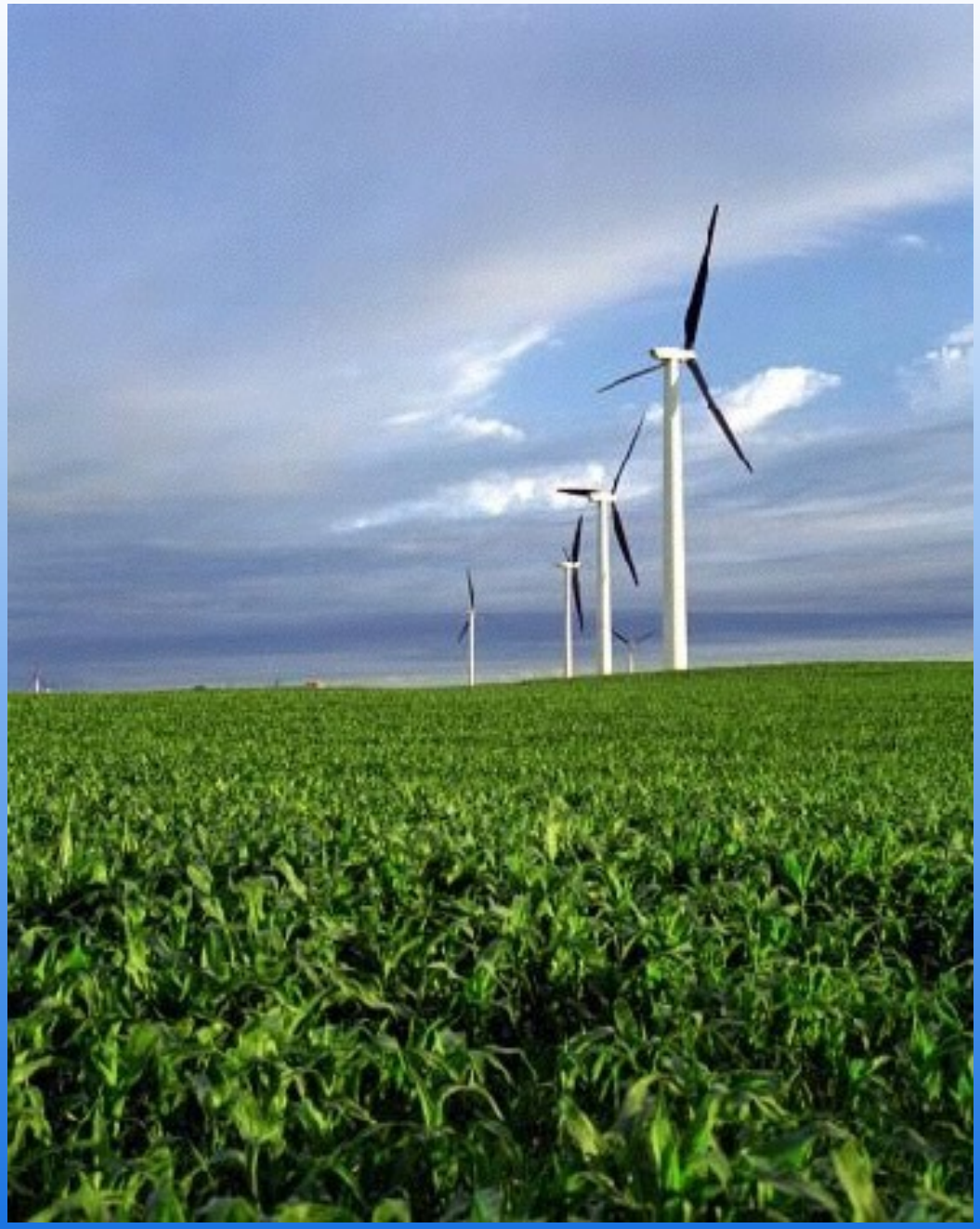


Oklahoma Wind Power Initiative

Why wind? An overview of the recent past, present, and future of wind power development

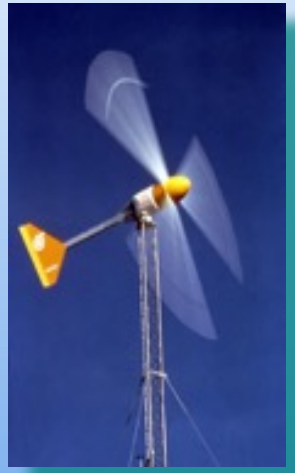
Scott Greene
OWPI Director
Professor, Department of Geography and Environmental Sustainability

Why Wind?

- **Gain energy independence**
- **Ease demand on the power grid**

- Reduce vulnerability to volatile utility prices
- Reduce air pollution from fossil electricity sources
- Economic Development

Sizes and Applications



Small (≤10 kW)

- Homes
- Farms
- Remote Applications

Intermediate (10-250 kW)

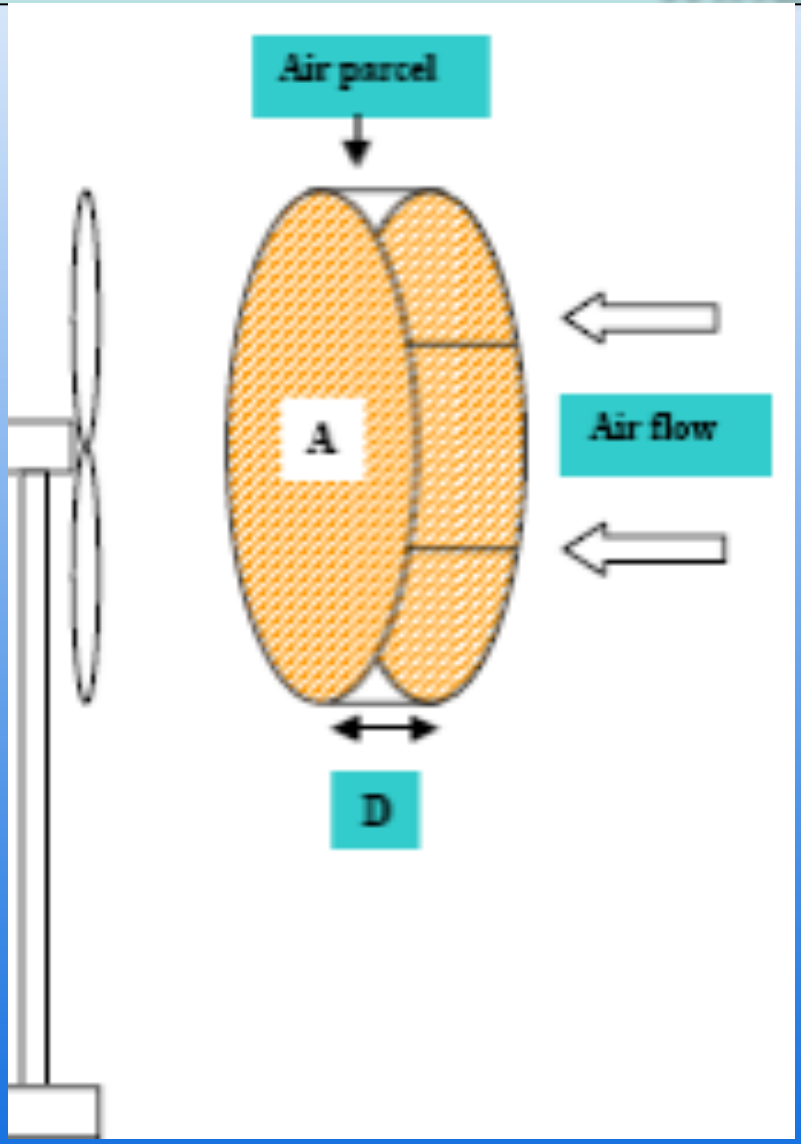
- Village Power
- Hybrid Systems
- Distributed Power

Large (660 kW - 2+MW)

- Central Station Wind Farms
- Distributed Power
- Community Wind

The Power In Wind

Wind Power Density



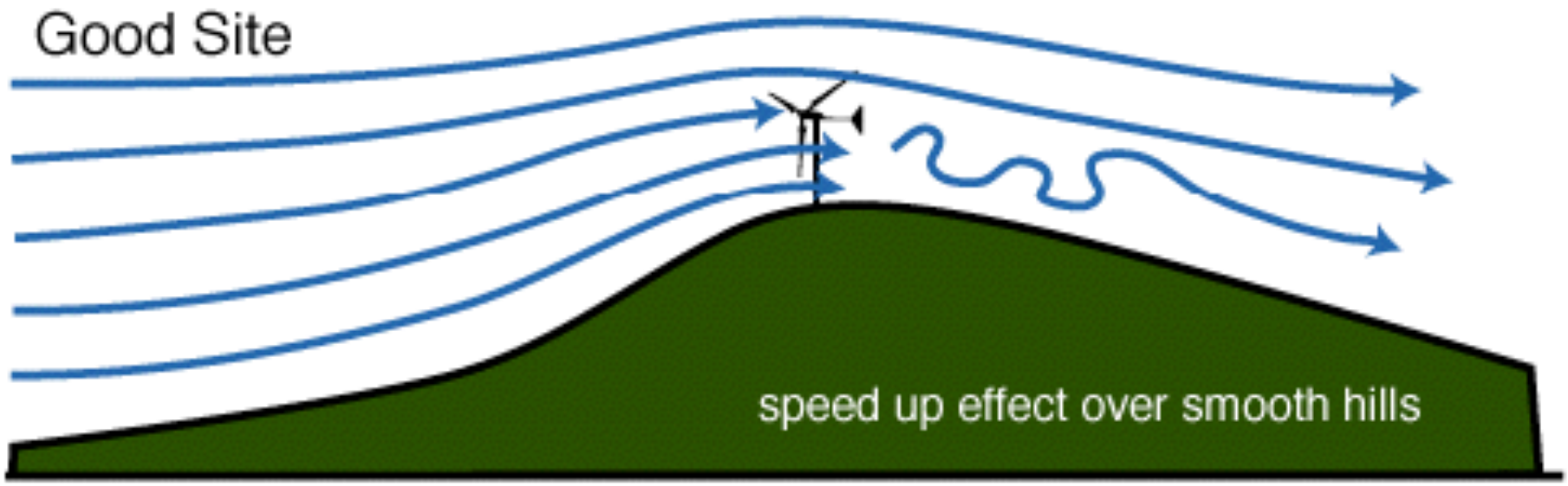
$$\mathbf{WPD = Pwr / A} = \tfrac{1}{2} * \rho * \mathbf{V}^3$$

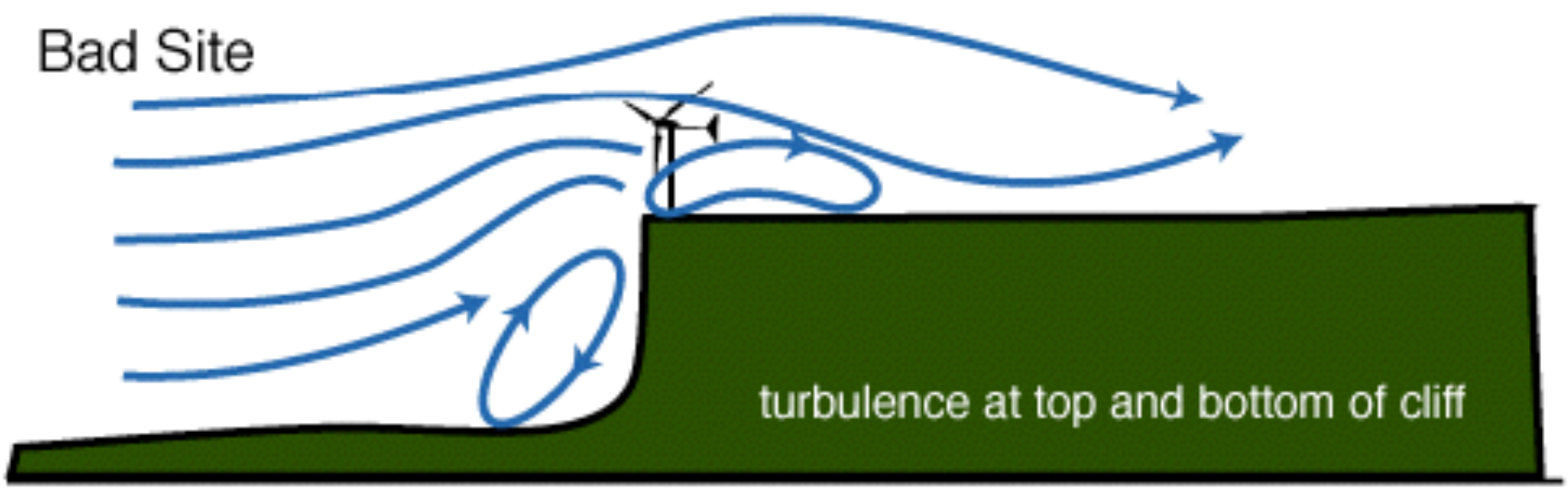
Important Point

Power is proportional to **CUBE** of wind speed

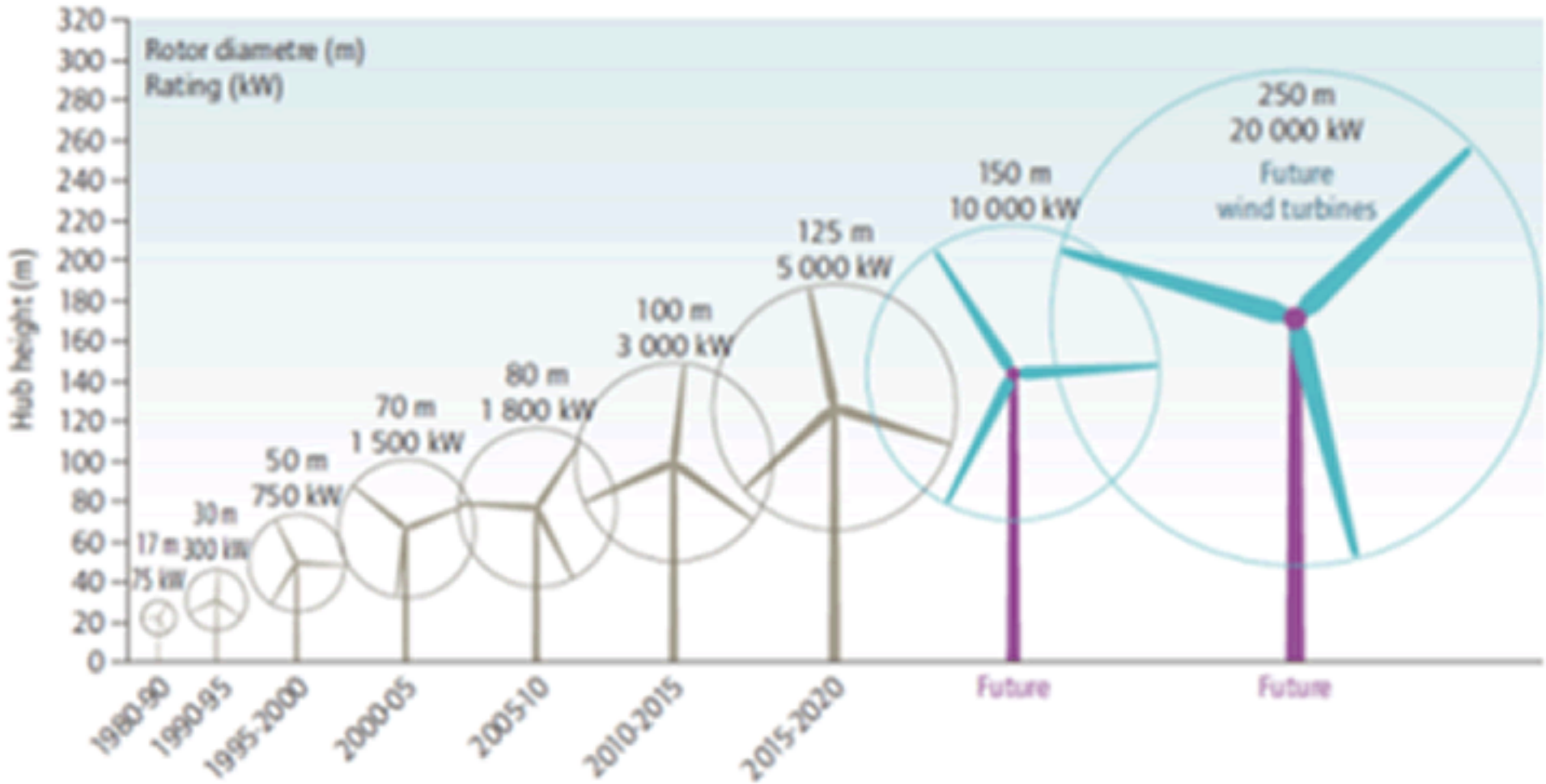
As wind speed goes up a little, wind power density increases a lot!

Location, location, location

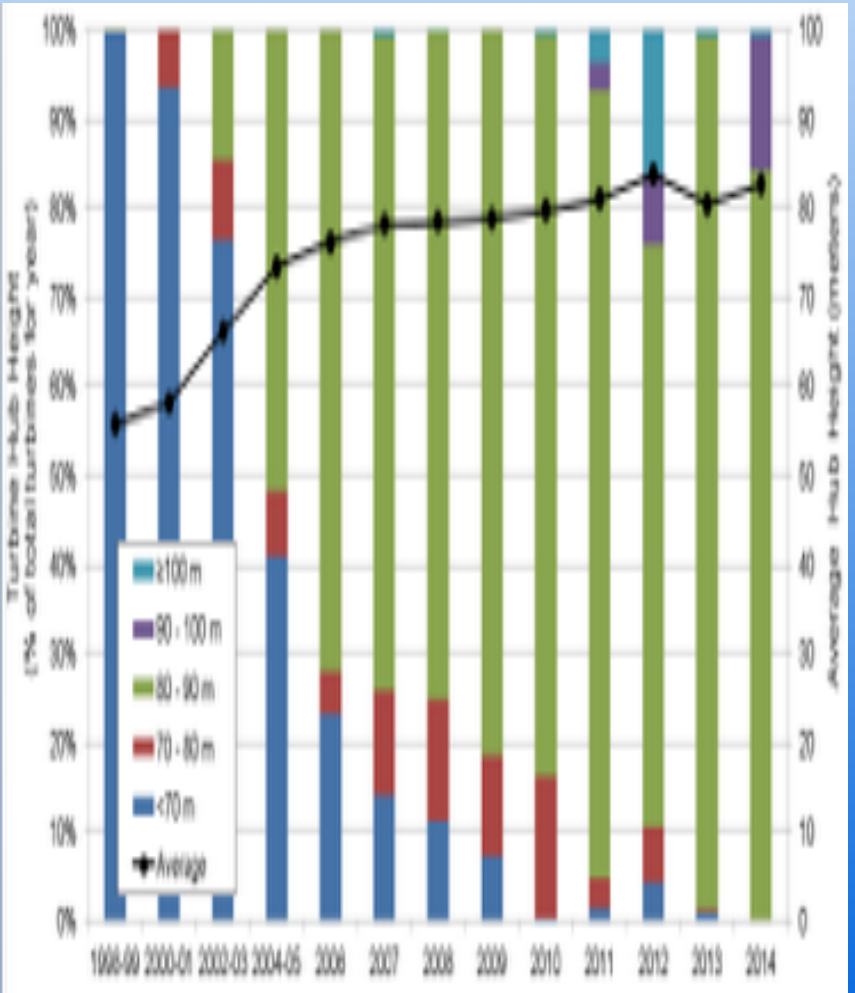


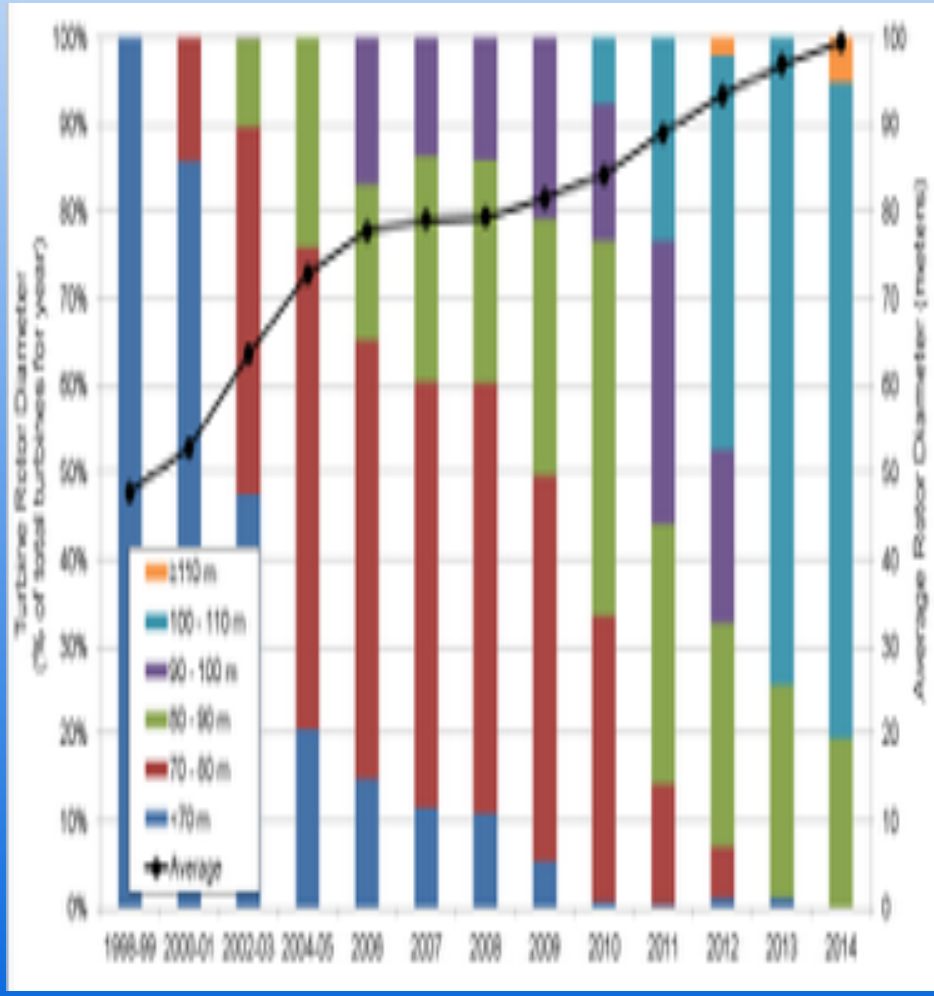


Average Size of Installed Wind Turbines

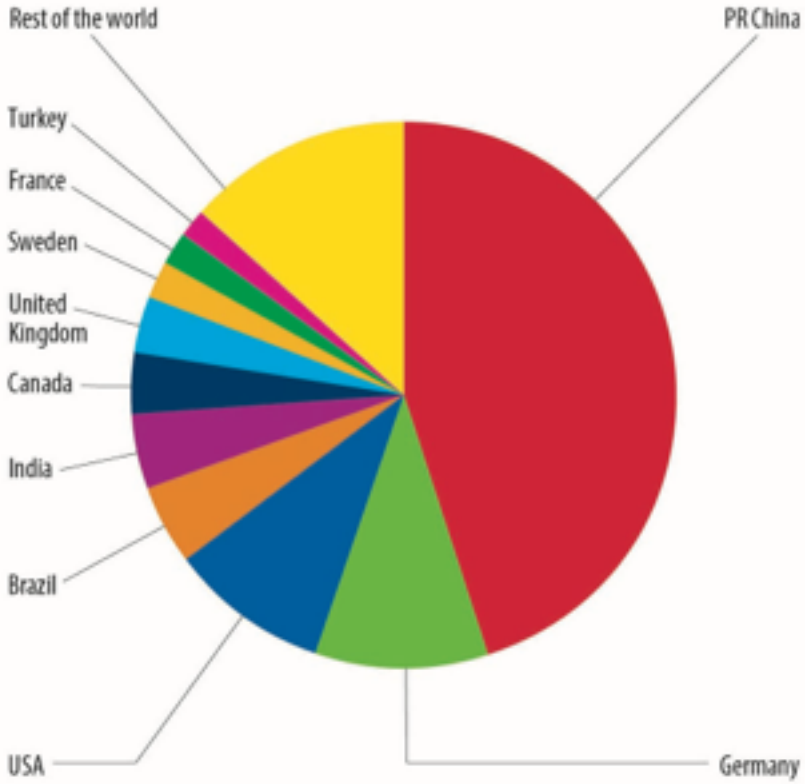


Growth in Rotor Diameter and hubheight





TOP 10 NEW INSTALLED CAPACITY JAN-DEC 2014

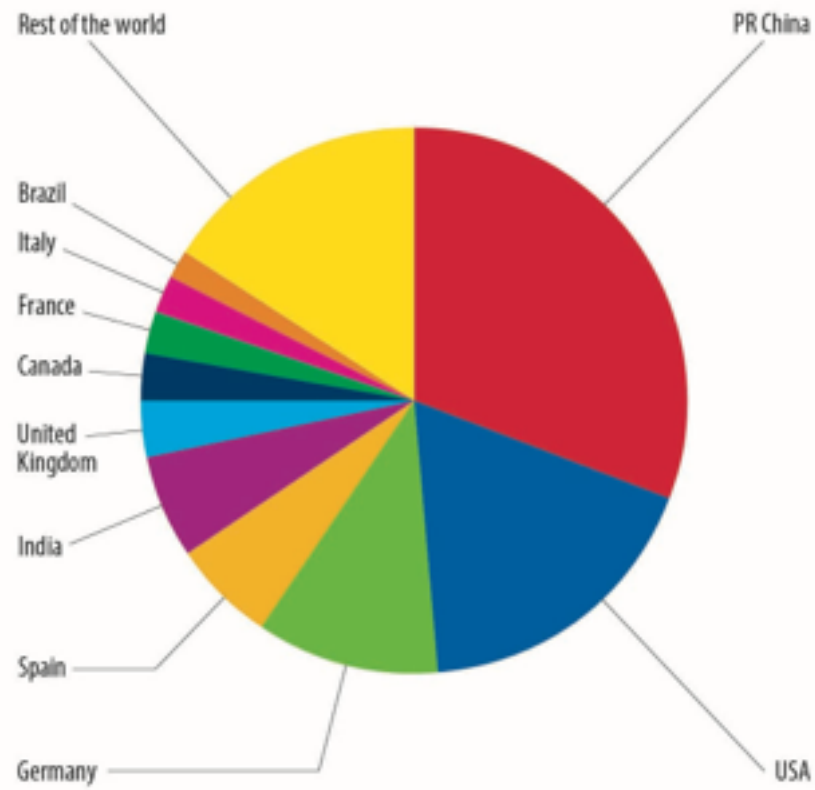


Country	MW	% SHARE
PR China	23,196	45.1
Germany	5,279	10.2
USA	4,854	9.4
Brazil*	2,472	4.8
India	2,315	4.5
Canada	1,871	3.6
United Kingdom	1,736	3.4
Sweden	1,050	2.0
France	1,042	2.0
Turkey	804	1.6
Rest of the world	6,852	13.3
Total TOP 10	**44,620**	**87**
World Total	**51,473**	**100**

** Projects fully commissioned, grid connection pending in some cases*

Source: GWEC

TOP 10 CUMULATIVE CAPACITY DEC 2014

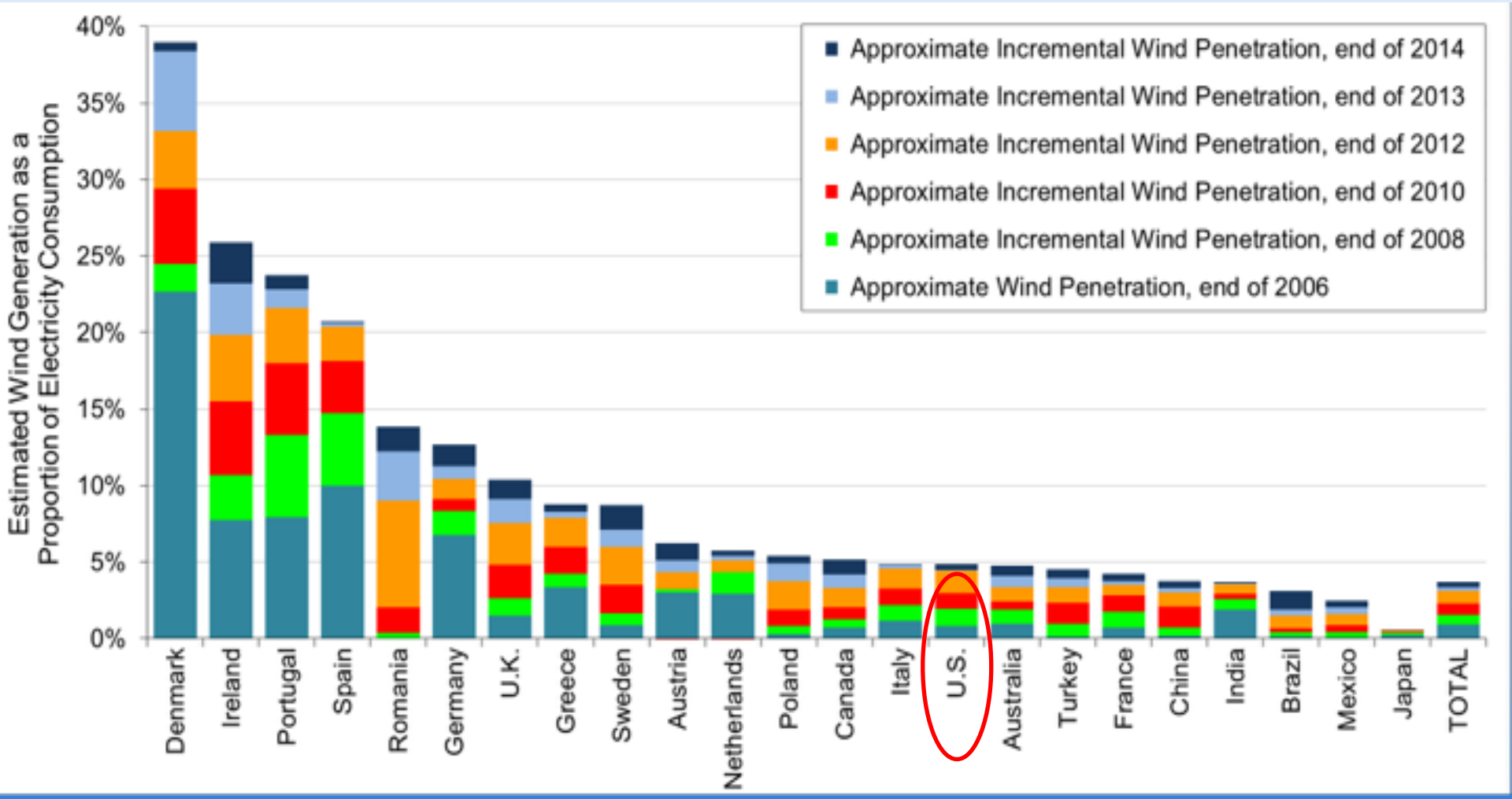


Country	MW	% SHARE
PR China	114,609	31.0
USA	65,879	17.8
Germany	39,165	10.6
Spain	22,987	6.2
India	22,465	6.1
United Kingdom	12,440	3.4
Canada	9,694	2.6
France	9,285	2.5
Italy	8,663	2.3
Brazil*	5,939	1.6
Rest of the world	58,473	15.8
Total TOP 10	**311,124**	**84.2**
World Total	**369,597**	**100**

** Projects fully commissioned, grid connection pending in some cases*

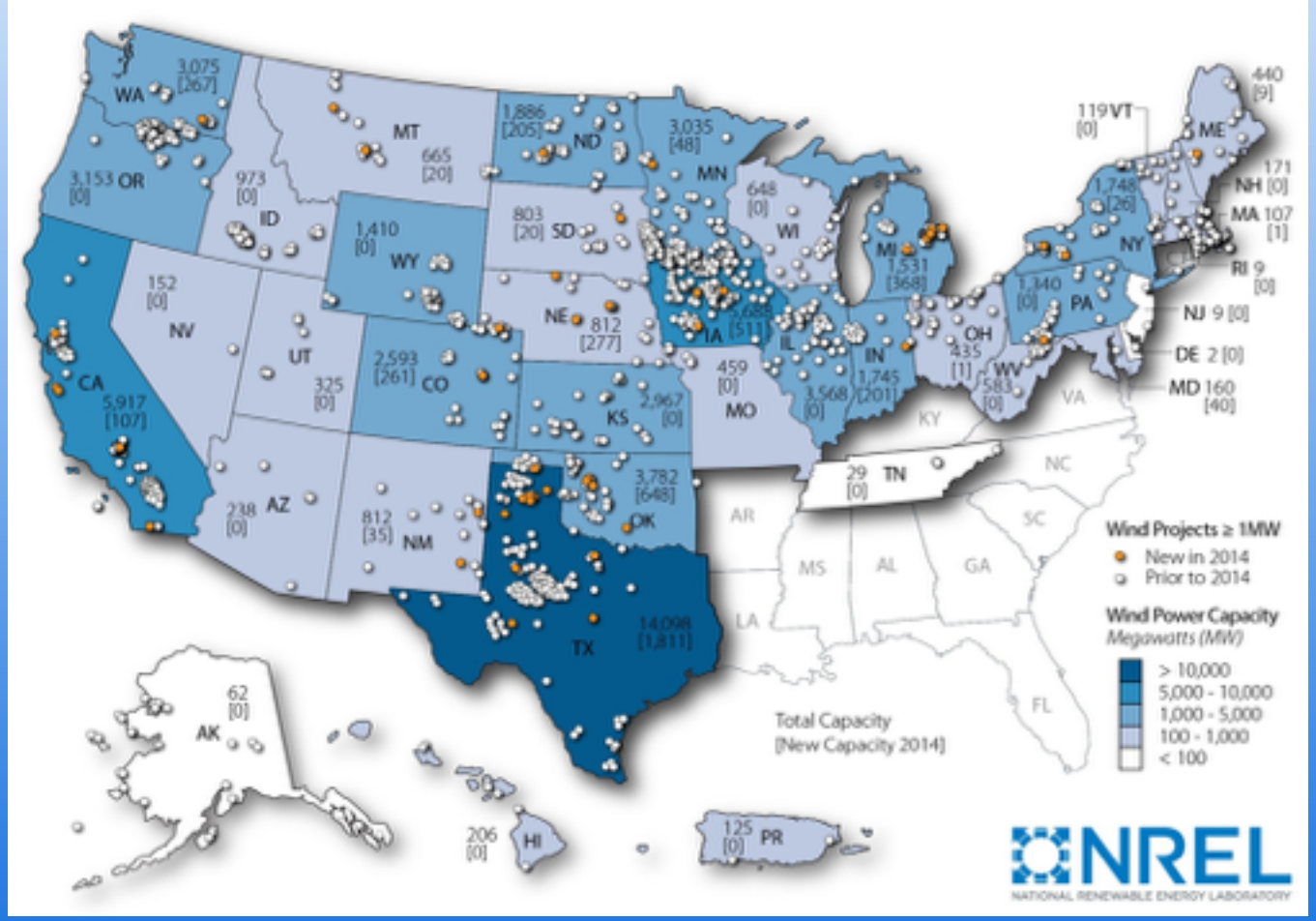
Source: GWEC

Wind Penetration as a Percentage of Electricity Consumption



Note: Figure only includes the countries with the most installed wind power capacity at the end of 2014

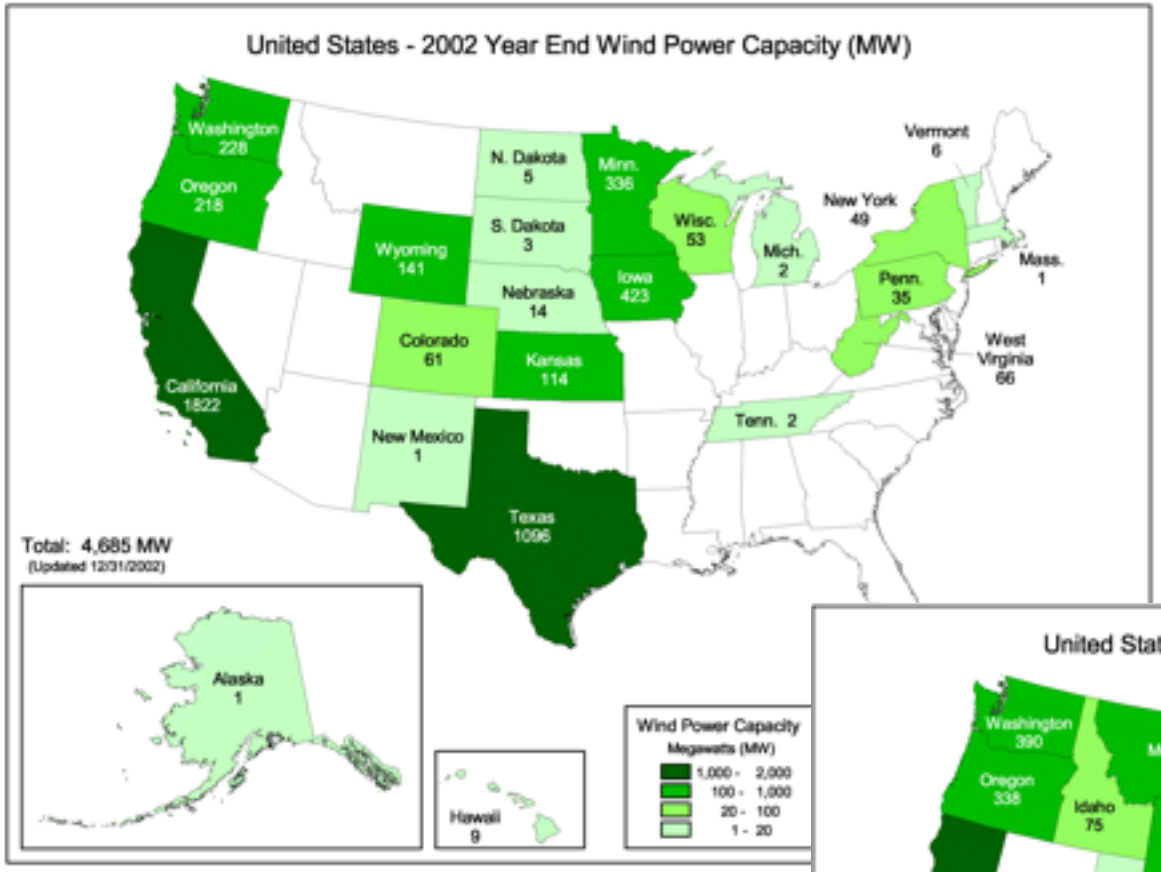
Geographic Spread of Wind Projects in the United States Is Reasonably Broad

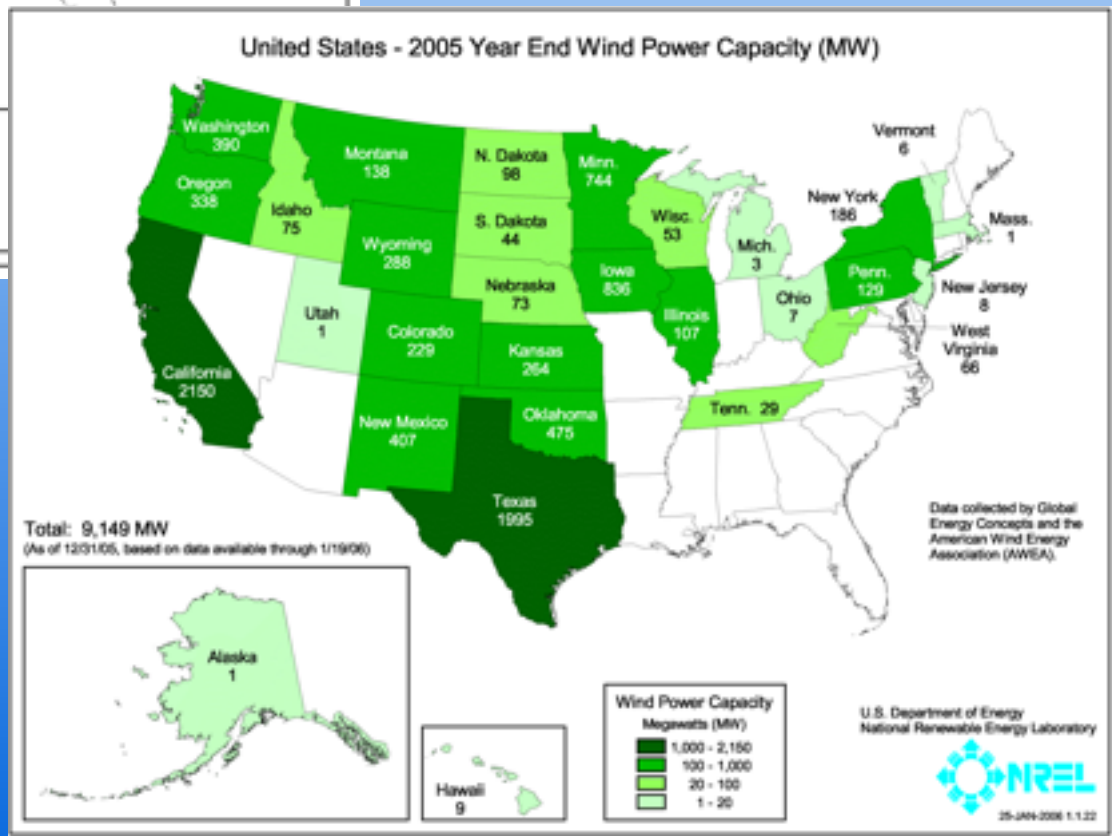


Note: Numbers within states represent cumulative installed wind capacity and, in brackets, annual additions in 2014

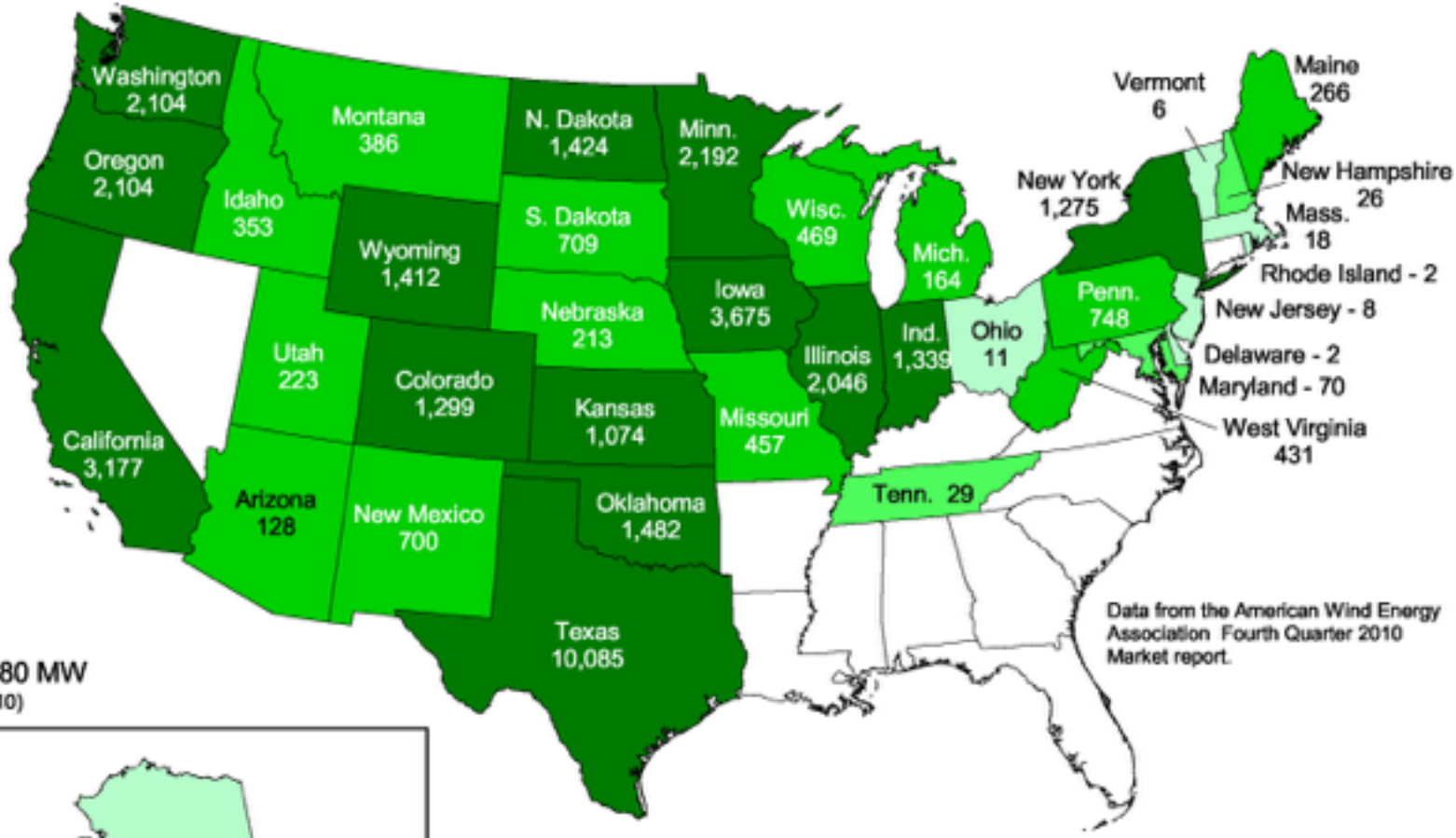
Installed Capacity (MW)				Percentage of In-State Generation	
Annual (2014)		Cumulative (end of 2014)		Actual (2014) *	
Texas	1,811	Texas	14,098	Iowa	28.5%
Oklahoma	648	California	5,917	South Dakota	25.3%
Iowa	511	Iowa	5,688	Kansas	21.7%
Michigan	368	Oklahoma	3,782	Idaho	18.3%
Nebraska	277	Illinois	3,568	North Dakota	17.6%
Washington	267	Oregon	3,153	Oklahoma	16.9%
Colorado	261	Washington	3,075	Minnesota	15.9%
North Dakota	205	Minnesota	3,035	Colorado	13.6%
Indiana	201	Kansas	2,967	Oregon	12.7%
California	107	Colorado	2,593	Texas	9.0%
Minnesota	48	North Dakota	1,886	Wyoming	8.9%
Maryland	40	New York	1,748	Maine	8.3%
New Mexico	35	Indiana	1,745	New Mexico	7.0%
New York	26	Michigan	1,531	California	7.0%
Montana	20	Wyoming	1,410	Nebraska	6.9%
South Dakota	20	Pennsylvania	1,340	Montana	6.5%
Maine	9	Idaho	973	Washington	6.3%
Ohio	0.9	New Mexico	812	Hawaii	5.9%
Massachusetts	0.6	Nebraska	812	Illinois	5.0%
		South Dakota	803	Vermont	4.4%
Rest of U.S.	0	*Rest of U.S.*	4,941	*Rest of U.S.*	0.9%
TOTAL	**4,854**	**TOTAL**	**65,877**	**TOTAL**	**4.4%**

* Based on 2014 wind and total generation by state from EIA's *Electric Power Monthly*.


United States - 2002 Year End Wind Power Capacity (MW)
Washington 228
Oregon 218
California 1822
Wyoming 141
N. Dakota 5
S. Dakota 3
Nebraska 14
Colorado 61
Kansas 114
New Mexico 1
Texas 1096
Minn. 336
Iowa 423
Wisc. 53
Mich. 2
Tenn. 2
Penn. 35
New York 49
Vermont 6
Mass. 1
West Virginia 66
Alaska 1
Hawaii 9
Total: 4,685 MW
(Updated 12/31/2002)
Wind Power Capacity
Megawatts (MW)
1,000 - 2,000
100 - 1,000
20 - 100
1 - 20


United States - 2005 Year End Wind Power Capacity (MW)
Washington 390
Oregon 338
California 2150
Idaho 75
Montana 138
Wyoming 288
Utah 1
Colorado 229
New Mexico 407
N. Dakota 98
S. Dakota 44
Nebraska 73
Kansas 264
Oklahoma 475
Texas 1995
Minn. 744
Iowa 836
Wisc. 53
Illinois 107
Mich. 3
Ohio 7
Tenn. 29
Penn. 129
New York 186
Vermont 6
Mass. 1
New Jersey 8
West Virginia 66
Alaska 1
Hawaii 9
Total: 9,149 MW
(As of 12/31/05, based on data available through 1/19/06)
Data collected by Global Energy Concepts and the American Wind Energy Association (AWEA).
Wind Power Capacity
Megawatts (MW)
1,000 - 2,150
100 - 1,000
20 - 100
1 - 20
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
25-JAN-2006 1:1:22

2010 Year End Wind Power Capacity (MW)



Total: 40,180 MW
(As of 12/31/2010)

Wind Power Capacity
Megawatts (MW)

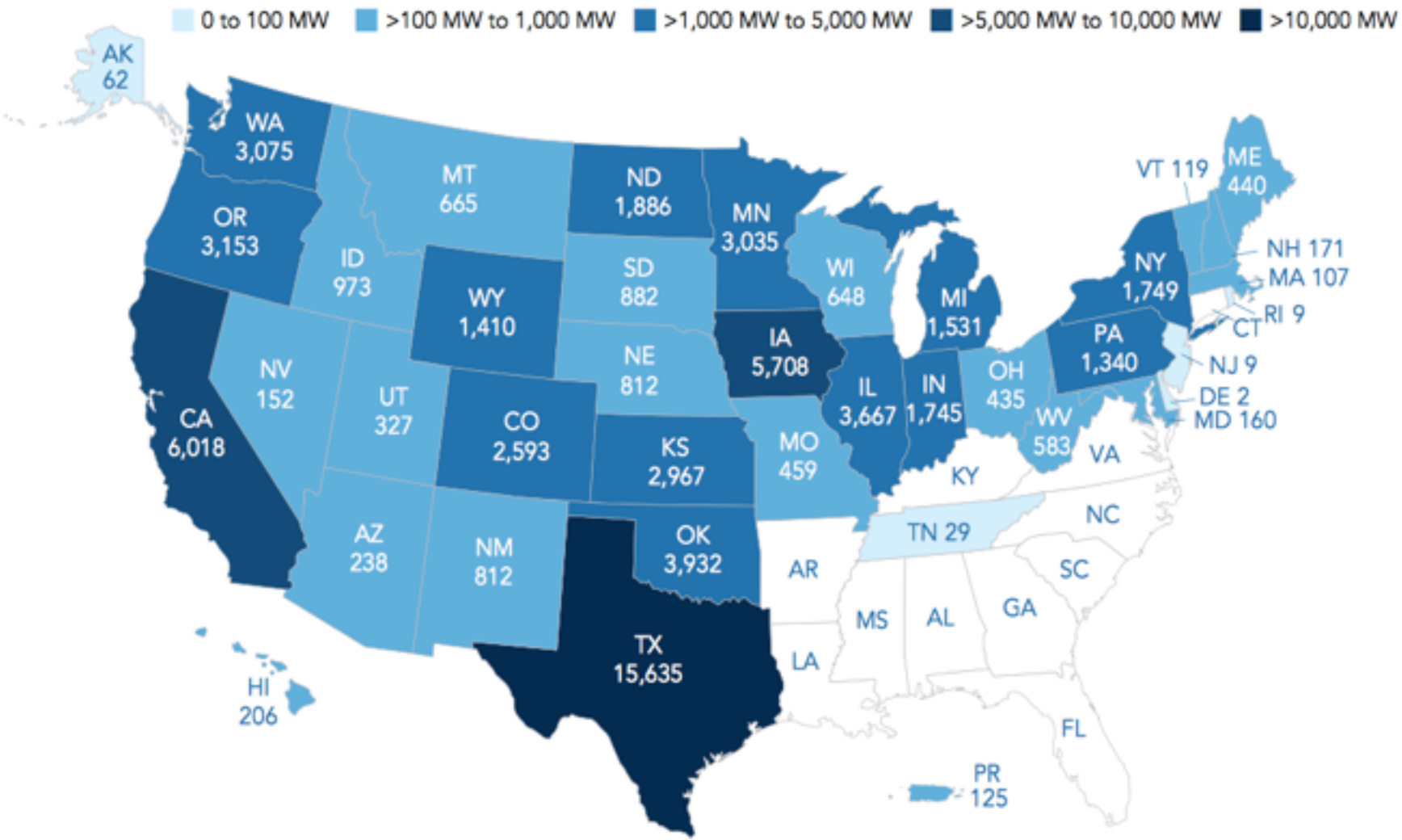
- 1,000 - 10,100
- 100 - 1,000
- 20 - 100
- 1 - 20

Data from the American Wind Energy Association Fourth Quarter 2010 Market report.

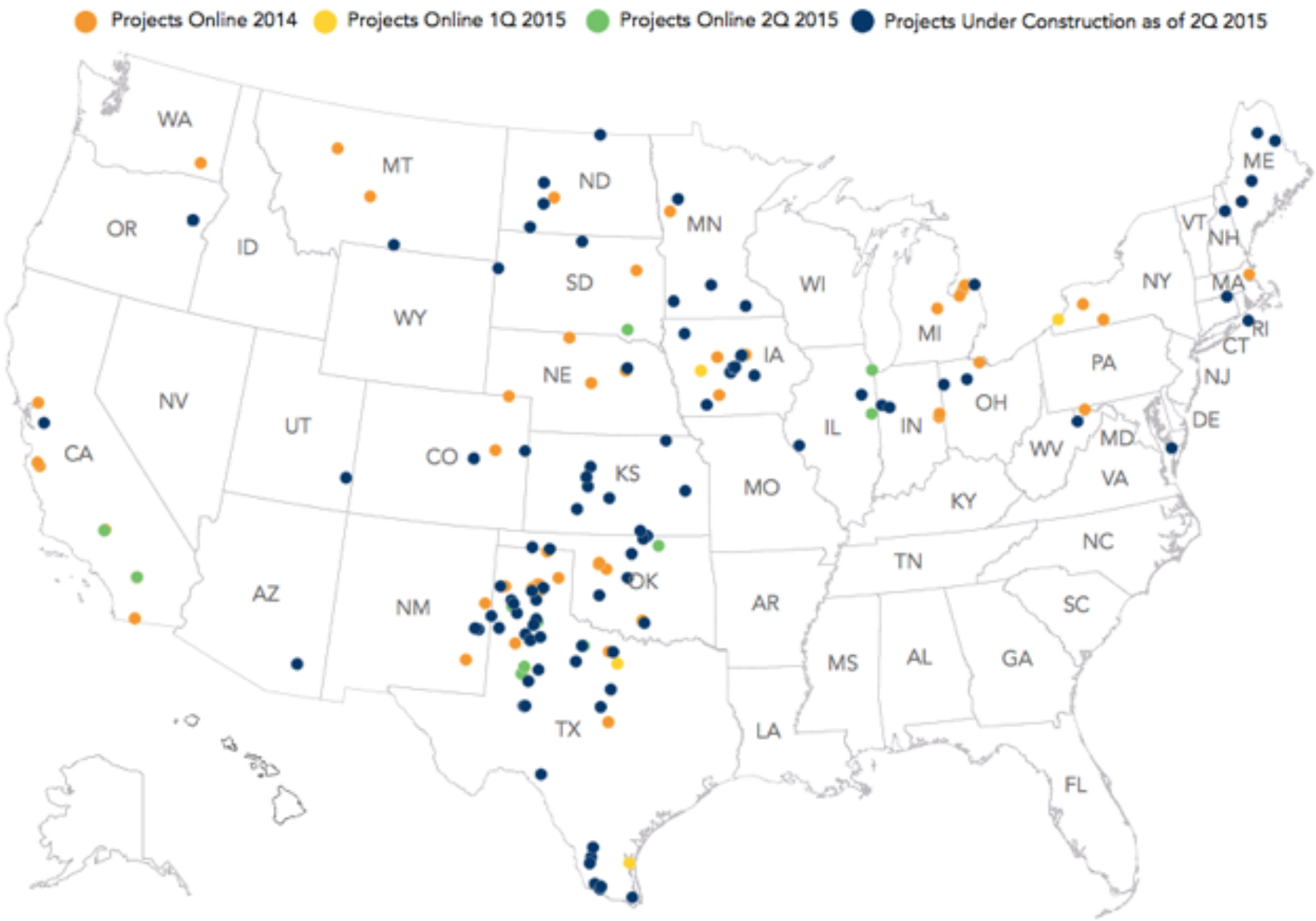
U.S. Department of Energy
National Renewable Energy Laboratory

17-MAR-2011 1.1.35

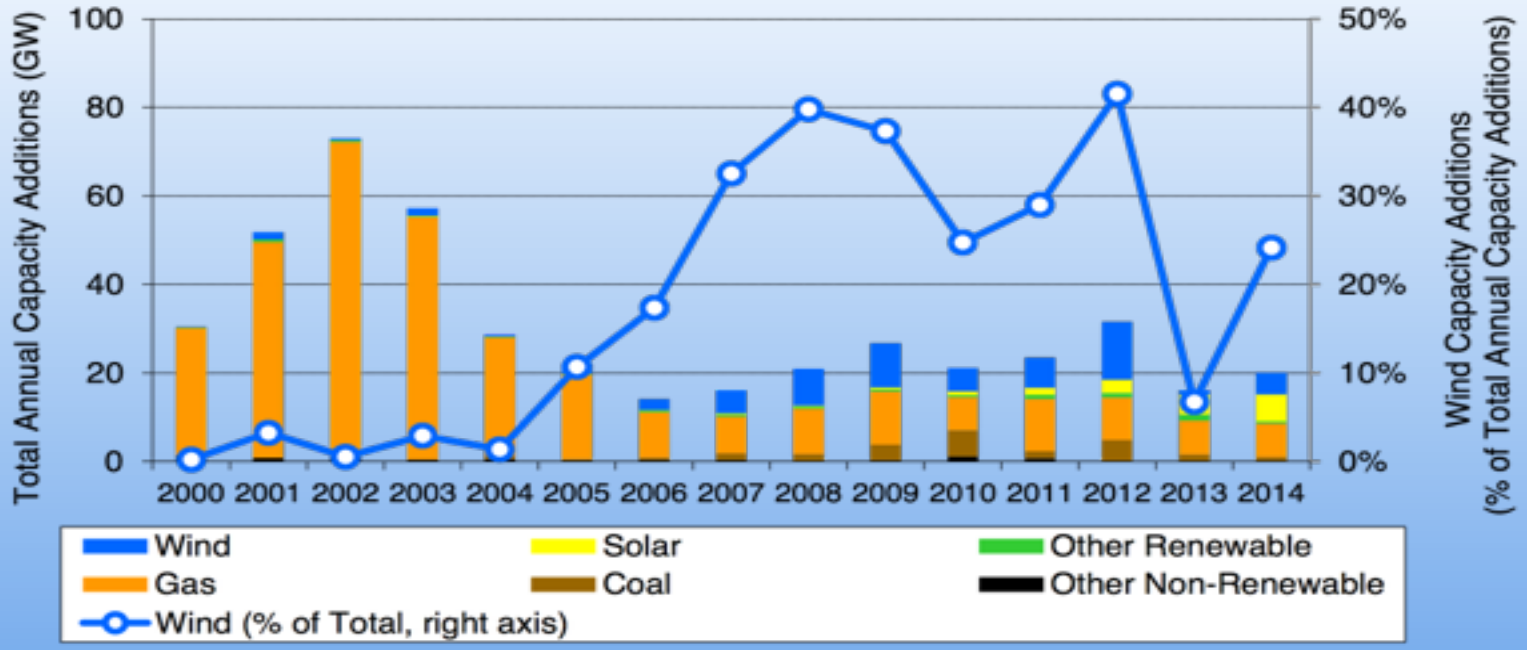
Installed Wind Capacity
June 30, 2015

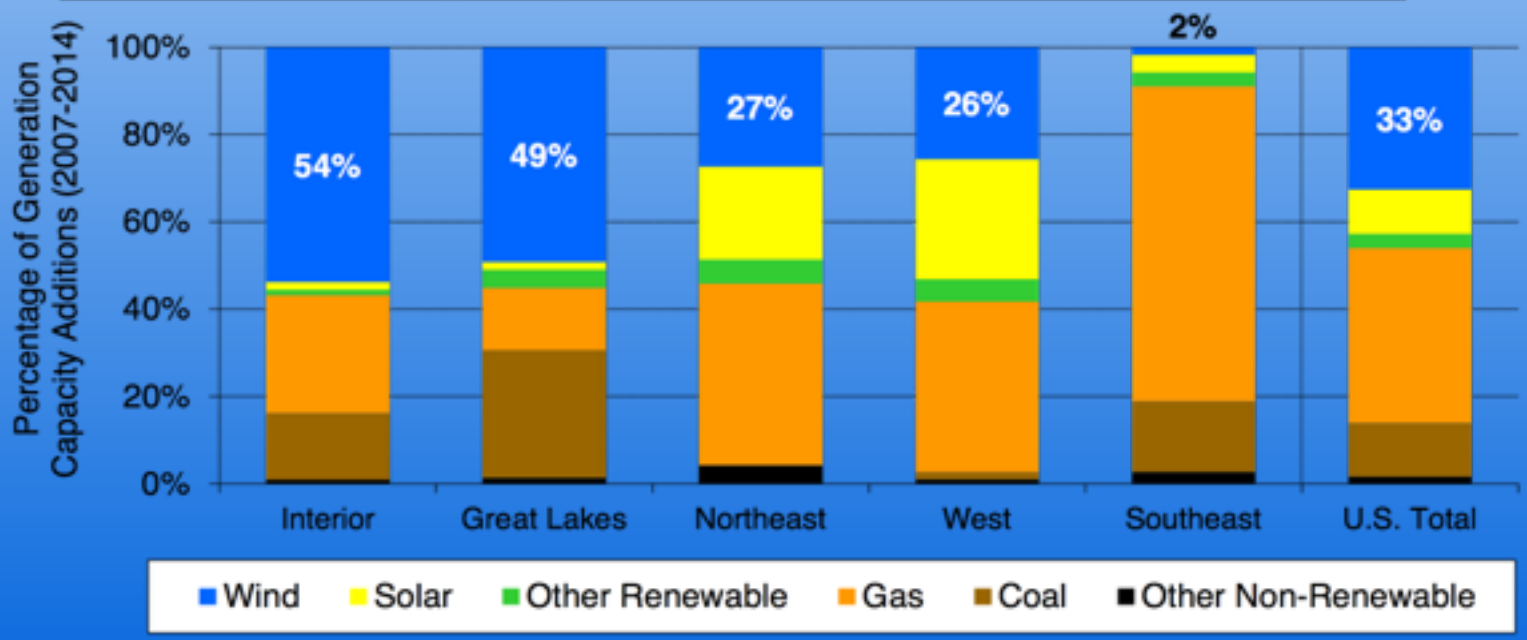


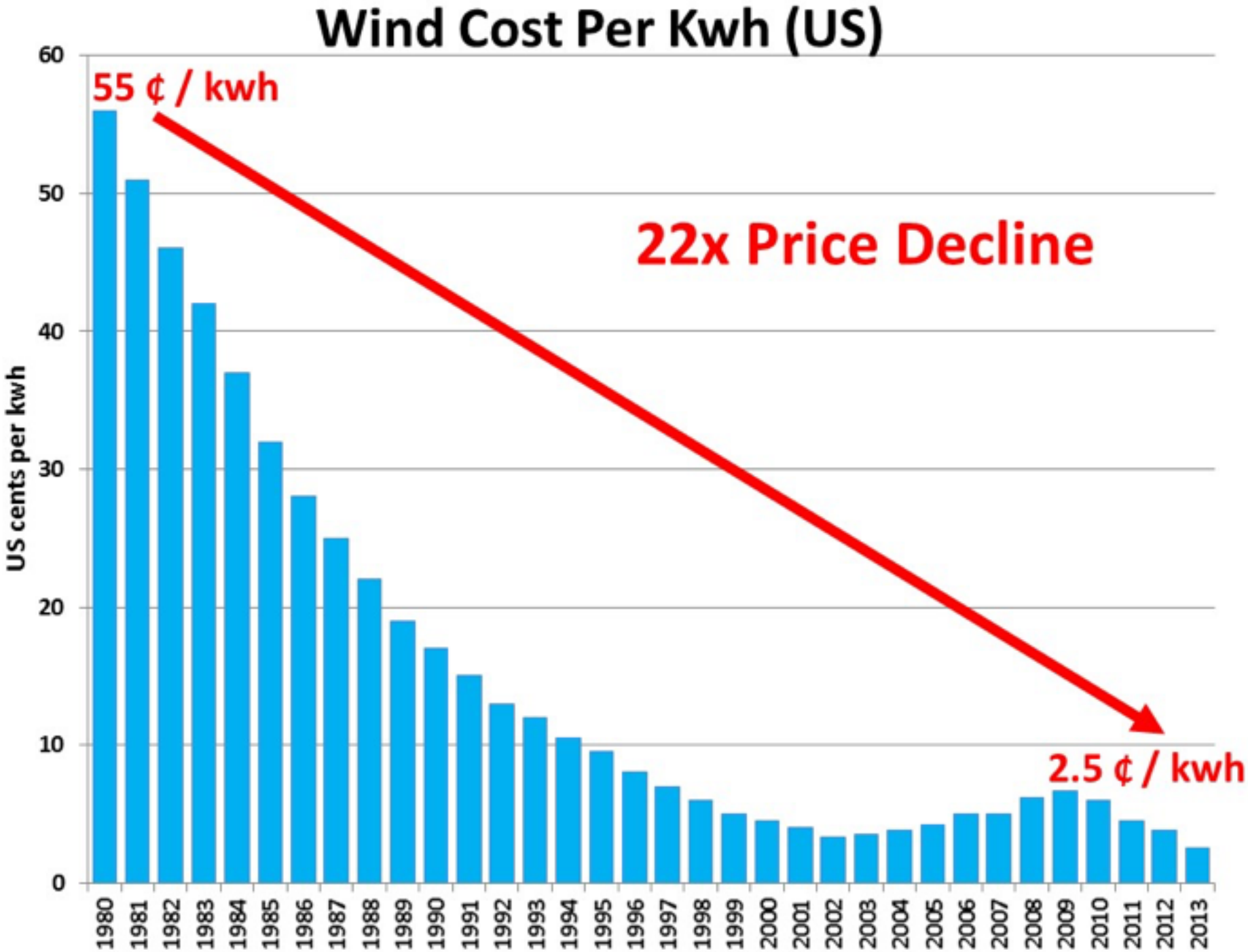
Map of Projects Online & Under Construction in 2015



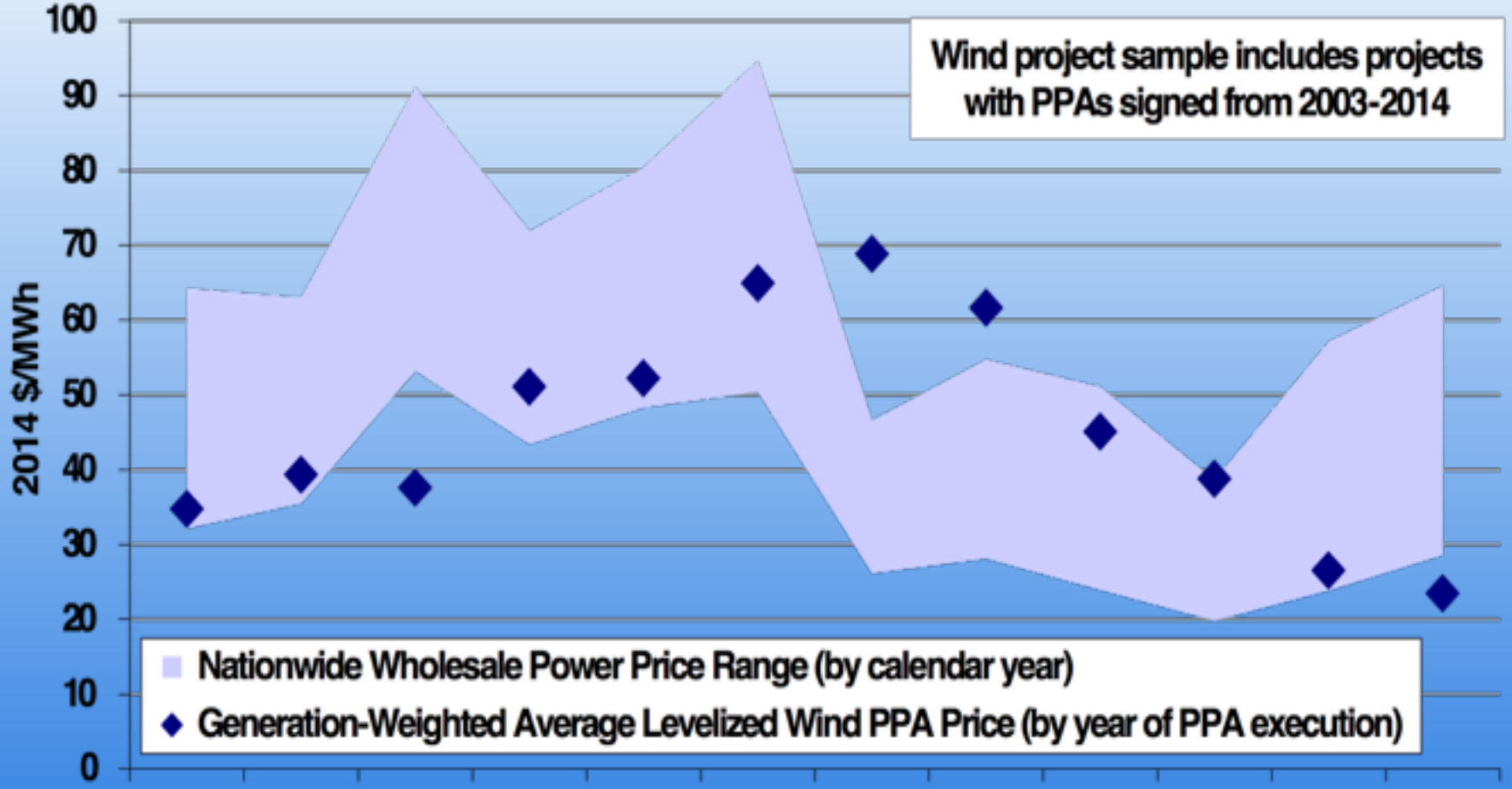
New Electric-Generating Capacity





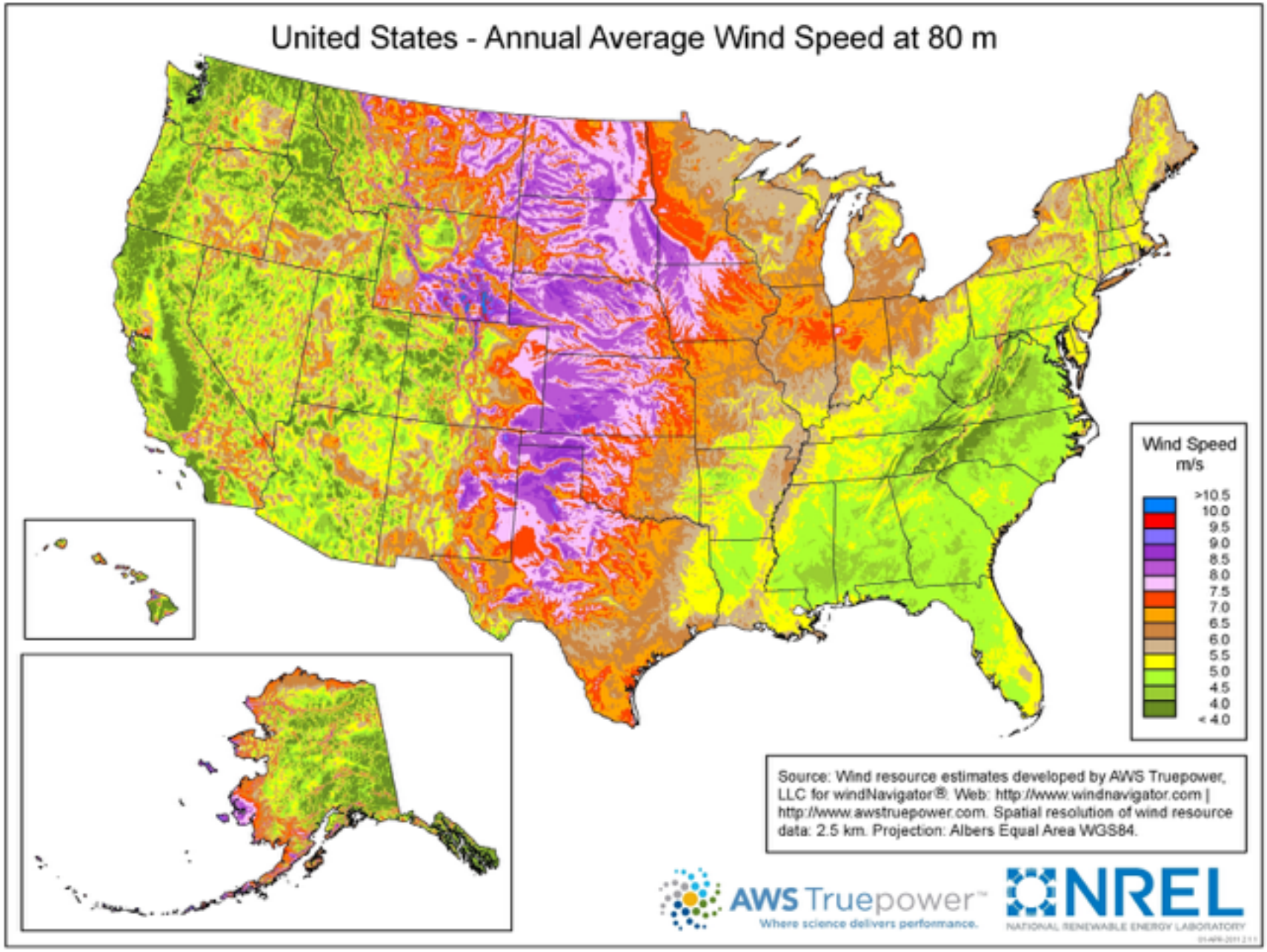

Wind Cost Per Kwh (US)
55 ¢ / kwh
22x Price Decline
2.5 ¢ / kwh
US cents per kwh
60
50
40
30
20
10
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

Wholesale Electricity Price Comparison

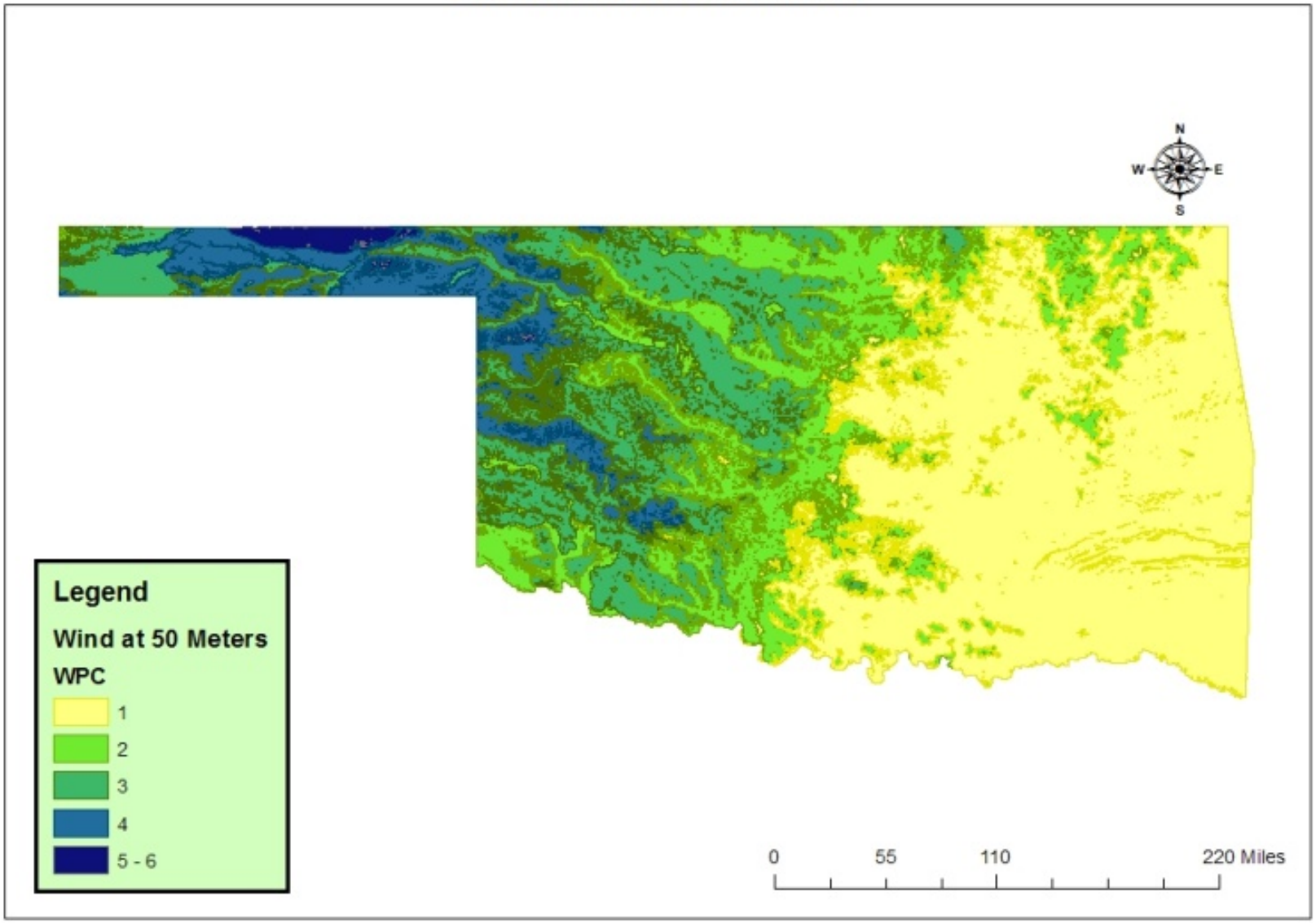


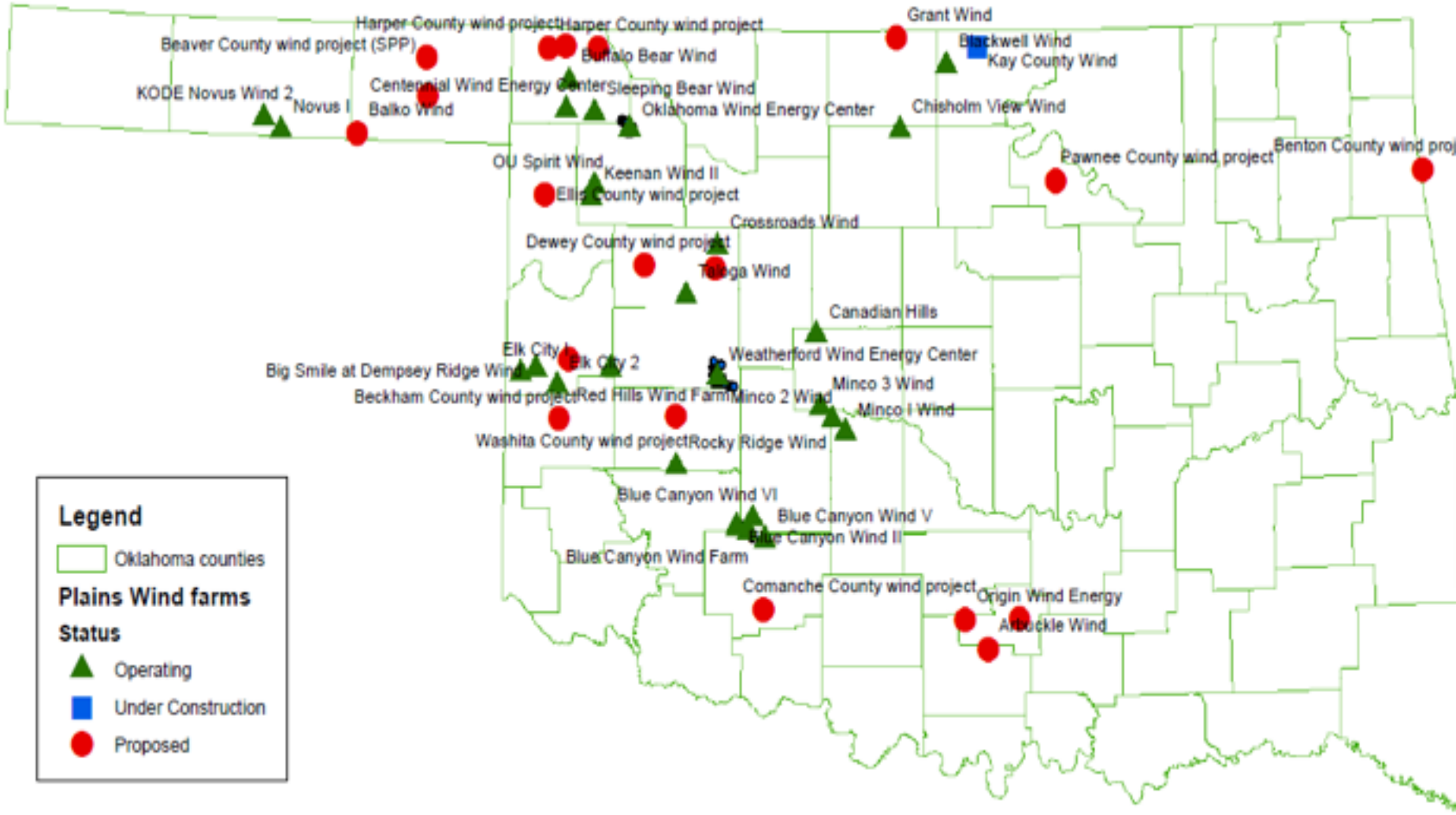
PPA year:	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Contracts:	9	13	17	30	26	39	49	48	42	14	26	13
MW:	570	547	1,643	2,311	1,781	3,465	4,048	4,642	4,572	985	3,674	1,768

Wind Energy in Oklahoma


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

Oklahoma Wind Classification





N

0 30 60 120 Miles

KEIN

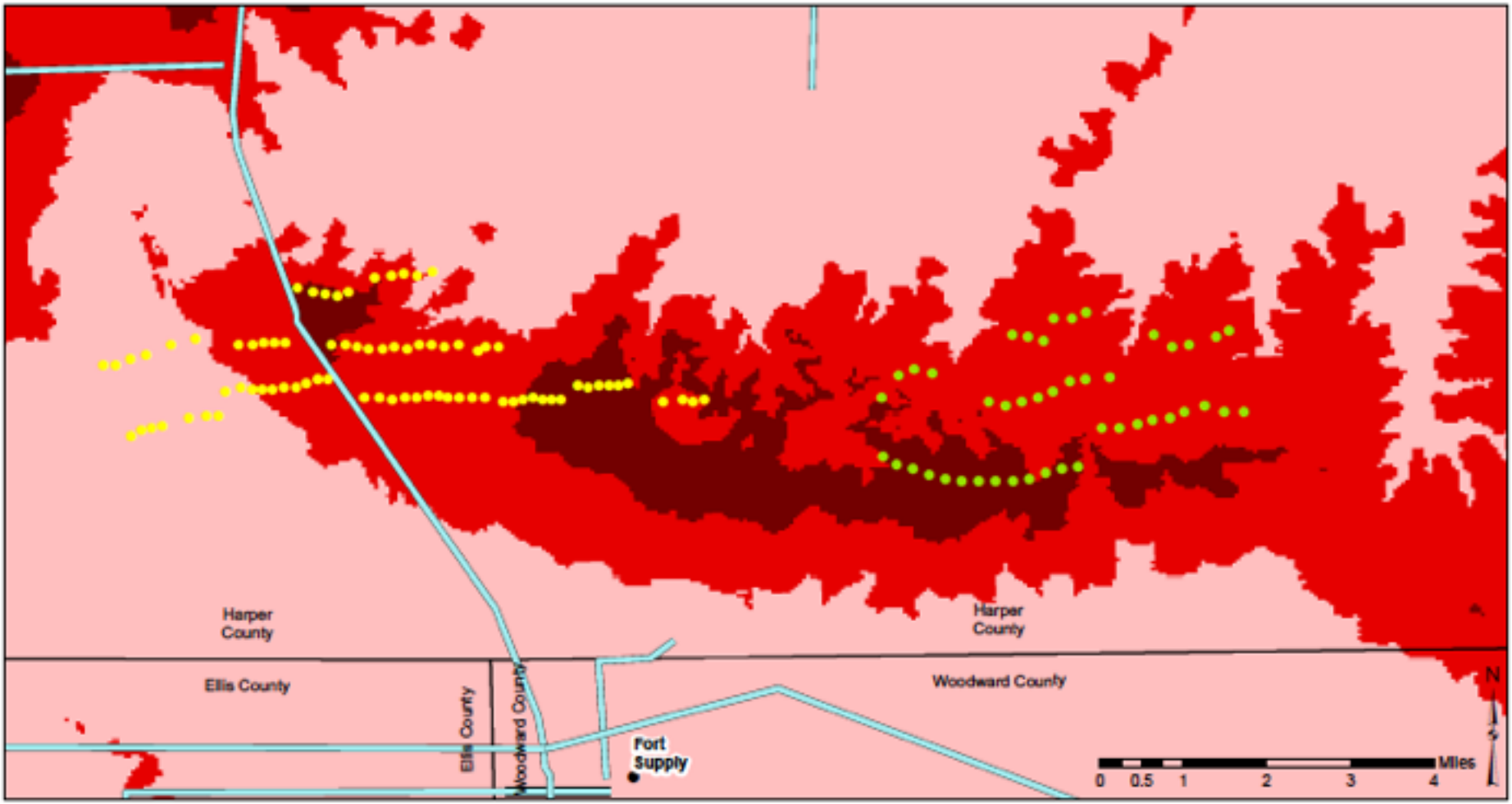
Kansas Energy Information Netw

For more information on Oklahoma Wind Projects, go to the Kansas Energy Information Network. Oklahoma wind projects

Oklahoma Stats

- Oklahoma Ranks 8th in the nation for wind resource capacity
  - Some estimate OK can provide 3% of entire nation's electricity via wind power
- Oklahoma Ranks 4th in the nation as of the end of 2014 for total wind power production
- Wind power accounts for ~18.4% of OK's electricity (Jan-May 2015)

Centennial and Sleeping Bear Wind Farms



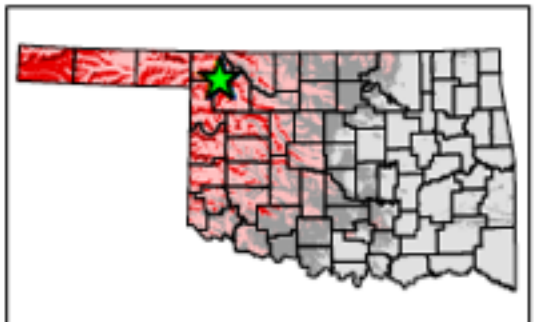
Oklahoma Wind Power Initiative

owpi

Wind Resource Potential at 50 meters

- Excelent
- Good
- Fair
- Marginal
- Poor

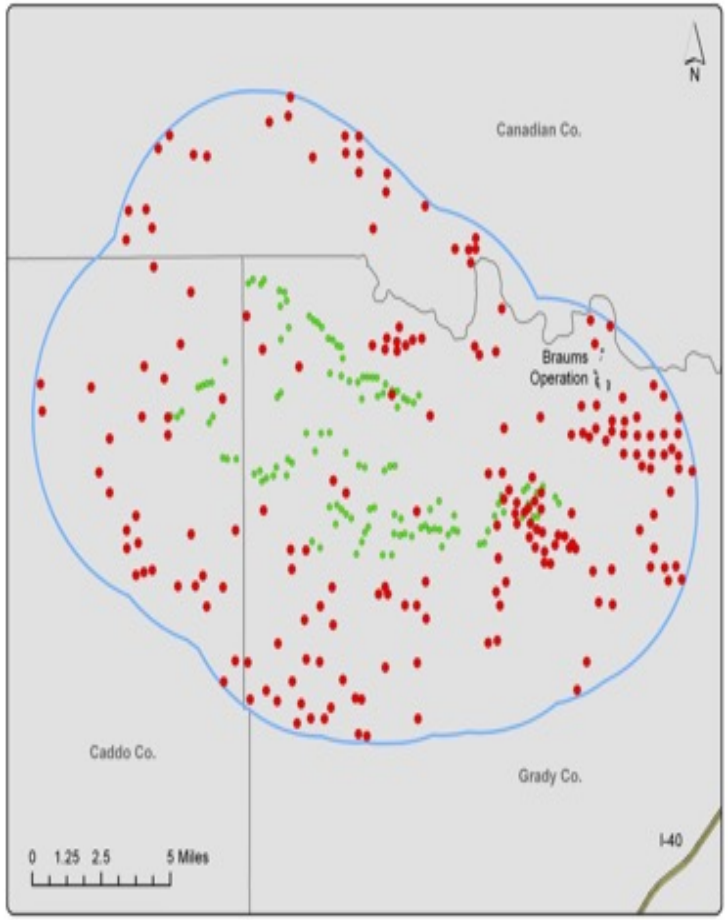
- Centennial Wind Farm
- Sleeping Bear Wind Farm
- Transmission Lines



Perceptions of Wind Energy

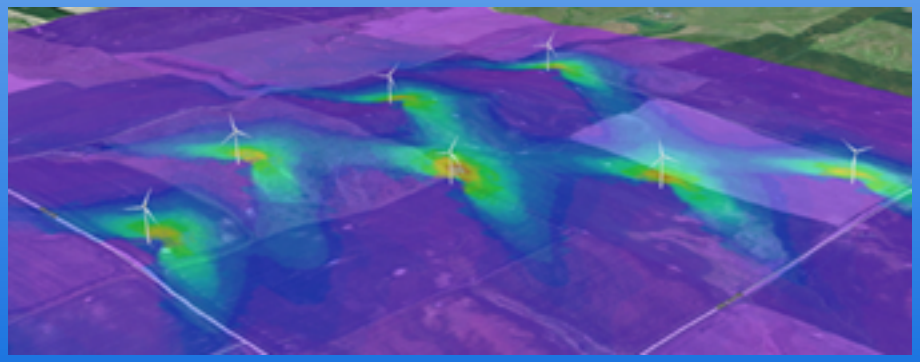
Perceptions of Wind Energy

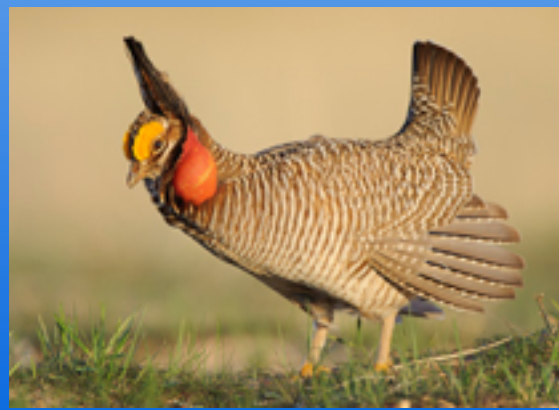
Oil and Gas Sites Within Five Miles of Minco Wind Farm



Potential Issues

- Visual impact Analysis
- Radio/TV signal interference studies
- Environmental
  - Wildlife, migratory birds, bats, lesser prairie chicken, etc.





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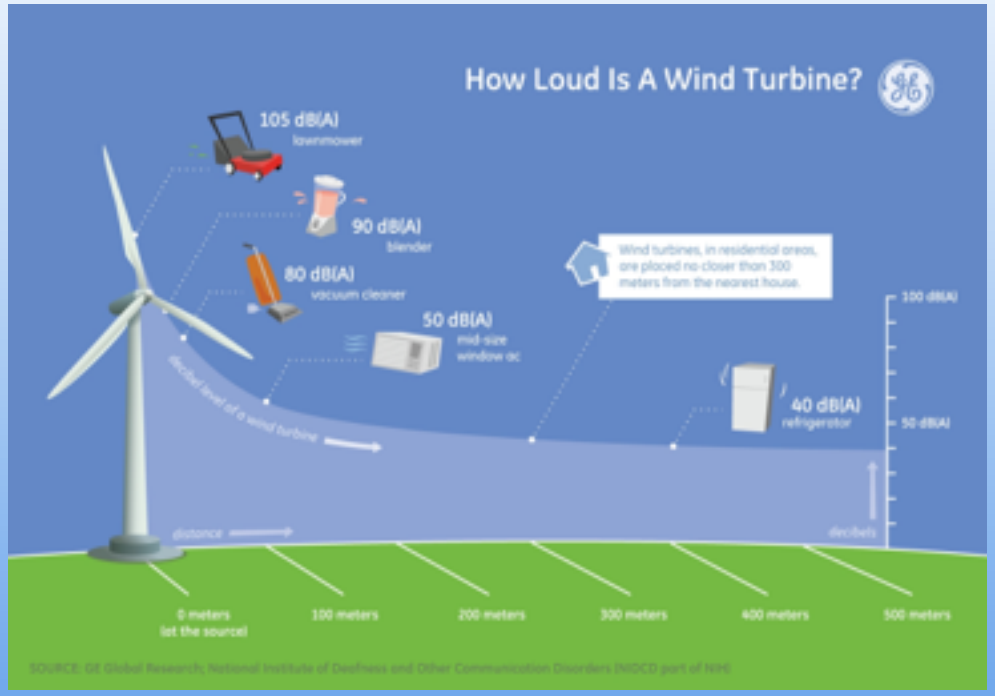
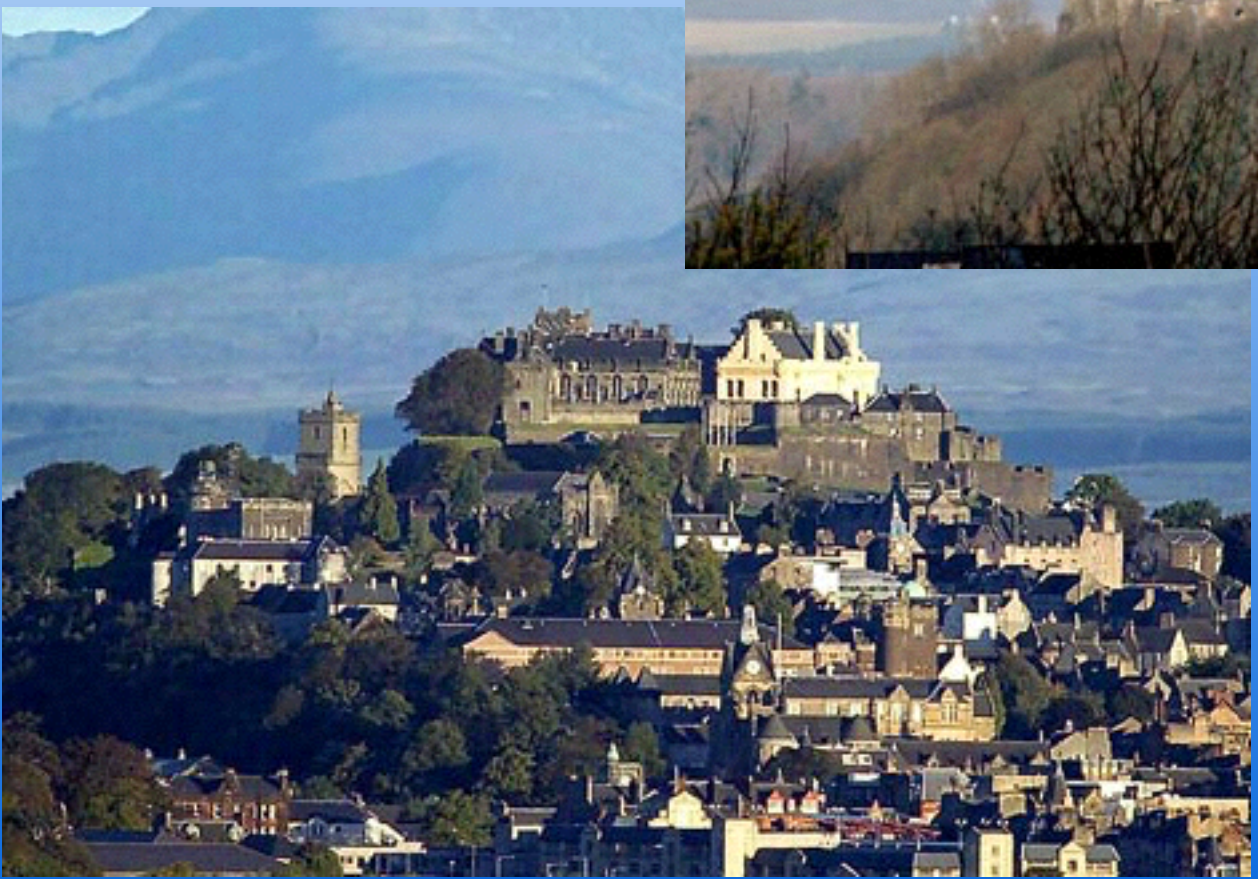


Noise?

Shadow Flicker?

Activity: Siting a Wind Farm

Galway County Wind Farm



Vogelsberg before...

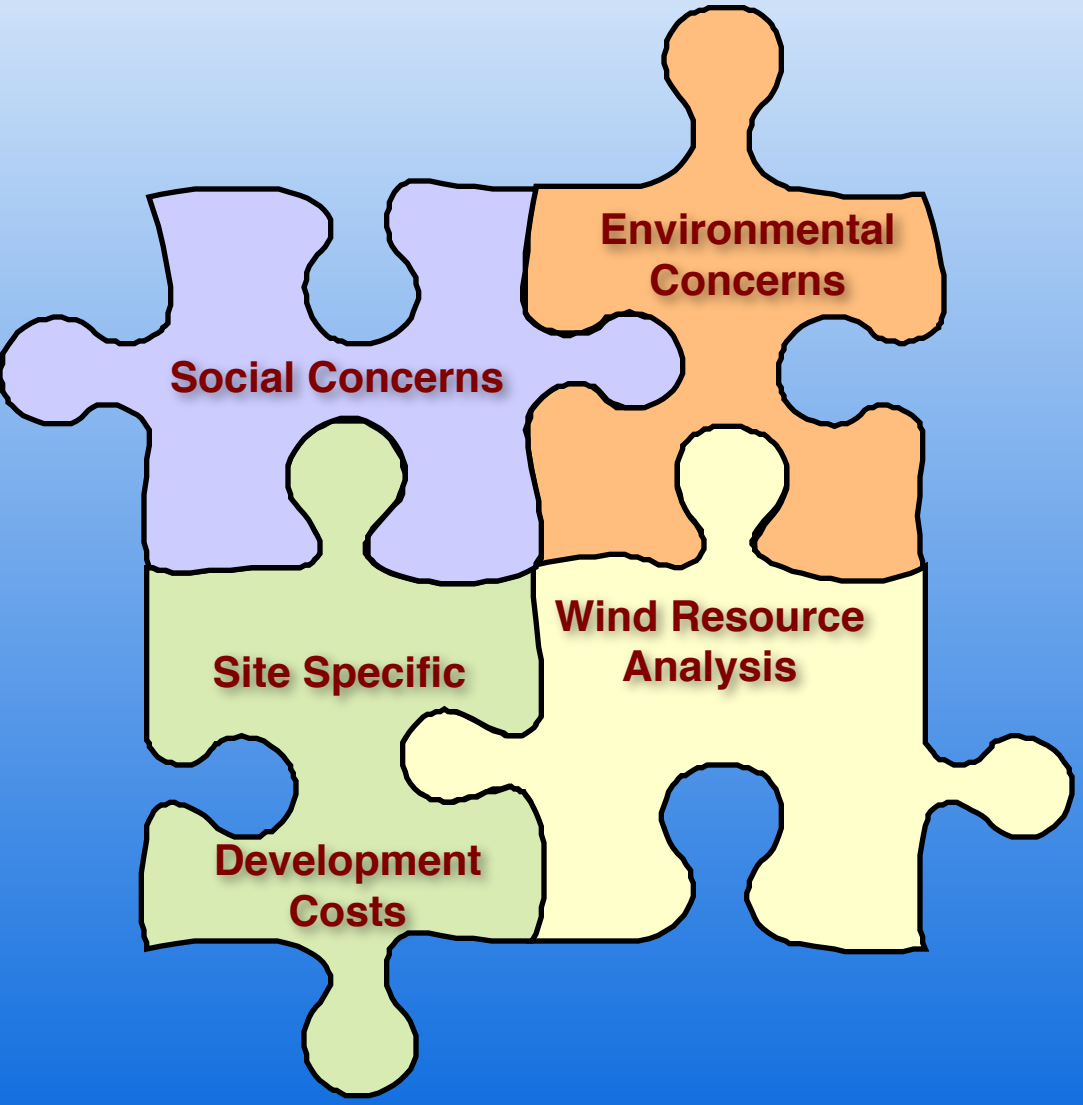
Vogelsberg after

Wind Energy as part of a Sustainable energy future

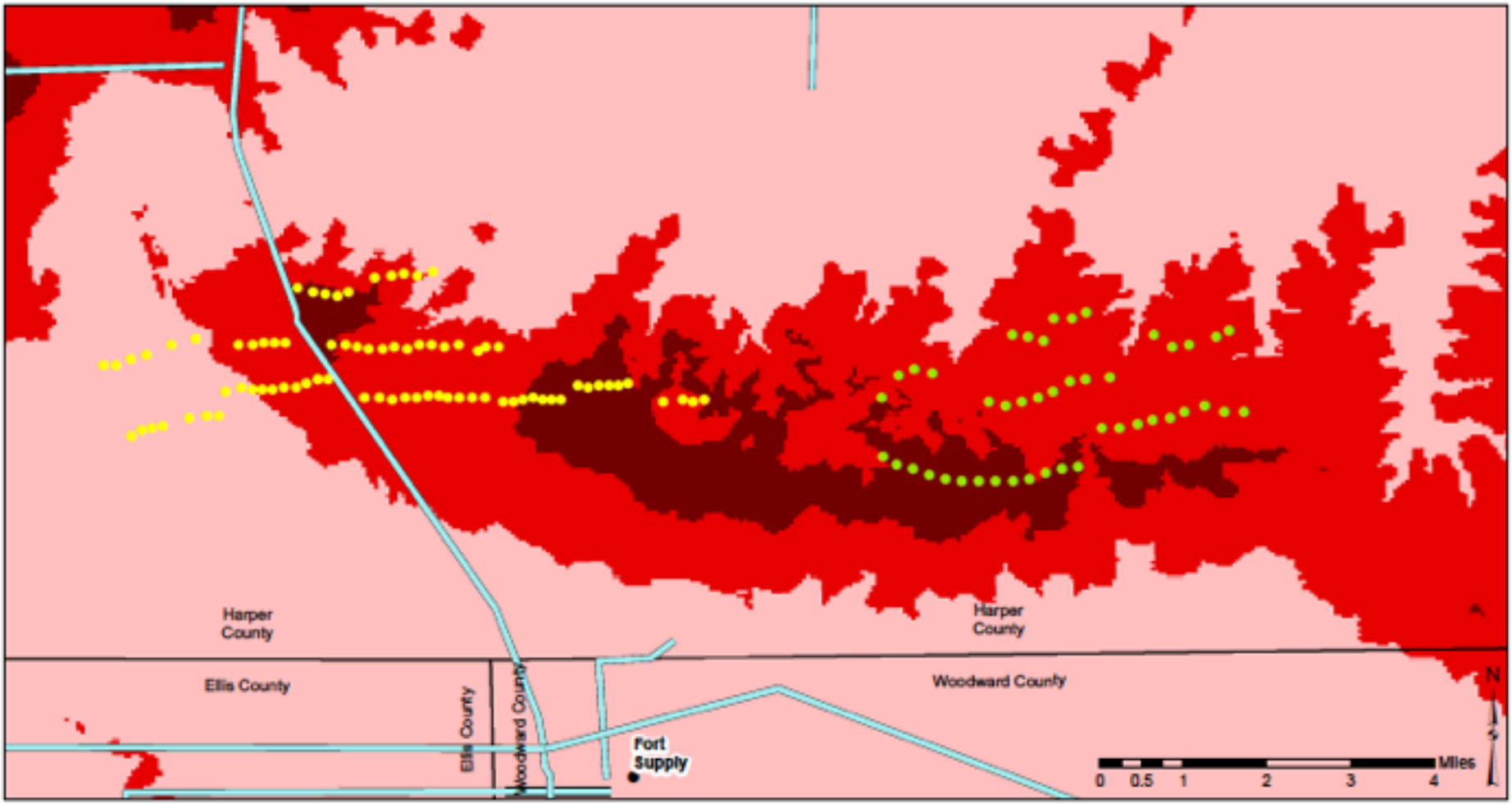
- **Geographers working on or assisting in:**
  - **Site Assessment**
  - **Spatial Decision Support Systems**
  - **Electronic Control**
  - **Forecasting**

The Past and Future of Energy

Geospatial Analysis



Centennial and Sleeping Bear Wind Farms



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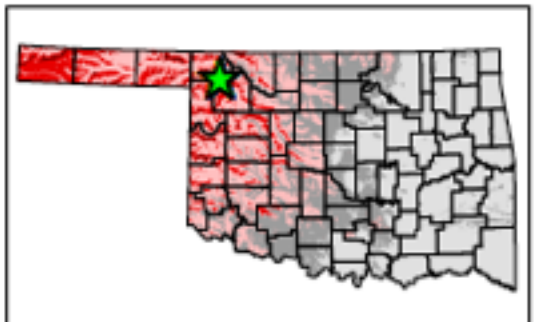

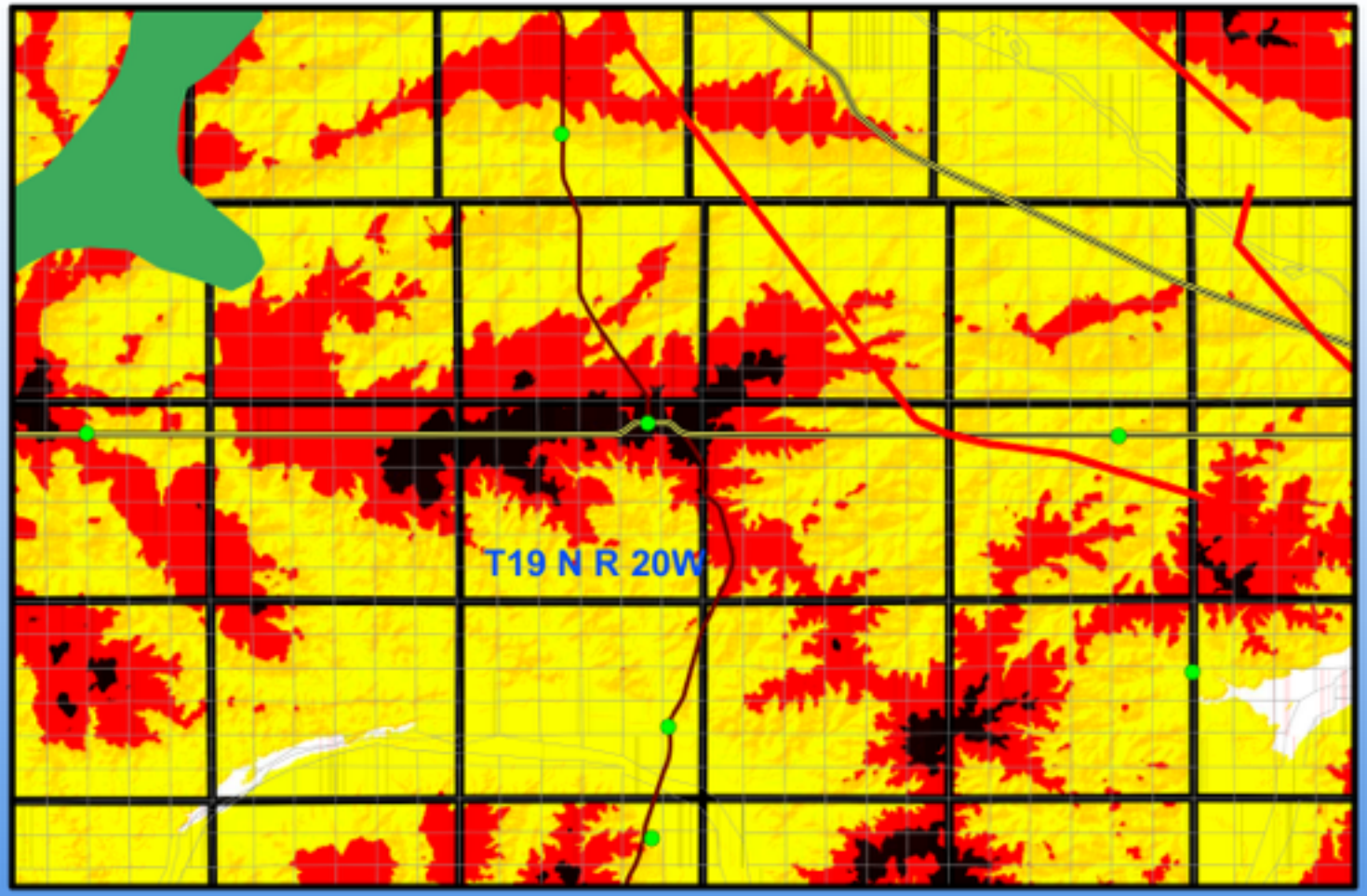

Legend

- Cities
- Interstate Highways
- Utility Lines
- US Highways
- State Highways
- Railroads
- Lesser Prairie Chicken Distribution
- SECTIONS
- Township and range

Wind Resource

Wind Classes

- Excellent
- Good
- Fair
- Poor

0 4 8 16 Kilometers