Wind Energy Research Center

UNIVERSITY OF WYOMING

Wind Energy Technology and an Evolving Western Energy Grid

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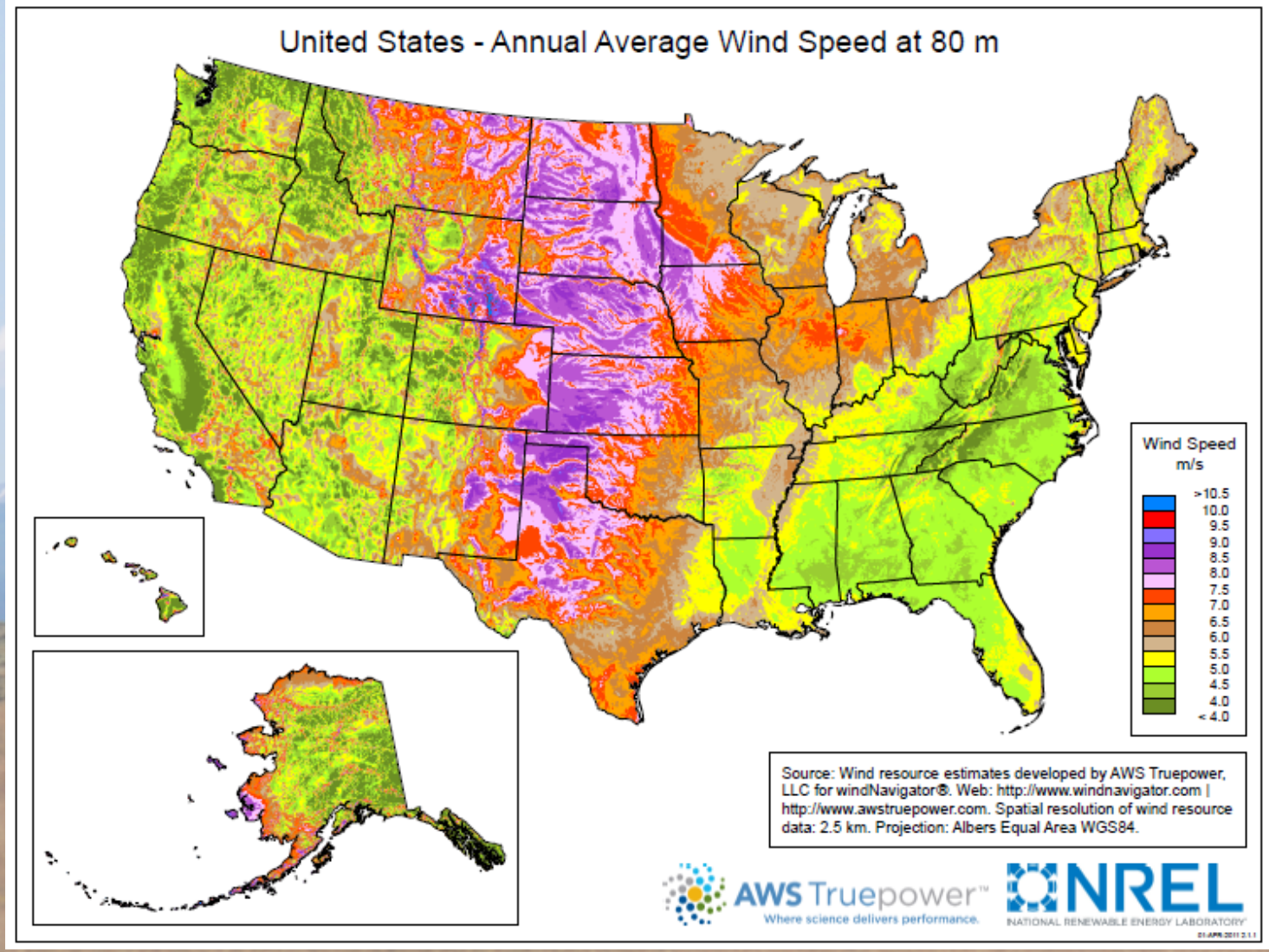
ENGINEERING APPLIED SCIENCE

Overview

- Why wind has grown – cost of energy
- Where is wind in the U.S.
- What is happening with wind in Wyoming
- Integration of renewables
- Final thoughts

WHY WIND HAS GROWN

Why Wind has Grown – Cost of Energy
Fantastic Resource



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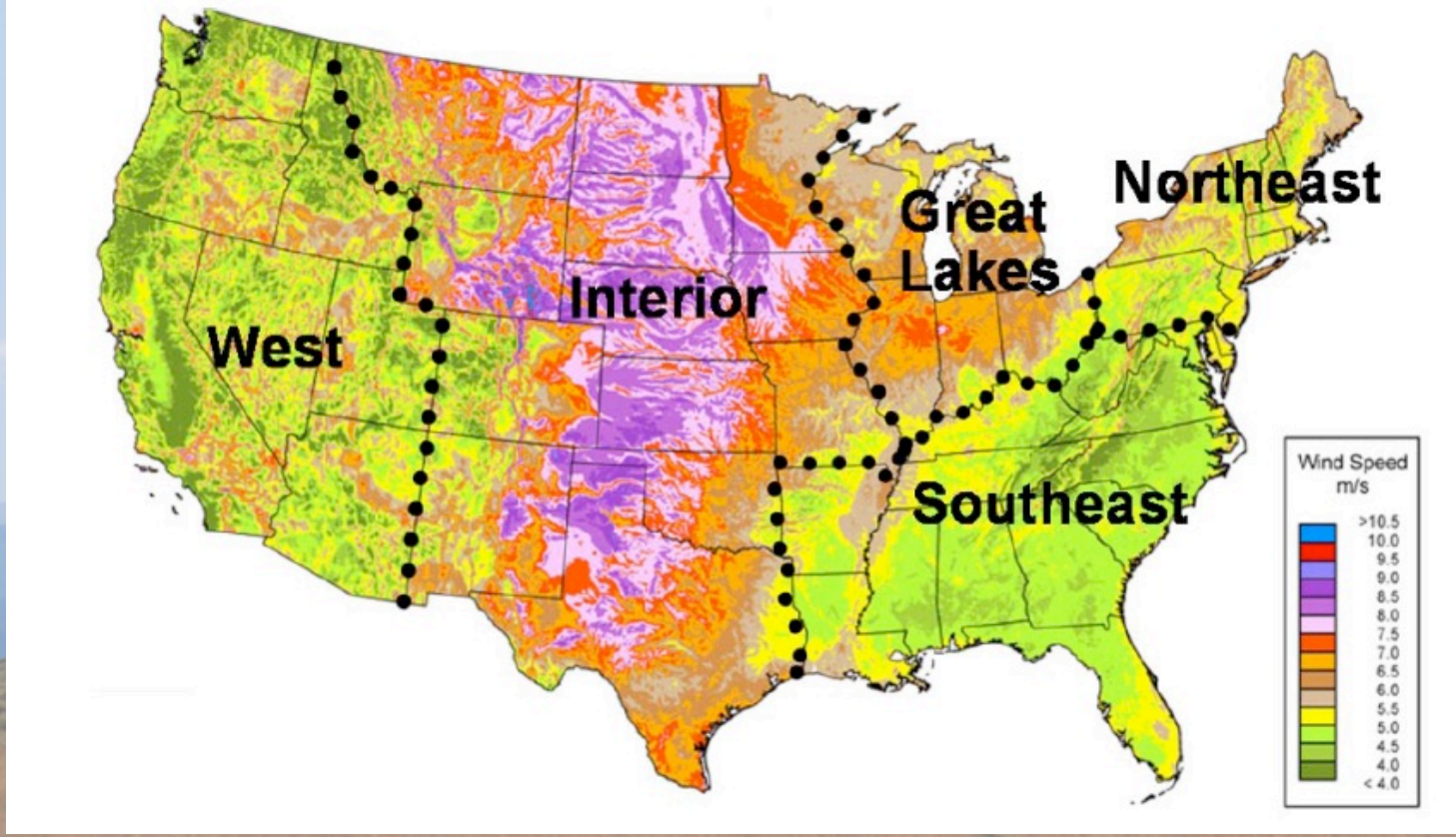
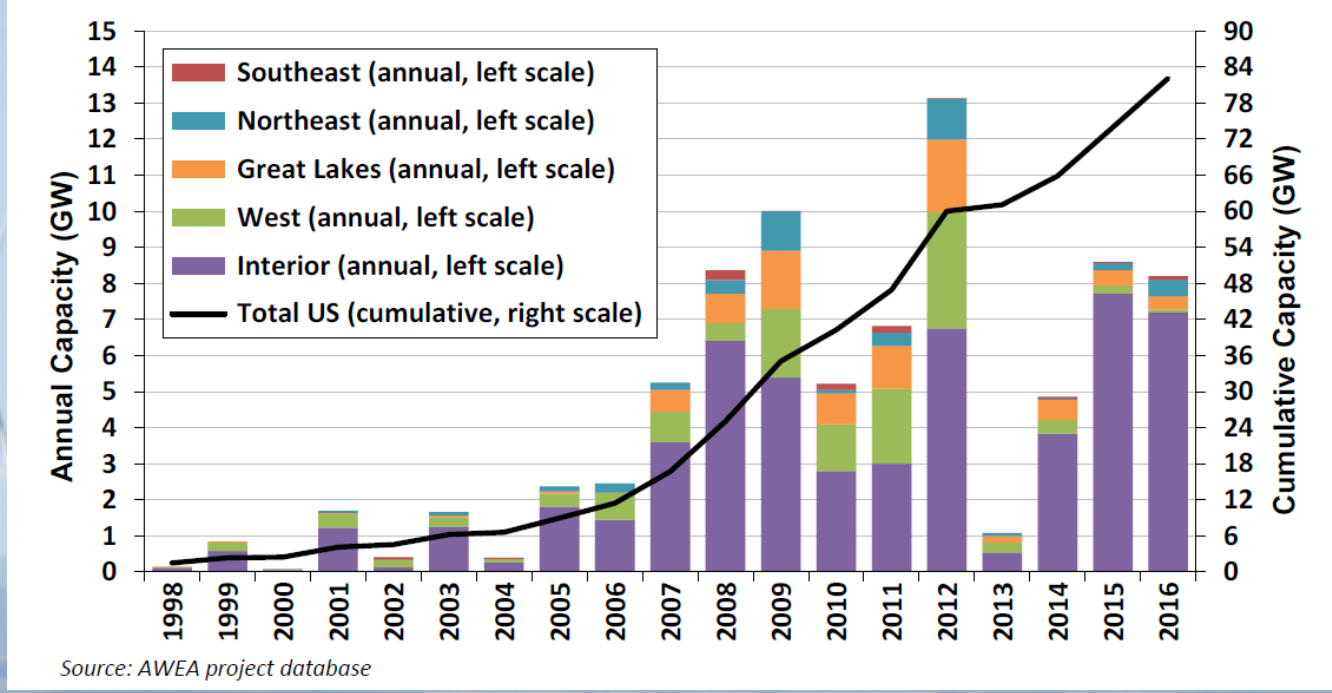


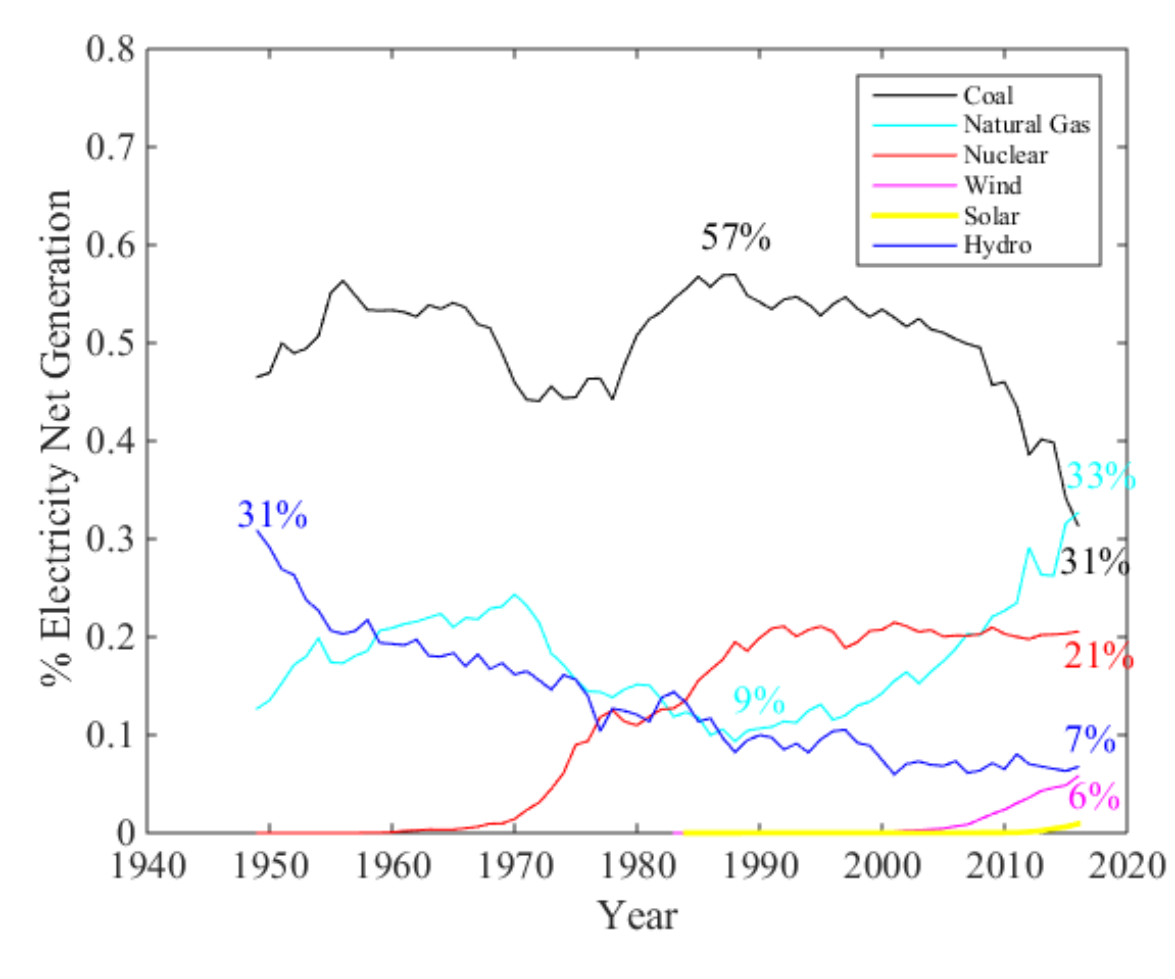
Why Wind has Grown – Cost of Energy
Growth of Wind



2016 Wind Technologies Market Report, DOE

- **U.S. installed 8.2 GW of new wind capacity in 2016 and now has over 84 GW (AWEA)**
- **Wind energy is now the largest source of renewable generating capacity in the U.S. (AWEA)**
- **In 2017, wind produces >5.8% of the U.S. electricity (EIA)**
- **In 2015, U.S. produced more power by wind than any other country in the world (IEA)**

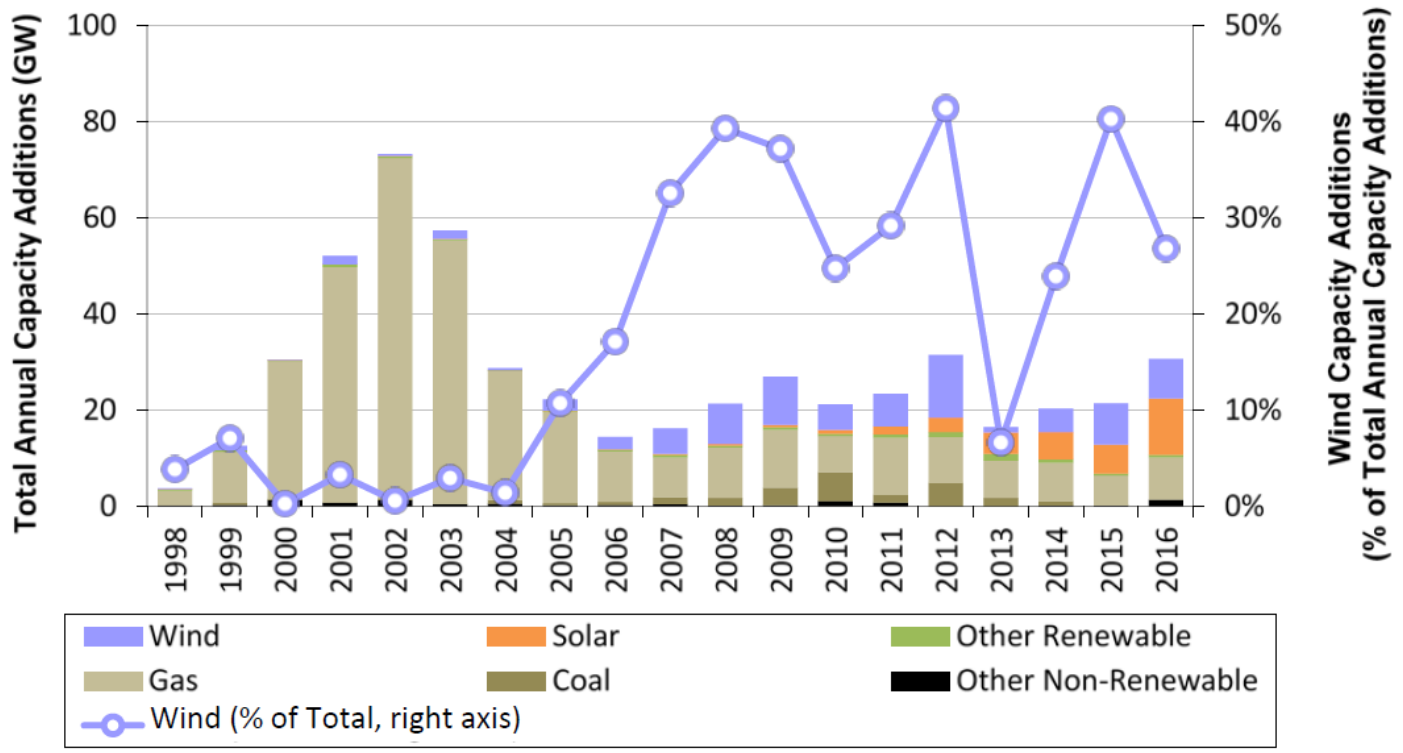
Why Wind has Grown – Cost of Energy Changes in Energy Generation



- **Many factors at play**
  - Electricity demand has been flat since 2008
  - Recent electricity capacity additions have been largely natural gas and wind
  - Result is a rapidly decreasing percentage of electricity generated by coal

Data from the
March 2017 Monthly Energy Review
U.S. Energy Information Administration

Why Wind has Grown – Cost of Energy Generation Addition



Source: ABB, AWEA, GTM Research, Berkeley Lab

2016 Wind Technology Market Report
Department of Energy

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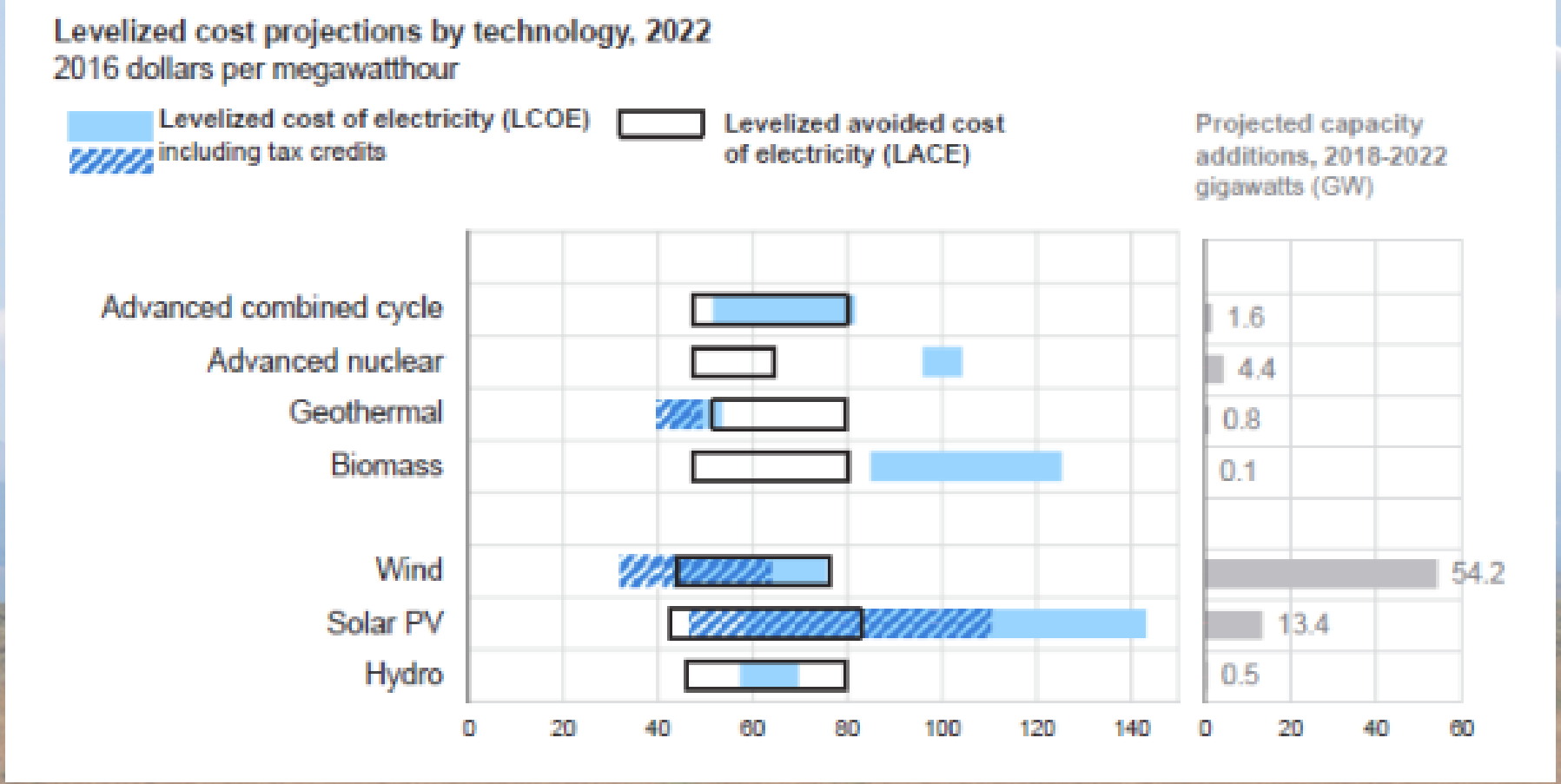
Why Wind has Grown – Cost of Energy Wind is Competitive

- **The cost of wind energy has decreased to the point where it is highly competitive**
  - True with or without tax credits
  - True when making "apples-to-apples" comparison



Annual Energy Outlook 2017
U.S. Energy Information Administration

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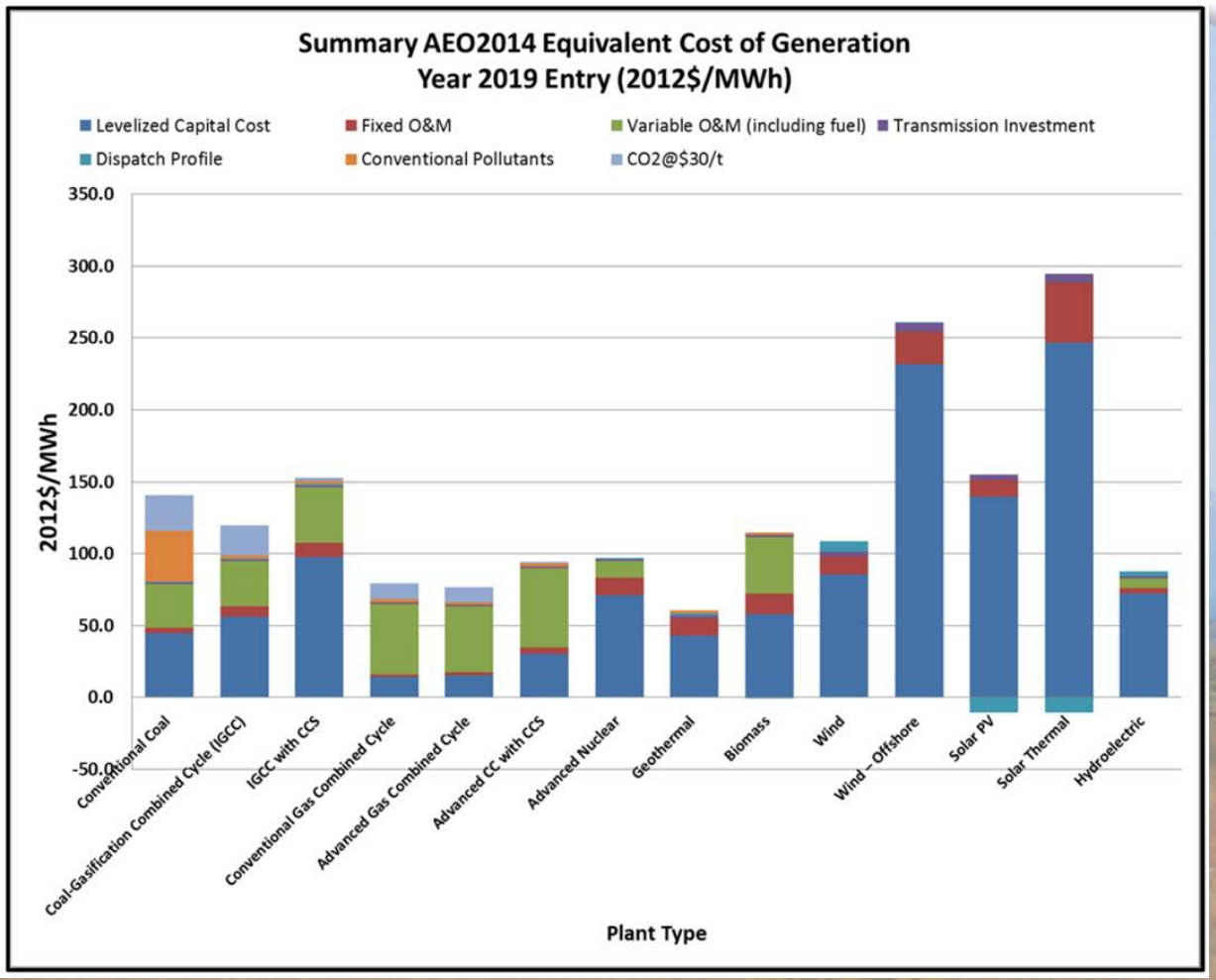
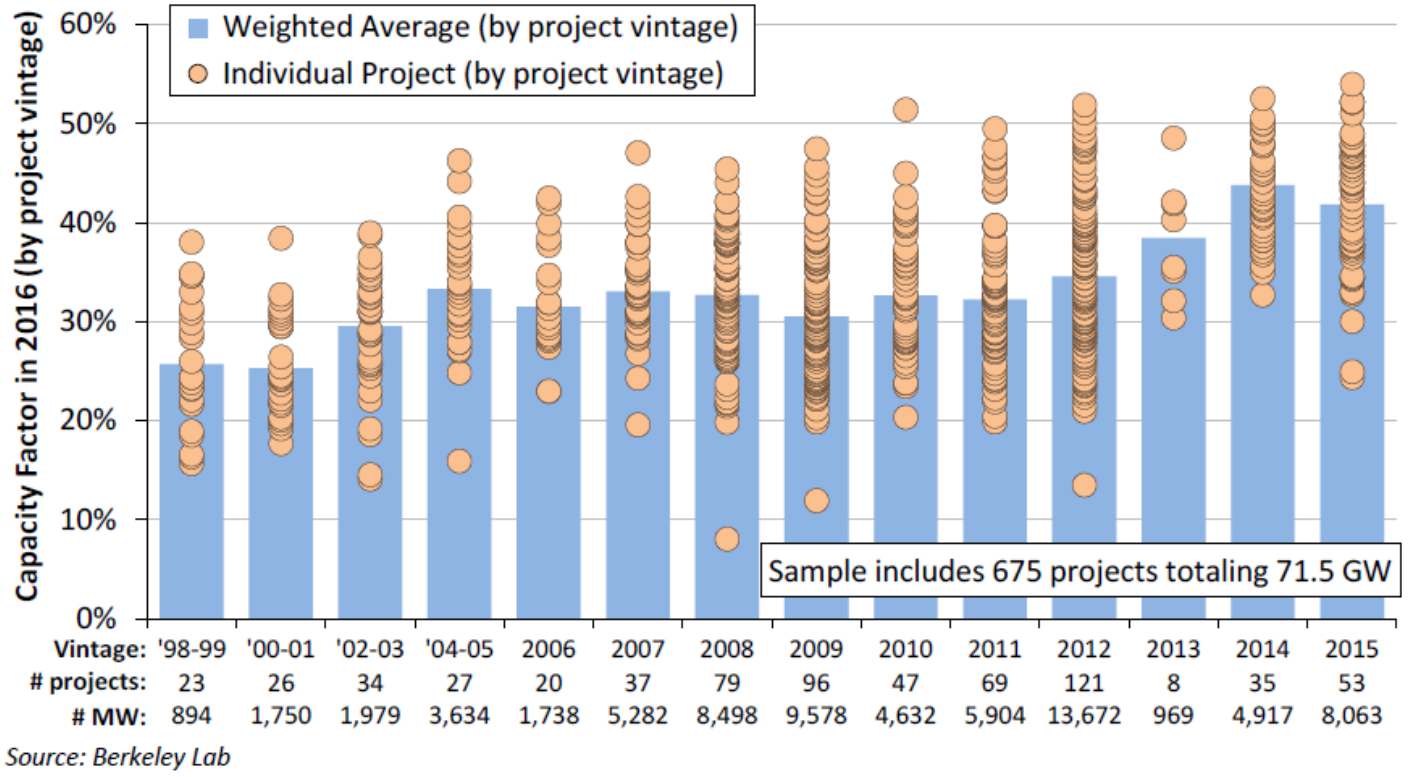


Electricity Markets and the Clean Power Plan
William W. Hogan, 2015

Why Wind has Grown – Cost of Energy Turbine Technology

- **What factors have contributed to this rapidly decreasing cost of electricity from wind?**
  - Increasing capacity factors due to technology improvements
  - Larger hub heights
  - Increased rotor diameter



2016 Wind Technology Market Report Department of Energy

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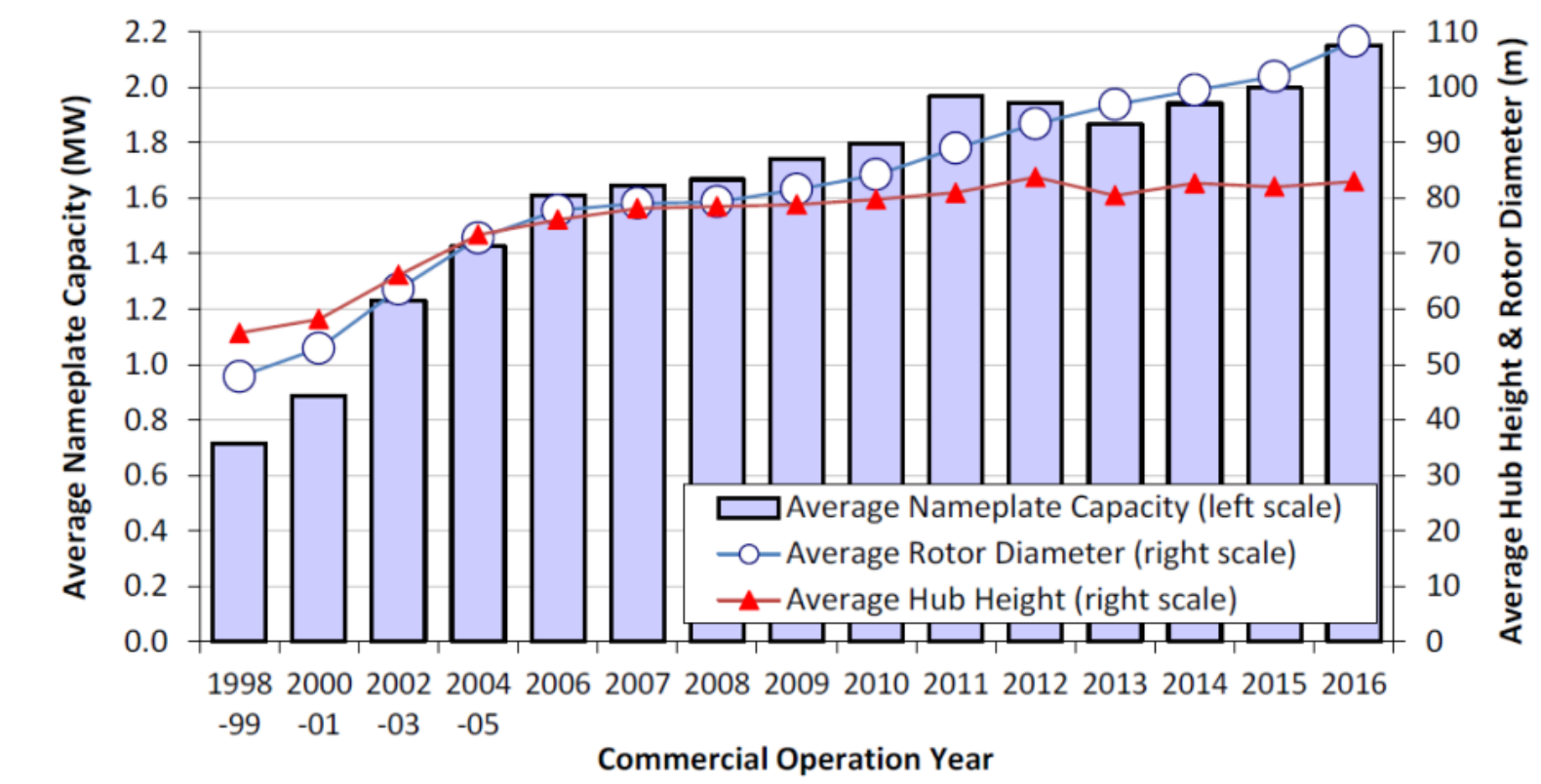

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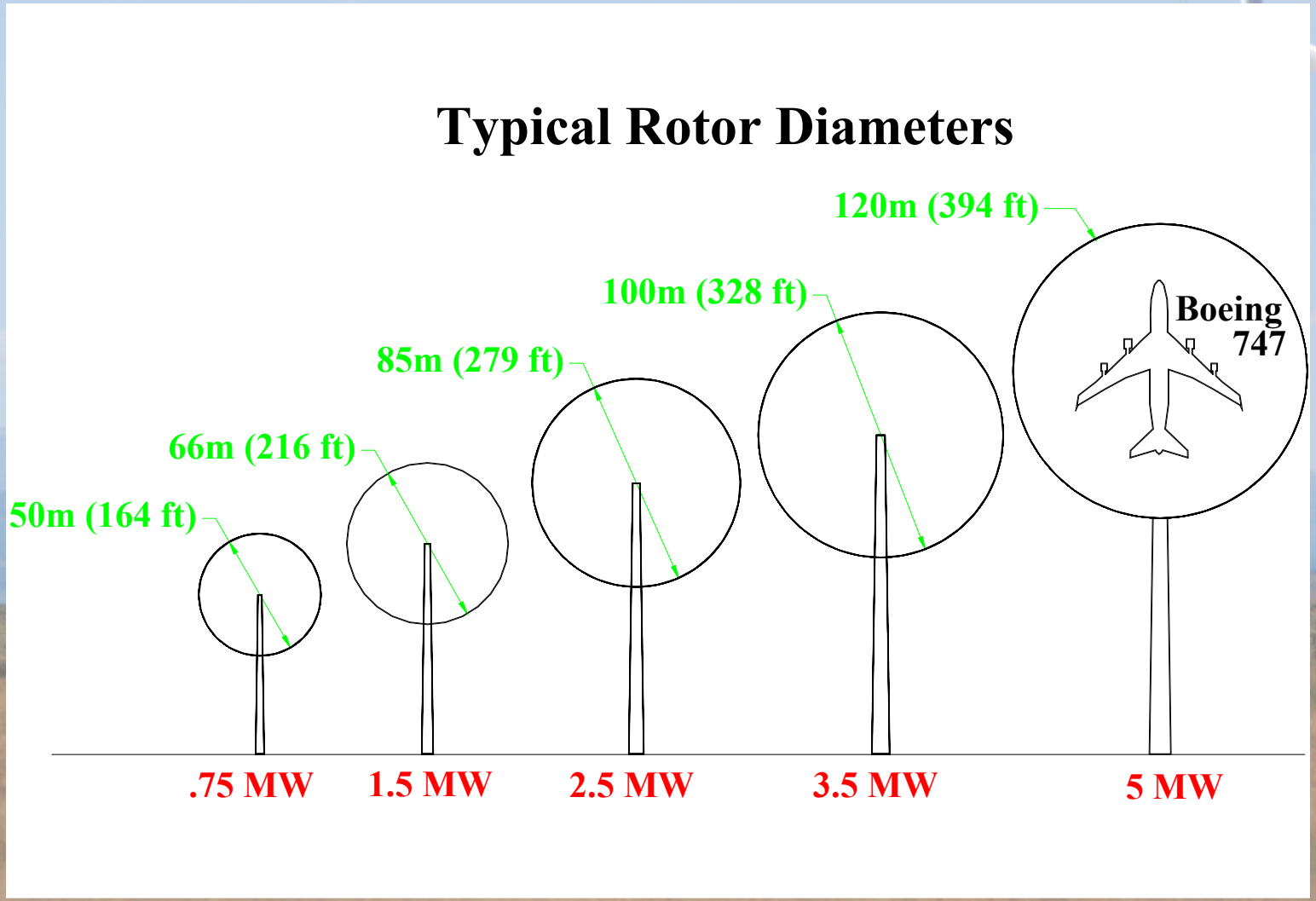

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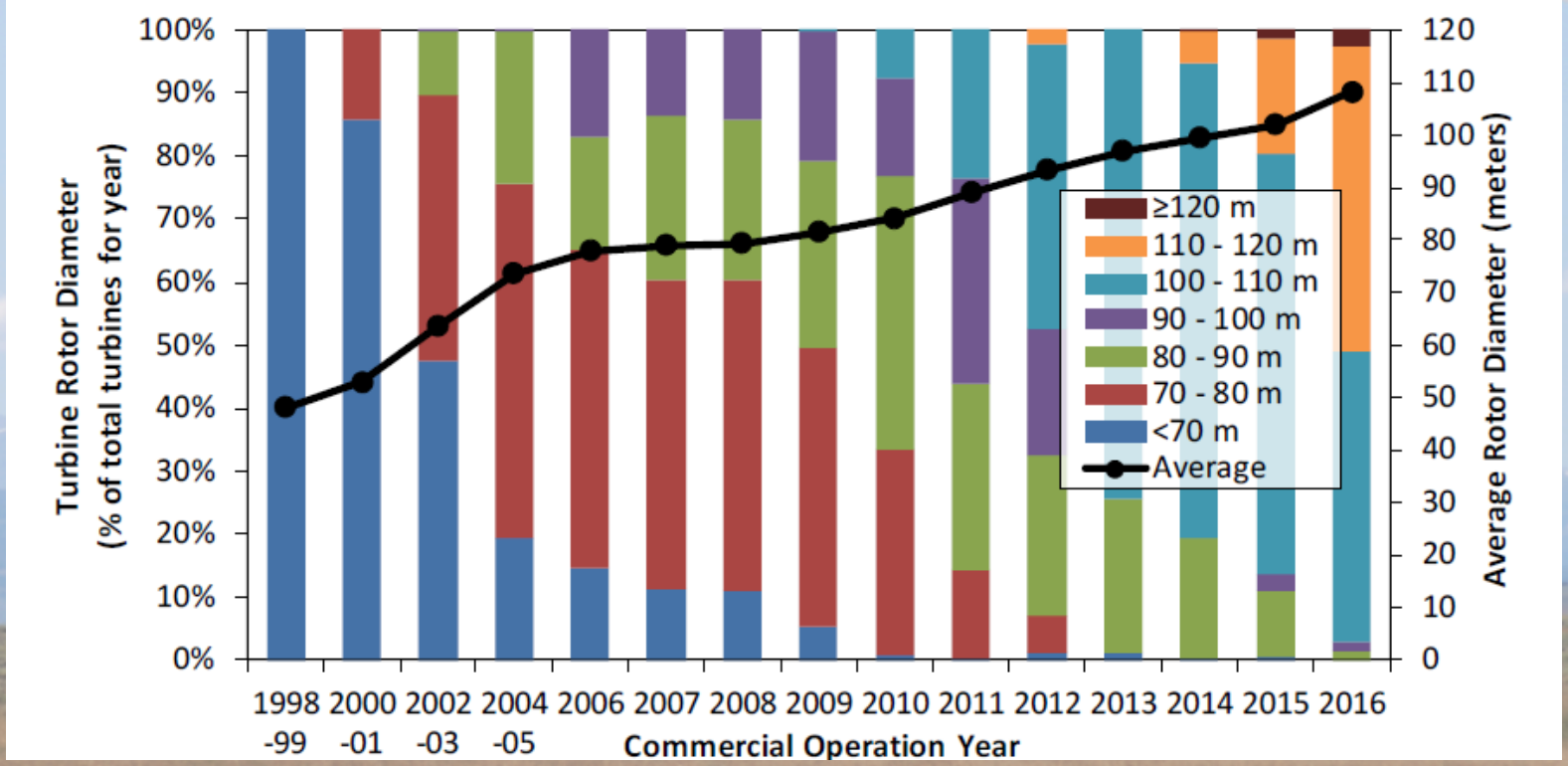
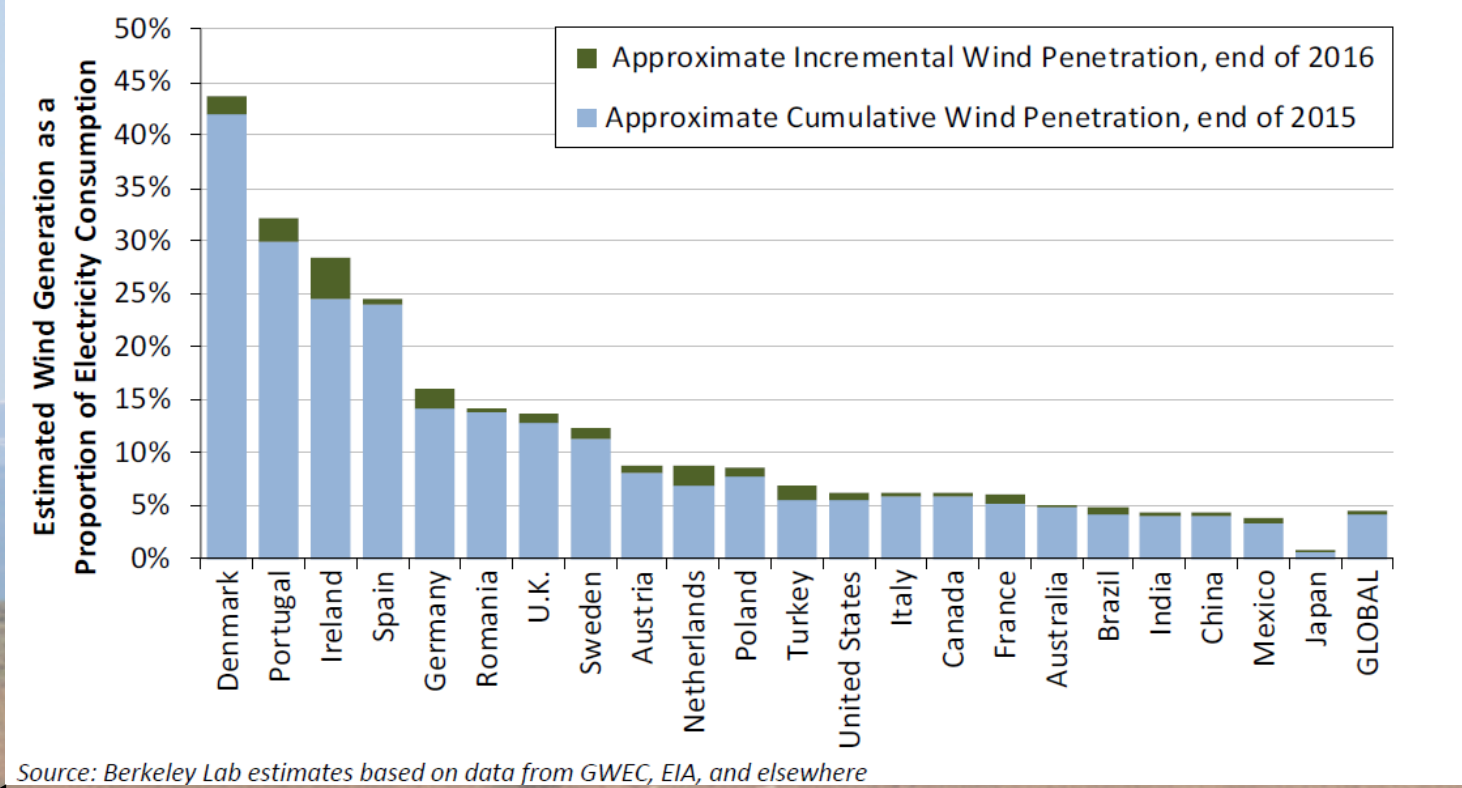


2016 Wind Technology Market Report
Department of Energy

Why Wind has Grown – Cost of Energy
World is Turning to Wind Energy

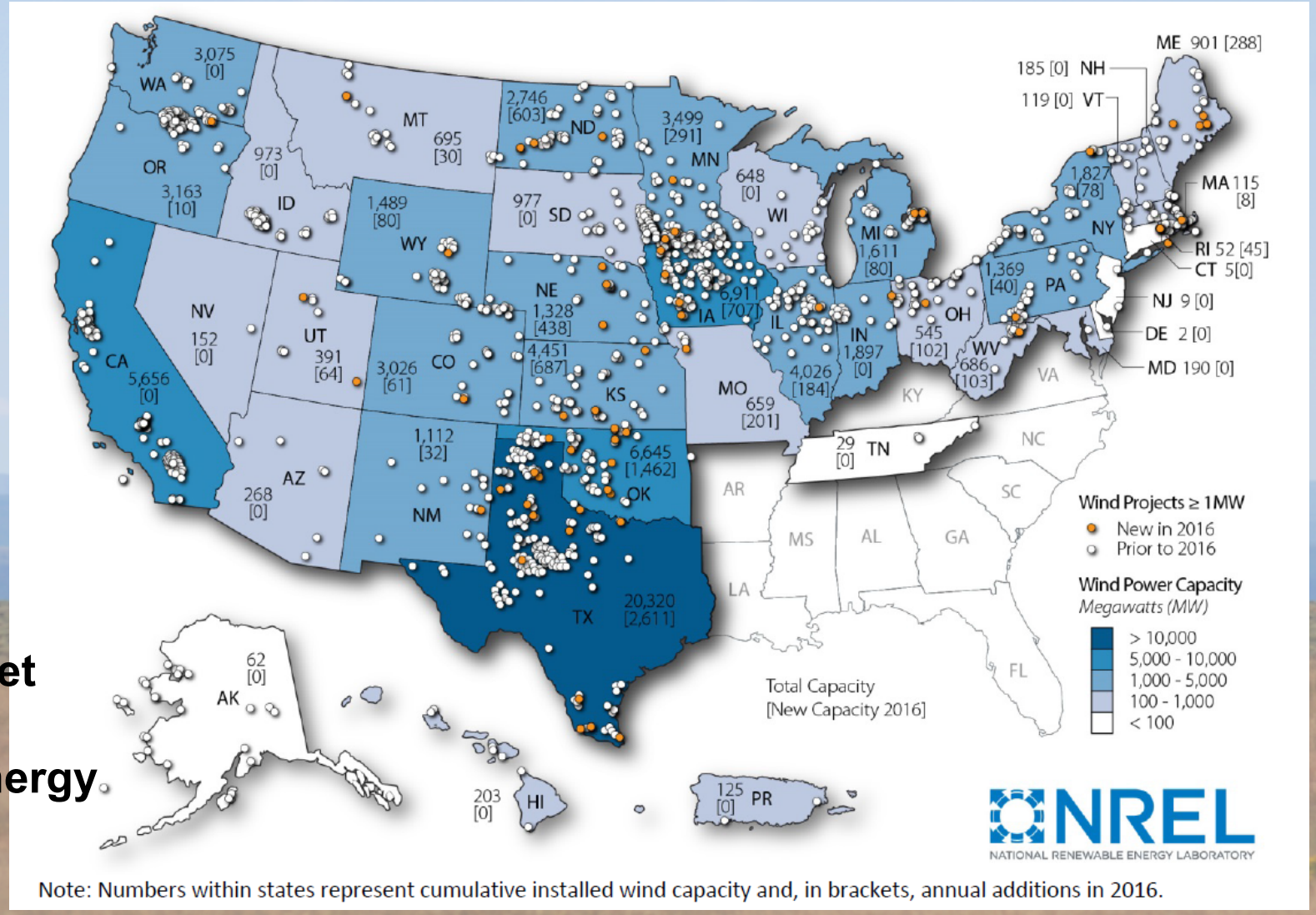
- **Due to the reduced cost of energy, world is using increased amounts of wind energy**
  - U.S.
    - **First in production of wind energy**
    - **6% of energy production**
    - **13th in fraction of energy produced by wind energy**
  - Denmark
    - **>40% of energy production**



2016 Wind Technology Market Report
Department of Energy

WHERE IS WIND IN THE U.S.

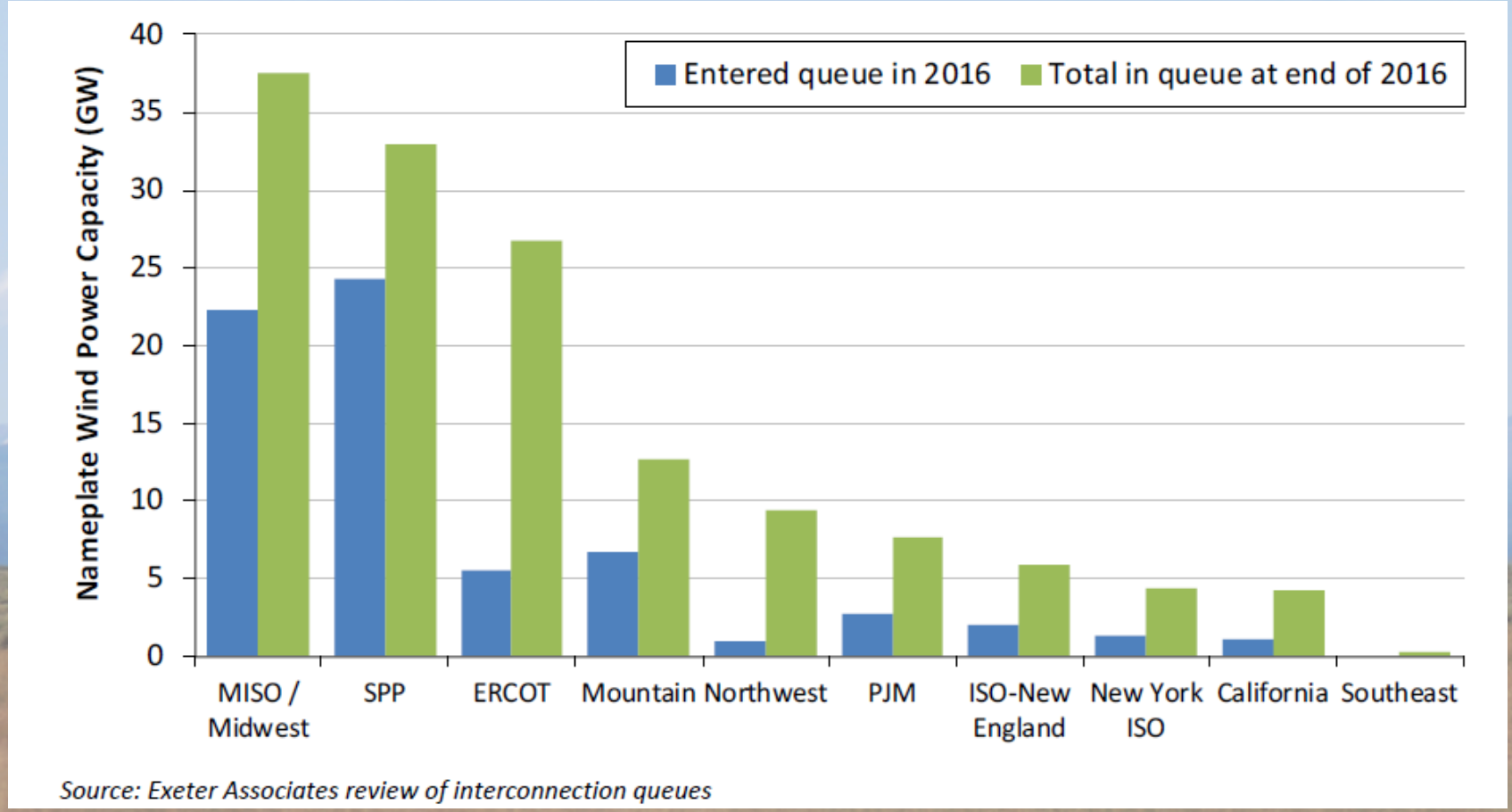
Where is Wind in the U.S. Wind Generation



2016 Wind Technology Market Report
Department of Energy

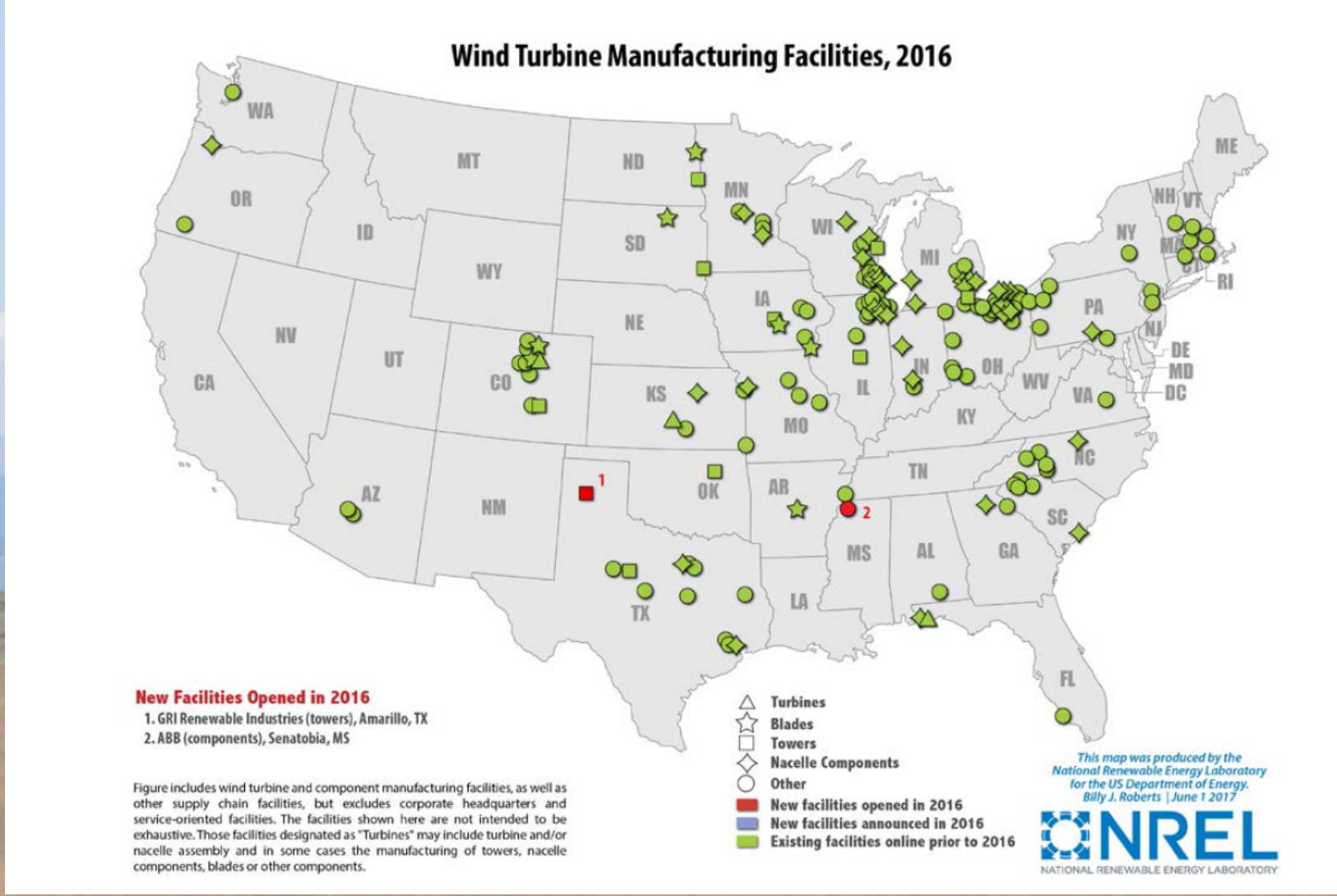
Where is Wind in the U.S.
Where is wind Growing the Fastest

2016 Wind Technology Market Report Department of Energy

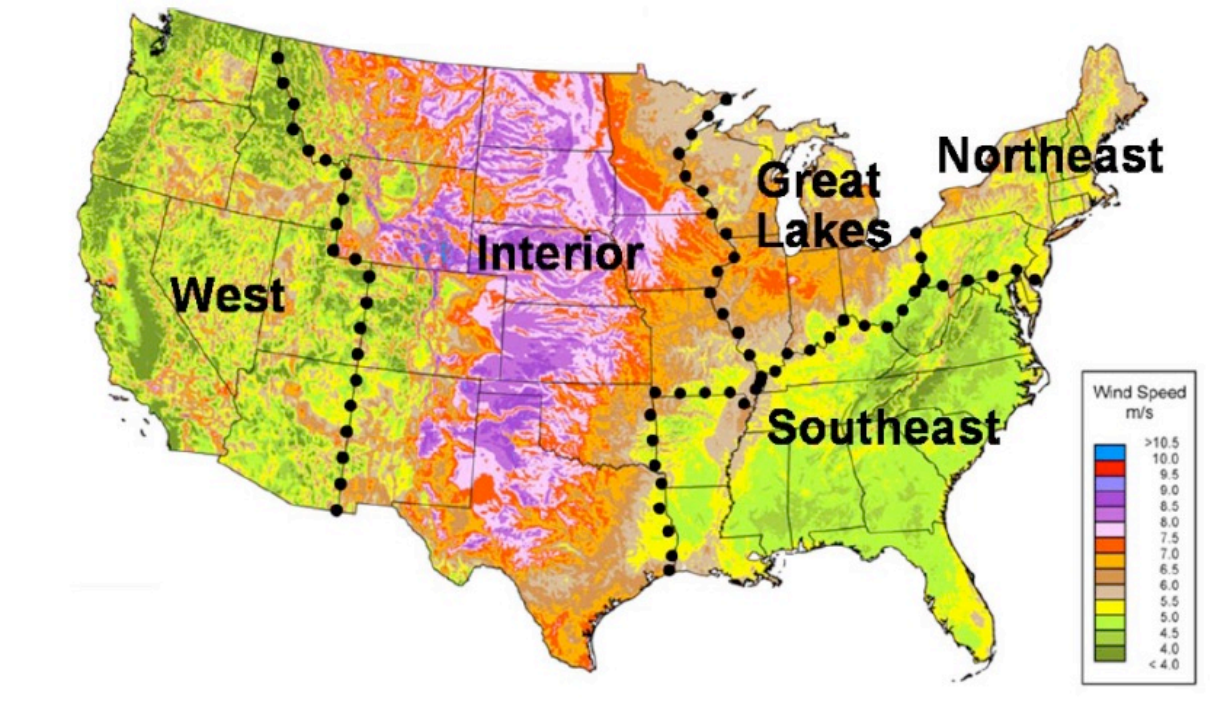


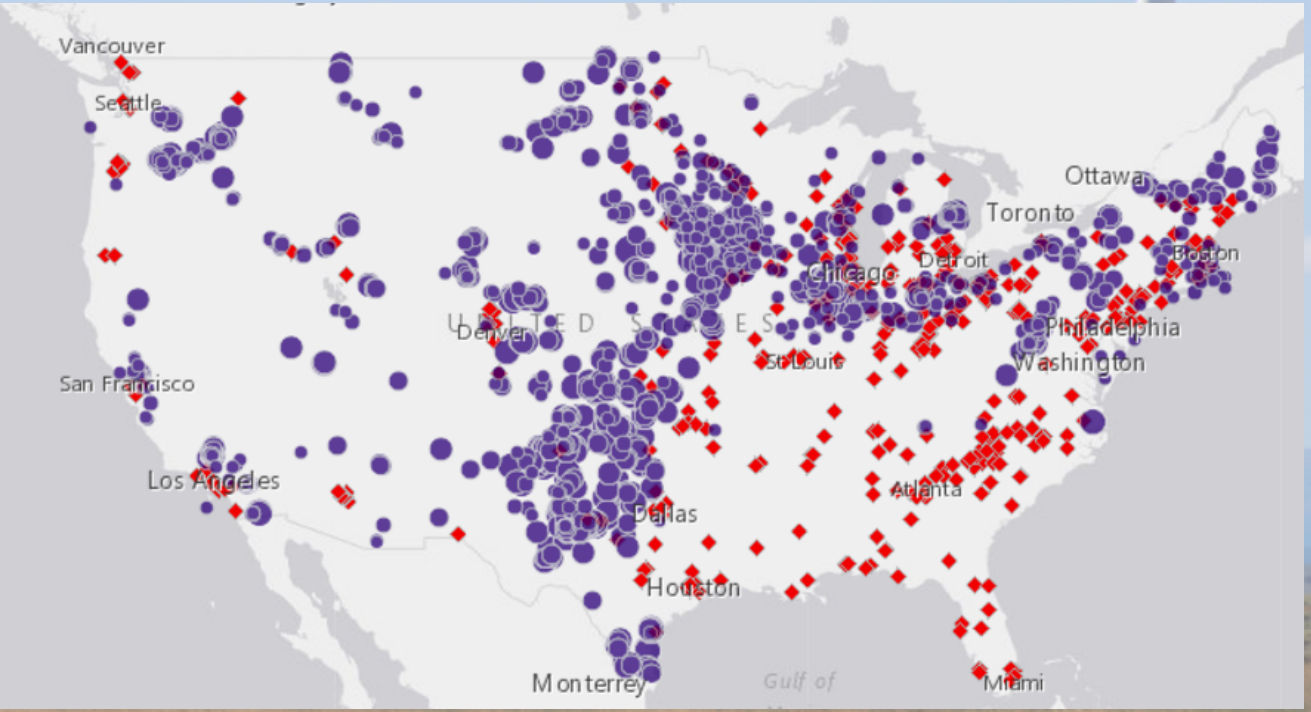
Where is Wind in the U.S. Manufacturing

2016 Wind Technology Market Report Department of Energy



Where is Wind in the U.S. Summary





Where is Wind in the U.S. Distribution and Cost

- LCOE as low as $36/MWh
- Lower prices due to production tax credit
- Recent projects and low cost are in the interior region
- Without subsidy, likely to be competitive with natural gas

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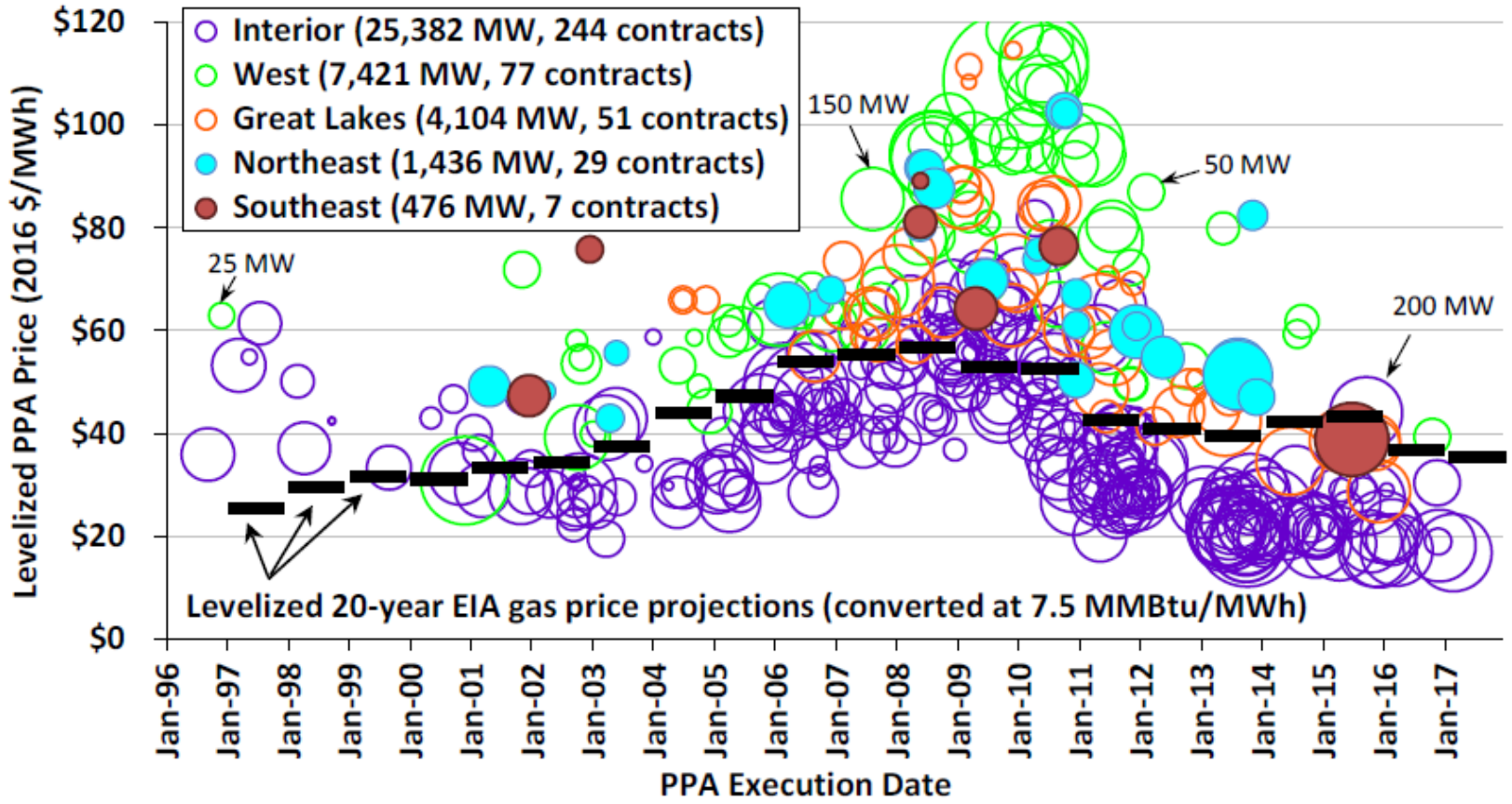

Note: Area of "bubble" is proportional to contract nameplate capacity

Source: Berkeley Lab, Energy Information Administration

Where is Wind in the U.S. Future Outlook

- **Negative influences**
  - Expiration of PTC
  - Low natural gas prices, solar competition
  - Modest electricity demand growth
  - Lower impact of RPS
  - Inadequate transmission
- **Positive Influences**
  - Decline in Levelized Cost of Energy (LCOE)
  - Corporate demand for wind energy
  - RPS policies still in force
  - New transmission
  - Transportation Electrification

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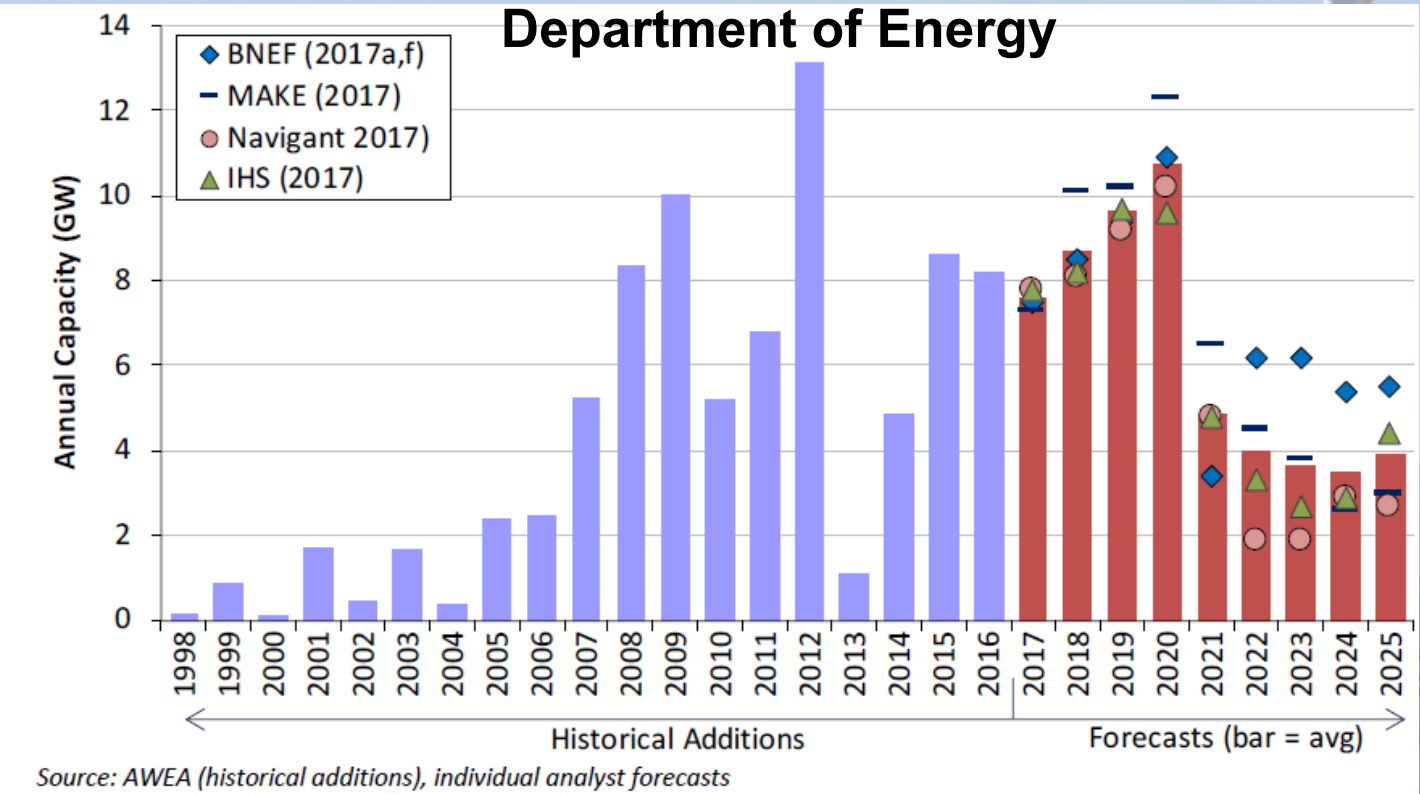
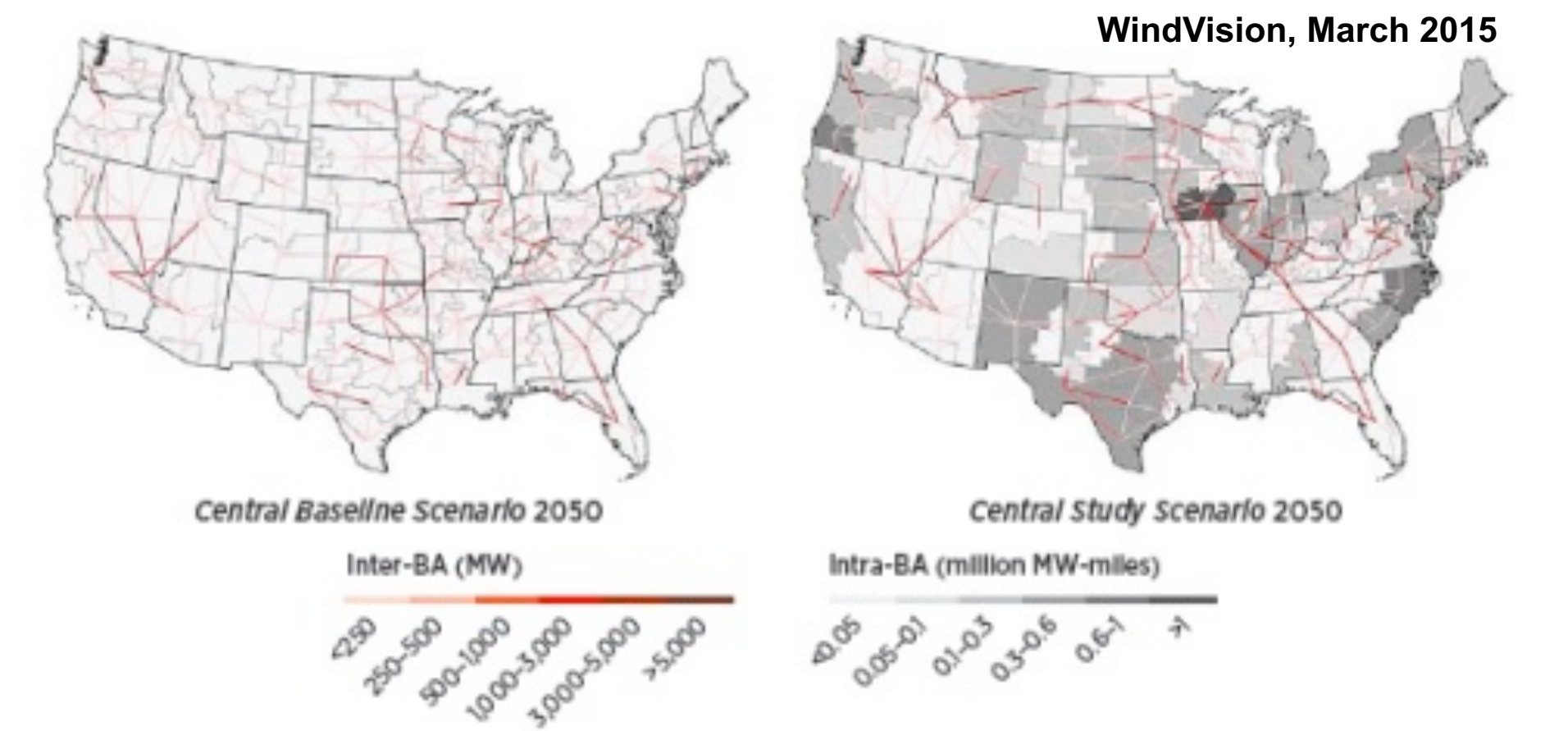


Aggressive cost reductions will be necessary to achieve the Wind Vision wind energy growth rate

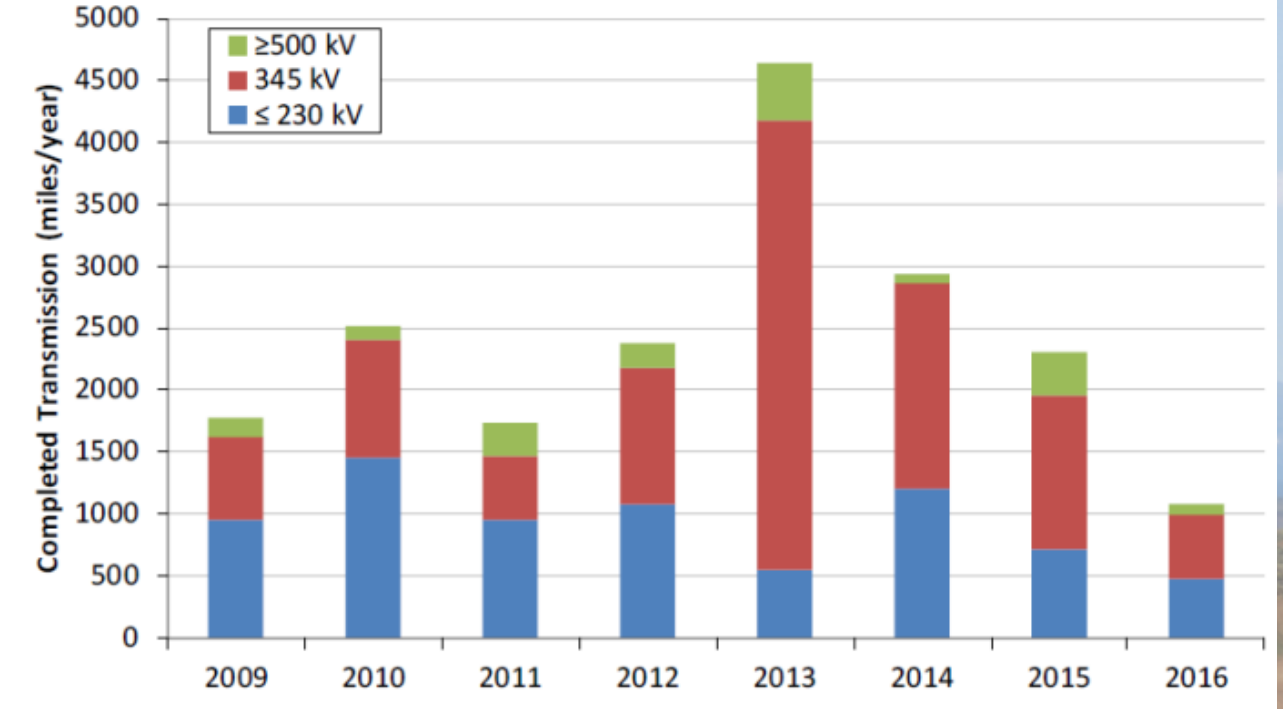
Where is Wind in the U.S. Transmission Development

- **How will it be brought to market?**



Where is Wind in the U.S. Transmission Development

- **Resources located far from load centers**
- **Transmission is being added to accomplish this**
- **Transmission costs associated with wind need to be factored in**
  - Typically these are small compared to the wind generation cost
  - Project cost (wind + transmission) competitive if wind resource is good



Source: FERC monthly infrastructure reports

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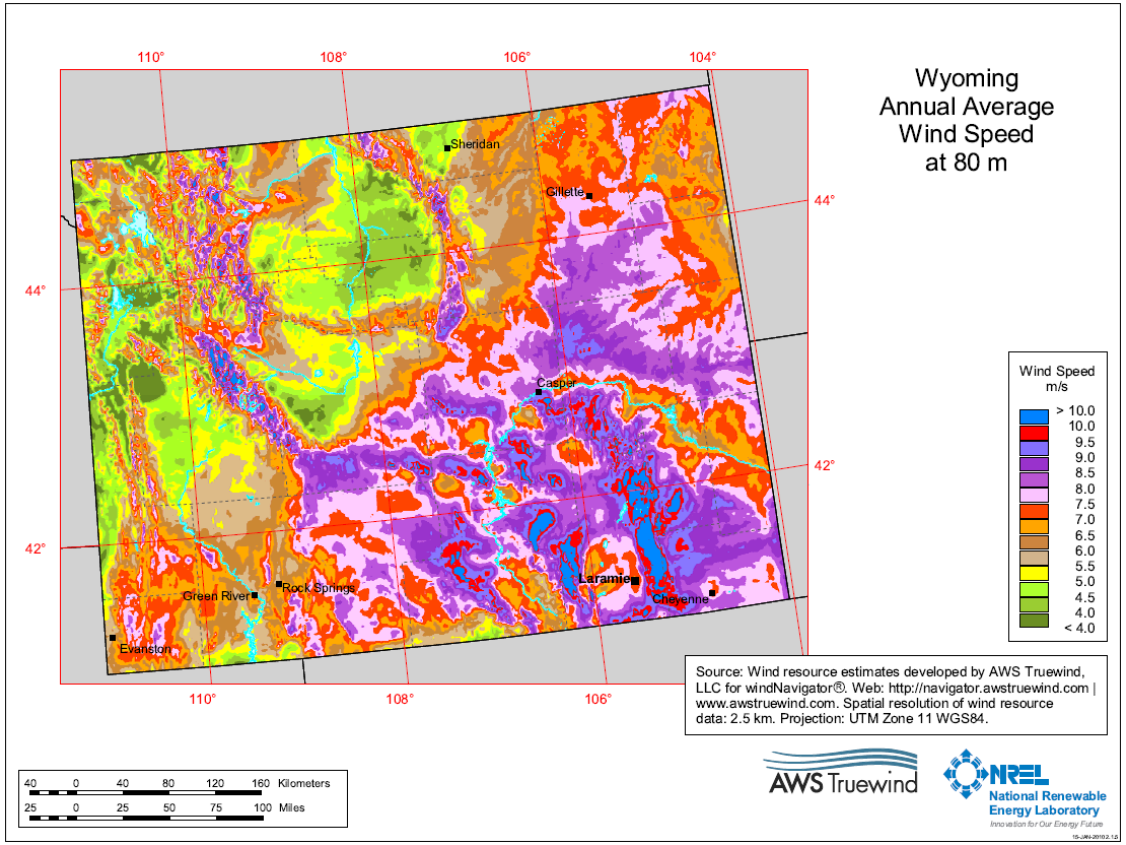
Department of Energy

WHAT IS HAPPENING WITH WIND IN WYOMING?

What is Happening with Wind in Wyoming?
Wyoming Wind Plants

- **1489 MW**
- **28 Wind Plants, 21 > 10MW**
- **15th in US installations**

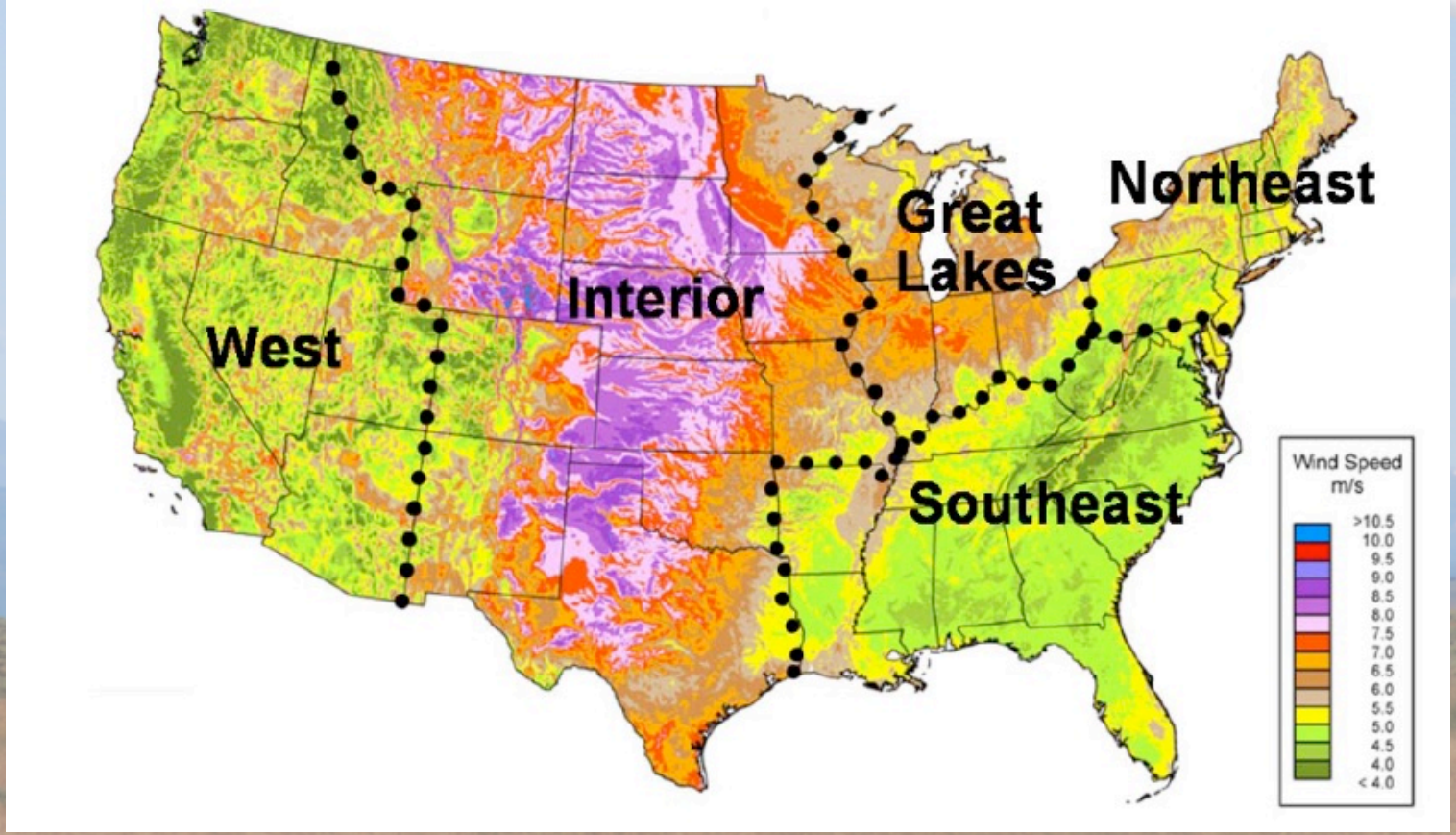


What is Happening with Wind in Wyoming? Wyoming Wind Plants

- **Existing Wyoming Wind Plants**
  - 28 Installations
  - 21 with >10 MW
  - 1489 MW Installed
    - **Earliest Commercial Plant in 1999**
    - **Most Installed in 2008-2010**
    - **80 MW installed between 2010-2017**
  - >1000 turbines installed
  - Most common supplier
    - **General Electric**
  - Wind installations clustered
    - **Southeast**
    - **Central**
    - **Southwest**

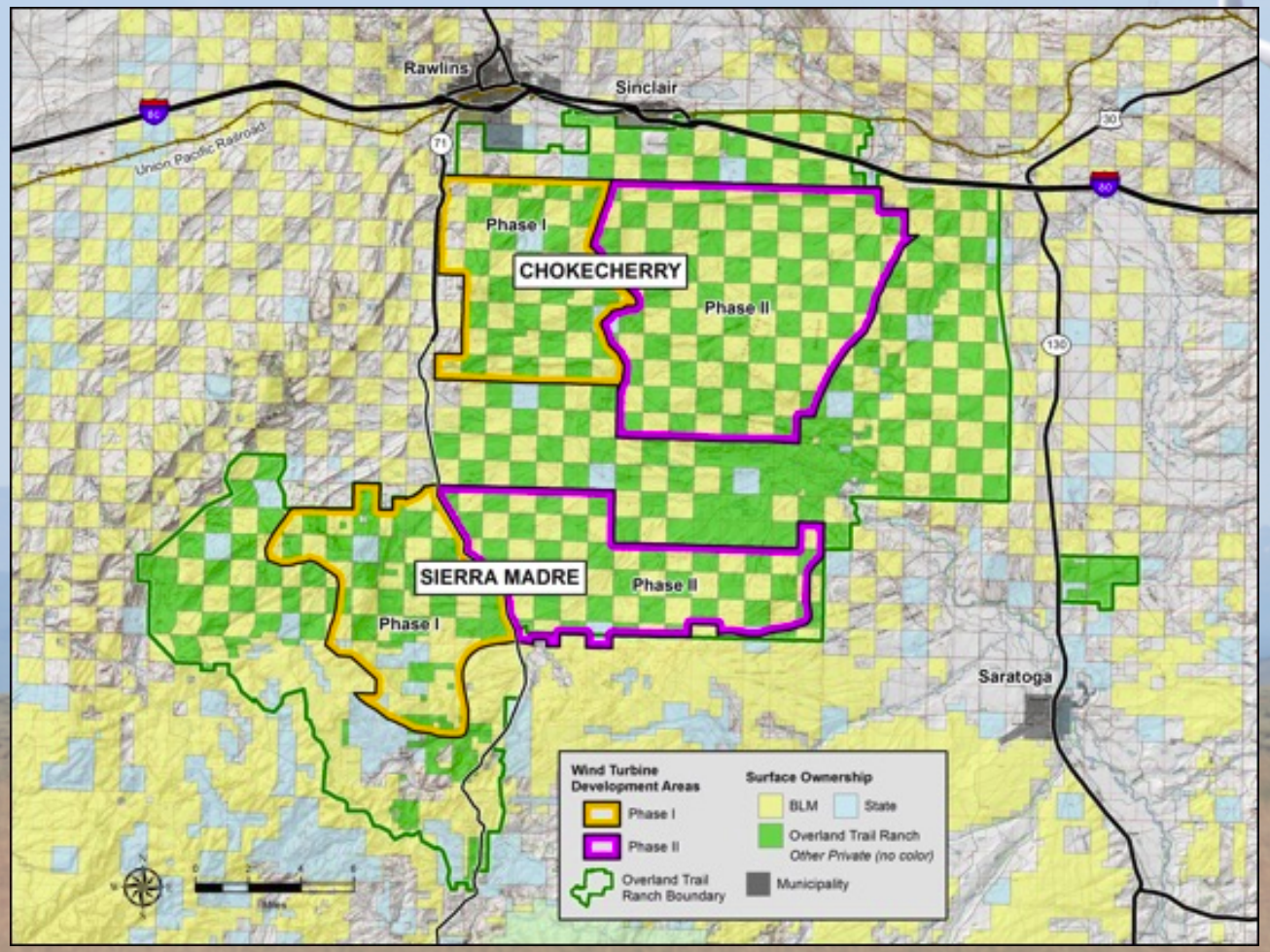
What is Happening with Wind in Wyoming?
Factors Affecting Wind Development in Wyoming

- **Negative influences**
  - Lack of transmission
  - State policies
  - Lack of need for new electricity generation
  - Wyoming is a net exporter
- **Positive Influences**
  - Fantastic resource
  - Proximity to West Coast
  - Drop in cost of wind energy
  - Changing attitudes
  - New transmission generation



What is Happening with Wind in Wyoming? Planned Wind Facilities

- **Chokecherry/Sierra Madre**
  - 3000 MW
  - 1000 Turbines, 3 MW
  - 350,000 Acres
    - **50% private/50% federal**
- **Viridis Eolia**
  - 1870 MW
  - 748 Turbines, 2.5 MW
  - 98,381 Acres
    - **Nearly 100% federal**



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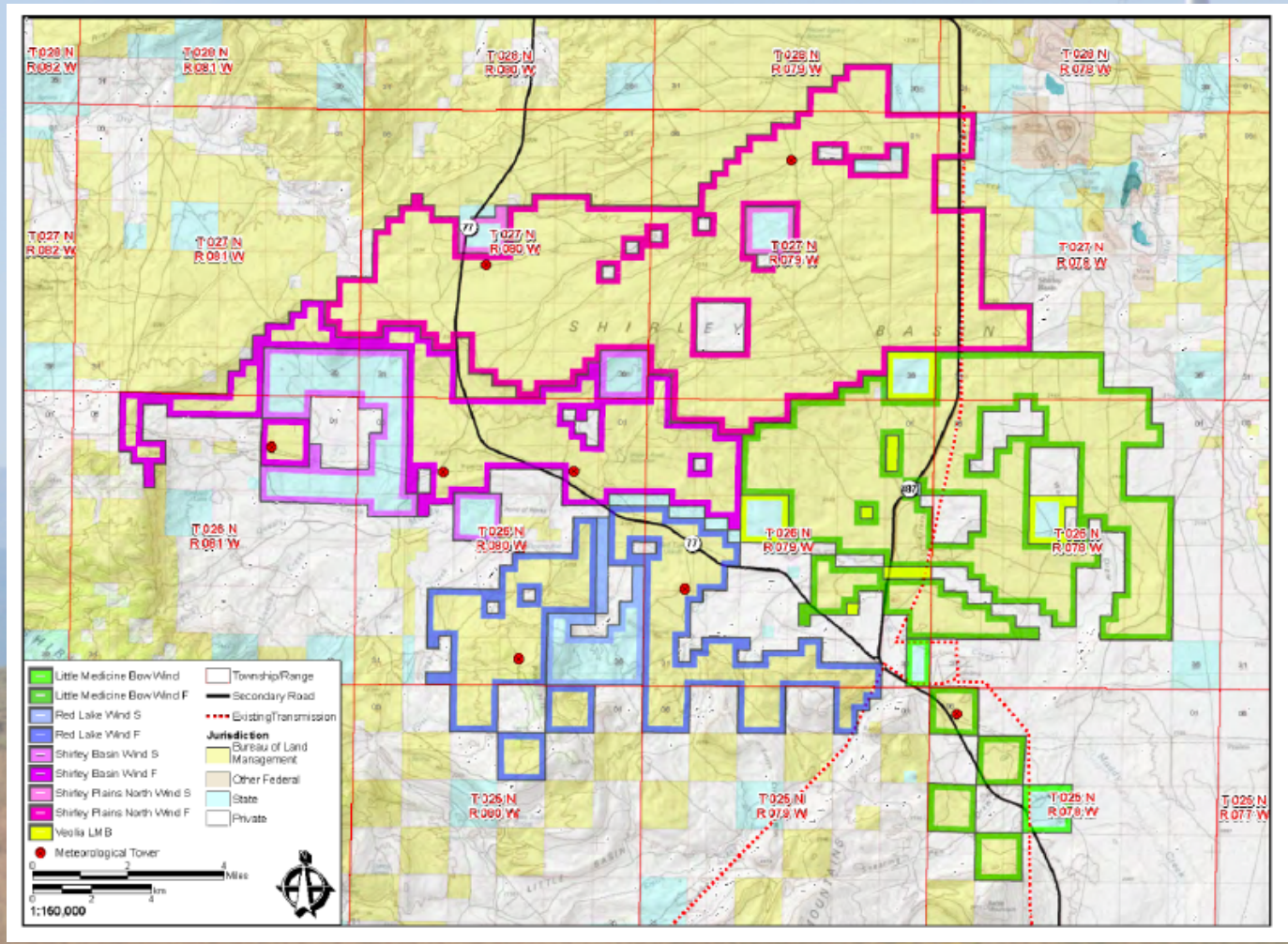
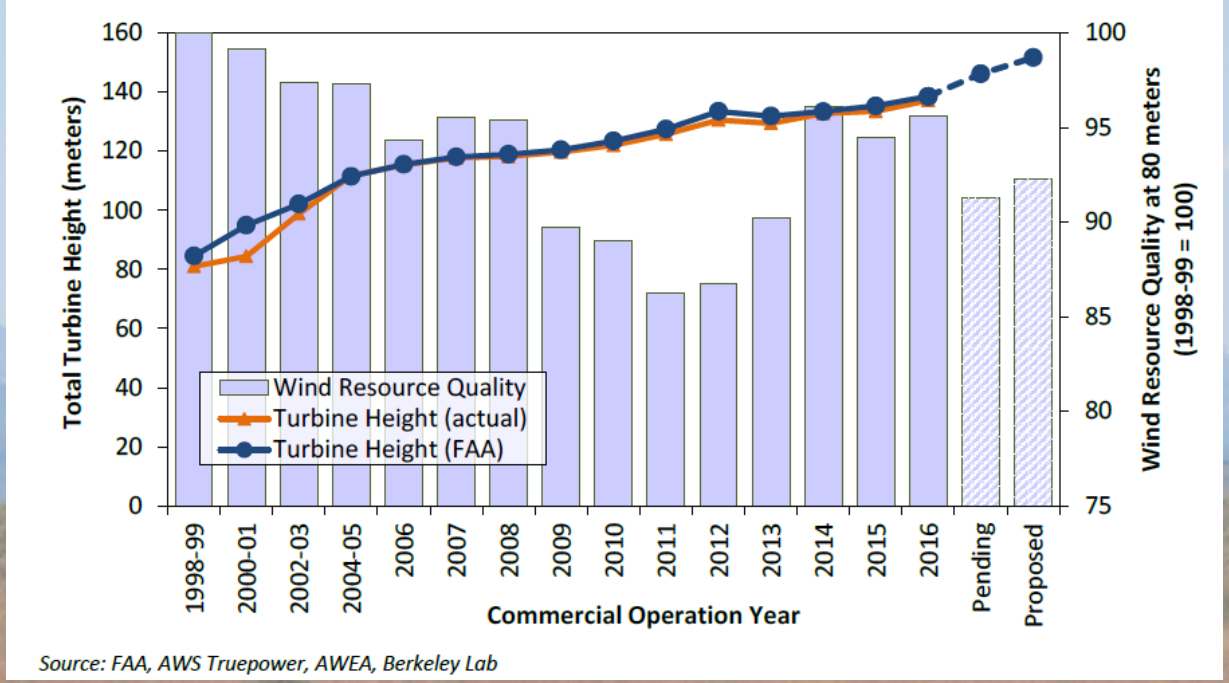


What is Happening with Wind in Wyoming? Planned Wind Facilities

- **Intermountain Wind/Altera**
  - Boswell Springs
    - **320 MW**
    - **Albany County**
- **Invenergy**
  - TB Flats
    - **500 MW**
    - **Carbon County**
  - Ekola
    - **250 MW**
    - **Carbon County**
- **Rocky Mountain Power Projects**
  - Upgrading 900 MW of wind generation
  - Facilitate 1100 MW of additional generation

What is Happening with Wind in Wyoming? Limited Time to Capitalize

- **Wyoming has a limited time to capitalize on its outstanding resources**
  - Technology is improving enabling wind energy production at lower quality sites
  - Wind is being built out at a rapid rate and will meet the need
  - Offshore resources are very good and prices for offshore wind are dropping



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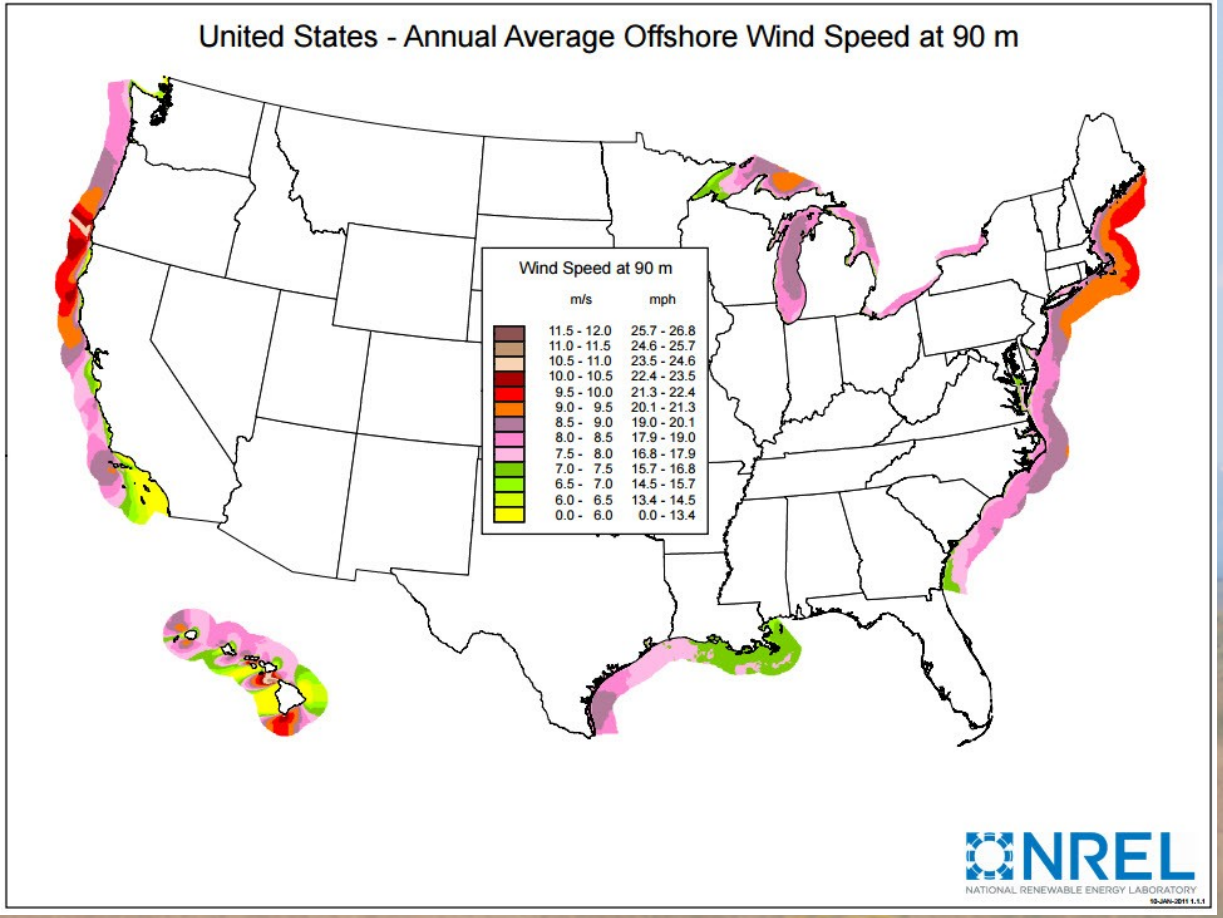
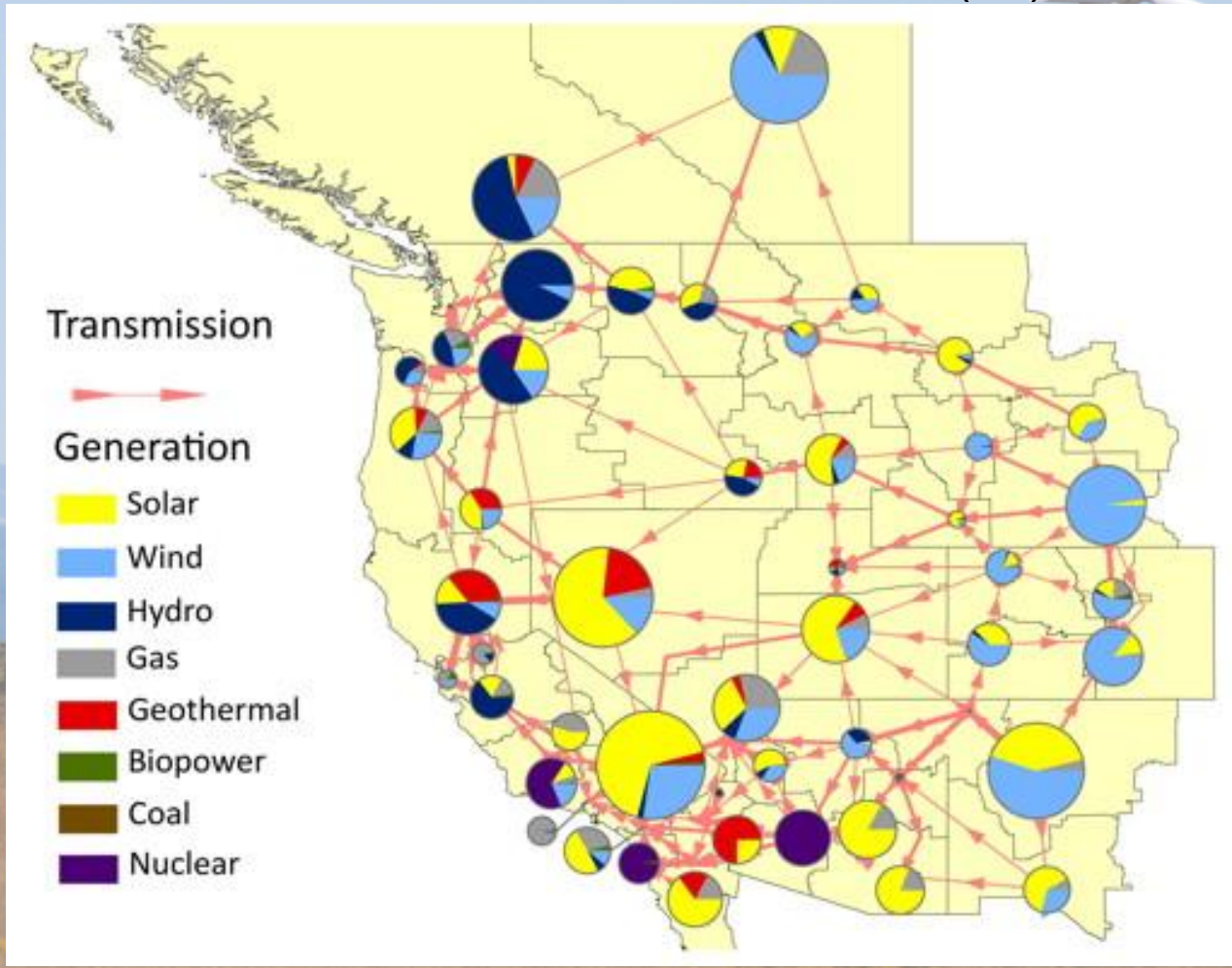


What is Happening with Wind in Wyoming? Transmission Development

Environ. Sci. Technol., **2013**, *47* (16)

- **Transmission Development is Key for Wyoming Wind Development**
  - Wyoming is a net exporter of electricity
    - **Wyoming is at Eastern edge of Western Interconnect**
    - **Load is primarily on West Coast**
  - Transmission lines have been near capacity
    - **New development required**
    - **Transmission needed to get electricity from where the good resources are to where it is needed**



What is Happening with Wind in Wyoming? Transmission Development

- **New WY Transmission**
  - Transwest Express
    - **600 kV DC**
    - **3000 MW**
    - **2020**
  - Gateway West
    - **500 kV AC**
    - **3000 MW**
    - **2019-2021**
  - Gateway South
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    - **1500 MW**
    - **2020-2024**

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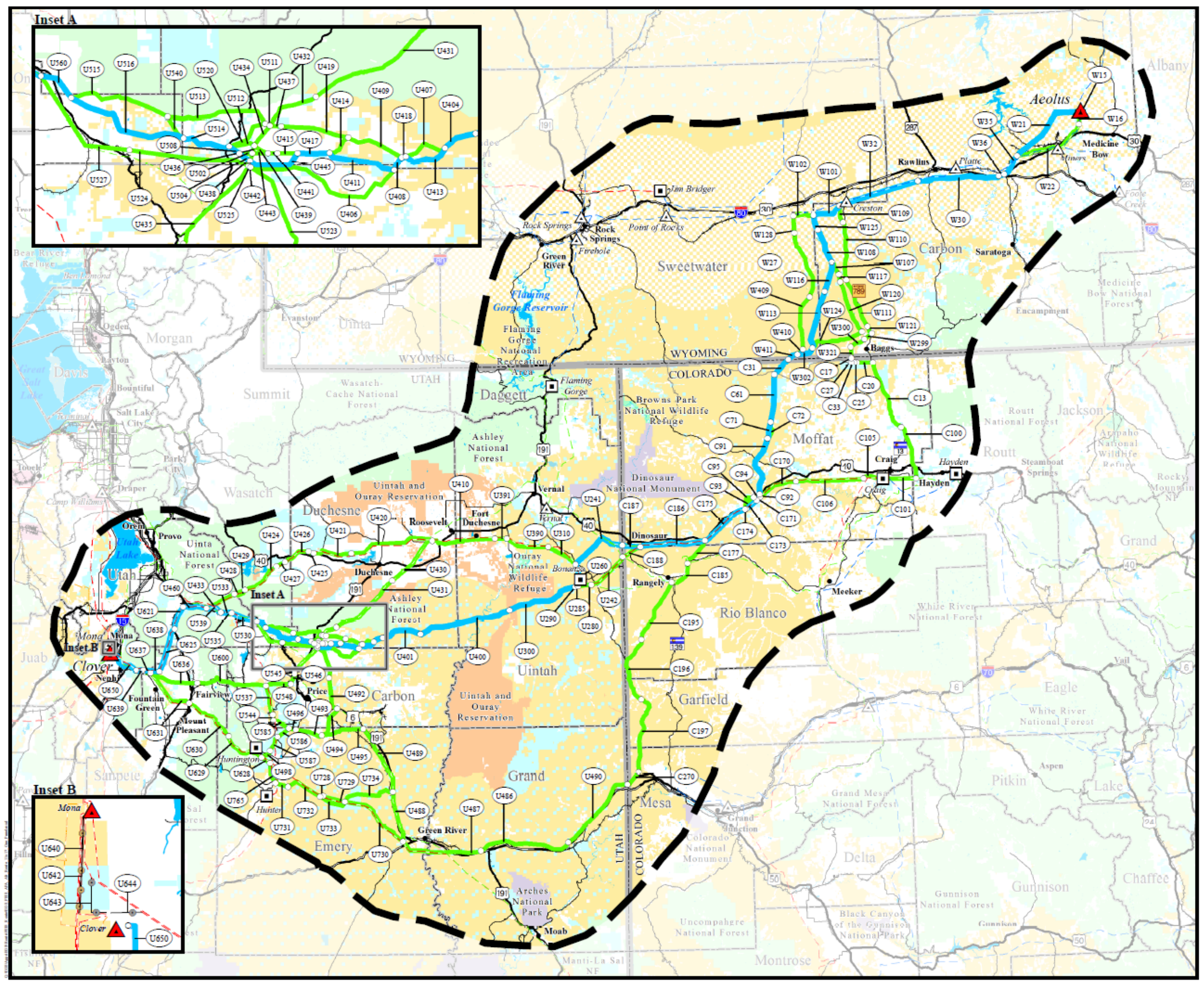
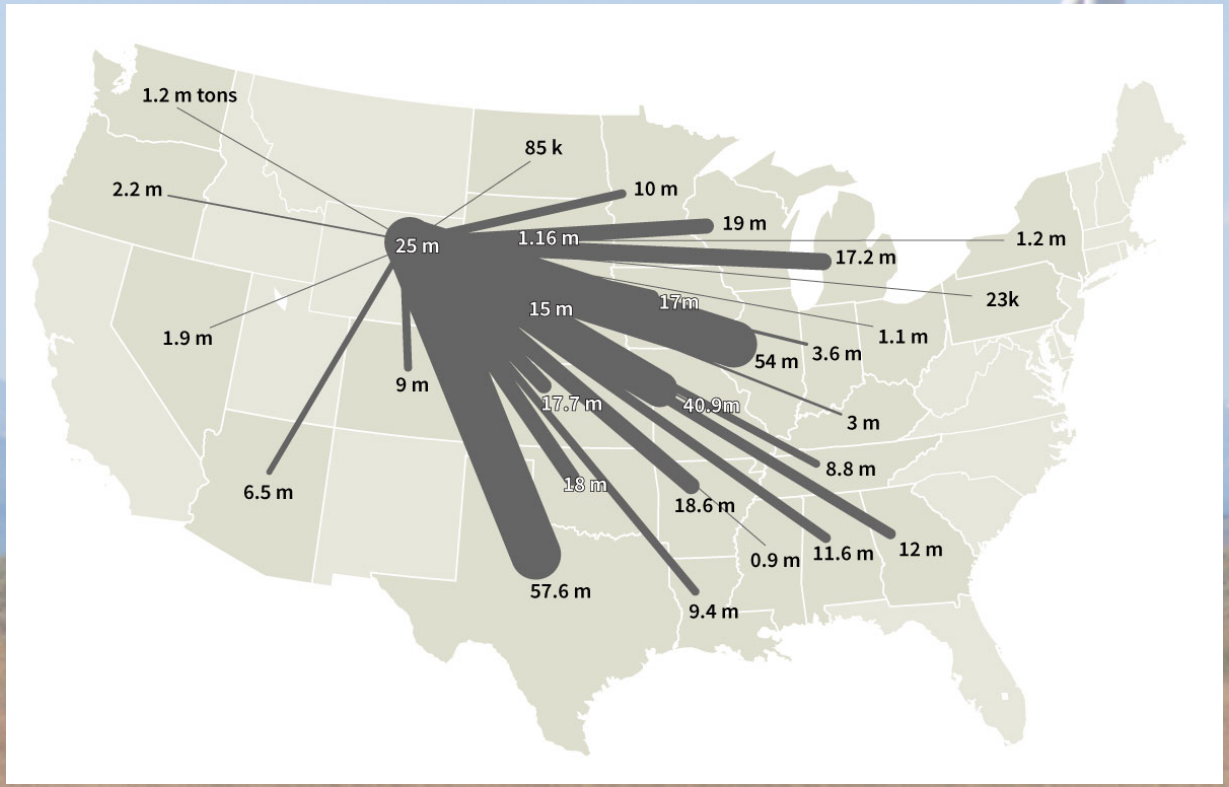


What is Happening with Wind in Wyoming?
WY Wind Development Effect on WY Coal

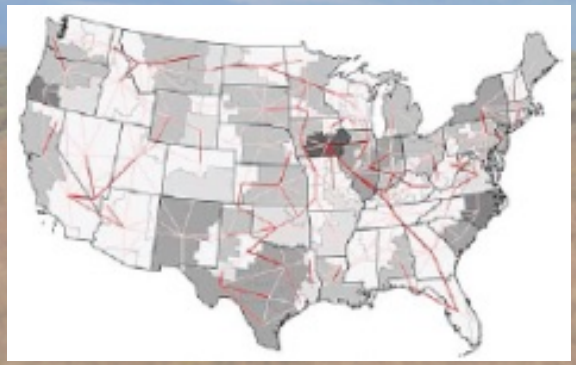
- **Wyoming Coal Use**
  - 93% of coal is exported from Wyoming
    - **Primarily ships East**
    - **Wyoming is on Western Interconnect**
  - 4% of coal used to generate electricity for export
    - **Ships both East and West**
- **What Affects WY Coal Demand?**
  - What other locations decide to use for generating electricity
- **Not developing WY wind resources simply encourages other places to do so**

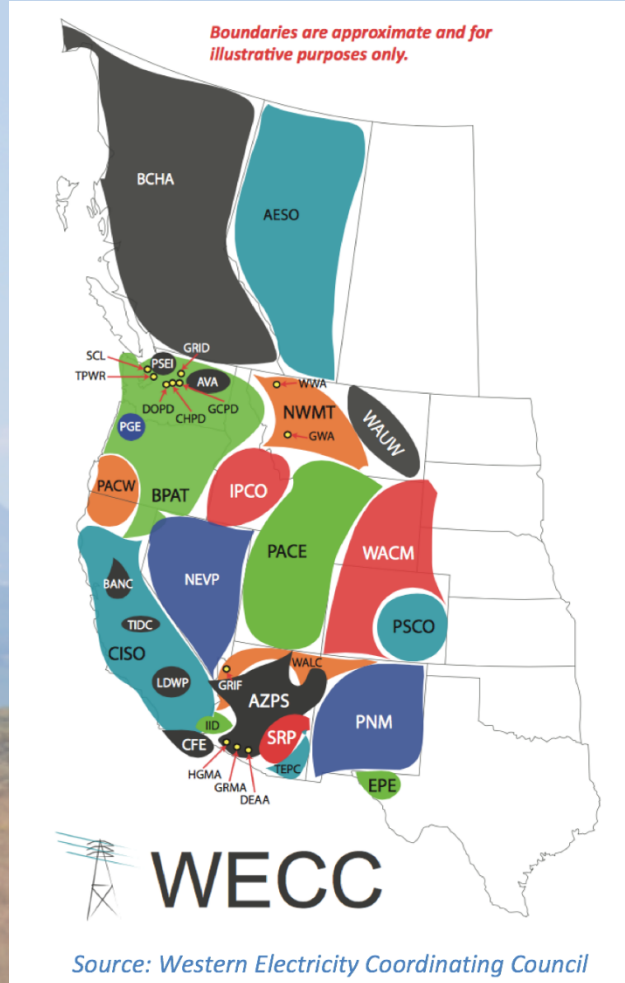


INTEGRATION OF RENEWABLES

Integration of Renewables
The Challenges

- **Addition of wind and solar put new demands on the power system**
- **Solution has multiple components**
  - Incorporate larger balancing areas
  - Identify transmission additions needed to move power around
  - Incentivize a change in electrical consumption habits
  - Add storage





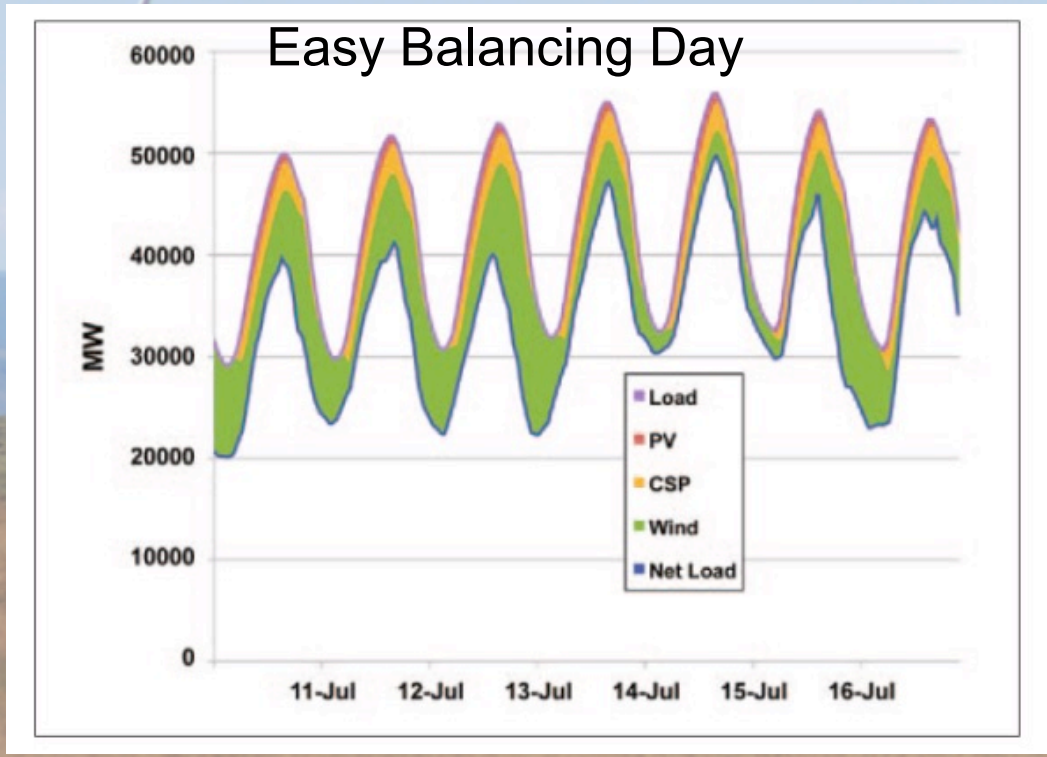
Source: Western Electricity Coordinating Council

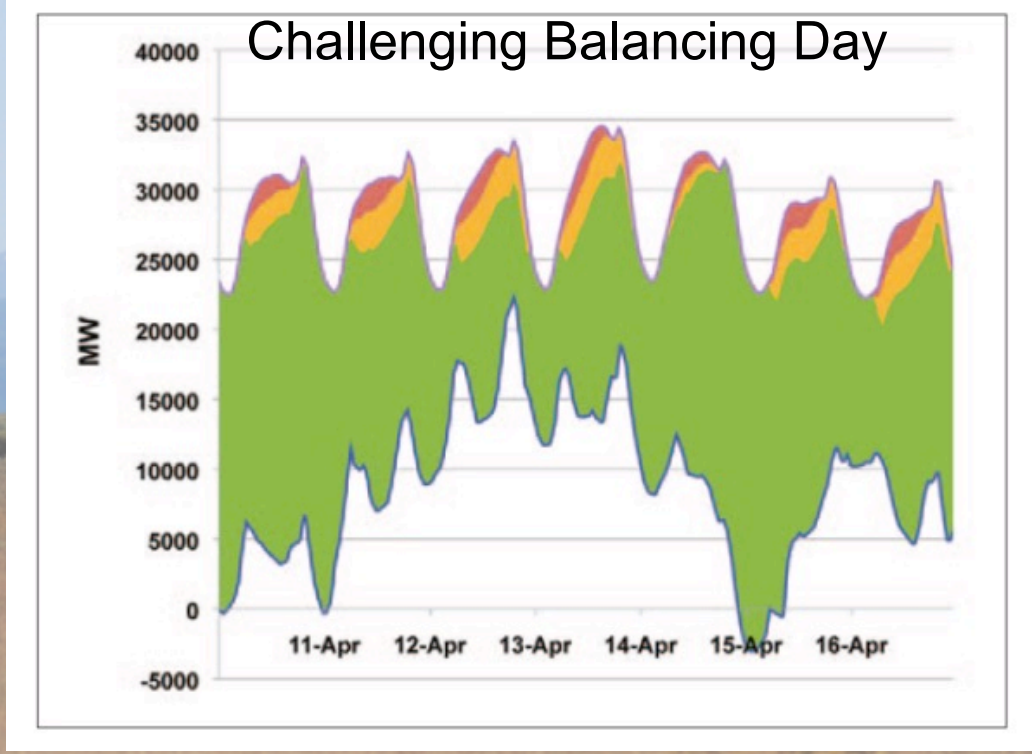
Figure 2. Thirty-eight Western BAs

Integration of Renewables
The Challenges

- **As renewables are added to the grid, balancing becomes more demanding**

Western Wind and Solar Integration Study
NREL 2010

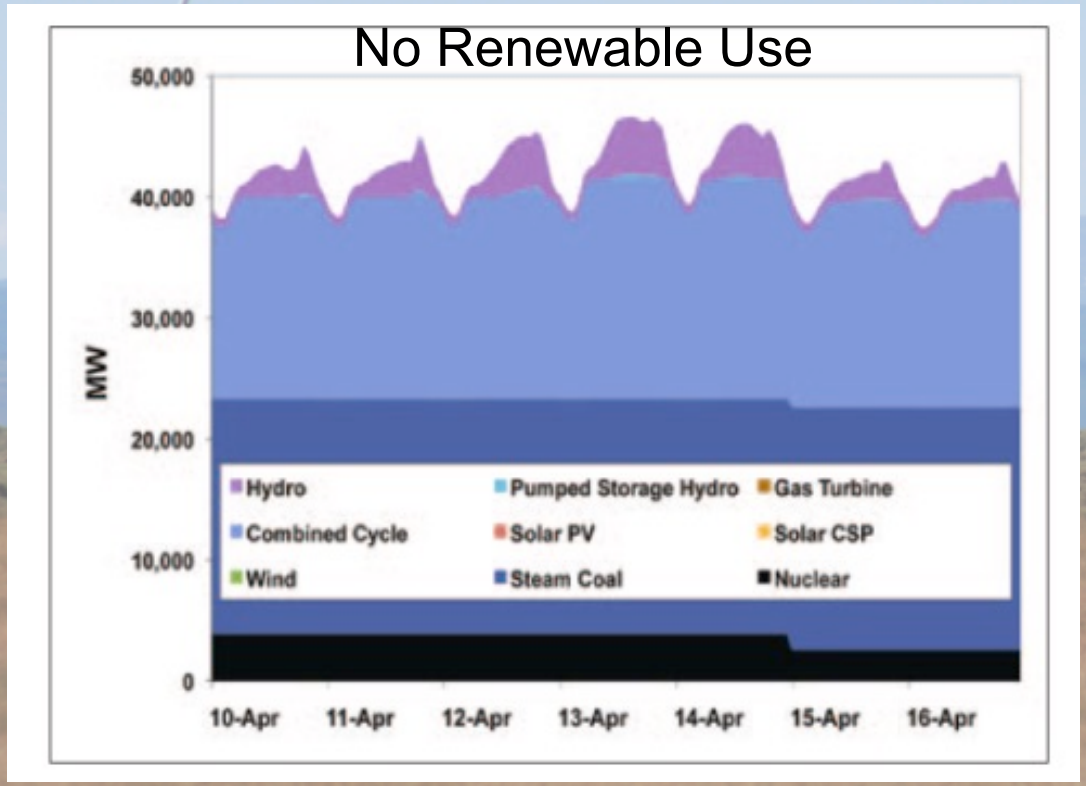


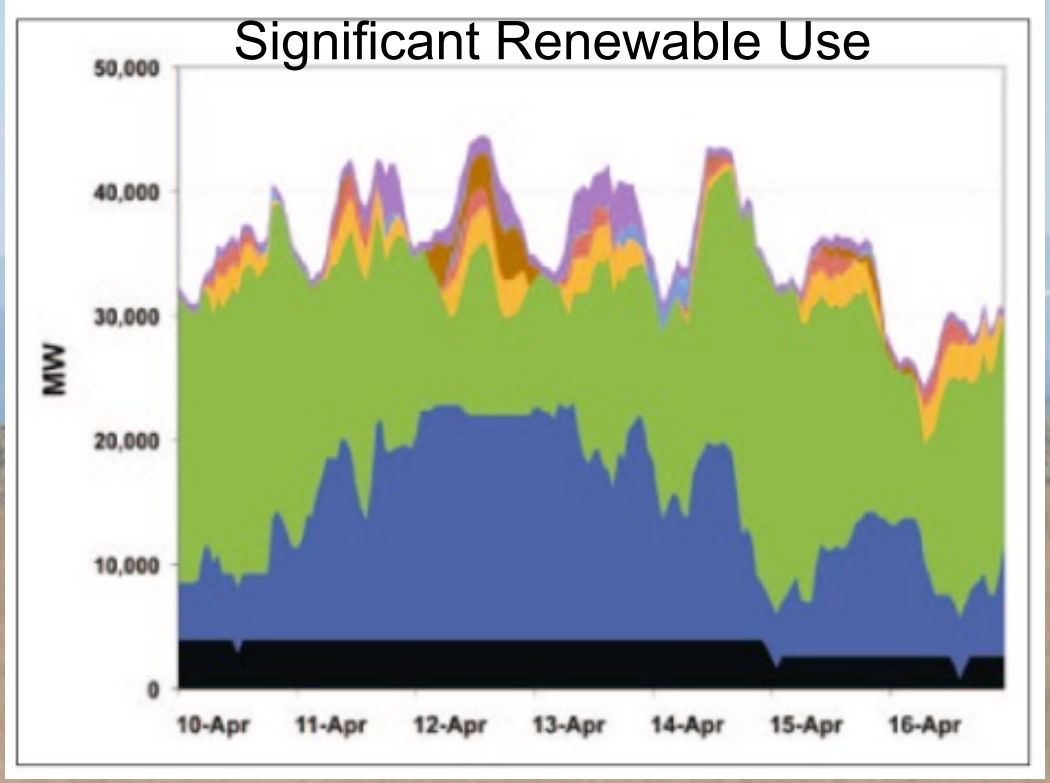


Integration of Renewables
The Challenges

- **This puts demands on the resources that have conventionally been used**

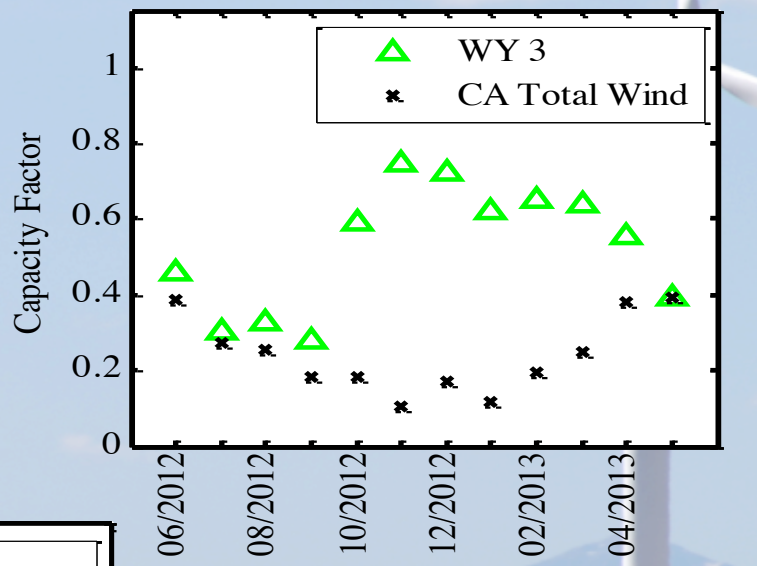
Wester Wind and Solar Integration Study
NREL 2010

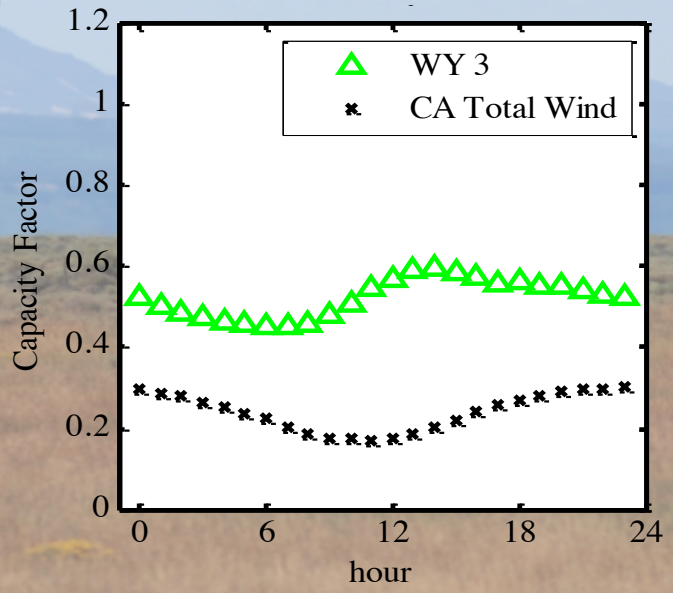




Integration of Renewables Overcoming the Challenges

- **Larger Balancing Areas**
  - Facilitates use of renewables
  - Renewable resource at widely separated location is rarely showing similar trends
    - **Geographic Diversity**
    - **One area has low production from renewables can import renewable power from another part of the system**
  - Allows for optimization of the system
    - **Locate production where the best resources are**
    - **Develop transmission where needed**





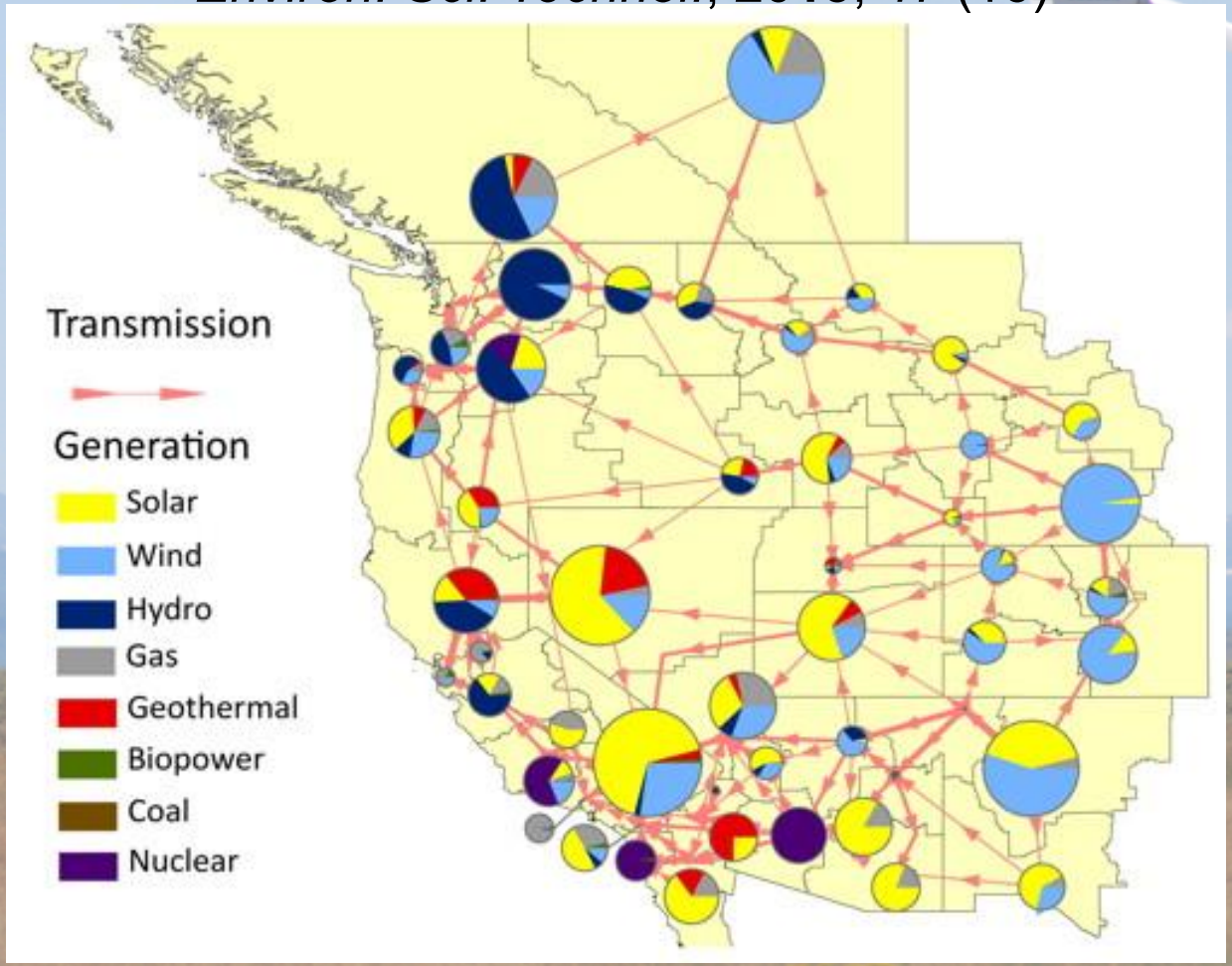
Wind Diversity Enhancement of Wyoming/California Wind Energy Projects: Phase 2 WIA Report

Integration of Renewables Overcoming the Challenges

- **Adding Transmission**
  - For large scale penetration of renewables, power must be able to move around
    - **Always better to use power as it is produced**
    - **Allows for taking advantage of geographic and resource diversity**

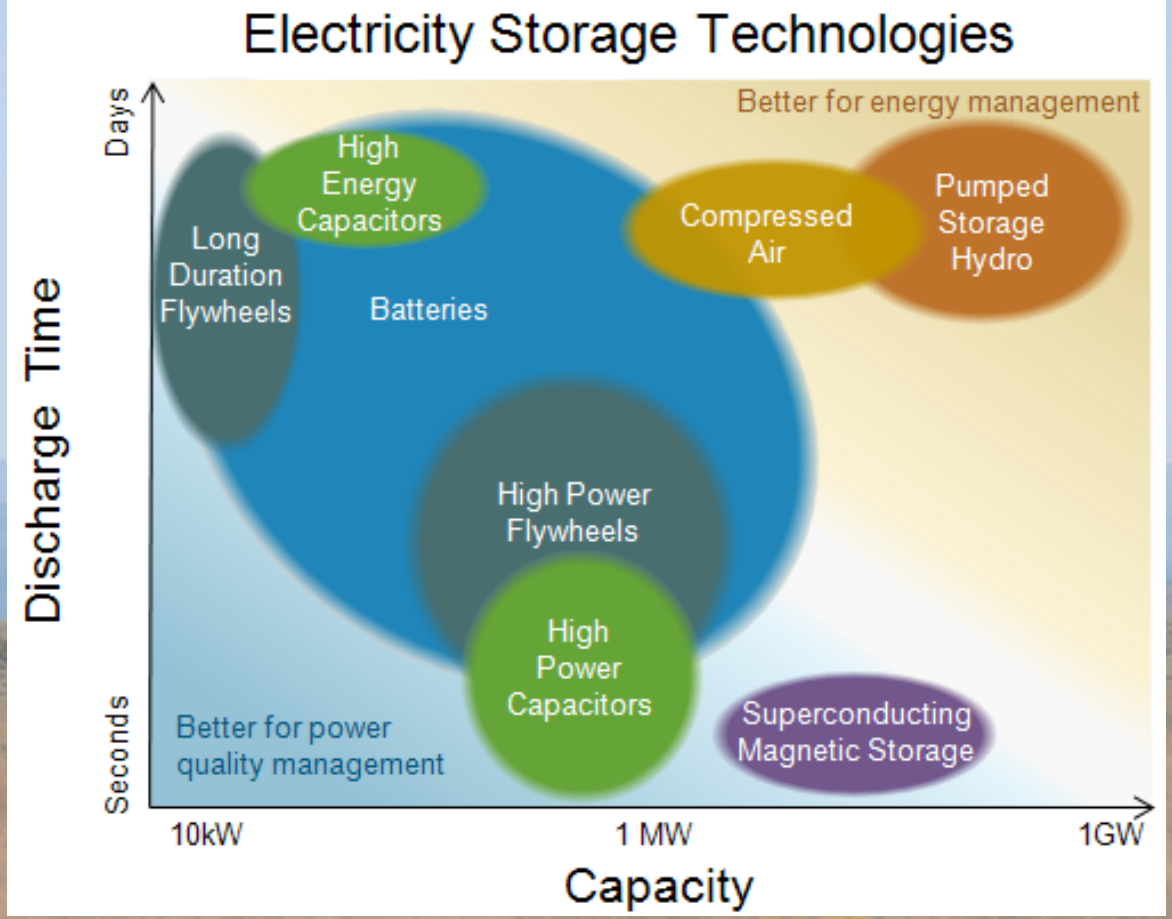
- **Incentivize a change in electrical consumption habits**
  - Demand response
  - When production is low, incentivize reducing power use
  - When production is high, incentivize power use

Environ. Sci. Technol., **2013**, *47* (16)



Integration of Renewables
Develop Grid Scale Storage Technology

- **Once all other approaches have been used, then add storage**
  - Significantly reduces amount of storage needed
    - **Storage is expensive**
    - **Storage has limitations**
- **Storage is used for different purposes**
  - Power quality management
  - Energy management
- **A limited number of options exist**
  - Energy management becomes important as renewable energy penetration grows



Integration of Renewables Overcoming the Challenges

- **Example – Mid American Energy**
  - Development
    - **2004**
      - 70% Coal
      - 0% Wind
    - **2016**
      - 46 % Wind
      - 31% Coal
    - **Wind XI**
      - 2000 MW
      - When complete 89% Wind

MidAmerican ENERGY

  - Future
    - **100% Renewables**
  - Critical Factors
    - **Part of MISO**
    - **Effective transmission and diverse renewables**

FINAL THOUGHTS

Final Thoughts

- **The time appears right for wind and transmission development in Wyoming**
  - Development must be done carefully, but wind energy offers a significant economic impact to counties and the State
  - Putting off development here will not stop the development of wind at this point – only leave Wyoming out of the development
- **The greater economic impact may come from the other economic development that inexpensive electricity may inspire**
  - Electricity-intensive industry

QUESTIONS?