# State & Federal Energy Storage Technology Advancement Partnership (ESTAP) Webinar:

# Optimizing the Benefits of a PV with Battery Storage System

**September 16, 2013**

CleanEnergy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

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# State & Federal Energy Storage Technology Advancement Partnership (ESTAP)

Val Stori, Project Director
Clean Energy States Alliance

CleanEnergy States Alliance
Sandia National Laboratories
U.S. DEPARTMENT OF ENERGY

# Thank You:

**Dr. Imre Gyuk**
U.S. Department of Energy,
Office of Electricity Delivery and
Energy Reliability

**Dan Borneo**
Sandia National Laboratories

CleanEnergy States Alliance

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# ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

- Information Exchange
- Partnership Development
- Joint Projects (National RPS Collaborative, Interstate Turbine Advisory Council)
- Clean Energy Program Design & Evaluations
- Analysis and Reports

CESA is supported by a coalition of states and public utilities representing the leading U.S. public clean energy programs.

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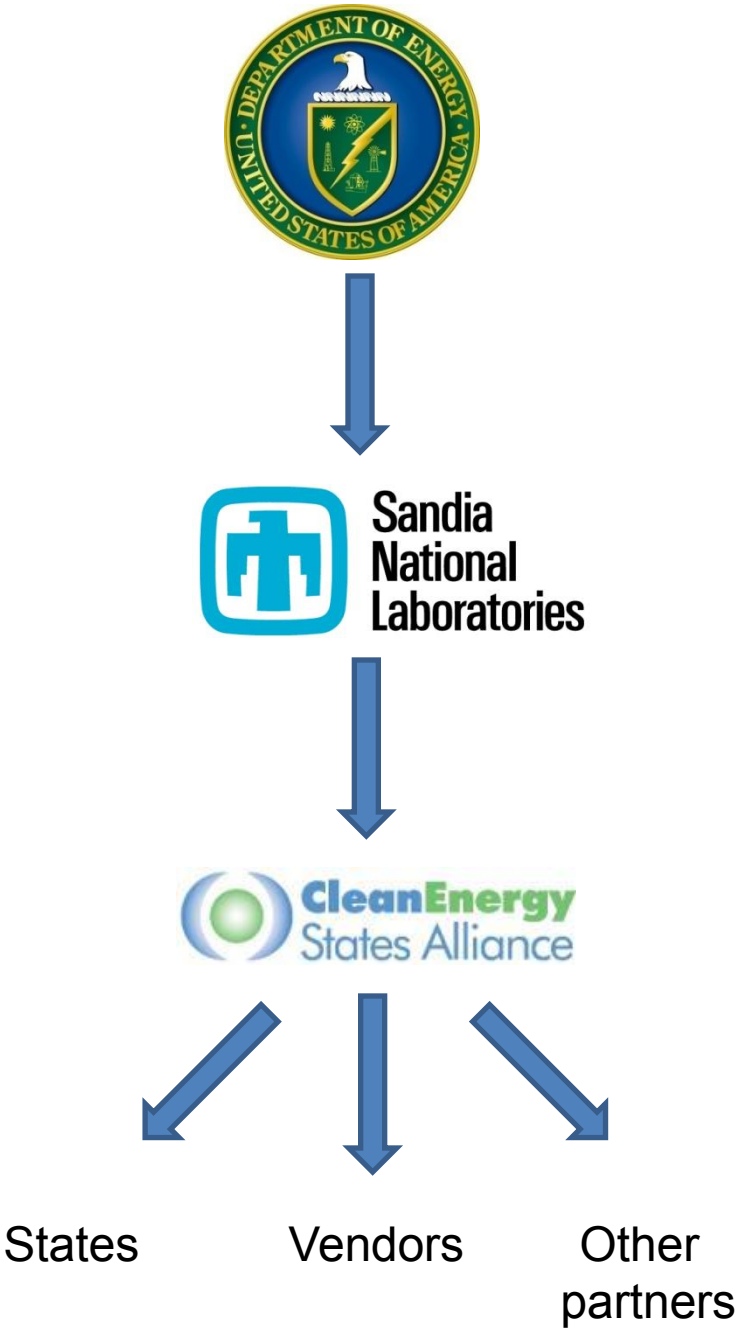
# ESTAP* Overview

**Purpose:** Create new DOE-state energy storage partnerships and advance energy storage, with technical assistance from Sandia National Laboratories

**Focus:** Distributed electrical energy storage technologies

**Outcome:** Near-term and ongoing project deployments across the U.S. with co-funding from states, project partners, and DOE




* (Energy Storage Technology Advancement Partnership)

# ESTAP Key Activities

1. Disseminate information to stakeholders
   - ESTAP listserv >500 members
   - Webinars, conferences, information updates, surveys
2. Facilitate public/private partnerships at state level to support energy storage demonstration project development
   - Match bench-tested energy storage technologies with state hosts for demonstration project deployment
   - DOE/Sandia provide $ for generic engineering, monitoring and assessment
   - Cost share $ from states, utilities, foundations, other stakeholders

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# ESTAP Webinars

## Policy Webinars:

- Introduction to the Energy Storage Guidebook for State Utility Regulators
- Briefing on Sandia's Maui Energy Storage Study
- The Business Case for Fuel Cells 2012
- State Electricity Storage Policies
- Highlights of the DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA

## Technology Webinars:

- Smart Grid, Grid Integration, Storage and Renewable Energy
- East Penn and Ecoult Battery Installation Case Study
- Energy Storage Solutions for Microgrids
- Applications for Redox Flow Batteries
- Introduction to Fuel Cell Applications for Microgrids and Critical Facilities
- UCSD microgrid

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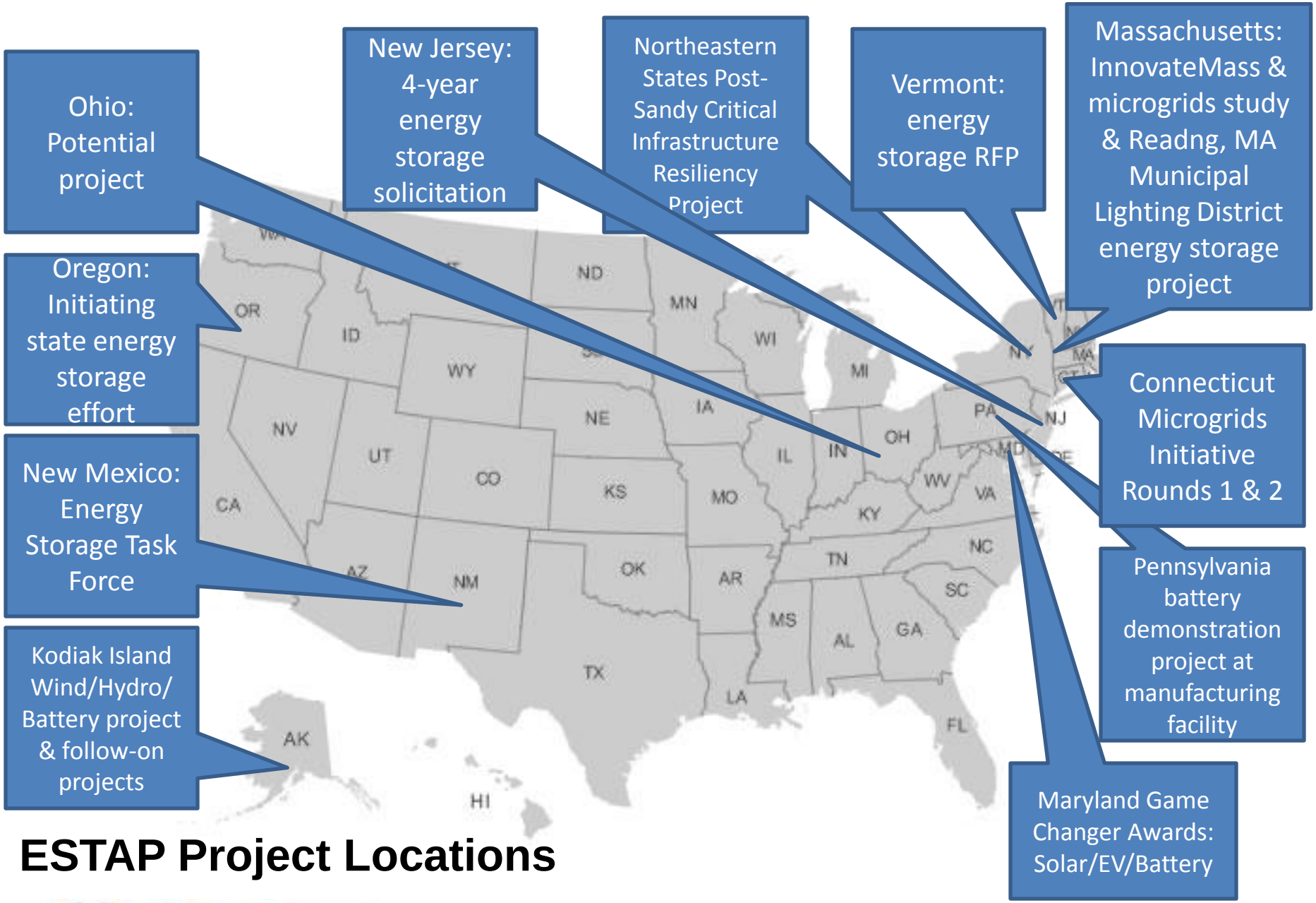
Ohio: Potential project
New Jersey: 4-year energy storage solicitation
Northeastern States Post-Sandy Critical Infrastructure Resiliency Project
Vermont: energy storage RFP
Massachusetts: InnovateMass & microgrids study & Readng, MA Municipal Lighting District energy storage project
Oregon: Initiating state energy storage effort
Connecticut Microgrids Initiative Rounds 1 & 2
New Mexico: Energy Storage Task Force
Pennsylvania battery demonstration project at manufacturing facility
Kodiak Island Wind/Hydro/ Battery project & follow-on projects
Maryland Game Changer Awards: Solar/EV/Battery
ESTAP Project Locations
CleanEnergy States Alliance
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# Today's Speakers

**Dr. Imre Gyuk,** U.S. Department of Energy,
Office of Electricity Delivery and Energy Reliability

**Dan Borneo,** Sandia National Laboratories

**Steve Willard,** PNM Resources

CleanEnergy States Alliance

Sandia National Laboratories

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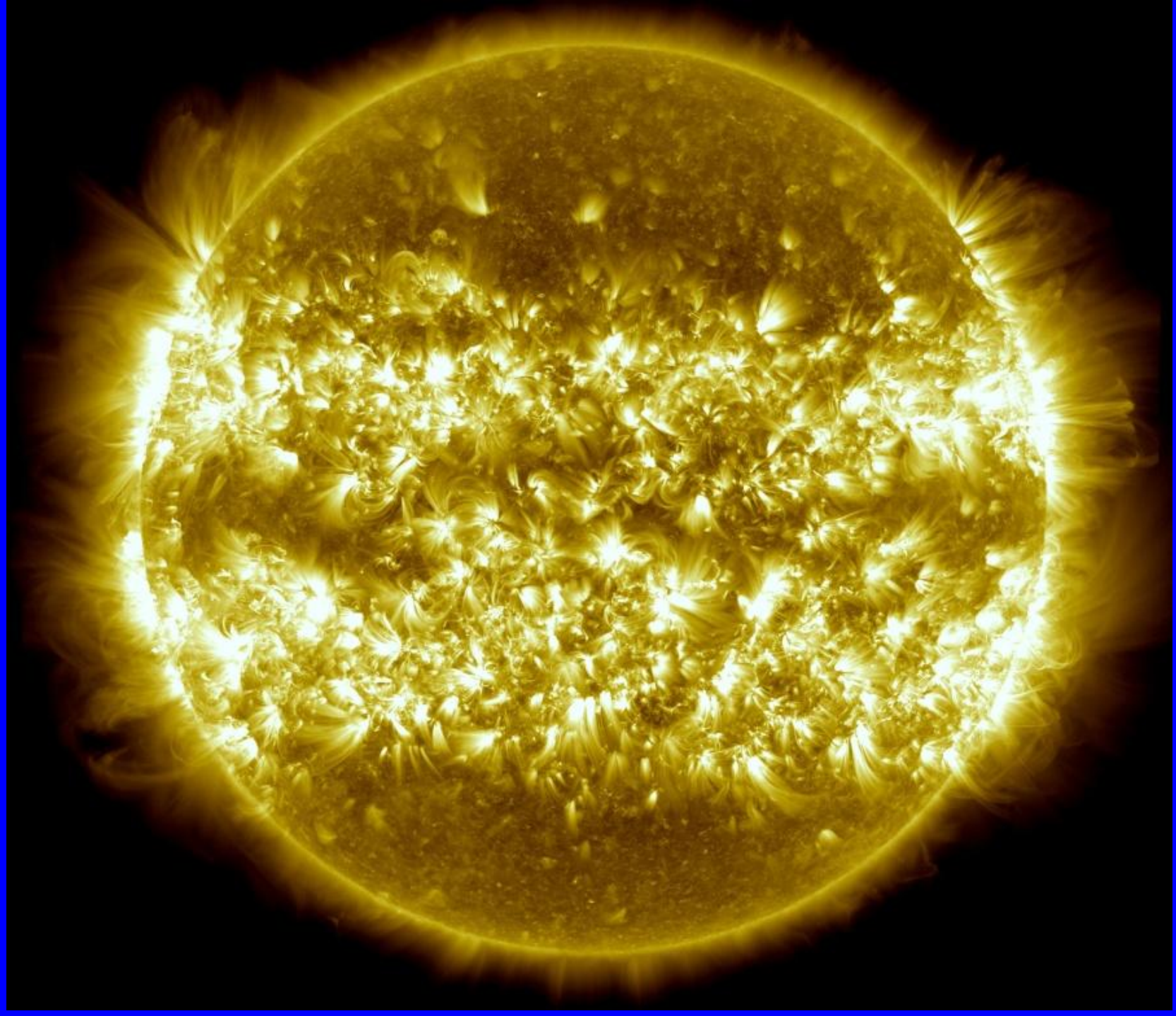
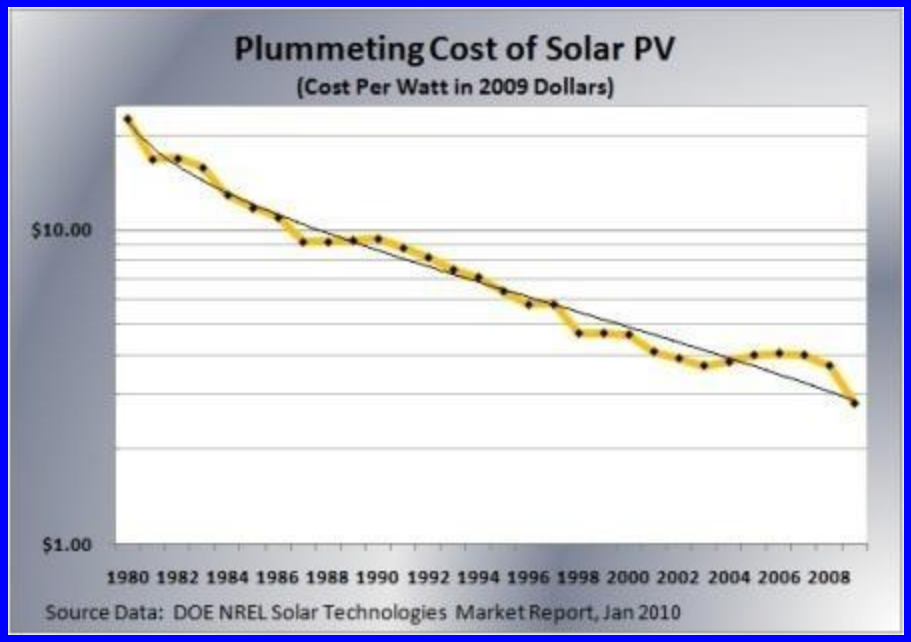
# Energy Storage and Solar PV

IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE

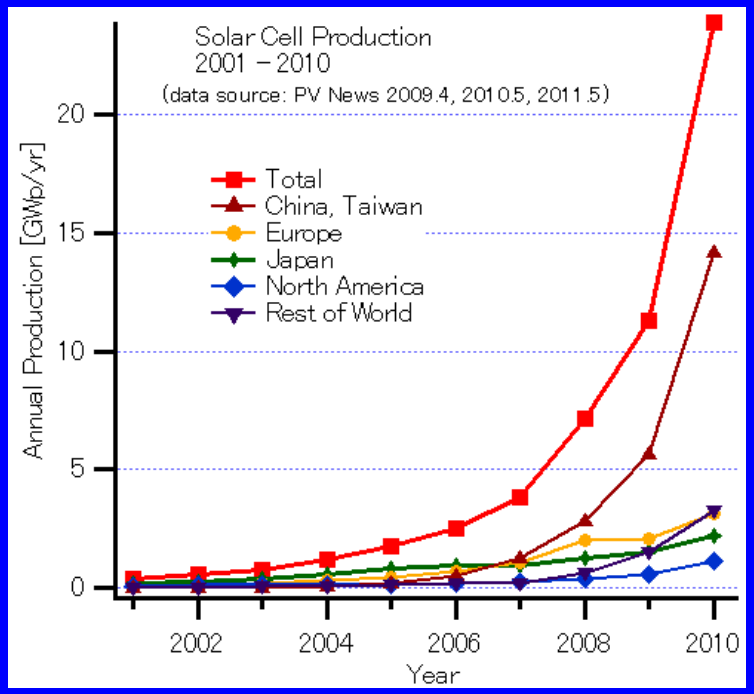


All Energy Ultimately derives from the Sun!

PV Solar is an Attractive, Sustainable Option




# As PV Costs Decline, Production Soars!

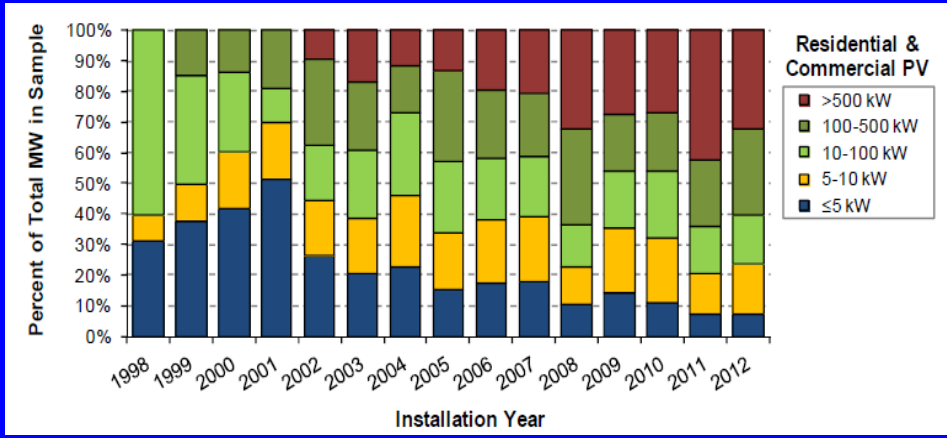


Rooftop PV -

or Solar Farm?

US: 8.9 GW
Japan: 10 GW

Approximately 50%
of PV installations
are Grid Scale, >100kV



# But there are certain Issues

Moonlight is not enough!

Diurnal Load Patterns don't Match PV Generation

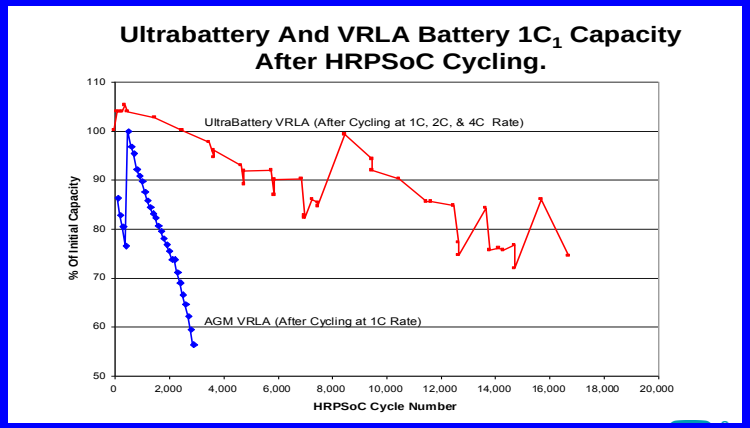
Clouds drift past!

Intermittency requires Backup

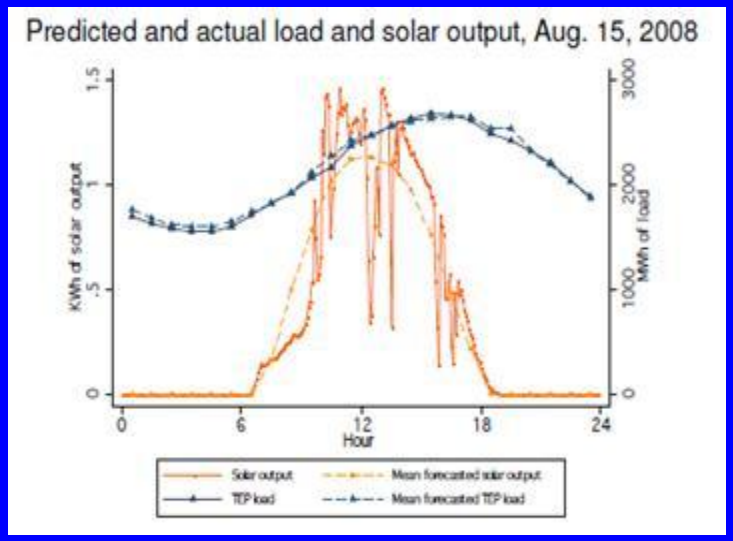
PV needs Storage for Capacity Firming!

# Medium Size Projects: 1-5 MW

ARRA – Public Service NM:
500kW, 2.5MWh for Smoothing and Peak Shifting of a 500kW PV installation; Using EastPenn Lead-Carbon Technology




PbC Testing at Sandia




Load & PV Output in Tucson, AZ

Commissioned Sep. 24, 2011 Integrator: Ecoult

Analysis and Modeling:

- Public Service New Mexica
- University of New Mexico
- Northern New Mexico College
- Sandia National Laboratories
- Ecoult and East Penn Manufacturing
- U.S. Dept. of Energy, Office of Electricity

Extensive 1-second data has been gathered and is being statistically analyzed through a numerical methods optimization approach to determine the optimal level of smoothing.

The algorithm running these functions automatically retrieves cloud cover predictions, feeder loadings from PNM's SCADA, as well as real time and forecasted peak prices. It is now using these inputs to make optimized decisions

# Primus Power / Raytheon

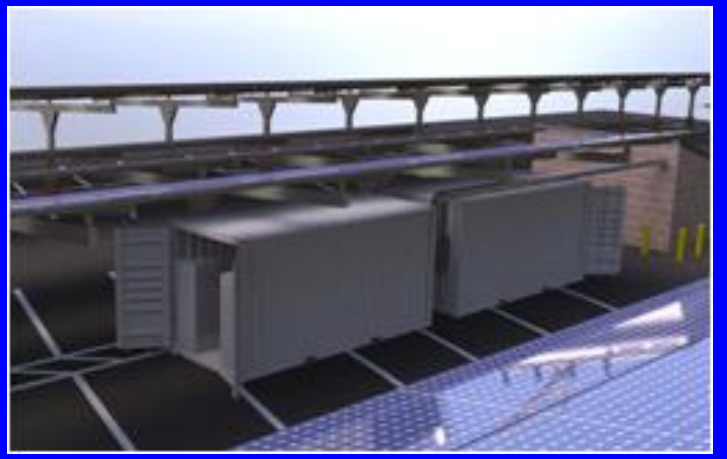
## Marine Corps Air Station
## Miramar, CA
## An ESTCP Project

250kW- 4hr EnergyPod™ (ZnBr) for 230kW PV with micro-grid capability. Completion 2014

Mission critical backup power
Islanding and Peak Shaving capability

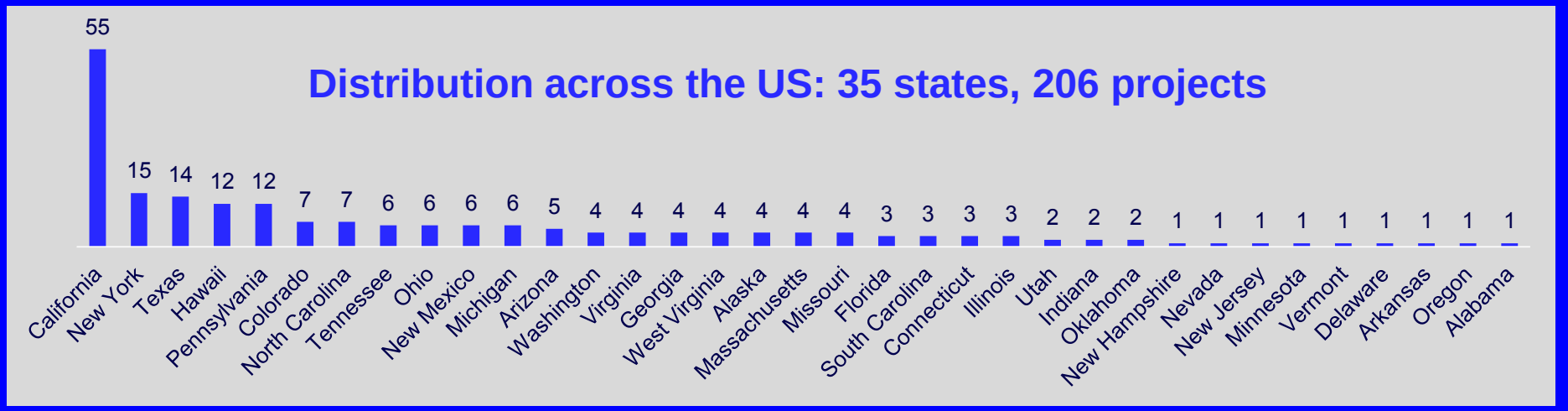
**Miramar lost power in September 2011 Great Southwest Blackout**

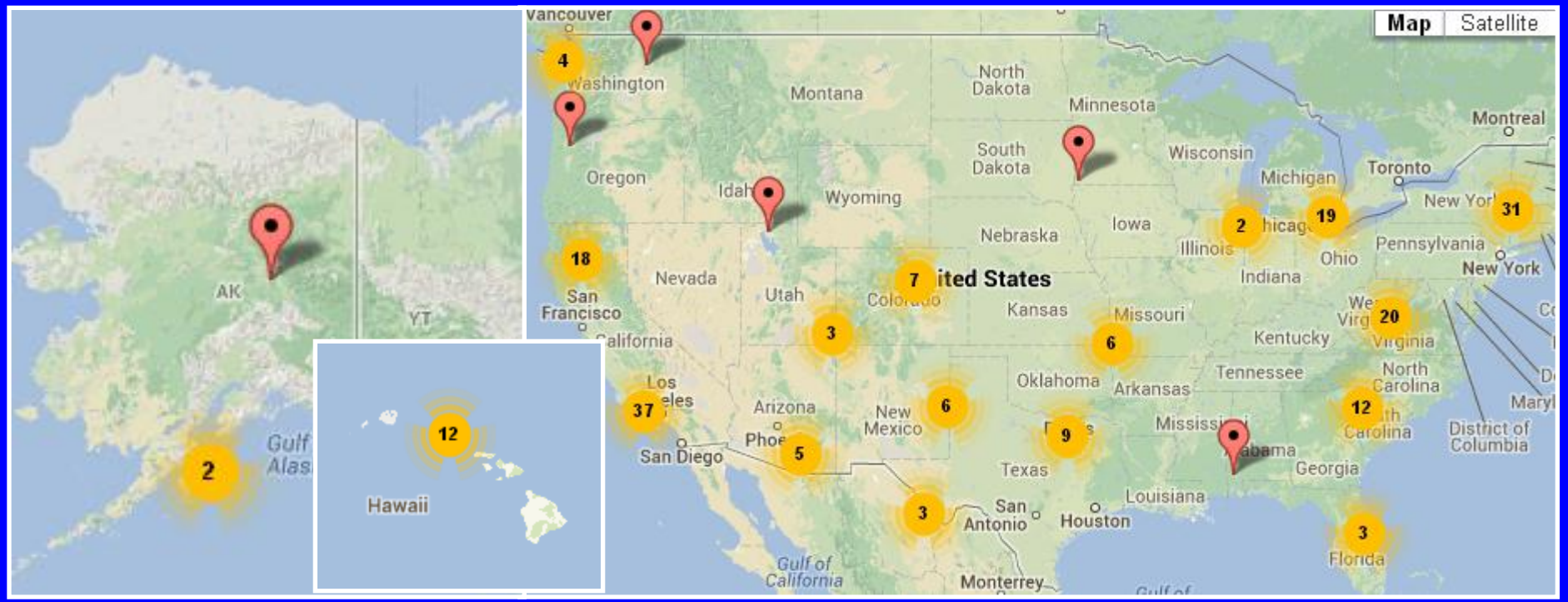
- **Training missions cancelled**
- **Planes grounded**
- **25% of diesel generators had trouble starting**



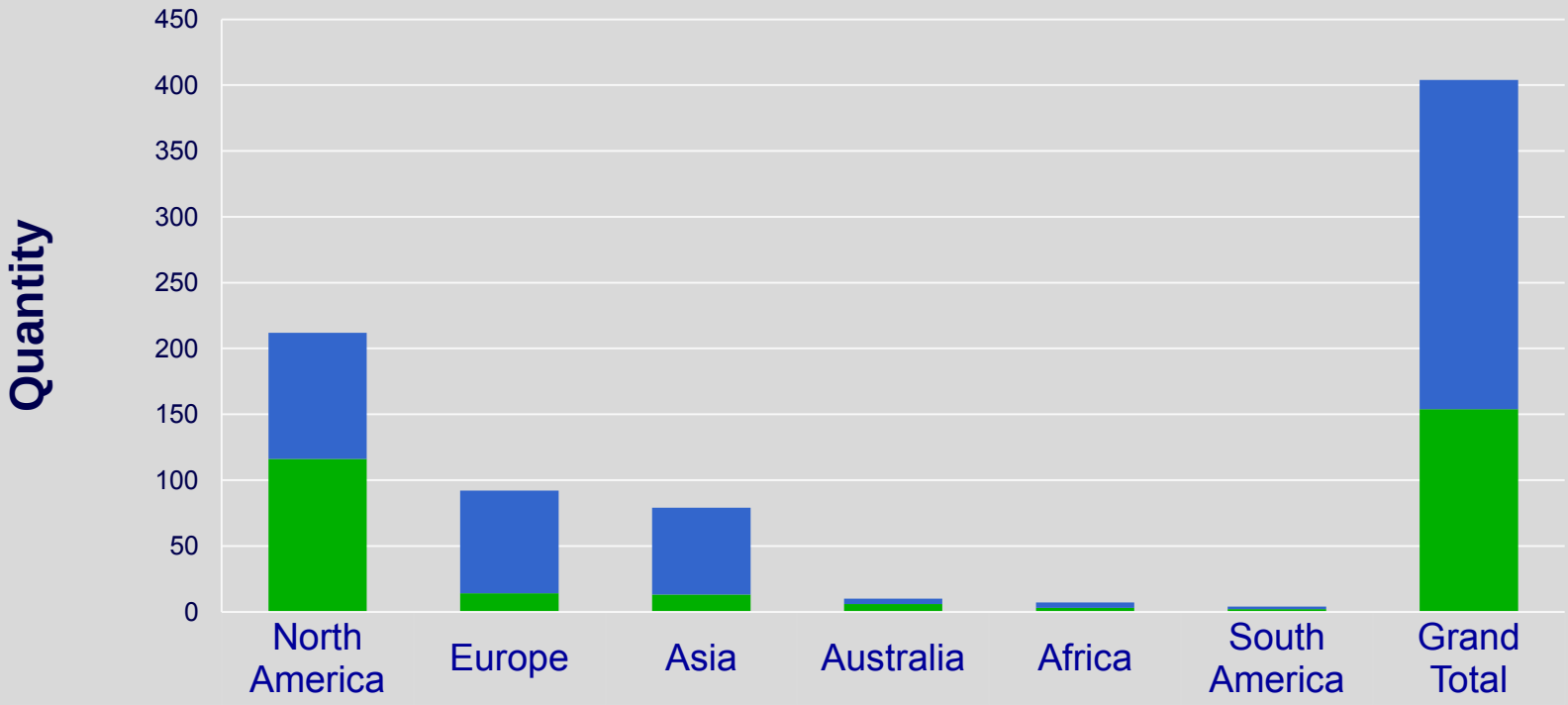
Battery system developed under ARRA

# The DOE International Energy Storage Data Base



# Projects by Region: 6 continents, 404 projects




| | North America | Europe | Asia | Australia | Africa | South America | Grand Total |
|---|---|---|---|---|---|---|---|
| Verified | 96 | 78 | 66 | 4 | 4 | 2 | 250 |
| Unverified | 116 | 14 | 13 | 6 | 3 | 2 | 154 |

# PNM's Prosperity Energy Storage Project

## Optimizing the Benefits of PV with a Battery Storage System

PNM Resources®

# Agenda

System Description

PV Smoothing Algorithm Results and Optimization

PV Firming Algorithm Results

Peak Shaving Results and Optimization

Stacked Benefits Approach

Economic Analysis Framework

NEDO/Prosperity Project Integration

Lessons Learned

# Prosperity Project Description

## Project Description

- Designed to both smooth PV intermittency and shift PV energy for on-peak delivery
- First of 16 DOE Smart Grid Storage Demonstration Projects to go on line – Sept 2011
- Successfully demonstrating true Storage/PV integration to Utility operations with >90% availability

## 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

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

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THE UNIVERSITY of NEW MEXICO

# Prosperity Project Goals

•Develop an even more beneficial Renewable Resource Transferable Nationwide

•Created a dispatchable, renewables-based peaking resource – *achieved*

•Combined PV and storage at a substation targeting 15% peak-load reduction – *achieved*

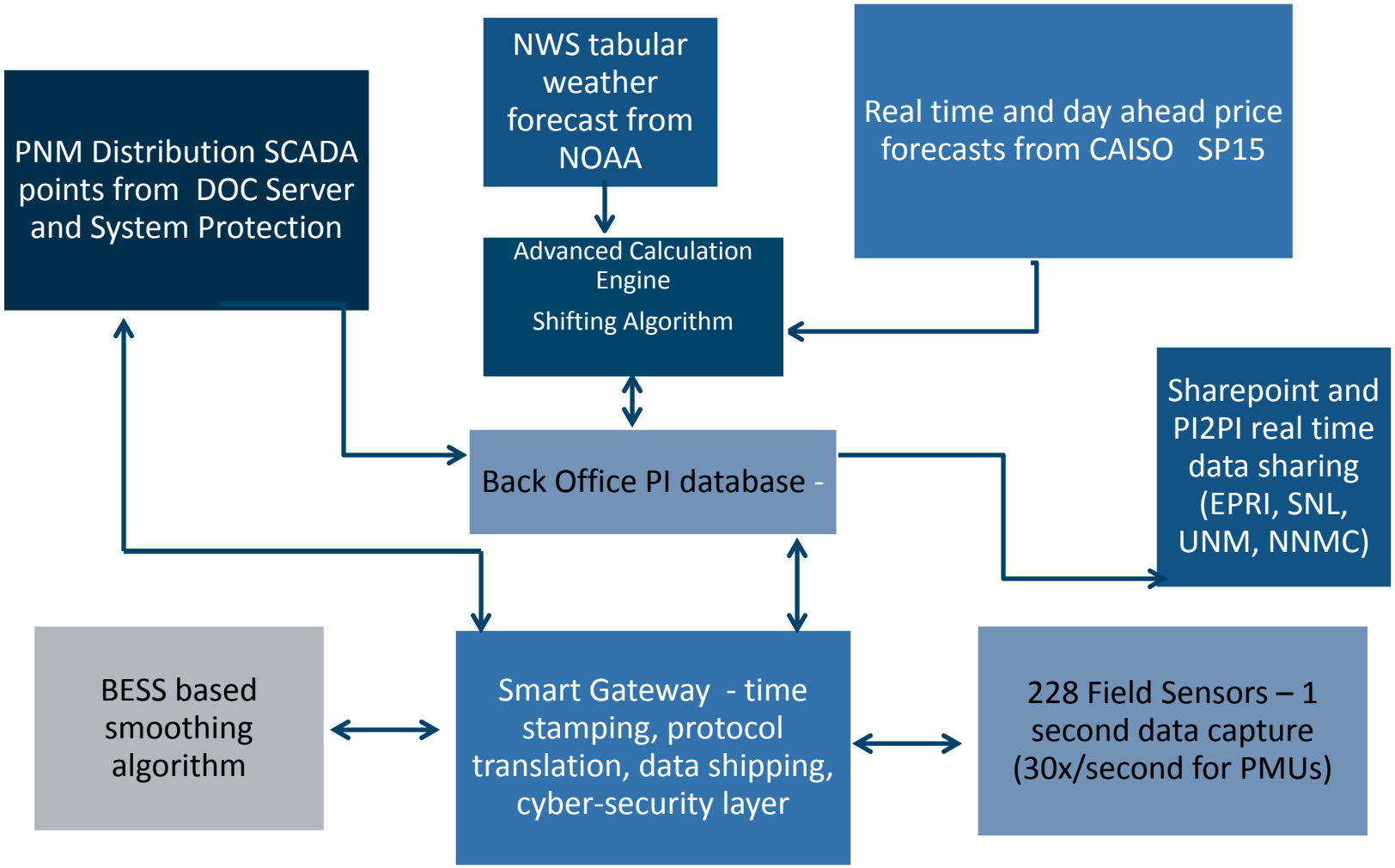
•Demonstrating a combination  that can simultaneously mitigate voltage-level fluctuations as well as enable load shifting – *achieved*

•Developed power system models (baseline and projected), and cost/benefit economic models *achieved/underway*

•Generating, collecting, analyzing and sharing resultant data – Strong public outreach – *achieved*

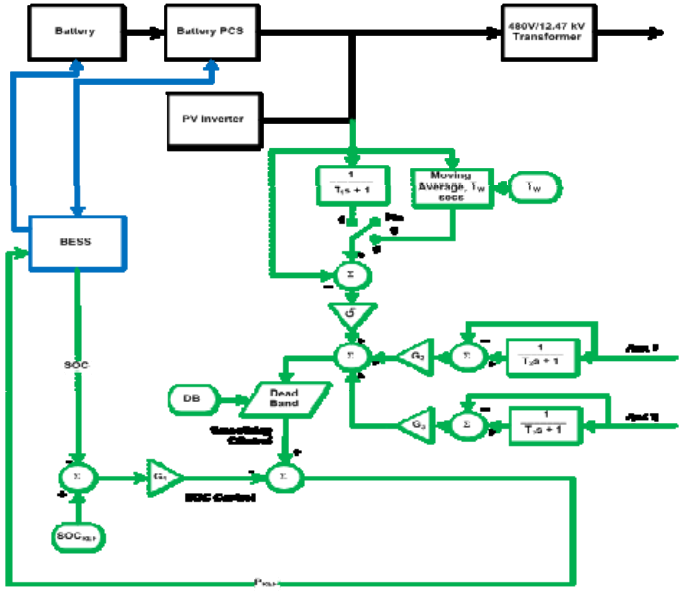
•Enable distributed solutions that reduce GHG emissions through the expanded use of renewables – *underway*

# Prosperity Control/Communication Overview – Utility Grade Smart Grid Sophistication



# Prosperity - PV Smoothing Algorithm and Tests

## Smoothing Algorithm Flow Diagram



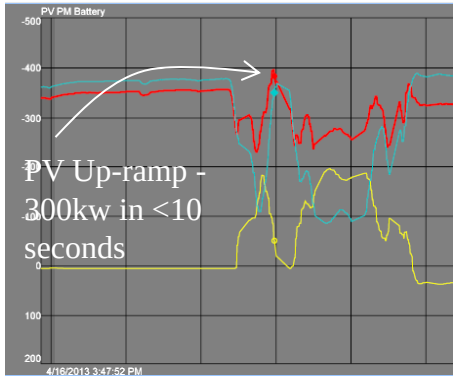

•Developed by Sandia Labs - Capable of changing inputs, gains and calculation routines as well as accommodate external inputs (from outside the system)

•MATLAB modeled by SNL and UNM to pretest and validate field data

## Smoothing Test Plan

Various configurations and control inputs tested since Sept 2011

- Algorithm
  - Moving Average
  - Low Pass Filter
- Percent battery capacity (40, 60, 80 100%)
- Control Inputs
  - PV Meter
  - Irradiance sensors (single and average)
- Tested to large ramp rates from co-sited PV (PSi panels)

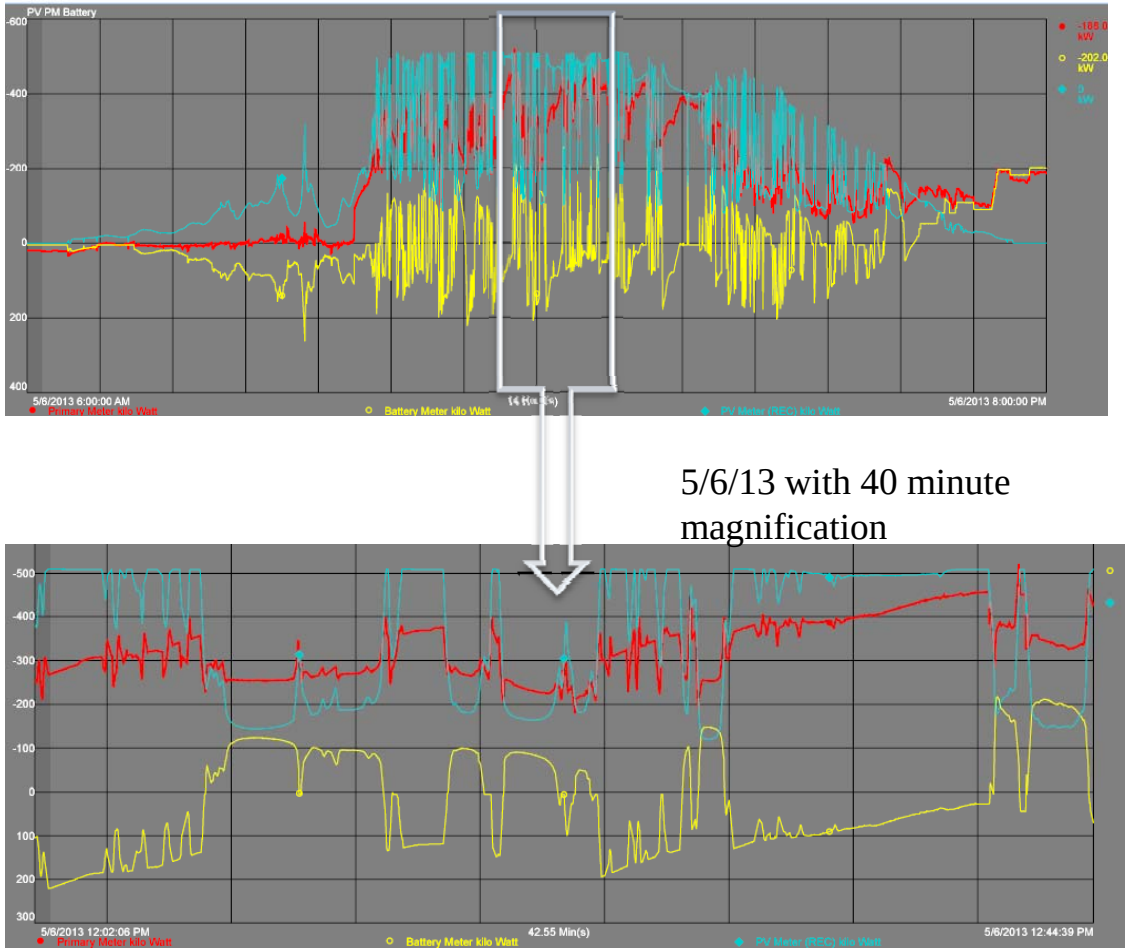



PV Up-ramp - 300kw in <10 seconds

# PV Smoothing Demonstration

## Smoothing Test Plan Results

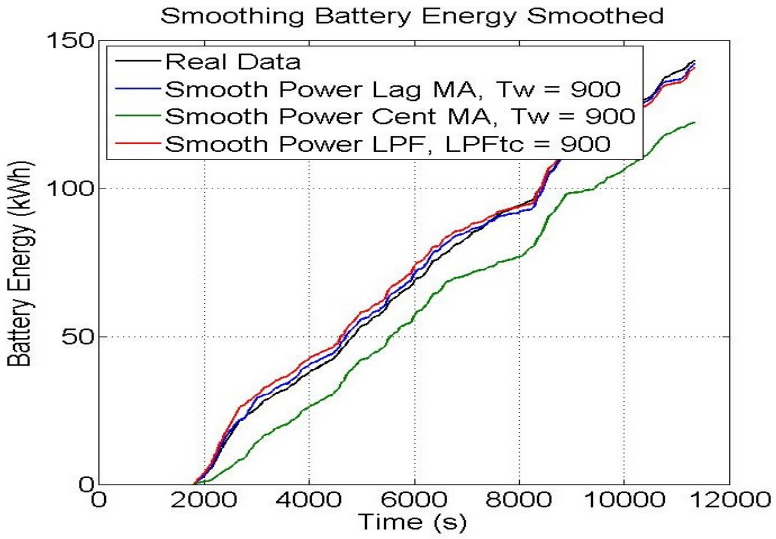
- Variety of control inputs – PV Meter, Irradiance Sensors (average, individual)
- Variety of gains on input – tests different capacities of battery use
- Optimization target: how much smoothing is enough?

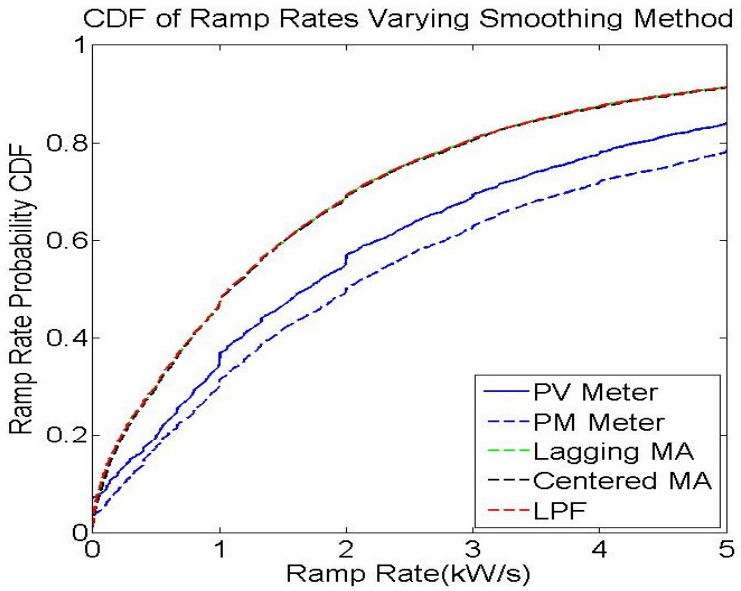



5/6/13 with 40 minute magnification

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

# Moving Average vs Low Pass Filter Smoothing




**Energy Use Analysis**

Shows LPF uses 18% more energy use compared to MA

Real Energy includes parasitic loads – models will calibrate this in next step

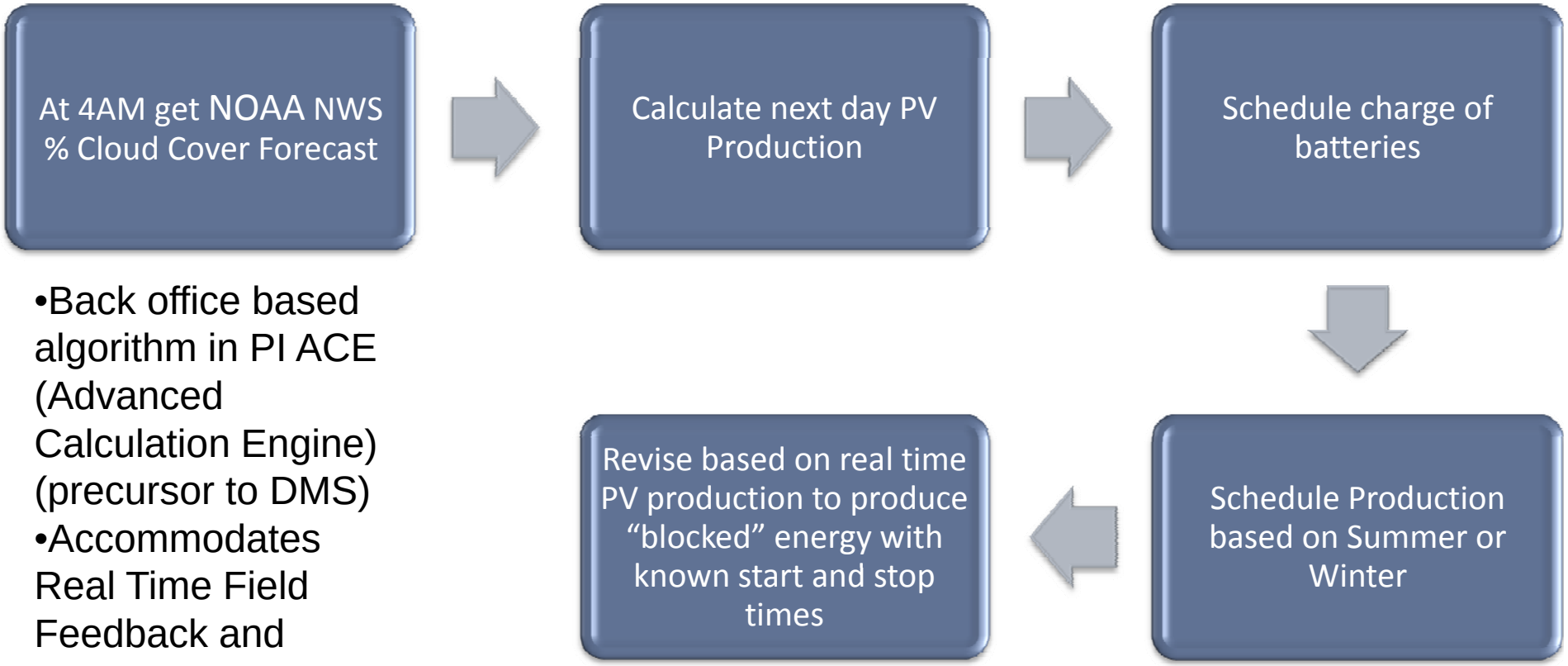
**CDF Analysis**

Shows effective smoothing (quantified) but does not show a big real difference between LPF and MA

**Load Tap Changer Analysis**

Further analysis targeting LTC operation counts and incorporating cost per operation

# Firming PV Algorithm Flow Diagram



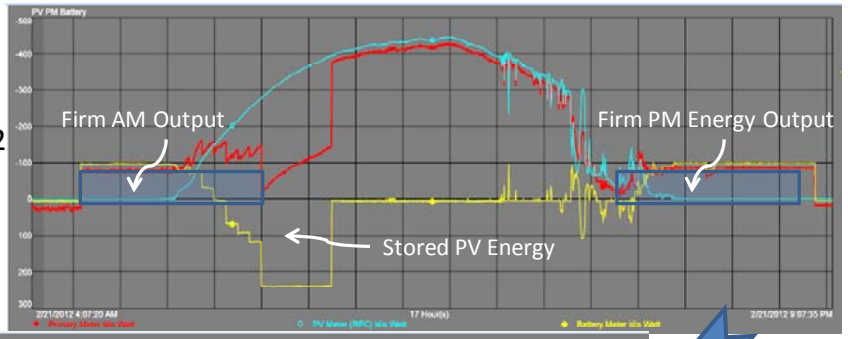

- Back office based algorithm in PI ACE (Advanced Calculation Engine) (precursor to DMS)
- Accommodates Real Time Field Feedback and External Inputs
- Utilizes PV prediction engine and Battery SoC model

# PV Firming Results

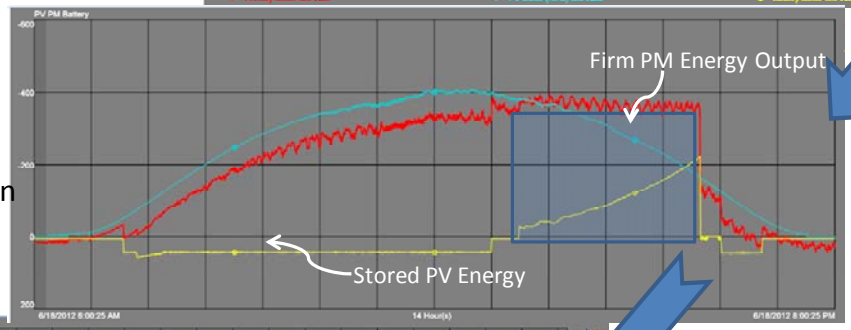
## Firming Test Plan Results

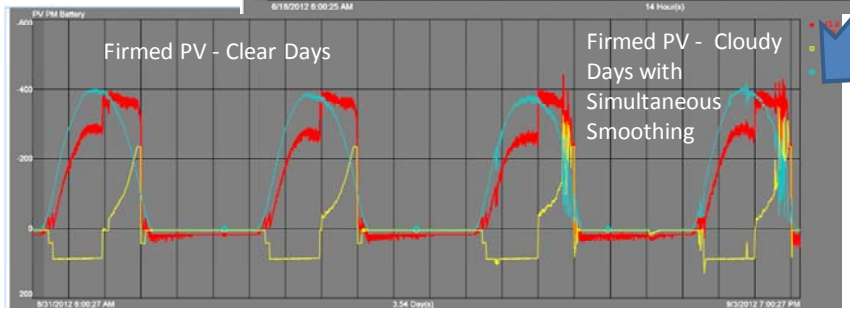
- Advancing Automation and Sophistication for firming PV
- Automated cloud forecast retrieval
- Automated PV energy calculation
- Recently added:
  - CAISO Real Time and Next Day LMP price signals
  - Substation peak shaving signals

Manual Shifting Implemented 2/21/12 Target is firm delivery for morning and evening peak




Automated Shifting- In service starting 4/12. Target is firm delivery for afternoon peak

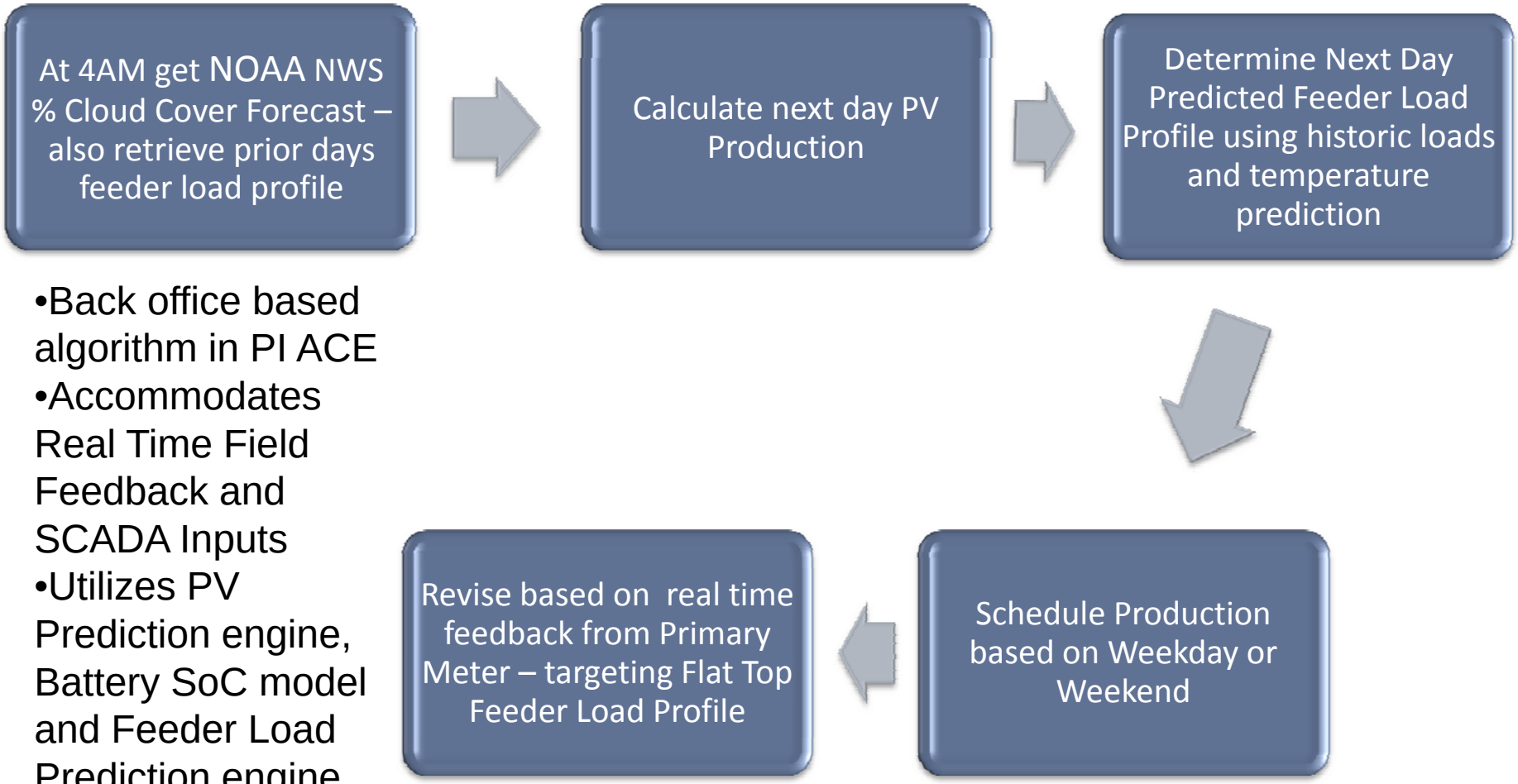



Refined Automated Shifting service starting 10/12. Automated NWS weather forecast incorporated into shifting Algorithm

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

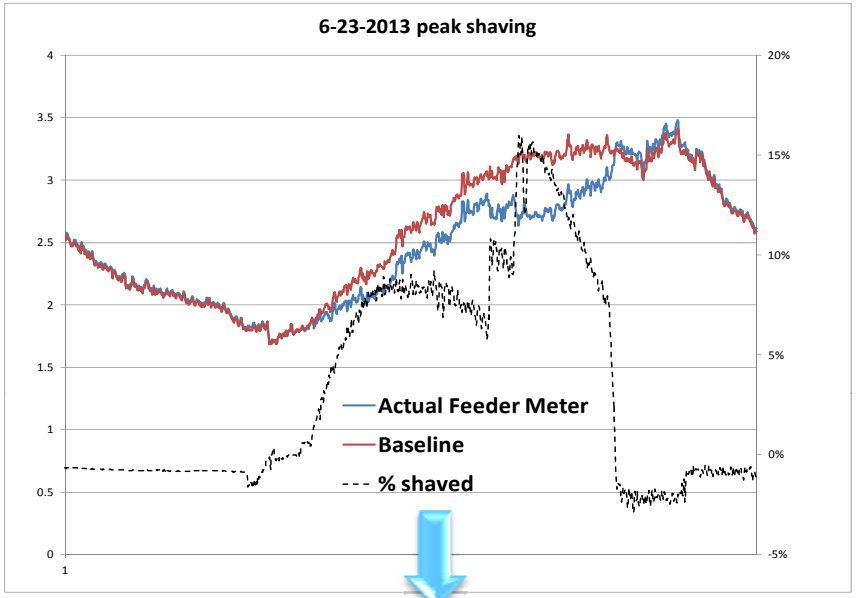
# Peak Shaving Algorithm Flow Diagram



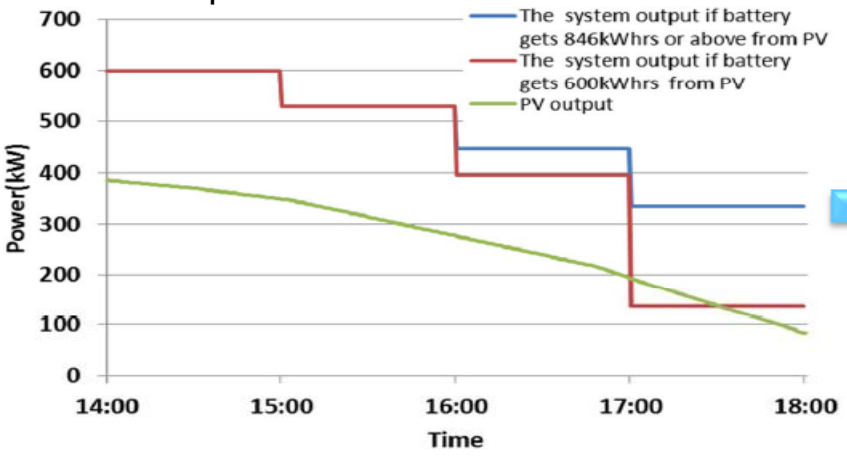

- Back office based algorithm in PI ACE
- Accommodates Real Time Field Feedback and SCADA Inputs
- Utilizes PV Prediction engine, Battery SoC model and Feeder Load Prediction engine

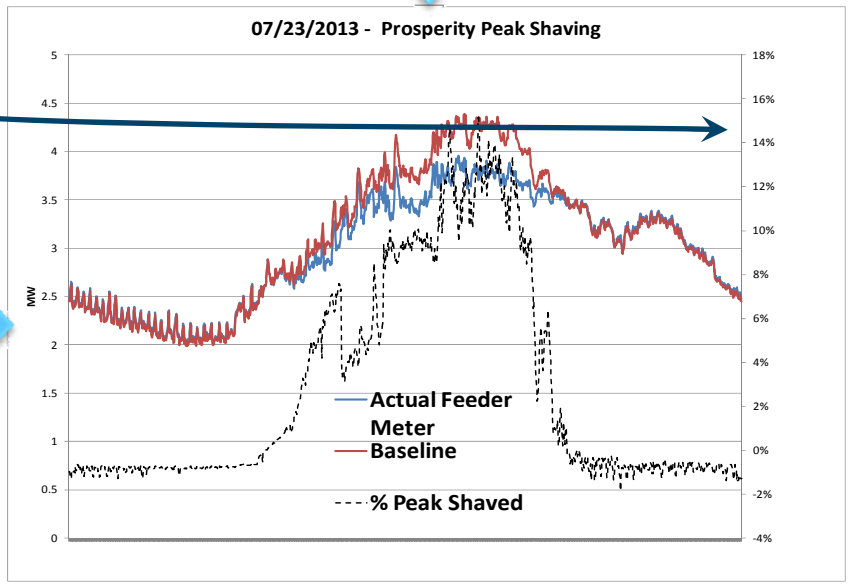
# Peak Shaving Results - Summer 2013

- Initial algorithm was refined to better predict feeder load profile
- Optimization required better historic knowledge in order to predict next day profile
- Refined PV production prediction was also incorporated
- 15% target reduction of feeder load apparent in optimized version
- Example of the embedded optimization table below

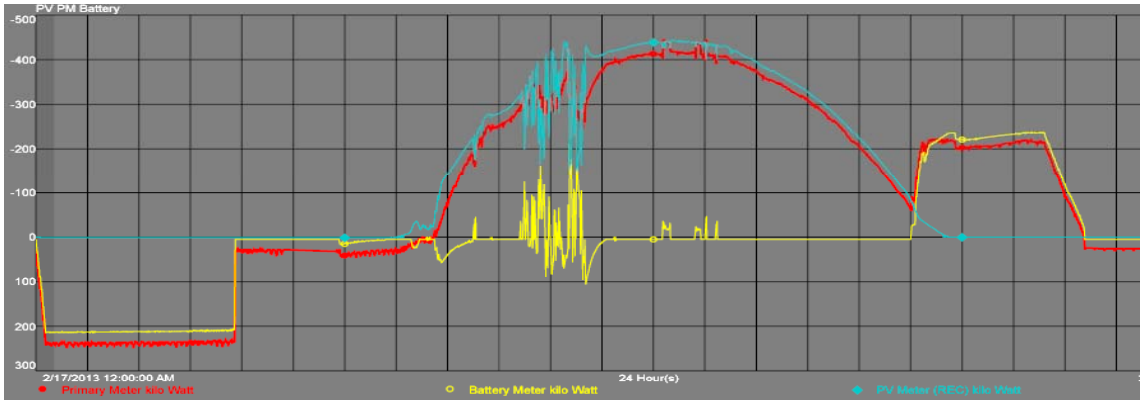



Optimization Table

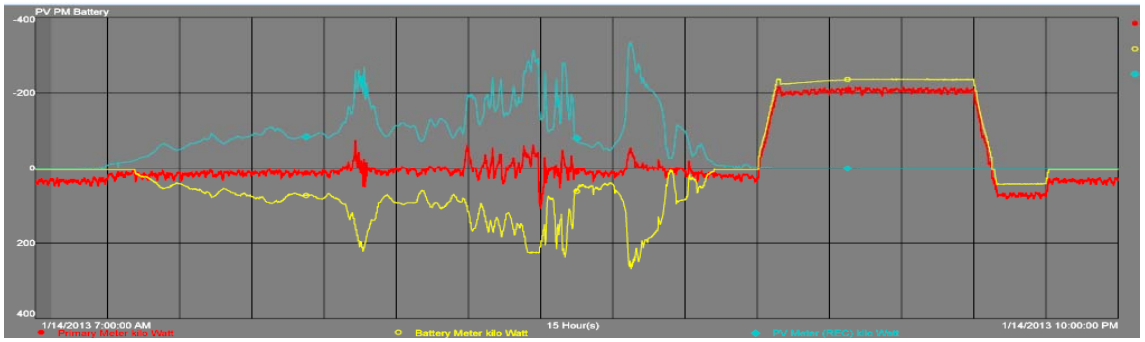


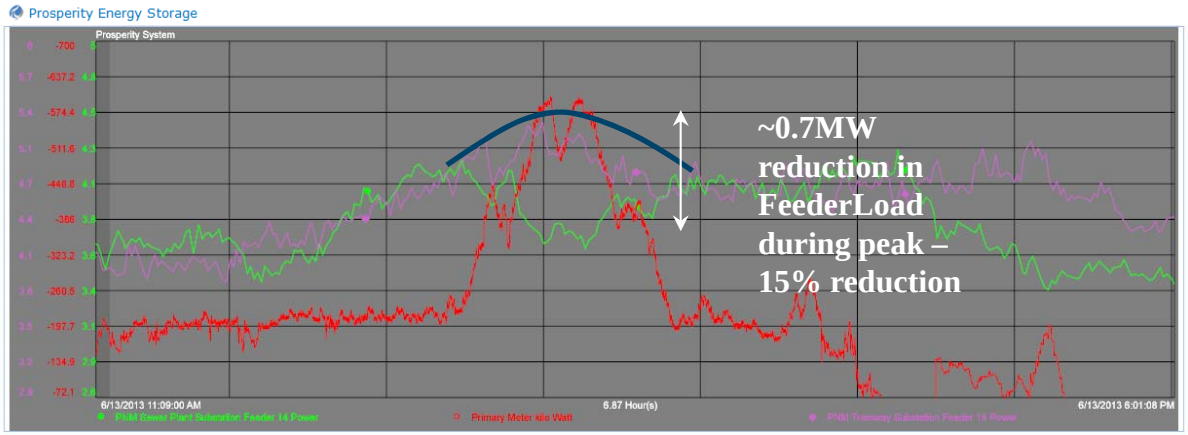
# Overall Examples – Stacked Benefits – Which do we pick?




**Energy stored from the Grid due to predicted high cloud cover (which didn't happen) .** Control system automatically decides when to store energy based on cloud predictions

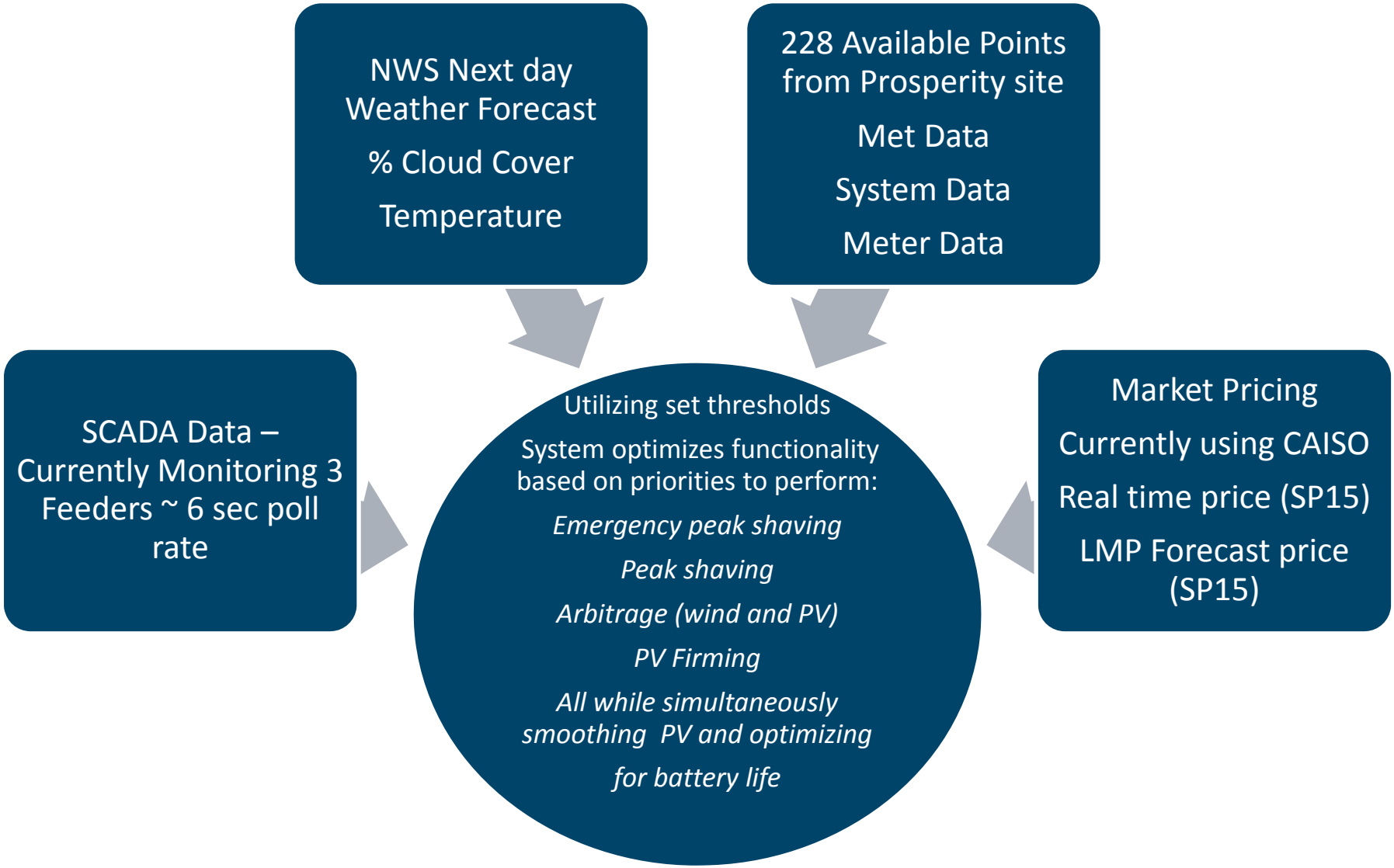



**Simultaneous Shifting and smoothing –** during a very cloudy day and dispatching a block of energy during evening peak.




**Local Feeder Peak Shaving –** Requires PV production and feeder prediction (Green Line is Feeder)

# Optimization of All Applications - Smart Grid Functionality



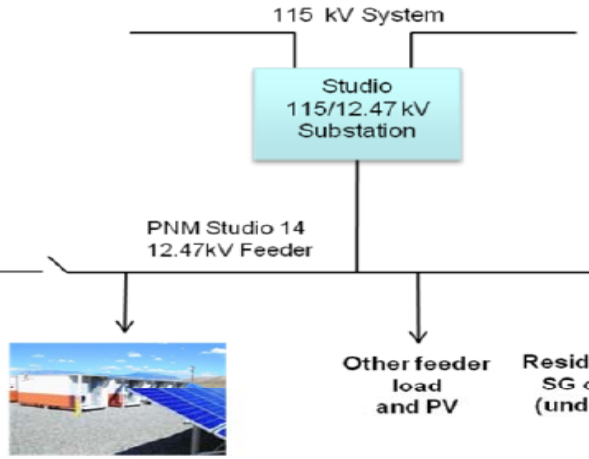
# Economic Evaluation Framework

- EPRI OpenDSS
  - Derive smoothing characteristics on feeder
  - Define peak shaving and smoothing impacts on LTC, transformers and other equipment and power quality on the feeder
- Matlab and other analysis
  - Determine optimal battery size and algorithm parameters for smoothing
  - Determine optimized battery operation in overall stacked configuration
    - Model Predictive Control
      - Overall optimization of shifting algorithm
      - High end sophistication to further optimize battery life versus benefit to grid
- EPRI ESVT
  - Derive economic $ benefits
- DOE Storage Computational Tool
  - Sensitivity Analysis of $ benefits

# Lessons Learned

- Shifting algorithms are dependent on weather forecasts
  - % cloud cover for PV prediction is weak and a better product is needed
  - Peak shaving success is highly dependent on accurate feeder load shape – historic load data and accurate temperature forecasts are a necessity
- Smoothing benefits are feeder specific
  - In order to gauge battery size and benefits dynamic modeling of PV and grid impacts is required
  - More needs to be learned about the effects of voltage swings and reverse power flow
- Economic models need to accommodate stacked benefits and ability of storage system to prioritize
  - Requires 8760 hour DG, load and pricing data inputs with high end sophistication DOE Storage Computational Tool
- Energy Storage is a great tool for the grid
  - Proven ability to provide multiple benefits – some simultaneously
  - Requires lots of data input
  - Back office DMS that accommodates the data and dispatches multiple units in a cyber secure fashion needs development – this is the centerpiece that enables multiple PV/Storage assets to solve grid issues both independently and in concert

# Integrating Smoothing Batteries with Gas Engine from separate site on the same Feeder

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**PNM Prosperity Project**

- Large-scale PV (500 kW)
- Large-scale Storage
  - 250 kW 4 hr. energy battery
  - 500 kW, 40 min power battery
- Smart Grid / SCADA integration

NEDO

Sandia National Laboratories

UNM

Mesa del Sol

**NEDO Mesa del Sol MicroGrid**

- Energy storage (small)
- Gas Engine (240 kW)
- Fuel Cell (80 kW), PV (50 kW)
- Demand response -- 100 kW Dummy load
- Electric Chiller/Thermal storage

| | |
|---|---|
| DER Smart Grid Integration | • **Coordinated operation of a gas engine from Mesa del Sol and Prosperity batteries for smoothing PV plant output** |
| Test Goals | • **Show Battery life extension by supplementing smoothing with the gas engine. Validate operation of separate DERs acting together via PI2PI** |
| Test Plan – used SNL Smoothing Algorithm | • **Performed 08/06-09 – initial results being analyzed – successful integration completed with minimal latency issues. Gas engine assigned "AUX" input into SNL algorithm** |

**Reference: Sandia Report SAND2-13-1603. "PV Output Smoothing using a Battery and Natural Gas Engine-Generator"**

# Public Outreach www.pnm.com/solarstorage


**Real time data presentation**

**Presentations**

**Publications**

**Education & Outreach**

**Articles**


## Solar storage

| | |
|---|---|
| Student Outreach– UNM and NNMC | • Mid School Friday technical projects for Espanola School District – via NNMC<br>• Project data and analysis used in wide curriculum at NNMC and UNM<br>• Project engrained in Graduate and PhD studies at UNM Engineering<br>• 18 IEEE and other source Technical Papers published or accepted |
| PNM Outreach | • Formal Alignment between PNM, UNM NNMC, SNL and EPRI<br>• 30 Project presentations at various forums – nationwide and globally<br>• Over 40 project site tours to local and national stakeholder groups |
| Industry Outreach | • EPRI Technology Transfer Award - 2013<br>• Over 20 Industry presentations on project results<br>• Local and national press coverage |

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