U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Electricity Transmission System Workshop: EERE Issues and Opportunities

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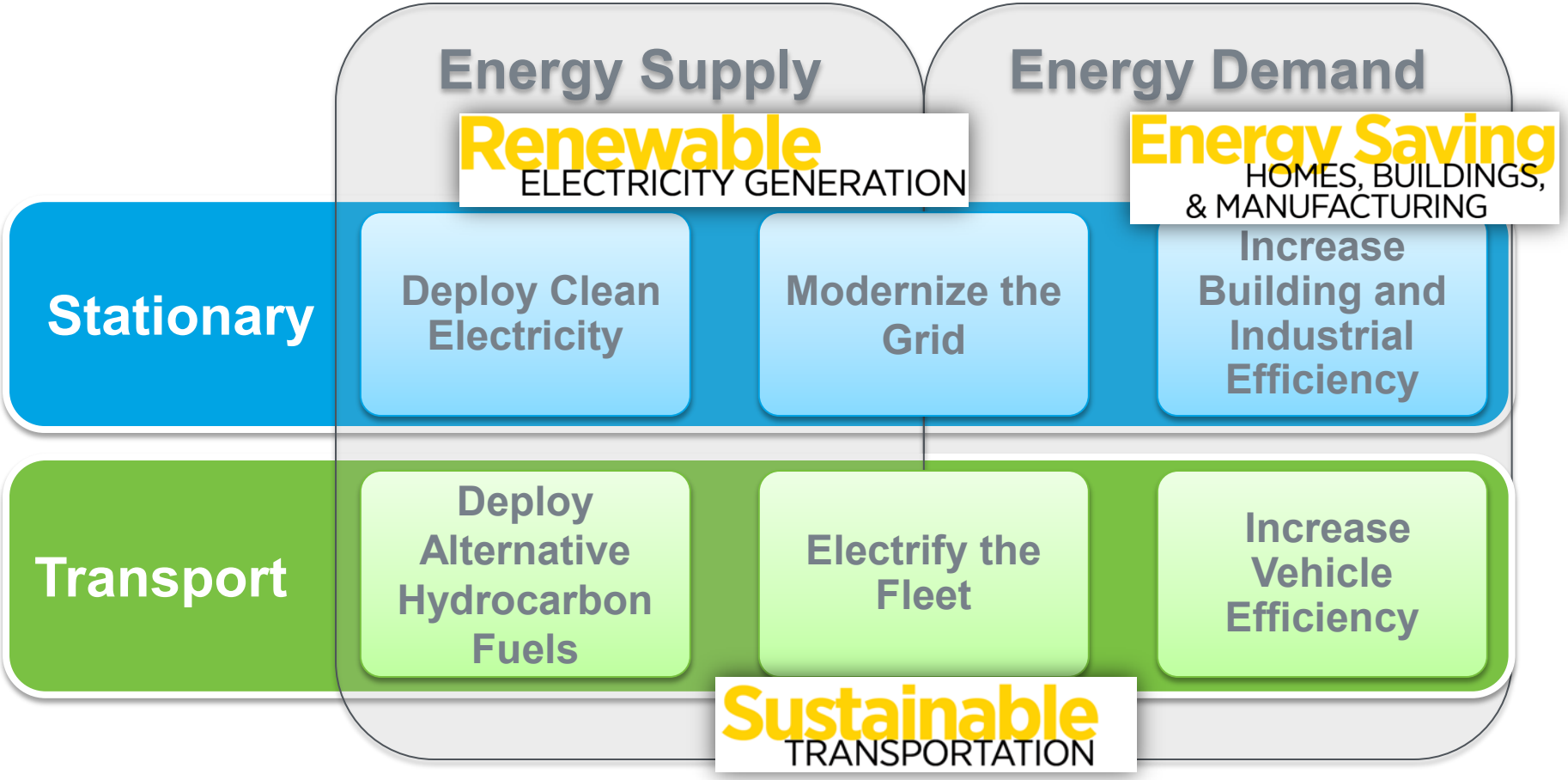
"If you can't solve a problem, expand it."

- Dwight D. Eisenhower

Energy Saving
HOMES, BUILDINGS, & MANUFACTURING

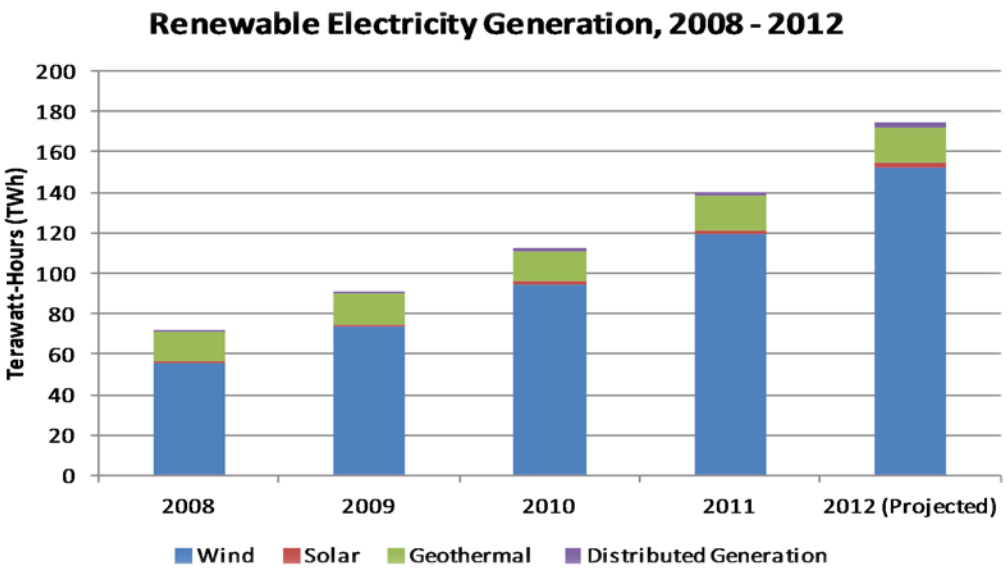
Renewable
ELECTRICITY GENERATION

Sustainable
TRANSPORTATION



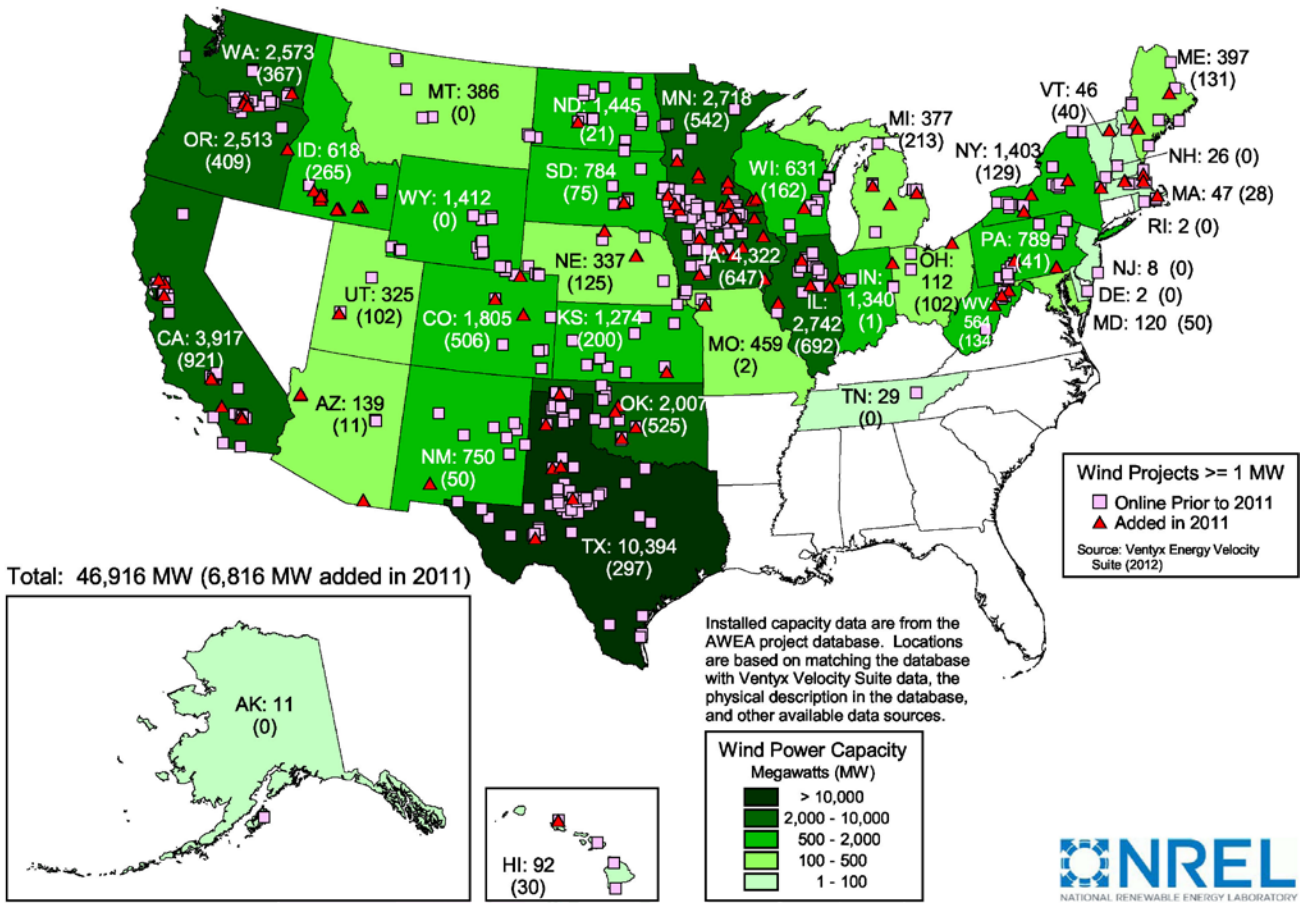
Source: DOE ,*Quadrennial Technology Review*, September 2011

Rapid Growth in Renewable Electricity



Since 2008, the U.S. has doubled renewable energy generation from wind, solar, and geothermal

Rapid Growth in Wind



- 50GW+ installed
- 87% cost decrease since 1980
- 3% US electricity
- 75,000 jobs
- 8 of 10 top wind manufacturers w/ U.S. mfg (only 1 in 2004)

Note: Numbers within states represent cumulative installed wind capacity and, in parentheses, annual additions in 2011.

Rapid Growth in Solar

- 60%+ annual growth rates
- 1.8GW installed in 2011
- 7GW total capacity in 2012
- 80% price reduction last 4 years

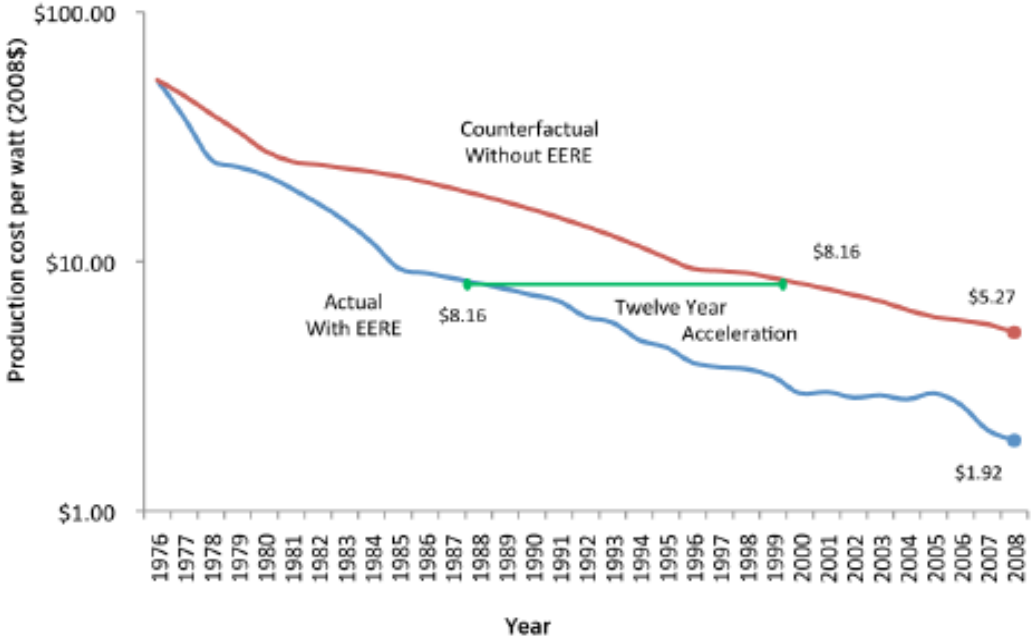


Figure 1: Actual and Counterfactual PV Module Production Cost

3x+	12+	30%+	57%	$60M	$1.6B
cost drop	years	patents	world records	incubator funds	private follow-on

Sources: DOE/EERE, "Linkages from DOE's Solar Photovoltaic R&D to Commercial Renewable Power Generation from Solar Energy," Rosalie Ruegg and Patrick Thomas, April 2011; DOE/EERE "Retrospective Benefit-Cost Evaluation of DOE Investments in Photovoltaic Energy Systems," O'Connor, A., R. Loomis, and F. Braun, 2010

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Renewable Electricity Futures Study

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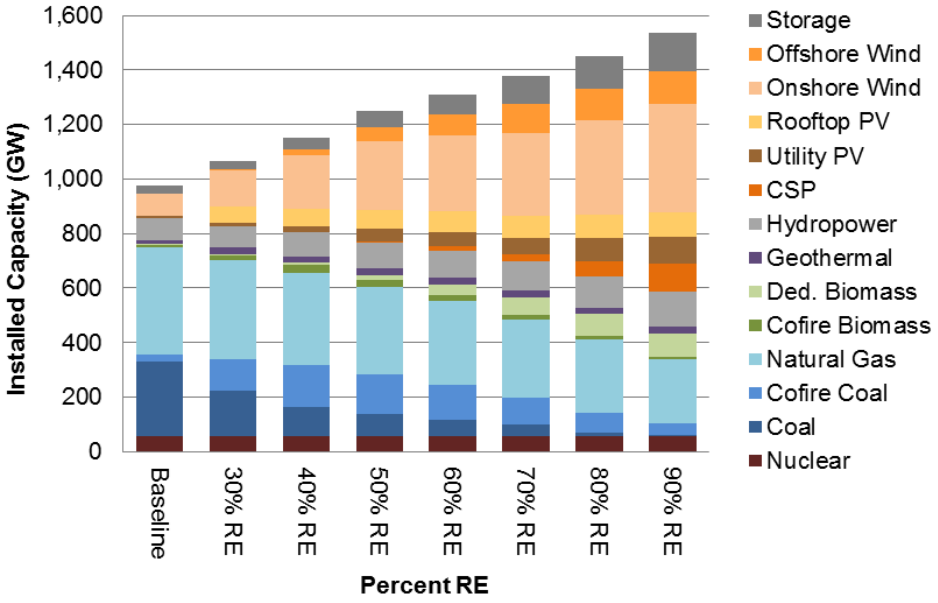
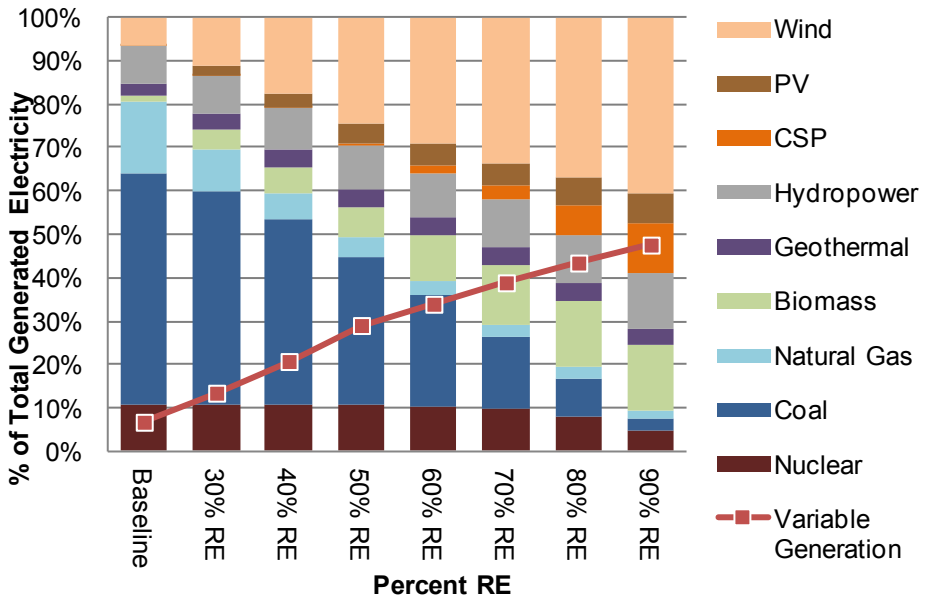
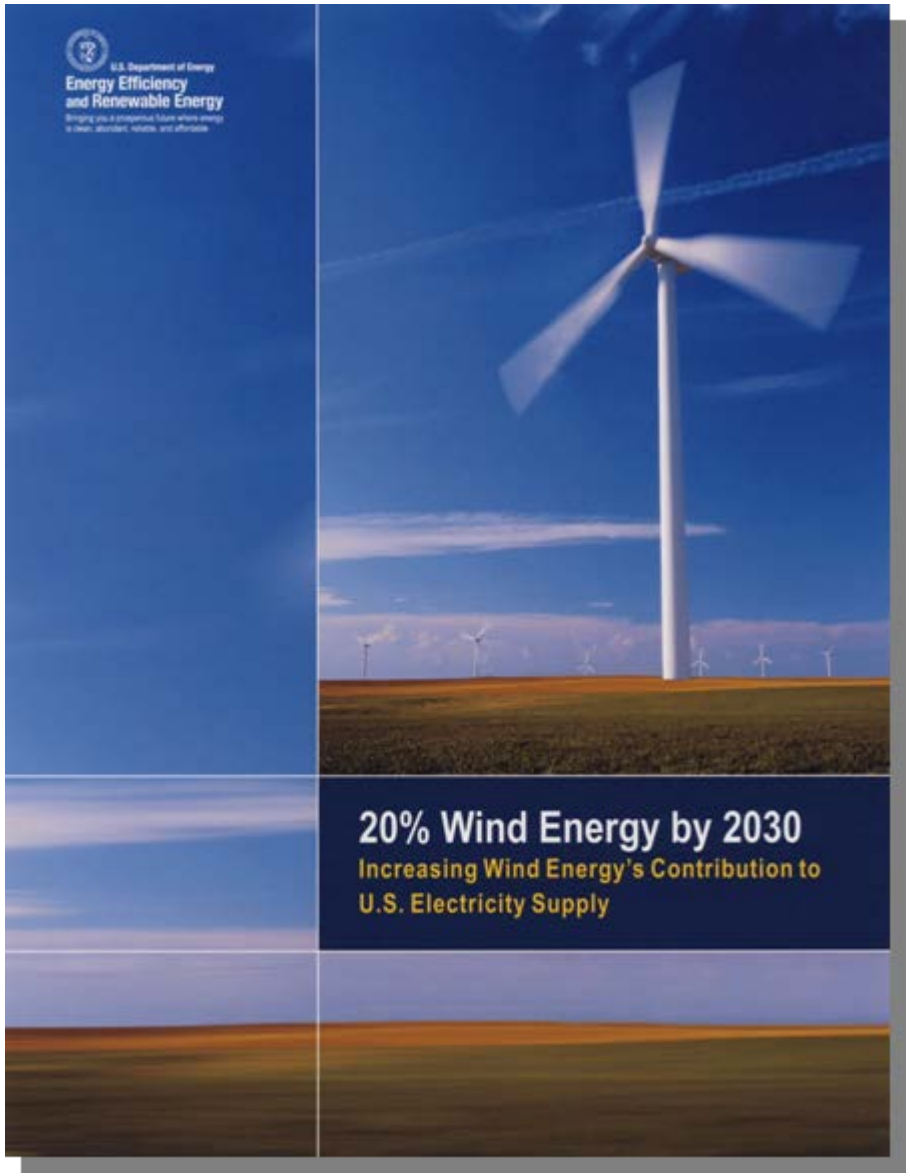
Renewable generation resources could adequately supply 80% of total U.S. electricity generation in 2050 while balancing supply and demand





20% Wind by 2030

- Released in 2008
- Explores one scenario for reaching 20% wind energy by 2030 and contrasts it to a scenario in which no new U.S. wind power capacity is installed
- Does not assume specific policy support for wind
- Involved more than 100 individuals, 2006-08 (government, industry, utilities, NGOs)
- Primary Findings:
  - 20% wind electricity would require about 300 GW (300,000 MW) of wind generation
  - Affordable, accessible wind resources available across the nation
  - Cost to integrate wind modest
  - Emissions reductions and water savings
  - Transmission a challenge



Wind: Barriers to Market Entry

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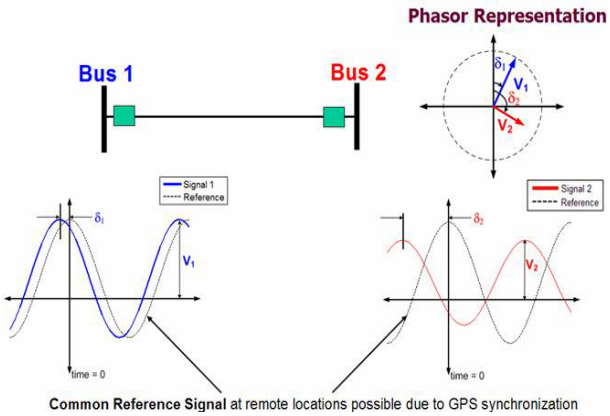
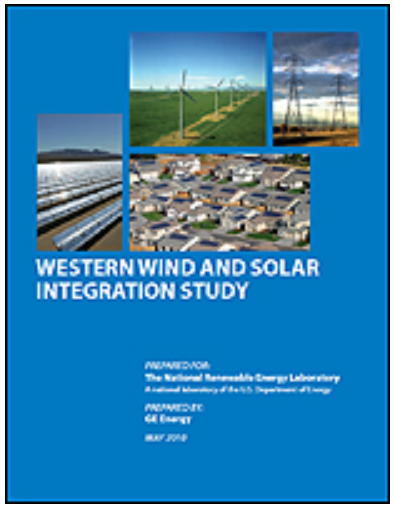
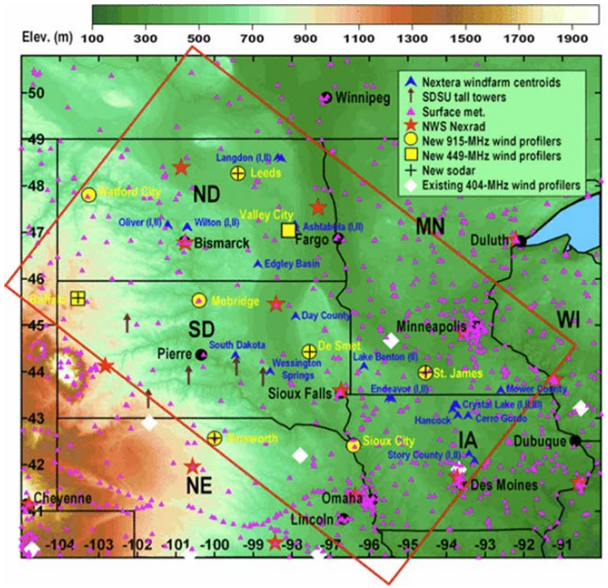


Concurrent Cooling Models

Active Power Controls





Wind Forecasting

Wind Integration Cost Analysis

Wind & Solar Integration Studies

Wind Grid Integration priorities focused on enabling cost effective wind deployment with high reliability

SunShot: Direct Cost Competitive Solar by 2020

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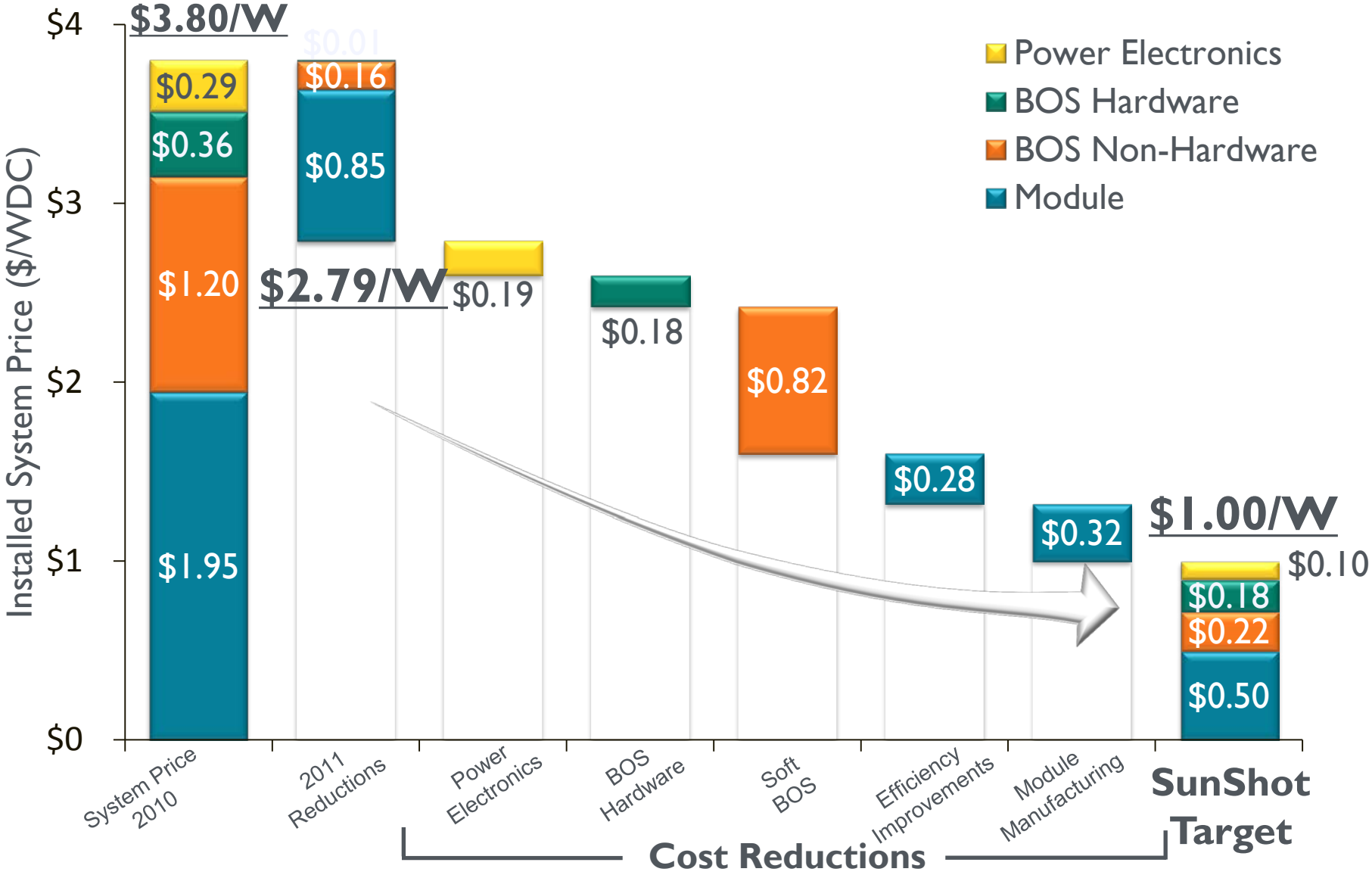
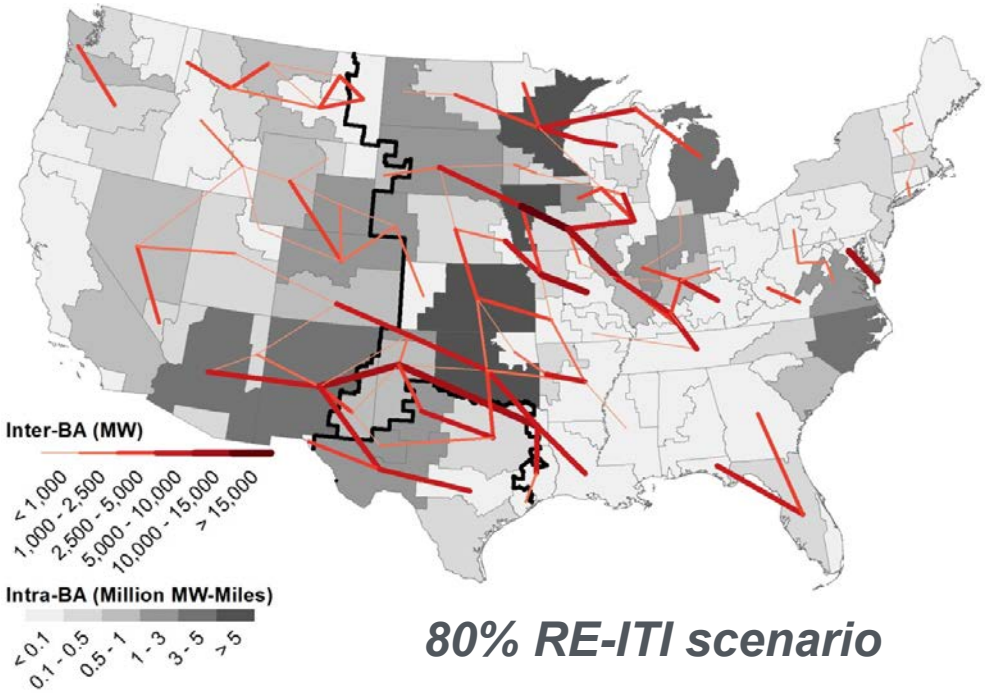


Solar: Key Barriers to Continued Rapid Growth

Goals

- **BOS Costs:** Reducing the costs of power electronics and balance of system hardware
- **Bankability:** Reducing the risk associated with the use of new technologies
- **Grid Integration:** Establishing a timely process for integrating high penetrations of solar technologies into the grid in a safe, reliable, and cost-effective manner while providing value to the system owner and the utility grid

As RE Deployment Increases, Additional Transmission Infrastructure is Needed



80% RE-ITI scenario

- In most 80%-by-2050 RE scenarios, 110-190 million MW-miles of new transmission added
- AC-DC-AC interties are expanded to allow greater power transfer between interconnects
- However, 80% RE is achievable even when transmission is severely constrained (30 million MW-miles)—greater reliance on local resources (e.g. PV, offshore wind)
- Annual transmission and interconnection investments in the 80%-by-2050 RE scenarios range from B$5.7-8.4/year, which is within the range of recent total investor-owned utility transmission expenditures
- High RE scenarios lead to greater transmission congestion, line usage, and transmission & distribution losses

New Thrusts: Vehicles & Buildings Grid Integration

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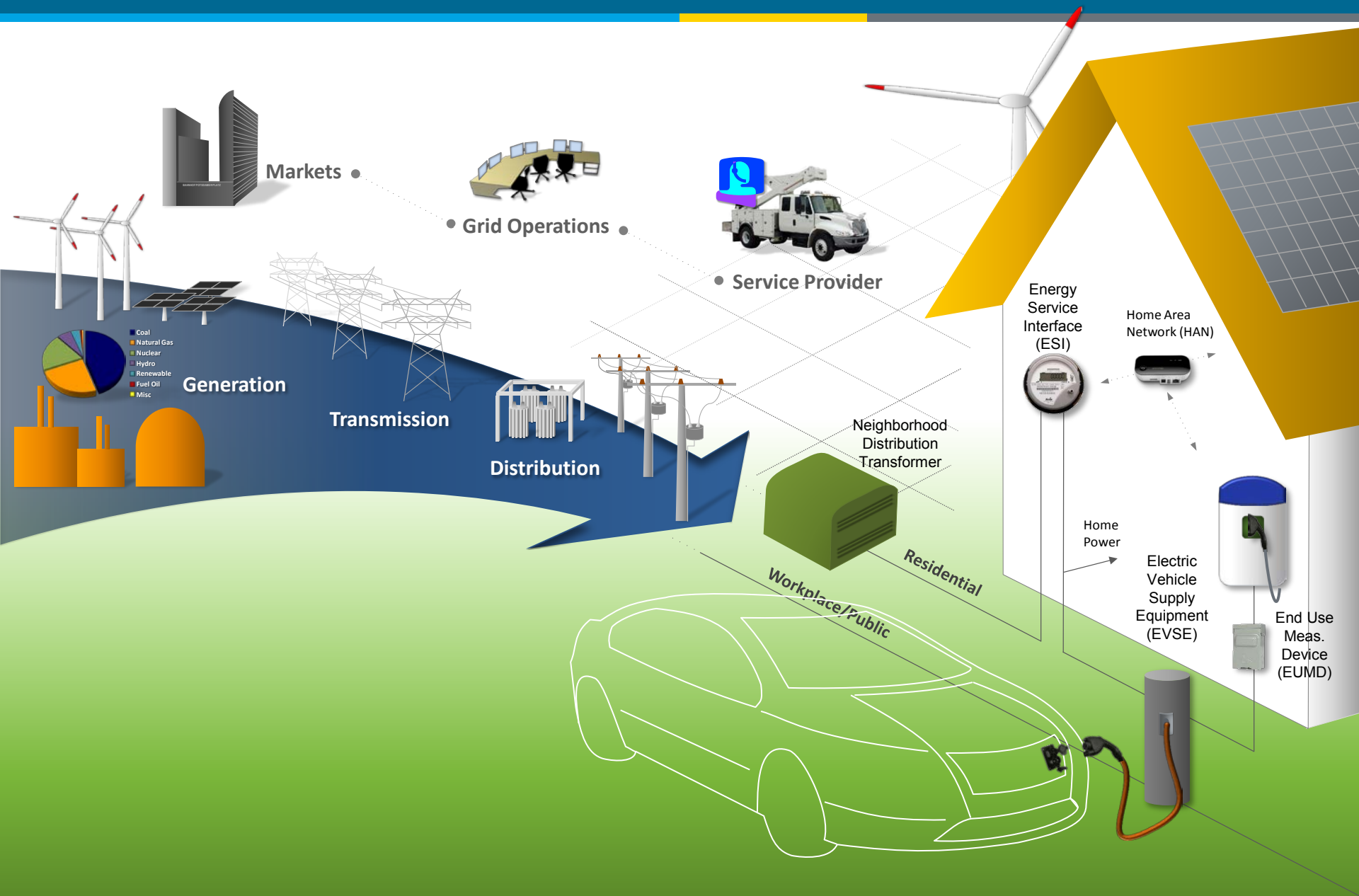
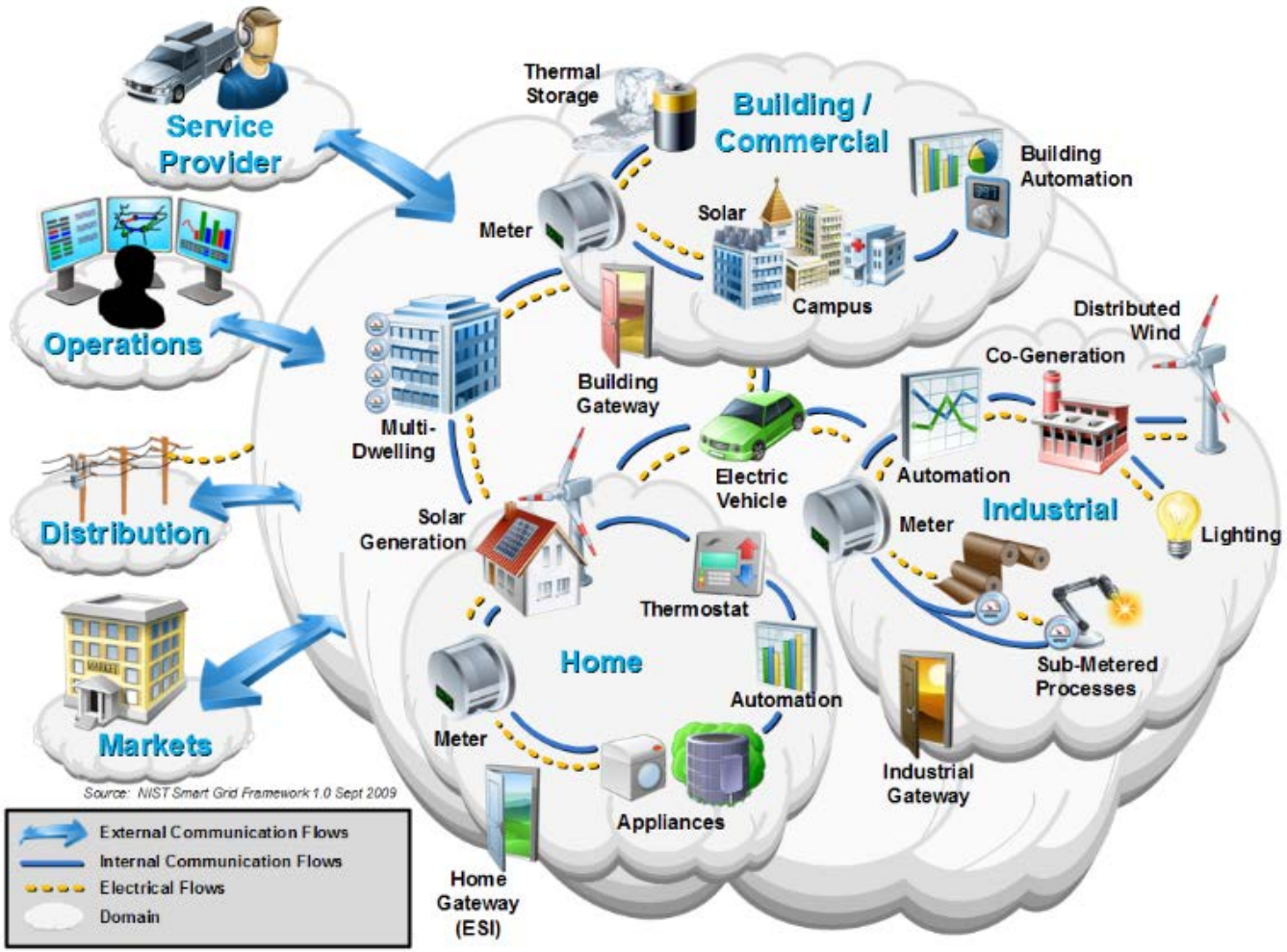


The Vision: Grid Integration



Thank you.

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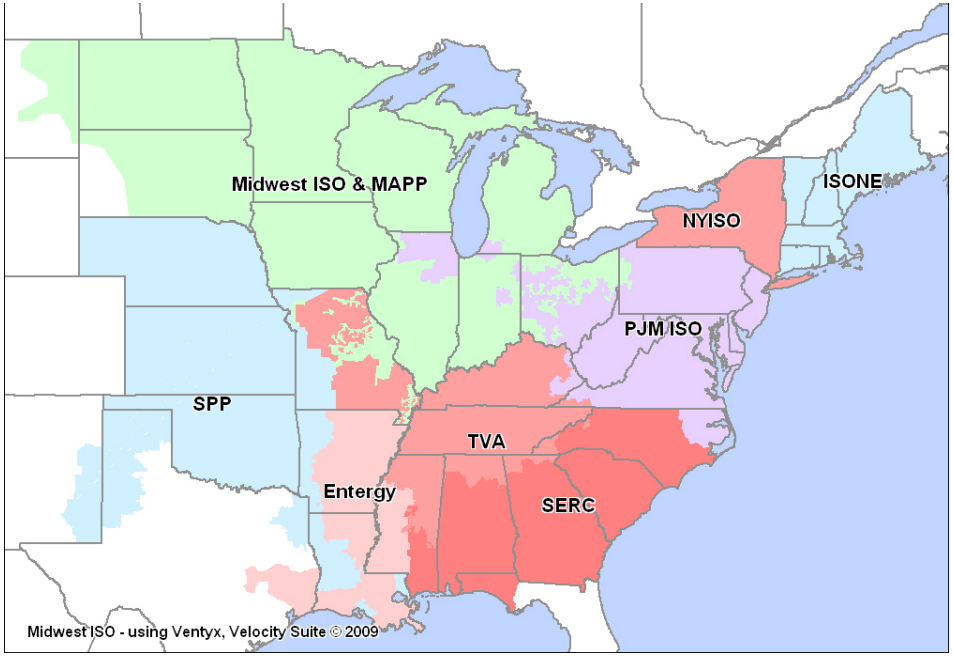
Eastern Wind Integration and Transmission Study

- Evaluate the power system operating impacts and transmission associated with increasing wind energy to 20% and 30%. Impacts include operating due to variability and uncertainty of wind; reliability
- Build upon prior wind integration studies and related technical work;
- Develop high quality wind resource data sets for the wind integration study area
  - 3 years of time series data (2004-2006)
  - 10-minute data at 2 km spatial resolution
- Coordinate with current regional power system study work
- EWITS found substantial requirements for transmission



Western Wind and Solar Integration Study

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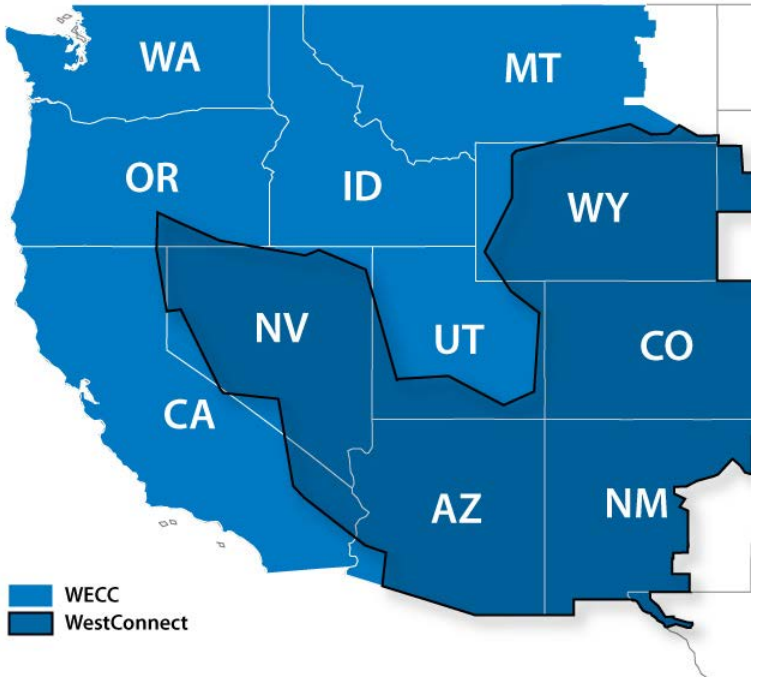
Can we integrate 35% wind and solar in the West?

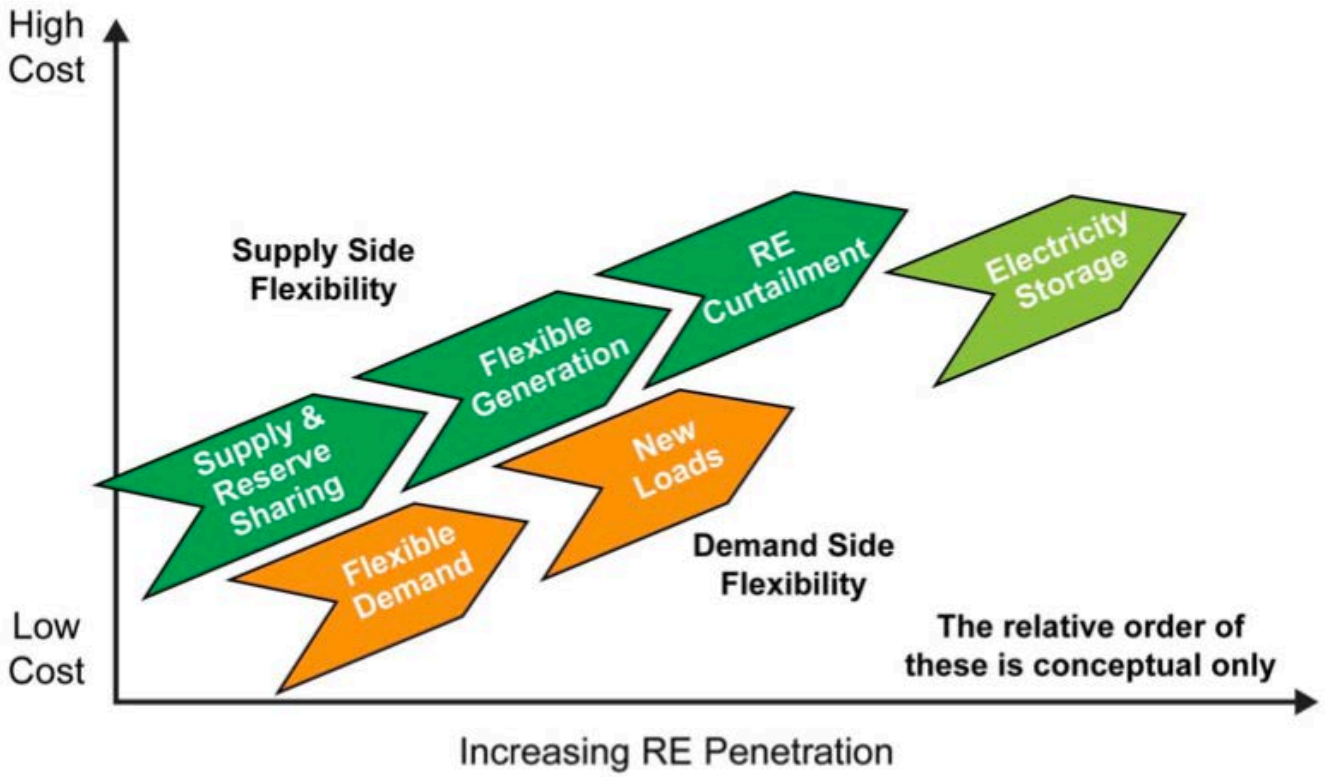
Goal - To assess the operating impacts and economics of wind and solar on the WestConnect grid.

- How do local resources compare to remote, higher quality resources via long distance transmission?
- Can balancing area cooperation help manage variability?
- Do we need more reserves?
- Do we need more storage?
- How does geographic diversity help?
- What is the value of forecasting?



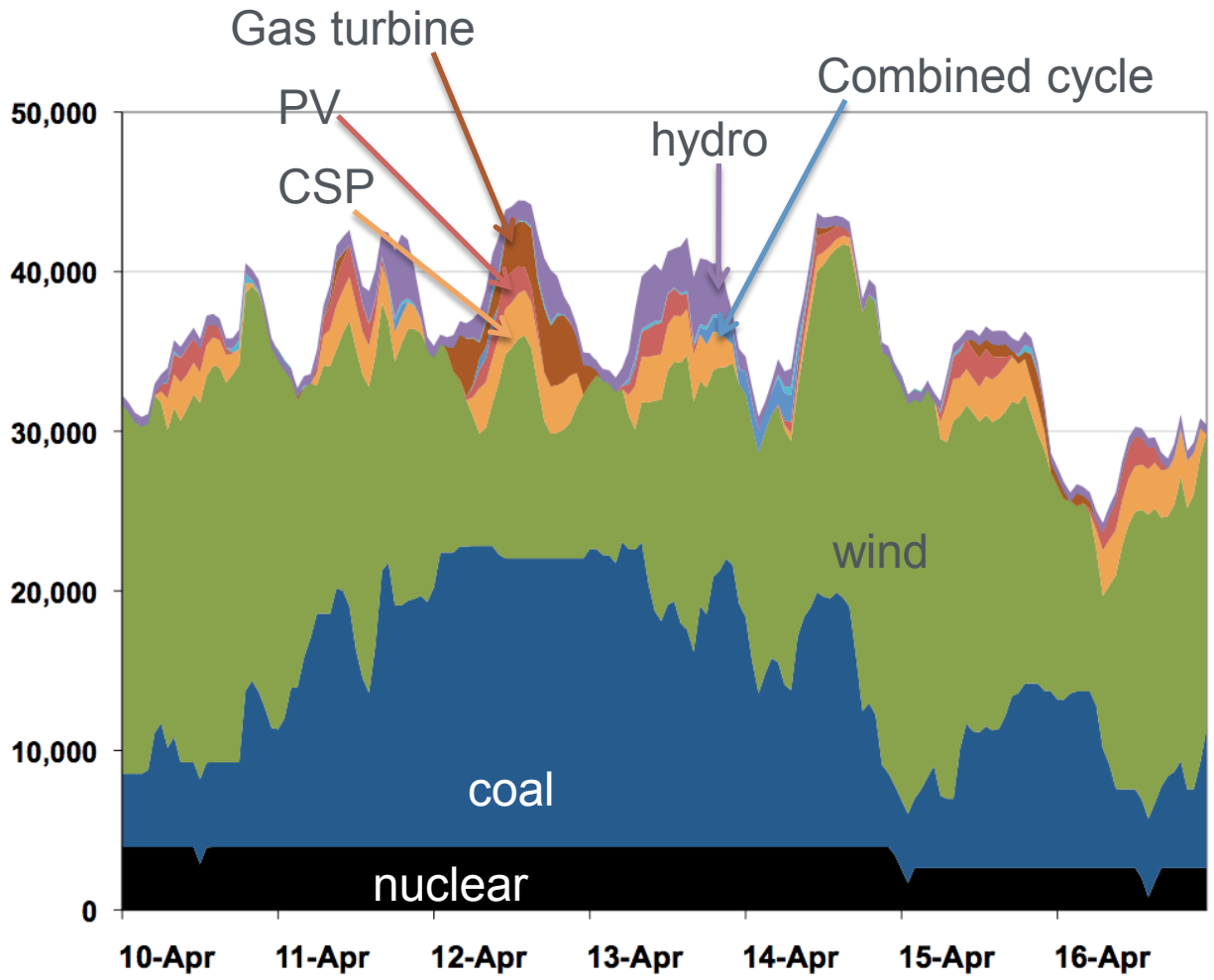
WestConnect Feasibility

It Is Operationally Feasible for WestConnect to Accommodate 30% Wind and 5% Solar Under Certain Conditions



Phase 2 of the West Connect Study

- Wear and tear costs of cycling and ramping
- Emissions impacts from cycling and ramping
- Optimize unit commitment and 5 minute economic dispatch
- Compare wind and solar



The worst week of three years

Hawaii Renewable Integration and Transmission Study

- Supports the HCEI Energy Agreement in which Hawaiian utilities and cooperatives will integrate large amounts of renewable energy onto their electric grids
- First study to evaluate power system impacts from variable renewable energy sources on the electrical generators, grid, and transmission expansion analysis (e.g., cable)
- System planning work to date focuses on:
  - OWITS- Up to 400 MW wind from Lanai and/or Molokai via undersea cable; 100 MW of wind in Oahu; 100 MW of PV in Oahu
  - Expansion of solar work on Kauai, Lanai, and new PV study looks at Oahu/Maui
- Our Resource Planning work assesses the resources across the state

The Renewable Electricity Futures Study

- The Renewable Energy Futures Study is an analysis of the U.S. electric sector focused on 2050 that explores:
  - Whether the U.S. power system **can supply electricity to meet customer demand** with high levels of renewable electricity, including variable wind and solar generation
  - Grid integration using models with **unprecedented geographic and time resolution** for the contiguous U.S.
  - **Synergies, constraints, and operational issues** associated with a transformation of the U.S. electric sector

All Regions of the Country Could Contribute Substantial Renewable Electricity Supply in 2050

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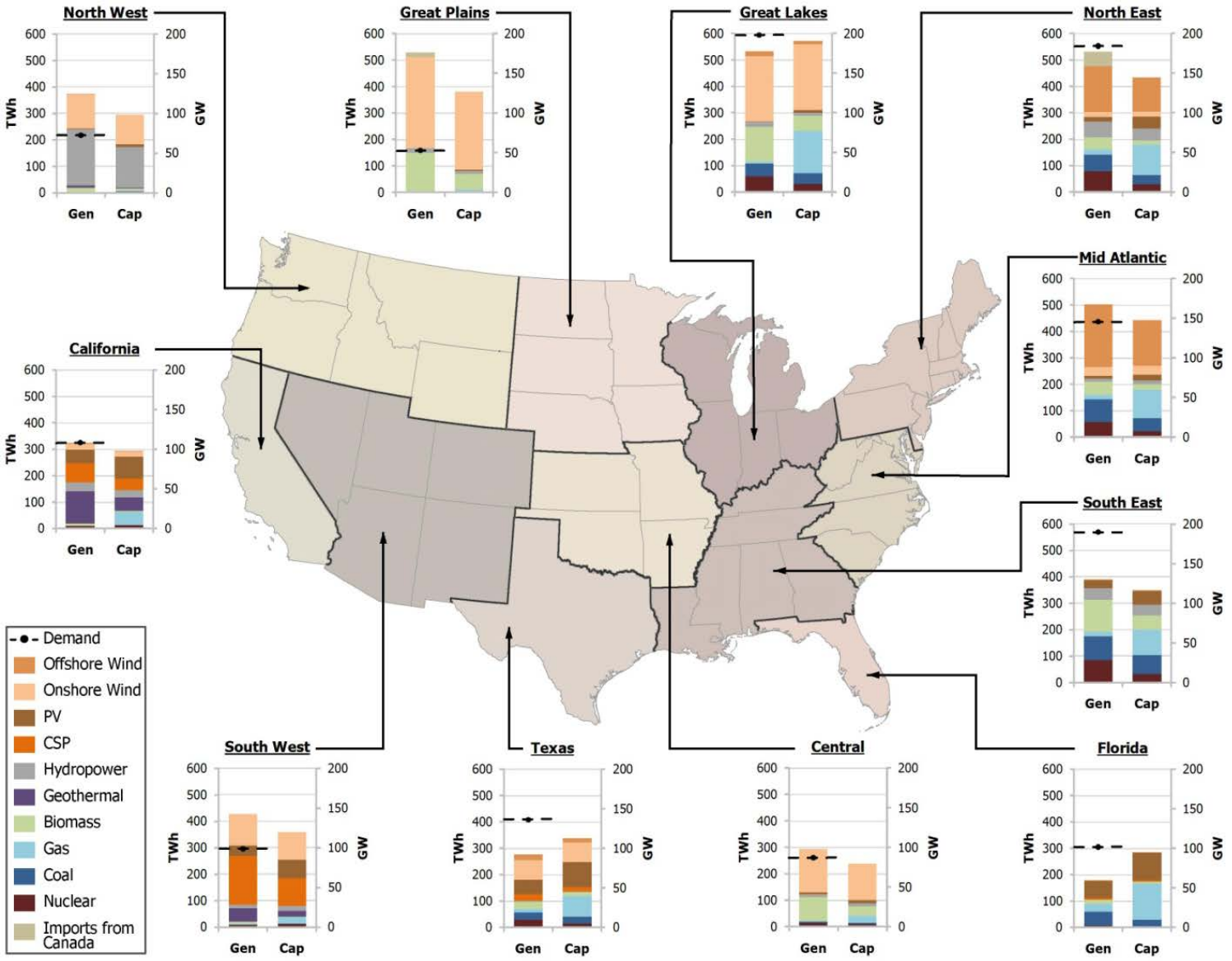

80% RE-ITI scenario

Grid Integration: A Few Near-Term Targets

- Solar Energy
  - Improve solar (wind) forecasting to assist power system operations.
  - Develop plug & play PV systems for easy installation, seamless grid integration.
- Wind Energy
  - Develop/develop active wind power controls to support power system operations.
- Buildings
  - Develop sensors and controls for open hardware energy management systems.
- Transportation
  - Develop lower cost charging systems consistent with smart grid.
- Hydrogen:
  - Evaluate mid-scale hydrogen systems and their potential grid integration with RE.
- Industry
  - Develop and facilitate deployment of advanced CHP DG systems
- Geothermal:
  - Explore Geothermal-Solar hybrids to improve performance, assist grid integration.

Future Work Needed

- A comprehensive cost-benefit analysis to better understand the economic and environmental implications of high renewable electricity futures relative to today's electricity system
- Further investigation of power system reliability
- Improved understanding of the institutional challenges associated with development of market mechanisms
- Analysis of the role and implications of energy research and development activities in accelerating technology advancements

A Transformation of the U.S. Electricity System

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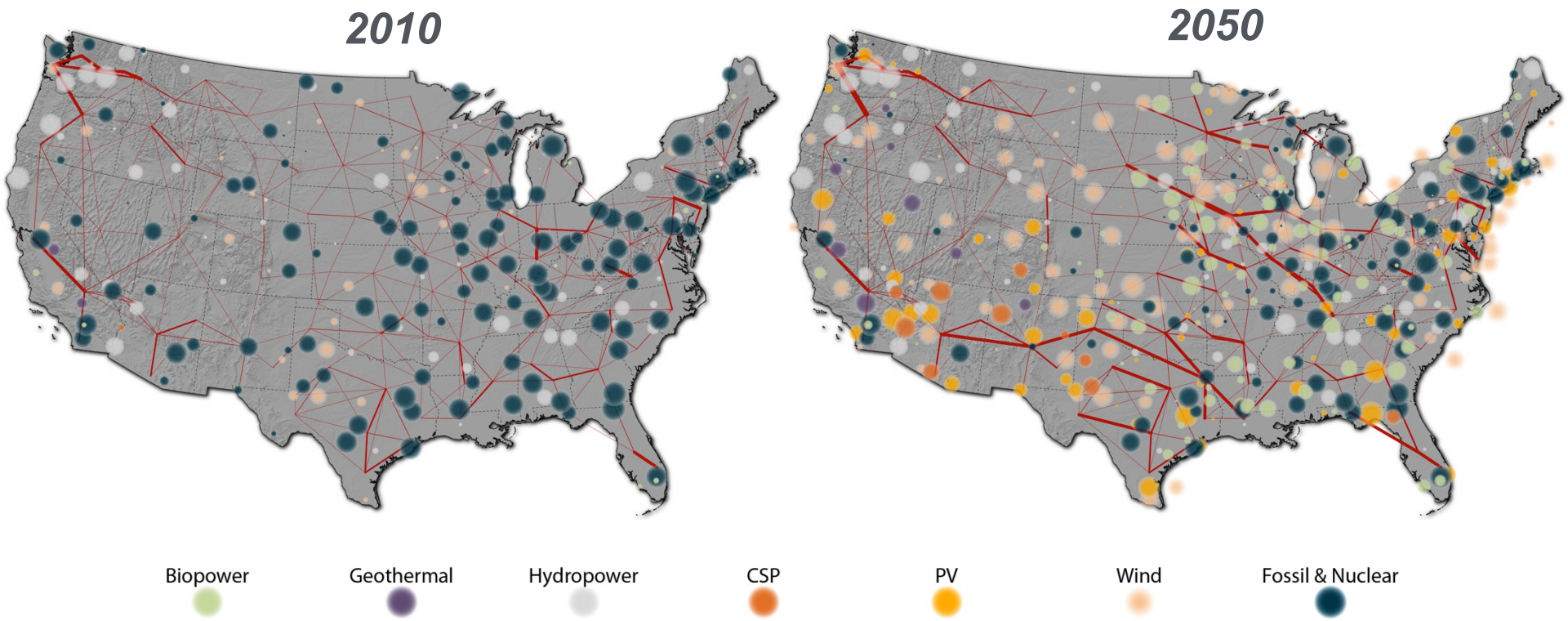

A future U.S. electricity system that is largely powered by renewable sources appears possible at the hourly level. Further work is warranted to investigate this clean generation pathway. http://rpm.nrel.gov/refhighre/dispatch/dispatch.html

20% Wind by 2030: Existing and New Transmission Needed

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