NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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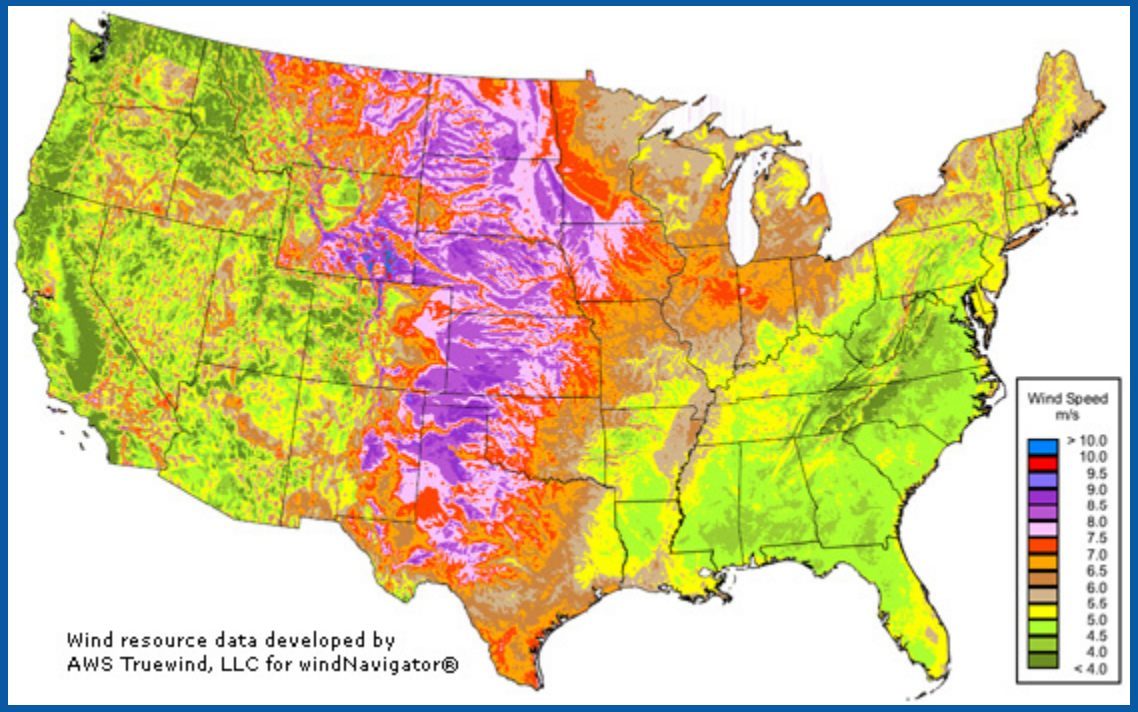
New Wind Energy Resource Potential Estimates for the United States



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Second Conference on Weather, Climate and the New Energy Economy

January 27, 2011

91st Annual Meeting of the American Meteorological Society

Seattle, Washington

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

U.S. Wind Mapping Rationale

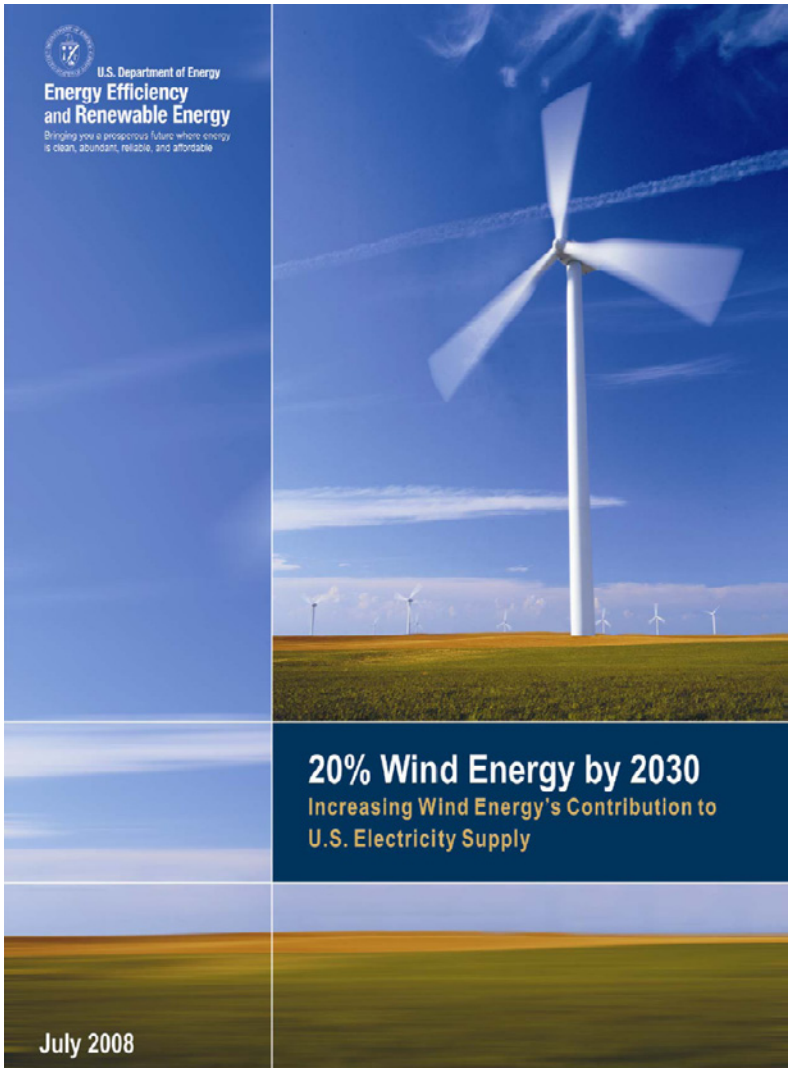
Provides accurate information about the wind resource in each state

- For federal and state policy discussion, analysis, and implementation
- To support the 20% wind future
- To facilitate wind prospecting
- To support state, regional, and national wind integration analyses

Validates wind resource maps

- Essential to ensure stakeholder confidence in accuracy of map estimates

Supports the Program's mission of eliminating barriers to wind energy.



Technical Approach: Wind Mapping & Validation

Produce maps based on:

- Numerical modeling (AWS Truepower) and adjustments
- Empirical and analytical methods
- 1 km^2 or finer horizontal-resolution wind resource maps

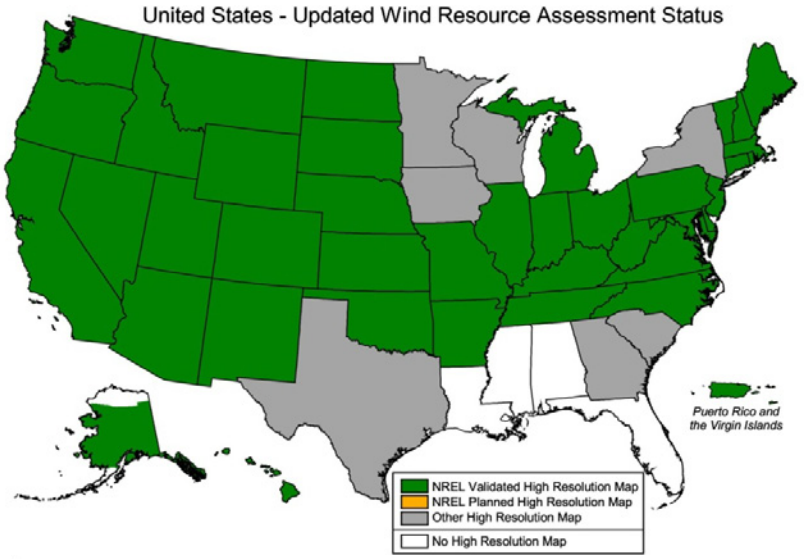
Validate preliminary maps using public and private wind measurement data

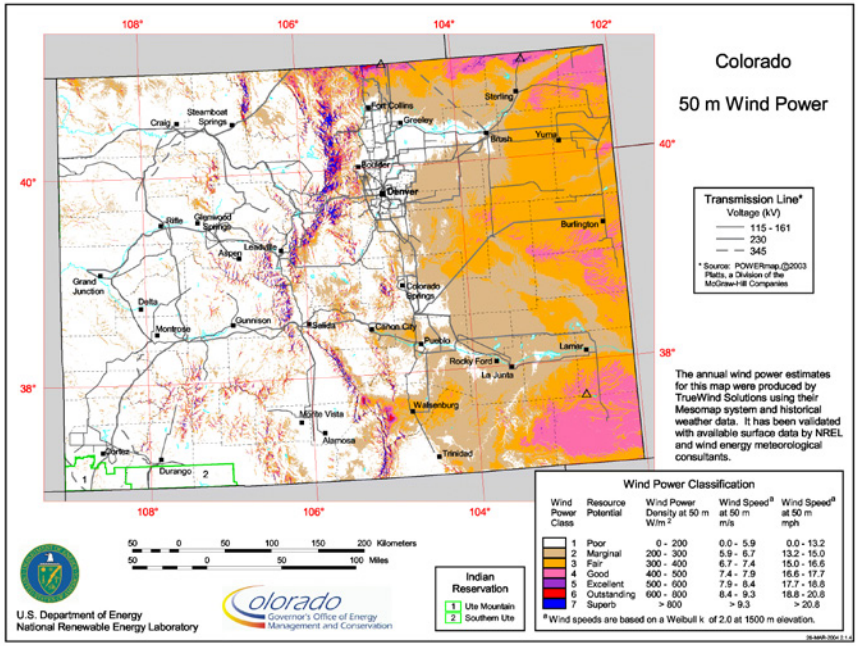
Develop and validate maps at 50-m height for 39 states

Update mapping at 80- & 100-m heights for 48 contiguous states

- Develop wind potential estimates (net of exclusions)

Publish on DOE's Wind Powering America (WPA) Web site

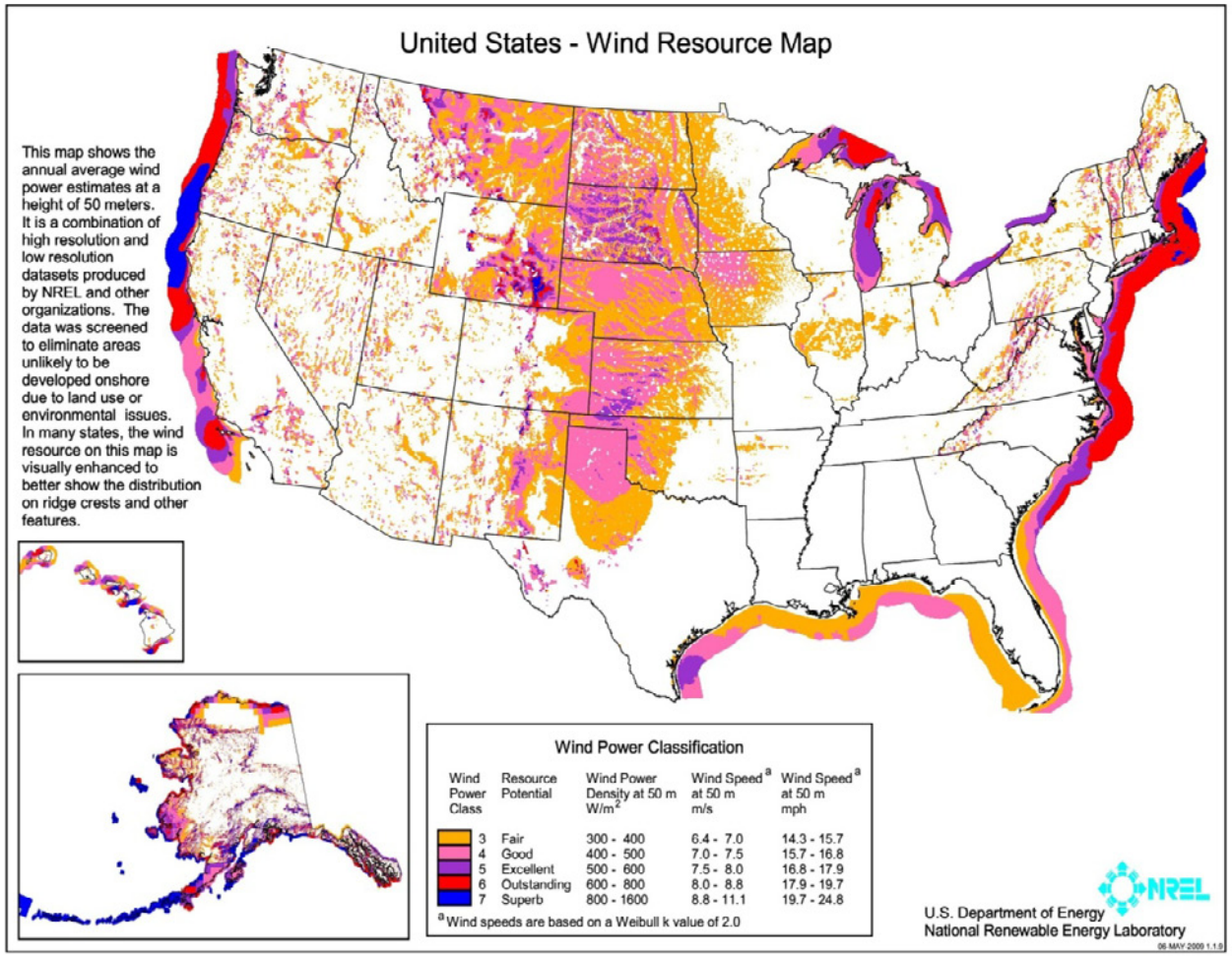




U.S. Wind Mapping and Potential: 50-m Height

50-m wind mapping (2001-2009)

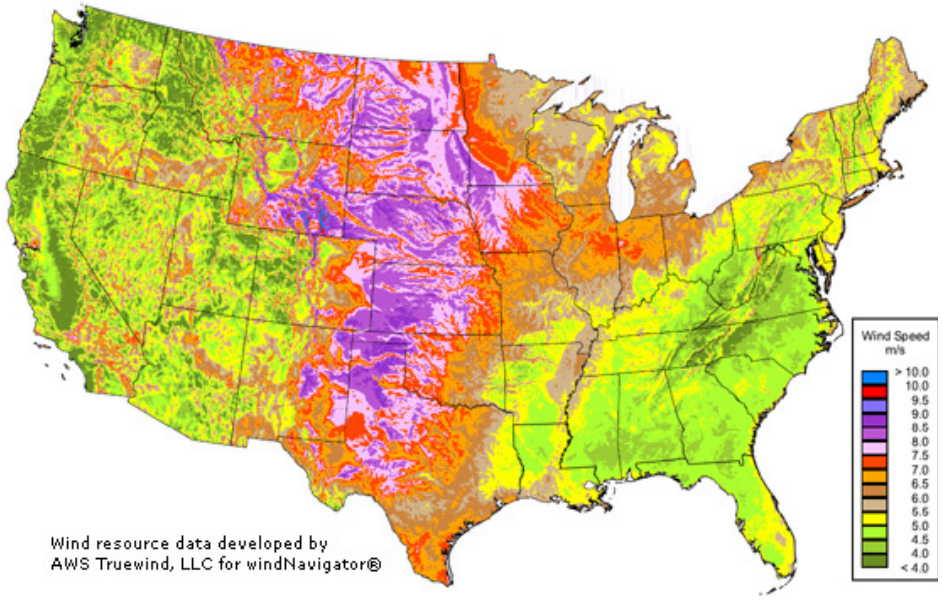
- Culmination of long-term project that began in 2001; jointly funded by states and DOE/WPA
- Comprehensive validation of WPA maps using available measurement data
- Incorporated state maps by others to produce a national wind map ("patchwork quilt" evident in some regions)
- 50-m wind potential estimates to support U.S. 20% wind scenario study

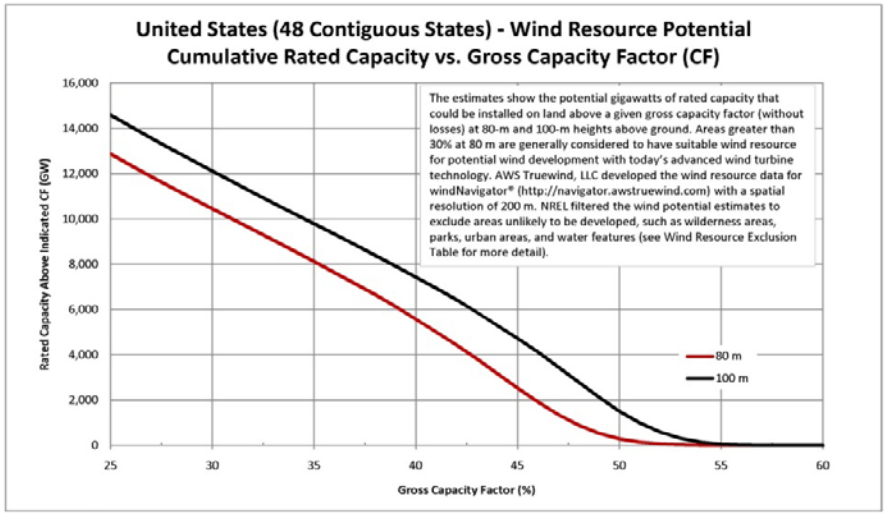


U.S. Wind Mapping and Potential: 80- & 100-m Heights

80- & 100-m mapping and potential estimates (2009-2010)

- New products for contiguous United States and each state developed through a collaborative project with AWS Truepower
- Annual average wind speed maps at 80- and 100-m heights
- NREL validated 19 selected state maps with tower measurement data from 300+ locations
- Wind potential estimates at 80 m and 100 m based on modeled wind turbine capacity factor (CF) data – CF example: 1-MW rated turbine at 30% CF = an average of 300 kW
- Posted new products to WPA Web site (broke all-time DOE/EERE records for most hits)
- Hosted national Webinar to discuss new products and methodology
- Responded to many media and stakeholder requests about the new products





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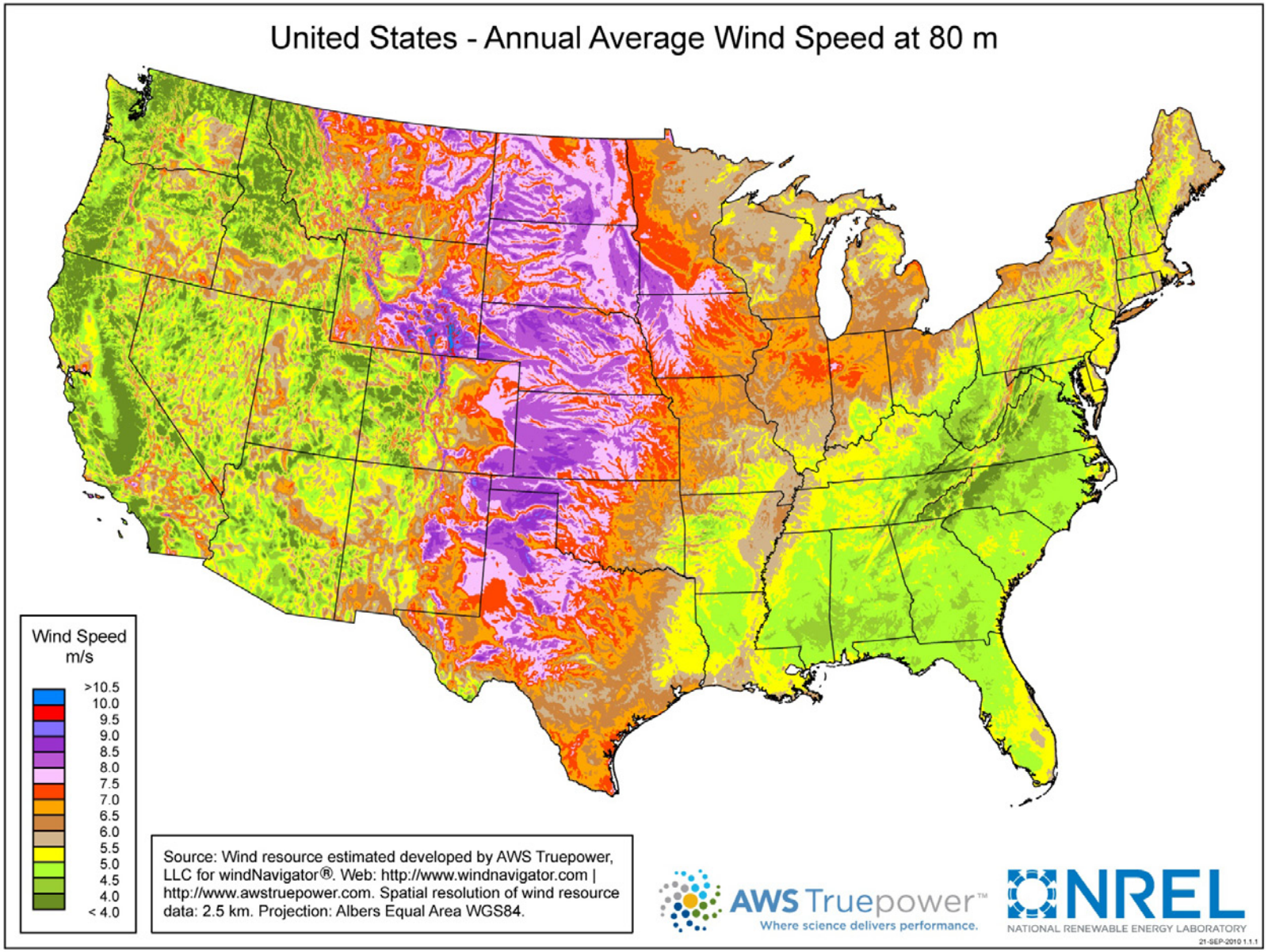
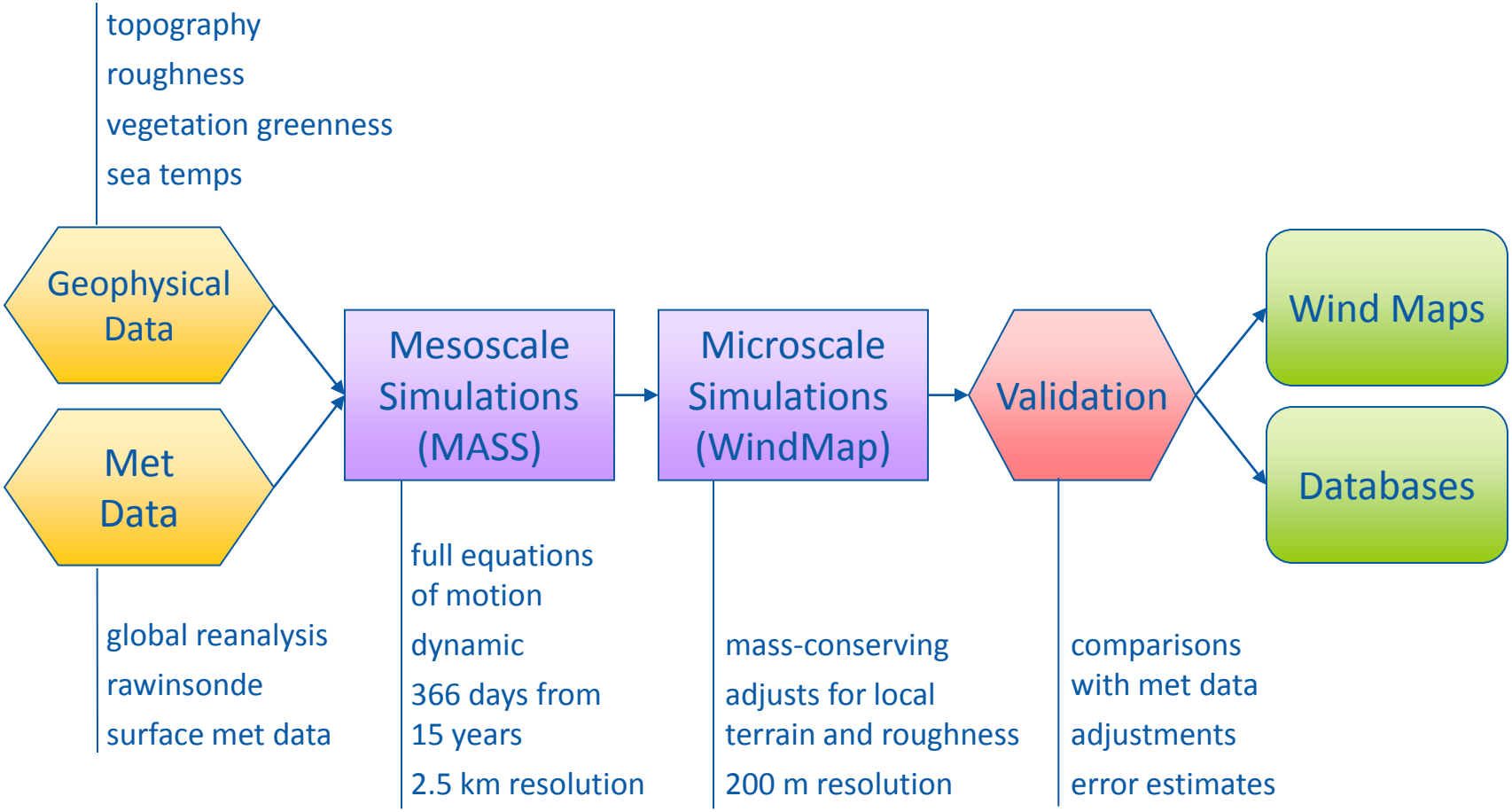
80-m United States Wind Resource Map

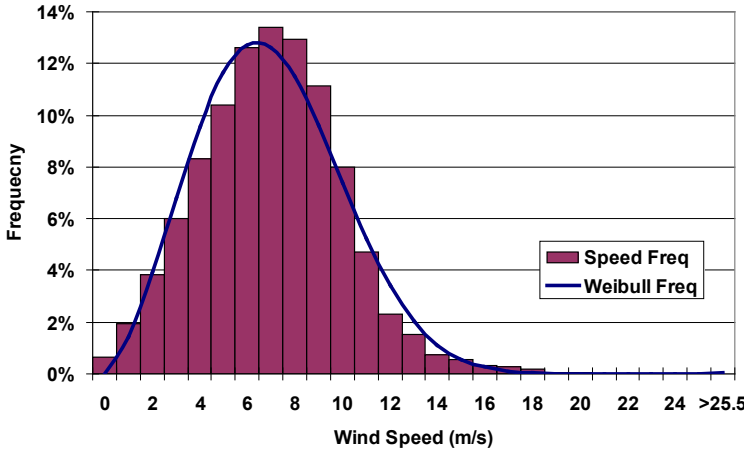


AWS Truepower's MesoMap Process

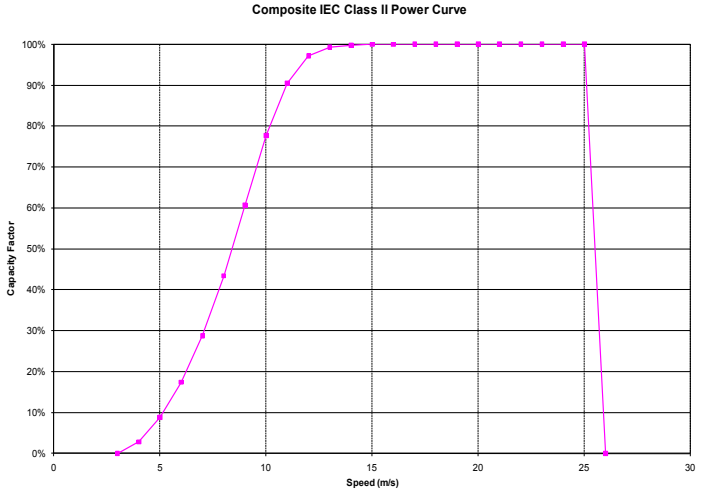


AWS Truepower's Estimation of Plant Output

For each point, wind speed distribution created from 12 years of weather simulations (*windTrends*)



Then gross turbine output calculated for a generic IEC Class 2 turbine power curve, corrected for air density



Development of Wind Potential Estimates

- AWS Truepower produced a national dataset of estimated CF (not adjusted for losses)
  - **Spatial resolution of 200 m**
  - **Heights of 80 m and 100 m**
  - **Land-based areas only** (no offshore), 48 contiguous states

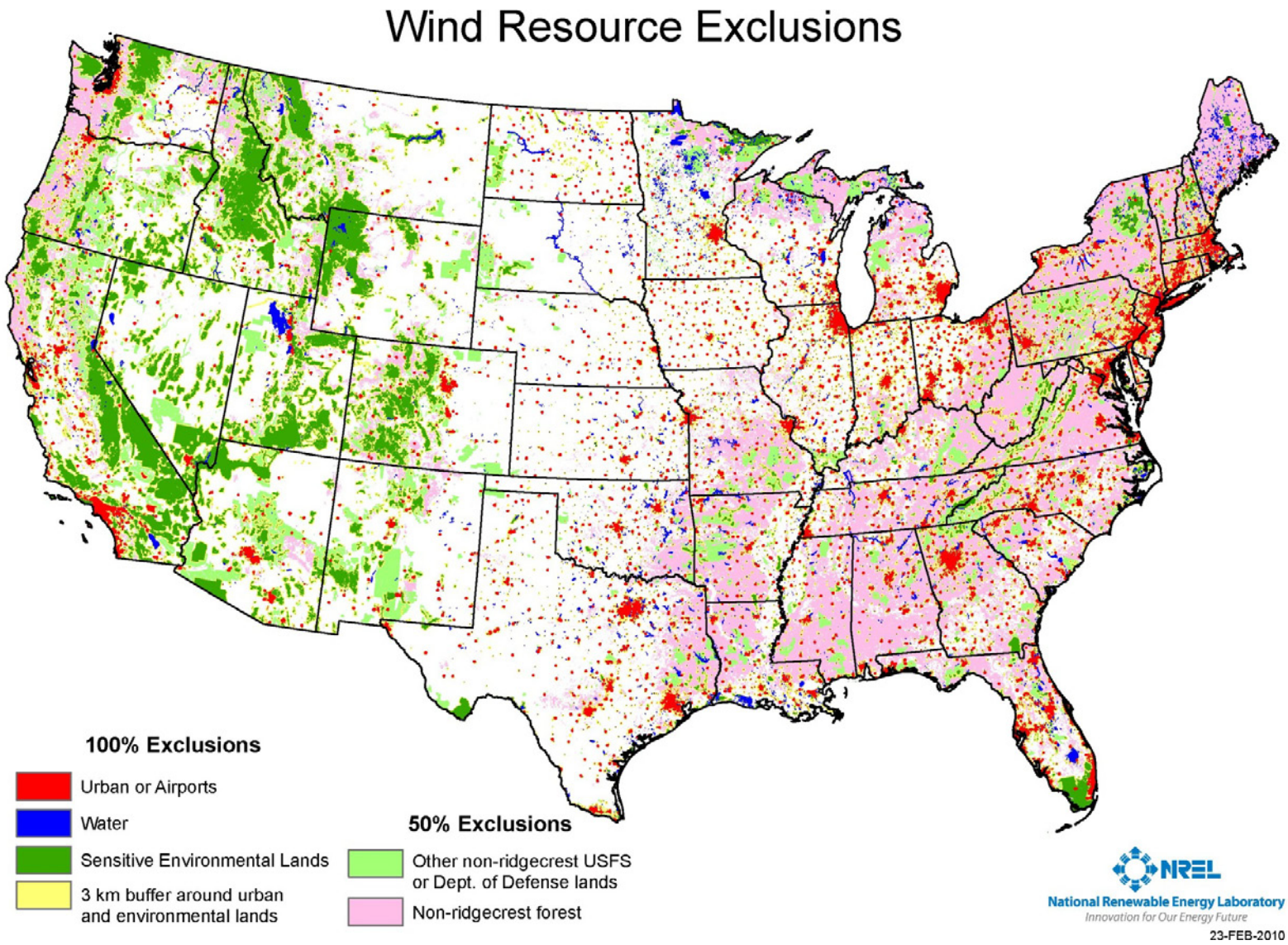
- NREL used the CF data to estimate the land area and wind potential for each state
  - **Windy land defined as areas with >= 30% CF**, which are generally considered to be suitable for wind energy development
  - Areas with CF >=30% have mean annual wind speeds of about 6.4 m/s and greater
  - **Excluded sensitive environmental lands and incompatible land-use areas**
  - **For wind potential, assumed 5 MW/km^2** of installed nameplate capacity

Why use CF and not Power Class to produce wind potential estimates?

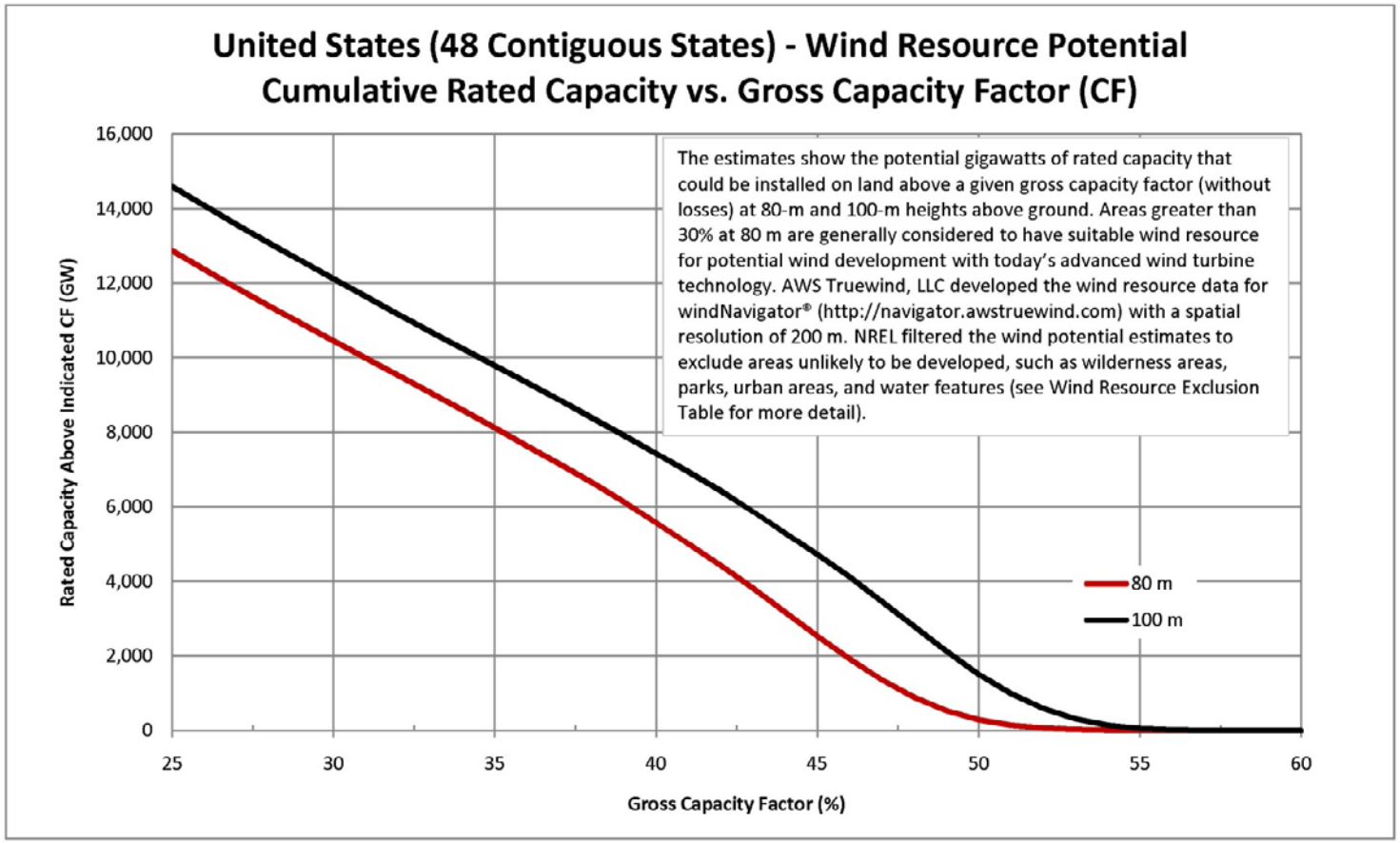
CF is representative of power output from large wind turbines.

Power class is representative of theoretical energy in the wind.

National Exclusion Map



Wind Resource Potential at 80 & 100 m - United States



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Capacity factor (CF) example: 1-MW rated turbine at 30% CF = an average of 300 kW

Tables of State Wind Potential

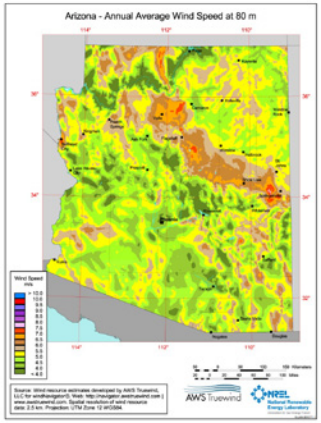
Estimates of Windy Land Area and Wind Energy Potential by State For Areas >=30% Capacity Factor at 80 m

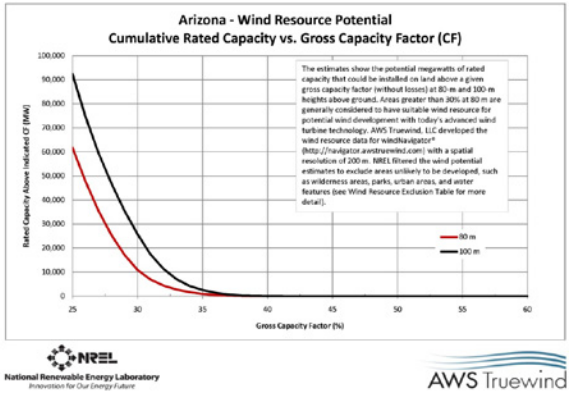
(Tables are also available for other CF categories and heights)

	Windy Land Area >= 30% Gross Capacity Factor at 80m						Wind Energy Potential	
State	Total (km^2)	Excluded[2] (km^2)	Available (km^2)	Available % of State	% of Total Windy Land Excluded		Installed Capacity[3] (MW)	Annual Generation (GWh)
Alabama	80.4	56.7	23.6	0.02%	70.6%		118.2	333
Arizona	4,545.0	2,364.1	2,180.8	0.74%	52.0%		10,904.1	30,616
Arkansas	4,663.2	2,823.2	1,840.1	1.34%	60.5%		9,200.3	26,906
California	26,901.3	20,079.2	6,822.0	1.67%	74.6%		34,110.2	105,646
Colorado	95,830.4	18,386.5	77,443.9	28.73%	19.2%		387,219.5	1,288,490
Connecticut	31.4	26.1	5.3	0.04%	83.1%		26.5	73
Delaware	36.6	34.7	1.9	0.04%	94.8%		9.5	26
Florida	9.6	9.5	0.1	0.00%	99.2%		0.4	1
Georgia	281.3	255.3	26.0	0.02%	90.7%		130.1	380
Idaho	13,420.4	9,805.3	3,615.1	1.67%	73.1%		18,075.6	52,118
Illinois	70,763.6	20,787.1	49,976.4	34.25%	29.4%		249,882.1	763,529
Indiana	46,255.2	16,609.7	29,645.5	31.63%	35.9%		148,227.5	443,912
Iowa	134,900.1	20,757.3	114,142.8	78.32%	15.4%		570,714.2	2,026,340
Kansas	211,861.3	21,387.1	190,474.2	89.38%	10.1%		952,370.9	3,646,590

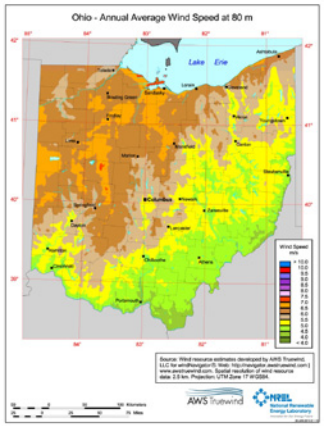
Installed Capacity – assumes 5 MW/km^2 of available windy land area
Annual Generation – annual wind energy generation that could be produced from the installed capacity

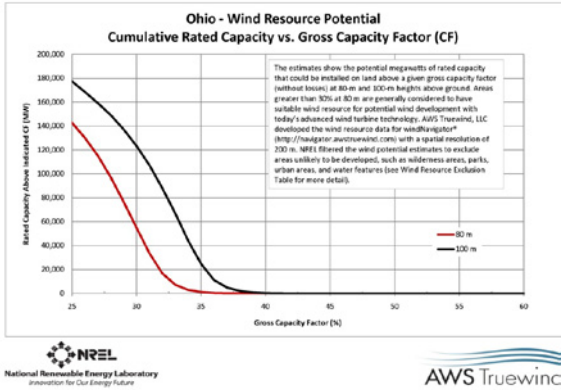
Comparison of State Wind Maps and Potential Graphs



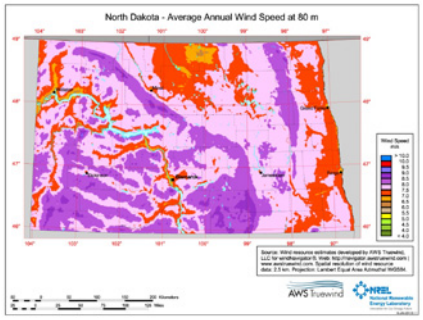


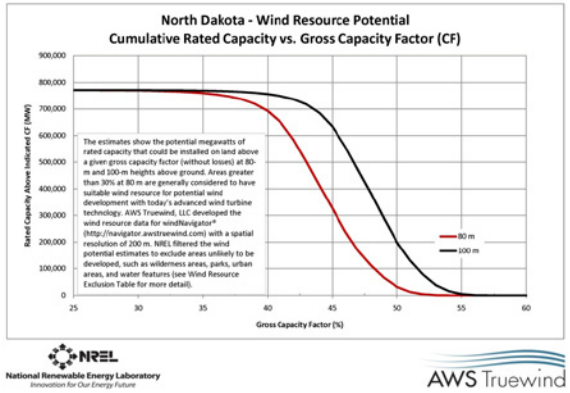
Arizona





Ohio





North Dakota

Wind Potential – Key Findings

U.S. wind potential from areas with CF>=30% is enormous

- At **80 m**, almost **10,500 GW** capacity
- At **100 m**, **12,000 GW** capacity

Most of the wind potential comes from windy central regions, but many eastern and western states have significant wind potential

- **35 states with >1,000 MW** capacity at **80 m**
- **38 states with >1,000 MW** capacity at **100 m**

For higher CF ranges at 80 m, U.S. wind potential is still very large

- **CF>=35%, >8,000 GW** and 28 states >1,000 MW
- **CF>=40%, >5,500 GW** and 19 states >1,000 MW

Top 10 states with CF >=30% at 80 m

- By Installed Capacity: TX, KS, MT, NE, SD, ND, IA, WY, OK, NM
- By Annual Generation: TX, KS, NE, SD, MT, ND, IA, WY, OK, MN

– Available at: **http://www.windpoweringamerica.gov/wind_maps.asp**

Proposed Next Steps

- Develop new 80- and 100-m wind resource maps and potential estimates for Alaska and Hawaii
- Update national maps to include entire United States
- Incorporate new offshore maps as they become available
- Develop maps at 30-m height for small wind turbine industry
- Initiate comprehensive program to validate 80- and 100-m maps
- Review and update exclusion methodology
- Identify key areas for new measurements and updated assessments