Module Quality Assurance: 
Risk Mitigation and Safeguarding Project Value

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CEA is a solar PV advisory firm that is able to provide unrivaled insight into the manufacturing process to ensure the success of PV projects worldwide.

- More than 60 employees
- Over 35 engineers
- A presence in 8 countries
- Over 8 years history
- Client engagements in 27 countries
- Audited 125+ solar factories worldwide

Engineering Services
Technical Advisory
Supply Chain Management
Quality Assurance

Over 8GW experience

Certified by
Proud member of
Technical Advisors in the past have overemphasized downstream quality without looking as closely on the product in more detail.
Module Bankability is resting on two problematic pillars: warranties and certifications.

### Warranties

- Long duration (25-30 years)
- Limited terms
- Many exclusions
- Not comprehensive
- Diagnostics costs not covered
- Lost revenue not covered
- Replacement costs not covered
- Lengthy claim process
- Replacement retrofits are technically challenging

### Certifications

- IEC standards by design offer only a very basic level of assurance
- Most experts agree that IEC standards are only good for 10 years in the field
- Even extended testing only proves the manufacturer’s ability to produce a small number (20 pcs) of good modules
- Bill of Materials compliance during production is not assured
- Stability of production processes is not assured
CEA’s Quality Assurance Program (CQAP) prevents risk and ensures that downstream project stakeholders maximize the output of their system.

**Pre-Production**
- Supplier’s certification
- Product and factory certification liaising TUV, SGS, UL, CE, etc. assessment centers
- Bill of Materials [BOM] inspection data review

**Production Monitoring**
- Input material monitoring
- Production environmental control; monitoring of inventory storage and manufacturing workshop
- Production process control; monitoring of equipment calibration, stringing, lay-out, lamination, curing and framing

**Pre-shipment**
- Product Inspection
- Visual inspection
- Functional test
  - EL test
  - IV test
- ISO 2859 Sample rule
- QC standard
- AQL rule

**Container Loading**
- Proper Packing
  - Container type
  - Container number
  - Seal number
  - Shipment plan
  - Content Listing
  - Packaging list
  - Inspection certificate
Typical PV Module Production Process Flowchart: multiple steps, leading to multiple potential failure points
CQAP has been performed in various facilities of Tier 1 manufacturers and the distribution of defect rates has showed surprising results.

Defect data from QA performed on over 100 projects totaling many GWs of modules
CEA has analyzed 4 case study QA projects and the insights gained can show the value of performing quality work on future projects.

1. Projects demonstrate highly variable defect rates
2. Defect distribution varies greatly with project, location and in time
3. FMECA risk analysis (IEC 60812) similarly shows great risk variability
4. Even a 1% excess yield loss, can lead to substantial financial loss
4 case studies of typical projects produced at Tier 1 manufacturers shows the variability across manufacturers.
Applying the FMECA methodology, the RPN defects are ranked for severity, occurrence and detectability to produce each RPN.

**RPN (Risk Priority Numbers): high values show relative high risk**

<table>
<thead>
<tr>
<th>Project</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1</td>
<td>3,290</td>
</tr>
<tr>
<td>Project 2</td>
<td>2,758</td>
</tr>
<tr>
<td>Project 3</td>
<td>1,944</td>
</tr>
<tr>
<td>Project 4</td>
<td>1,463</td>
</tr>
</tbody>
</table>

Projects with seemingly low defect rates, may have a high RPN, and vice versa, when defect risk analysis is performed.
Scattered defect distribution show that even on the same production lines as module assembly processes are not stable.
CEA model for assumed module degradation per defect category*

Assumed losses

* in excess of warranted degradation, at project midlife, based on reasonable assumptions about degradation caused by defects
Correlation of defect rates to average power loss derived from 4 project case studies. This loss will be mitigated if Quality Assurance is performed.

**Average defect rate**
5.68%

**Average avoided power loss due to defects**
(calculated according to degradation model) *
1.10%

* in excess of warranted degradation, at project midlife, based on reasonable assumptions about degradation caused by defects

**QA Virtuous Effect:**
The presence of a 3rd party performing Quality Assurance leads to a “virtuous effect”. Overall quality improves. The absence of a 3rd party oversight, inevitably leads to higher defect rates, and subsequently to higher calculated power losses by a factor.
Example of calculated NPVs for 2 projects, produced with and without Quality Assurance program, using three scenarios

Projects with Quality Assurance (no excess loss)
- Project A
  - Good scenario: $25.4 M
  - Medium scenario: $23.0 M
  - Bad scenario: $21.8 M
- Project B
  - Good scenario: $25.4 M
  - Medium scenario: $23.0 M
  - Bad scenario: $21.8 M

Projects without Quality Assurance
- Project A
  - Good scenario: $14.6 M
  - Medium scenario: $12.5 M
  - Bad scenario: $11.5 M
- Project B
  - Good scenario: $25.4 M
  - Medium scenario: $23.0 M
  - Bad scenario: $21.8 M

Bad scenario: manufacturer shows a big drop in quality w/o QA program (4 x 1% defect loss, or 4% in excess of warranty in project midlife)
Medium scenario: manufacturer shows a medium drop in quality w/o QA program (3 x 1% defect loss, or 3% in excess of warranty in project midlife)
Good scenario: manufacturer shows a small drop in quality w/o QA program (2 x 1% defect loss, or 2% in excess of warranty in project midlife)
NPV loss in $/W for the 2 projects, without applying Module Quality Assurance Programs, using three scenarios

Bad scenario: manufacturer shows a big drop in quality w/o QA program (4 x 1% defect loss, or 4% in excess of warranty in project midlife)
Medium scenario: manufacturer shows a medium drop in quality w/o QA program (3 x 1% defect loss, or 3% in excess of warranty in project midlife)
Good scenario: manufacturer shows a small drop in quality w/o QA program (2 x 1% defect loss, or 2% in excess of warranty in project midlife)
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