NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Integrating Renewables and the Smart Grid

for
2010 Advanced Energy Conference

Robert A. (Bob) Hawsey
Associate Laboratory Director
Renewable Electricity & End Use Systems

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Energy efficiency is one of the lowest-cost resources to help reduce carbon emissions from electric supply

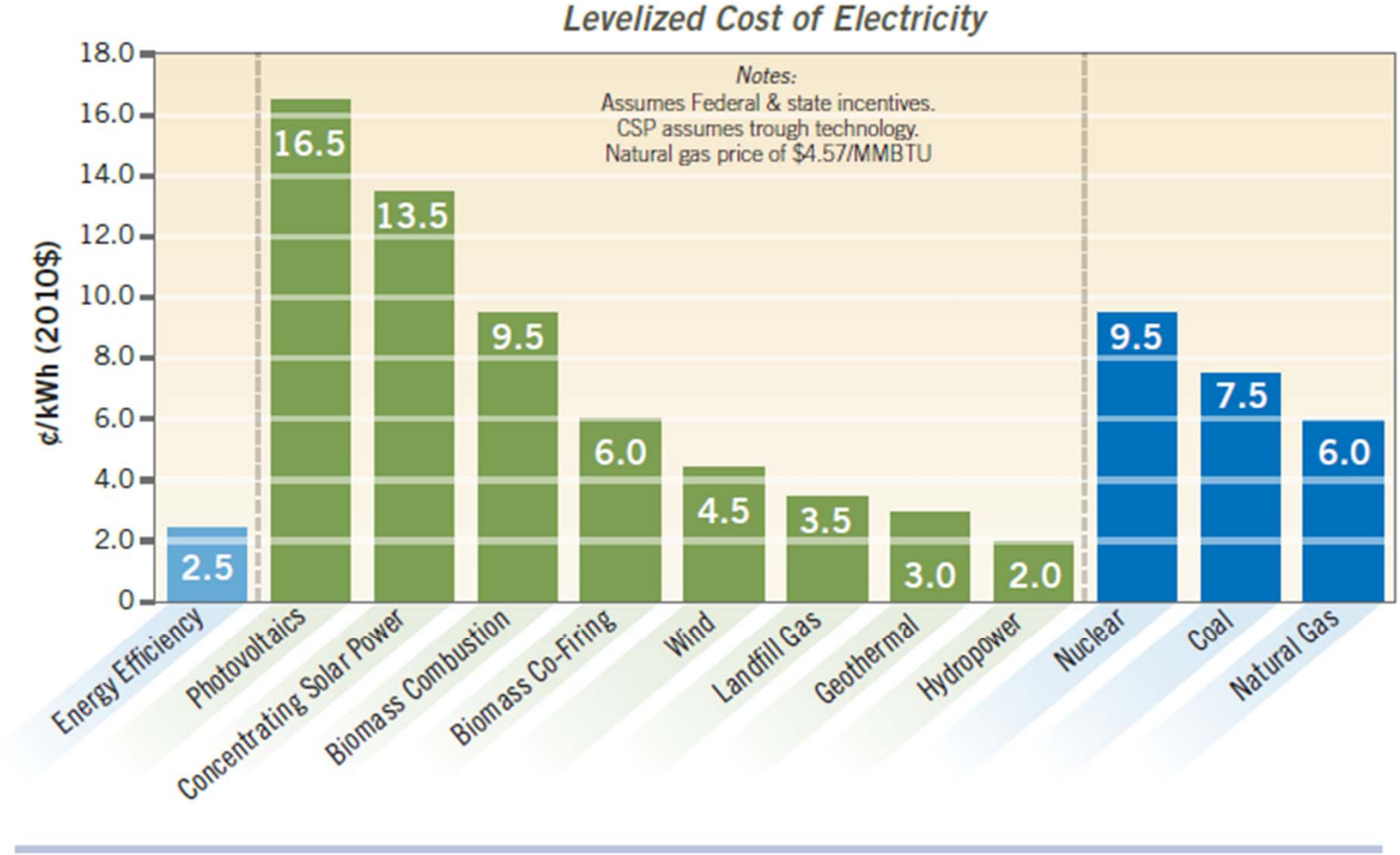
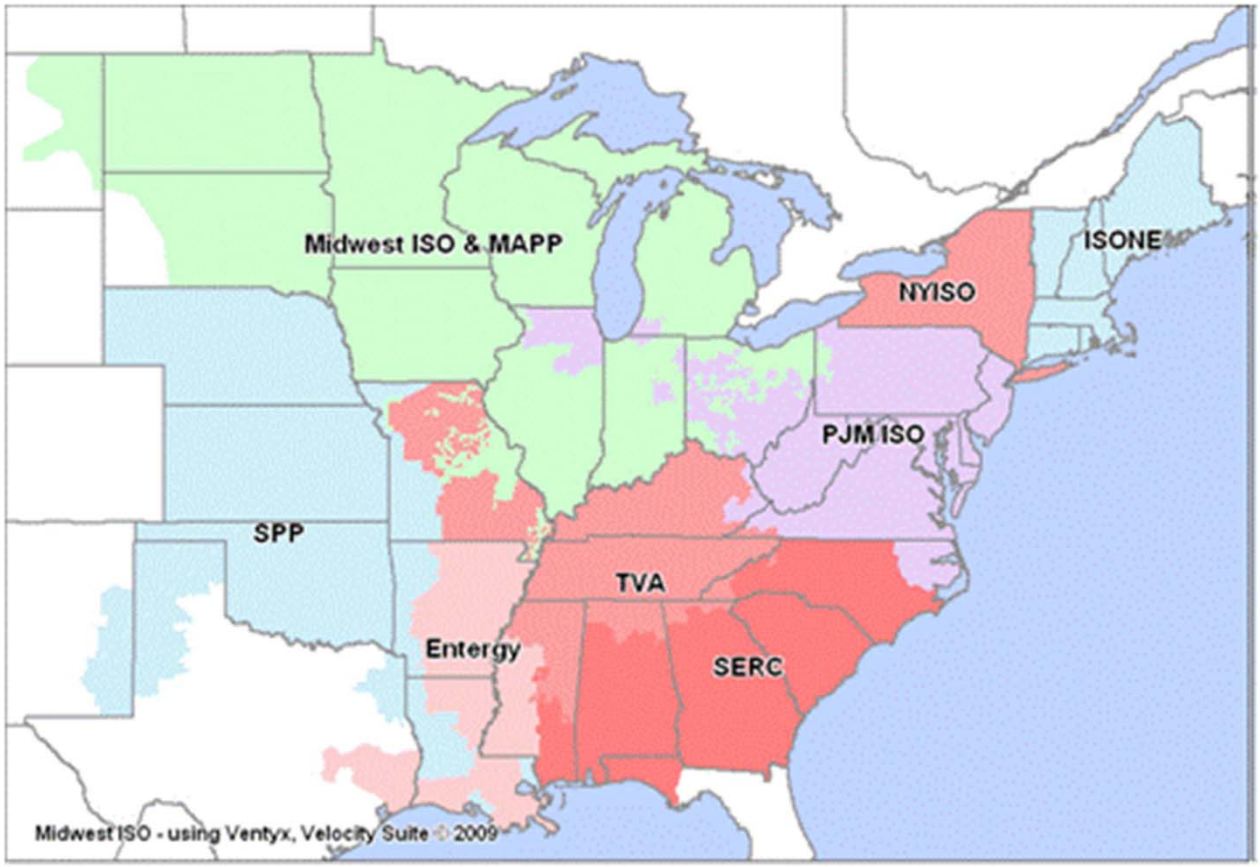


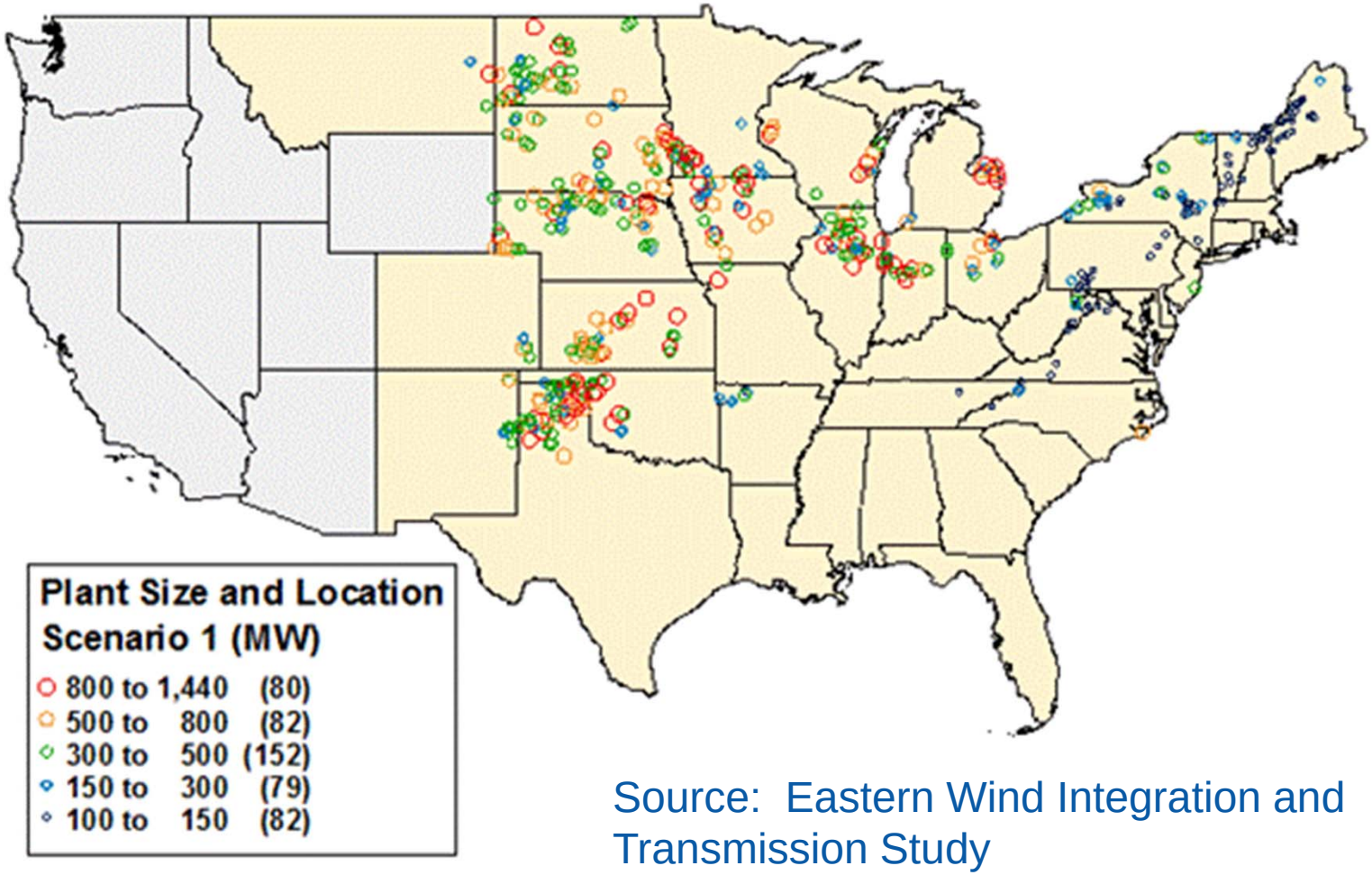
Figure ES-2: *Cost of EE as Compared to Other Resources*
Source: Navigant Consulting, Inc.

Credit: "The 21st Electric Utility: Positioning for a Low-Carbon Future," July 2010; commissioned by Ceres, 99 Chauncy Street, Boston, MA 02111; www.ceres.org

There are no fundamental barriers to integrating up to 30% wind in the eastern interconnection region of North America…



…but some regions may be required to supply more wind energy than others based upon resource availability & cost



Source: Eastern Wind Integration and Transmission Study

http://www.nrel.gov/wind/systemsintegration/ewits.html

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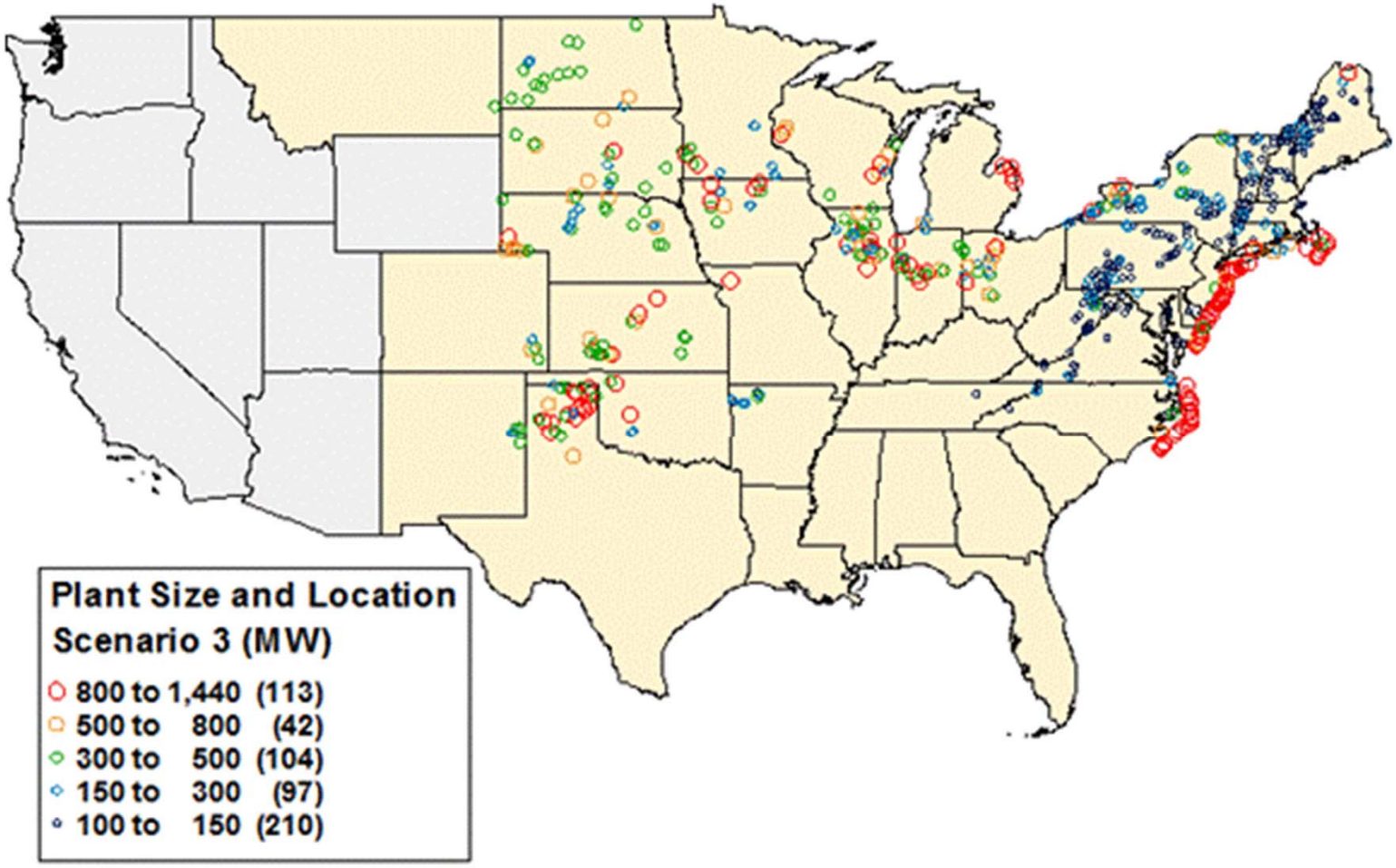
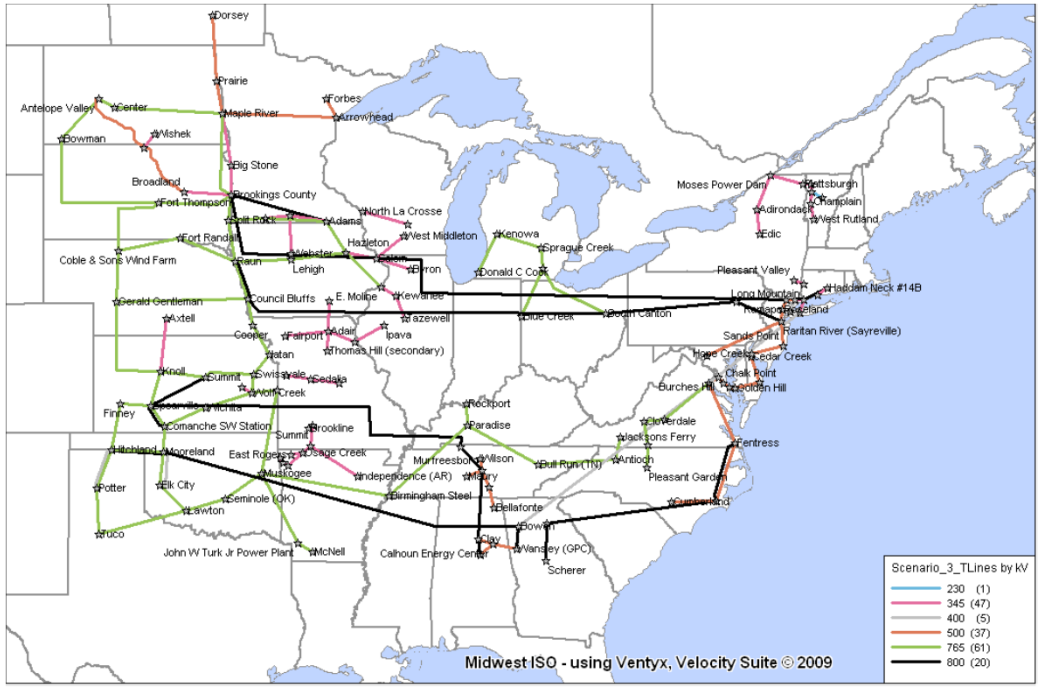


Aggressive offshore wind scenario

A continuing evolution of transmission planning and system operation policy and market development is needed

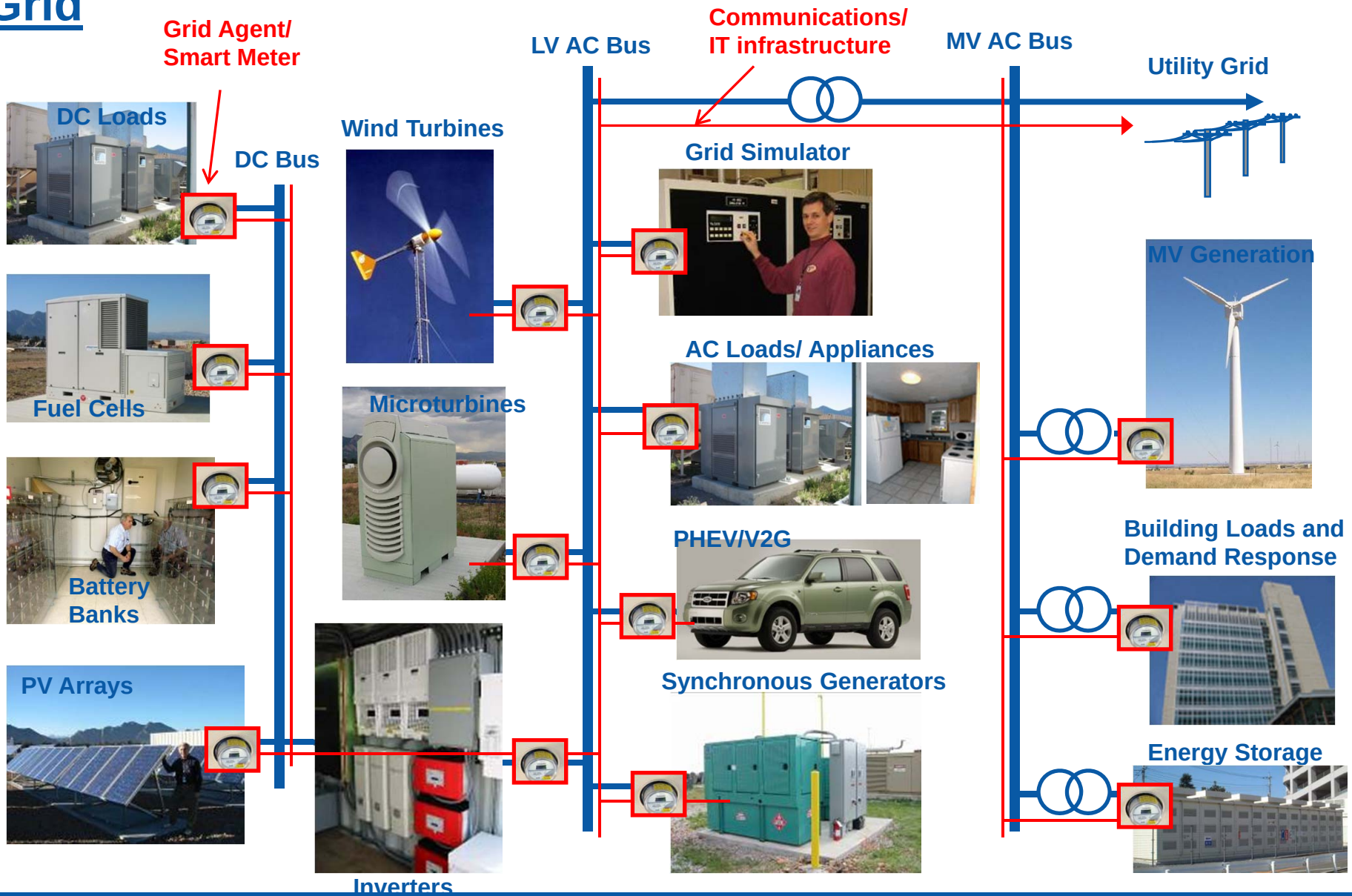
- Without transmission enhancements, substantial curtailment of wind generation will occur
- Costs for integrating large amounts of wind generation are manageable with large regional operating pools



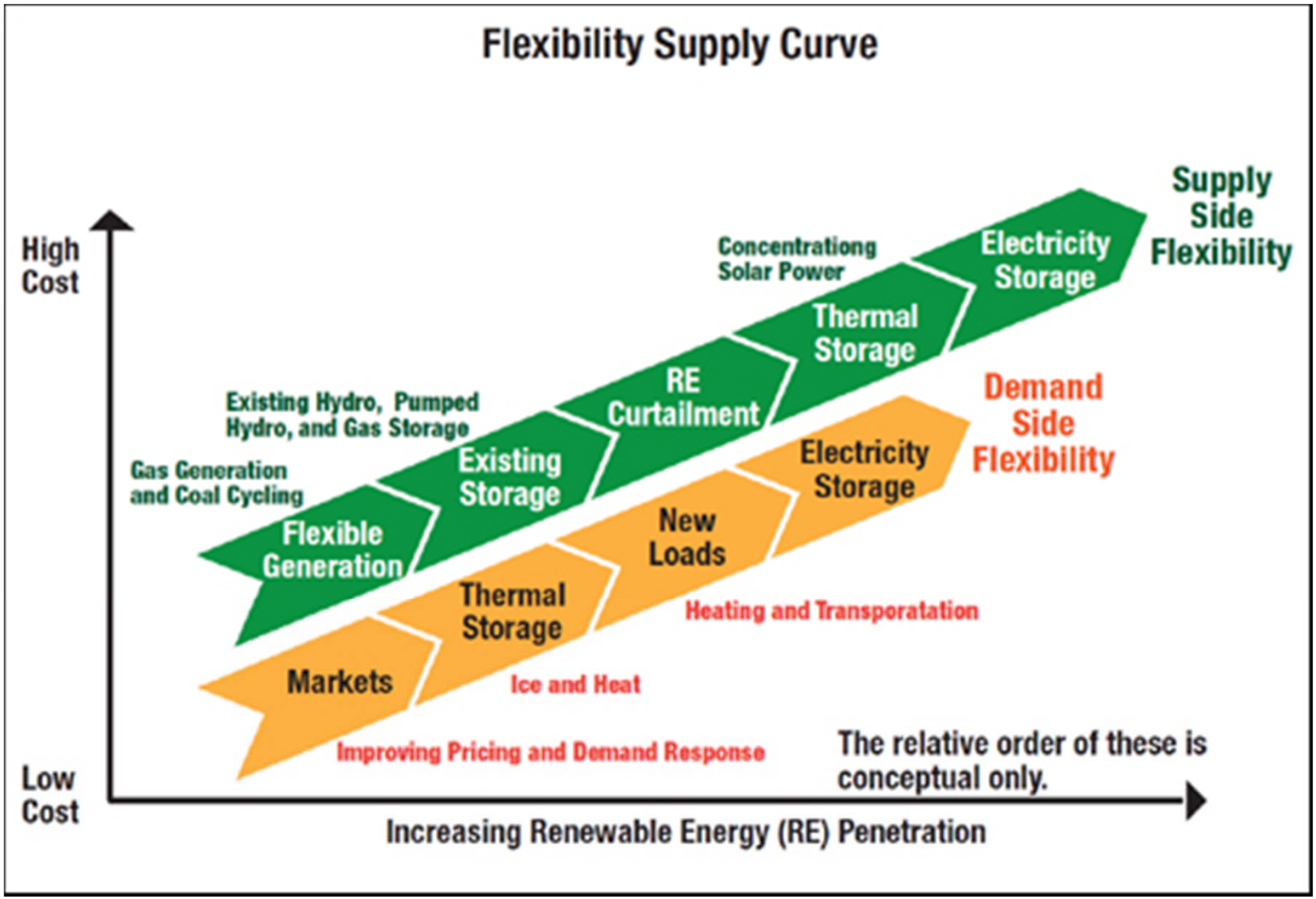
- Energy Policy Act (2005) Cites and Requires Consideration of IEEE 1547 Standards and Best Practices for Interconnection.
- Energy Independence and Security Act (2007) Established NIST as Lead to Coordinate Framework and Roadmap for Smart Grid Interoperability Stds & Protocols.

Federal 2009 ARRA: standards use cited for Smart Grid, and, High Penetration Distributed Energy Resources Projects.

Smart Grid Standards Enable High Penetration RE Technology Interconnection and Interoperability with the Grid

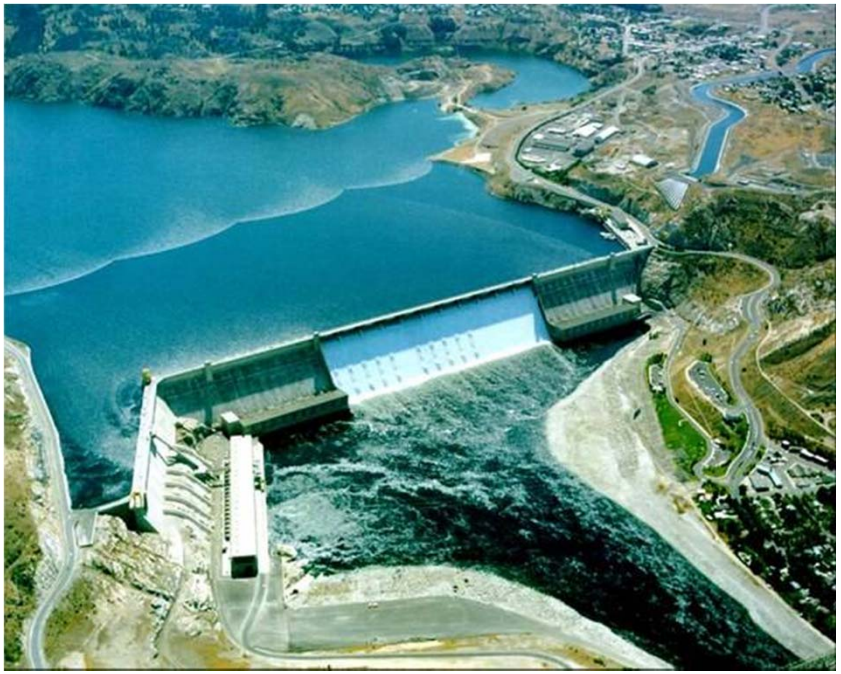


Variable renewable generation is one source of electric system flexibility



Does wind need backup or storage?

- Increased operating reserves may be necessary, but not dedicated backup
- Although new storage has value, it may not be cost effective
- There is typically already storage on the system
  - Natural gas in the pipeline or storage facility
  - Controllable hydro
- A recent study by Xcel Energy in Colorado found
  - existing pumped storage provided $1.30/MWh offset to wind integration cost
  - Enlarging existing gas storage facility was economic at large wind penetration

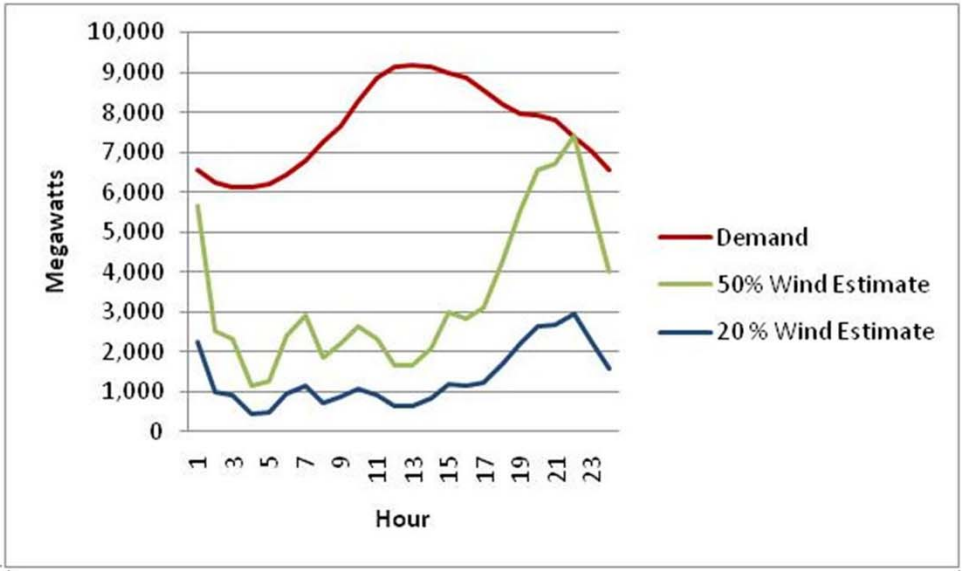


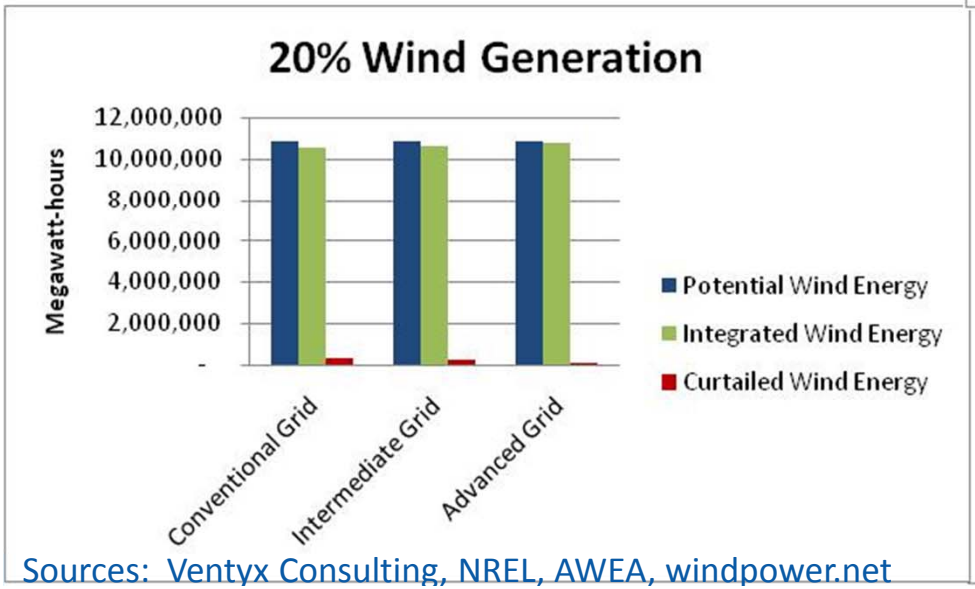
Credit- EnerNex: Xcel Colorado Wind Integration Study

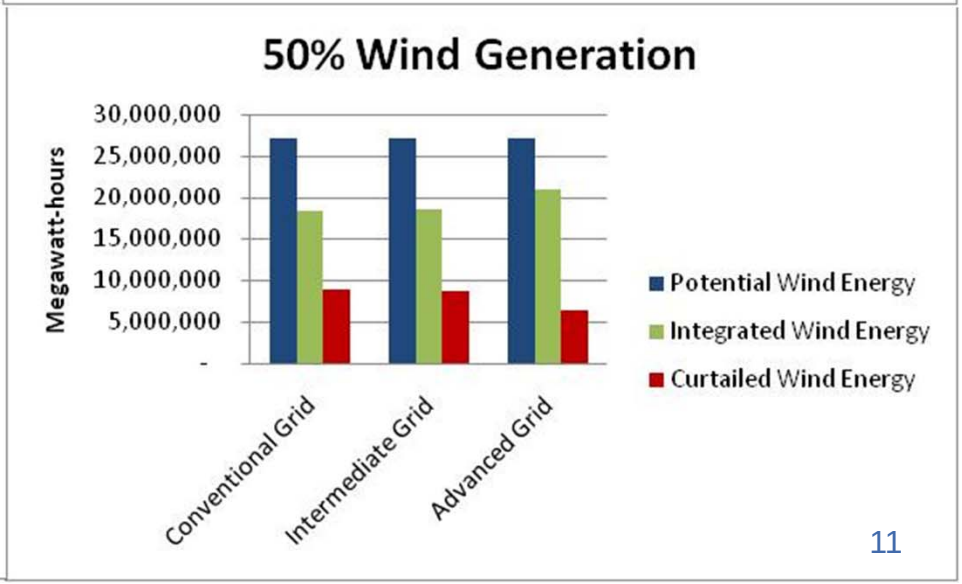
Wind Penetration	10%	15%
$/ MWH Gas Impact No Storage Benefits	$2.17	$2.52
$ / MWH Gas Impact With Storage Benefits	$1.26	$1.45

A Smart Grid supports wind integration by aligning demand with renewable generation

- At 20% wind generation, the benefit is relatively small.
- At 50% wind generation, the benefit is significant.



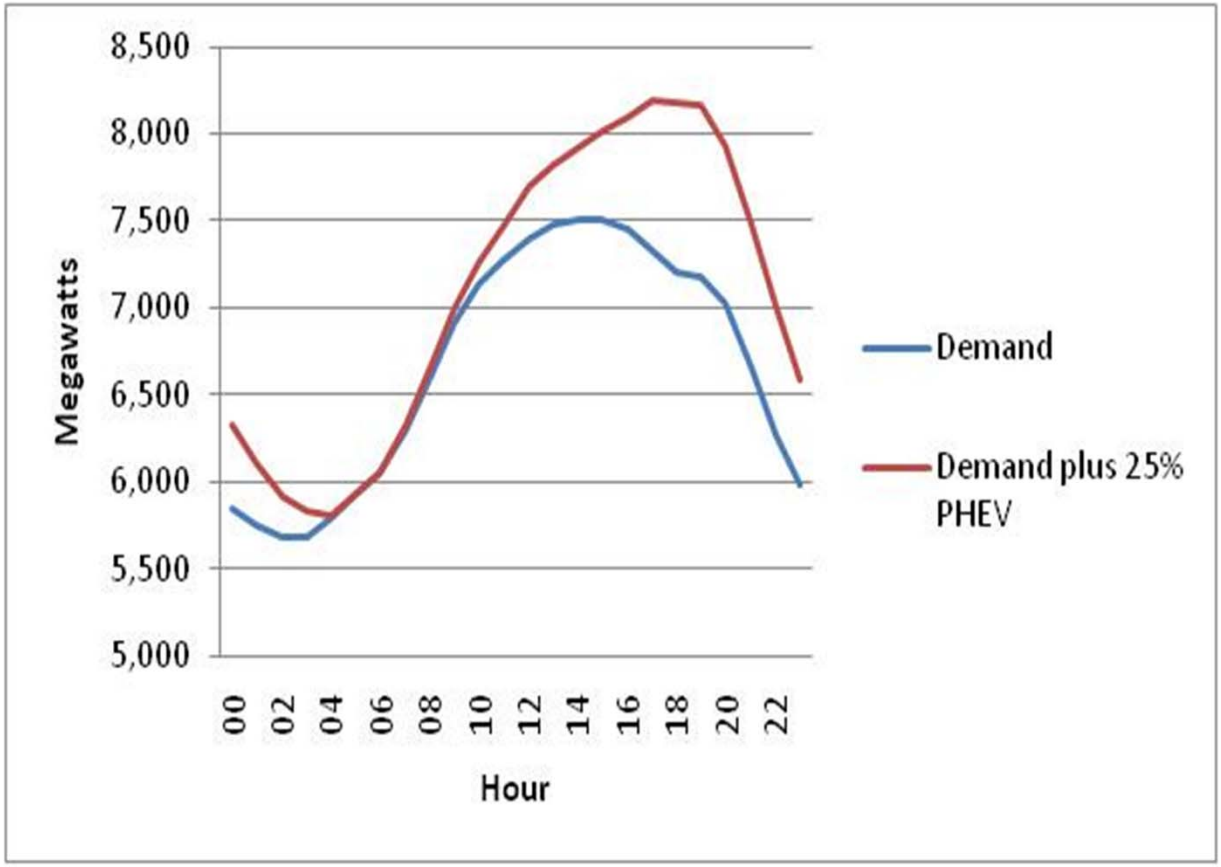




Sources: Ventyx Consulting, NREL, AWEA, windpower.net

A Smart Grid may enable "smart charging" at off-peak periods

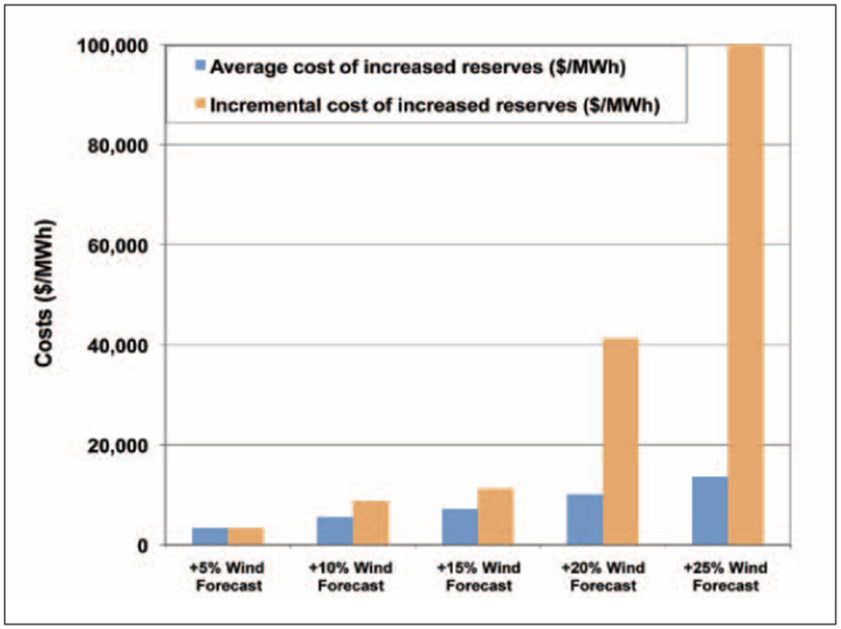
- Unmanaged charging of PHEV coincident with peak demand.
- Problematic for distribution system.
- PHEVs without smart charging a "deal breaker."



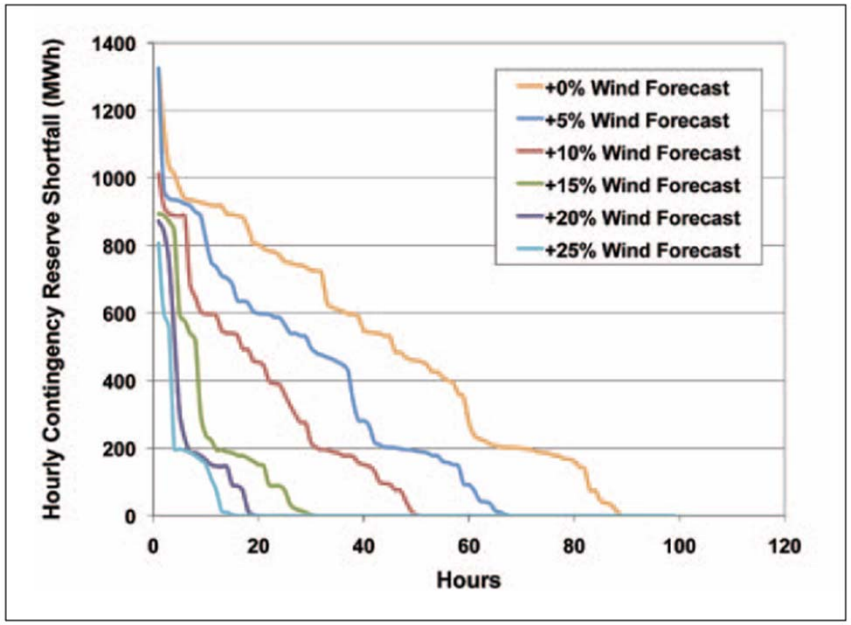
Sources: Ventyx Consulting, General Motors

A Smart Grid can help enable demand response

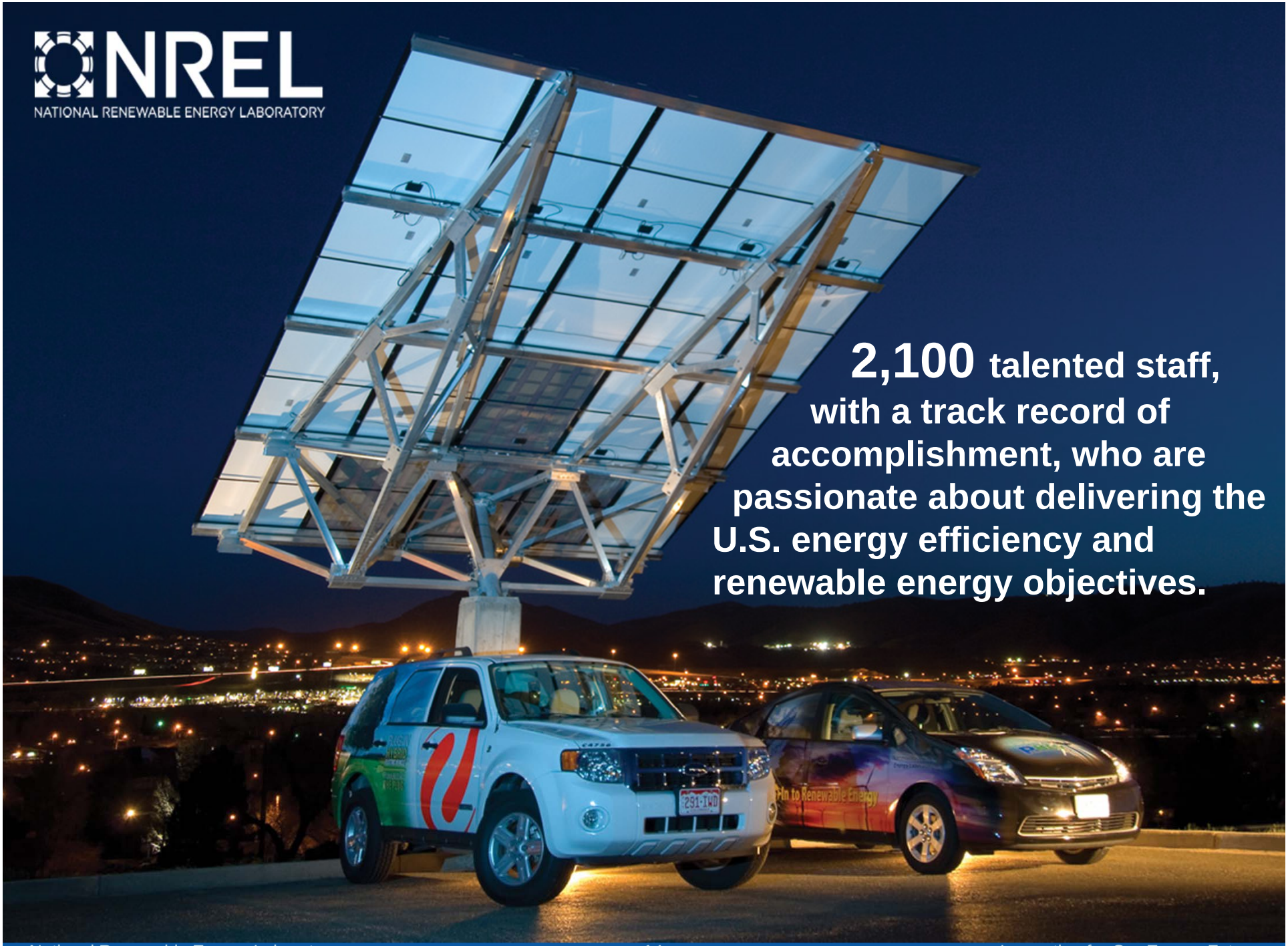
Cost of increasing spinning reserves



A demand response program would have 1300 MW of participants and require participation 35 hrs/yr



It's cheaper to pay interruptible load to turn off (demand response) for the 89 hours (1%) that are an issue for the utility than to increase spinning reserves for 8760 hours/year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