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# The Challenges of Accurately Predicting PV System Performance

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Differentiating Quality PV
Standards & Methodology for Underwriting Certainty

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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# Introduction

- **Predicting how a conventional PV system will perform in the future is a challenging task**
  - Estimate future weather (irradiance, temperature, wind, etc…)
  - Characterize the technology
    - Model and technology-specific parameters and test methods
  - Choose and run a performance model
    - Models are generally opaque. Hard to know how inputs affect results, how methods are implemented, etc…
    - Estimate derate factors (soiling, shading, wiring losses, etc.)
  - Adjust performance for expected availability
    - O&M policy is important
- **Further challenges for new technologies and designs.**

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# Estimating Future Weather

- **Which data sources to use?**
  - Typical Meteorological Years (TMY, TMY2, TMY3)
    - Most of this data is not directly measured.
    - What is typical?  How to estimate variability (e.g., P90)
  - Satellite data (various vendors)
    - Indirect, calibrated model to few locations
  - Ground data (limited timeframe)
  - Hybrid methods
    - Measure, Correlate, Predict (ground-satellite)
    - Multi-year runs
- **Data quality is very important for energy estimates**
- **Uncertainty vs. variability**

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# Module Characterization

## Current Situation

- Modules are rated at STC which does not tell you how the technology will perform at a given site.
- Module performance parameters describe performance under different conditions but are model-specific (.PAN files, diode parameters, Sandia parameters, etc.)
- Diverse and nonstandard methods for estimating parameters (spec sheet, Photon table, test lab, indoor vs. outdoor, proprietary code).

## Recommendations

- Develop standard reporting of performance characteristics that can translate to how the technology will perform at a given site (e.g., IEC 61853-1 or reduced set).
- Develop and promote standard methods for estimating parameters (will be model-specific but should not be model-exclusive)
  - Quantify uncertainty in coefficient sets
  - Insist on validation

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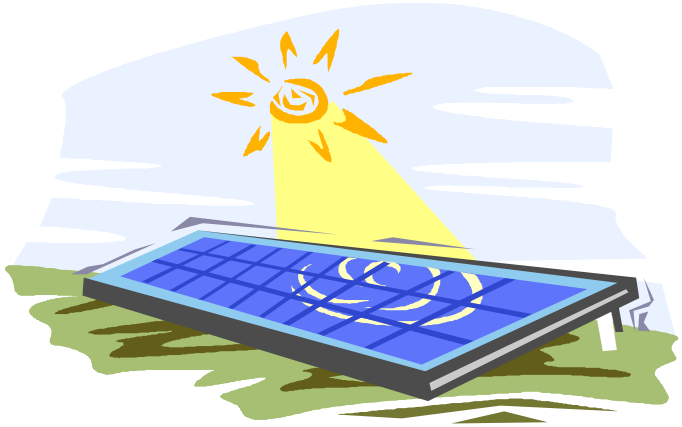
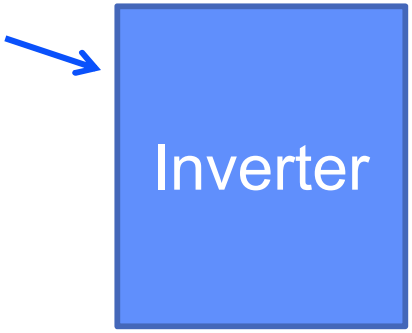
# Choose and Run a Performance Model

Seems like a simple problem, right?





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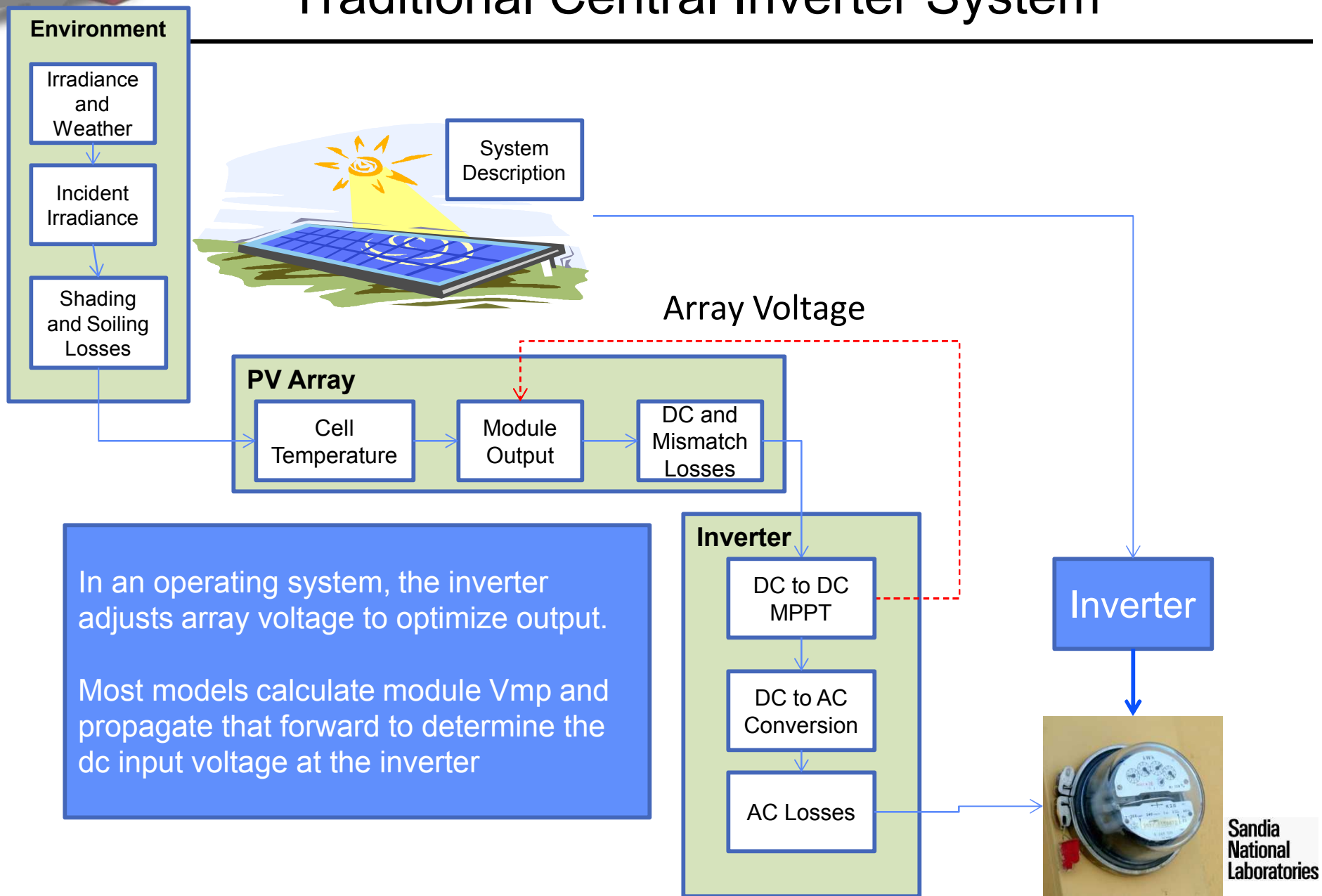
# Reality is More Complicated
## Traditional Central Inverter System




In an operating system, the inverter adjusts array voltage to optimize output.

Most models calculate module Vmp and propagate that forward to determine the dc input voltage at the inverter

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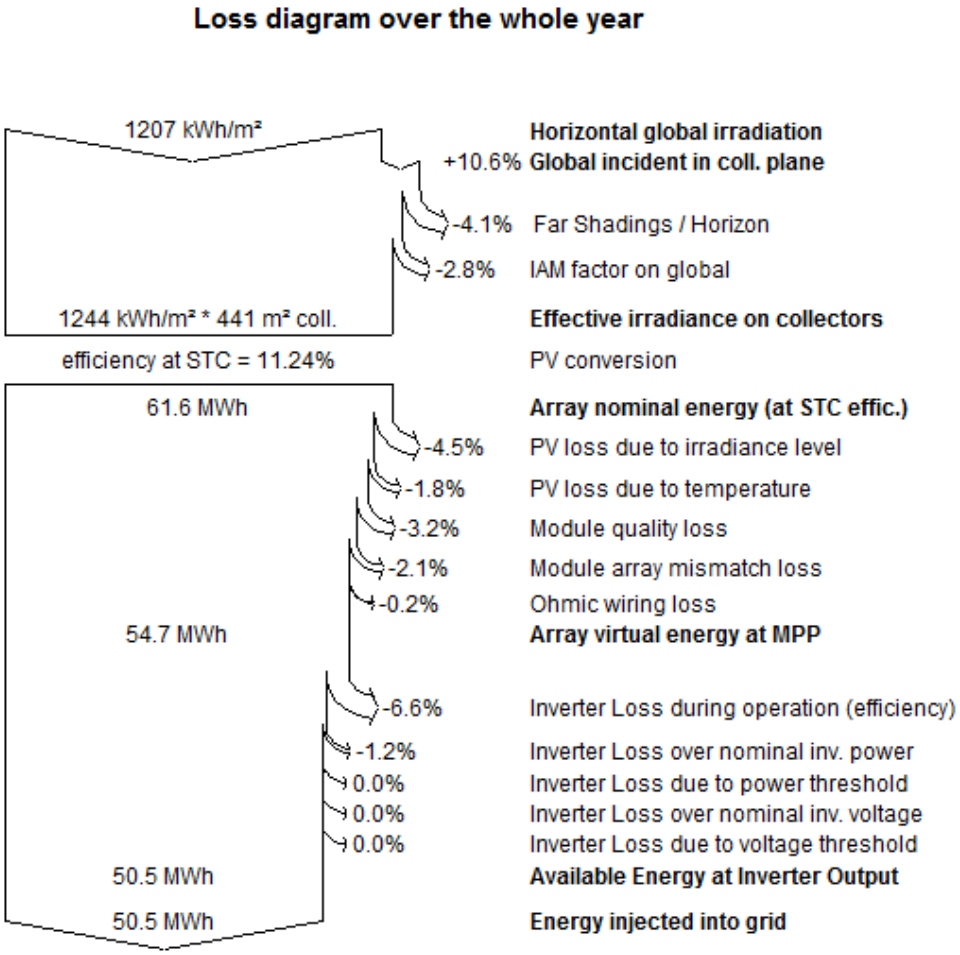
# Choose and Run a Performance Model

- **PV performance models are really modeling applications.**

## Standard Modeling Steps

1. **Irradiance and Weather**
2. **Incident irradiance**
3. **Shading, soiling, reflection**
4. **Cell temperature**
5. **Module output**
6. **DC and mismatch losses**
7. **DC to DC MPPT**
8. **DC to AC conversion**
9. **AC losses**




**PVsyst Example**

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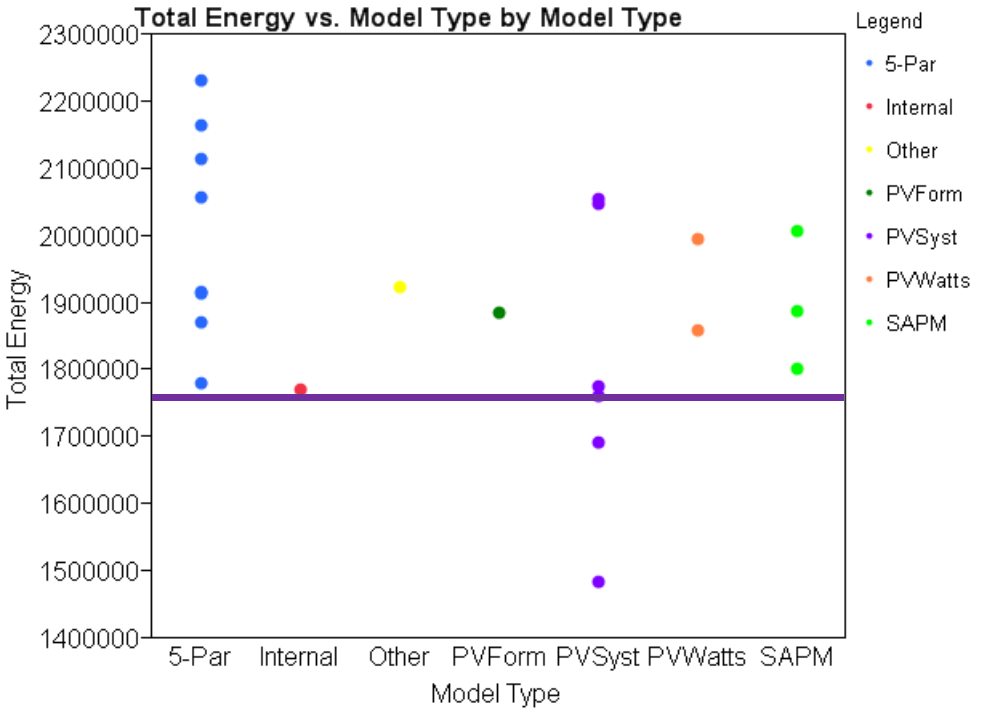
# The Problem: Wide Variation in Modeling Results

- **Variable levels of detail and sophistication in available models**
- **Models Do Not Always Agree**
  - Field validation is rarely available to improve confidence
- **Model accuracy and uncertainty have not been generally and independently verified**
  - Uncertainty (x ± y) generally not stated
  - No validation standards
- **New technology faces a barrier to inclusion into models**
  - Rely on component databases with little QA or consistency




- **Sandia Blind Study (2010)**
  - **20 modelers**
  - **7 models**
- **Results differ within and between models**

Many knobs to turn – submodels, database selection, derates…

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# Reliability and O&M Factors

- **PV plants are complex interconnected systems with thousands of components**
- **As profit margins tighten, effective design and operation and maintenance (O&M) strategies become vital to ensure that the plant operates as designed and delivers a return on investment.**
- **Important questions include:**
  - What is the value of increased component reliability?
  - What level of monitoring maximizes my profits?
  - Should problems be fixed as soon as identified or as part of a periodic maintenance program?
  - What is the cost/risk/value of the warranty?

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# How Do We Succeed?

- **Organized development of consensus standards that allow stakeholders in the value chain to:**
  - Provide trusted PV production estimates using approved standard and valid methodologies and data
  - Evaluate pros and cons of different technologies
  - Demonstrate actual performance meets expectations
- **Other industries provide great examples to follow**
  - HVAC, EnergyStar, MPG ratings, others?
- **DOE and National Labs can help to:**
  - Facilitate, organize, and contribute to developing such standards
  - Conduct independent, applied research to support standard methodologies, model validation, and procedures.

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