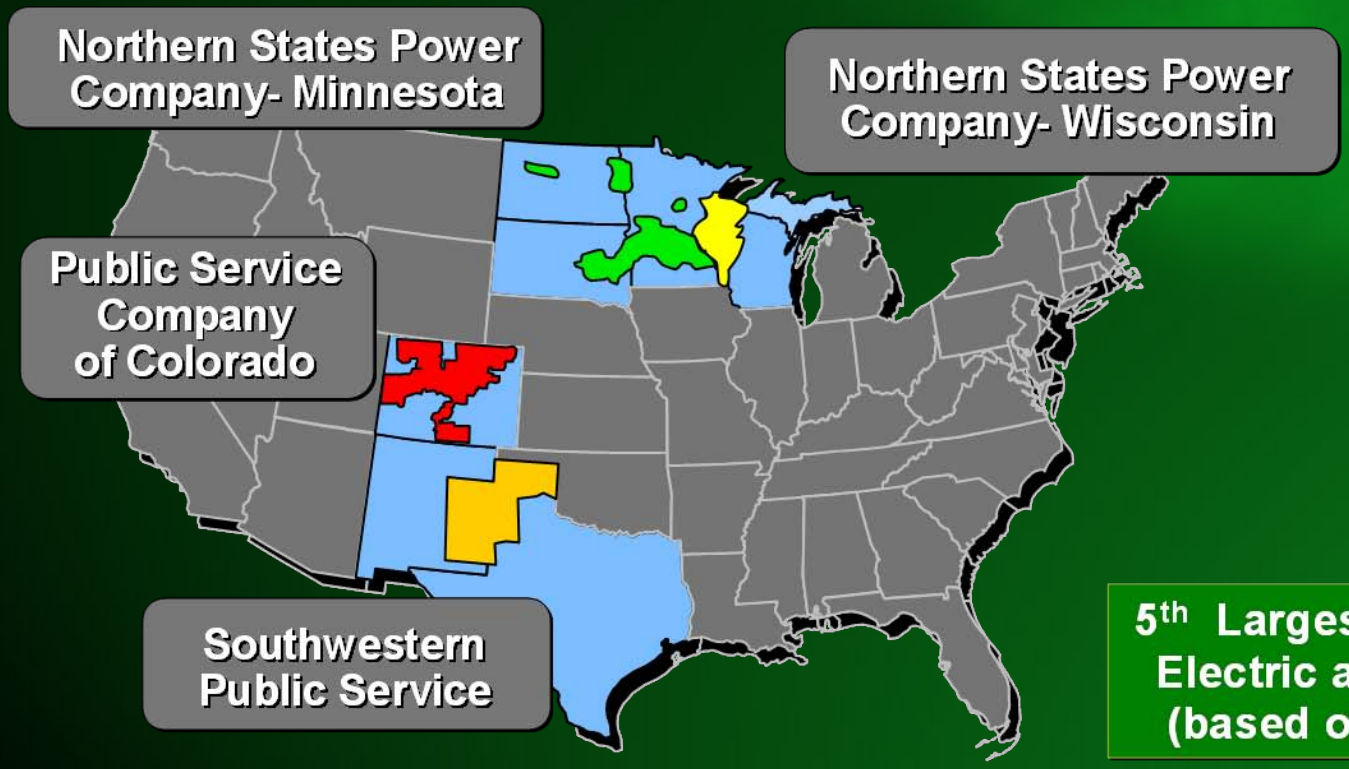
System Integration

Keith Parks
Sustainable Energy and Atmospheric Sciences
March 19 2009

Xcel Energy



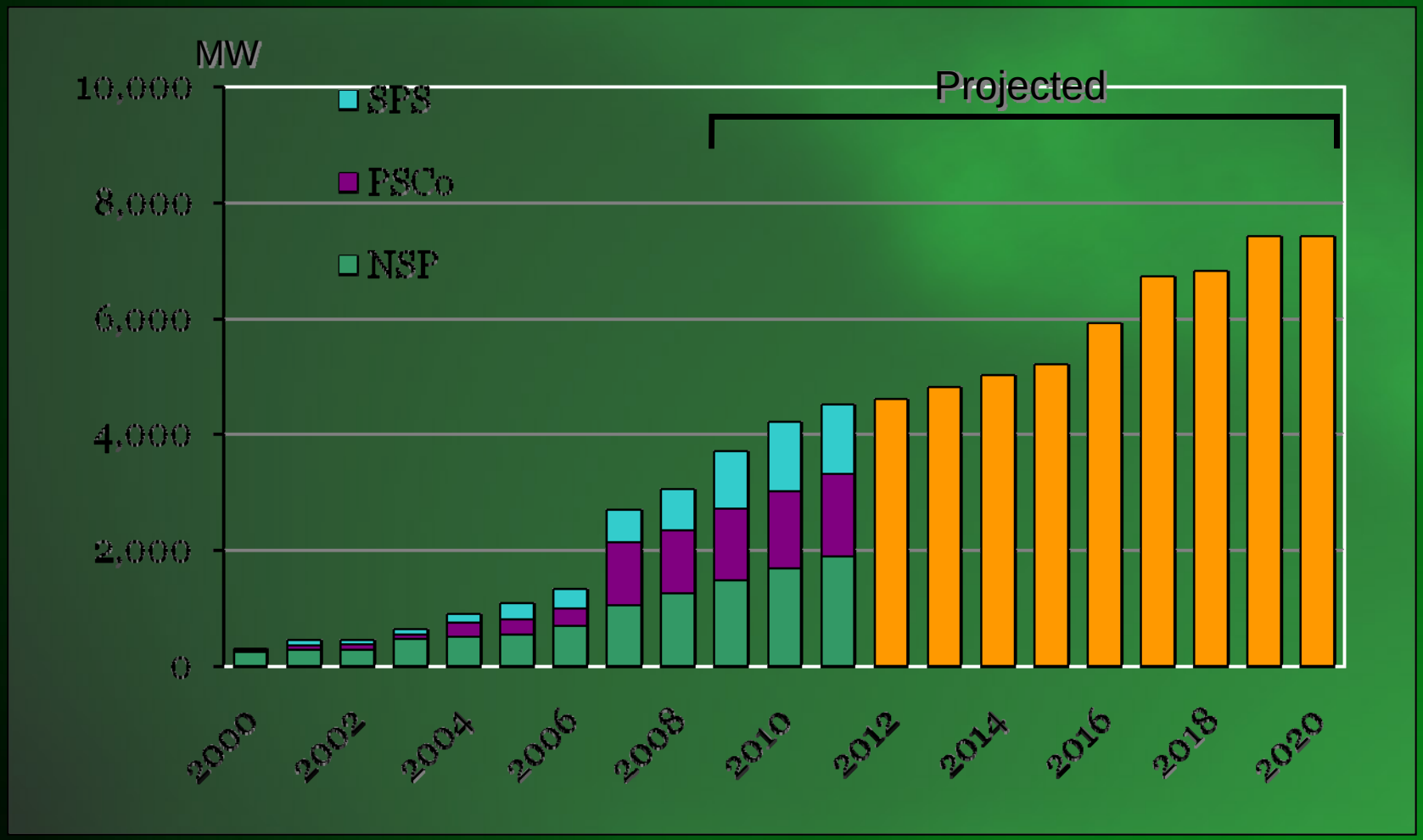
5th Largest Combination Electric and Gas Utility (based on customers)

Environmental Leadership

- No. 1 Wind Energy Provider
- Windsource®, Largest Renewable Pricing Program
- Dow Jones Sustainability Index
- Industry Leading Voluntary Emissions Reduction
- Industry Leading Carbon Management Strategy
- Wind-to-Hydrogen
- Smart Grid City

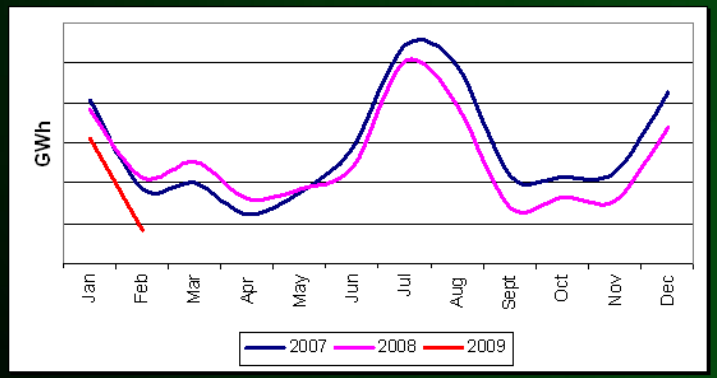
Dow Jones Sustainability Indexes
Member 2007/08

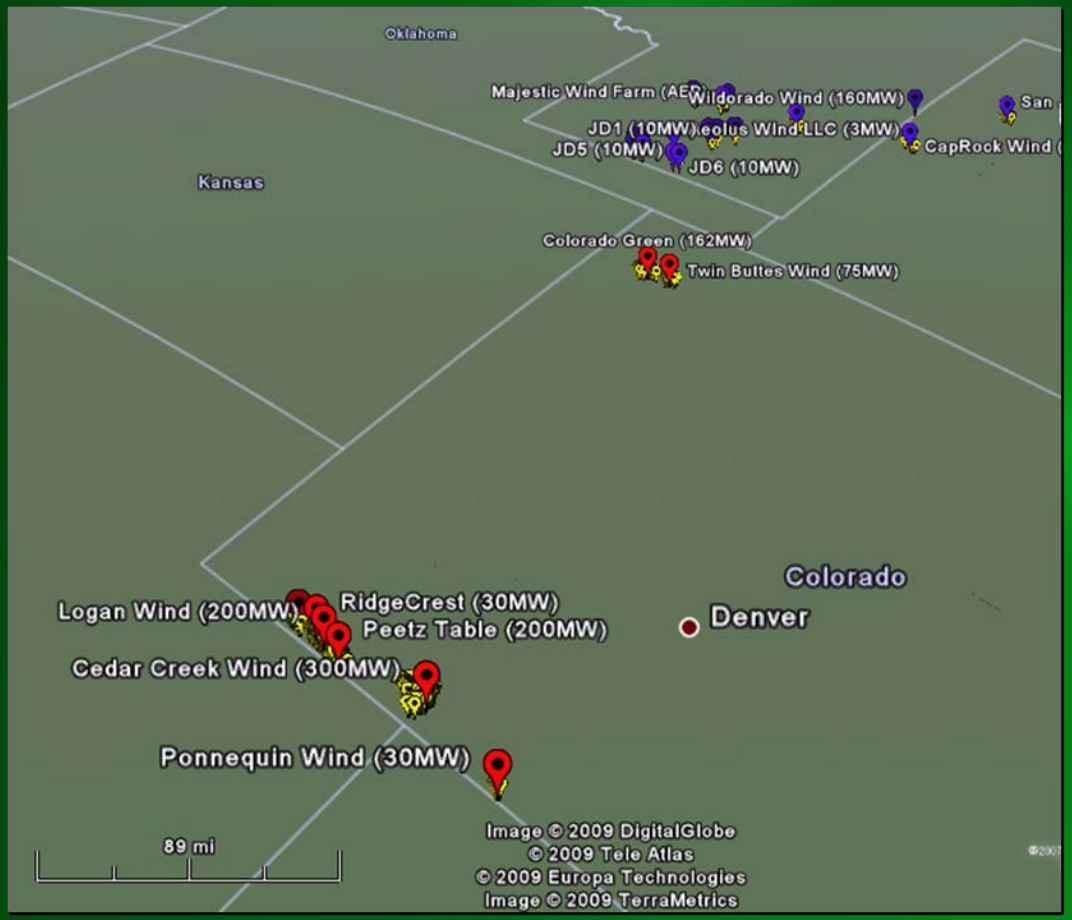
Xcel Wind Generation Projected Growth



2008 PSCo Wind Resources

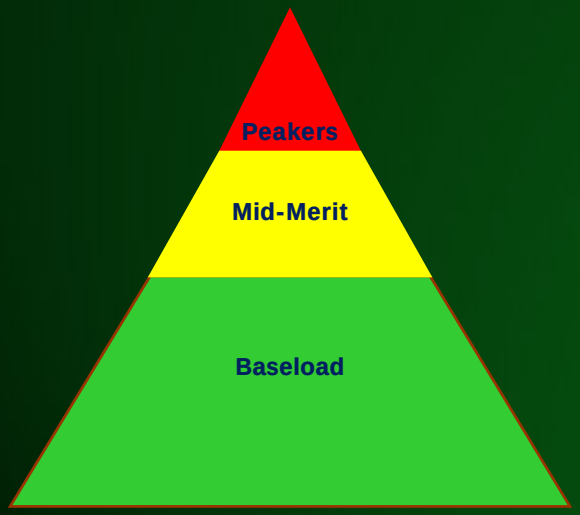
- PSCo
- 2007
  - 282MW
  - 4% Pk Load
  - 2.5% Energy
- 2008
  - 1,057MW
  - 15% Pk Load
  - 10% Energy



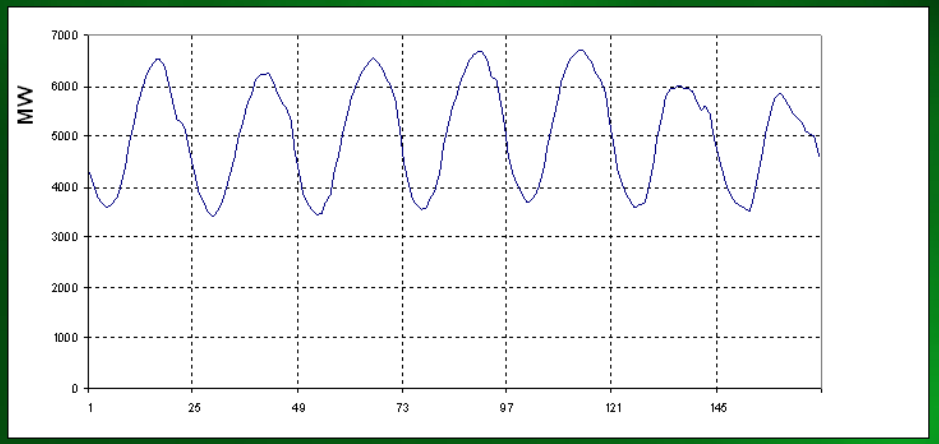


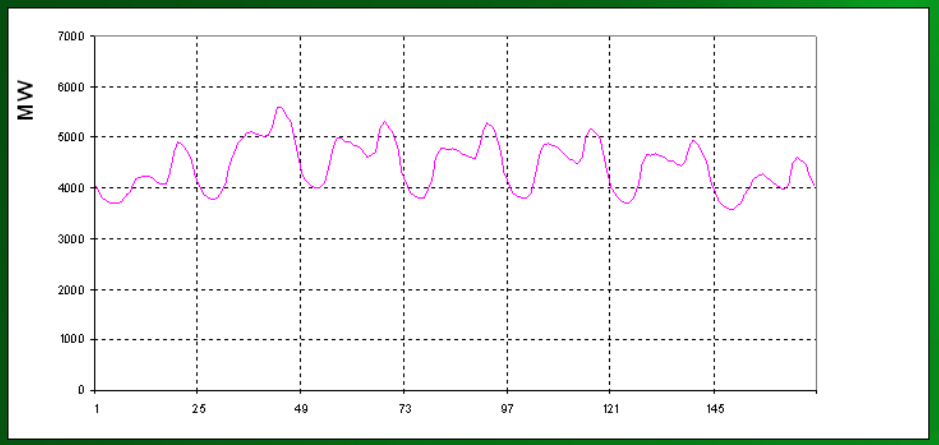
Loads and Resources

- **Obligations and resources are maintained in balance at all times (eg +/-56MW)**



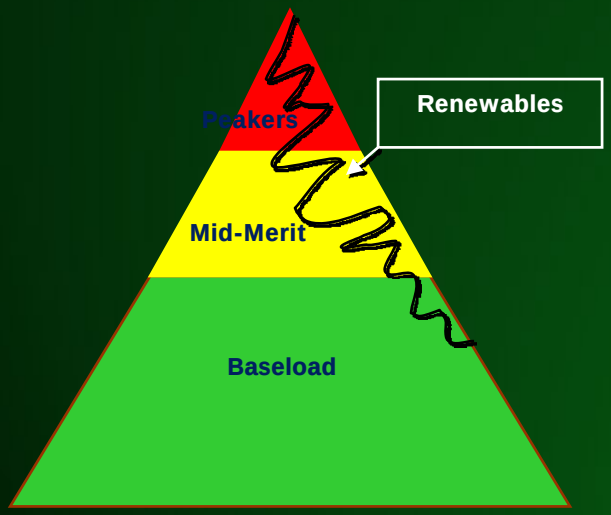
Traditional Utility Paradigm





Loads and Resources (Jul/Jan)

- **Net Load – Obligations less non-dispatchable renewable energy.**



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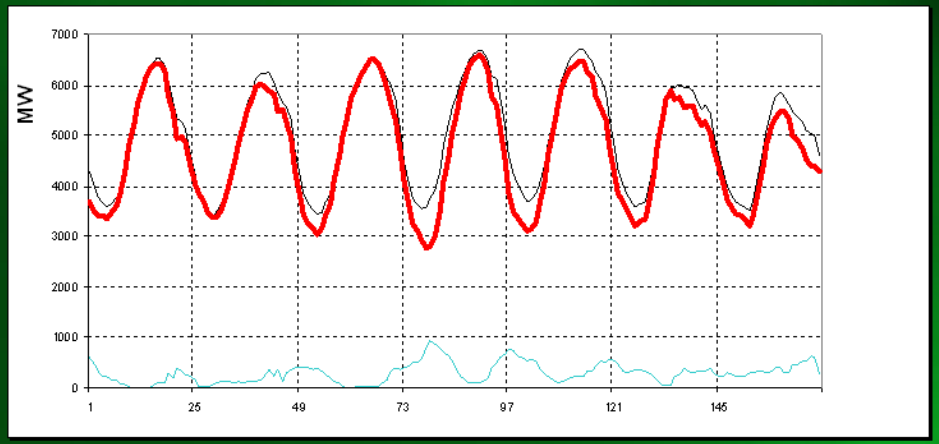
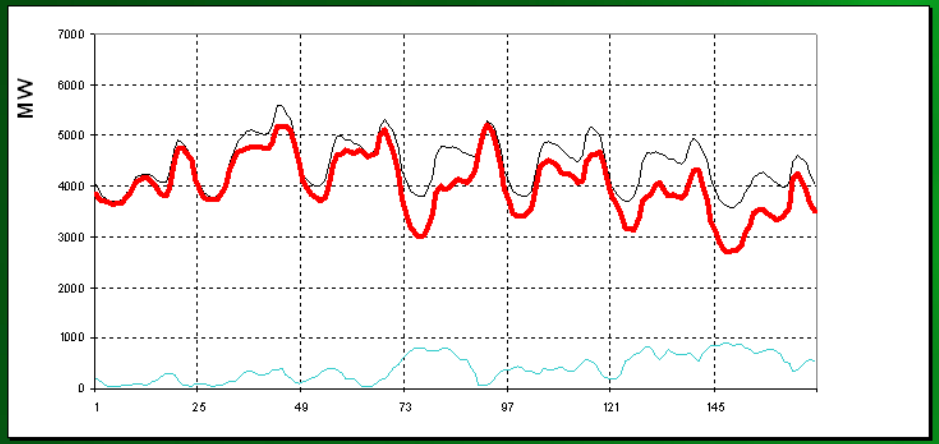
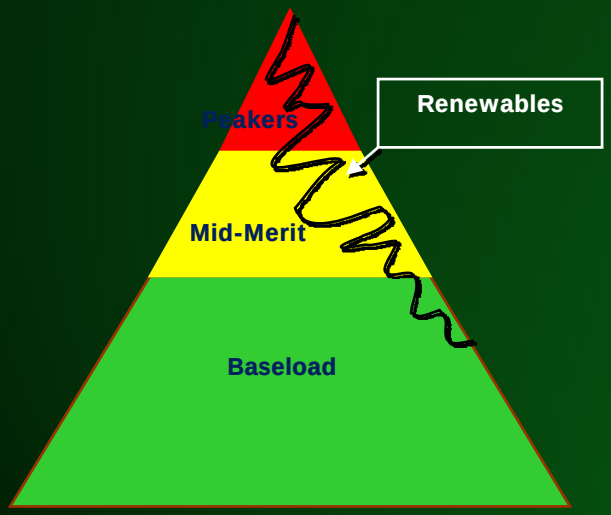




Loads and Resources (Apr/Oct)

- Expand focus to all hours of the year to manage uncertainty (Apr/Oct).



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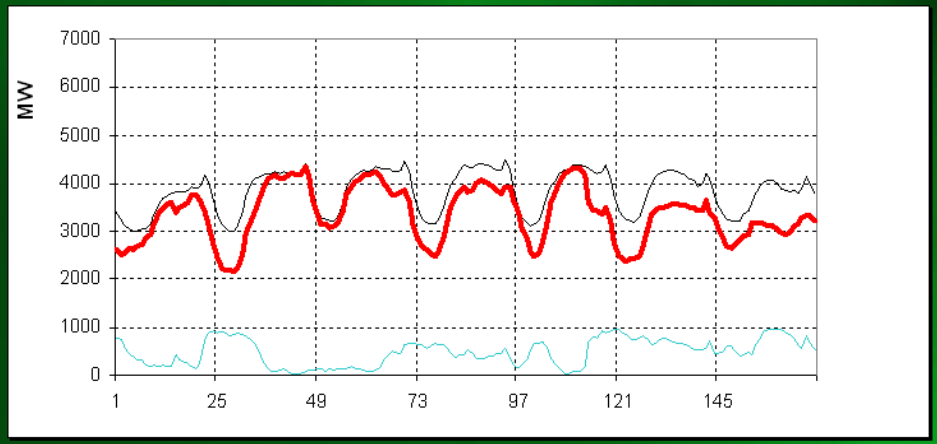
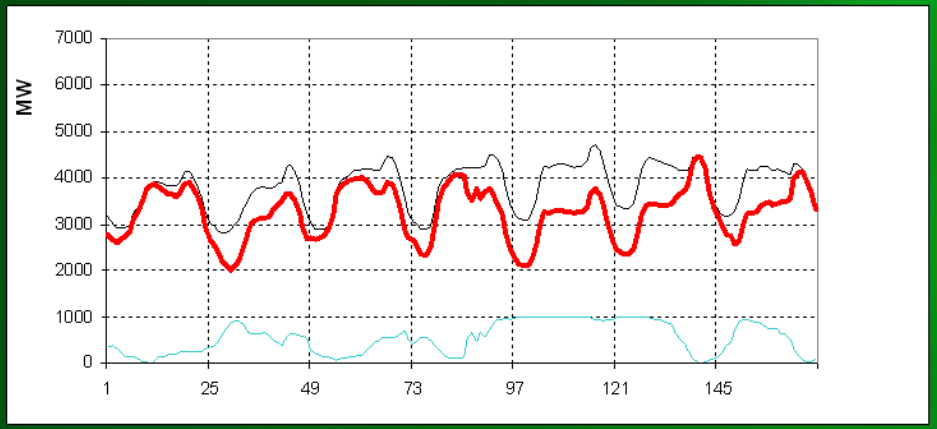
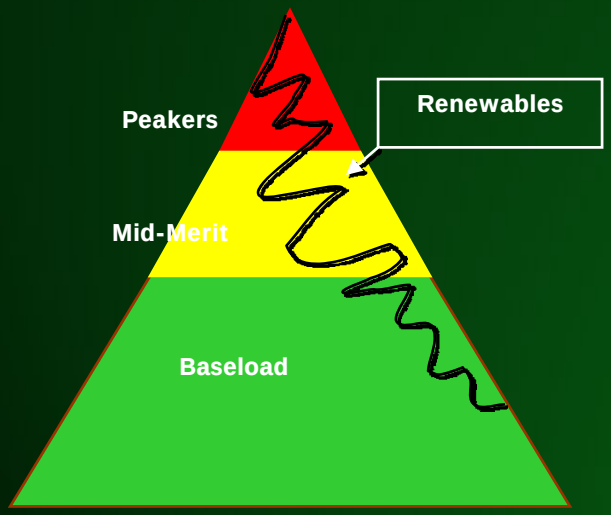




Loads and Resources (2015)

- **Spread between diurnal high/low loads increase. Timing of ramps uncertain.**



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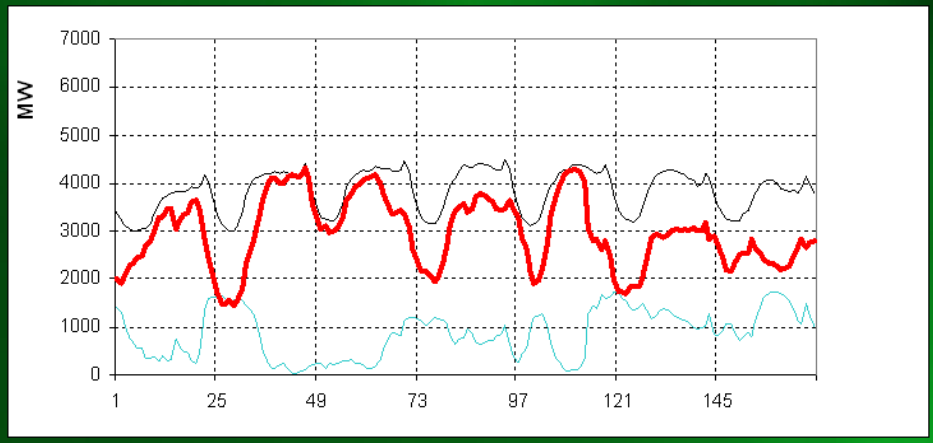
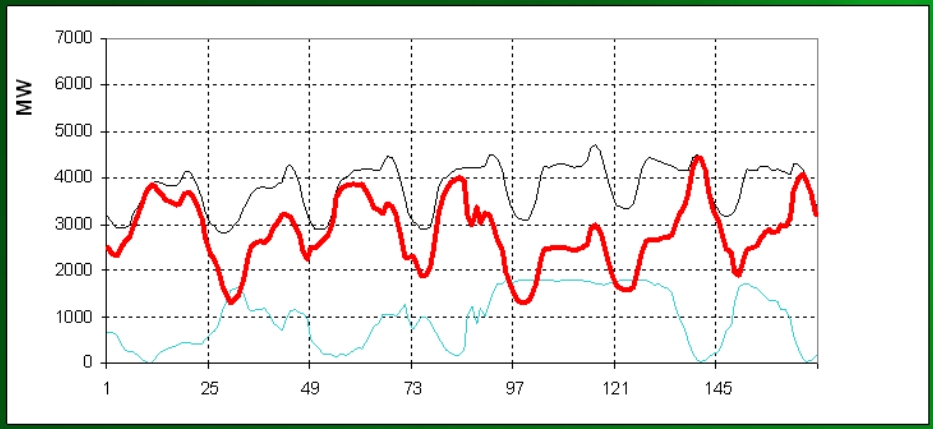
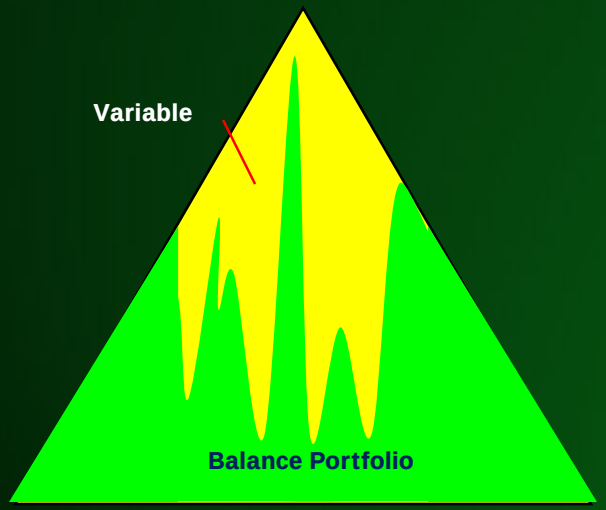


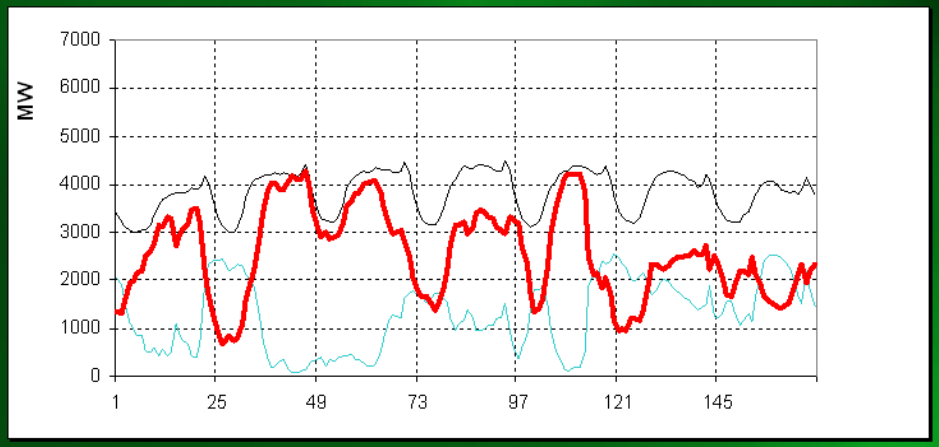


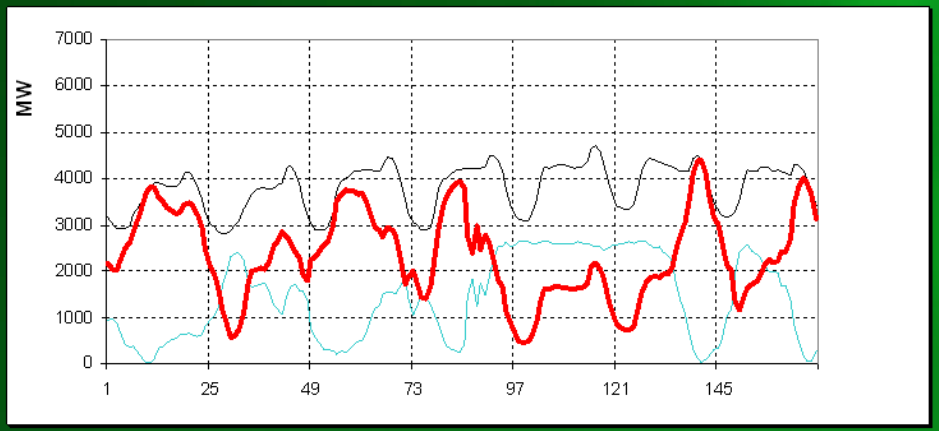
Loads and Resources (2020)

- **New paradigm: Flexible & Informed Grid**



High Penetration Portfolio



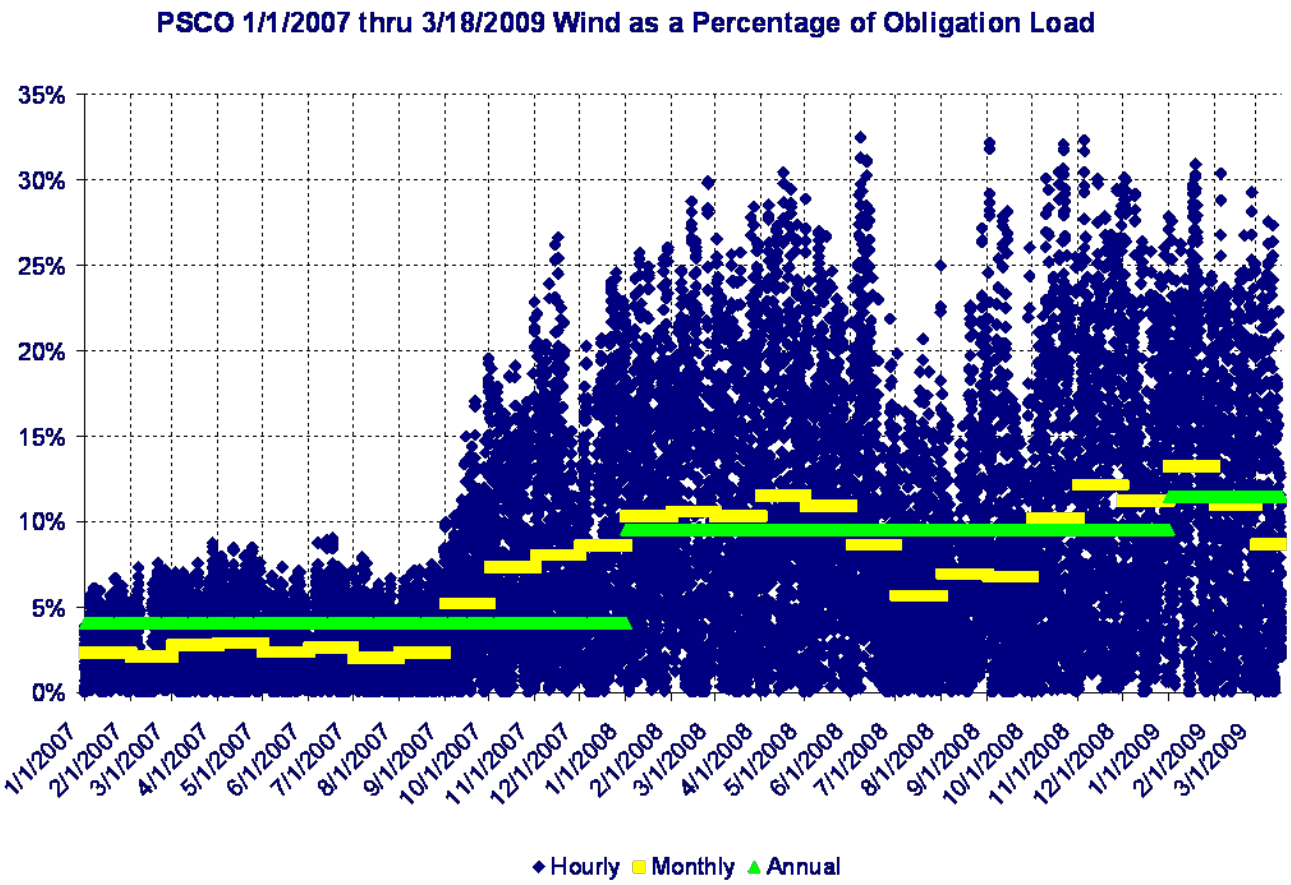


System Integration

- System integration is identifying economic and reliability impacts and finding cost-effective technical and operational solutions to integrate an ever larger renewables portfolio.

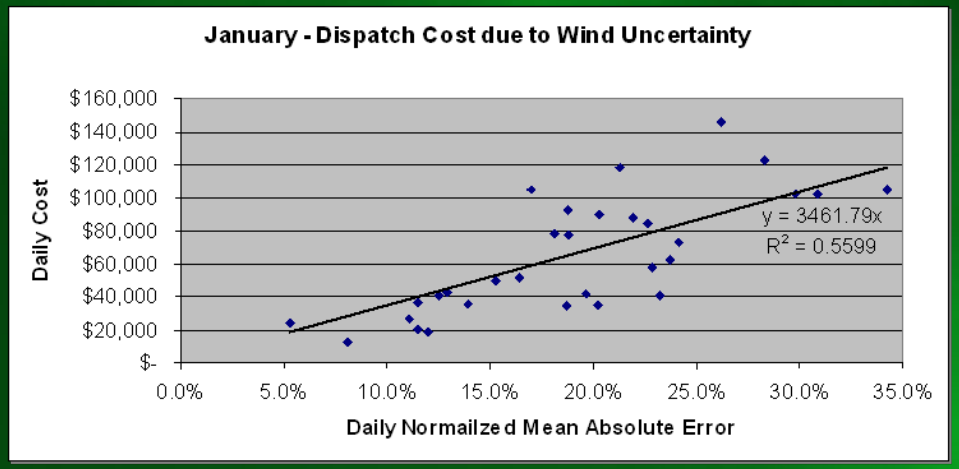
- Impacts
  - Uncertainty
  - Variability
  - Cycling
  - Bottoming
- Solutions
  - Forecasting
  - Flexibility
  - Staged Commit & Dispatch
  - Long-Term Planning

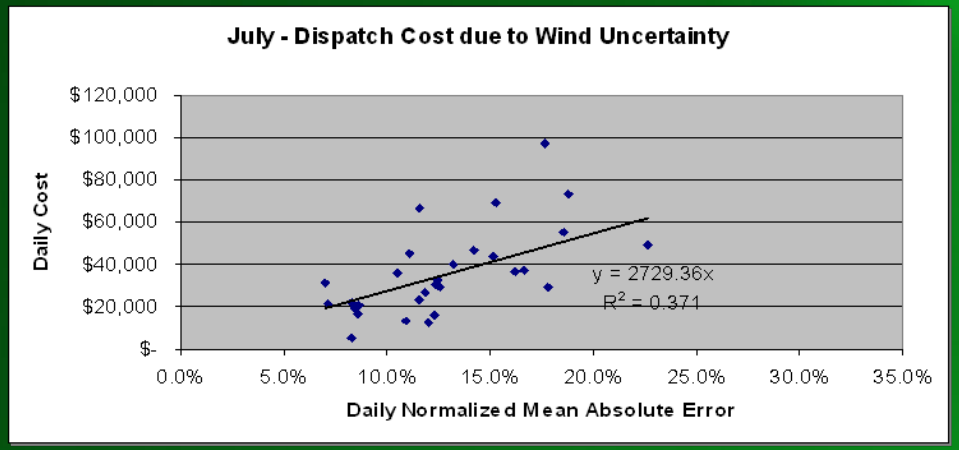
Wind Energy as a % of Total Load



Forecasts Provide Value

- Internal backcast studies show lower costs with lower error
- ~$1.2M/%MAE*
- Savings potential greater with more wind

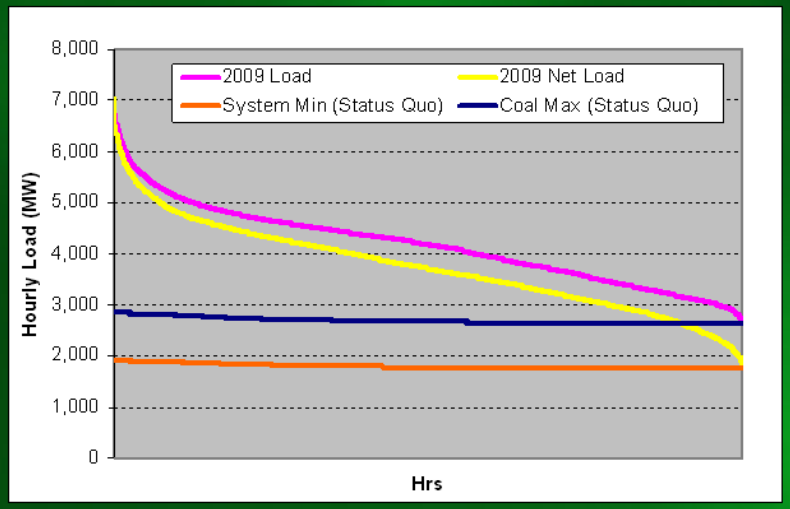


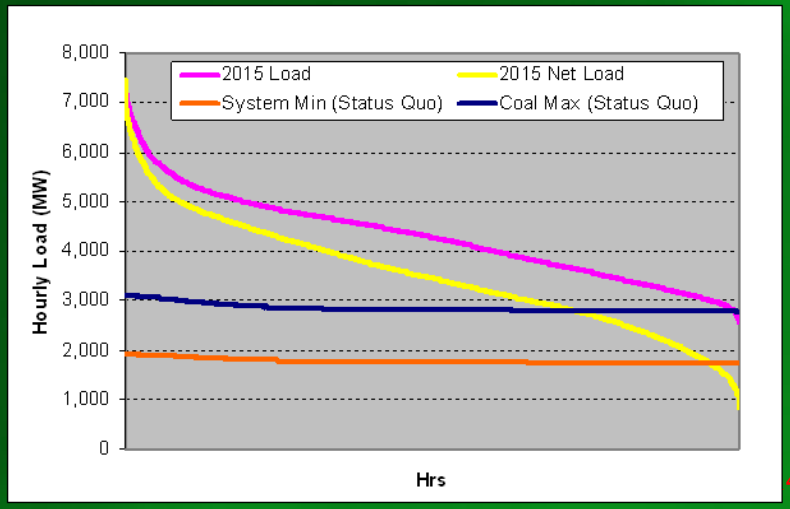


*Annualized for period Jan thru Oct 2008

Cycling (on/off & load following) and System Bottom

- Nocturnal load following by inflexible base load facilities will soon be the norm
  - Increases O&M
  - Costs increase with deep cycling
- System bottoming will force wind curtailment





Anticipation: Ramps

False Ramp (aka “Head Fake”) – A smaller duration ramp with similar ramp rate inside some forecasting time window

ex. If a 60-min 300 MW ramp is forecast, another 10-min 50 MW ramp inside the window of 5 hours would be a false ramp

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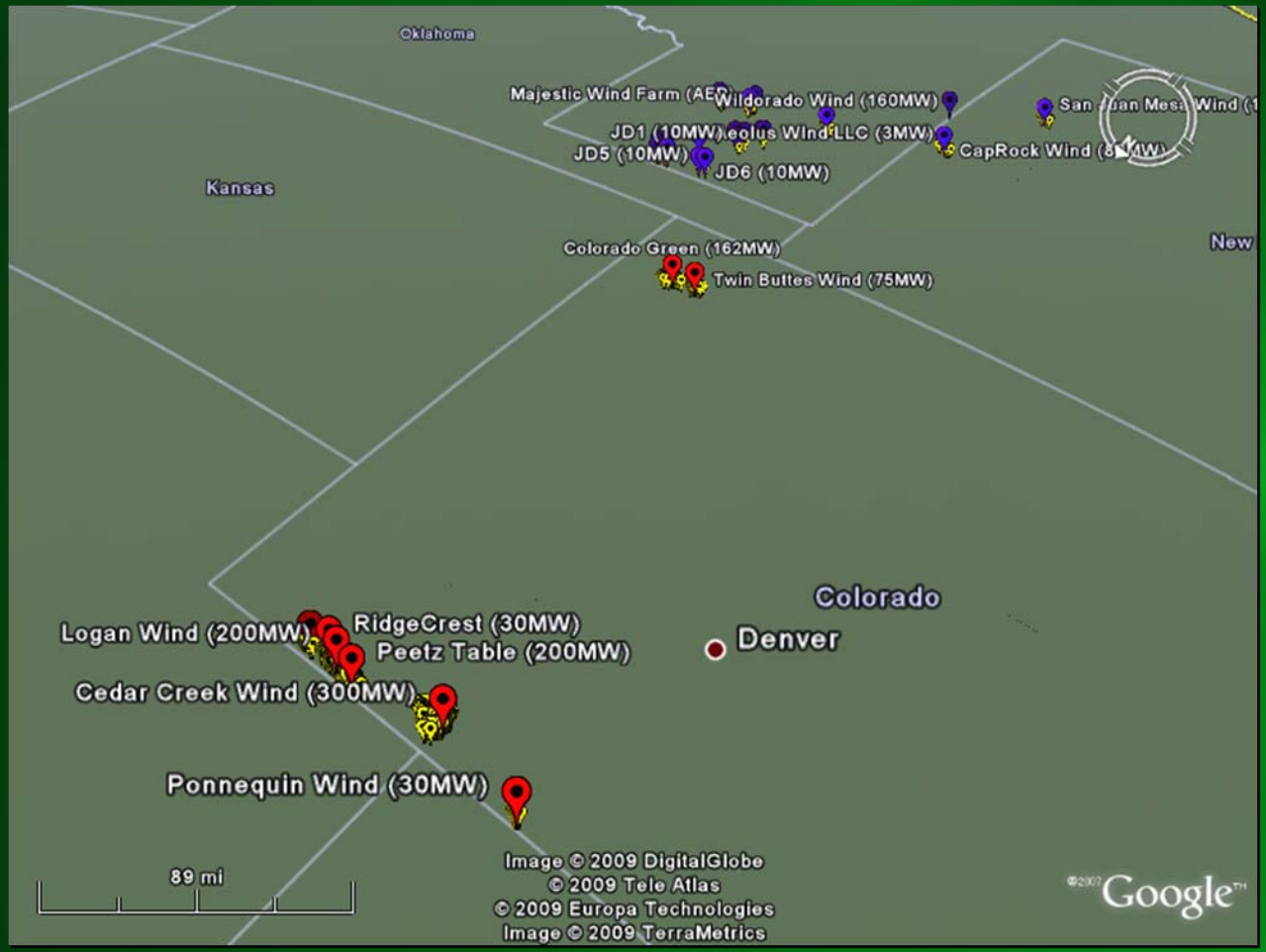
- Diversity costs energy & transmission, which costs money

- More cost-effective to build large, central wind farms in windy places

- Transmission is limited to bring resources from far afield



2008 – Ramp Stats*

	Total	Up	Down	Average Duration	Max Duration
Ramps over 250 MW in 60 mins	359	202	157	68 m	230 m
Ramps over 350 MW in 60 mins	87	58	29	67 m	190 m
Ramps over 500 MW in 60 mins	19	16	3	49 m	90 m

- Ramp ups are more frequent
- Large ramps are more severe

*Erik Ela (NREL)

2008 – Time of Day Stats*

Ramps over 250 MW in 60 mins	Ramps	Max 60 m up ramp	Max 60 m down ramp	Average False Ramps	Maximum False Ramps
Hour 0 - 5	70	731	-422	.49	3
Hour 6 - 11	62	537	-471	.58	4
Hour 12 - 17	103	574	-478	.82	7
Hour 18 - 23	120	750	-468	1.14	6

- "Anticipation" Costs (Staging)
  - Making headroom for flexible resources to stay on-line to accommodate an eventual ramp down.
  - Moving base load generation down ahead of time in anticipation of a ramp up.
  - Friend or Foe? Lacking solid identification.

*Erik Ela (NREL)

Future Focus…

SYSTEM OPERATIONS

- Maintain a flexible fleet that operates in ALL hours
  - Multi-mode CCs and quick-start facilities
- Capture cycling costs
- Lower the floor
  - Cost effectively lower plant minimums
  - Bulk electricity storage
- Share the burden
  - Flexible bi/multi-lateral contracts (e.g. regional market solutions, better reliability standards or other methods)
- AND/OR…
  - Manage Wind output through remote SCADA control

BETTER FORECASTING

- Emphasis on 1hr to 12hr forecasts
- Shorter forecast refresh times
- Assimilate real-time information
- More granular time and spatial resolution
- Friend or Foe? Tune in Ramp Identification
- Collect lots of data

What Can NOAA Do?

- Collect LOTS of data
- Faster data refresh & assimilation
- Refine understanding of atmospheric physics
- Improve numeric methods
- Focus on wind and solar energy drivers
- Correlate weather to obligations (HVAC)
- Increase resolution

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