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solar energy

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Reducing Uncertainty in Solar Energy Estimates
A Case Study

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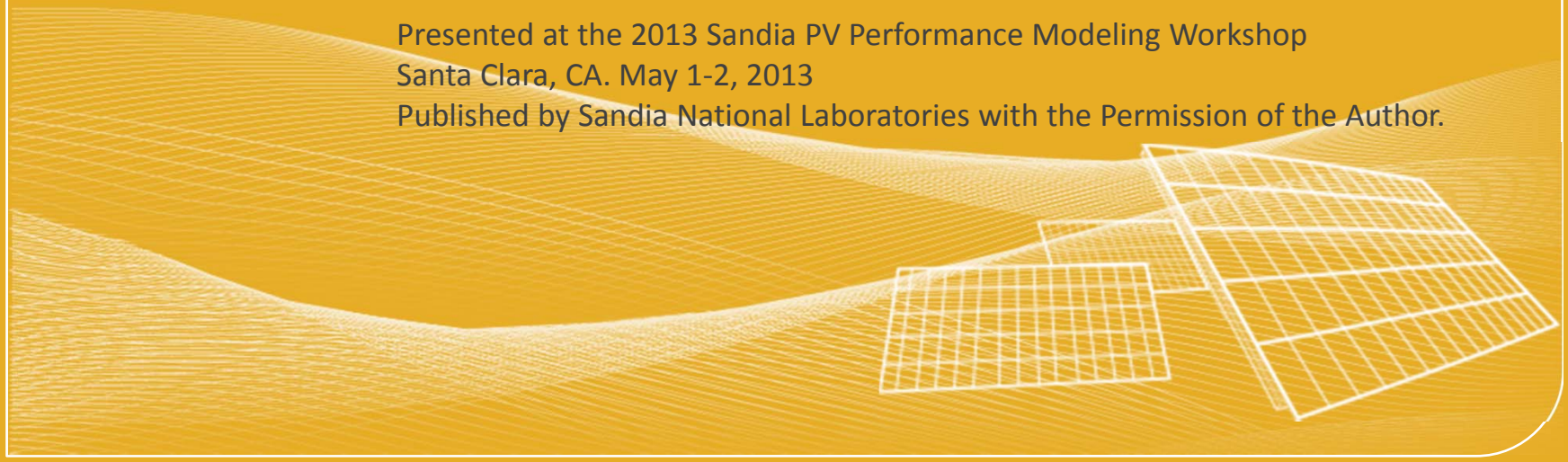
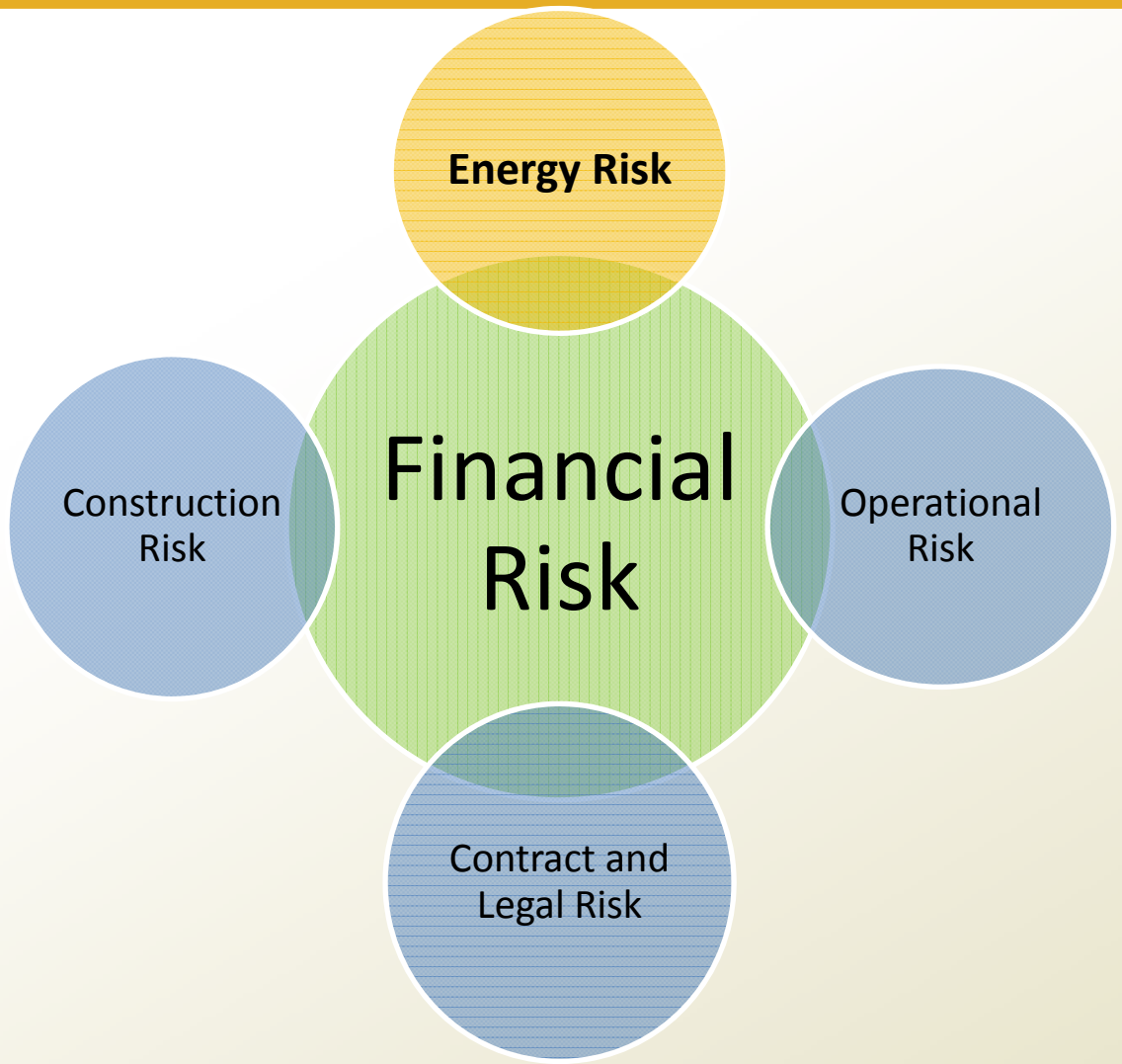
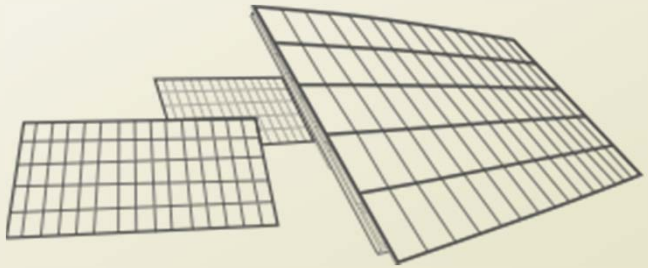


Uncertainty Matters

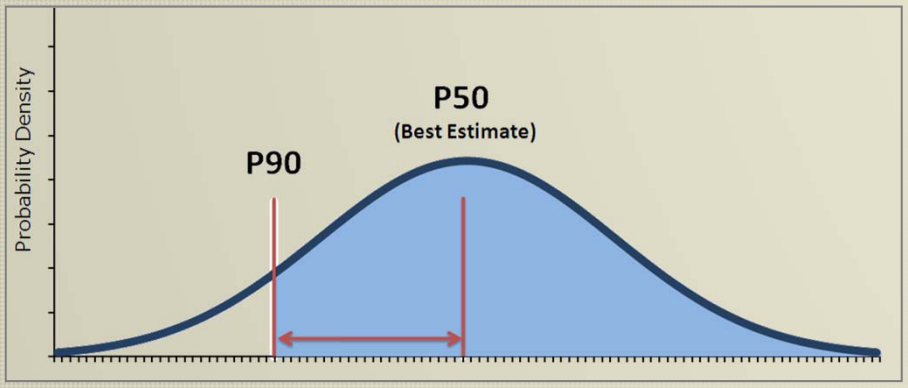
Uncertainty Matters



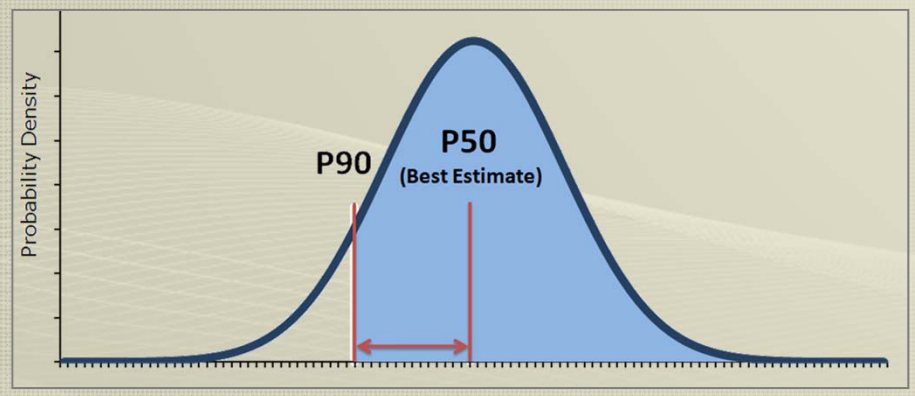
1. Sources of Energy Uncertainty
2. Solar Resource & Data Sources
3. Case Study: Impact of On-Site Data on Energy Assessment
4. Results: Impact on Project Finance



Energy Estimates and Probability of Exceedance



Example 1: Base Case



Example 2: Reduction of risk

Probability of exceedance:
the level of confidence that a plant's actual energy production will be at least a certain value

Reduced Uncertainty

↓

Increased Value of P90

Industry Expectations

As the solar industry matures, on-site data is becoming more and more important for the financial community…

Fitch Ratings – Rating Criteria for Solar Power Projects (February 2011)

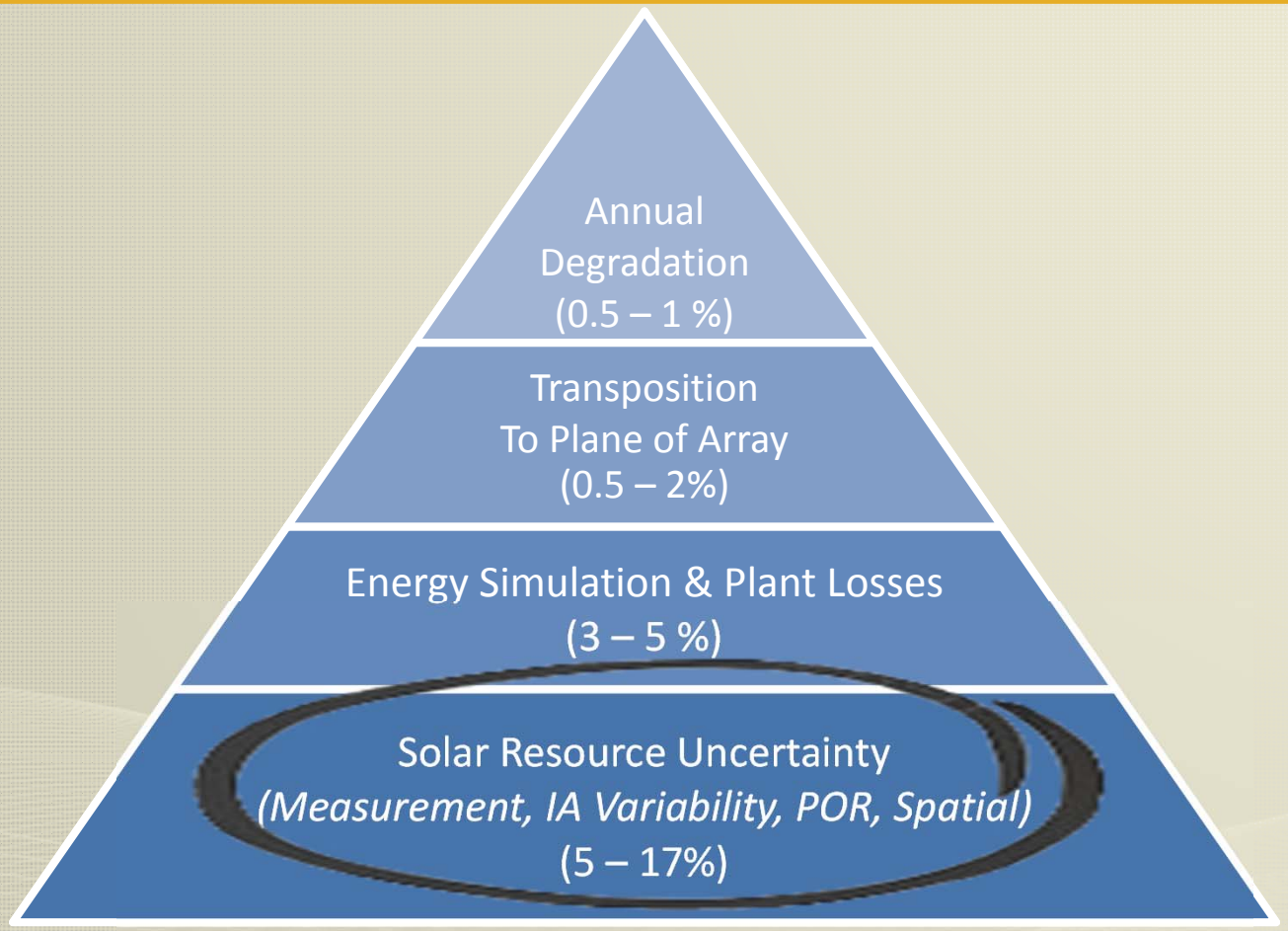
"Fitch looks for a minimum of one year, hourly, well-maintained, onsite data for a complete solar resource supply assessment. Shorter data periods than one year will not capture the full seasonal and diurnal characteristics of solar irradiance at a particular site, and would be considered either midrange or weaker. Confirmation that the instruments used to collect the data were appropriate and properly calibrated and maintained is also expected."

"Fitch considers a solar resource assessment that provides three output probability scenarios, a P50, a one-year P90, and a one-year P99, to be stronger…may not rate a solar debt issue that provides as P50 alone."

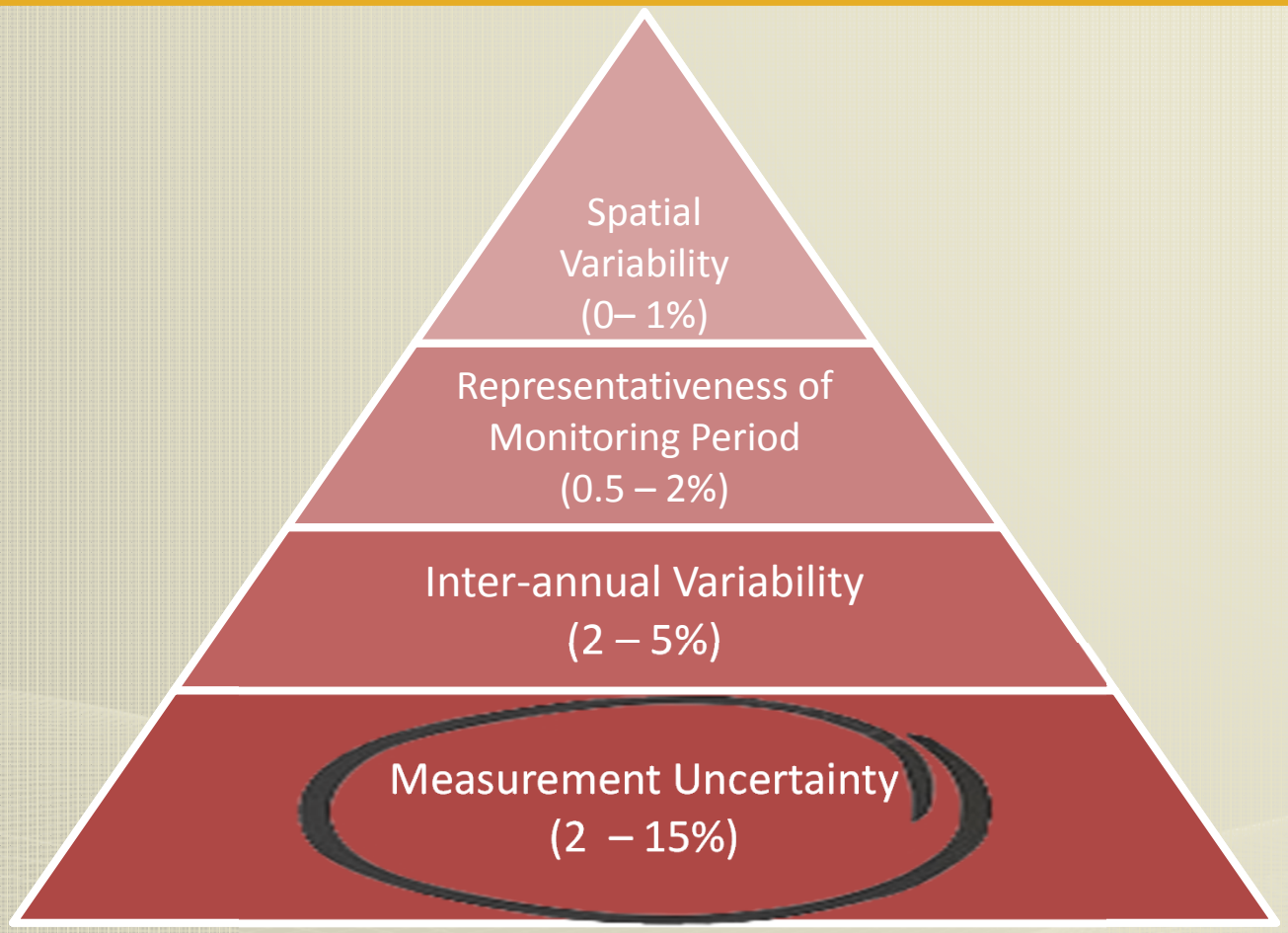
Moody's Investors Service – PV Solar Power Generation Projects (July 2010)

"…there has to be high degree of confidence that solar irradiation will meet or exceed certain minimum levels. For PV solar projects, Moody's will likely use a P90 forecast in calculating base case financial ratios…"

Sources of Energy Uncertainty



Sources of Solar Resource Uncertainty



Reducing measurement uncertainties in the solar resource assessment will make the project more attractive and less risky to outside investors

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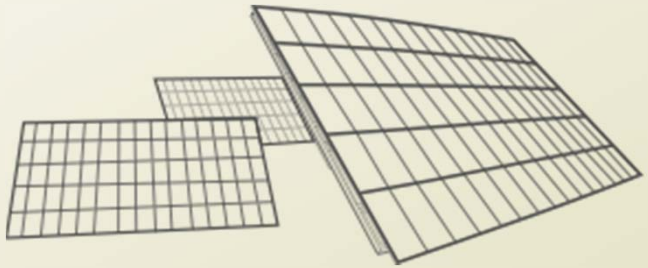
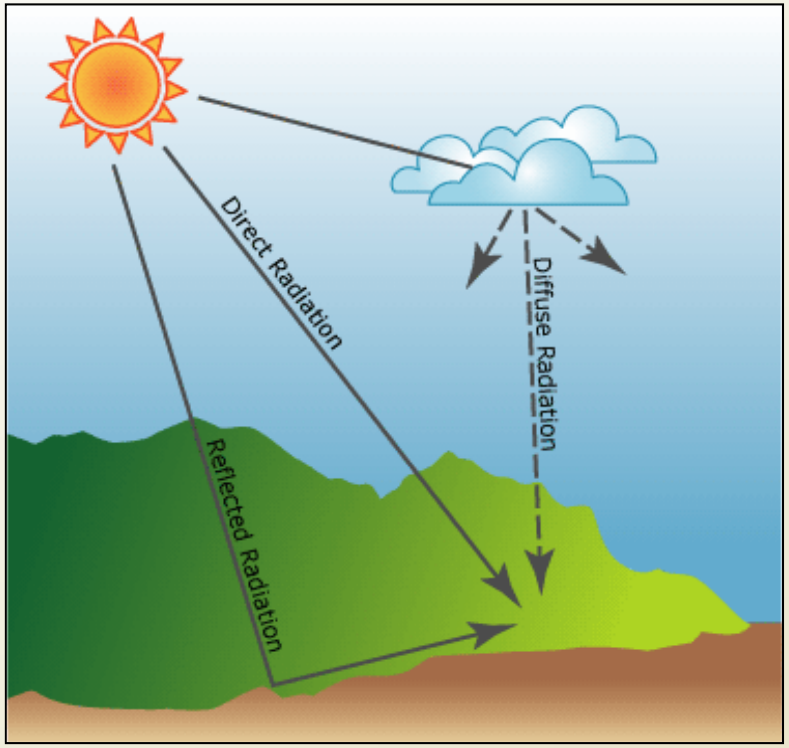


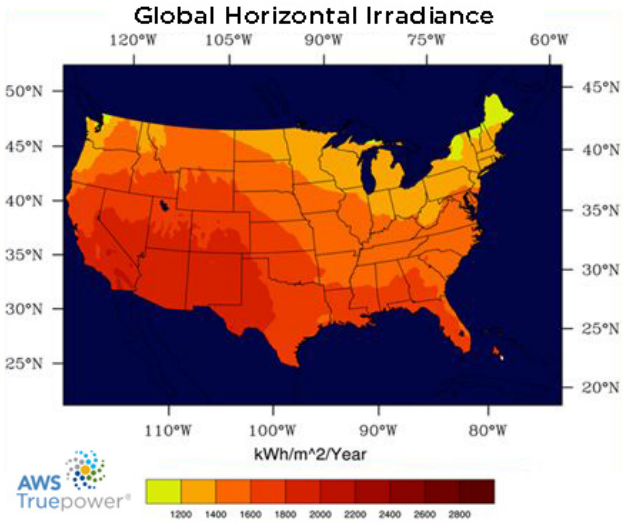
Elements of Solar Radiation

- Global Horizontal Irradiation (GHI)
- Direct Normal Irradiation (DNI)
- Diffuse Horizontal Irradiation (DHI)
- Solar PV primarily relies on GHI for energy estimates
- CPV and CSP rely on DNI



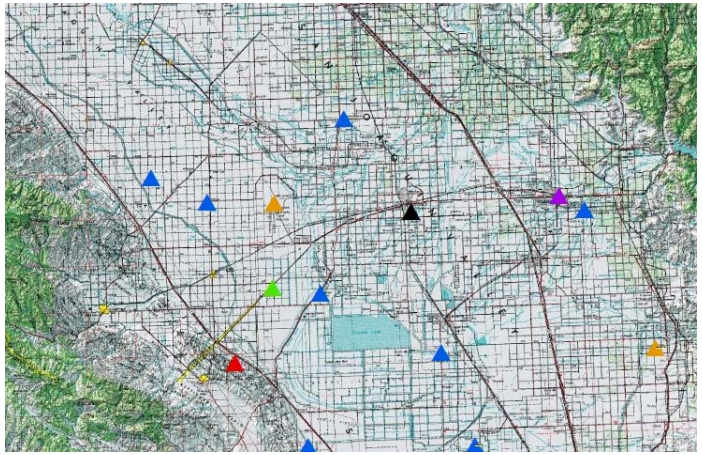
Source: ESRI, Inc.

Modeled Data – Various Sources



On-site Measured Data

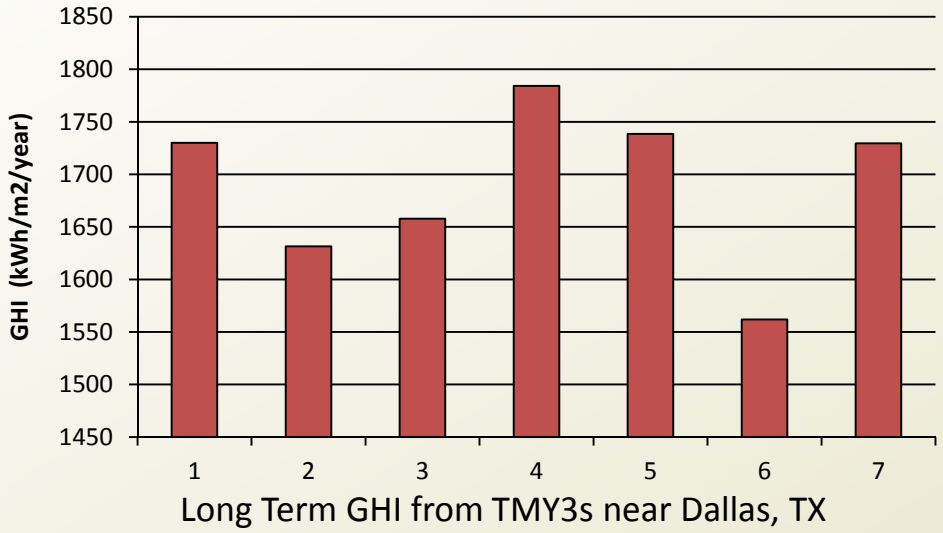
Nearby Reference Station Data



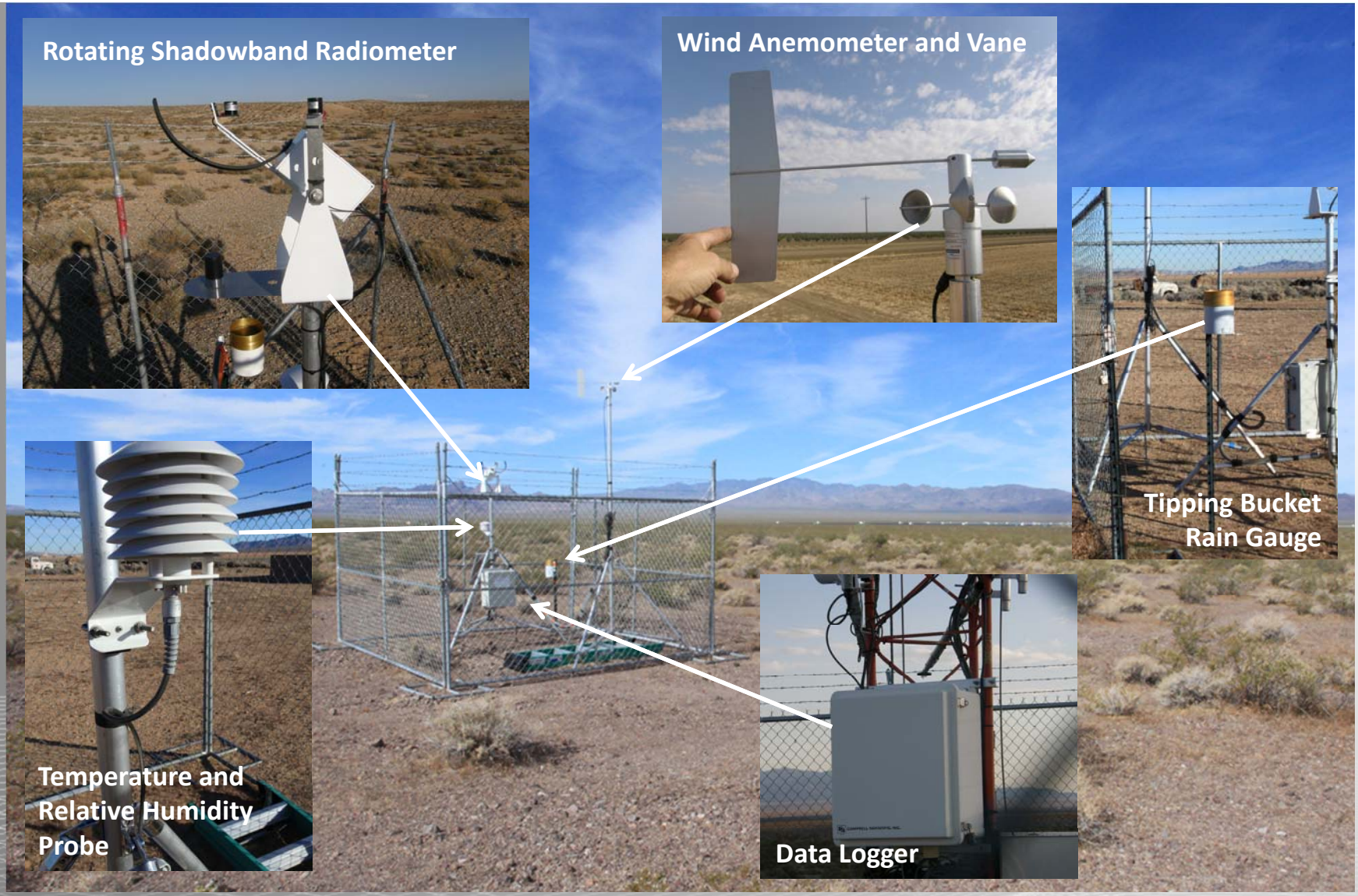
Data Sources

Modeled Data Sources

- US National Solar Radiation Database (NSRDB)
  - Mostly modeled solar data using numerical and satellite models
  - NSRDB TMY3 data set for specific locations in U.S



  - 14% difference in a 60km radius around Dallas, TX
- Other sources of public and private modeled data (Meteonorm, NASA, others)



An Example Solar Resource Monitoring System

On-Site Monitoring Best Practices

Measurement Plan

- Solar instrumentation
- Meteorological: temperature, wind speed, precipitation
- Sampling/recording rate
- Measurement period

Installation and Commissioning

- Site selection
- Sensor verification
- Communications and data QA
- Documentation

Site Maintenance

- Regular schedule
- Clean, level instrumentation
- Site security

Data Validation and Quality Control

- Regular system monitoring
- Comparison with reference data and concurrent satellite data
- Visual data screening
- Clear sky / extreme values

Data Source Advantages and Limitations

Data Source	Advantages	Limitations and Risks	Intended Use
Modeled	• Grid-cell specific • Publicly available • High data recovery	• Grid resolution • Regional biases • Greater uncertainty	• Initial prospecting • Smaller projects • Correlation with on-site data
Observed Reference Station	• Ground measurements • Period of record may be longer • Publicly available	• Scarcity of sites • Location compared to project site • Uncertainty: quality of O&M, instrumentation, inconsistencies in data	• Confirm trends • Identify regional biases • Correlation with on-site data
On-Site Measurements	• Site-specific data • Customized for project needs • Station details well-known • Reduced uncertainty	• Shorter period of record (correlate with long-term data)	• High-confidence resource and energy estimates • Bankable reports • In-depth characterization of seasonal and diurnal climate

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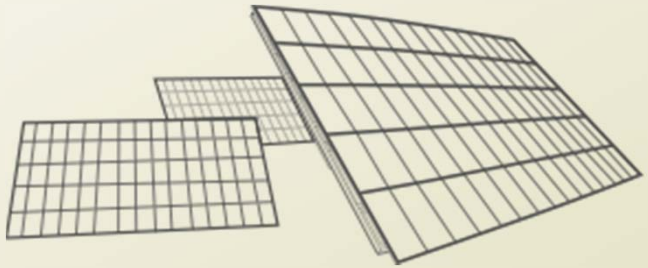


The Case Study

Why we did it

- AWS Truepower has long held the position that the risk of using modeled data alone can add unnecessary risk to a solar project when characterizing a project site.

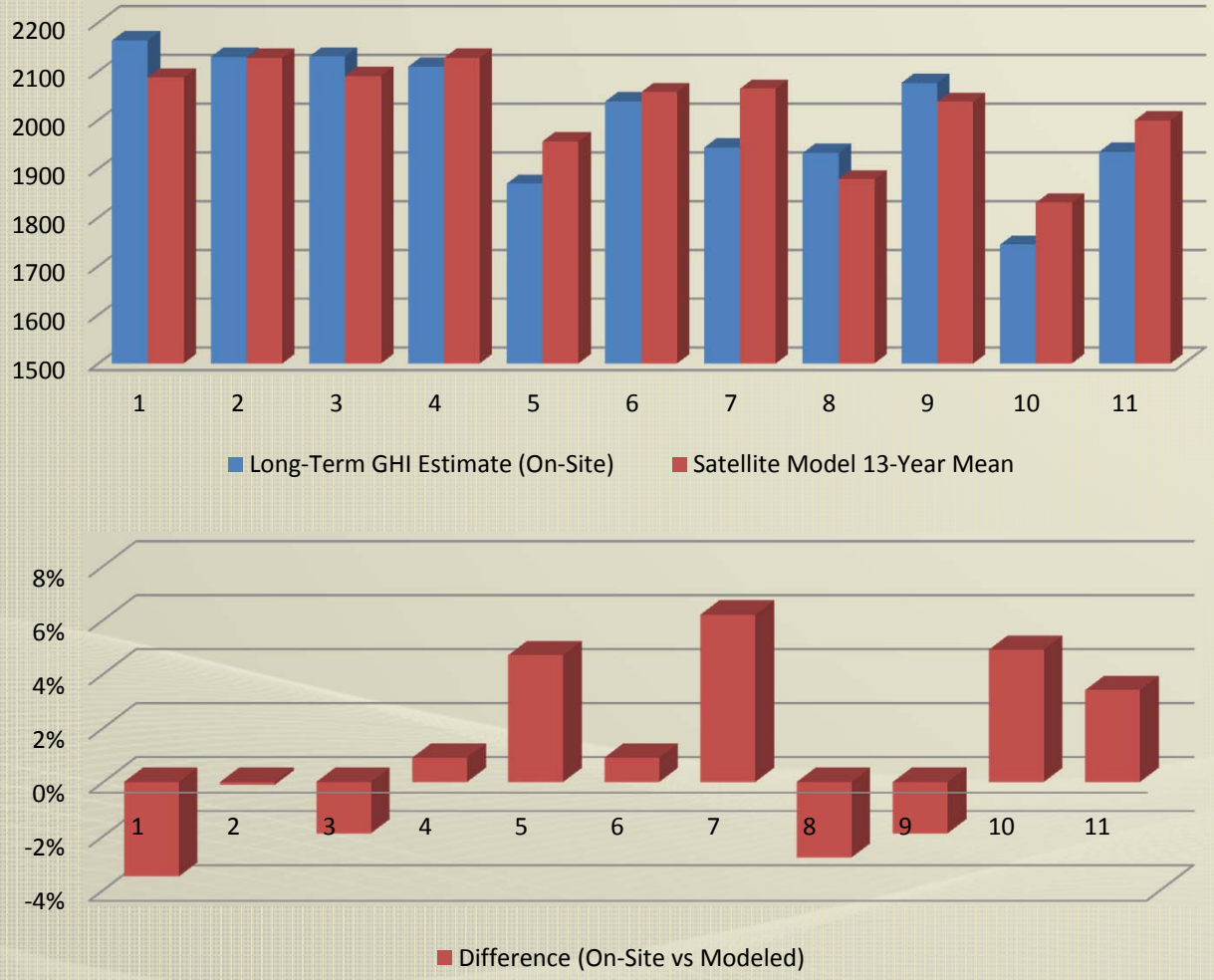
- To further validate that on-site monitoring supports high confidence energy estimates (i.e. P90, P99) for bankable energy analysis, and quantify the differences between modeled and on-site measurement.

The Case Study

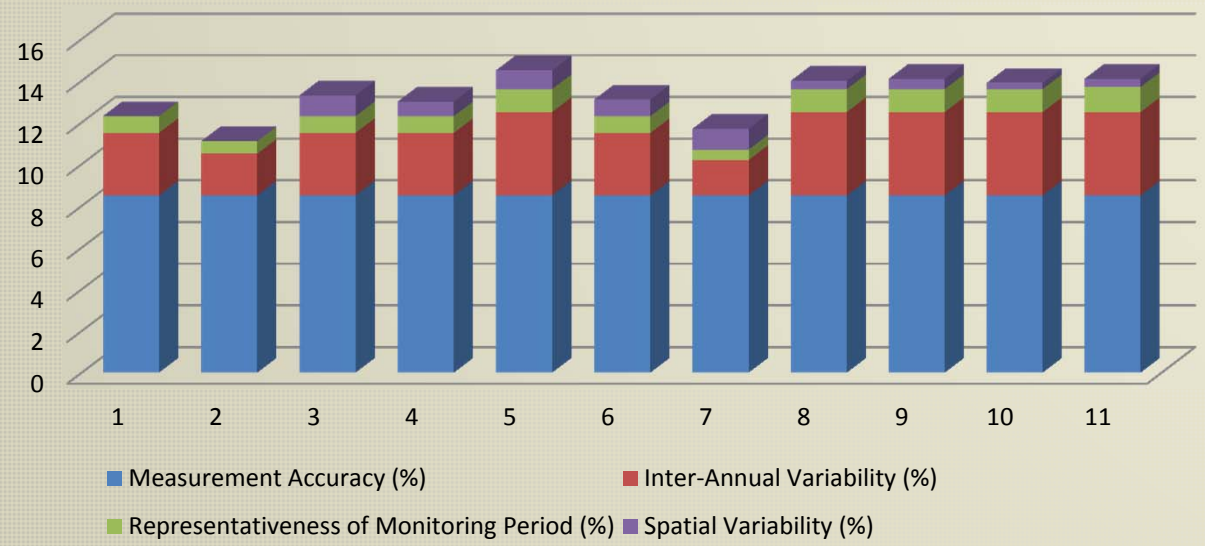
How we did it

- 11 sites with 1-2 years of data
- 2 solar energy assessments for each site
  - Modeled data alone
  - On-site measurements projected over project life
- Uncertainty assessment for each scenario

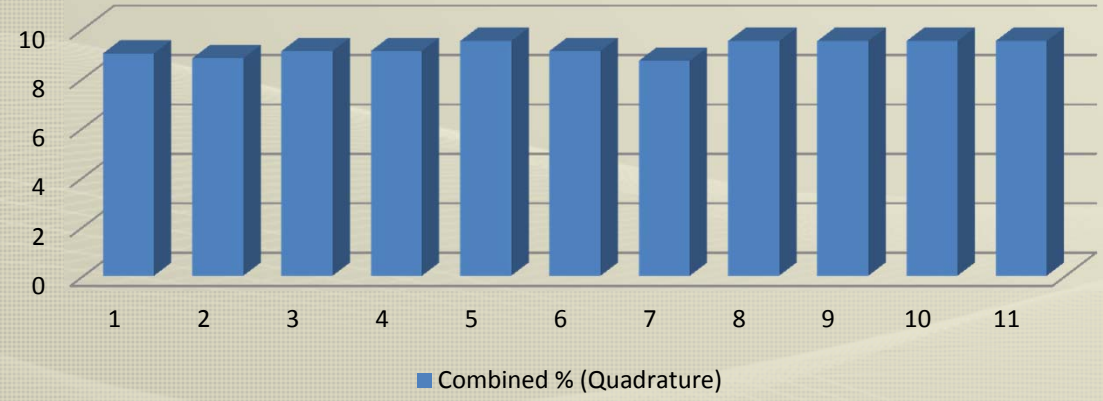
Solar Resource Difference – Modeled vs. Measured



Uncertainty Assessment Using Modeled Data

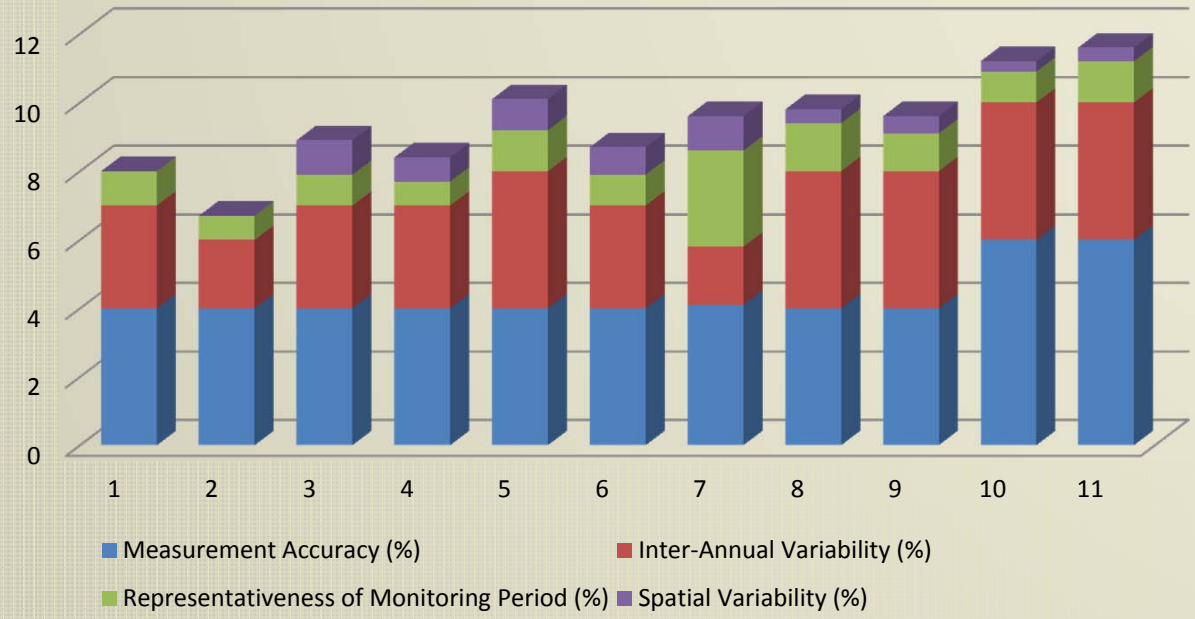


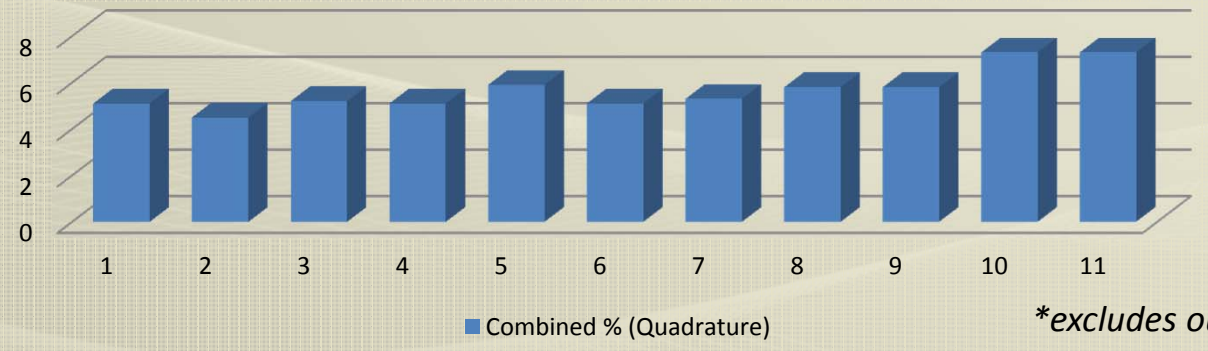
A uniform measurement uncertainty of 8.5% was used for our modeled scenario. In reality it would vary by site.



8.7% to 9.5%

Uncertainty Assessment Using On-site Measurements





4.5% to 5.9%*

**excludes outliers (10&11)*

Uncertainty Difference: Modeled vs. Onsite

Average uncertainty reduction of over 3.5%, range from 2.2% to 4.6%
(3.9% reduction excluding outliers for maintenance practices)

Sites 10 and 11 represent monitoring programs that didn't employ best practices, corresponding to higher uncertainty.

What Does it Mean?

Based on this case study, combined project uncertainty (solar resource and energy uncertainty) was compared for modeled data and on-site data:

Solar Data Source	Solar Resource Uncertainty (from case study)	Typical Uncertainty for Energy	Combined Project Uncertainty
Modeled Data	8.7 - 9.5%	5.0%	10.0 – 11.0%
On-Site Measured Data	4.5 – 5.9%	5.0%	6.7 – 7.7%

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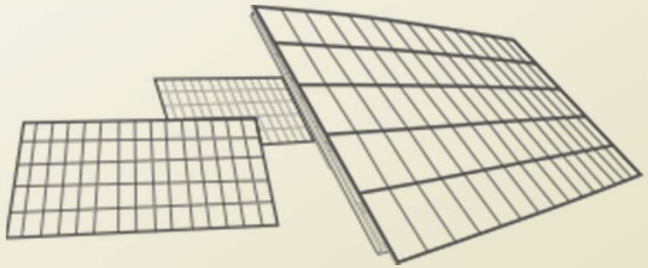
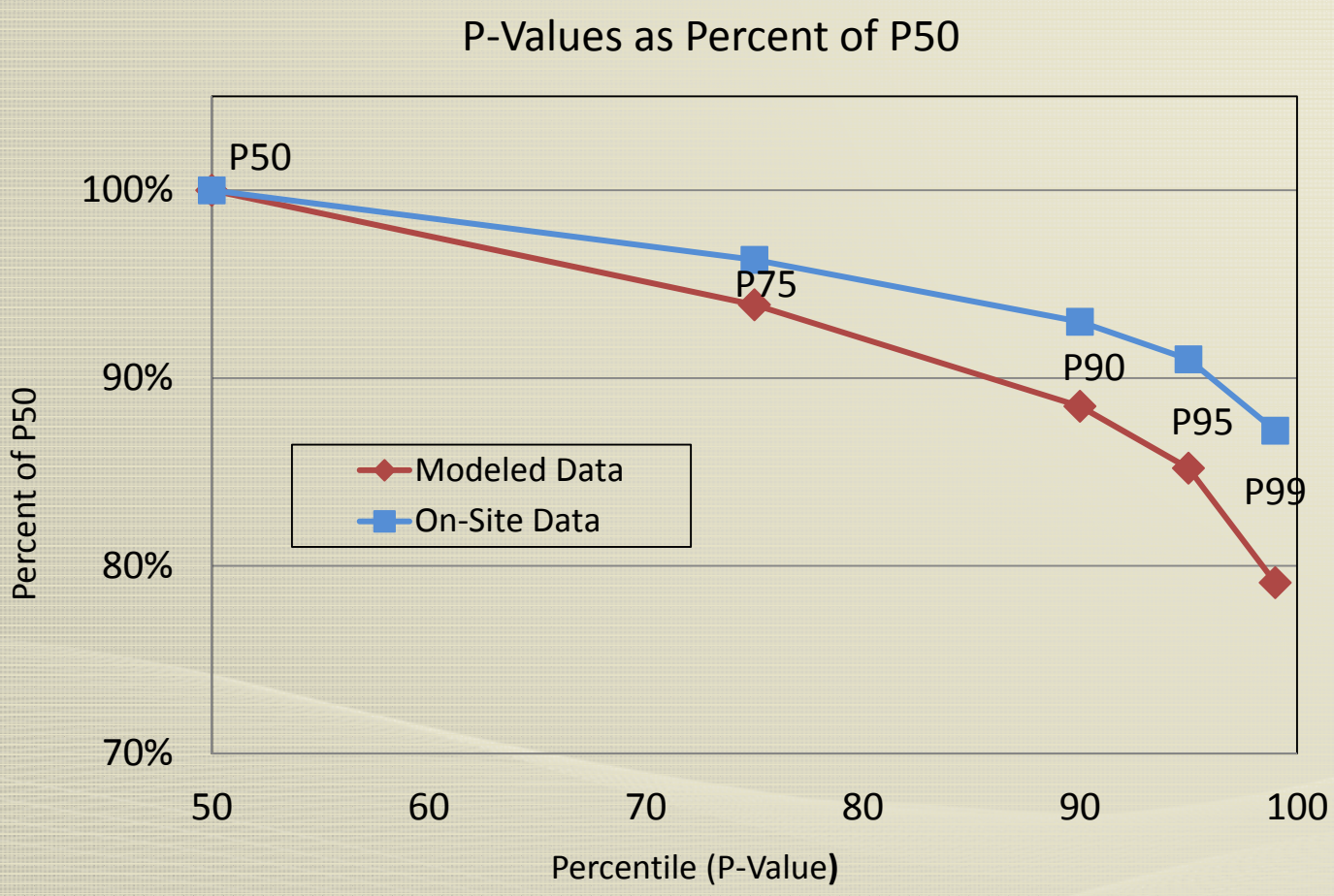


Uncertainty Impact at Different Confidence Intervals



Effect of uncertainty is greater for higher confidence energy estimates (i.e., P90, P95,P99)

Impact on Project Finance

An accurate P50 is important because:

- P50 too low → additional potential funding left on table
- P50 too high → project returns reduced during operational phase

Low uncertainty is important because:

- P90 and P99 are higher
- Level of debt is dependent on value of P90/P99
- Greater P90/P99 = greater debt sizing

Effect of Uncertainty

On-Site Solar Data

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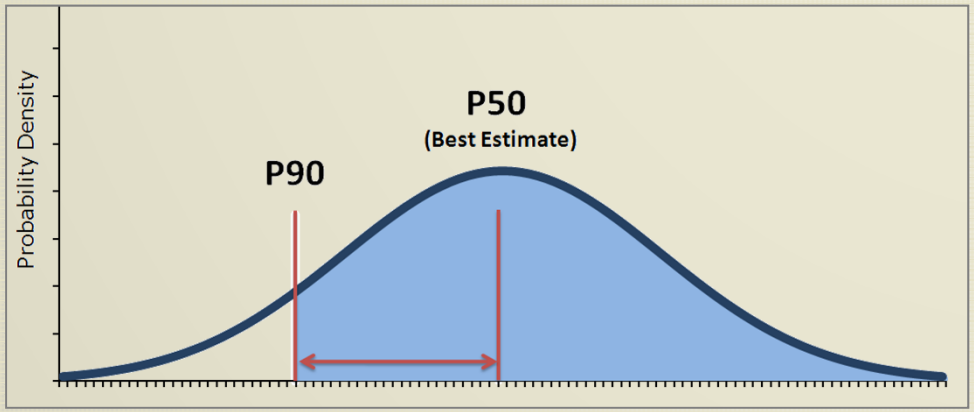
Reduced Uncertainty

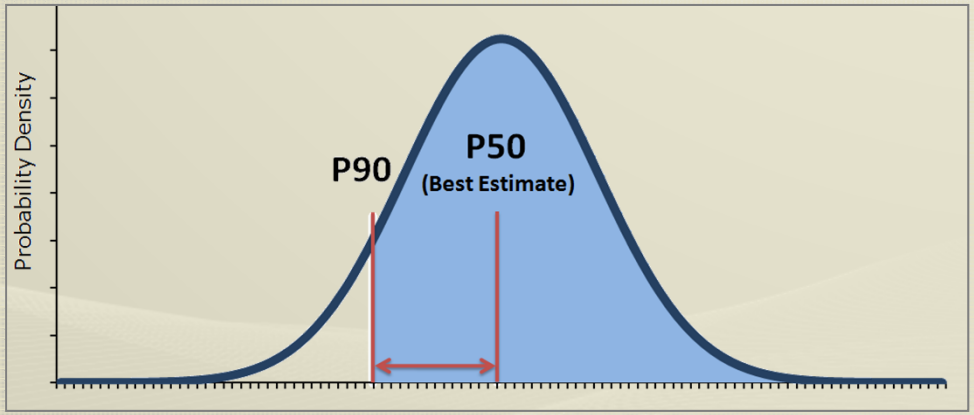
↓

Higher Confidence in Project Return

↓

Project More Attractive To Investors





Conclusions

- On-site monitoring increases accuracy of P50.
- On-site monitoring with best practices reduces energy uncertainty by 3.5% or greater.
- On-site monitoring can increase the P90 by over 5% and the P99 by over 10%.
- Best practices for on-site monitoring mitigate risks from the start to avoid bigger risks later in the project.
- **On-site monitoring = lower financial risk**

Company Snapshot

- Established in 1983; nearly 30 years of renewable energy industry experience
- Independent assessments on 50,000+ MW
- Project roles in over 80 countries
- Over 100 professional staff
- Experts in meteorology, spatial analysis, environment, and engineering
- Seasoned project managers and field technicians

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Questions

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