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November 8, 2016

MEMORANDUM

TO: **Power Committee**

FROM: **Gillian Charles, Energy Policy Analyst**

SUBJECT: **Update on Wind Technology and Development Trends**

BACKGROUND:

Presenter: Gillian Charles

Summary: After significant development of wind power in the region over the past decade, a lull in development followed the boom in 2012. As utilities are on track to meet their near-term renewable portfolio standards obligations, the load forecast is projected to be fairly flat going forward, and the cost of solar photovoltaics has dropped significantly, what opportunities remain for wind power in the region?

This presentation will summarize the history of wind power in the US and region, and introduce new technological enhancements and cost reductions in equipment. In addition, staff will discuss what the future of wind development could look like in the region.

Relevance: The Council is continuously monitoring and tracking developments in existing and emerging technologies. This information is particularly important when preparing and developing the generating resource assumptions for the power plan.

Workplan: Power Division Work Plan. C.4. Prepare for the Eighth Plan; Generation Resources

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Update on Wind Technology and Development Trends

Gillian Charles

Power Committee

November 15, 2016

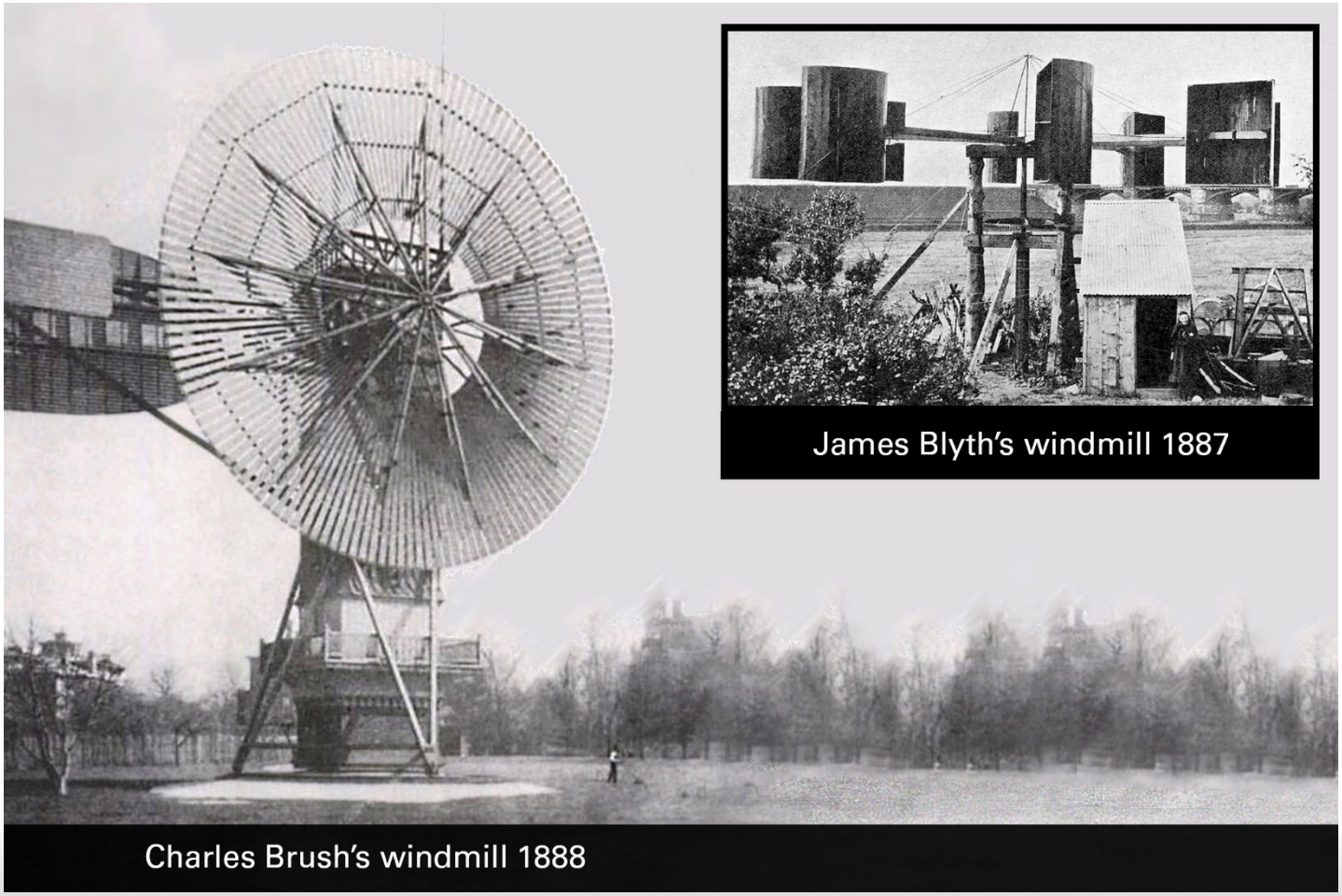
Outline

- Historical wind development trends in the region and nation
- Wind technology advances
- Looking forward – what can we expect in terms of cost and development?
- New development opportunities – repowering existing wind projects

Tucannon Wind Farm. Source: PGE Flickr

WIND POWER HISTORY AND DEVELOPMENTS TO-DATE

First wind turbines built to produce electricity in the 1880's



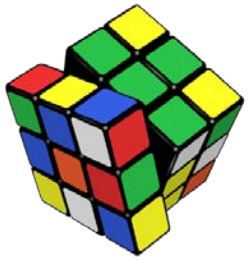
1900's

1900's – Small, solo wind turbines used in isolated cases

1941 – Smith-Putnam 1.25MW in Vermont; operated for 1100 hrs*

1970's – Oil and gas prices climb sharply as shortages occur, creating renewed interest in alternative energy sources, e.g. wind

1978 – Public Utility Regulatory Policies Act (PURPA) signed



1980's and 1990's

1980 – First wind farm built in US in New Hampshire (30 turbines, 600kw plant)

Mid 1980's – Government & industry work together to advance large turbine technology; Utility-scale wind developed in California

Late 1980's – Price of oil lowers so that wind power becomes uneconomical and development slows

1992 – Production Tax Credit (under the Energy Policy Act of 1992) adopted

Late 1990's – Renewable portfolio standards developed in several states

2000's

2000's – Expansions in technology, integration, and mitigation

2005 – Energy Policy Act signed

2006 – Wind development in US tops 10,000 MW capacity

2008 – … tops 20,000 MW capacity

2009 – American Recovery and Reinvestment Act (ARRA) signed

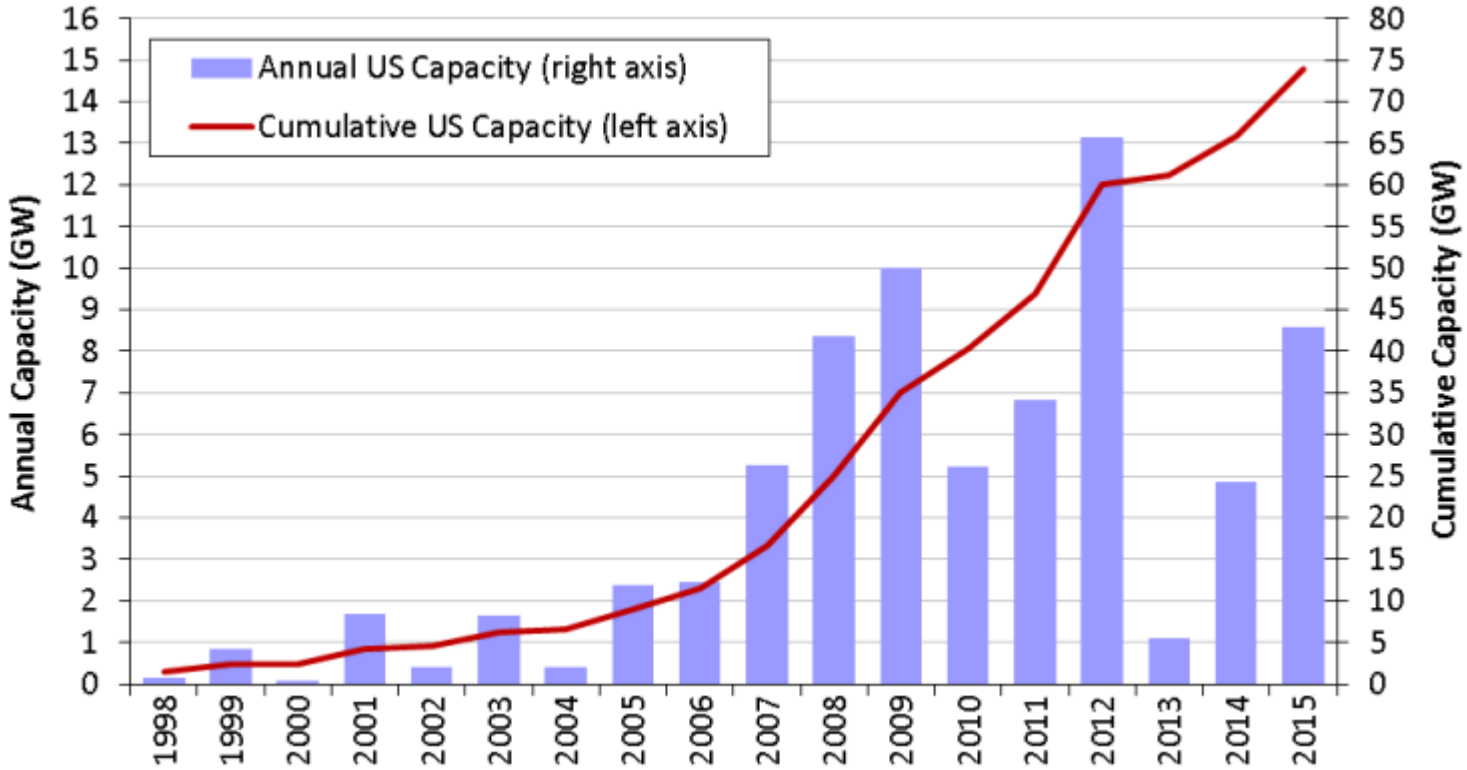
2012 - … tops 60,000 MW capacity

*History developed from the American Wind Energy Association

Today

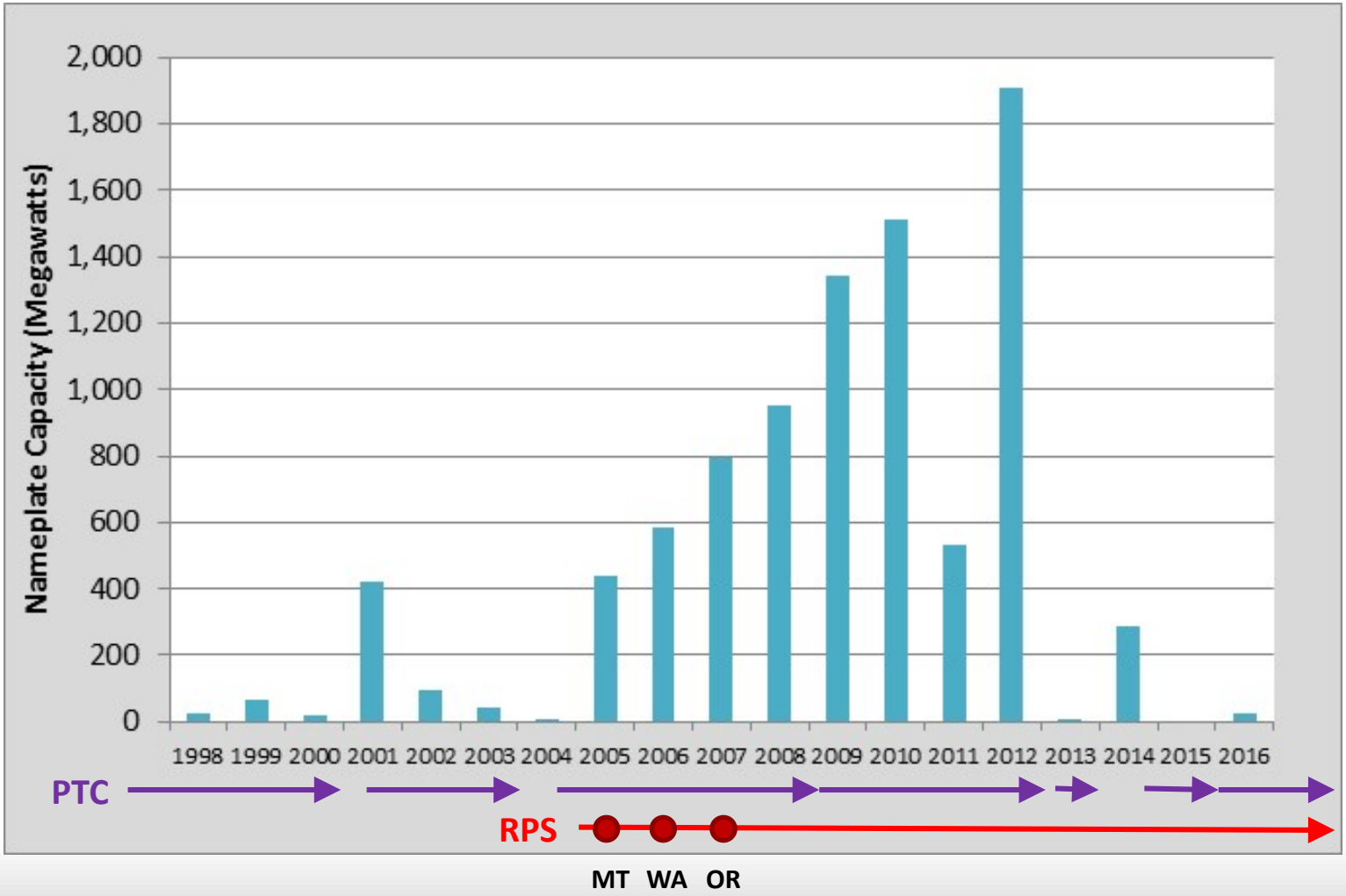
- Wind power provides about 5% of the electricity delivered to the US grid
  - Over 75,000 MW installed in US
- Local manufacturing – about 70% of a wind turbine is manufactured in the US
  - ~550 manufacturing facilities across US

Despite drop off in 2013, US wind development is up again in 2014 and 2015

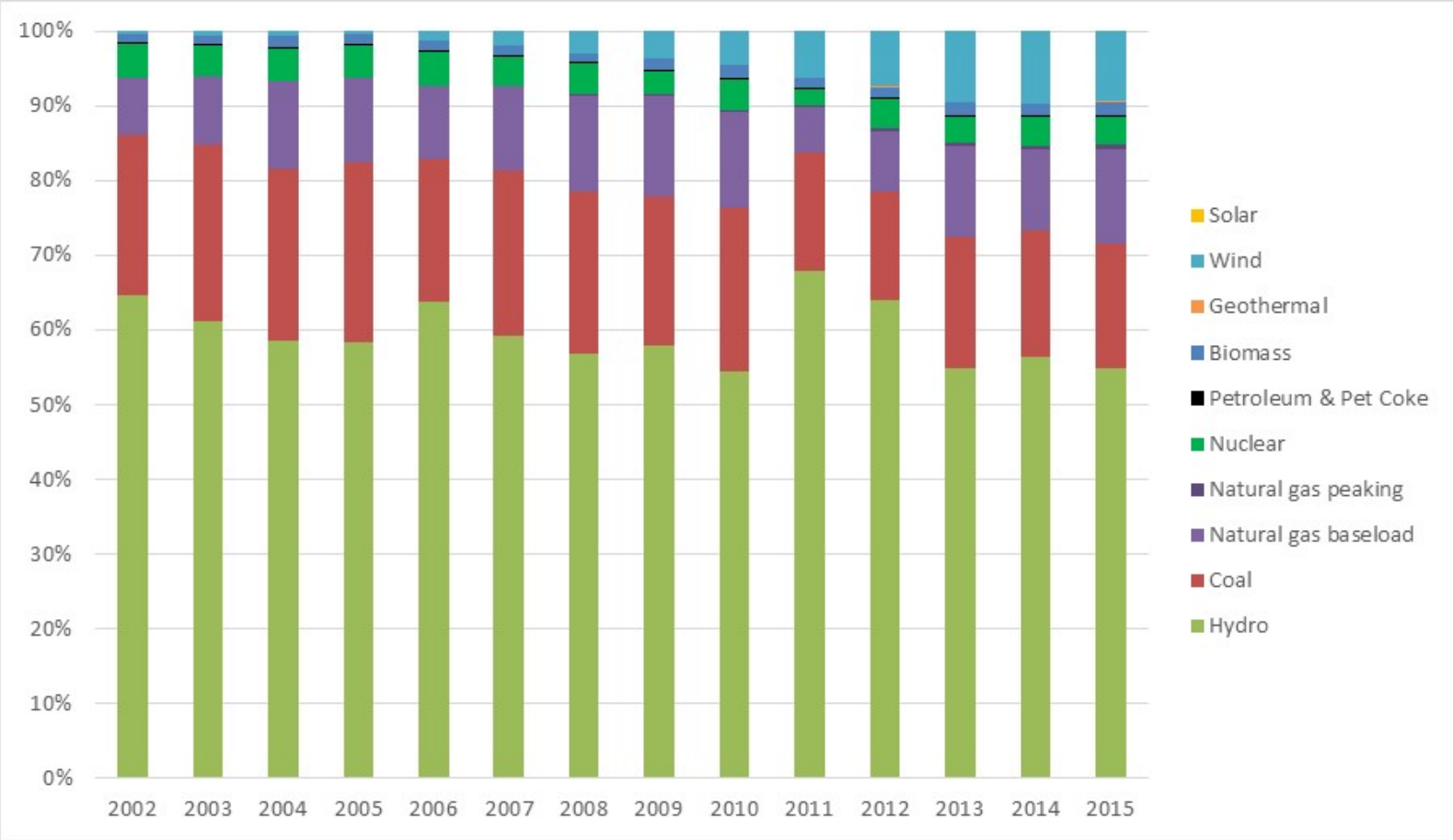


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

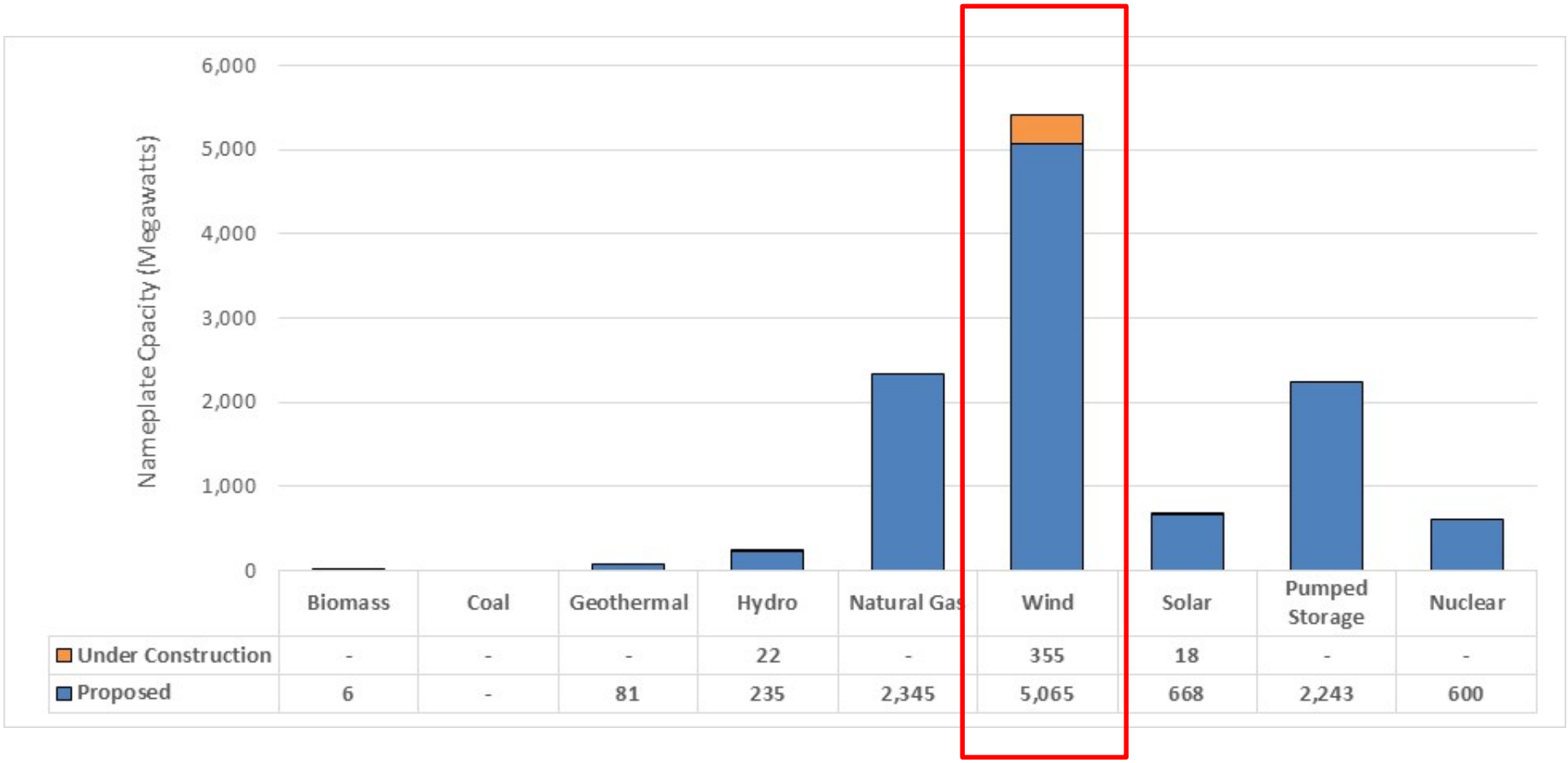
In the region, same drop off in 2013 but with little development since



Wind's contribution to regional annual generation has grown to about 10%



How much wind is under construction and proposed in the region?



	Biomass	Coal	Geothermal	Hydro	Natural Gas	Wind	Solar	Pumped Storage	Nuclear
Under Construction	-	-	-	22	-	355	18	-	-
Proposed	6	-	81	235	2,345	5,065	668	2,243	600

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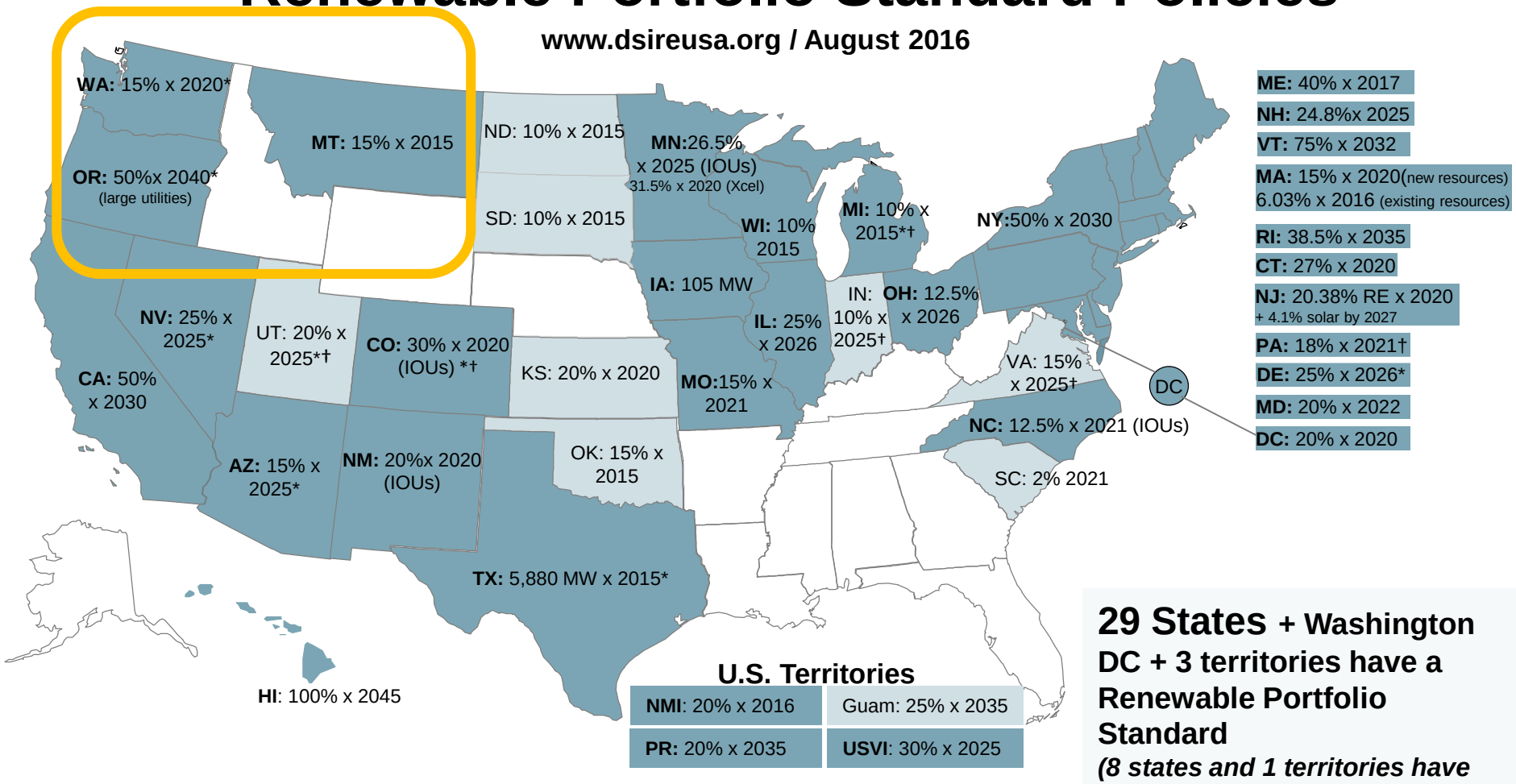
Renewable Portfolio Standard Policies

www.dsireusa.org / August 2016



ME: 40% x 2017
NH: 24.8%x 2025
VT: 75% x 2032
MA: 15% x 2020(new resources) 6.03% x 2016 (existing resources)
RI: 38.5% x 2035
CT: 27% x 2020
NJ: 20.38% RE x 2020 + 4.1% solar by 2027
PA: 18% x 2021†
DE: 25% x 2026*
MD: 20% x 2022
DC: 20% x 2020

U.S. Territories

NMI: 20% x 2016	Guam: 25% x 2035
PR: 20% x 2035	**USVI**: 30% x 2025

29 States + Washington DC + 3 territories have a Renewable Portfolio Standard
(8 states and 1 territories have renewable portfolio goals)

Renewable portfolio standard
Renewable portfolio goal

* Extra credit for solar or customer-sited renewables
† Includes non-renewable alternative resources

Federal Tax Incentives: Wind

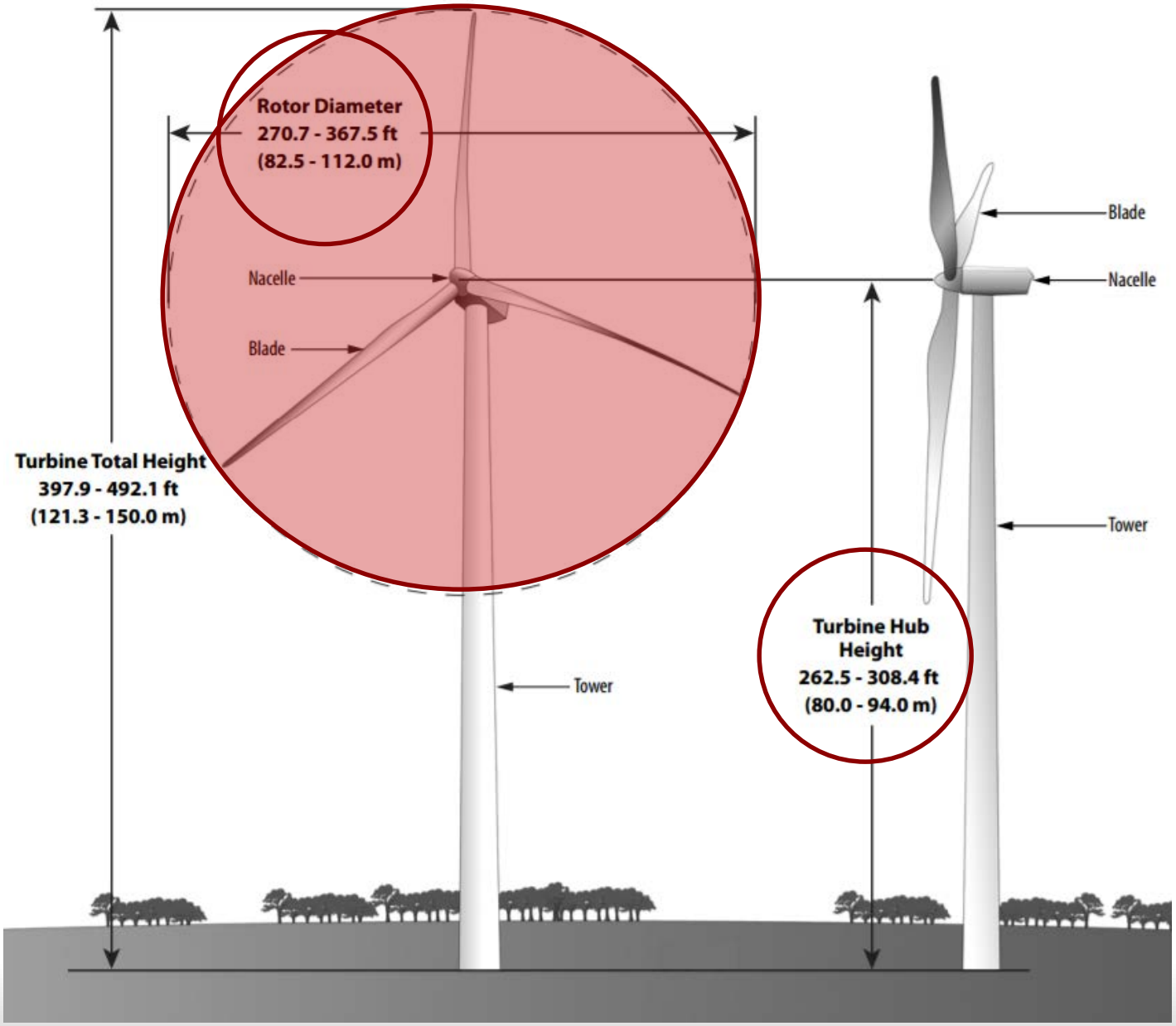
Production Tax Credit (PTC). Production-based income tax credit for kWh produced and sold in first 10 years of operation

- Credit amount begins to phase down after 2016, expires EOY 2019

Investment Tax Credit (ITC). Front-loaded tax incentive based on capital expenditures

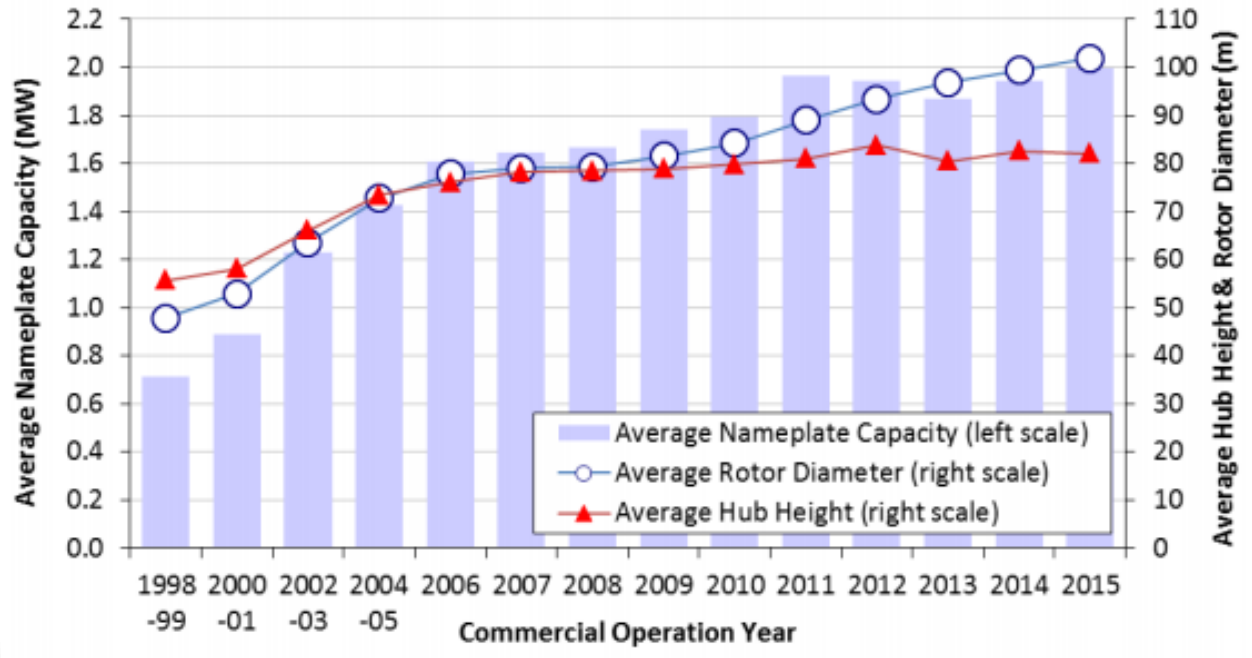
- Credit amount begins to phase down after 2016, expires EOY 2019

Both the PTC and ITC were extended long-term in 2015 through the Consolidated Appropriations Act


Rotor Diameter
270.7 - 367.5 ft
(82.5 - 112.0 m)
Nacelle
Blade
Turbine Total Height
397.9 - 492.1 ft
(121.3 - 150.0 m)
Tower
Blade
Nacelle
Tower
Turbine Hub Height
262.5 - 308.4 ft
(80.0 - 94.0 m)

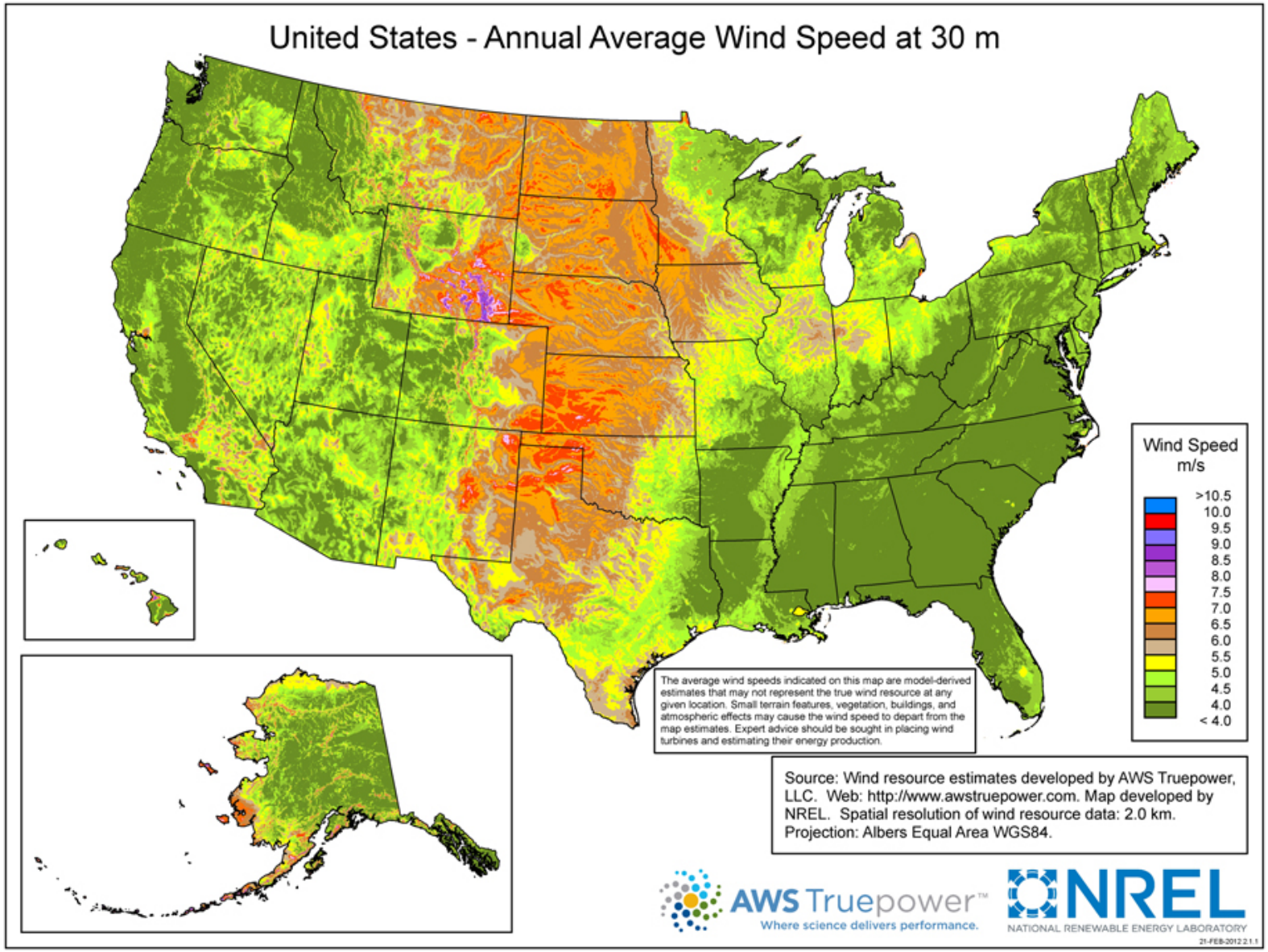
Wind technology updates (1)

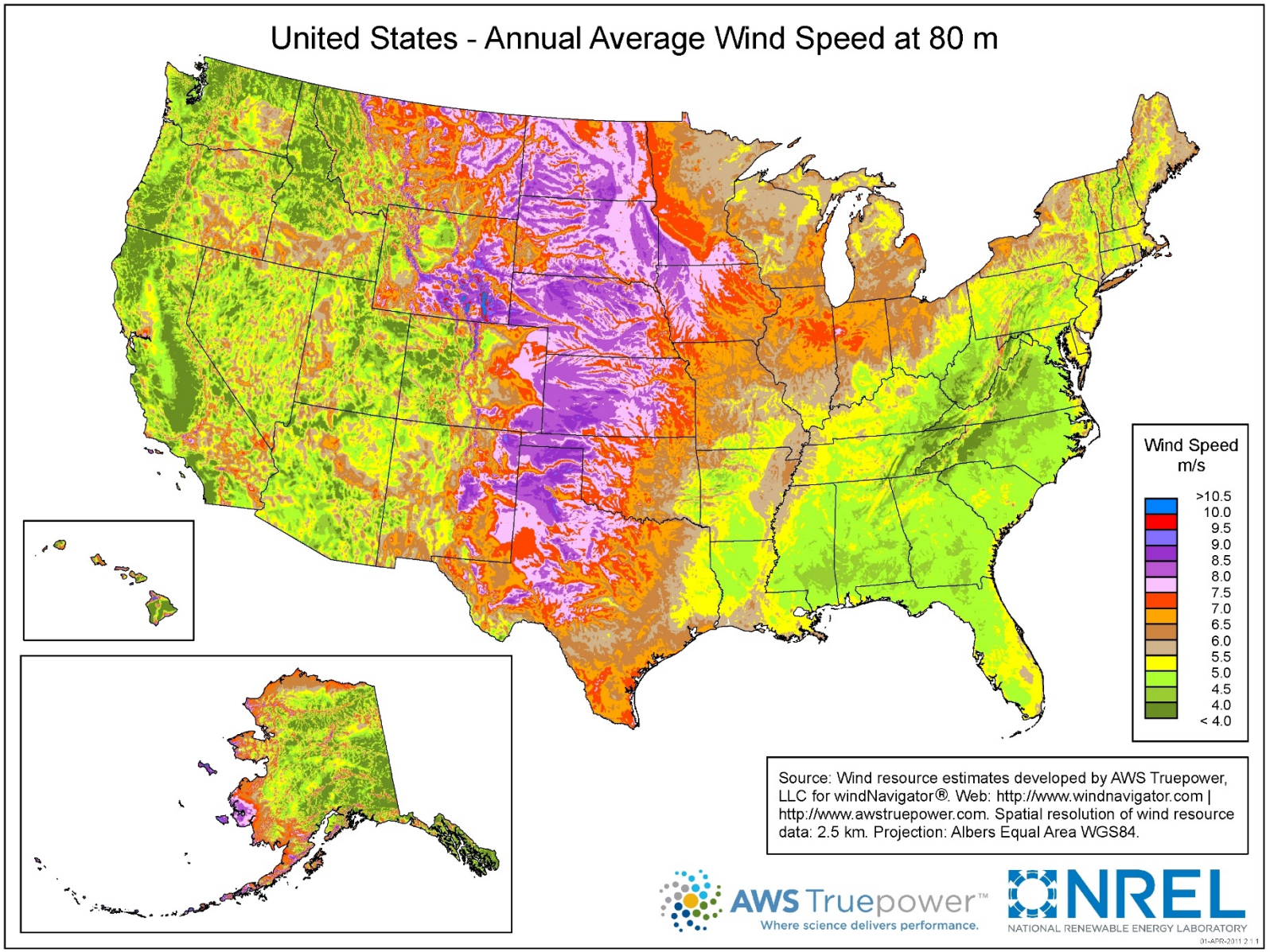
- Long-term growth in rotor diameter, hub height, and turbine nameplate capacity…

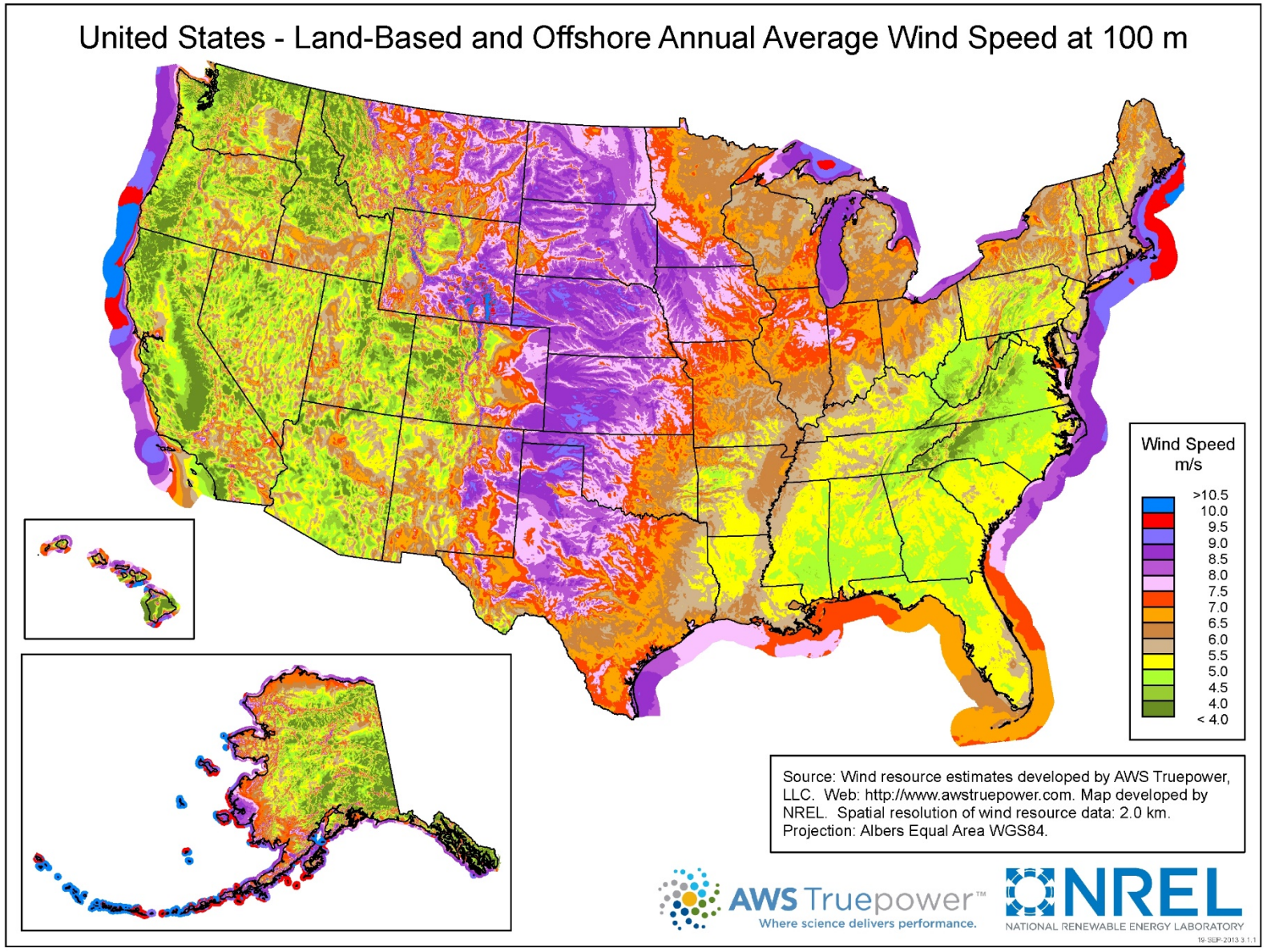


BERKELEY LAB

Graphic source: LBNL


United States - Annual Average Wind Speed at 30 m
Wind Speed
m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
The average wind speeds indicated on this map are model-derived estimates that may not represent the true wind resource at any given location. Small terrain features, vegetation, buildings, and atmospheric effects may cause the wind speed to depart from the map estimates. Expert advice should be sought in placing wind turbines and estimating their energy production.
Source: Wind resource estimates developed by AWS Truepower, LLC. Web: http://www.awstruepower.com. Map developed by NREL. Spatial resolution of wind resource data: 2.0 km. Projection: Albers Equal Area WGS84.
AWS Truepower™
Where science delivers performance.
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
21-FEB-2012 2.1.1


United States - Annual Average Wind Speed at 80 m
Wind Speed
m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: http://www.windnavigator.com | http://www.awstruepower.com. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.
AWS Truepower™
Where science delivers performance.
NREL
NATIONAL RENEWABLE ENERGY LABORATORY


United States - Land-Based and Offshore Annual Average Wind Speed at 100 m
Wind Speed m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truepower, LLC. Web: http://www.awstruepower.com. Map developed by NREL. Spatial resolution of wind resource data: 2.0 km. Projection: Albers Equal Area WGS84.
AWS Truepower™
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NREL
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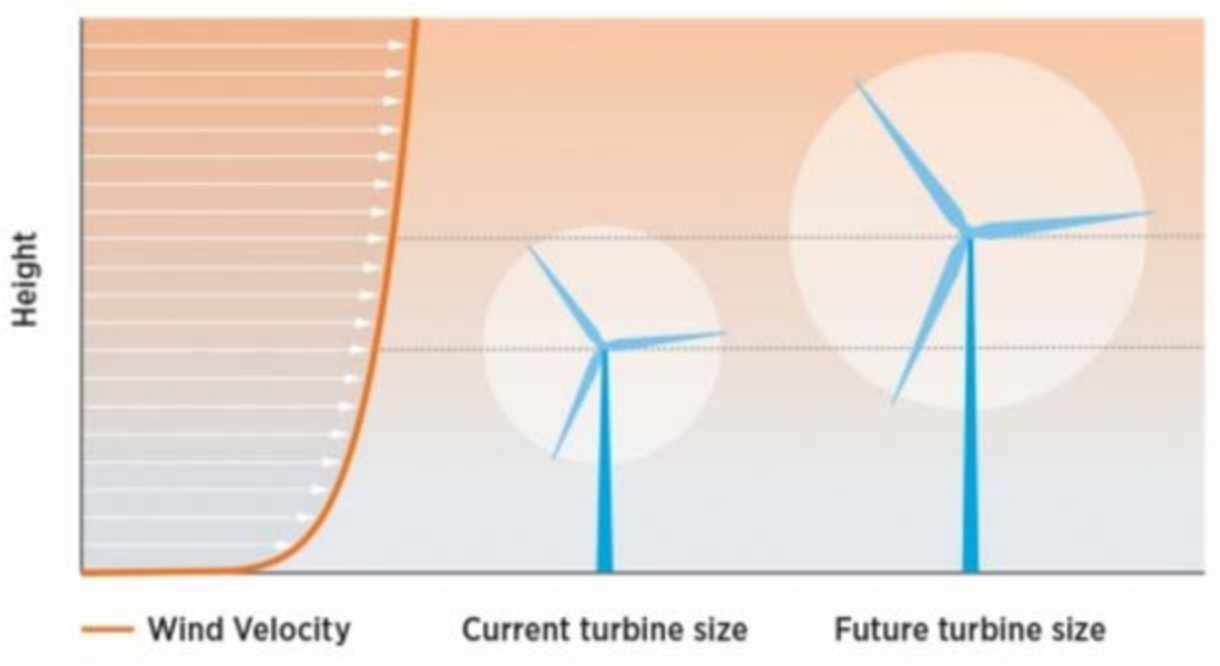
19-SEP-2013 3.1.1

Higher hub heights and greater rotor diameter unlock access to the higher velocity wind areas

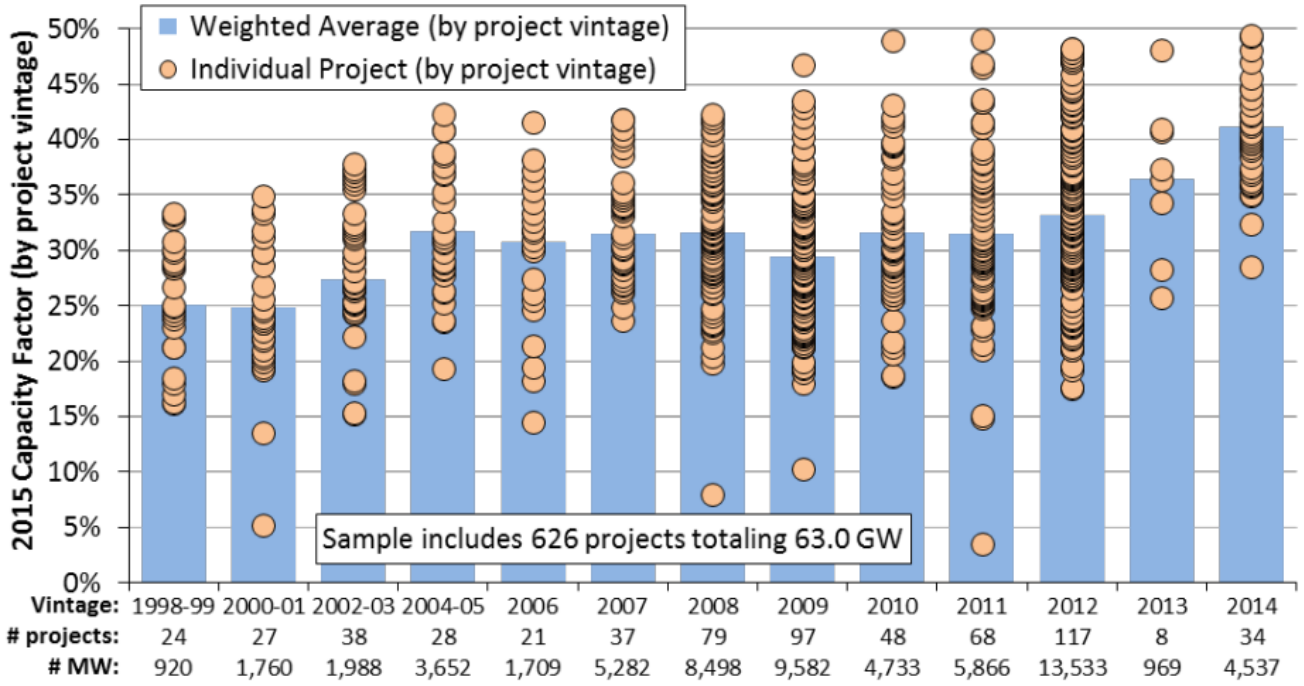


http://energy.gov/eere/articles/unlocking-our-nation-s-wind-potential

Graphic source: DOE

Wind technology updates (2)

- ...Lead to long-term grown in turbine capacity factors and performance



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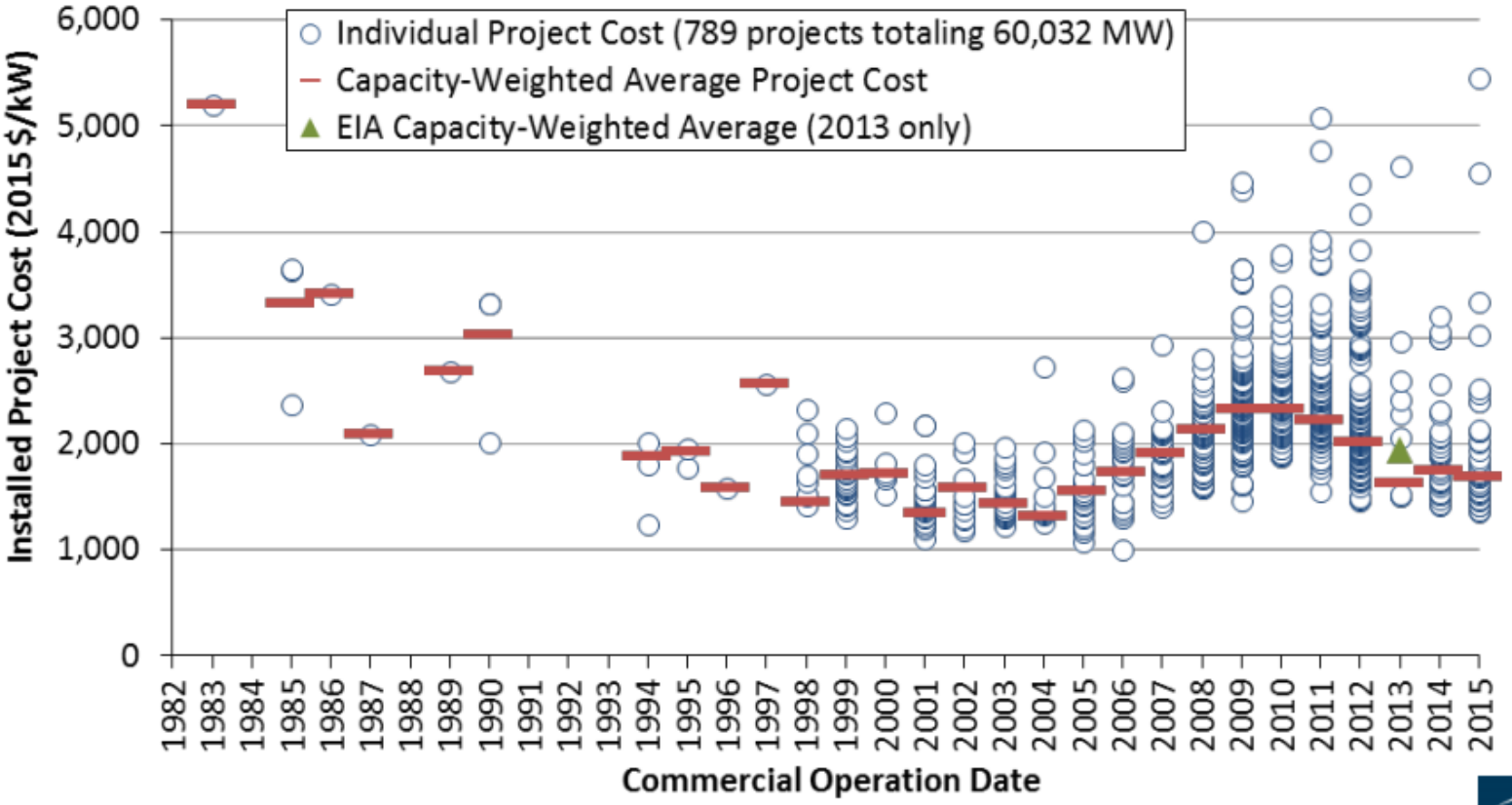
Graphic source: LBNL

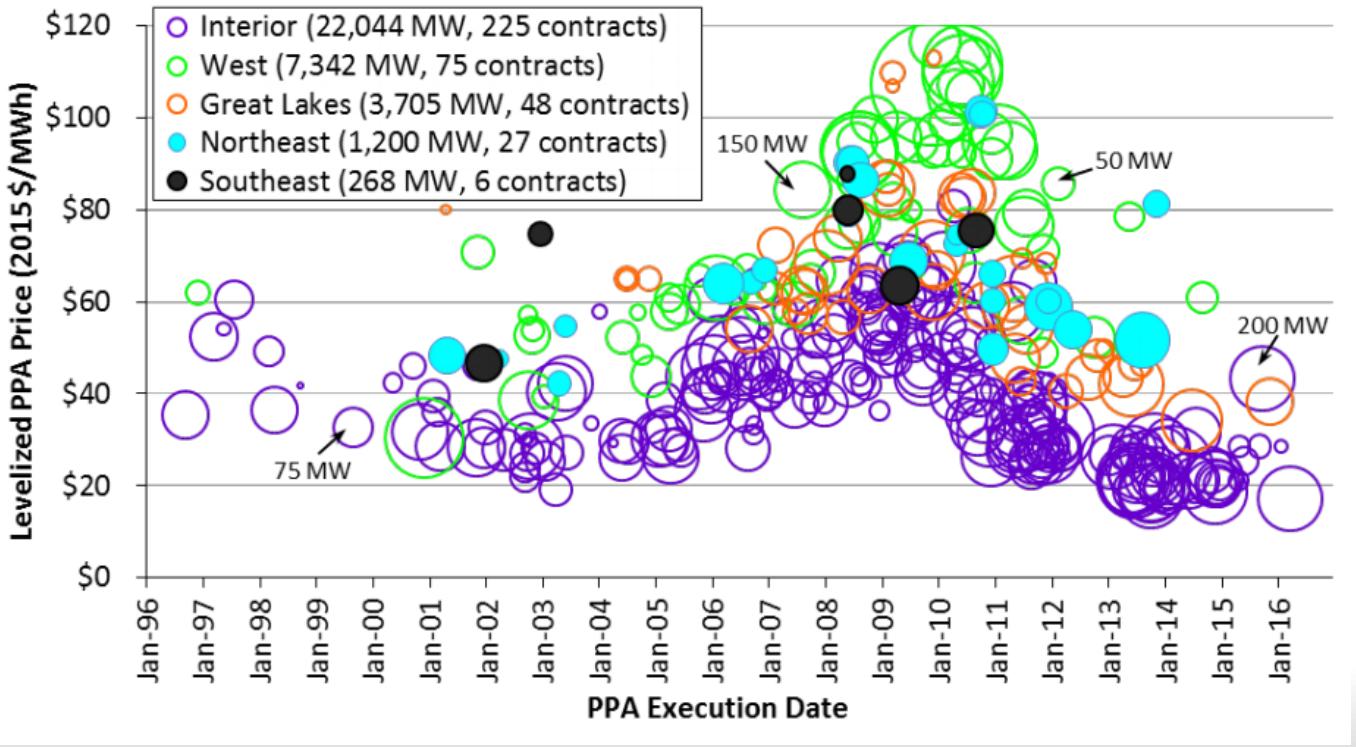
Capital cost of wind projects declining again after recession



Graphic source: LBNL

Power Purchase Agreements follow similar cost reduction pattern

- Lowest PPA prices are in the high wind resource areas of the US interior



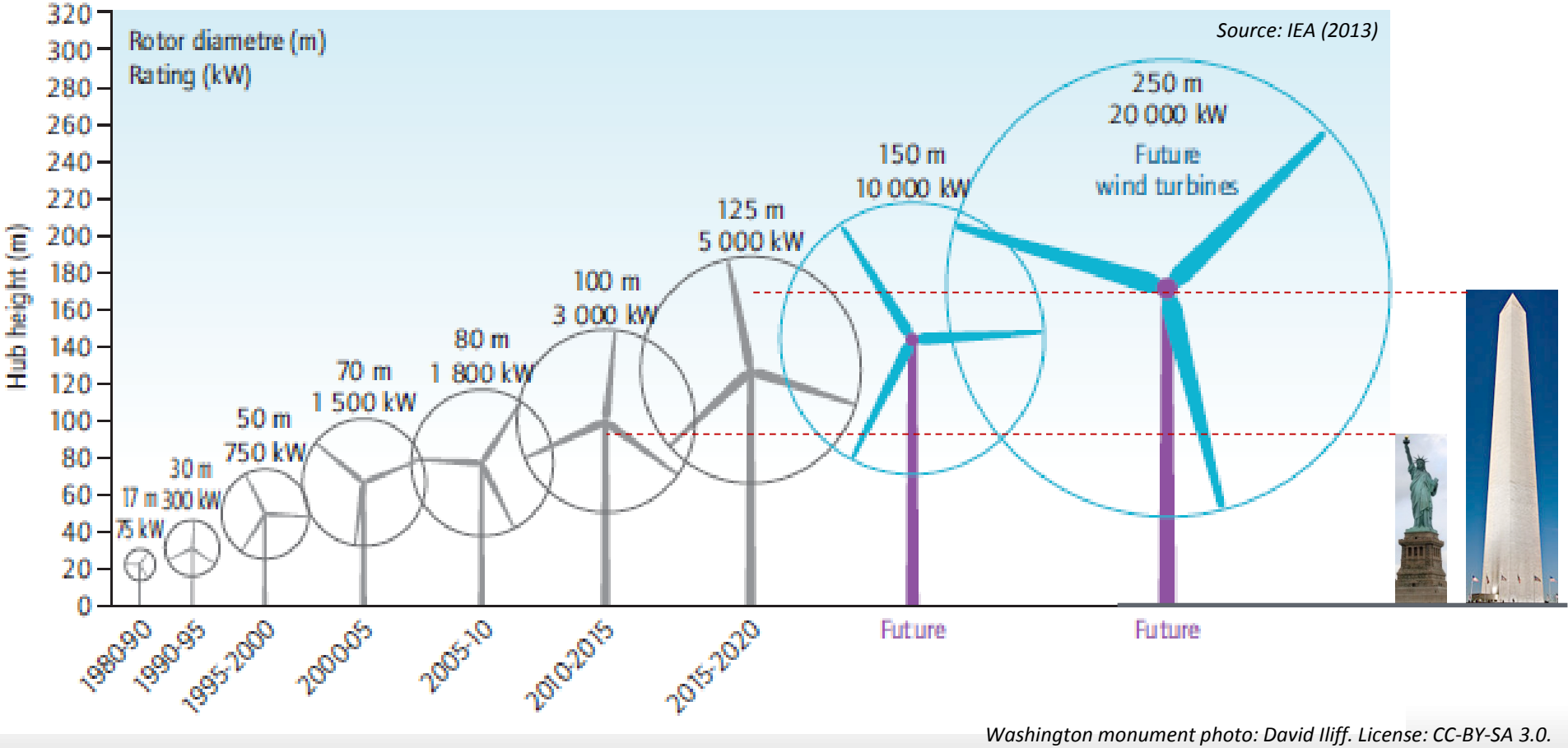
Graphic source: LBNL

Altaeros Energies, buoyant air turbine

WHAT'S NEXT?

University of Liverpool, solar-powered wind turbines

Hub heights and rotor diameters predicted to continue to increase

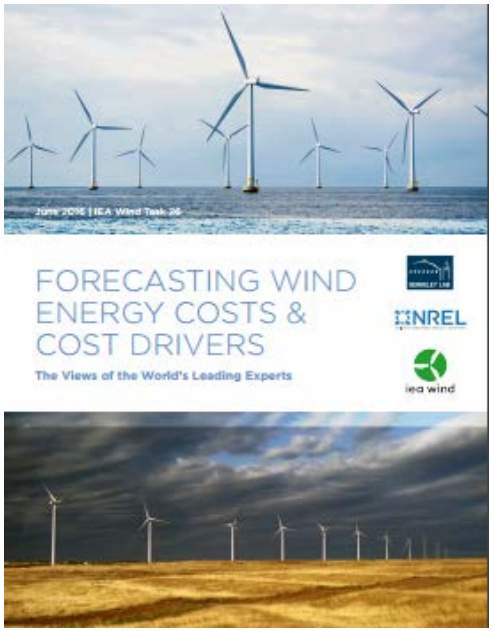


Washington monument photo: David Iliff. License: CC-BY-SA 3.0.
Statue of liberty photo: public domain

Graphic source: Sandia Wind Turbine Blade Workshop (2014)

LBNL and NREL 2016 Wind Cost and Cost Drivers Survey

- Expert elicitation survey of top leading wind technology experts worldwide
- Recognizing the technology innovations, cost reductions and policy contributions of the past, what can we expect for the future cost of wind?

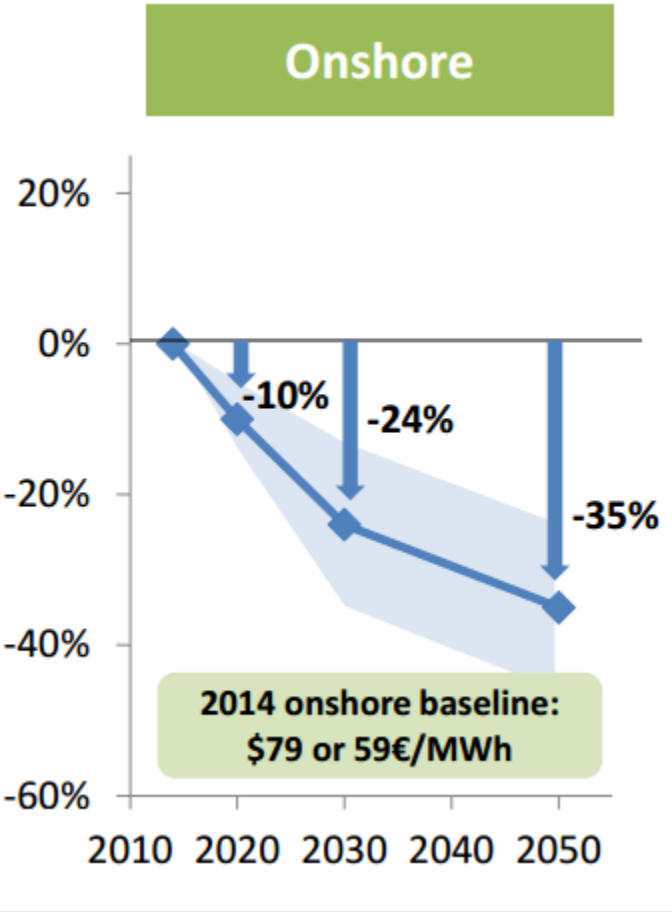


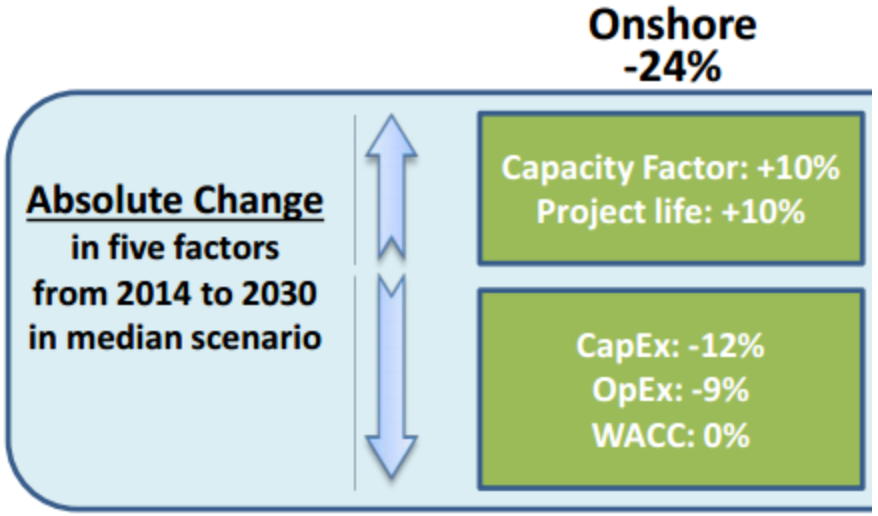
LBNL and NREL 2016 Wind Cost and Cost Drivers Survey

Future cost based on levelized cost of energy:

- Capital cost (CapEx)
- Fixed and variable O&M costs (OpEx)
- Weighted average cost of capitol (WACC)
- Capacity factor
- Economic life (Project life)

Results of survey: Costs predicted to continue to decline*



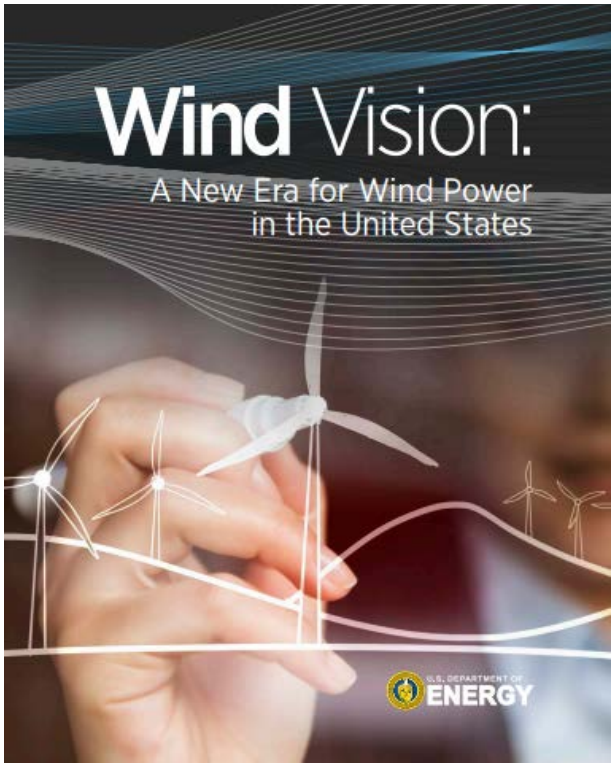


*Results of the median scenario. Experts were also asked to forecast a high and low scenario

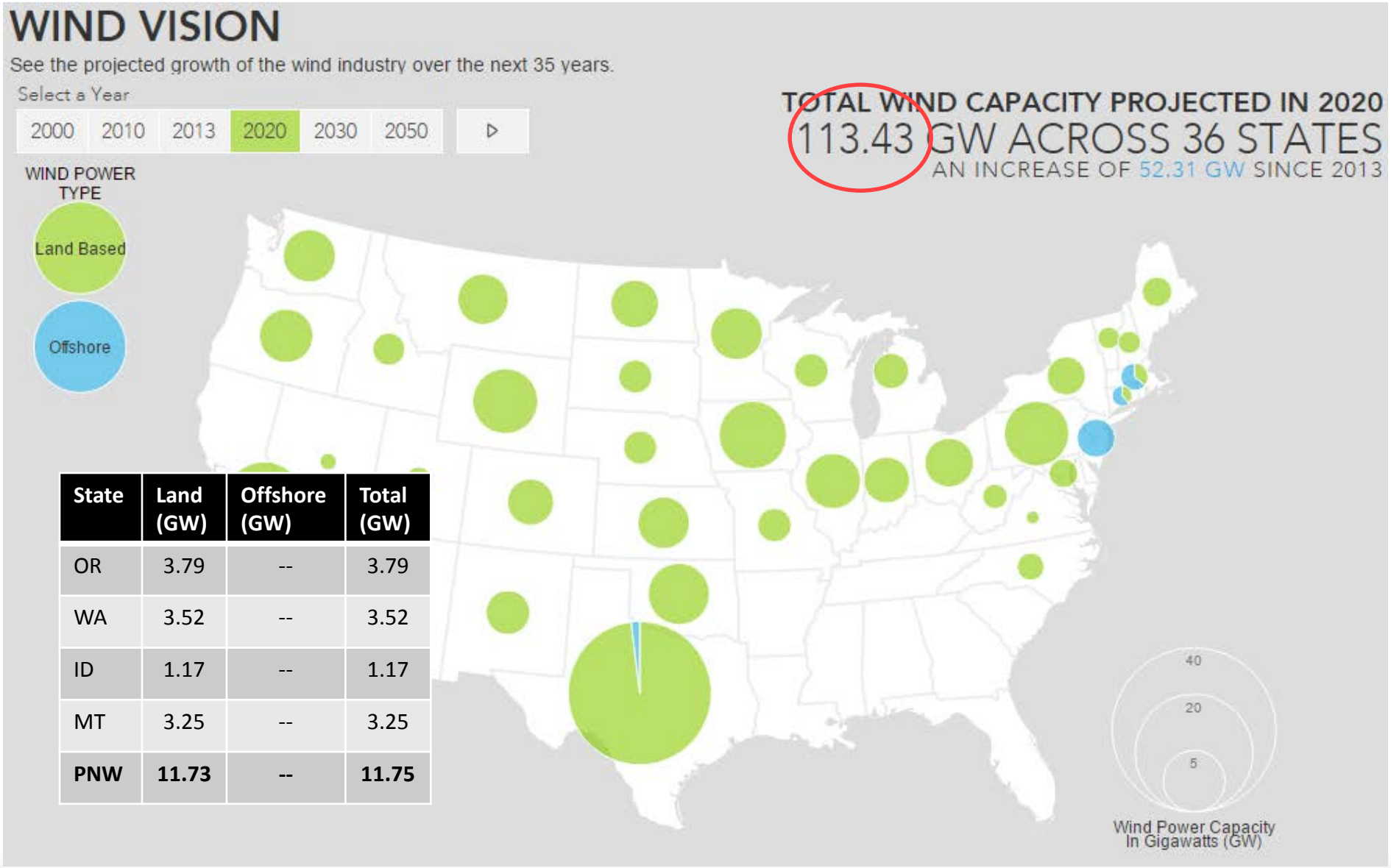
Conclusions of survey

- A lot of uncertainty and difference of opinion, but agreement that costs will continue to go down
- All aspects of LCOE need to be considered in order for cost reductions to occur
  - Not just capital expenditures
- Survey based on expert opinion; meant to serve as one forecasting tool, to be considered with others
  - When compared with other forecasts, survey is rather aggressive
- Learning curves – e.g. historical based-learning – also a good tool to predict future costs

DOE's WindVision Report



- Released in 2015
- Documents existing state of wind industry and development
- Identifies future potential and areas of growth
- Creates actionable items to support future achievement

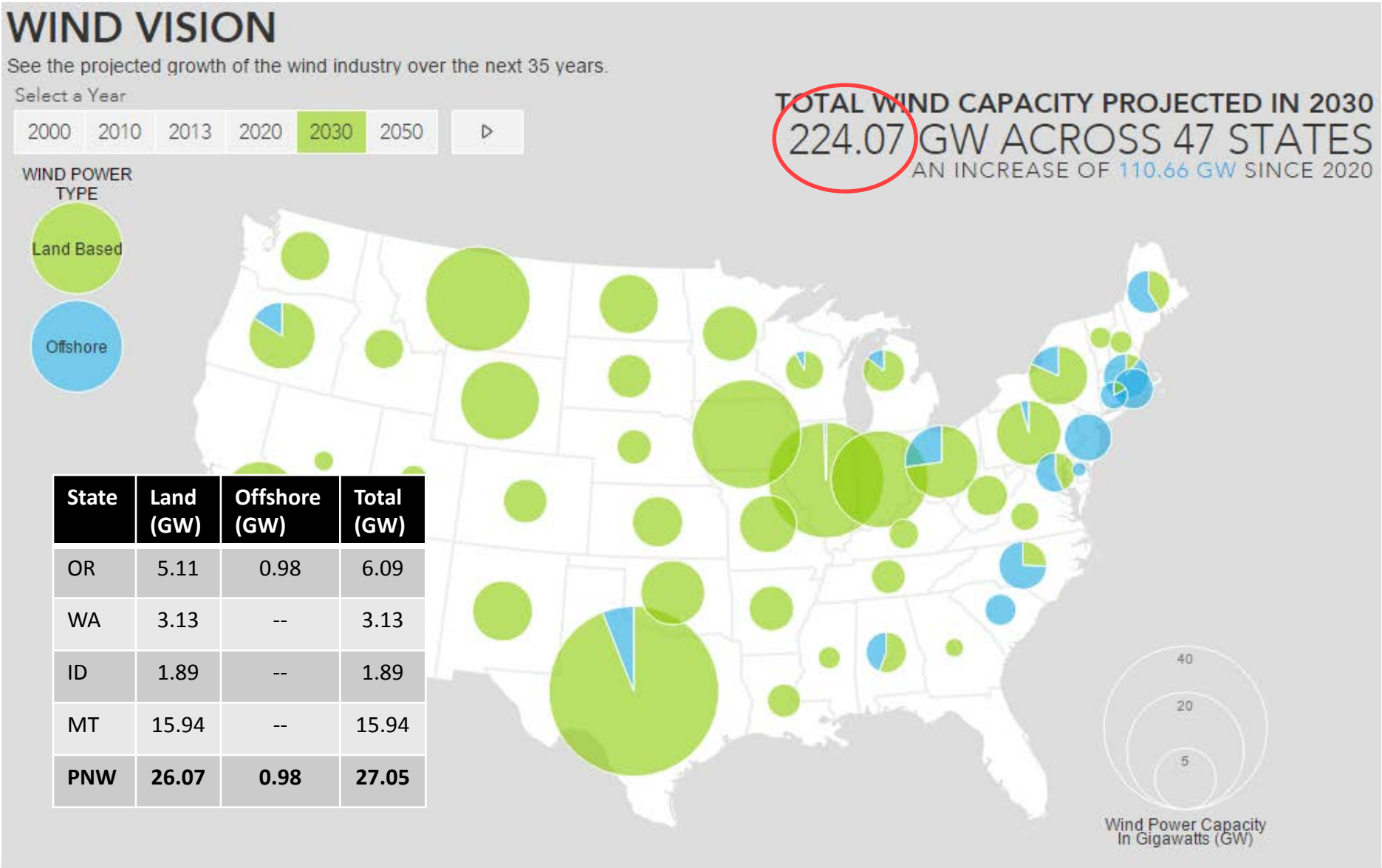


State	Land (GW)	Offshore (GW)	Total (GW)
OR	3.79	--	3.79
WA	3.52	--	3.52
ID	1.17	--	1.17
MT	3.25	--	3.25
PNW	**11.73**	**--**	**11.75**

http://www.energy.gov/maps/map-projected-growth-wind-industry-now-until-2050

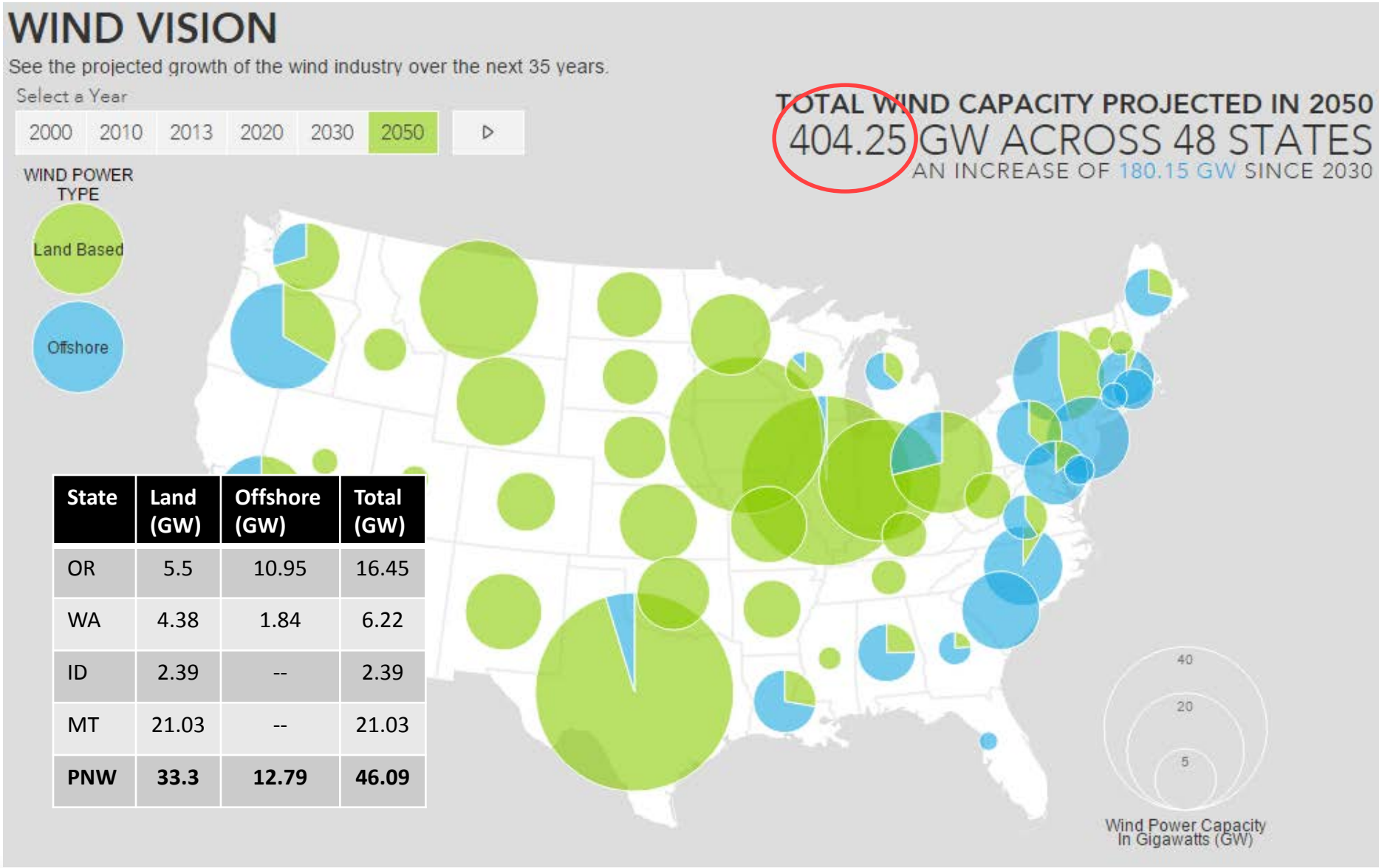
WIND VISION

See the projected growth of the wind industry over the next 35 years.



State	Land (GW)	Offshore (GW)	Total (GW)
OR	5.11	0.98	6.09
WA	3.13	--	3.13
ID	1.89	--	1.89
MT	15.94	--	15.94
PNW	**26.07**	**0.98**	**27.05**

http://www.energy.gov/maps/map-projected-growth-wind-industry-now-until-2050

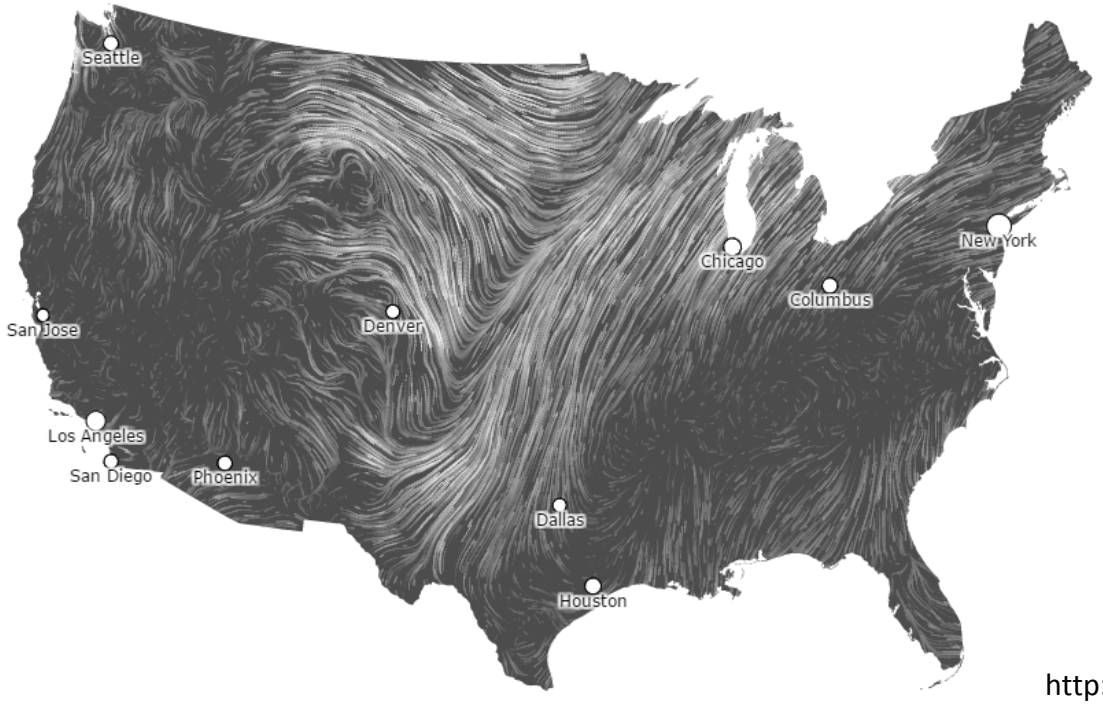


State	Land (GW)	Offshore (GW)	Total (GW)
OR	5.5	10.95	16.45
WA	4.38	1.84	6.22
ID	2.39	--	2.39
MT	21.03	--	21.03
PNW	**33.3**	**12.79**	**46.09**

http://www.energy.gov/maps/map-projected-growth-wind-industry-now-until-2050

WindVision: Roadmap

- **Reduce wind costs**, with a focus on aspects of the LCOE
- **Expand developable areas**, including improving access (transmission) to hard to reach, higher wind speed areas
- **Capture and maximize benefits of wind power**, including growing US manufacturing, workforce. Also, leverage as alternative to fossil fuel resources and price volatility.



http://hint.fm/wind/

ADDITIONAL OPPORTUNITIES

Repowering: What is it?

- The complete (full) or partial replacement of power plant components; to extend the life and improve the production and efficiency
- Wind power repowering:
  - Full repowering more realistic?
    - Replace entire wind turbine to greatly improve the capacity/efficiency of older machines
  - Partial repowering restricted in scope due to existing turbine structure – limited to smaller-scale replacements in hardware

Repowering: Benefits

- Replacing old wind turbines with modern turbines often means fewer, larger turbines and greater installed plant nameplate capacity
  - Higher nameplate capacity per turbine
  - Greater performance and capacity factor → greater wind sweep area
  - Improved integration to the grid
  - Maintaining use of high wind resource areas
  - Lower visual and acoustic impact
  - Historic operating and wind speed data
- Sell old equipment in second-hand markets

Repowering: Considerations

- Capability with existing structure, transformers, substation, etc.
  - May limit scope of partial repowering OR require added investment in existing infrastructure
- Larger rotor swept area – may change avian and wildlife impact assessment, need new environmental review
- New contracts – PPAs, O&M agreements, offtake agreements (min/max limits, rates, terms, etc.), financing
- May be an impact to nearby facilities and cause downwind effects

Repowering: Tax Credits

- IRS issued ruling in 2016 that repowered wind projects could qualify for the PTC tax credit
  - 80/20 rule: Cost of new components must be 4x the market value of the existing components
  - Same phasing down of credits and construction deadlines/rules apply
- May make repowering before end of useful life an attractive economic investment

Repowering: Process

- The process to repower a wind plant is much the same as developing a new wind plant
  - State/local permitting process
  - Site certificates
  - Environmental review
- Preserves local jobs and local tax revenues to communities, in contrast to decommissioning the project

Repowering in Europe

- Several European countries were at the forefront of the wind development in the 1990's and early 2000's
  - Germany and Denmark have repowering incentives available and lead the repowering market
  - GlobalData – by 2020, Denmark on schedule to replace 200MW of aging capacity with 1,000MW of repowered capacity annually
- Secondary market is international
  - Typically more viable if the repowering has occurred before the end of useful life

NextEra press release

- October 31, 2016 – NextEra released Q3 earnings
- Identified ~1,300 MW of repowering opportunities within their existing US wind portfolio

NextEra Energy Resources owns and operates a portfolio of wind, solar, natural gas, and nuclear. In the US, NextEra operates over 110 wind projects totaling over 12,400 MW. NextEra owns about 420MW in the Pacific Northwest over three projects.

Repowering Opportunities in the PNW

- ~1,000 MW wind capacity built before 2006 in the region
  - Stateline (Dec 2001, 300 MW)
  - Vansycle 1 (Dec 1998, 25 MW)
- Repowering efforts unknown at this time
  - Too early?

What about offshore wind?

- Significant wind resource potential off the PNW coastline
- DOE's WindVision report identifies substantial opportunities for OR and WA in next 30 years
- Nascent industry in the US; learn from successful installations in Europe
- ANLYS-15: Scope and identify ocean energy technologies – potential, cost, opportunities, barriers
  - GRAC meeting early 2016; presentation on offshore wind opportunities to Power Committee ~Fall 2016