PV Equipment Testing: Historical Data and Best Practices for Product Qualification
Combined strength to support Energy customers
DNV GL is the world’s largest independent energy & renewables advisory firm.

We have over 2500 energy experts. More than 1000 are focused on renewables.

DNV GL has advised over 5500 solar projects.

Extensive experience in solar technology and applications.

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150 years
350 offices
14,000 employees
100 countries

RESEARCH & INNOVATION

About DNV GL
78% of installed capacity deployed in past 5 years
Depolyments expected to increase 2.5x in the next 5 years
Global blended module price

- ~80% drop in module price since 2010
- ~30-50% (!) drop since early 2016
NREL Degradation Study “High Quality” Dataset

![Degradation Rate Bar Chart]

<table>
<thead>
<tr>
<th>Mean degradation rate</th>
<th>Median degradation rate</th>
<th>P90 degradation rate</th>
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</thead>
<tbody>
<tr>
<td>0.5 – 0.6 % / year</td>
<td>0.4 – 0.5 % / year</td>
<td>1.2 % / year</td>
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Aging mechanisms leading to PV module degradation

- Solder joints / internal circuit recurring failure mechanism

- Review of Failures of Photovoltaic Modules, IEA PVPS 2014
1. **Product Qualification Program:** downstream partners obtain data / reports at zero cost. Support for managing Approved Vendor List or RFP invites

- **PV Modules**
  - Testing for BOM
  - Extended Reliability Testing
  - Performance Testing
    - PAN Files
    - IAM coefficients
    - LID
    - NOCT

- **PV Inverters**
  - Reliability Testing
  - Envelope Characterization
  - Transient Response
  - Low Light Performance
  - Efficiency
  - Arc / ground fault
  - Micro, string, and utility scale
  - AFCI nuisance trip

- **Energy Storage**
  - Round Trip Efficiency
  - Self-Discharge
  - Response Time & Ramp Rate
  - Overvoltage / undervoltage Protection
  - SOC Validation
  - Full System Cycle Testing
  - Environmental Testing
  - Cell Level Testing

2. **Statistical Batch Testing:** Statistical testing at the project by project level to screen for defects and to verify that you got what you paid for
Product Qualification Program (PQP) – At a Glance

Manufacturers
- Sign up for and pay for PQP testing
- Sign waiver to share reports

Downstream Partners
- Share Reports
- Provide Active Support
  AT NO COST
- Sign Engagement Letter including NDA
- Testing per BOM

- Independent witness of build to ensure no “golden samples”
Thermal Cycling (200 cycles) Results from DNV GL Labs

- 6% of commercially available modules don’t meet IEC certification criteria
Scorecard

- Using the qualification program data we have released the **PV module reliability scorecard** – Free download on the DNV GL website

- Report contains high level test results – details are available to downstream partners – *BOM and factory location is critical*

- **Inverter qualification scorecard** coming in 2017
thermal cycling (600 cycles)

- 22 manufacturers across 40 module models with 49 unique BOMs participated

Top performers to left of green line, listed below in alphabetical order

Lower performers anonymized
Thermal Cycling (600 cycles): Country of Production

- RED: China
- YELLOW: Asia
- BLUE: ROW
Thermal Cycling (600 cycles): Manufacturer Size

- RED: Top 10 largest by shipment volume
- BLUE: other
Module types may have very different bill-of-materials

- Same module type – Different bill of material
- DNV GL defines one BOM with 107 parameters (EVA, backsheet, etc.)
- Factory location is one element of the BOM
### Recommended Procedure to Assess Module Risk

#### Before Production

**Product Qualification Program (PQP)**
- BOM and manufacturing facility qualification
  - Extended reliability testing reports
  - Performance evaluation (PAN files, etc.)
  - Factory witness

**1. Before production:**
**Product Qualification Program**

#### During Production

- Check BOM qualification

**Statistical Batch Testing**
- Test on actual modules from the project
- Factory production oversight

**2. During production:**
**Statistical Batch Testing**
Thank you.

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