

Wind Energy: Resource, Technology, Market



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Types of Lift Turbines

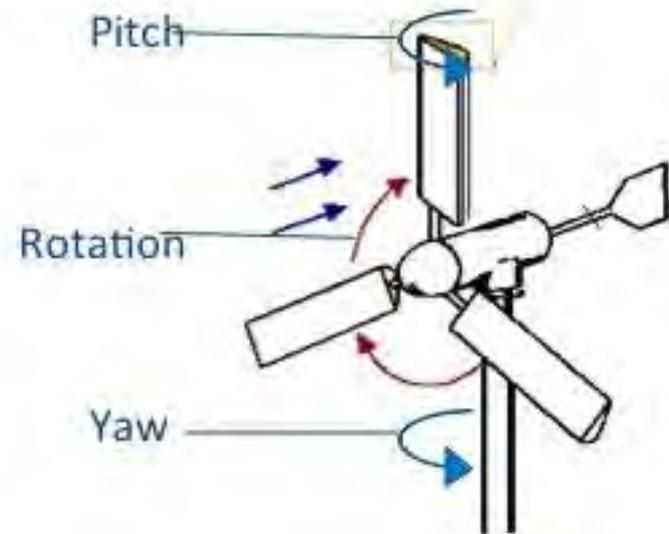
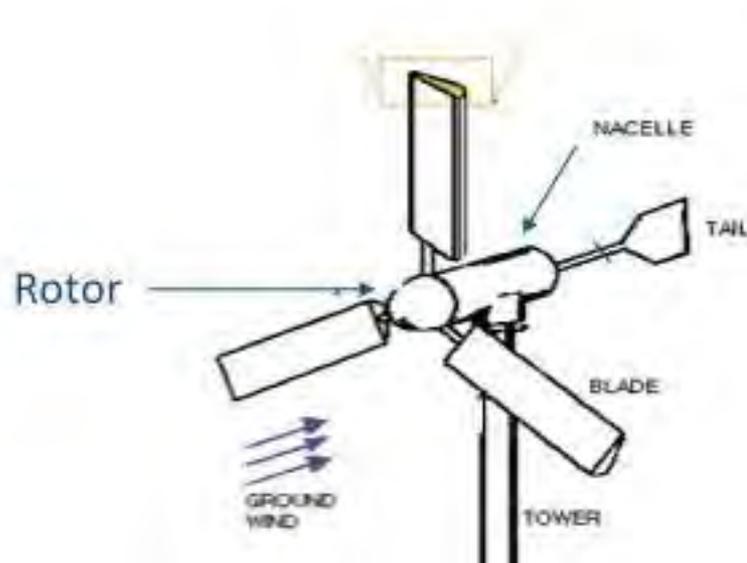
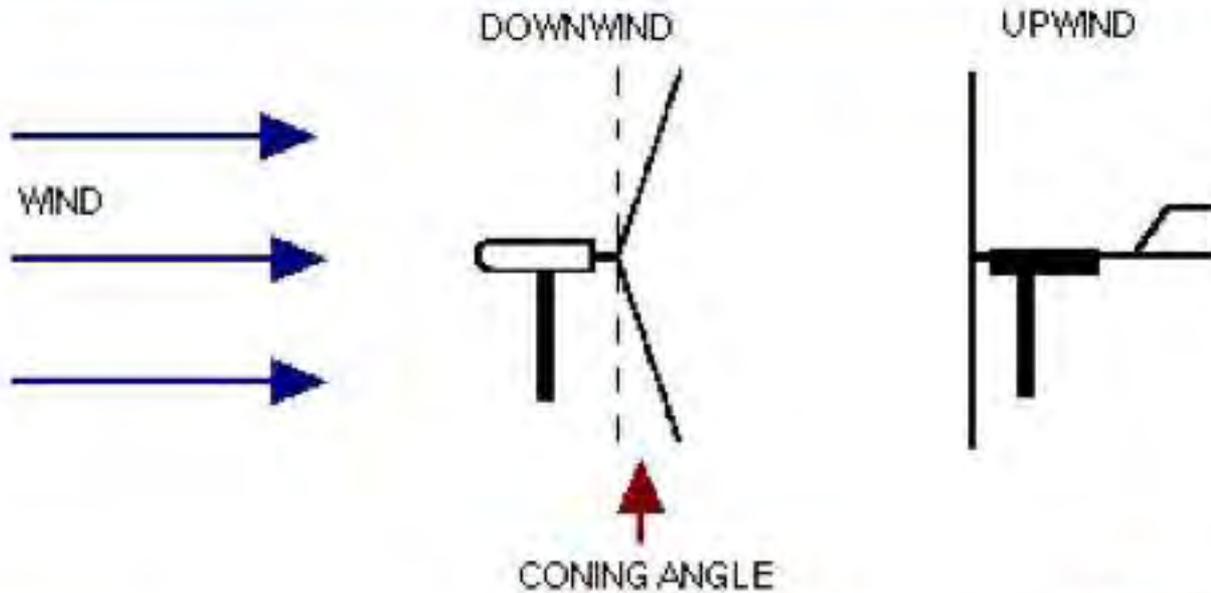
HAWT



VAWT



Basic Properties of HAWT



Turbine Sizes



Small (≤ 100 kW)

Homes

Farms

Remote Applications

Community Wind



Mid-Sized (100 - 1000 kW)

Village Power

Distributed Energy

Community Wind



Large > 1 MW

Utility-scale

Distributed Energy

Community Wind

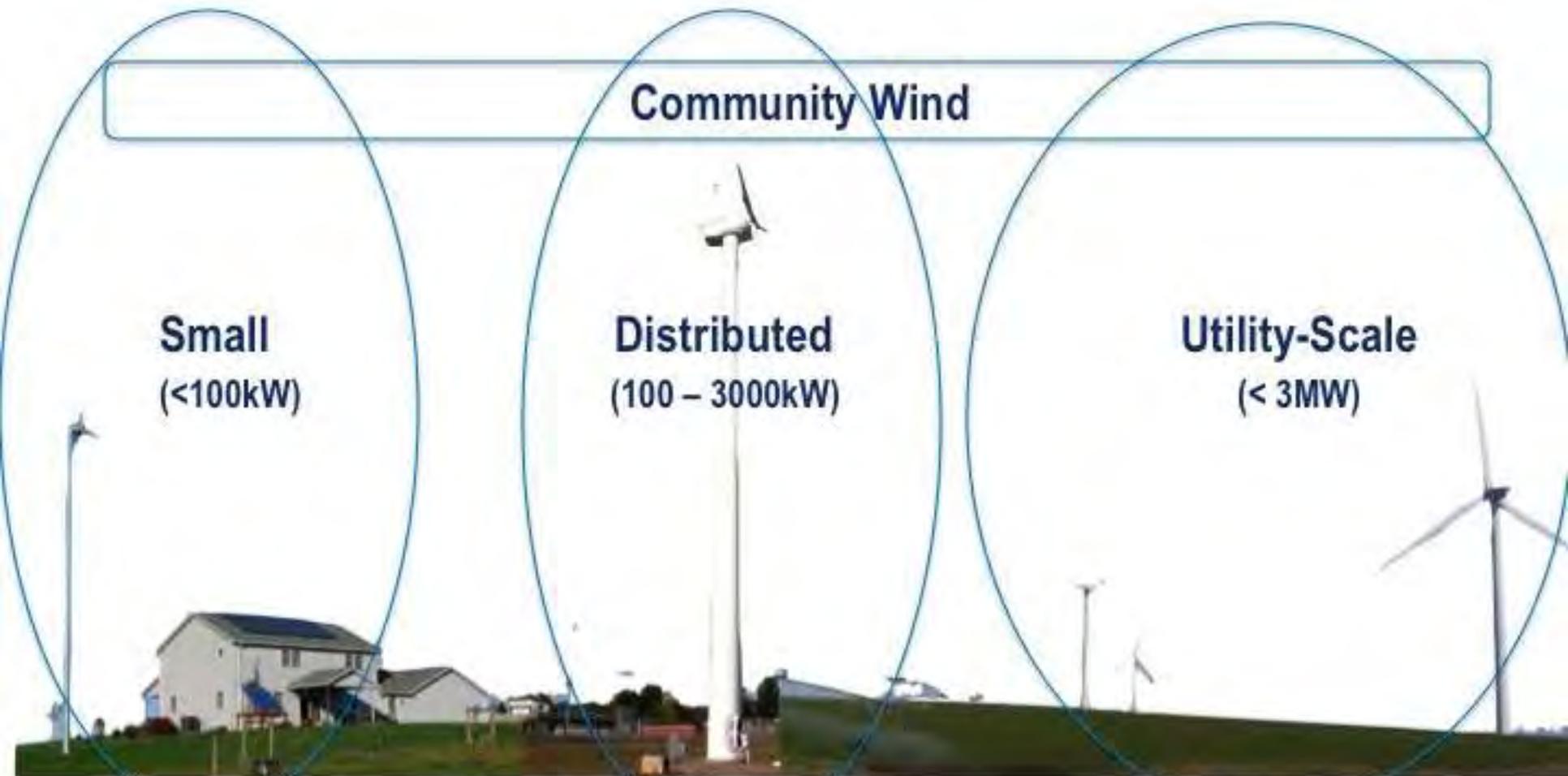
Wind Applications

Community Wind

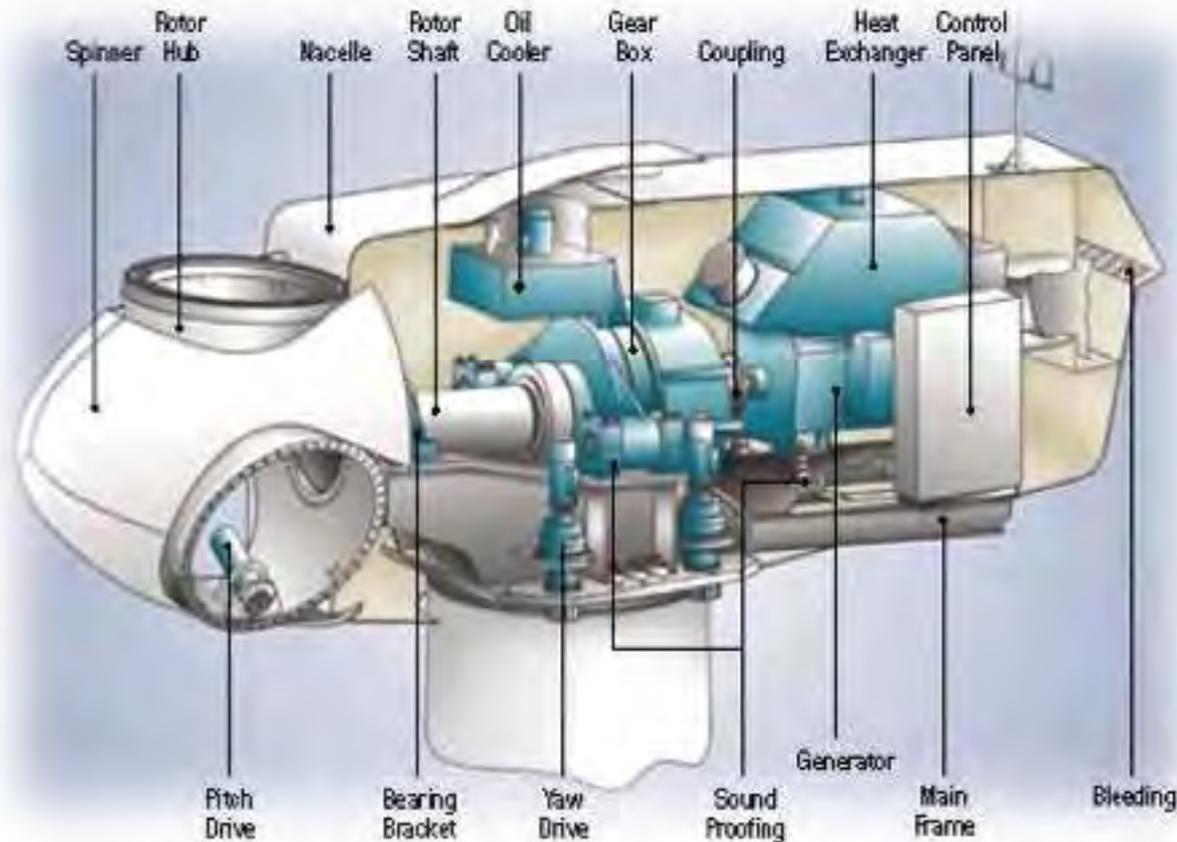
Small
($<100\text{kW}$)

Distributed
($100 - 3000\text{kW}$)

Utility-Scale
($< 3\text{MW}$)



Modern Wind Turbines



Typically induction or
variable speed
permanent
magnet
generators

Create AC power
supplied to the
grid

Actively controlled

Large by Comparison

GE 1.5 SLE: 77m rotor
Boeing 747-200: 60m wingspan



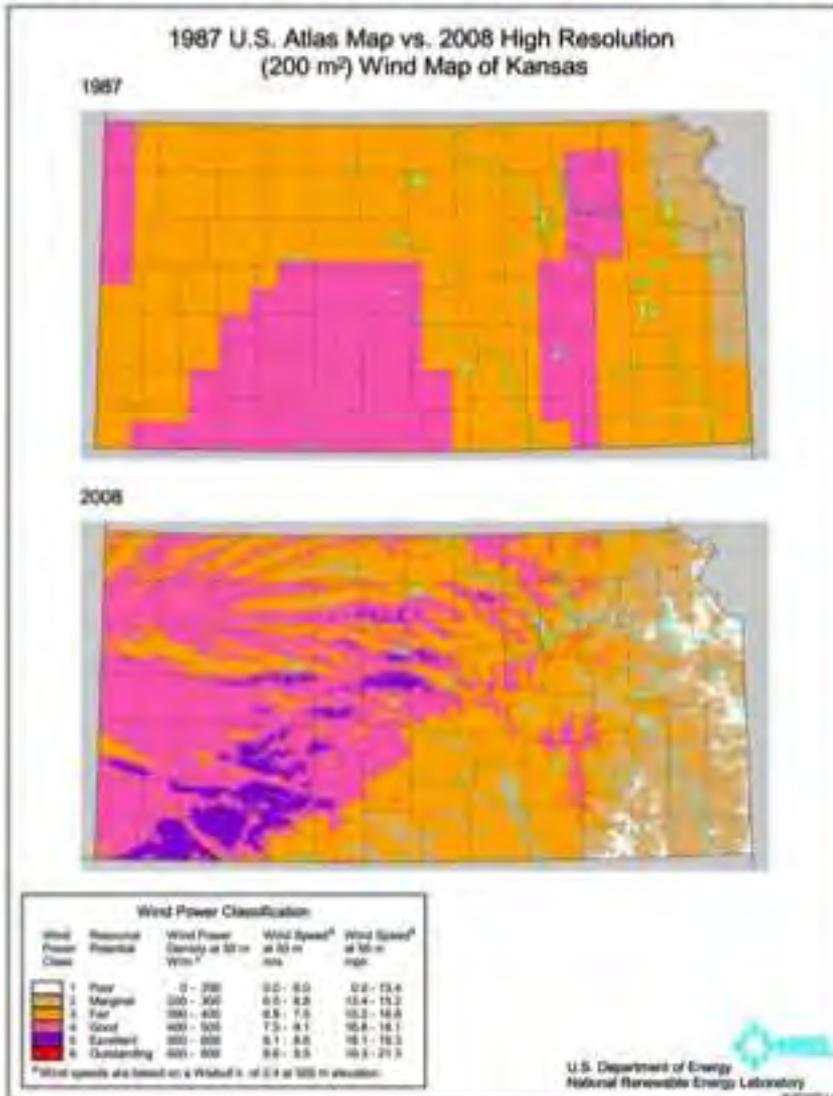
Very Large by Any Account



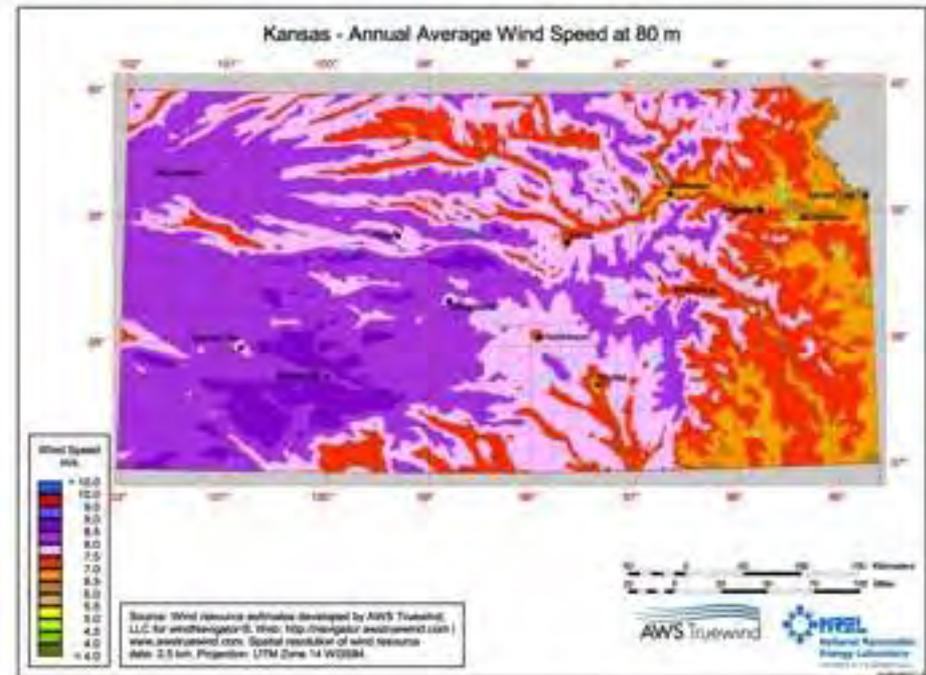
| | |
|------------------|---------------------|
| Rotor: | 127m (416') |
| Hub Height: | 135m (443') |
| Total Height: | 198m (650') |
| RPM: | 5 – 11 |
| Power Rating: | 7.5 MW |
| Tower wall (max) | 18" |
| Total Weight: | 13.2 Million Pounds |

Kansas Wind Map Changes Over Time

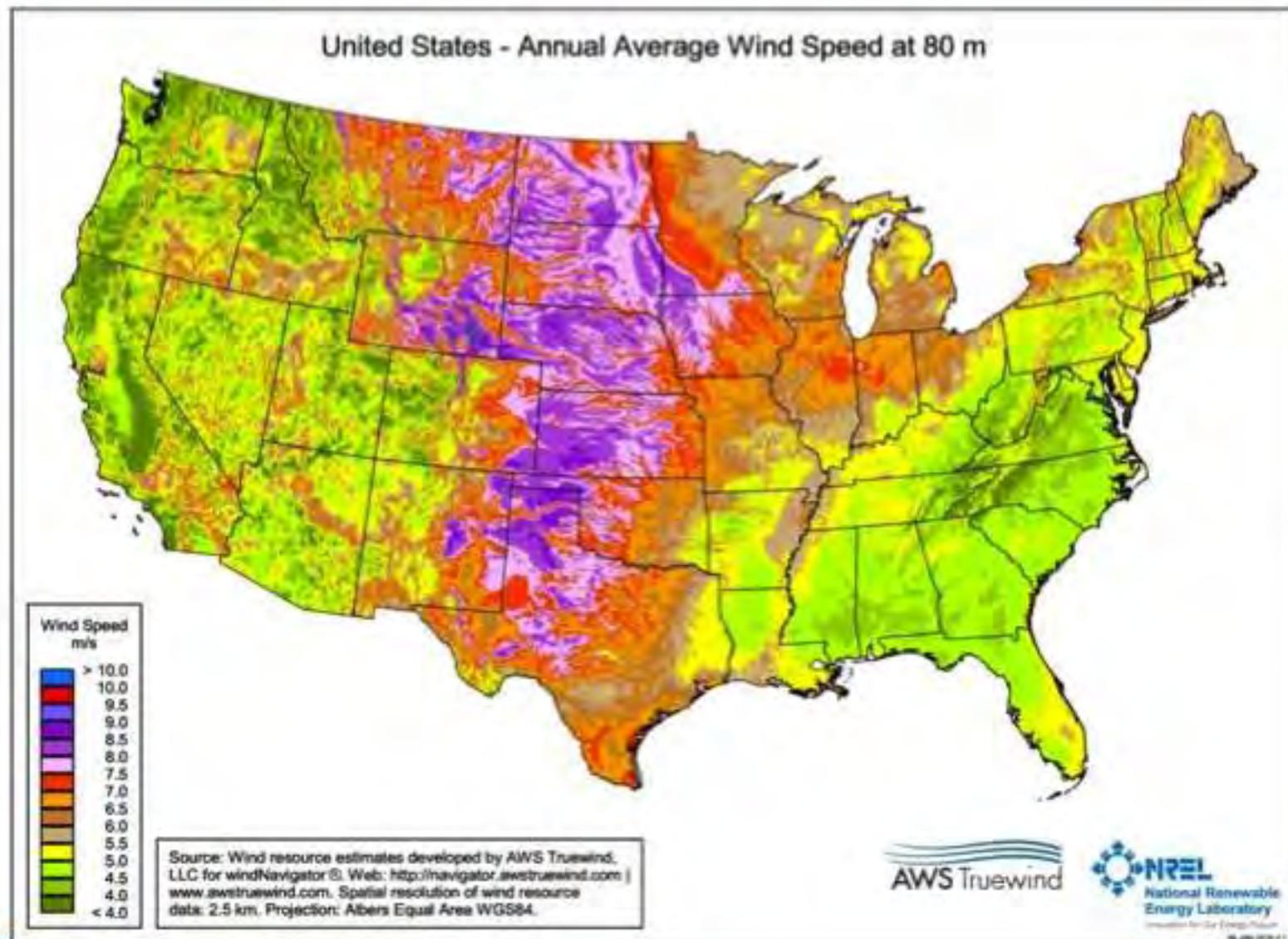
1987 & 2008 Wind Power Maps at 50 m



2010 Wind Speed Map at 80 m



Strong National Wind Resource

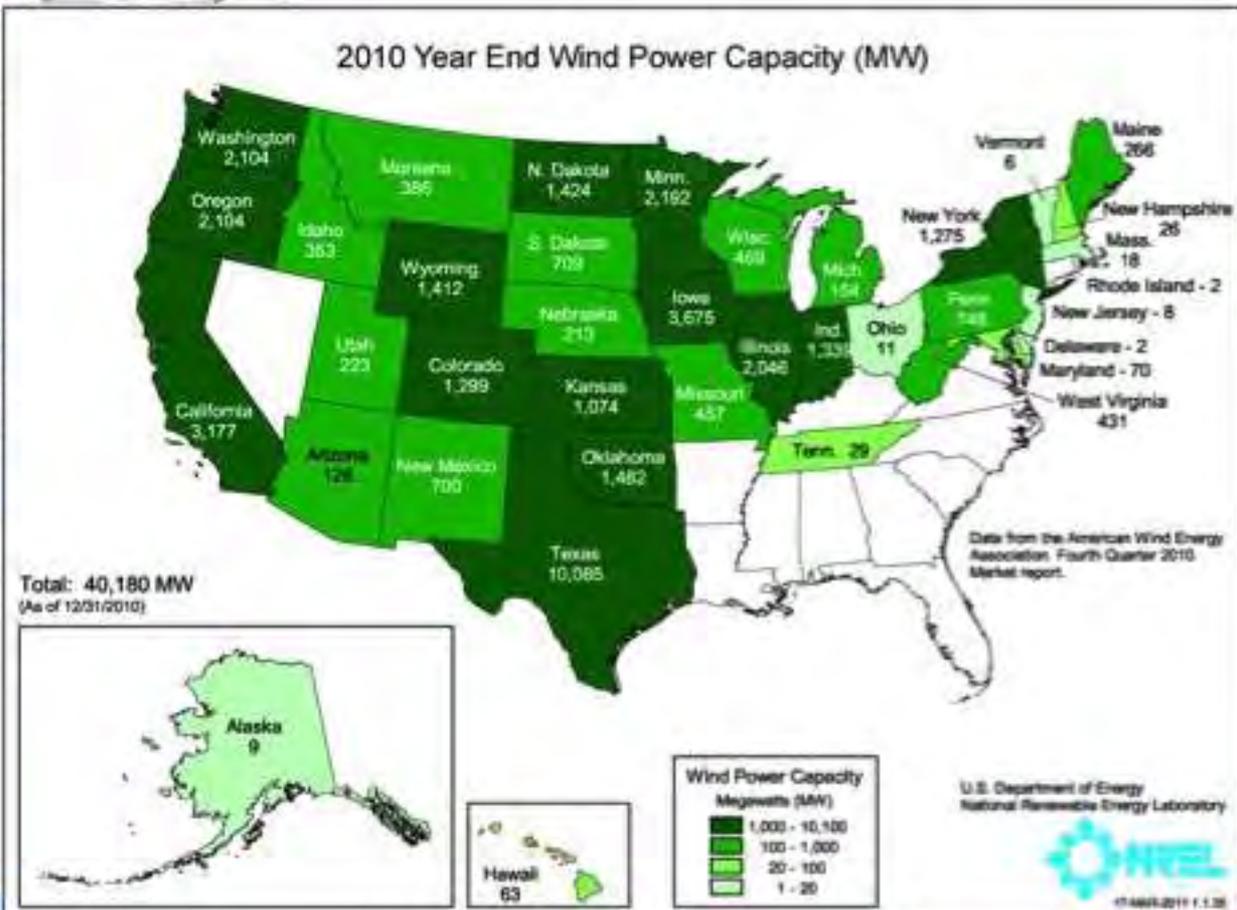


Installed Wind Capacities (1999 – 2010)

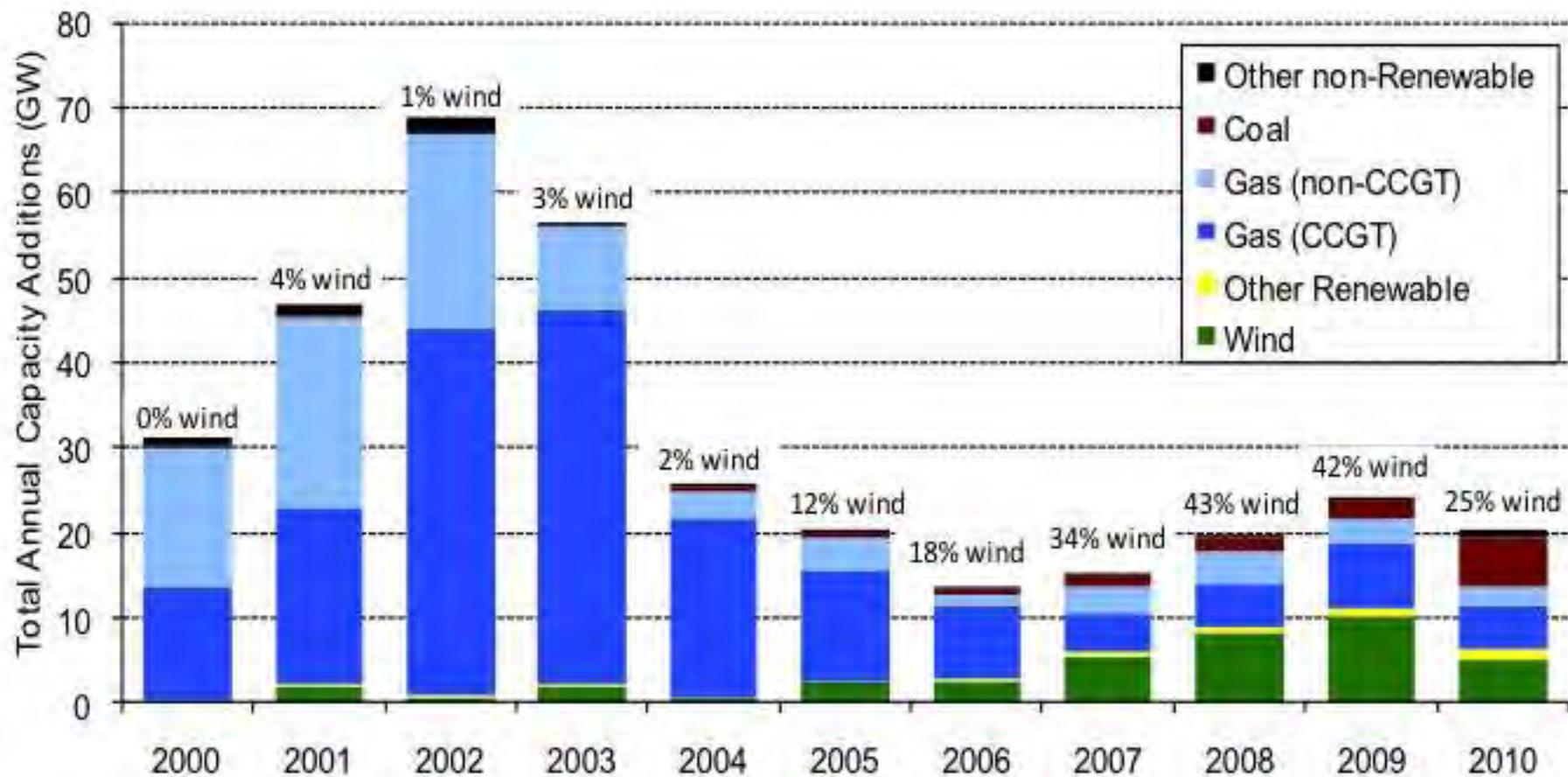
1999 Year End Wind Power Capacity (MW)



2010 Year End Wind Power Capacity (MW)

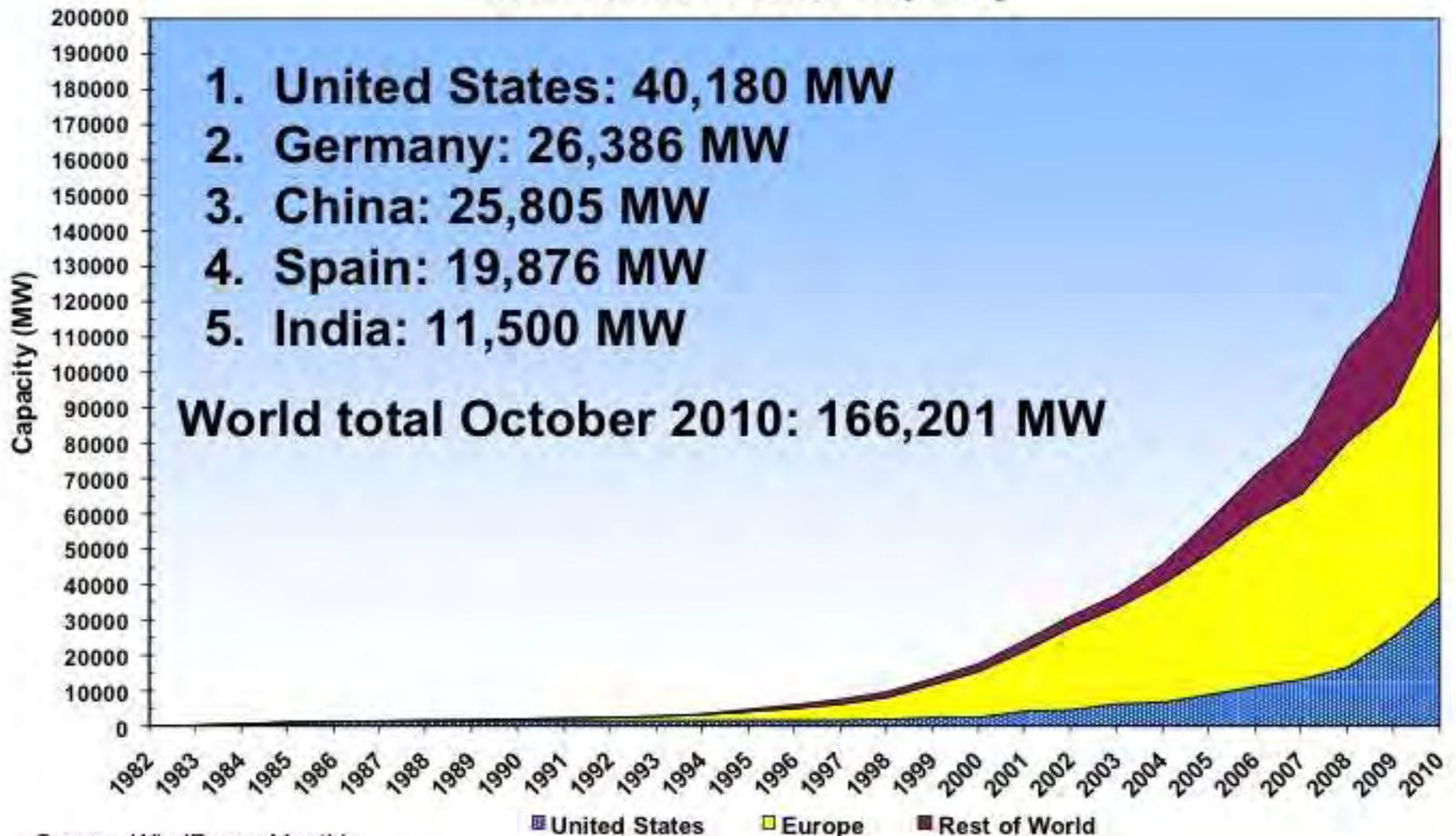


Wind Is a Major Source of New Capacity:



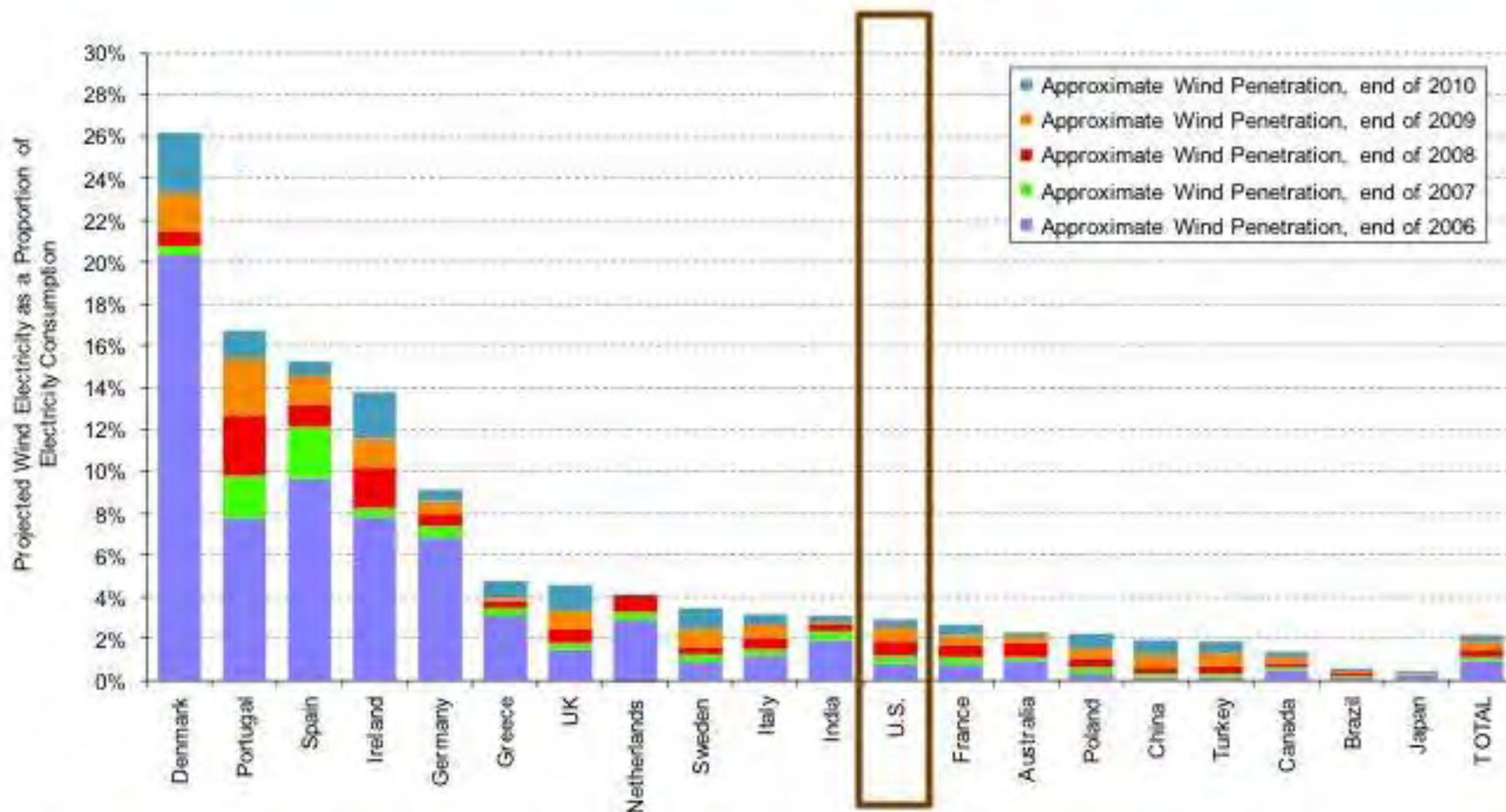
Strong Industry Acceleration

Total Installed Wind Capacity



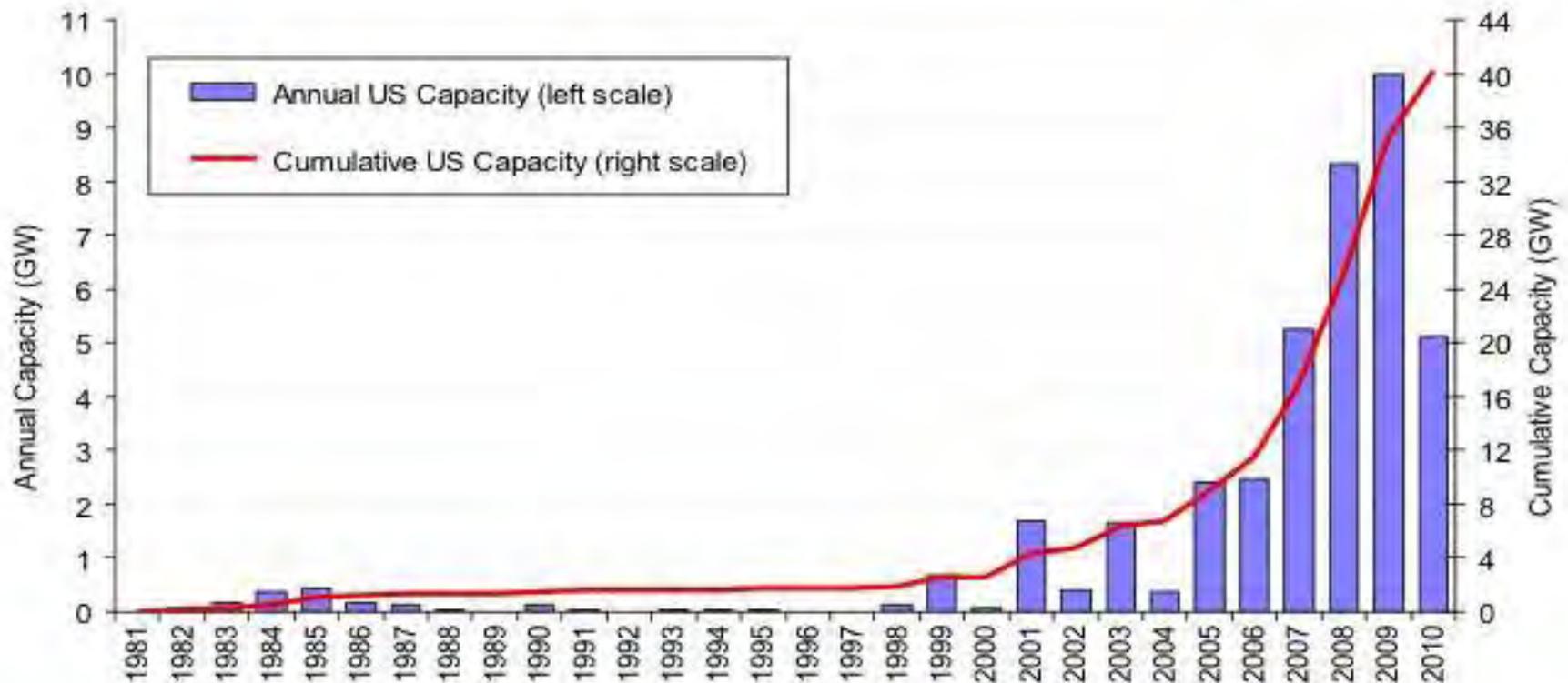
Source: WindPower Monthly

Wind Capacity at End of 2010 Equates to ~2.9% of U.S. Electricity Consumption



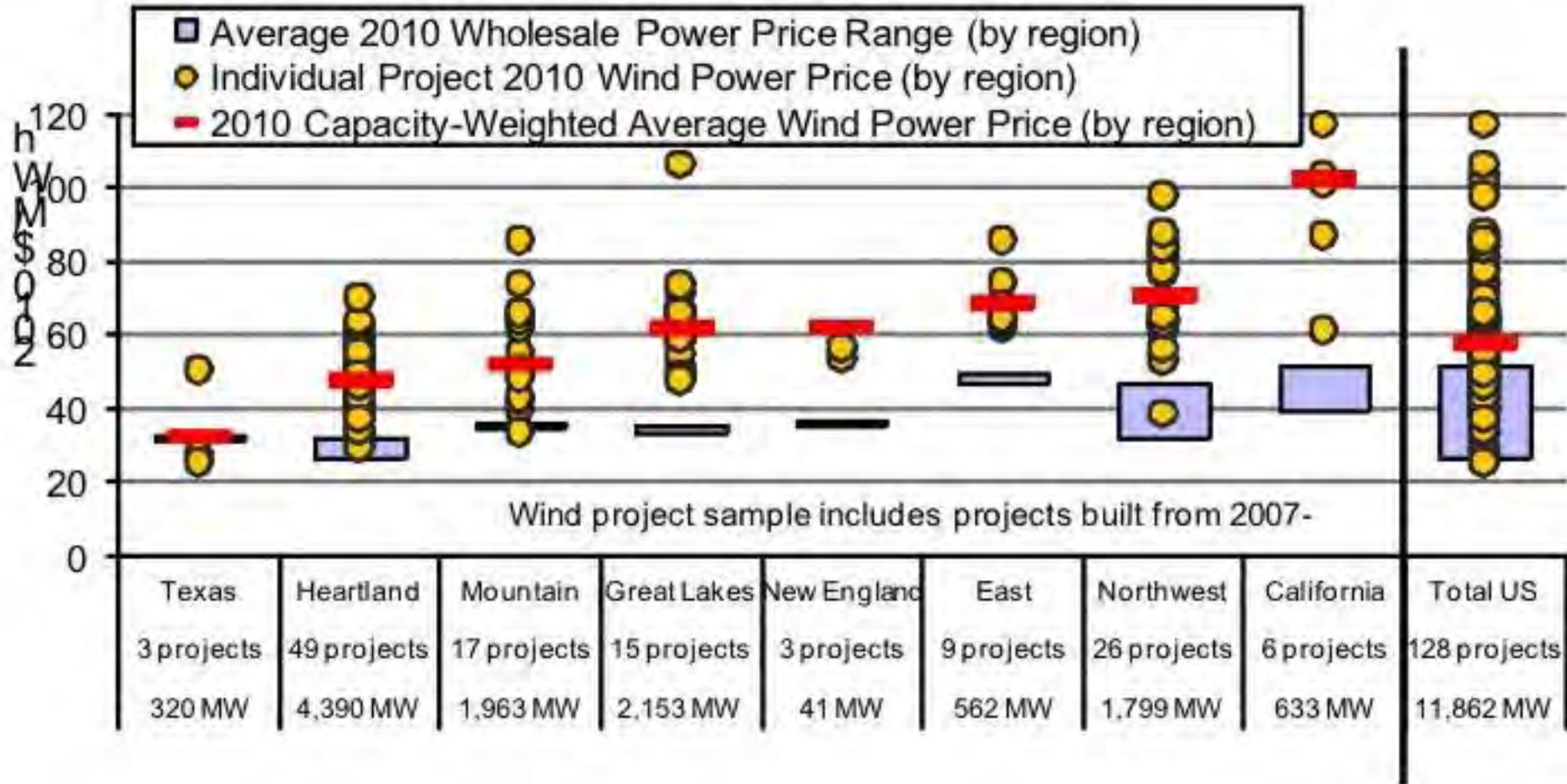
Note: Figure only includes the 20 countries with the most installed wind capacity at the end of 2009

Slower Growth Environment in 2010

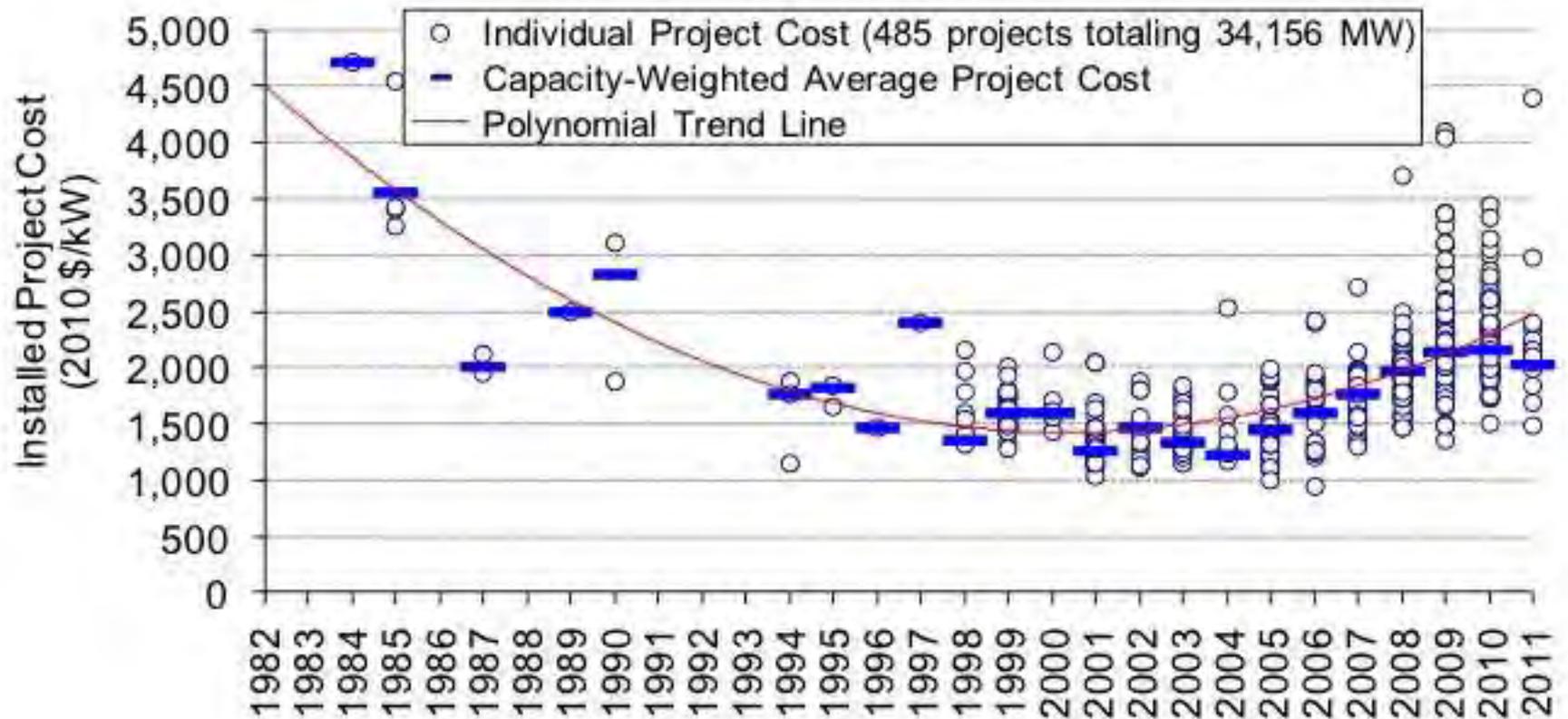


- 5,113 MW Added; \$11 billion Investment
- Capacity additions $\frac{1}{2}$ that seen in 2009; 40% below 2008
- Low wholesale electricity prices, relatively high wind energy prices, weakness of economy, reduced demand for (renewable) energy, transmission limitations, etc.

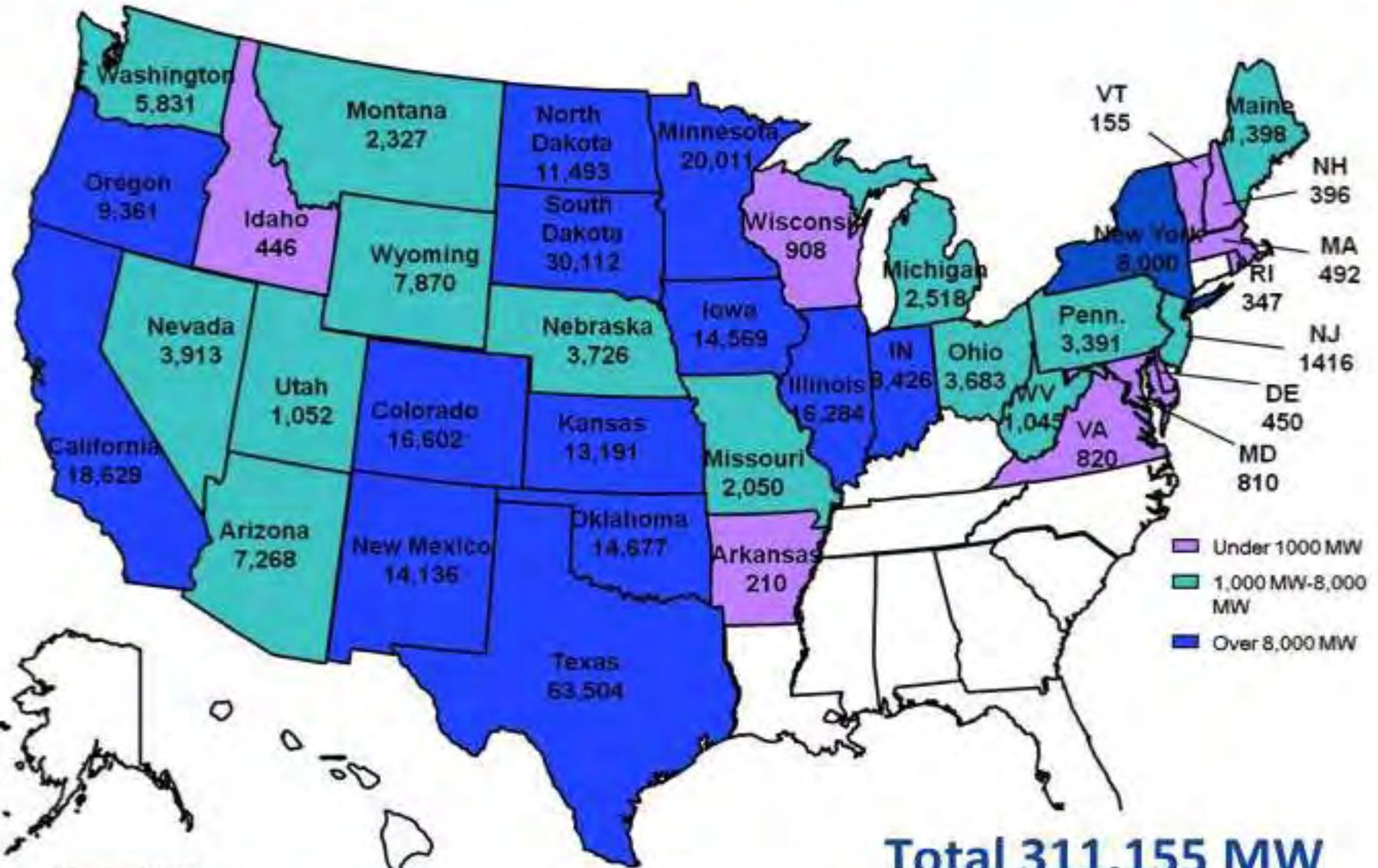
Combined with Low Wholesale Prices, Economics Became More Challenging



Lower Turbine Pricing Working Its Way into Installed Project Costs: 2-year Lag

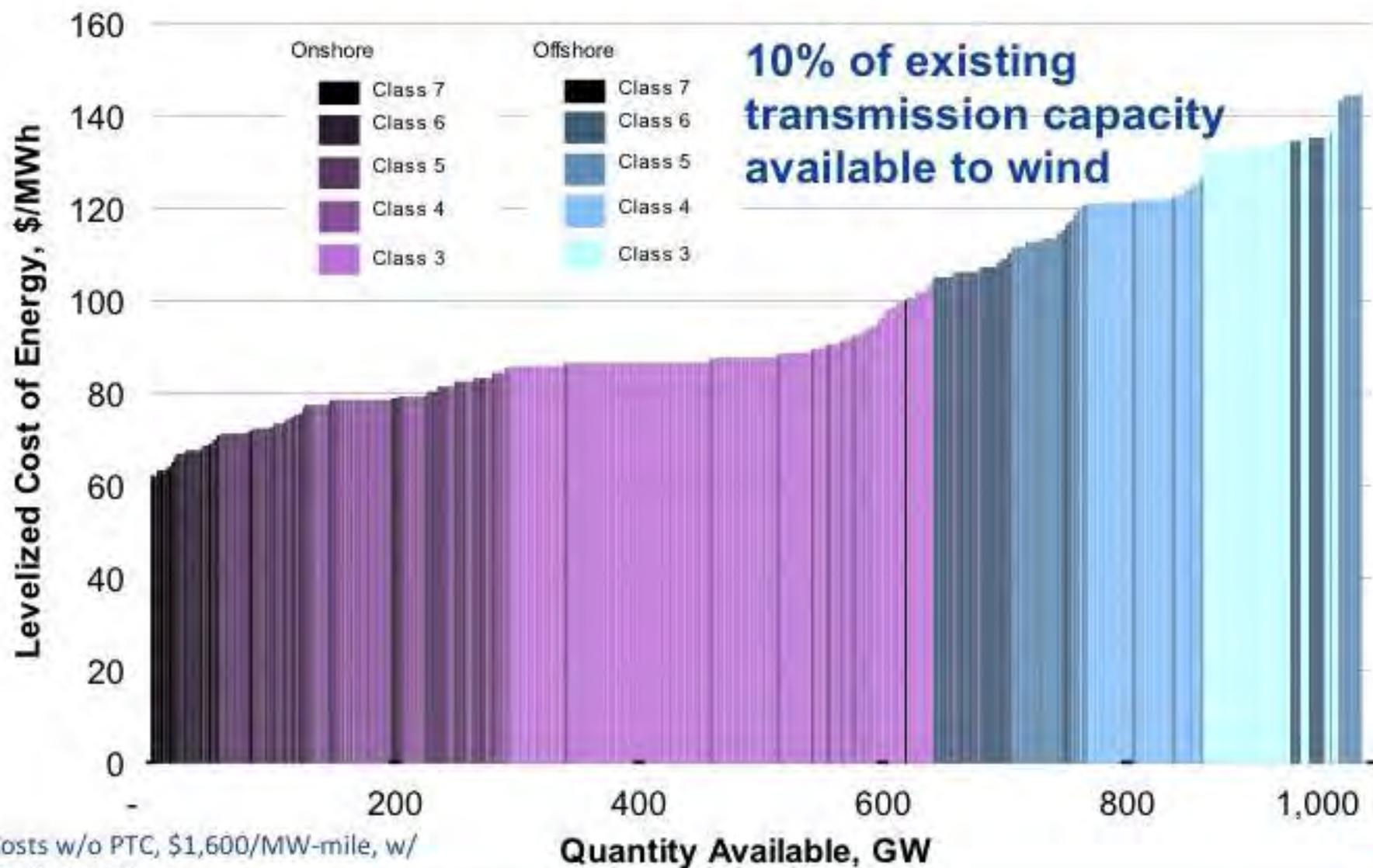


Wind Power in Queues (MW)



Total 311,155 MW

Supply Curve for Wind Energy: Energy and Transmission Costs



Average Non-GHG Damage from Coal Power in 2005 = 3.2 cents/kWh

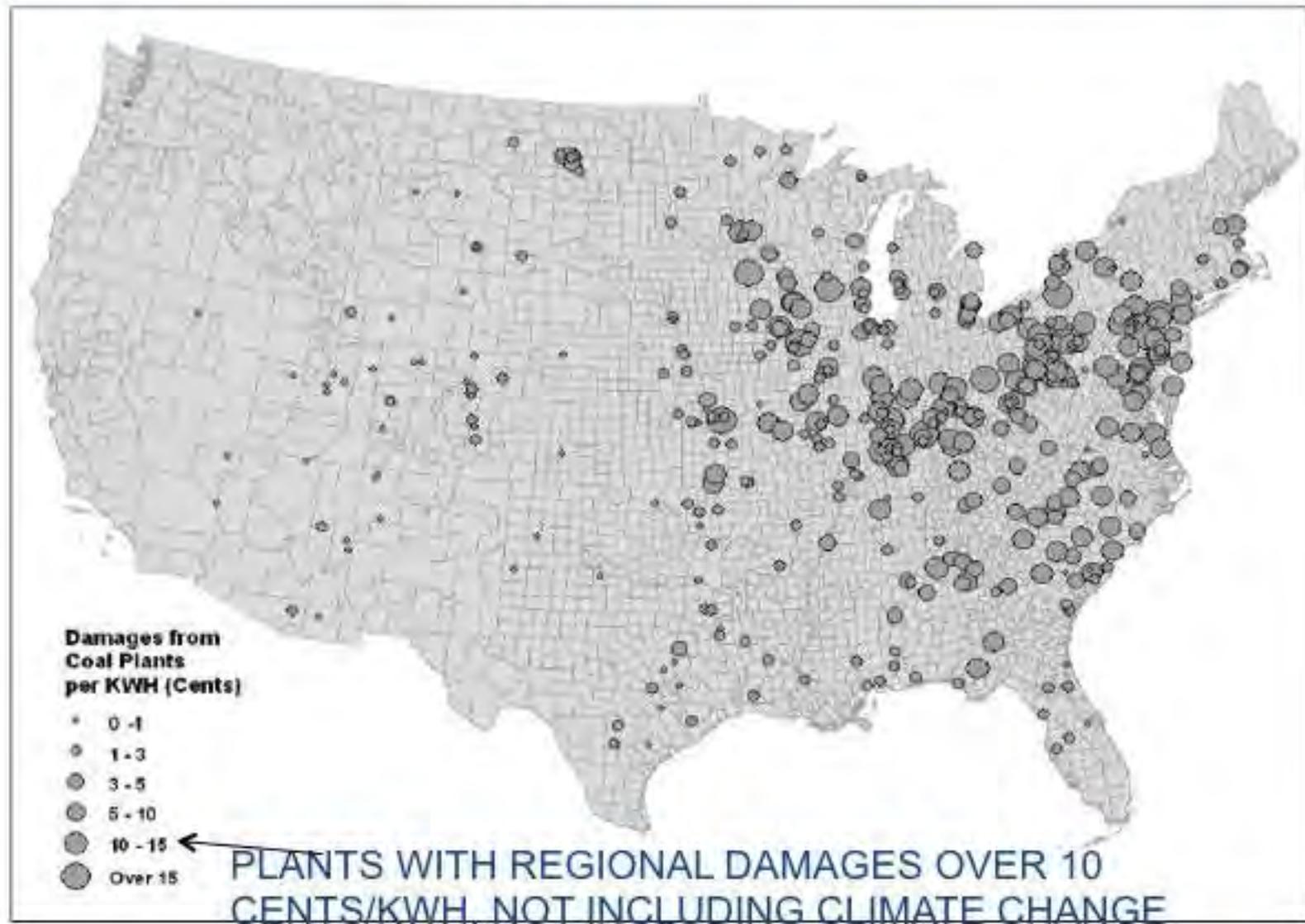
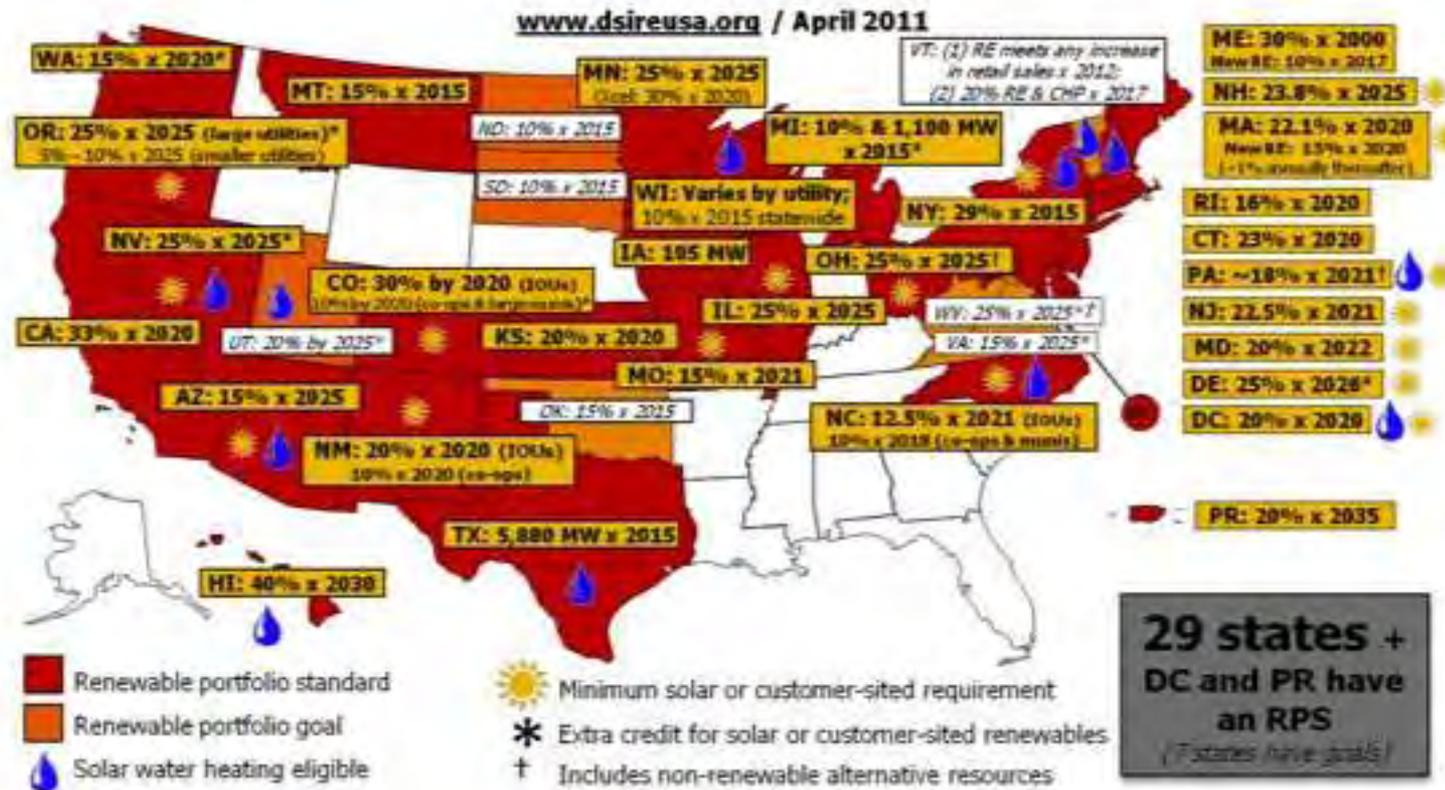


FIGURE 2-8 Regional distribution of air pollution damages from coal generation per kWh in 2005 (USD 2007). Damages related to climate change are not included.

Renewable Portfolio Standards

Current policy is largely driven by states through the electoral process (aka the people)



But there are federal incentives:

- Production Tax Credit (PTC): ~2.5 cent/kWh of energy produced
- Investment Tax Credit (ITC): Tax credit on 30% of the capital cost
- Treasury 1603 grant: Cash grant instead of tax credit (limited tax apatite)
- Clean Renewable Energy Bonds (CREB's): Bonds for non-taxable enteties

Key Issues for Wind Power

Policy Uncertainty

Transmission:

- FERC rules, access, development time for new lines, allocation of costs

Operational impacts:

- Intermittency, ancillary services

Accounting for non-monetary value

- Green power, no fuel price risk, reduced emissions

Siting and Permitting:

- Environmental impact, avian, federal land

Social Acceptance

- Noise, visual, home values, public perception



Visual Impact & Land Ownership



Kasigluk, Alaska



Cedar Ridge, Eden, Wisconsin

- Clear, but not very well documented impact.
- Based on data from new and existing wind plants – you do see a dip – but no statistically significant long-term cost impact to housing near wind farms, even for large homes
 - People who have demonstrated economic benefit are much more likely to support the project – up to \$10k/turbine/year
 - Define the discussion, don't let project proponents do that.
 - A large amount of visualization tools available to allow people to see what the site will look like – take advantage of them

Public Perception..

There are varied public perceptions about large wind development

Many different flavors

- Wind turbine syndrome
- Subsidies driven
- Government forced
- Does not reduce GHG
- Requires vast grid upgrades
- Other better options just around the corner
- Takes up to much space *

Usually based on a kernel of truth but don't believe everything on the web

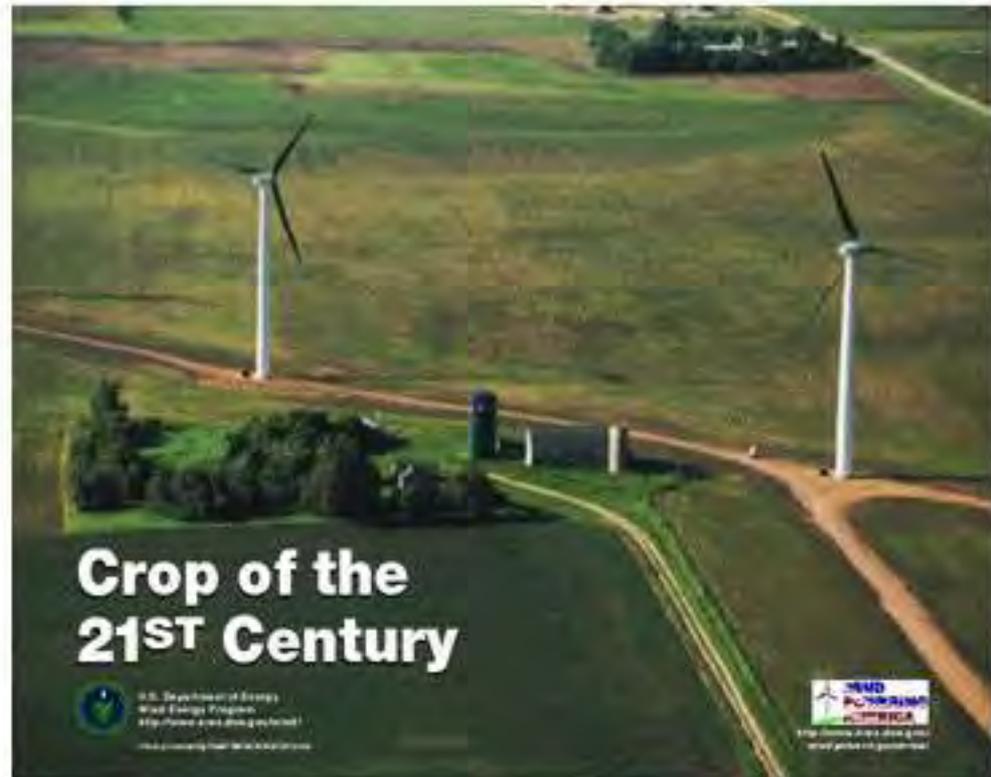


*Chernobyl = 750 sq. km, Fukushima = 600 sq. km

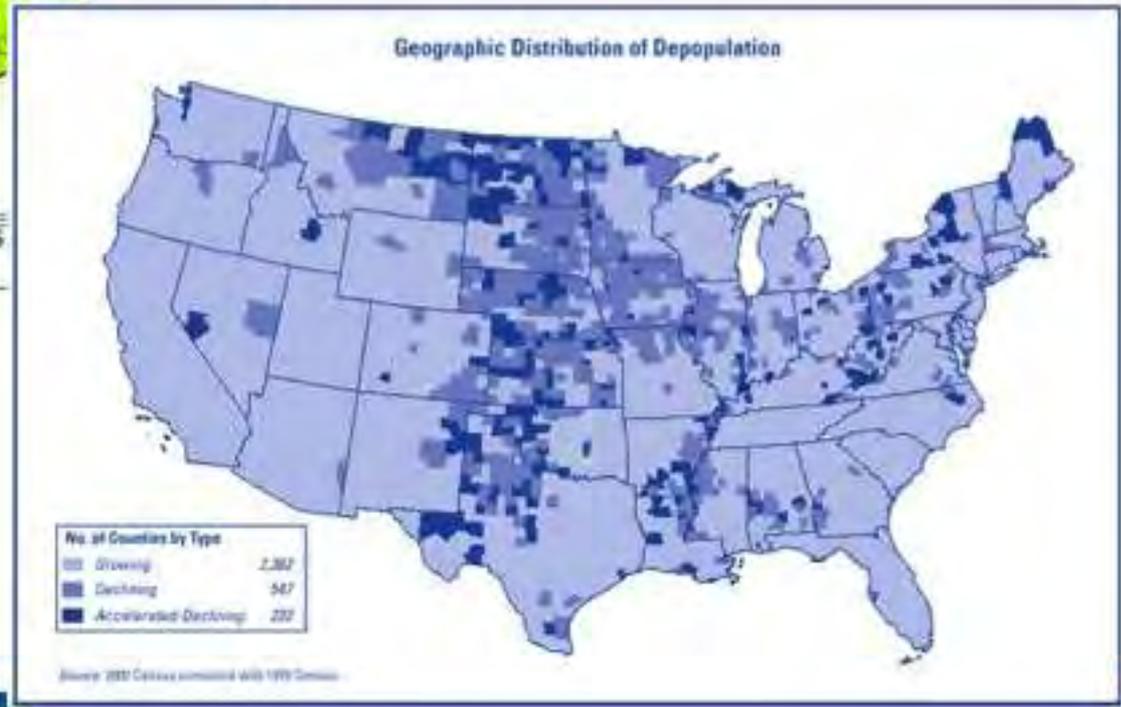
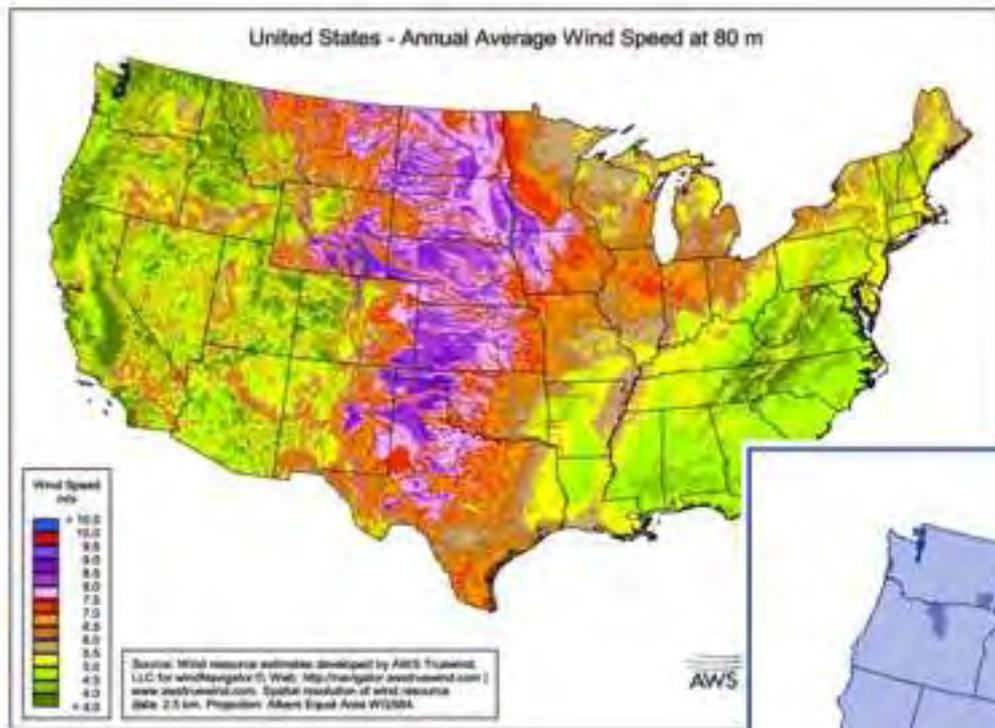
Glenmore, Wisconsin

Drivers for Wind Power

Competitive Wind Costs
Fuel Price Uncertainty
Federal and State Policies /
Public Support
Green Power
Economic Development
Energy Security
Environmental drivers
Carbon Risk



Windy Rural Areas Need Economic Development



Jobs and Economic Impacts from the JEDI Model

1,000 MW of New Wind Power in Colorado

Wind energy's economic "ripple effect"

Project Development & Onsite Labor Impacts

- Landowner Revenue:**
 - \$3 million/year
- Local Property Taxes:**
 - \$5.7 million/year
- Construction Phase:**
 - 502 new jobs
 - \$39 million to local economies
- Operational Phase:**
 - 51 new jobs
 - \$3.4 M/year to local economies



Turbine & Supply Chain Impacts

- Construction Phase:**
 - 3,059 new jobs
 - \$414.8 million to local economies
- Operational Phase:**
 - 73 new jobs
 - \$16.3 million/year to local economies

Induced Impacts

- Construction Phase:**
 - 1,197 new jobs
 - \$143.1 million to local economies
- Operational Phase:**
 - 63 new jobs
 - \$7.6 million/year to local economies

Totals (construction + 20 years)

- Total economic benefit: \$1.32 billion
- New local jobs during construction: 4,758
- New local long-term jobs: 187

Construction Phase = 1-2 years
Operational Phase = 20+ years

Conclusions

- Wind technology is competitive in the market
- There are many drivers to the expanded development of wind
- Wind is no longer a niche technology in the US and around the world
- There are issues to wind development – so wind is not applicable everywhere
- Change is hard – and there are many who like the way things are working now
- The nation needs energy and all energy has an impact
- 20% wind energy penetration is possible but will not happen under business as usual scenario
- Policy choices will have a large impact on the timing and rate of achieving a 20% goal
- 20% Vision report: May 2008 (www.20percentwind.org)

Further Information / References

Web Based:

- American Wind Energy Association <http://www.awea.org/>
- Wind Powering America <http://www.eere.energy.gov/windpoweringamerica/>
- Danish Wind Industry Association guided tour and information. <http://www.windpower.org/en/tour/>
- 2009 Wind Technologies Market Report. http://www1.eere.energy.gov/windandhydro/pdfs/2009_wind_technologies_market_report.pdf

Publications:

- Ackermann, T. (Ed's), *Wind Power in Power Systems*, John Wiley and Sons, west Sussex, England, (2005).
- Wind Energy Explained, J. F. Manwell, J. G. McGowan, A. L. Rogers John Wiley & Sons Ltd. 2002.
- Paul Gipe, *Wind Energy Basics: A Guide to Small and Micro Wind Systems*, Real Goods Solar Living Book.
- AWS Scientific Inc. "Wind Resource Assessment Handbook" produced by for the National Renewable Energy Laboratory, Subcontract number TAT-5-15283-01, 1997



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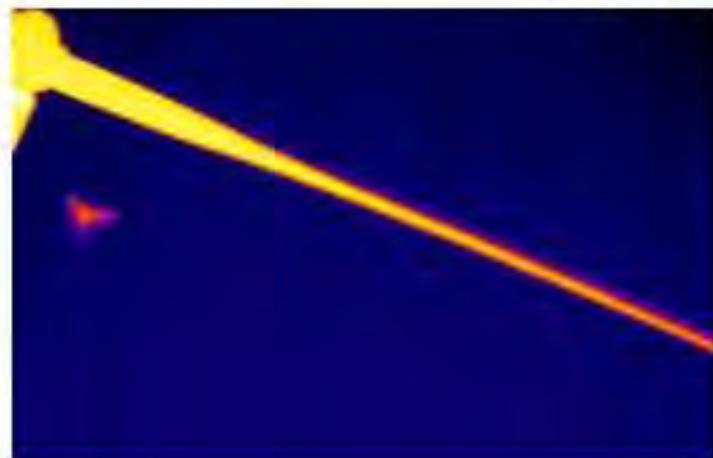
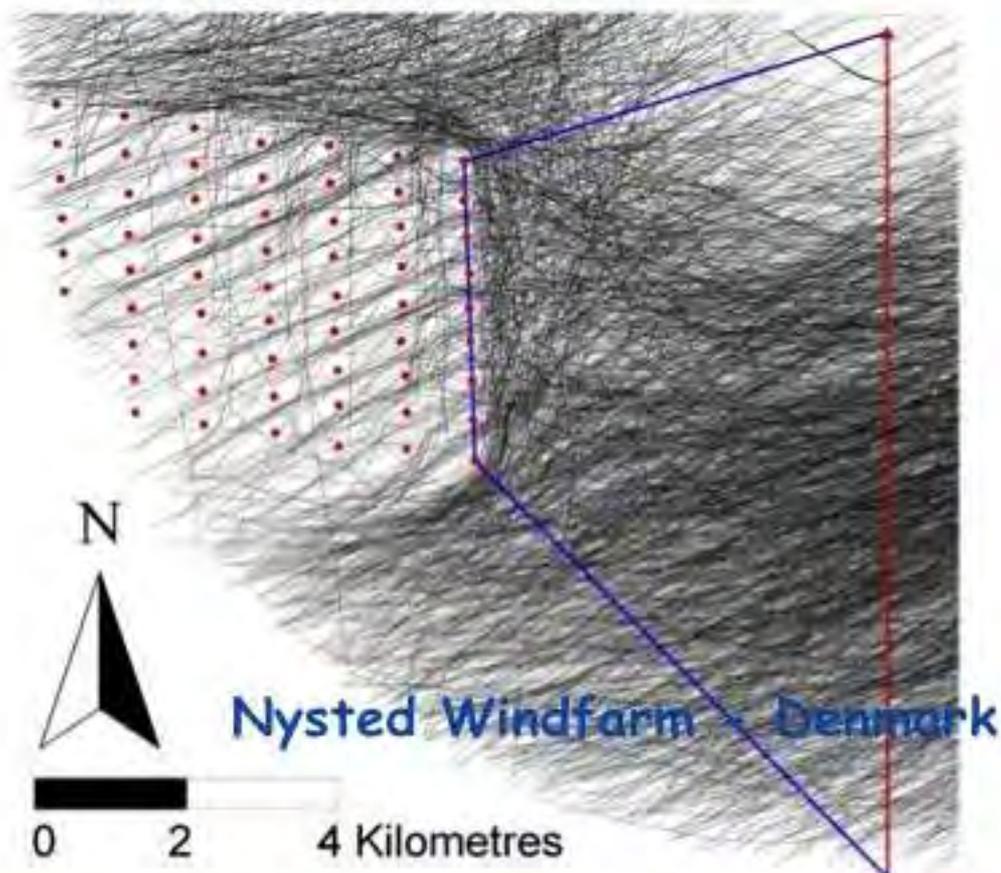
National Wind Technology Center &
Deployment & Industrial Partnerships

303-384-7020

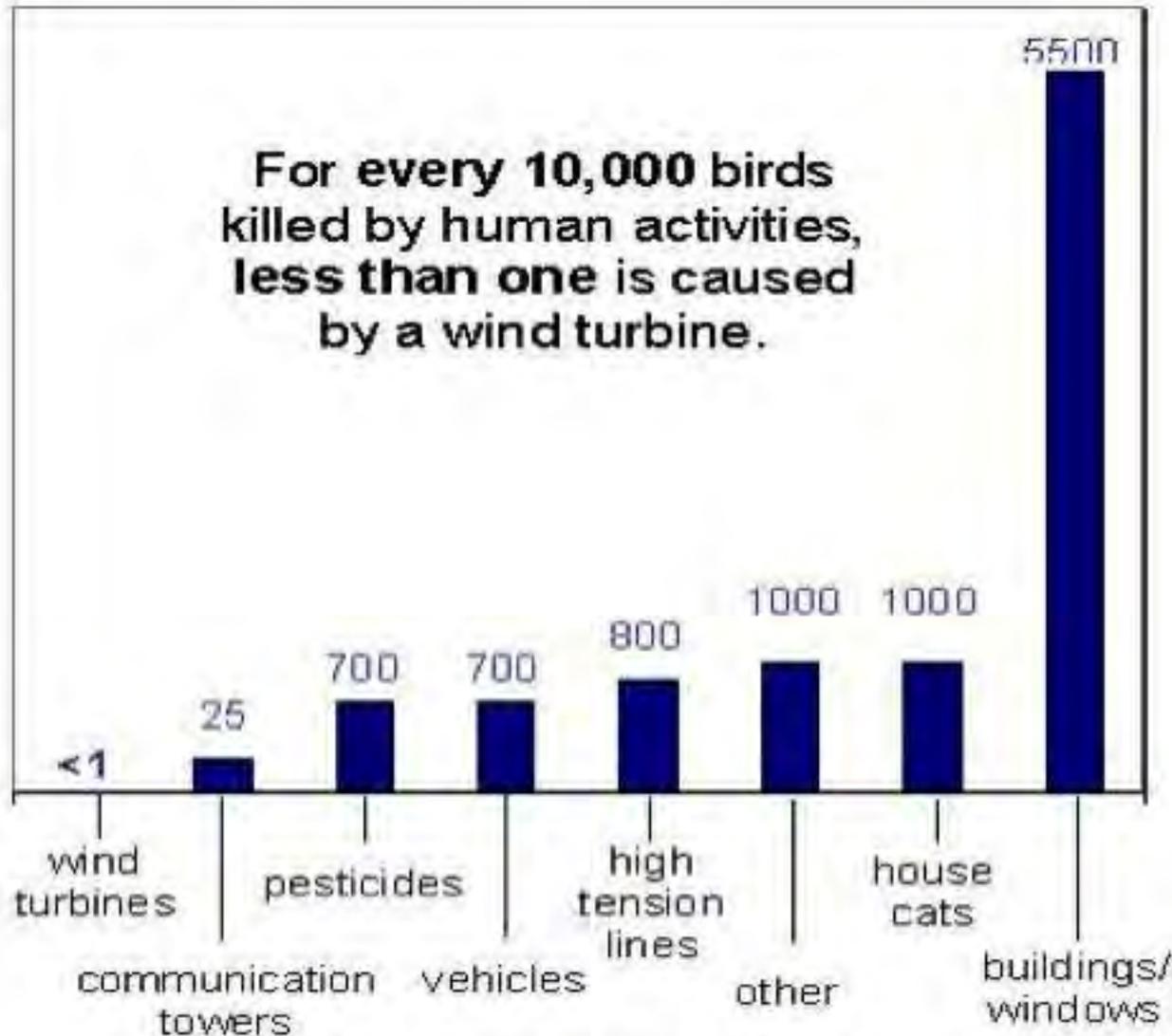
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Avian (Bird) Research

- Over 200 projects, two problem sites.
- Biggest problem was in the Altamont Pass.
- Managed by environmental screening, impact modeling, and careful site selection.



For every 10,000 birds killed by human activities, less than one is caused by a wind turbine.



Summary of Anthropogenic Causes of Bird Mortality,
- Erickson et. al., 2002



http://www.fs.fed.us/psw/publications/documents/psw_gr191/Asilomar/pdfs/1029-1042.pdf

Installation of enough wind to power eliminate all anthropogenic CO2 emission worldwide would result in between 1.4 to 14 million deaths – less than 1% that were killed by the Avian flu pandemic in 2005 – Jacobson Dec 2008

Mitigation & management options

Implementation mitigating

- Pre-Construction Assessment... Determine and avoid high risk areas
- Impact Mitigation
- Protecting other critical habitat

Operational mitigation...

- Curtailment during high risk periods ~ 75% reduction in fatalities

Technological...

- Development of techniques that deter or alert animals



Are Wind Turbines Noisy?

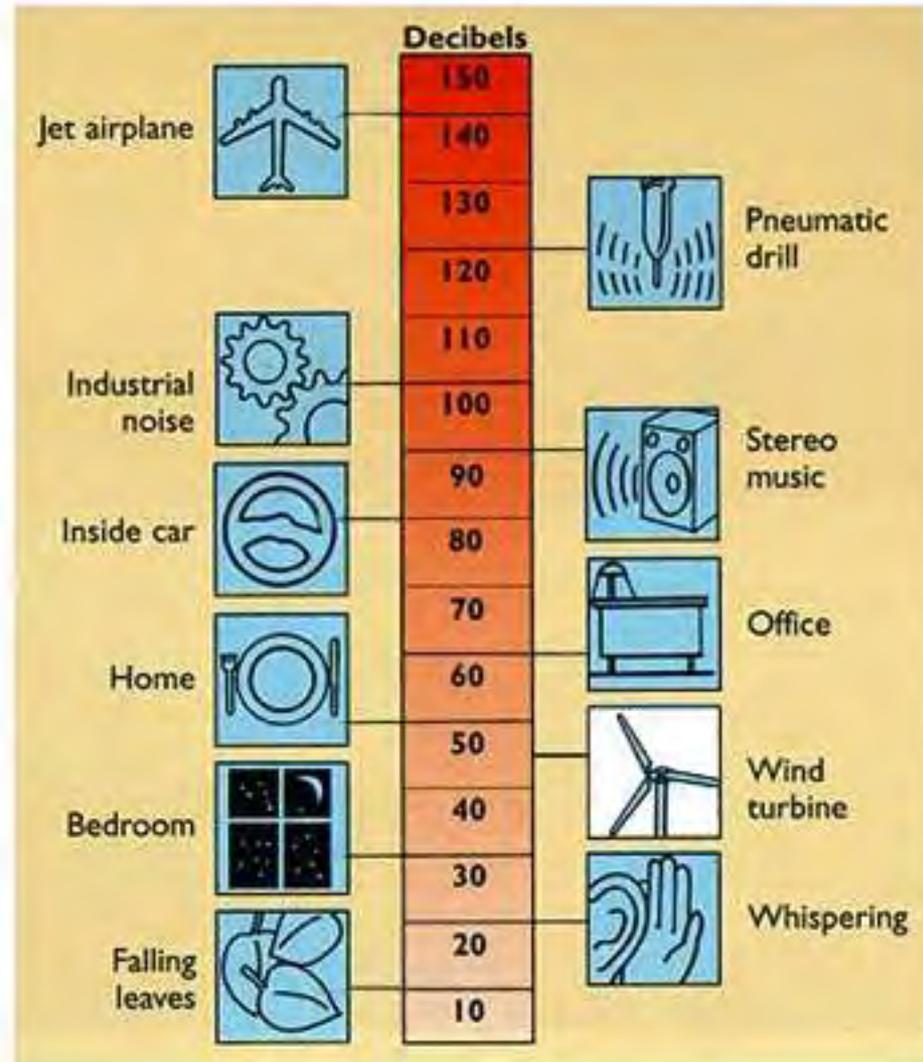
Yes – they make noise and that noise has an impact

What is the sound level of a utility wind turbine?

- Depends on the turbine but a maximum of 45 db at 350 meters
- Sound analysis is very common

But that's not the whole story

- Relative level of noise as it relates to background level
- Individual noise sensitivity
- Average vs. instantaneous levels
- Noise can impact health – though:
 - Those who “use” the land
 - Those that “own” the land
 - People who like the concept vs. people who have a negative view



The key is to visit a wind turbine