Solar Bankability – Final Public Workshop
February 7-8th, 2017, Renaissance Hotel, Brussels

Business Model and Profitability Assessment
Impact of Failures on Internal Rate of Return

Matthias v. Armansperg, ACCELIOS Solar
## Business Model Selection

<table>
<thead>
<tr>
<th>Business model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential rooftop PV system with crystalline modules located in central Europe (5.6 kW, c-Si, Germany)</td>
</tr>
<tr>
<td>2</td>
<td>Residential rooftop PV system with crystalline modules and battery storage located in central Europe (5.2 kW c-Si + storage, Germany)</td>
</tr>
<tr>
<td>3</td>
<td>Utility scale ground mounted PV system with crystalline modules, central inverters, located in northern Europe (7.6 MW, c-Si, UK)</td>
</tr>
<tr>
<td>4</td>
<td>Utility scale ground mounted PV system with CdTe modules, string inverters, located in southern Europe (0.6 MW, CdTe, Italy)</td>
</tr>
</tbody>
</table>
Risk Modelling Software

Input parameters
- BM4
- BM3
- BM2
- BM1
  - Business Model techn./finance

Modelling software
- Yield
  - Aux-Excel
- Financing
  - Aux-Excel
- Cashflow
  - Excel
- Dashboard
  - Excel
- Risk modelling
  - Visual Basic

Output parameters
- BM4
- BM3
- BM2
- BM1
  - Single risk impact
  - Risc scenario impact

Techn. risk database
- BM1
- BM3
- BM2
- BM4

Repair & maint. cost factors
- BM1
- BM3
- BM2
- BM4

• Solar Bankability – Final Workshop 08/02/2017
## Selection of Technical Risks

### Top 10 generic technical risks

<table>
<thead>
<tr>
<th>Number</th>
<th>Component</th>
<th>Name</th>
<th>BM1</th>
<th>BM2</th>
<th>BM3</th>
<th>BM4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk xx00</td>
<td>Module (C-Si)</td>
<td>Potential induced degradation (PID)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx00</td>
<td>Module (CdTe)</td>
<td>Low Power/TCO corrosion</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Risk xx10</td>
<td>Module</td>
<td>Failure of bypass diode/junction box</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx20</td>
<td>Module</td>
<td>Hotspot</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx30</td>
<td>Module</td>
<td>Theft or vandalism</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx40</td>
<td>Inverter</td>
<td>Fan failure and over-heating</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx50</td>
<td>Inverter</td>
<td>Lightning strike</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx60</td>
<td>Mounting</td>
<td>Mismatch of module clamp</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx70</td>
<td>Cable</td>
<td>UV aging of string cable</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx80</td>
<td>Cable</td>
<td>Wrong/absent cable connection</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Risk xx90</td>
<td>Cable</td>
<td>Cabling damaged by rodents</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

### Selected technical risks by business model

<table>
<thead>
<tr>
<th>Number</th>
<th>Component</th>
<th>Name</th>
<th>BM1</th>
<th>BM2</th>
<th>BM3</th>
<th>BM4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk 1100</td>
<td>Module</td>
<td>Glass breakage by hail</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk 1110</td>
<td>Module</td>
<td>Soiling of module</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk 2100</td>
<td>Battery</td>
<td>Failure of battery</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Risk 2110</td>
<td>Inverter</td>
<td>Failure of battery inverter</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Risk 3100</td>
<td>Inverter</td>
<td>Flooding of inverter</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Risk 3110</td>
<td>Module</td>
<td>Soiling of module</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Risk 4100</td>
<td>Module</td>
<td>Glass breakage, frameless module</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

---

**Risk matrix with more than 140 Technical risks**
Bottom-up Failure Cost Calculation

Fixing costs due to repair/substitution (Euros)
- Cost of detection (visual inspection, monitoring system, IR for hotspots, EL for crack cells, etc)
- Cost of transportation
- Cost of labour
- Cost of repair/substitution of components

Downtime costs due to downtime and/or power loss (kWh to Euros)
- Failures might cause partial or complete power loss
- Downtime duration from occurrence of failure till completion of repair/substitution
- Failures at component level might affect other components (e.g. module failure might bring down the whole string)
Failure Classification by Categories

The impact of risks is measured by failure categories based on a 12 month revenue reserve account.

- **Reference base (100%)**: 12 months revenues from first calendar year of full operations
- **Failure category 0 - (0-xx%)**: Regular operations and maintenance provisions
- **Failure category 1 - (0-50%)**: Covered by 6 months reserve accounts
- **Failure category 2 - (>50-100%)**: Covered by 12 months reserve account
- **Failure category 3 - (>100-200%)**: Not covered by reserve account, potential need for additional equity
- **Failure category 4 - (>200%)**: Not covered by reserve account, potential need for additional equity capital
Failure Category Distribution

Business Model 1

Business Model 2

Business Model 3

Business Model 4

- Solar Bankability – Final Workshop 08/02/2017 7
Failure Impact – Business Model 3 (Example)

Failure impact on base case IRR of 5.52%

Distribution of failure costs
## Risk Scenario – Business Model 3 (Example)

### Risk scenario - business model 3

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk number</th>
<th>Risk name</th>
<th>Start Date</th>
<th>Case</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk 1</td>
<td>3020</td>
<td>Hotspot of modules</td>
<td>01.01.2012</td>
<td>Best</td>
<td>Infant</td>
</tr>
<tr>
<td>Risk 2&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>3101</td>
<td>Flooding of inverter</td>
<td>01.08.2017</td>
<td>Worst</td>
<td>Mid-life</td>
</tr>
<tr>
<td>Risk 3&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>3051</td>
<td>Lightning strike of inverter</td>
<td>01.06.2020</td>
<td>Worst</td>
<td>Mid-life</td>
</tr>
<tr>
<td>Risk 4</td>
<td>3011</td>
<td>Failure of bypass diode and junction box</td>
<td>01.10.2026</td>
<td>Worst</td>
<td>Wear-out</td>
</tr>
</tbody>
</table>

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

### Cumulative cash flow

![Cumulative cash flow graph](image)

- **Base case**
- **Risk scenario**

- Solar Bankability – Final Workshop
- 08/02/2017
Financial Stability of Business Models

IRR (Base case)

Cumulative cash flow (Base case)
Four Step Risk Management Plan

- Initial risks
- Identified risks
- Identified risks
- Identified risks
- Identified risks
- Identified risks
- Identified risks
- Residual risks

- Prevent
- Reduce
- Transfer
- Bear

Unidentified risks (gaps)
Risk Prevention and Reduction

- **Infant Phase**: Commissioning check
- **Mid-life Phase**: End of warranty check, Mid-life advanced inspection
- **Wear-out Phase**: Online-Monitoring

Years:
- Year 1 to Year 20

Warranty:
- Guarantee Level 1
- Guarantee Level 2

- Solar Bankability – Final Workshop
- 08/02/2017
# Contractual Risk Transfer

<table>
<thead>
<tr>
<th></th>
<th>Engineering Procurement Construction</th>
<th>Operations</th>
<th>Decommissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 0</strong></td>
<td>Service warranty (material &amp; workmanship)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Year 1-N</strong></td>
<td>Service warranty (material &amp; workmanship)</td>
<td>Performance guarantee</td>
<td>Product return and disposal guarantee</td>
</tr>
<tr>
<td><strong>Year &gt; N</strong></td>
<td>Product warranty (material &amp; workmanship)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **EPC/Installer**
- **O&M**
- **Component manufacturer**
- **Insurance**
  - General liability insurance
  - Construction risk insurance
- **Investor (Owner/Operator)**
  - Residual risks
- **Bank**
  - Creditor default risk (Pre-financing)
  - Creditor default risk (Financing)
Solar Bankability best practice guidelines provide an important contribution to meet new capital market regulations, i.e. under Basel III or Solvency II.
For Further Information Visit
www.solarbankability.eu

Thank You!
Matthias v. Armansperg, ACCELIOS Solar