

# Eastern Renewable Generation Integration Study



**American Wind Energy Association (AWEA)  
WINDPOWER 2014**

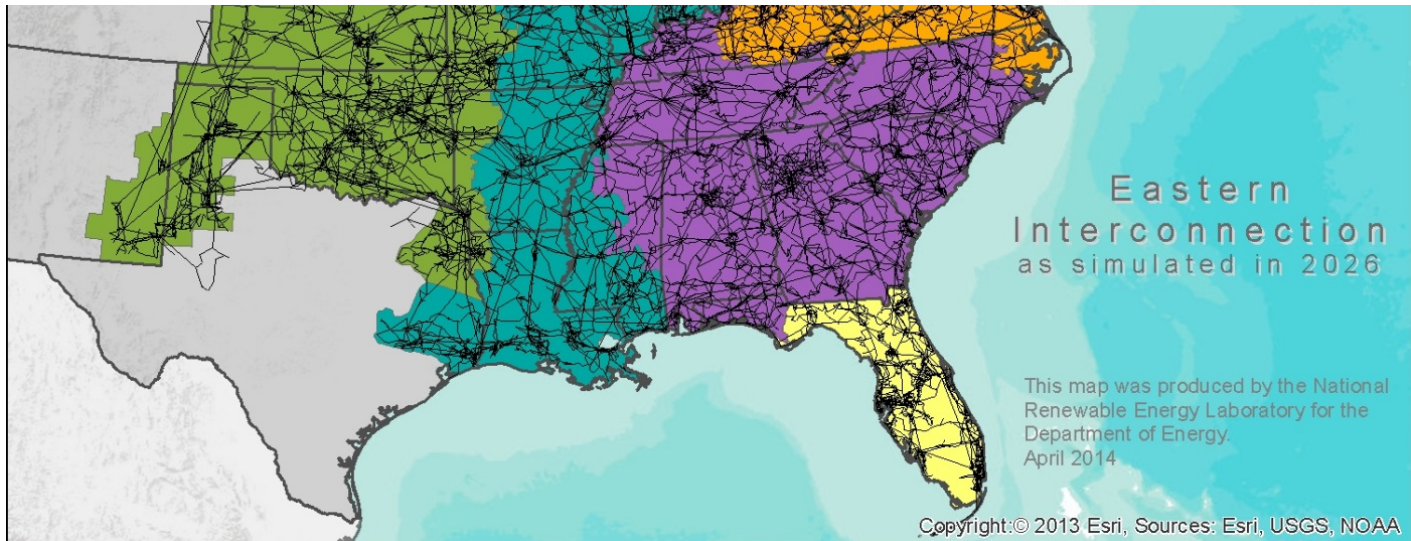
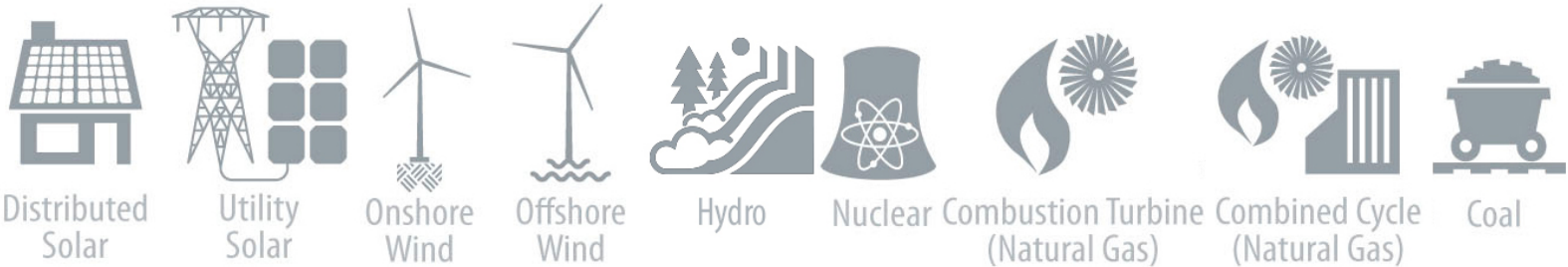
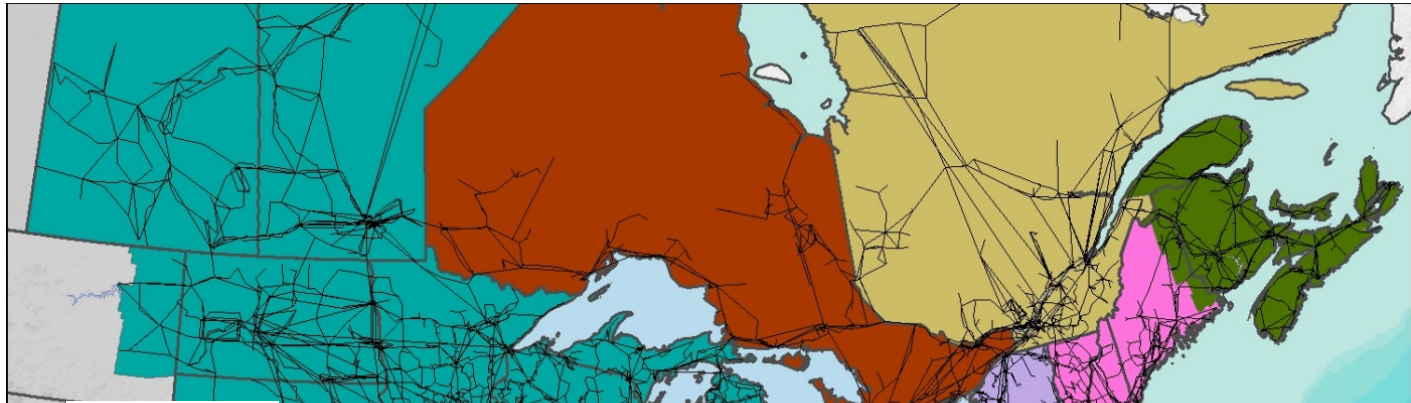
**Aaron Bloom**

**May 7, 2014**

**Las Vegas, Nevada**

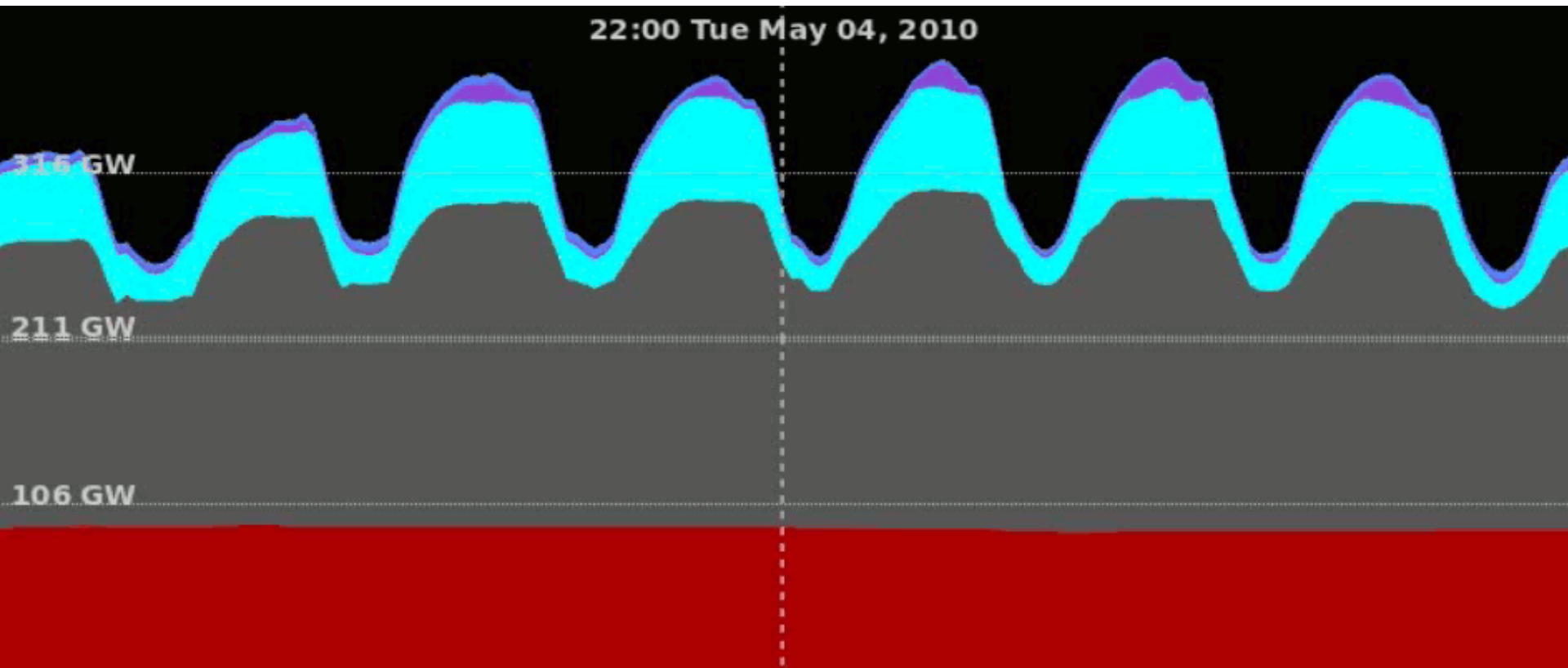
**NREL/PR-6A20-61434**

# Eastern Renewable Generation Integration Study



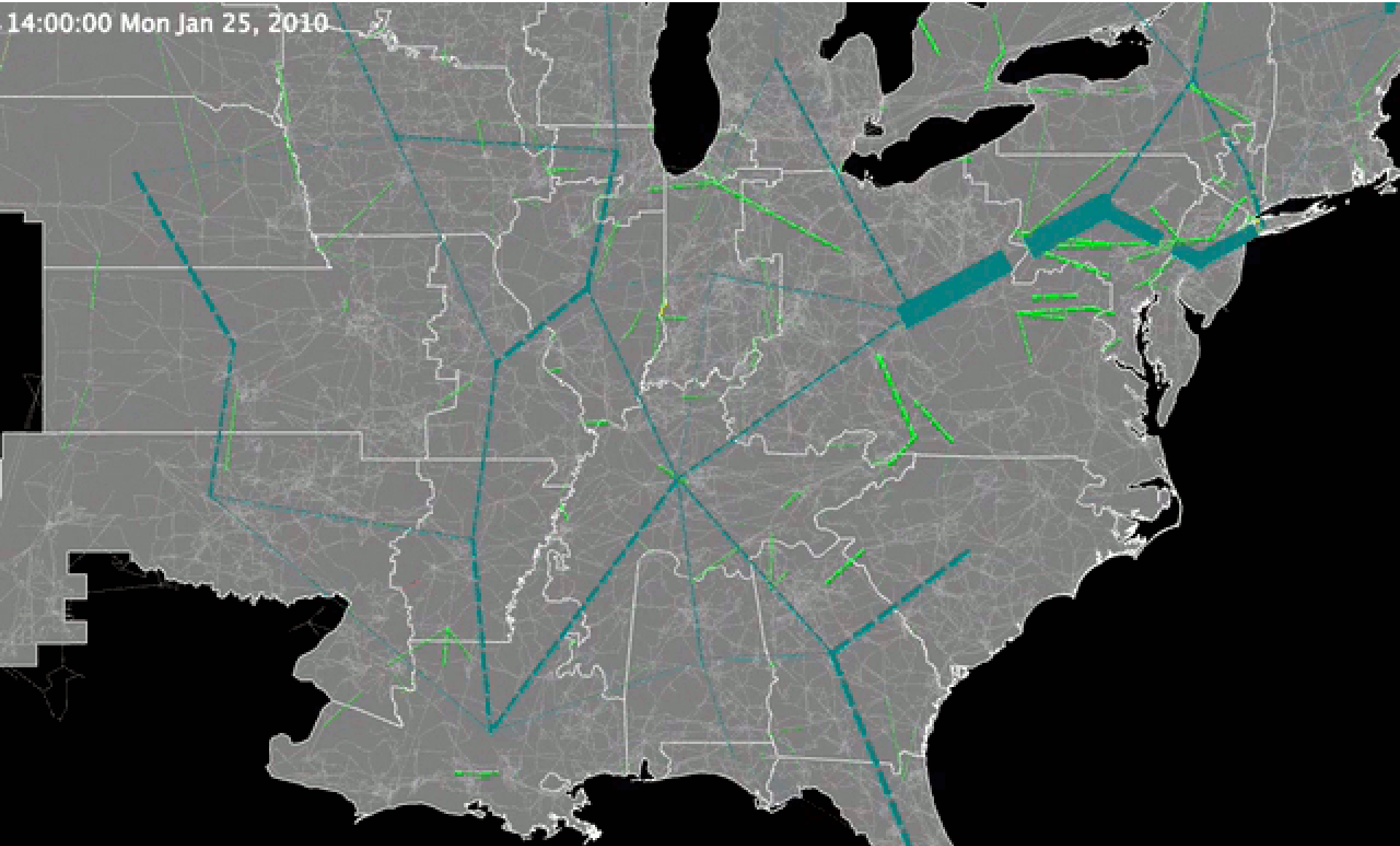
Copyright:© 2013 Esri, Sources: Esri, USGS, NOAA

# Dispatch Stacks

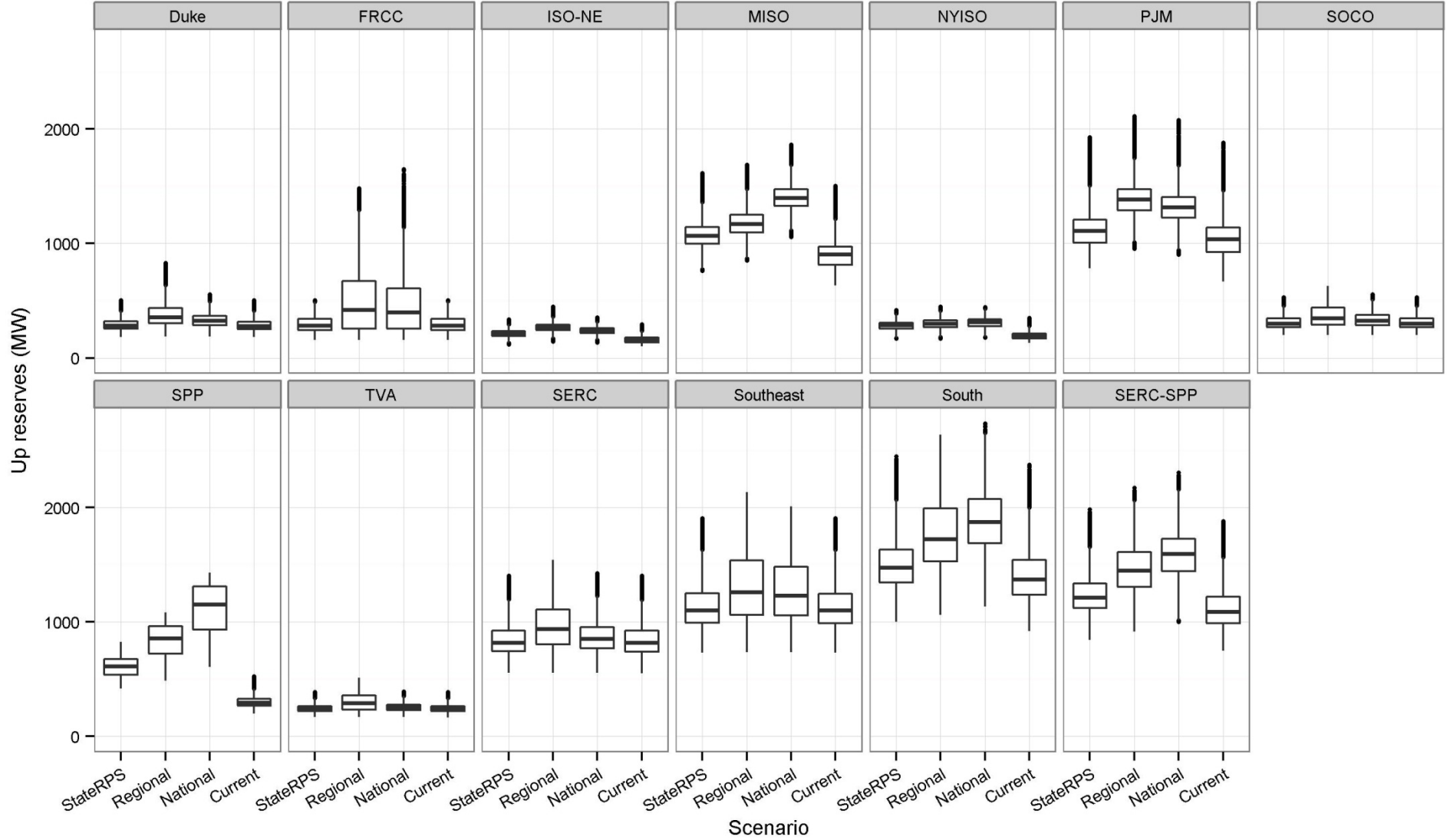


# Transmission Flows

14:00:00 Mon Jan 25, 2010



# Statistics



# Inform Decision Makers

---

*Critical questions:*

- **How might power system operations be impacted by wind and solar power generation?**
- **Could the operational impacts differ based on policy decisions about regional versus national deployment strategies?**
- **How might high penetrations of wind and solar impact current regional practices?**

# Study Limitations

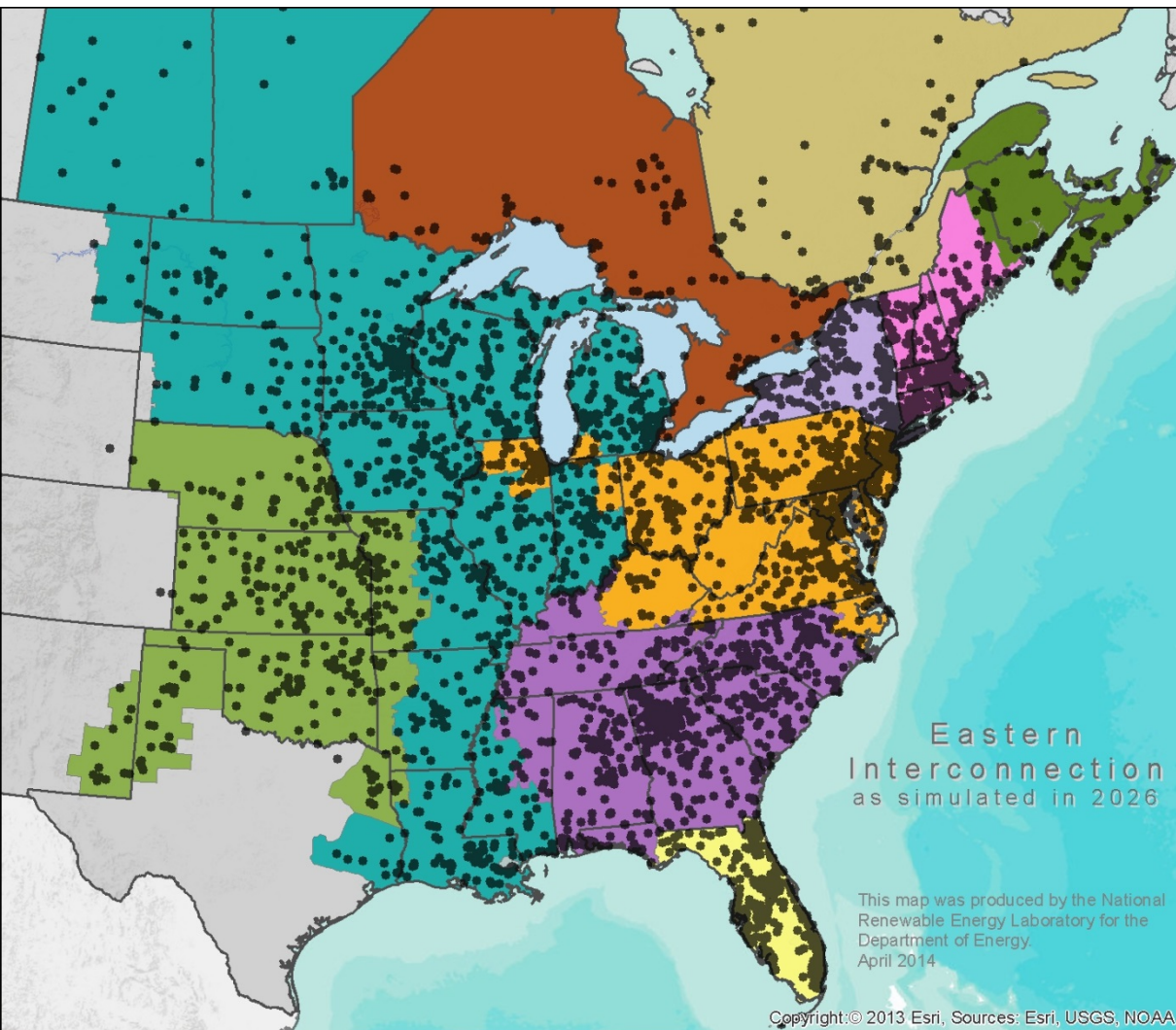
- **We lack:**

- Bilateral power purchase and other contractual agreement data
- Detailed operational constraints and/or complete unit-specific data in the generation models
- Capability to simultaneously model different dispatch intervals in different balancing authority areas

- **Uncertainties:**

- Future cooperation and/or sub-hourly dispatch across the interconnection
- The amount and location of variable generation
- Transmission system additions
- Generation additions and retirements
- Gas and coal prices

# The Eastern Interconnection



- Generating capacity: 700 GW
- Generating units: 7,500
- Load: 3,000 TWh
- Population: 240 million people
- 70% of US Load
- Transmission length: 459,000 miles
- Nodes: 60,000
- Transmission lines: 50,000

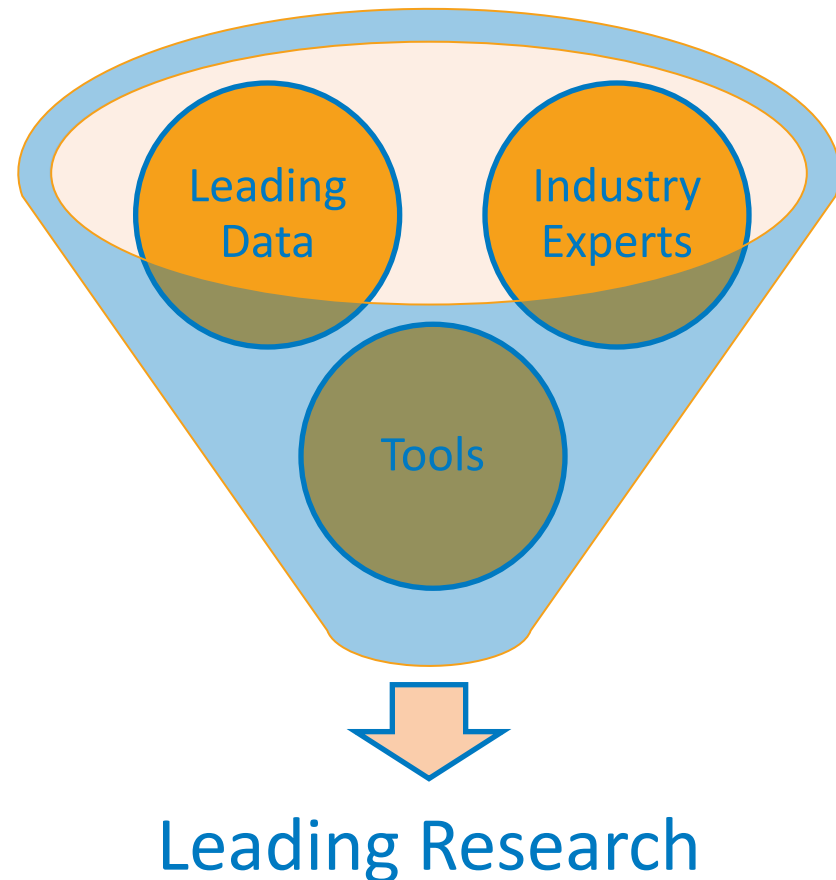


# Approach

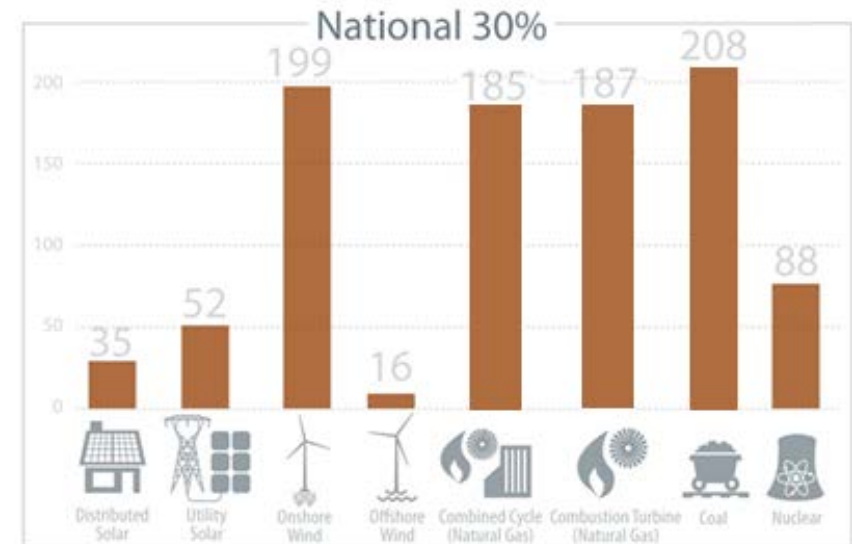
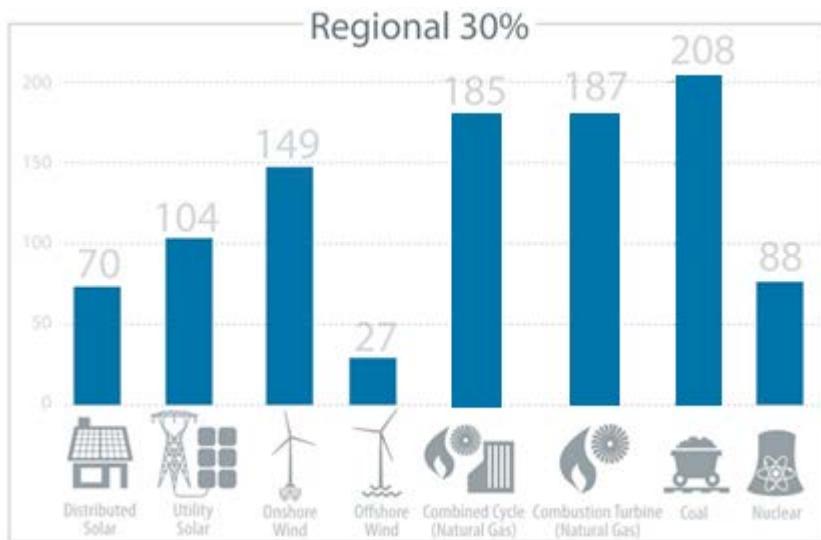
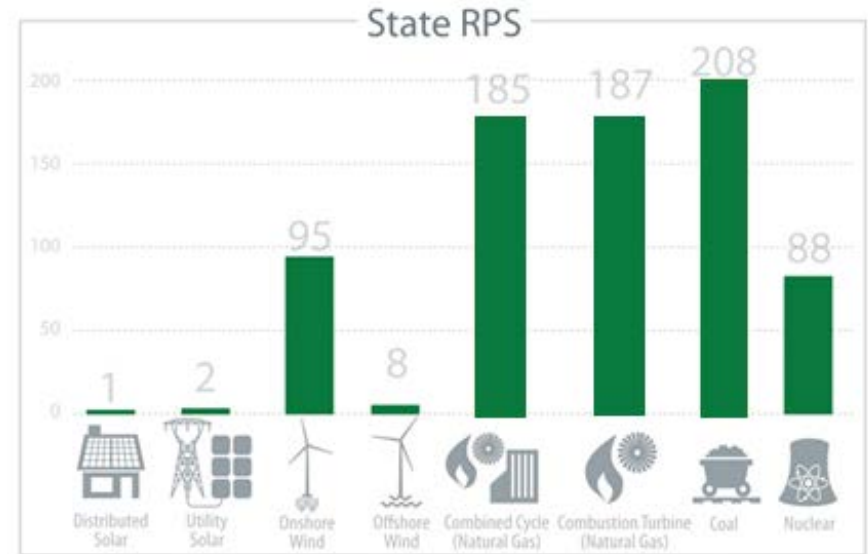
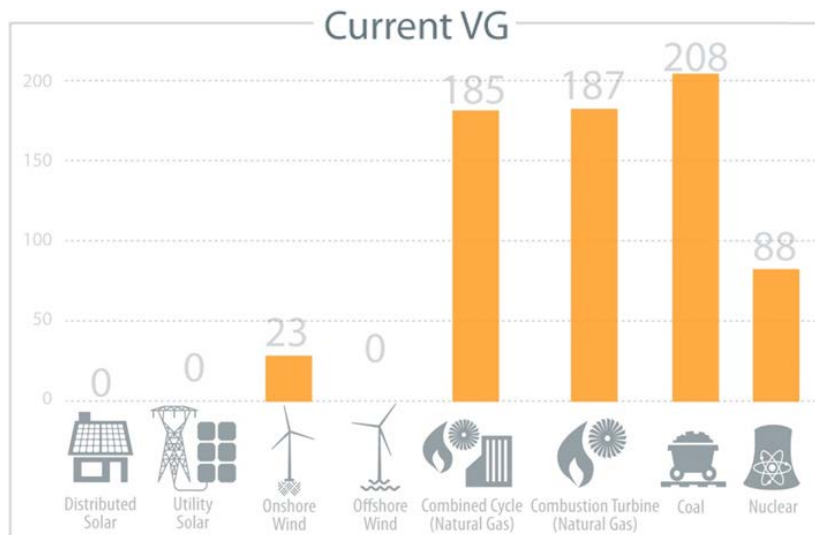


# Technical Review Committee

- **Industry experts:**
  - RTO/ISO
  - Utilities
  - Cooperatives
  - National Laboratories
- **Provide guidance on:**
  - Scenarios
  - Methods
  - Assumptions
  - Results



# 2026 Study Scenarios



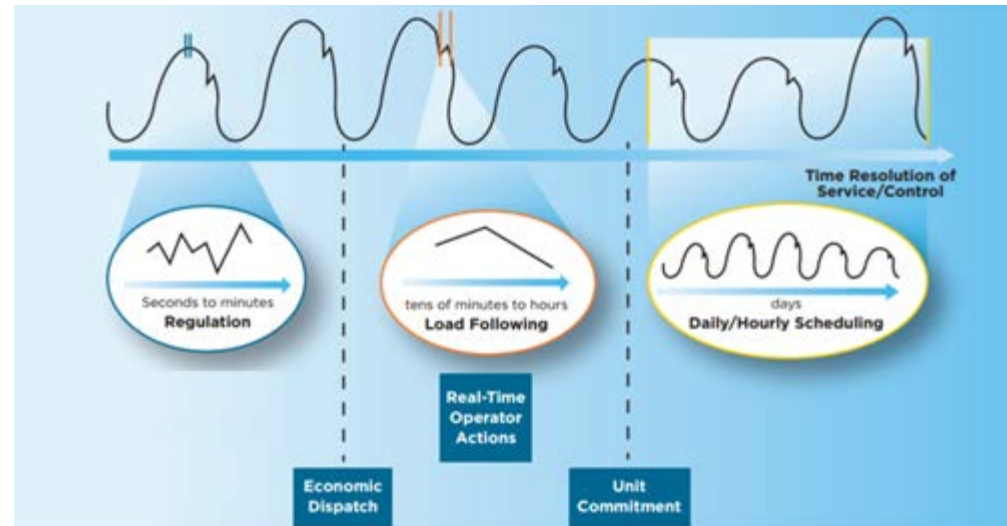
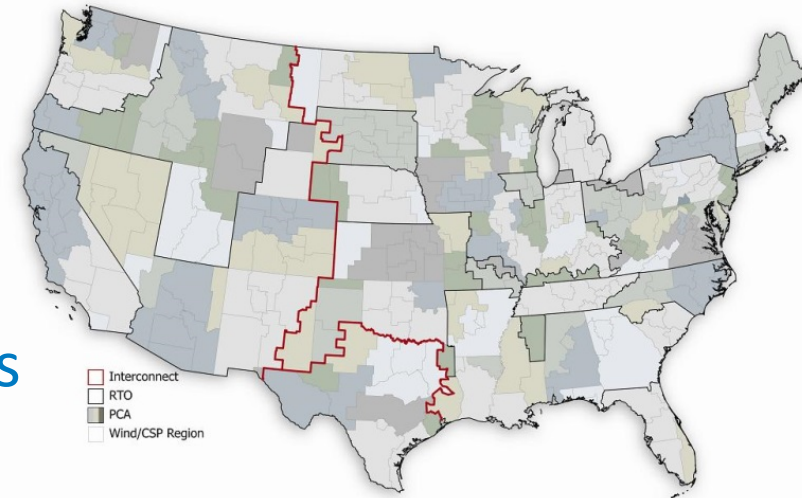
# Modeling Tools

- **ReEDS**

- Capacity expansion
- Variability in wind and solar
- Ancillary service requirements

- **PLEXOS**

- Unit commitment and economic dispatch
- Nodal DC power flow
- Day-ahead (hourly)
- Real-time (5-minute)
- Mixed-integer

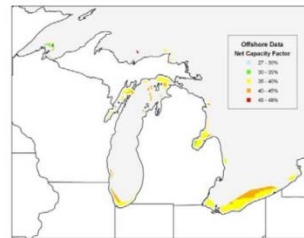
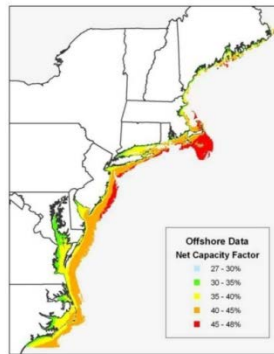
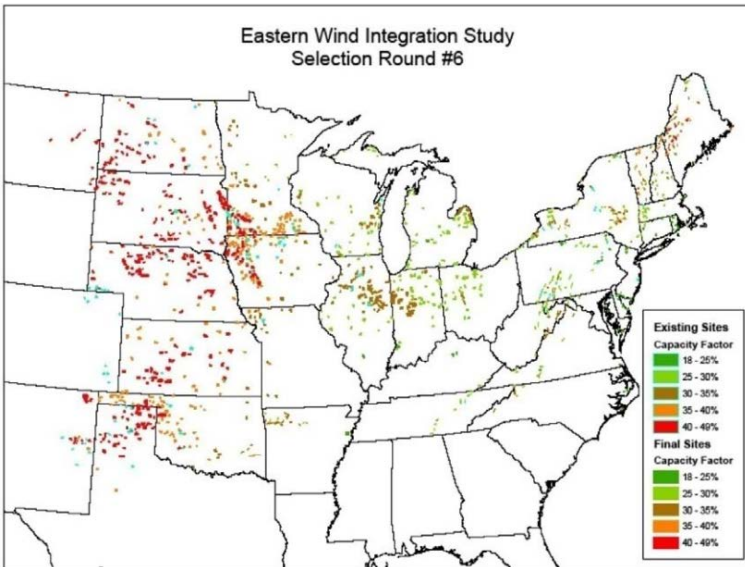


# Eastern Wind Data Set

## About the data

- Simulated power data
- Sites: 1,326
- Years: 2004–2006
- Time: 10-minute resolution
- Capacity: 580 GW
- Mesoscale model
- 2-km resolution

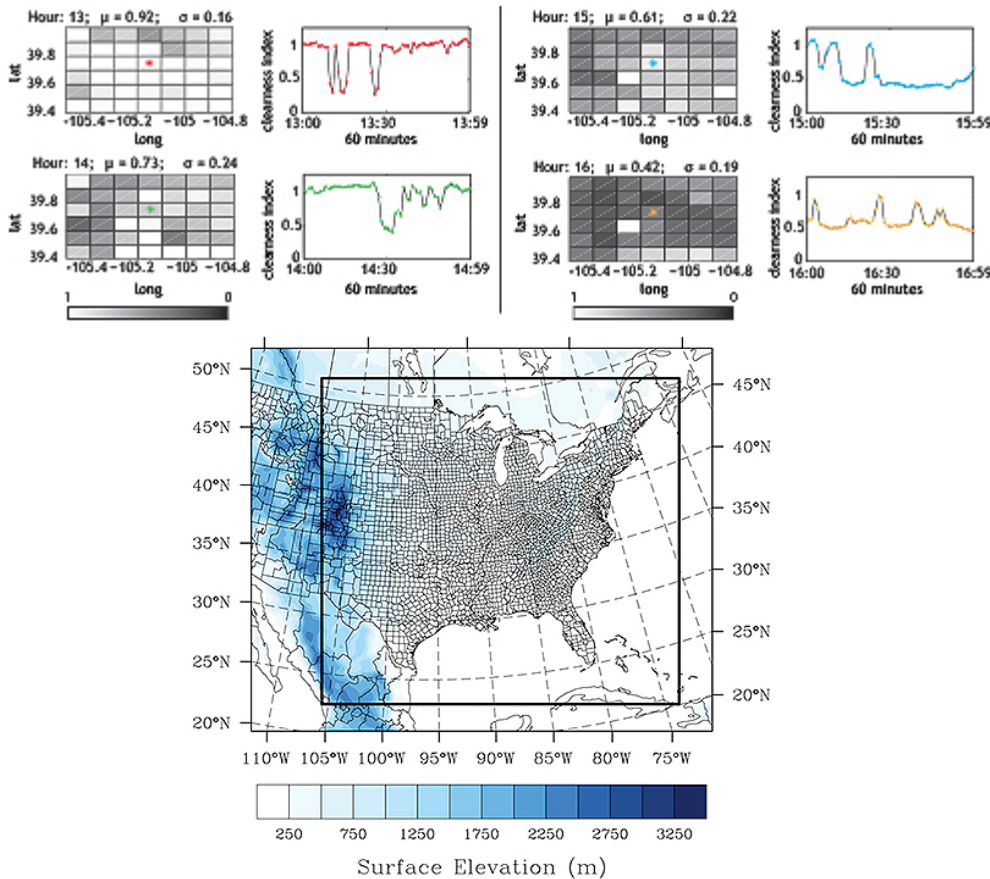
Eastern Wind Integration Study  
Selection Round #6



## Where to get it:

[http://www.nrel.gov/electricity/transmission/eastern\\_wind\\_methodology.html](http://www.nrel.gov/electricity/transmission/eastern_wind_methodology.html)

# Solar Integration Data Set



## About the data

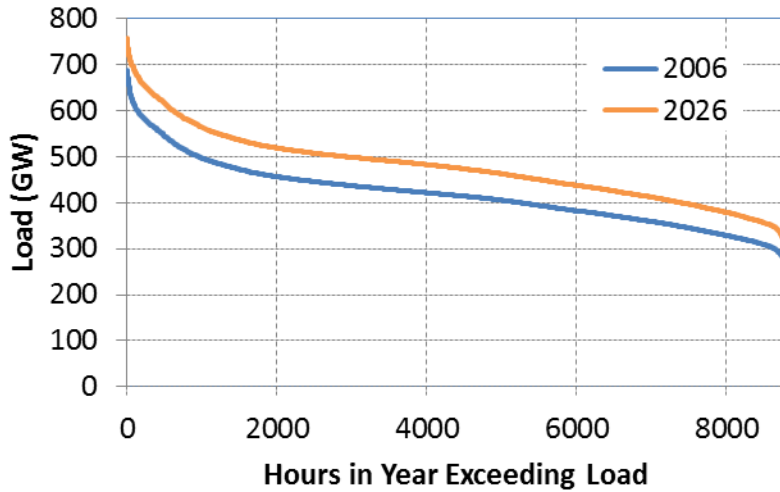
- Simulated power data
- Sites: 4,089
- Years: 2006
- Time: 5-minute resolution
- Capacity: 174 GW
- Multiple forecasts

## Where to get it:

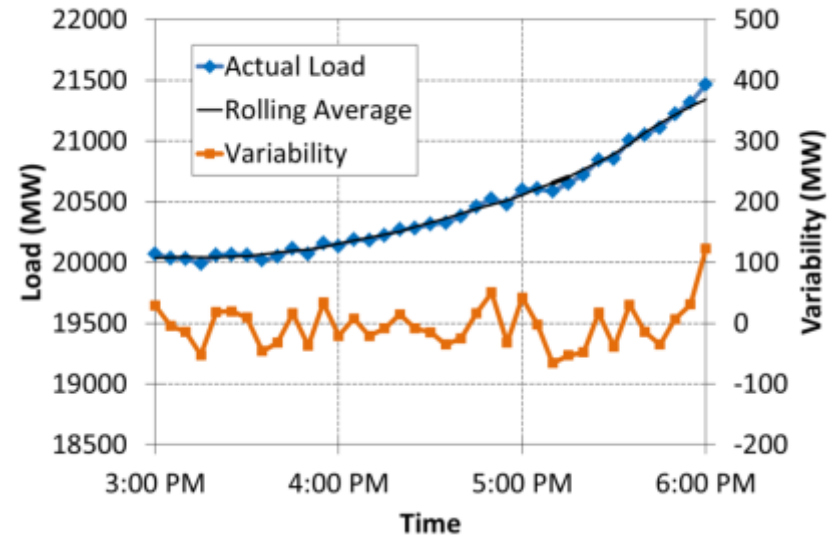
[http://www.nrel.gov/electricity/transmission/solar\\_integration\\_methodology.html](http://www.nrel.gov/electricity/transmission/solar_integration_methodology.html)

# Sub-Hourly Load Data for 2026

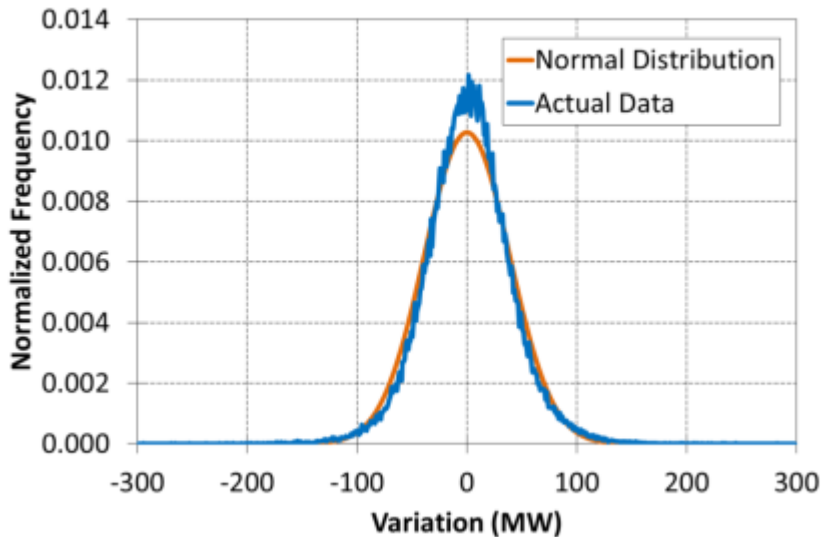
### 2026 Load-Duration Curve



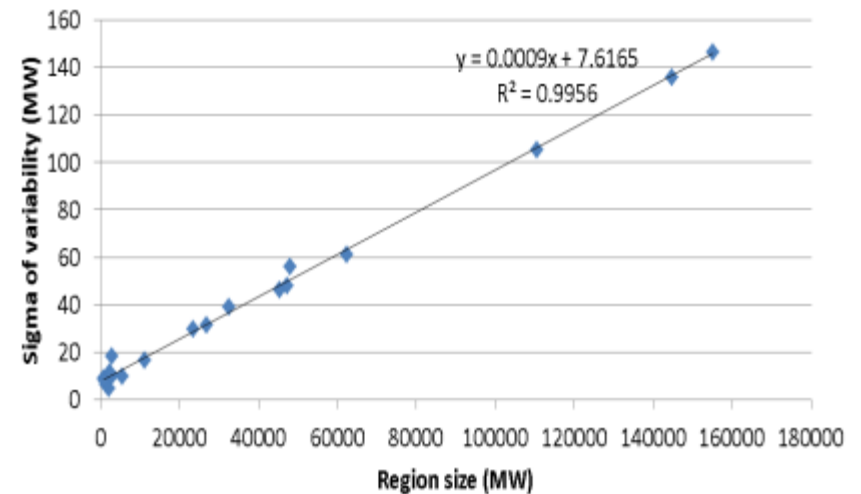
### Variability in Actual Load Data



### Distribution of Variation



### Variability for Regions of Various Sizes



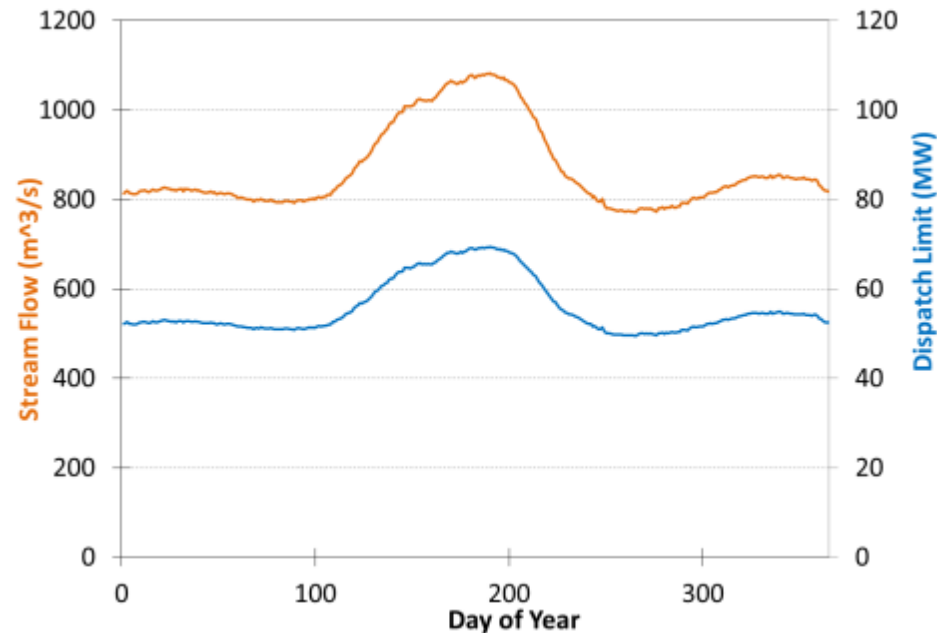
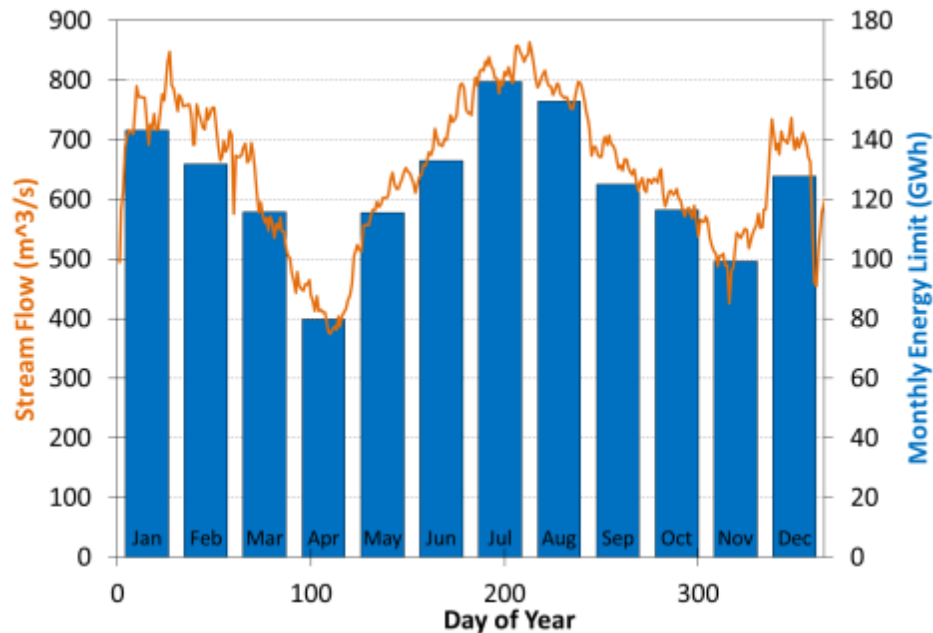
# High-Resolution Hydro Data

- Calculate energy limits based on annual energy generation and monthly or daily flow data
- US EI hydro generating capacity: 30 GW
- Canadian EI and HQ hydro generating capacity: 60 GW
- **Monthly limits**

$$Limit = \sum_{year} generation \times \frac{\sum_{month} flow}{\sum_{year} flow}$$

- **Daily dispatch limits**

$$Limit = \sum_{year} generation \times \frac{\sum_{day} flow}{\sum_{year} flow} \times \frac{1}{24}$$



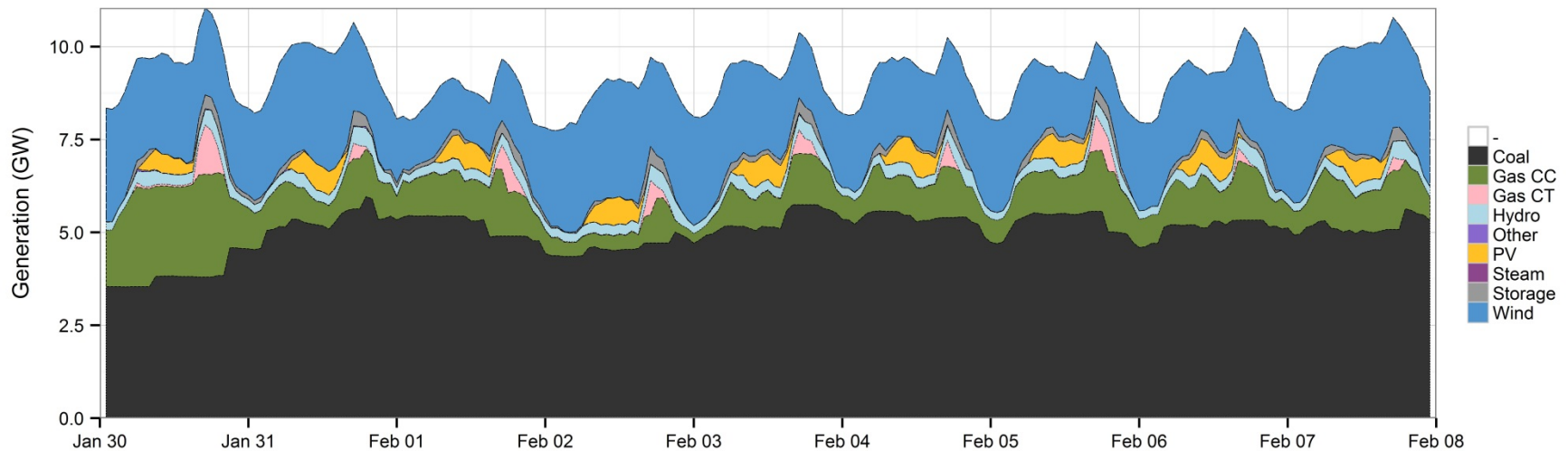


# High Performance Computing



# Computational Challenge

- As resolution and system size increase simulation becomes computationally intractable
- Multi-week simulation solve times led to a variety of model simplifications
- Initial estimated solve time for ERGIS > 2 months!

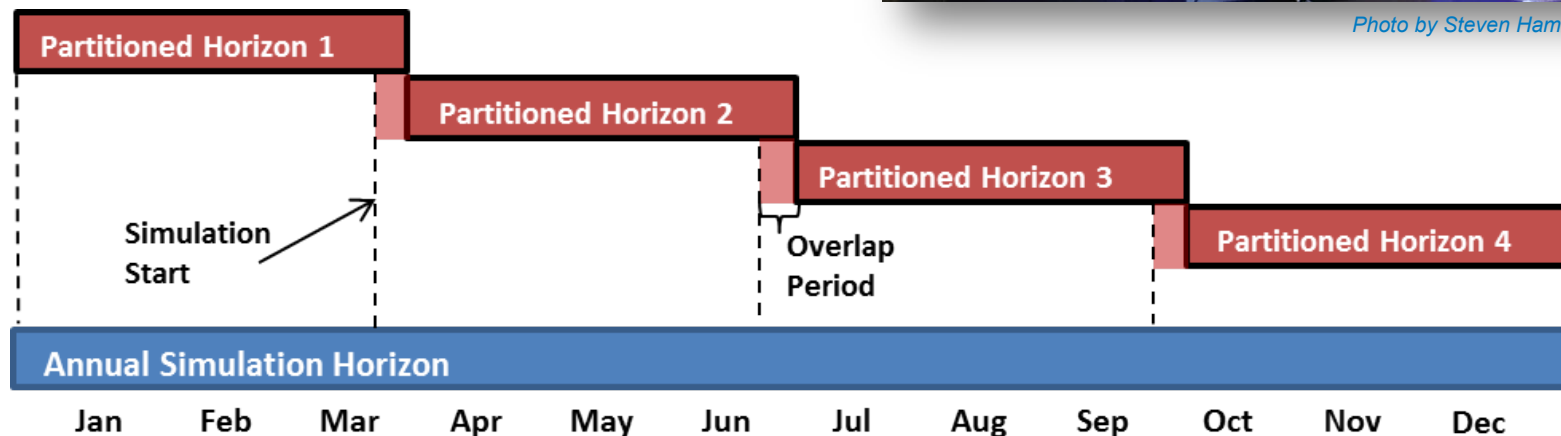


# Rethinking Unit Commitment and Dispatch

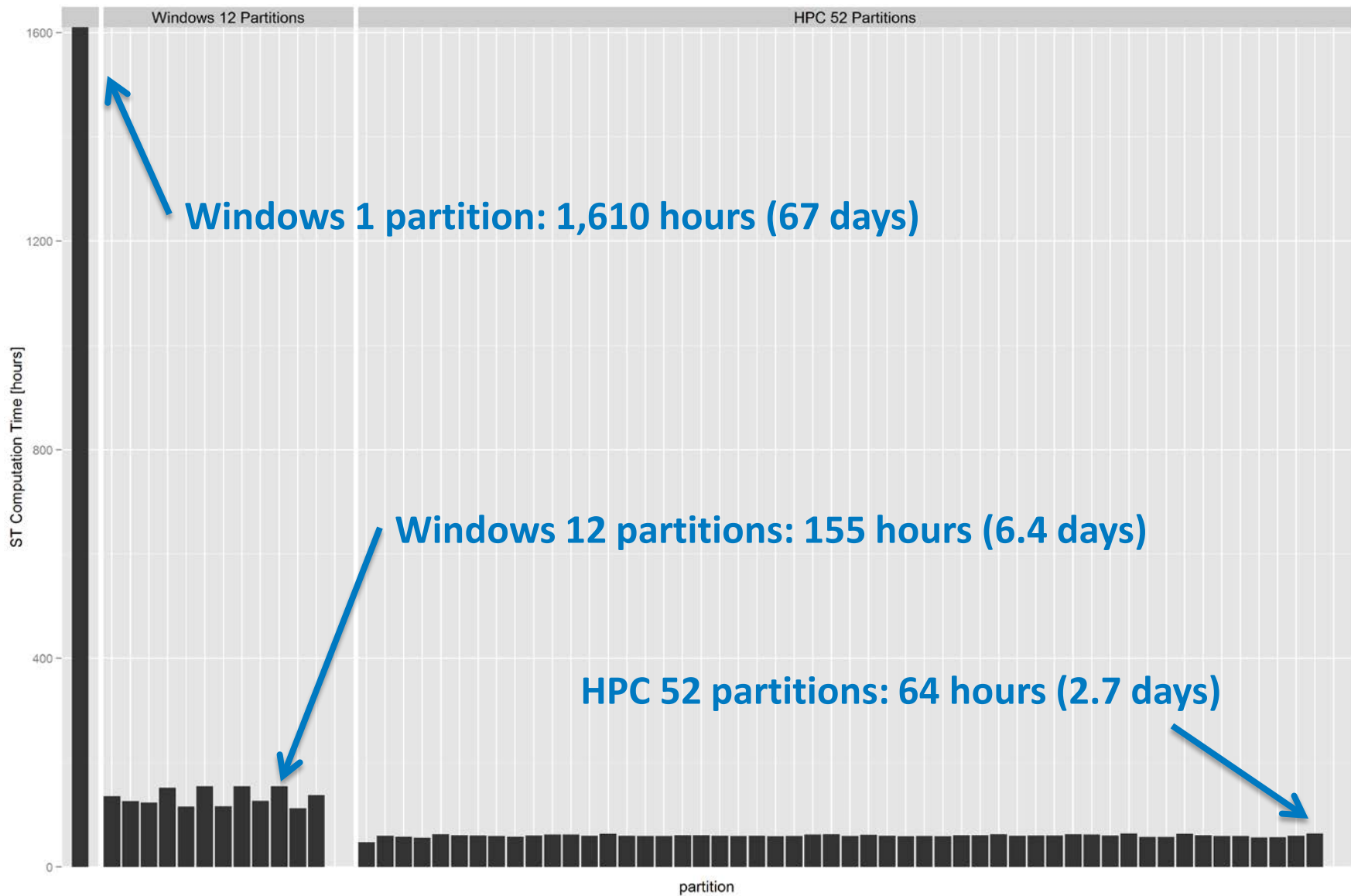
- A decision at time  $t$  is not dependent on the state of the system at previous time intervals, given a delay of  $n$  time periods.



Photo by Steven Hammond, NREL



# Simulation Time Comparison

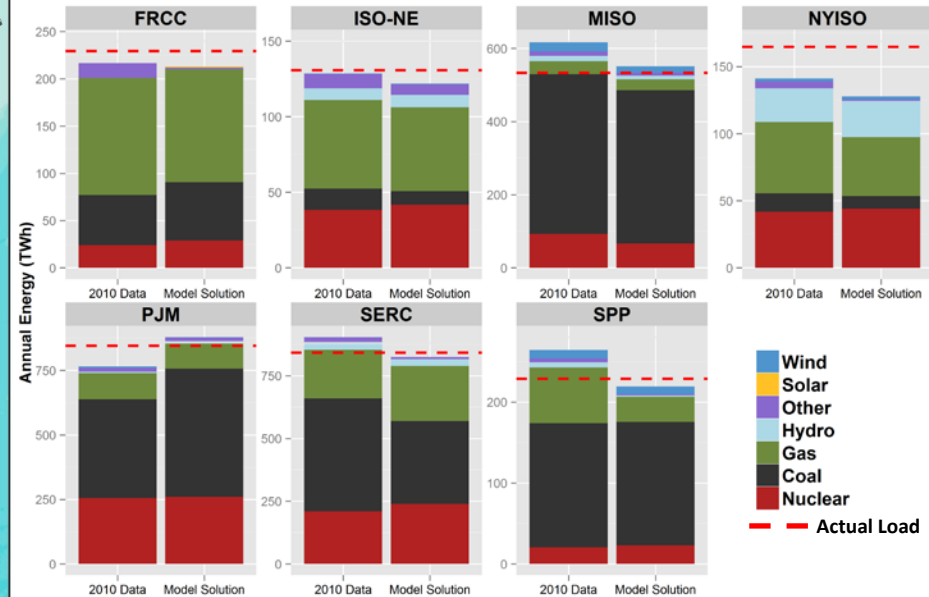
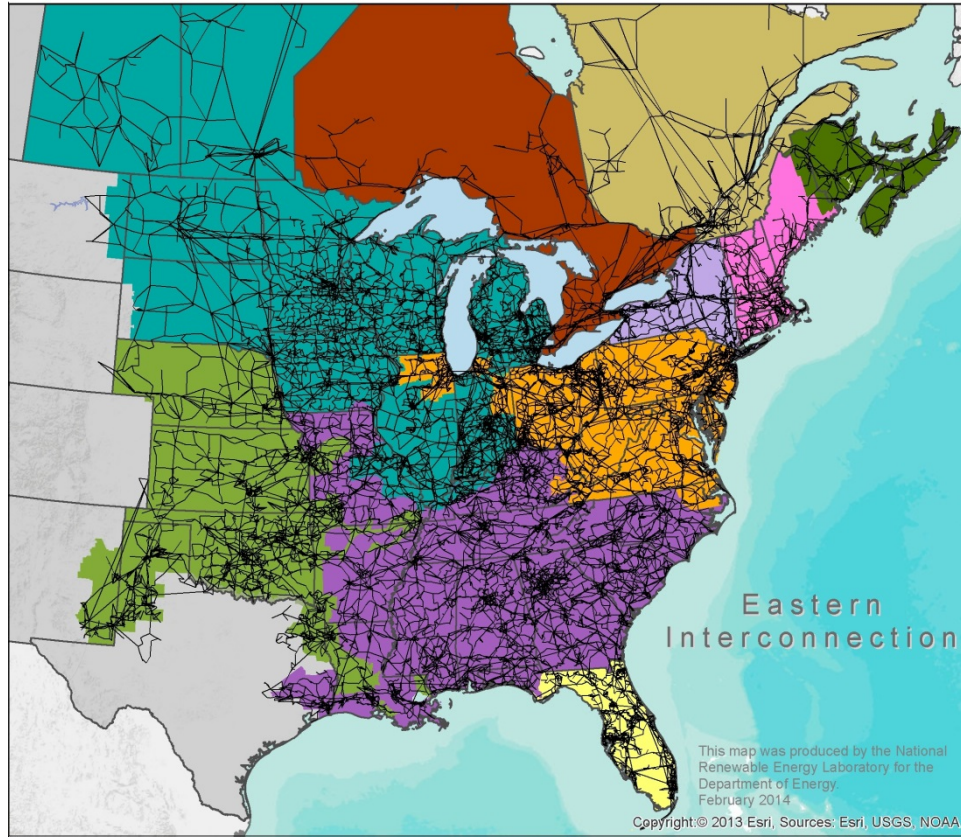


# Simulations



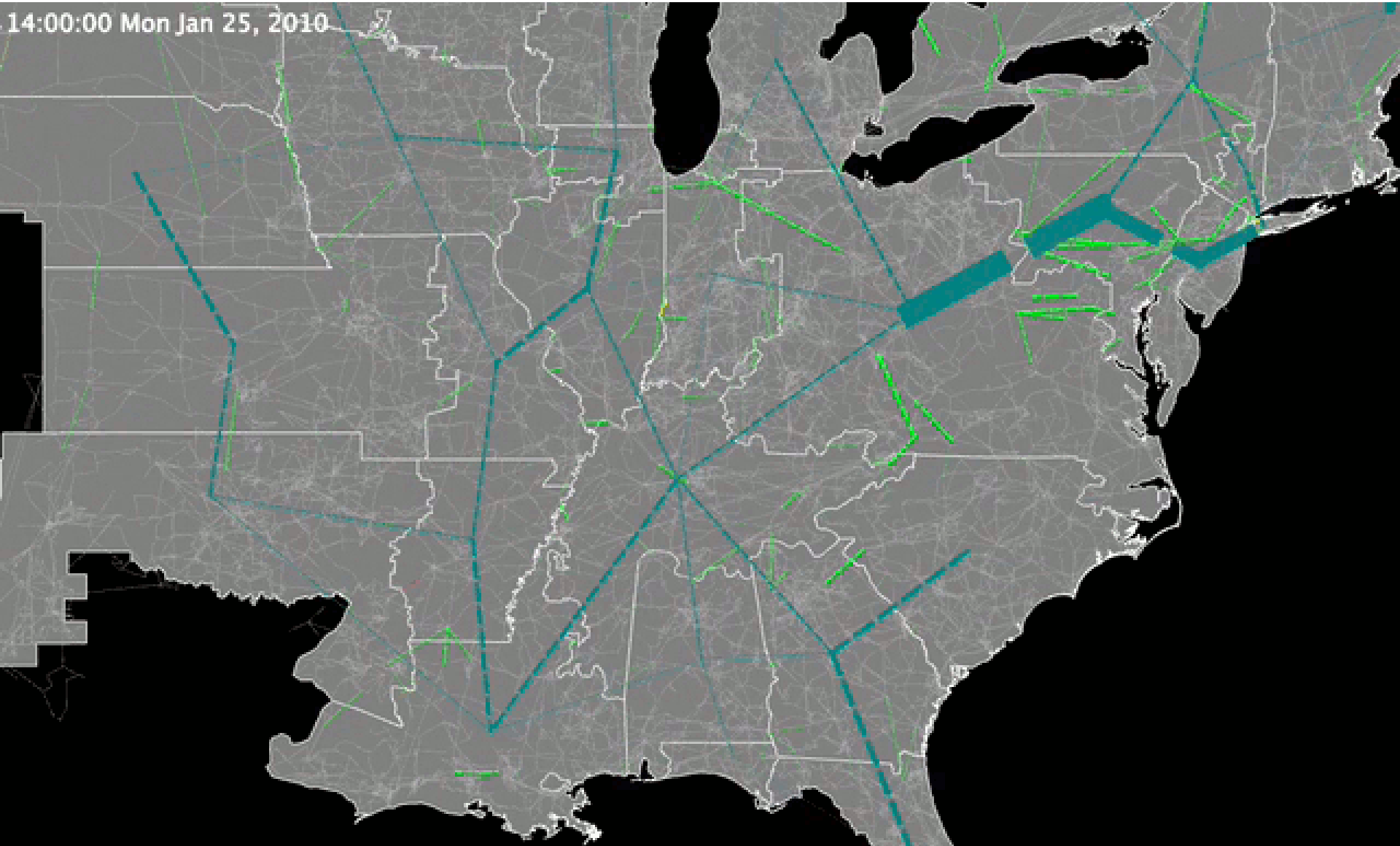
# 2010 Benchmarking Results

## 60,000-node model



# Transmission Monitoring & Visualization

14:00:00 Mon Jan 25, 2010







# Get Involved

---

- **Learn more:**

[http://www.nrel.gov/electricity/transmission/eastern\\_renewable.html](http://www.nrel.gov/electricity/transmission/eastern_renewable.html)

- **Get data:**

[http://www.nrel.gov/electricity/transmission/data\\_resources.html](http://www.nrel.gov/electricity/transmission/data_resources.html)

- **Final Report : Winter 2015**

- **Contact:**

[aaron.bloom@nrel.gov](mailto:aaron.bloom@nrel.gov)

This work was supported by the U.S. Department of Energy under Contract No. DE-AC36-08-GO28308 with the National Renewable Energy Laboratory.