Reduced Network Modeling of the Western Electricity Coordinating Council (WECC) as a Market Design Prototype

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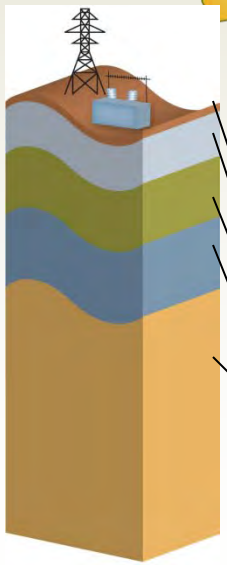
PSERC Webinar

September 6, 2011

Agenda

- Overview of California ISO and its markets
- Development of simplified WECC model through PSERC projects
- Illustration of upcoming issues
- Illustration of applying model to operational issues: How effective will various forms of storage & demand response be?
- Other topics where models have been applied to current issues

California ISO provides open, non-discriminatory access to transmission grid



1.8% coal
12.2% large hydro
13.9% hydro, geothermal, biomass, wind, solar
15.3% nuclear
56.7% natural gas

Source: 2009 Total Electricity System Power, California Energy Commission

Responsibilities:

- Reliability, grid planning, outage coordination
- Market development, operations, monitoring

CAISO manages approximately 80% of California's electricity load

- 55,183 MW in-state power plant capacity
- 10,000 MW import capacity
- 50,270 MW record peak demand (7/24/2006)
- 25,526 circuit-miles of transmission lines
- 30 million people served
- 286 million annual megawatt-hours of electricity delivered annually
- 38,000 generation & transmission outages per year
- Over 30,000 day-ahead market transactions per day, similar volume for real-time market

California ISO
Your Link to Power

CAISO markets match supply & demand for reliability in day-ahead through real-time

Day Ahead Market

Hourly market for 24 hours of next day

Establish energy and ancillary service schedules

Manage congestion (transmission access) using Full Network Model (FNM)

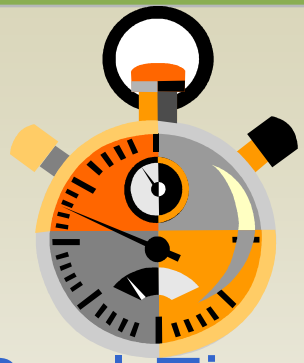
Determine residual unit commitment requirements

Hour Ahead Scheduling

Prior to real-time (RT) market, schedule energy and ancillary services for static interchange for 24 individual hours

Manage congestion using FNM

As one of 4 RT pre-dispatch processes, establish unit commitment & advisory schedules for internal & dynamic resources



Real Time Market

Manage energy flows on transmission grid with telemetry and 1-minute state estimator solutions

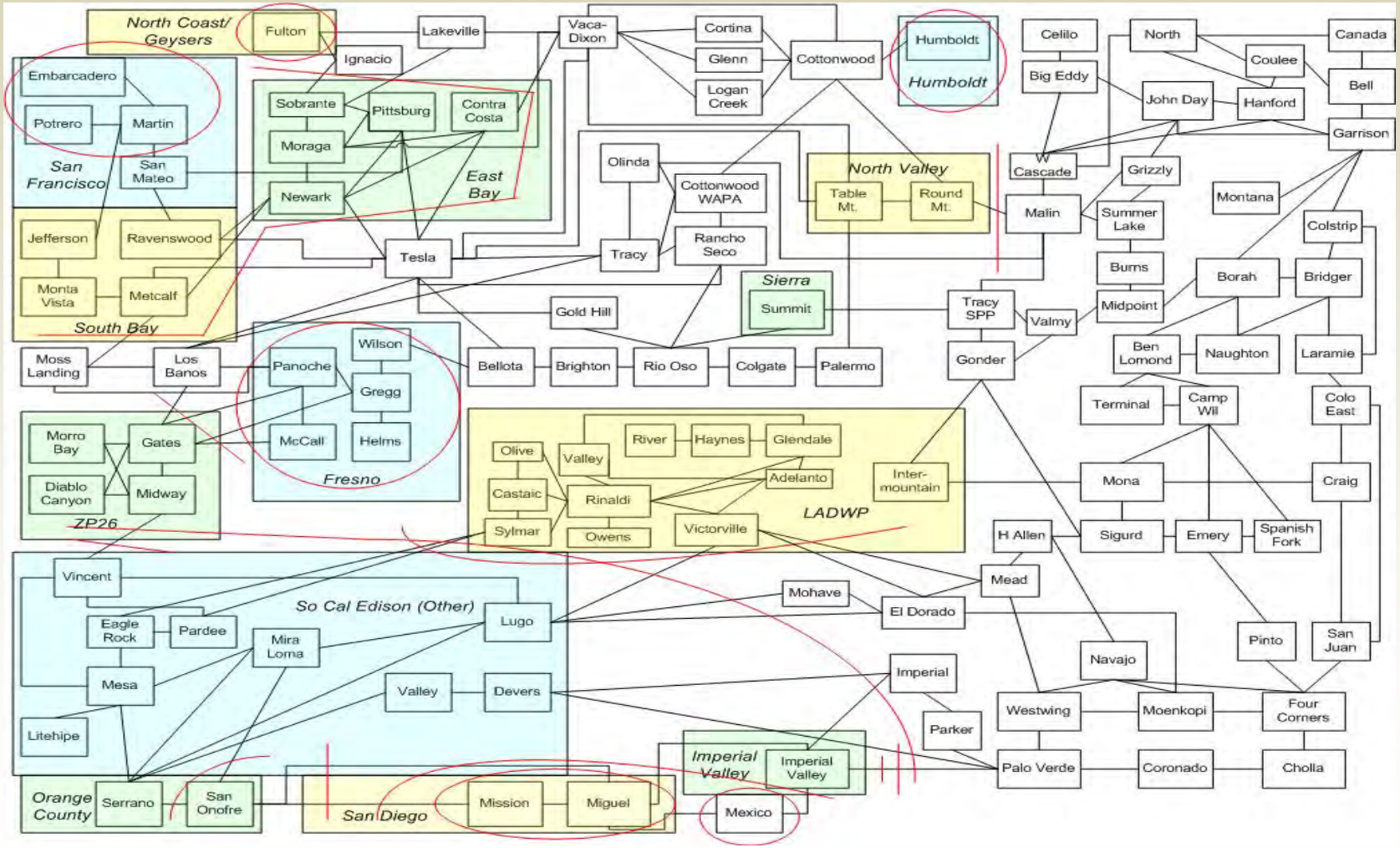
Update FNM for RT conditions

Dispatch balancing energy/ ancillary service

A theme across CAISO markets is foundation on Full Network Model

- In production, full network model provides needed detail for accurate market and dispatch
- For research, simpler model can be adequate, while detail in results can hide trends.
- PSERC projects using simplified WECC models:
  - M-13: Agent Modeling for Integrated Power Systems
  - M-21: Technical & Economic Implications of Greenhouse Gas Regulation in a Transmission Constrained Restructured Electricity Market
  - M-24: Interactions of Multiple Market-based Energy and Environmental Policies in a Transmission-Constrained Competitive National Electricity Market

Contributing to PSERC & own research, CAISO assembled 240-bus WECC model



Model characteristics

- Hourly loads for 11 areas within CAISO and aggregated sub-regions outside CAISO
- Hourly profiles for wind & solar resources: 3 wind areas & 1 solar area in CAISO, 13 aggregated wind & 4 solar areas outside CAISO
- Hourly geothermal & biomass aggregations in CAISO
- Hydro optimization profiles using PLEXOS software
  - Necessarily simplified, but focus is on differences between cases
- 23 aggregated gas-fired generators in CAISO (associated with owners) and 27 in WECC modeled as dispatchable, 17 coal plants & 4 nuclear as base-loaded

Changes over the next 10 years present operational (and research) challenges

- Over 20,000 MW of wind and solar capacity is expected to be interconnected by 2020 – **Increased supply volatility**
- Approximately 18,000 MW of thermal generation will be repowered or retired in next 10 years – **Uncertainty surrounding thermal resources**
- Potential changes to load patterns as a result distributed generation and electric vehicles – **Changing less predictable load patterns**

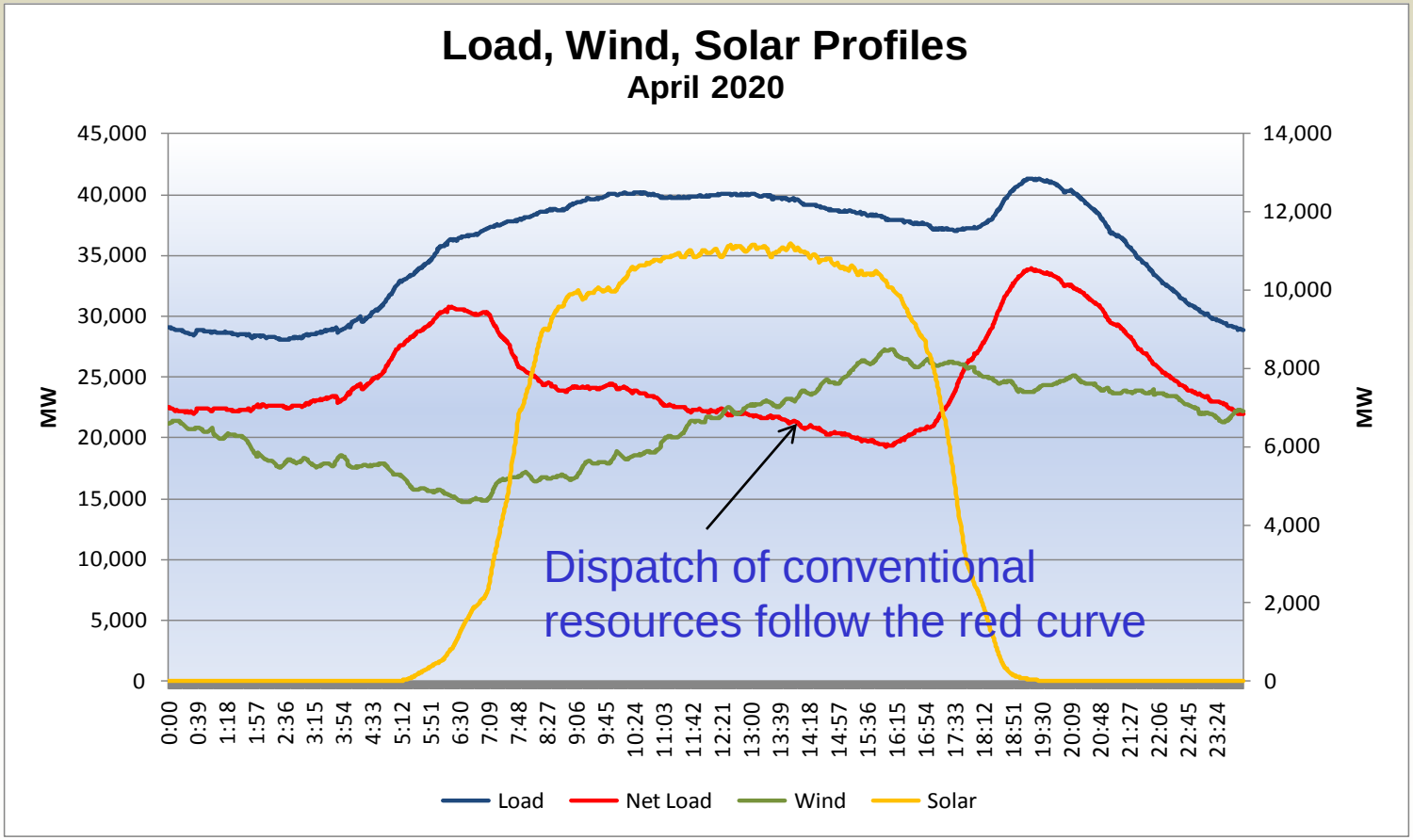
20% and 33% Renewable Portfolio Standards lead to significant new resources

	Biogas/ Biomass	Geo-thermal	Small Hydro	Solar Thermal	Solar PV	Wind
2006 Reference Case	701	1,101	614	420		2,648
Reference Case with 20% Renewables	701	2,341	614	2,246		6,688
Reference Case with 33% Renewables	1409	2,598	680	6,902	5,432	11,291

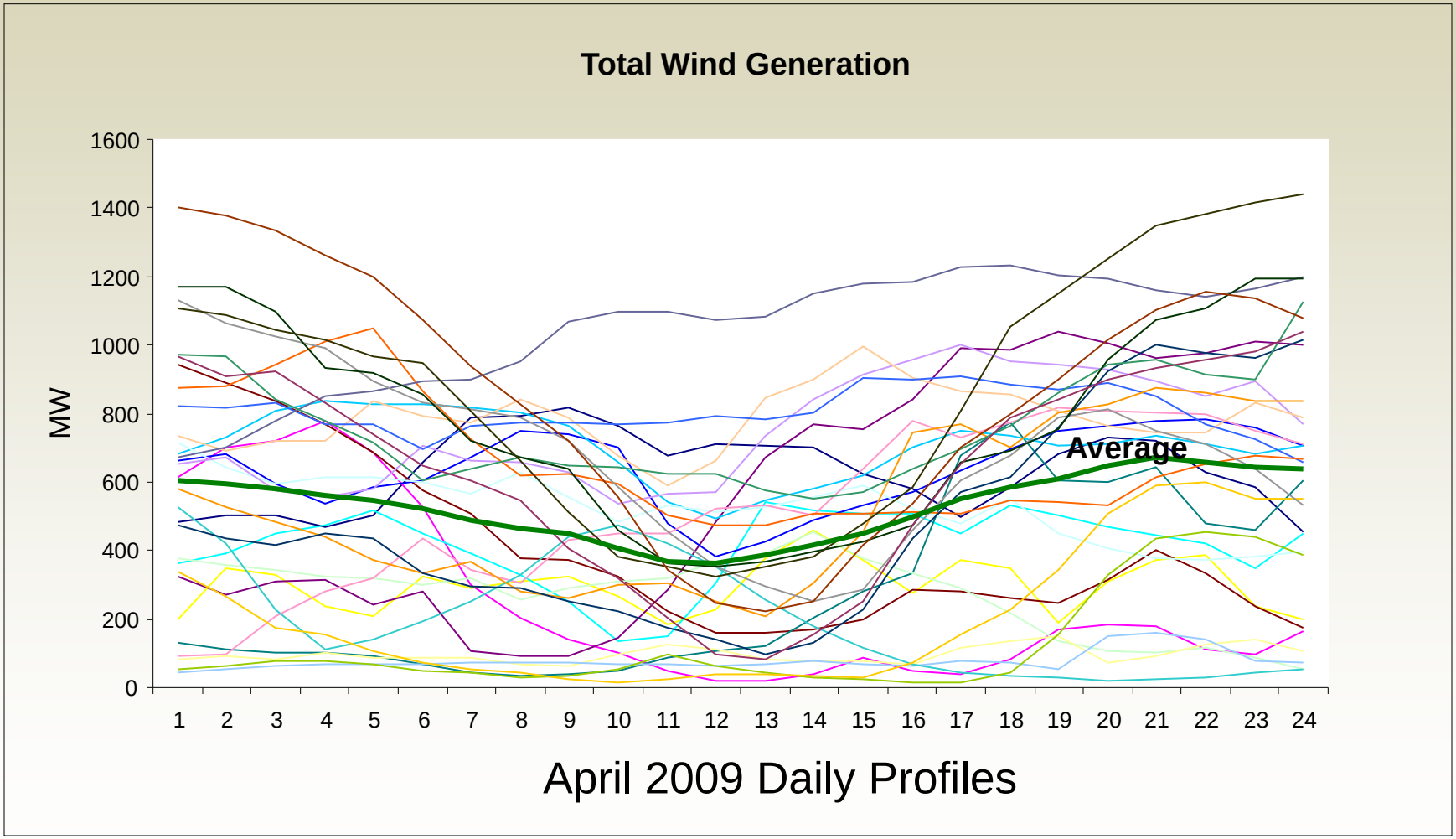
33 % solar PV includes 2,262 MW of customer side PV

Dispatch of conventional resources would not follow the typical pattern – emerging trend

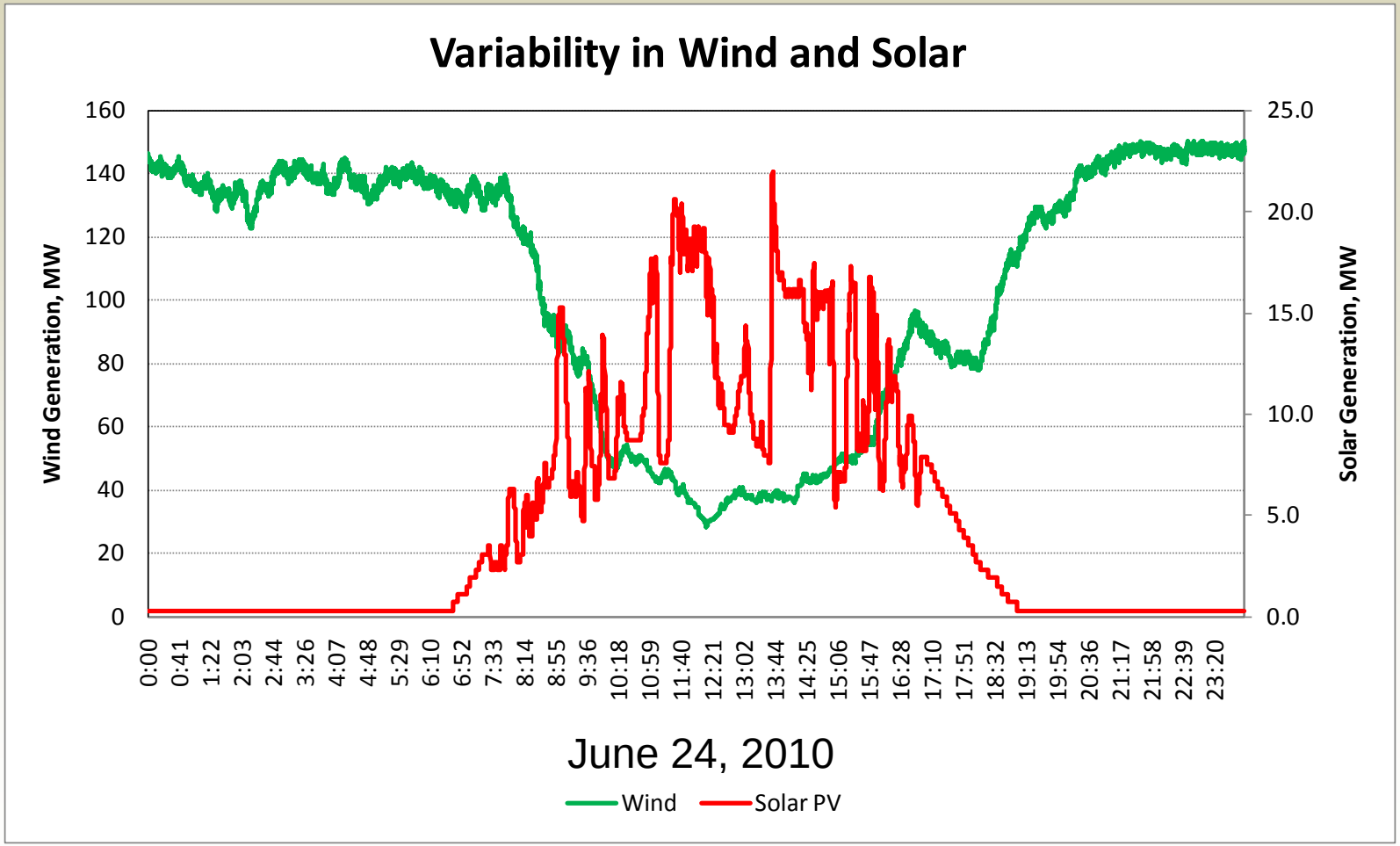
Source: CAISO Renewable Resource Integration Studies



Wind production varies greatly from day to day and intra-day



Wind and solar resources can vary significantly within days



A 150 MW wind plant and a 24 MW solar resource

California ISO
Your Link to Power

CAISO will need operational and market enhancements to support renewable integration

- Operational Enhancements
  - Wind & solar forecasting tools (output, ramping requirements)
  - More sophisticated grid monitoring systems
  - Over-generation mitigation procedures
  - Coordination with neighboring balancing areas
  - Generation interconnection standards
  - ***Pilot projects (includes storage, demand response)***
- Market Enhancements
  - New market products & changes to market rules
  - Increased regulation and reserve requirements
  - More sophisticated day-ahead unit commitment algorithms

Requirements for integration of renewables

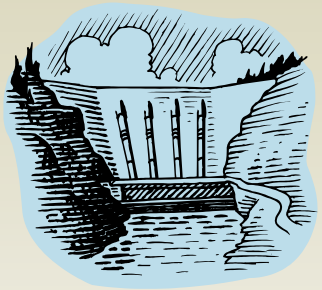
Resources Required for Renewables Integration

Wind Generation

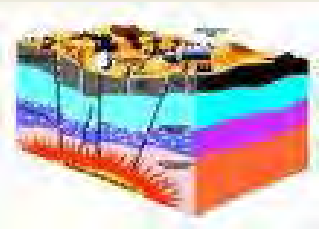
Solar Generation

"Partners in Success"

Generation Portfolio	Storage	Demand Response
Quick Start Units	Shift Energy from off-peak to on-peak	Price sensitive load
Fast Ramping	Mitigate Over Generation	Responsive to ISO dispatches
Wider Operating Range (lower P_{min})	Voltage Support	Frequency Responsive
Regulation capability	Regulation capability	Responsive to Wind Generation Production



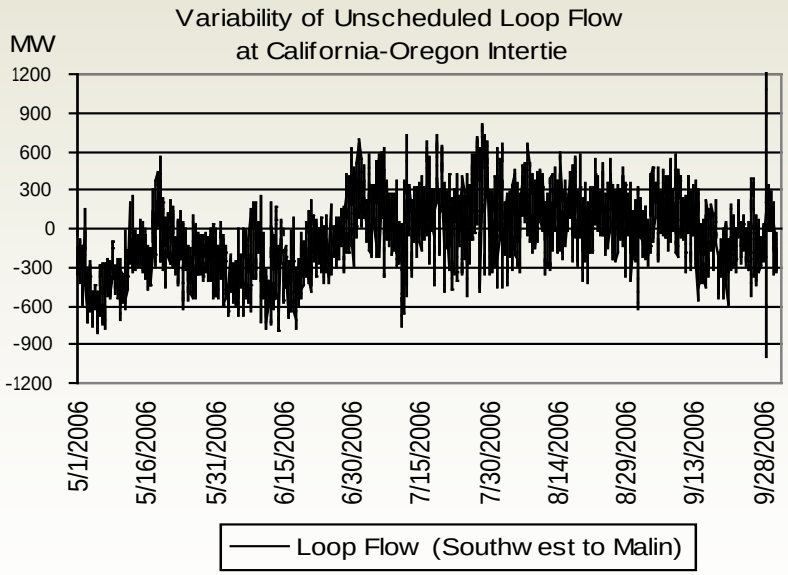
Hydro

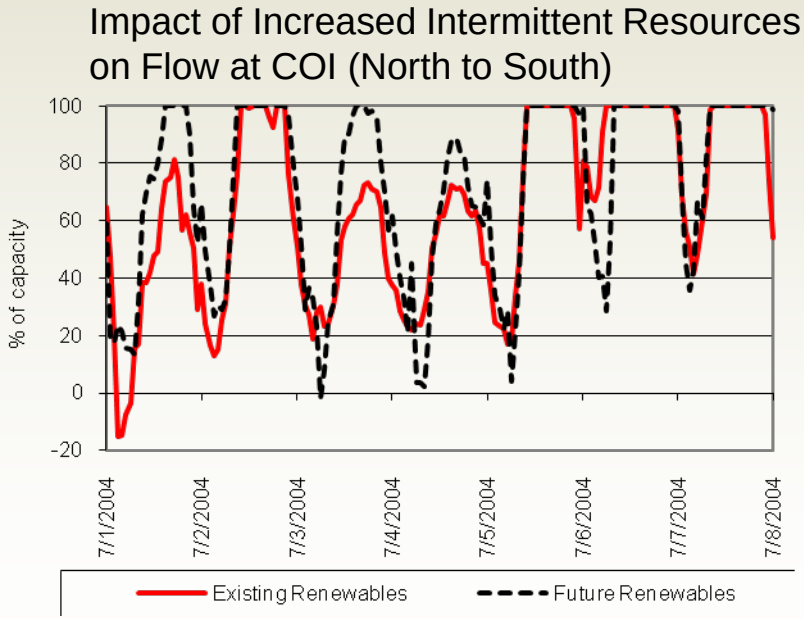


Geo-thermal Generation

Past CAISO research using simplified WECC model identified regional flow variability

Findings in paper 2010GM0783 (2010 IEEE General Meeting): existing issues of unscheduled flow at California-Oregon Intertie may increase as renewable resources develop throughout WECC region





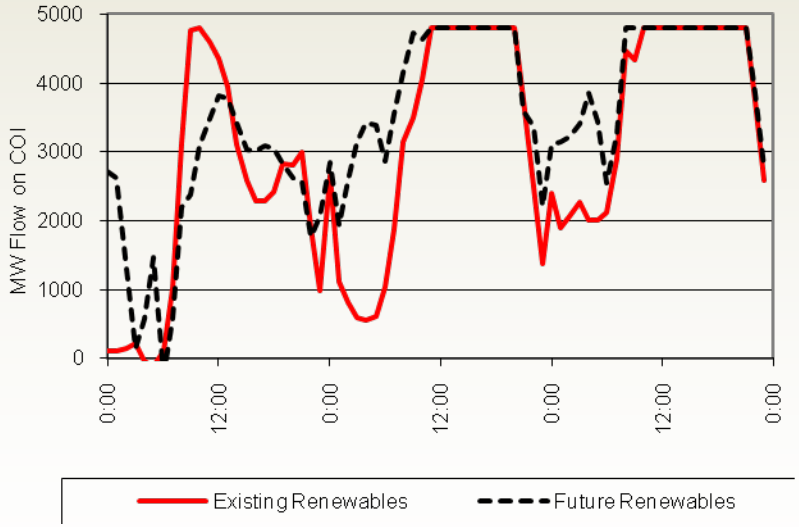
Issues to explore: How effective will various forms of storage & demand response be?

Modeling for 2011 IEEE PES paper (2011GM0942) provides similar preliminary results as previous paper:

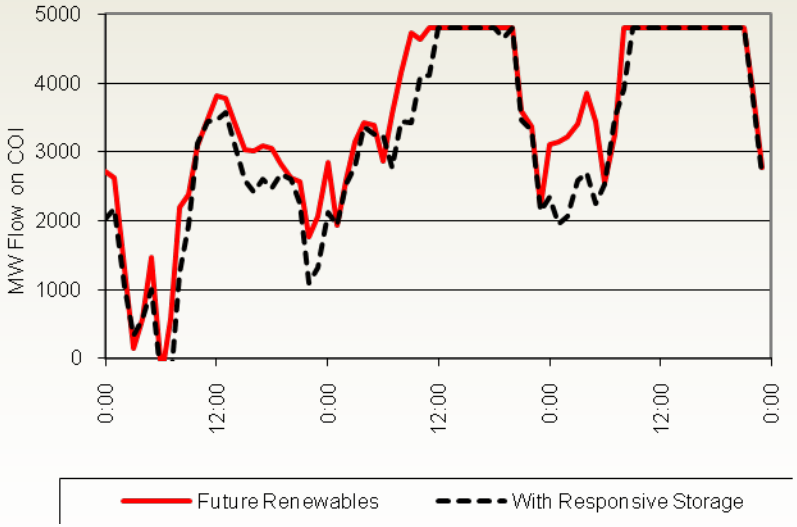
- Comparison of existing vs. future resources shows similar increases in congestion

Adding storage may stabilize flows & reduce congestion

Impact of Increased Intermittent Resources on Flow at COI (North to South)



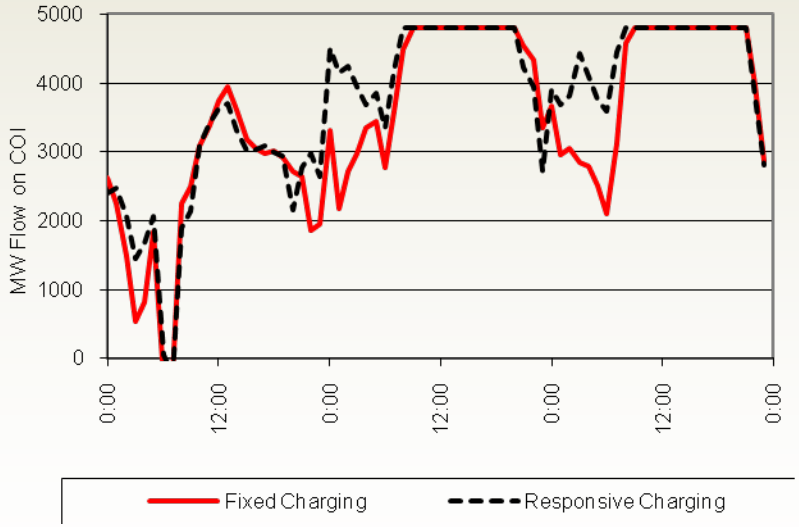
Adding storage may reduce variability & reduce congestion



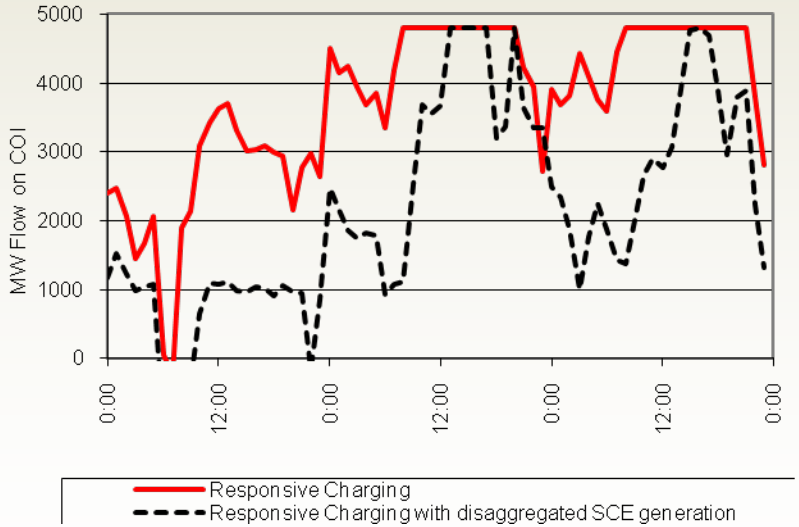
More issues remain to be explored in modeling

- Demand of electric vehicles may be added with or without coordination of charging with system conditions. Coordination may allow higher transmission utilization.
- Aggregating generators simplifies model but impacts results.

Coordinating electric vehicle charging may improve transmission utilization.



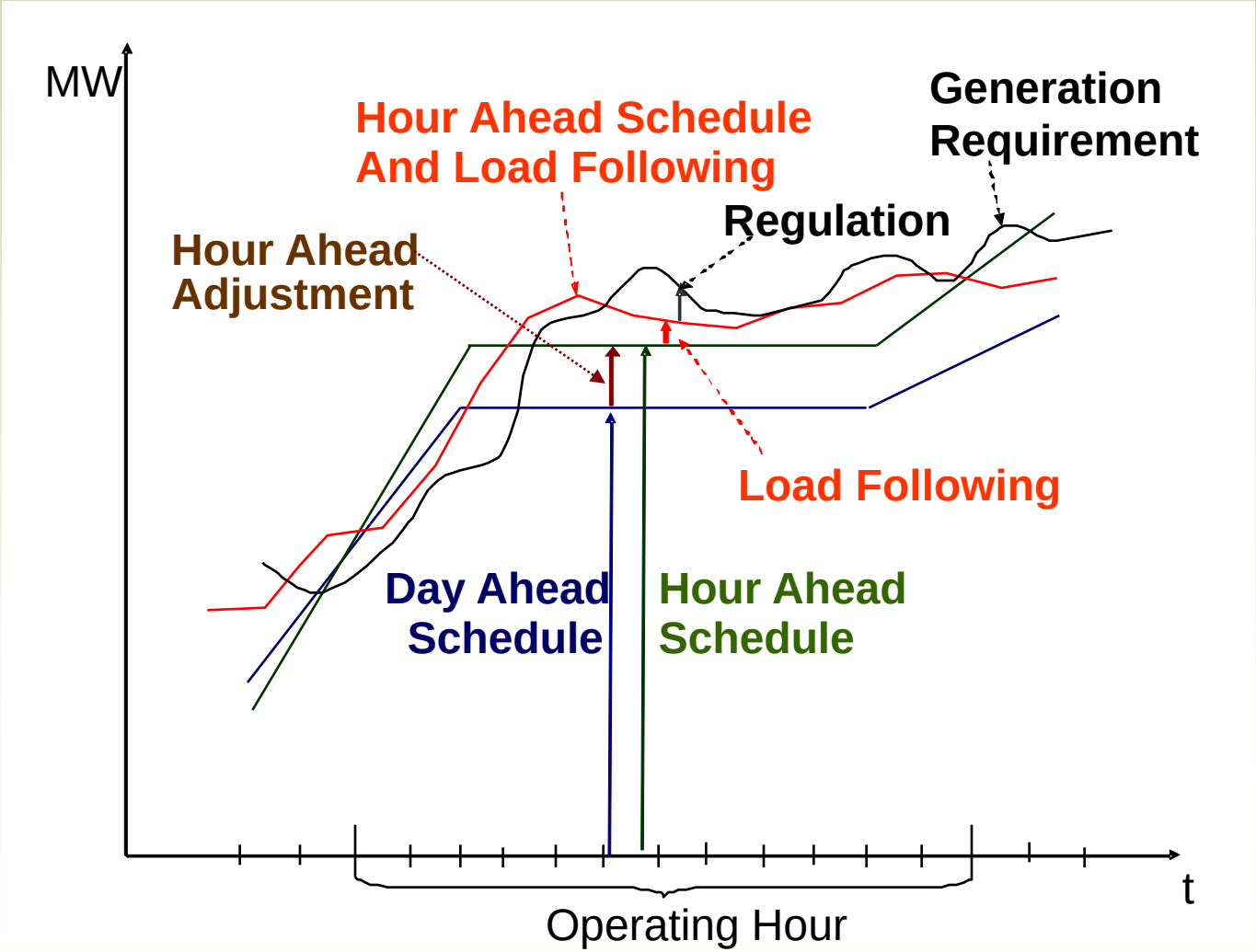
Disaggregating 4 of 166 generators (to 24 units) may have significant difference in results



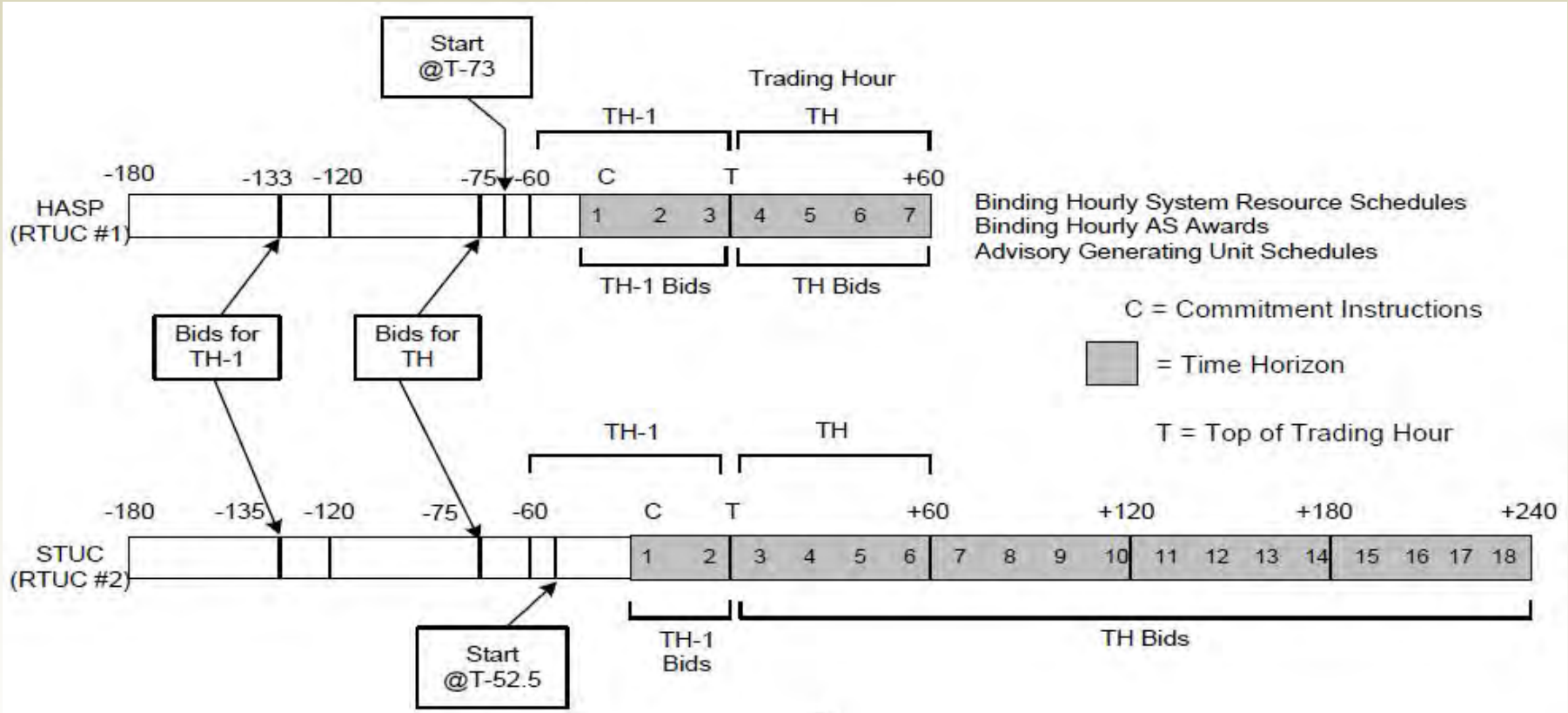
Simple model as prototype for market shows potential for focusing research

- Experience with model confirms increased ease of testing market alternatives compared to fully detailed full network model.
- As PSERC project M-24 progresses, model access will be identified through PSERC project report (to be available at www.pserc.org).
- Modeling results illustrate impacts of attention to model details, e.g., level of aggregation.

Next example for modeling market issues: supply variability requires flexibility in dispatch of controllable resources

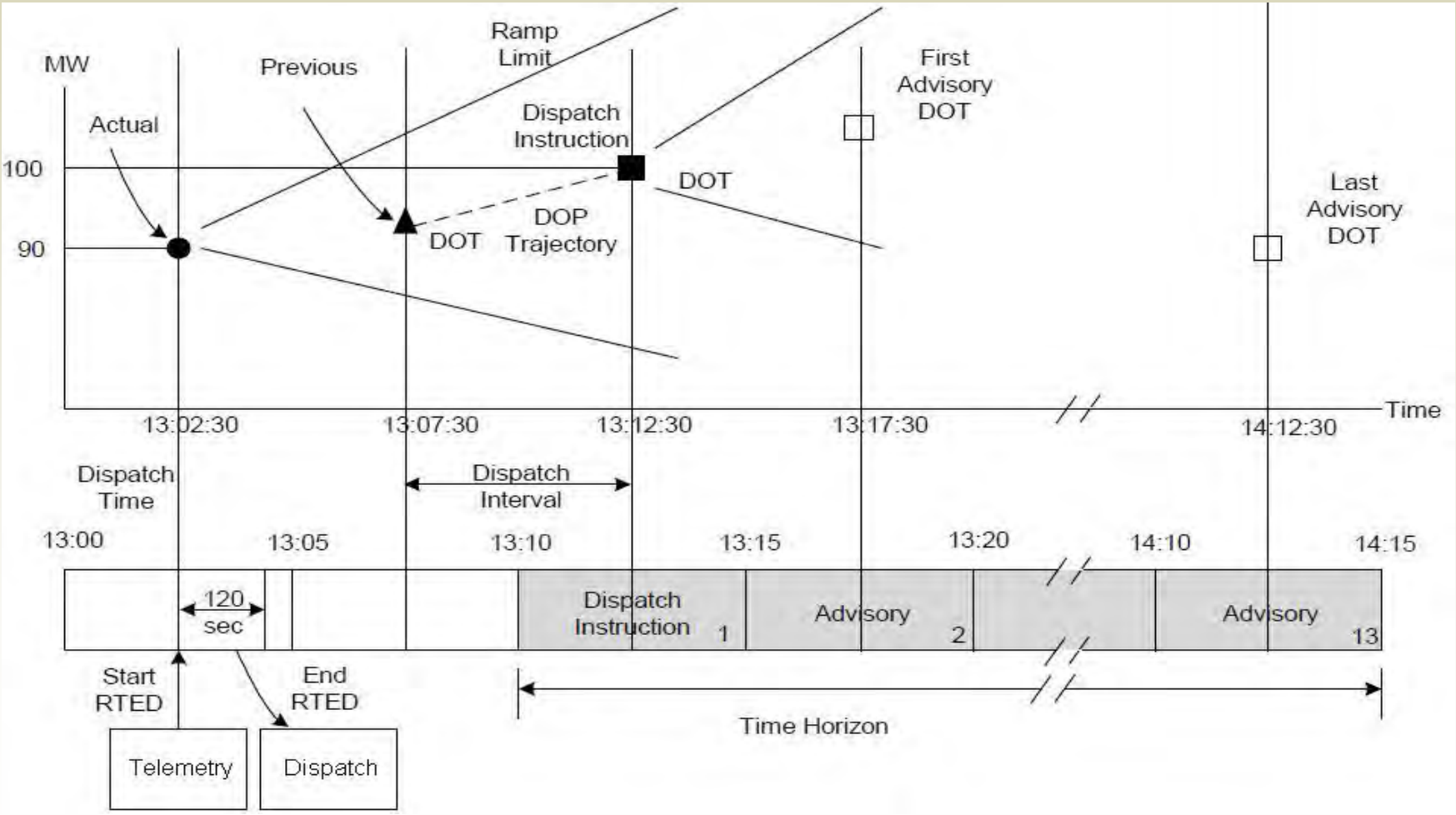


Real-Time Unit Commitment (RTUC) prepares for Real-Time Economic Dispatch



HASP = Hour Ahead Scheduling Process
STUC = Short Term Unit Commitment

Real-Time Economic Dispatch (RTED) meets energy balance in 5-minute intervals



Existing processes: Extremely Long-Start Commitment (ELC) provides longer horizon

- Residual Unit Commitment (RUC) considers up to 18-hour start-up
- ELC follows RUC, with 48-hour commitment
  - Allows operators to consider start-up of a subset of generators
- ELC still has shortcomings
  - Adds to operator workload, may not be optimal
  - Manual steps address cycling issues but may exacerbate over-generation

Enhancements now in progress to improve process

- 72-hour RUC process
  - Extends RUC to multi-day optimization, to determine whether generators remain on-line
  - Binding commitment & financial settlement consistent with existing ELC rules
- Flexible ramping constraint
  - Proposal in stakeholder process: RTUC will ensure sufficient upward ramping capability for RTED
  - Compensation based on opportunity costs

CAISO's annual prioritization of future initiatives considers future enhancements

- Potential future enhancements in prioritization process include:
  - Simultaneous RUC & market dispatch
  - Multi-day commitment in day-ahead market
  - Bid cost recovery changes for units running over multiple operating days
  - Consideration of limited run time or start-ups
  - Unit commitment and price formation improvements

Illustration of analysis leading to consideration of potential changes

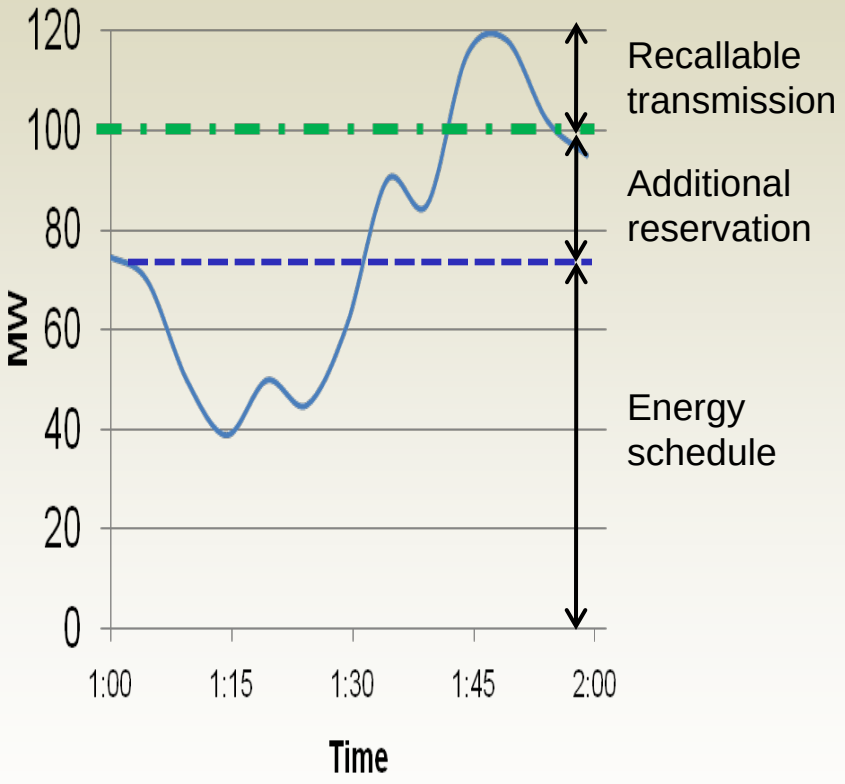
- Example: unit commitment improvements
  - Model from competitive path assessment, using stochastic unit commitment in PLEXOS software
- Initial results suggest analysis needed before reaching conclusions:
  - Average cost of $54.82/MWh with standard optimization is comparable to to $54.51 with day-ahead stochastic optimization
  - Preliminary result shows further examination warranted: increase in average cost to $55.32 in stochastic analysis if real-time resources restricted to those committed in standard day-ahead commitment

Additional example: dynamic transfer of renewable resources to meet Renewable Portfolio Standards

- Issues of congestion management and other reliability issues in ISO markets:
  - Data and forecasting requirements
  - Dispatchability requirements
  - Curtailment rules
  - Transmission reservations and utilization
  - Locational modeling and pricing
- Supporting analyses:
  - Meaningful compliance, transmission utilization

Transmission & congestion management proposals maximize transmission use

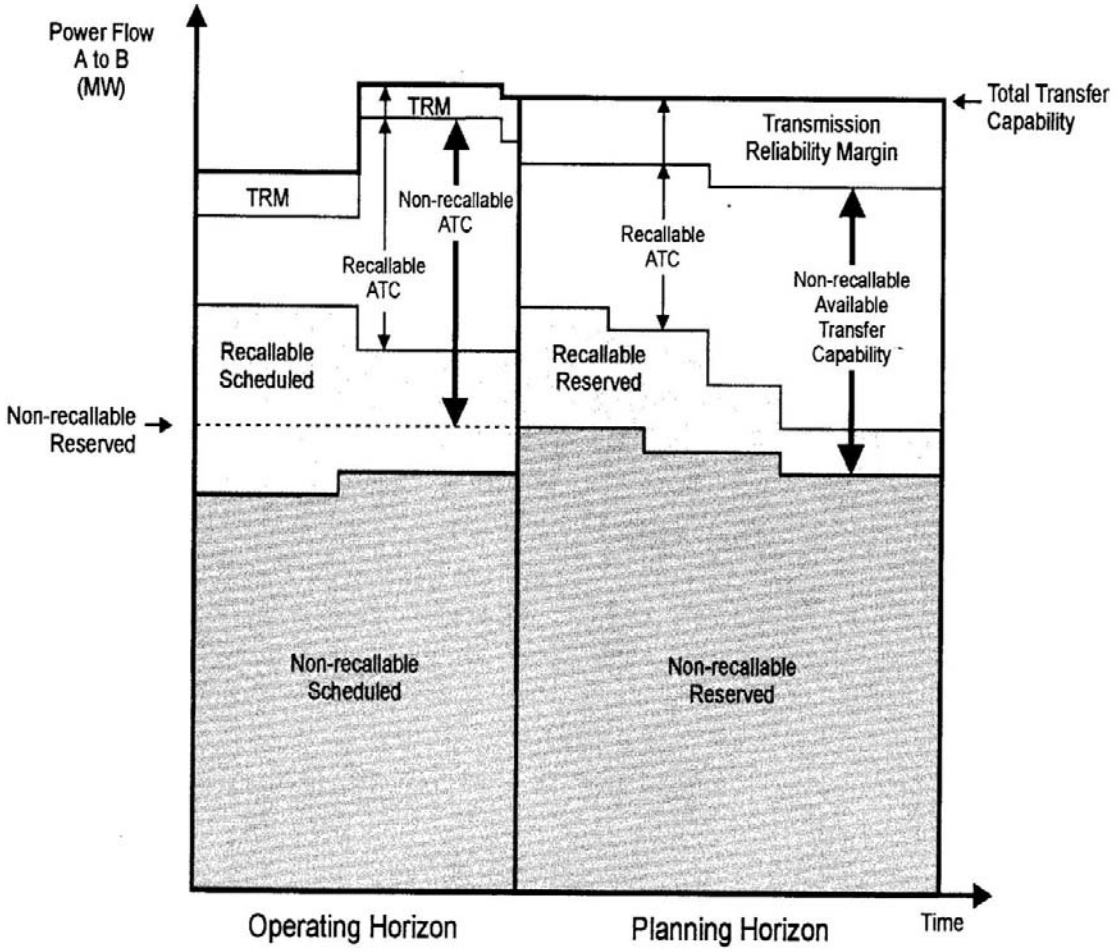
- Dynamic scheduling allows (but does not require) transmission reservation exceeding expected energy – room for variable delivery.
- Options for 5-minute real-time scheduling of recallable transmission allow filling unused capacity while managing congestion.
- After economic dispatch, operating orders ensure compliance for reliability.



Transmission reservations are part of interchange scheduling

If capacity is available, dynamic transfer can exceed initial (non-recallable) reservation, as recallable schedule.

- Non-recallable reservations cannot exceed capacity
- Non-recallable schedules + recallable schedules cannot exceed capacity
- Reserved capacity may be used by recallable schedules
- Non-recallable reservations + recallable use can exceed capacity



Source: NERC's "Available Transfer Capability Definitions and Determination"

Dynamic Transfer Capability study examined limits on variability of resources

- Study reviewed potential limits on transfer of variable resources while shaping and firming energy within ISO:
  - Impacts to existing path limits that accommodate planned hourly variations from 20 minute ramping period
  - Voltage control issues
  - Risk to stability or excitation of low frequency modes of oscillation
- ISO concluded no limits need to be applied within the ISO's BAA at this time but will monitor operational issues and coordinate with other BAAs on regional issues affecting dynamic transfer capability.
- Having studied reliability issues, remaining question was potential for market impacts

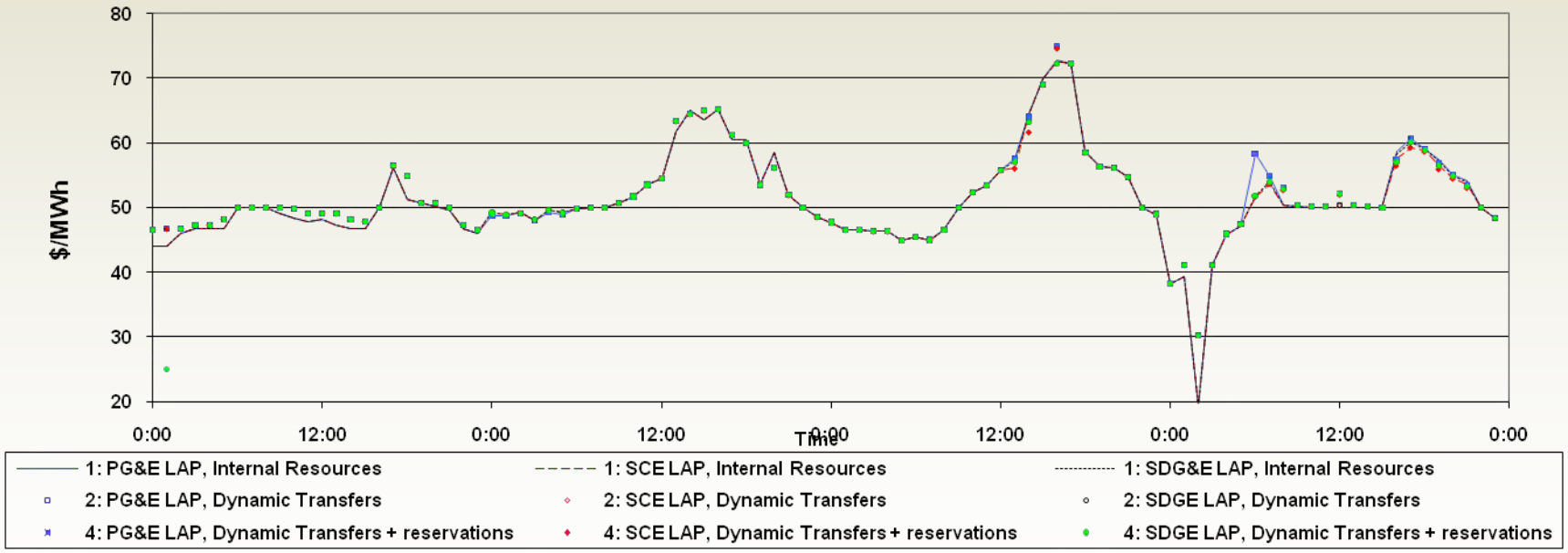
Market impact study: PLEXOS model establishes benchmarks and simulates market

Potential for market impacts compared four scenarios:

1. Reference case, internal intermittent resources: adding wind & solar generation within ISO isolates impact of dynamics from simply having new generation
2. Add renewable dynamic transfers without transmission reservations: adding low cost MWh without new market design features establishes additional benchmark
3. Dynamic transfers bid for transmission reservations beyond their energy schedules: represents pre-scheduling in DAM & HASP, before RT dispatch
4. RT dispatch, with hourly intertie schedules fixed from Case 3: in RT dispatch, hourly intertie schedules are limited to their pre-scheduled amounts

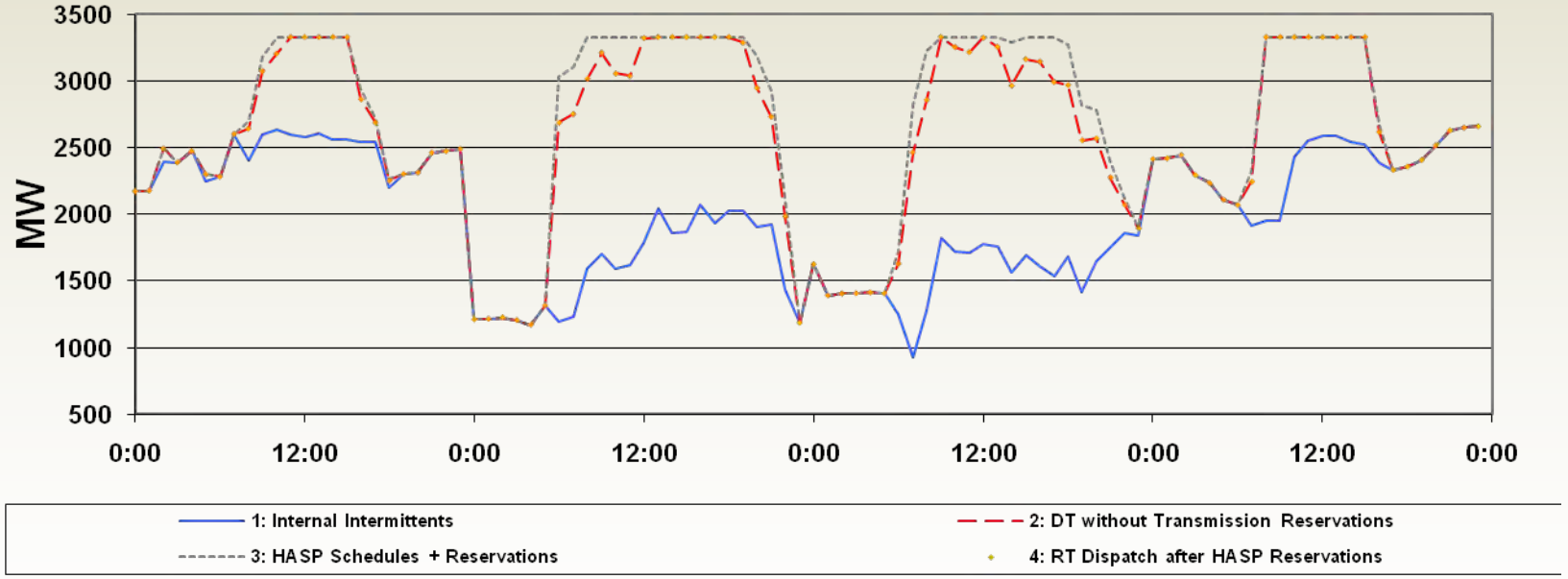
Results show very limited impact on market prices in ISO's load aggregation areas

- Market prices are higher in cases 2 & 4 than in case 1 simply due to existing limits on importing new generation into ISO
- Prices in cases 2 & 4 are indistinguishable in most hours: price impacts of adding reservations are limited in frequency and size



New resources add to congestion, but transmission reservation has limited impact

- Comparing cases 1 & 2 at Palo Verde intertie shows impact of simply adding renewable resources scheduled as imports.
- Case 4 adds impact of transmission reservations, but usage in case 4 has little change in most hours from case 2.



Conclusions

- Market models have provided insights into a variety of market design issues:
  - Simplified WECC market model used in areas including agent modeling of market power mitigation, technical & economic implications of environmental policies, regional power flow variations, market design for demand response & storage
  - Optimization for unit commitment
  - Market impacts of changing resource portfolios
- In some areas, results are preliminary and will be pursued further in future research