Large Wind Project Development

GOVENERGY 2008

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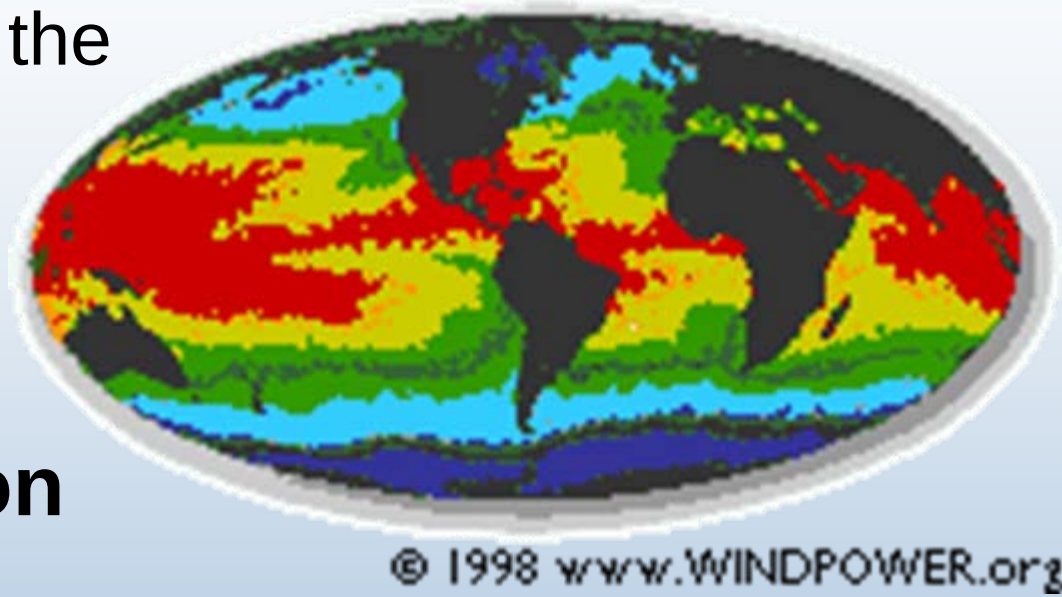
National Wind Technology Center, NREL

Large Wind Development Outline

- Wind energy
- Industry
- Wind turbines & costs
- 10-step wind development process
- Federal case studies
- Conclusions

What is Wind Power?

•Wind energy is created by uneven solar heating of the earth



Basic Wind Equation

Sun warms land mass + hot air rises + cooler air rushes in to take the place of the vacated air = ***wind***

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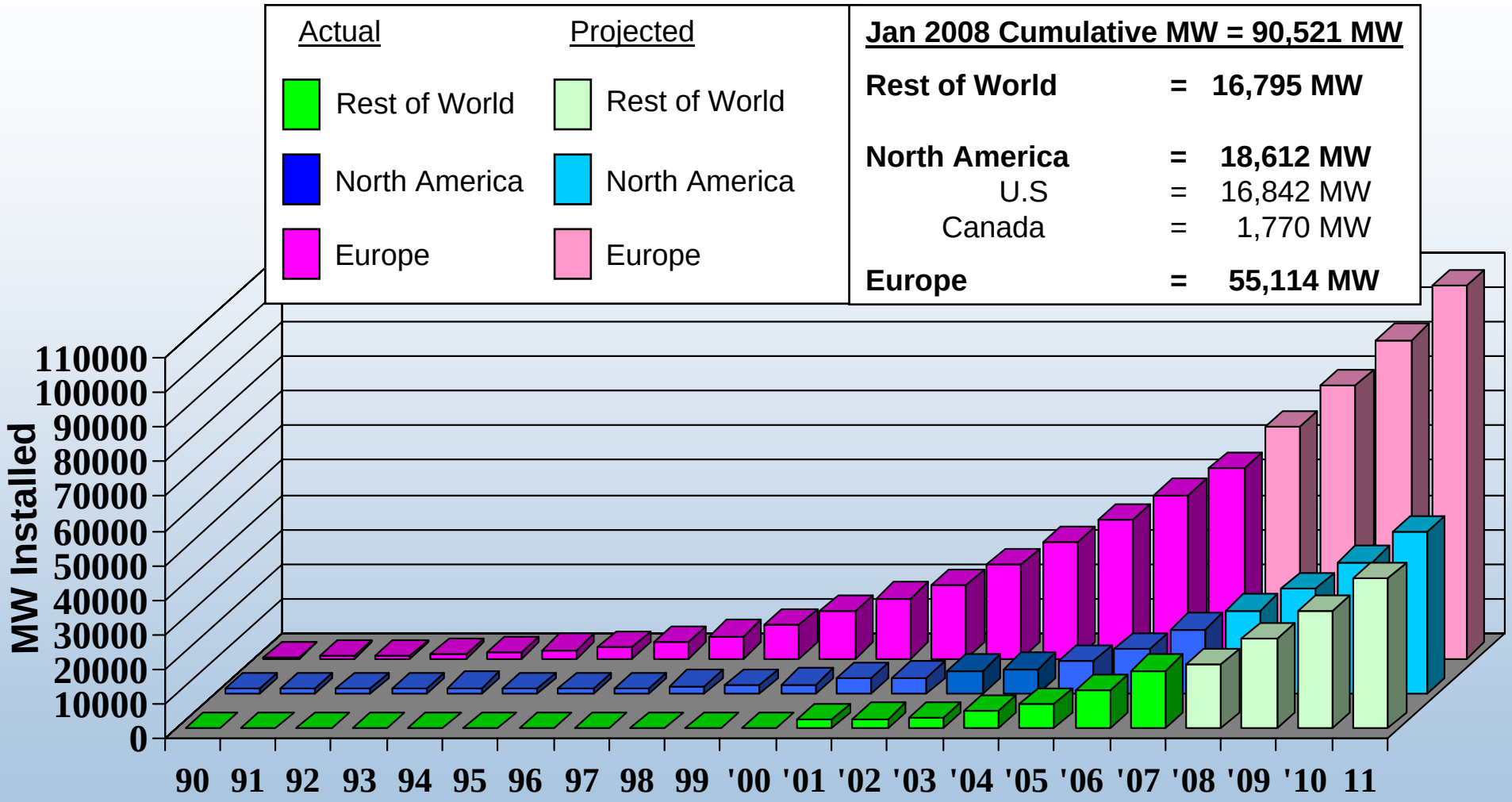
Growth of Wind Energy Capacity Worldwide



Sources: BTM Consult Aps, March 2007
Windpower Monthly, January 2008
*NREL Estimate for 2008

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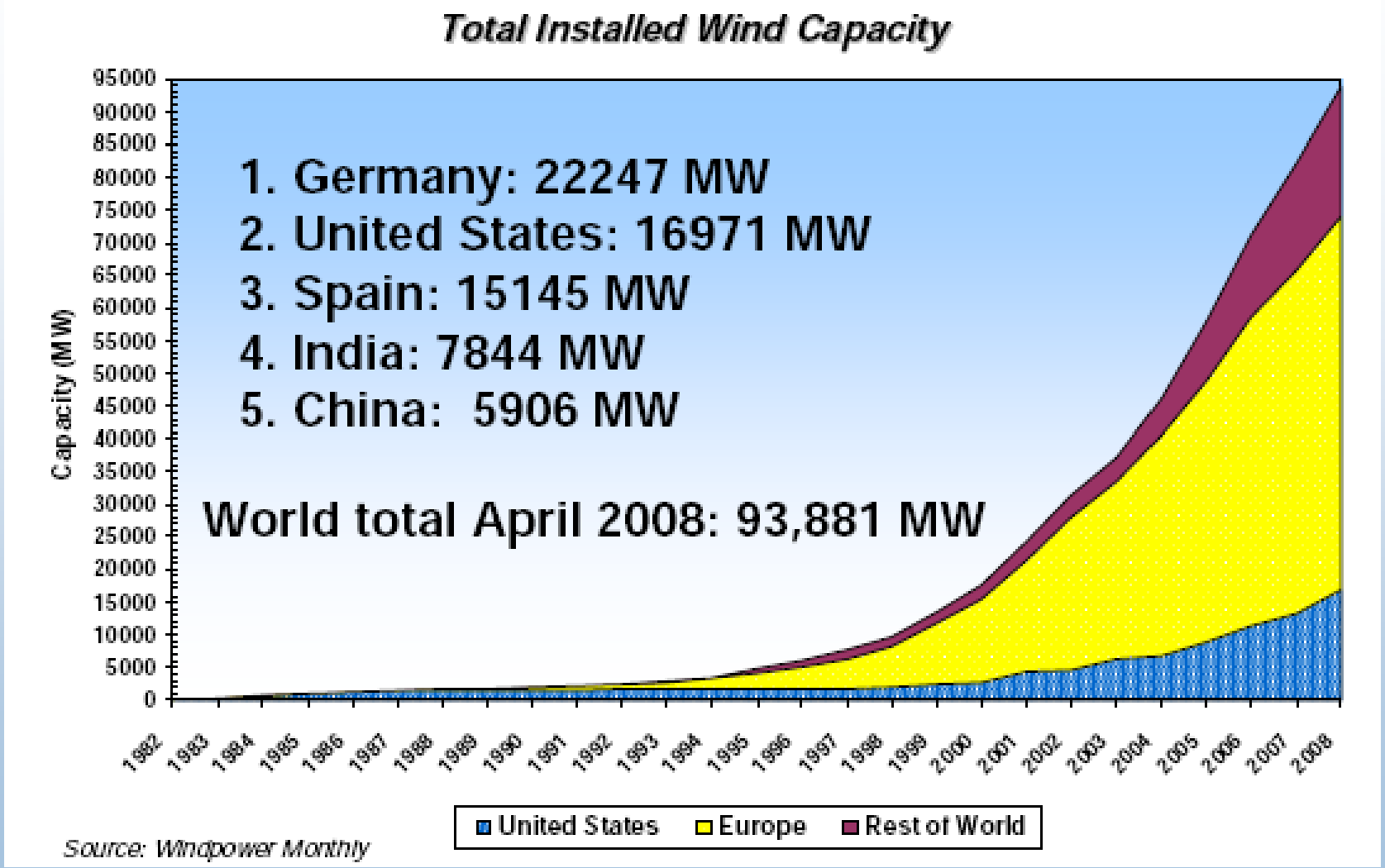
Who is Doing Wind?



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

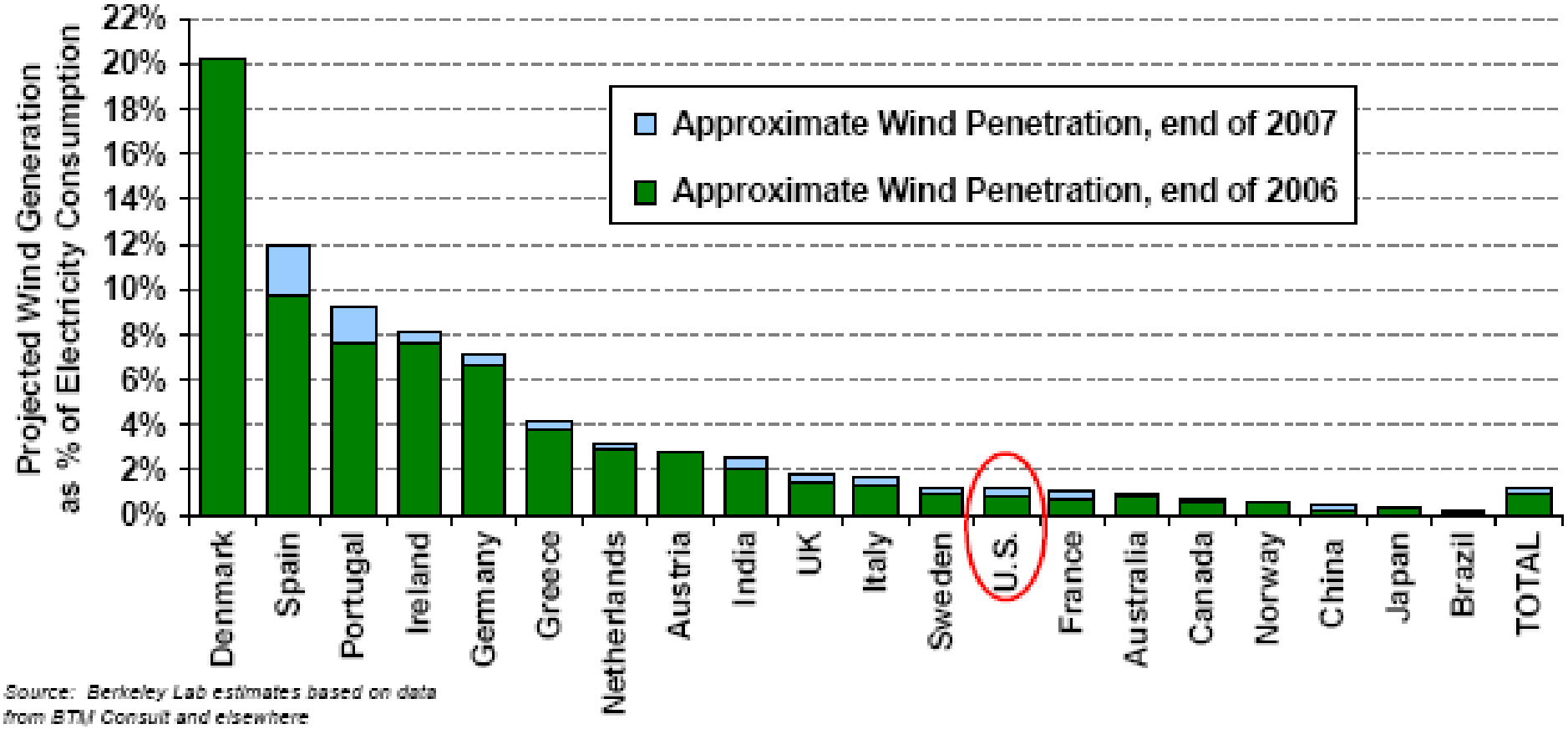
Incremental Capacity (2007, MW)	
U.S.	**5,329**
China	3,287
Spain	3,100
Germany	1,667
India	1,617
France	888
Italy	603
Portugal	434
U.K.	427
Canada	386
Rest of World	2,138
TOTAL	**19,876**

Cumulative Capacity (end of 2007, MW)	
Germany	22,277
U.S.	**16,904**
Spain	14,714
India	7,845
China	5,875
Denmark	3,088
Italy	2,721
France	2,471
U.K.	2,394
Portugal	2,150
Rest of World	13,591
TOTAL	**94,030**

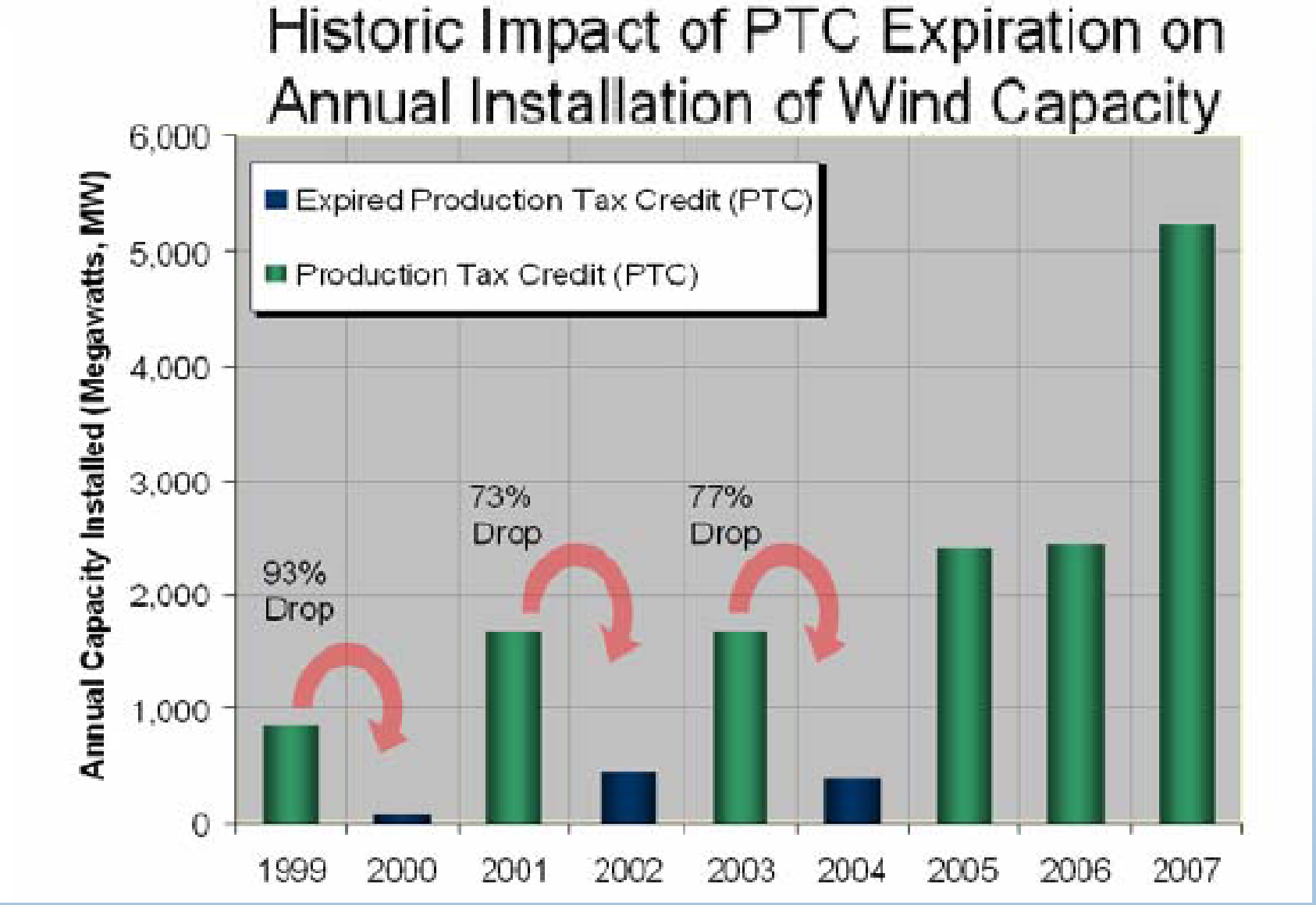
Source: BTM Consult; AWEA project database for U.S. capacity.

Wind – not just "How Many Installed MW?"

What Percentage of Energy is from Wind?



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



Source: AWEA PTC Facts Sheet

Policy Drives Investment

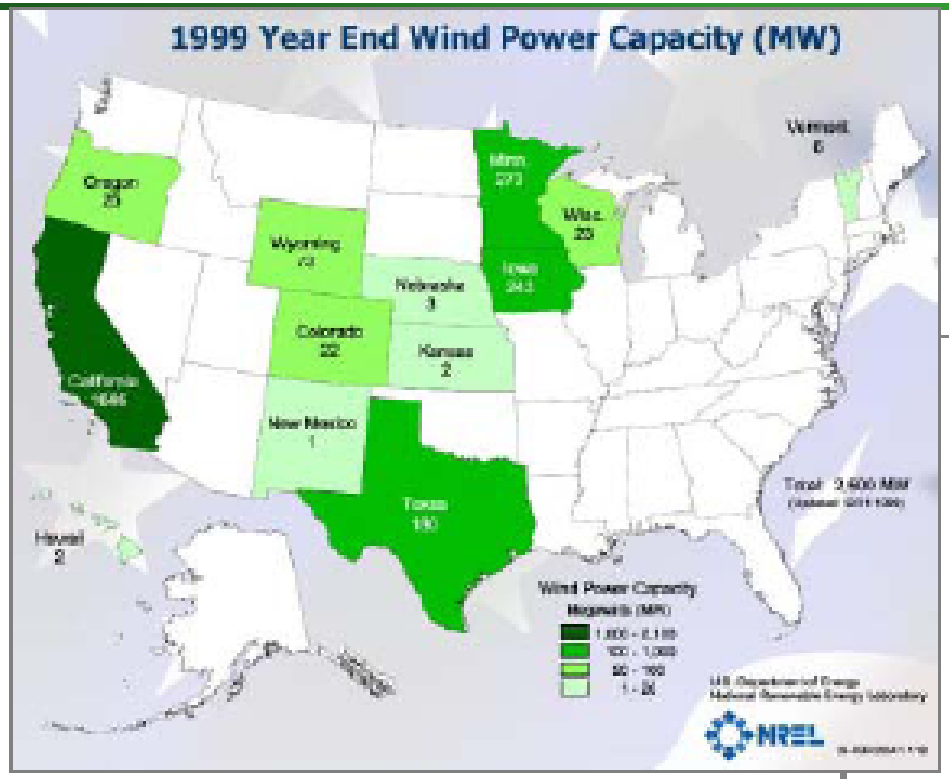
2006 new wind-related manufacturing plants established in:

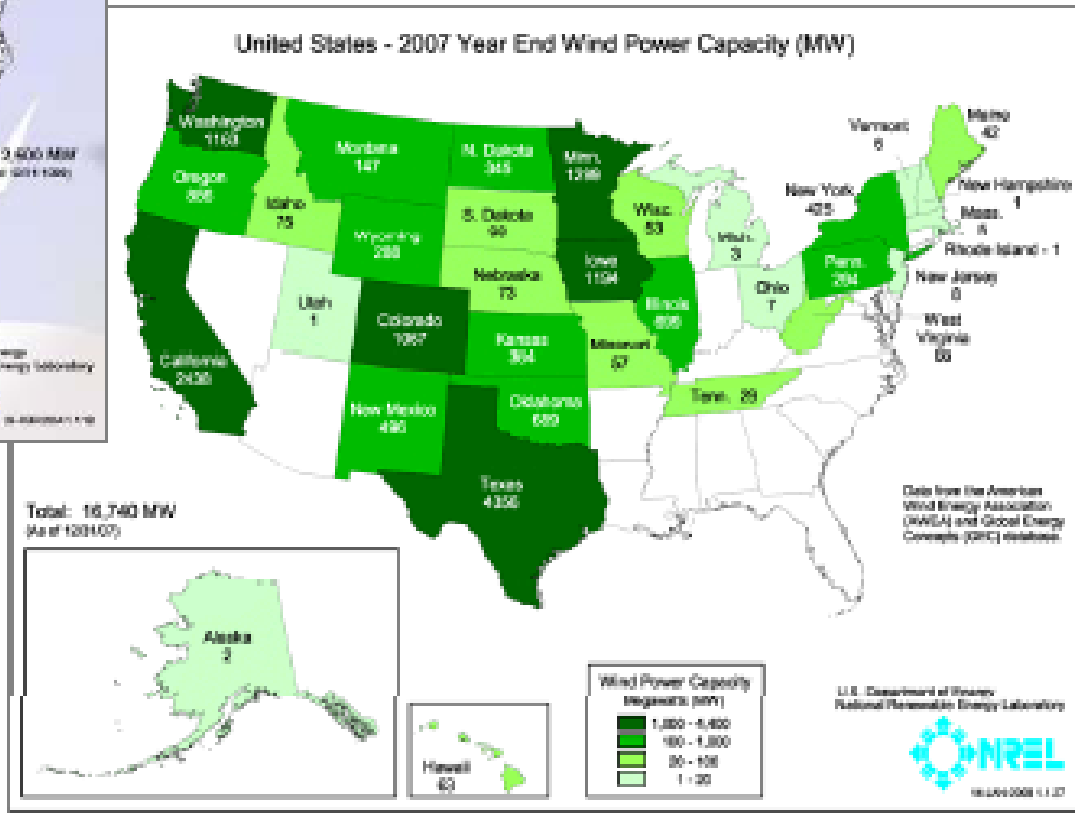
- Iowa (Clipper Windpower)
- Minnesota (Suzlon)
- Pennsylvania (Gamesa).
- And GE Energy, the most prominent U.S. wind turbine manufacturer, captured 47% of domestic wind turbine sales in 2006

2008

- Colorado (Vestas)

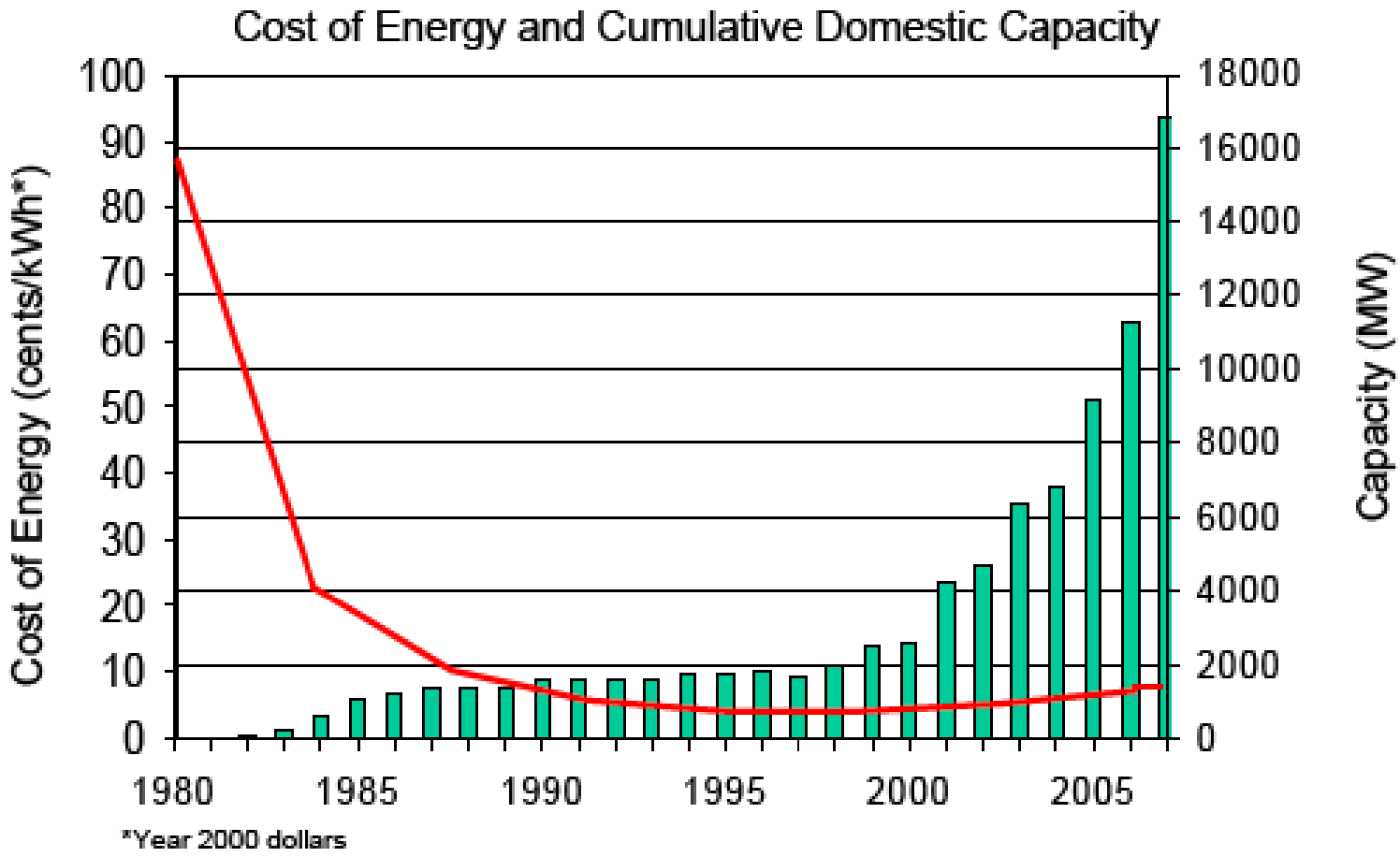
U.S. Installed Wind Capacities 1999 - 2007





*Preliminary data

Capacity & Cost Trends



Increased Turbine Size - R&D Advances - Manufacturing Improvements

A New Vision
For Wind Energy in the U.S.

"The future ain't what it used to be."

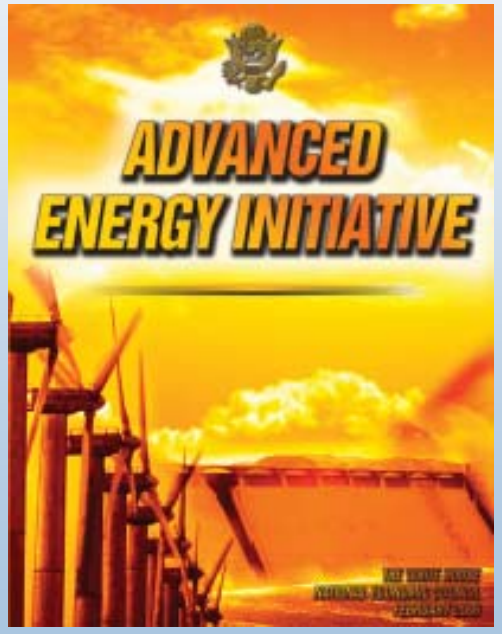
- Yogi Berra

Advanced Energy Initiative

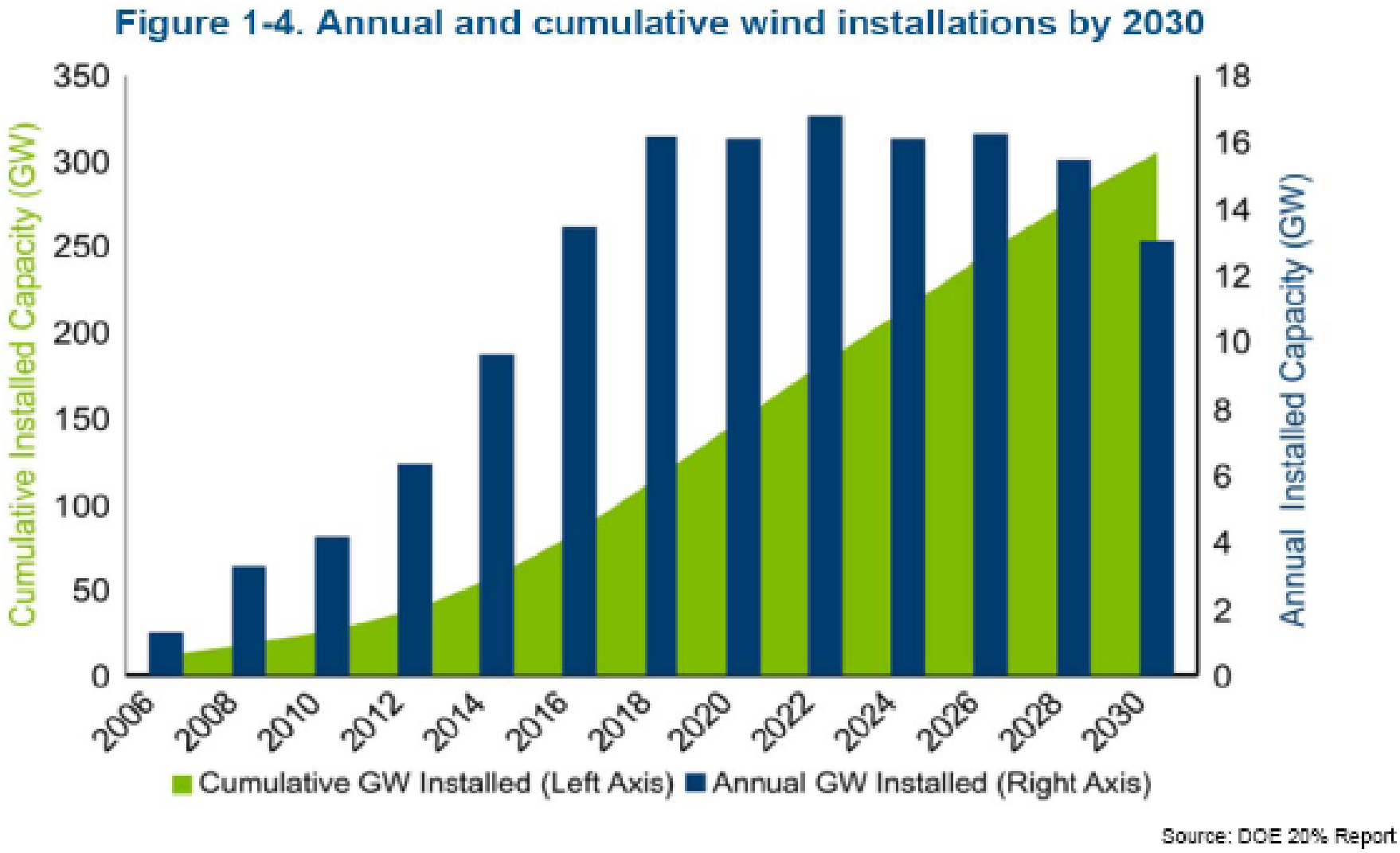
"Areas with good wind resources have the potential to **supply up to 20% of the electricity** consumption of the United States."

20% Wind by 2030 Report

www.eere.energy.gov/windandhydro



What does 20% Wind look like?



Conceptual Map of How to Get There - Transmission

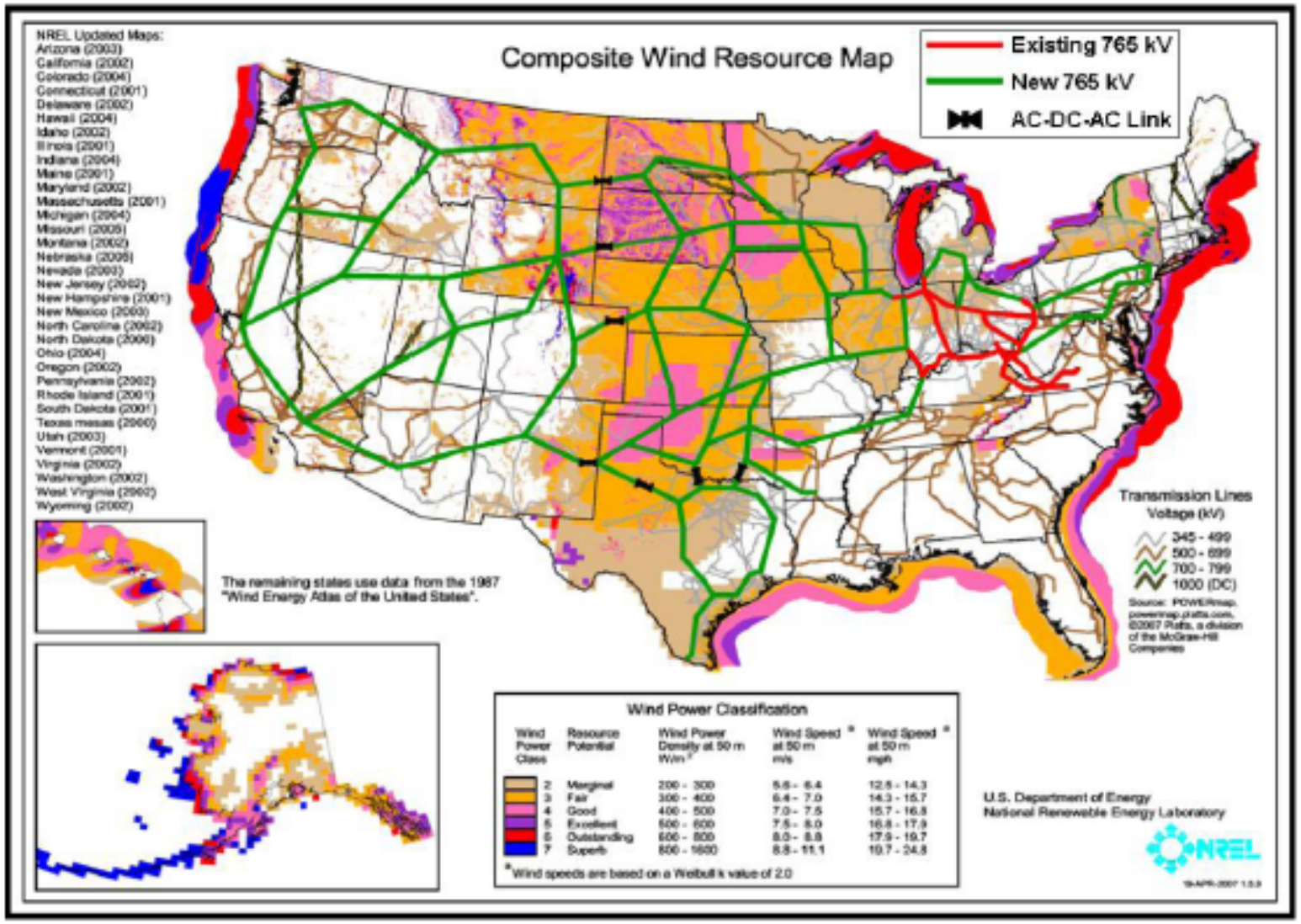


Exhibit 1: Conceptual 765 kV backbone system for wind resource integration (edited by AEP).

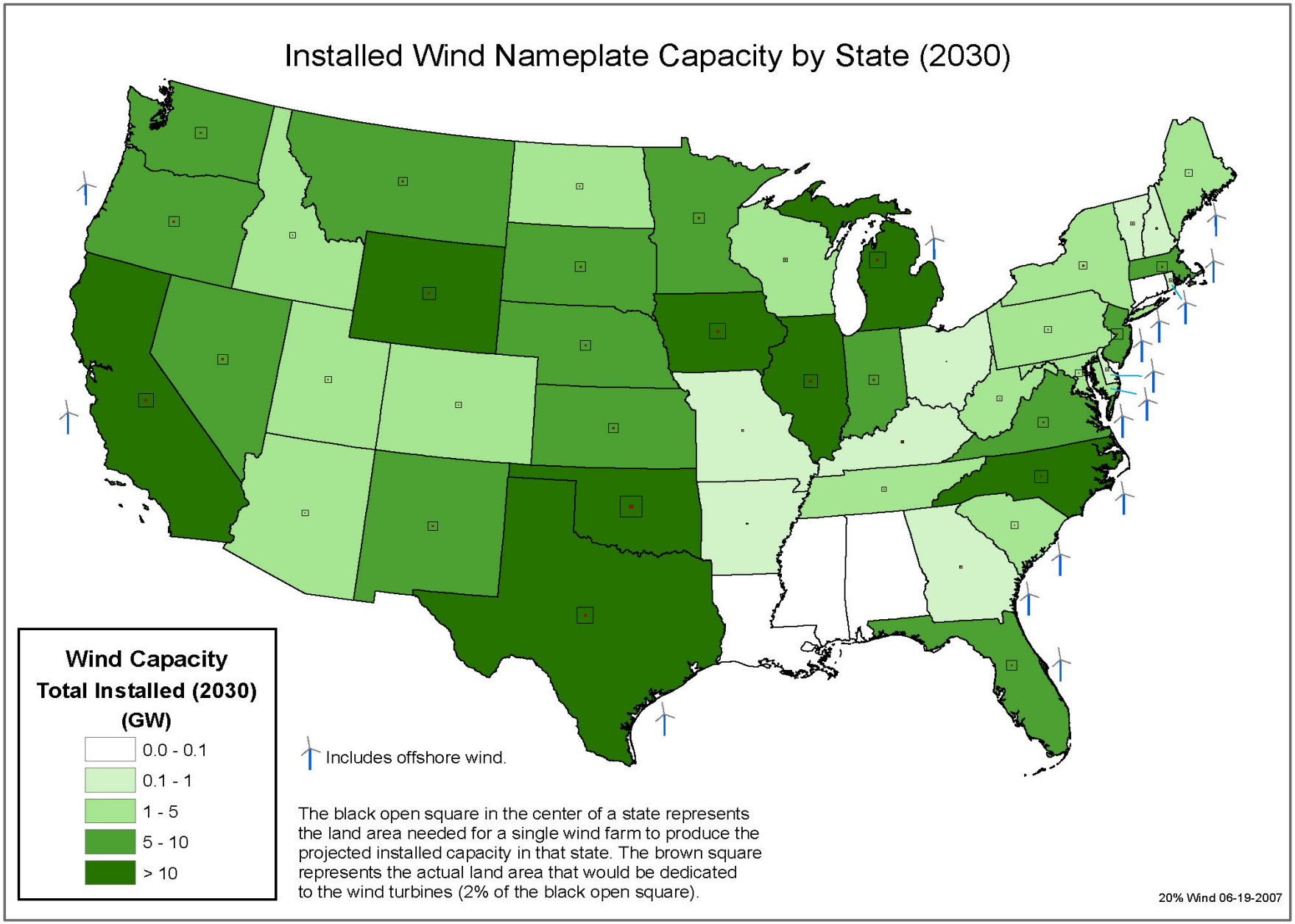
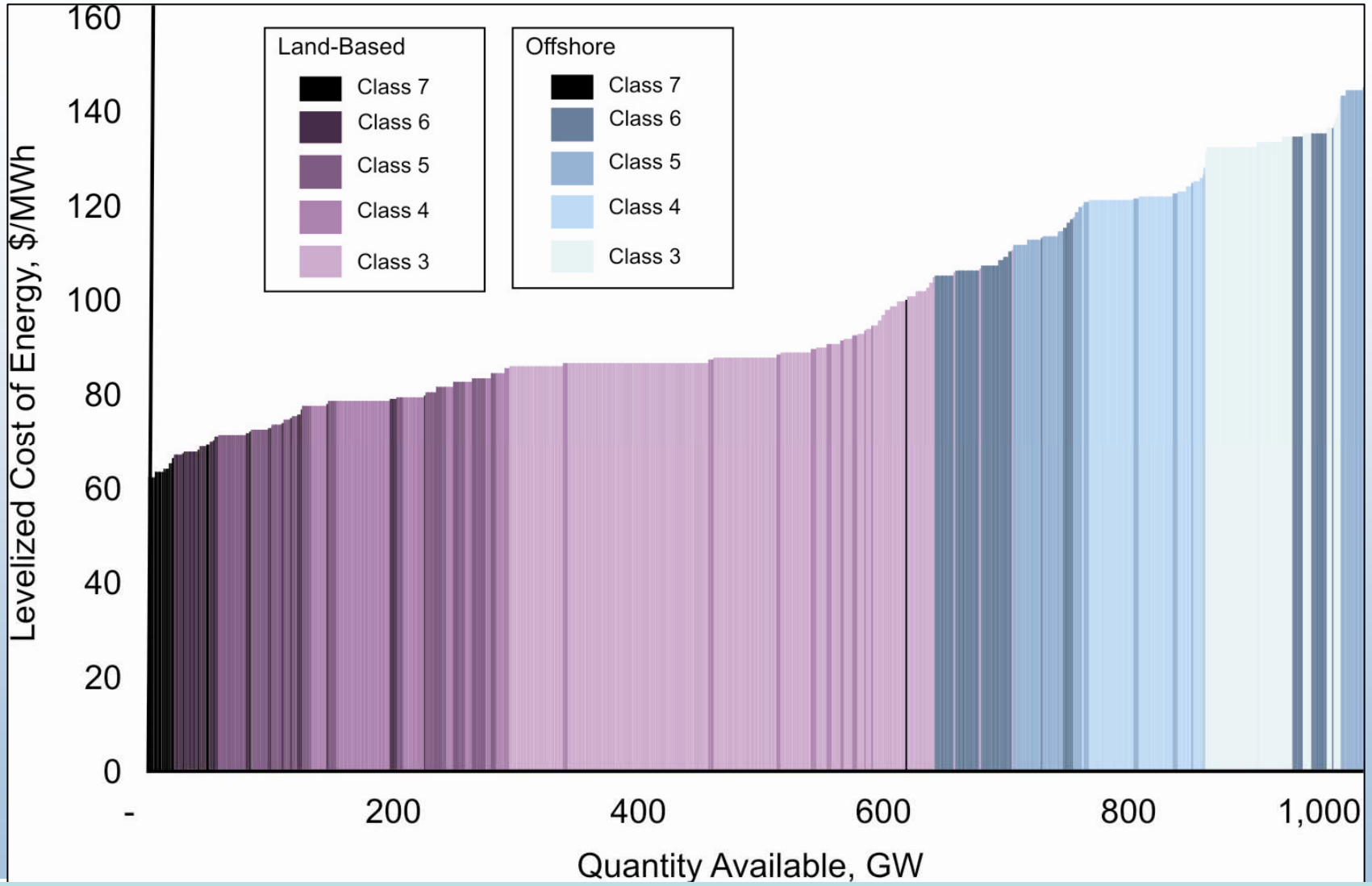

Installed Wind Nameplate Capacity by State (2030)
Wind Capacity
Total Installed (2030)
(GW)
0.0 - 0.1
0.1 - 1
1 - 5
5 - 10
> 10
Includes offshore wind.
The black open square in the center of a state represents the land area needed for a single wind farm to produce the projected installed capacity in that state. The brown square represents the actual land area that would be dedicated to the wind turbines (2% of the black open square).
20% Wind 06-19-2007

Fig 1-6

Wind Energy Supply Curve



Excludes PTC, includes transmission costs to access 10% existing electric transmission capacity within 500 miles of wind resource.

Sizes and Applications

Small (≤10 kW)

- Homes
- Farms
- Remote Application

Intermediate (10-250 kW)

- Village Power
- Hybrid Systems
- Distributed Power

Large (600 kW – 5 MW)

- **Central Station Wind Farms**
- Distributed Power
- Community Wind

Utility-Scale Wind Power

600 kW – 5 MW wind turbines

- –Typically wind farm application of 10 – 400 MW
- –Professional maintenance crews
- –16+ mph (7+ m/s) average wind speed or greater (Class 4+)

1st GE 3.2 MW – land based
Offshore rated at 3.6 MW

Large Wind Turbines

- Towers: 60-100m
- Rotors: 80-120m
- Weight: 200-400 tons

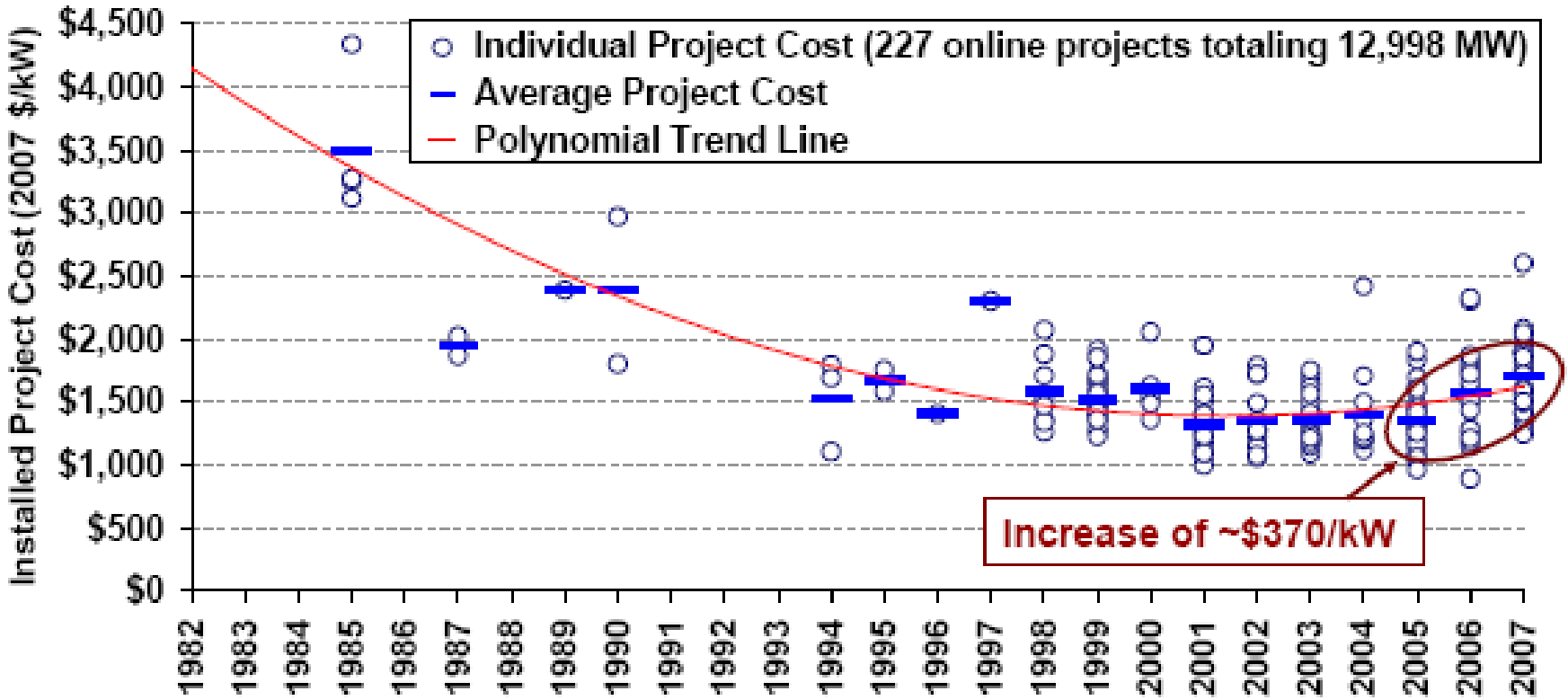
Issues:

- Roads & bridges
- Cranes

Costs of Wind Energy

- Installed capital costs
  - Turbine
  - Foundation
  - Transportation
  - Installation
  - Balance of system
- Other costs
  - Interconnection study
  - NEPA compliance
  - Operation and maintenance
  - Financing
- High initial costs, no fuel costs low O&M costs

Wind Project Cost Trends



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

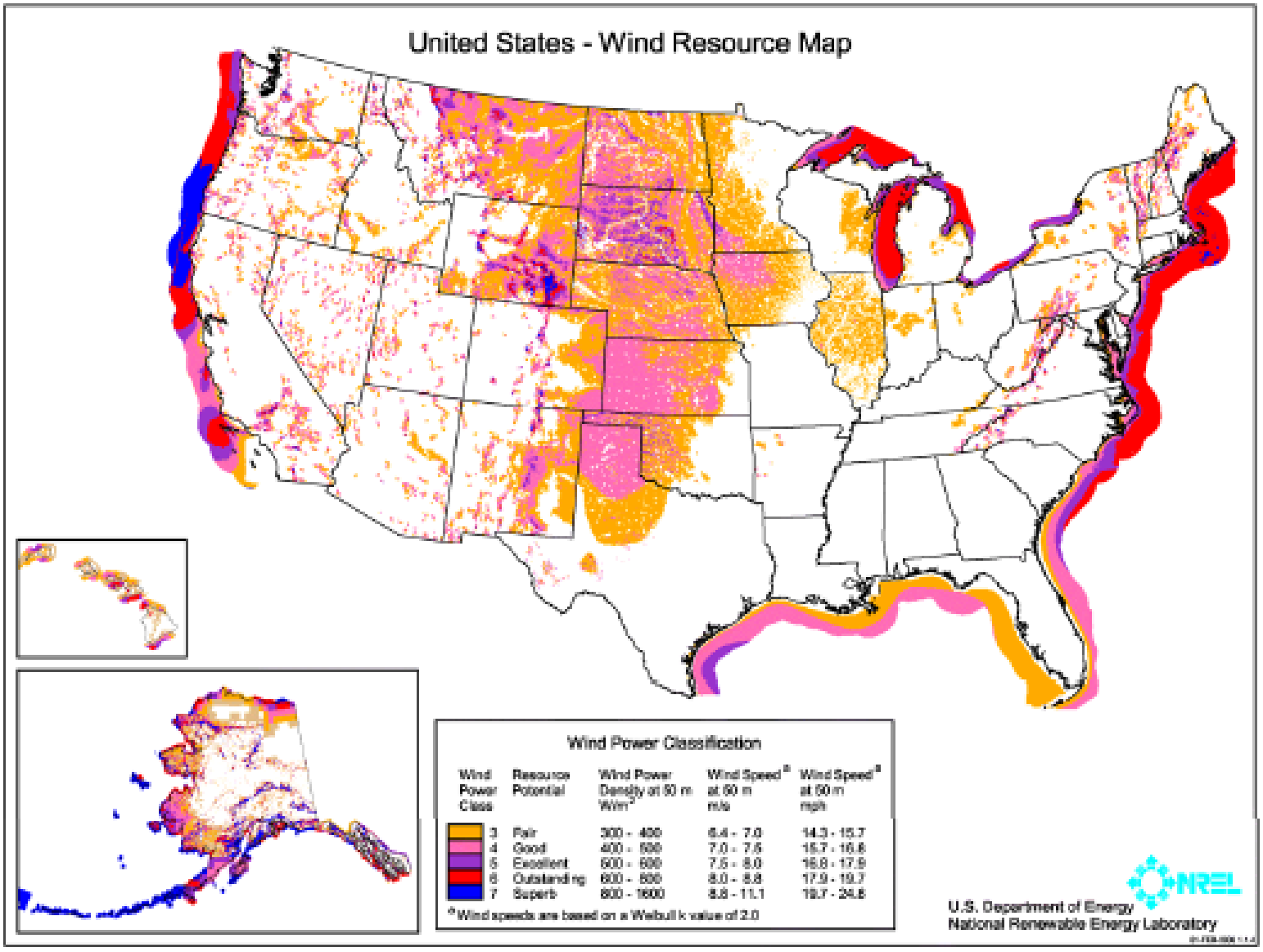
Projects proposed for construction in 2008 (not shown in graphic) are ~$210/kW higher still (averaging ~$1,920/kW)

The Wind Development Process

- Site Selection
- Land Agreements
- Wind Assessment
- Environmental Review
- Economic Modeling
- Interconnection Studies
- Permitting
- Financing
- Sales Agreements
- Turbine Procurement
- Construction Contracting
- Operations & Maintenance

3 Most Important Factors when Siting Wind Turbines

U.S. Wind Map


United States - Wind Resource Map
Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50 m W/m²
Wind Speed[a] at 50 m m/s
Wind Speed[a] at 50 m mph
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb 800 - 1600 8.8 - 11.1 19.7 - 24.8
[a] Wind speeds are based on a Weibull k value of 2.0
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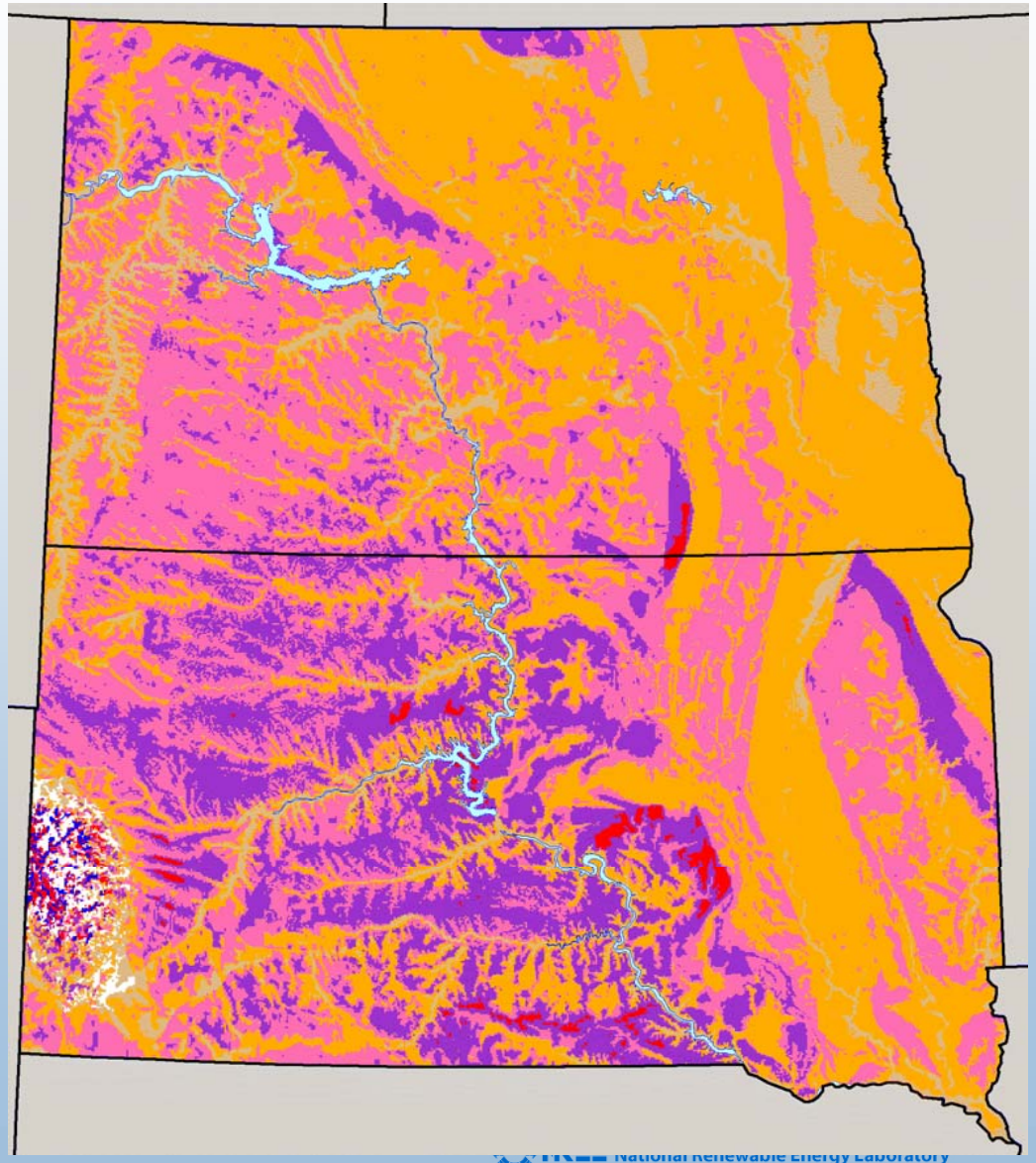
Wind Data Sources

- Wind maps
- Regional wind atlases
- Biological indicators
- Environmental monitoring data
- Airport data
- Local knowledge



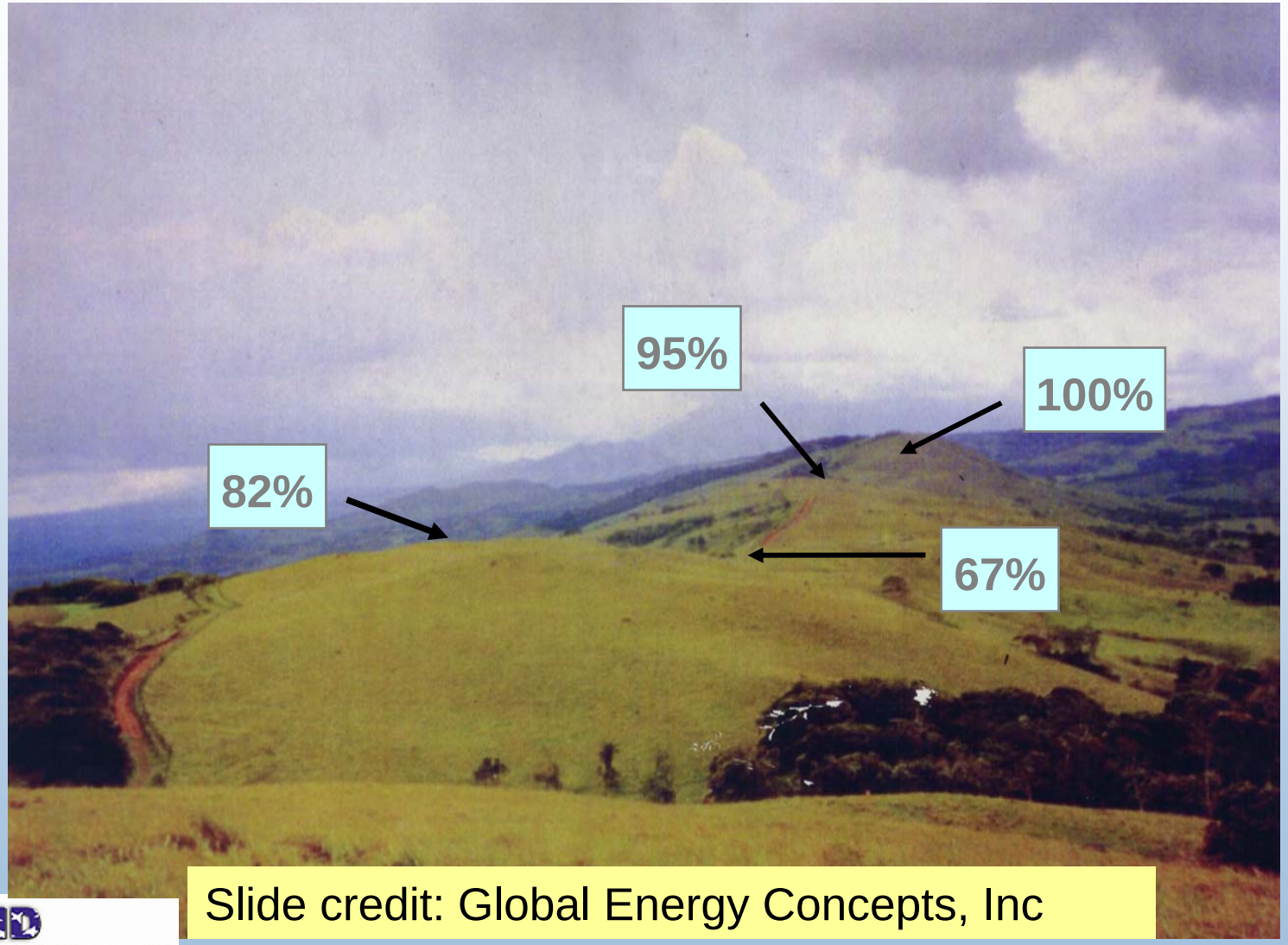
Wind Power Density Classes

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

Micro-siting makes a difference – one or multiple turbines in both complex or simple terrain



Slide credit: Global Energy Concepts, Inc

Large Turbine O&M Costs and Lifetime

- O&M costs
  - Planned maintenance and testing
  - Blade cleaning
  - Unplanned maintenance
- Typical O&M costs
  - 0.005 - 0.013 $/kWh – escalation over 20 yrs
  - 1 – 2% of initial installed cost/year
- O&M costs may increase as a turbine ages
- Turbine are now designed of 20-30 years lifetimes

Federal Wind Capacity

Federal Wind Projects

	# of turbines	turbine size	wind plant size
	[#]	[MW]	[MW]
San Clemente Island	3	0.225	0.7
Guantanamo Bay	4	0.96	3.8
Warren Air Force Base	2	0.6	1.2
Ascension Island	4	0.225	0.9
Victorville Prison	1	0.75	0.8
Camp Williams	2	.225 & .66	0.9
Total	**16**		**8.3**

Wind energy is kinetic energy -- mass and momentum

Derived from K.E. = ½ mv^2

$$P = A \times \rho V^3/2$$

- P = Power of the wind [Watts]
- A = Windswept area of rotor (blades) = $\pi D/4 = \pi r^2$ [m^2]
- ρ = Density of the air [kg/m^3] (at sea level at 15°C)
- V = Velocity of the wind [m/s]

Wind energy is proportional to velocity cubed (V^3):

–If velocity is doubled, power increases by a factor of eight ($2^3 = 8$).

–Small differences in average speed cause big differences in energy production.

Wind Assessment

3 sites – all with 6.3 m/s wind at 10m

- Average annual wind power:

  220 W/m^2

  285 W/m^2

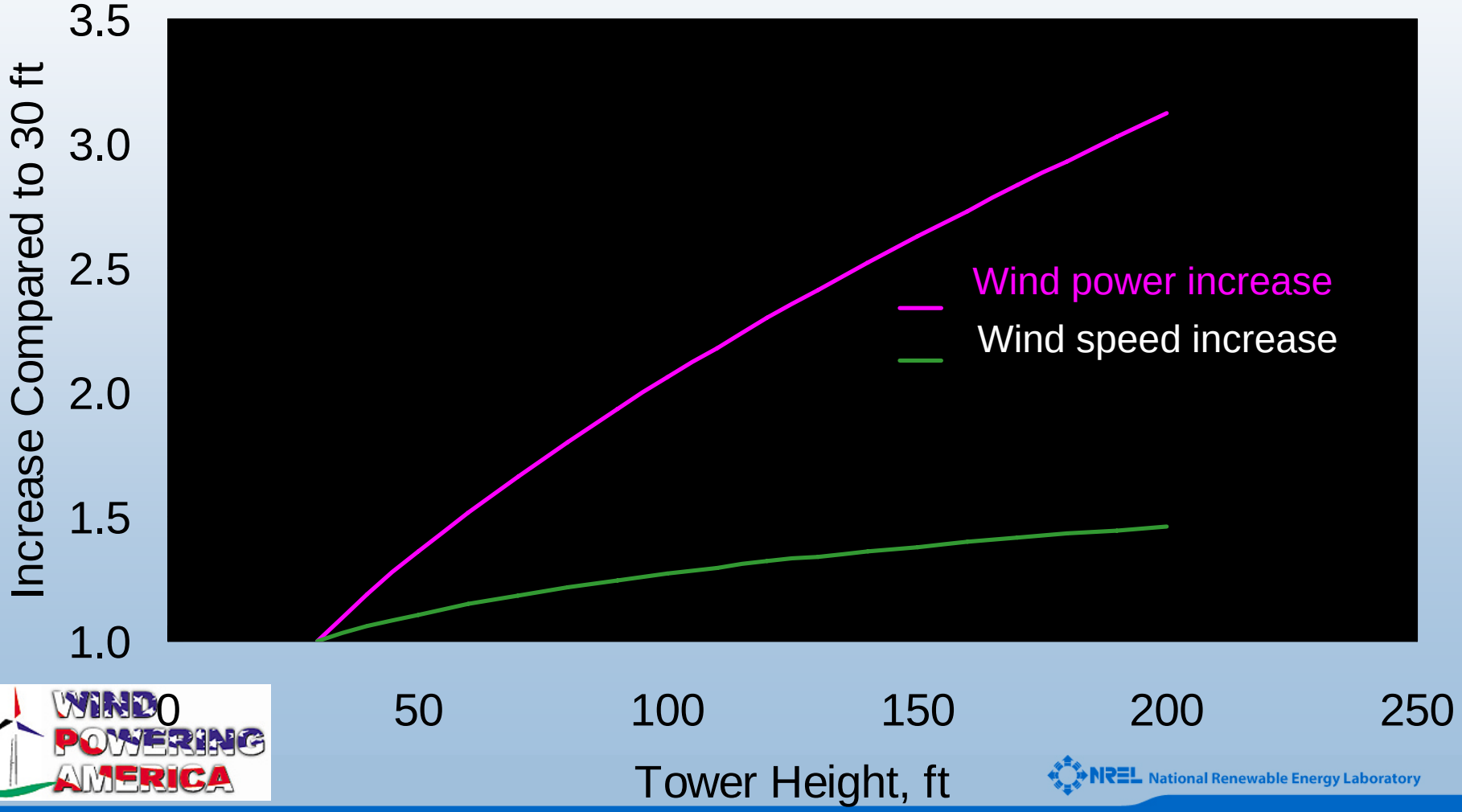
  365 W/m^2

  Varies by over 2 Wind Classes !

The actual data matters

– not just annual wind speed !

Wind Speed and Power Increase with Height Above the Ground



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Relative Size of Swept Area

$A = Pi\ D^2 / 4$

Credit: Paul Gipe

Federal Wind Activities

Navy – MET – Yokusuka, Japan – 2008?

Navy – multiple METs – Guam - 2008

Nat Park Ser – MET done – Truro, Cape Cod – 2006-7

Marines – 1.25MW – Barstow CA

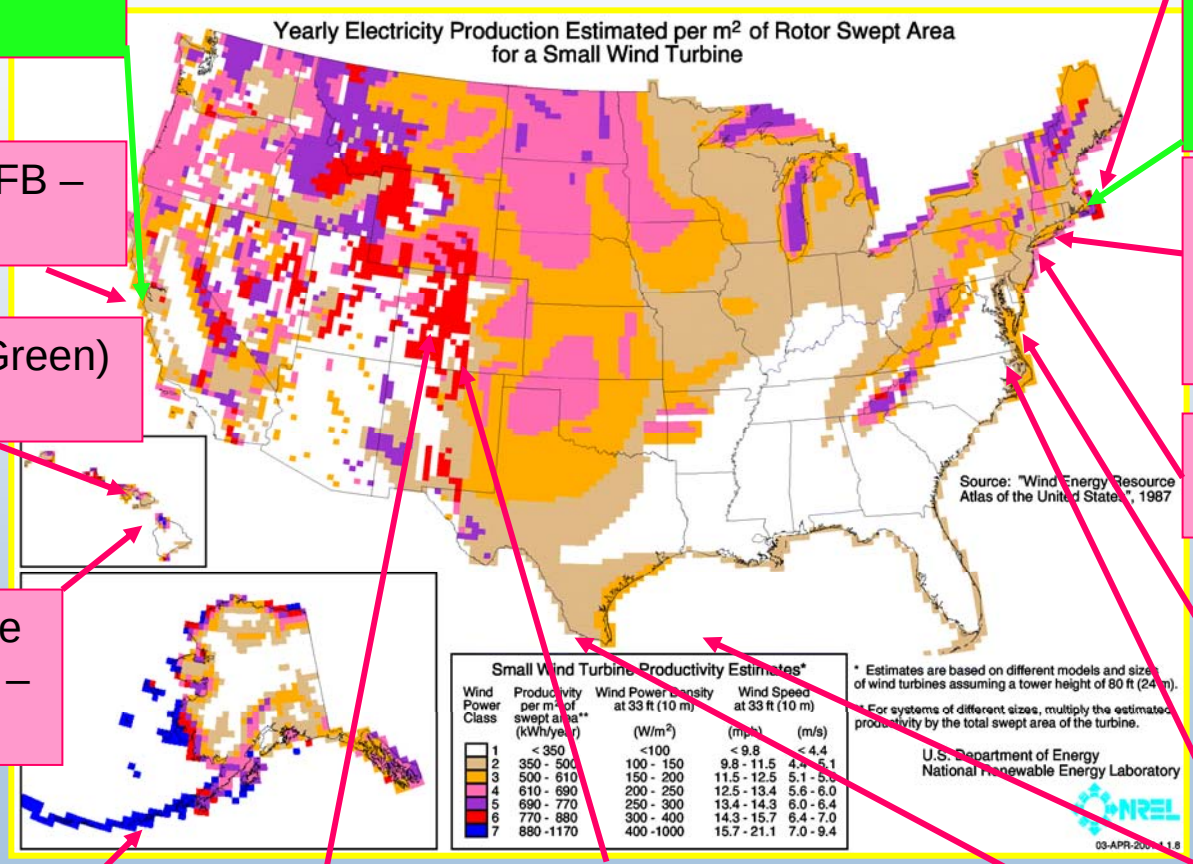
AFCEE –MET done 2.5MW Cape Cod – 2006-7

Vanderberg AFB – MET tower ?

Army Nat Grd – MET & SODAR – GE 1.5MW Sea Girt NJ - 2008

DOD-MET(J Green) Hawaii-2008

USCG – MET – Cape May NJ-2007



NASA MET done – 2006-7 Wallops Island VA

Navy – multiple bases - METs – Hawaii -2008

USCG – MET – E-City NC - 2008

USCG – MET Kodiak AK 2005-8

Fort Carson – MET & SODAR - Colo Springs CO - 2007

Schriever AFB MET - Colo Spgs CO-2007

GSA – MET – McAllen TX - 2008

GSA – MET – Donna TX - 2008

DOE Screening for Renewable Opportunities

DOE Sites with Class 4 Wind Resource

DOE site number	DOE Faciility	City	State	Class 5 Area (km^2)	Utility Name	Utility Rate ($/kwh)
141	PANTEX SITE OFFICE	Panhandle	TX	309	Energas & New Century Energies	$0.054
121	NEVADA TEST SITE	Mercury	NV	39	Nevada Power & Lincoln County Po	$0.065
2811	NAVAL PETROLEUM RESERVE NO 3	Casper	WY	30	Pacific Power	$0.039
603	IDAHO NATIONAL LABORATORIES-SCOVILLE	Scoville	ID	18	Intermountain Gas Company	$0.042
1301	RICHLAND OPERATIONS OFFICE 100	Richland	WA	11	Bonneville Power Admin & Benton	$0.032
144	SNL-NEVADA	Tonopah	NV	6	Sierra Pacific Power Co.	$0.104

DOE Sites with Class 3 Wind Resource

DOE site number	DOE Faciility	City	State	Class 5 Area (km^2)	Utility Name	Utility Rate ($/kwh)
603	IDAHO NATIONAL LABORATORIES-SCOVILLE	Scoville	ID	240	Intermountain Gas Company	$0.042
121	NEVADA TEST SITE	Mercury	NV	173	Nevada Power & Lincoln County Po	$0.065
1301	RICHLAND OPERATIONS OFFICE 100	Richland	WA	46	Bonneville Power Admin & Benton	$0.032
304	BROOKHAVEN NATIONAL LABORATORY	Upton	NY	23	Authority & Long Island Power	$0.066
144	SNL-NEVADA	Tonopah	NV	16	Sierra Pacific Power Co.	$0.104
303	FERMI NATIONAL ACCELERATOR	Batavia	IL	9	Commonwelth Edison & NiCOR	$0.050
331	OAK RIDGE OFFICE	Oak Ridge	TN	8	City of Oak Ridge	$0.072
146	Y-12 SITE OFFICE	Oak Ridge	TN	4	TVA	$0.048
301	ARGONNE NATIONAL LAB SITE-D	Argonne	IL	3	Duke Energy and Services	$0.053
2811	NAVAL PETROLEUM RESERVE NO 3	Casper	WY	2	Pacific Power	$0.039
101	LOS ALAMOS NATIONAL LABORATORY	Los Alamos	NM	2	Power Pool	$0.051

Victorville Prison

1 750kW turbine

Funding source: ESPC

Projected 8% of annual electricity

Camp Williams

225kW NEG Micon

660kW Vestas – V47

Funding source:

ECIP

Load: 5.5-6.3 GWh/yr **Wind Energy**: 1.1-1.2 GWh/yr

COE: $0.035/kWh (2004)

Annual Savings: $40-45k/yr **Payback:** 25-30 yrs

San Clemente Island - Navy

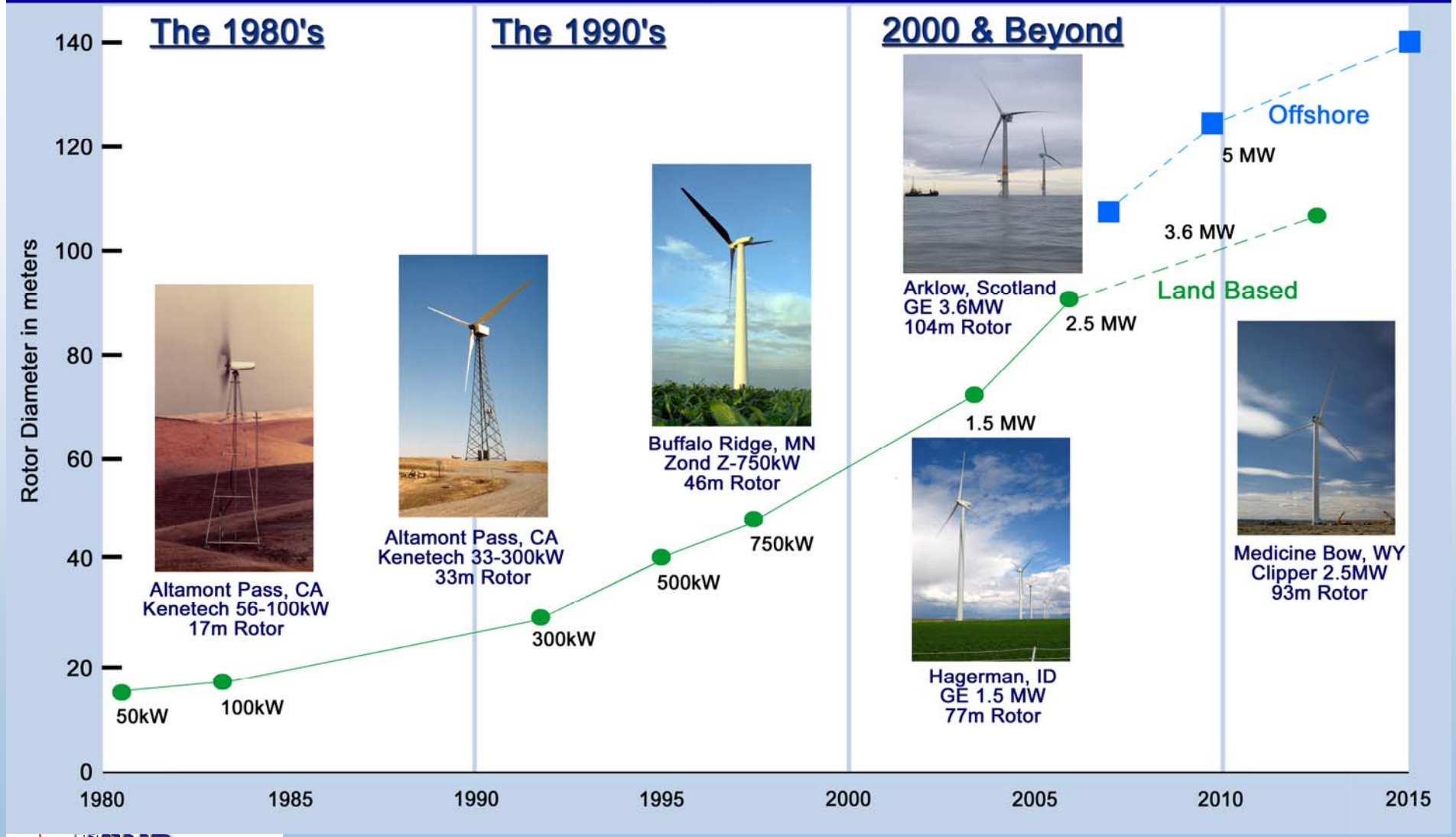
3 NEG Micon 225kW

Funding Source:

DOE and FEMP

Provides ~ 17% of the island's electricity
Annual energy saving of ~$112,000

Evolution of U.S. Commercial Wind Technology



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A Future Vision for Wind Energy Markets

Today 2007

Bulk Power Generator
5-9¢ at 13mph*
With No PTC

- Land Based
- Bulk Electricity
- Wind Farms

Less than 1% of Electricity Market

Tomorrow

Land Based Electricity Path

Land-Based Turbines 2–5 MW

Transmission Barriers

Land-based Turbines:
- **Cost Reduction**
- **Increased Energy & Reliability**
- **20% of Electricity Market**

Offshore Electricity Path

Offshore Turbines 5 MW and Larger

Cost & Regulatory Barriers

Offshore Turbine:
- Higher Wind Sites
- Shallow/***Deep*** *water*
- Coastal Cities
- 35% Cost Reduction needed

New Applications Path

- **Hydrogen**
- **Clean Water**
- **Storage: PHEV-CAES**

Cost & Infrastructure Barriers

Custom Turbines for Multi-markets:
- Electricity
- H2 production
- Desalinate water

2020 and Beyond

* Note: The site wind speed is measured at 10m and assumes a 1/7 power law wind shear giving a hub height wind speed of 18mph, while the siting, land and related project costs are assumed to be average for the US.

Carpe Ventem

www.windpoweringamerica.gov

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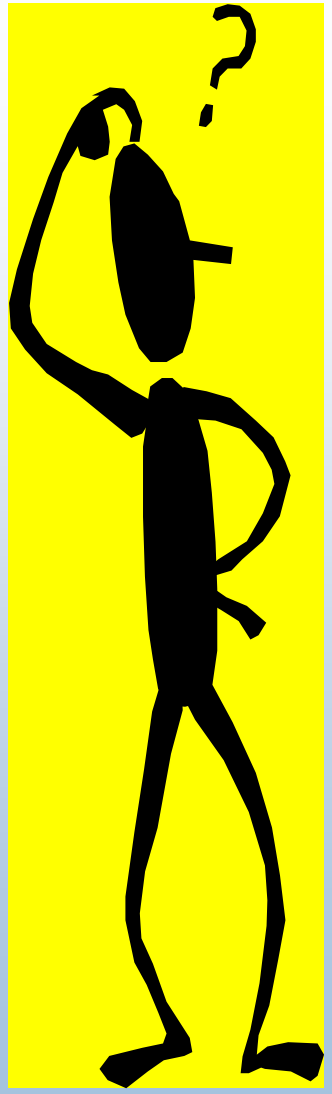
Questions?

For more info:

http://www.nrel.gov/wind/

http://www.eere.energy.gov/windandhydro/windpoweringamerica/

http://www.awea.org/

http://rredc.nrel.gov/wind/pubs/atlas/