Integrating PV into Utility Planning and Operation Tools

Final Presentation

March 11, 2014

Project Partners

UNIVERSITY AT ALBANY
State University of New York

UCSD

SEPA

EPRI

Itron

Primary Funders

PUBLIC UTILITIES COMMISSION · EUREKA · STATE OF CALIFORNIA

GO solar CALIFORNIA

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

pier

Power Industry

SMUD™

PG&E

California ISO
Your Link to Power

Project Lead

Clean Power Research®

Current Work is Result of Multiple Projects

- CSI Phase 3

  Address cost-effective strategies for integrating large amounts of PV into distribution systems by integrating PV modeling into utility planning and operation tools

- CEC Forecasting (Completed)

  Validate ability of satellite-derived solar data to forecast PV fleet output with CAISO and integrate into planning processes

- DOE Sunrise (In Progress)

  Demonstrate improved net utility load forecast by incorporating behind-the-meter PV forecast for CAISO and all PV in California

Objective:
Accomplish Three Grid-integration Tasks

1. Extend the SolarAnywhere Enhanced Resolution solar resource database, create high resolution (1-km, 1-minute resolution) solar resource data, and benchmark data accuracy.

2. Validate previously developed PV fleet simulation methodologies using measured ground data from fleets of PV systems connected to California's grid.

3. Integrate PV fleet simulation methodologies into utility software tools for use in activities ranging from distribution planning to balancing area operation using CAISO as a test case.

Benefits to California

- **Solar Resource Data**
  - State-of-the-art high spatial resolution 1-km data freely available for duration of grant; developers obtaining lower financing rates because of lower risk
  - High temporal resolution 1-min data (for variability studies)

- **PV Fleet Simulation Validation**
  - Validation results indicate ~5% MAE (relative to energy, not capacity)
  - Grid operators gaining confidence in models prior to their use

- **PV Fleet Simulation Integration Into Utility Software Tools**
  - CAISO receiving forecasts for 175,000 behind-the-meter PV systems every 30 minutes; system in operation for one year
  - Behind-the-meter fleet forecasting available for all CA utilities
  - PV fleet simulation available for distribution planning

Task 1 Description: Irradiance Data

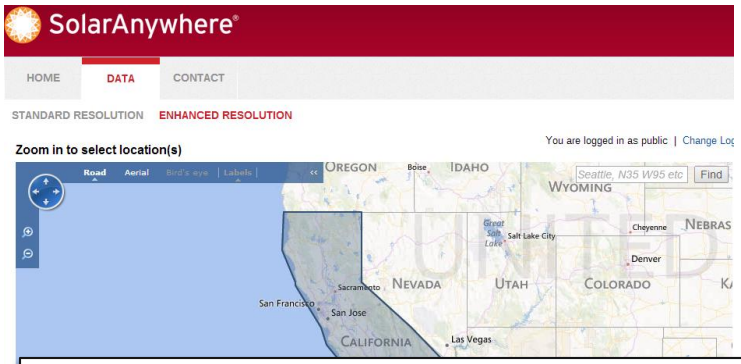
Extend the SolarAnywhere Enhanced Resolution solar resource database, create high resolution (1-km, 1-minute resolution) solar resource data, and benchmark data accuracy

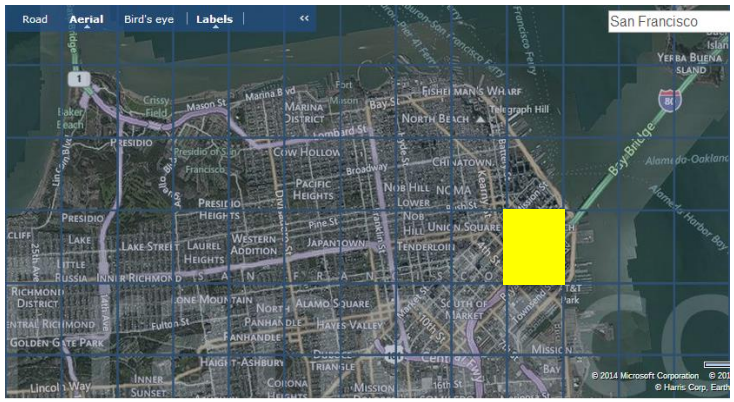
Task 1: Accomplishments

- Extended freely available SolarAnywhere Enhanced Resolution solar resource database (1-km, 30-minute resolution)
- Created high resolution (1-km, 1-minute resolution) data
- Benchmarked data accuracy

Freely Available Enhanced Resolution Data

Visit SolarAnywhere.com





Select 1 km Location

Download ½ Hour Data

	A	B	C
1	ObservationTime(LST)	Global Horizontal Irradiance (GHI) W/m2	Direct Normal Irradiance (DNI) W/m2
2	1/1/2014 6:00	0	0
3	1/1/2014 6:30	0	0
4	1/1/2014 7:00	0	0
5	1/1/2014 7:30	0	0
6	1/1/2014 8:00	43	69
7	1/1/2014 8:30	129	300
8	1/1/2014 9:00	205	539
9	1/1/2014 9:30	280	630
10	1/1/2014 10:00	346	692
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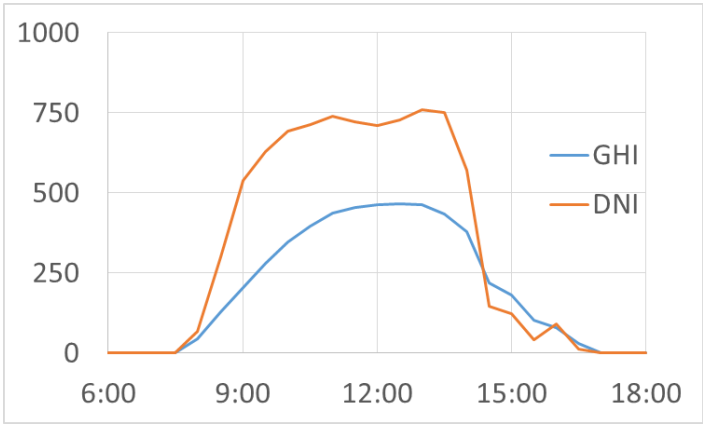

Analyze Results

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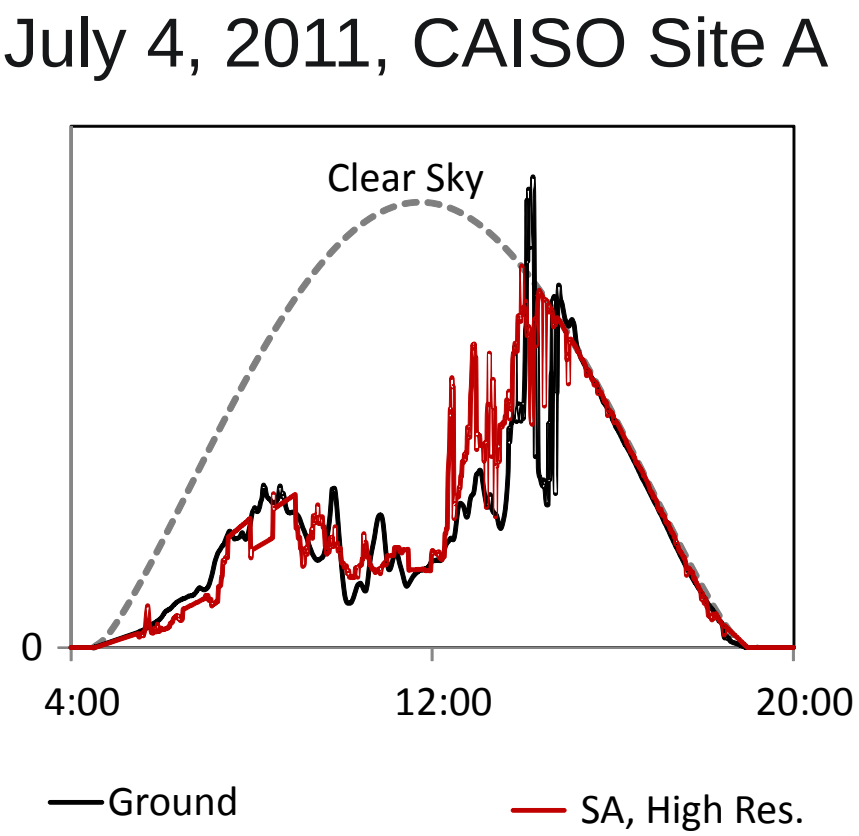
Produced High Resolution (1 km, 1 min) Data (Useful for Grid Integration Studies)



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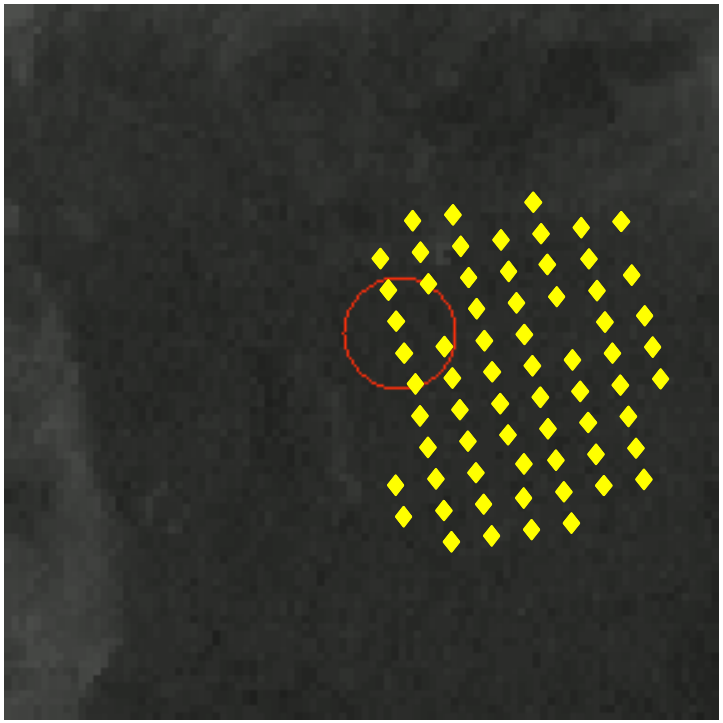
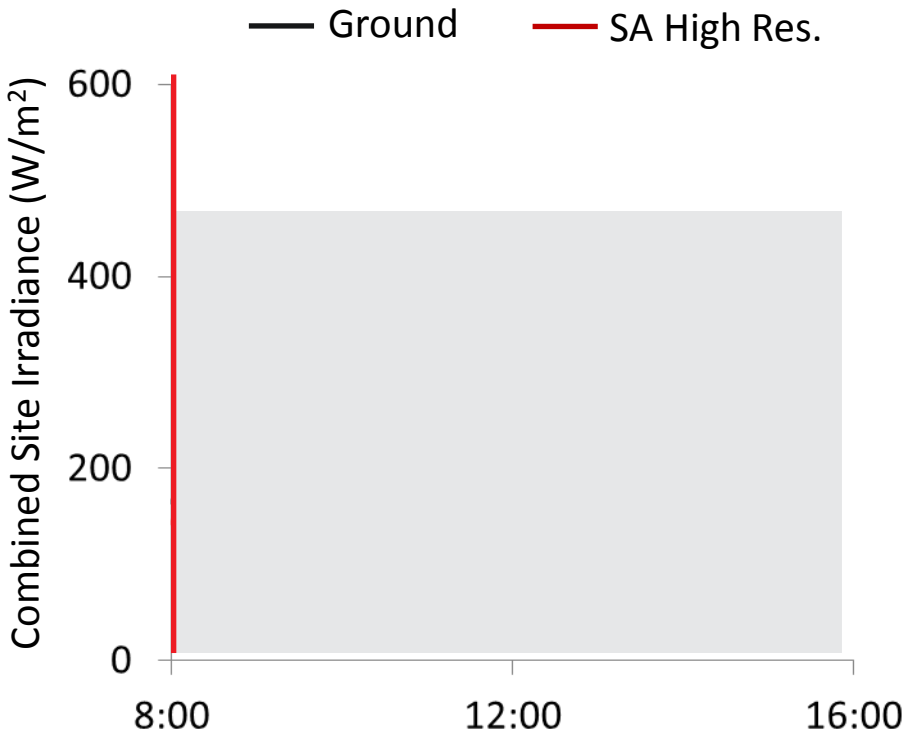
Example Using SMUD's Solar Data Network on Highly Variable Day (Nov. 18, 2011)





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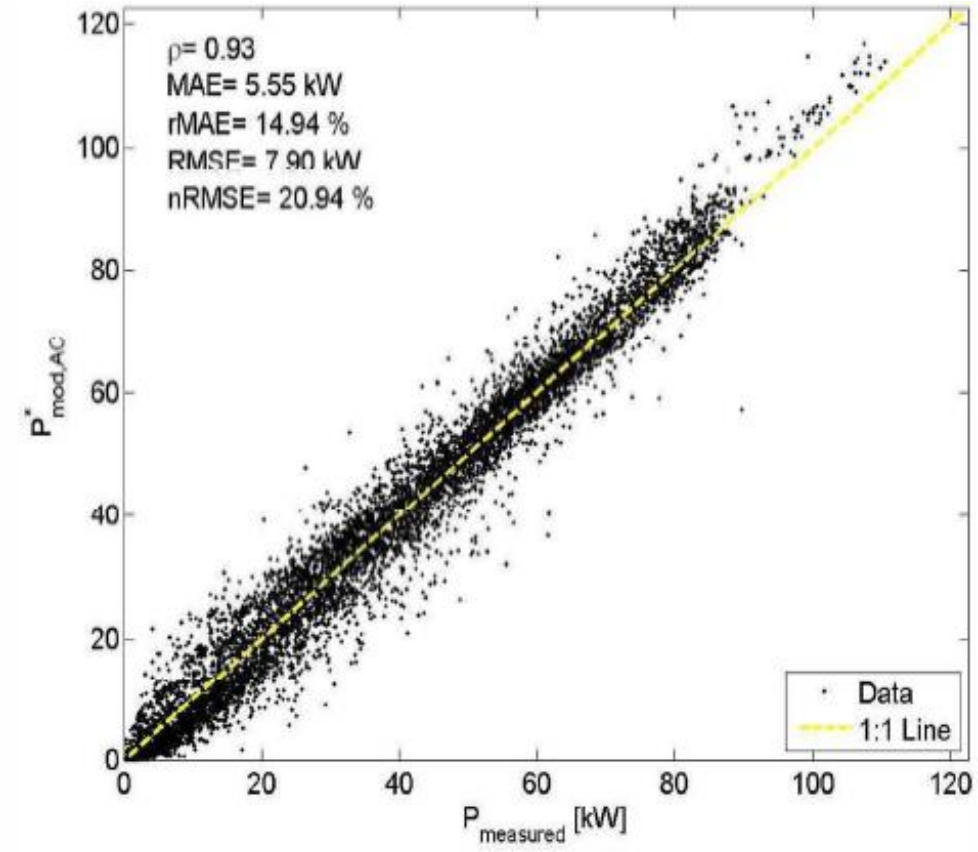
Validated SolarAnywhere Enhanced Resolution Data (UCSD)



Calibrated SolarAnywhere performance, with 30-min time step, versus CSI measured output (averaged over two 15-min time steps), for 86 PV sites in 2009 in San Diego, CA

Source: Jan Kleissl, UCSD

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Questions

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Task 2 Description: PV Fleet Simulation

Validate previously developed PV fleet simulation methodologies using measured ground data from fleets of PV systems connected to California's grid

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Task 2 Accomplishments

- Validated fleet simulation using CAISO data

- Validated fleet simulation using SMUD behind-the-meter data

45 PV Plants Connected to CAISO

PV on commercial buildings (SCE service area – Google Maps)

Large central station PV (Copper Mountain, NV, pv-magazine.com)

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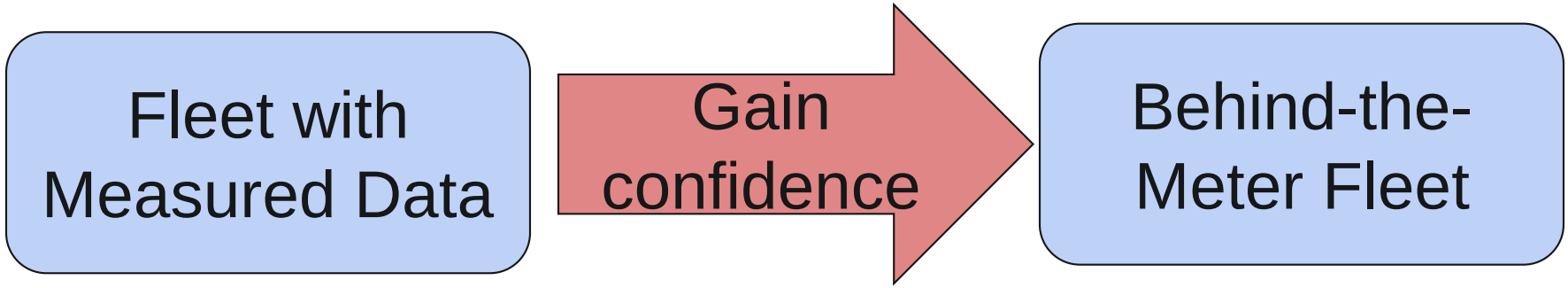
How to Validate Forecast Accuracy When Historical Data is Unavailable?

- Validate accuracy using measured PV production
  - Use backcasting to:
    - Validate PV performance model
    - Identify PV performance issues
  - Quantify forecast accuracy
- Gain confidence in behind-the-meter fleet forecast



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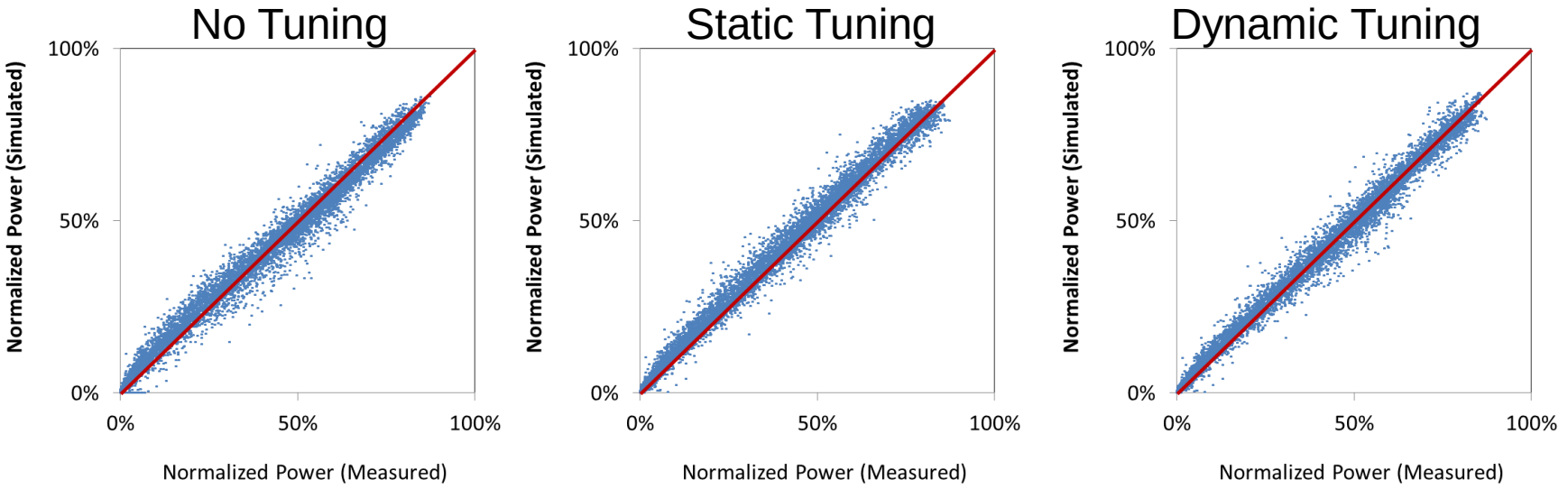
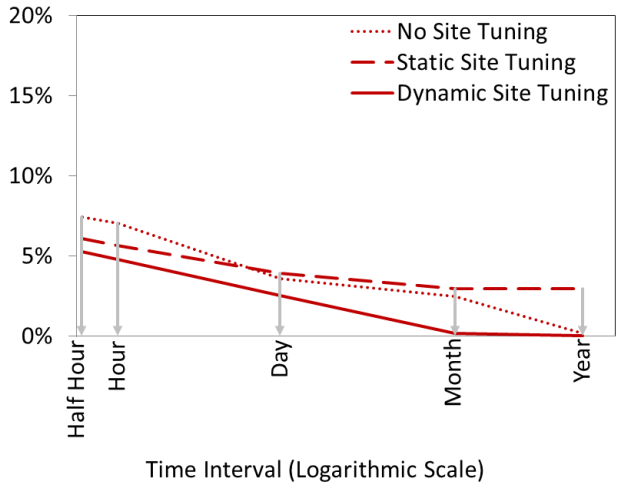
CAISO Fleet Results



Measured Data

- 18 PV systems
- Sept. 2011 to Aug. 2012
- Half-hour data
- Capacity normalized to eliminate effect of PV size
- Presented on scale of 0 to 100%



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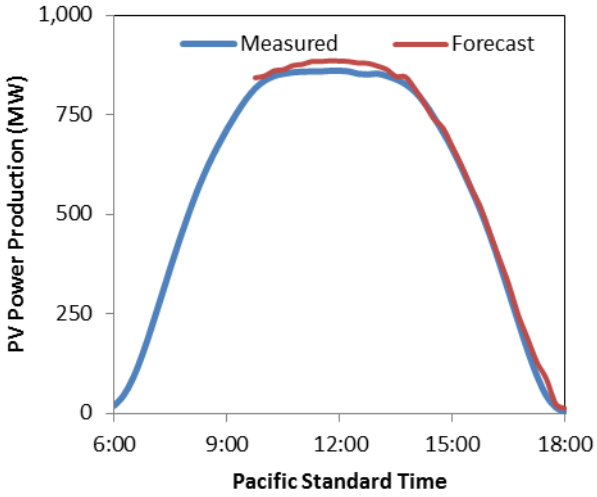
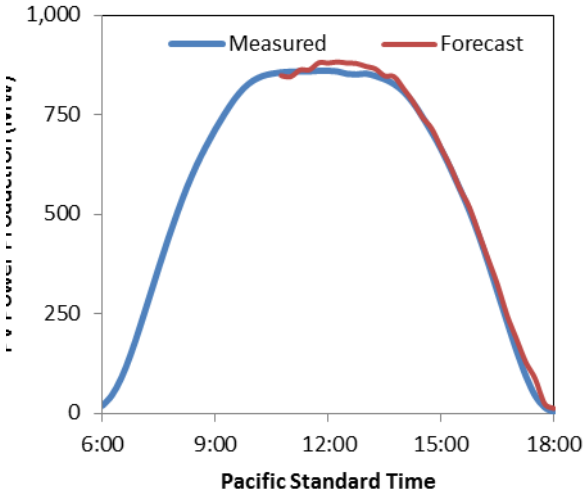
Short-Term Forecast Validation for 45 Systems (Clear Day) March 24, 2013

Time Horizon (Relative to Forecast Delivery)

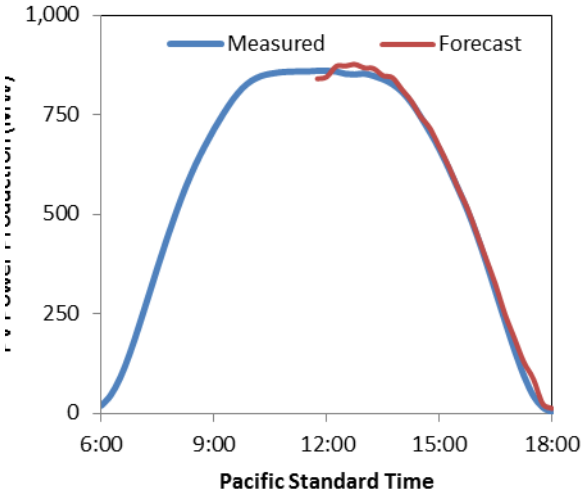
0 – ¼ Hours



1 – 1¼ Hours



2 – 2¼ Hours



Add 45 minutes to obtain time horizon relative to **image creation time**
Short-term forecasts are available after visible, daylight satellite images are obtained

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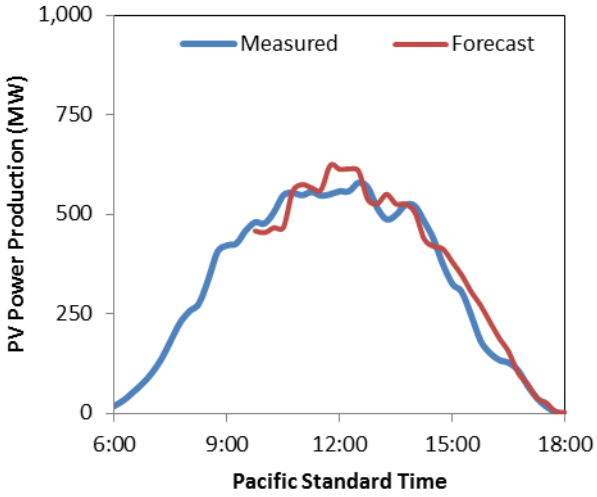
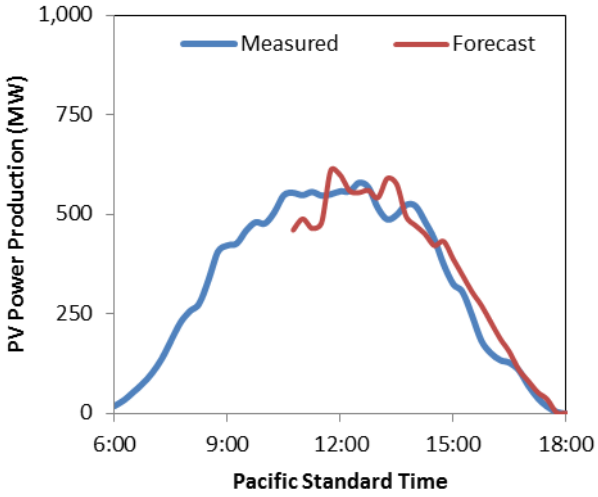
Short-Term Forecast Validation for 45 Systems (Cloudy Day) March 20, 2013

Time Horizon (Relative to Forecast Delivery)

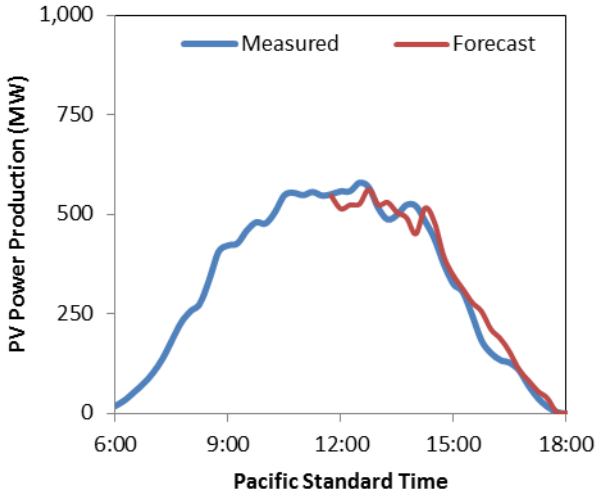
0 – ¼ Hours



1 – 1¼ Hours



2 – 2¼ Hours



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2,000+ Behind-The-Meter PV Systems at SMUD

Premier Gardens Zero Energy Home Community

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Challenges of Behind-The-Meter PV Simulations

SMUD area PV system examples

Object shading

Module azimuth rotation

Multiple module layouts

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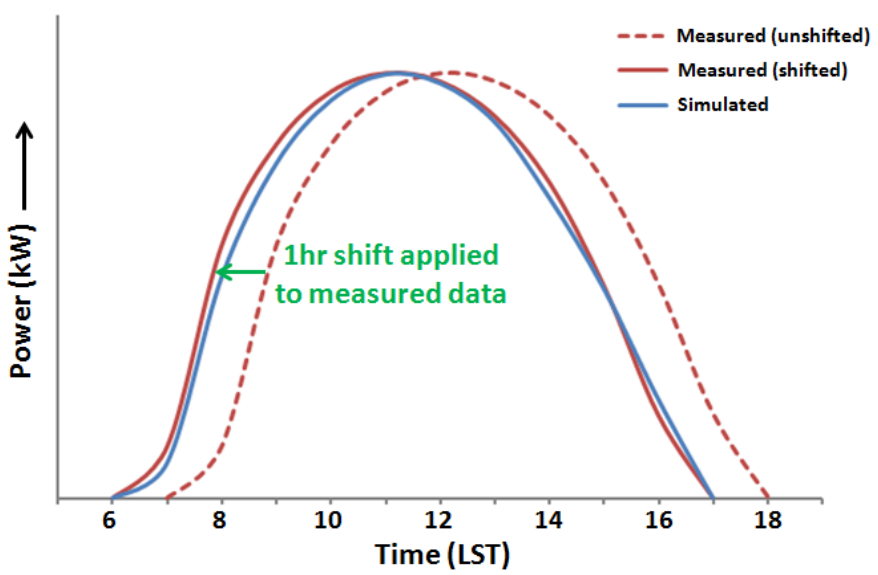
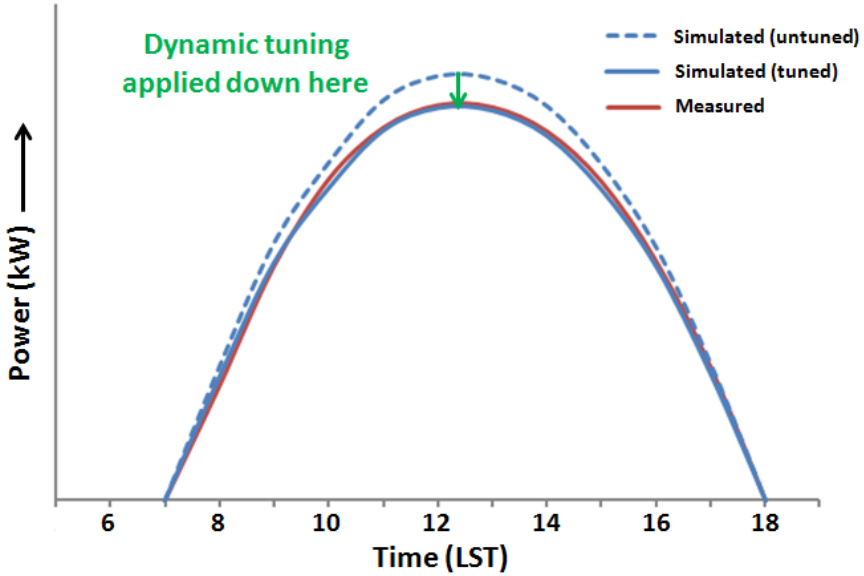
Quality Control Measures

Measured Data Time Shifts



Measured power is individually checked for spurious time shifts for each production system in the SMUD PV fleet.

Simulation Tuning



Simulated power is uniquely tuned (down in this case) for each production system in the SMUD PV fleet.

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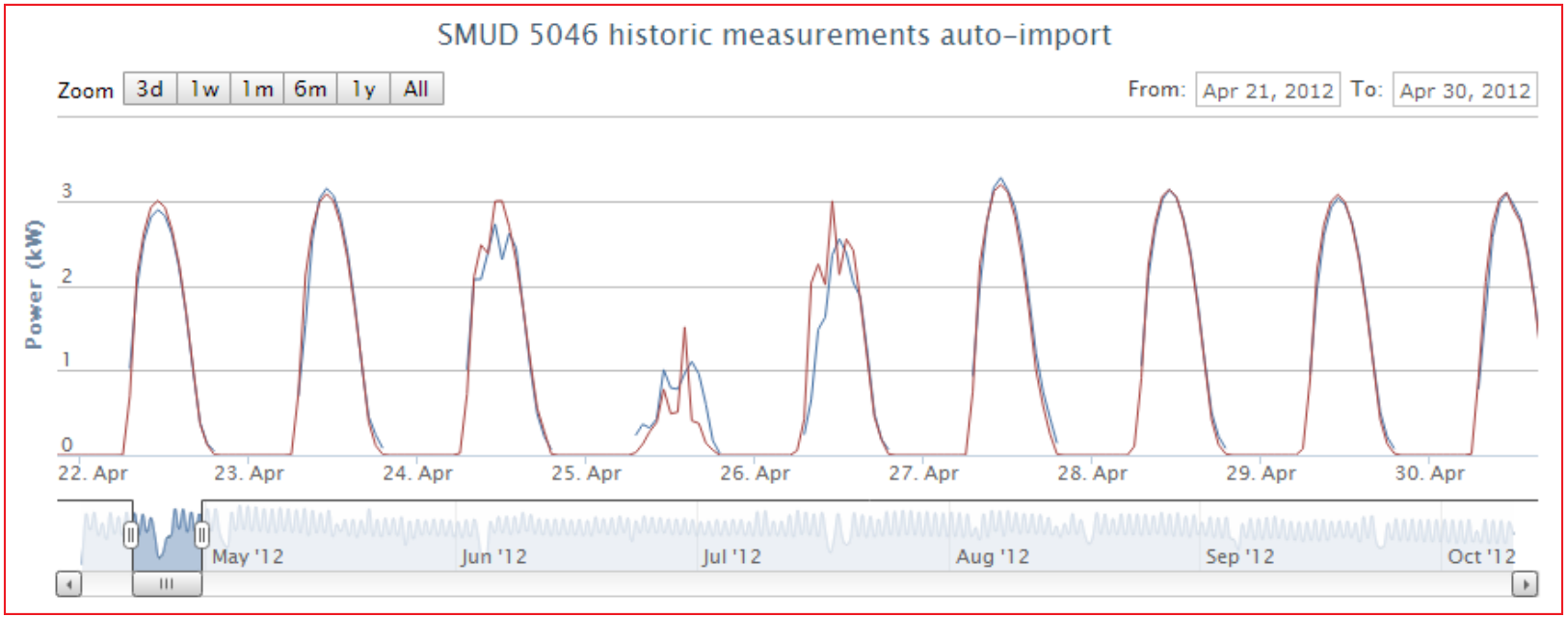
Well-Characterized PV Simulations

Example simulated (red line) and measured (blue line) production



17 Enphase inverter system – well matched!

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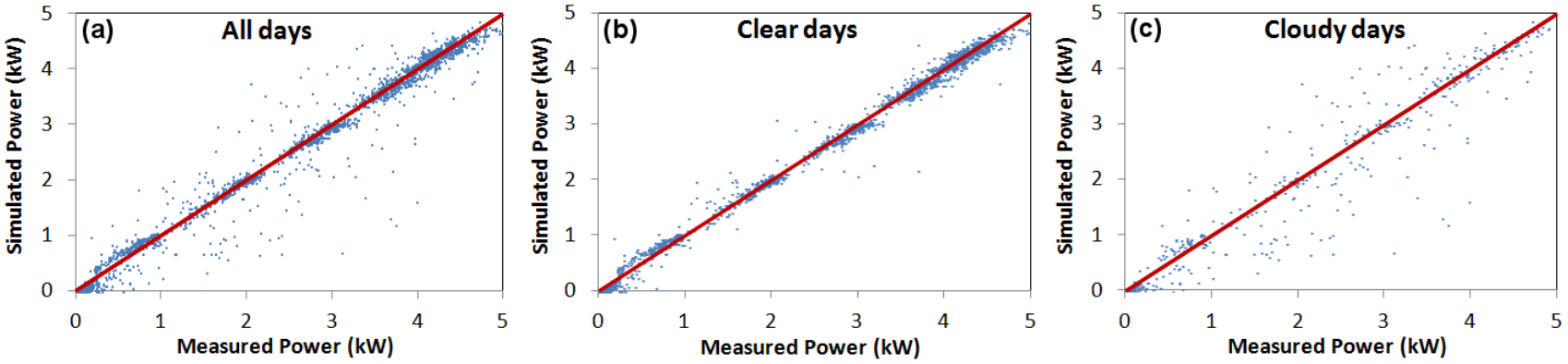
Well-Characterized PV Simulation

Single 5.2 kW-AC PV System
(4/16/2012 – 10/10/2012)



	Clear Days	Cloudy Days	All Days
rMAE	3.3%	13.6%	4.9%
Ave Daily Energy	34.5 kWh	28.1 kWh	33.3 kWh
Number of Days	145 days	32 days	177 days

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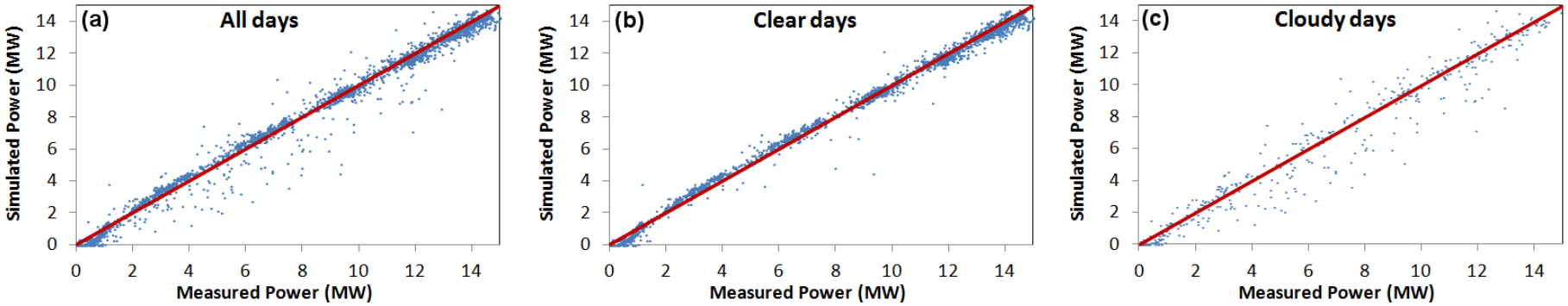
Fleet of Well-Behaved PV Systems

Fleet of 1,102 PV Systems
(4/16/2012 – 10/10/2012)



	Clear Days	Cloudy Days	All Days
rMAE	3.5%	10.0%	4.5%
Ave Daily Energy	112.8 MWh	88.3 MWh	108.4 MWh
Number of Days	145 days	32 days	177 days

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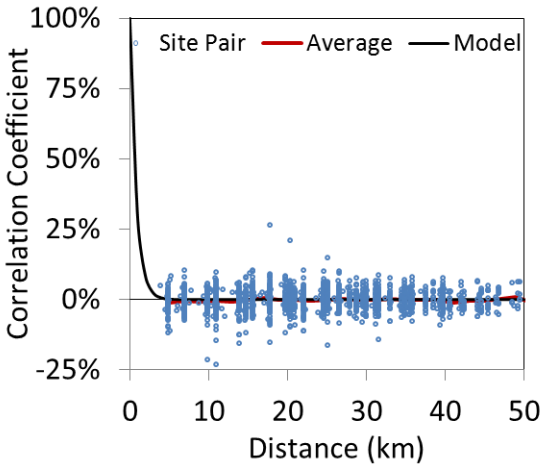
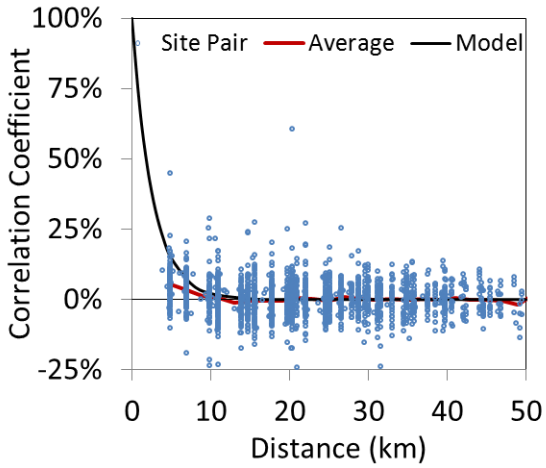
Validate Variability Results Using SMUD's 66 Sensor Network

Time Interval

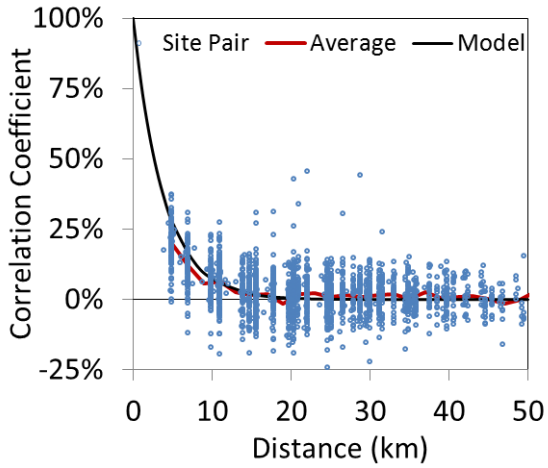
1 Minute



5 Minutes



10 Minutes



Results based on most variable days in SMUD's network from July 1, 2011 to December 31, 2011

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Questions

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Task 3 Description: Integrate Into Utility Tools

Integrate PV fleet simulation methodologies into utility software tools for use in activities ranging from distribution planning to balancing area operation using CAISO as a test case

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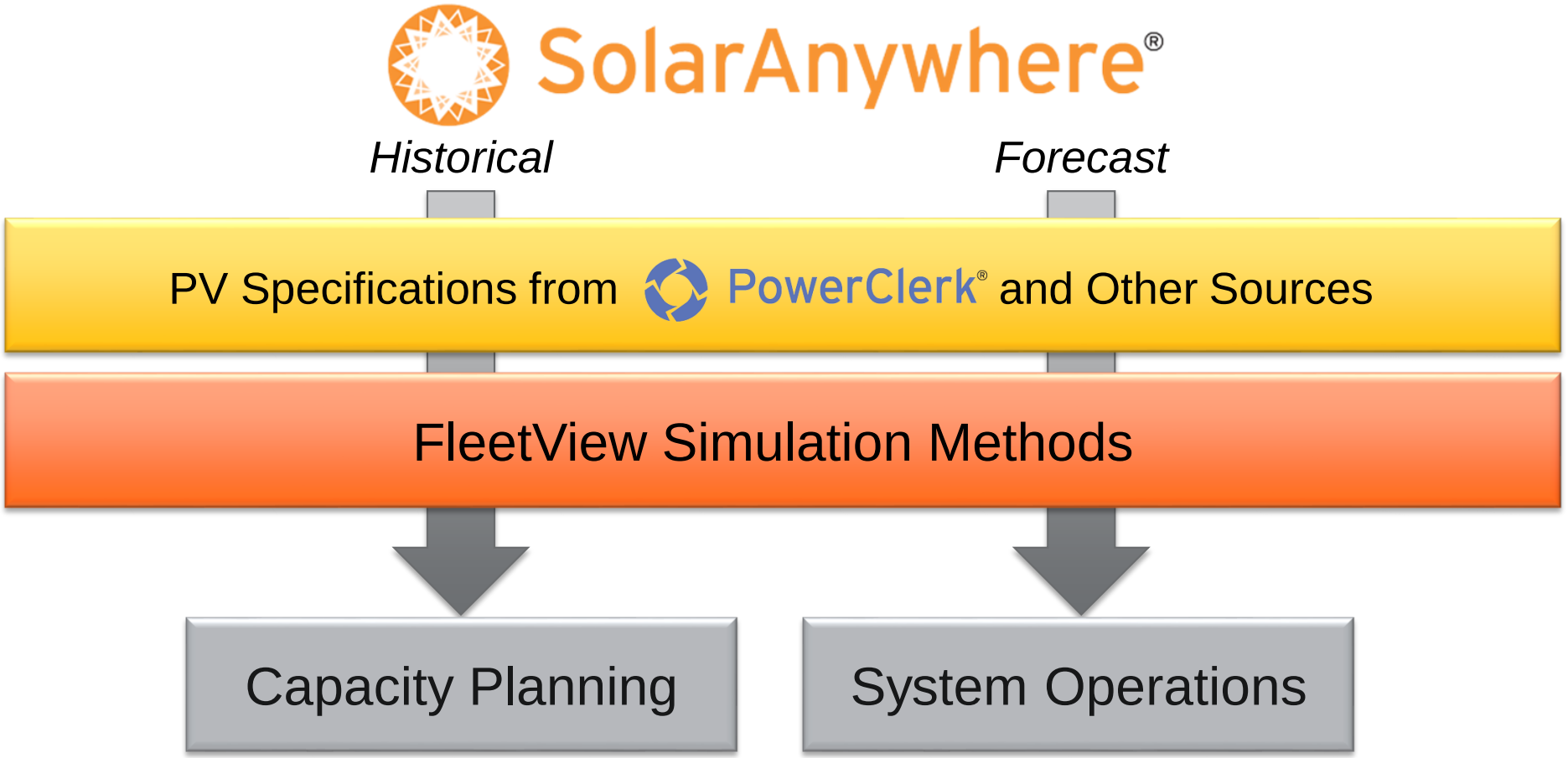
Task 3 Accomplishments

- Original grant proposal was to test fleet forecasting in variety of applications
- CASIO was focused on for this work
- Behind-the-meter fleet forecasting for all of California has been operational for about a year
- CAISO has initiated testing to determine the benefit derived from forecasts

Simulate Fleet Output Using SolarAnywhere® FleetView™



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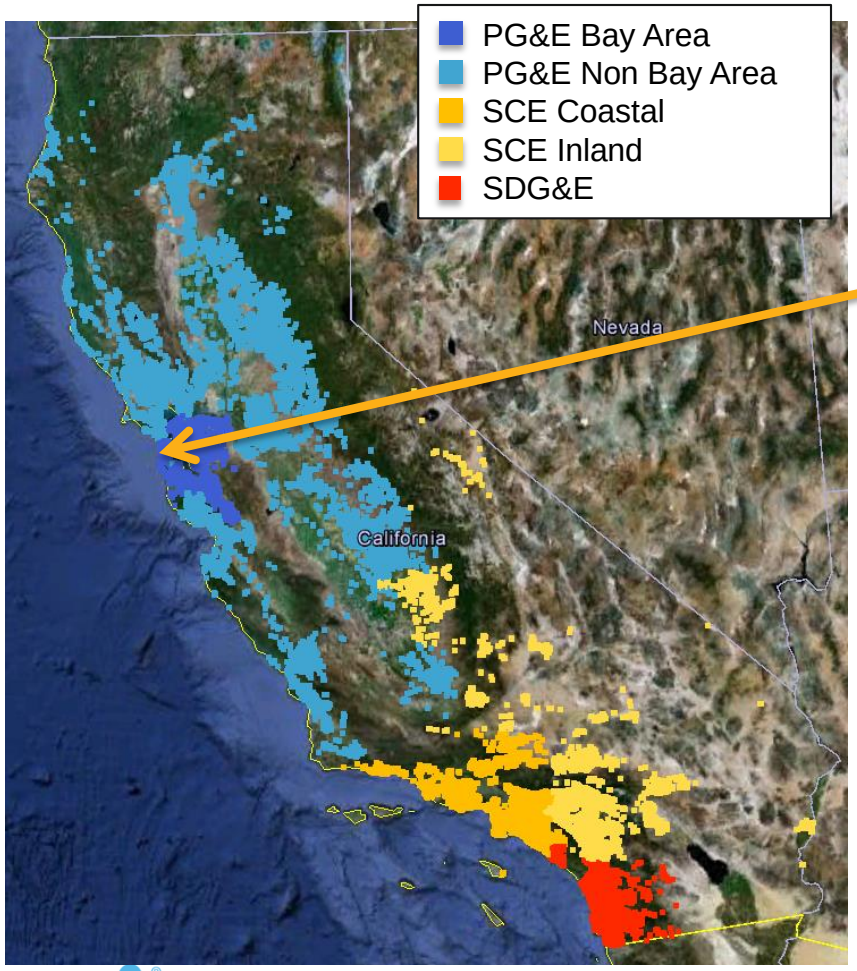
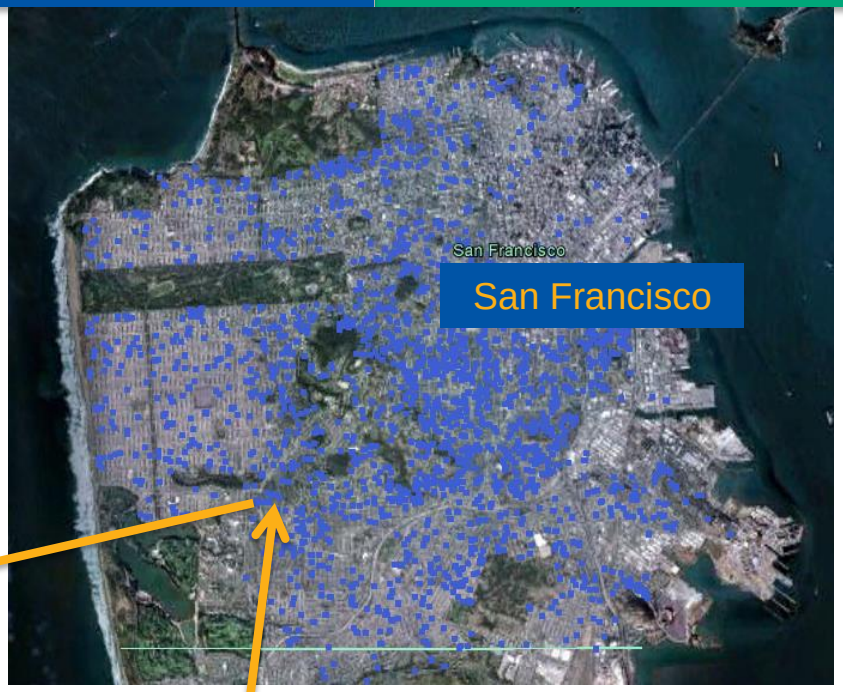
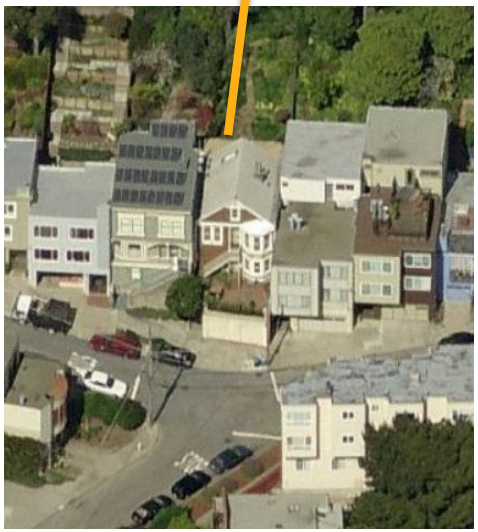
CA Behind-the-Meter PV Mapping







- 4.49 kW-AC
- SunPower Inverter (SPR-5000X, 240V)
- 27 Modules (SunPower 210 W, SPR-210-WHT)
- 37.76281º N, 122.44313º W
- Commissioned April 2008

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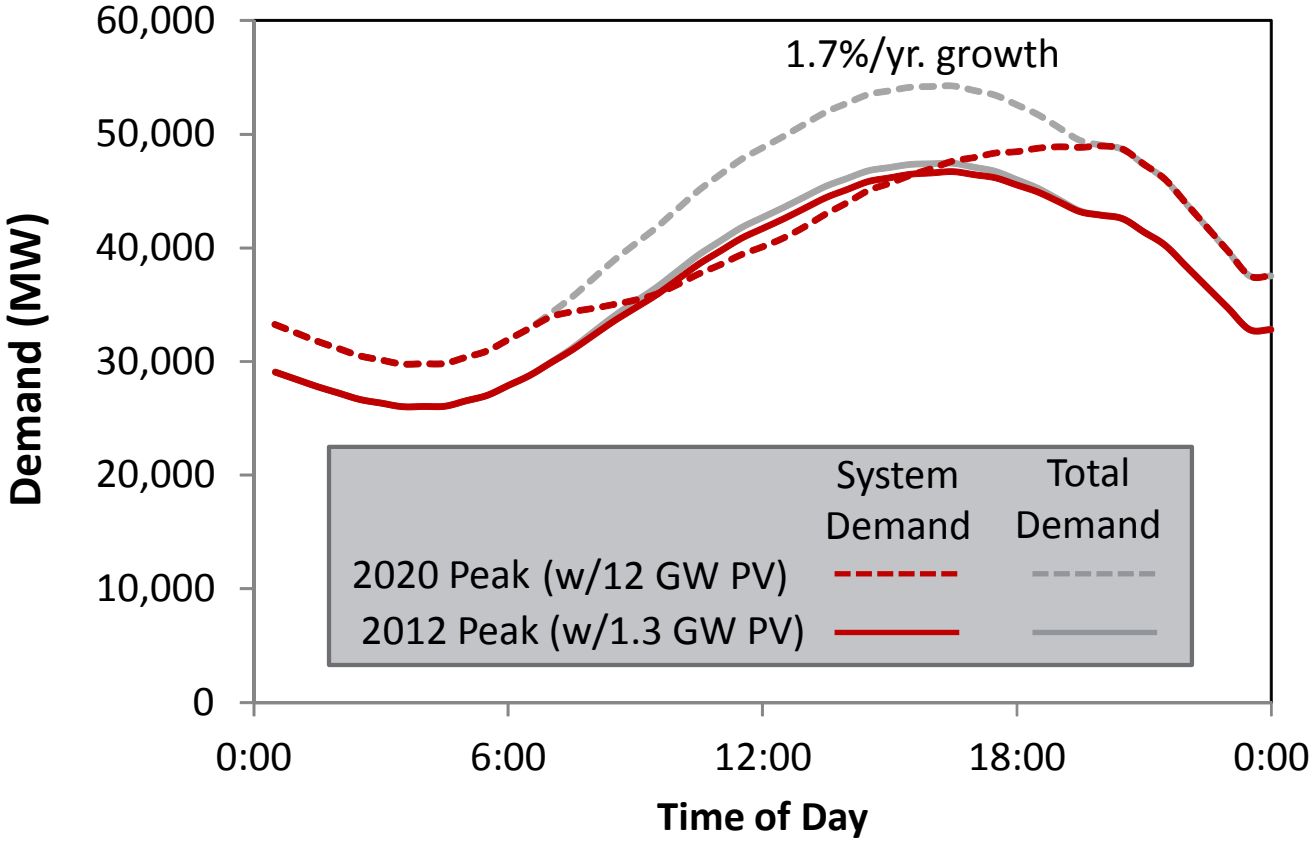
Using FleetView for Capacity Planning



Peak Day: August 13, 2012

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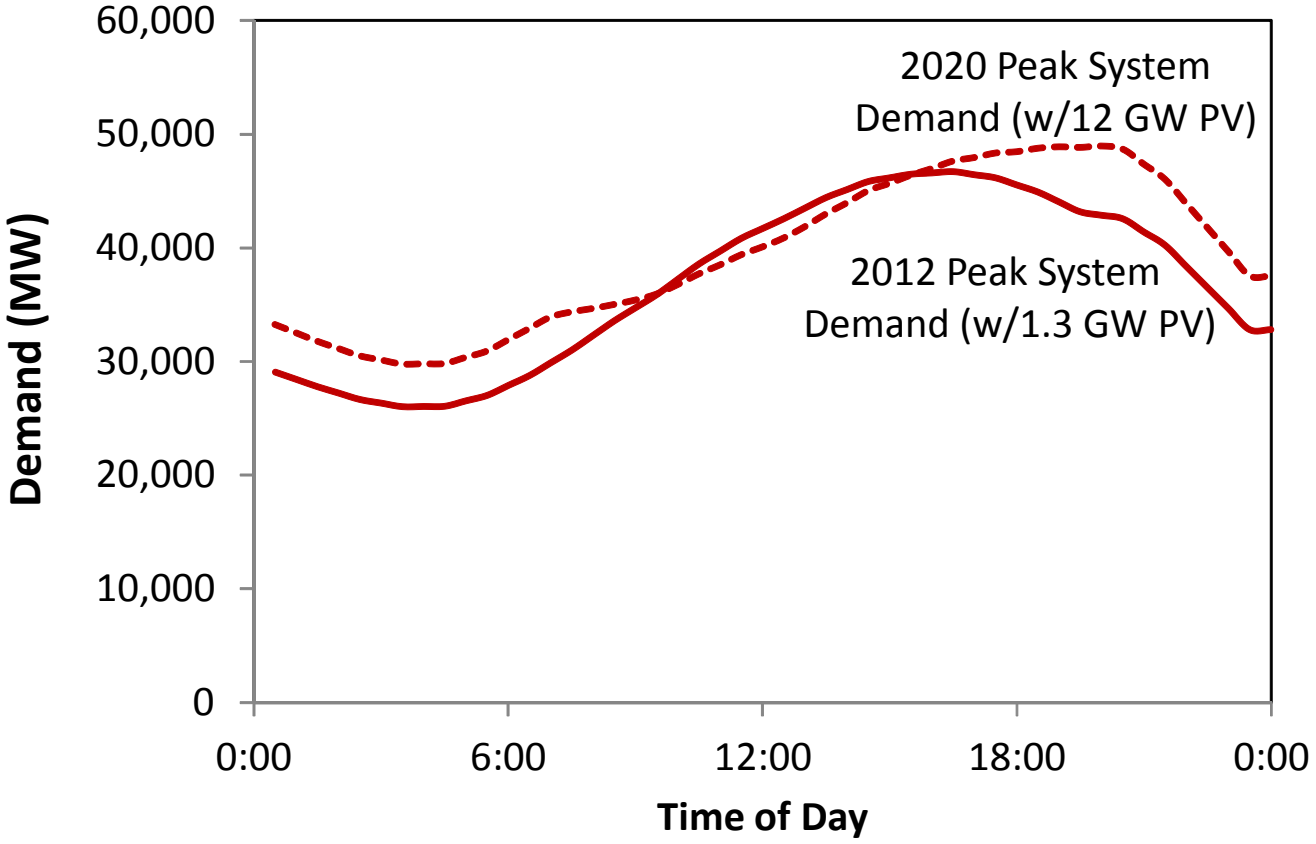
Using FleetView for Capacity Planning



Peak Day: August 13, 2012

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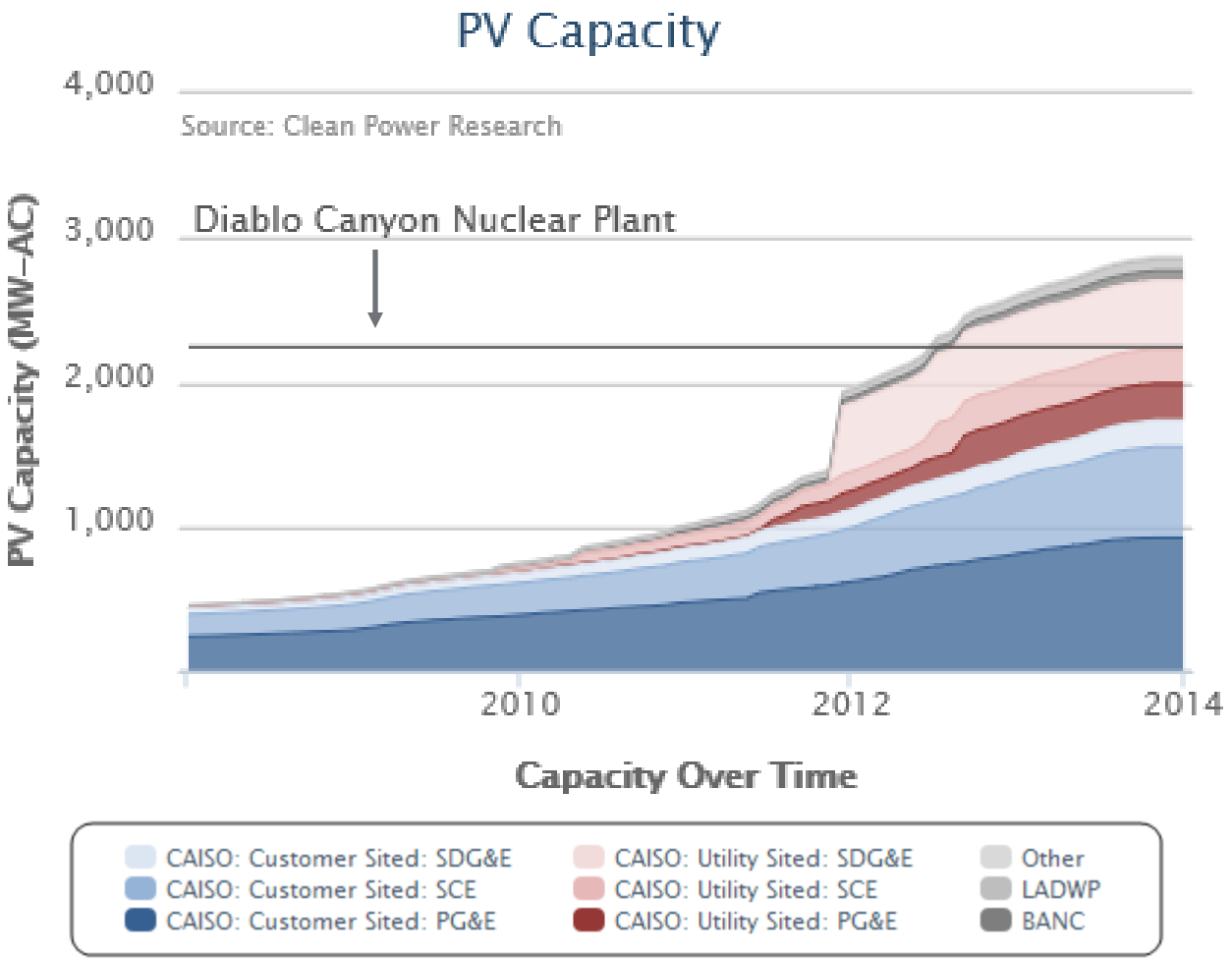
California PV Capacity by ISO Areas



Note: Utility-sited systems include intertie systems in NV and AZ

SolarAnywhere – 1 km data

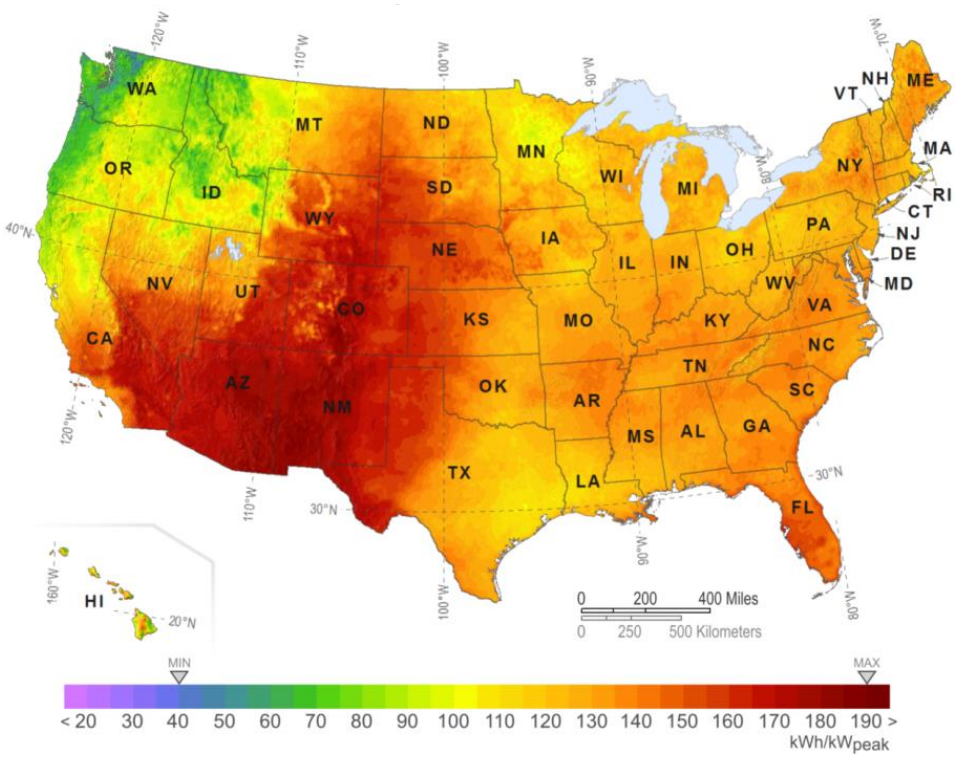
Web-accessible solar irradiance data & analytical tools

Irradiance data

- Historical satellite-derived time-series data from 1998 through latest hour
- Forecasts up to 7-days in advance by combining cloud motion vector and NWP approaches

Analytical tools

- PV system modeling (FleetView)
- PV benchmarking (DataCheck)
- PV fleet variability



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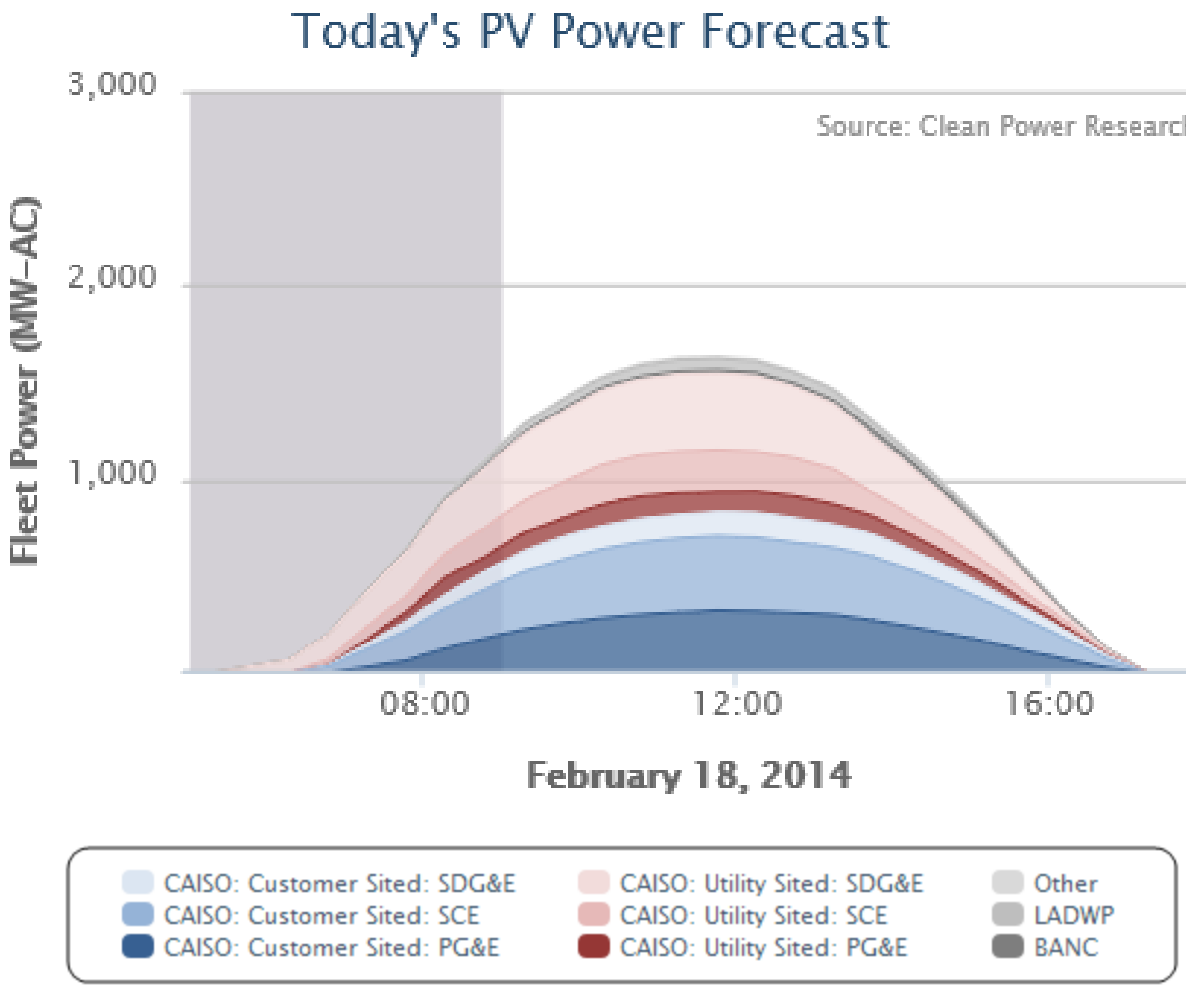
Using FleetView for Net Load Forecasting



Note: Utility Sited systems include intertie systems in NV and AZ

Technology Transfer/Outreach

- 8 conferences/journals (ASES, SEPA USC, SEPA, SPI, UVIG)
- State-of-the art solar resource database for all of California
- 6 patent applications
- Upcoming: SEPA Webinar (w/ Jim Blatchford, CAISO) March 20

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Conclusions

- **Solar Resource Data**
  - State-of-the-art high spatial resolution 1-km data freely available for duration of grant
  - High temporal resolution 1-min data available for variability studies

- **PV Fleet Simulation Validation**
  - Validation results indicate ~5% MAE (relative to energy, not capacity)
  - Grid operators gaining confidence in models prior to their use

- **PV Fleet Simulation Integration Into Utility Software Tools**
  - CAISO receiving forecasts for 175,000 behind-the-meter PV systems every 30 minutes; system in operation for one year
  - Behind-the-meter fleet forecasting available for all CA utilities
  - PV fleet simulation available for distribution planning

Questions

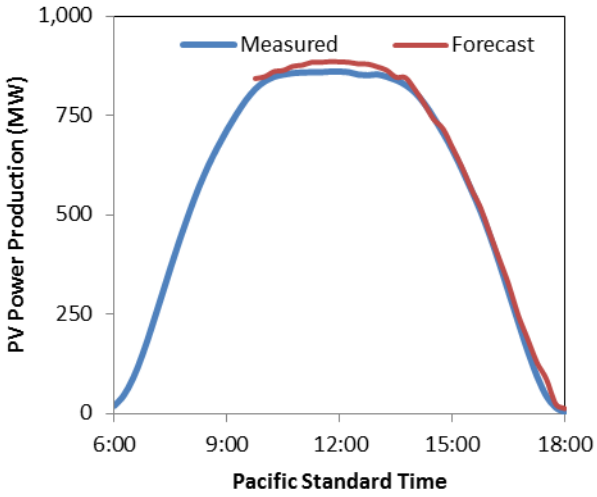
Work in Progress Under DOE Sunrise

- Move from static to dynamic accuracy validation
- Implement improved techniques to reduce forecast error
- Implement and test rapid fleet simulation method
- Incorporate uncertainty and ramp rate forecasting

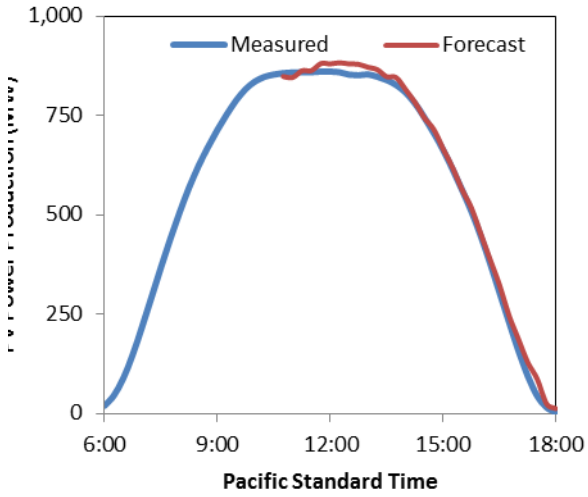
Transition From Static To Dynamic Validation

Time Horizon (Relative to Forecast Delivery)

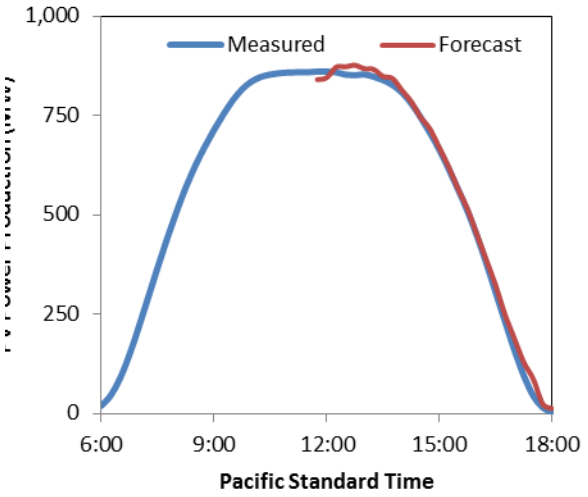
0 – ¼ Hours



1 – 1¼ Hours



2 – 2¼ Hours



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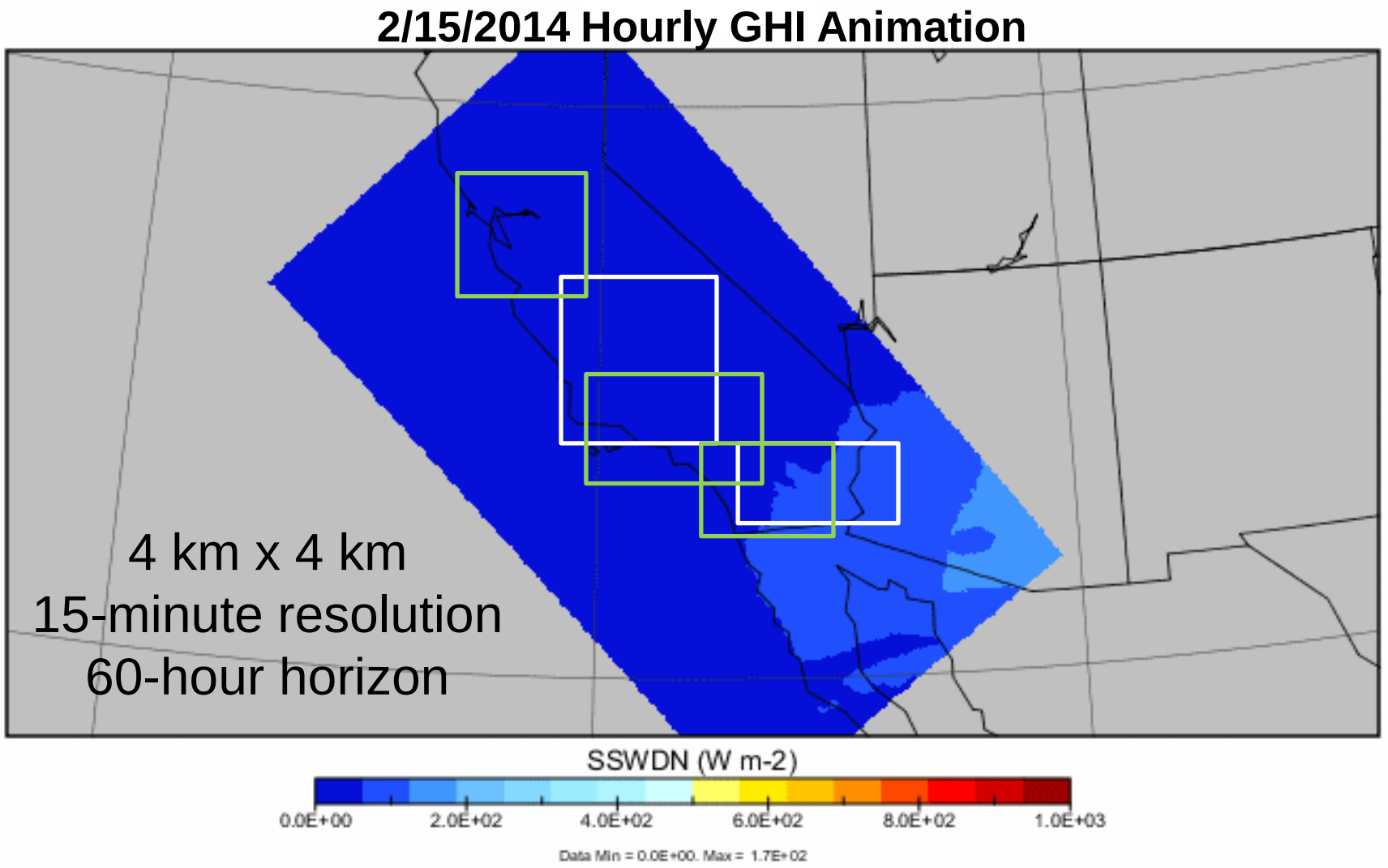
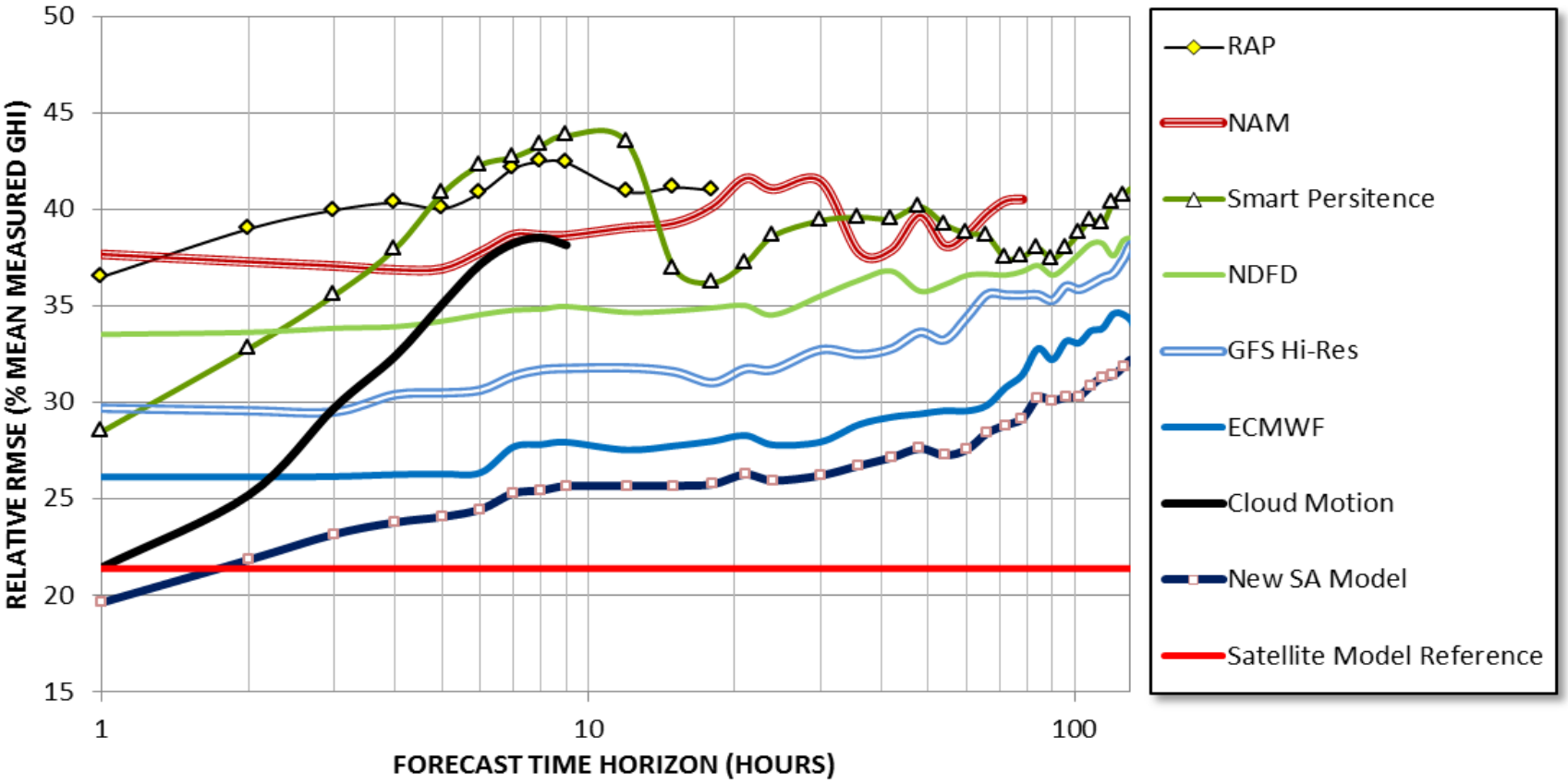
Improve Forecasts Using WRF Modeling (Dr. Kleissl - UCSD)



Improve Forecasts Using Ensemble Methods (Dr. Perez - SUNY)



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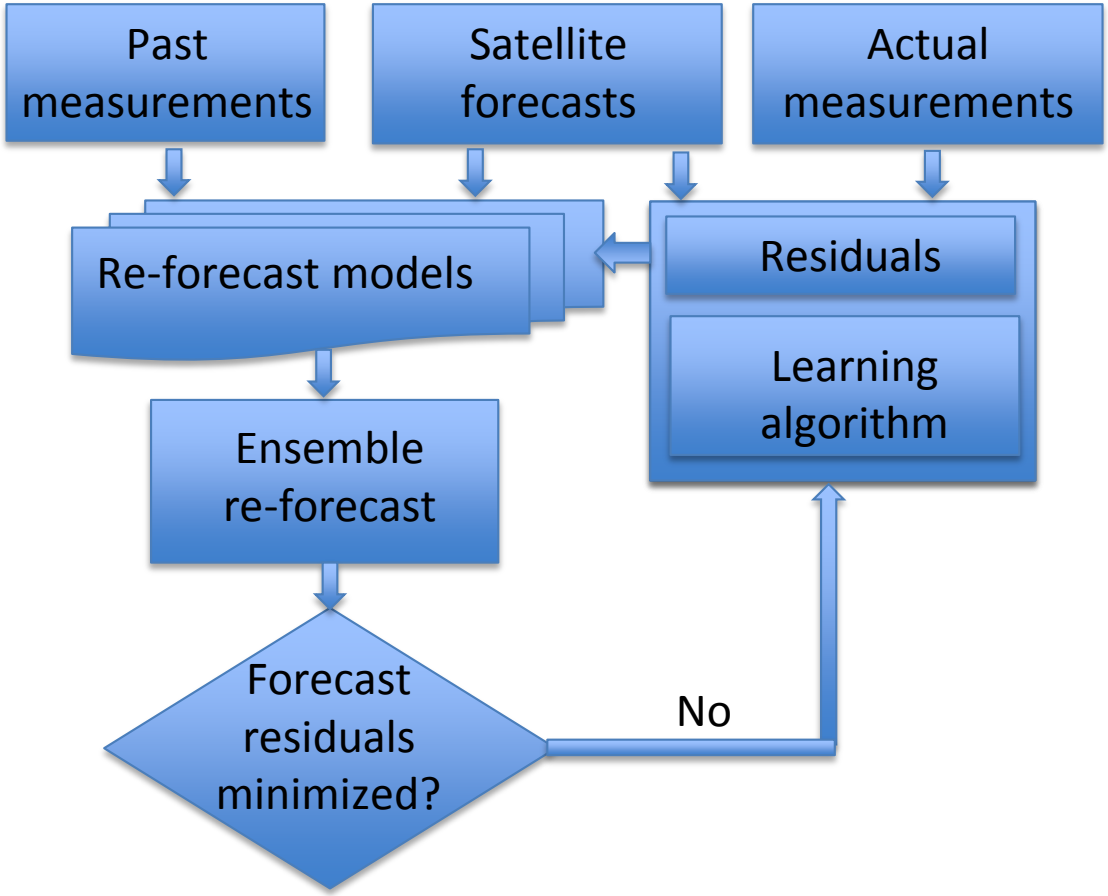
Improve Forecasts Using Machine Learning (Dr. Coimbra - UCSD)



Real-Time Smart Re-forecasting

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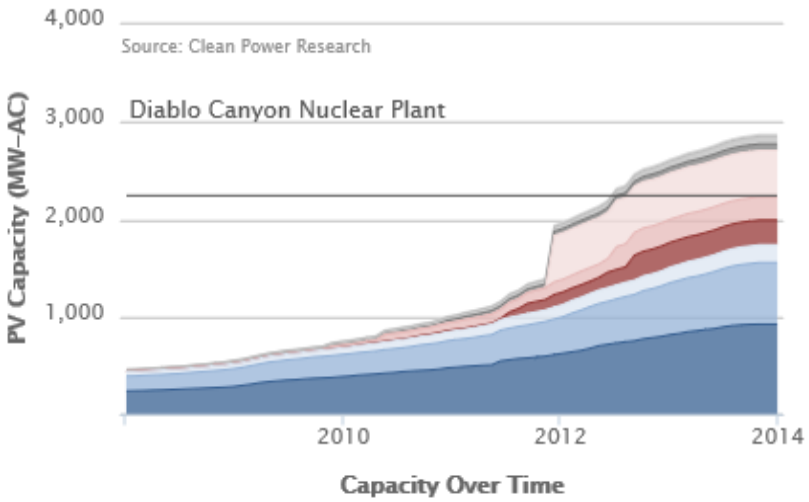
Concern

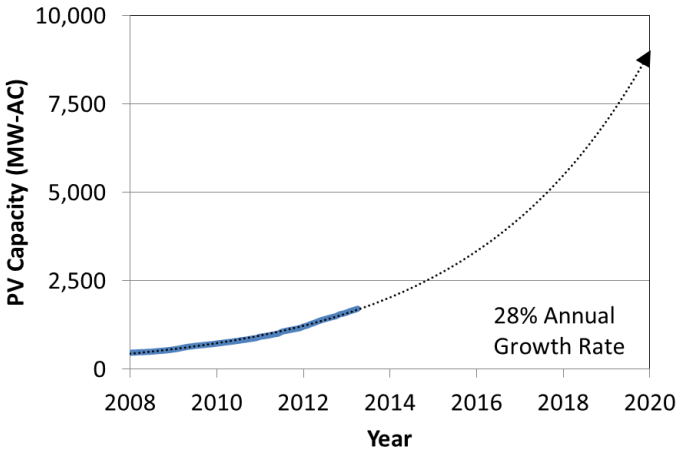
- Much effort has been devoted to developing a state wide database of all PV systems in California
- More systems are starting to be installed outside of incentive process
- California has started to lose easily accessible and possible more detailed information about the installed PV base

Need for New Method to Collect Specs

Current Capacity



Projected Behind-the-Meter Capacity



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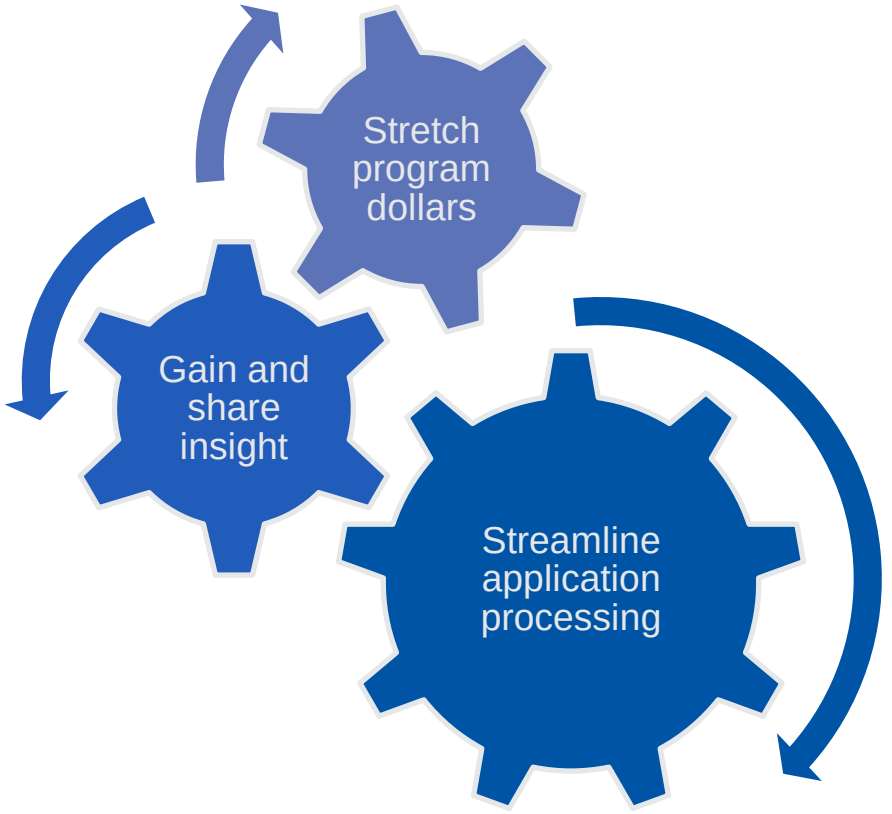
PowerClerk for Interconnection

- CPR background was incentive and program *design*
- Customer pain point was prog. *operations*
- Customers asked us to build PowerClerk Incentives
- SunShot Incubator award: commercialization of next PowerClerk platform – interconnection, incentives …



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Questions

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Thank you

Please feel free to contact us for any details or clarification related to presentation

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