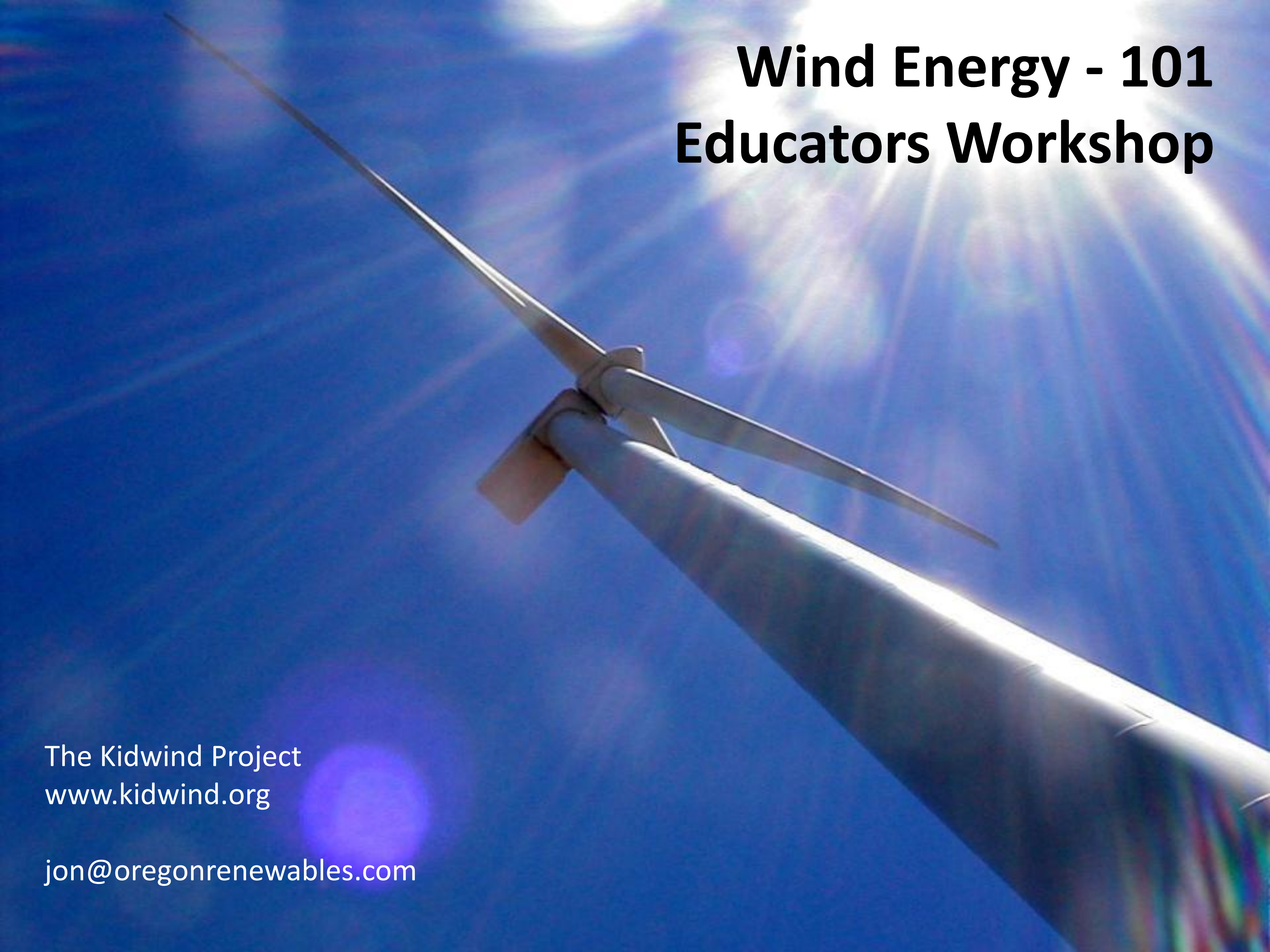
Wind Energy - 101
Educators Workshop



The Kidwind Project
www.kidwind.org

jon@oregonrenewables.com

What is KidWind?

The KidWind Project is a team of teachers, students, engineers, and practitioners exploring the science behind wind and other renewable forms of energy. Our goal is to make renewable energy widely accessible through hands-on activities which are challenging, engaging and teach basic science and engineering principles.

“Engaging minds for a responsible future…”

Why Renewable Energy & Efficiency?

Humanity's Top Ten Problems for next 50 years

1. **ENERGY**
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism & War
7. Disease
8. **EDUCATION**
9. Democracy
10. Population

Source: Nobel Laureate Richard Smalley

Science Literacy

- In the U.S., anthropogenic climate change is still a "debate"
- Recent studies have shown that 50% of Americans cannot name an example of *renewable energy*.
- 8% of Americans can pass basic energy literacy test
- How can we "conserve" energy if we don't understand basic energy concepts?

PACIFIC POWER

Questions about your bill: 1-888-221-7070
Call toll free 24 hours a day, 7 days a week
www.pacificpower.net

BILLING DATE:	Mar 18, 2013
ACCOUNT NUMBER:	18880585-001 7
DATE DUE:	Apr 3, 2013
AMOUNT DUE:	$ 234.06

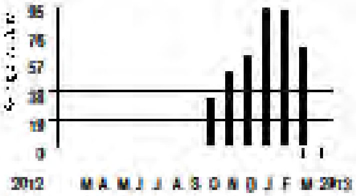
Your Balance With Us

Previous Account Balance	294.41
Payments/Credits	-294.41
New Charges	+234.06
Current Account Balance	**$ 234.06**

Payments Received

DATE	DESCRIPTION	AMOUNT
Mar 8, 2013	Payment Received - Thank you	294.41
Total Payments		**$ 294.41**

Historical Data - *ITEM 1*



Your Average Daily kwh Usage by Month

PERIOD ENDING	MAR 2013	MAR 2012
Avg. Daily Temp.	46	43
Total kwh	2053	0

Detailed Account Activity

ITEM 1 - ELECTRIC SERVICE 2027 N Williams Ave Portland OR
Residential Schedule 4

METER NUMBER	SERVICE PERIOD From	To	ELAPSED DAYS	METER READINGS Previous	Current	METER MULTIPLIER	AMOUNT USED THIS MONTH
41380289	Feb 13, 2013	Mar 15, 2013	30	62807	64860	1.0	2,053 kwh

Next scheduled read date: 04-15. Date may vary due to scheduling or weather.

NEW CHARGES - 03/13	UNITS	COST PER UNIT	CHARGE
Basic Charge - Single Phase			9.0
Delivery Charge	2,053 kwh	0.0423500	86.94
Generation Credit	2,053 kwh	-0.0013400	-2.75
Supply Energy Charge Block 1	986 kwh	0.0518100	51.08
Supply Energy Charge Block 2	1,067 kwh	0.0706900	75.43
Public Purpose		0.0300000	6.59
Energy Conservation Charge	2,053 kwh	0.0027900	5.73
Low Income Assistance			0.85
J C Boyle Dam Removal	2,053 kwh	0.0003300	0.68
Copco & Iron Gate Dams Removal	2,053 kwh	0.0010100	2.07
B P A Columbia River Benefits	986 kwh	-0.0052800	-5.21
Portland City Tax		0.0150000	3.30
Multnomah County Fee		0.0016000	0.35
Total New Charges			**234.06**

Kilowatt-hours (kWh)

Contact us at 1-888-221-7070 to enroll in the fixed donation program. You can add an amount you choose to your monthly bills in order to help your neighbors in need with assistance on their electric bills. Donations are tax-deductible.

Late Payment Charge for Oregon
A late payment charge of 1.7% may be charged on any balance not paid in full each month.

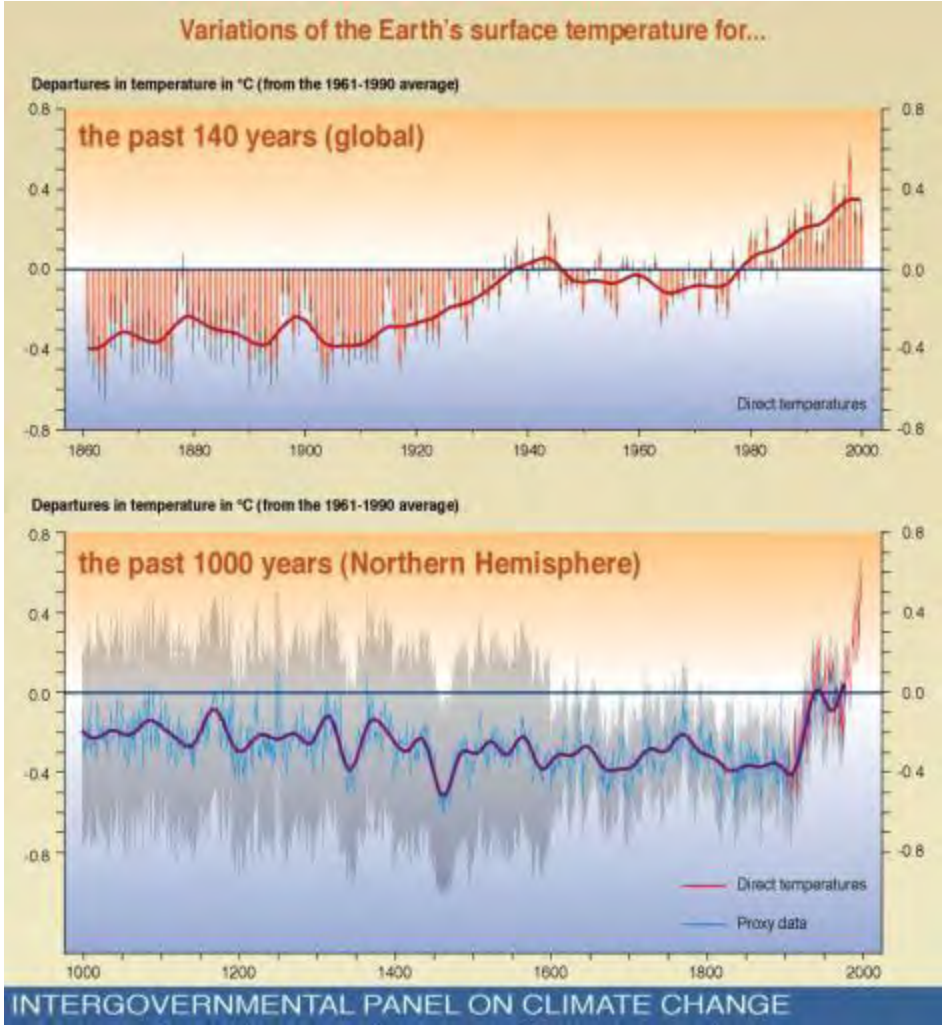
Write account number on check & mail to: Pacific Power, 1033 NE 6th Ave, Portland, OR 97256-0001

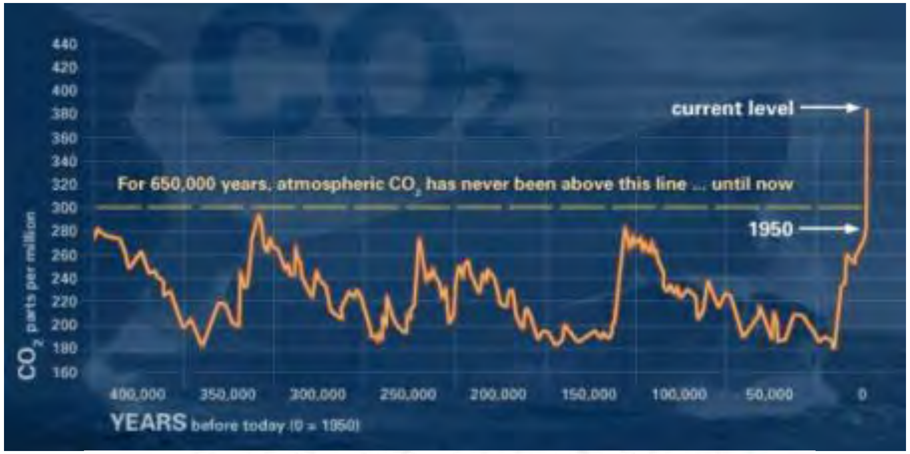
RETAIN THIS PORTION FOR YOUR RECORDS.
RETURN THIS PORTION WITH YOUR PAYMENT.

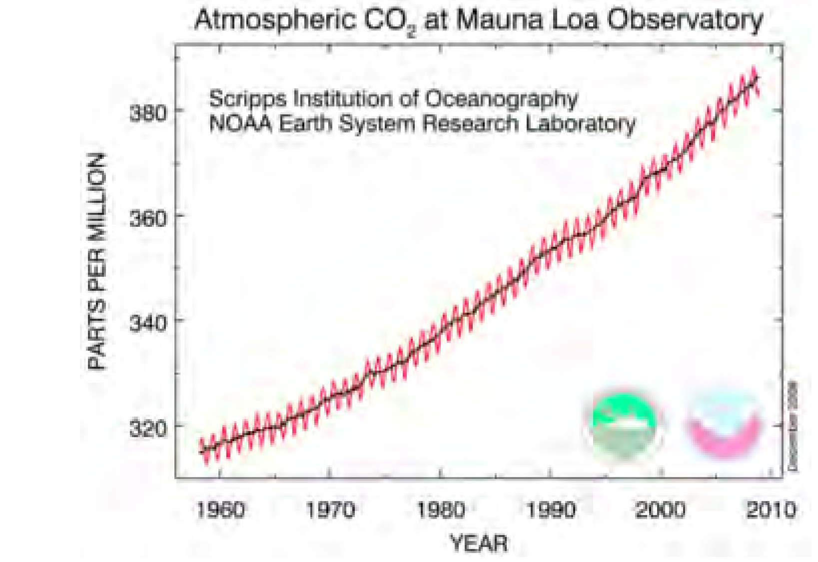
PACIFIC POWER

Change of Mailing Address or Phone?

Atmospheric Carbon vs. Temp





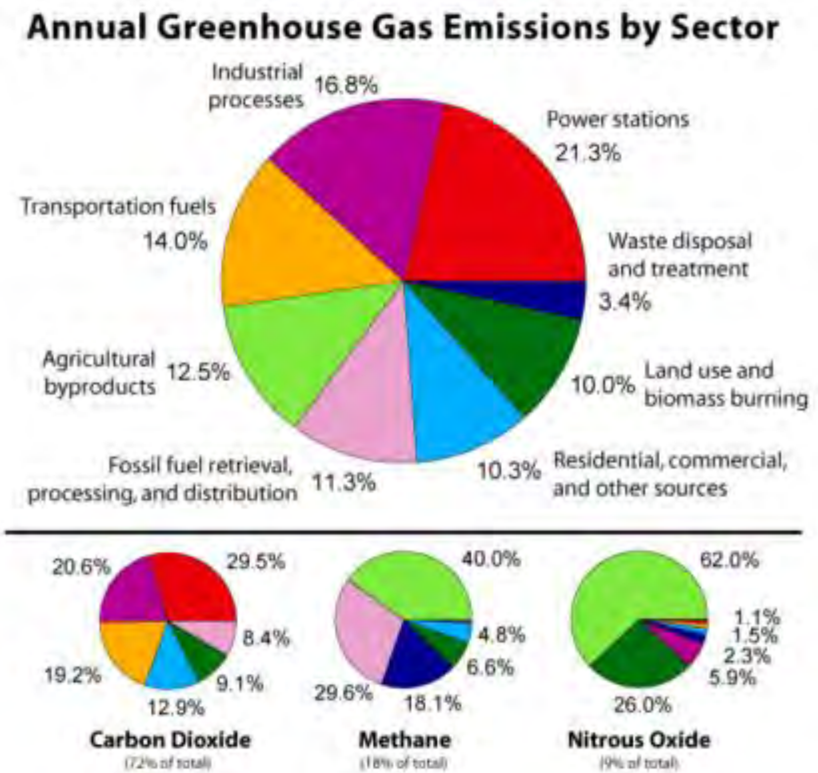


Recent News

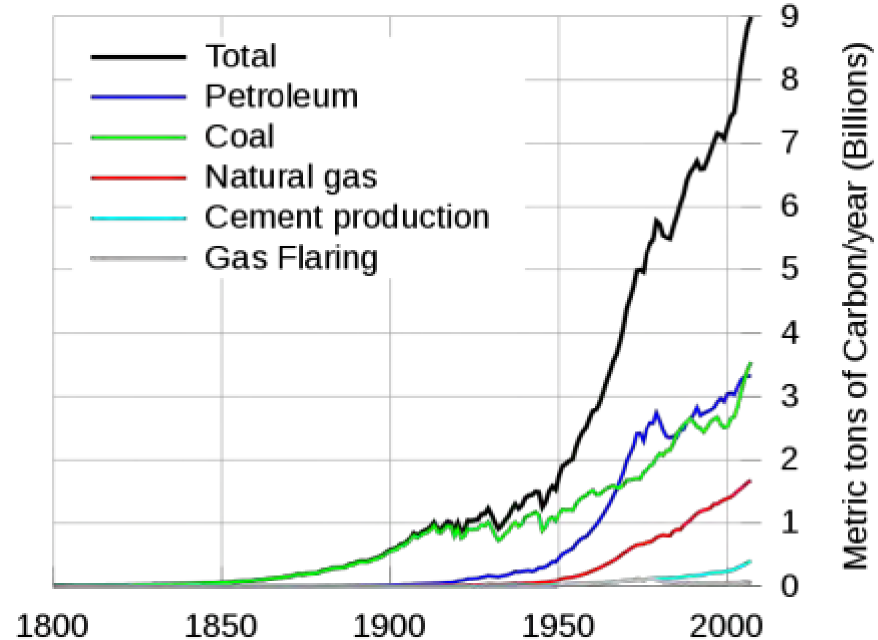

Bloomberg Businessweek
IT'S GLOBAL
WARMING
STUPI


The Economist
The dangerous Cyprus deal
Global warming slows down
What to do about Heathrow
Cyberwar: the arms trade
Sex in the Middle East
Can India become a great power?

Where does the Carbon Come From

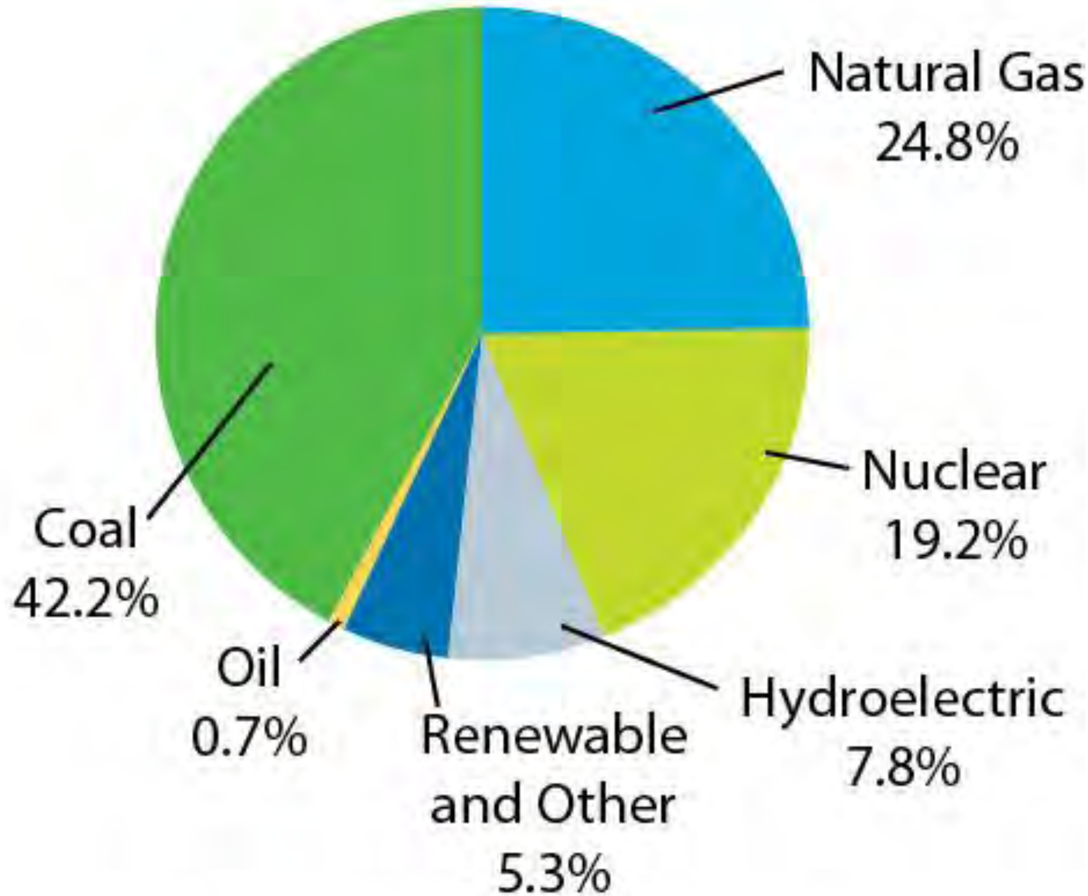


This figure shows the relative fraction of man-made greenhouse gases coming from each of eight categories of sources, as estimated by the Emission Database for Global Atmospheric Research version 3.2.



Global annual fossil fuel carbon dioxide emissions through year 2004, in million metric tons of carbon, as reported by the Carbon Dioxide Information Analysis Center

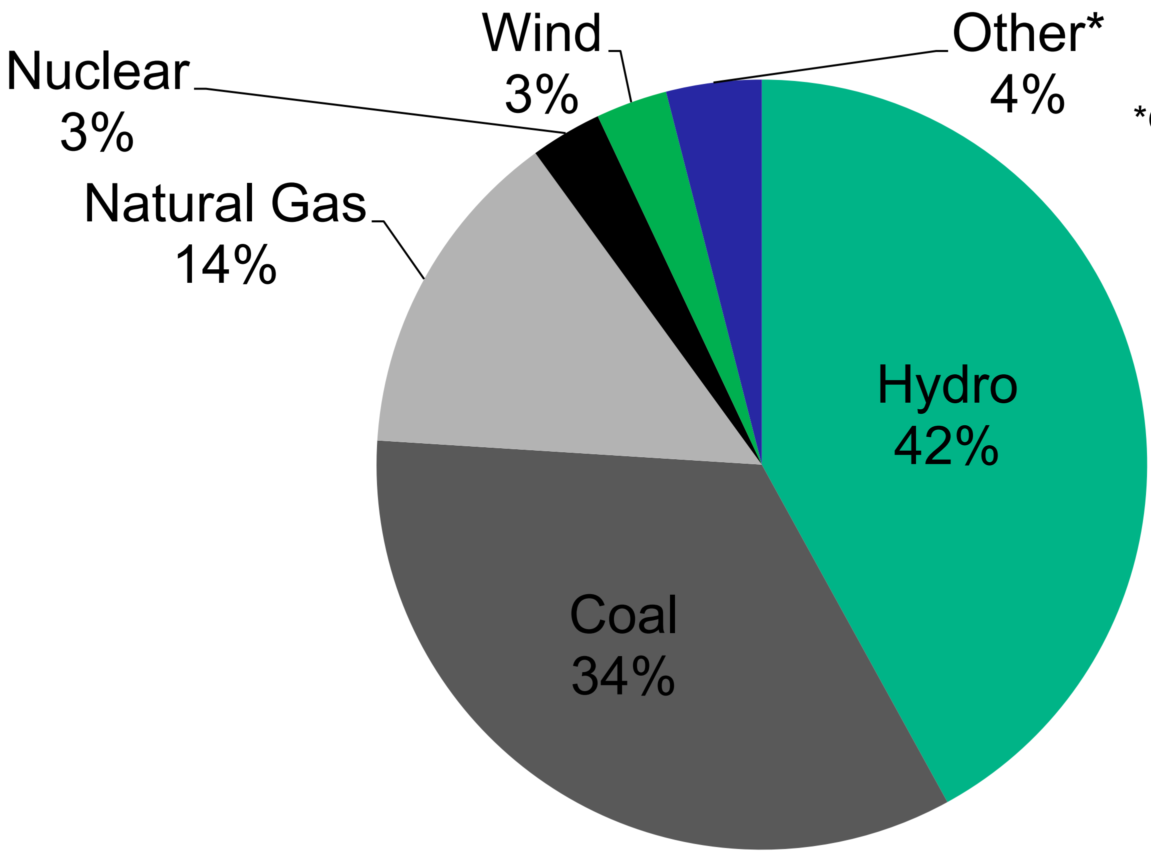
U.S. Electricity Generation Fuel Shares 2011



Source: U.S. Energy Information Administration

Oregon's Energy Mix, 2011

(Investor-Owned Utilities)



*Other:
- Cogeneration 1 %
- Biomass 0.5 %
- Waste 0.3 %
- Petroleum 0.2 %
- Geothermal 0.1 %

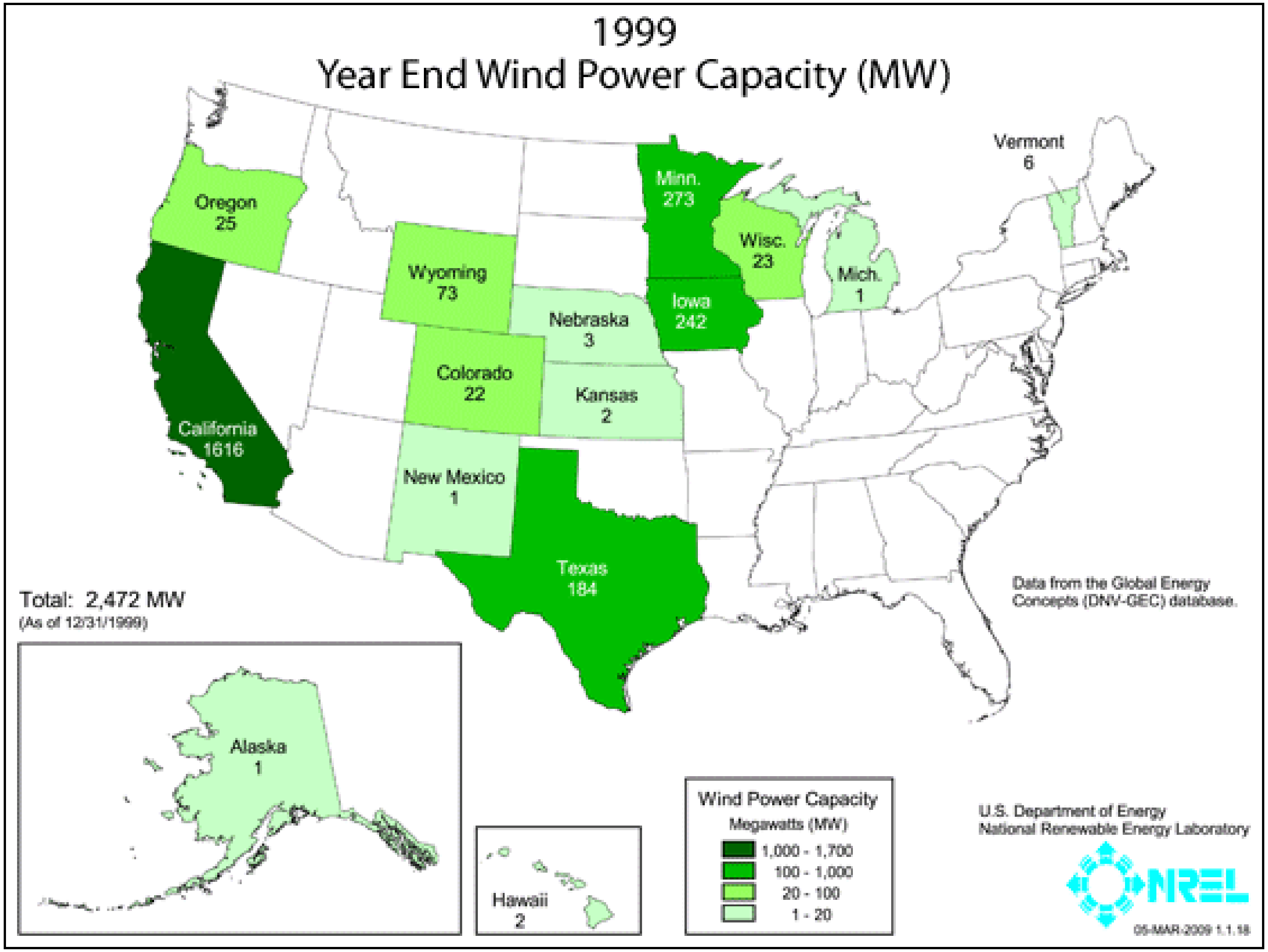
Where's Solar??

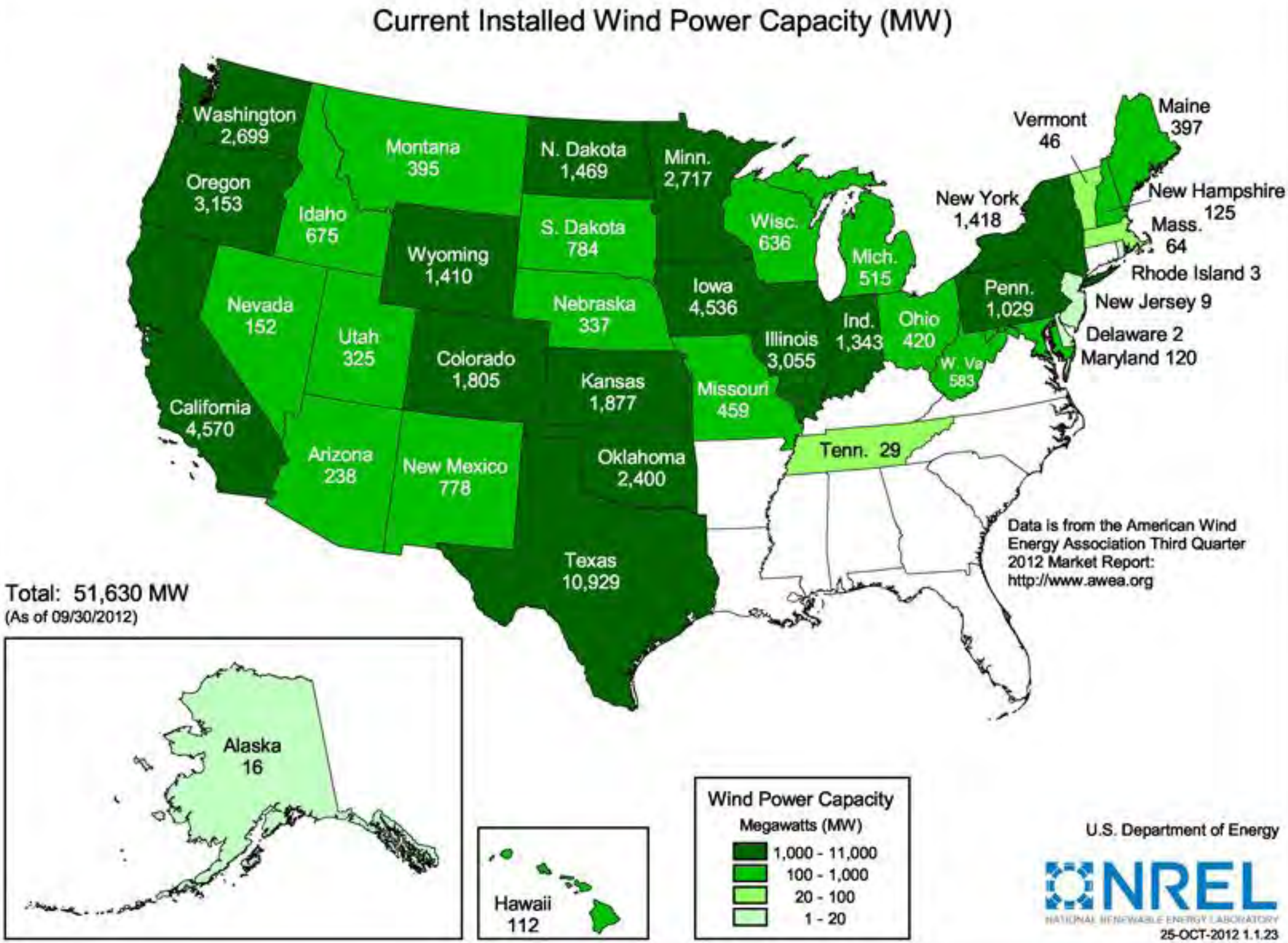
****Credit: www.oregon.gov/ENERGY/Oregons_Electric_Power_Mix.shtml**

Why Clean Energy Science in K-12 ?

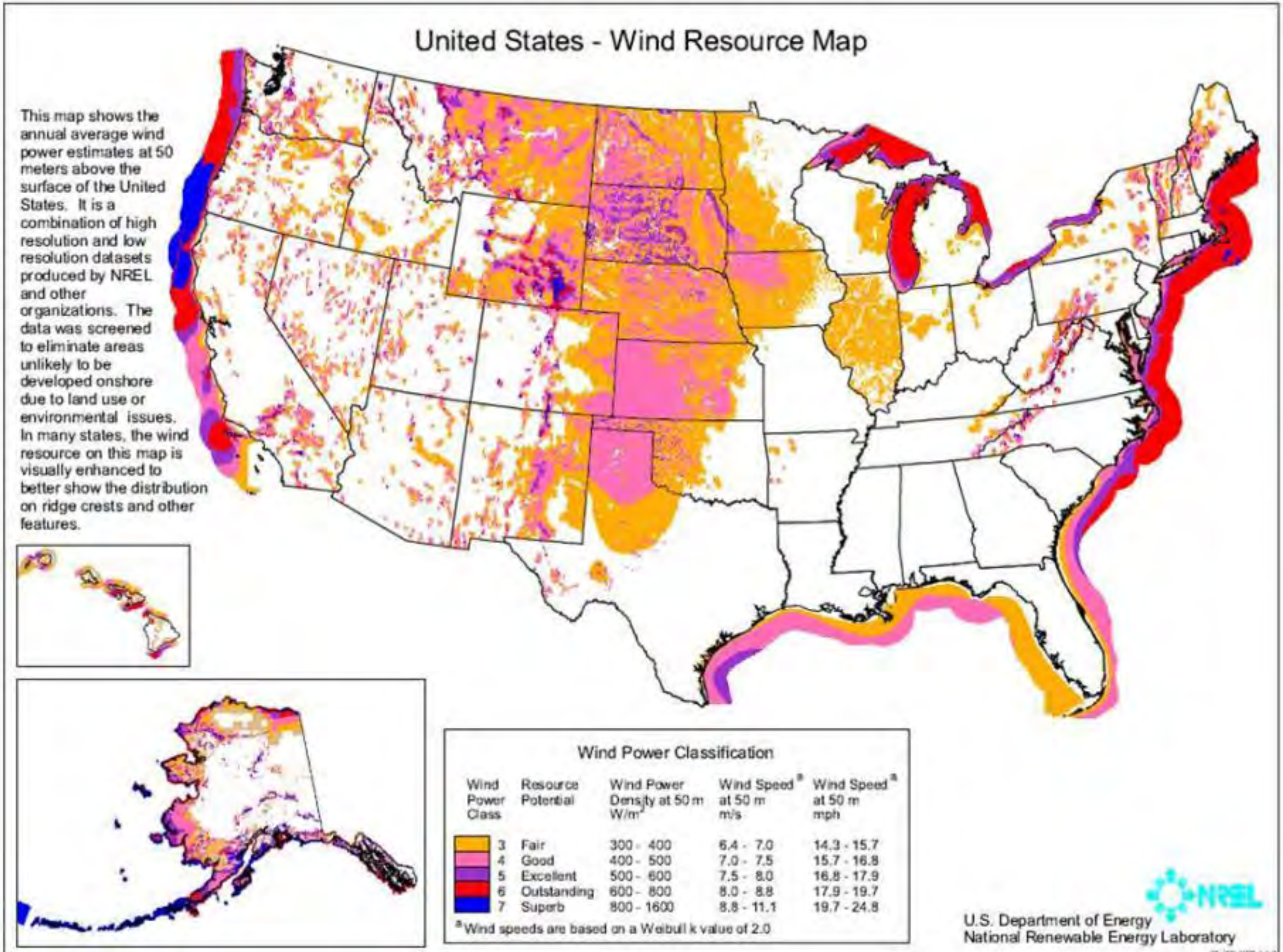
- Students learn science/math **standards**
  - Lessons are completely scalable from elementary through college level
- Addresses **myths and misconceptions** regarding renewable energy
- Encourages higher interest in Science and Math
  - Science/Math activities with “larger **social purpose**”
- Students learn about **jobs/careers** in renewable energy industry, as well as opportunities for **further training**
- Educate the next generation of leaders and decision makers to make more informed choices

Where is the Wind Power?





Current Installed Wind Power Capacity (MW)
Washington 2,699
Oregon 3,153
Montana 395
Idaho 675
N. Dakota 1,469
Minn. 2,717
S. Dakota 784
Wyoming 1,410
Nevada 152
Utah 325
Colorado 1,805
Nebraska 337
Iowa 4,536
Wisc. 636
Mich. 515
Kansas 1,877
Illinois 3,055
Ind. 1,343
Ohio 420
W. Va 583
Missouri 459
California 4,570
Arizona 238
New Mexico 778
Oklahoma 2,400
Texas 10,929
Tenn. 29
Penn. 1,029
New York 1,418
Vermont 46
Maine 397
New Hampshire 125
Mass. 64
Rhode Island 3
New Jersey 9
Delaware 2
Maryland 120
Data is from the American Wind Energy Association Third Quarter 2012 Market Report: http://www.awea.org
Total: 51,630 MW
(As of 09/30/2012)
Alaska 16
Hawaii 112
Wind Power Capacity
Megawatts (MW)
1,000 - 11,000
100 - 1,000
20 - 100
1 - 20
U.S. Department of Energy
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
25-OCT-2012 1.1.23


United States - Wind Resource Map
This map shows the annual average wind power estimates at 50 meters above the surface of the United States. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.
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
U.S. Department of Energy
National Renewable Energy Laboratory

Why such growth…costs!

1979: 40 cents/kWh

2000:
4 - 6 cents/kWh

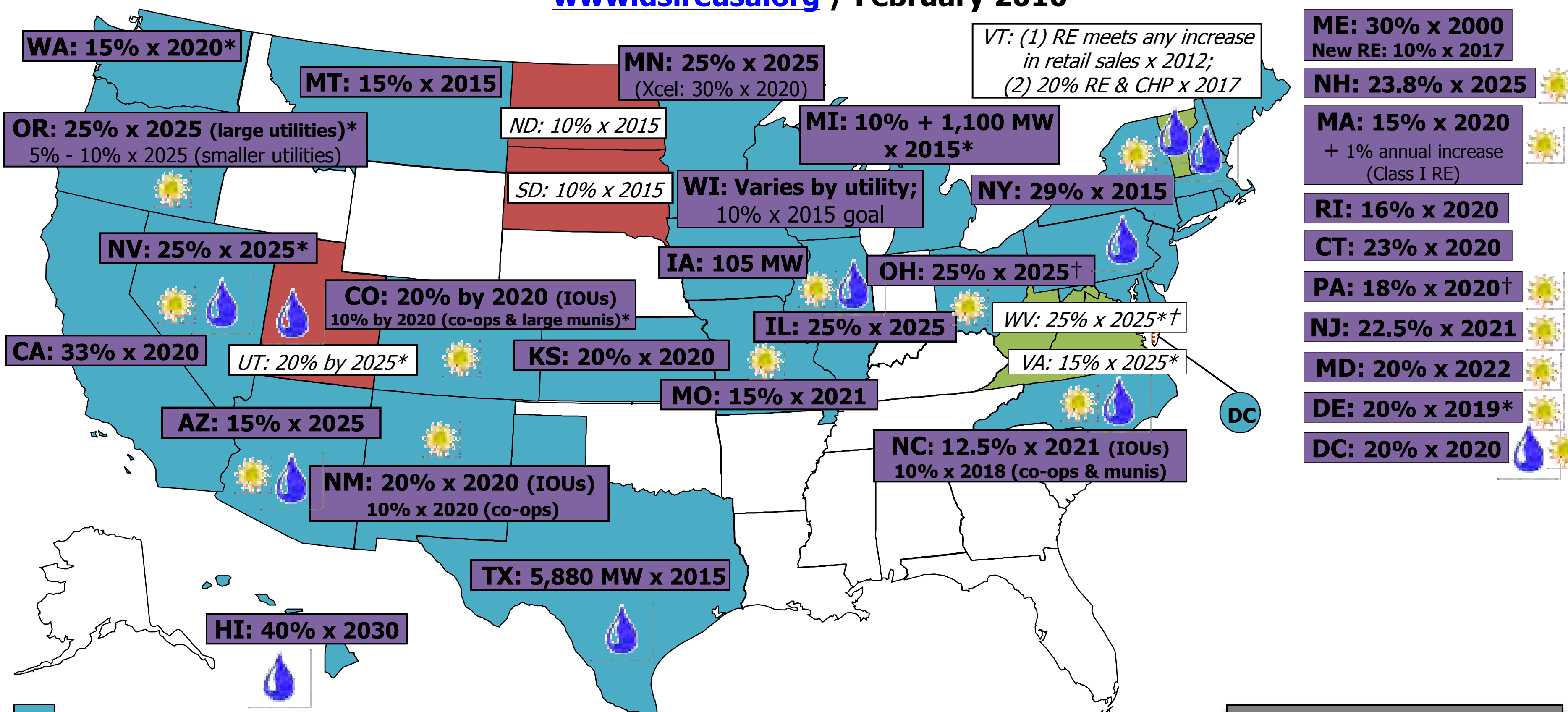
2011:
4-5 cents/kWh

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements

NSP 107 MW Lake Benton wind farm
4 cents/kWh (unsubsidized)

Renewable Portfolio Standards

www.dsireusa.org / February 2010



State renewable portfolio standard

State renewable portfolio goal

Solar water heating eligible

Minimum solar or customer-sited requirement

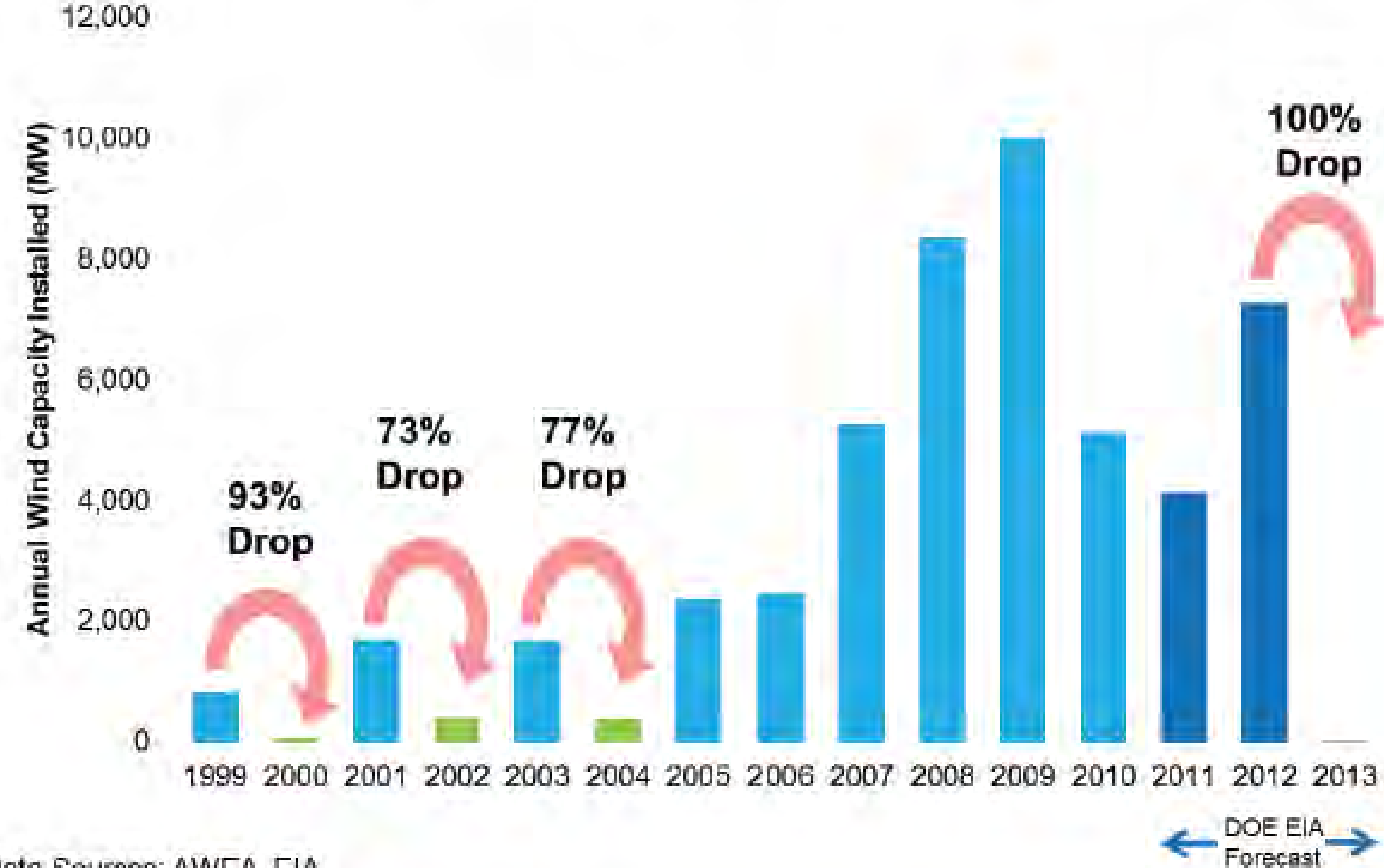
* Extra credit for solar or customer-sited renewables

† Includes non-renewable alternative resources

29 states + DC have an RPS
(6 states have goals)

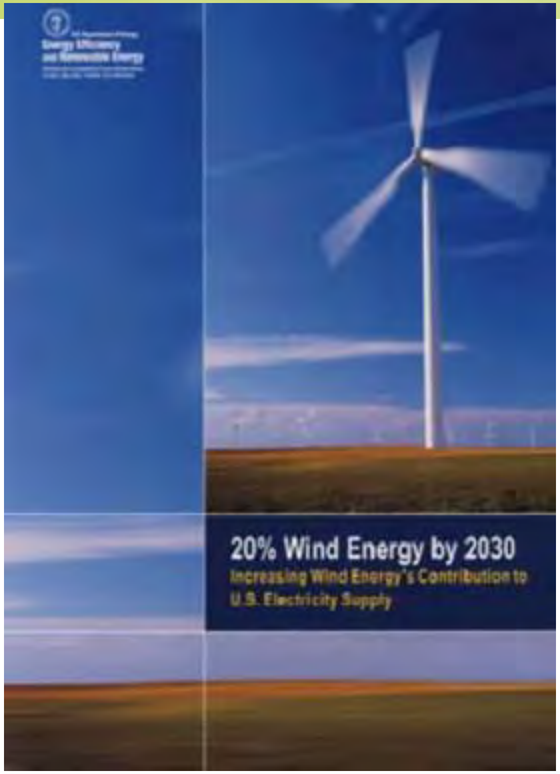
KidWind Project | www.kidwind.org

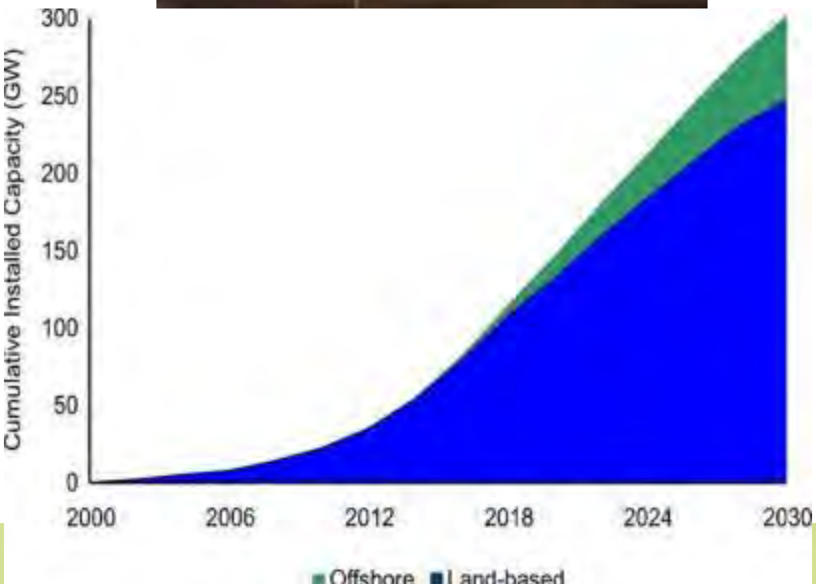
Historic Impact of PTC Expiration on Annual Wind Installation



Data Sources: AWEA, EIA

20% Wind by 2030





- Requires 300 GW (300,000 MW) of wind generation
- Report shows that affordable, accessible wind resources are available across the nation
- Wind Industry would support 500,000 jobs
- Major Challenges:
  - Transmission
  - Technology improvements
  - Project Siting

Wind Power

- History
- Technology
- Impacts
- Wind in the Classroom

Early "Windmill" in Afghanistan (900AD)

Architecture of the Islamic World, Its History and Social Meaning; Page 188;
Edited by George Michell; 1978 Thames & Hudson Ltd, London

Jacobs Turbine – 1920 - 1960

WinCharger – 1930s – 40s

Smith-Putnam Turbine

Vermont, 1940's

1.25 MW

Modern Windmills

Rotor Orientation

Vertical Axis Turbines

Advantages

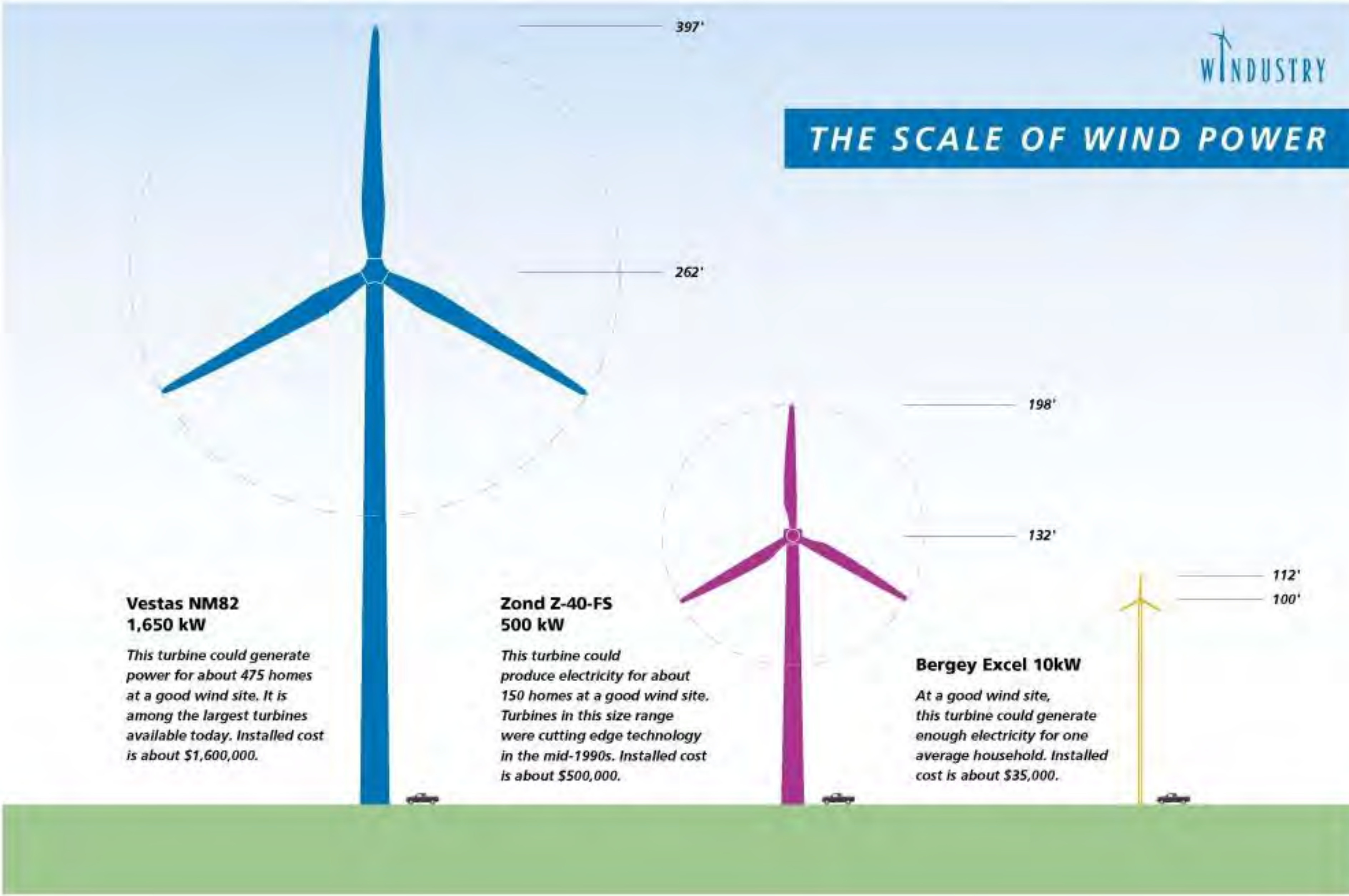
- Components can be mounted at ground level
  - Ease of service
  - Lighter weight towers
- Can theoretically use less materials to capture the same amount of wind

Disadvantages

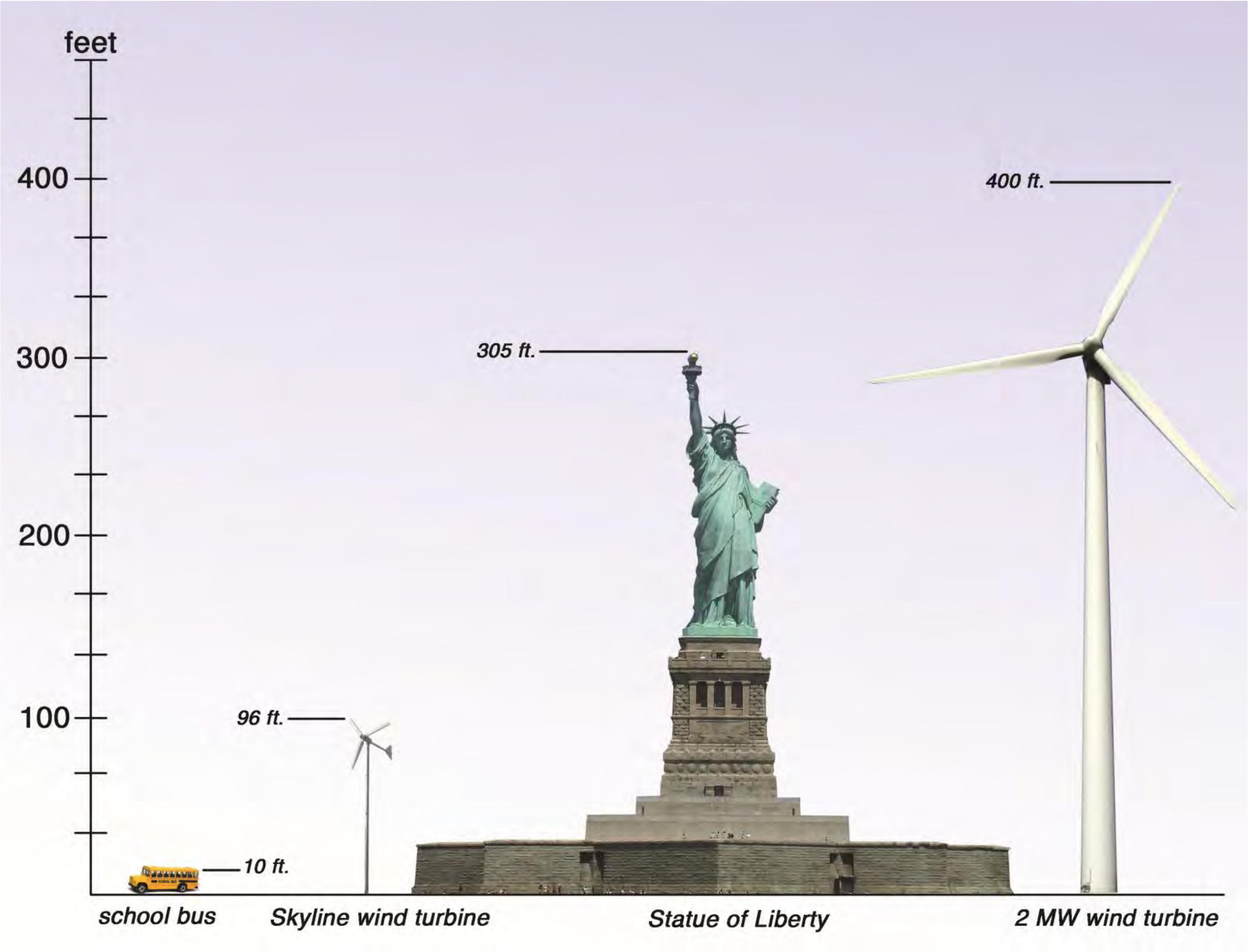
- Rotors generally near ground where wind is poorer
- Centrifugal force stresses blades
- Poor self-starting capabilities
- Requires support at top of turbine rotor
- Requires entire rotor to be removed to replace bearings
- ½ of rotor travels upwind
- Have never been commercially successful
- Cost per kilowatt-hour
- Overall poor performance and reliability

Horizontal Axis Wind Turbines

- Rotors are usually Up-wind of tower
- Some machines have down-wind rotors, but only commercially available ones are small turbines
- Proven, viable technology



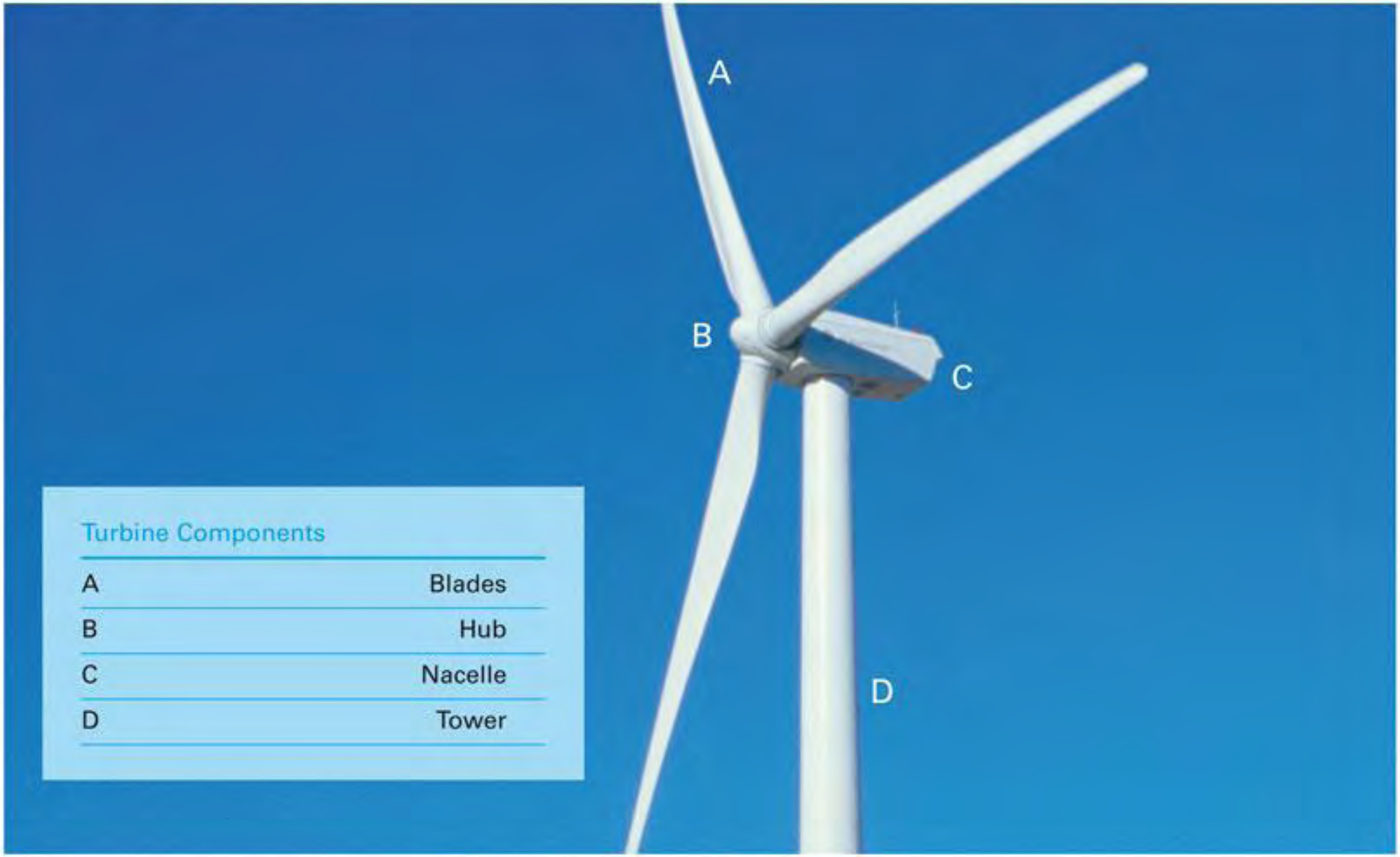
WINDUSTRY
THE SCALE OF WIND POWER
397'
262'
198'
132'
112'
100'
Vestas NM82
1,650 kW
This turbine could generate power for about 475 homes at a good wind site. It is among the largest turbines available today. Installed cost is about $1,600,000.
Zond Z-40-FS
500 kW
This turbine could produce electricity for about 150 homes at a good wind site. Turbines in this size range were cutting edge technology in the mid-1990s. Installed cost is about $500,000.
Bergey Excel 10kW
At a good wind site, this turbine could generate enough electricity for one average household. Installed cost is about $35,000.

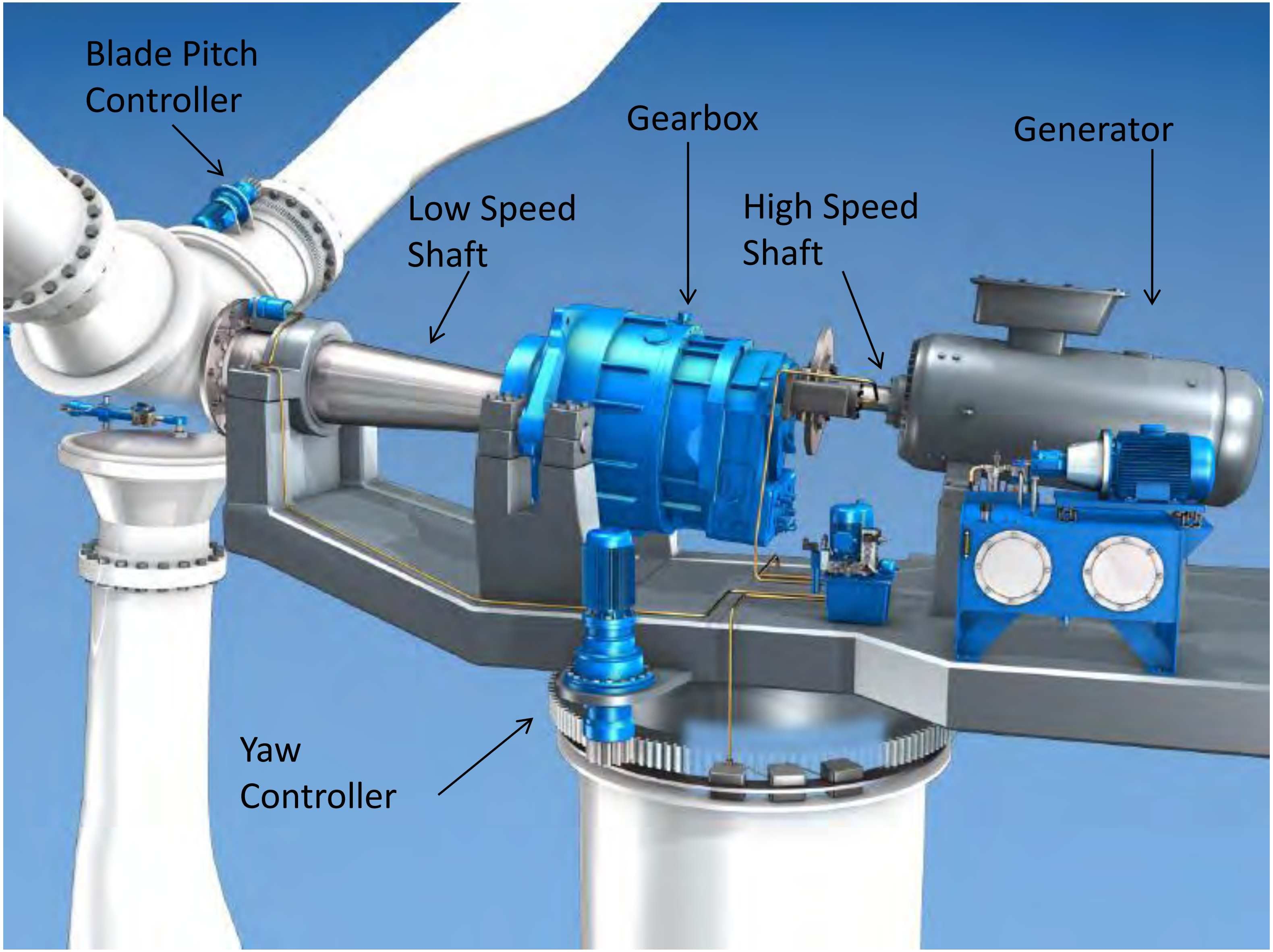

feet
400
300
200
100
400 ft.
305 ft.
96 ft.
10 ft.
school bus
Skyline wind turbine
Statue of Liberty
2 MW wind turbine

Wacky Designs out there…

Large Wind Turbines

Wind turbine components




Blade Pitch
Controller
Gearbox
Generator
Low Speed
Shaft
High Speed
Shaft
Yaw
Controller

Over-Speed Protection

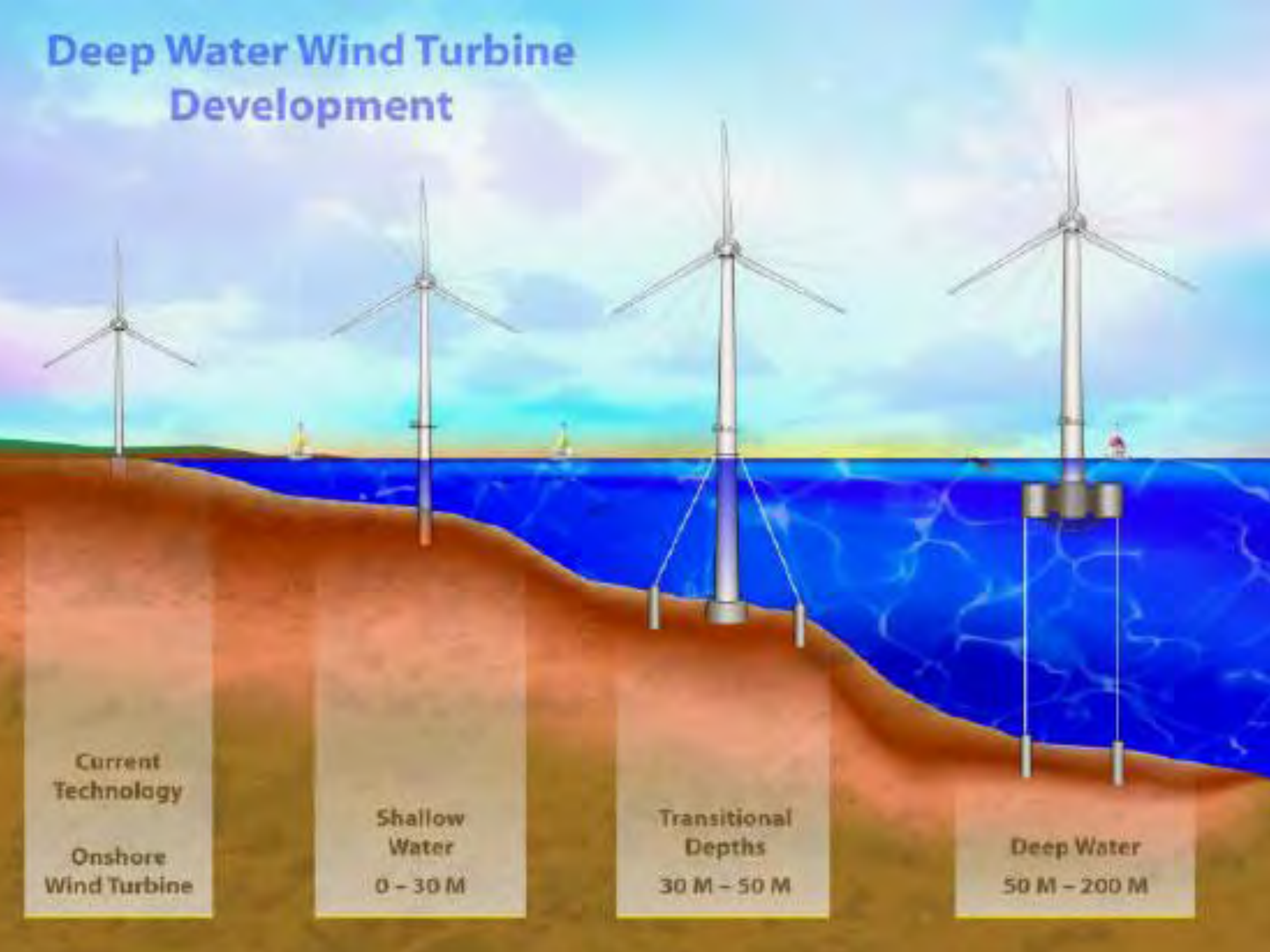
Blade Pitch Regulation

- Modern industrial scale turbines are shut down at wind speeds of 25 m/s (55 mph).
- This is done by pitching the blades flat so the rotor will not turn.
- A mechanical brake can also be applied to the driveshaft.

Maintenance


Crop of the
21ST Century
U.S. Department of Energy
Wind Energy Program
http://www.eren.doe.gov/wind/
WIND POWERING AMERICA
http://www.eren.doe.gov/windpoweringamerica/

Off-Shore Wind Farms


Deep Water Wind Turbine Development
Current Technology
Onshore Wind Turbine
Shallow Water
0 – 30 M
Transitional Depths
30 M – 50 M
Deep Water
50 M – 200 M

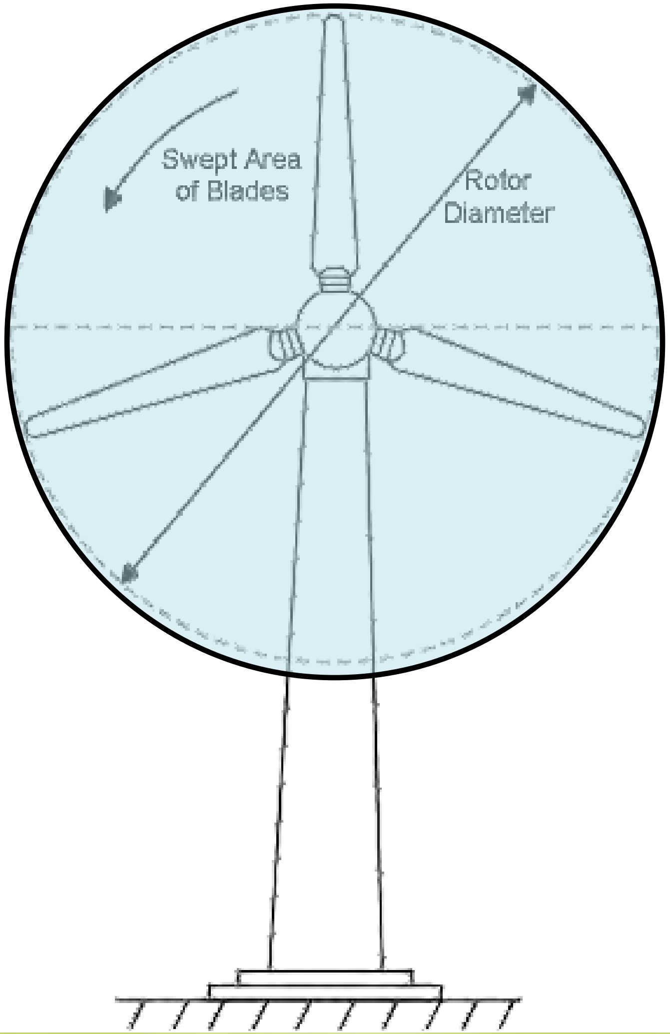
Importance of the WIND RESOURCE

Site Assessment Rule #1

Keep in mind what we're after…

<u>Power in the wind</u>

- –Air density, ρ
- –Swept area, A
- –Wind speed, V



Calculating Power in the Wind

Power = ½ ρ

– Air density, ρ

We can't do much about this…density is what it is.

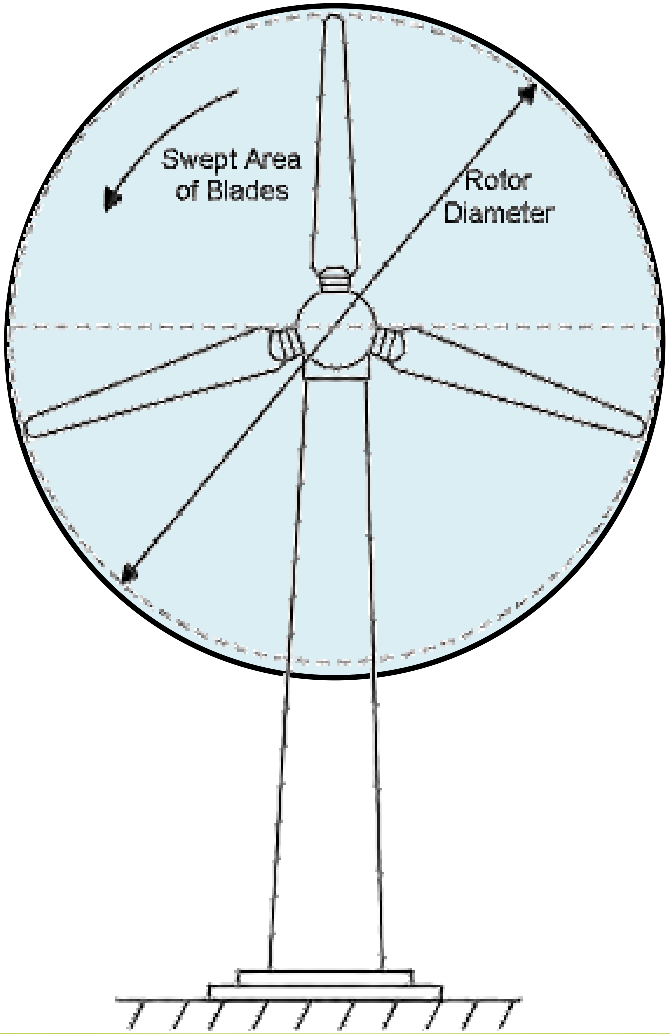
Calculating Power in the Wind

Power = ½ ρ A

– Air density, ρ

– Swept area, A

We could select a bigger rotor…



Calculating Power in the Wind

Power = ½ ρ A x V

- Air density, ρ
- Swept area, A
- Wind speed, V…

Calculating Power in the Wind

Power = ½ ρ A x V x V

- –Air density, ρ
- –Swept area, A
- –Wind speed, V…

Calculating Power in the Wind

Power = ½ ρ A x V x V x V

– Air density, ρ

– Swept area, A

– Wind speed, V

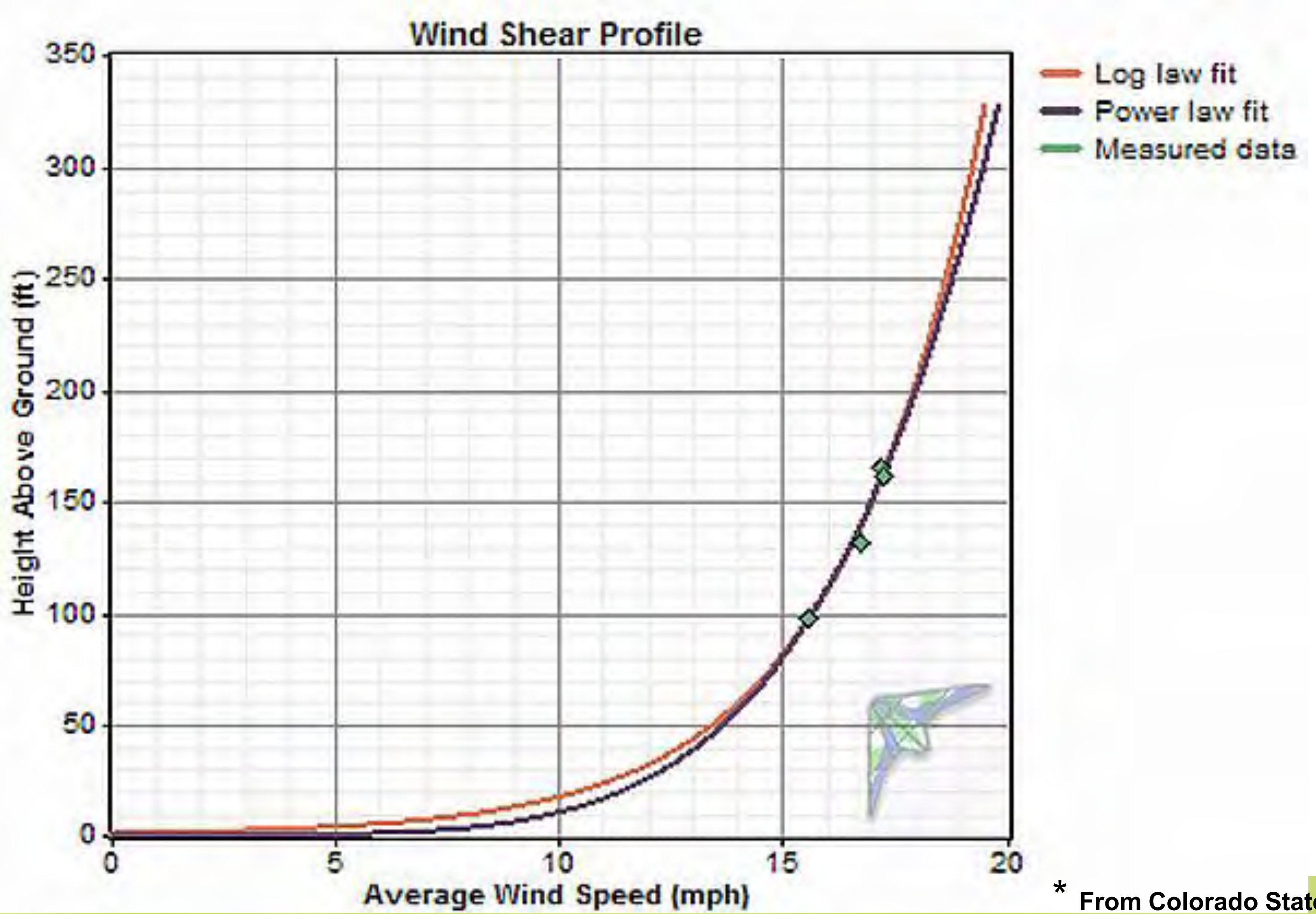
Calculating Power in the Wind

Power = $\frac{1}{2} \rho AV^3$

- –Air density, ρ
- –Swept area, A
- –Wind speed, V

Q: How do we get a higher wind speed?

More Tower, More Power



* From Colorado State Univ. Study

Why do wind speeds climb with elevation??

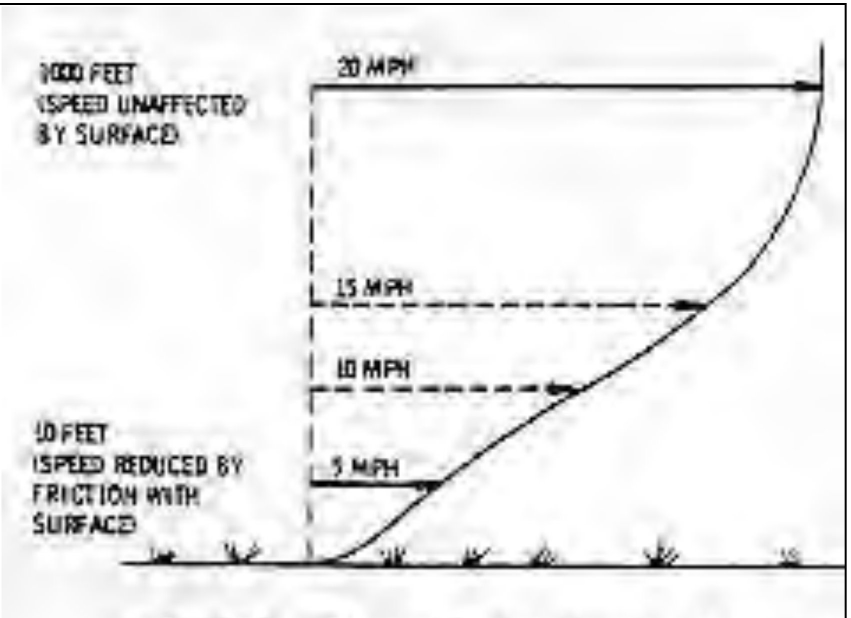
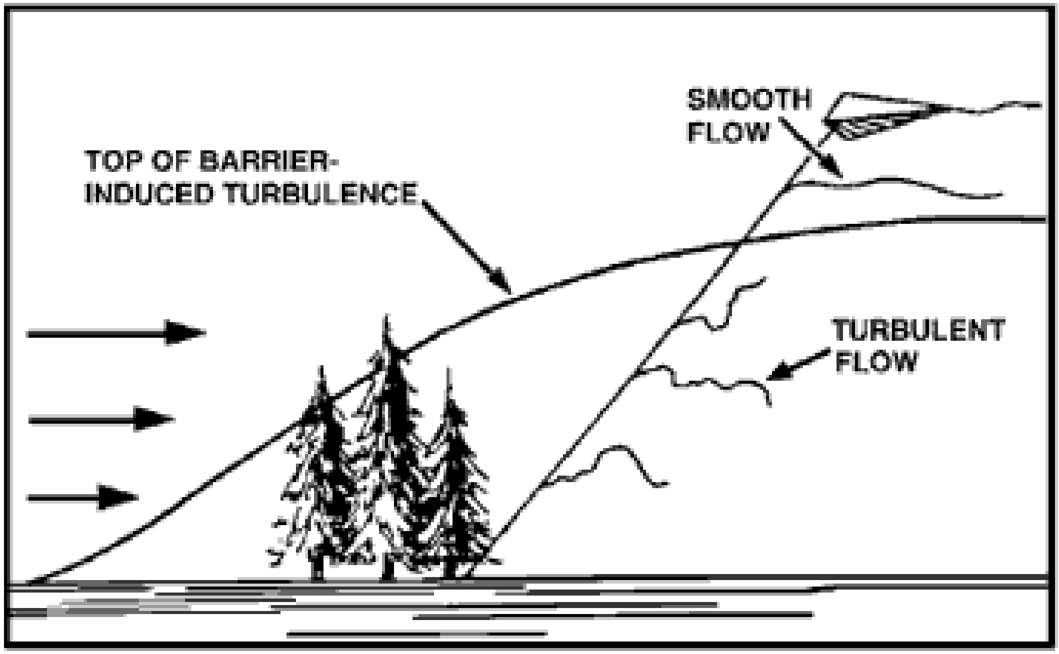


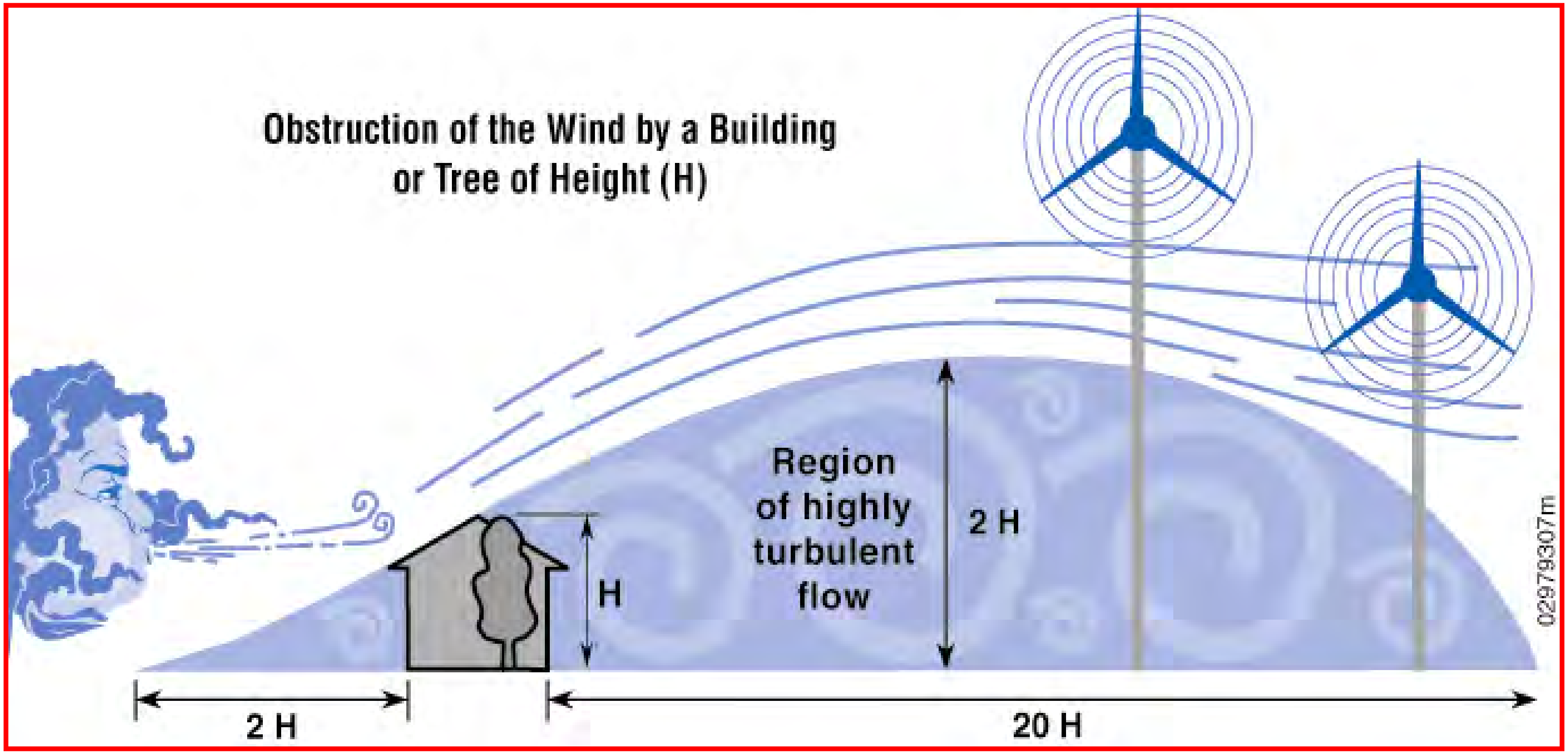
FIGURE 2. Effect of Surface Friction on Low-Level Wind



The Kite Test

…Think of a comparison to flowing water

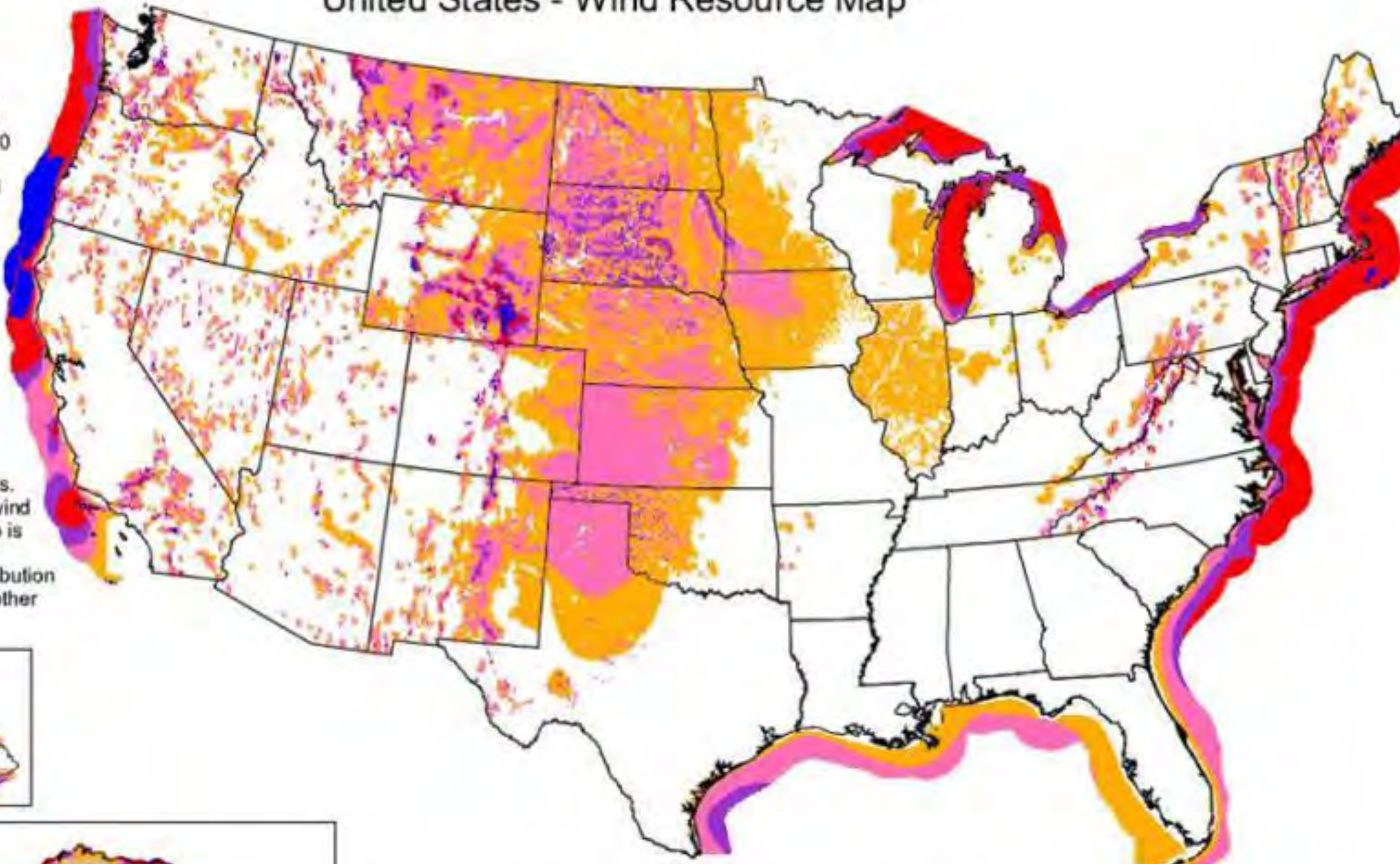
Turbulent wind is bad wind

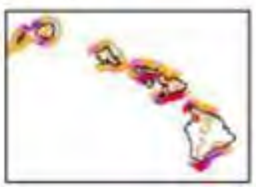


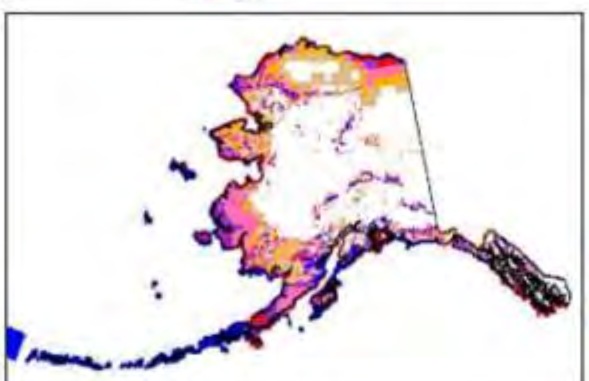
Again…think of a comparison to water

United States - Wind Resource Map

This map shows the annual average wind power estimates at 50 meters above the surface of the United States. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.







Wind Power Classification

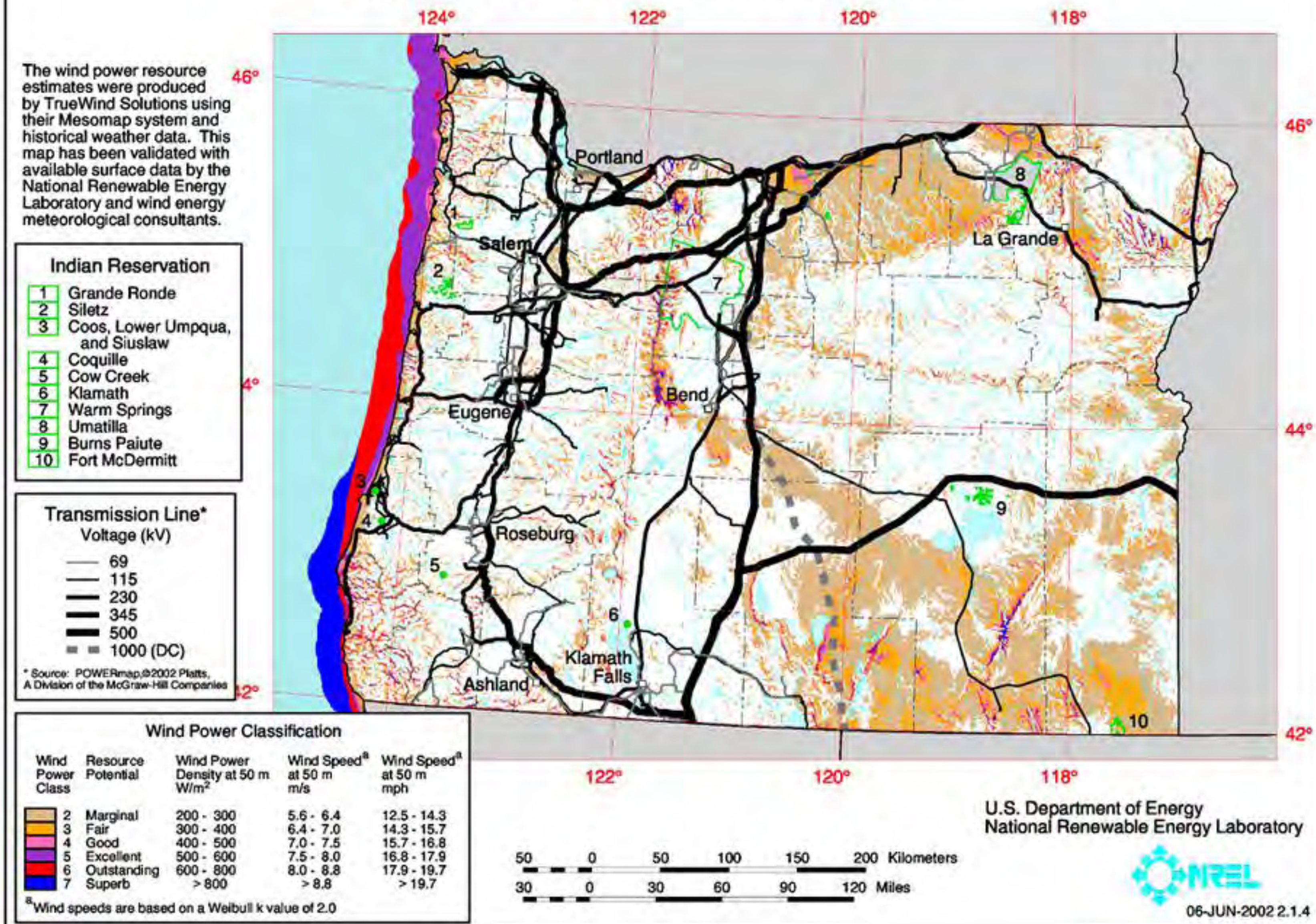
Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

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

NREL

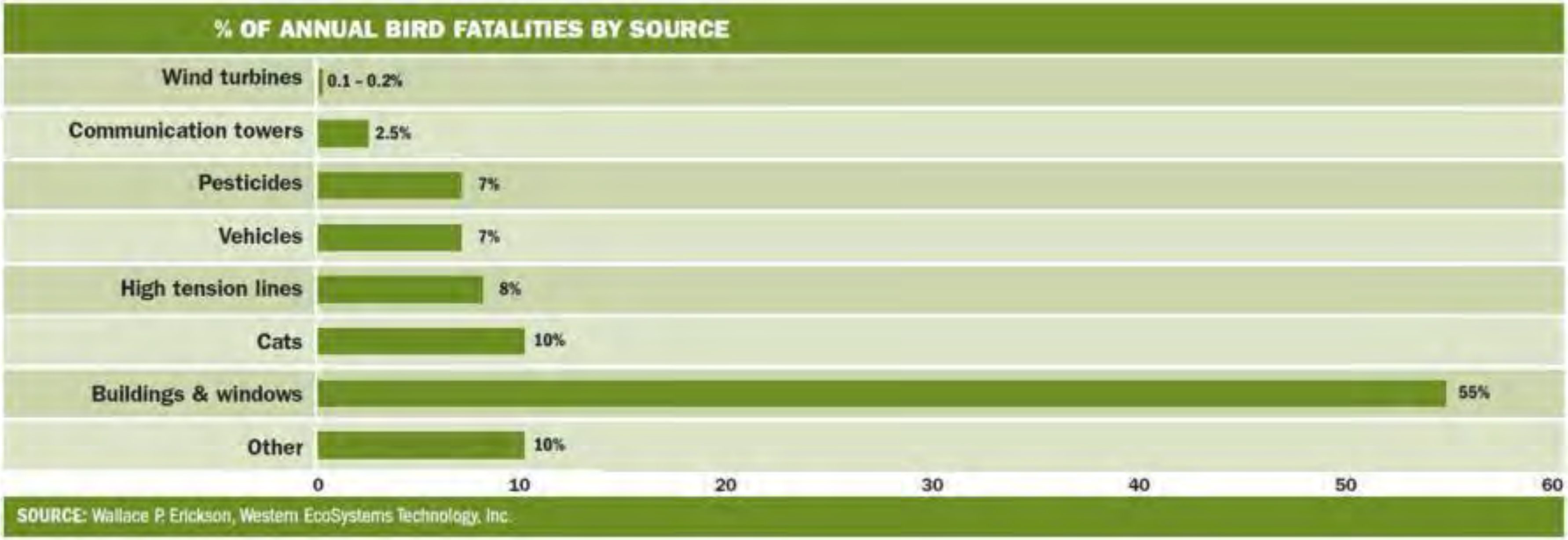
U.S. Department of Energy
National Renewable Energy Laboratory

Oregon - Wind Power Resource Estimates

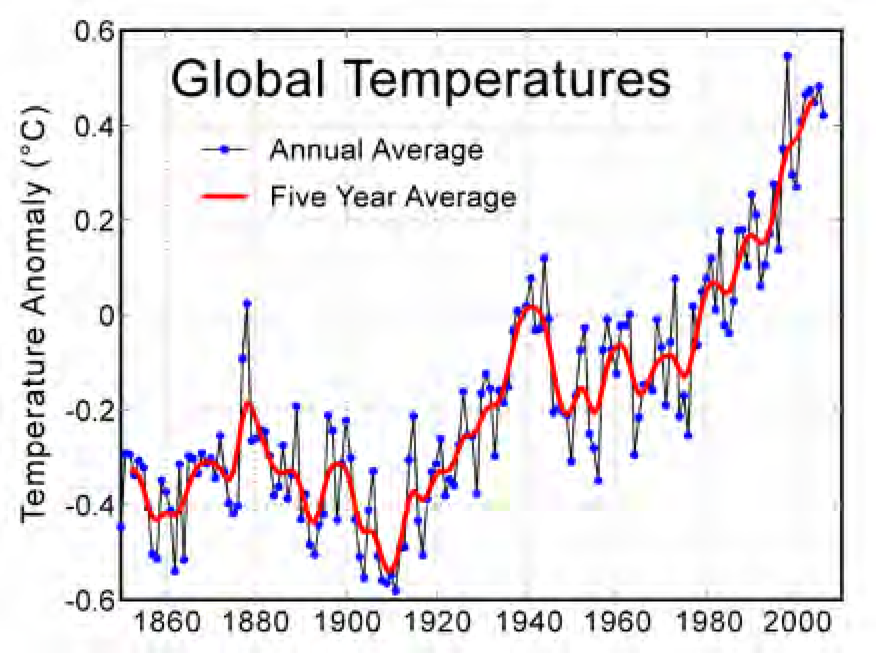


Positive Impacts

- No air pollution or greenhouse gas emissions
  - CO_2, NO_x, SO_x, Mercury…
- No water consumption or pollution
- Diversifies national energy portfolio
- Economic Benefits
  - Jobs
  - Cost of energy
  - Landowner revenue
  - Contribution to local taxes

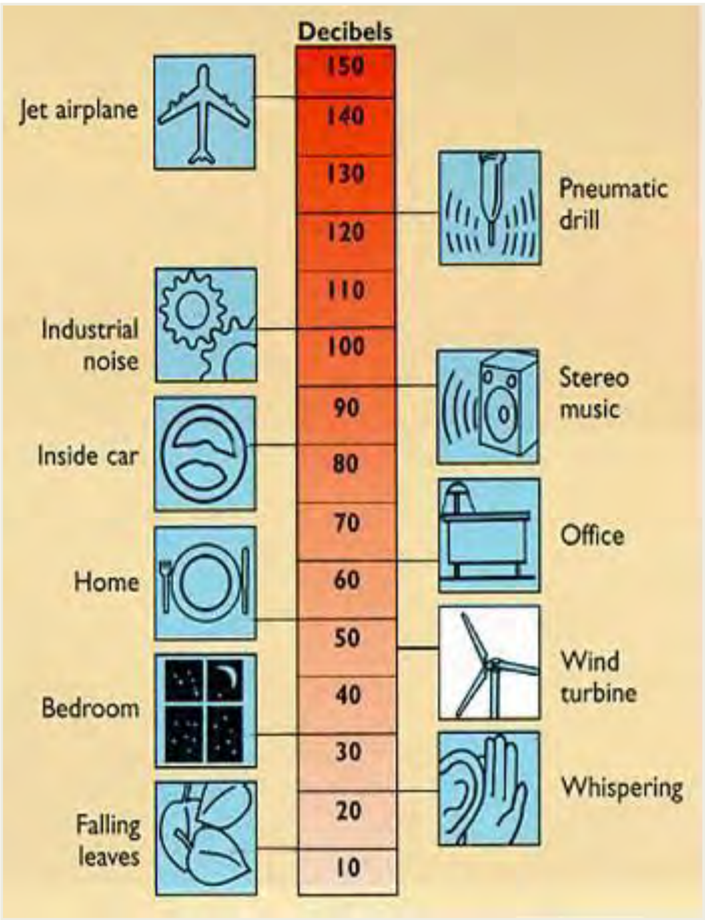

% OF ANNUAL BIRD FATALITIES BY SOURCE
Wind turbines
0.1 - 0.2%
Communication towers
2.5%
Pesticides
7%
Vehicles
7%
High tension lines
8%
Cats
10%
Buildings & windows
55%
Other
10%
0
10
20
30
40
50
60
SOURCE: Wallace P. Erickson, Western EcoSystems Technology, Inc.

- In the November-December Audubon Magazine, John Flicker, President of National Audubon Society, wrote a column stating that Audubon "strongly supports wind power as a clean alternative energy source," pointing to the link between global warming and the birds and other wildlife that scientist say it will kill.



Bat Impacts

Impacts of Wind Power: *Sound*

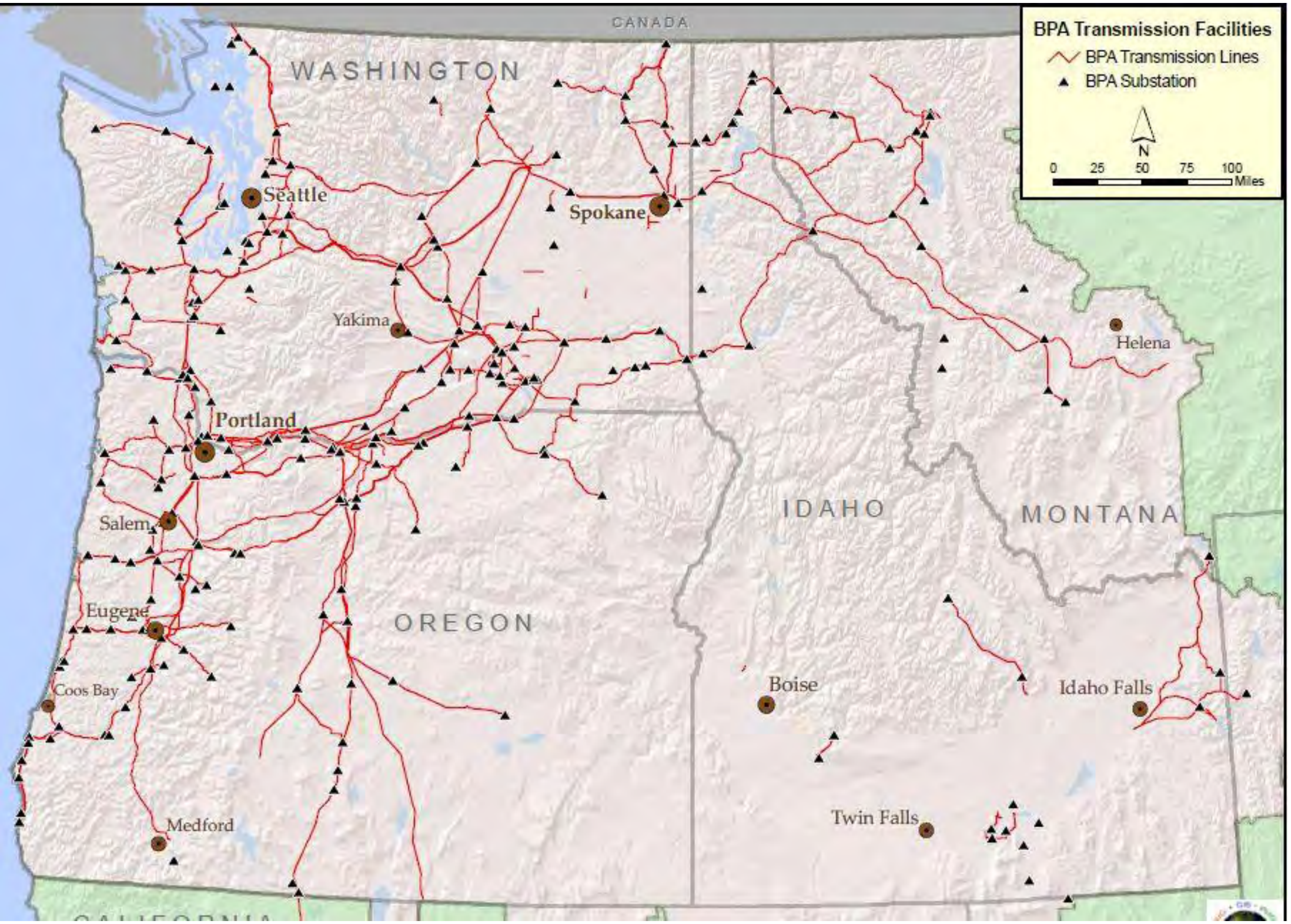


- Modern turbines are relatively quiet
- Rule of thumb – stay about 3x hub-height away from houses
- Annoyance is subjective
- VERY CONTROVERSIAL

Siting and NIMBY

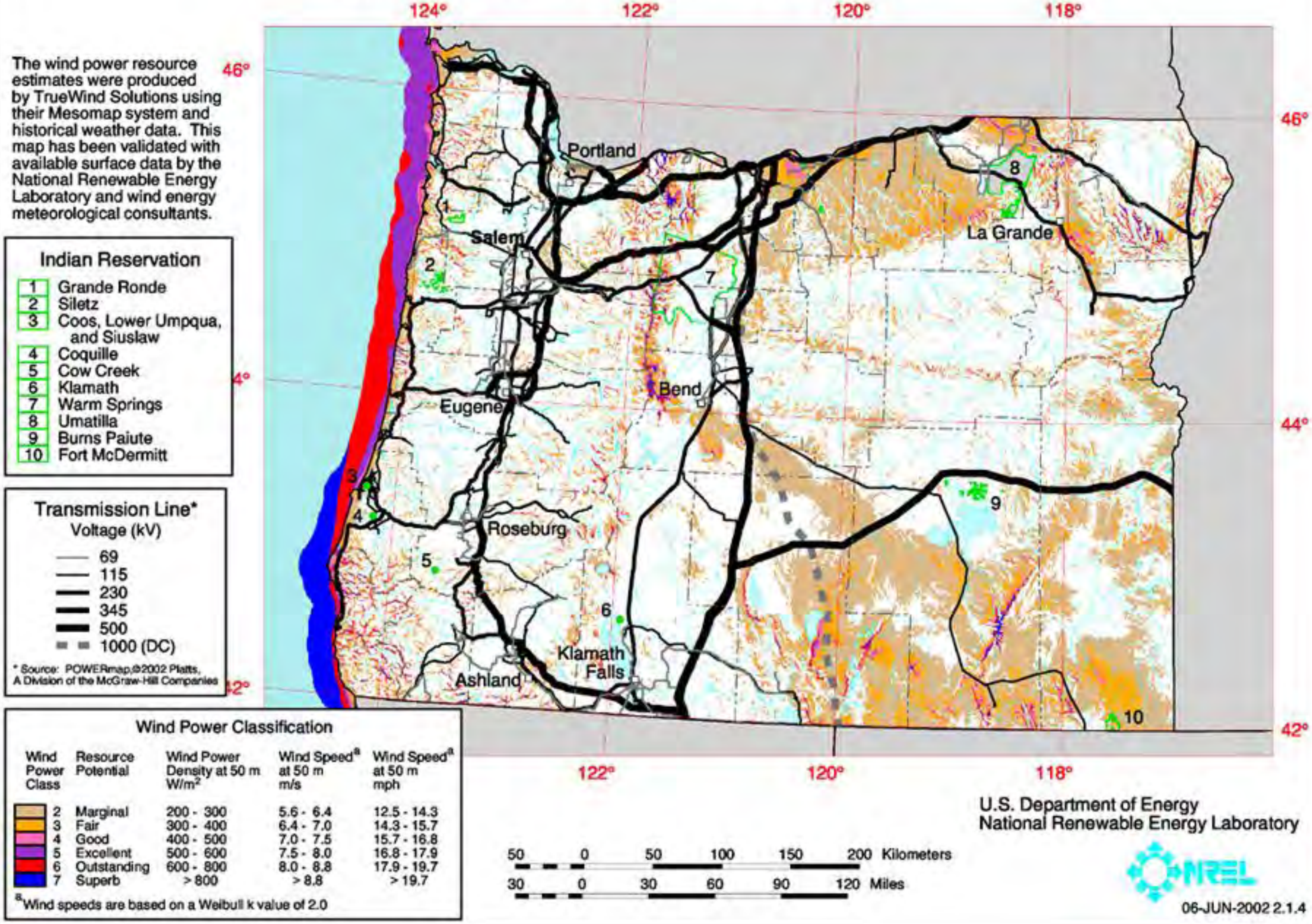
Siting and NIMBY

Transmission Problems



- *Where is the wind?*
- *Where are the population centers?*
- *Where are the wind farms?*
- *How do we get wind energy from the wind farms to the population centers?*

Oregon - Wind Power Resource Estimates



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
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
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	> 8.8	> 19.7

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

Wind Energy in the Classroom

Standards/Skills

- Scientific Inquiry (Collecting & Presenting Data, Performing Experiments, Repeating Trials, Using Models)
- Use of Simple Tools & Equipment
- Motions and Forces
- Transfer of Energy (Forms of Energy)
- Science and Technology in Society
- Populations, resources, and environments
- Circuits/Electricity/Magnetism
- Weather Patterns
- Renewable – Non Renewable Energy
- … much more in STEM

windwise education

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Questions???


The KidWind Project
www.kidwind.org
jon@oregonrenewables.com

How Does A Windmill Work?
WindWise Lesson 8

- Know the fundamental parts of a windmill
- Be able to use the scientific method to isolate and adjust variables in a model windmill
- Understand energy conversion/transfers and how a windmill converts moving air into mechanical energy

Which Blades Are Best?
WindWise Lesson 10

- Understand how wind energy is converted to electricity
- Know the process of scientific inquiry to test blade design variables
- Be able to collect, evaluate, and present data to determine which blade design is best
- Understand the engineering design process

Key Concepts

How do windmills spin?

- Force of the wind
  – Deflection
  – Equal & opposite reaction

Rotor

Wind Speed – Power in the Wind

Torque (turning force)

– a.k.a. leverage

Driveshaft

– Pulley ratio (simple machines)
– Friction

Rotor Variables

- Blade pitch
- Blade shape
- Blade size
- # of blades
- Solidity

Extensions (Advanced Concepts)

ENERGY (J) = Mass (kg) x Acceleration of Gravity (9.8 m/s^2) x Height (m)

POWER (W) = Energy (J) / Time (s)

Economics: Each item you use has a dollar value attributed to it. What was the cost of your windmill? Cost of energy?