

# Wind Energy Update

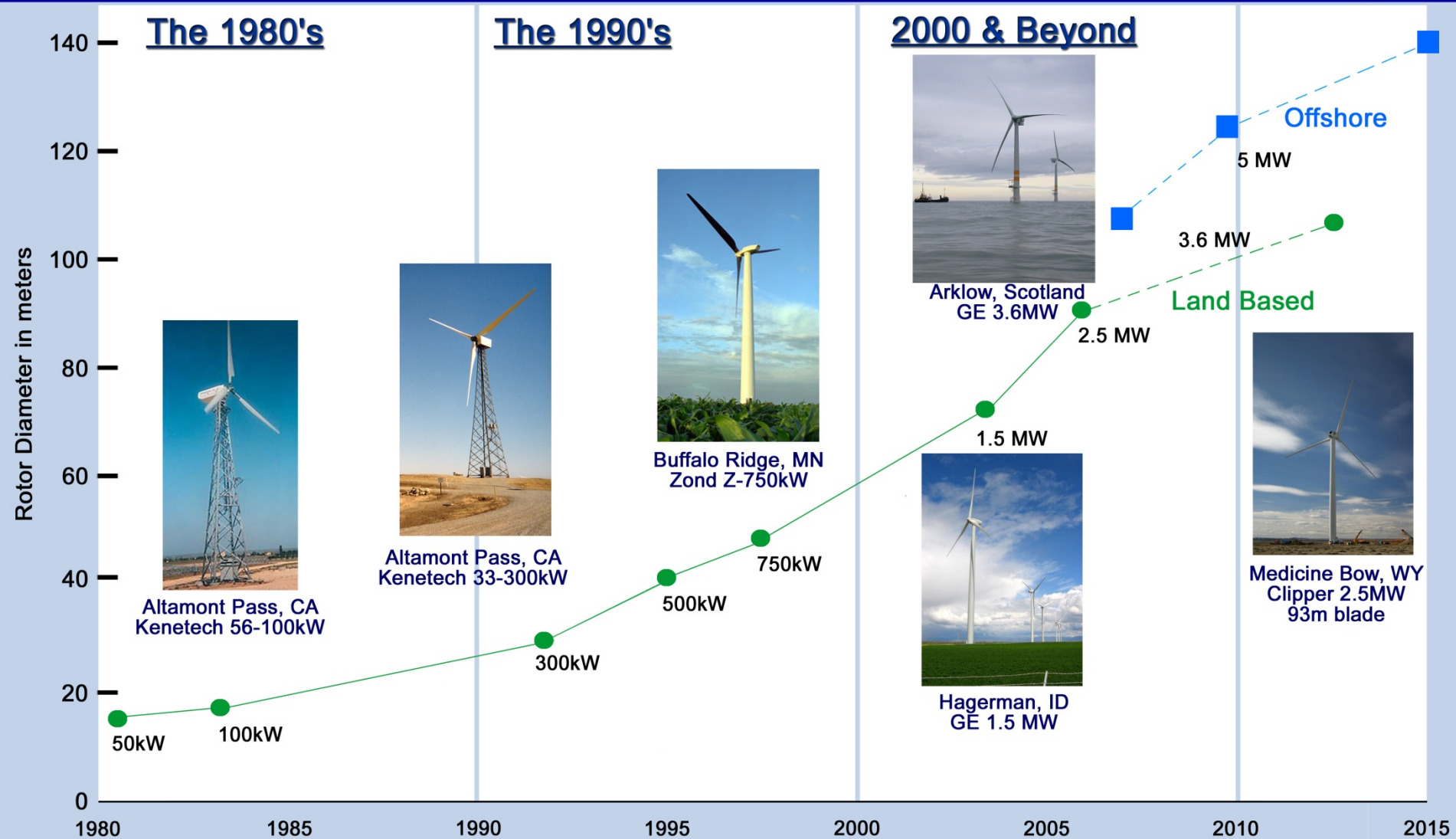


Larry Flowers

National Renewable Energy Laboratory

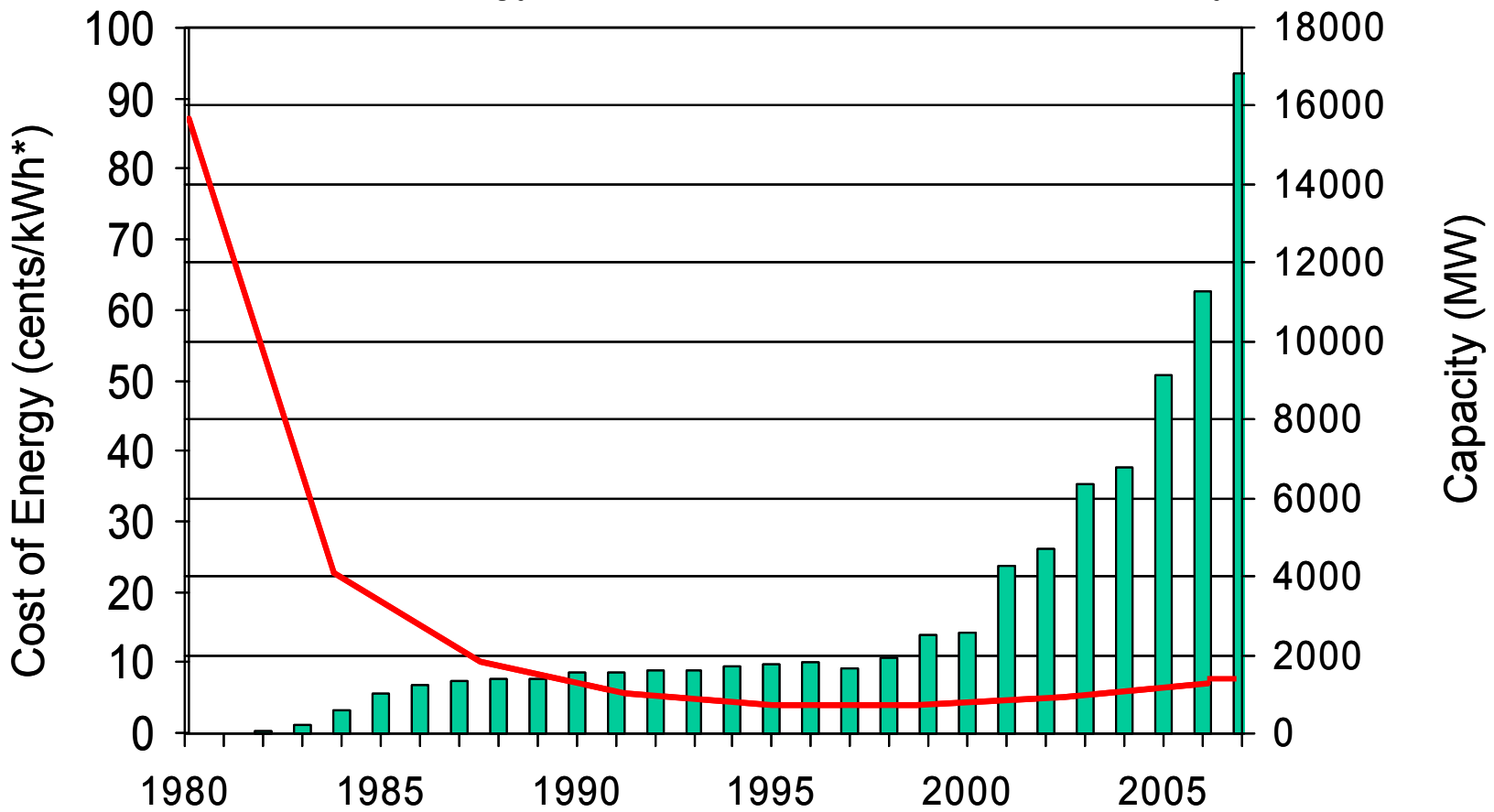
January 2009

# Evolution of U.S. Commercial Wind Technology



# Capacity & Cost Trends

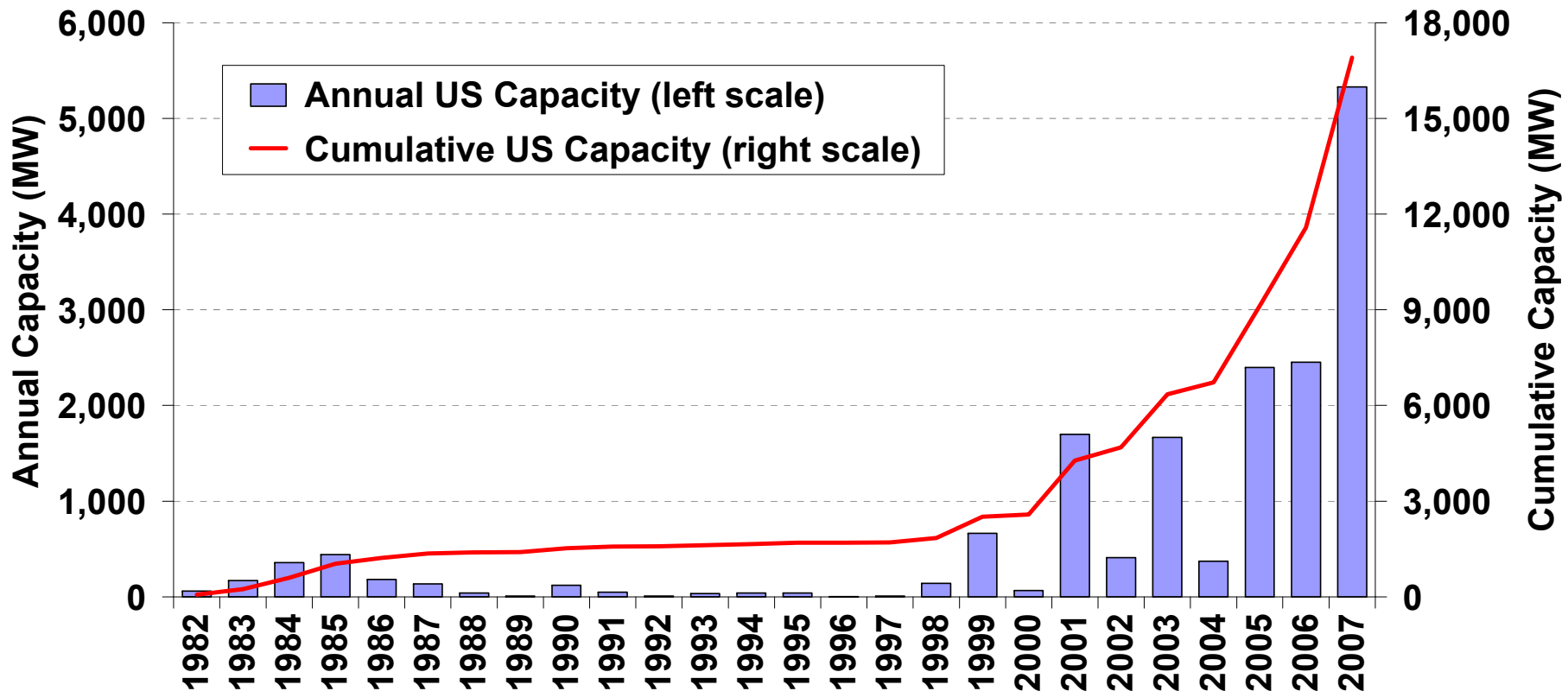
## Cost of Energy and Cumulative Domestic Capacity



\*Year 2000 dollars

Increased Turbine Size - R&D Advances - Manufacturing Improvements

# U.S. Wind Power Capacity Up 46% in 2007



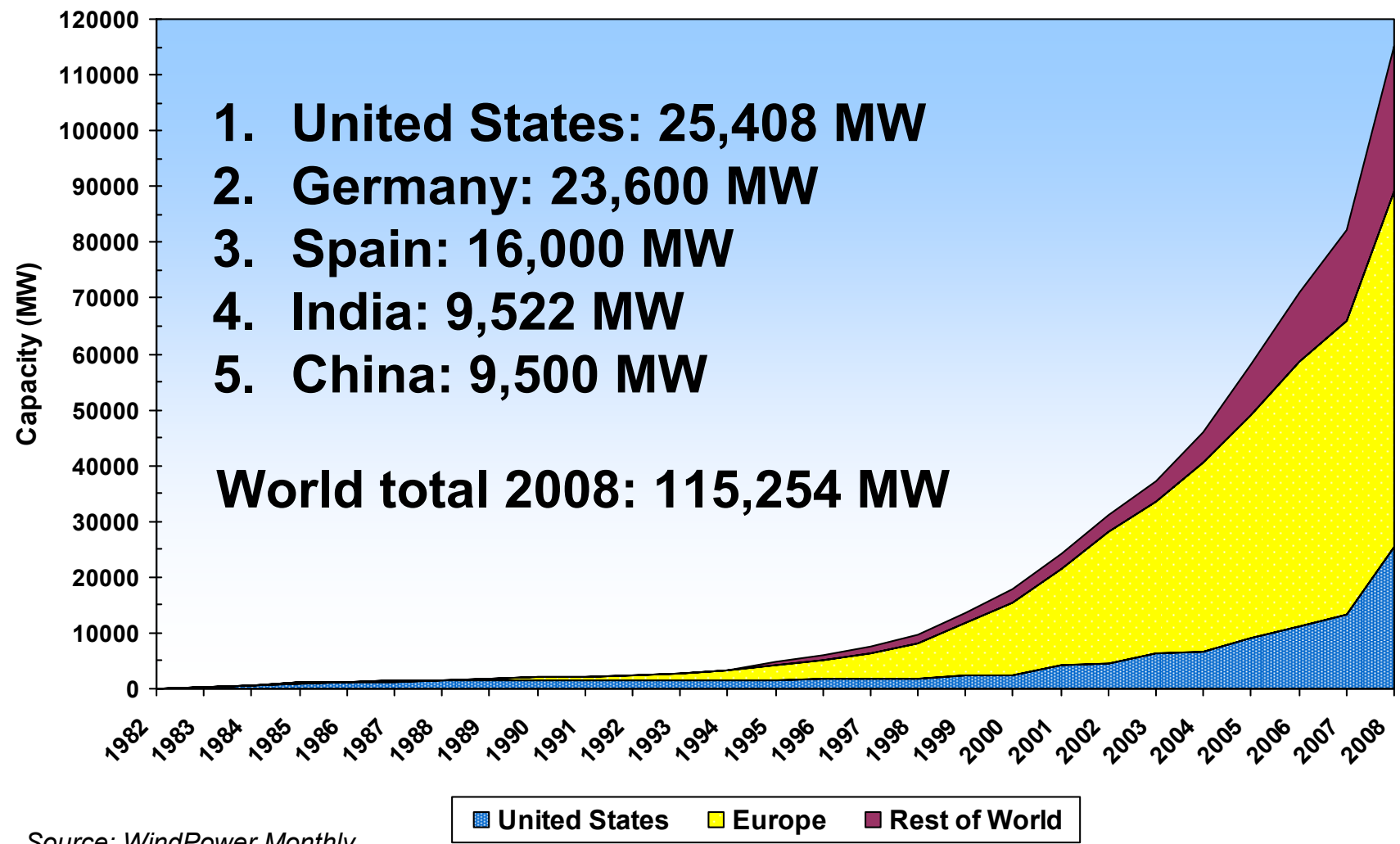
Source: AWEA

## Record year for new U.S. wind capacity:

- 5,329 MW of wind added (*more than double* previous record)
- Roughly \$9 billion in investment

# People Want Renewable Energy!

## Total Installed Wind Capacity



Source: WindPower Monthly

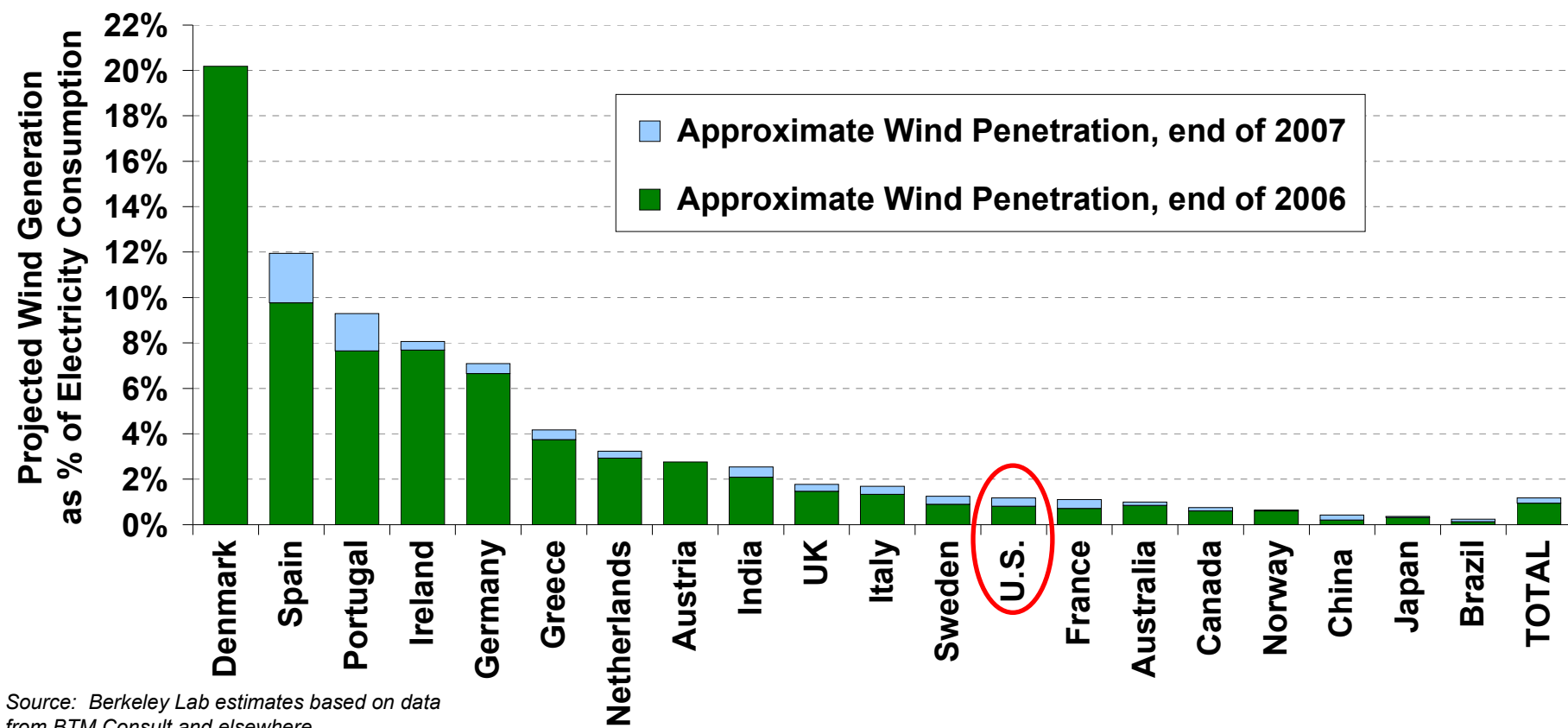
# U.S. Led the World in 2007 Wind Capacity Additions; Second in Cumulative Capacity

Incremental Capacity (2007, MW)		Cumulative Capacity (end of 2007, MW)	
<b>U.S.</b>	<b>5,329</b>	Germany	22,277
China	3,287	<b>U.S.</b>	<b>16,904</b>
Spain	3,100	Spain	14,714
Germany	1,667	India	7,845
India	1,617	China	5,875
France	888	Denmark	3,088
Italy	603	Italy	2,721
Portugal	434	France	2,471
U.K.	427	U.K.	2,394
Canada	386	Portugal	2,150
<i>Rest of World</i>	2,138	<i>Rest of World</i>	13,591
<b>TOTAL</b>	<b>19,876</b>	<b>TOTAL</b>	<b>94,030</b>

Source: BTM Consult; AWEA project database for U.S. capacity.



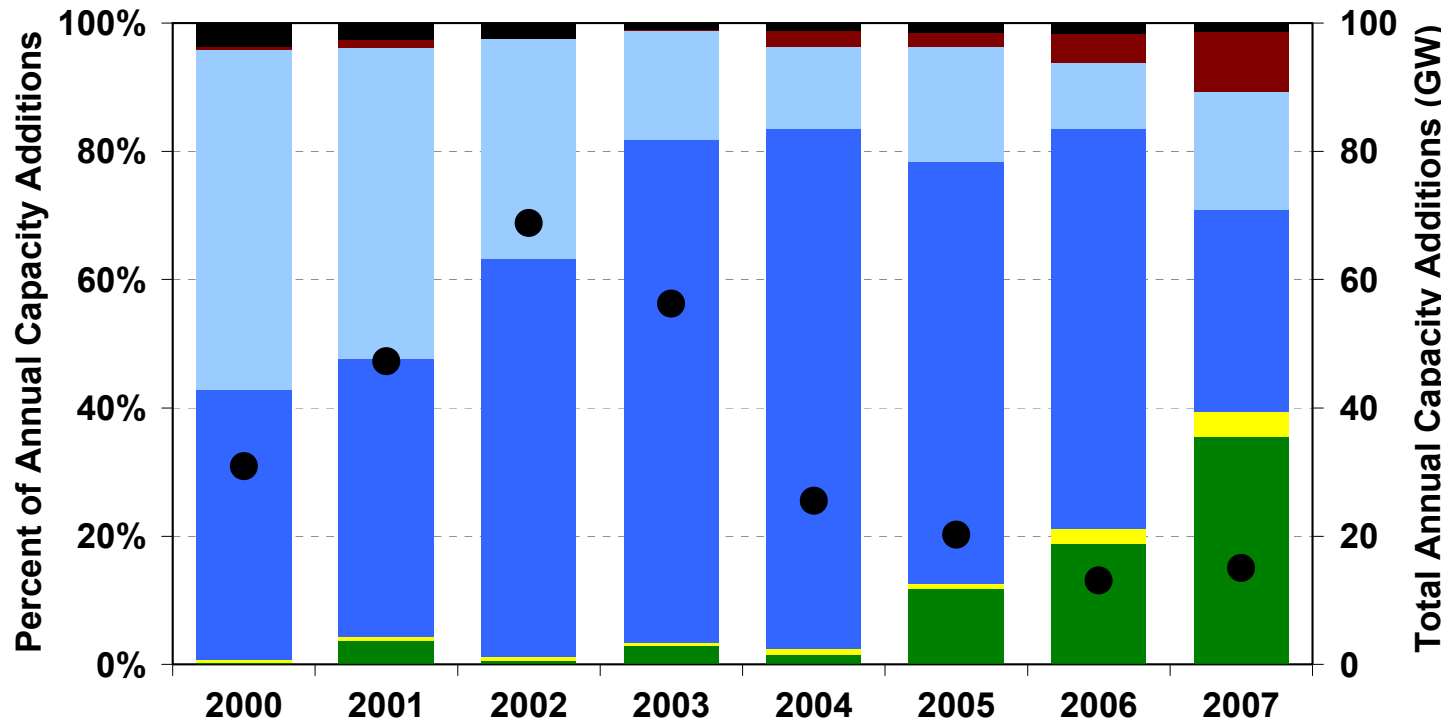
# U.S Lagging Other Countries in Wind As a Percentage of Electricity Consumption



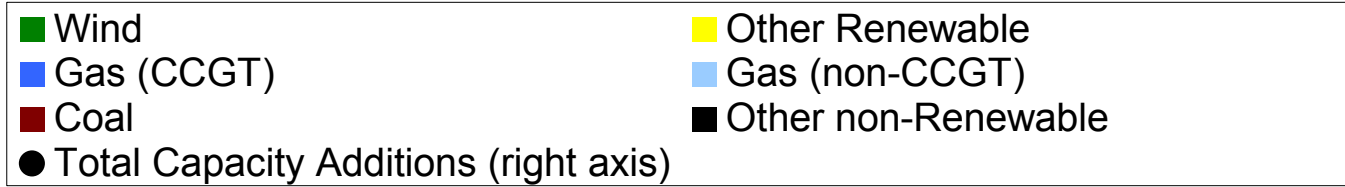
Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere

**Note: Figure only includes the 20 countries with the most installed wind capacity at the end of 2007**

# Wind Power Contributed 35% of All New Generating Capacity in the US in 2007



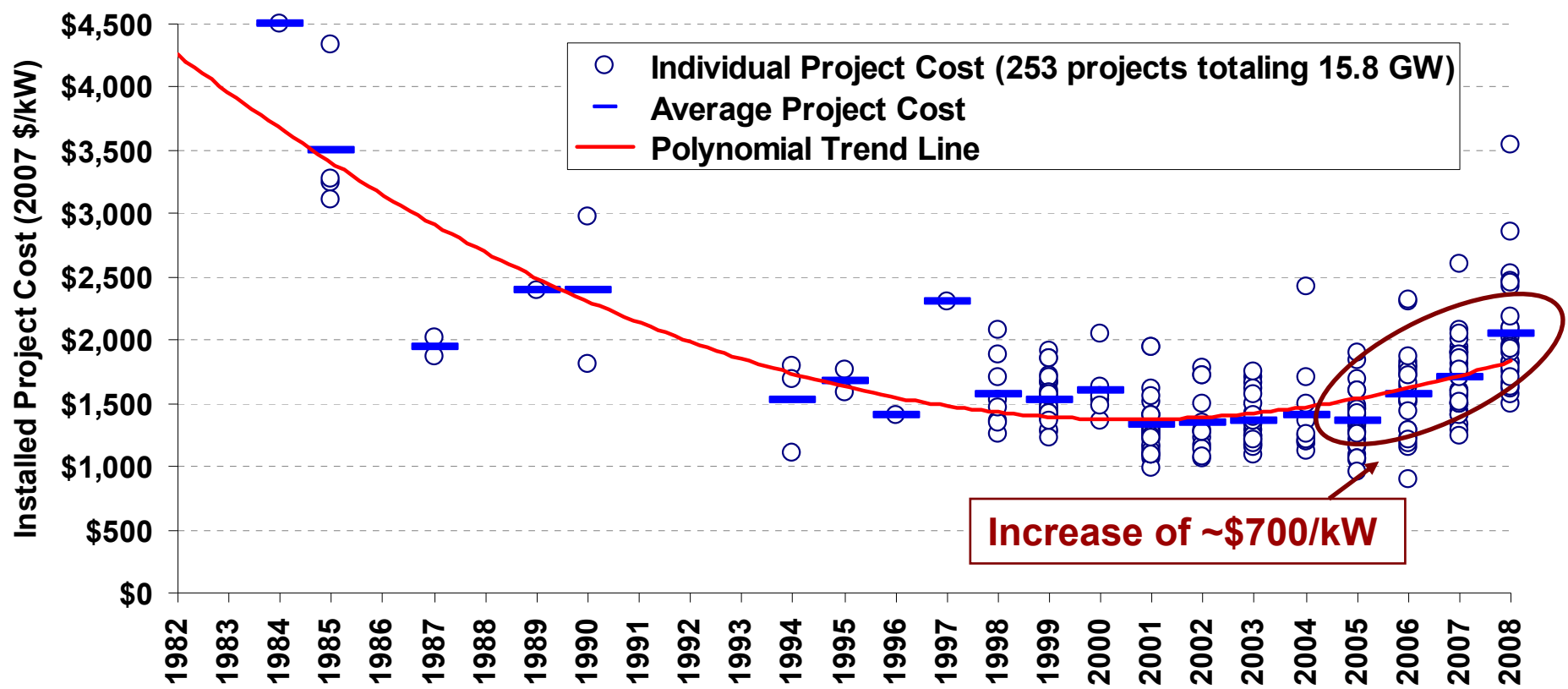
- Wind was the 2<sup>nd</sup>-largest resource added for the 3<sup>rd</sup>-straight year
- Up from 19% in 2006, 12% in 2005, and <4% in 2000-2004



Source: EIA, Ventyx, AWEA, IREC, Berkeley Lab



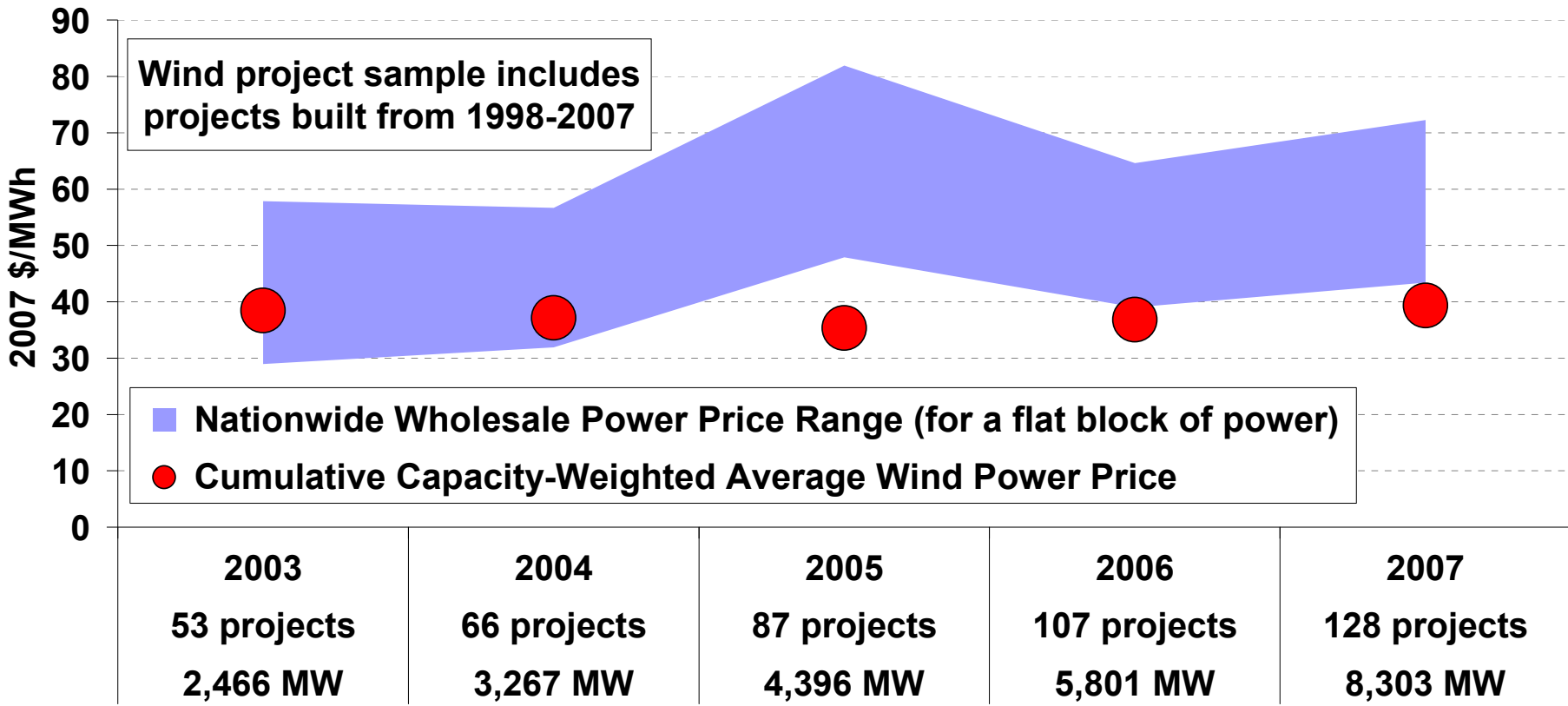
# Installed Project Costs Are On the Rise, After a Long Period of Decline



Source: Berkeley Lab database (some data points suppressed to protect confidentiality)

Note: Includes 227 projects built from 1983-2007, totaling ~13 GW (77% of capacity at end of 2007); additional ~2.8 GW of projects proposed for installation in 2008

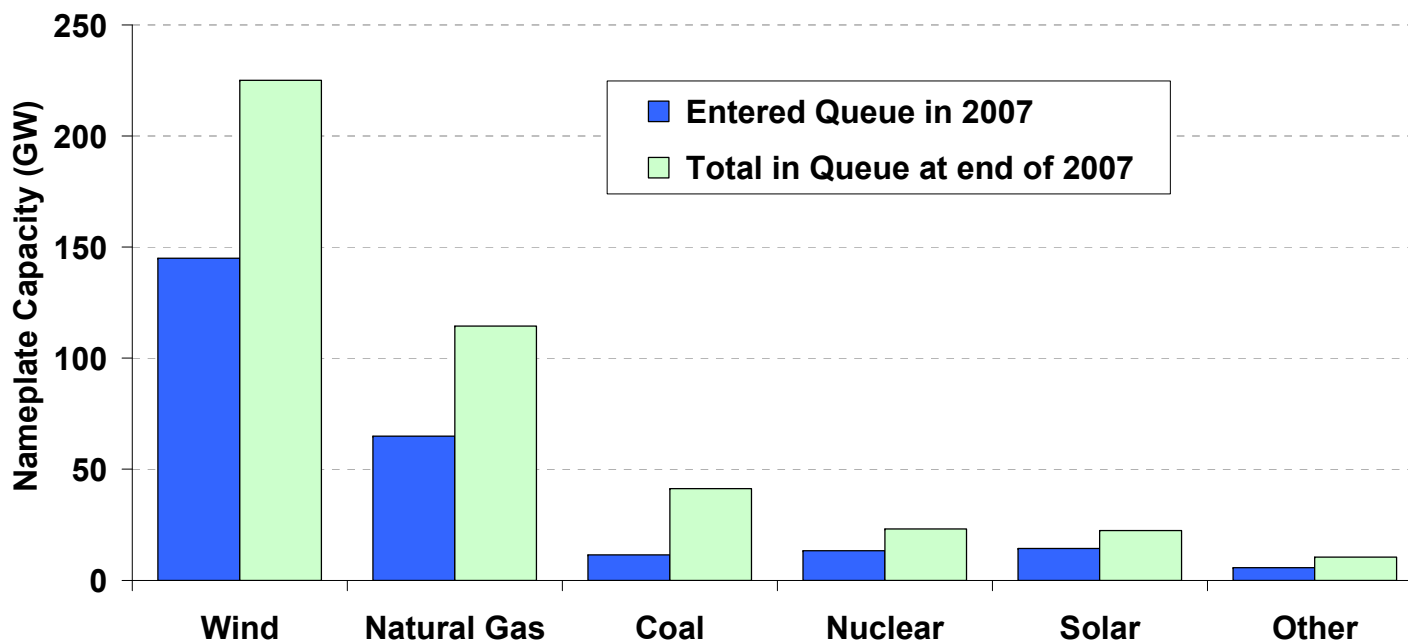
# Wind Has Been Competitive with Wholesale Power Prices in Recent Years



Source: FERC 2006 and 2004 "State of the Market" reports, Berkeley Lab database, Ventyx

- Wholesale price range reflects flat block of power across 23 pricing nodes (see previous map)
- Wind prices are capacity-weighted averages from cumulative project sample

# Regardless of these pricing trends, more than 225 GW of wind has applied for interconnection

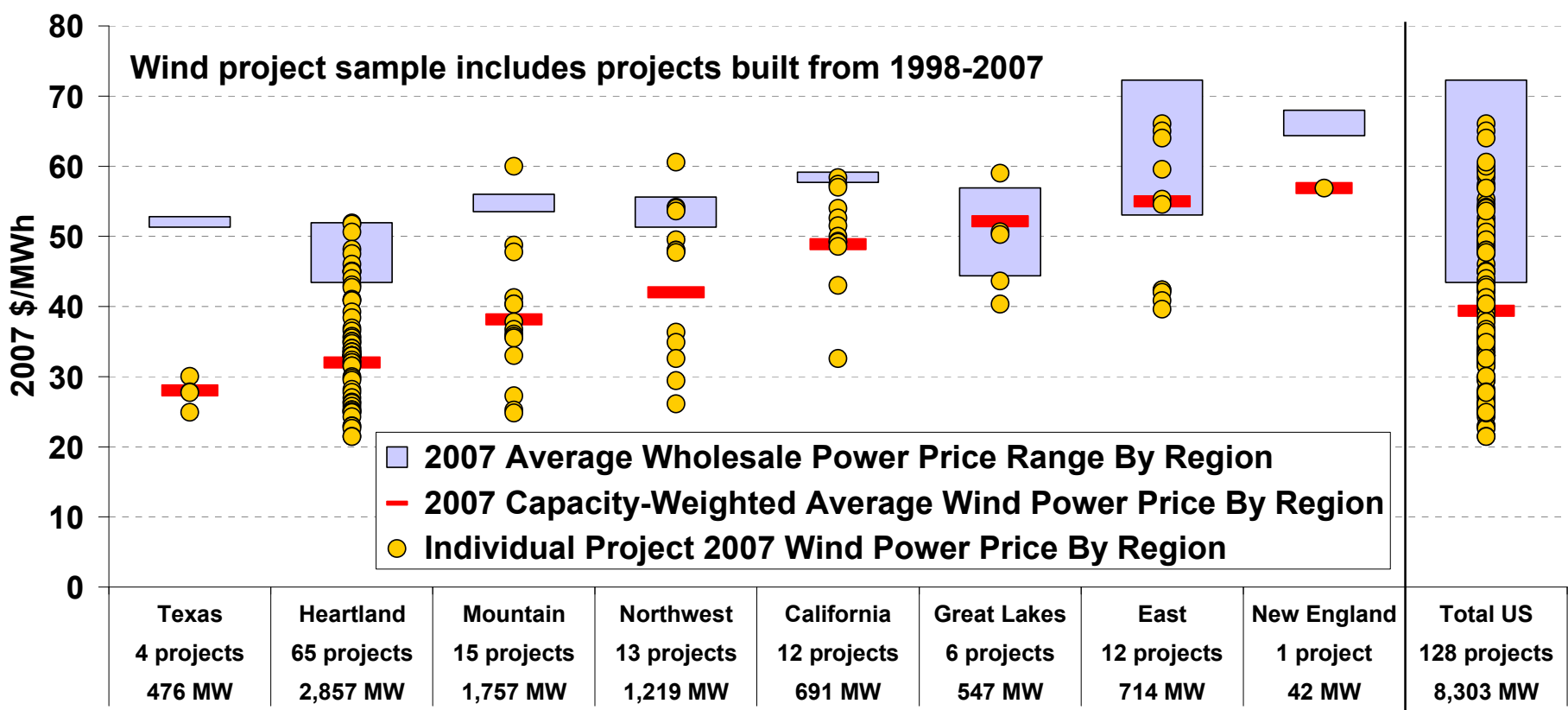


Source: Exeter Associates review of interconnection queues

Note: Figure includes data from 11 wind-relevant interconnection queues, so does not represent a truly national picture

- MISO (66 GW), ERCOT (41 GW), and PJM (35 GW) make up 2/3 of total
- Twice as much wind as next largest resource (natural gas) in these queues
- ***Not all of the capacity will be built, but demonstrates enormous interest***

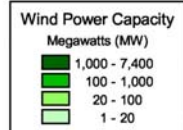
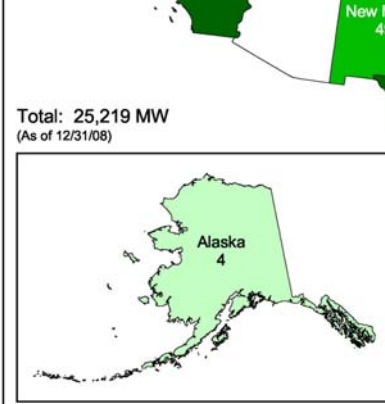
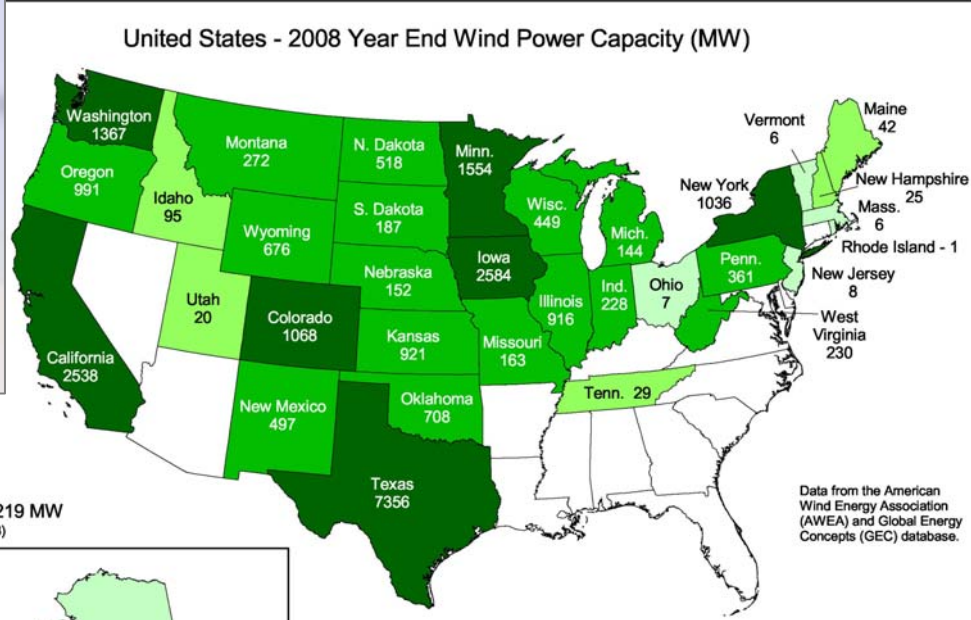
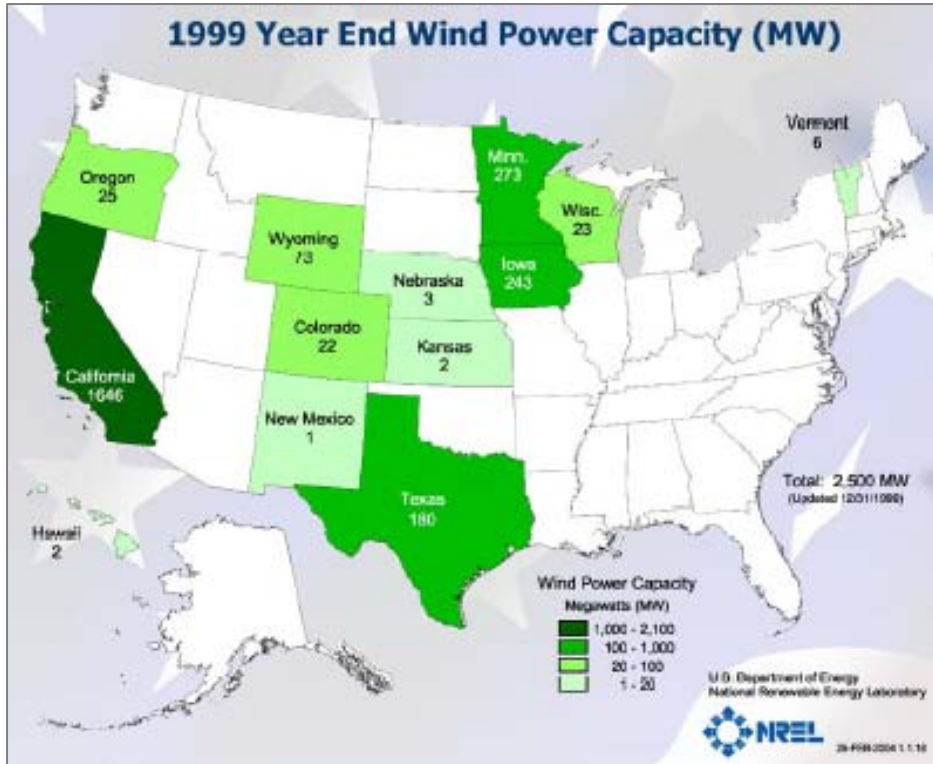
# Wind Built After 1997 Was Competitive with Wholesale Prices in Most Regions in 2007



Source: Berkeley Lab database, Ventyx

Note: Even within a region there are a range of wholesale power prices because multiple wholesale price hubs exist in each area (see earlier map)

# Installed Wind Capacities (‘99 – ‘08)



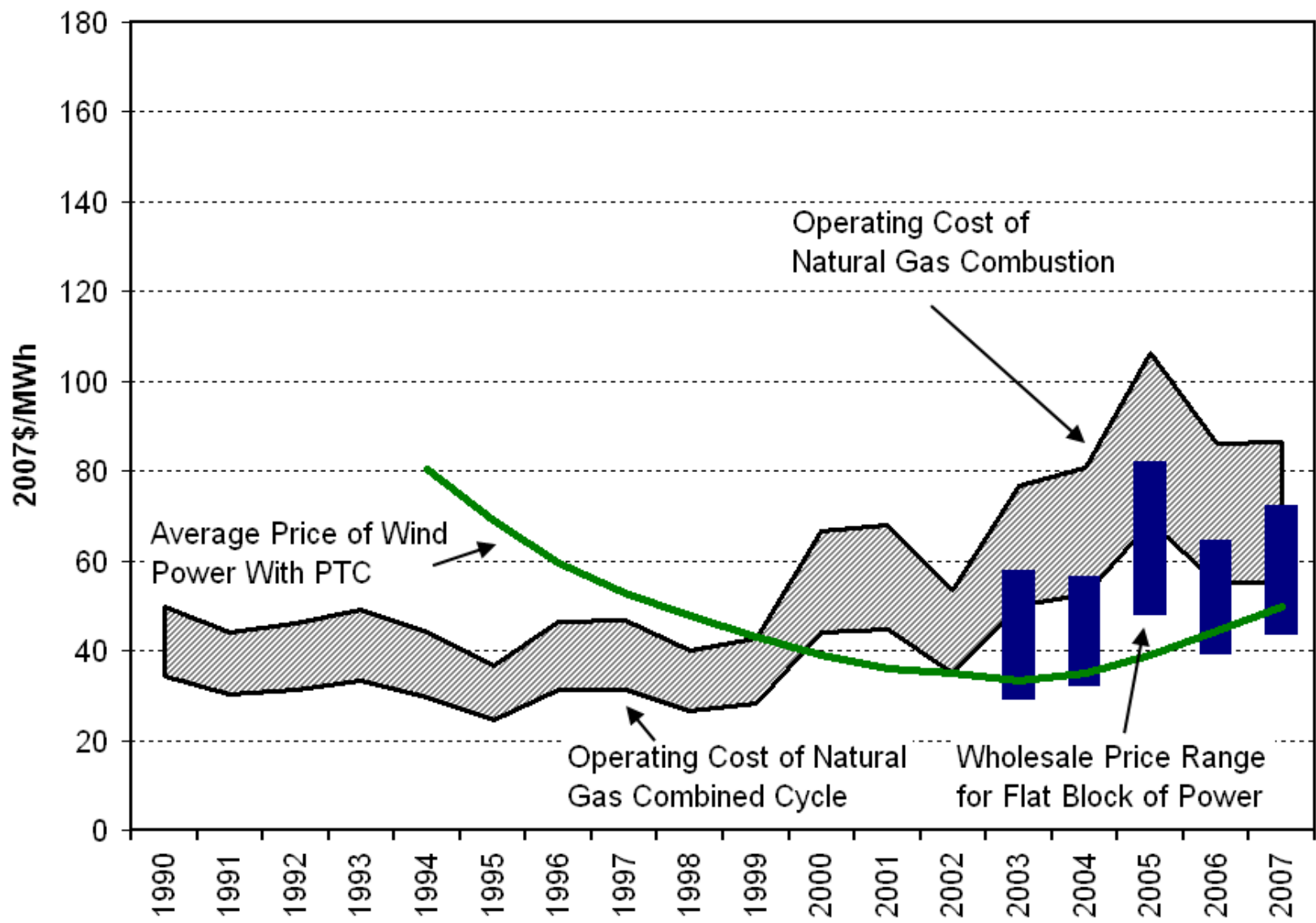


# Drivers for Wind Power

- Declining Wind Costs
- Fuel Price Uncertainty
- Federal and State Policies
- Economic Development
- Public Support
- Green Power
- Energy Security
- Carbon Risk

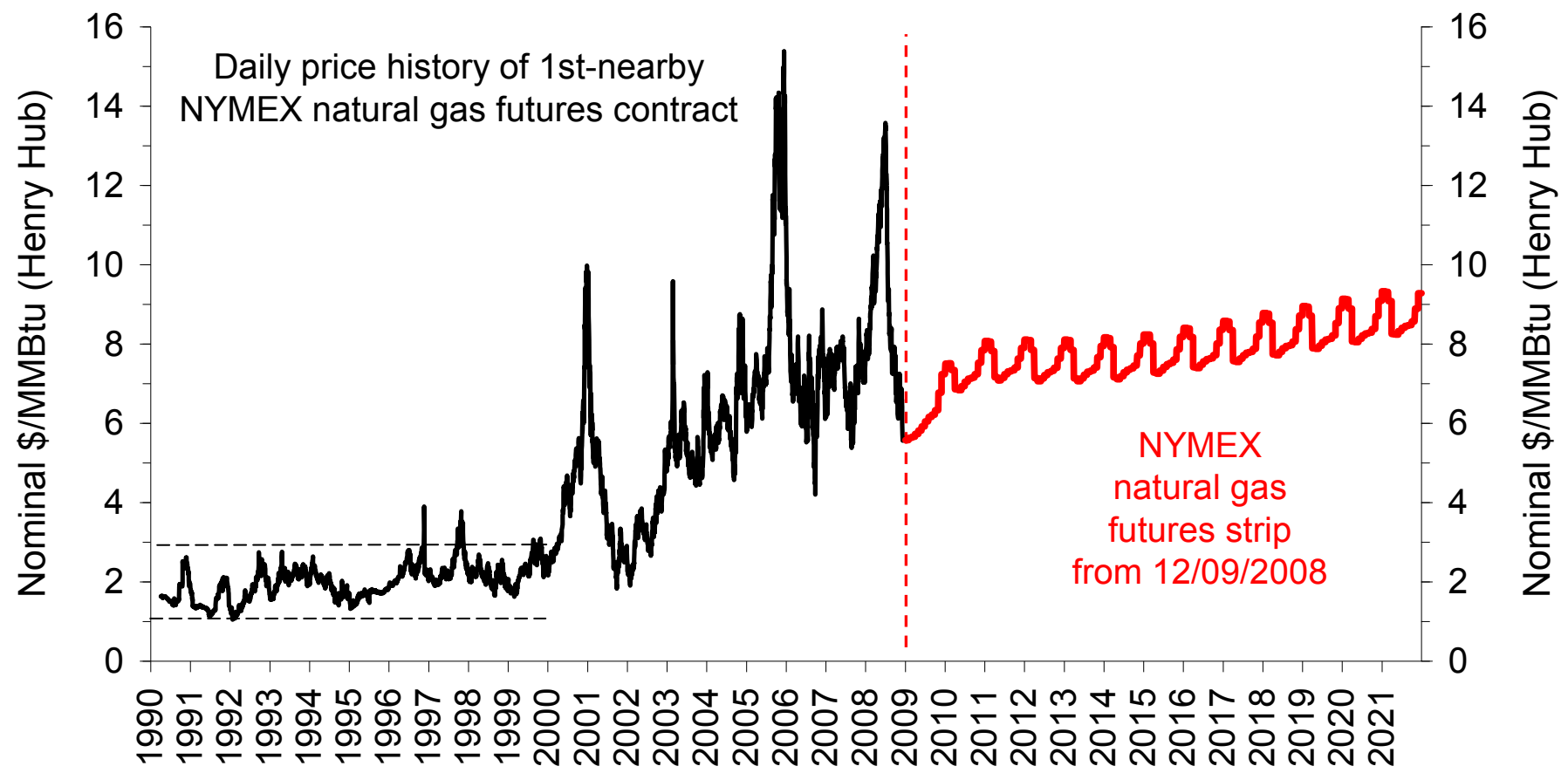


# Comparative Generation Costs



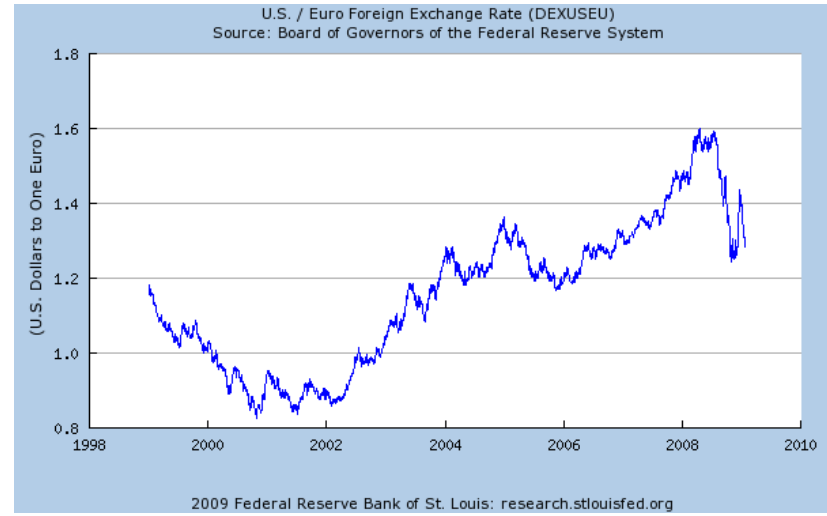
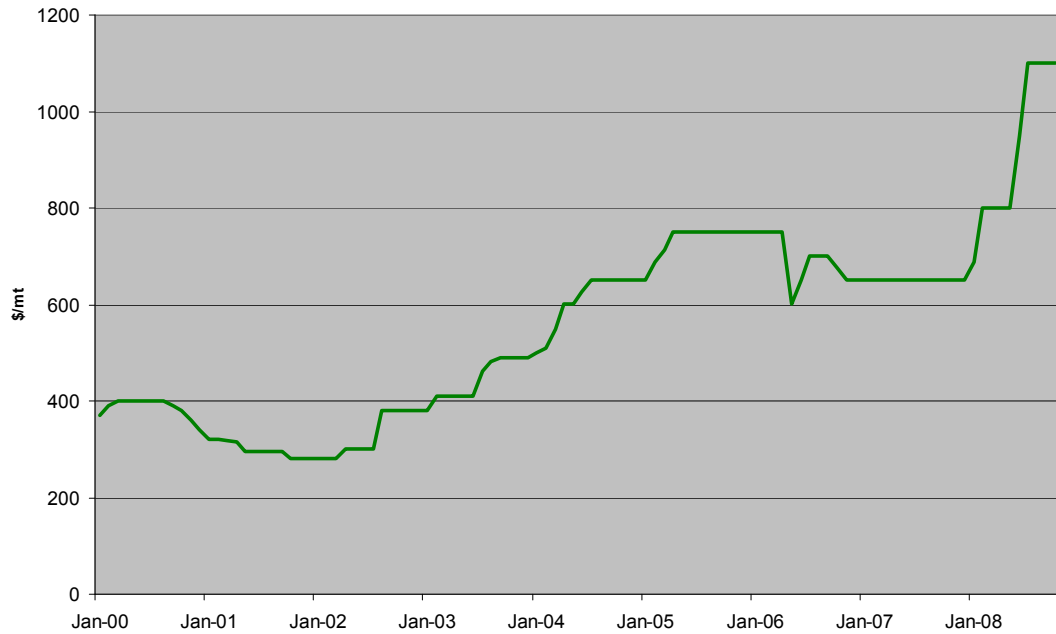


# Natural Gas – Historic Prices



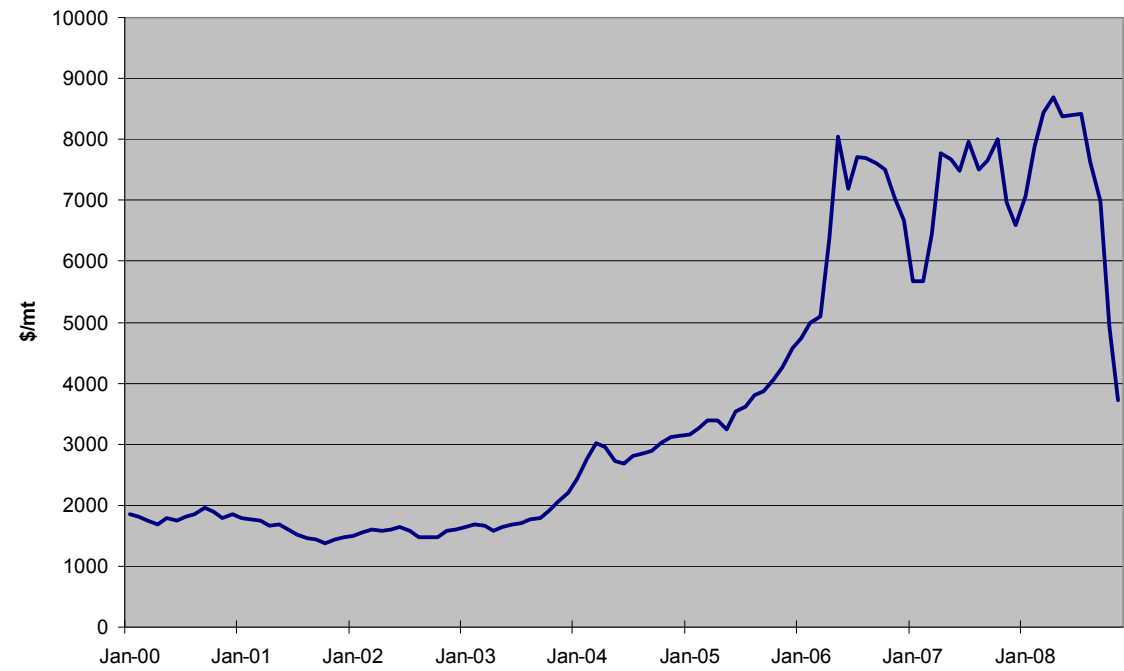
Source: LBNL

**Historic Steel Prices - Cold Rolled**



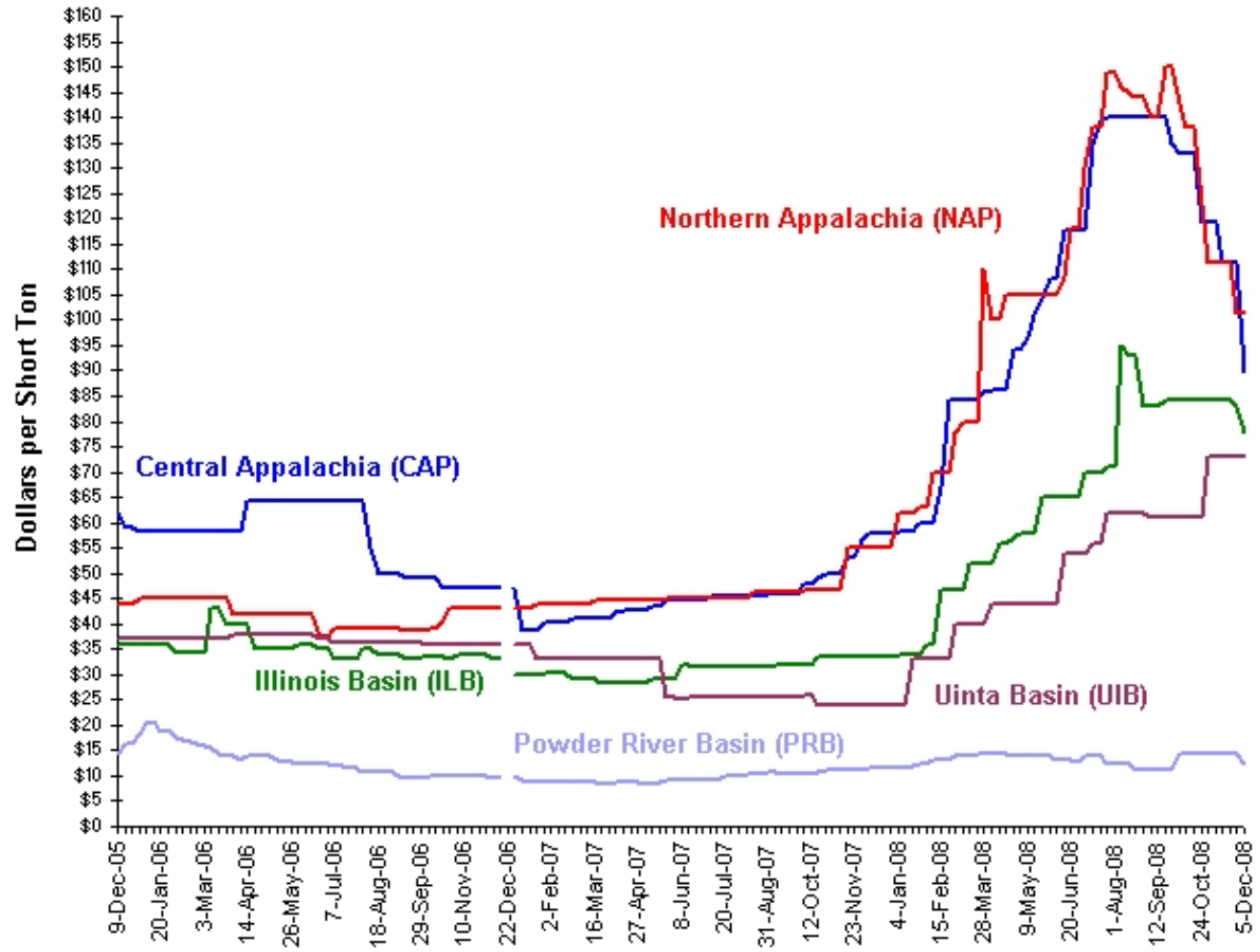
# Wind Cost Drivers

**Historic Copper Prices**



Copper & Steel Price Source: World Bank, Commodity Price Data

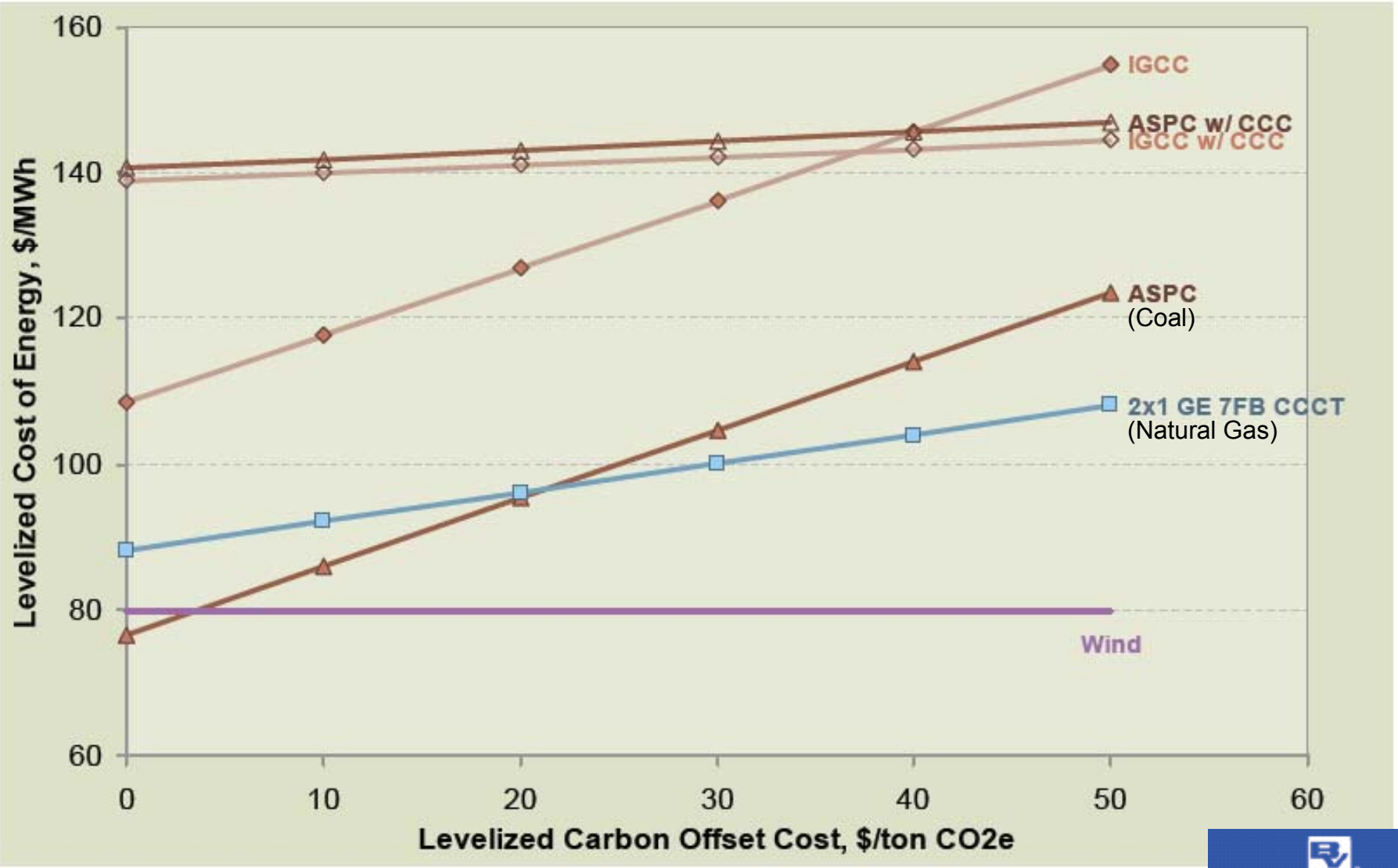
# Historical Coal Prices



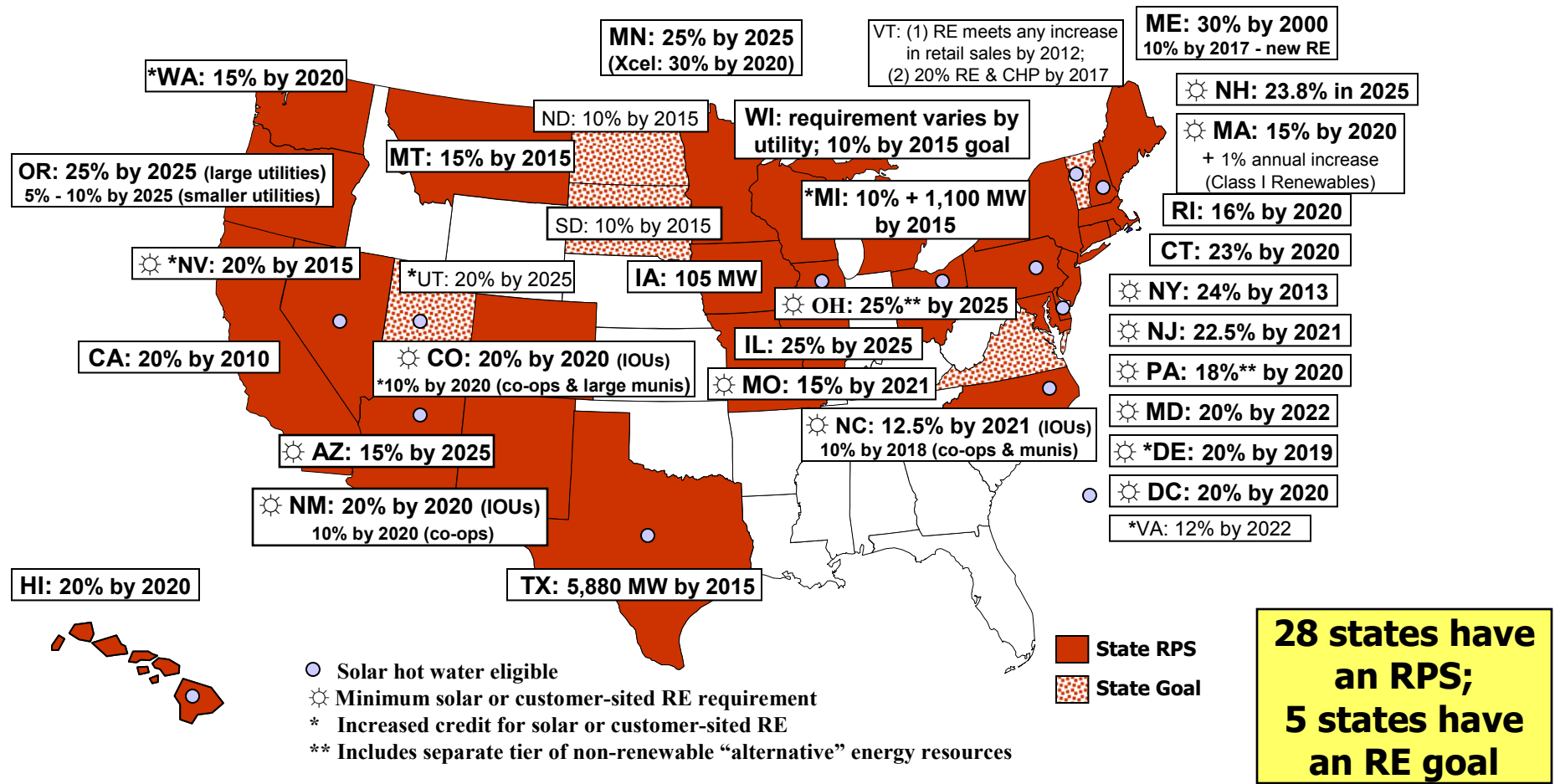
**Key to Coal Commodities by Region**

<u>Central Appalachia:</u>	Big Sandy/Kanawha 12,500 Btu, 1.2 lb SO <sub>2</sub> /mmBtu	<u>Powder River Basin:</u>	8,800 Btu, 0.8 lb SO <sub>2</sub> /mmBtu
<u>Northern Appalachia:</u>	Pittsburgh Seam 13,000 Btu, <3.0 lb SO <sub>2</sub> /mmBtu	<u>Uinta Basin in Colo.:</u>	11,700 Btu, 0.8 lb SO <sub>2</sub> /mmBtu
<u>Illinois Basin:</u>	11,800 Btu, 5.0 lb SO <sub>2</sub> /mmBtu		

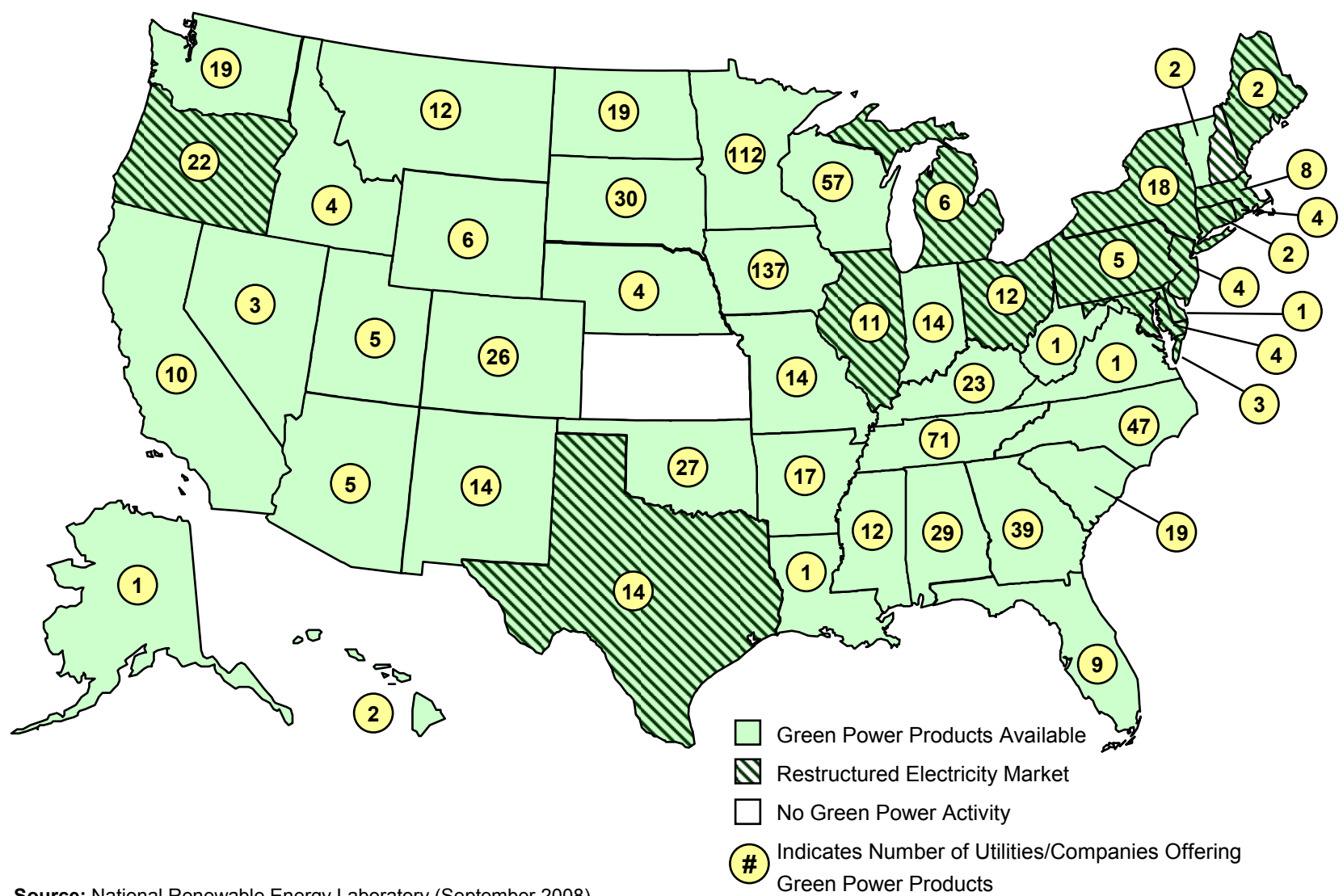
# CO<sub>2</sub> prices significantly increase the cost of coal



# Renewables Portfolio Standards



# States with Green Power Programs



Source: National Renewable Energy Laboratory (September 2008)

# Wind Energy Investors



**SIEMENS**



BP Solar



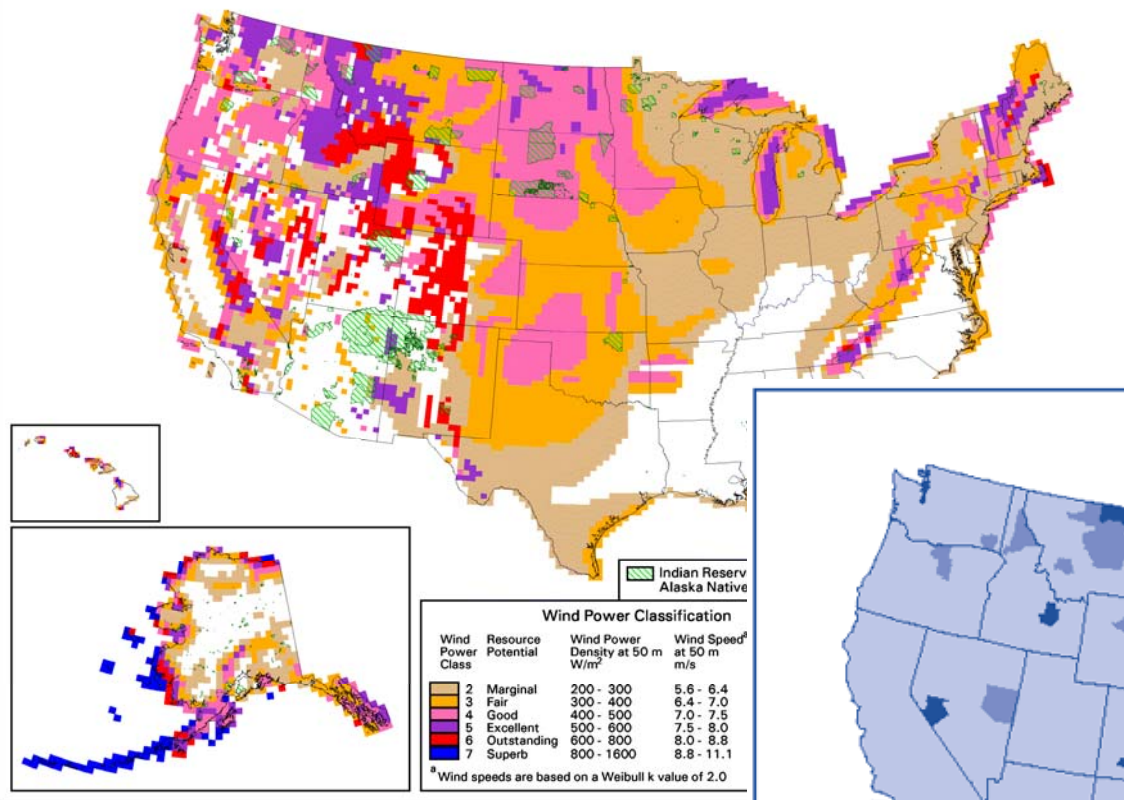
**JOHN DEERE**



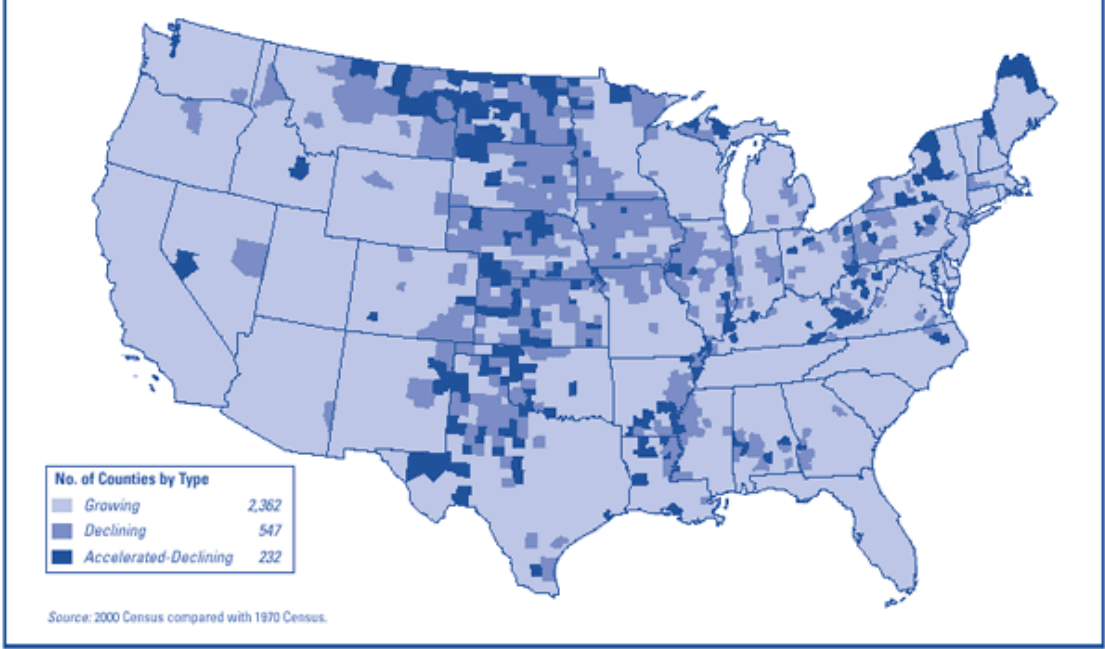


# Windy Rural Areas Need Economic Development

United States - Wind Resource Map



Geographic Distribution of Depopulation



# Economic Development Impacts

- **Land Lease Payments:** 2-3% of gross revenue \$2500-4000/MW/year
- **Local property tax** revenue: ranges widely - \$300K-1700K/yr per 100MW
- 100-200 **jobs**/100MW during construction
- 6-10 permanent O&M **jobs** per 100 MW
- Local construction and service industry: concrete, towers usually done locally





# Direct jobs and parts during construction



Truck drivers,  
crane operators



Wind Turbine Components



Earth moving, cement pouring



Management and support



Construction



# Direct wind project jobs during operations

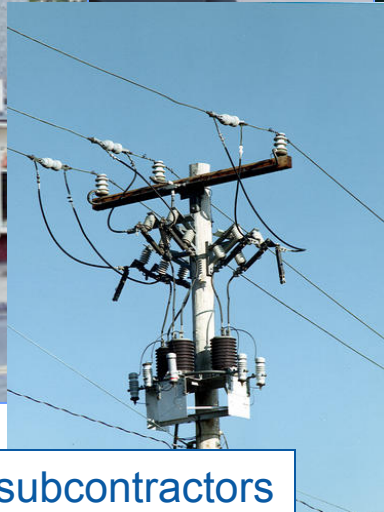


Operations and maintenance, management

Landowner royalties



Parts and materials purchased



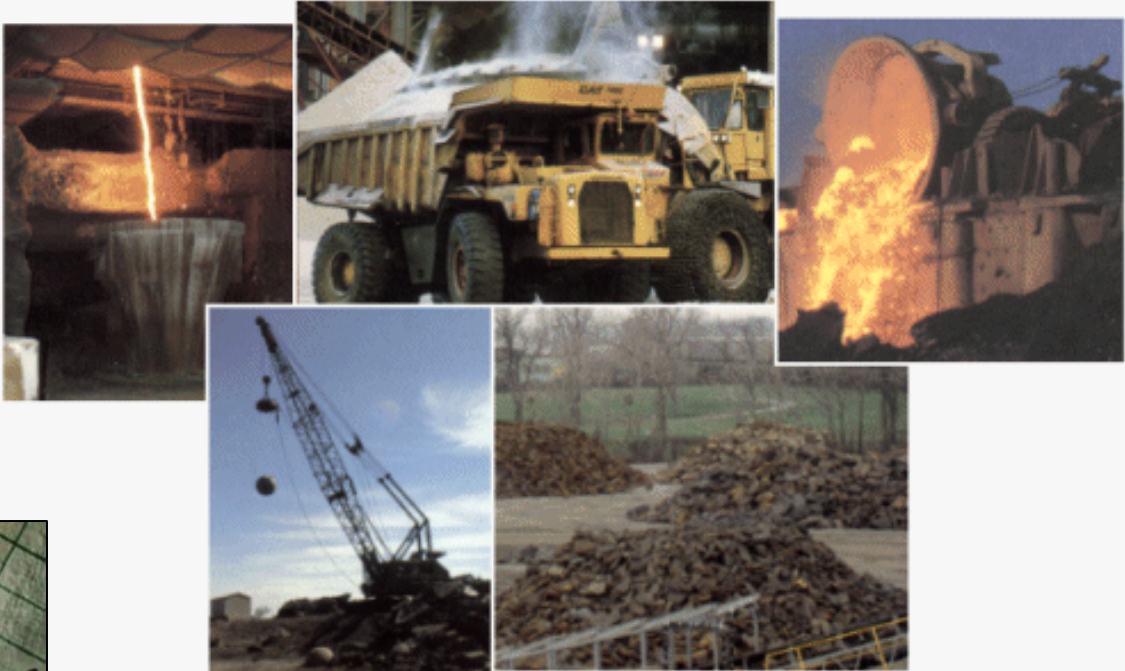
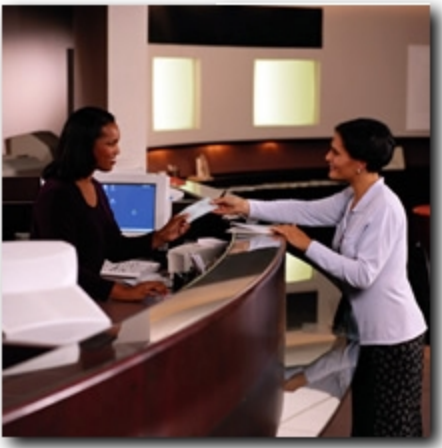
Utility services and subcontractors





# Indirect jobs, services, materials

Property taxes



Steel mill jobs, parts, services  
Photos: E.C.Levy, Inc, Detroit, MI

Financing, banking, accounting



Wind subcomponent manufacturing and sales

# Induced jobs, services, materials

Child care, grocery store, clothing, other retail, public transit, new cars, restaurants, medical services





# Wind Energy's Economic impacts

On-site direct, off-site direct, Indirect, Induced

*Wind energy's economic "ripple effect"*

## Direct Impacts

### On-site

Construction workers  
Management  
Administrative support

### Off-site

Boom truck & management, gas and gas station workers, blades and towers & workers

Cement truck drivers, road crews, maintenance workers

Hardware store purchases and workers, spare parts and their suppliers



## Indirect Impacts

These are jobs in and payments made to supporting businesses, such as **bankers** financing the construction, **contractor**, **manufacturers and equipment suppliers of subcomponents.**

## Induced Impacts

These jobs and earnings result from the spending by people directly and indirectly supported by the project, including benefits to **grocery store clerks, retail salespeople and child care providers.**



# Case Study: Iowa

## 240-MW Iowa wind project

- \$640,000/yr in lease payments to farmers (\$2,000/turbine/yr)
- \$2M/yr in property taxes
- \$5.5M/yr in O&M income
- **40 long-term O&M jobs**
- **200 short-term construction jobs**
- Doesn't include multiplier effect



# South Dakota Wind Energy Center

- 40.5 MW (1.5-MW turbines)
- Landowner payments: \$3,500-\$4,000/year
- 100 – 125 workers during peak construction
- 3 fulltime O&M positions
- **Property taxes: \$220,000/year**
- Sales and use tax: \$1.2 million payable in 2003
- Located near Highmore, SD (population 808)
- Owned by FPL Energy
- Constructed in 2003



# Peetz Table Wind Energy Center, CO

- 400.5 MW (1.5-MW turbines)
- Landowner payments: \$2 million/year, \$65 million over 30-year period
- 300 – 350 workers during peak construction (80% local)
- **16 – 18 O&M positions**
- Total annual tax payments: \$2.3 million/year (10% of total county budget); \$70 million over 30 years
- Located near Peetz, CO
- Owned by FPL Energy
- Constructed in 2007



# Weatherford Wind Energy Center, OK

- 147 MW (1.5-MW turbines)
- **Landowner payments: \$300,000 in annual lease payments**
- 150 workers during peak construction
- 6 fulltime O&M positions
- Property taxes: \$17 million over 20 years
- Sawartzky Construction received \$300,000 in revenue from the project
- Owned by FPL Energy
- Constructed in 2005



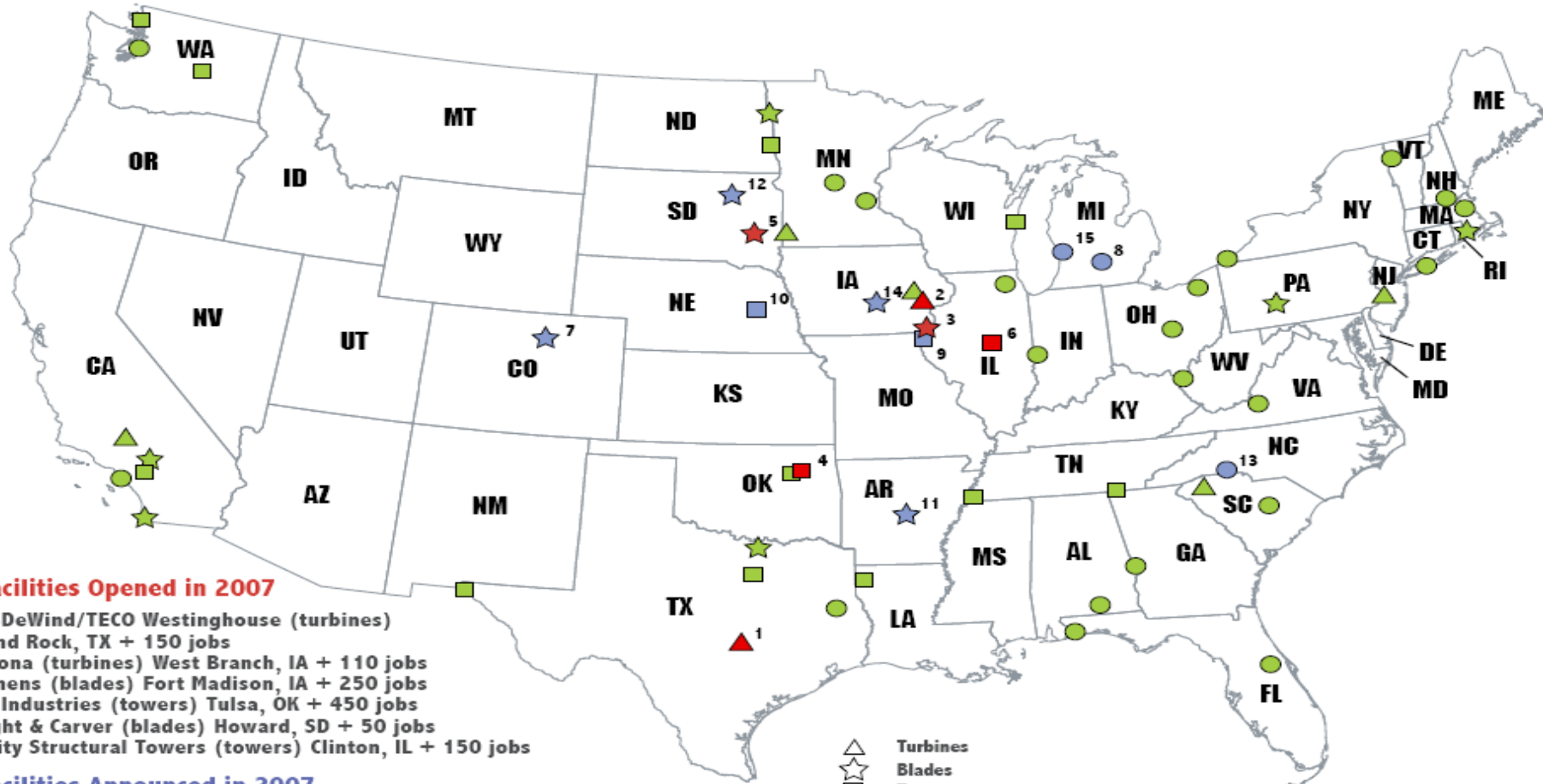
# Wyoming Wind Energy Center

- 144 MW (1800-kW turbines)
- Landowner payments: \$18 million over the life of the project
- 175 workers during peak construction (25% local)
- 8 fulltime O&M positions
- Property taxes: \$1 million (2006/7)
- **50 Wyoming companies subcontracted during the construction period**
- Located in Uinta County, WY (population 20,213)
- Owned by FPL Energy
- Constructed in 2003





# Soaring Demand Spurs Expansion of U.S. Wind Turbine Manufacturing



## New Facilities Opened in 2007

1. CTC-DeWind/TECO Westinghouse (turbines) Round Rock, TX + 150 jobs
2. Acciona (turbines) West Branch, IA + 110 jobs
3. Siemens (blades) Fort Madison, IA + 250 jobs
4. DMI Industries (towers) Tulsa, OK + 450 jobs
5. Knight & Carver (blades) Howard, SD + 50 jobs
6. Trinity Structural Towers (towers) Clinton, IL + 150 jobs

## New Facilities Announced in 2007

7. Vestas (blades) Windsor, CO + 650 jobs
8. Dowding Industries (turbine components) Eaton Rapids, MI + 200 jobs
9. Hendricks Industries (towers) Keokuk, IA + 350 jobs
10. Katana Summit (towers) Columbus, NE + 120 jobs
11. LM Glasfiber (blades) Little Rock, AR + 1,000 jobs
12. Molded Fiberglass (blades) Aberdeen, SD + 750 jobs
13. PPG Industries (fiberglass) Shelby, NC + not available
14. TPI Composites (blades) Newton, IA + 500 jobs
15. Genzink Steel (nacelles) Holland, MI + 10 jobs

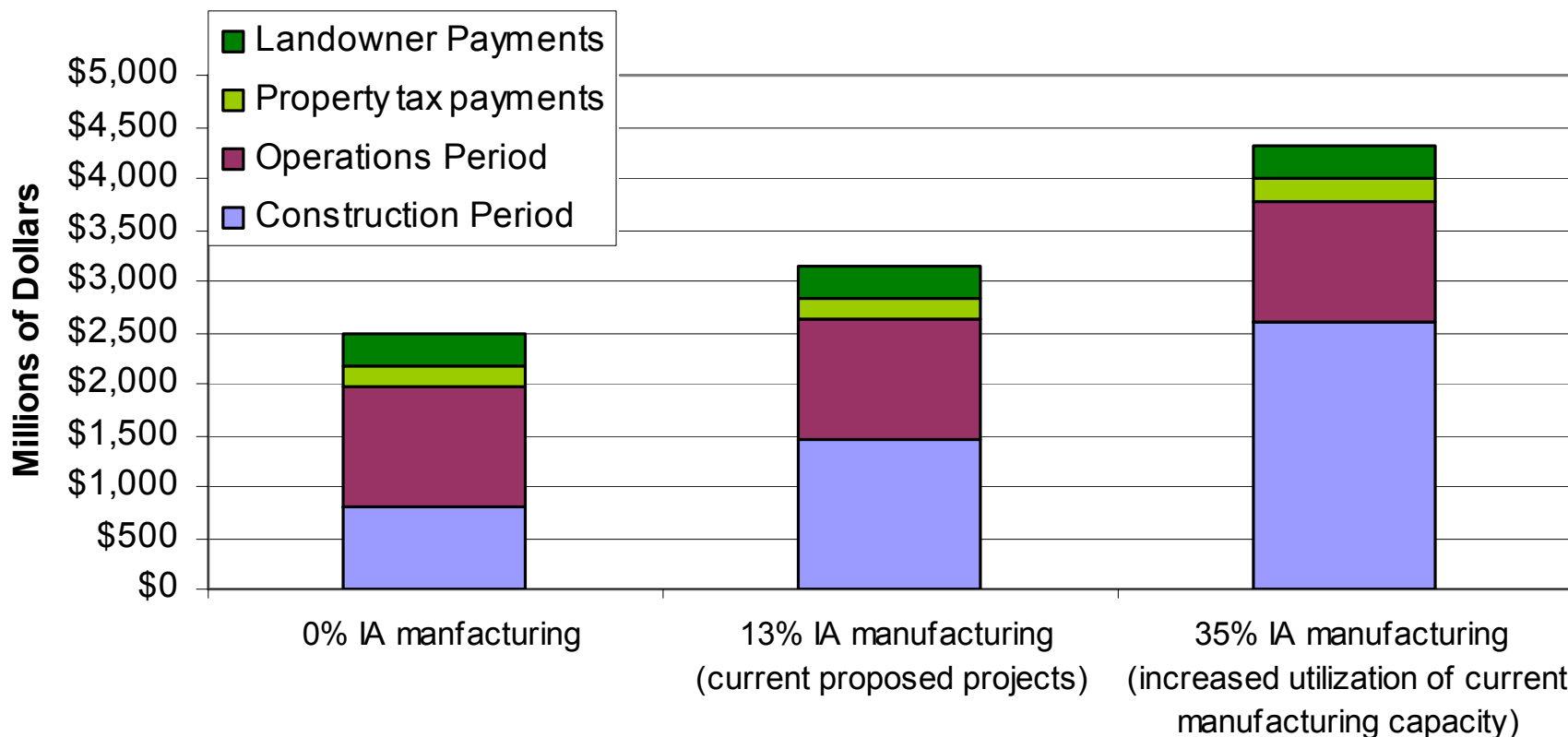
- △ Turbines
- ☆ Blades
- Towers
- Other
- Existing facilities online prior to 2007
- New facilities opened in 2007
- New facilities announced in 2007

*Note: Map is not intended to be exhaustive*

Figure includes wind turbine and component manufacturing facilities, as well as other supply chain facilities, and excludes corporate headquarters and service-oriented facilities. The facilities highlighted here are not intended to be exhaustive. Those facilities designated as "turbines" may include turbine assembly as well as component manufacture including, in some cases, towers and blades.

# Manufacturing and Economic Development

**Total economic development impacts in Iowa  
(2,400 MW of development)**





# Local Ownership Models

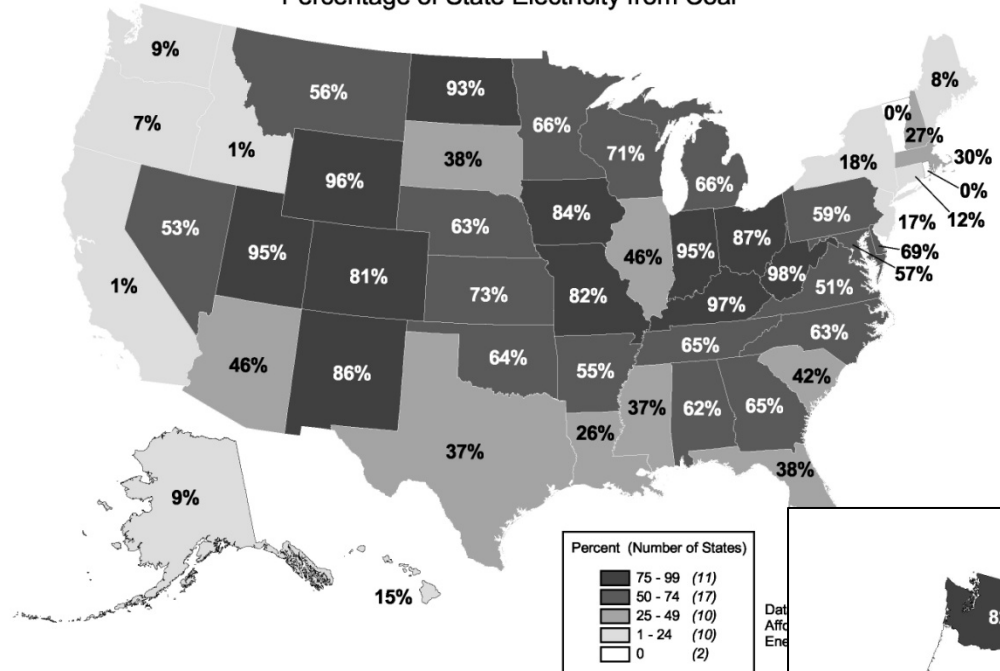
- Minnesota farmer cooperative (Minwind)
- FLIP structure
- Farmer-owned small wind
- Farmer-owned commercial-scale



© L. Kennedy



Percentage of State Electricity from Coal

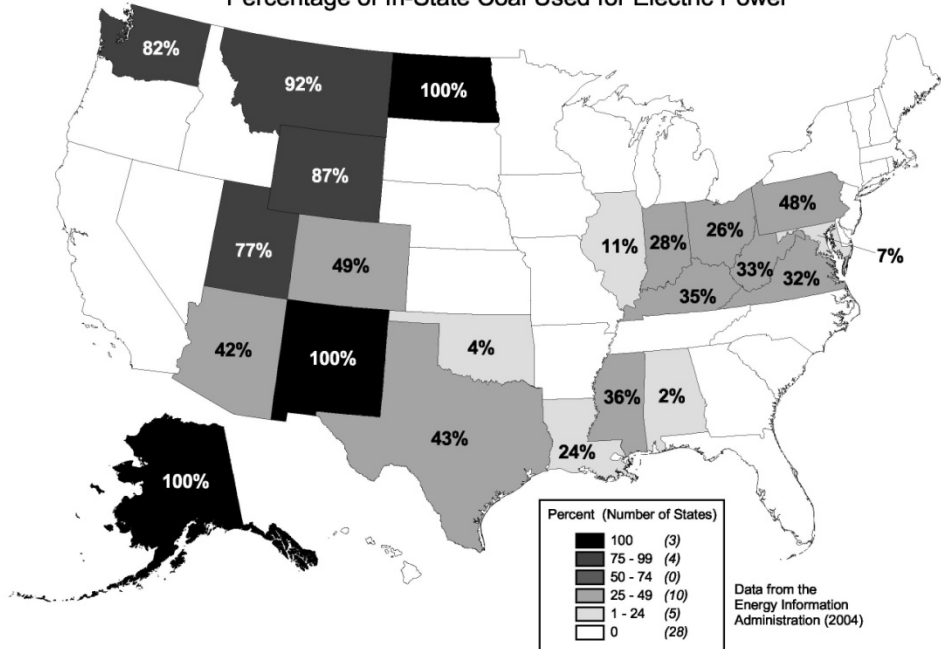


Percent (Number of States)

75 - 99	(11)
50 - 74	(17)
25 - 49	(10)
1 - 24	(10)
0	(2)

Data from the Energy Information Administration (2004)

Percentage of In-State Coal Used for Electric Power

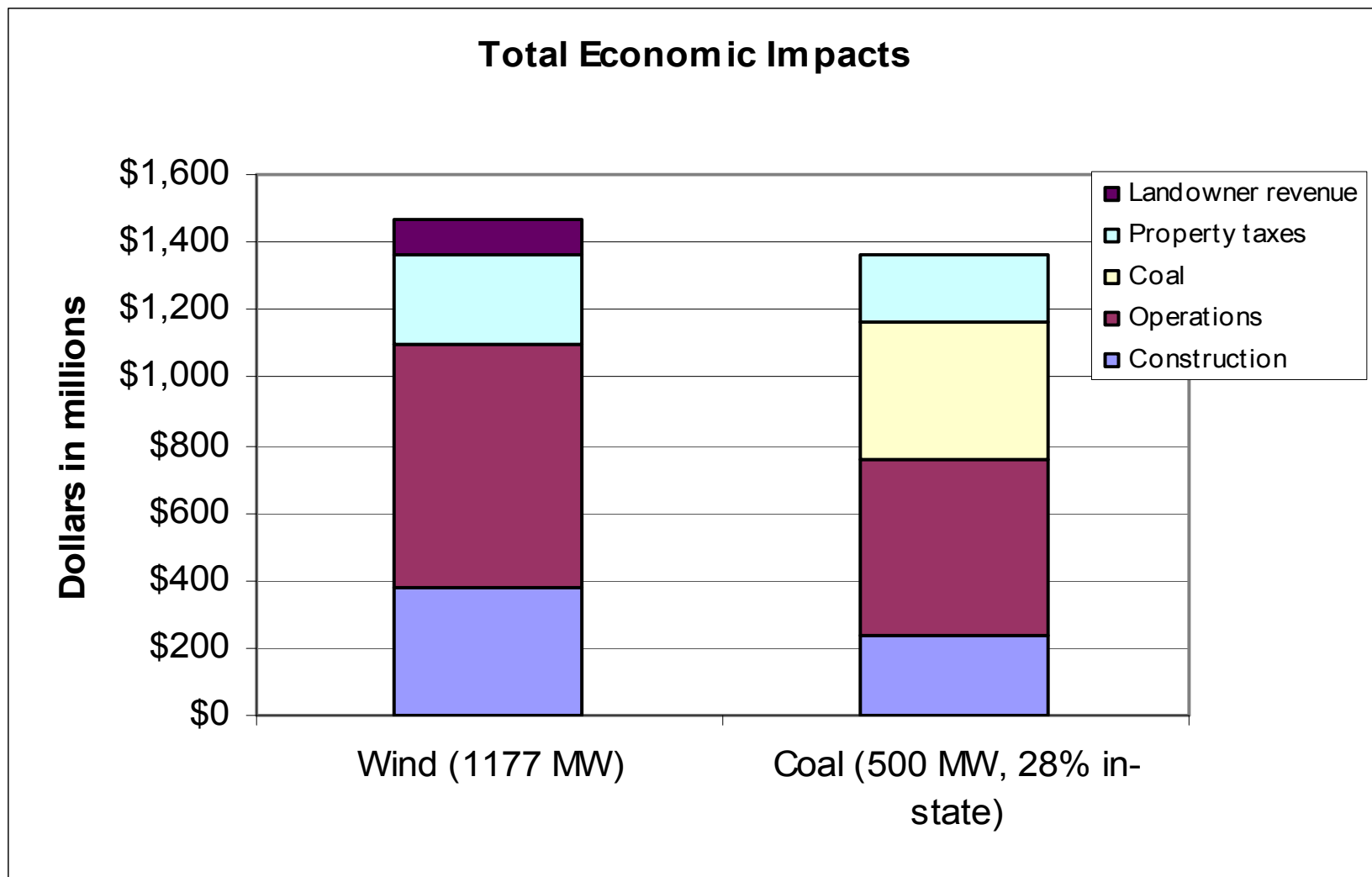


Percent (Number of States)

100	(3)
75 - 99	(4)
50 - 74	(0)
25 - 49	(10)
1 - 24	(5)
0	(28)

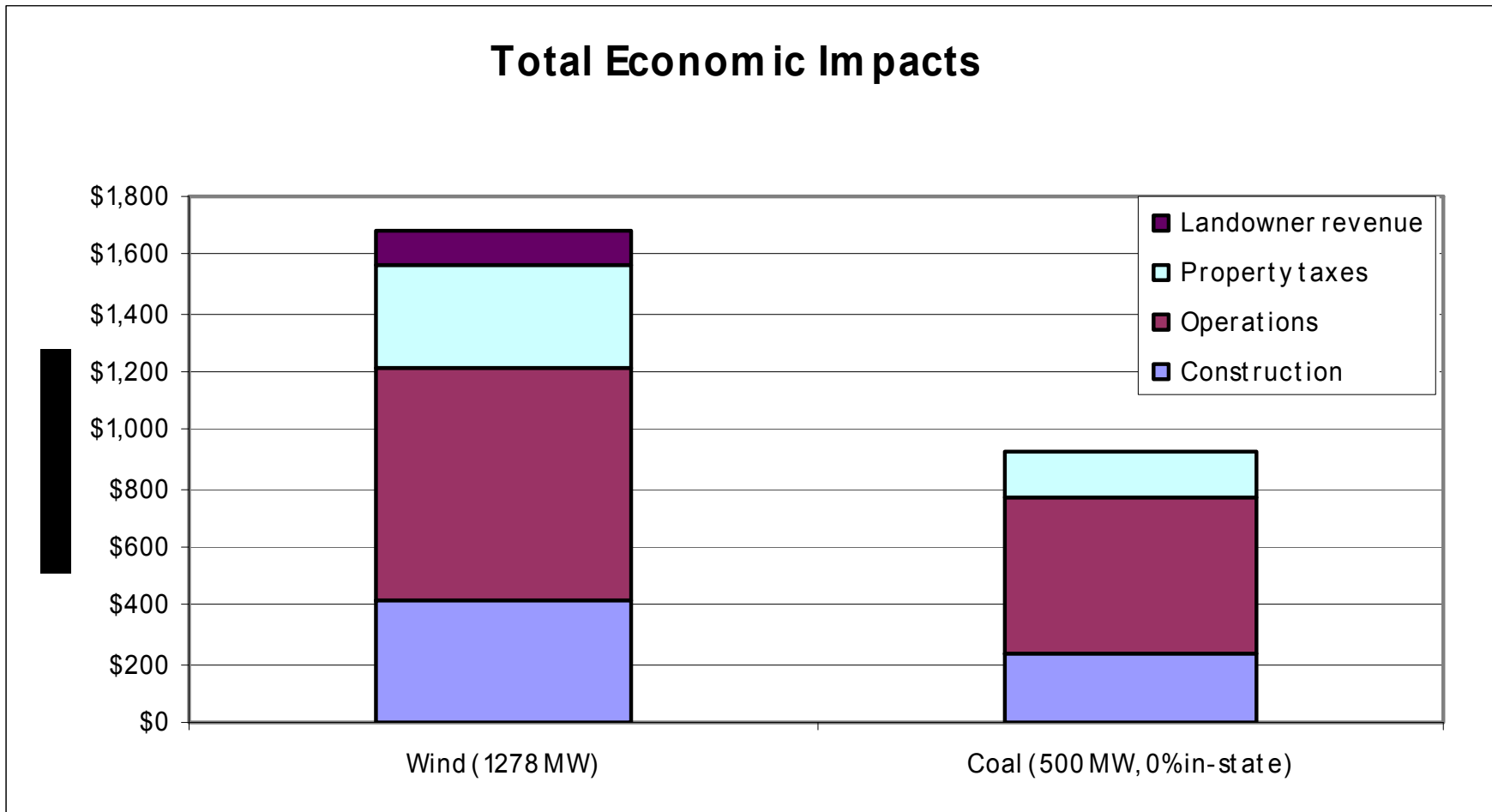
Data from the Energy Information Administration (2004)

# Comparing wind and coal in Indiana



# Comparing wind and coal in Michigan

## Total Economic Impacts



# Colorado – Economic Impacts

from 1000 MW of new wind development

*Wind energy's economic "ripple effect"*

## Direct Impacts

### Payments to Landowners:

- \$2.5 Million/yr

### Local Property Tax Revenue:

- \$4.6 Million/yr

### Construction Phase:

- 912 new jobs
- \$133.6 M to local economies

### Operational Phase:

- 181 new long-term jobs
- \$19.3 M/yr to local economies



## Indirect & Induced Impacts

### Construction Phase:

- 807 new jobs
- \$92.7 M to local economies

### Operational Phase:

- 129 local jobs
- \$15.6 M/yr to local economies

## Totals

(construction + 20yrs)

**Total economic benefit = \$924.3 million**

**New local jobs during construction = 1,719**

**New local long-term jobs = 310**

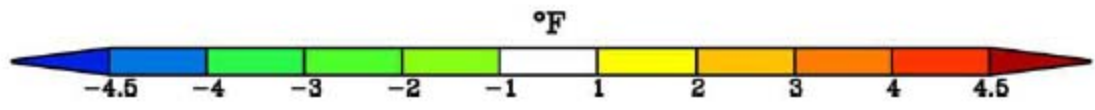
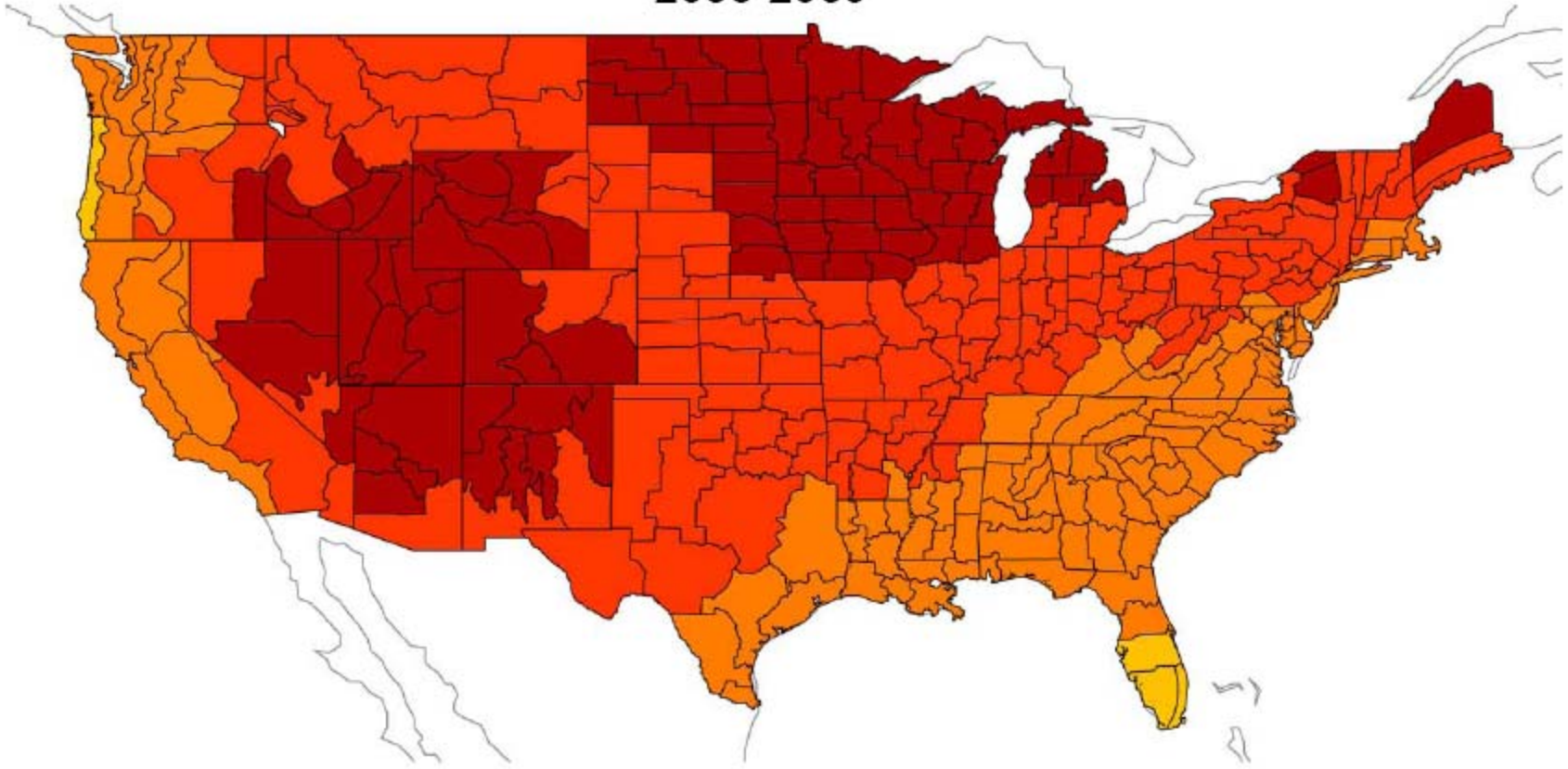
# Environmental Benefits

- No SO<sub>x</sub> or NO<sub>x</sub>
- No particulates
- No mercury
- No CO<sub>2</sub>
- No water



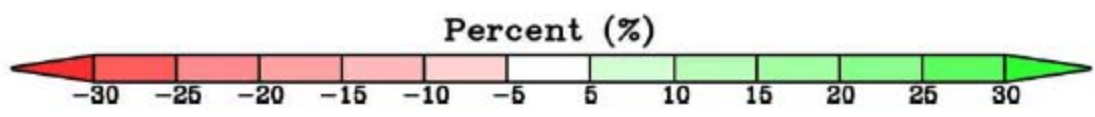
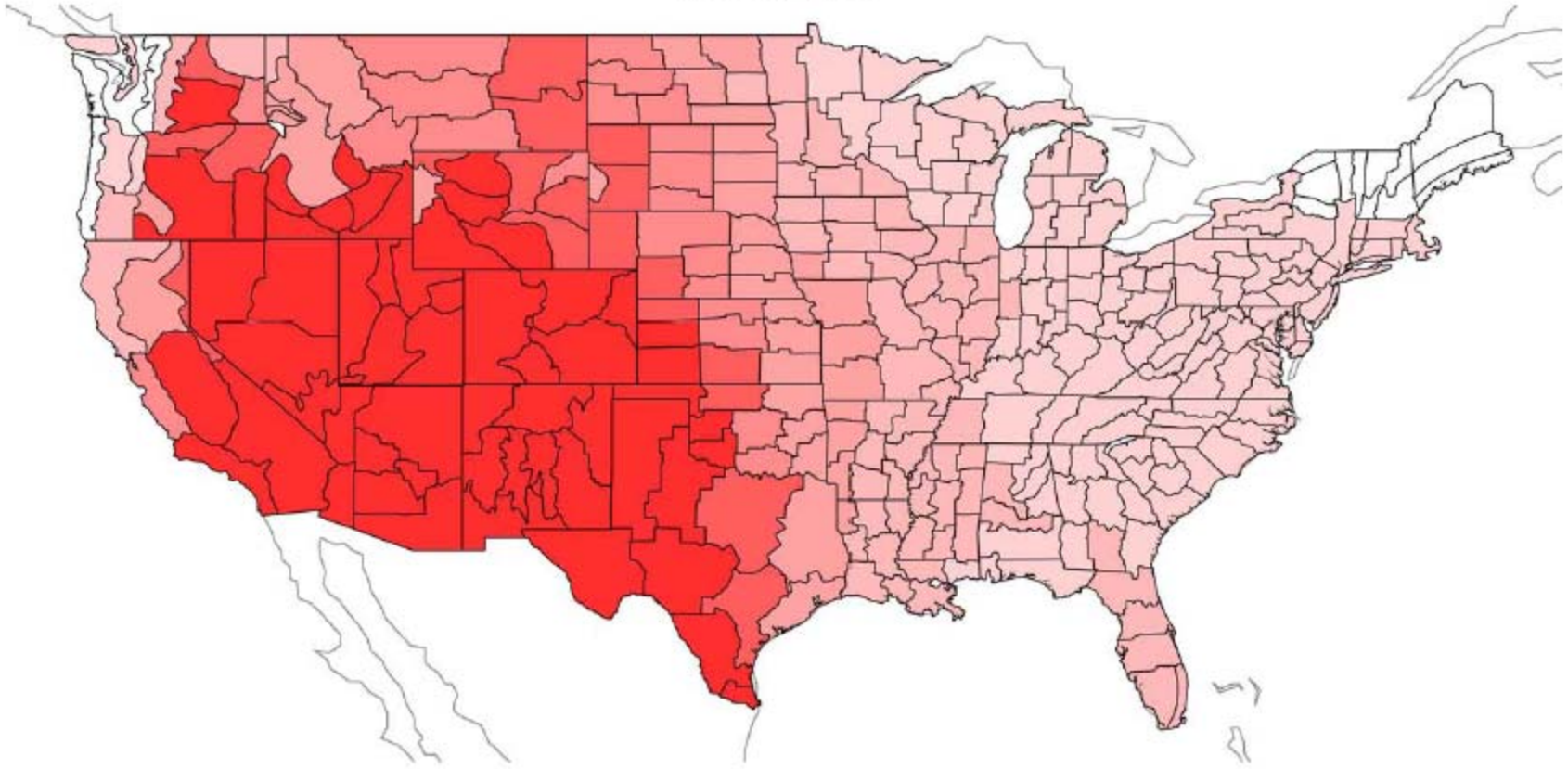


# Change in Annual Temperature 2035-2060

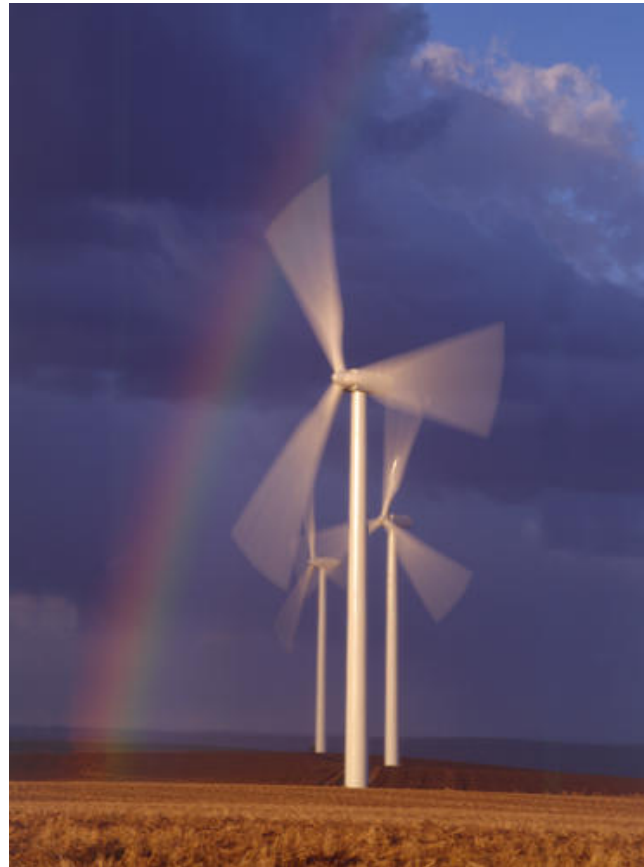


Source: NOAA

# Change in Annual (PCPN-Potential Evapotranspiration) 2035-2060



# Energy-Water Nexus





# Key Issues for Wind Power



- Policy Uncertainty
- Siting and Permitting: avian, noise, visual, federal land
- Transmission: FERC rules, access, new lines
- Operational impacts: intermittency, ancillary services, allocation of costs
- Accounting for non-monetary value: green power, no fuel price risk, reduced emissions

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“The future ain’t what it used to be.”

- Yogi Berra

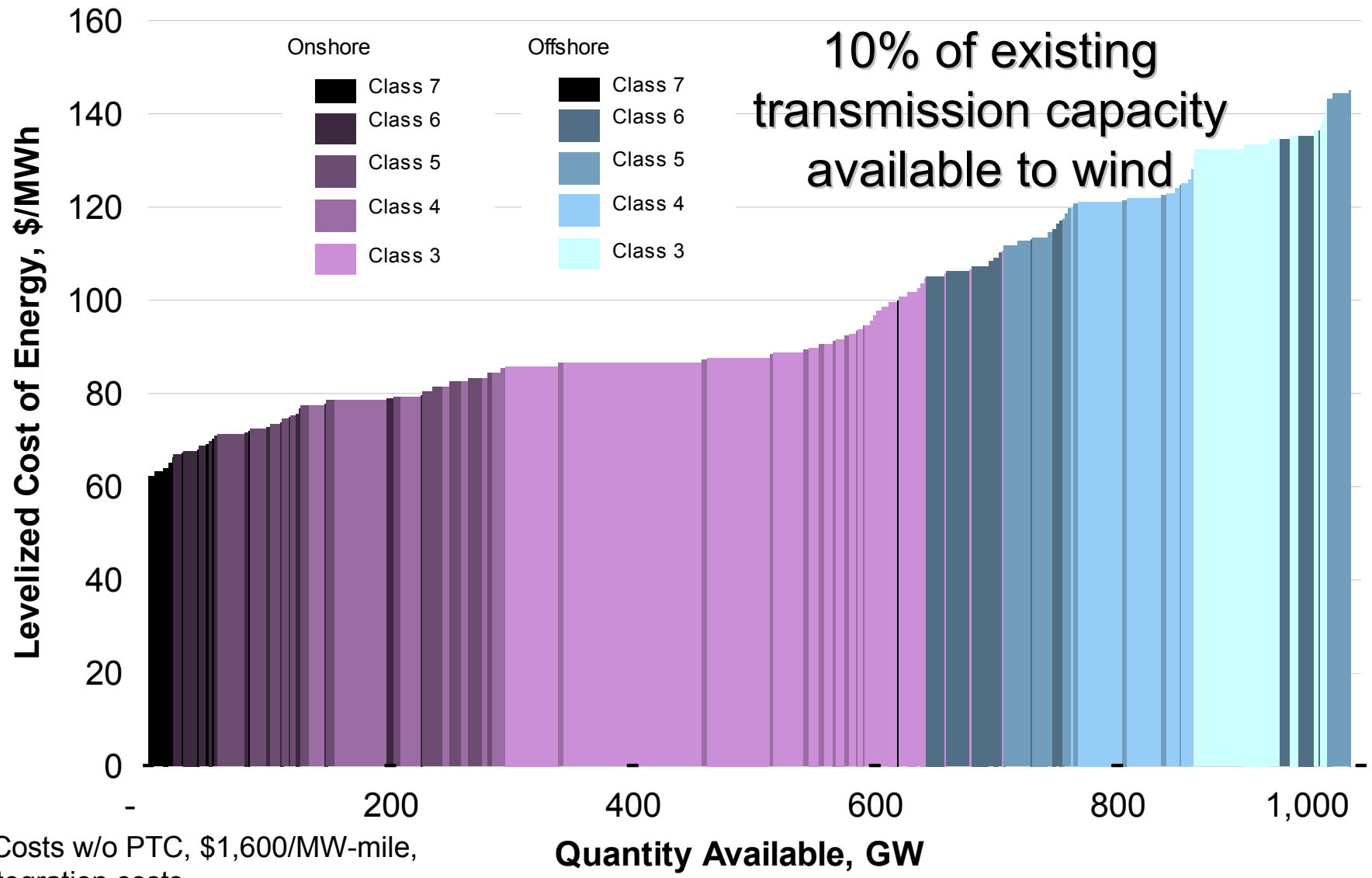
# The 20% Technical Report

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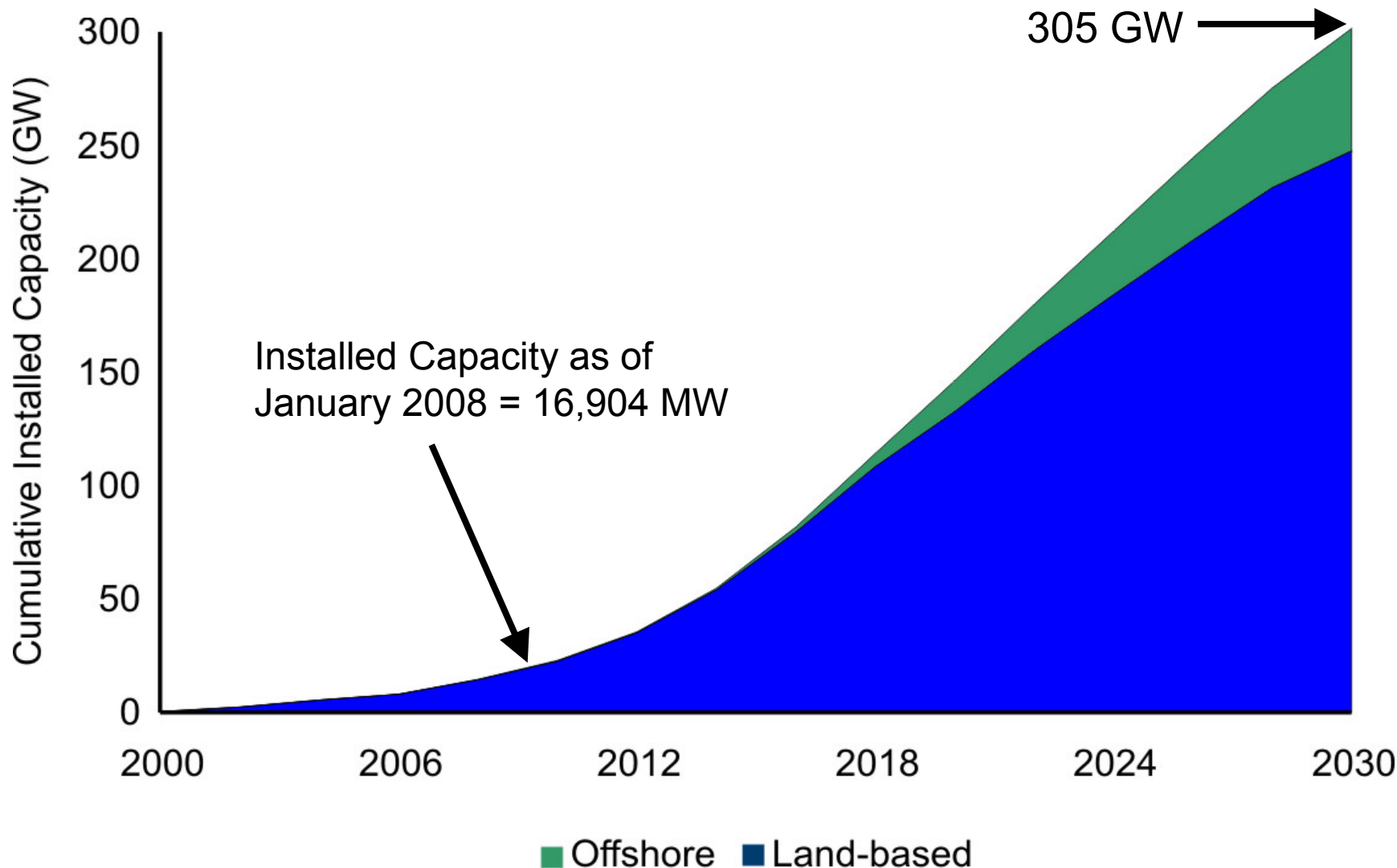
- Explores one scenario for reaching 20% wind electricity by 2030 and contrasts it to a scenario in which no new U.S. wind power capacity is installed
- Is not a prediction, but an analysis based on one scenario
- Does not assume specific policy support for wind
- Is the work of more than 100 individuals involved from 2006 - 2008 (government, industry, utilities, NGOs)
- Critically examines wind's roles in energy security, economic prosperity and environmental sustainability



# Supply Curve for Wind Energy: Energy and Transmission Costs

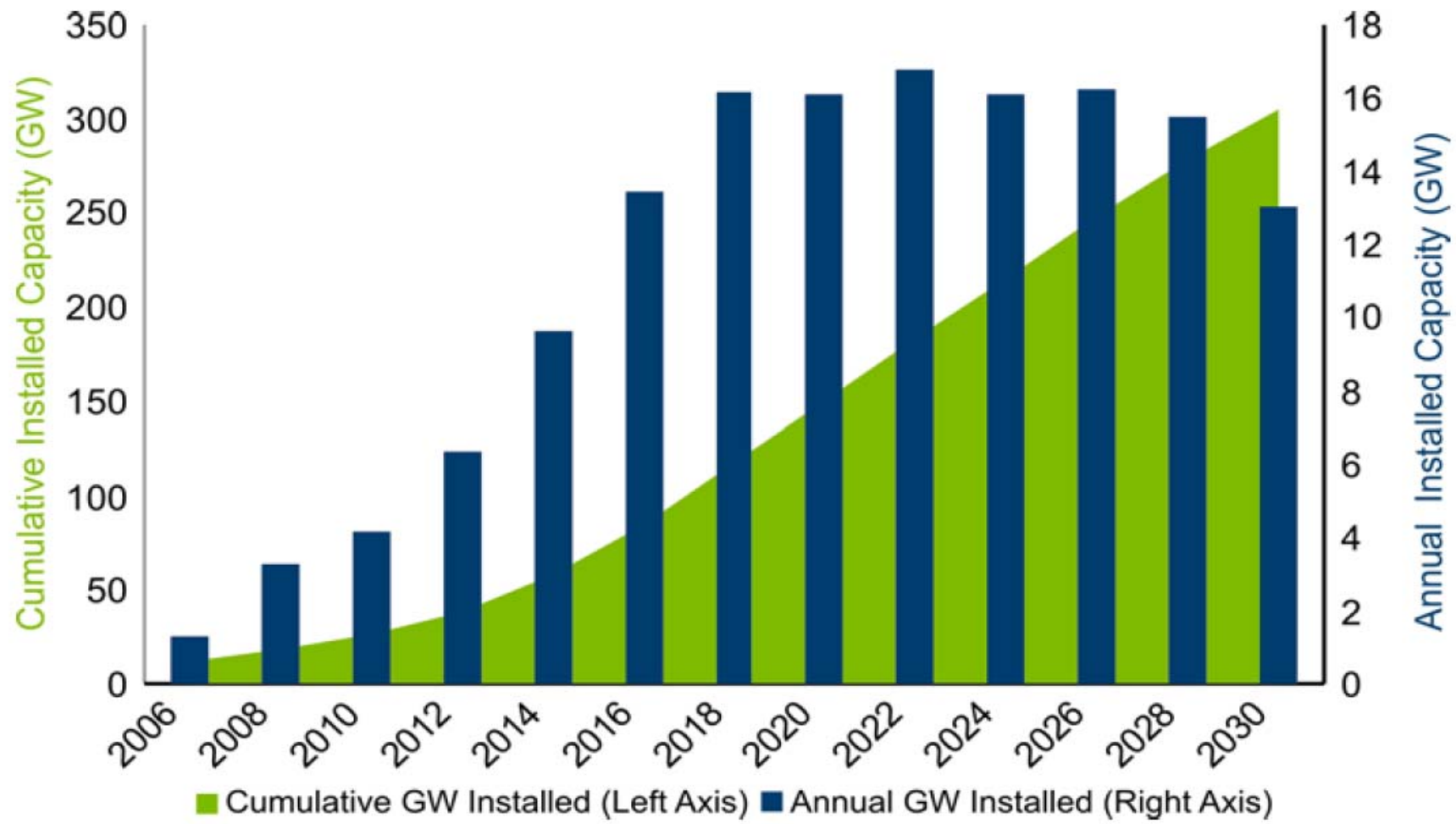


# 20% Wind Scenario

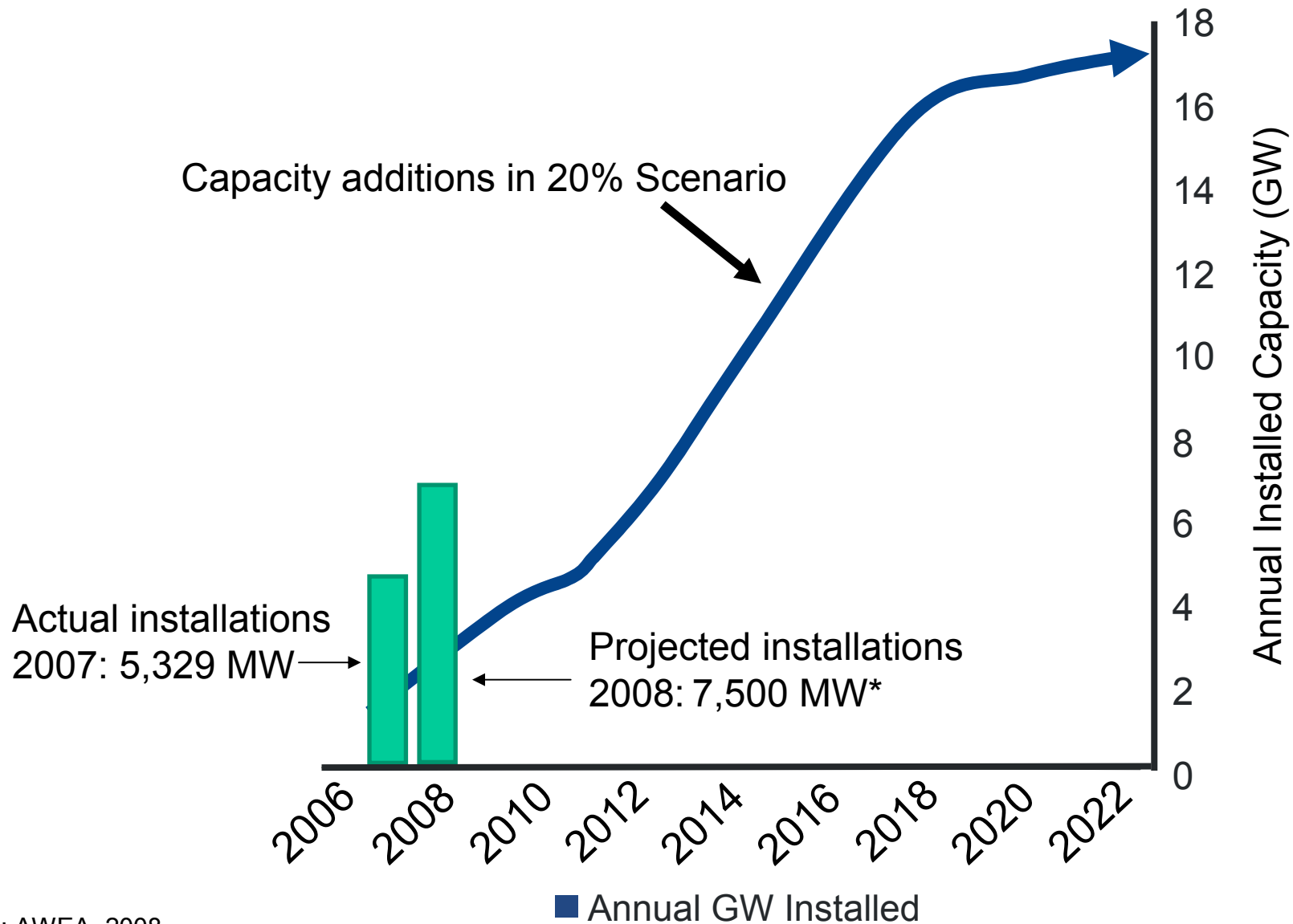


# What does 20% Wind look like?

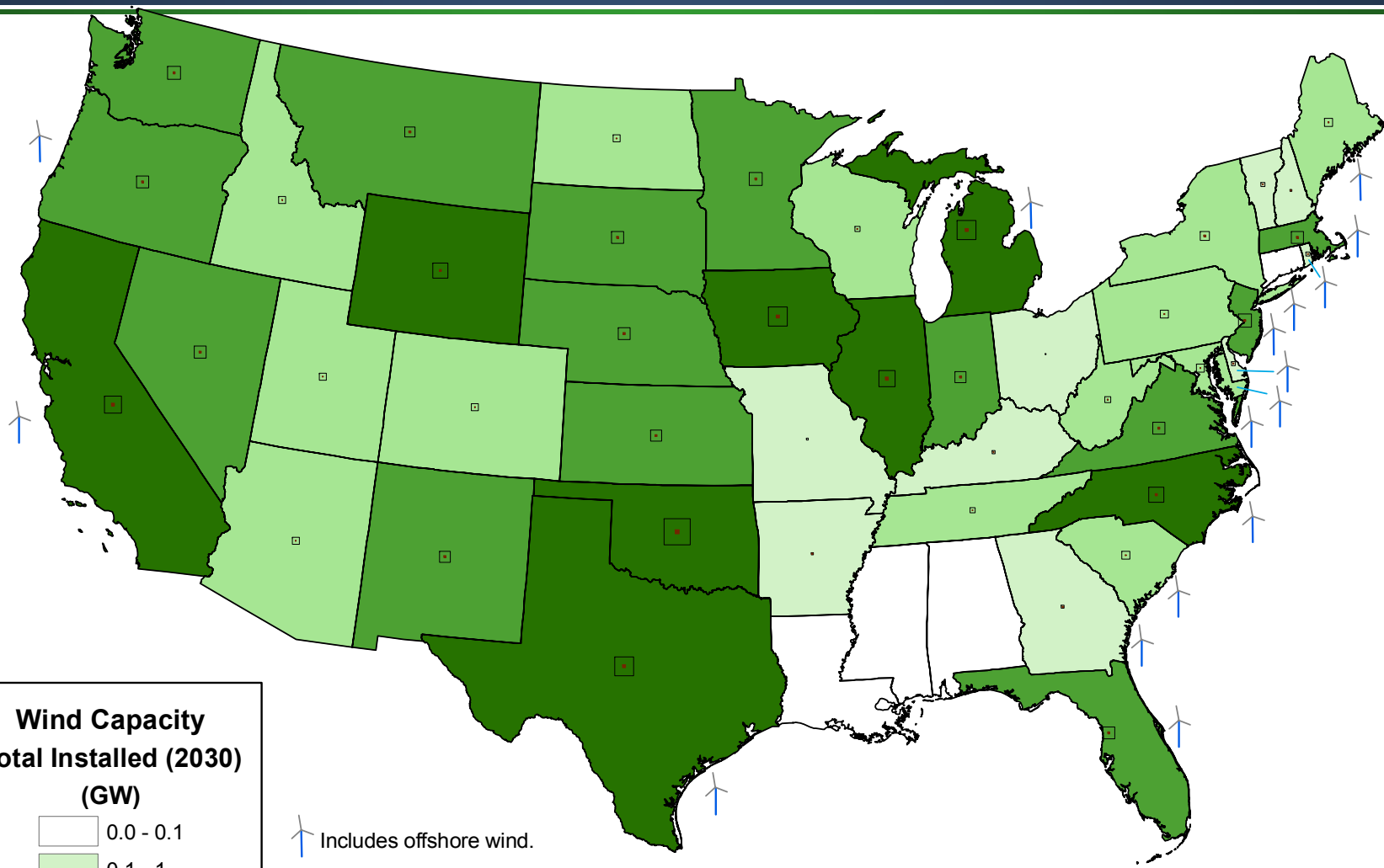
Figure 1-4. Annual and cumulative wind installations by 2030



# Annual Installed Capacity vs. Current Installed Capacity



# Substantial Wind Development by 2030



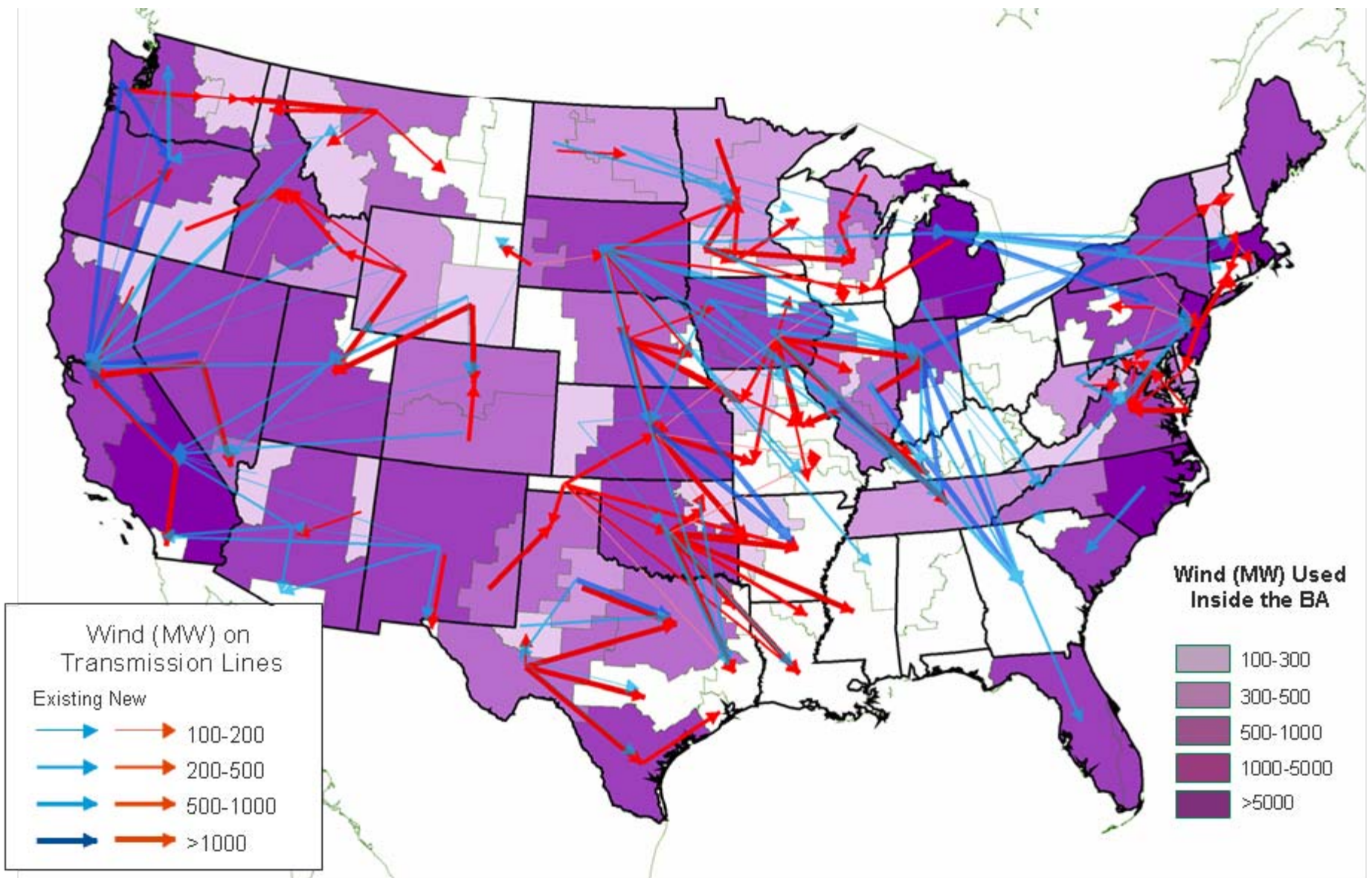
**Wind Capacity  
Total Installed (2030)  
(GW)**

	0.0 - 0.1
	0.1 - 1
	1 - 5
	5 - 10
	> 10

Includes offshore wind.

The black open square in the center of a state represents the land area needed for a single wind farm to produce the projected installed capacity in that state. The brown square represents the actual land area that would be dedicated to the wind turbines (2% of the black open square).

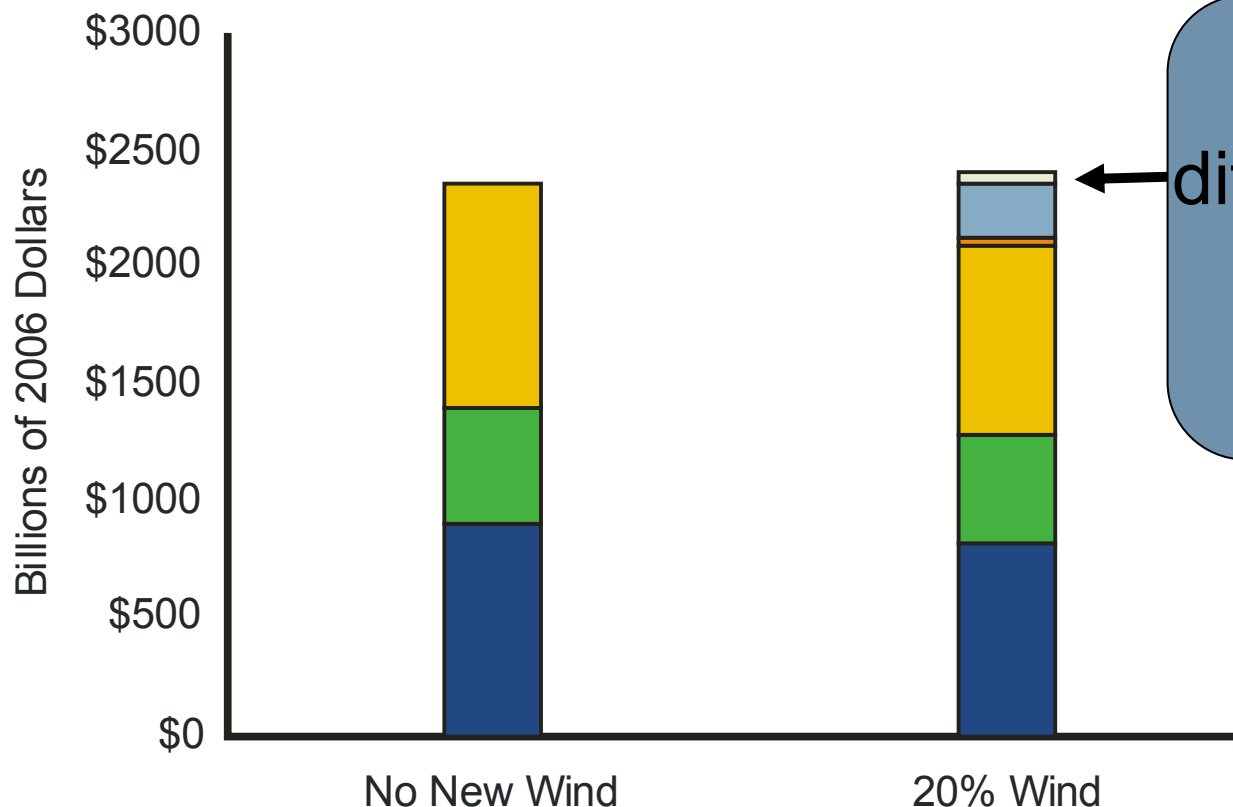
# Need for New Transmission: Existing and New in 2030





# Economic Costs of 20% Wind Scenario

Incremental investment cost of 20% Wind Scenario



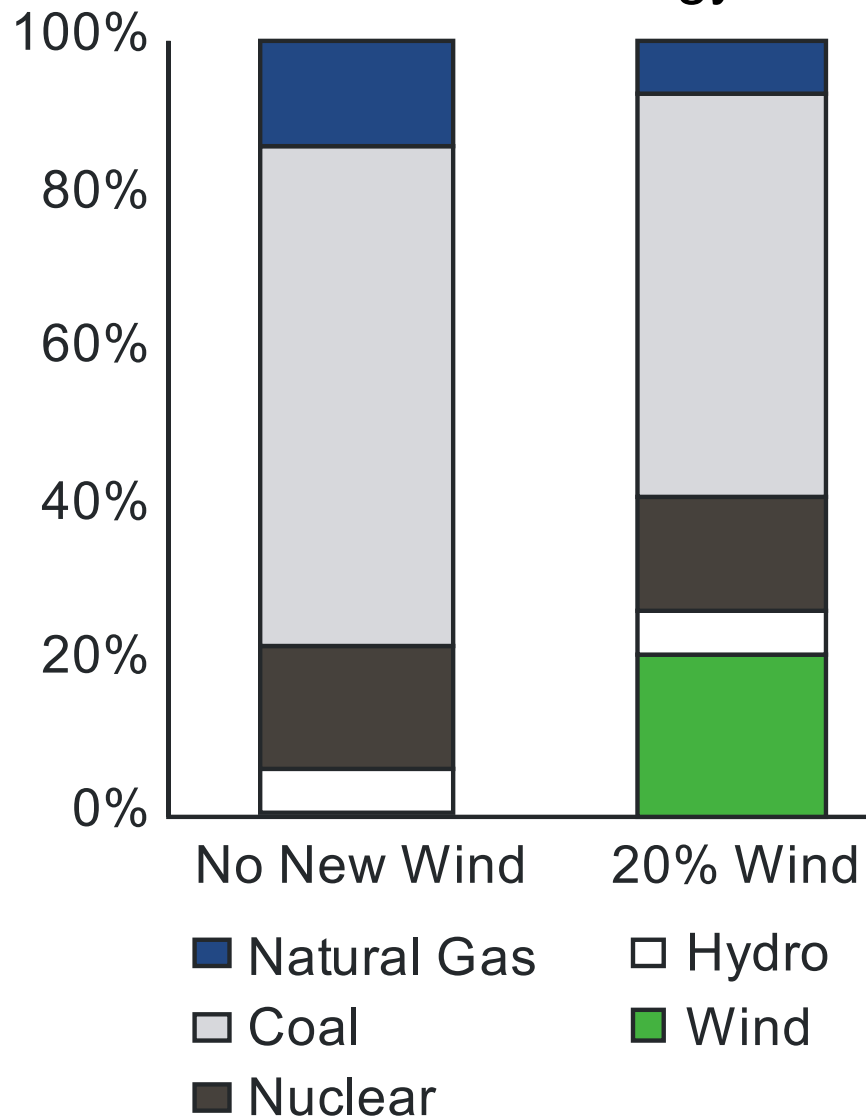
2% investment difference between 20% Wind and No New Wind

- Wind O&M Costs
- Fuel Costs
- Wind Capital Costs
- Conventional O&M Costs
- Transmission Costs
- Conventional Capital Costs

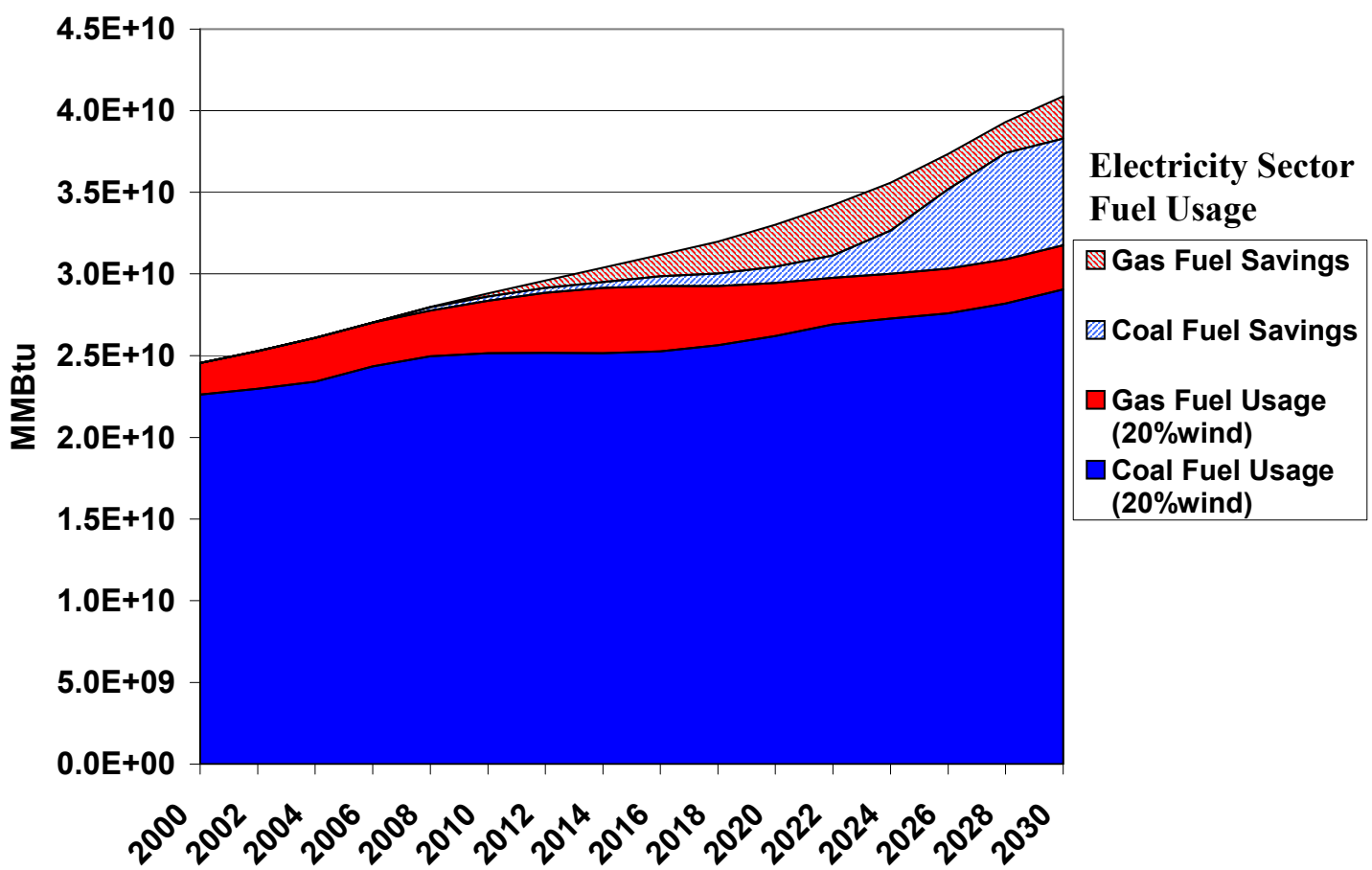
# 20% Wind Scenario Impact on Generation Mix in 2030

- Reduces electric utility natural gas consumption by 50%
- Reduces total natural gas consumption by 11%
- Natural gas consumer benefits: \$86-214 billion\*
- Reduces electric utility coal consumption by 18%
- Avoids construction of 80 GW of new coal power plants

U.S. electrical energy mix



# Fuel Savings from Wind

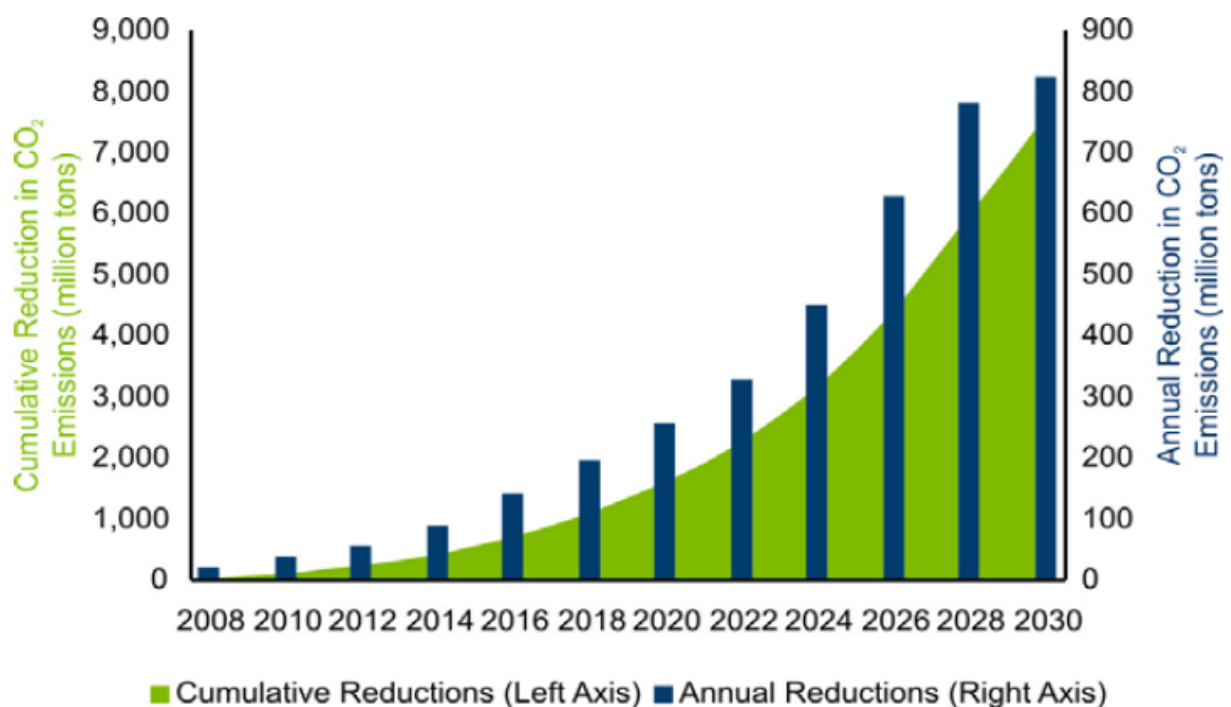


Reduction in National Gas Consumption in 2030 (%)	Natural Gas Price Reduction in 2030 (2006\$/MMBtu)	Present Value Benefits (billion 2006\$)	Levelized Benefit of Wind (\$/MWh)
11%	0.6 - <b>1.1</b> - 1.5	86 - <b>150</b> - 214	16.6 - <b>29</b> - 41.6

# Cumulative Carbon Savings

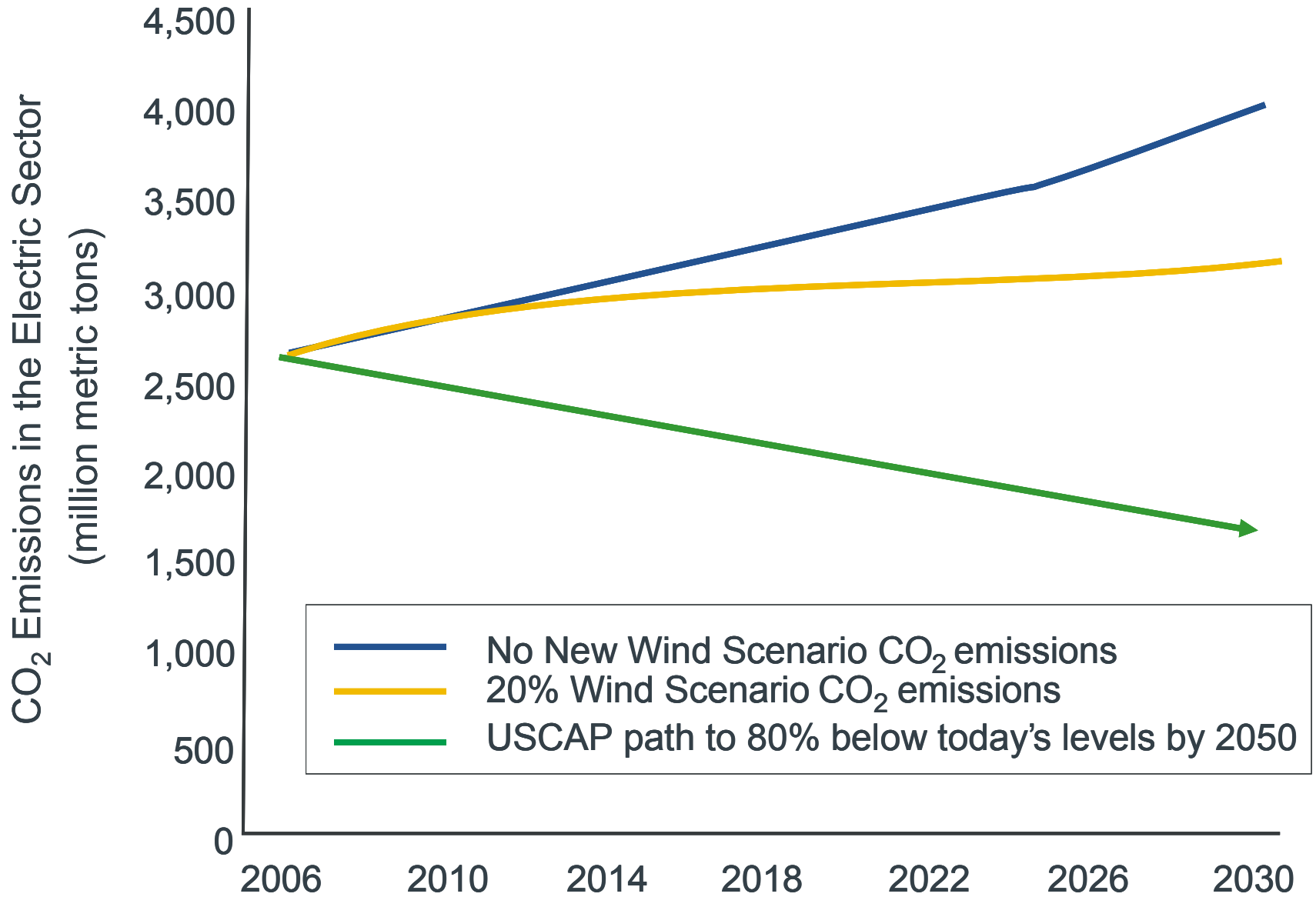
**Figure 1-12. Annual CO<sub>2</sub> emissions avoided (vertical bars) would reach 825 million tons by 2030.**

The cumulative avoided emissions by 2030 would total 7,600 million tons.



Cumulative Carbon Savings (2007-2050, MMTCE)	Present Value Benefits (billion 2006\$)	Levelized Benefit of Wind (\$/MWh-wind)
4,182 MMTCE	\$ 50 - \$145	\$ 9.7/MWh - \$ 28.2/MWh

# CO2 Emissions from the Electricity Sector





# National (U.S.) – Economic Impacts

Cumulative impacts from 2007-2030

From the 20% Scenario- 300 GW new Onshore and Offshore development

## *Wind energy's economic "ripple effect"*

### Direct Impacts

**Payments to Landowners:**

- \$782 M

**Local Property Tax Revenue:**

- \$1,877 M

**Construction Phase:**

- 1.75 M FTE jobs
- \$ 293 B to the US economy

**Operations:**

- 1.16 M FTE jobs
- \$122 B to the US economy



### Indirect & Induced Impacts

**Construction Phase:**

- 4.46 M FTE jobs
- \$651 B to the US economy

**Operations:**

- 2.15 M FTE jobs
- \$293 B to the US economy

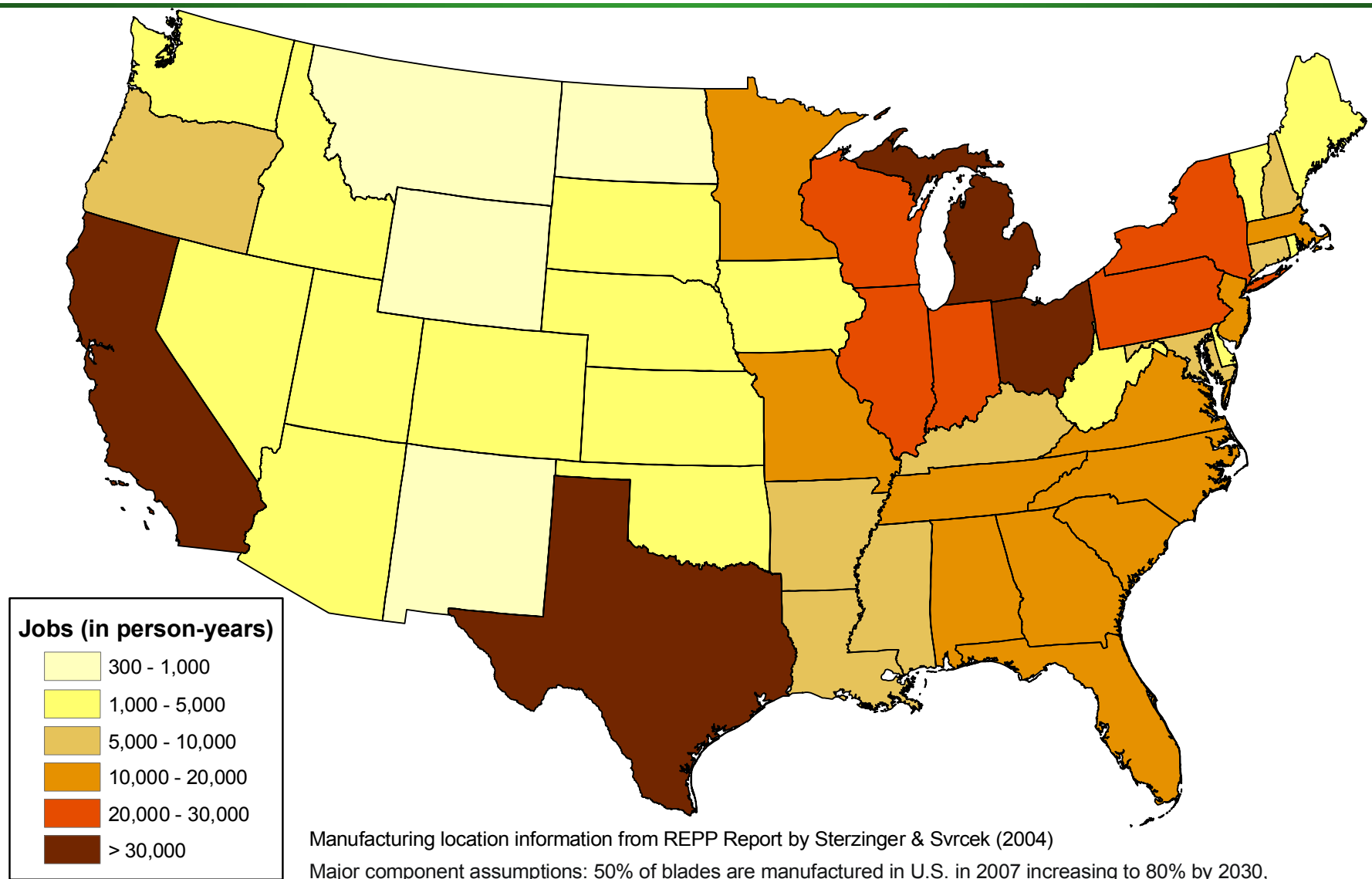
### Totals

(construction + 20yrs)

- **Total economic benefit = \$1,359 B**
- **New jobs during construction = 6.2 M FTE jobs**
- **New operations jobs = 3.3 M FTE jobs**

All monetary values are in 2006 dollars.  
Construction Phase = 1-2 years

# Manufacturing Jobs Supported by State

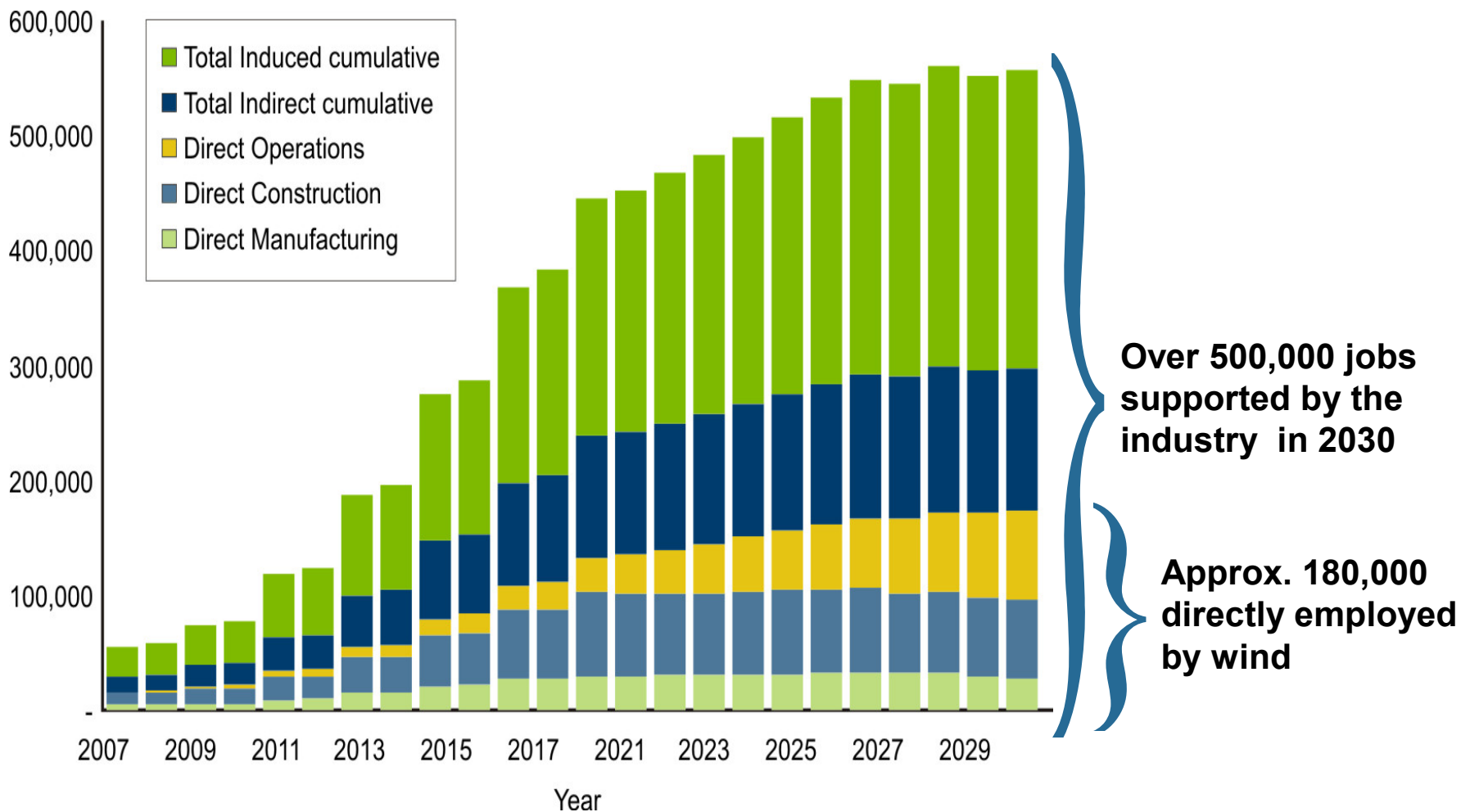


Manufacturing location information from REPP Report by Sterzinger & Svrcek (2004)

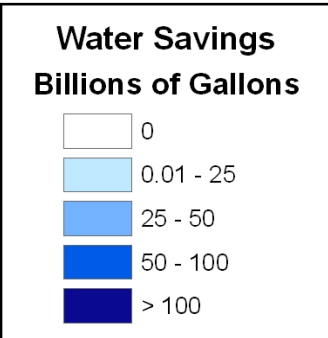
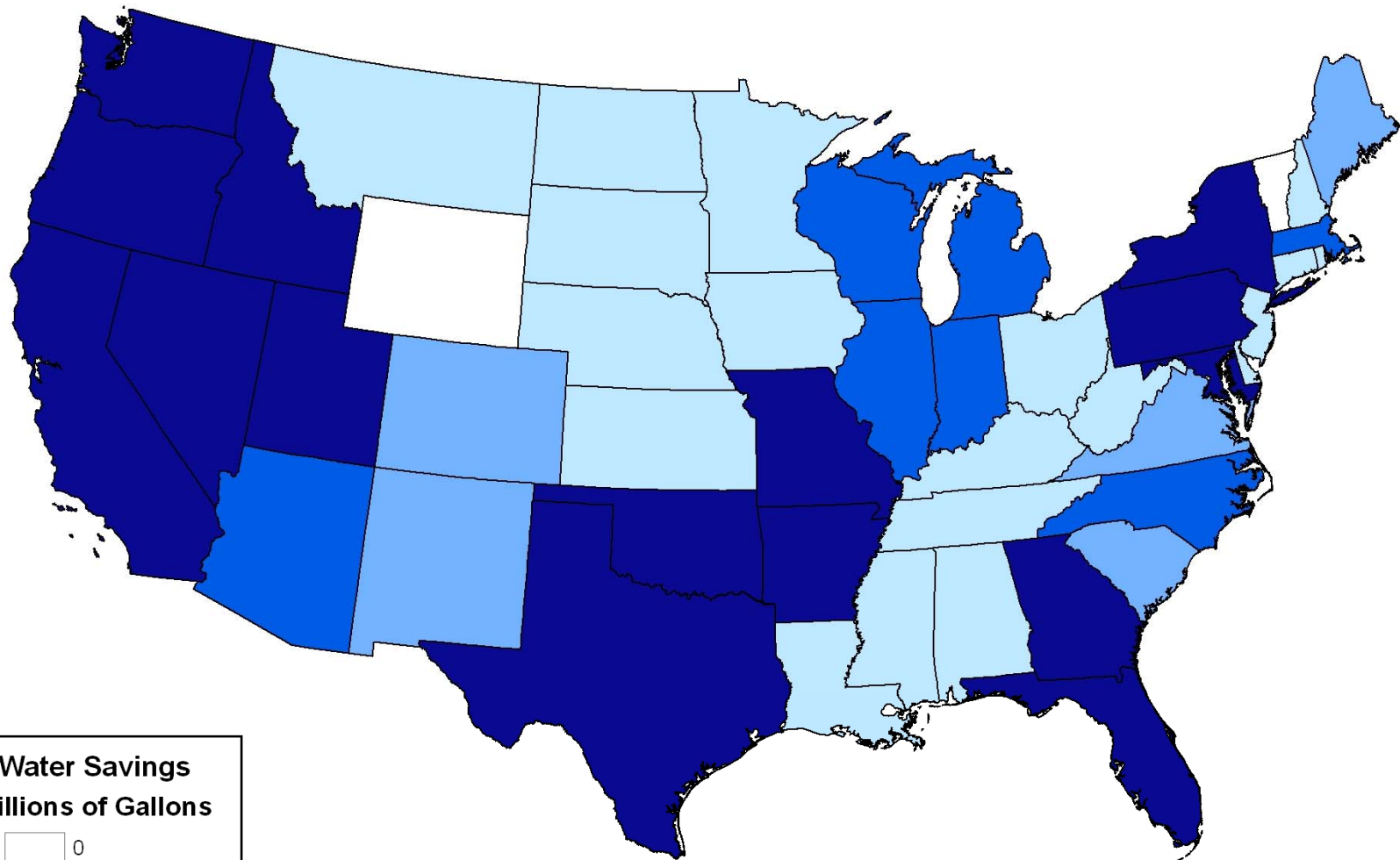
Major component assumptions: 50% of blades are manufactured in U.S. in 2007 increasing to 80% by 2030, 26% of towers are from the U.S. in 2007 increasing to 50% by 2030 and 20% of turbines are made in the U.S. increasing to 42% by 2030.

# Jobs Supported by the 20% Scenario

**Over 500,000 jobs would be supported between 2007 and 2030**



# Cumulative Water Savings from 20% Scenario



*Reduces water consumption of 4 trillion gallons through 2030  
(represents a reduction in electric sector water consumption by  
17% in 2030)*

# Wind Power Avoids Other Negative Impacts

- Wind power avoids the negative impacts of fossil fuel-based electricity generation:
  - Air emissions of mercury or other heavy metals
  - Emissions from extracting and transporting fuels
  - Lake and streambed acidification
  - Production of toxic solid wastes, ash, or slurry



Photo courtesy: NREL

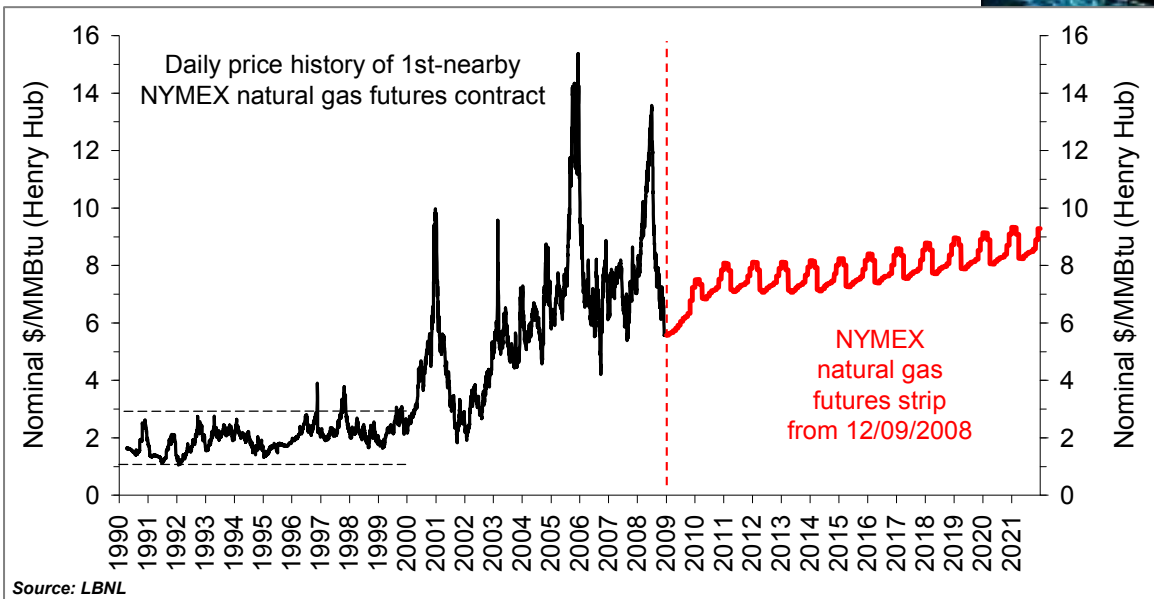


# Other Benefits of 20% Wind Energy

- Improves energy security by diversifying electricity portfolio with an indigenous energy source
- Reduces fossil fuel demand and fuel prices, helping to stabilize electricity rates



Source: BG



# Results: **Costs** & **Benefits**

Incremental direct cost to society	<b>\$43 billion</b>
Reductions in emissions of greenhouse gasses and other atmospheric pollutants	825 M tons (2030) <b>\$98 billion</b>
Reductions in water consumption	8% total electric 17% in 2030
Jobs created and other economic benefits	150,000 direct <b>\$450 billion total</b>
Reductions in natural gas use and price pressure	11% <b>\$150 billion</b>
<b>Net Benefits: \$205B + Water savings</b>	

# Conclusions

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- 20% wind energy penetration is possible
- 20% penetration is not going to happen under business as usual scenario
- Policy choices will have a large impact on assessing the timing and rate of achieving a 20% goal
- Key Issues: market transformation, transmission, project diversity, technology development, policy, public acceptance
- 20% Vision report: May 2008 ([www.20percentwind.org](http://www.20percentwind.org))



# *Carpe Ventem*

