Uncertainty in Solar Energy Estimates

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Introduction to SAIC

- Since the 1980s, SAIC has worked with clients around the world to evaluate the viability of energy development.
- We have advised clients on more than 1,000 power, infrastructure, and industrial projects in roughly 75 countries and territories.
- We have expertise in all conventional and renewable power technologies, including solar, hydro, wind, geothermal, and biofuels.
- SAIC was ranked as the top independent engineering firm for renewable energy by the trade magazine *Infrastructure Journal*.
- Our energy-focused consulting practice is backed by the full strength of SAIC – a diversified, 40,000-employee, FORTUNE™ 500 company.
Sources of Error in Estimating any Solar Resource

• Period of record
  – Will an estimate based on X years of data represent the coming 25 years, even if the model/measurements are exactly correct? (Neglecting climate change.)

• Spatial uncertainty
  – For satellite, spatial averaging over pixel vs. exact project location, and/or in many cases a project site spanning multiple pixels
  – For ground measurements, distance between reference data source and project site

• Model and/or measurement uncertainty
  – Discussed in previous presentations today, for purposes of this discussion let’s assume these uncertainties are known or at least knowable

• For purposes of this discussion, not treating inter-annual variability as an “uncertainty”
## Case Study – Southern Central Valley, California

<table>
<thead>
<tr>
<th>Location</th>
<th>Data Source</th>
<th>Complete Years of Data</th>
<th>Approx. Dist. from Project (km)</th>
<th>Ele. (m)</th>
<th>Annual GHI (kWh/m²)</th>
<th>% Delta vs. Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Project Site (South Pixel)</td>
<td>CPR GHI Average Months</td>
<td>15</td>
<td>N/A</td>
<td>170</td>
<td>1,946</td>
<td>N/A</td>
</tr>
<tr>
<td>B Project Site (North Pixel)</td>
<td>CPR GHI Average Months</td>
<td>15</td>
<td>N/A</td>
<td>170</td>
<td>1,954</td>
<td>+0.4</td>
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<tr>
<td>C Project Site (South Pixel)</td>
<td>Prospector GHI</td>
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<td>N/A</td>
<td>170</td>
<td>1,973</td>
<td>+1.4</td>
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<td>D Project Site (South Pixel)</td>
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<td>N/A</td>
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<td>1,951</td>
<td>+0.3</td>
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<tr>
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<td>N/A</td>
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<td>1,975</td>
<td>+1.5</td>
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<tr>
<td>G Bakersfield</td>
<td>TMY3 Class I</td>
<td>24</td>
<td>25</td>
<td>150</td>
<td>1,895</td>
<td>-2.6</td>
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<tr>
<td>H Arvin-Edison</td>
<td>CIMIS</td>
<td>17</td>
<td>10</td>
<td>150</td>
<td>1,853</td>
<td>-4.8</td>
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<tr>
<td>I Shafter</td>
<td>CIMIS</td>
<td>26</td>
<td>50</td>
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<td>1,915</td>
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<tr>
<td>J Famoso</td>
<td>CIMIS</td>
<td>15</td>
<td>50</td>
<td>130</td>
<td>1,843</td>
<td>-5.3</td>
</tr>
</tbody>
</table>

CIMIS = California Irrigation Management Information System, CPR = Clean Power Research, GHI = global horizontal irradiance
km = kilometers, m = meters, kWh/m² = kilowatt-hours per square meter, TMY = typical meteorological year
Is There Really a ~7% Range Between Data Sources...

- ...before we even consider uncertainty?
  - Two CIMIS locations have significant anomalies (>20% below CPR in some years)
    - Not fully explained by missing data

- We are left with:
  - Six inherently related satellite values
  - One Class I TMY3
  - One long-term ground measured data source with unknown measurement uncertainty
    - Shafter CIMIS agrees quite well over 25+ years with NSRDB and CPR satellite data

- ~4% range min to max for these remaining data sources – is “the truth” in there?

NSRDB = National Solar Radiation Database
Questions to Ponder and Discuss

• For the project developers in the room:
  – Why didn’t you just save everyone all this trouble and install a high-quality MET station with redundant sensors at least one year in advance of anticipated financial close and keep those sensors carefully aligned, calibrated, and cleaned, with rigorous documentation of maintenance practices?
  – Even if this is the case, rigorously quantifying sensor uncertainty is not trivial

• If you choose the “most representative” TMY for your project site based on proximity, period of record, and data quality...
  – How different are the other data sources? Should they be different due to location, climate, and/or period of record? Do those differences make you more or less confident in the chosen source?
  – If multiple, independent sources give roughly the same answer, is it actually probable that the “truth” is at the far end of any of those error bars?

• If you take all viable data sources and average or weight (one way or another)...
  – Why does giving weight to less reliable, further away, and/or shorter-term data give a better answer?
  – Not saying it doesn’t or can’t, but these questions must be considered
Thank You

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Further References

  - [http://www.nrel.gov/docs/fy10osti/47465.pdf](http://www.nrel.gov/docs/fy10osti/47465.pdf)