Forecasting wind energy

GE Energy Consulting Group

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Imagination at work

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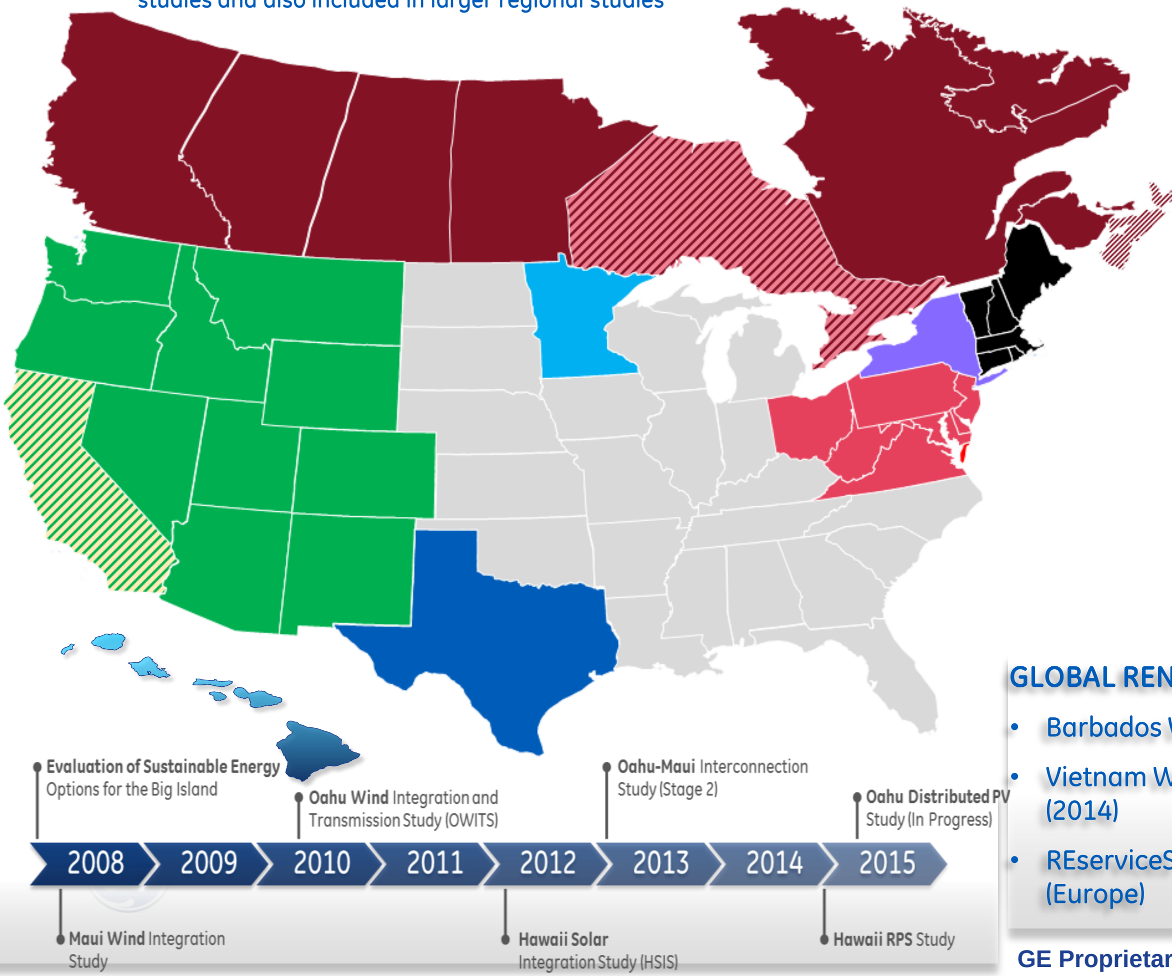
GE's integration of renewables experience

Studies commissioned by utilities, commissions, ISOs…

- Examine feasibility of 100+ GW of new renewables
- Consider operability, costs, emissions, transmission

Gradients indicate systems subject to individual studies and also included in larger regional studies



2004 New York
3 GW Wind
10% Peak Load
4% Energy

2005 Ontario
15 GW Wind
50% Peak Load
30% Energy

2006 California
13 GW Wind
3 GW Solar
26% Peak Load
15% Energy

2007 Texas
15 GW Wind
25% Peak Load
17% Energy

2009 Western U.S.
72 GW Wind
15 GW Solar
50% Peak Load
27% Energy

2010 New England
12 GW Wind
39% Peak Load
24% Energy

2012 Nova Scotia
~1500MW Wind
40% Energy

2013 PJM
96GW Wind
22GW Solar
30% Energy

2014 Minnesota
8 GW Wind
4.5 GW Solar
50% Energy

Underway

Pan-Canadian
~72GW Wind
30% Energy

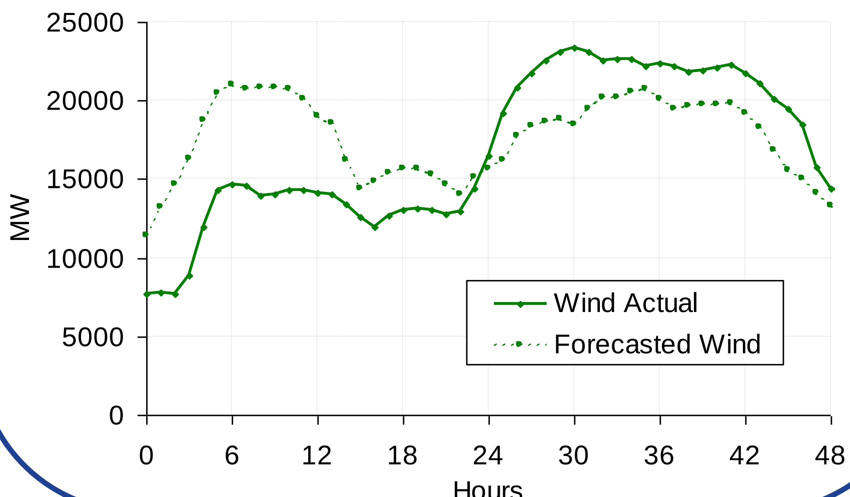
GLOBAL RENEWABLE INTEGRATION STUDIES

- Barbados Wind & Solar Integration Study (2015)
- Vietnam Wind Grid Code Development and Renewable Integration Study (2014)
- REserviceS Project Economic Grid Support from Variable Renewables (Europe)

Introducing Variability & Uncertainty

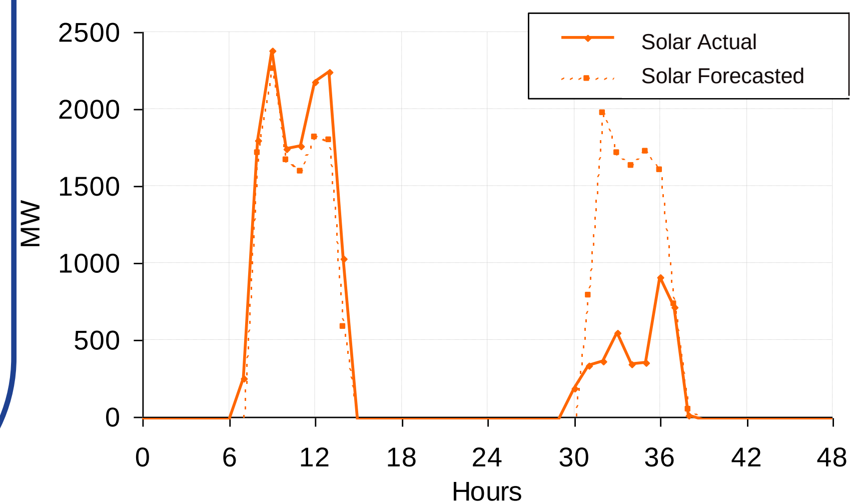
Uncertainty

- Wind generation are not always available when called upon
- Are not dispatchable … output is predicted by a **forecast**
  - Actual power output is different than forecast output



Variability

- Wind and solar generation vary as the intensity of their energy sources
- Several timescales … minute (regulation), hour (ramping), daily, seasonal

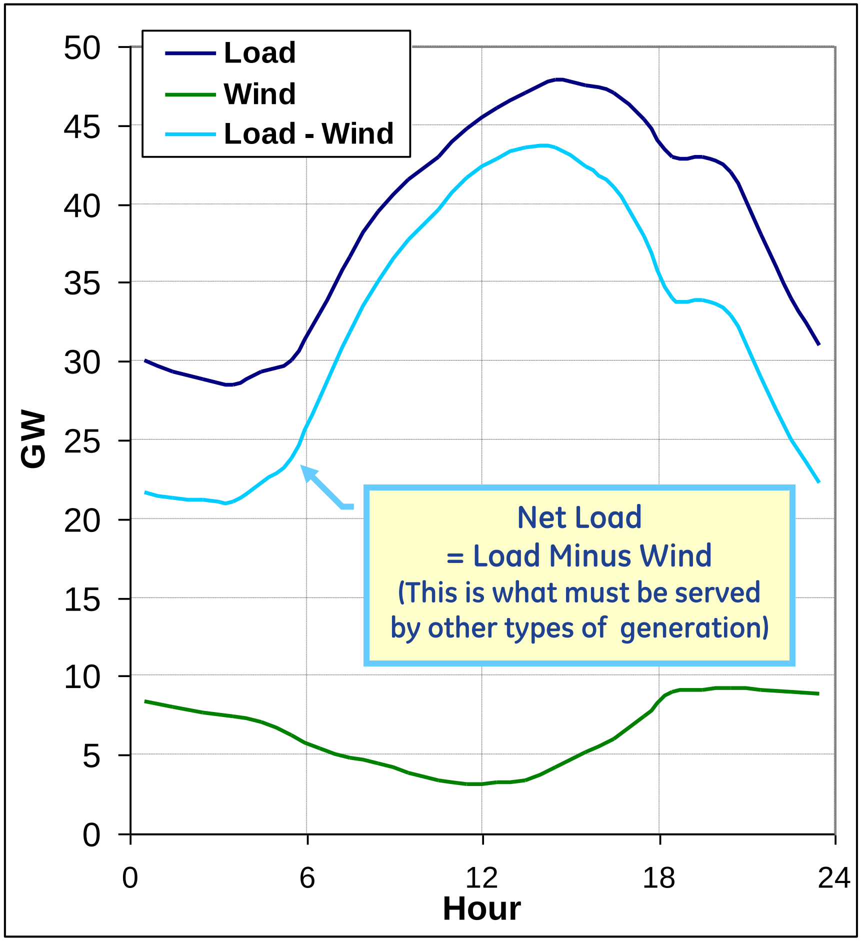


A perfect forecast eliminates uncertainty, but there is still variability

For grid operations, wind is “similar” to load

- Like load, wind can be forecasted accurately for planning purposes
- Grid operators can plan day-ahead (or shorter) operations based on a load forecast and a wind generation forecast
- Dispatchable generation is allocated to serve the net of the forecast load minus the forecast wind
- Uncertainty in the wind forecast adds to the uncertainty in the load forecast
- Adjustments are made using hour-ahead forecasts and real-time data

Dispatchable Generation Serves “Net Load”



Dealing with Uncertainty

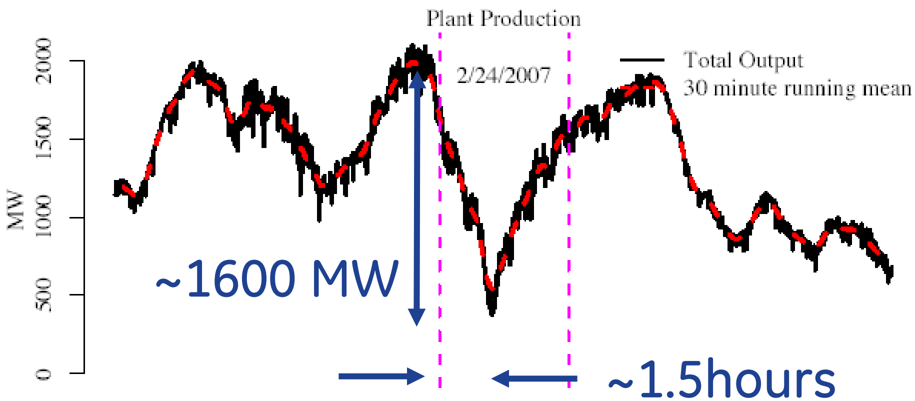
- Basic options are to increase reserves, demand response, curtail, rely on neighbors, storage
- Increasing reserves
  - Commit additional generation so that load will never be interrupted
  - Need to do it 100% of the time, because you do not know when the reserves will be required
  - Potential to increase system cost, additional capacity online may not be needed and runs the system less efficiently
- Demand response
  - Interrupt or reduce load occasionally, as need arises
  - A paid ancillary service
- Curtail when under forecasted

Forecasting can Help to Reduce Uncertainty

Forecasting increases economic value of renewable power

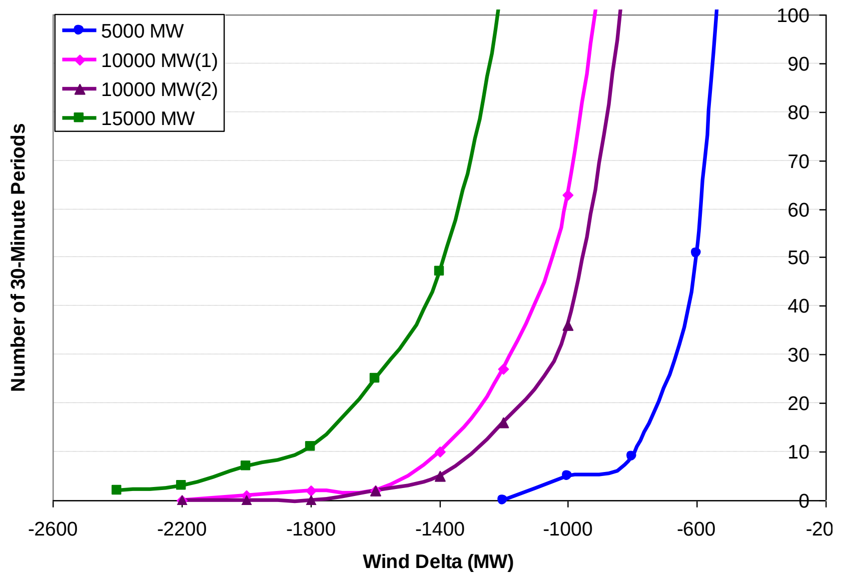
Wide-spread extreme events are predictable (e.g. widely publicized Texas events were predicted)

Texas February 24, 2007 event



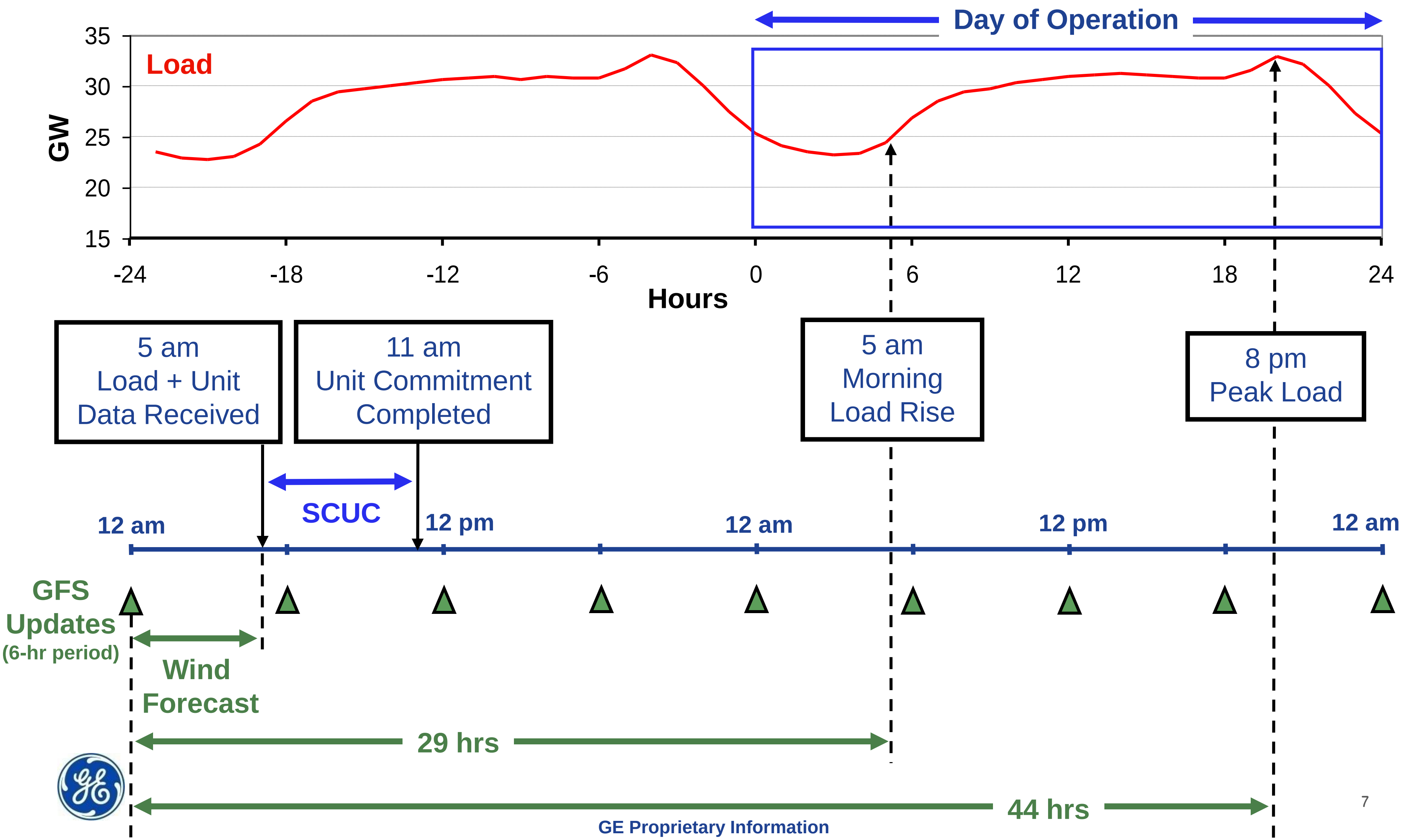
Arrival of such fronts is generally forecastable, several hours ahead within a 30-minute window

Extreme Thirty-Minute Wind Drops



Timing is Everything

Conceptual Timeline for Day-Ahead Unit Commitment

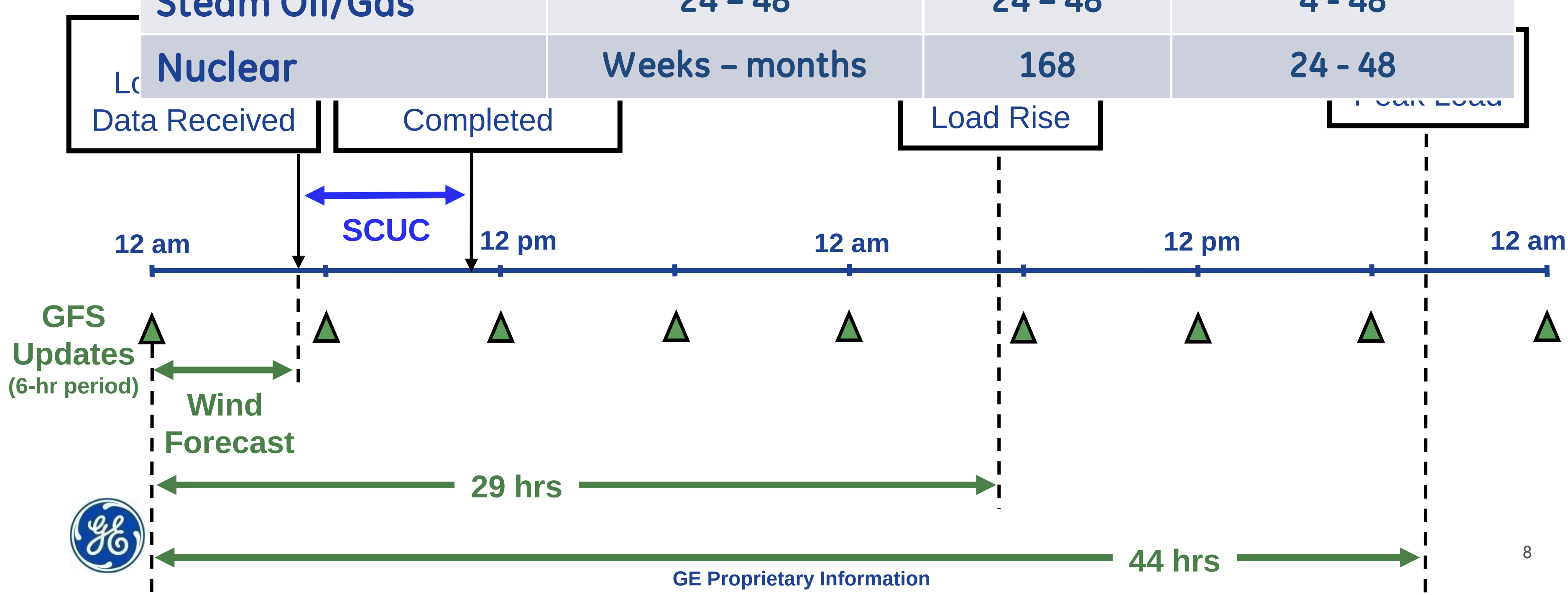


Start Times (warm): http://www.nrel.gov/docs/fy12osti/55433.pdf

Timing is Everything

Conceptual Timeline for Day-Ahead Unit Commitment

Type	Minimum Up-Time	Minimum Down-Time	Hours to Start
Combined Cycle	8	8	4-8
Combustion Turbine	1	2	0.6- 2
Steam Coal	24 – 48	24 – 48	12 - 48
Steam Oil/Gas	24 – 48	24 – 48	4 - 48
Nuclear	Weeks – months	168	24 - 48



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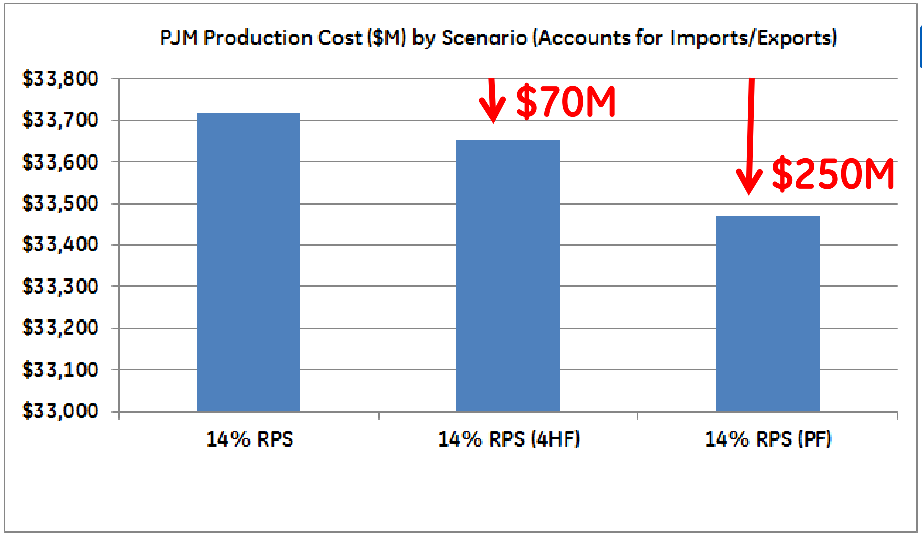
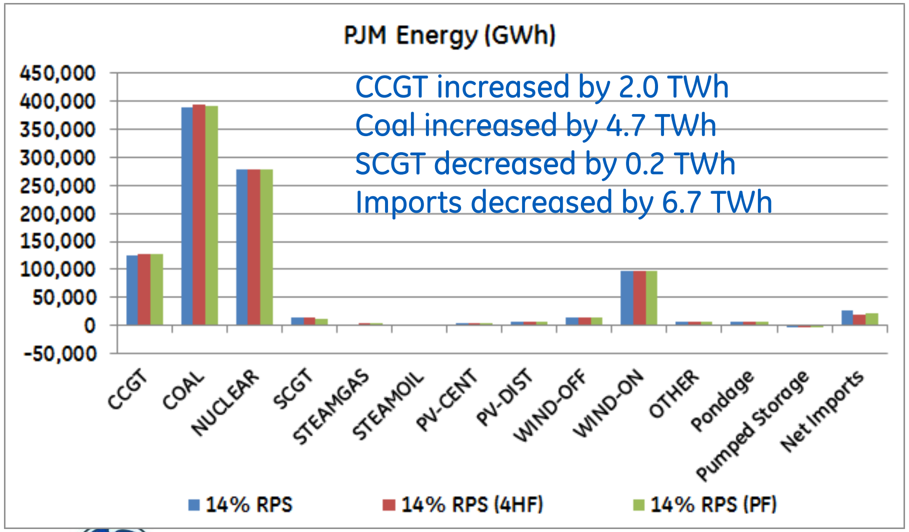
Short-Term Forecasting

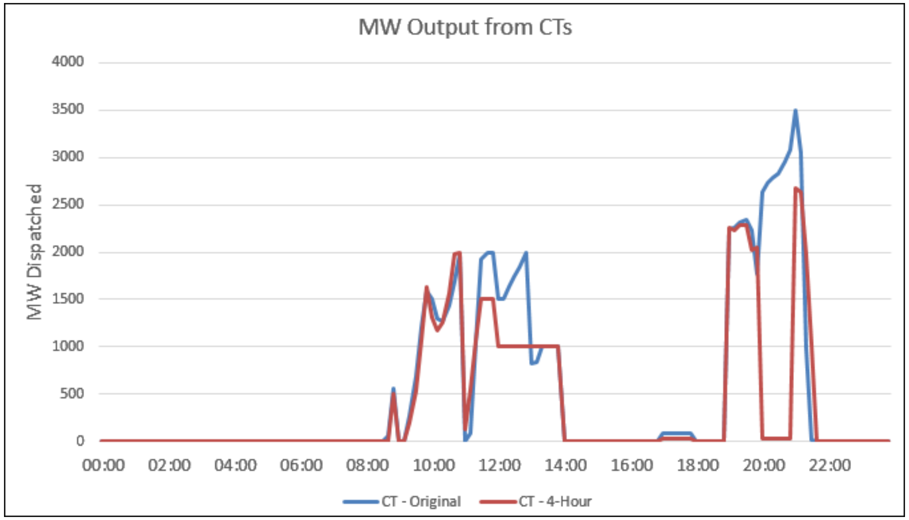


PJM Renewable Integration Study

Using a 4-Hour forecast resulted in a $70M reduction in production cost.

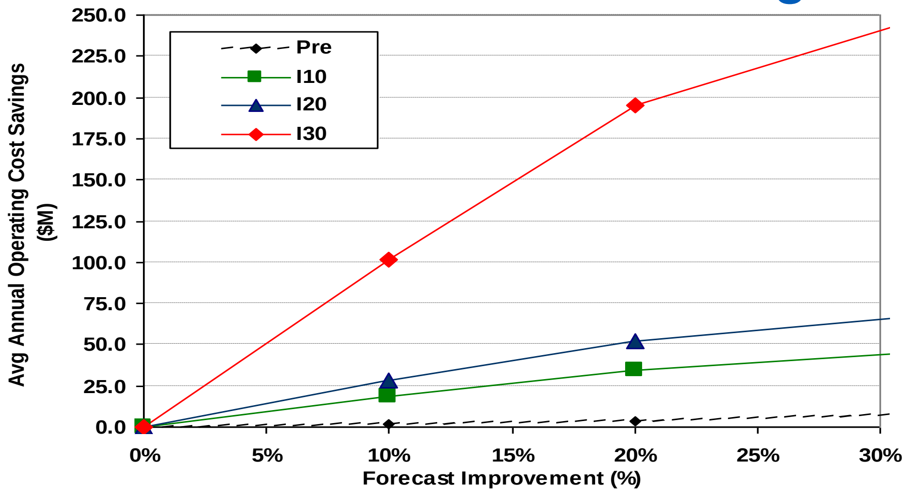
The reduction was a result of an improved commitment, shifting from CT to CC's.

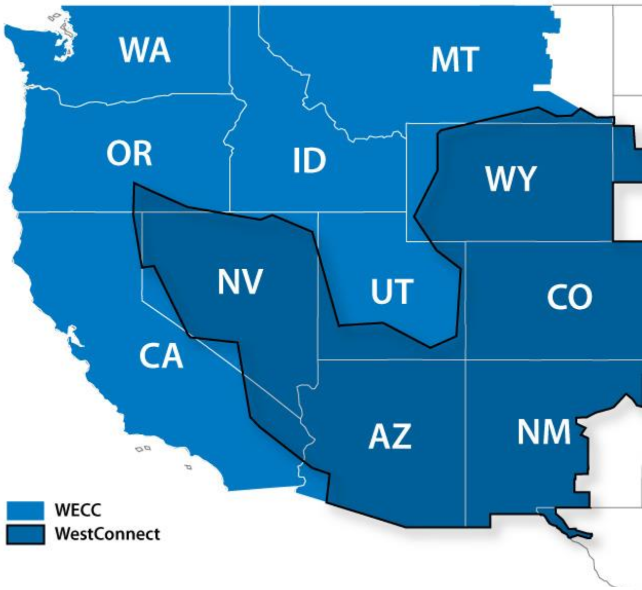


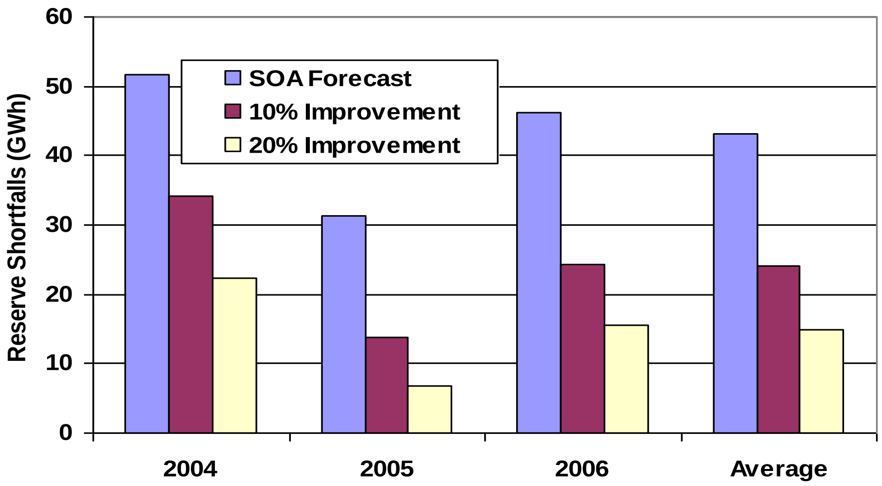


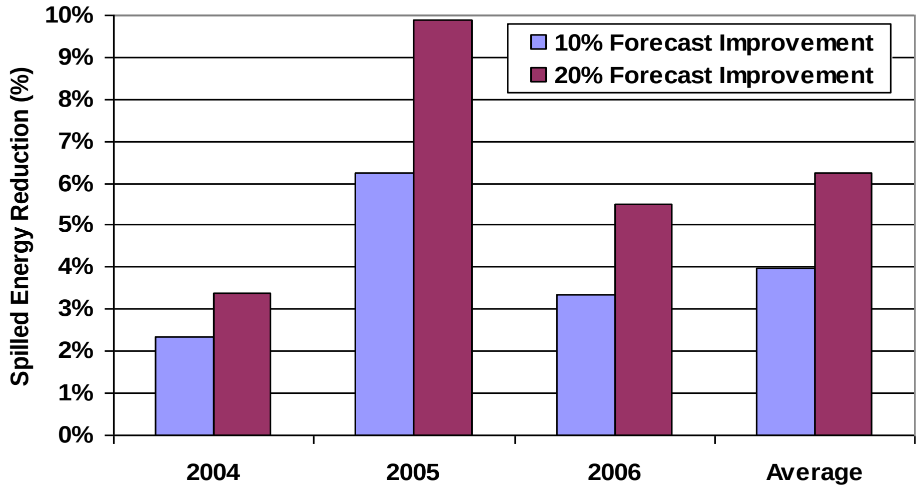
Improved SOA Wind Forecast

Western Wind & Solar Integration Study

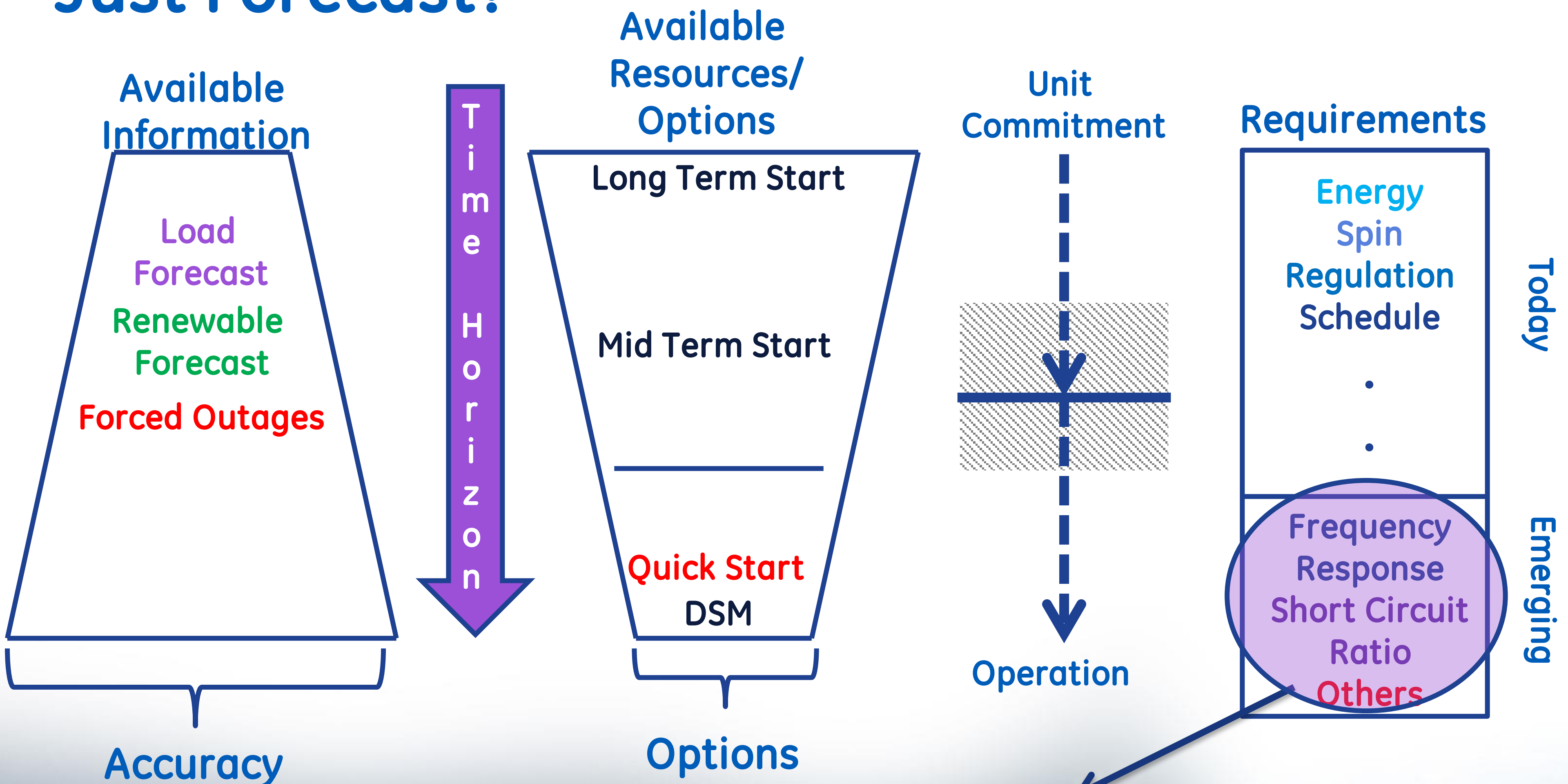








Just Forecast?



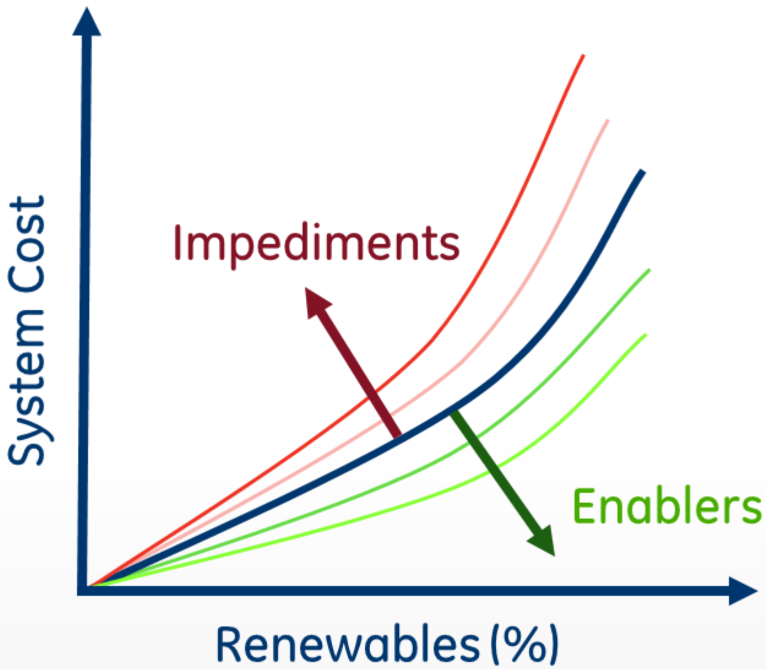
How should Markets factor these into decisions?

Conclusions

- The forecast schedule used depends on the system…
  - Isolated or Interconnected
  - Flexible generation or inflexible base load generation
  - Hydro availability and flexibility (environmental constraints)
- Forecasting improvements result in operating cost savings to the utility. These savings increase with increased wind penetration and increased forecast accuracy.
  - The savings is not proportional to the penetration level of wind energy
  - Diminishing returns with increased penetration
- A more accurate forecast, in general, can reduce operating reserve carried by a system for uncertainty
- Forecasting improvements reduce wind curtailment and reduce reserve shortfalls, increasing the efficiency of power system operations
- Other changes in operating practices are also needed to improve operating cost savings

Key lessons learned …

All power grids can accommodate substantial levels of wind and solar power… There is never a hard limit



Enablers

- Renewable forecasting
- Flexible thermal fleet
- Faster quick starts
- Deeper turn-down
- Faster ramps
- More spatial diversity of wind/solar
- Grid-friendly wind and solar
- Demand response ancillary services
- Energy storage and electric vehicles
- Markets & Grid Codes

Impediments

- Lack of transmission
- Lack of control area cooperation
- Market rules / contracts constraints
- Unobservable & uncontrollable DG – "behind the fence"
- Inflexible operation strategies during light load & high risk periods
- Markets & Grid Codes

Variability and Uncertainty… Layperson's terms

For Example…

Generator Owner… "I can guarantee 1000MW of hydro all day tomorrow."

System Operator… "OK, I will turn off 1000MW of other generation.

Variability:

Generator Owner…"I can guarantee 1000MW of hydro from 2PM to 4PM tomorrow."

System Operator… "OK, I may turn down 1000MW of other generation, rather then shutting it off."

Uncertainty:

Generator Owner…"I think I will have 1000MW of hydro sometime tomorrow."

System Operator…"OK, I may turn off only 600MW of other generation and I will keep 400MW spinning and have quick start capacity ready to fire."