New Mexico Society of Professional Engineers

E Week 2012

Renewable Energy and the Need for Energy Storage

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PNM

Renewable Energy and the Need for Energy Storage - Agenda

- Rules for operating the grid – matching load to resource - always
- Impacts of Renewables
- Need for Storage
- Solutions - What's available and What PNM is doing

Framework for Accommodating Renewables - Net Electricity Generation by Energy

Energy Source	Net Electricity Generation (GWh)	Percent of Total Net Generation
Coal	2,000,000	48.5
Petroleum liquids[a]	31,200	0.8
Petroleum coke	14,200	0.4
Natural gas	877,000	21.3
Other gases[b]	11,600	0.3
Nuclear	806,000	19.6
Hydroelectric	248,000	6.0
Other renewables[c]	124,000	3.0

In a general sense this has to change to 20% by 2020

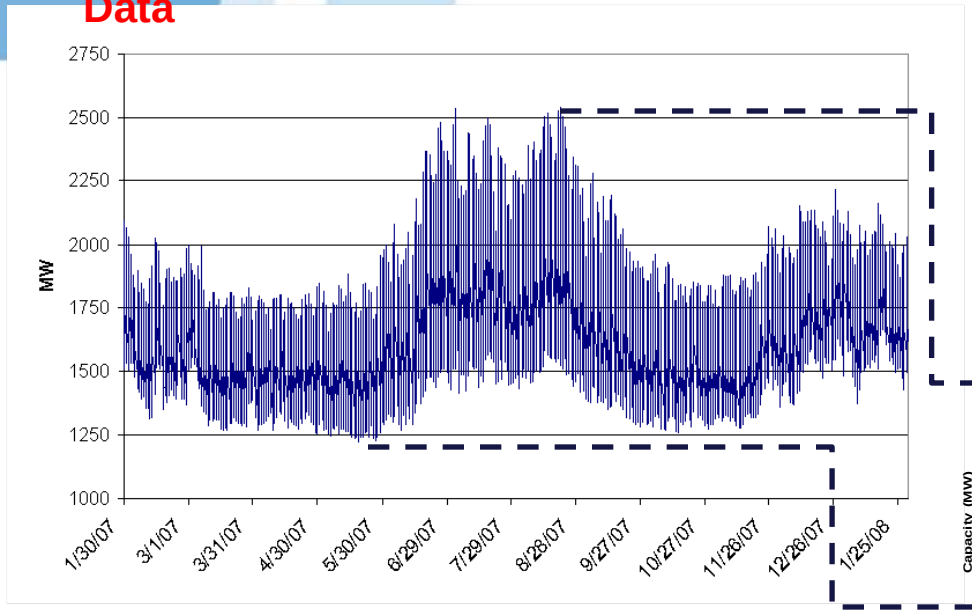
Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use (2010), National Academies Press

Framework for Accommodating Renewable Energy – Operating Rules

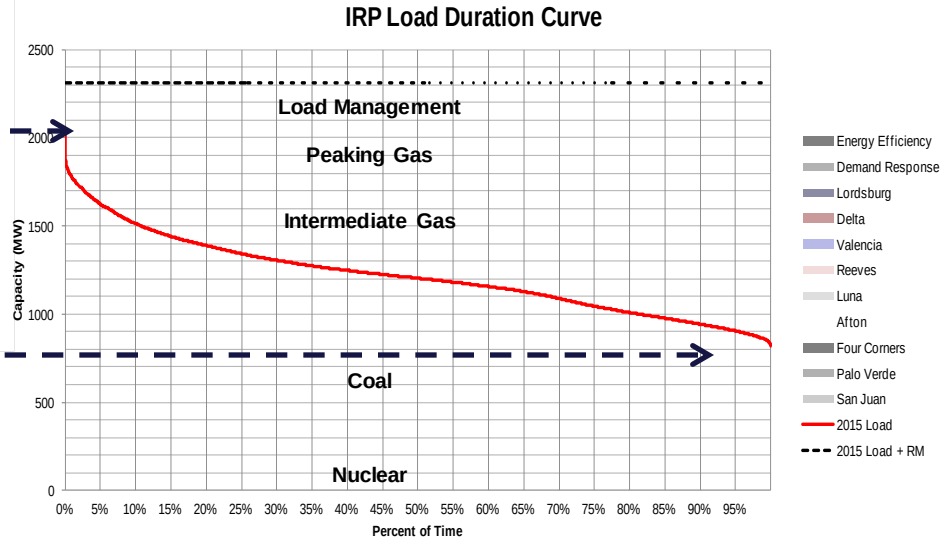
- Resources have to match load – always (365/24/7/525600/31536000/1892160000) - down to 60Hz
  - Transmission Level – High Voltage – Federal (NERC) Jurisdiction
    - Issues can cascade and cause very big problems on an interconnected Transmission Network
    - Straying from rules invokes serious penalties ($M enforced by Federal Regulators)
- Customer Loads are very sensitive (and growing more sensitive) and have to be served with quality power
  - Distribution Level – Lower Voltages - NMPRC Jurisdiction
    - Voltage variances directly affect customer loads/equipment

Key Rule – Load must match output of generation resources – always

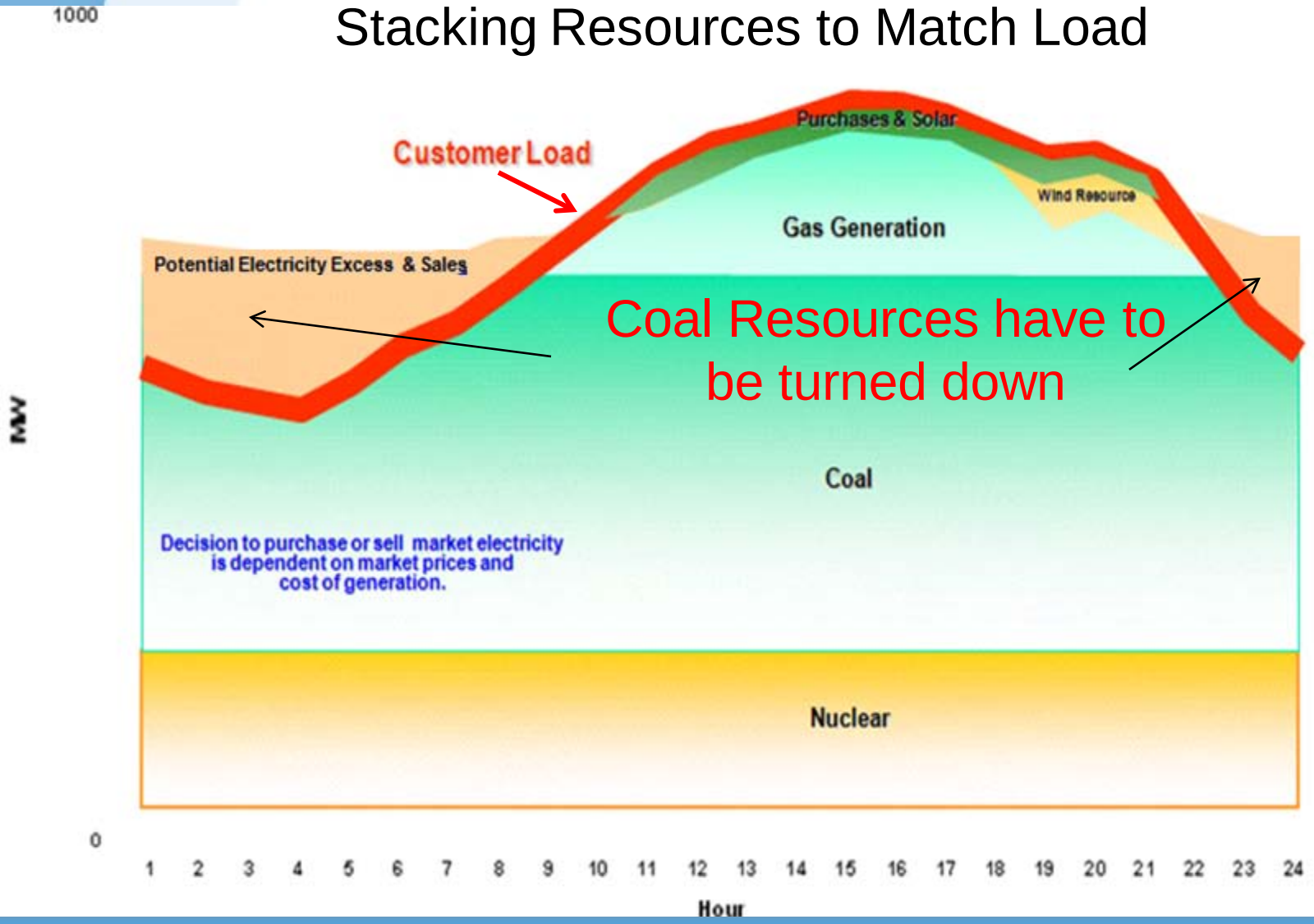
1 Year - PNM Balancing Authority Load Data



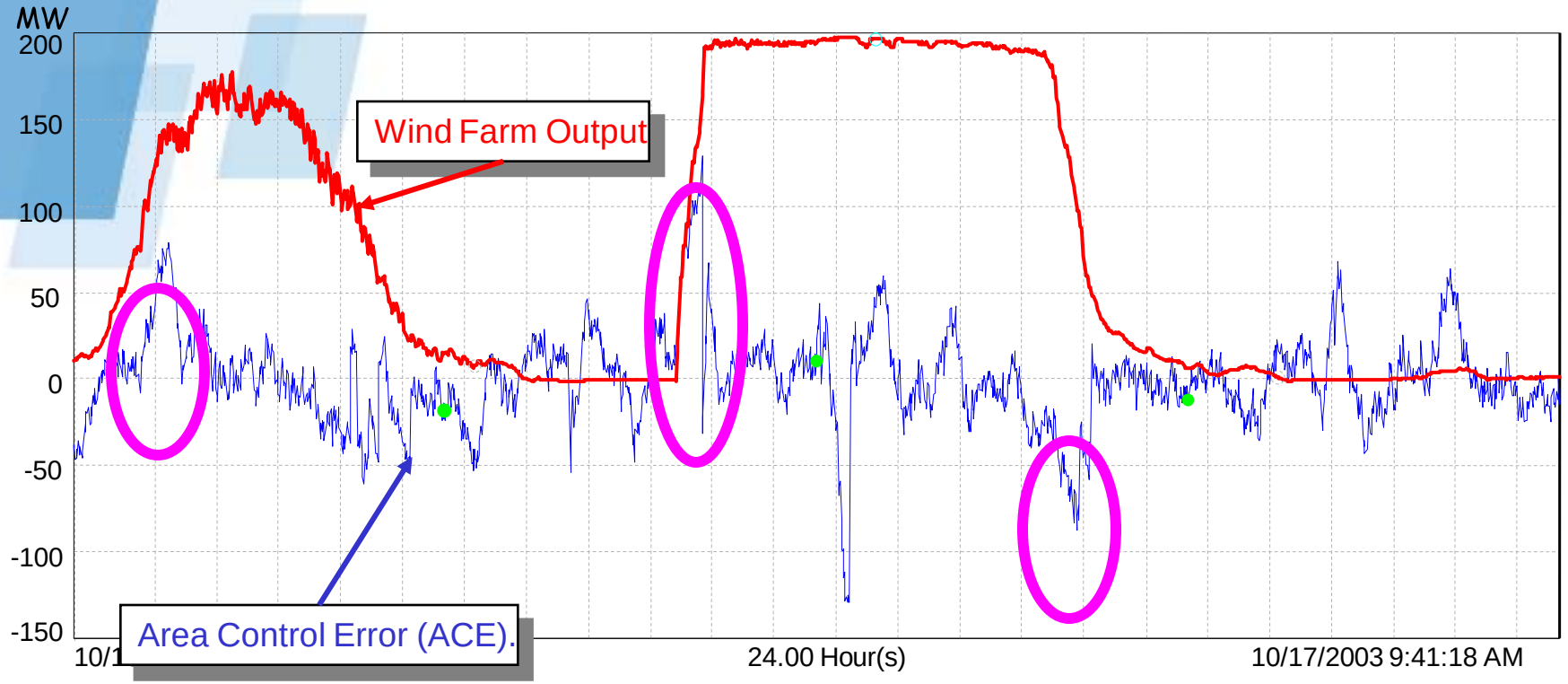
Variety of resources are stacked to meet load – some operate only a few hrs/yr, others all the time



How the Match is Made – 24 Hour View on Stacking Resources to Match Load



Wind Variability – Transmission and Generation Level Impacts



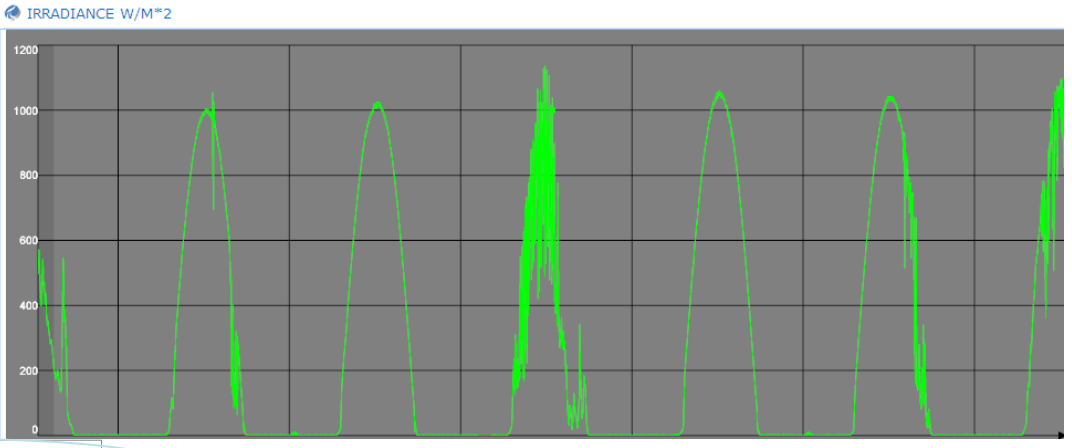
➢NERC CPS-2: The average ACE for at least 90% of a clock-ten-minute periods during a calendar month must be within a specific limit. *PNM's current limit is ± 38 MW.*

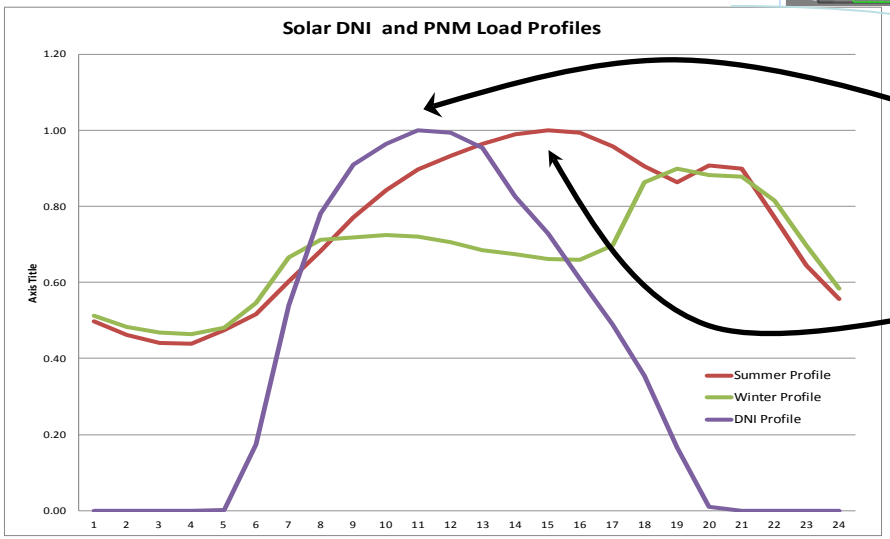
➢ACE deviates by more than 40 MW as a result of rapid changes in wind power output, affecting CPS-2 for this sample month (average CPS-2 was still above 90%)

Solar PV Variability - Feeder Voltage Stability and Misalignment to Peak

1 second interval PV output data from PNM Prosperity Energy Storage Site – 500kW c-Si PV

2/16 to 2/22/2012





Solar peak occurs ~ 2 hours prior to:

system peak in summer, offset by ~4 to 8 hours in winter

Addressing Renewable Intermittency – Potential Solutions

1. Characterize Issue: Energy vs. Power
   - Power – fast acting (seconds to minutes) – Voltage and Frequency Issue
     - Wind - Regulation of fast output changes
     - PV – Voltage stability of high penetration feeders
   - Energy – slower (minutes to hours) - Aligning to Peak Hours
     - Align PV to peak periods – 2 hour shift in summer
     - Wind – many hour shift (problematic)

2. Screen Solutions based on
   - Energy or Power
   - Size of Problem (kW or MW)
   - Low to High Life Cycle Cost
   - Readiness and Viability

Storage Types

Batteries - Power and Energy

- **Multiple types of chemistries**

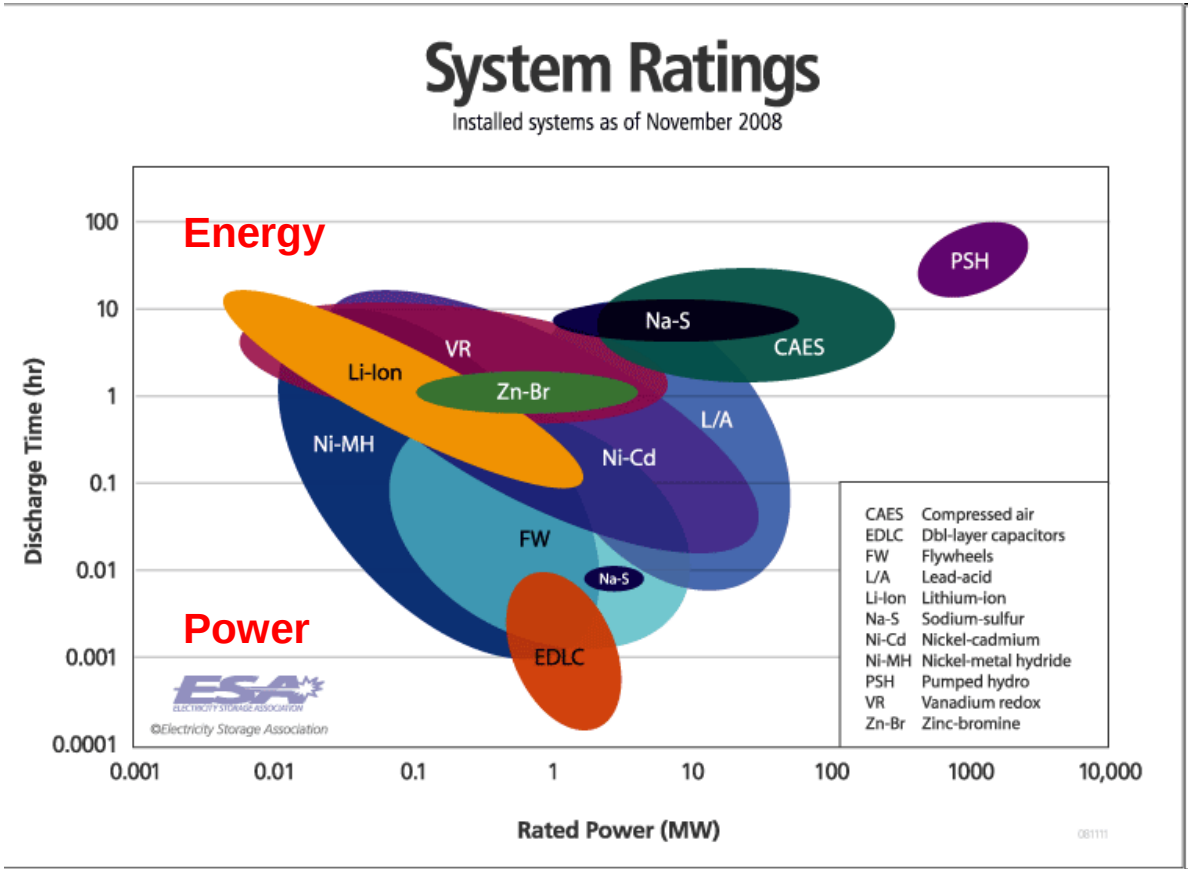
Thermal - Energy

Flywheels - Power

Supercapacitors/ Ultracapacitors - Power

Compressed Air Energy Storage (CAES) - Energy

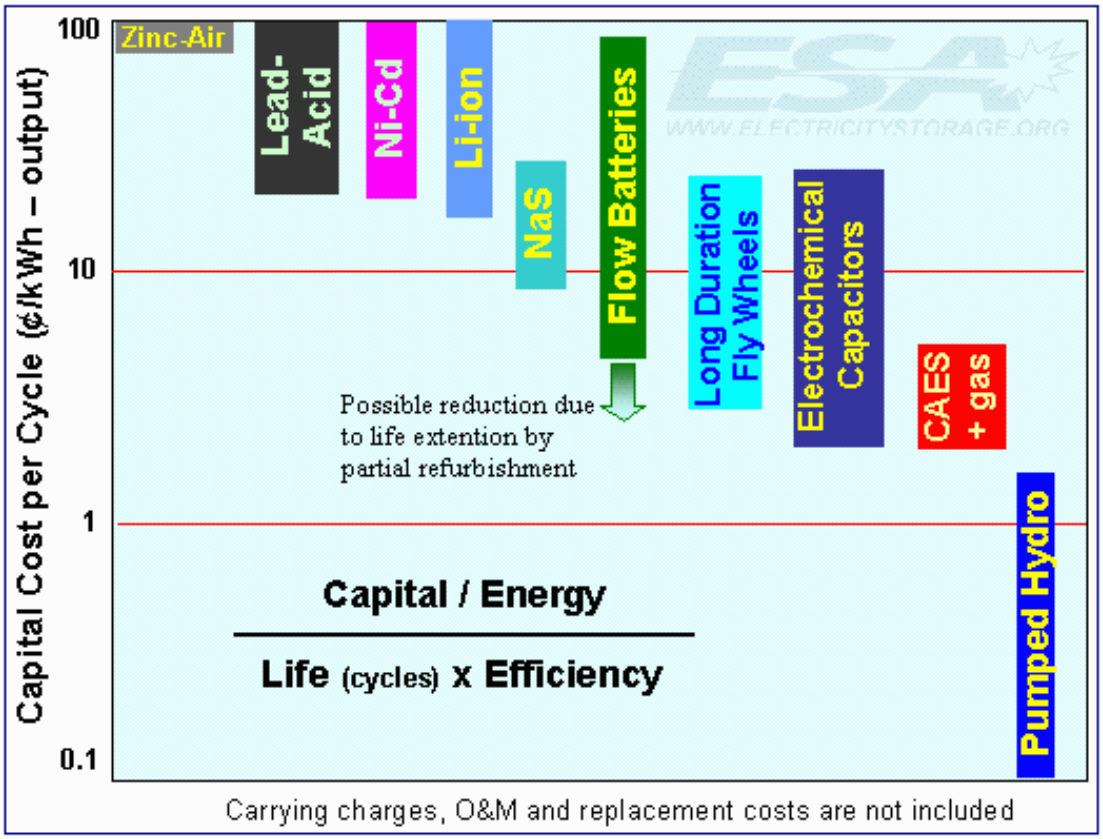
Pumped Hydro – Energy



Source: Electricity Storage Association

Storage Costs

- More expensive than some traditional solutions
  - Gas Peaking
  - Gird Voltage Stability
  - LTCs
  - Cap Banks
- Battery costs are eroding with increased R & D and manufacturing
  - Lowering cost
  - Increasing Life

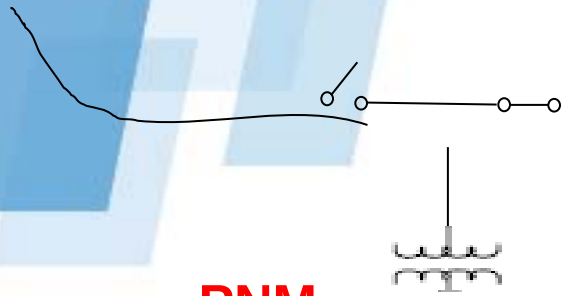


Source: Electricity Storage Association

What's PNM doing?

- PNM/EPRI Smart Grid Demo
  - Use Case Analysis 2008
  - Feeder Modeling 2009-2011
  - Communication/control system architecture development 2009-2011
- PNM/DOE – Prosperity Energy Storage
  - Utility Side Project
  - One of 16 DOE Smart Grid Storage Demonstration Projects
  - First to come on-line, on budget on-time Sept 2011
- NEDO/Mesa del Sol Project –
  - Implementing various customer side technologies – Spring 2012
- NIST Cybersecurity
  - PNM actively participating in Stakeholder Process – on-going

Mesa del Sol – Proximate Collaboration of Numerous Related Efforts



PNM installed PV + Battery Storage

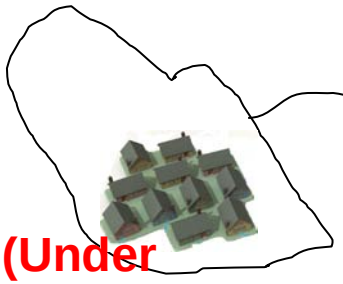
To Studio Substation-Feeder 14

Switchgear

Fraunhoffer Solar Test Facility

Studio Substation – Feeder 14

Phase 1 Residential



Residential (Under Construction)

Albuquerque Studios

Town Center

Site for MdS/NEDO commercial Energy Efficient building

Prosperity Energy Storage Project Creating Hi Value Renewable Utility Scale Resource

Project

- Is designed to both smooth intermittency and store energy for later usage
- Development of control algorithms is key to this project

Equipment

- 500 kW PV (energy for about 100 homes)
- Battery system for “shifting”
- Battery system for “smoothing”
- Cyber Secure , High Resolution Data Acquisition

- **System Commissioned September 2011**
- **First of 16 ARRA Funded DOE Smart Grid Storage Demonstration Projects to go on line**

PNM/DOE Smart Grid Storage Demonstration Project Objectives

Prove a battery system can achieve multiple Benefits – simultaneous Smoothing and Shifting (Power and Energy)

Create a dispatchable, renewables-based peaking resource

Combine PV and storage at a substation to achieve a minimum of 15% peak-load reduction on an associated distribution feeder

Demonstrate that this combination can mitigate voltage-level fluctuations as well as enable load shifting

Quantify and refine the associated performance requirements, operating practices, and cost:benefit, particularly for regions well-suited for distributed generation

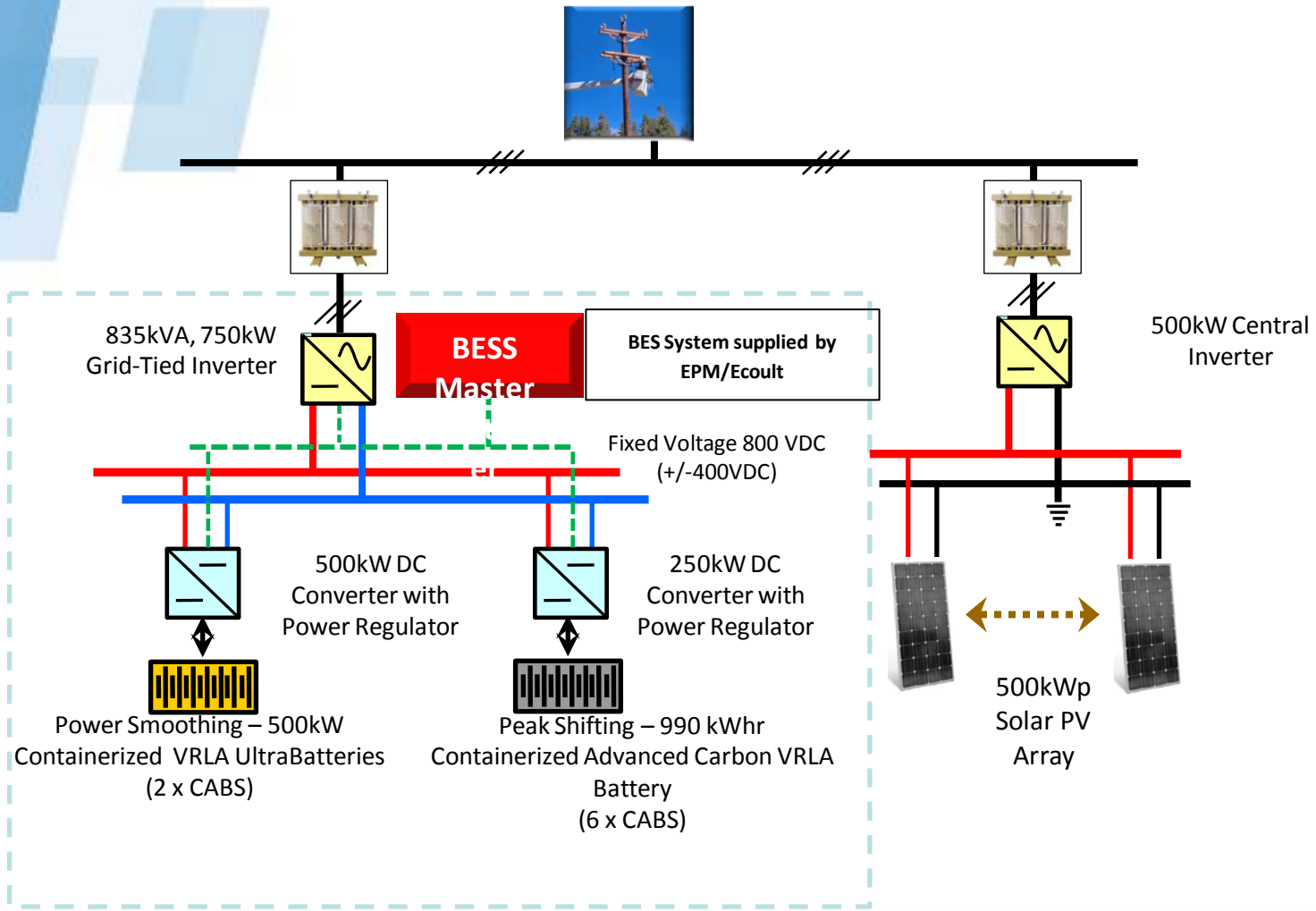
Generate, collect, analyze and share resultant data

Enable distributed solutions that reduce GHG emissions through the expanded use of renewables

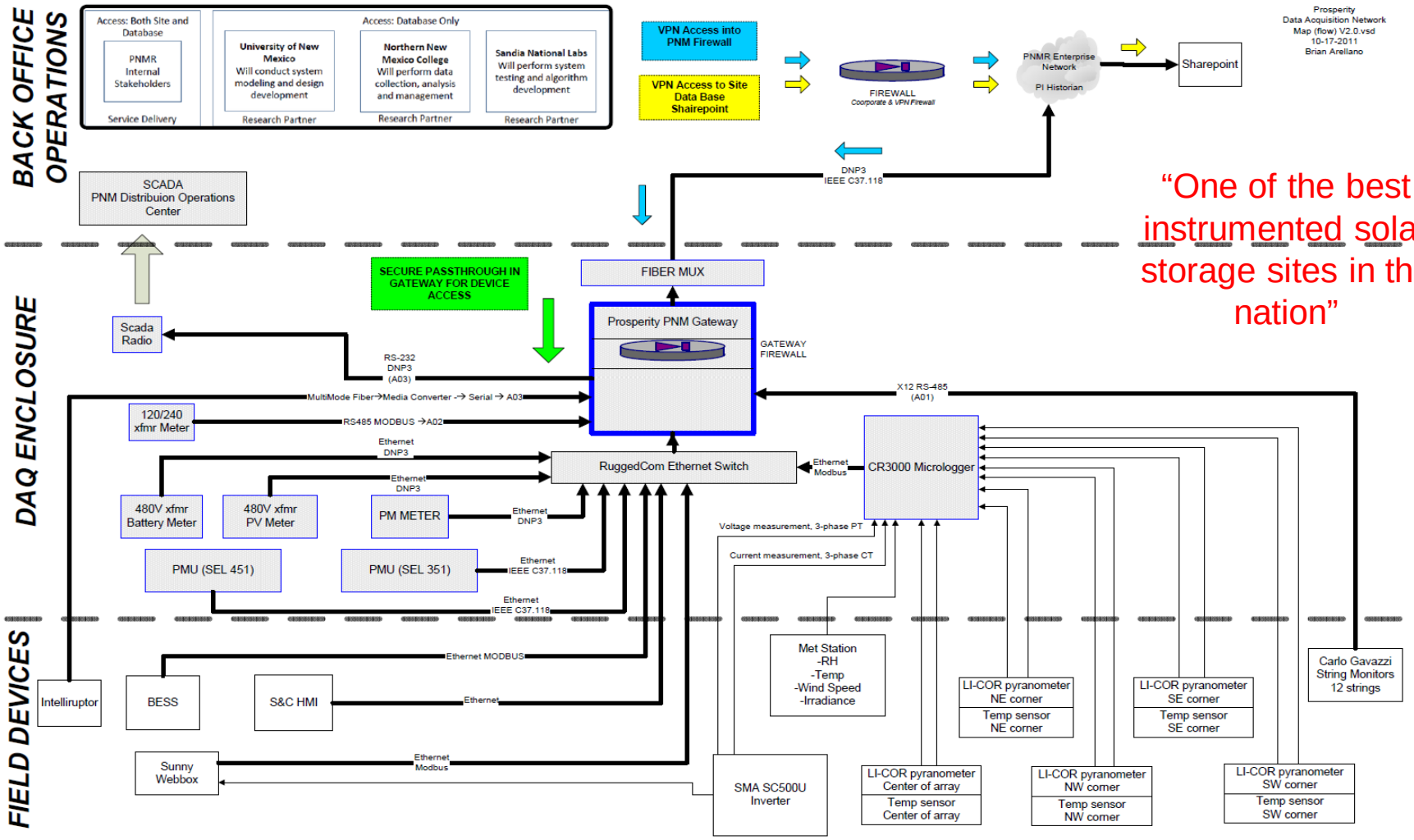
Modeling – Key to Field Success

- UNM Based Effort
- Utilizing Leading Edge Distribution System Models
  - OpenDSS (EPRI)
  - GRIDLAB-D (PNNL)
- Allows understanding and quick development of control methodologies
- Allows system wide assessment of benefits
- Allows results to be transferable to the Utility Industry

Schematic of the Prosperity PV/Energy Storage System



Details – Data Acquisition System Specification/Engineering Architecture Diagram



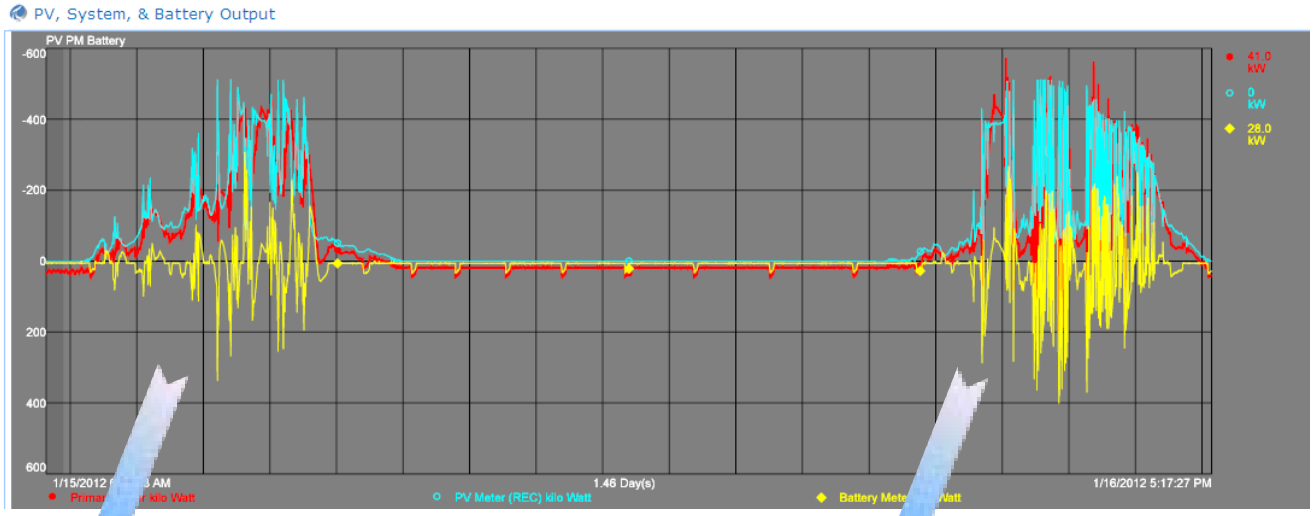
"One of the best instrumented solar storage sites in the nation"

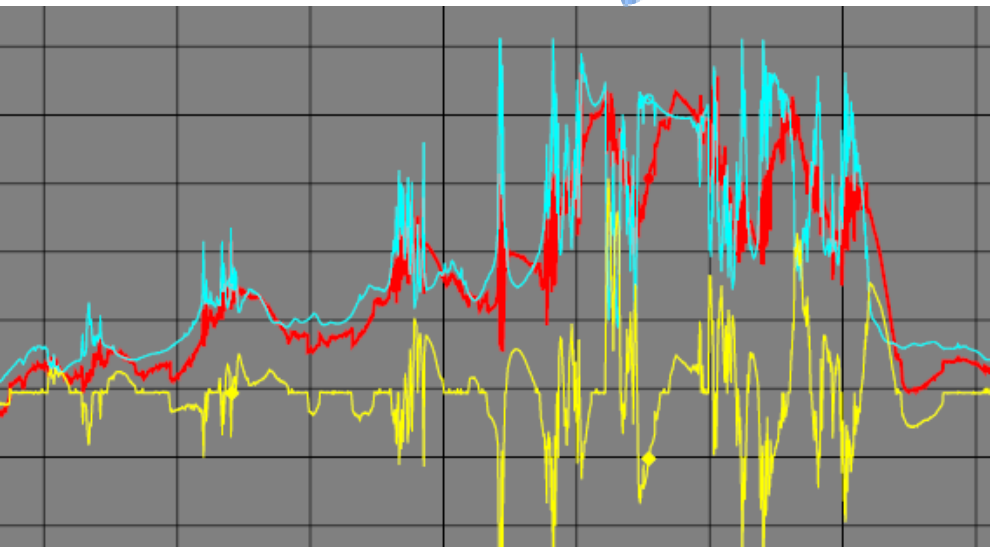
Smoothing Continually Demonstrated

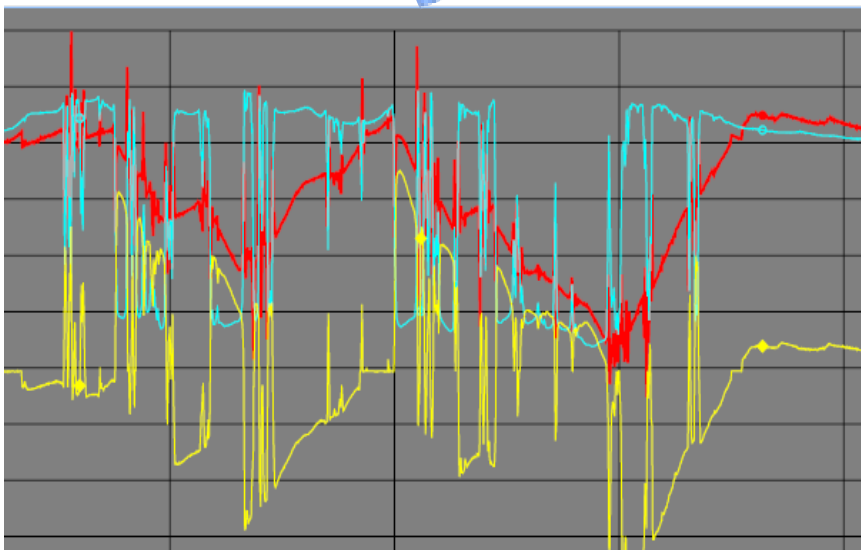
Data: 1/16/2012

Various inputs/gains being tested

Blue – PV Output
Yellow – Battery Output
Red – Primary Meter (Site Output)

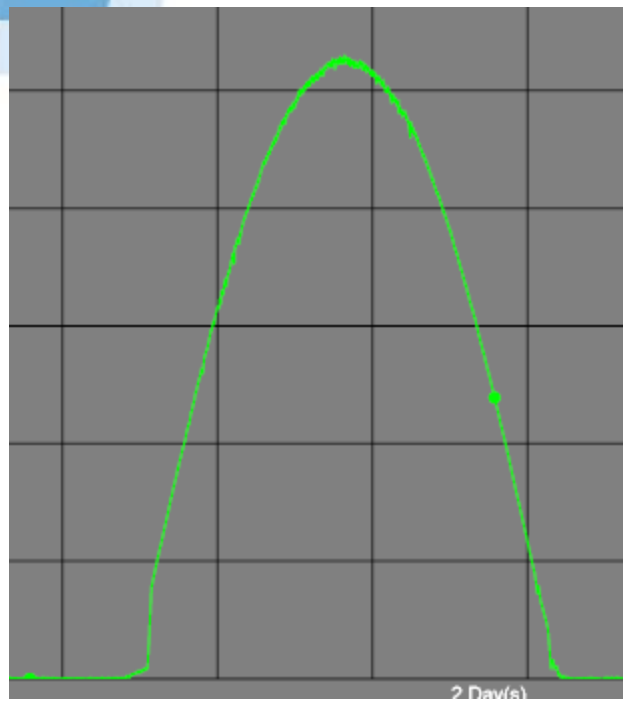




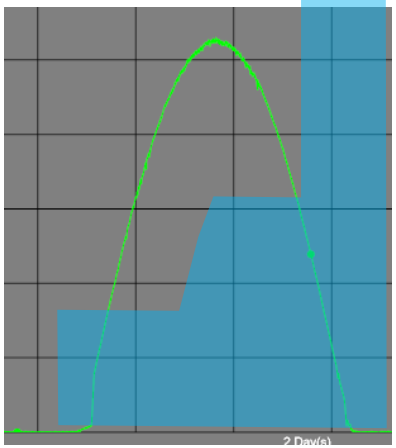


Applying Storage – Battery Shifting Concept – Firming

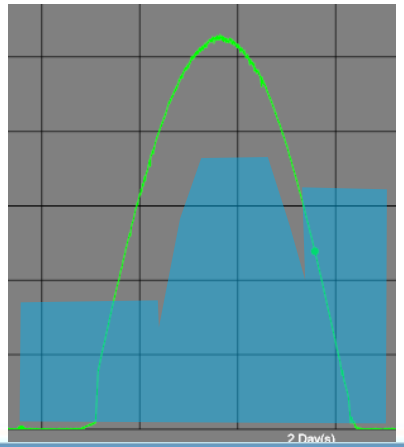
Feb 20 , 2012 actual data



Idealized Summer Profile Targeting single PM Peak

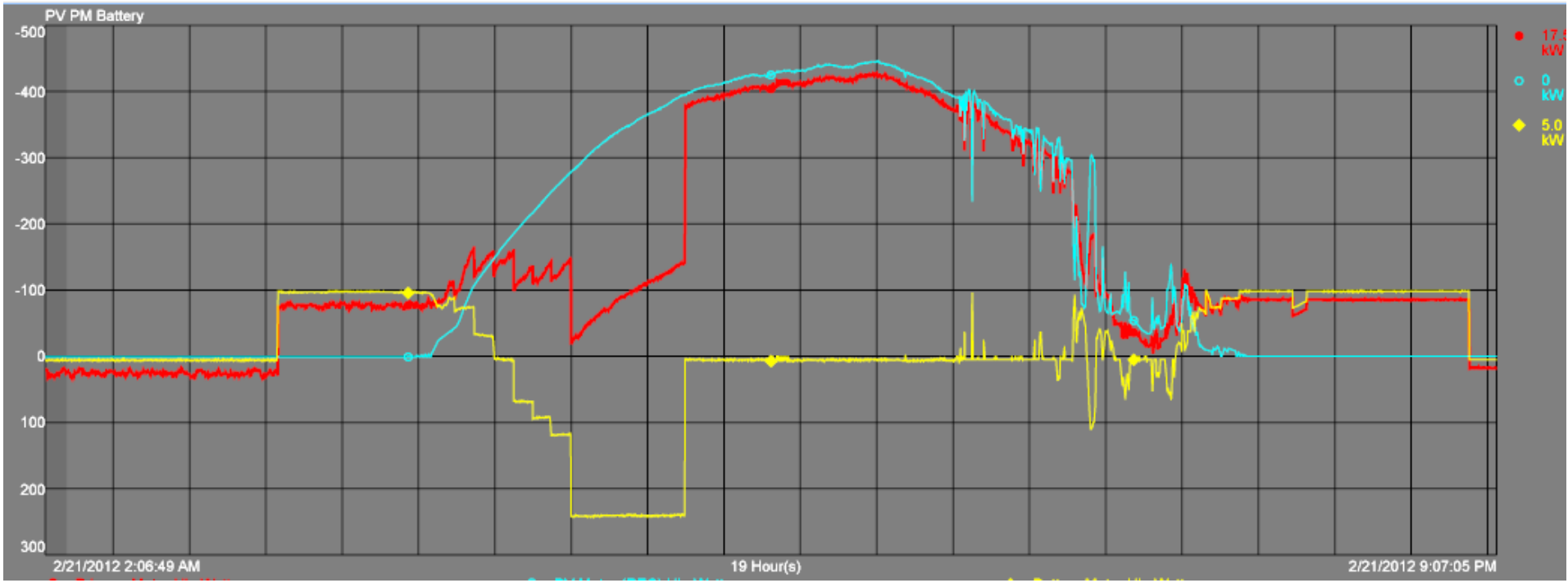


Idealized Winter Profile Targeting dual AM/PM Peaks



Applying Storage – Battery Shifting Data Next Step Implementation

First iteration of Shifting using Predictive Algorithm 02/21/12



Next Steps - Implementing Test Plans

- **Algorithm Development**
  - Smoothing– coded V1 in place – testiing various inputs and filters throughout test period
  - Shifting – Initial algorithm developed and manually implemtned
  - Next step to refine predictive elements and increase complexity
    - Need for accurate next day PV forecast
    - Result forecasted to be multi-variant /optimization based algorithm – extensive effort – start simple and grow in complexity
- **5 Test plans – 2 initiated**
  - Smoothing – Oct 2011 through Dec 2013
  - Peak Shaving – winter and summer peaking period 2012-2013
  - Firming – winter and summer 2012 and 2013
  - Arbitrage – Shoulder periods throughout test period
  - All of the above – summer 2013

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