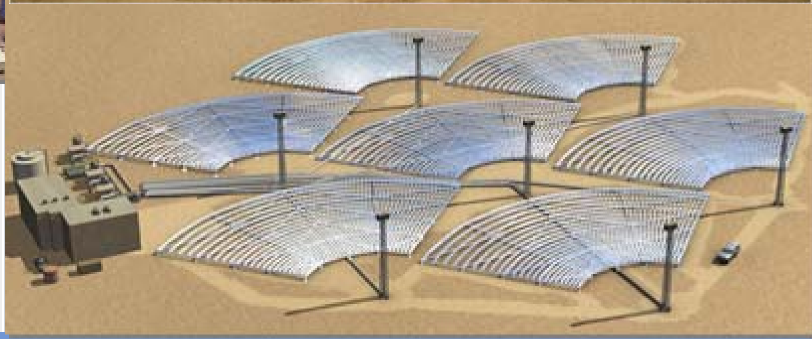
Integrating Renewables into the Power Grid

An Overview by Barney Speckman

November 2010






Nexant
Energy Solutions

Overview

- Why do we have to “integrate” renewables
- What is meant by integrating renewables
- How does one think about renewable integration needs
- What are some of the challenges
- What are the options to meet the system’s integration needs
- Q&A

Why do we have to integrate renewables?

- **Before renewables, generation was added for**
  - Low cost (coal, CCGT, hydro, geothermal)
  - Cost/Performance Ratio (GT, Pumped Hydro), and
  - Controllability and predictability was normally a given
- **With the most common renewables (wind and solar)**
  - Production is variable and
  - Production is uncertain
- **For the first time, significant amounts of generation are being added that are not controllable and by their nature (variable and uncertain) they** <u>require a higher level of controllability</u> **and because of potential forecast error they** <u>require more resources be held in "reserve"</u>

What is meant be Integrating Renewables?

- **"Integration" can be thought of as the collection of steps or measures that are needed to operate the power system reliably with relatively large levels of renewables**
- **A simple way to think about it is the electric power system must still**
  - Serve customer needs and
  - Serve them reliably
  - Operate the system to meet the control requirements of the NERC and WECC -control the power system from the seconds to hours to day time frames
  - Maintain efficient "dispatch" through control and market mechanisms to result in low costs

How does one think about integration needs

- **Lets look at California as an example to show the integration problem and one type of analysis to find potential solutions**
- **California Legislature passed AB32 in 1996 and the voters supported its implementation with the defeat of Prop 23 in Nov. 2010**
- **Lets look at what it does and how one might think about what steps are needed to integrate the renewables envisioned by AB 32**

Assembly Bill 32

- AB 32 (2006) Requires California to reduce GHG emissions to 1990 levels by 2020
- California Air Resources Board (CARB) has been assigned task of developing a plan to implement AB 32
- CARB's proposed plan includes establishing a 33% Renewable Portfolio Standard for the California electric industry
- Currently a mandatory 20% RPS (by 2010) is in place for the states investor owned utilities (PG&E, SCE, SDG&E) with many Municipal Utilities voluntarily implementing RPS targets

How the 33% RPS works

- **Would require 33% of the amount of energy sold to customers to be produced by eligible renewable resources**
- **Applies to all companies selling energy at retail in CA**
- **Sets 2020 as date to meet the 33% Standard**
- **Establishes penalties for non compliance**

How might the 33% RPS be met

No none knows for certain!!!

- Many degrees of freedom in the implementation thus many uncertainties will have to be dealt with
- What technologies will utilized?
- Where, when and what plants will be built?
- How will the power be delivered to customers?
- What other infrastructure will be needed?
- How will integration needs be met?

Several studies have/are being conducted

Possible 33% Renewable Futures

- **Recent CPUC study used to consider several possible futures as a way to bracket the future implementation of the 33% RPS**
- **Examines cost, difficulty, GHG reductions for several mixes of technology, infrastructure requirements and integration requirements**
- **Looks at:**
  - 33% Reference
  - 27.5% Reference
  - High Wind
  - High Imports
  - High Distributed Generation

Possible 33% Futures (Cont'd)

- **Energy and Capacity Requirements based upon CPUC Forecast compared to 2007**

Renewable Portfolio Standard	Additional Energy Required	Additional Renewable Capacity Required (Approx)
20% RPS	35 TWh	10,000 MWs
33% RPS	75 TWh	22,000 MWs

2007 Renewable Energy was 27 TWh

TWh = 10^{12} Watt-hours

Lets Look at the Technologies in California

- **Major contributors (potentially) to new production**
  - Wind
  - Solar Thermal
  - Solar PV (utility and customer)
  - Geothermal
- **Lesser contributors to new production**
  - Biomass
  - Biogas
  - Small Hydro
- **Large percentage of new renewables in California are in Southern part of the state**

Renewable Portfolios: Incremental (MW) and Existing Renewables (MWh) for Cases Studied - Preliminary

	Biogas	Biomass	Geothermal	Small Hydro	Solar Thermal	Solar PV	Wind
20% Reference	**30**	**324**	**1,052**	**37**	**107**	**333**	**5,024**
33% Reference	**279**	**429**	**1,497**	**40**	**6,513**	**3,165**	**8,338**
Out-of-State	**279**	**339**	**2,532**	**49**	**1,753 (534 Outside CA)**	**890**	**10,870 (6,290 Outside CA)**
High Distributed Generation	**234**	**328**	**1,298**	**37**	**1,095**	**15,959 (15,098 DG)**	**5,067**
27.5%	**30**	**328**	**1,298**	**40**	**4,868**	**2,864**	**5,977**
Low Load	**30**	**328**	**1,299**	**40**	**4,907**	**2,867**	**7,091**

	Biogas	Biomass	Geothermal	Small Hydro	Solar Thermal	Solar PV	Wind
Existing (MW-hrs)	**0**	**6,256**	**13,647**	**687**	**724**	**0**	**6,229**

Nexant Study - Assumed Locations of Incremental Renewables in California - 33% RPS, 2020 Preliminary

Excluded areas with high population density, national parks, landmarks, sensitive areas, etc., to exclude areas not practical for renewable project development

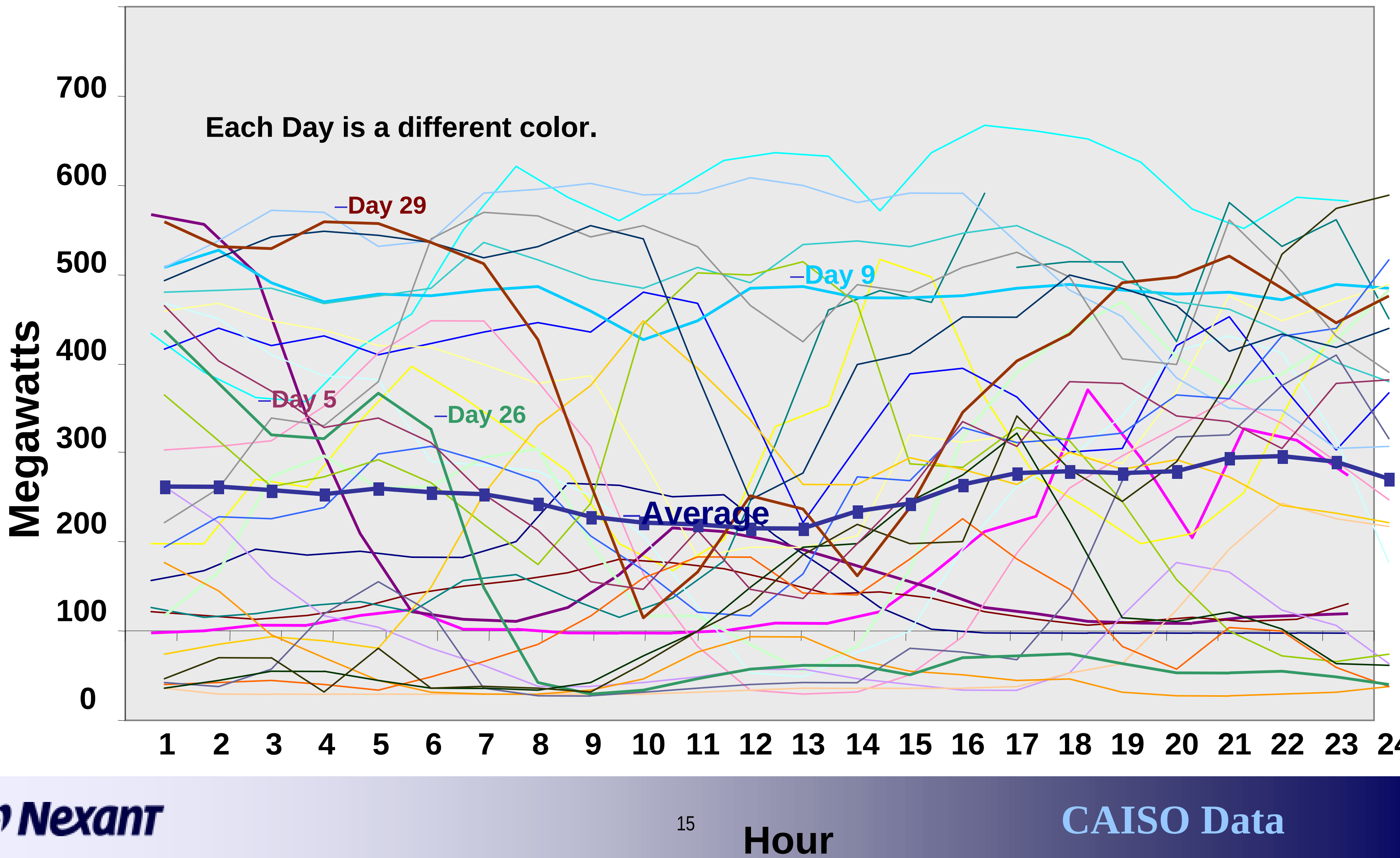
Lets Look at the Technologies in California
Wind Generation

Wind Generation Characteristics

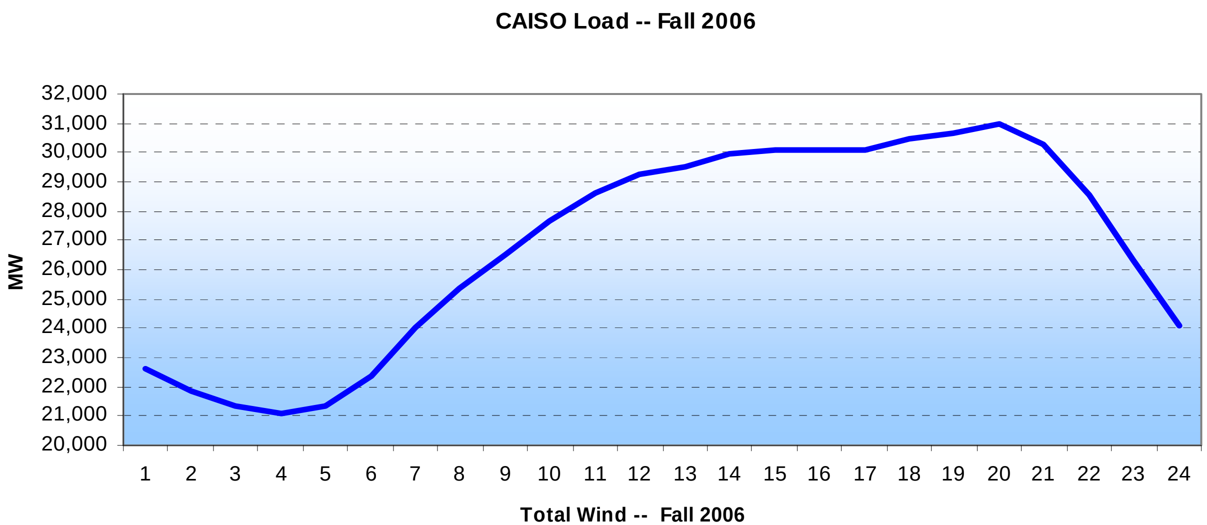
- **Low cost technology on an energy basis**
- **Production is**
  - Variable
  - Uncertain
  - Often Remotely Located
  - Not highly correlated in time with system load
- **Capacity credit 8-30% of nameplate for long range planning purposes**
- **Thus is considered a source of energy but not a significant source of capacity**

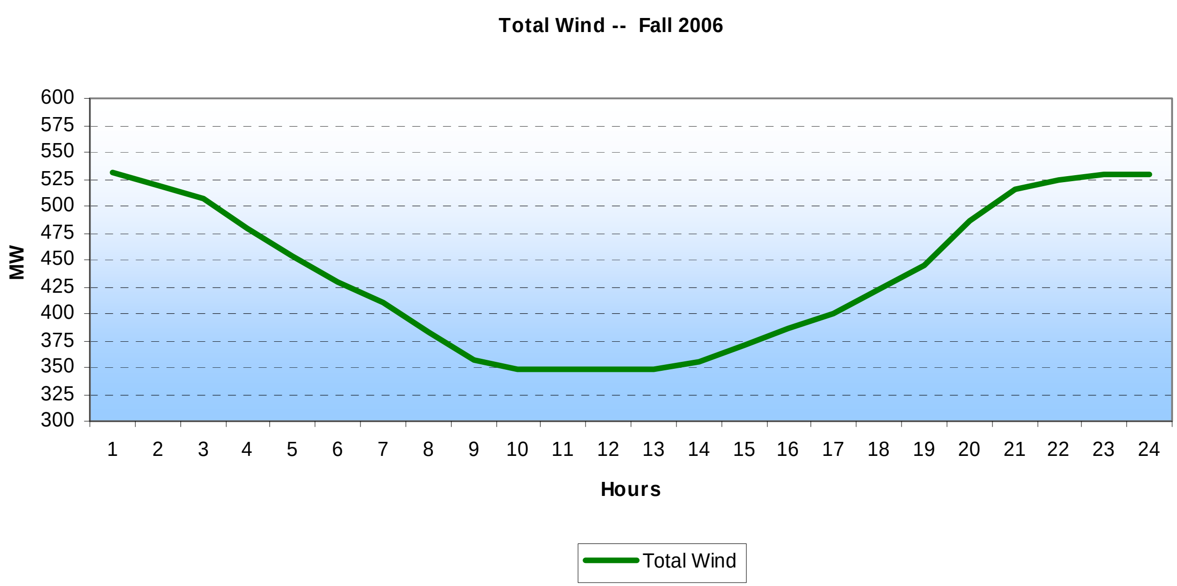
Tehachapi Wind Generation in April – 2005

Variable and Uncertain

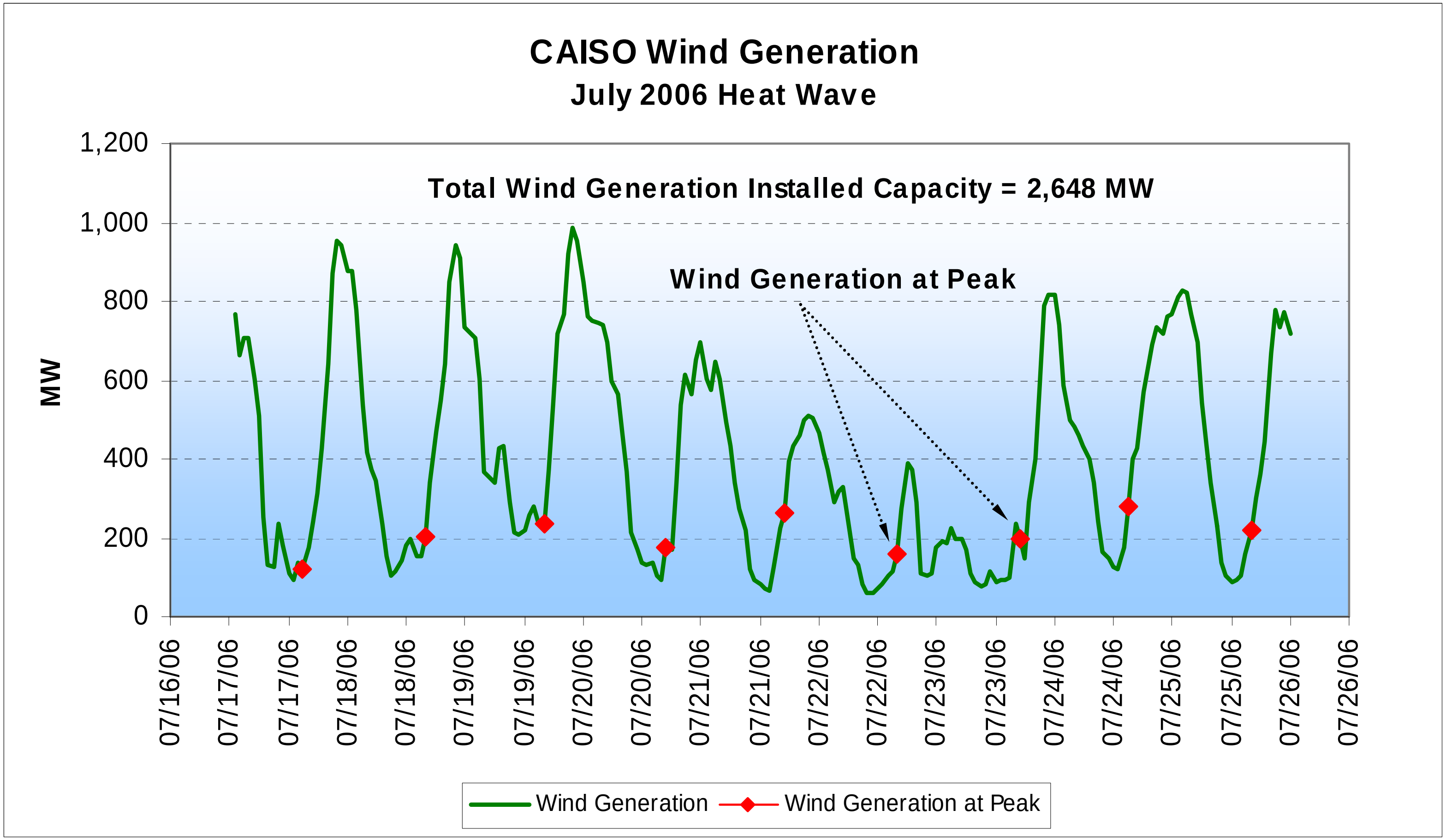


Wind generation tends to be inversely correlated to daily system load





Wind vs. Actual Load on a Typical Hot Day in 2006



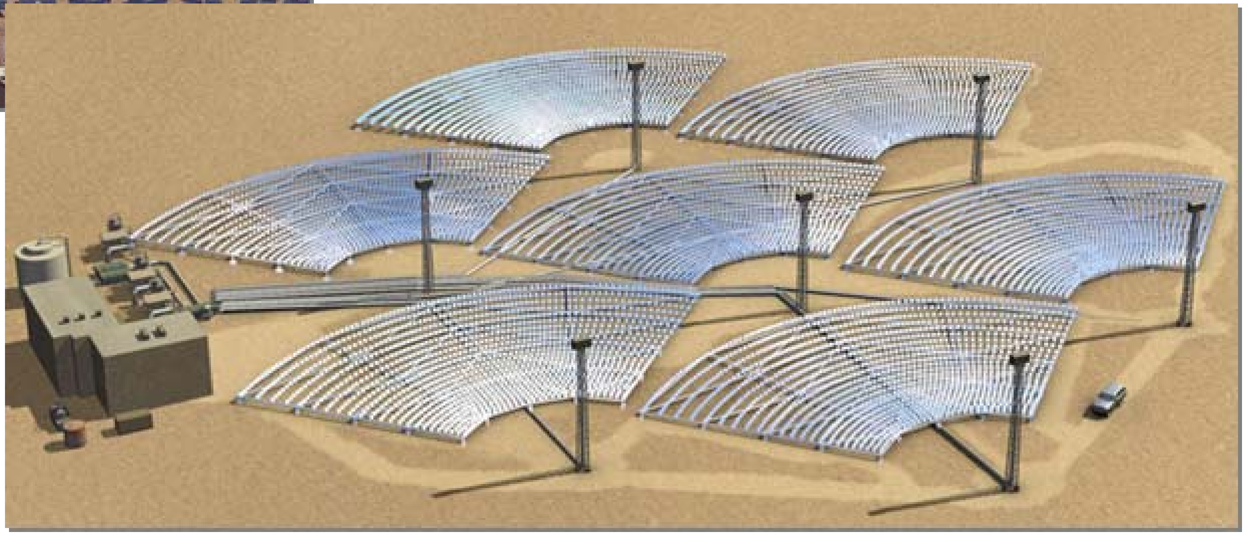
Lets Look at the Technologies in California Solar Characteristics

- **Higher cost on an energy basis**
- **Several technologies**
  - Thermal (central tower, trough, Sterling, etc)
  - Thermal with storage or supplemental gas firing
  - PV roof top
  - PV large scale (> 1MW)
- Irradiation is variable but absent clouds relatively certain
- With clouds, production is less certain
- Solar production correlates better with system load
- Technologies with larger thermal mass tend to filter out short term variability (e.g. solar thermal)
- Solar Capacity Credit 60% – 95% (depending upon technology) for the purpose of long range planning

Lets Look at the Technologies in California Solar Thermal Generation

Solar II Solar Central Receiver

Trough Design



eSolar's Modular Solar Power Plant Concept

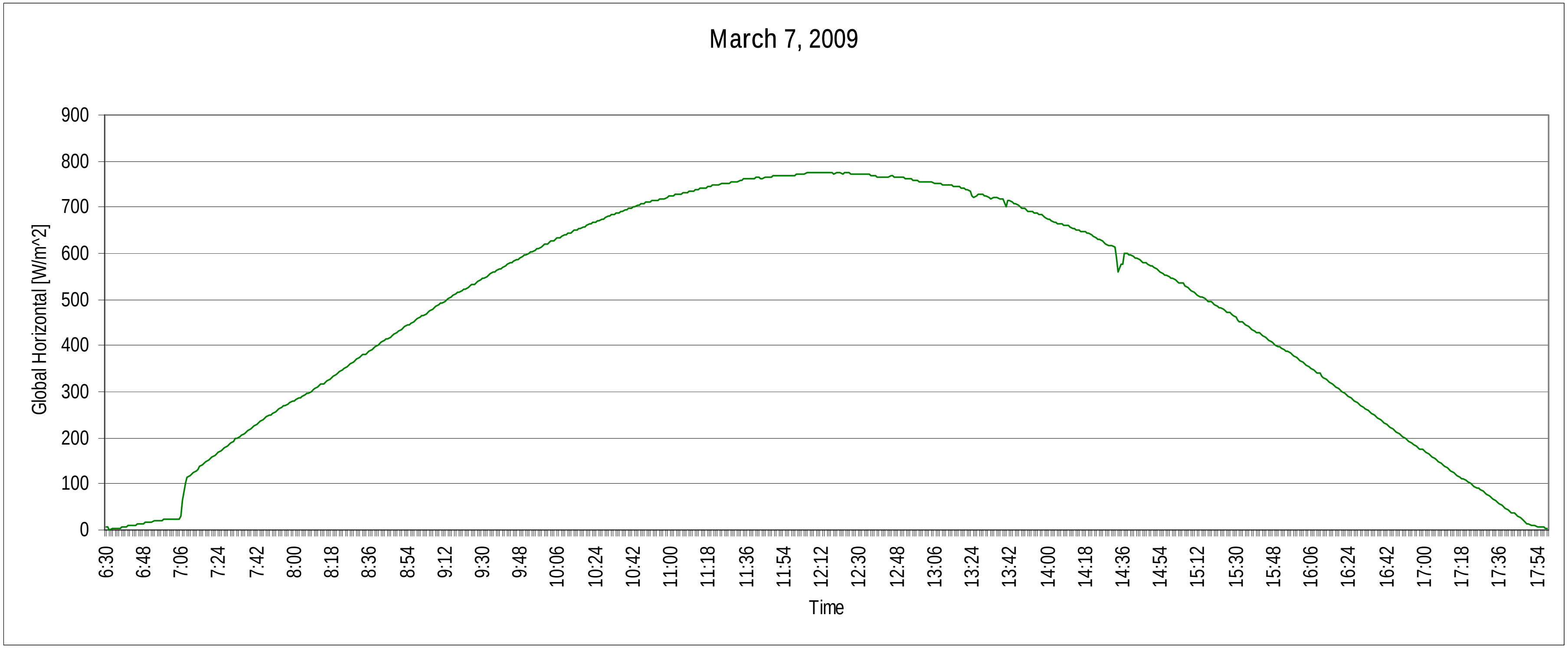
Lets Look at the Technologies in California Solar PV

Solar Irradiation Examples – Sacramento Area

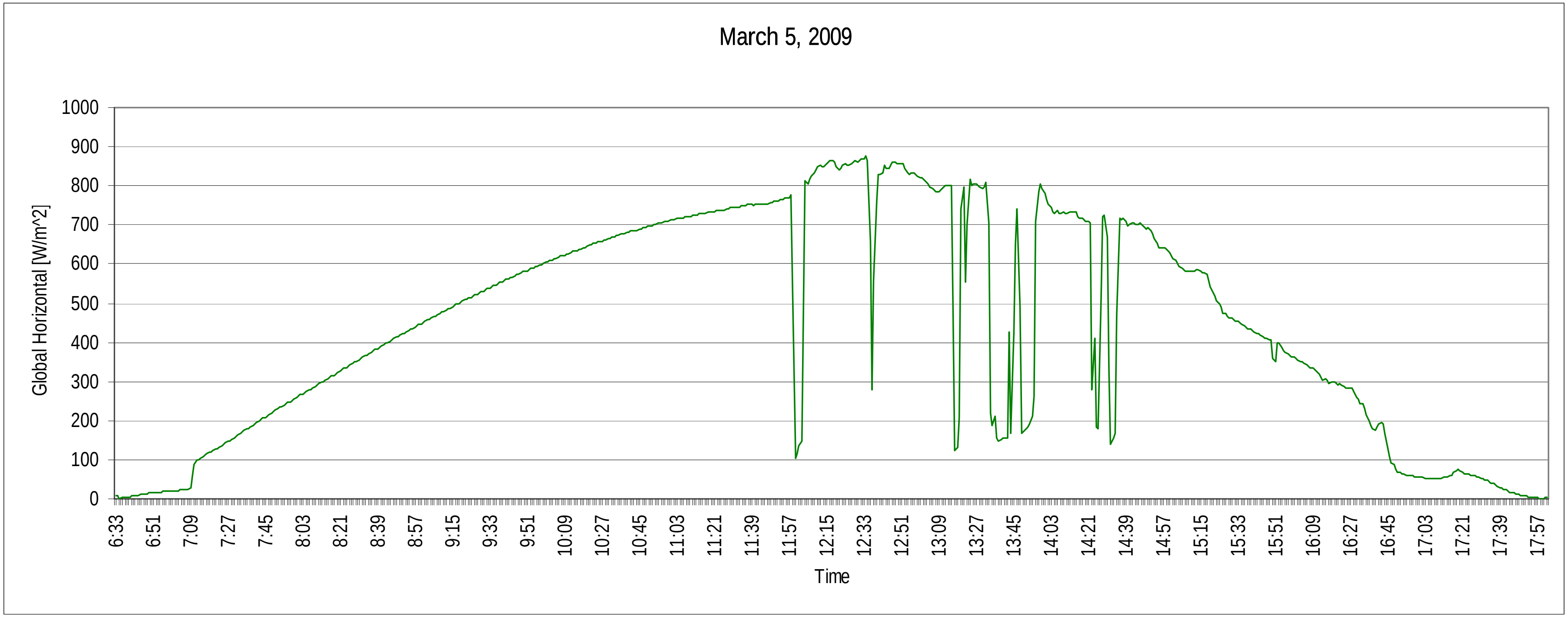
- Spring 2009 data collected at SMUD PV site
- Data is collected at 1 minute intervals
- Several days shown in first week of March and May
- Indicative of Solar production, especially PV

Source: http://www.nrel.gov/midc/

Solar Irradiation Examples – Sacramento March 7



Solar Irradiation Examples – Sacramento March 5



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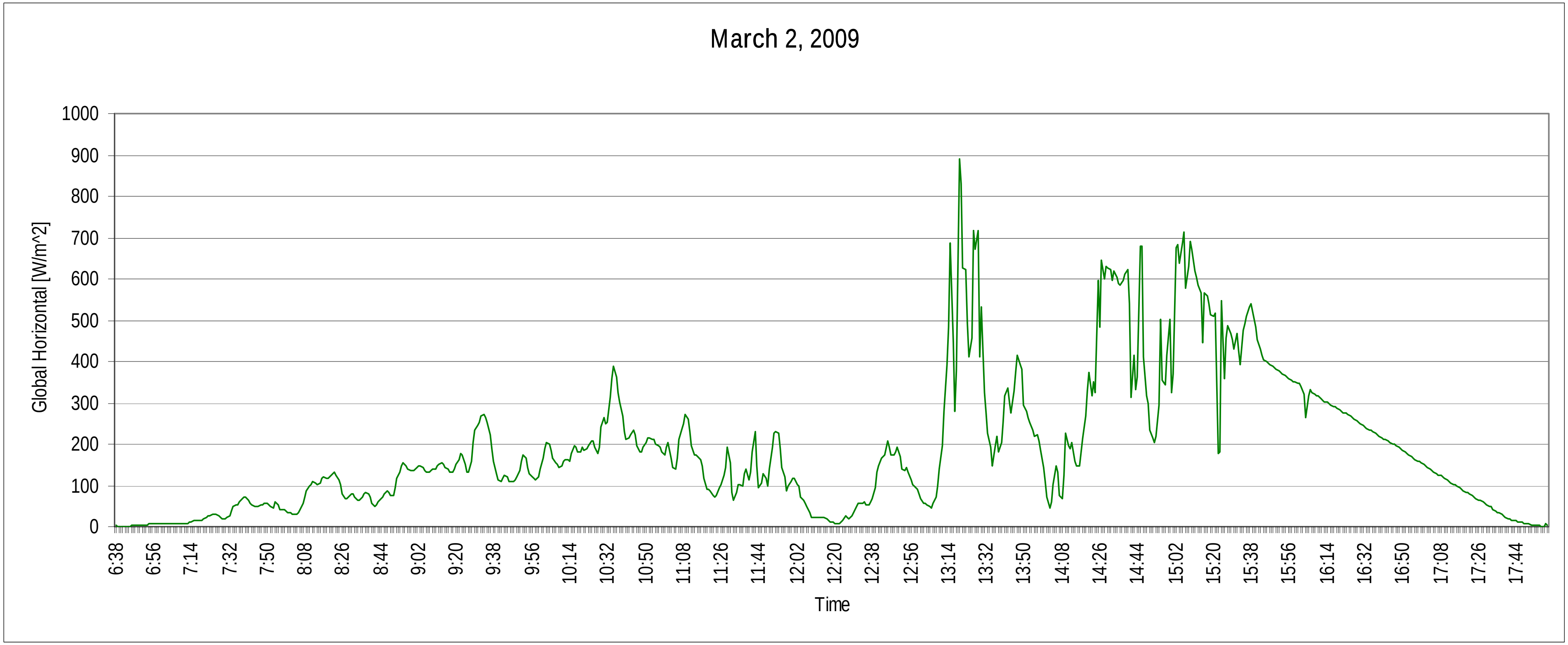
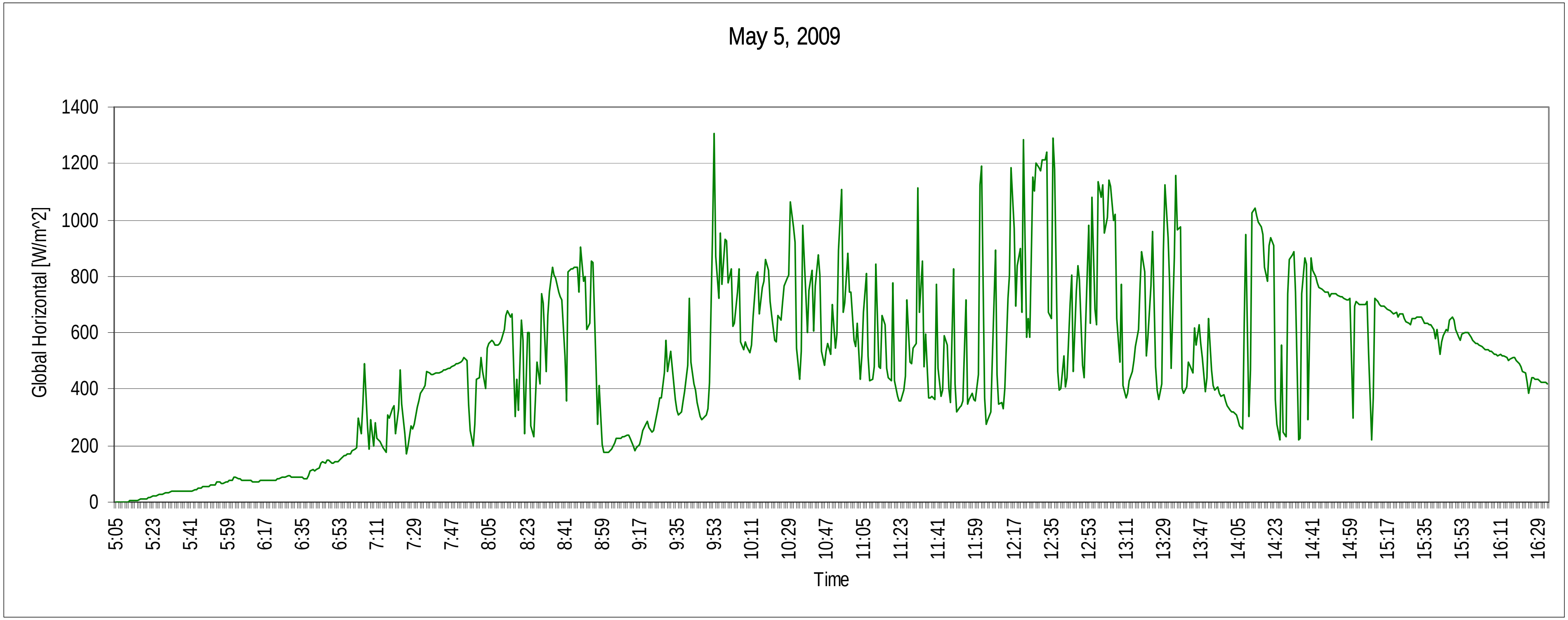
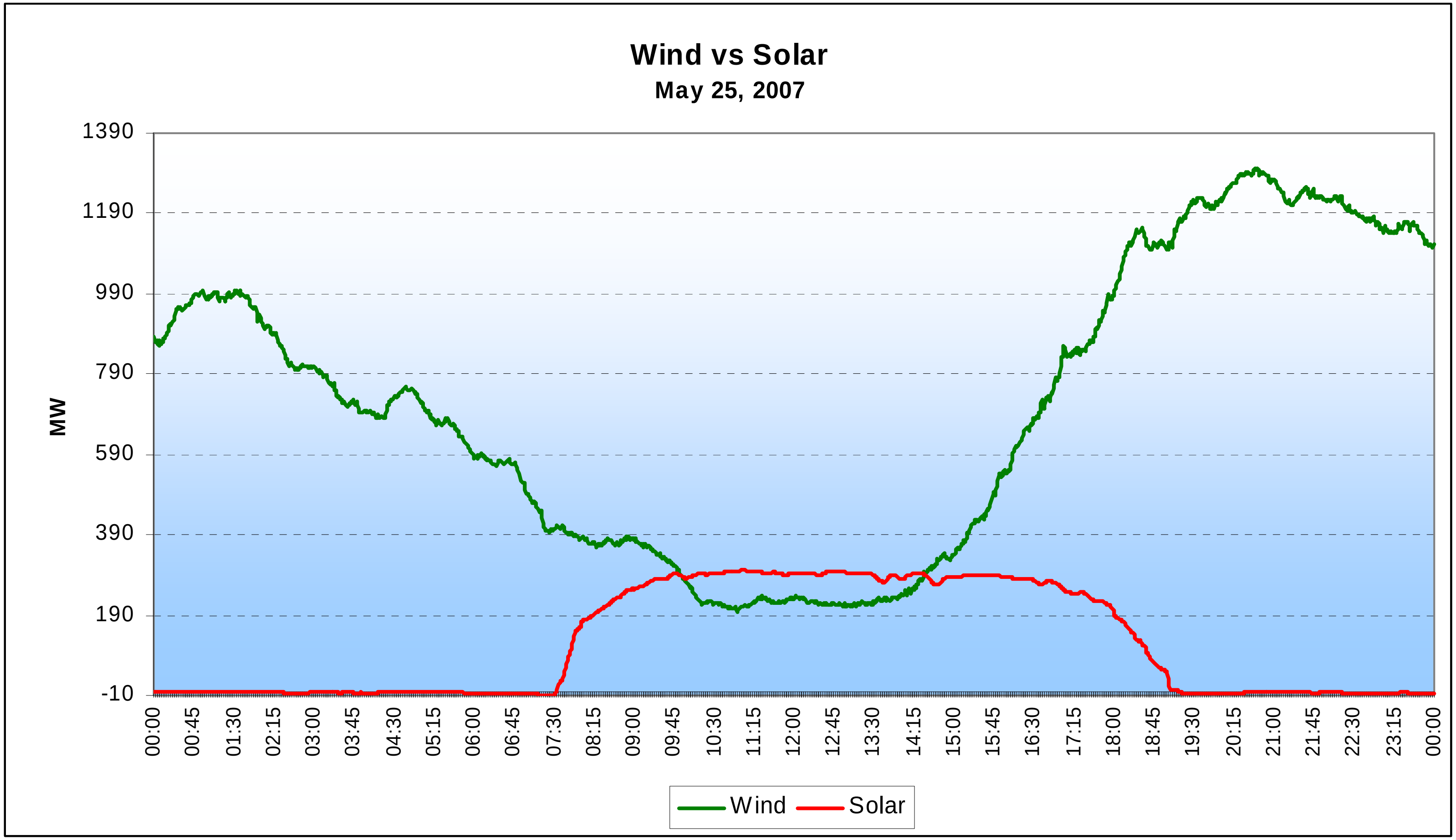
Solar Irradiation Examples – Sacramento March 2



Solar Irradiation Examples – Sacramento May 5



Typical Daily Wind vs. Solar Generation Pattern Shows Complimentary Nature



CAISO Data

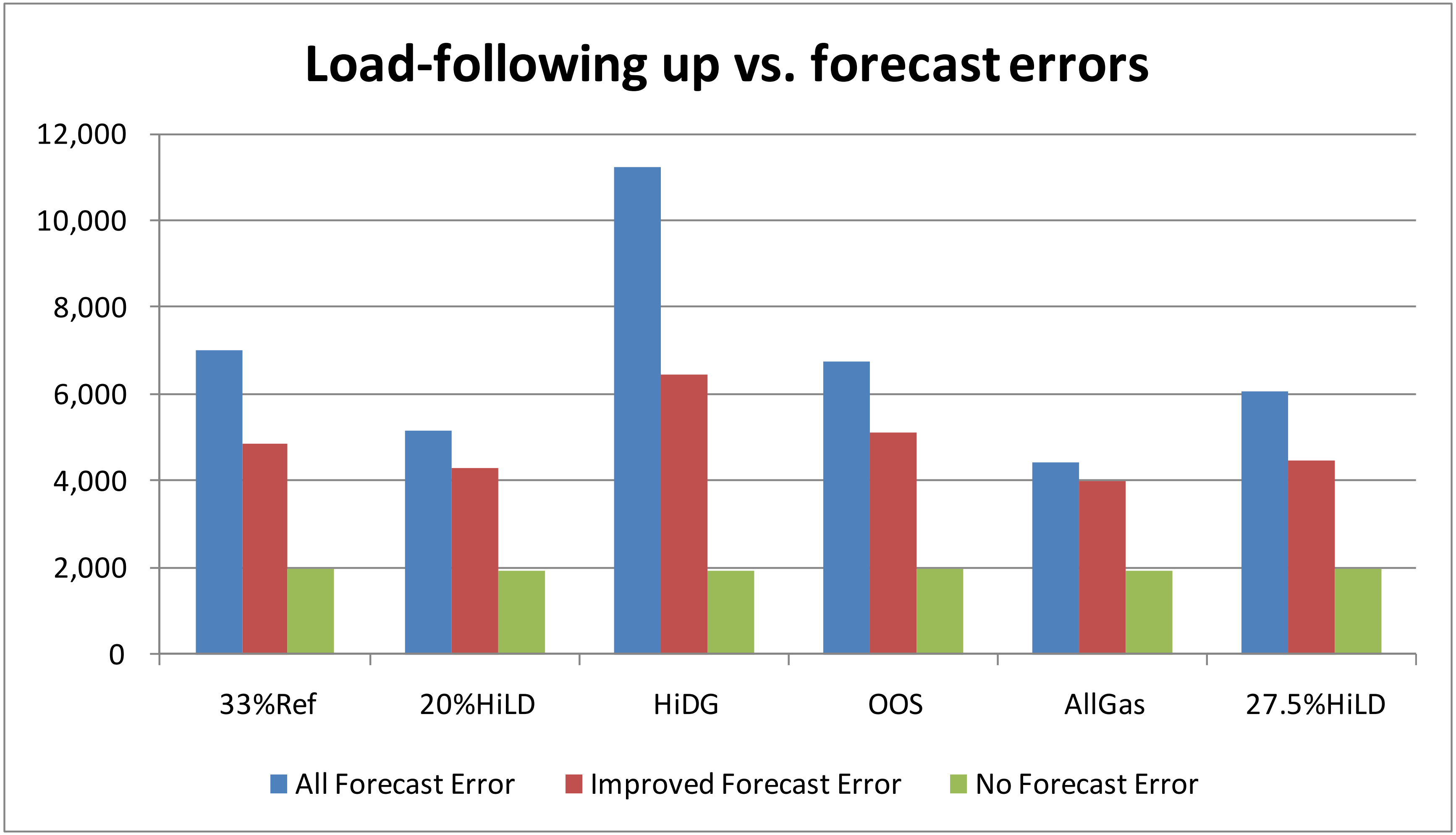
System Operations – Renewable Integration

Operating the Power System Reliably Requires:

- Sufficient Regulation (second to second Auto Generation Control of generators or other resources) and
- Within-the-hour Net Load Following (ramping generators or other resources minute to minute) and
- Inter-hour Net Load Following (ramping over hour to hour) and
- Unit commitment to cover the peak plus reserves and
- Increased unit commitment requirements due to Variability and Uncertainty (forecast error)

All of these are a function of the mix of renewables

Load-Following Up requirements under alternative, Summer 33% RPS Reference Case - Preliminary



System Operations – Renewable Integration

Over-generation potential increases with renewables

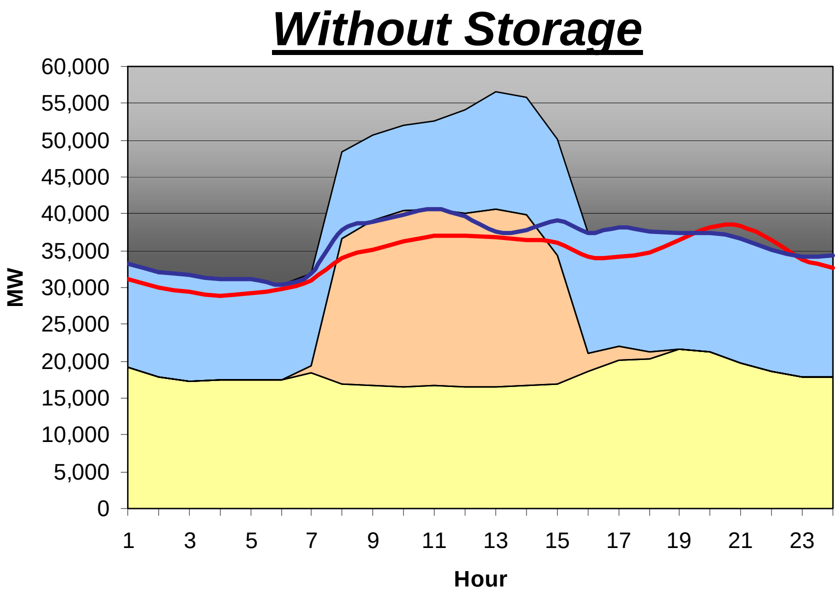
- Overgen occurs when inflexible generation exceeds load plus planned exports
- "Energy Dump" occurs when over-gen can not be sold to willing buyers in neighboring areas
- 2008 Nexant studies indicate
  - **Technology dependent**
  - **With high solar penetration can occur during high load hours**

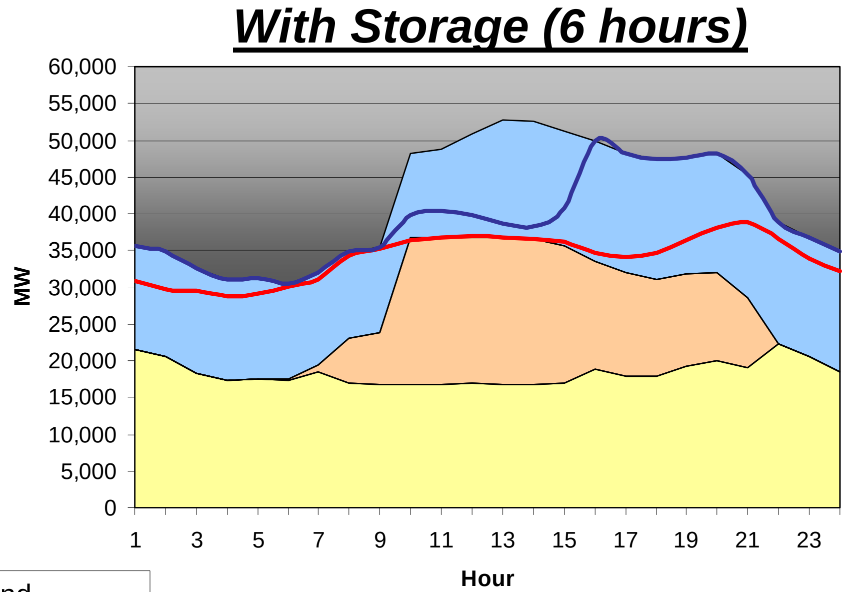
System Operations – Renewable Integration Overgen/Dump Energy – Nexant Results

- Most likely to happen in March-May period when hydro, wind and solar production can all be high and on weekends when load is low
- In 2008 simulations, more than 90% of dump occurs in SCE territory
- Simulation understates dump due to simplified transmission model used in production simulation and normal hydro conditions assumed
- May require changes in current and future contract structure to allow more frequent curtailment, as well as needing to reduce minimum generation levels

Results – Dump Energy for 50% RPS (2008 Study)

- Storage Technologies reduce dump energy

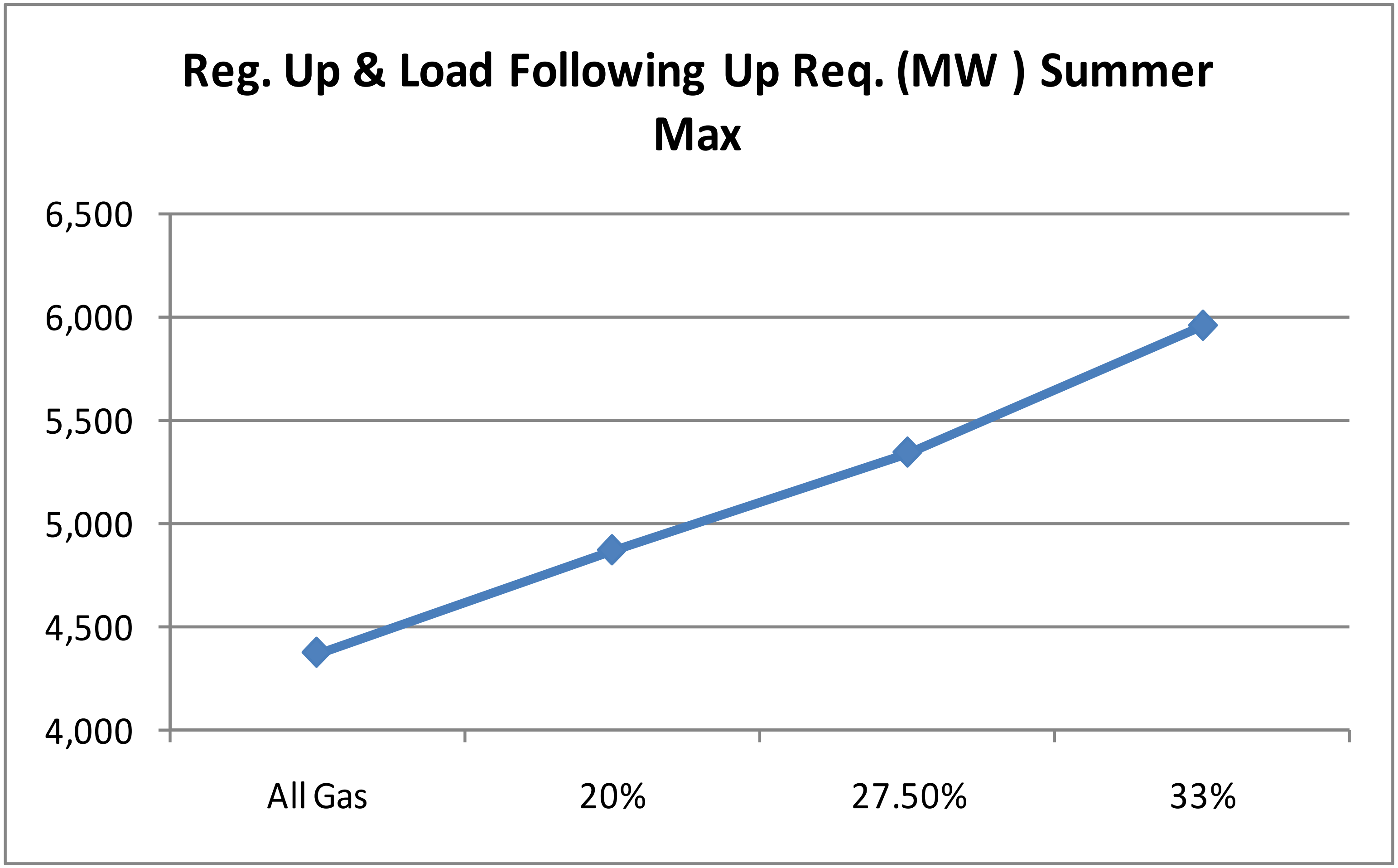




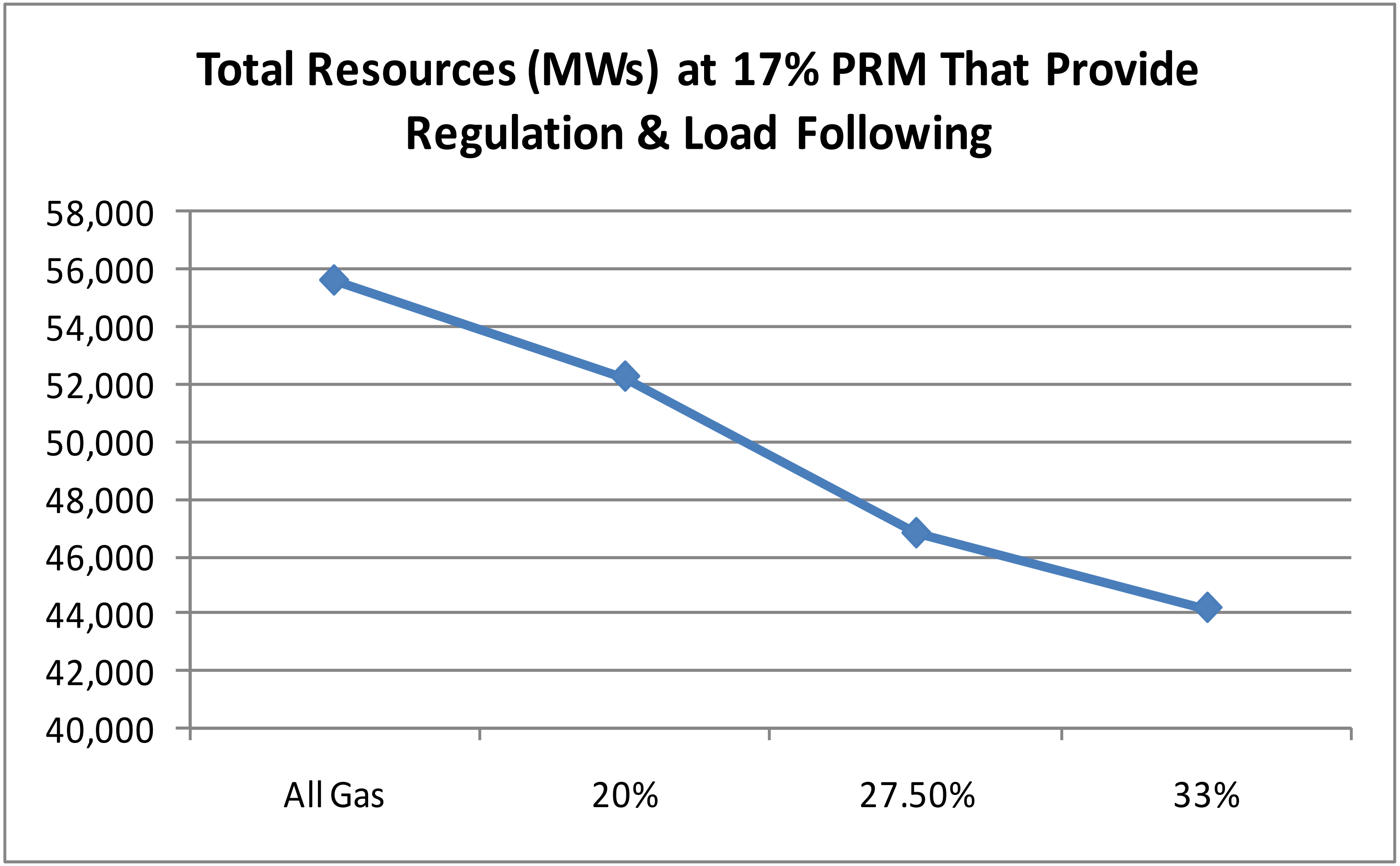
Wind
Solar
Traditional
Load+Exports
Load

- Conditions on a day with solar and wind conditions both high… 50% RPS

Analysis of generation fleet flexibility in 2020 with varying levels of renewables - Preliminary



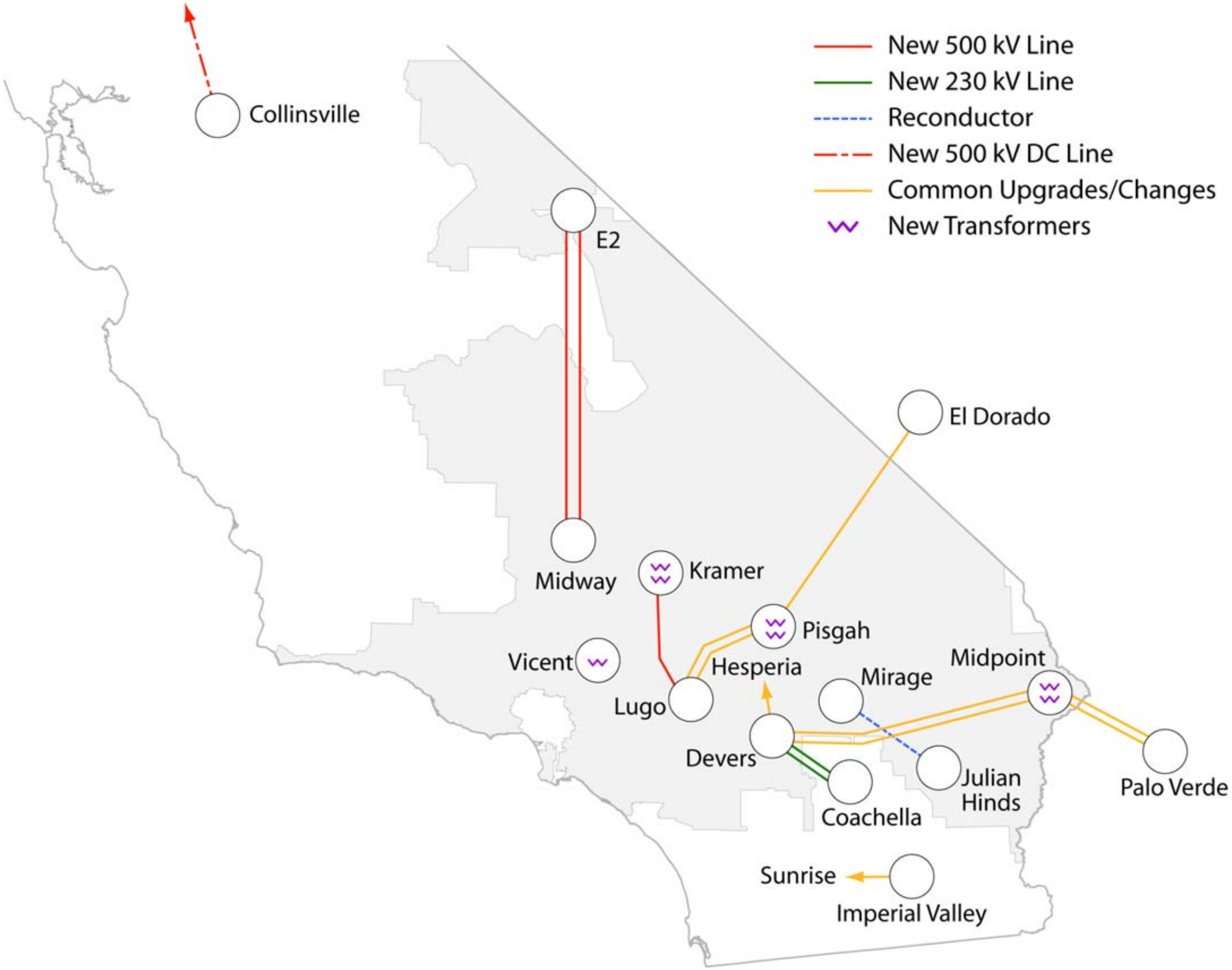
Analysis of generation fleet flexibility in 2020 - Preliminary



33% Implementation Challenges - Transmission

- Long lead time to build transmission
- Uncertain which generation projects will develop
- Uncertain where transmission upgrades will be needed
- 2009 CPUC Study shows need for up to 7 new major high voltage transmission projects
- Indicative Nexant results

Nexant Results – (2008) Transmission Expansion Bulk Transmission Upgrades For 33% RPS – 2020



33% Implementation Challenges - Transmission

Potential Source of Multi-Year Delay for HV Transmission

- **Typical lead-time 6-11 years**
- **Typical process involves:**
  - Project study and approval by CAISO (1-2 years)
  - CPUC approval (2-3 years)
    - Can add significant delays, e.g., delay in approval of Sunrise Project
    - Other litigation post CPUC approval can also delay the project
  - Engineering/Procurement (1-3 years)
  - Construction/Environmental Mitigation (2-3) years
    - Delays could be based on the route and degree of environmental mitigation

33% Implementation Challenges - Resources

- **Need for resources to integrate renewables dependent upon renewable mix**
- **For example a high wind case would require more "capacity" to meet Planning Margin than a high solar**
  - 3000 MW needed for Wind (10,000 MW) and Solar (2,000 MW)
  - 300 MW needed for Wind (4000 MW) and Solar (8000 MW)
  - Assuming wind at 15% and solar at 60% capacity credit
- **Regulation and ramping needs are dependent upon renewable mix**
  - Not well understood at this time for full mix of renewables
  - CAISO 33% RPS Integration studies underway to clarify requirements

What are some of the options to address these challenges

- Focused geographical development to streamline transmission siting to reduce the time to build transmission
- Improved longer term analytical tools to help narrow the uncertainty as 2020 approaches - more probabilistic
- Planning Reserve Margin (PRM) may have to be expanded to include integration requirements
- Potential increased use of distributed generation to reduce the transmission delays associated with larger scale remote wind and solar

Resources can potentially meet the system integration needs

In addition to traditional CCGTs and GTs

- Improved **control over new wind and solar** to deal with severe ramps and over-gen events
- Potential increased role for **demand side** responses to address regulation and ramps
- Potential increased role for **storage** to address regulation, load following and over-gen (full range of options from PP Hydro, CAES, batteries etc.)
- Improved **wind forecasting** to reduce daily uncertainty and thus reduce regulation and load following requirements
- Improved **solar generation forecasting** through better cloud cover forecasting to reduce daily uncertainty

What potentially can meet integration needs (2)

In addition

- Solar thermal generation with **integrated storage** or **supplemental firing** to reduce Reg and LF requirements
- Increased contribution from **existing hydro and pumped storage** – may result in increased maintenance and costs
- Increased contribution from **existing thermal generation** – may require capital improvements to achieve increased level of flexibility
- Fast regulation from **high speed batteries or inertial storage**
- **Electric Vehicle** battery management
- Increased reliance on RECs for out of state renewables

Questions

- Questions?