LESSONS LEARNED FROM OPERATIONAL ENERGY DATA TO INFORM PRE-CONSTRUCTION ESTIMATES
GLOBAL PRESENCE

143+
Countries with office locations

500+
Renewable energy experts

Key Locations
INTRODUCTION

• Review of operational projects

• Evaluation of:
  • Availability
  • Performance Ratio
  • Net Capacity Factor
  • Degradation

• Key Takeaways to inform pre-construction assumptions
ENERGY PRODUCTION ESTIMATES

- Loss factors inputs calibrated to plant design and site-specific conditions.
- PVSYST used for simulation.
- Results post-processed to address operational and long term loss factors.
DATA STATISTICS

• Projects from multiple data sources:
  • Supervisory Control and Data Acquisition (SCADA)
  • U.S. Energy Information Administration (EIA)
  • Operational energy production reviews (OEPR) based on Monthly Operational Reports (MORs)

• Detailed project information was not always available.

• AWST removed data from startup periods or that appeared erroneous or unrealistic.

• Primary data set: SCADA

• EIA and OEPR data used to inform understanding from SCADA results
## DATA STATISTICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SCADA</th>
<th>EIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Projects</td>
<td>55</td>
<td>41</td>
</tr>
<tr>
<td>Average Nameplate Capacity ($MW_{AC}$)</td>
<td>34</td>
<td>29</td>
</tr>
<tr>
<td>Average Period-of-Record (years)</td>
<td>2.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Total Number of Years Represented</td>
<td>100</td>
<td>172</td>
</tr>
<tr>
<td>Tracking - Fixed Tilt</td>
<td>91% - 9%</td>
<td>49% - 51%†</td>
</tr>
<tr>
<td>Crystalline - Thin Film - Mixed</td>
<td>65% - 29% - 5%</td>
<td>67% - 33% - 0%‡</td>
</tr>
<tr>
<td>DC-AC Ratio Average</td>
<td>1.31</td>
<td>-</td>
</tr>
<tr>
<td>Availability Average</td>
<td>98.6%</td>
<td>-</td>
</tr>
<tr>
<td>AC Capacity Factor Average</td>
<td>29.5%</td>
<td>24.2%</td>
</tr>
<tr>
<td>Performance Ratio Average</td>
<td>76.4%</td>
<td>-</td>
</tr>
</tbody>
</table>

† Calculated from projects where data were available.
AVAILABILITY OF INVERTERS

- Average of 98.6% (pre-construction estimate is usually ~99%)
- 31% of projects below 98% availability, non-normal distribution with low tail
- Standard deviation (annual): 1.2% (100 years)
- Standard deviation (monthly): 5.6% (1000+ months)
- Tracking vs. fixed-tilt: within 0.1% of each other
PERFORMANCE RATIO

- PR = Net Energy / Gross Energy = 1 – combined loss
- Gross Energy calculated from plane-of-array irradiance (POA) in SCADA
- Mean = 76.4%, about 3% lower than typical pre-con PRs (77-81%).
- Outliers suggest equipment performance or maintenance issues at two sites
NET AC CAPACITY FACTOR AND PERFORMANCE

- Monthly energy totals adjusted to first-year values using a typical modeled degradation rate of 0.65% per year.
- Net capacity factor (NCF) calculated from reported MW\textsubscript{AC}
- Presented as a function of reported POA
- Compared to typical pre-construction relationship between POA and NCF

![Graph showing relationship between annual plane-of-array irradiation and degradation-corrected AC NCF.](image)

Conclusion: AWST’s pre-construction estimates, on average, represent actual project performance.
NET AC CAPACITY FACTOR AND PERFORMANCE

- Operational performance is within 0.3% of AWST’s estimates (on average)
- Standard deviation of 2.1% from the regression line, somewhat influenced by configuration-specific factors not considered for operational relationship (equipment/technology, DC-AC ratio)
- AC over-sizing may compensate for the ~3% difference between pre-construction and operational PRs
- Outliers by 5-10% below regression (despite high availability) have poor PRs, suggesting equipment underperformance or poor O&M activities
DEGRADATION

- Degradation calculated as percent energy decrease after irradiance correction
- Projects with only four years of data showed a greater range of degradation rates due to a shorter assessment period.
- Early-year degradation rates are more uncertain, making them difficult to predict and analyze.
- System degradation rates may be greater than material-only impact
OEPR ANALYSIS

Approximately 50 Operational projects:
• Desert Southwest
• Canada
• South America
• India

Findings:
• Perceived underperformance sometimes due to optimistic PRs from some IEs (2% underperformance, or 2% over-prediction?)
• Key loss areas overlooked:
  • DC array performance loss (0.5-1.5%)
  • String-level mismatch (0.5%)
  • Snow loss under-prediction (up to 5-10%)
  • Plant operation of curtailment on string, inverter, or plant level
• Availability for well-maintained projects: 98-99%
• Annual degradation (system level) influenced by unresolved DC system failures
CONCLUSIONS

- Availability is within ~1% of pre-construction estimates
- AWST’s pre-construction estimates align well with operational experience; however:
  - Pre-construction performance ratios may be 2-3% optimistic
  - Some modelers overlook DC factors, leading to ~2% over-prediction
- Degradation:
  - Is difficult to estimate until year 5
  - Exceeds material-only degradation estimates (despite inverter limitation loss reclamation)
- Pre-construction estimates can be improved by considering:
  - Undetected/unmitigated/unaccounted-for DC array issues
  - O&M service consistency/quality
  - Snow loss underprediction in certain climates
  - Long-term degradation on a system-level, accounting for:
    - Mismatch increase
    - Unresolved DC array issues
THANK YOU FOR YOUR TIME

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