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# Renewable Energy Integration

## Issues and Analysis

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# Contents

# What is the big fuss about renewable integration?

**The ultimate question that RTOs and transmission utilities are asking is:**

**"How would adding significant amounts of variable resources impact operations and costs?"**

**… the natural next question is:**

**"Who should pay for these costs?"**

# What are the relevant renewable integration issues?

**FERC, in its January 2010 Notice of Inquiry, identified the following topics:**

- Data and forecasting
- Scheduling flexibility and incentives
- Day-ahead market participation and reliability commitments
- Balancing authority coordination
- Reserve products and ancillary services
- Capacity markets
- Real-time adjustments

**Today, we are going to touch on the highlighted items.**

# Defining the renewable integration problem

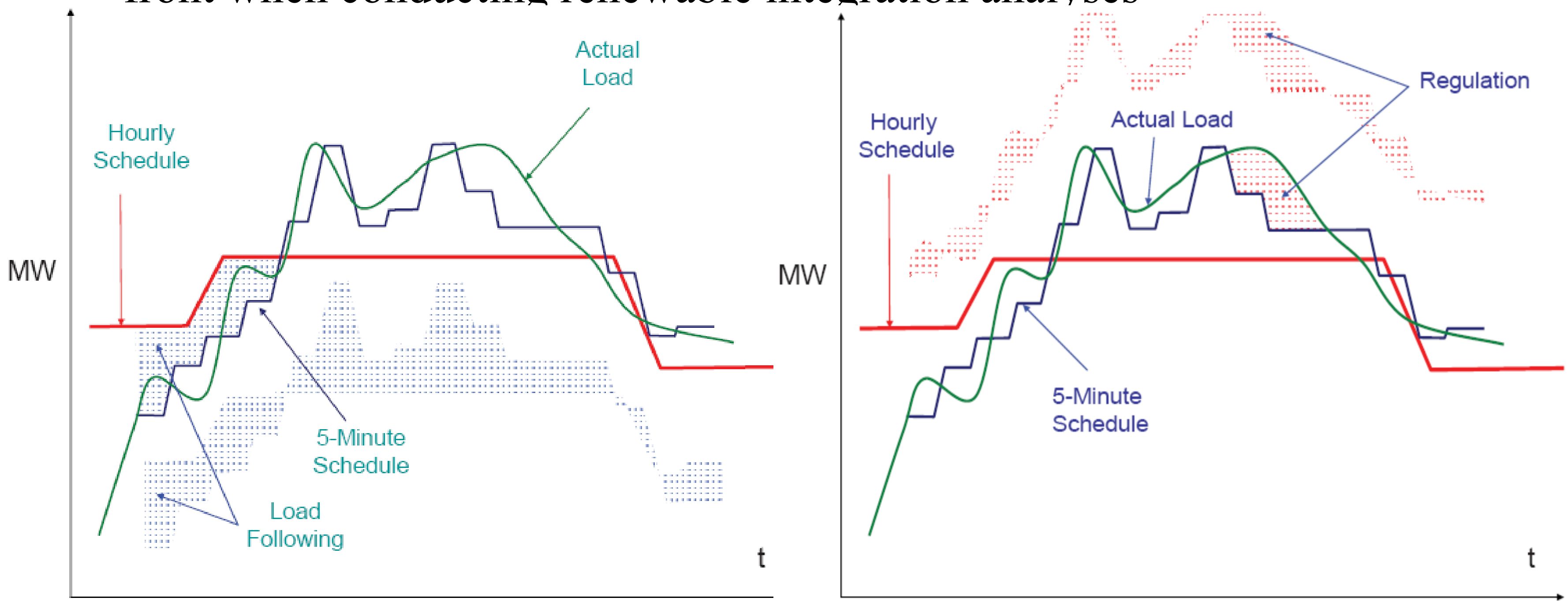
**<u>Variability</u> and <u>Unpredictability</u> associated with some renewable resources may require specific operational changes**

- When variability and unpredictability are smaller than that of load, the existing system may be able to accommodate the wind and solar resource additions without significant operational or investment changes
- However, as large volumes of wind and solar resources are added to the system, large swings can significantly affect system reliability

**So how do we measure the variability and unpredictability to assess whether they may impose additional costs to the system?**

# Define the integration issue in various time frames

- ♦ Movements of renewable energy and load need to be analyzed
- ♦ Each system defines "integration services" differently, each can be based on a set of unique operational time frame
- ♦ Different definitions sometimes make integration cost estimations incomparable
- ♦ Extremely important to define the operational requirements and services up-front when conducting renewable integration analyses

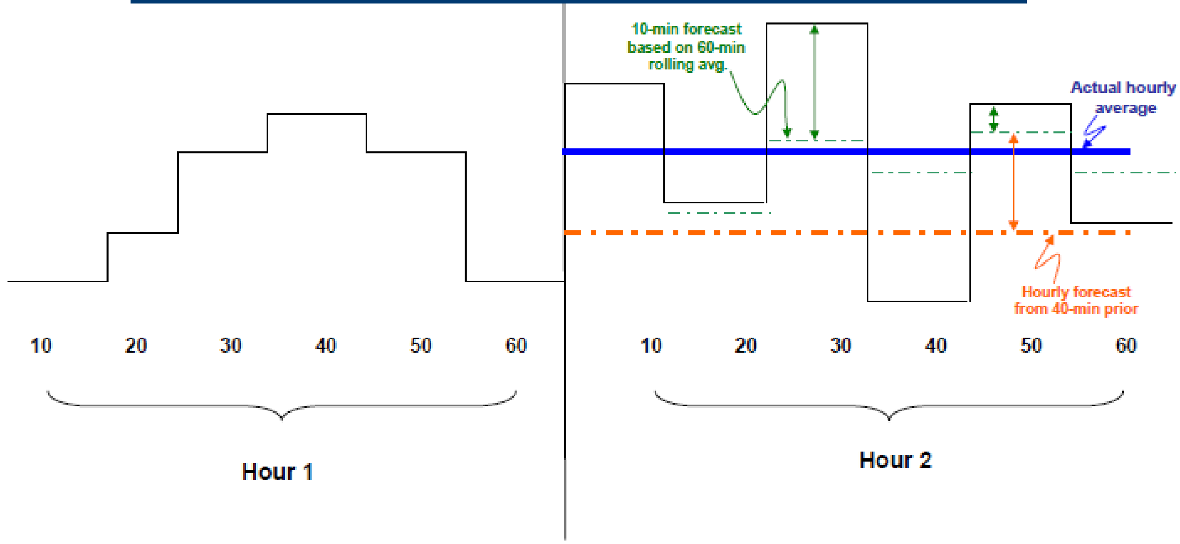



Source: CAISO Integration of Renewable Resource, November 2007

# To simplify, the overall method compares scheduled energy with actual delivery within various time frames

- **Deviations from schedules** are central to the question and analysis
  - Deviations from schedules simultaneously measures variability and unpredictability
  - Quantifying these deviations is the first step in the analysis
- **Start by asking system operations some critical questions**:
  - When and how often are wind and solar generation forecasts performed?
  - When and how are the forecast data incorporated into operations?
  - When are conventional resources scheduled? When are those schedules adjusted?
  - What resources are asked to respond to changes determined at different time frames?
  - How is load variability accommodated today? How is load forecast data incorporated into day-to-day operations?

**Sample forecast and actual comparison**

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# How are integration costs estimated?

- Different renewable integration studies have used different methodologies
- Common features include:
  - Compare actual and scheduled energy delivery on granular time scale
    - Can be done on a minute-by-minute or slightly longer basis (*e.g.* 10-minute)
    - Often limited by availability of historical data
  - Assess the need for regulation and load-following services based on statistical variance of energy delivery
- Integration costs are estimated through three primary methods:
  1. Simulate the incremental operational impact and estimate the associated variable and fixed costs
  2. Simulate the full system with and without variable wind resources
  3. Use historical resource needs and costs as proxy for future needs, which may involve applying a fixed cost per MW of incremental service need

# Each method has its own advantages and disadvantages

| Methodology | Advantages | Disadvantages |
|---|---|---|
| **1. Simulate full system with production cost models** | • Simulate the details of the system's capability<br>• Can show each generator's actual service delivery and system performance in each hour<br>• Many modelers are used to using production cost models | • Many assumptions can bog down the analysis and mask the central issue<br>• Must simulate scenarios of "with" and "without" variable renewables resources – which are never easy to define<br>• Must translate needs into ancillary services that the models can accept<br>• Ignores incremental capital cost implications |
| **2. Simulate incremental operational and capacity needs** | • Focus on the central issue<br>• Estimate the incremental impact<br>• Can conduct quick estimations under many different assumptions<br>• Easy to benchmark | • Not model full systems on a hour-by-hour basis<br>• Not model the unit commitment under different renewable assumptions |
| **3. Use historical resource needs and costs as proxy for future needs** | • Simple calculations<br>• Can be adjusted over time | • Resource needs and associated costs may change over time<br>• Ignores any incremental capital cost implications |

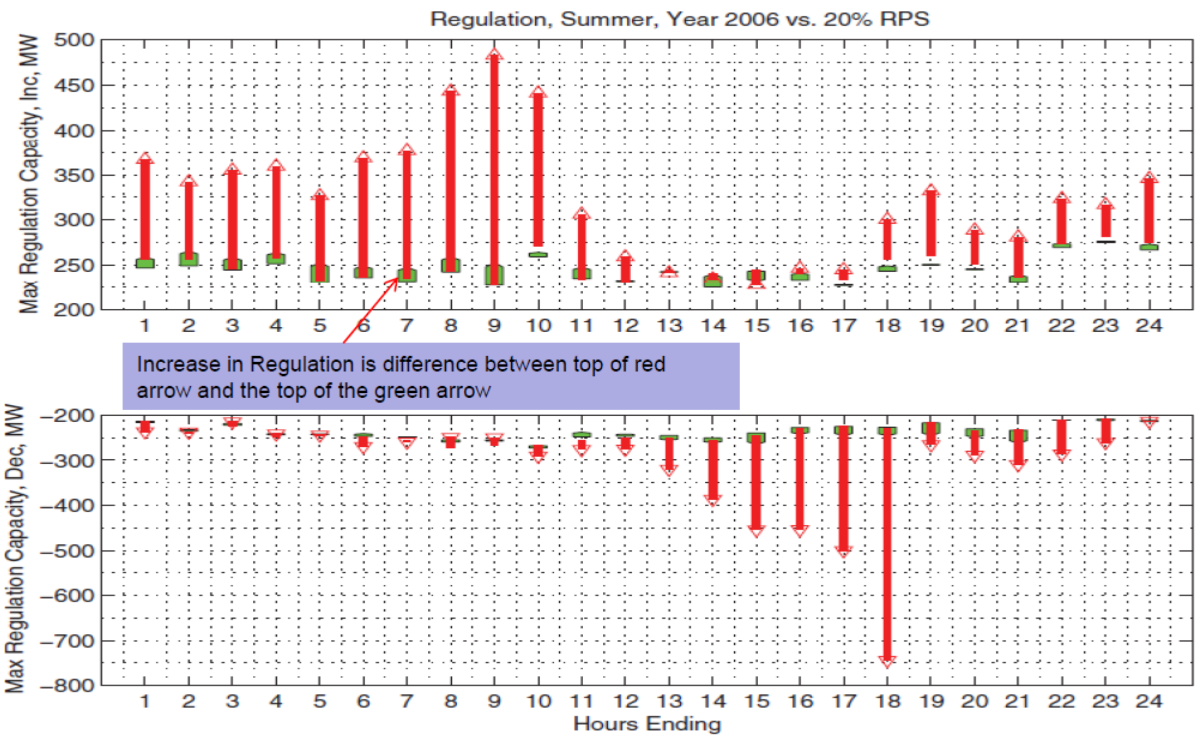
# Renewable integration analyses show that additional ancillary services will be needed

**Various studies for CAISO, NYISO, ERCOT, NREL, and SPP employing a range of distinct methodologies, yielding different results**

**But all studies agree that challenges include:**

- Increased need for regulation, spinning reserves, and load-following
- Steeper system ramping requirements
- More frequent and more serious over-generation events
- Less efficient dispatch of conventional resources
- Suppressed energy market prices

**Graphs show the California ISO's estimated Regulation need for adding ~6,700 MW of wind to its system**

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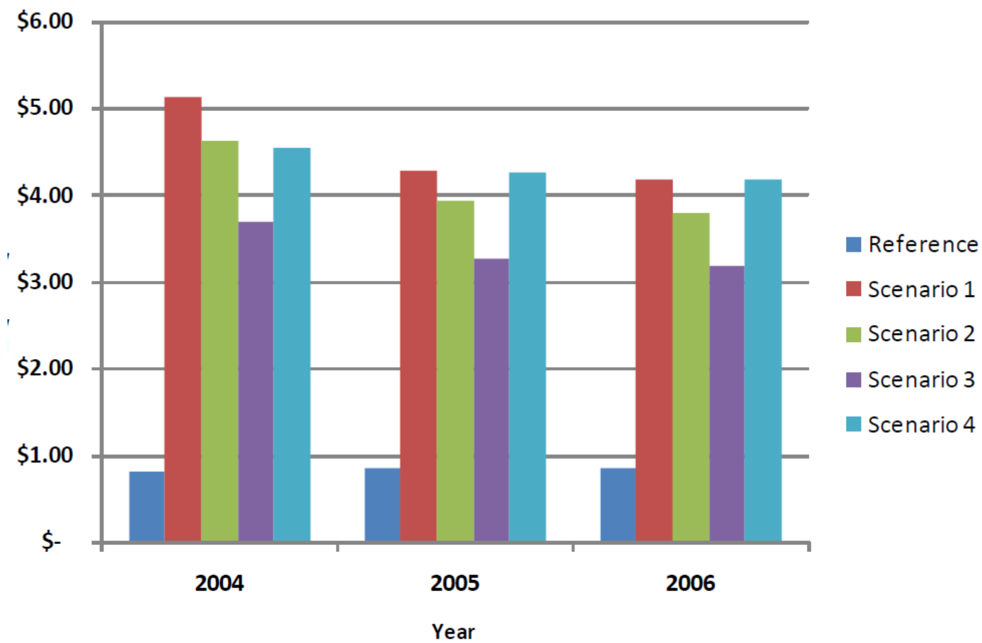
# Some studies have quantified the variable integration costs

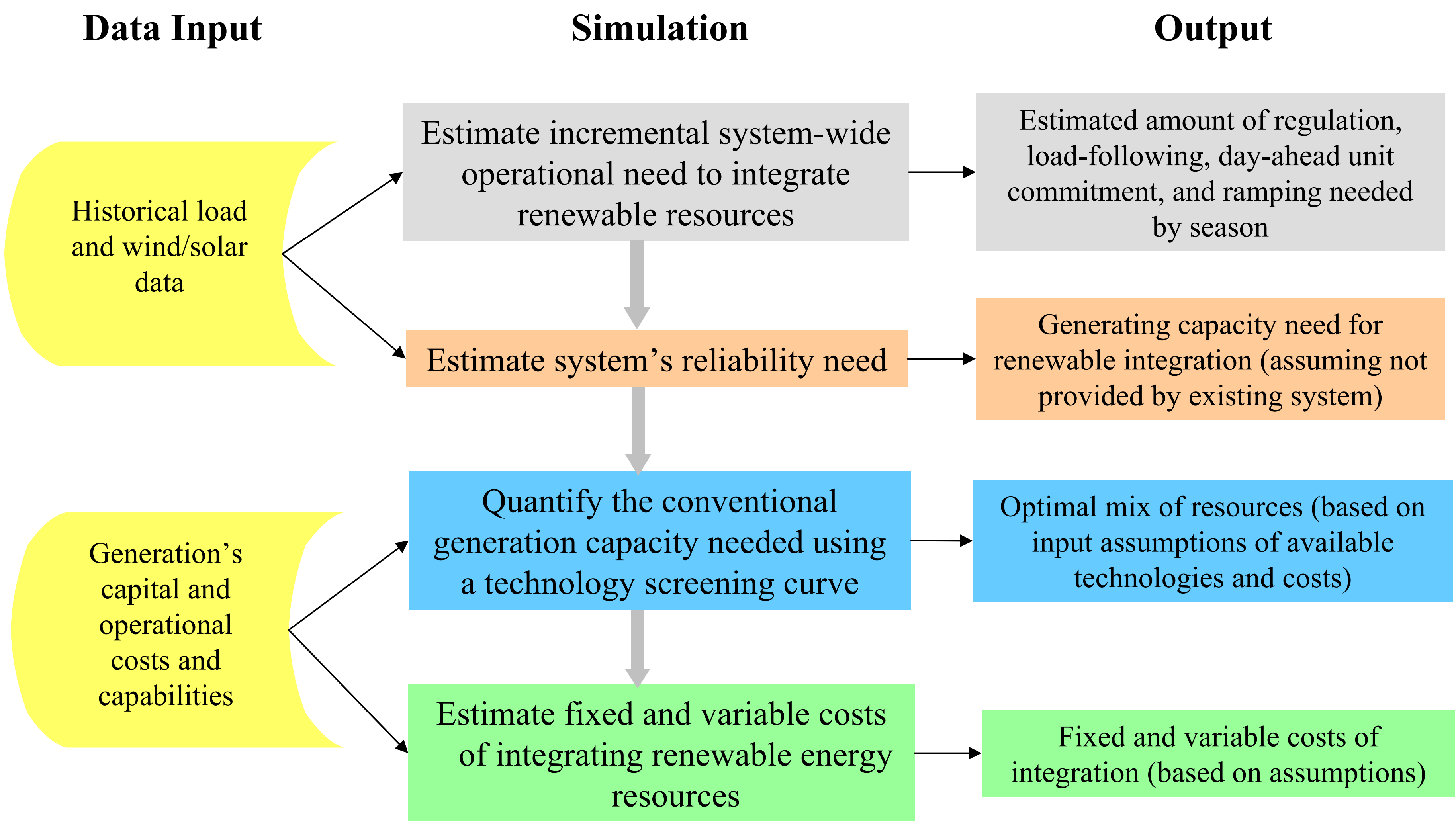
- NREL's Eastern Wind Study estimated the variable portion of wind integration cost to be between $3.5 to $5.0/MWh of wind in the future (in 2024 dollars)
- The study also shows that without transmission enhancements, substantial curtailment of wind generation would be required for a 20% wind penetration
- Further, NREL concludes that significant market, tariff, and operational changes would be needed across the eastern interconnection to manage the cost of integration large amounts of wind



# Some key issues are not yet addressed

- ***Incremental capacity may be needed*** in the future to help integrate variable renewable resources, implying additional capital cost may be incurred
  - As more wind and solar are added to the system, most planners expect existing conventional resources to run less
  - But wind resources add little capacity value, and therefore much of the conventional resources will continue to be needed
  - Operational needs can exceed the resource adequacy need on a system
  - Thus, integration cost includes more than the variable costs associated with operating the existing resources
- ***Ramp rate requirements will increase*** with additional wind resources, implying new technology may be needed
  - Purchasing faster ramping resources may require additional costs
- ***Unit commitment may significantly change*** depending on how wind and solar participate in the day-ahead schedule/market

# Renewable Integration Model (RIM) focuses on the heart of the issue directly



# RIM can be used to help utilities and RTOs conduct cost estimations as assumptions change

| Functionality | *The Brattle Group*'s Renewable Integration Model (RIM) | Compared to Existing Studies |
|---|---|---|
| **Data Usage** | **Uses the most granular data available** to derive regulation and load-following and ramping requirements | Some studies aggregate granular data into average hourly information and in turn loses the important intra-hour information |
| **User Driven** | **Input assumptions are user-driven** which allows one to estimate impact of forecast and operations improvements | Most studies are static in nature. While studies report that forecast improvements will have a significant impact, that impact is not readily quantified |
| **Incremental Analysis** | **Can provide "incremental" or "aggregate" analyses** to better estimate the effects of adding certain resources onto an existing system | Most studies focuses on certain load and renewable levels |
| **Renewable Portfolio Combinations** | **Accommodates portfolios of mixed resources**, accounting for geographical and technology diversities | Most studies are static in nature, with assumptions about the size and mix of renewable resources |
| **Cost assumptions** | **Capacity and variable costs can be adjusted** to account for technology improvements and market dynamics | Most studies are based on current technologies and costs |

# What are utilities and RTOs doing to address integration cost issues?

**Generally, the renewable integration analyses have fallen under three categories of uses:**

- Utilities (*e.g.* Xcel, PacifiCorp) are estimating the integration costs associated with procuring certain renewable resources, as part of system resource plans
- Utilities (*e.g.* Westar, Puget Sound, BPA) are estimating the integration cost associated with wind resources "exported" off their system
- RTOs (NYISO, ISO-NE, CAISO, ERCOT) are estimating the likely system operational impact and potential associated costs

**Above analyses are then translating into:**

- Requiring renewable energy resource buyers to purchase more ancillary services
- Some RTOs are considering charging wind generators for a portion of ancillary services needs and credit them for supply others
  - Charges for regulation and reserve (for schedule deviation that increase A/S needs)
  - "Reliability credits" for wind generators that can offer primary frequency response, voltage support, inertial-like response, metered contribution during ERCOT peak
- Limit wind ramp rates when given (or released from) curtailment instructions
- Further improve wind forecasting to reduce wind-related ancillary services requirements
- Evaluating new resources that can address ramping challenge

# Related renewable energy issues explored in various markets

- **Integrate wind into energy markets** (bid-based dispatch) and ancillary services provision
- **Improve balancing area coordination**, such as WECC's effort to create region-wide residual energy imbalance market with dynamic interchange schedules
- **Integrate wind with electricity storage and demand-response initiatives**
- **Improve wind forecasting services** (e.g., CAISO, ERCOT) and visualization tools for real-time system operations that incorporate real-time wind output and forecast data
- **Analyze wind integration on operating costs**
  - CAISO simulations of operating requirements (locational A/S, ramping, economic dispatch)
  - Expanding models to address sub-hourly operational challenges
  - Expansive data collection for better system dispatch, forecasting, and integration studies
- **Transmission overlay planning**:
  - Efforts in MISO, SPP, ISO-NE (including analyses of cost allocation proposals)
  - Eastern Interconnection-wide planning studies

# Additional Reading


Chang and Hanser, "*Renewable Integration Model*", California Long-Term Procurement Plan Workshop, Energy Division of the California Public Utilities Commission (CPUC), CPUC Auditorium, San Francisco, August 25, 2010

Chang, Madjarov, Baldick, Alvarez, Hanser, "*Renewable Integration Model and Analysis*," IEEE 2010 Transmission and Distribution Conference and Exposition, New Orleans, LA, April 21, 2010.

Pfeifenberger, Chang, Hou, Madjarov, "*Job and Economic Benefits of Transmission and Wind Generation Investments in the SPP Region*," *The Brattle Group*, Inc., March 2010.

Murphy, Aydin, Chupka, Chang, "*Plugging In: Can the grid handle the coming electric vehicle load?*" Public Utilities Fortnightly, June 2010.

Fox-Penner, Chang, Hou, Hledik, "*Transmission Super Highways: Assessing the Potential Benefits of Extra-High-Voltage Transmission Overlays in the Midwest*" *The Brattle Group*, Inc., March 2009.

# About *The Brattle Group*: Services and Contact

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