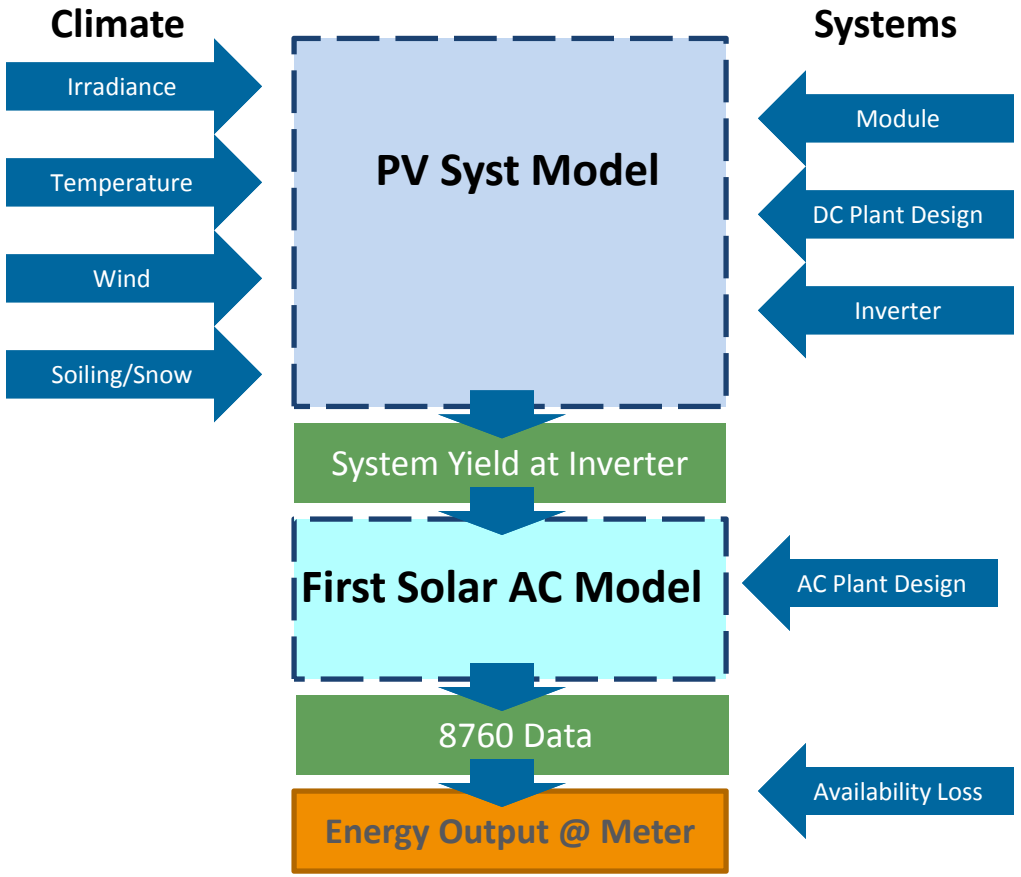
Agenda

- Introduction
- Needs and Issues in System Performance Modeling
  - Technical
  - Ownership
  - Standards

Introduction – First Solar Performance and Prediction

- First Solar Performance and Prediction Group
  - 11 analysts, engineers and field technicians in US and Germany
  - Responsible for :
    - Monitoring and characterization of deployed system performance
      - 50+ systems
      - ~150 MW monitored
    - Development and validation of system performance model
      - PVSyst primary tool
      - Develop own *.PAN files, system loss parameters based on measured data
    - Providing estimates of energy production for prospective and existing projects
      - Weather “prospecting”, input meteorological data choices

First Solar Energy Modeling Overview



Meteorological Inputs

- In most cases, meteorological data (irradiance in particular) is the single largest source of model uncertainty
- Ideas (wish list?) for how simulation software could help reduce/mitigate this uncertainty:
  - Model multiple years at once (processing power is cheap – why not model all the data we have access to?)
  - Allow comparisons between multiple source inputs (e.g Meteocontrol vs. SUNY vs. CIMIS, etc)
  - Allow sub-hourly time-steps of input data
    - Impacts energy prediction (e.g. inverter clipping)
    - Helps characterize variability
    - Stochastic generator (sub-hourly from hourly?)

Soiling and Snow

- Highly site-specific → high risk, highly contentious
- Need much more work on predictive models for soiling and snow
- First Solar working to characterize soiling losses at existing and prospective sites
- Measured relatively small rates of soiling accumulation at dry desert sites in US SouthWest

Modules

- Models could be improved incrementally, but model INPUTS are bigger issues
- Manufacturing tolerances/distributions
  - Explicitly model total array power, mismatch based on input mean, standard deviation, fill factor, etc?
- Need 3rd-party measurement of model input parameters (especially temperature coefficients)
  - Data sheet values should not be included in 3rd-party software
- Model coefficients should be based on measurements of multiple individuals
  - Need commercial labs with sufficient testing capacity
- Thin films difficult to model using single diode model – empirical models may be better approach

What is average device operating temperature?

- Important for yield modeling AND capacity testing
- System models assume array is at uniform temperature
- Hourly models assume static temperature, but know that temperature will lag irradiance
- Explicit, high-accuracy modeling is extremely complex (array shape, prevailing winds, height, spacing of rows, thermal capacity, etc)
  - Does the sensitivity warrant this level of modeling?
  - Difficult to validate models because measurement is very difficult

In large arrays, module operating temperatures differ by 10 ^{o}C or more between edge and center

Uncertainty

- Critical for understanding warranties and guaranties
- Needed for informed comparisons of measured to modeled data
- May help increase investor awareness/savvy if reported by software programs, however,
- Uncertainty of model depends on uncertainty of input parameters, and end user controls these…
- …Ultimately end user determines overall model uncertainty, so burden should lie with end user
  - Software packages could facilitate reporting by including a framework for uncertainty analysis enabling users to enter uncertainty of inputs then calculating overall model uncertainty using user inputs and key model equations

Ownership of Models

- Software IP – significant investment in software implementation
- Technology IP – manufacturers may not want to publish detailed information about module models
- What's the right approach?
  - 3rd-party owned
  - Manufacturer owned
  - Open source
  - 3rd-party verification

	Pros	Cons
3rd-Party Owned	Accepted by investors	Can't be everything to everyone
Manufacturer Owned	Incorporates best module-specific data, models	"Fox guarding the henhouse"

Model Standards

- Standard approach to model validation, evaluation
- System of model validation, rating, and certification would increase transparency to end users, investors, and other stakeholders
  - Understand applicability of model to desired module, system, climate, etc
  - Transparency to end users about appropriateness of model, uncertainties and risks

First Solar Locations

Global Headquarters	Tempe, Arizona, USA
North America	Bridgewater, New Jersey, USA Oakland, California, USA New York, New York, USA Sarnia, Ontario, Canada
Asia/Pacific	Beijing, China Sydney, Australia
Europe	Berlin, Germany Brussels, Belgium Madrid, Spain Mainz, Germany Paris, France
Manufacturing	Frankfurt (Oder), Germany Kulim, Malaysia Perrysburg, Ohio, USA