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Grid of the Future

Integration of Renewables

Energy Storage

Smart Grid

Presentation by
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Lead Renewables Power Engineer
Grid Operations

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Grid of the Future

Current Power System

Gen. ➡ Trans. ➡ Dist.Cust.

- Just in time power delivery system
- NERC and WECC rules all focused on metrics for ensuring instantaneous energy delivery and system balance
- Market based generation
- Hourly energy schedules
- Must serve load demand

Future Power System (Next 3-5 Years)

- Lots of variable generation challenges the hourly scheduling
- Distributed Gen. - PV
- Energy storage changes “just in time delivery” requirement
- Controllable Loads
- Smart Grid

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Potential Portfolio of Renewables for 20% & 33%

Accurate predictions of Renewable Additions is Impossible.

Best estimates based on CPUC and Interconnection Queue data

	Plant Capacity in Megawatts			
Year	2009 (Existing)	2012 Forecast (20% RPS)	2020 low (33% RPS)	2020 high (33% RPS)
PV	400	830	3,234	3,234
Conc. Solar	400	996	7,297	10,000
Wind	3,000	5,917	10,972	13,000
Geothermal	900	1,039	2,400	2,400
Small Hydro	844	844	844	844
Biomass/Biogas	900	950	1000	1000

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Renewable Generation Resources - Wind

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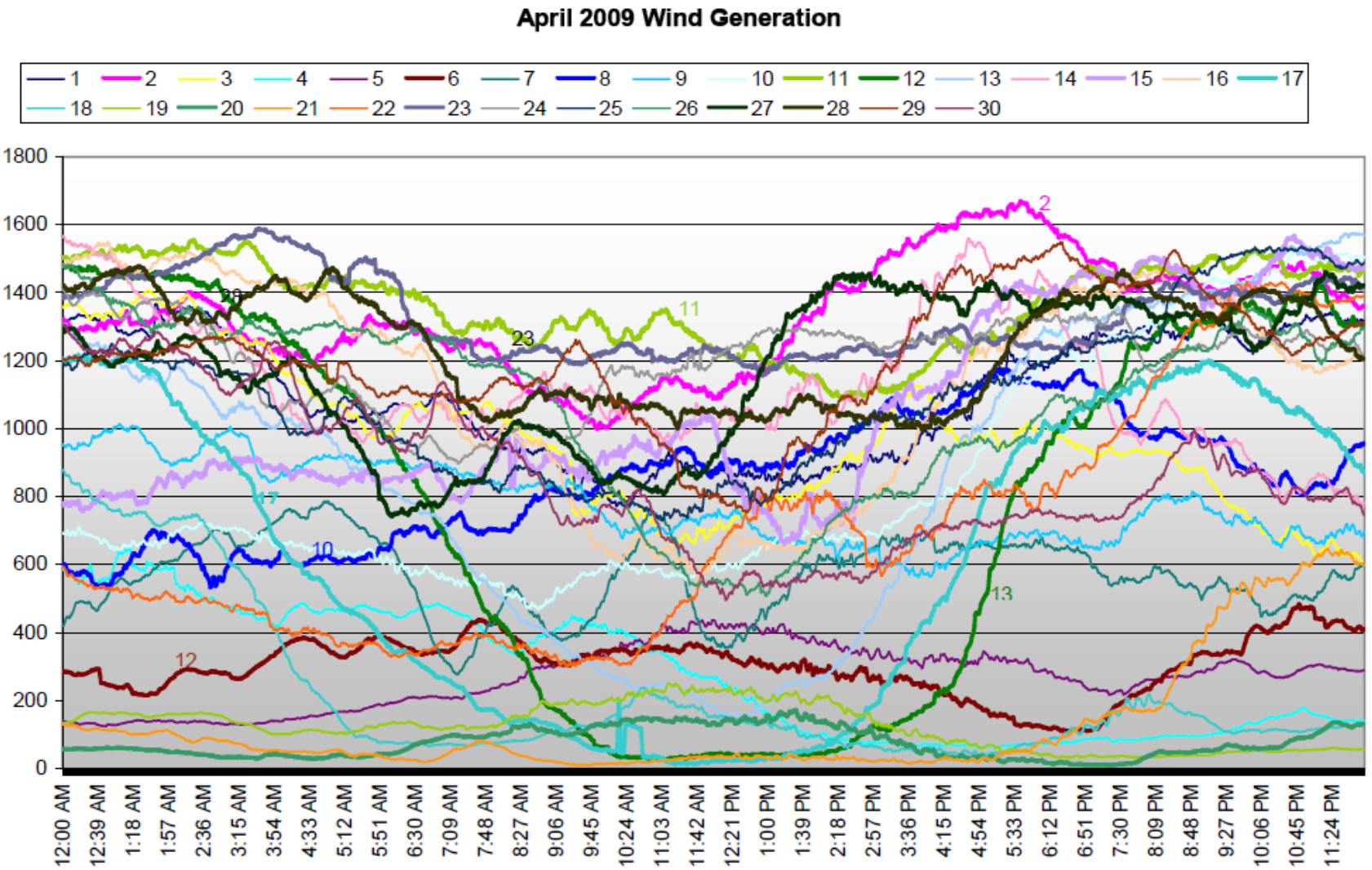
Wind energy production is a challenge to forecast



Forecasting Time Periods

- 8 – Day Ahead
- 3 – Day Ahead
- 1 – Day Ahead
  - 18-42 hours ahead
- Hour Ahead
  - 105 Minutes
- Intra hour forecasts
  - 15 minute time line - out 2 hours
- Event Prediction
  - Large changes in short periods

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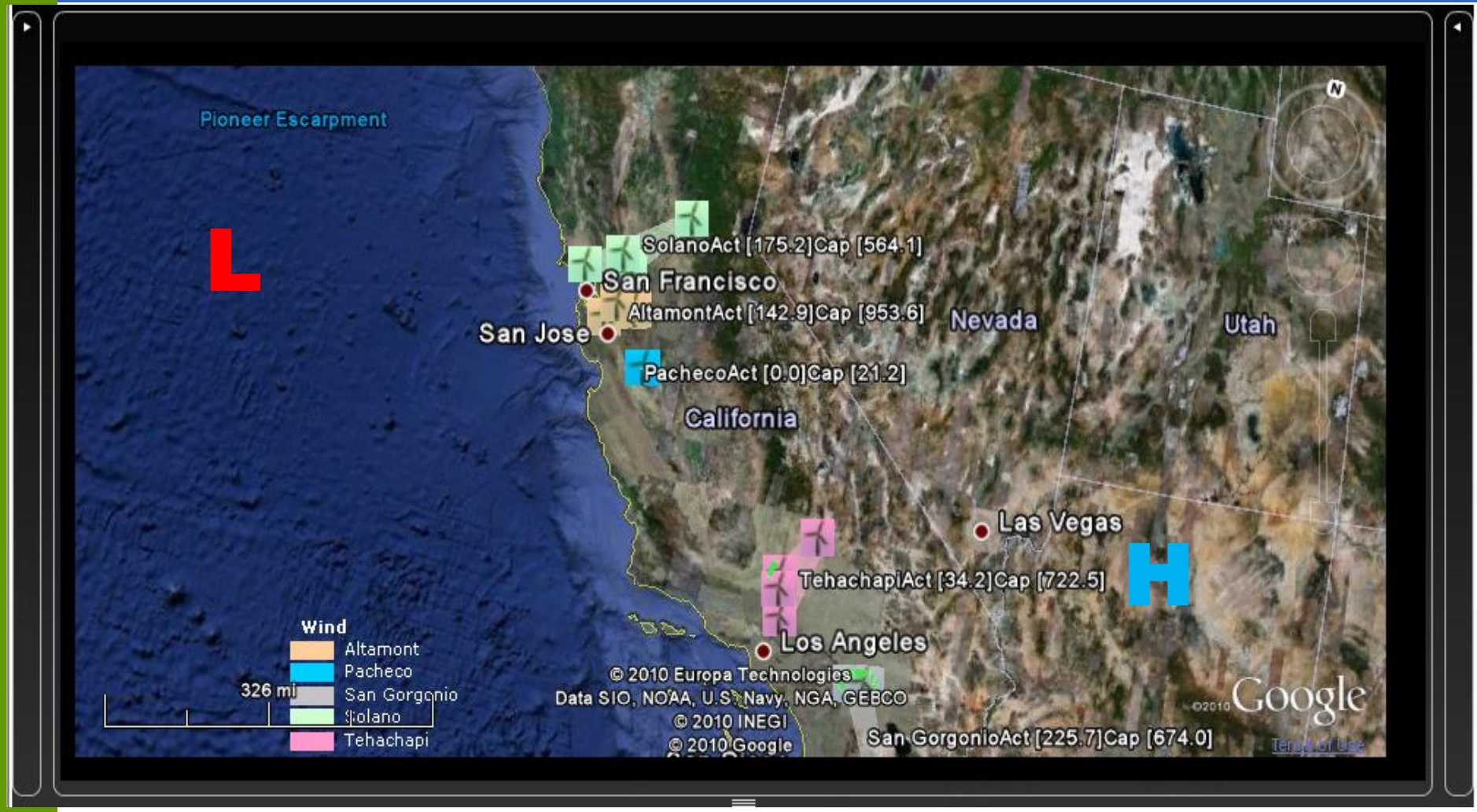
Visualization Tools Google Earth Display – Statewide



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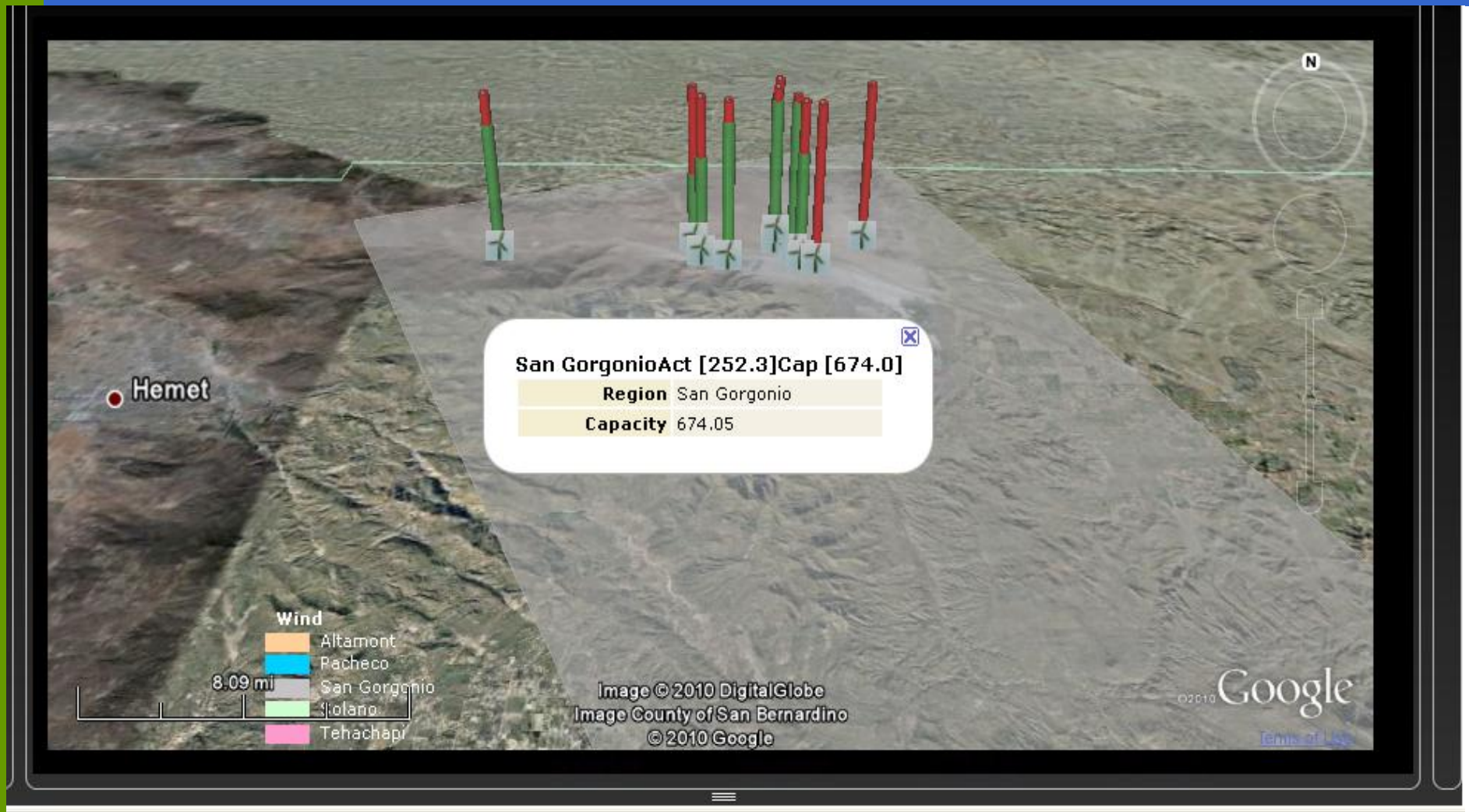
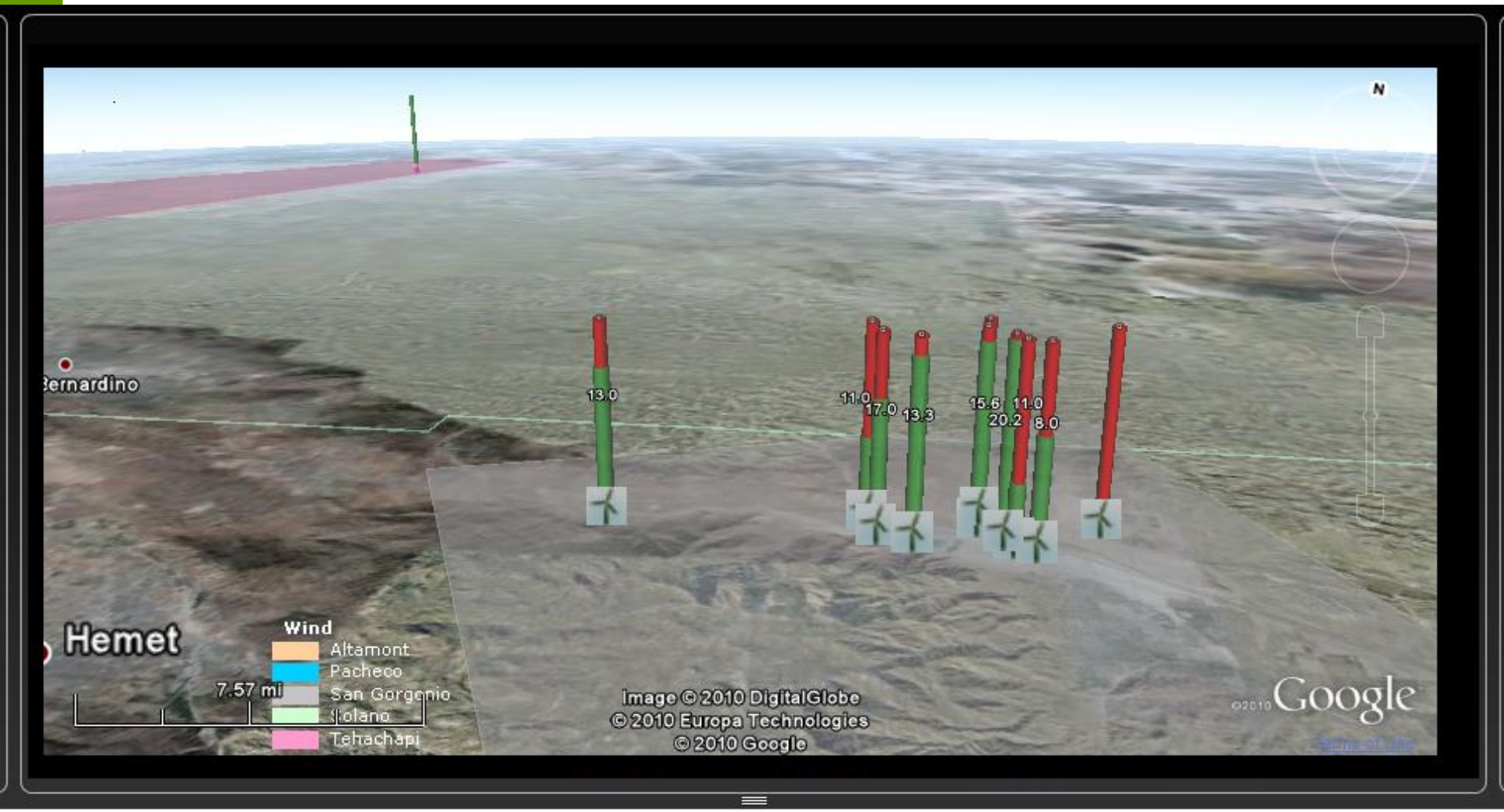
Visualization Tools Google Earth - Zoomed to Area



Visualization Tools Google Earth –Individual Parks



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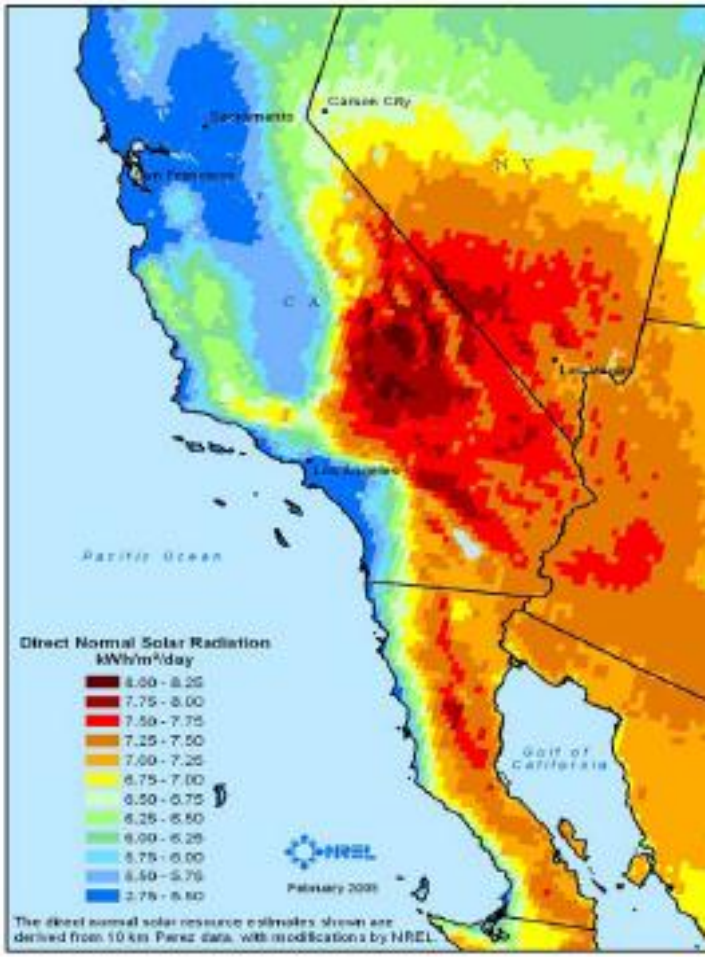
Here comes the sun . . .

Southwestern area has solar energy potential equal to the total amount of energy from oil in Saudi Arabia



Parabolic Trough

Parabolic Dish-Engine

Power Tower

Concentrating Photovoltaic

Figure 2-1
CSP Systems
(Source: NREL)

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2013 Solar Ramps will be an issue to manage

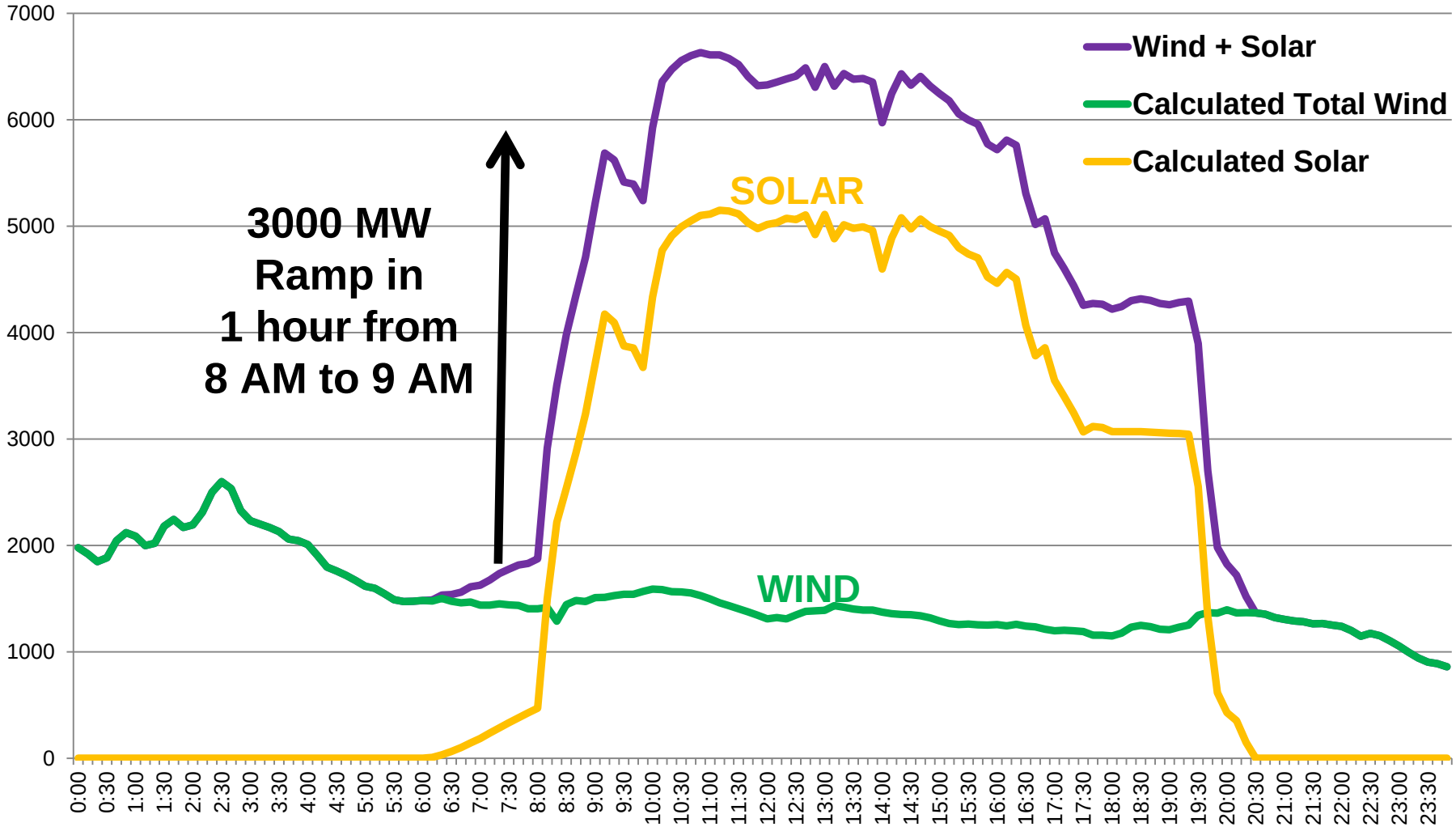

Chart based on March 2010 actual data and escalated to amount of renewables expected in 2013

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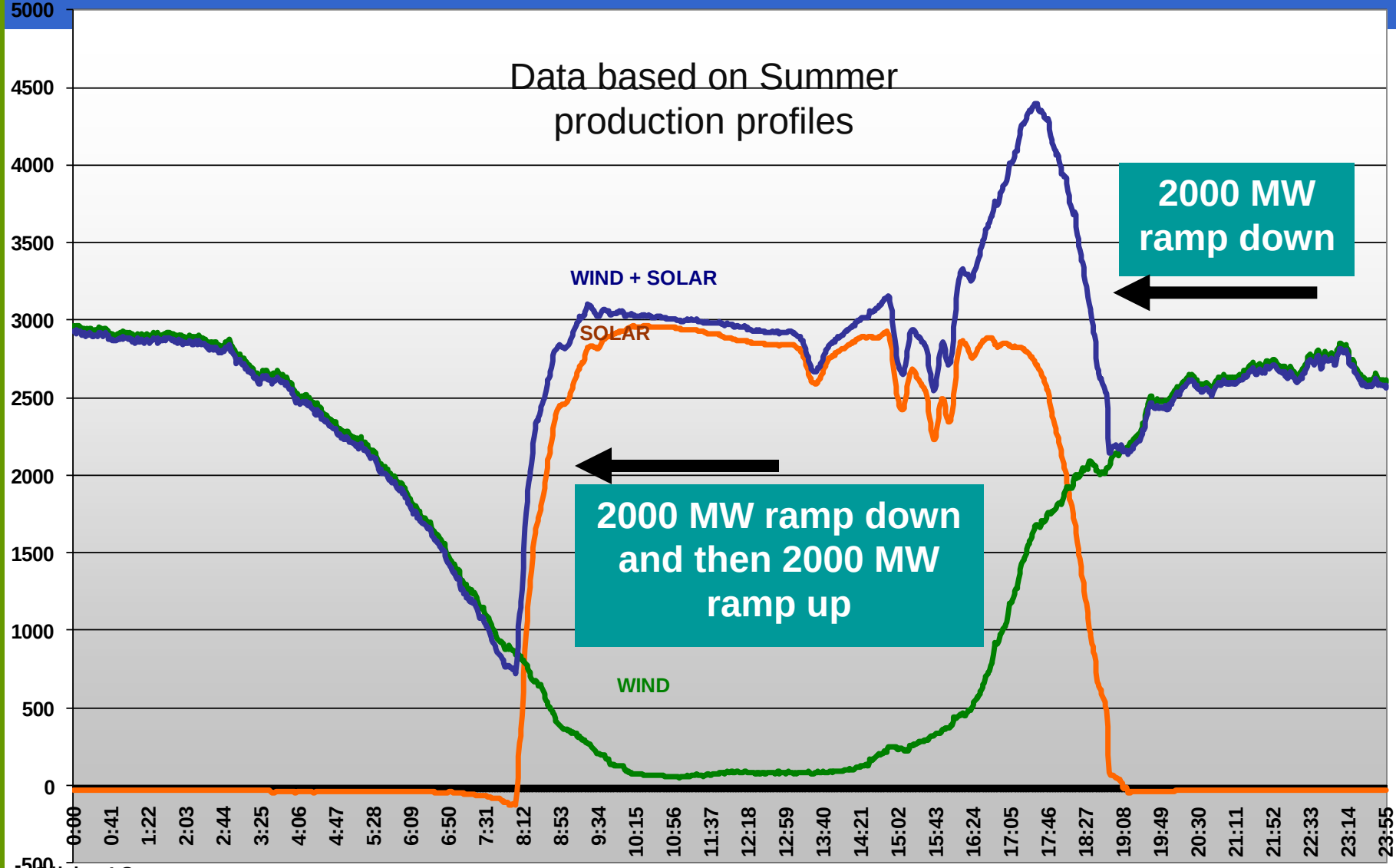
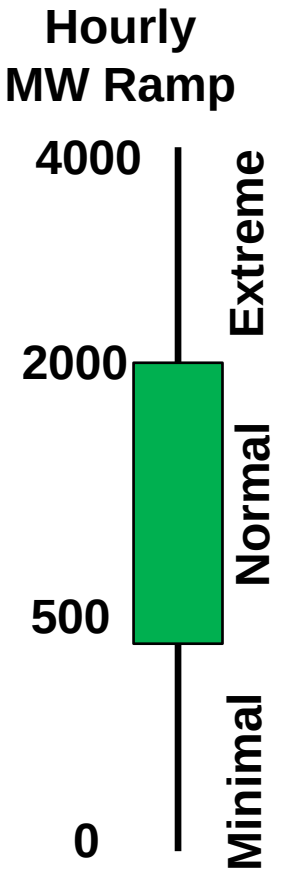
4000 MW SOLAR and 6000 MW WIND Nameplate Capacity



Large Ramp Strategies



- **Active control of wind & solar required to limit ramps**
- Increase amount of regulation and number of resources providing regulation (MW/Min criteria as well as $/MW)
- Peaker Generators, Large Storage, Demand Response
- Fast Ramping Energy Storage and Hydro Generation For Regulation and Supplemental Energy Dispatches
- Existing generation fleet for Supplement Energy and Regulation and Operating Reserves
- Existing Generation fleet – normal operation

Large Ramps will challenge BA's ability to meet NERC Control Performance Standards for frequency, ACE and Transmission Congestion

Smart Grid is a key *enabler* to Grid Modernization

Renewable Integration – *Addressing variability and intermittence of large-scale wind generation*

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Key Energy Storage Questions

1. What Type of Storage?
2. How Much?
3. Where?

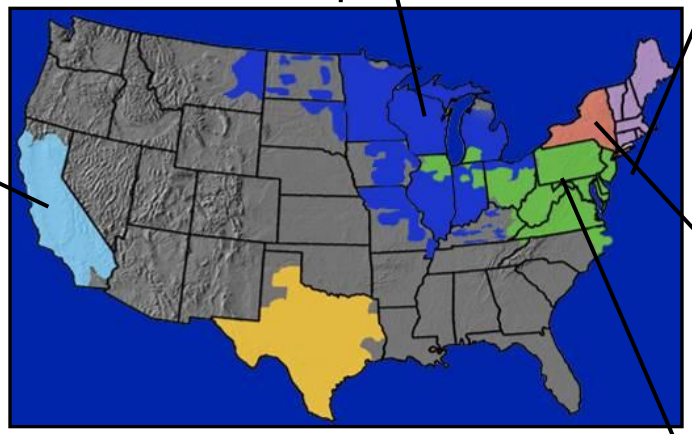
- **Major Drivers:**
  - Increase in the amount of variable generation (renewables)
    - Helpful for 20% RPS
    - Essential for 33% RPS
  - Regulation and ramp energy requirements will significantly increase
  - Need for load-shifting to match diurnal wind pattern
  - Green house gas (GHG) limitations under California law will limit thermal generation usage
  - Shut down of power plants using once-through cooling potentially eliminates as many as 45 power plants that supply ancillary services

Energy Storage in A/S Markets

Midwest ISO

Demonstrated:

- 2 MW AES Altairnano batteries



ISO New England

Operating:

- 3 MW Beacon Flywheels

California ISO

Demonstrated:

-100 kW Beacon Flywheel

Interconnected:

- 2 MW AES A123 batteries

New York ISO

Demonstrated:

- 100 kW Beacon flywheels

Planned:

- (2) 20 MW Beacon flywheel plants (Stephentown, Glenville)
- (3) 20 MW AES battery plant

PJM

Operating:

- 1 MW AES Altairnano batteries at PJM HQ

Planned:

- 20 MW Beacon flywheel plant (Chicago)

Limited Energy Storage Resources are successfully providing Regulation Service in ISO-NE and PJM; successfully demonstrated in NYISO, Midwest ISO and CAISO

CESA
CALIFORNIA ENERGY STORAGE ALLIANCE

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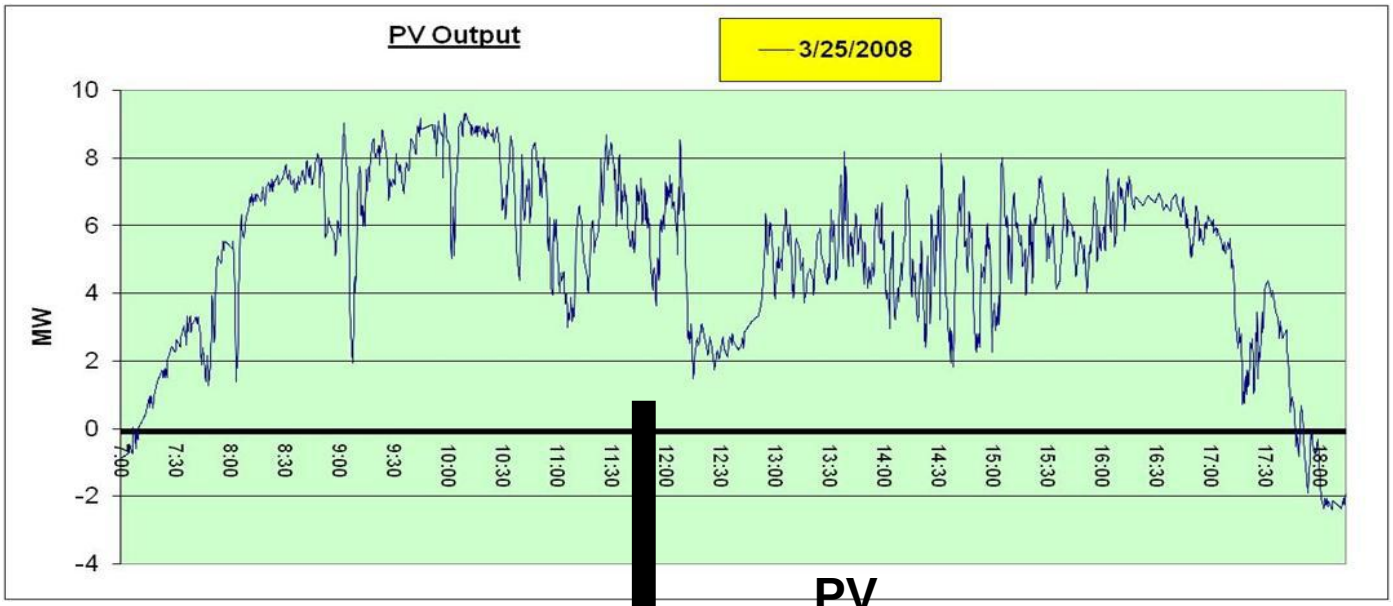
Energy Storage Applications

Utility scale storage – 1 MW to 1000 MW

Market Based Services

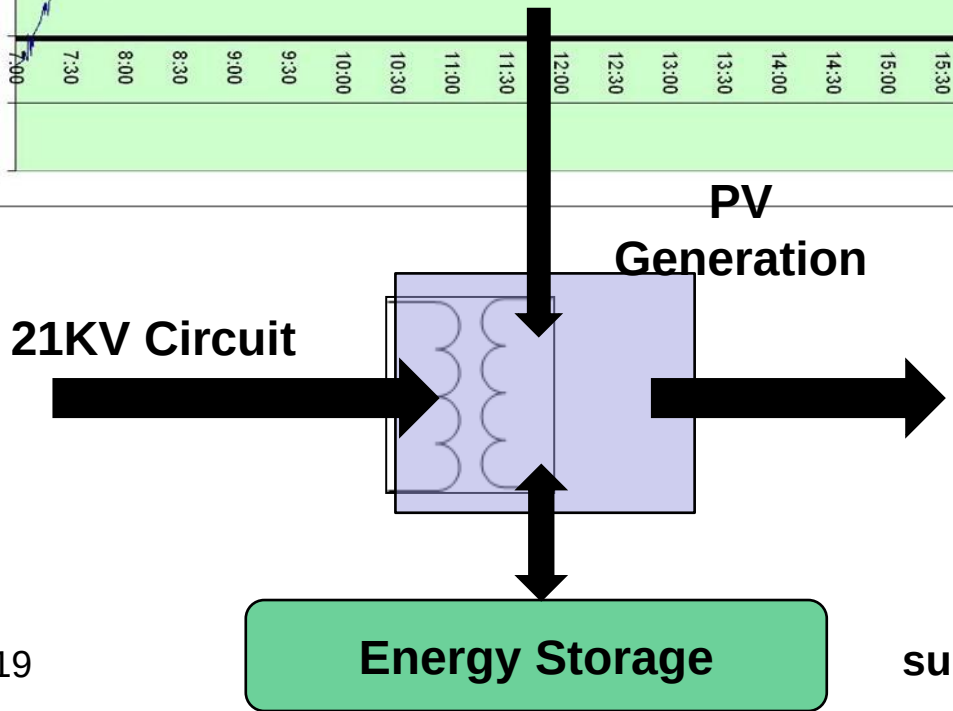
	Seconds to 1 Minute	1 Minute to 15 Minutes	15 Minutes to 60 Minutes	1 hour to 4 Hours	4 hours to 24 Hours	Multiple Days
Technology	Super Caps Flywheels Batteries	Flywheels Batteries	Batteries Flywheels (15 Min.)	Batteries Compressed Air Energy Storage (CAES)	Batteries CAES Pump Storage	CAES Pump Storage
Service	Distribution Power Quality mitigation due to solar PV	Distribution PQ Grid Frequency	AS Regulation & Contingency Reserves	Supple-mental Energy Dispatch	Supple-mental energy and energy shifting	Supple-mental energy and energy shifting
Value	Potential source for energy injection for grid stabilization	Voltage control and system frequency control	Meet BA control performance standards	Intra-hour energy change needs Transmission congestion	Load following & energy scheduling	Load following & energy scheduling

Solar PV plant output variability (partly-cloudy day, 10-second time-step)



Potential voltage control and power quality issues due to PV variability

Energy storage on distribution circuits may be essential

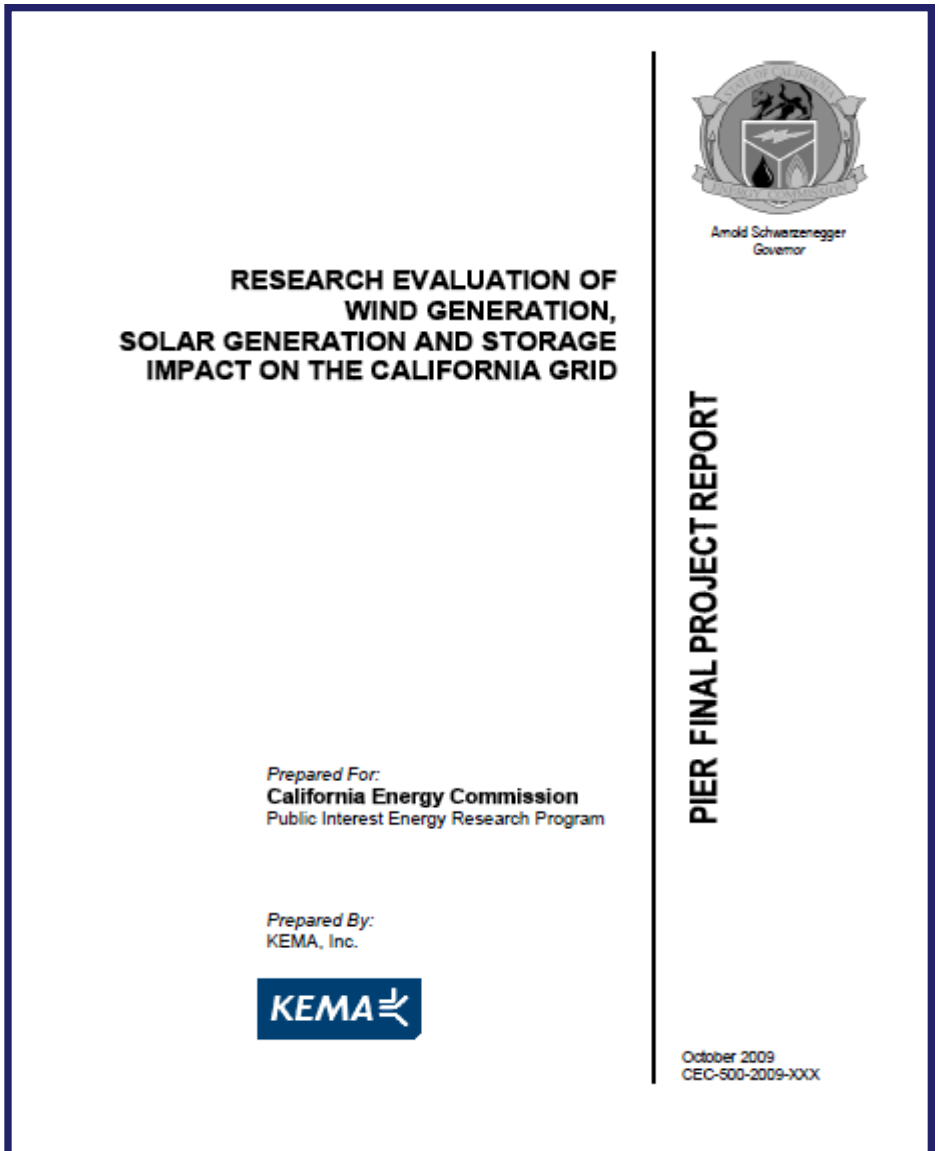


Added value – Back up power supply for emergency management

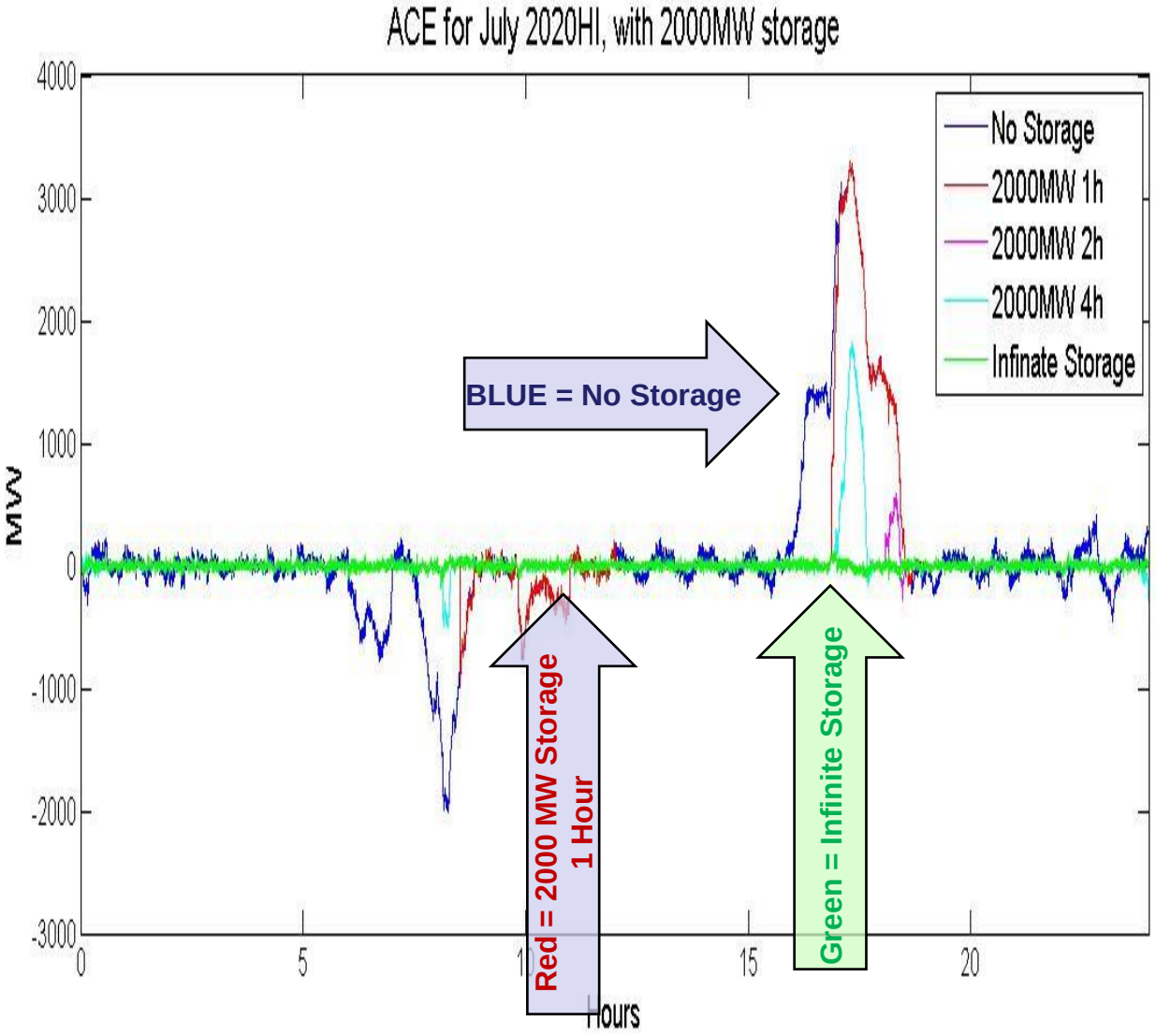
KEMA Model Study Report

Final Report should be available this month or early in April 2010 on both the CEC and CAISO web sites

Goal in 2010 is to do a more detailed modeling and analysis of 33% with detailed production cost data on hourly schedules



Energy Storage will play a key role at the 33% renewables level



2009 Study with KEMA's Simulation Tools indicate 2000 MW of energy storage with 2 hours to 4 Hours of capacity works to control ACE and Freq.

1 Hour of energy storage or less does not provide enough capacity to mitigate large ACE problems due to high ramps

<u>These are early results and more studies are needed.</u>

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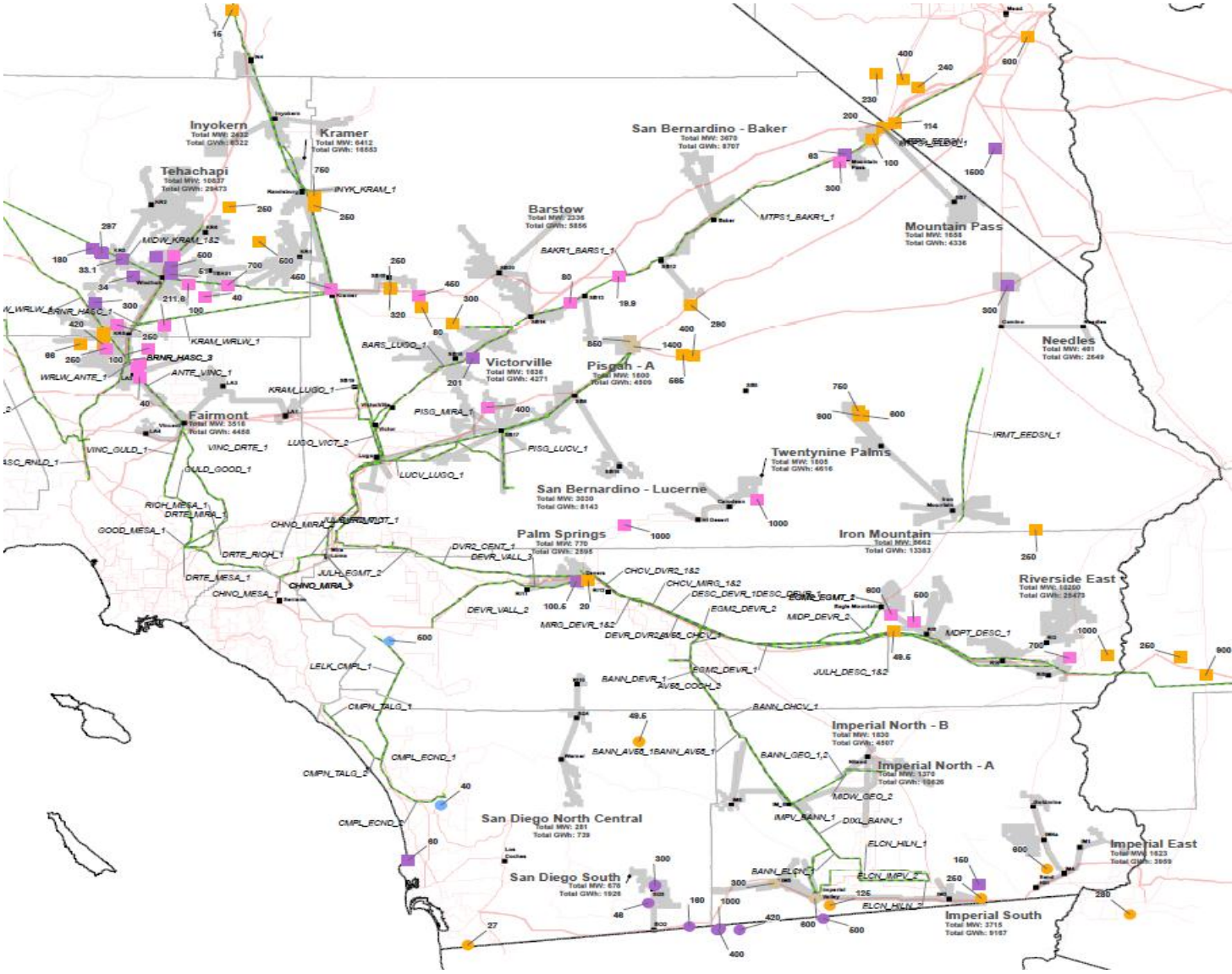
Storage should be located in areas with lots of renewables

Location of Potential Renewable Energy sites

Southern California



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Other potential uses of storage

- Local capacity value - compete with local generation requirements (LARS Process)
- Real-time transmission loading controls
- Frequency response capability
- Mitigate stability limits on transmission transfer capability
- Black-start energy source for CCCT plants

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Current Energy Storage Projects in California

- SANO Battery test for Regulation services
- AGC/Regulation signal improvements to provide an energy neutral reg. signal
  - EPRI project and PNNL Project
- Non-Generation Resources in AS Markets
- Intelligent Agent Project – 100 KVA flywheel
- Development of intra-hour simulation tool
  - CEC-KEMA project
- SCE 8 MW – 36 MW-Hr battery project
- PG&E CAES project & NaS Battery project

SANO Battery - Regulation

2 MW – 500 KW-Hr Lithium Ion Battery

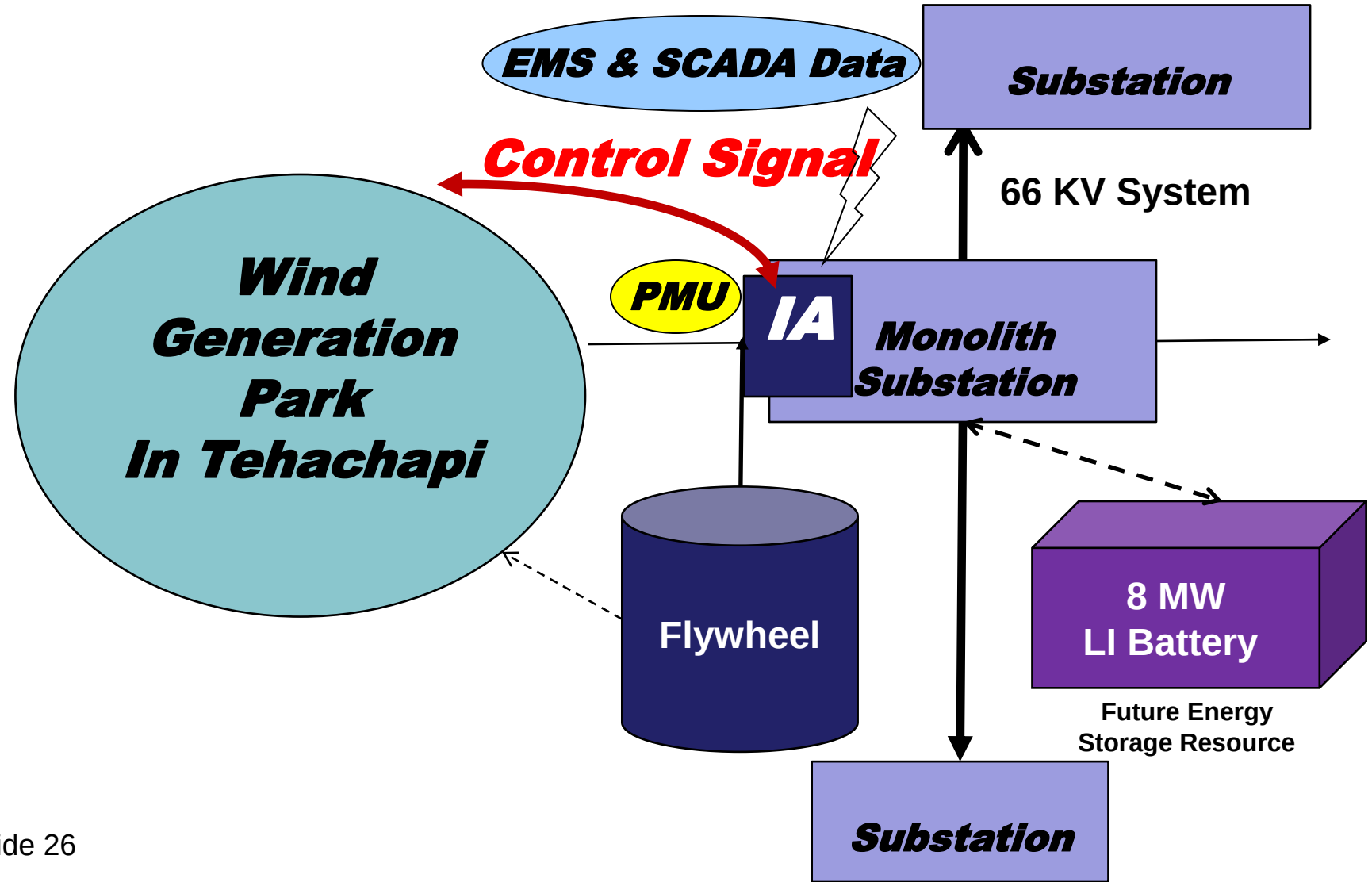
Installed in Southern California

Pilot Test for Regulation Services was done in February 2010

Series of 8 hour tests over a 3 week period

- **Test of market system to accept a battery storage resource for regulation**
- **Test of EMS / AGC signal**
- **Verification unit ramp rate**
- **Test of settlements system and financial consequences**

Application of Intelligent Agent Technology



Smart Grid is a key *enabler* to Grid Modernization

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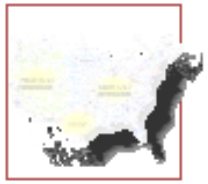

System Transparency – *Seeing and operating the grid as a national system in real-time*

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Direct control of large loads

- Large pump loads – Water Districts, Irrigation Pumps, & Aqueducts pumps
  - 2000 HP Pumps, Waste water treatment plants
- Building management systems
  - Thermal energy storage systems
- Load Aggregators
  - PHEV Loads in future
- Microgrids

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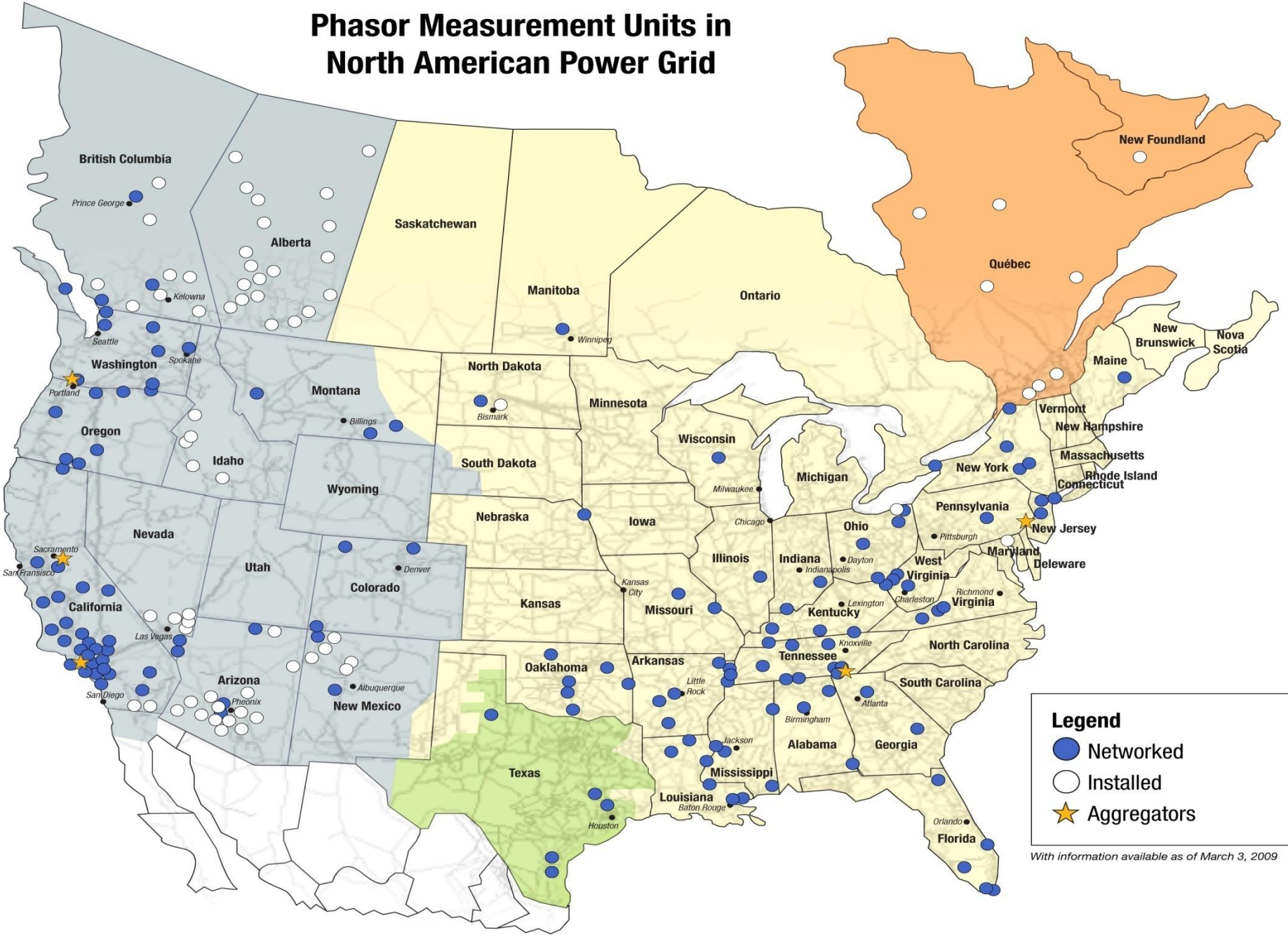
Phasor Measurement Units in North American Power Grid

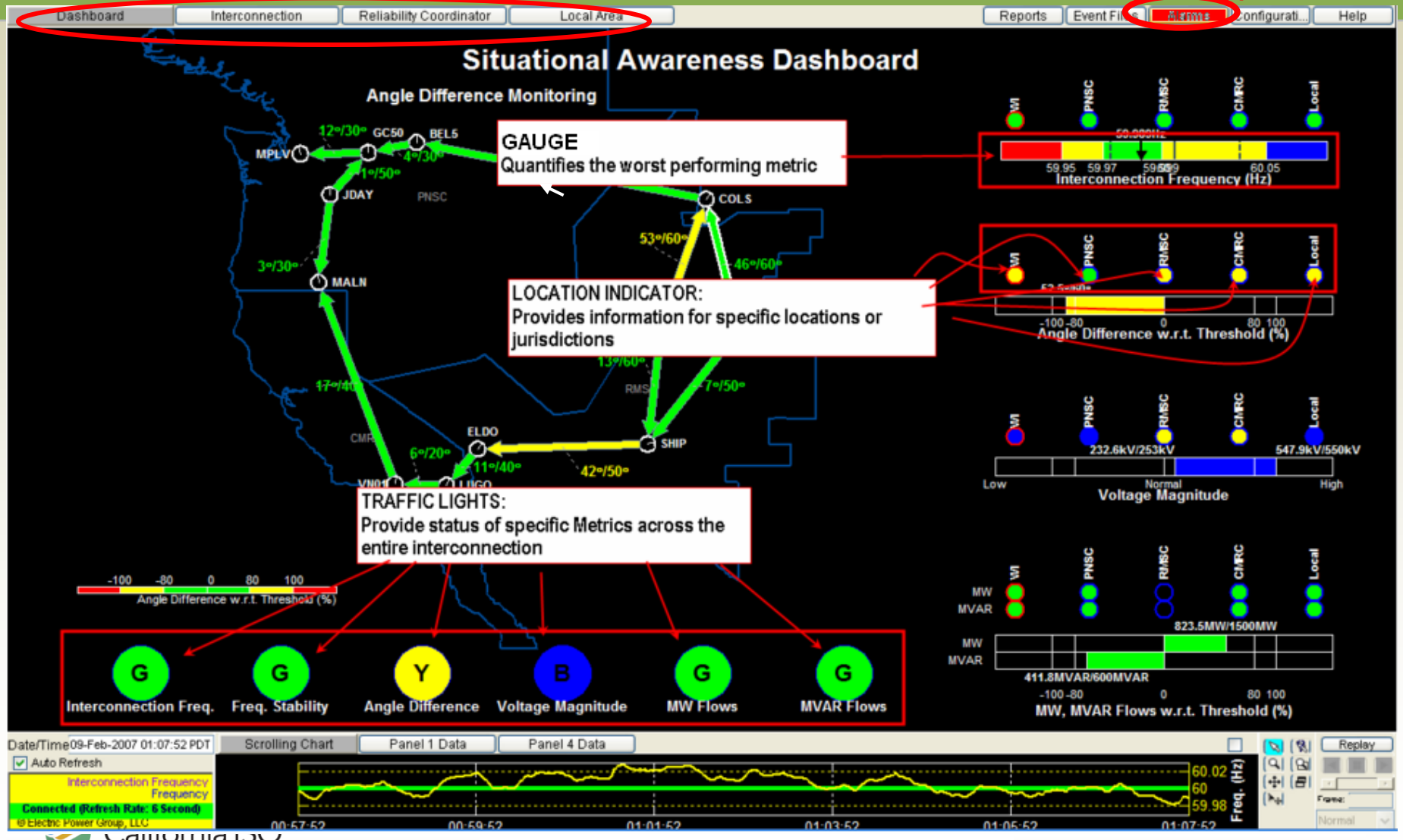


With information available as of March 3, 2009

Visualization – In Use at CAISO

Visualization Tiers – Dashboard, Interconnection, Reliability Coordinator, Local Area

Real Time Alarms within ALL RTDMS Client Applications



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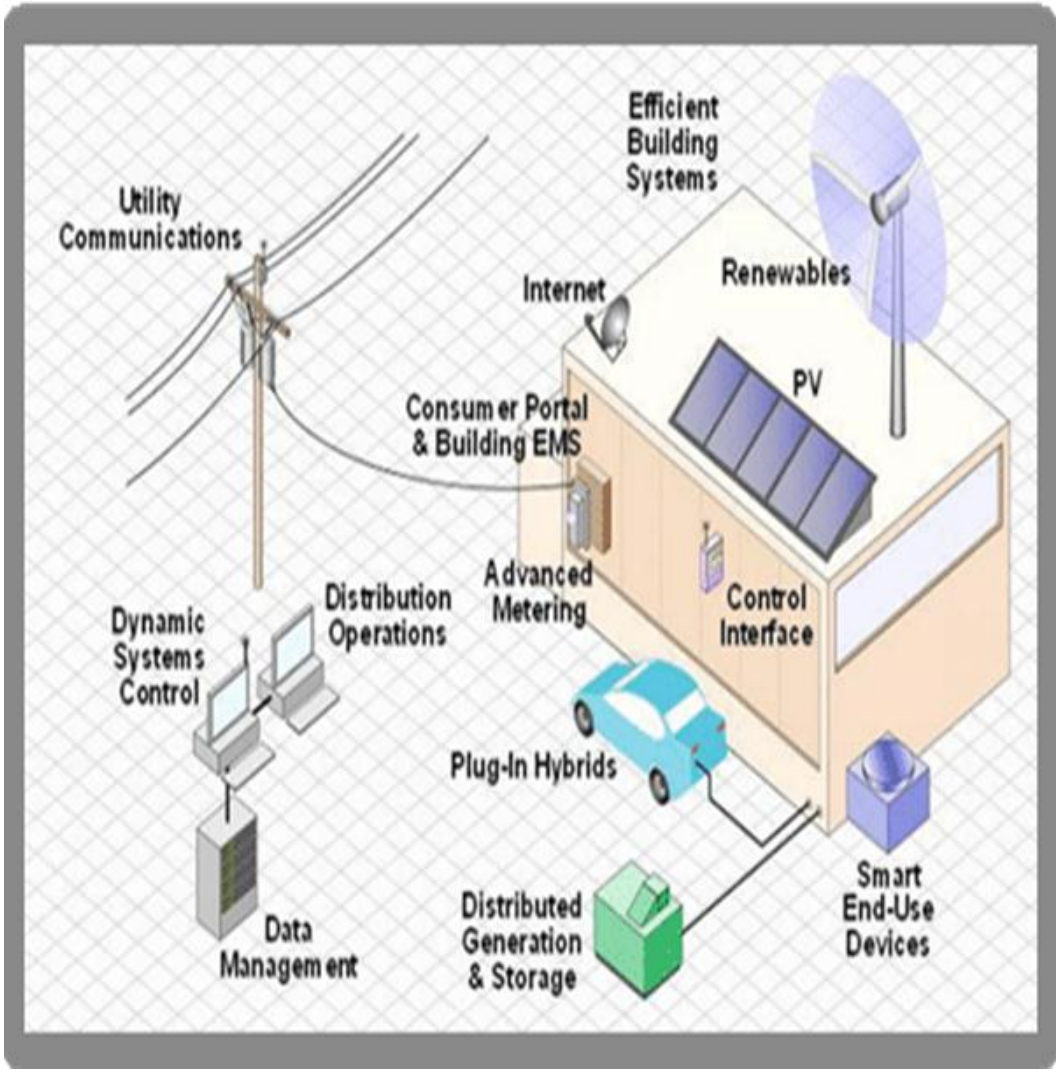
Smart Grid starts with Smart Meters

Smart Meters

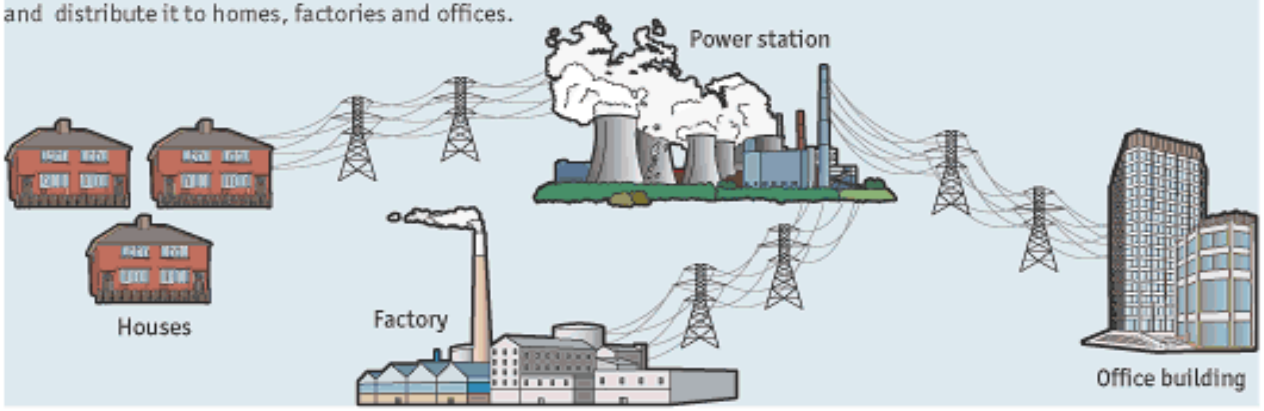
PHEV



The shape of grids to come?

Conventional electrical grid

Centralised power stations generate electricity and distribute it to homes, factories and offices.

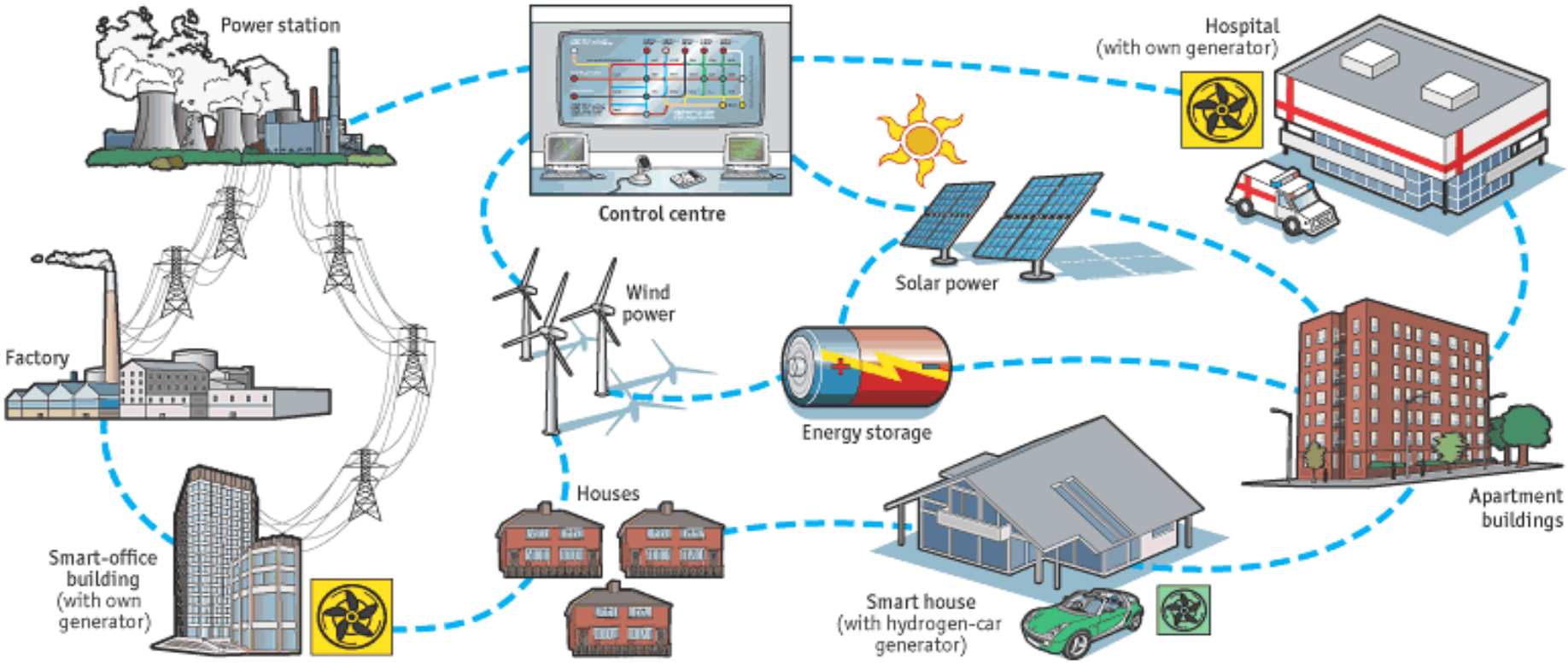


Energy internet

Many small generating facilities, including those based on alternative energy sources such as wind and solar power, are orchestrated using real-time monitoring and control systems.

Offices or hospitals generate their own power and sell the excess back to the grid. Hydrogen-powered cars can act as generators when not in use. Energy-storage technologies smooth out fluctuations in supply from wind and solar power.

Distributing power generation in this way reduces transmission losses, operating costs and the environmental impact of overhead power lines.



Sources: *The Economist*; ABB

Summary:

- Grid of the Future will include:
  - Large amounts of renewable generation
    - PV Panels in parking lots and electric outlets for charging the vehicles
  - Smart Meters and customers able to shape their usage of energy
  - Smart appliances and building management systems
    - Thermal storage for heating and air conditioning
  - Plug In Hybrid Vehicles
  - Energy Storage

Any Questions?

Thank you!

CAISO Web Site

http://www.caiso.com

Look for Integration of Renewables Resources Project - IRRP

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