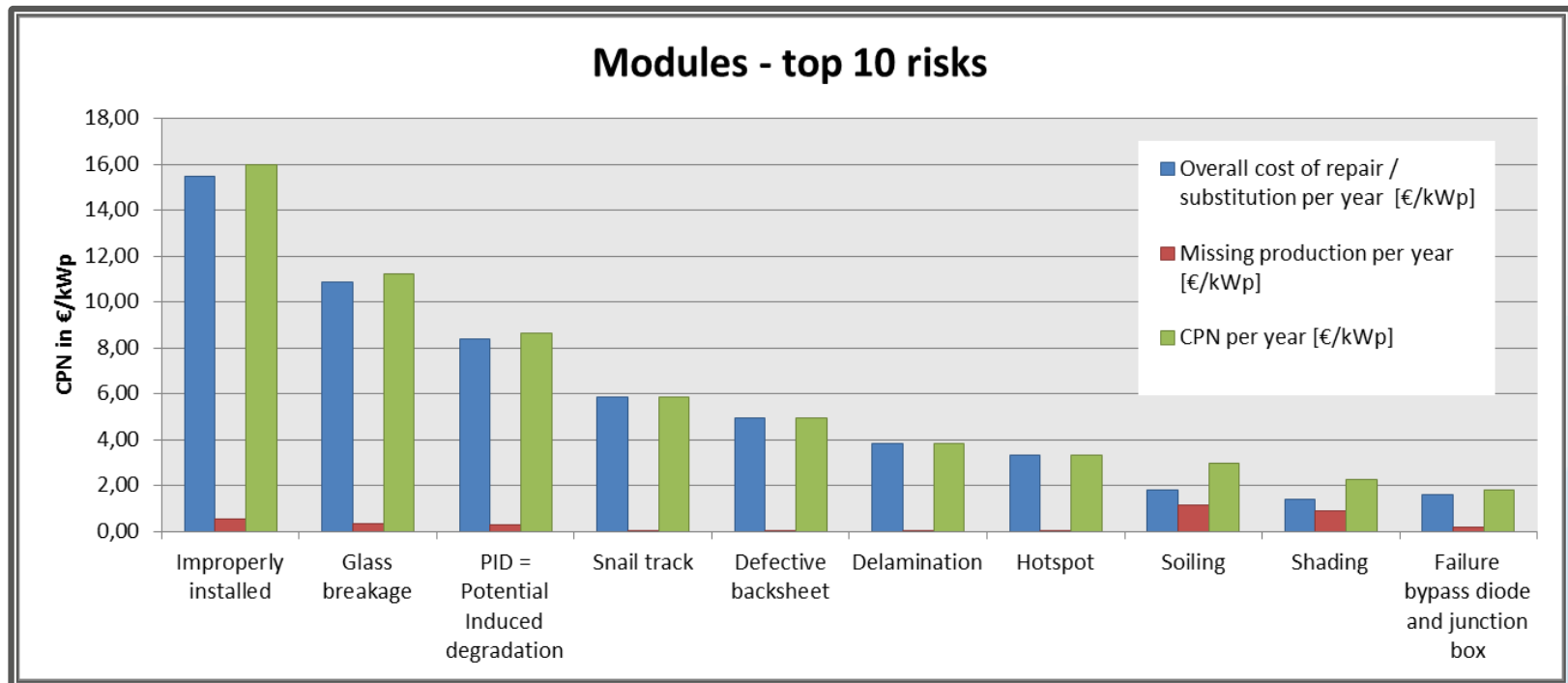
(II) Risk Assessment – CPN Analysis of Failures in Risk Matrix



	Product testing	Planning	Transportation / installation	O&M	Decommissioning
Modules
Inverter
Mounting structure
Connection & distribution boxes
Cabling
Potential equalization & grounding, LPS
Weather station, communication, monitoring
Infrastructure & environmental influence
Storage system
Miscellaneous

Risk matrix with more than 140 Technical risks

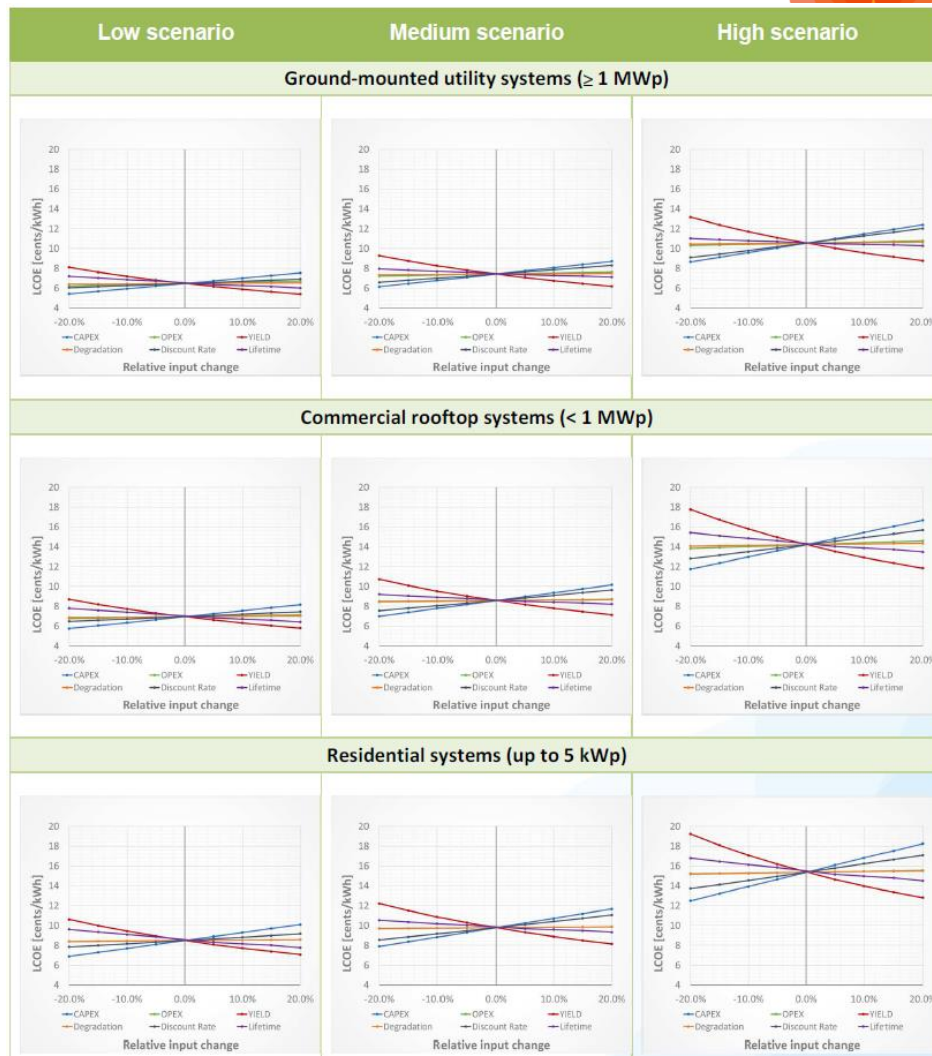
(II) Risk Assessment – e.g. CPN Ranked PV Module Failures (Utility Scale)



- Installation failures dominant (mishandling, connection failures, missing fixation, etc.)
- Variety of failures detected by different techniques (VI, IR, EL, IV-curve tracing)

(II) Risk Assessment – Impacts on LCOE

- Sensitivity analysis by varying LCOE inputs by $\pm 20\%$
 - 3 market segments
 - 3 scenarios of CAPEX + OPEX (low, medium, high)

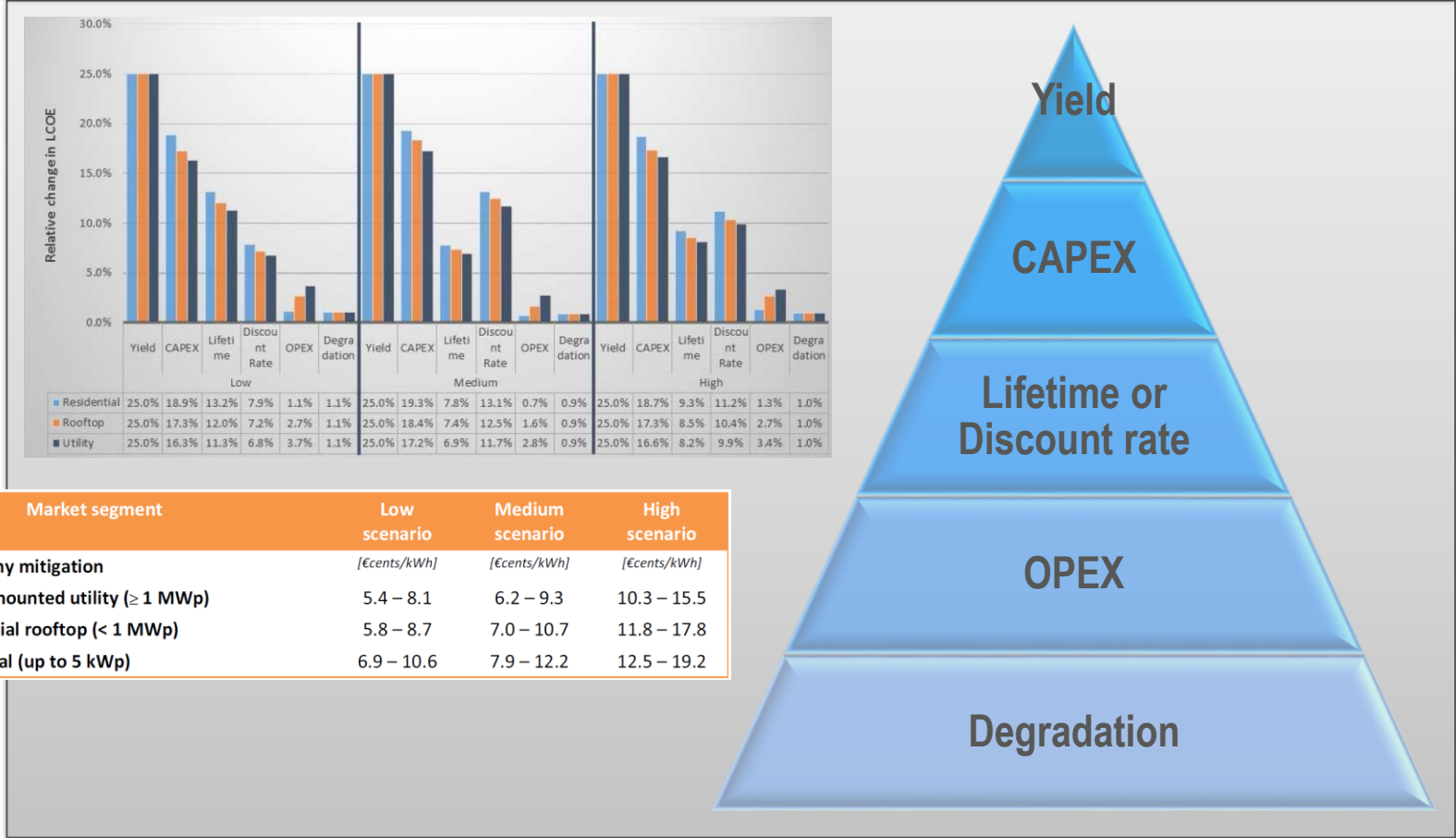


LCOE calculation excel tool available for public download on project website

(II) Risk Assessment – LCOE Sensitivity Ranking



Sensitivity of LCOE in 2015-2016 on its input parameters





(II) Risk Assessment – Impacts on Business Model

- Modelling economic impact of technical risks on PV project cash flow requires:
 - Select business model to use
 - Identify associated technical risks
 - Determine likely risk scenario
 - Taking assumptions of underlying costs
- Case studies in Solar Bankability:
 1. 4 business models
 2. Introduce risk scenario
 3. Simulation using in-house developed financial modelling software
 4. Assess impacts on 12-month revenue

(II) Risk Assessment – Case Studies for Risk Impacts on Business Model



4 business models

		Description
Residential	Business model 1	Residential rooftop PV system with crystalline modules located in central Europe (5,6 kW, c-Si, Germany)
	Business model 2	Residential rooftop PV system with crystalline modules and battery storage located in central Europe (5,2 kW c-Si + storage, Germany)
Utility scale	Business model 3	Utility scale ground mounted PV system with crystalline modules, central inverters, located in northern Europe (7,6 MW, c-Si, UK)
	Business model 4	Utility scale ground mounted PV system with CdTe modules, string inverters, located in southern Europe (0,6 MW, CdTe, Italy)

Introduce up to 4 technical risks: 2 from technical risk matrix + 2 generic technical risks

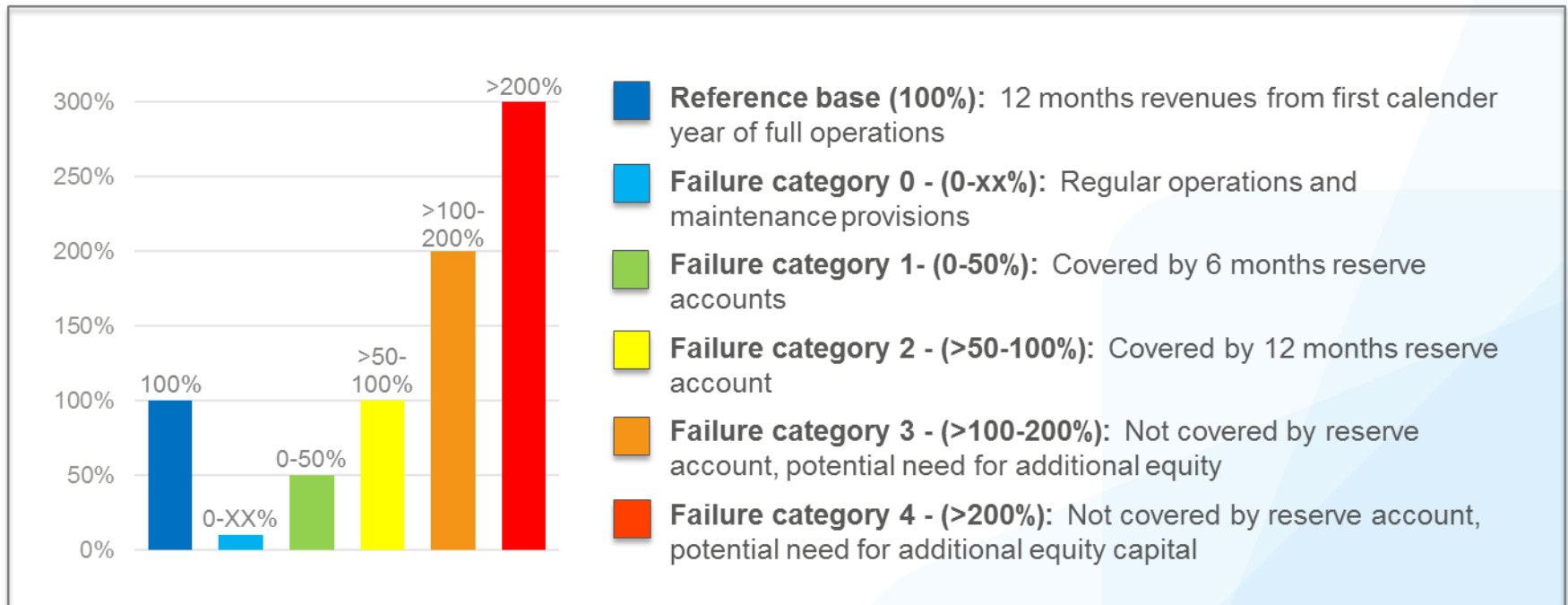
Top 10 generic technical risks						
Number	Component	Name	BM1	BM2	BM3	BM4
Risk xx00	Module (C-Si)	Potential induced degradation (PID)	x	x	x	1)
Risk xx00	Module (CdTe)	Low Power/TCO corrosion				x
Risk xx10	Module	Failure of bypass diode/junction box	x	x	x	x
Risk xx20	Module	Hotspot	x	x	x	2)
Risk xx30	Module	Theft or vandalism	x	x	x	x
Risk xx40	Inverter	Fan failure and overheating	x	x	x	x
Risk xx50	Inverter	Lightning strike	x	x	x	x
Risk xx60	Mounting	Mismatch of module clamp	x	x	x	x
Risk xx70	Cable	UV aging of string cable	x	x	x	x
Risk xx80	Cable	Wrong/absent cable connection	x	x	x	x
Risk xx90	Cable	Cabling damaged by rodents	x	x	x	x

Selected technical risks by business model						
Number	Component	Name	BM1	BM2	BM3	BM4
Risk 1100	Module	Glass breakage by hail	x			
Risk 1110	Module	Soiling of module	x			
Risk 2100	Battery	Failure of battery		x		
Risk 2110	Inverter	Failure of battery inverter		x		
Risk 3100	Inverter	Flooding of inverter			x	
Risk 3110	Module	Soiling of module			x	
Risk 4100	Module	Glass breakage, frameless module				x



(II) Risk Assessment – Failure Categories

- The impact of risks is measured by failure categories based on a 12-month revenue

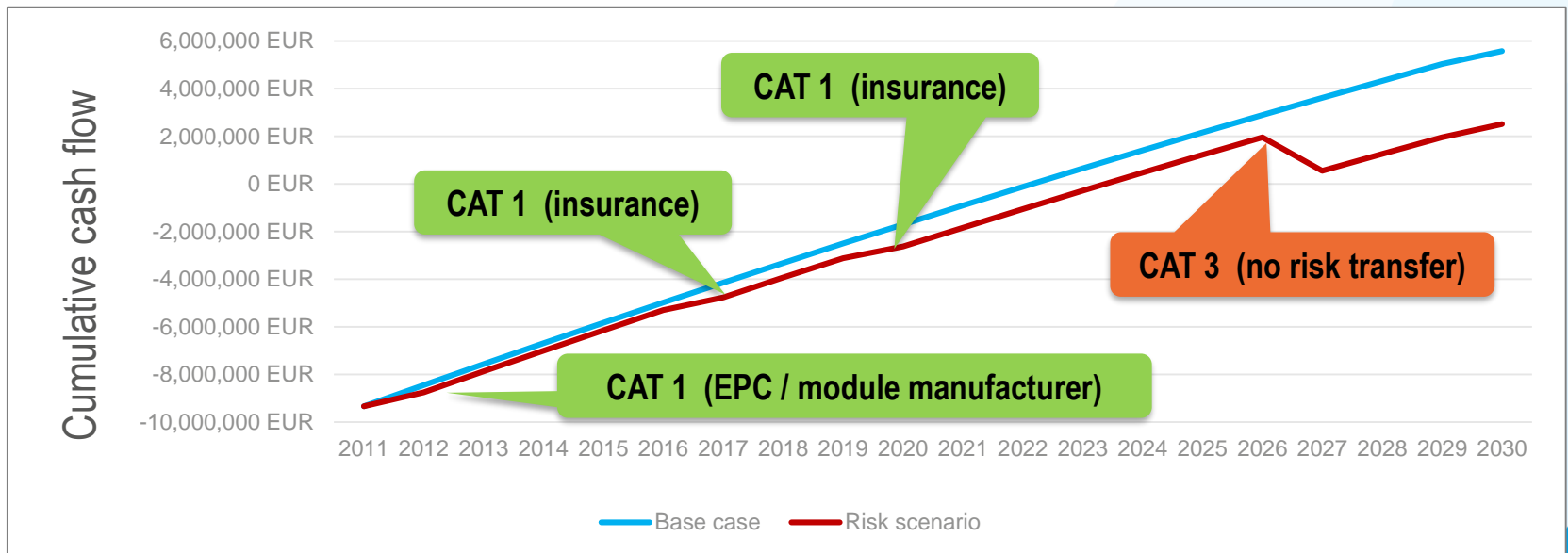


(II) Risk Assessment – Cash Flow Modelling of Technical Risk Impacts on Business Model #3 (example)

Risk scenario - business model 3					
Risk	Risk number	Risk name	Start Date	Case	Phase
Risk 1	3020	Hotspot of modules	01.01.2012	Best	Infant
Risk 2 ²⁾	3101	Flooding of inverter	01.08.2017	Worst	Mid-life
Risk 3 ¹⁾	3051	Lightning strike of inverter	01.06.2020	Worst	Mid-life
Risk 4	3011	Failure of bypass diode and junction box	01.10.2026	Worst	Wear-out

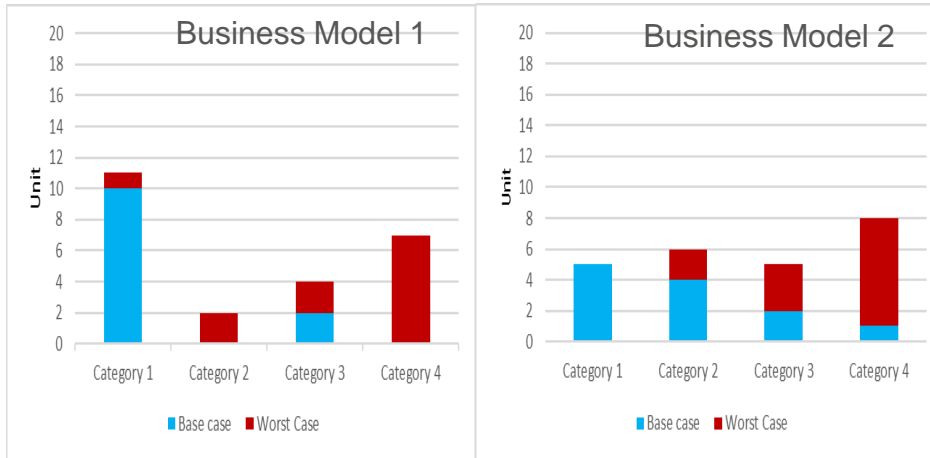
Comments

1) External cause independent from project phase
 2) Business model specific risk, i.e. due to system design/technology, geographic/climatic conditions



(II) Risk Assessment – Case Studies Results

Residential



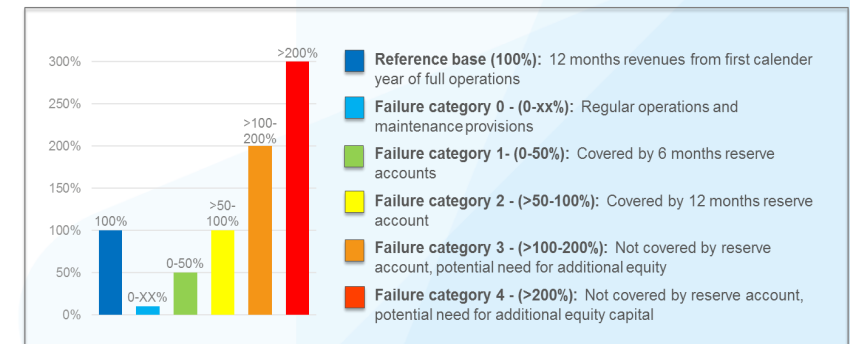
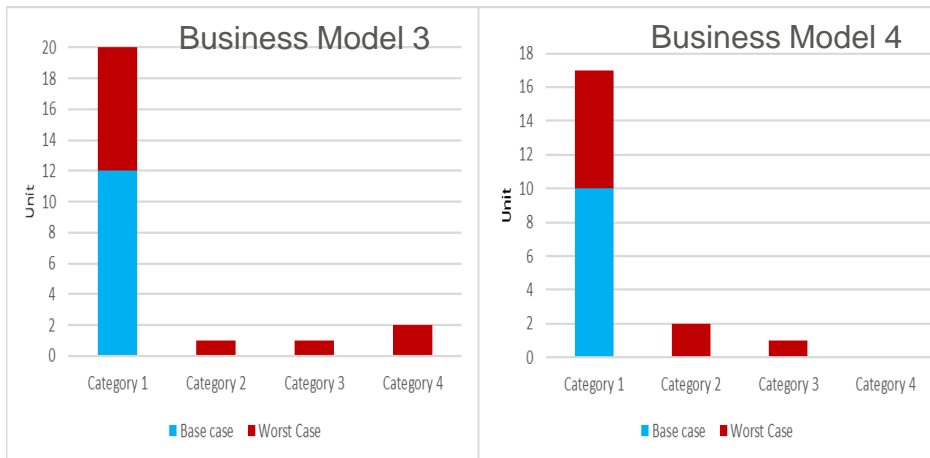
Residential-sized business models are most affected by impact of technical failures:

- Labor + spare parts costs + prolonged downtime costs due to missing monitoring systems

Utility PV system more robust:

- Online monitoring + O&M service contract → reduce downtime
- Economies of scale

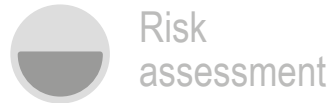
Utility scale



(III) Risk Management



Risk identification



Risk assessment



Risk management



Risk controlling

Two tools to mitigate and manage technical risks:

1. List of mitigation measures

- recommended mitigation measures to manage common PV technical risks

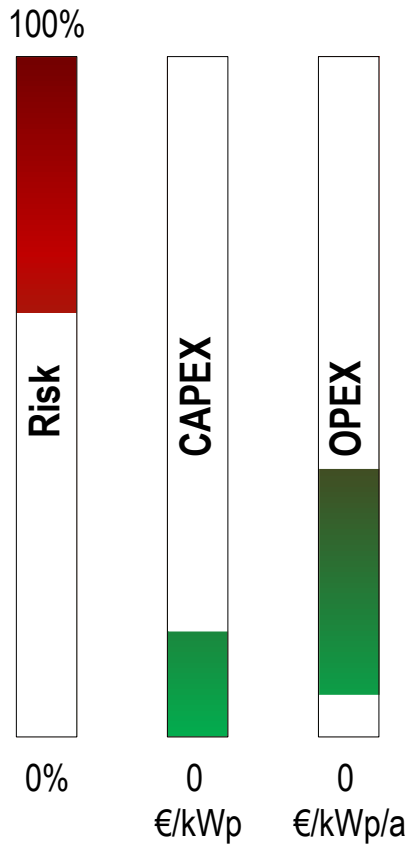
2. Best practice guidelines

- 6 checklists as guidelines for best practices in EPC and O&M contract technical aspects

In addition to risk mitigation, **risk transfer** is also a risk management strategy!



(III) Risk Mitigation – Why & How

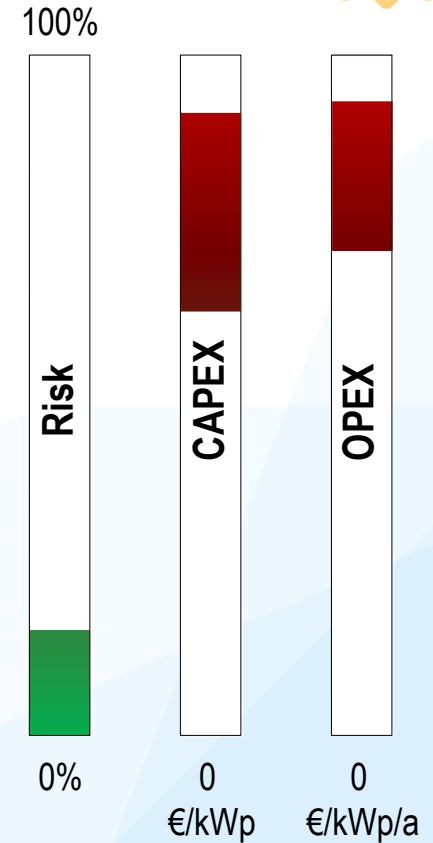


Σ CPNs = ~120€/kW/year

Who bears the cost?
Who bears the risk?

Risk
minimization

Σ CPNs = ~XX €/kW/year



CAPEX & OPEX depending on mitigation measures

CAPEX & OPEX depending on mitigation measures



(III) Risk Mitigation Measures

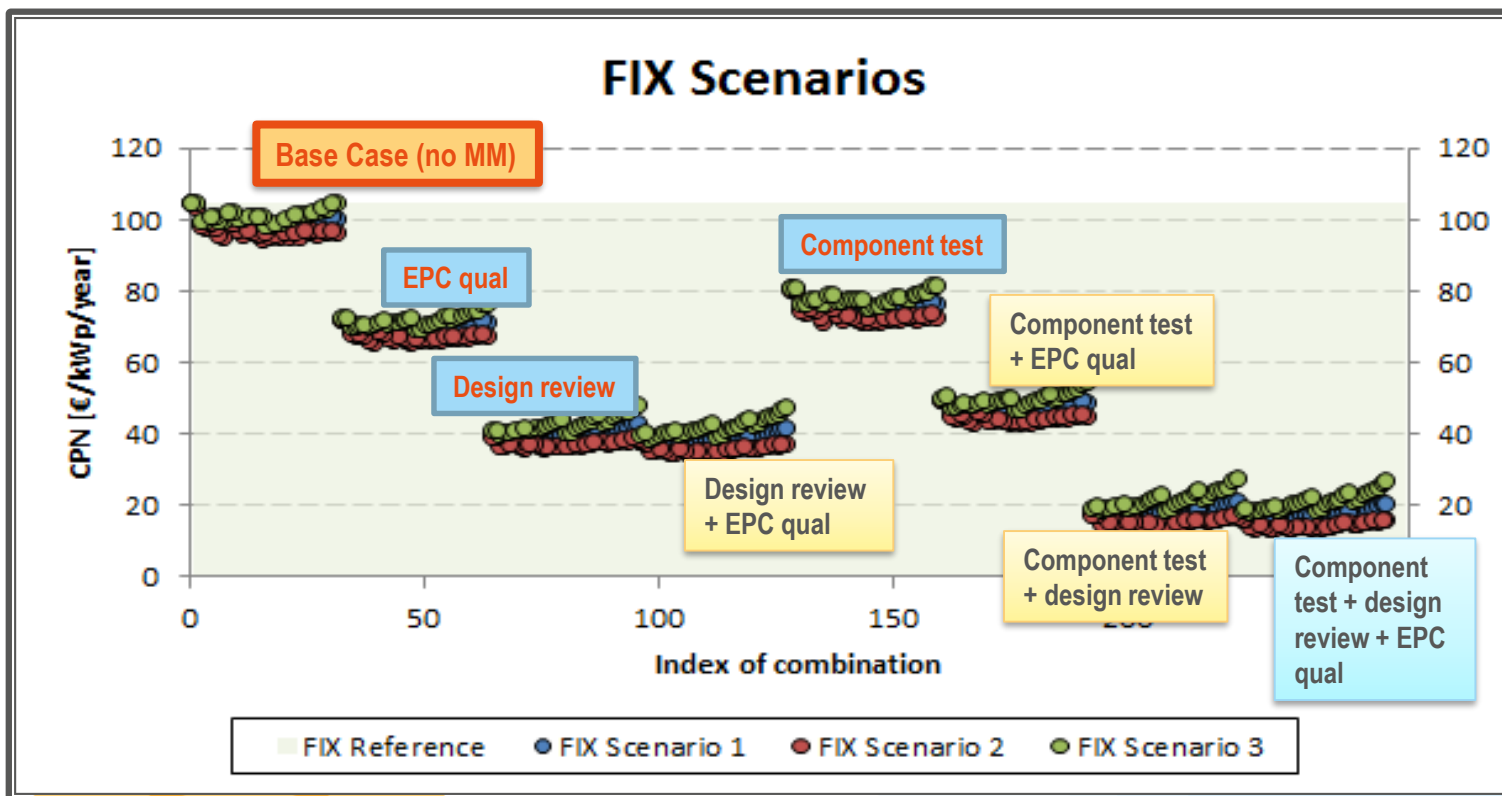
- 8 mitigation measures proposed based on analysis of technical failures in Risk Matrix

	Mitigation Measure	Improving	Costs (medium scenario)
Preventive measures (CAPEX)	Component testing – PV modules	number of failures	3 €/kWp
	Design review + construction monitoring	number of failures	20 €/kWp
	Qualification of EPC	number of failures	3 €/kWp
Corrective measures (OPEX)	Advanced monitoring system	time to detection	2 €/kWp/year
	Basic monitoring system	time to detection	0.5 €/kWp/year
	Advanced inspection	time to detection	2 €/kWp/year
	Visual inspection	time to detection	1 €/kWp/year
	Spare part management	time to repair/substitution	0.5 €/kWp/year

(III) Risk Mitigation Measures – Impacts on CPN

- Different combinations of 8 mitigation measures and resulting CPN

Preventive measures have higher impacts in reducing CPN, especially for poor quality plant. For good quality plan, CPN helps to understand the impacts of corrective measures.



(III) Risk Mitigation Measures – Impacts on LCOE

- Different combinations of 8 mitigation measures and resulting LCOE
- Mitigation measures increases CAPEX and OPEX but also yield (utilization rate)!

Preventive measures have higher impacts in lowering LCOE

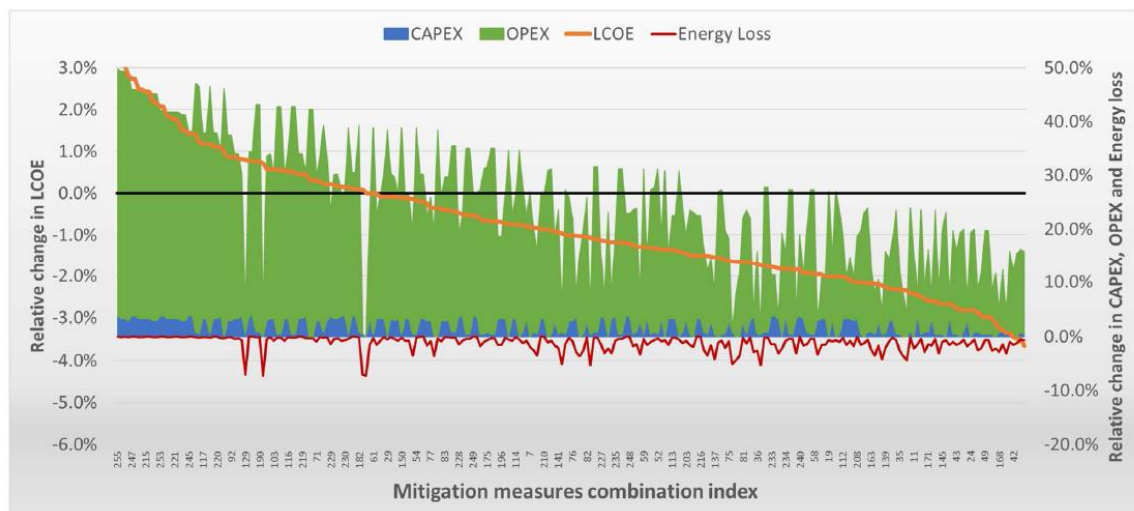
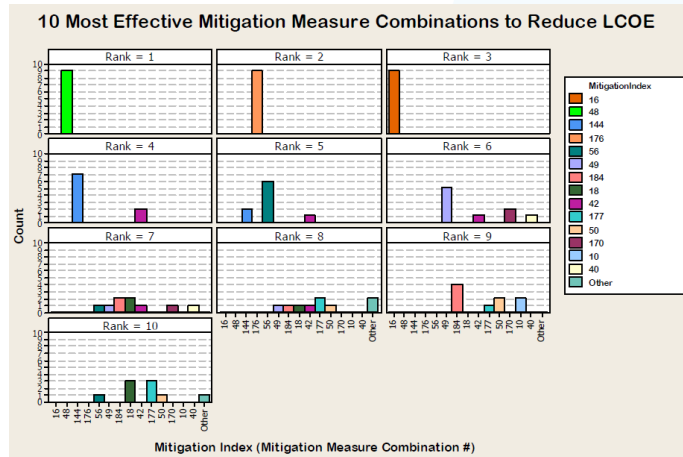


Figure 7: Sorted relative change in LCOE for 255 mitigation measure combinations for ground-mounted utility system for “low” scenario



- Mitigation measures most effective in lowering PV LCOE are:
1. Qualification of EPC;
 2. Component testing prior to installation; and
 3. Advanced monitoring system for early fault detection.



(III) Risk Mitigation Measures – LCOE after Mitigations Implementation

- 3.6 to 5.1% reduction in LCOE observed

Market segment	Low scenario	Medium scenario	High scenario
LCOE without any mitigation	<i>[€cents/kWh]</i>	<i>[€cents/kWh]</i>	<i>[€cents/kWh]</i>
Ground-mounted utility (≥ 1 MWp)	5.4 – 8.1	6.2 – 9.3	10.3 – 15.5
Commercial rooftop (< 1 MWp)	5.8 – 8.7	7.0 – 10.7	11.8 – 17.8
Residential (up to 5 kWp)	6.9 – 10.6	7.9 – 12.2	12.5 – 19.2
% maximum LCOE reduction			
Ground-mounted utility (≥ 1 MWp)	3.6%	3.8%	4.2%
Commercial rooftop (< 1 MWp)	4.6%	4.8%	5.0%
Residential (up to 5 kWp)	4.8%	5.0%	5.1%
LCOE after best mitigation combination	<i>[€cents/kWh]</i>	<i>[€cents/kWh]</i>	<i>[€cents/kWh]</i>
Ground-mounted utility (≥ 1 MWp)	5.2 – 7.8	5.9 – 8.9	9.9 – 14.8
Commercial rooftop (< 1 MWp)	5.5 – 8.4	6.7 – 10.3	11.2 – 17.0
Residential (up to 5 kWp)	6.6 – 10.1	7.5 – 11.6	11.9 – 18.2



(III) Risk Management – Best Practice Guidelines

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
4. Checklist for as-built documents – types and details
5. Checklist for record control
6. Checklist for reporting indicators

Annex C – Best Practice Checklists

The annex presents 6 checklists which are aimed for use for utility-scale (ground-mounted) and floating solar PV installations. The checklists for technical aspects are presented in the report 'Technical Summary Guidance - Recommendations to Enhance Technical Quality of PV Investment'.

C.1. Best Practice Checklist for EPC Technical Aspects

Section	Requirements
A. Contractual considerations	<ul style="list-style-type: none"> EPC contract authority Responsibility and accountability Clear definition of roles and responsibilities Clear definition of the project goals and objectives Clear definition of the project risks and liabilities Clear definition of the project milestones and timeline Clear definition of the project budget and cost control
B. Design and construction	<ul style="list-style-type: none"> Design and construction quality control Design and construction safety Design and construction environmental protection Design and construction social and community relations Design and construction health and safety Design and construction quality assurance Design and construction risk management Design and construction change management
C. Range of work - engineering	<ul style="list-style-type: none"> Design and construction of the PV system Design and construction of the PV system components Design and construction of the PV system infrastructure Design and construction of the PV system ancillary services

Best Practice Guidelines for PV Plant Operations

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

Section	Requirements
A. Operational considerations	<ul style="list-style-type: none"> Operational safety Operational quality Operational environmental protection Operational social and community relations Operational health and safety Operational quality assurance Operational risk management Operational change management
B. Design and construction	<ul style="list-style-type: none"> Design and construction quality control Design and construction safety Design and construction environmental protection Design and construction social and community relations Design and construction health and safety Design and construction quality assurance Design and construction risk management Design and construction change management
C. Range of work - engineering	<ul style="list-style-type: none"> Design and construction of the PV system Design and construction of the PV system components Design and construction of the PV system infrastructure Design and construction of the PV system ancillary services

Best Practice Guidelines for PV Plant Operations

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

Section	Requirements
A. Data collection and management	<ul style="list-style-type: none"> Data collection quality Data collection safety Data collection environmental protection Data collection social and community relations Data collection health and safety Data collection quality assurance Data collection risk management Data collection change management
B. Design and construction	<ul style="list-style-type: none"> Design and construction quality control Design and construction safety Design and construction environmental protection Design and construction social and community relations Design and construction health and safety Design and construction quality assurance Design and construction risk management Design and construction change management
C. Range of work - engineering	<ul style="list-style-type: none"> Design and construction of the PV system Design and construction of the PV system components Design and construction of the PV system infrastructure Design and construction of the PV system ancillary services

Best Practice Guidelines for PV Plant Operations

C.4. Checklist for As-Built Documents – Types and Details

No.	Requirement	Description
1	Site information	<ul style="list-style-type: none"> Location map (GPS coordinates) Topographic map Aerial photograph Site plan Site layout plan Site boundary plan Site access plan Site security plan Site safety plan Site environmental plan Site social and community relations plan Site health and safety plan Site quality assurance plan Site risk management plan Site change management plan
2	Project overview	<ul style="list-style-type: none"> Project description Project objectives Project scope Project budget Project timeline Project risks Project quality Project safety Project environmental Project social and community relations Project health and safety Project quality assurance Project risk management Project change management
3	Project details	<ul style="list-style-type: none"> Design and construction details Operational details Maintenance details Quality assurance details Risk management details Change management details
4	Project management	<ul style="list-style-type: none"> Project management plan Project management organization Project management communication Project management reporting Project management control Project management improvement
5	Project risks	<ul style="list-style-type: none"> Risk management plan Risk management organization Risk management communication Risk management reporting Risk management control Risk management improvement
6	Project quality	<ul style="list-style-type: none"> Quality management plan Quality management organization Quality management communication Quality management reporting Quality management control Quality management improvement
7	Project safety	<ul style="list-style-type: none"> Safety management plan Safety management organization Safety management communication Safety management reporting Safety management control Safety management improvement
8	Project environmental	<ul style="list-style-type: none"> Environmental management plan Environmental management organization Environmental management communication Environmental management reporting Environmental management control Environmental management improvement
9	Project social and community relations	<ul style="list-style-type: none"> Social and community relations management plan Social and community relations management organization Social and community relations management communication Social and community relations management reporting Social and community relations management control Social and community relations management improvement
10	Project health and safety	<ul style="list-style-type: none"> Health and safety management plan Health and safety management organization Health and safety management communication Health and safety management reporting Health and safety management control Health and safety management improvement
11	Project quality assurance	<ul style="list-style-type: none"> Quality assurance management plan Quality assurance management organization Quality assurance management communication Quality assurance management reporting Quality assurance management control Quality assurance management improvement
12	Project risk management	<ul style="list-style-type: none"> Risk management management plan Risk management management organization Risk management management communication Risk management management reporting Risk management management control Risk management management improvement
13	Project change management	<ul style="list-style-type: none"> Change management management plan Change management management organization Change management management communication Change management management reporting Change management management control Change management management improvement

Best Practice Guidelines for PV Plant Operations

C.5. Checklist for Record Control

No.	Requirement	Description
1	Record management	<ul style="list-style-type: none"> Record management plan Record management organization Record management communication Record management reporting Record management control Record management improvement
2	Record creation	<ul style="list-style-type: none"> Record creation plan Record creation organization Record creation communication Record creation reporting Record creation control Record creation improvement
3	Record maintenance	<ul style="list-style-type: none"> Record maintenance plan Record maintenance organization Record maintenance communication Record maintenance reporting Record maintenance control Record maintenance improvement
4	Record disposal	<ul style="list-style-type: none"> Record disposal plan Record disposal organization Record disposal communication Record disposal reporting Record disposal control Record disposal improvement
5	Record security	<ul style="list-style-type: none"> Record security plan Record security organization Record security communication Record security reporting Record security control Record security improvement
6	Record integrity	<ul style="list-style-type: none"> Record integrity plan Record integrity organization Record integrity communication Record integrity reporting Record integrity control Record integrity improvement
7	Record availability	<ul style="list-style-type: none"> Record availability plan Record availability organization Record availability communication Record availability reporting Record availability control Record availability improvement
8	Record access	<ul style="list-style-type: none"> Record access plan Record access organization Record access communication Record access reporting Record access control Record access improvement
9	Record retention	<ul style="list-style-type: none"> Record retention plan Record retention organization Record retention communication Record retention reporting Record retention control Record retention improvement
10	Record storage	<ul style="list-style-type: none"> Record storage plan Record storage organization Record storage communication Record storage reporting Record storage control Record storage improvement
11	Record backup	<ul style="list-style-type: none"> Record backup plan Record backup organization Record backup communication Record backup reporting Record backup control Record backup improvement
12	Record recovery	<ul style="list-style-type: none"> Record recovery plan Record recovery organization Record recovery communication Record recovery reporting Record recovery control Record recovery improvement
13	Record disaster recovery	<ul style="list-style-type: none"> Record disaster recovery plan Record disaster recovery organization Record disaster recovery communication Record disaster recovery reporting Record disaster recovery control Record disaster recovery improvement
14	Record business continuity	<ul style="list-style-type: none"> Record business continuity plan Record business continuity organization Record business continuity communication Record business continuity reporting Record business continuity control Record business continuity improvement
15	Record compliance	<ul style="list-style-type: none"> Record compliance plan Record compliance organization Record compliance communication Record compliance reporting Record compliance control Record compliance improvement

Best Practice Guidelines for PV Plant Operations

C.6. Checklist for Reporting Indicators

No.	Requirement	Indicator	Frequency	Responsibility
1	Production	Production	Hourly	Production
2	Availability	Availability	Hourly	Production
3	Energy yield	Energy yield	Hourly	Production
4	Energy production	Energy production	Hourly	Production
5	Energy production per kW	Energy production per kW	Hourly	Production
6	Energy production per kWh	Energy production per kWh	Hourly	Production
7	Energy production per m ²	Energy production per m ²	Hourly	Production
8	Energy production per m ² per kW	Energy production per m ² per kW	Hourly	Production
9	Energy production per m ² per kWh	Energy production per m ² per kWh	Hourly	Production
10	Energy production per m ² per m ²	Energy production per m ² per m ²	Hourly	Production
11	Energy production per m ² per kW per m ²	Energy production per m ² per kW per m ²	Hourly	Production
12	Energy production per m ² per kWh per m ²	Energy production per m ² per kWh per m ²	Hourly	Production
13	Energy production per m ² per m ² per kW	Energy production per m ² per m ² per kW	Hourly	Production
14	Energy production per m ² per m ² per kWh	Energy production per m ² per m ² per kWh	Hourly	Production
15	Energy production per m ² per m ² per m ²	Energy production per m ² per m ² per m ²	Hourly	Production
16	Energy production per m ² per m ² per kW per m ²	Energy production per m ² per m ² per kW per m ²	Hourly	Production
17	Energy production per m ² per m ² per kWh per m ²	Energy production per m ² per m ² per kWh per m ²	Hourly	Production
18	Energy production per m ² per m ² per m ² per kW	Energy production per m ² per m ² per m ² per kW	Hourly	Production
19	Energy production per m ² per m ² per m ² per kWh	Energy production per m ² per m ² per m ² per kWh	Hourly	Production
20	Energy production per m ² per m ² per m ² per m ²	Energy production per m ² per m ² per m ² per m ²	Hourly	Production

Best Practice Guidelines for PV Plant Operations

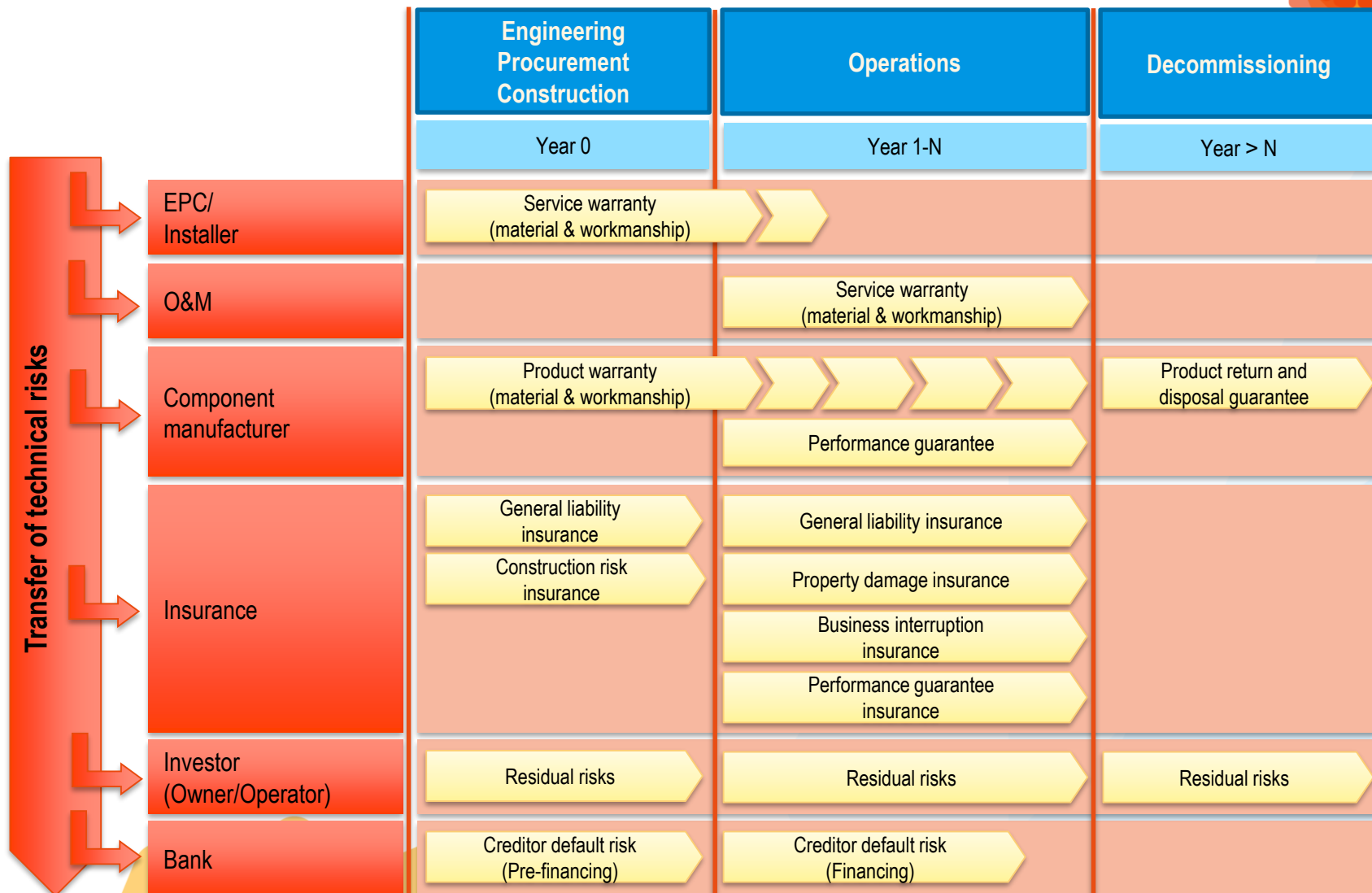


(III) Technical Aspects to Look for in EPC & O&M Contracts

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

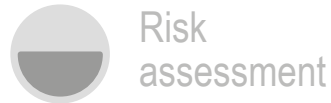
(III) Risk Transfer to Manage Risks



(IV) Risk Controlling



Risk
identification



Risk
assessment



Risk
management



Risk
controlling

Improve regulation in PV project financing:

1. Financial market regulations

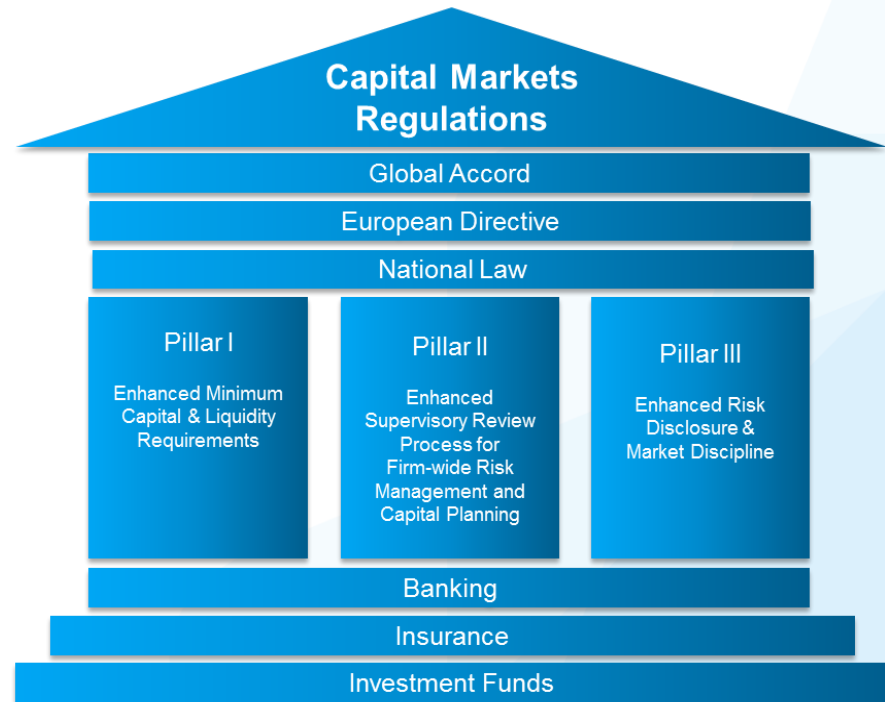
- improve transparency for institutional investors (banking – insurance – investment fund)



(IV) Risk Controlling – Capital Market Regulation

In a harmonized effort, financial regulatory bodies on a global, European and national level have developed a set of regulations for each capital market sector:

- Banking (Basel III)
- Insurance (Solvency II)
- Investment Funds (UCITS V / AIFM)



Solar Bankability



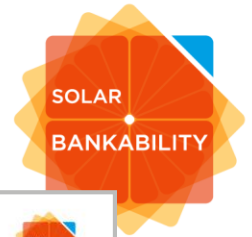
In summary ...




Solar Bankability – Tools & Best-Practice Guidelines for Professional Risk Assessment & Management



Project Reports: www.solarbankability.eu







Technical risks in PV projects


Report on technical risks in PV project development and PV plant operation

Merged Deliverable D1.1 and D2.1 (M12)
Version 1.0



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Minimizing Technical Risks in Photovoltaic Projects


Recommendations for Minimizing Technical Risks of PV Project Development and PV Plant Operation

Merged Deliverable D1.2 and D2.2 (M16)



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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

27/07/2016, Version 1.0



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Best Practice Guidelines for PV Cost Calculation


Accounting for Technical Risks and Assumptions in PV LCOE

13/12/2016



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SOLAR BANKABILITY


PV Business Model Country Snapshots

August 31st, 2015



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Financial Modelling of PV Risks


Financial Modelling of Technical Risks in PV Projects

Deliverable D4.2 (M18)



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Technical Bankability Guidelines


Recommendations to Enhance Technical Quality of existing and new PV Investments

February 15th, 2017



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PV Investment Technical Risk Management

Best Practice Guidelines for Risk Identification, Assessment and Mitigation

Deliverable D5.8
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Thank you!

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