Renewable Energy Integration: Technological and Market Design Challenges

Task 3.1: Direct and Telemetric Coupling of Renewable Power Resources with Deferrable Load

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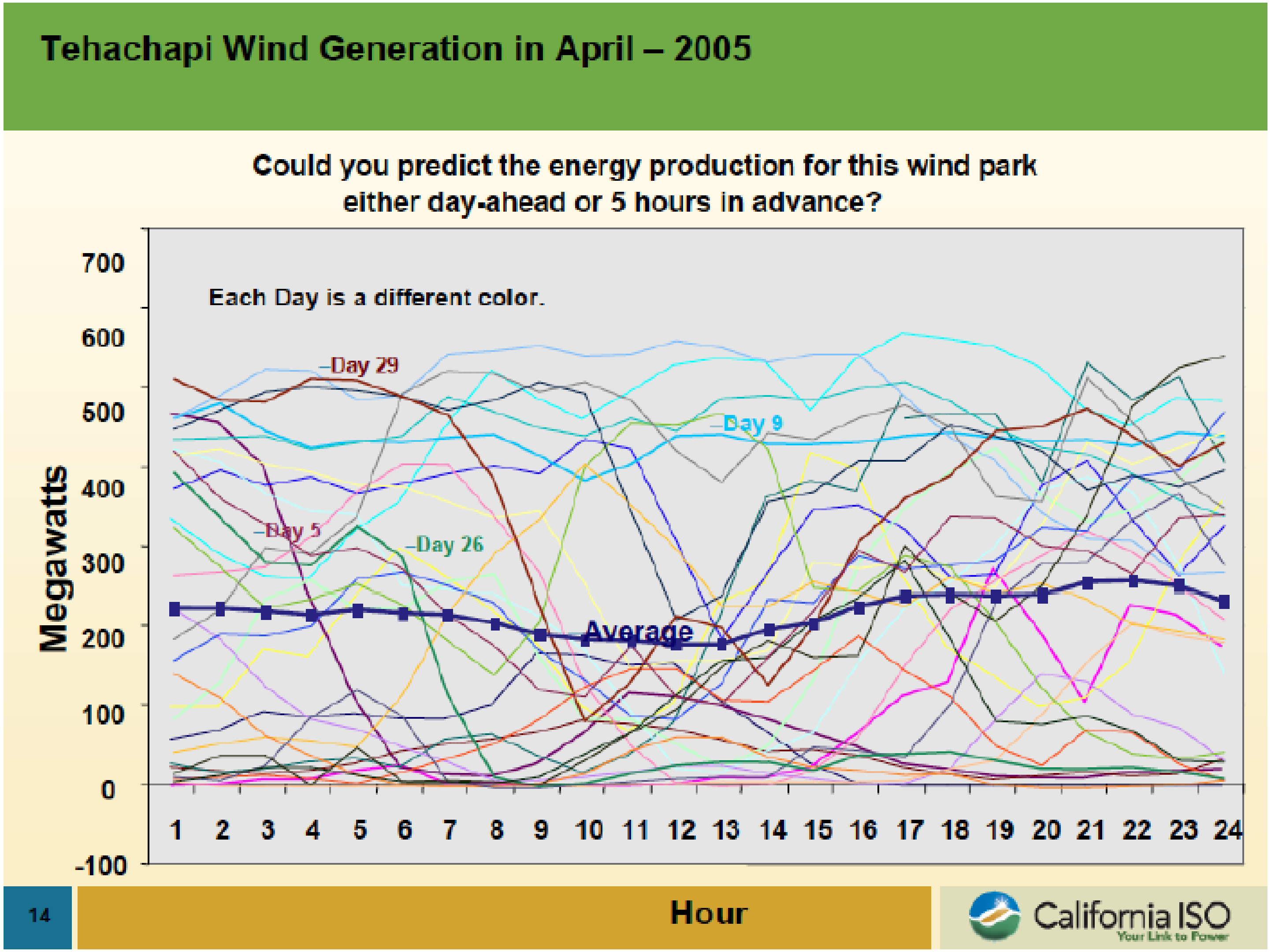
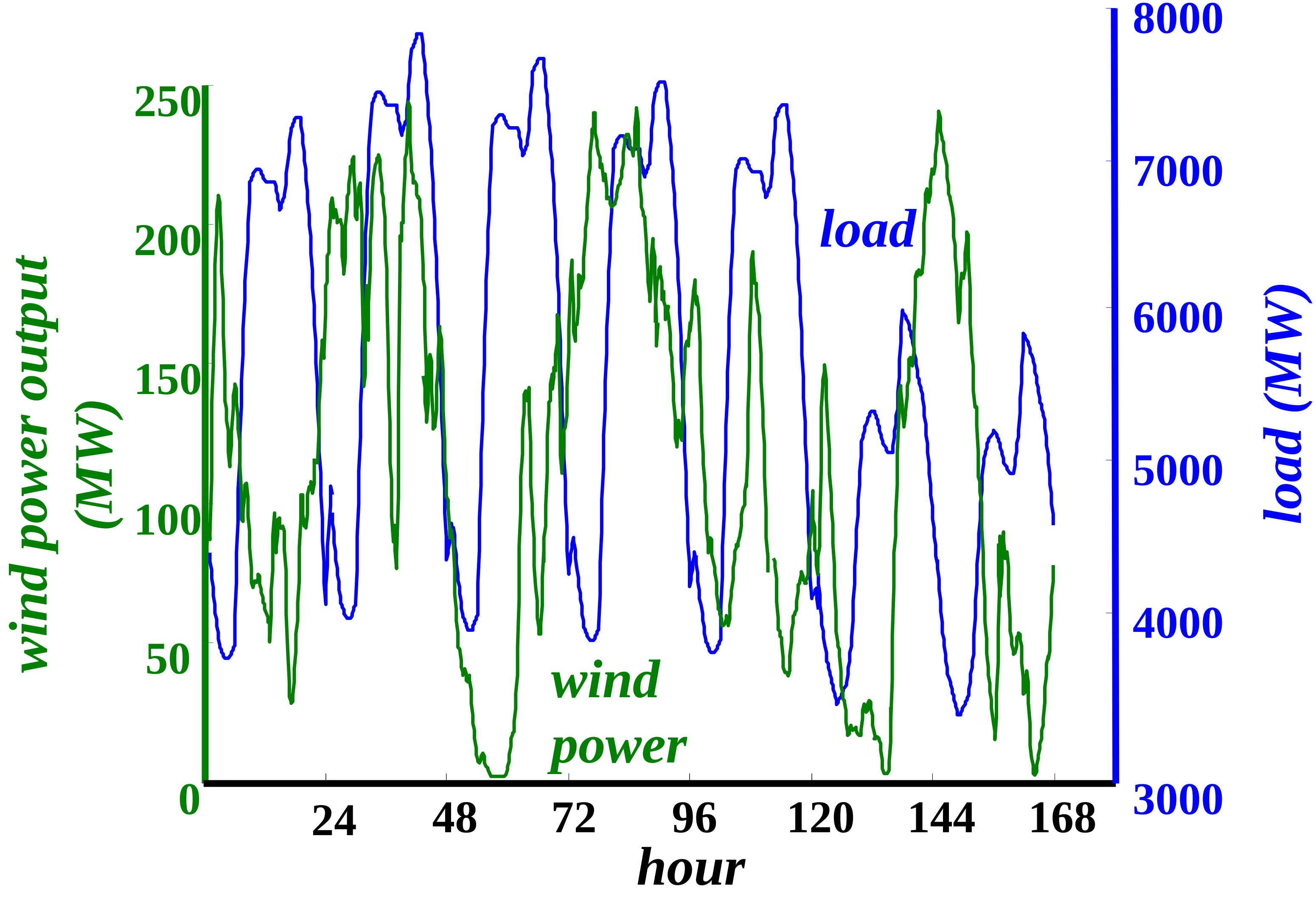
Accomplishments

- Developed a stochastic optimization method for efficient reserves deployment in an environment with high renewables penetration
- Developed a consistent method for assessing alternative demand response integration strategies (direct coupling vs. market)
- Advanced the state of the art for stochastic unit commitment at practical scale, employing High Performance Computing
- Developed and calibrated a statistical model characterizing the spatial and temporal behavior of wind power
- Applied above to a case study of the California system under alternative renewable penetration scenarios

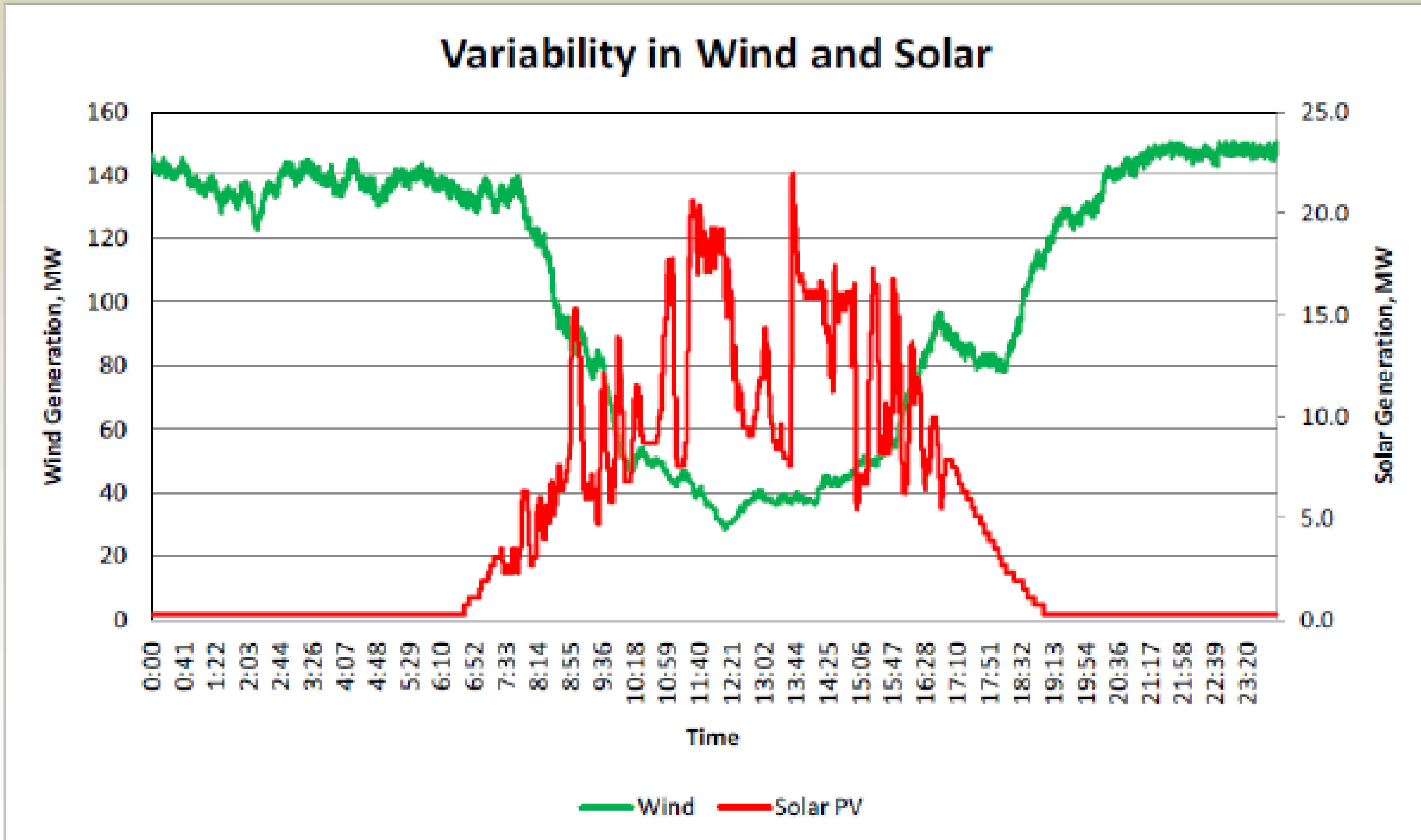
Wind Power Uncertainty



Wind Power is Negatively Correlated with Load



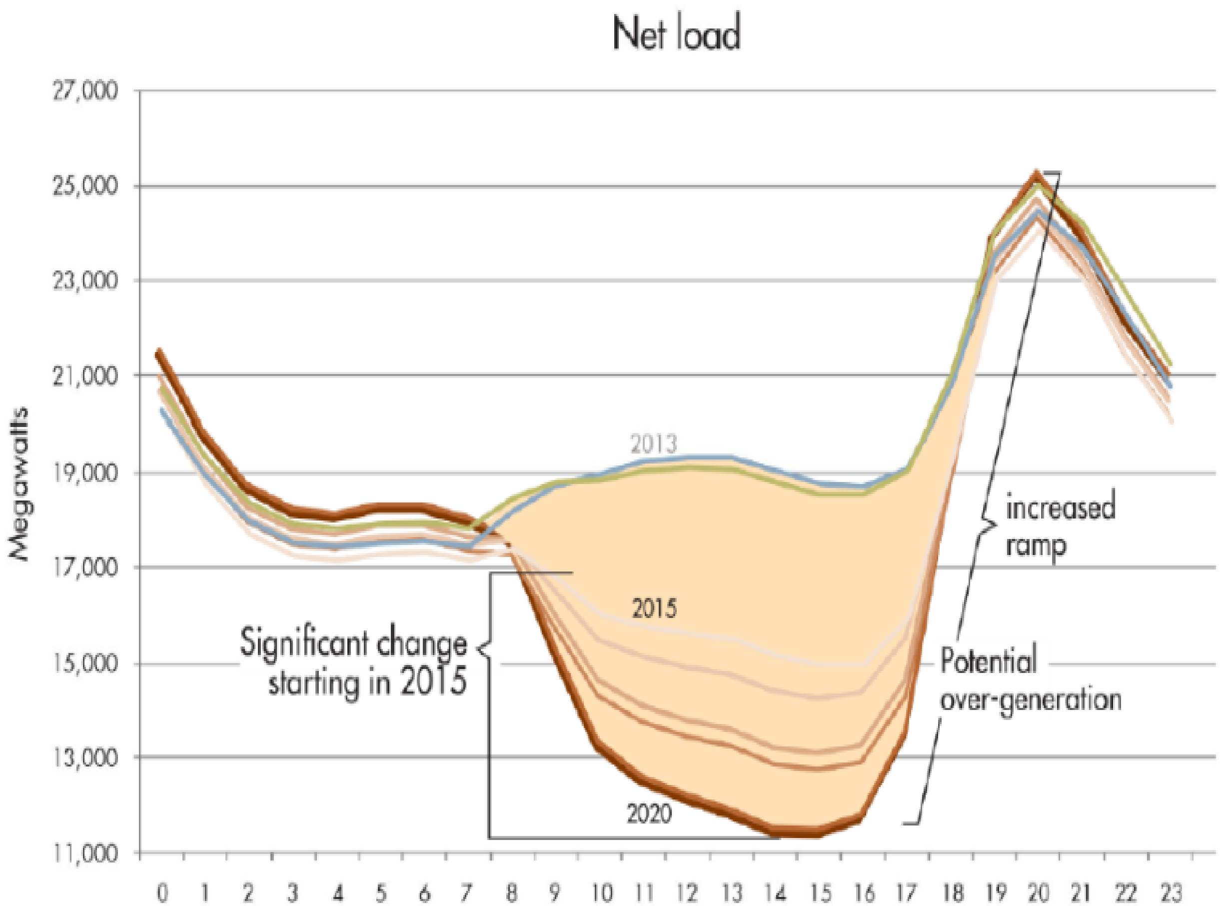
Variability of wind and solar resources - June 24, 2010



A 150 MW wind plant and a 24 MW solar resource

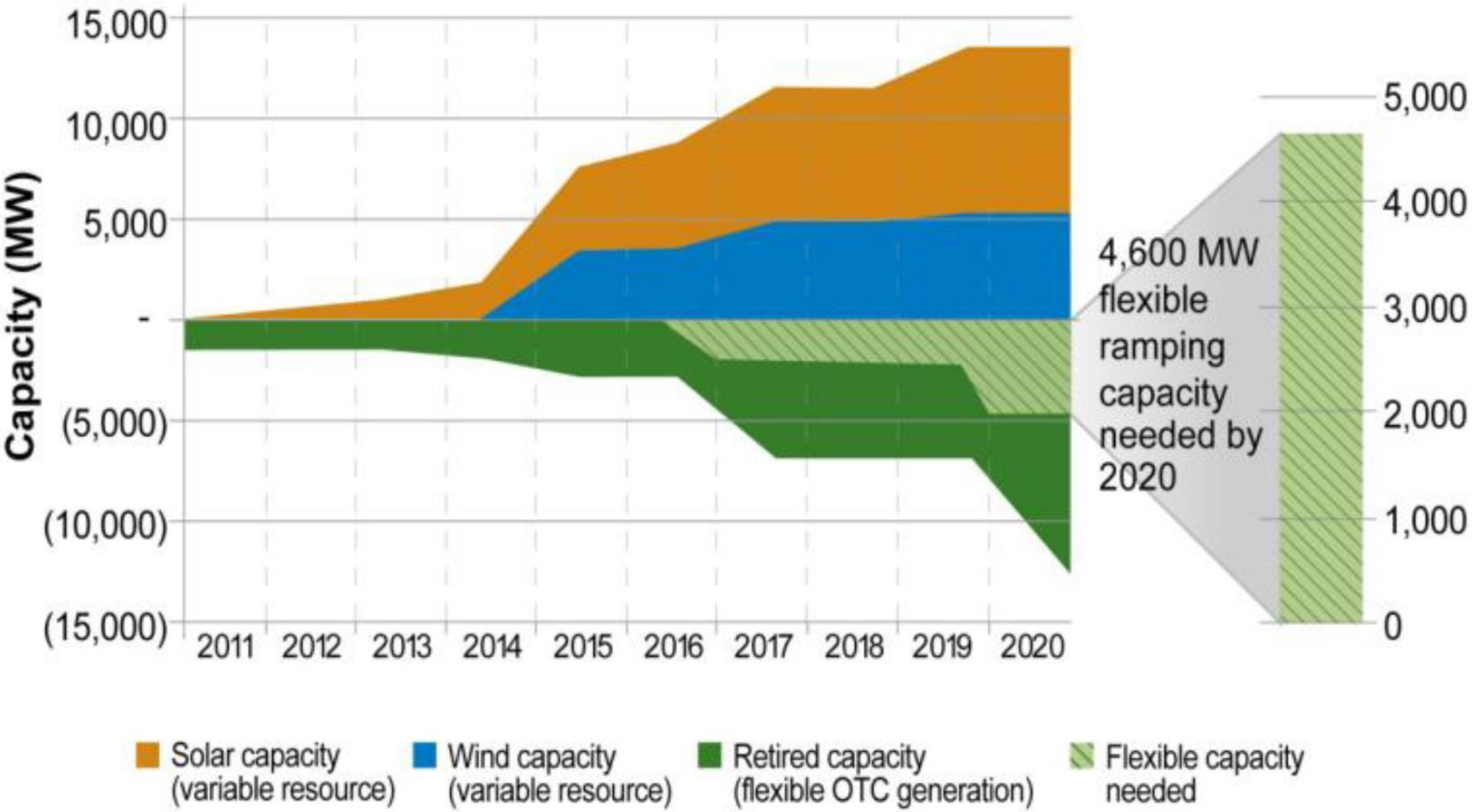
Ramping Challenge (The Duck Chart)

Chart 1: CAISO' Projected Net Load by Hour, using Avg. Projected Usage (aka "Duck Chart")



Source: CAISO

Conventional Solution



Source: CAISO

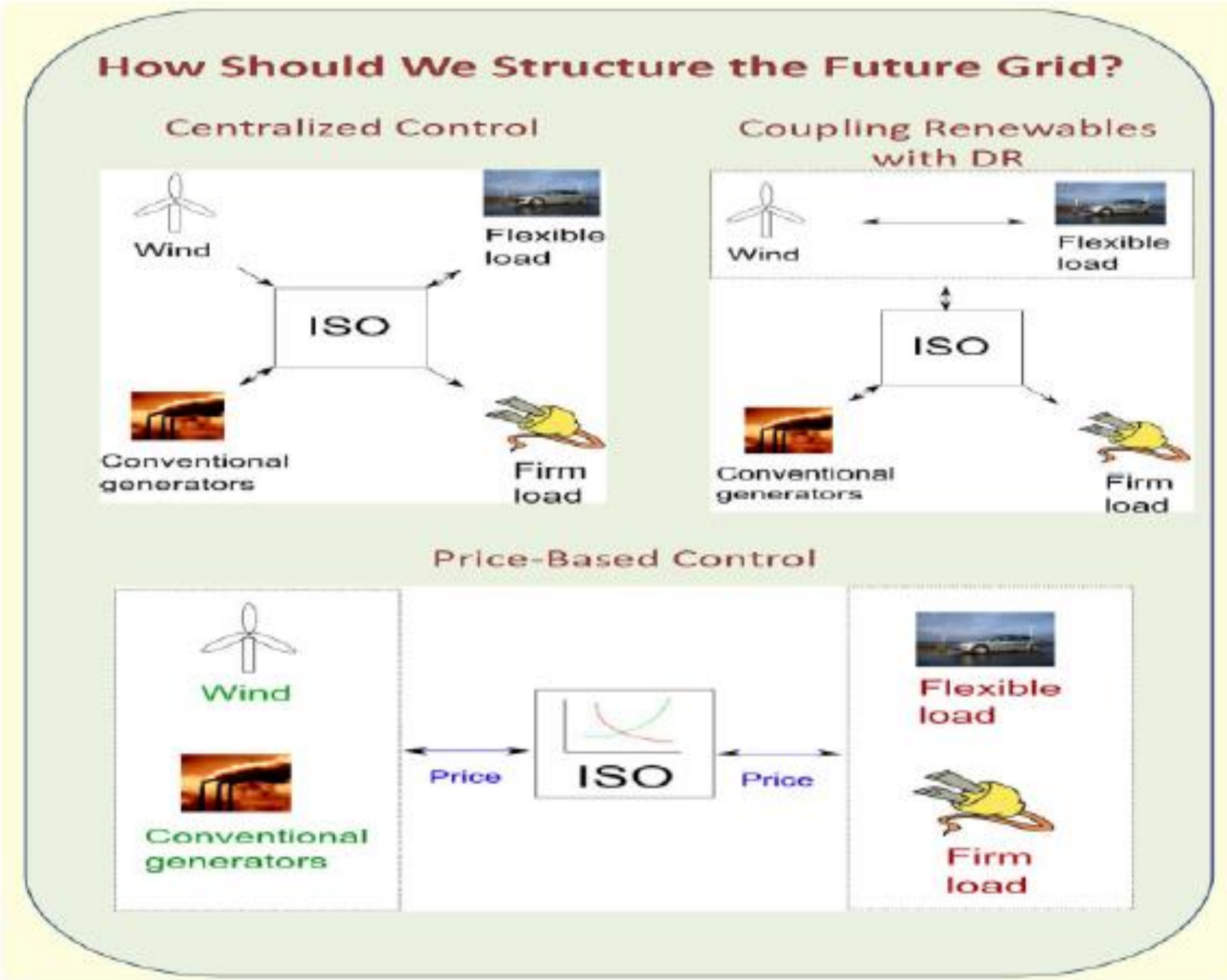
Making The Grid Smarter

- Accounting explicitly for uncertainty in operation and planning
  - Stochastic unit commitment (with endogenous reserves determination) to support renewable penetration and demand response
  - Probabilistic planning and simulation models (accounting for renewables, storage and demand response
- Mobilizing demand response (DR) and a paradigm shift to "load following available supply" provides an economically viable and sustainable path to a renewable low carbon future.

Alternative DR Paradigms

1. Centralized co-optimization of dispatchable supply resources and flexible loads by system operator
2. Price response:
   - Renewable producers bid in centralized real-time market
   - Consumers can communicate with system through instantaneous response to price
3. Coupling aggregated load with renewables:
   - Flexible loads communicate basic needs to renewable suppliers
   - Flexible loads follow dynamic supply signal from renewable resources, system operator faces reduced variability

Alternative DR Paradigms

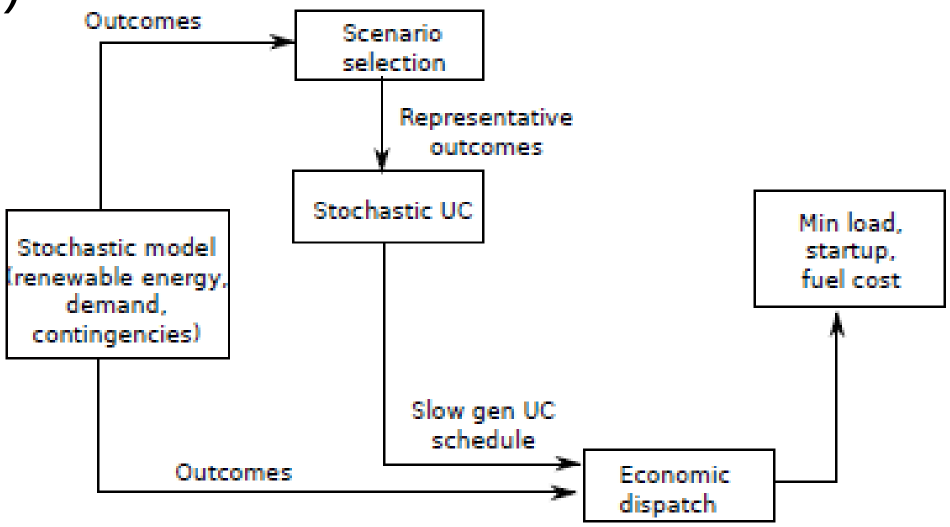


Evaluation Methodology

- Comparison of alternative approaches to flexible loads mobilization requires explicit consideration of uncertainty for consistent determination of locational reserves.
- Stochastic unit commitment optimization accounts for uncertainty by considering a limited sample of probabilistic wind and contingency scenarios, committing slow reserves early with fast reserves and demand response adjusted after uncertainties are revealed.
- Economic and reliability outcomes are calculated using Monte Carlo simulation with large number of probabilistic scenarios and contingencies

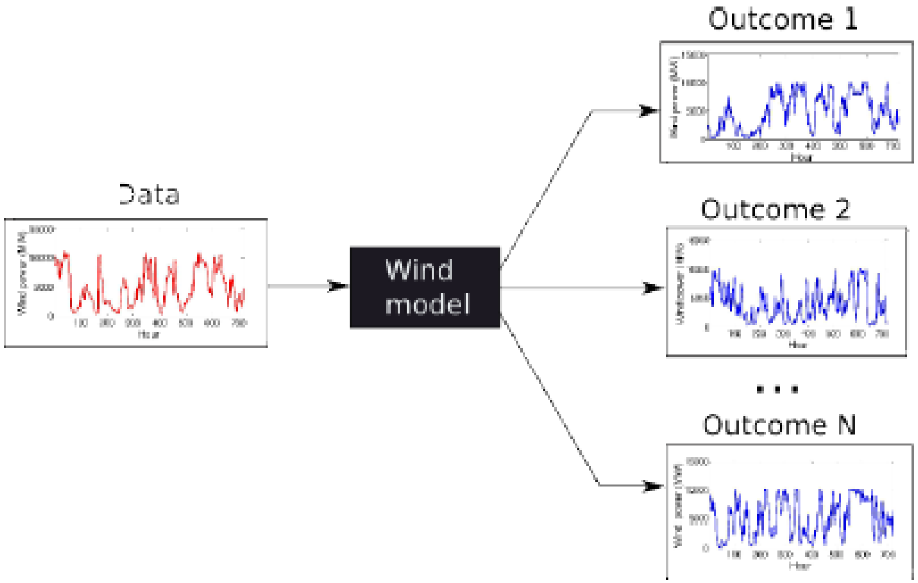
Model Structure

- Application: stochastic unit commitment for large-scale renewable energy integration
- Two-stage model representing DA market (first stage) followed by RT market (second stage)
- New scenario selection methodology inspired by importance sampling (using deterministic commitment cost as sampling criterion)



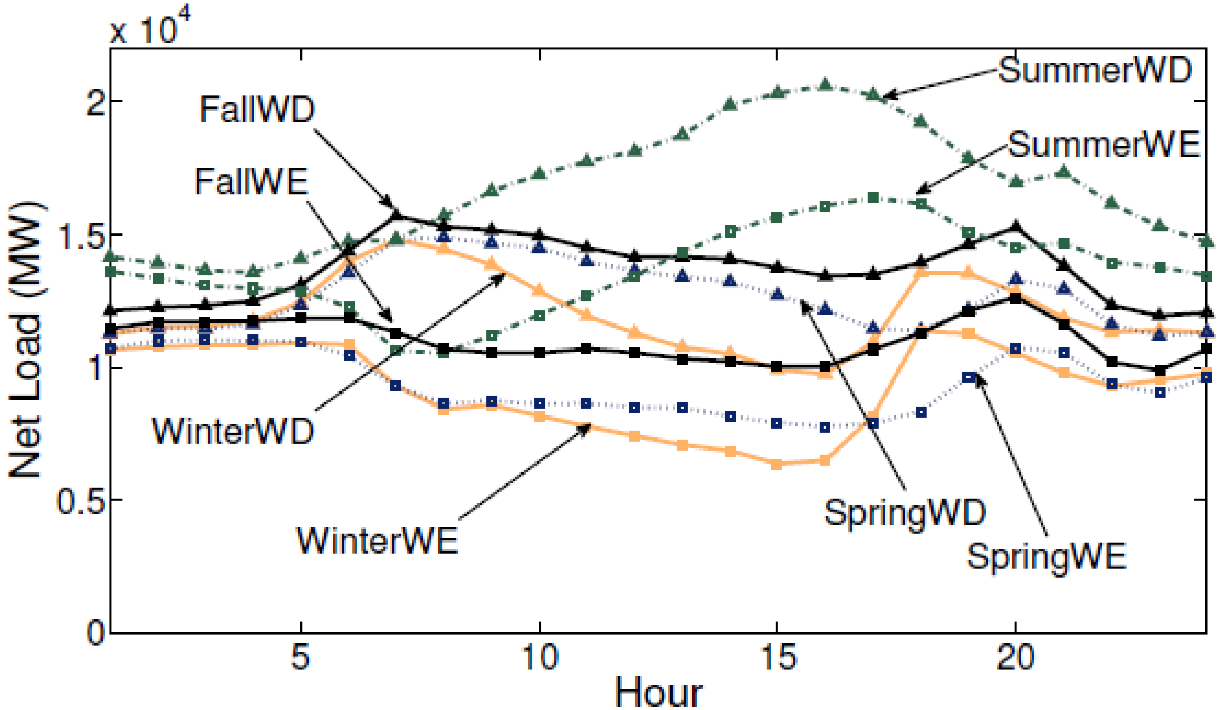
Wind Modeling and Data Sources

- 2 wind integration cases: moderate (7.1% energy integration, 2012), deep (14% energy integration, 2020)
- California ISO interconnection queue lists locations of planned wind power installations
- NREL Western Wind and Solar Interconnection Study archives wind speed - wind power for Western US

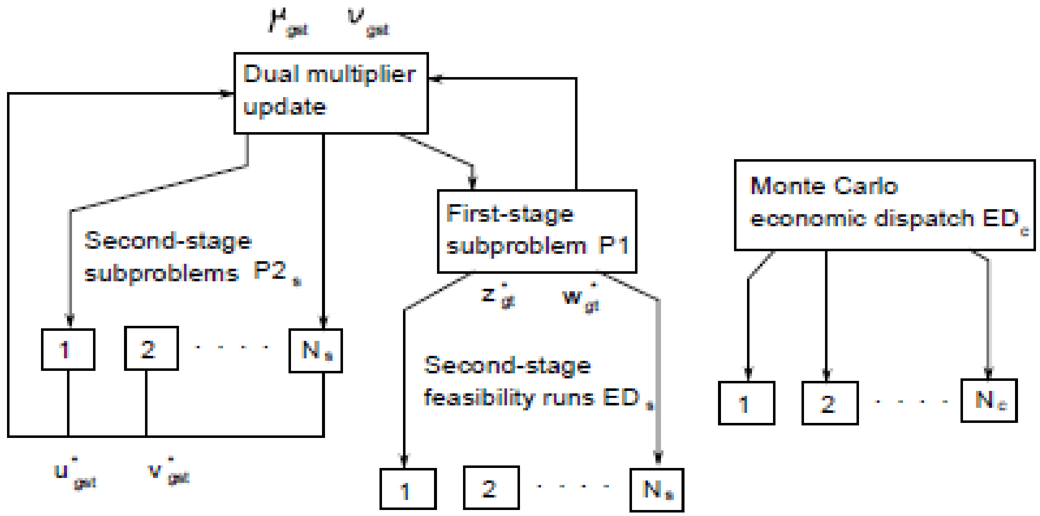


Load Variation Represented by Day Types

- 8 day types considered, one for each season, one for weekdays/weekends
- Day types weighted according to frequency of occurrence

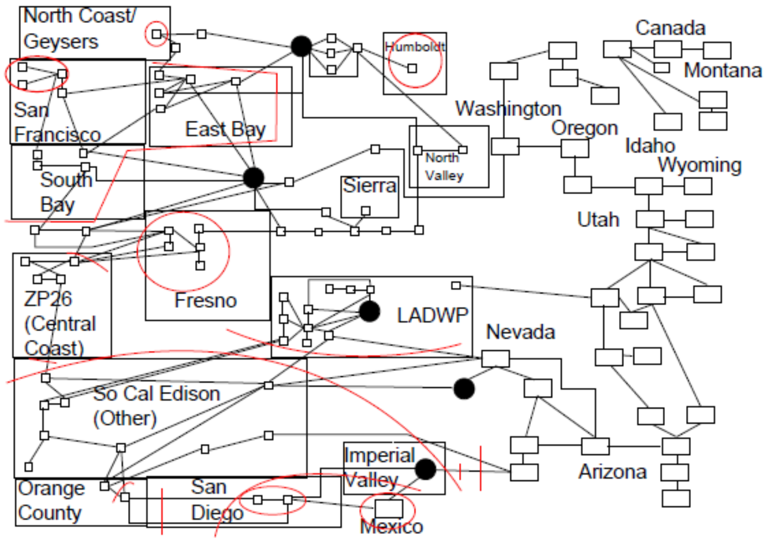


Parallelization and HPC application



- Lawrence Livermore National Laboratory Hera cluster: 13,824 cores on 864 nodes, 2.3 Ghz, 32 GB/node
- MPI calling on CPLEX Java callable library

California Case Study Results



- 225 buses
- 375 transmission lines
- 124 units (82 fast, 42 slow)
- 53665 MW power plant capacity
- 42 scenarios
- Four studies
  - With transmission constraints, contingencies:
    - No wind
    - Moderate (7.1% energy integration, 2012)
    - Deep (14% energy integration, 2020)
  - Deep (14% energy integration) without transmission constraints, contingencies

- Stochastic Optimization captures nearly 50% of gains under perfect forecasting of load and wind outcomes
- Direct coupling marginally more expensive than a centralized market but reduces load shedding due to better representation of load flexibility
- Transmission constraints can play a significant role in determining cost and resource adequacy

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