Mitigating Financial Risks in a PV Investment

Mike Green (M.G.Lightning Electrical Engineering), Mauricio Richter (3E), Jan Vedde (SiCon)
Financial Risks to a PV Investment

A PV project can be divided into 2 distinct stages:

1. Feasibility ➔ Design ➔ License ➔ Finance ➔ Shovel Ready

2. Bidding ➔ Building ➔ Commissioning ➔ Maintaining

PV project risk can be divided into 2 distinct causes:

• Uncertainties in the design data
• Lack of Quality Control
### Feasibility – based on parameters:

<table>
<thead>
<tr>
<th>Month</th>
<th>GlobalHor kWh/m²</th>
<th>T Amb °C</th>
<th>Globalinc kWh/m²</th>
<th>GlobEff kWh/m²</th>
<th>EArray MWh</th>
<th>E_Grid MWh</th>
<th>EffArr %</th>
<th>EffSys %</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>165.8</td>
<td>-0.28</td>
<td>74.1</td>
<td>65.5</td>
<td>424</td>
<td>442</td>
<td>12.80</td>
<td>12.93</td>
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<tr>
<td>February</td>
<td>174.0</td>
<td>2.40</td>
<td>96.7</td>
<td>93.7</td>
<td>648</td>
<td>624</td>
<td>13.21</td>
<td>12.72</td>
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<tr>
<td>March</td>
<td>110.1</td>
<td>7.95</td>
<td>132.3</td>
<td>126.1</td>
<td>646</td>
<td>615</td>
<td>12.87</td>
<td>12.40</td>
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<tr>
<td>April</td>
<td>115.7</td>
<td>12.60</td>
<td>173.2</td>
<td>166.3</td>
<td>1080</td>
<td>1041</td>
<td>12.55</td>
<td>12.10</td>
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<td>May</td>
<td>180.8</td>
<td>18.91</td>
<td>194.6</td>
<td>175.8</td>
<td>1112</td>
<td>1074</td>
<td>12.13</td>
<td>11.71</td>
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<tr>
<td>June</td>
<td>105.1</td>
<td>22.02</td>
<td>190.9</td>
<td>181.8</td>
<td>1133</td>
<td>1094</td>
<td>11.95</td>
<td>11.54</td>
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<tr>
<td>July</td>
<td>209.5</td>
<td>24.79</td>
<td>205.6</td>
<td>190.7</td>
<td>1295</td>
<td>1164</td>
<td>11.76</td>
<td>11.38</td>
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<tr>
<td>August</td>
<td>176.3</td>
<td>24.58</td>
<td>186.9</td>
<td>176.3</td>
<td>1096</td>
<td>1060</td>
<td>11.81</td>
<td>11.42</td>
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<td>September</td>
<td>131.1</td>
<td>16.14</td>
<td>157.1</td>
<td>150.8</td>
<td>990</td>
<td>920</td>
<td>12.30</td>
<td>11.86</td>
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<tr>
<td>October</td>
<td>90.0</td>
<td>12.95</td>
<td>117.7</td>
<td>111.9</td>
<td>732</td>
<td>705</td>
<td>12.52</td>
<td>12.06</td>
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<td>November</td>
<td>52.5</td>
<td>7.14</td>
<td>77.2</td>
<td>71.8</td>
<td>482</td>
<td>462</td>
<td>12.56</td>
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<td>December</td>
<td>40.1</td>
<td>1.23</td>
<td>61.3</td>
<td>54.5</td>
<td>376</td>
<td>359</td>
<td>12.36</td>
<td>11.79</td>
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<td>Year</td>
<td>1458.2</td>
<td>12.78</td>
<td>1659.7</td>
<td>1574.2</td>
<td>10133</td>
<td>9767</td>
<td>12.29</td>
<td>11.84</td>
</tr>
</tbody>
</table>

**Notes:**
- Global horizonal irradiation (GlobalHor): Horizontal global irradiation
- Ambient Temperature (T Amb): Ambient temperature
- Global incident in coll. plane (Globalinc): Global incident in coll. plane
- Global Eff. corr. for IAM and shadings (GlobEff): Effective Global, corr. for IAM and shadings
- EArray: Effective energy at the output of the array
- E_Grid: Energy injected into grid
- EffArr: Effic. Eout array / rough area
- EffSys: Effic. Eout system / rough area

**Additional Information:**
- Horizontal global irradiation
- Near Shadings, "according to strings"
- IAM factor on global
- Effective irradiance on collectors
- PV conversion
- Array nominal energy (at STC effic.)
- PV loss due to irradiance level
- PV loss due to temperature
- Module quality loss
- Module array mismatch loss
- Ohmic wiring loss
- Array virtual energy at MPP
- Inverter Loss during operation (efficiency)
- Inverter Loss over nominal inv. power
- Inverter Loss due to power threshold
- Inverter Loss over nominal inv. voltage
- Inverter Loss due to voltage threshold
- Available Energy at Inverter Output
- AC ohmic loss
- External transfer loss
- Energy injected into grid
Feasibility – based on parameters:

Short list of *some* PRODUCTION parameters:

**System Parameters**
1. Module power
2. Solar Resource
3. Ground/roof coverage
4. Module tilt
5. Array azimuth

**Loss Parameters**
1. Shading
2. Soiling
3. Temperature
4. Initial degradation
5. Annual degradation
Feasibility – based on parameters:

Short list of *some* PROJECT parameters:

Project Parameters

1. Licencing costs
2. Installation costs
3. Unavailability
4. O&M fixed costs
5. O&M contingencies
Feasibility – based on parameters:

Primary Equations:

\[
\text{Total Energy} = \text{Solar Energy} - \sum \text{Losses}
\]

\[
\text{Profit} = f(\text{Total Energy, Time, Costs, taxes})
\]

- What is the real Solar Resource over 20+ years?
- What are the accurate values for each of the losses?
An energy simulation is only as good as the input data

Garbage In = Garbage Out
### Feasibility – based on parameters:
Most parameters used in simulations are accompanied by a variance:

1. **Project**
   - **Module Power \([W_p]\)**
     - Best estimate: 270.0
     - Risk/uncertainty distribution function: Uniform distribution: \(\text{Min}=270.0; \text{Max}=278.1\) (-0/+3%)

2. **Site**
   - **Horizontal global irradiation \([\text{kWh/m}^2/\text{year}]\)**
     - 1.050.0
     - Normal distribution: \(\mu=1050; \sigma=5\% \text{ of 1050}\)
   - **Irradiation increase due to tilt angle \([\%]\)**
     - 15.00%
     - Normal distribution: \(\mu=0.15; \sigma=2\% \text{ of 0.15}\)
   - **Ground Coverage Ratio \([\%]\)**
     - 40.7%
     - Triangular distribution: \(\text{Min}=30\%; \text{Mode}=41\%; \text{Max}=50\%\)

3. **Energy yield assessment**
   - **Irradiation loss due to shading \([\%]\)**
     - 2.00%
     - Normal distribution: \(\mu=0.02; \sigma=1.5\% \text{ of 0.02}\)
   - **Irradiation loss due to soiling \([\%]\)**
     - 1.00%
     - Uniform distribution: \(\mu=0.0; \sigma=3.0\%\)
   - **Module loss due to temperature \([\%]\)**
     - 1.50%
     - Normal distribution: \(\mu=0.015; \sigma=1.0\% \text{ of 0.015}\)
   - **Module loss due to LID/deviation from nominal power \([\%]\)**
     - 2.00%
     - Triangular distribution: \(\text{Min}=0.0\%; \text{Mode}=2.0\%; \text{Max}=5.0\%\)

4. **Capital Expenditures**
   - **Turn-key installation cost in total \([\text{EUR/kWp}]\)**
     - 706.00
     - Uniform distribution: \(\text{Min}=600; \text{Max}=750\)

5. **Power production & power sales**
   - **Technical unavailability \([\%]\)**
     - 1.0%
     - Triangular distribution: \(\text{Min}=0.0\%; \text{Mode}=1.0\%; \text{Max}=3.0\%\)
   - **PV system (module) degradation \([\%/\text{year}]\)**
     - 0.50%
     - Triangular distribution: \(\text{Min}=0.0\%; \text{Mode}=0.5\%; \text{Max}=0.8\%\)

6. **Operational expenses**
   - **O&M - fixed yearly fee \([\text{EUR/year}]\)**
     - 40.000
     - Normal distribution: \(\mu=40.000; \sigma=5\% \text{ of 40.000}\)
Feasibility – based on parameters:

Uniform Distribution -0/+3%
Feasibility – based on parameters:
Feasibility – based on parameters:

Triangular Distribution
Feasibility – based on parameters:

P50

P90

Triangular Distribution
Feasibility – based on parameters:
A Feasible Outcome

First Year Energy Production

Revenue from Energy Sales

Project IRR by CAPEX

Leveraged IRR after Tax
A Feasible Outcome

First Year Energy Production

Pareto Plot for Power production delivered to the grid [MWh]

- **P90**: 10,000,000% (x = 264543.24)
- **P50**: 90,000,000% (x = 306098.22)
- 10,000,000% (x = 306098.22)

Probability

Cumulative probability

Power production delivered to the grid [MWh]

- 0% to 10%
- 10% to 20%
- 20% to 30%
- 30% to 40%
- 40% to 50%
- 50% to 60%
- 60% to 70%
- 70% to 80%
- 80% to 90%
- 90% to 100%

Values:

- 0% to 220,000
- 220,000 to 240,000
- 240,000 to 260,000
- 260,000 to 280,000
- 280,000 to 300,000
- 300,000 to 320,000
- 320,000 to 340,000
- 340,000 to 360,000

M.G. Lightning

Ministry of Energy & Water Resources
Visual Aids

Tornado Plot for Power production delivered to the grid [MWh]

- Horizontal global irradiation [kWh/m²/year]
- PV system (module) degradation (%/yr)
- Module loss due to LID/deviation from nominal power [%]
- Module Power [Wp]
- Irradiation loss due to soiling [%]
- Technical unavailability [%]
- Irradiation increase due to tilt angle [%]
- Module loss due to temperature [%]
- Ground Coverage Ratio [%]
- B1. O&M - fixed yearly fee [EUR/year]
- Turn-key installation cost in total [EUR/kWp]
- Irradiation loss due to shading [%]
- Inverter loss during operation (conversion efficiency) [%]

Conditional Mean. (scale factor = thousands)
Visual Aids

Spider Plot for Revenue from power sales [EUR]

- Horizontal global irradiation [kWh/m2/year]
- Irradiation loss due to soiling [%]
- Module loss due to LID/deviation from nominal power [%]
- PV system (module) degradation (%/yr)
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Quality Control

The Anderson Rule of 10:

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component manufacturing</td>
<td>X 1</td>
</tr>
<tr>
<td>Design process</td>
<td>X 10</td>
</tr>
<tr>
<td>Component selection</td>
<td>X 100</td>
</tr>
<tr>
<td>Installation</td>
<td>X 1,000</td>
</tr>
<tr>
<td>Commissioning and operations</td>
<td>X 10,000</td>
</tr>
</tbody>
</table>
Mitigating the Financial Risks - QC

✓ Strategize
✓ Classify
✓ Understand
✓ Manage
Mitigating the Financial Risks - QC

Strategize:

- Top level decision makers MUST take ownership of the QC management for ensuring CONTINUETY from the BEGINNING
- Define what must be done to ensure
  - Continuity
  - Desired level of product
- Assign the resources to achieve these goals
Mitigating the Financial Risks - QC

Classify:

- Ensure a wide variety of skill sets in the design team
- Brainstorm
- Checklists to ensure all potential risks are identified
- Classify risks in terms of occurrence frequency and severity in terms of financial impact
Mitigating the Financial Risks - QC

Understand:

- Analyze the root cause(s) of the various risk factors and interrelations between them
- Identify the most important influencers that may challenge the financial performance of the project.

Manage!
Conclusions:

✓ Analyzed the technical assumptions used in a financial model
  ✓ We have analyzed the areas of weakness in a PV project
  ✓ We have seen some levels of accuracy between design calculations and finished project

✓ Quantified the cost of a technical risk
  ✓ We have seen new methodology for calculating the benefit of a mitigating measure using cost-based FMEA
  ✓ Use of CPN for evaluating the cost of a mitigating action
Conclusions:

✓ Mitigating financial risk in the business plan
  ✓ Calculate the major indices of the business plan using both the parameter and its variance
  ✓ Use graphing tools to visualize the interdependence of these variables
  ✓ Ensure that a rigid QC regimen has ensured that the design parameters on which the business plan was built remain intact from feasibility through to O&M