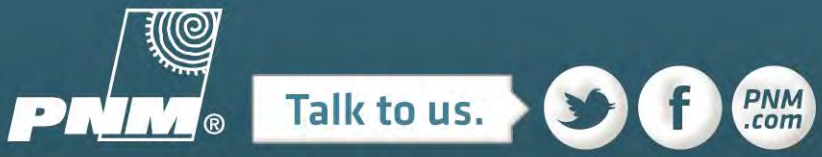
Optimized Integration of PV with Battery Storage: A Real World Success Story

AUGUST 2016

Jon Hawkins
Manager, Advanced Technology and Strategy



PNM PROSPERITY ENERGY STORAGE

Project Description

- First of 16 DOE Smart Grid Storage Demonstration Projects to go on line – Sept 2011
- Designed to both smooth PV intermittency and shift PV energy for on-peak delivery
- Successfully demonstrating Storage/PV integration to Utility operations

Equipment

- 500 kW PV (fixed C-Si panels) – not DOE funded
- Ecoult/East Penn - Advanced Lead Acid Battery system for “shifting” – 1MWh
- Ecoult/East Penn - “Ultra” Battery system for “smoothing - 500kW

U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories

THE UNIVERSITY of NEW MEXICO

Cyber Secure, High Resolution Data Acquisition and Control System 1 second and 30 samples per second data capture

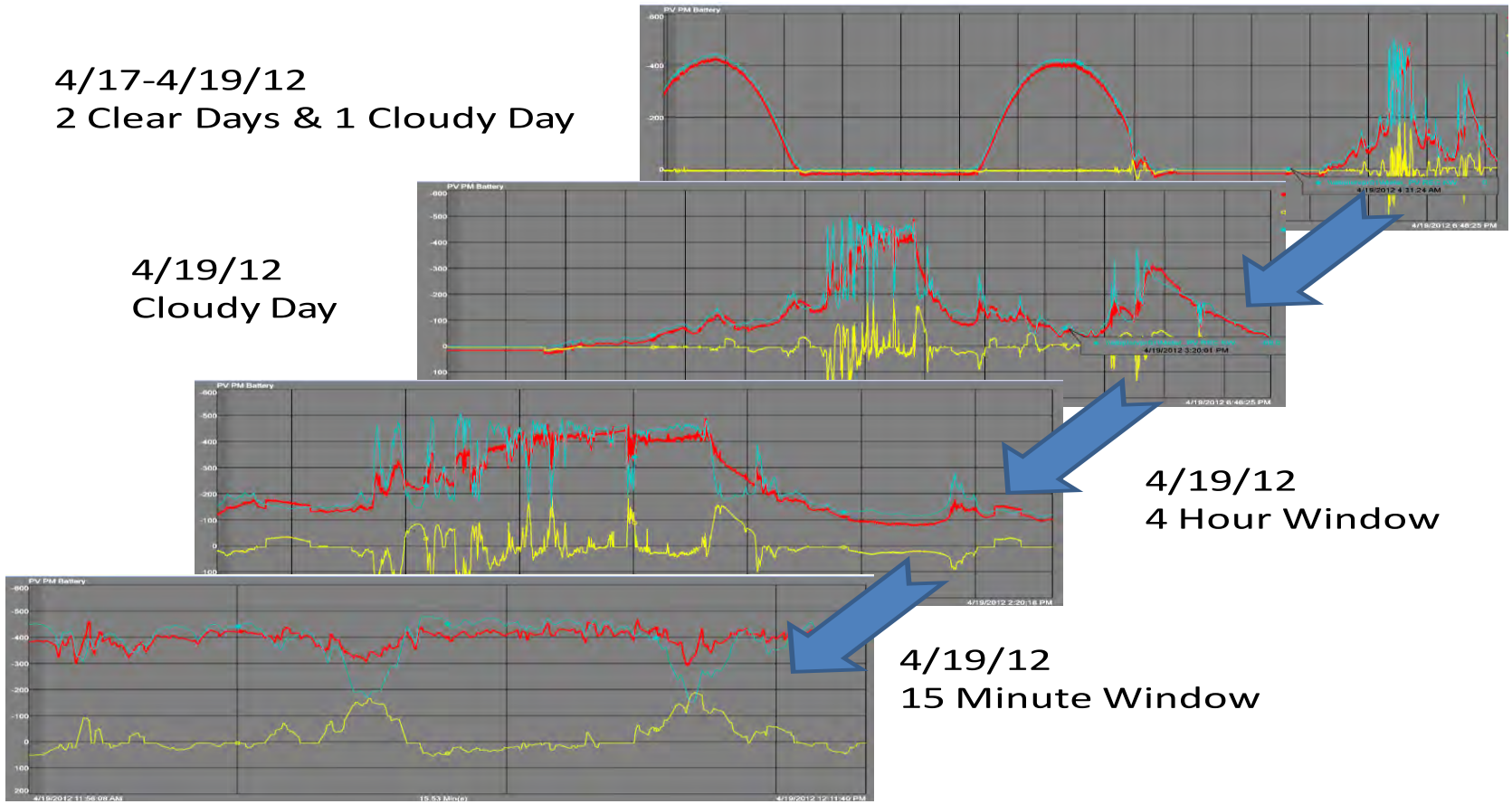
PROJECT GOALS

- Demonstrate simultaneous mitigation of voltage-level fluctuations and enable energy shifting
- Develop power system models (baseline and projected), and cost/benefit economic models
- Combine PV and storage at a substation targeting 15% peak-load reduction
- Generate, collect, analyze and share resultant data – Strong public outreach
- Create a dispatchable, renewables-based peaking resource
- Successfully demonstrate PV and storage integration into utility operations

REGULATION - PV SMOOTHING DEMONSTRATION

4/17-4/19/12
2 Clear Days & 1 Cloudy Day

4/19/12
Cloudy Day



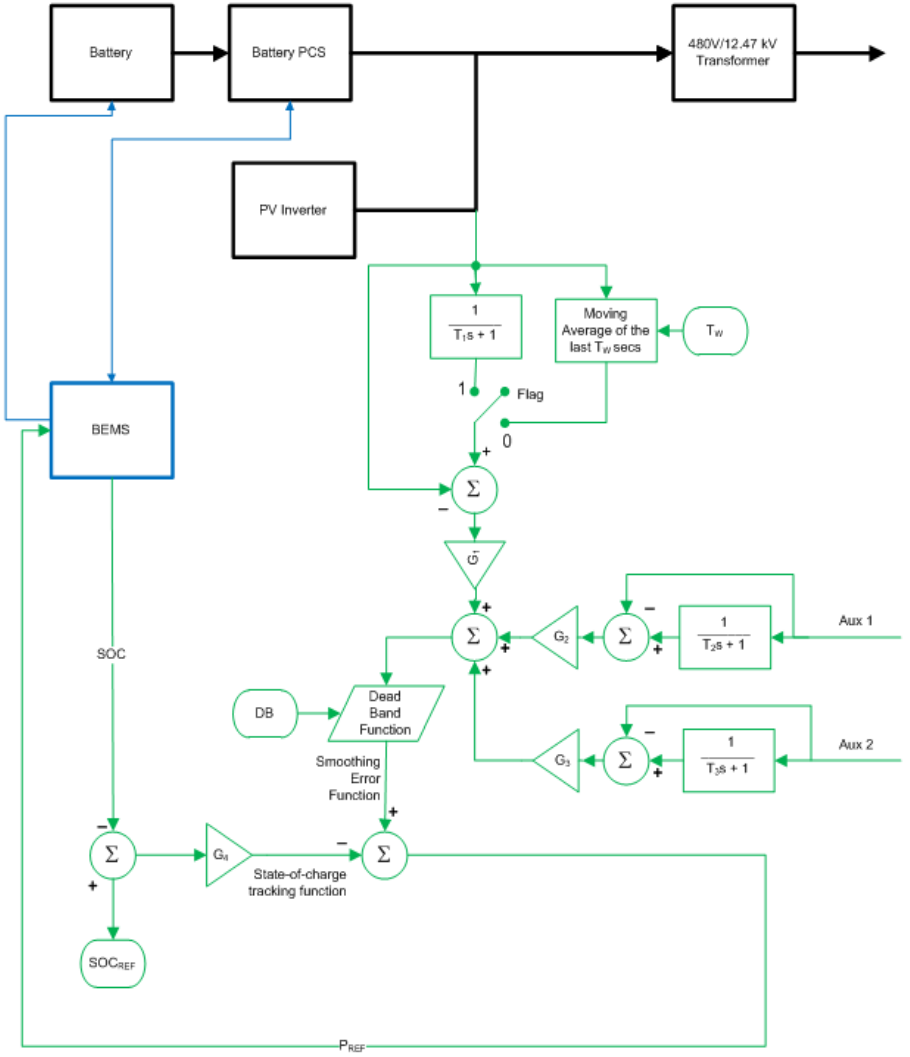
4/19/12
4 Hour Window

4/19/12
15 Minute Window

Key:	Yellow = Battery Output	Red=System Output	Blue=PV Output

SMOOTHING ALGORITHM IMPLEMENTATION

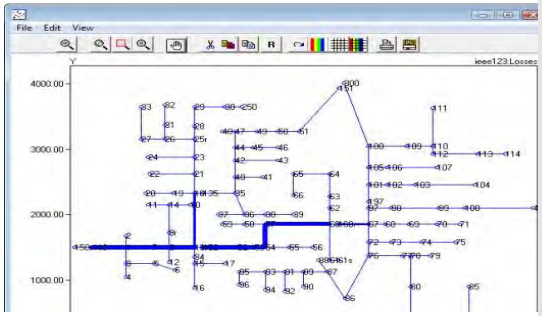
- Developed by Sandia National Laboratories, Implemented by Ecoult
  - Baseline algorithm to respond to the changes in solar output.
- Dynamic
  - Ability to optimize with different control source inputs.
  - Ability to be tuned by changing input parameter and gains within the equation
- Allowed investigation of optimization PV smoothing with energy storage
- Question: How much smoothing is enough?



FEEDER MODELING AND ANALYSIS

- Used to do analysis on feeders involved to determine effects from PV
- Supported analysis of the amount of regulation provided by substation tap changers (number of tap changes) under various conditions
  - Clear vs. Cloudy days
  - Central utility storage and customer sited
- Model was compared with some field testing. Showed some benefits to reduce number of tap changes, although did not match the model well.

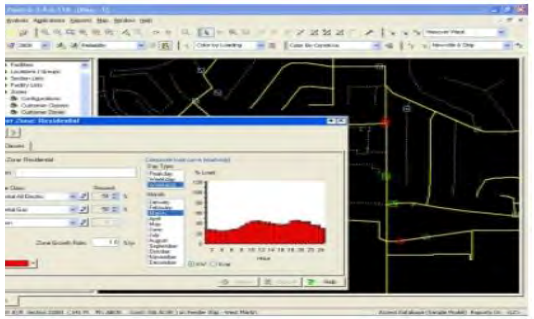
OpenDSS



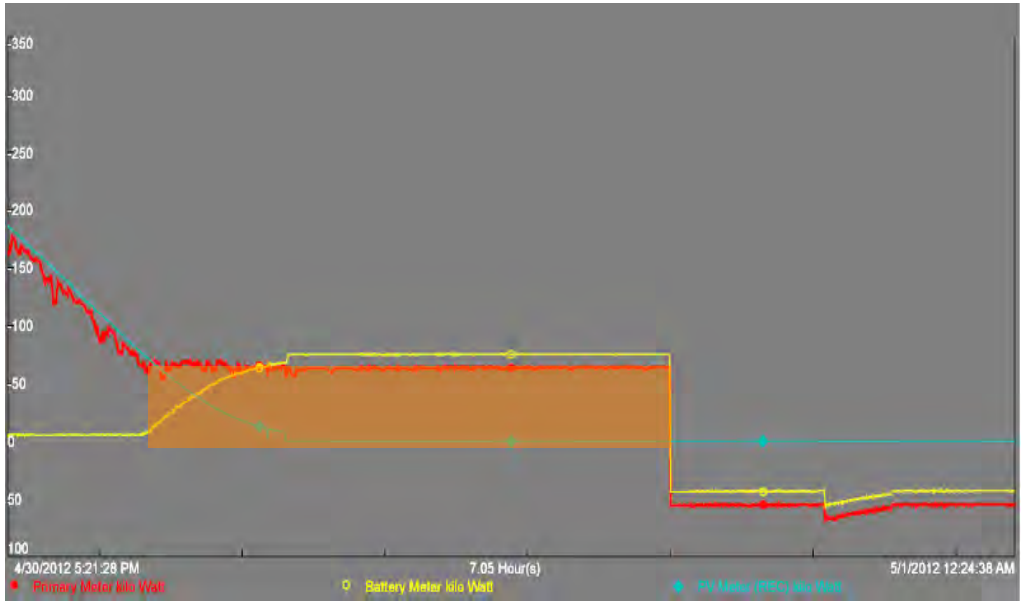
GridLAB-D

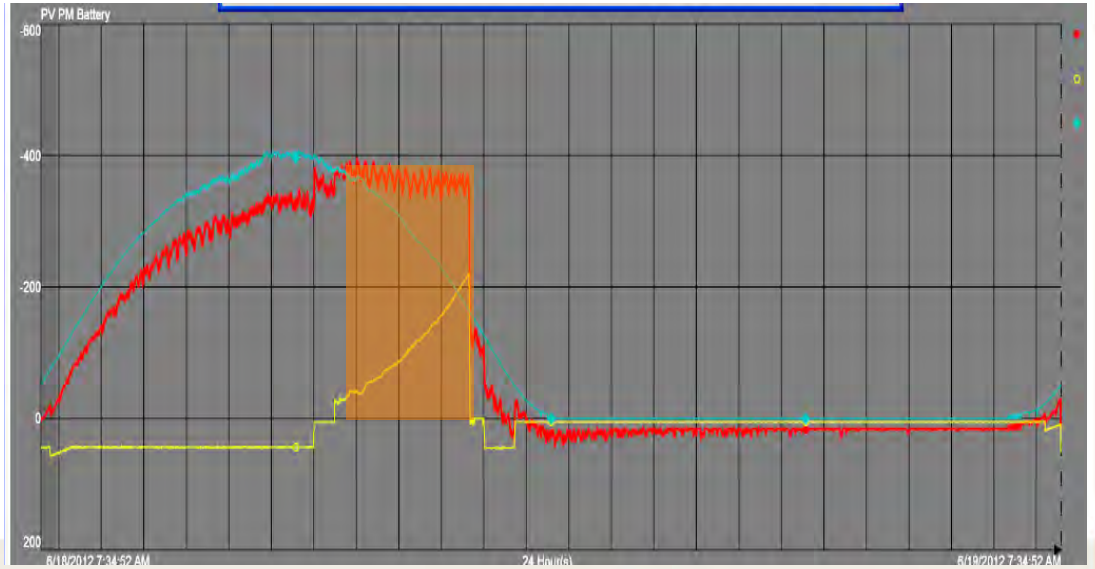
```
1  // This file contains 90 homes with analog loads
2  // residential enduse structure via implicit enc
3  // week and a recorder measures total power draw
4  // off during these simulations.  Number of home
5
6  clock {
7      timezone PST+8PDT;
8      starttime '2001-01-01 00:00:00 PST';
9      stoptime '2001-01-08 00:00:00 PST';
10 }
11
12
13 module powerflow;
14 module tape;
15 module residential {
16     //implicit_enduses NONE;
17 }
18
19 #define no_of_homes=10 // x9
20
21 object triplex_meter {
22     name Meter;
23     nominal_voltage 120.0;
```

SynerGEE



ENERGY SHIFTING/DISPATCHING STORED ENERGY

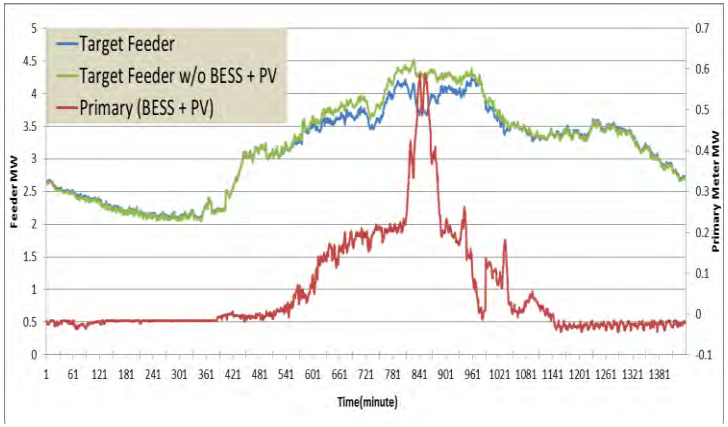




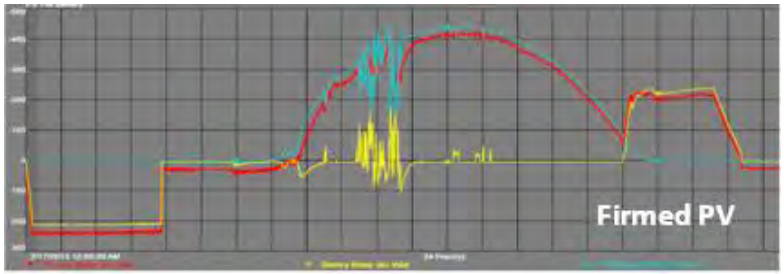
ENERGY SHIFTING/DISPATCH – OTHER APPLICATIONS

Internal Optimization Required

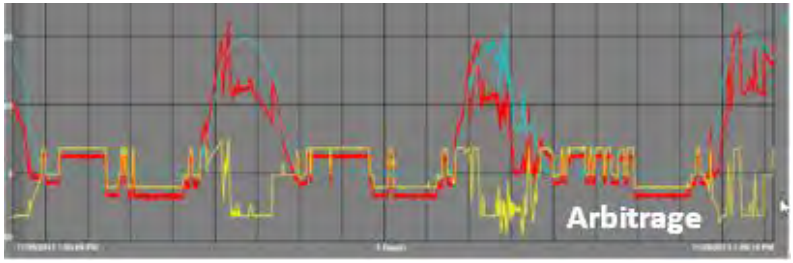
- Prioritization of Applications
- Reliability is top Priority - Peak Shaving
- Further Optimization Determines value of Firming vs Peak Shaving vs Arbitrage
- Life of battery and energy throughput also a consideration



Peak Shaving – Achieved 15%

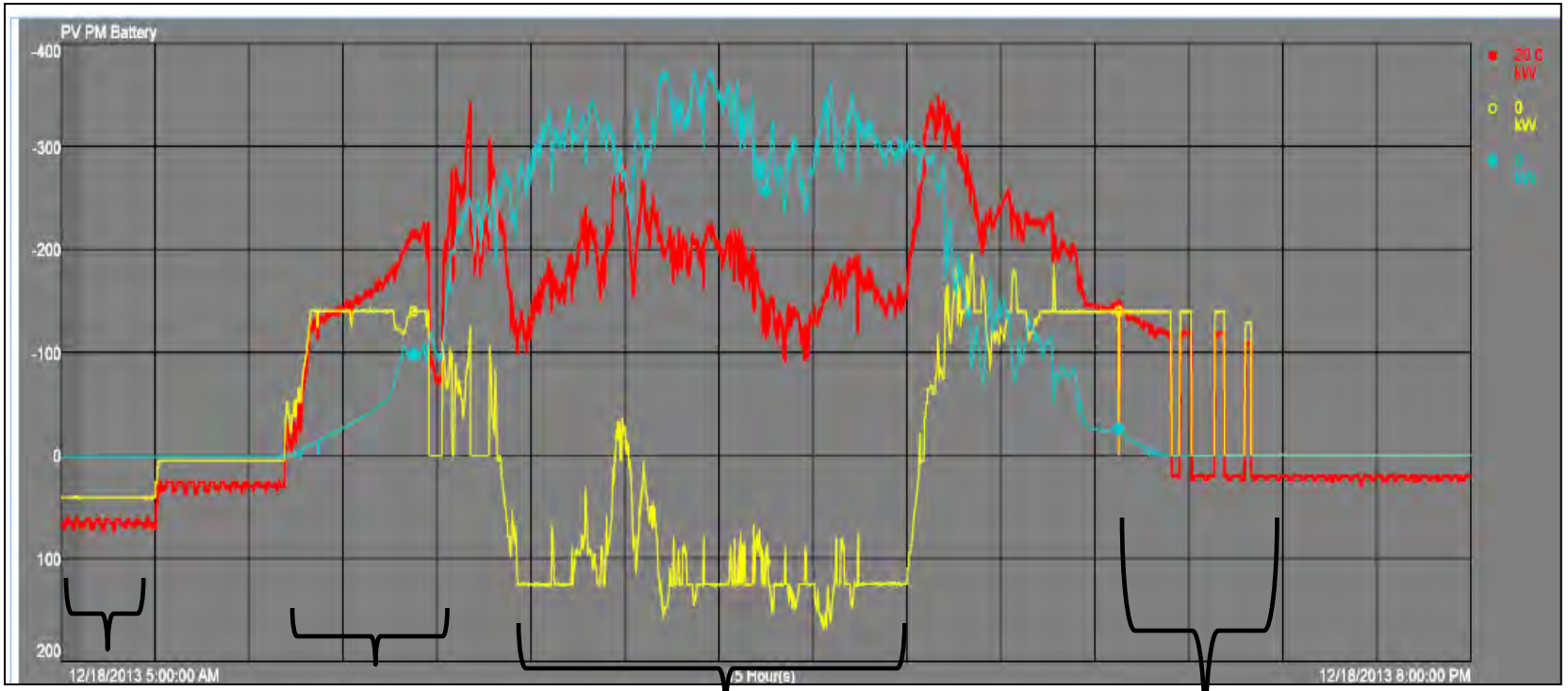


Firm dispatch – with weather prediction



Price arbitrage using CAISO pricing

MULTIPLE APPLICATION DEMONSTRATION



Charge due to RT price

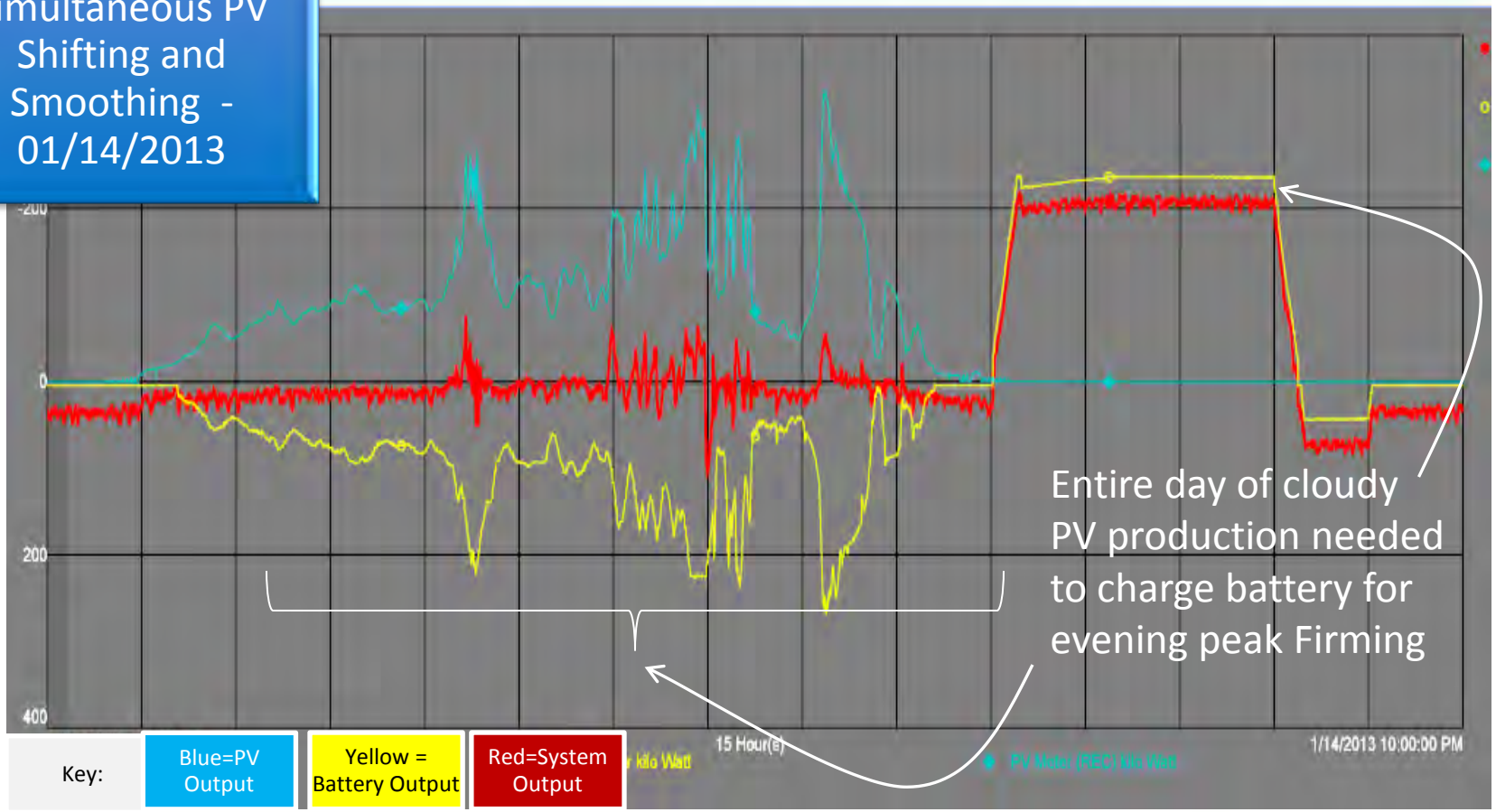
Emergency Peak Shaving

Charge due to State of Charge

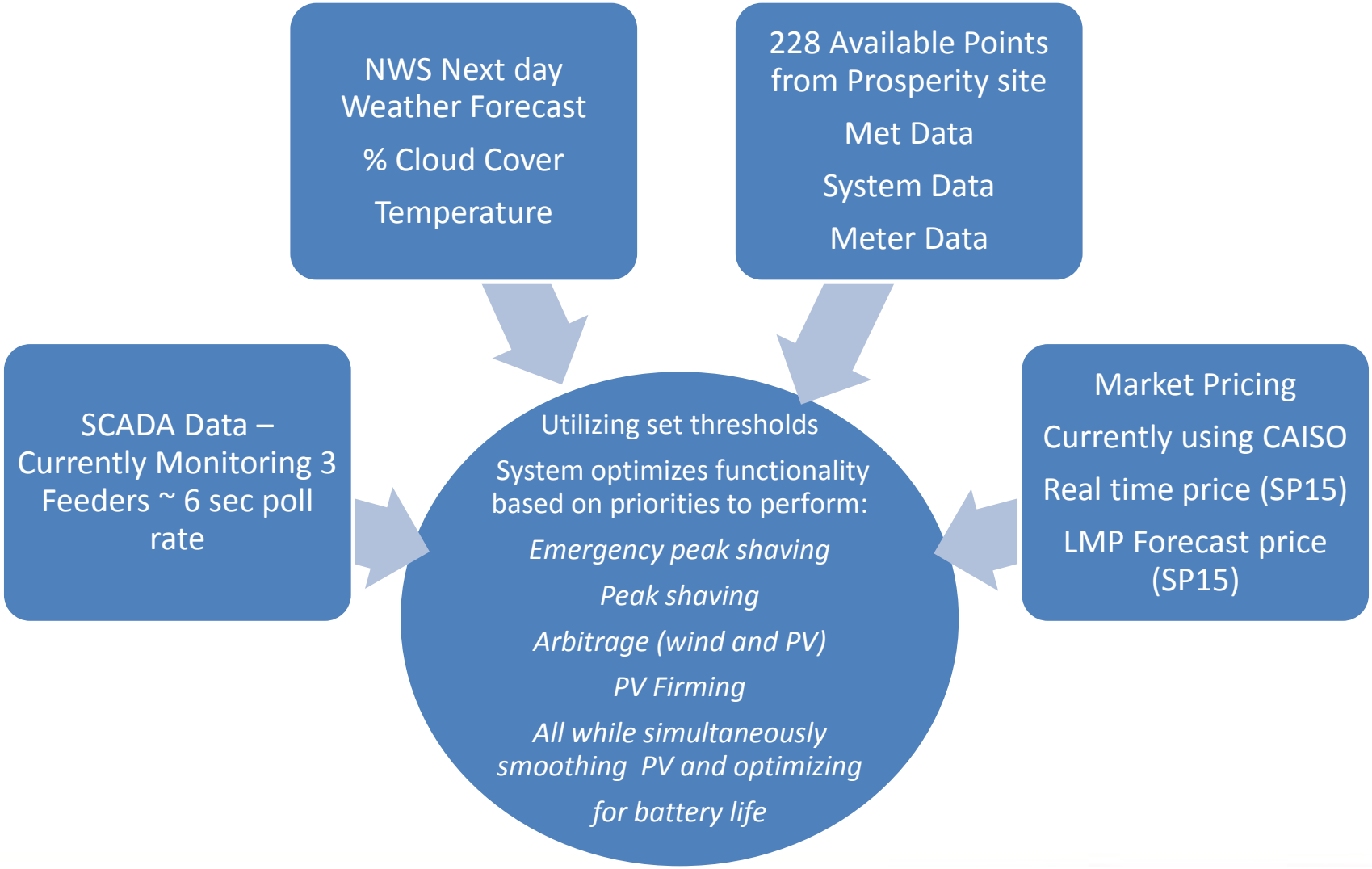
Winter Evening Firming

SIMULTANEOUS REGULATION AND DISPATCH

Simultaneous PV Shifting and Smoothing - 01/14/2013



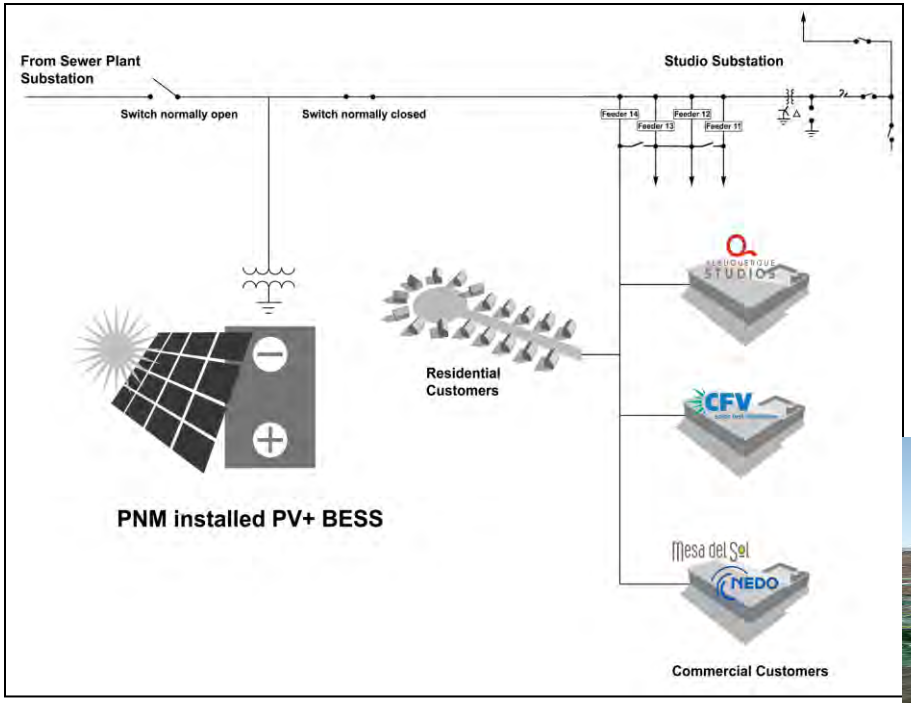
INTEGRATION INTO UTILITY OPERATIONS - OPTIMIZATION OF ALL CAPABILITIES



COST/BENEFIT ECONOMIC MODELS

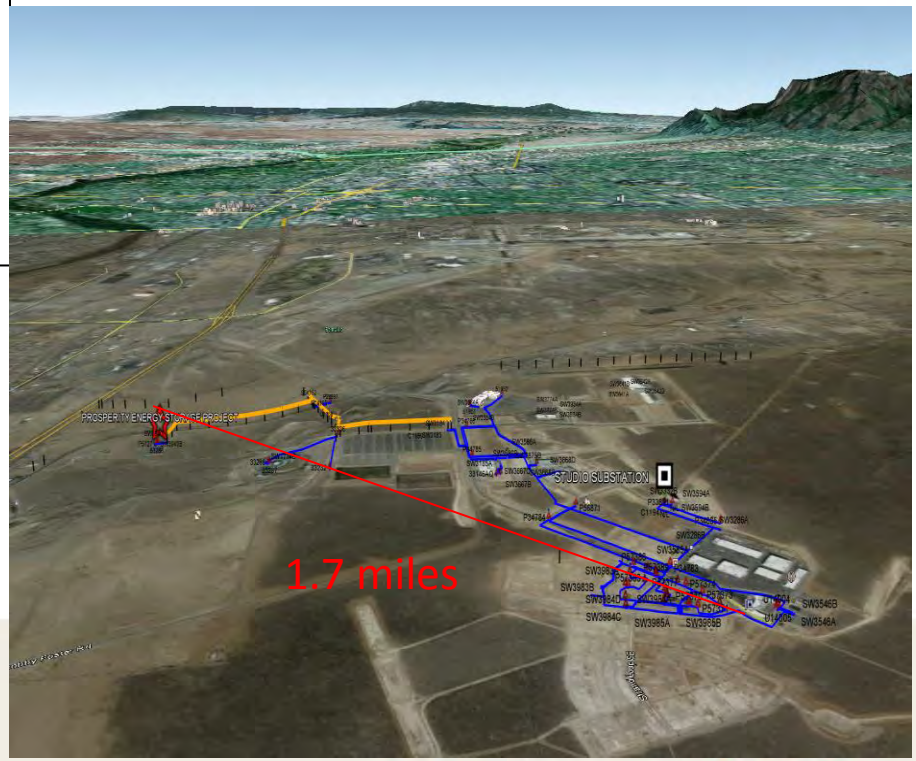
- Modeled both in EPRI's Energy Storage Valuation Tool (ESVT) and a cross check was done with the DOE Energy Storage Computational Tool (ESCT)
- Modeled peak shaving, arbitrage, and firming both individually and in combination.
- Smoothing was modeled separately and added
- PV Smoothing provided only nominal benefits
- Energy applications showed approximately a $625k benefit stream
- Break even analysis showed that capital cost would have to drop to approximately $450k to get a cost benefit of 1.

FEEDER CONFIGURATION

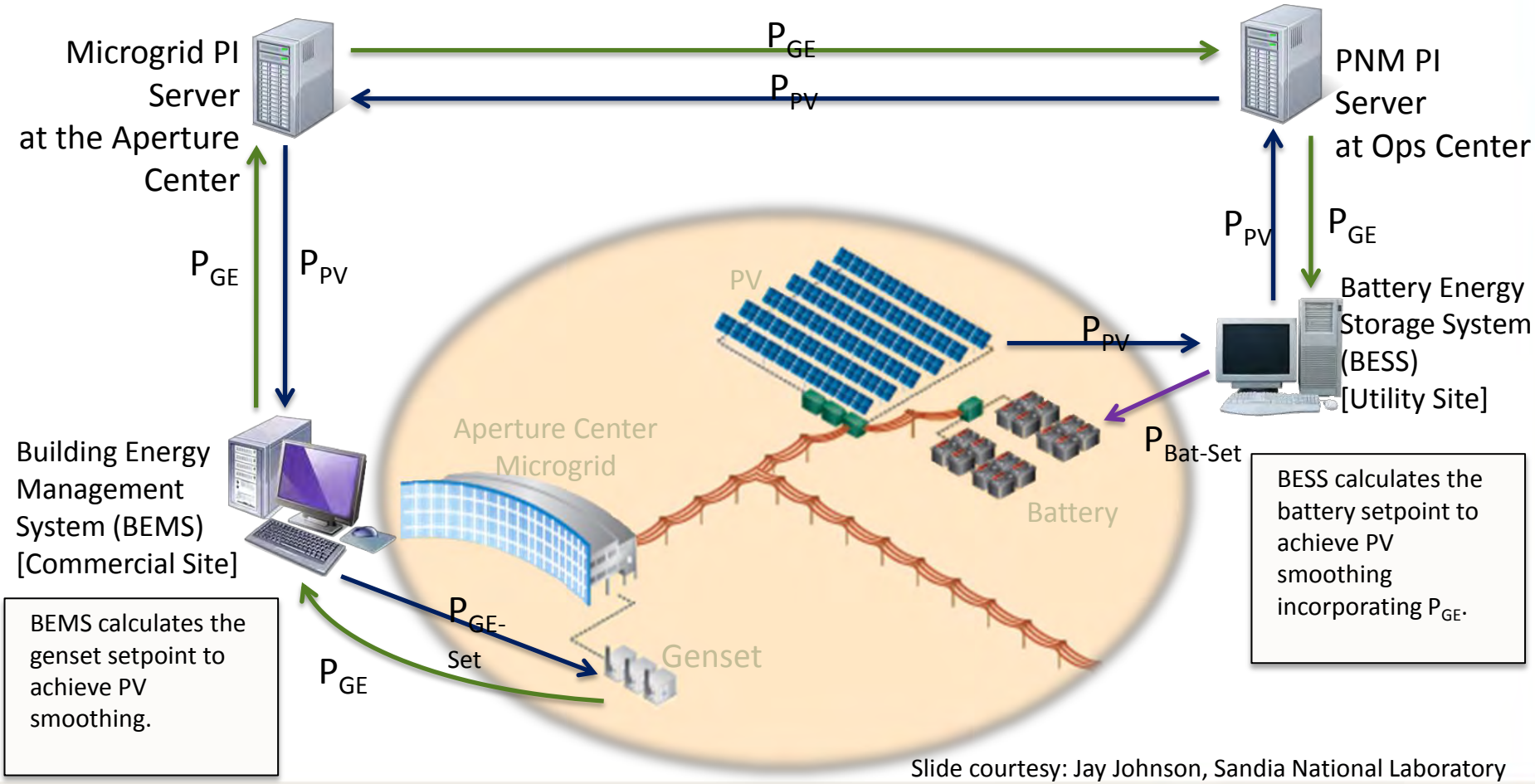


Approximately 1.7 miles between projects “as the crow flies

Approximately 2.5 circuit miles



COORDINATED, DISTRIBUTED PV SMOOTHING

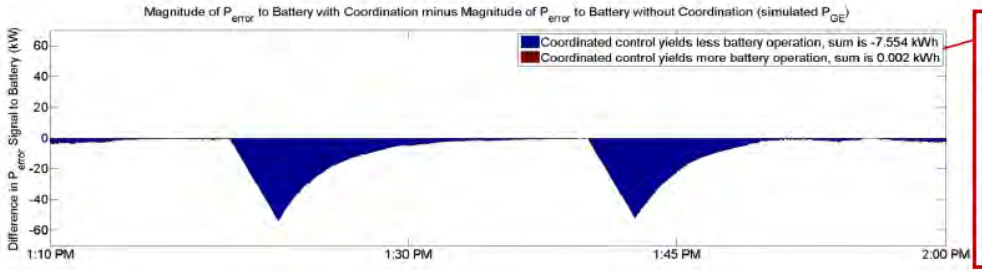


Slide courtesy: Jay Johnson, Sandia National Laboratory

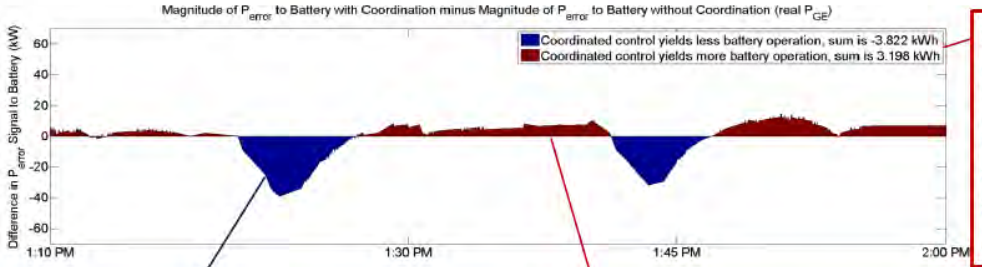
INTEGRATION WITH AREA "SMART GRID" SYSTEMS

- Objective: Reduce battery operation in PV-smoothing systems by novel control schemes.

- Smoothing PV power with a coordinated battery and gas genset reduces the required battery capacity and increases battery life, HOWEVER not by as much as predicted in modeling.



Simulation: Total energy throughput reduction from using the coordinated controller is 7.554 kWh



Experiment: Total energy throughput reduction from using the coordinated controller is 0.624 kWh

The blue area is where the coordinated battery is "working less" than the uncoordinated battery.

The red area means the coordinated battery is "working harder" than the uncoordinated battery.

Research Partners: PNM, NEDO, TOKYO GAS, Shimz, TOSHIBA, UNM, Mesa del Sol, Sandia National Laboratories

Special Thanks: Abraham Ellis[1], Atsushi Denda[2], Kimio Morino[2], Jon Hawkins[3], Brian Arellano[3], Takao Ogata[4], Takao Shinji[4], and Masayuki Tadokoro[4]

[1]Sandia National Laboratories
[2]Shimizu Corporation
[3]Public Service Company of New Mexico (PNM)
[4]Tokyo Gas Co., Ltd.

Acknowledgment of support to Dr. Imre Gyuk, Electricity Storage Program Manager, DOE Office of Electricity

Slide adapted from content provided by : Jay Johnson, Sandia National Laboratory

OUTREACH AND REPORTING

- Over 25 publications (IEEE, World Renewable Energy Forum, ASES, EESAT, Sandia Reports, EPRI Reports)
- Over 30 presentations in various forums (Distributech, IEEE, EPRI, DOE, ESA, local outreach, others) including 40+ site tours
- DOE Technical Progress Reports
  - https://www.smartgrid.gov/sites/default/files/doc/files/publicservice.pdf
  - https://www.smartgrid.gov/sites/default/files/doc/files/FTR%20FINAL%20PNM%2027May14.pdf
- Android app developed for access to the Project website – available on GooglePlay:
- DOE/EPRI Energy Storage Handbook, featuring the Prosperity Project and a variety of input from PNM:
  - http://www.sandia.gov/ess/publications/SAND2013-5131.pdf
- Coordination of Utility Scale Storage and microgrid documented in Sandia Report
  - http://energy.sandia.gov/wp-content/gallery/uploads/SAND2014-1546-Experimental-Comparison-of-PV-Smoothing-Controllers-using-Distributed-Generators-FINAL.pdf

GOALS

- Demonstrate simultaneous mitigation of voltage-level fluctuations and enable energy shifting
- Combine PV and storage at a substation targeting 15% peak-load reduction
- Create a dispatchable, renewables-based peaking resource
- Develop power system models (baseline and projected), and cost/benefit economic models
- Generate, collect, analyze and share resultant data – Strong public outreach
- Successfully demonstrate PV and storage integration into utility operations

- Investigation and optimization of regulating PV output with various inputs, approaches, and intensity
- Optimization of energy dispatch with weather prediction
- Demonstrate Energy Arbitrage
- Integration and coordination with local intelligent resources

Thank you