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WIND AND ITS POTENTIAL FOR ENERGY

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Wind Energy Potential In Rural America

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Disclaimer

The views presented in this presentations are mine and do not necessarily represent the views of any governmental agency, industry group, or NGO.

Is thar gold in dem thar…

- Hills?
- Plains?
- Sea Shores?
- Rangeland?
- Soybeans?
- Wheat?

Take Home Message: A Complete Resource Assessment is Essential

- Wind speed and direction at multiple levels
- Extreme Weather Events – including historical records
- Air density (pressure and temperature)
- Environmental Issues – birds, bats, scenic views
- Transmission Issues
- More

Meteorological Assessment

- Minimum of 3 years
- Compare to historical record – tremendous economic loss if extreme events are not included

Importance of Knowing the Real Wind Energy Resource

- Momentum = mv
- Kinetic Energy = $\frac{1}{2} mv^2$
- Power = $\frac{1}{2} \rho v^3$
  - where air density, $\rho = P/R_d T_v$

Wind Power is a Cubic Function of the Wind Speed

How much more power will I get from a 15 mph wind compared to a 13 mph wind (assume same air density) ?

$(15\ \text{mph})^3 / (13\ \text{mph})^3 =$

Wind Power is a Cubic Function of the Wind Speed

How much more power will I get from a 15 mph wind compared to a 13 mph wind (assume same air density)?

$$(15 \text{ mph})^3 / (13 \text{ mph})^3 = 1.54$$

While I Cannot Tell the Difference Between 13 mph and 15 mph Wind

The wind power potential of the 15 mph wind is 54% more than 13 mph.

That could be the difference between making money and going broke!

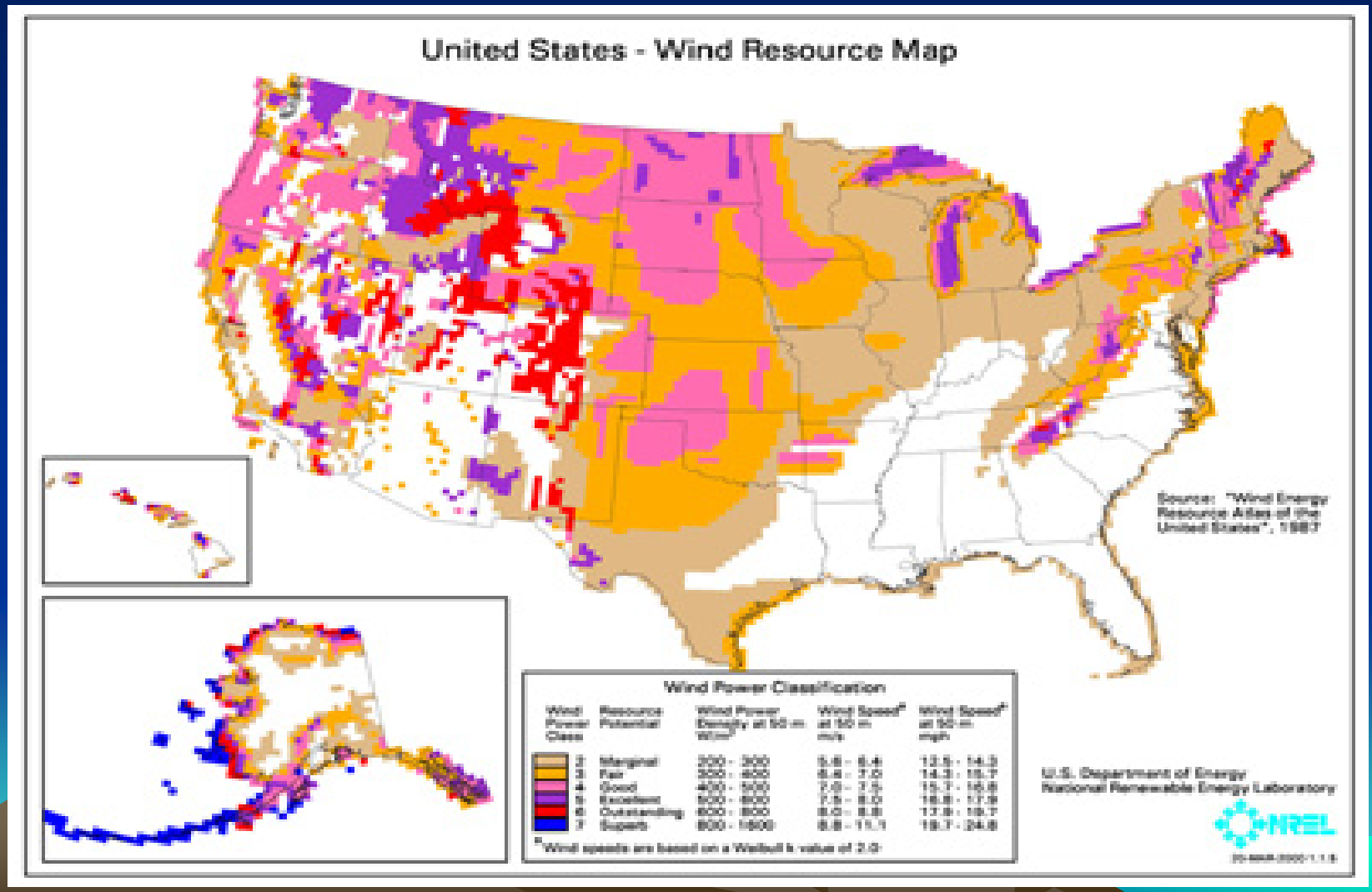
Steps in the Wind Energy Resource Assessment: A Brief Outline

- Wind Energy Resource Maps
- Site Selection
  - Wind resources
  - Network Connectivity
  - Environmental Concerns
- Collect a minimum of 3 years of data
- Social-Economic Analysis
  - Tax benefits
  - Public Interest
  - Political Support
- Go or No Go

I Am Going to Concentrate On

- Wind Energy Resource Maps
- Site Selection
  - Wind resources
  - Environmental Concerns
- Collect a minimum of 3 years of data

1980s National Wind Energy Resource Assessment

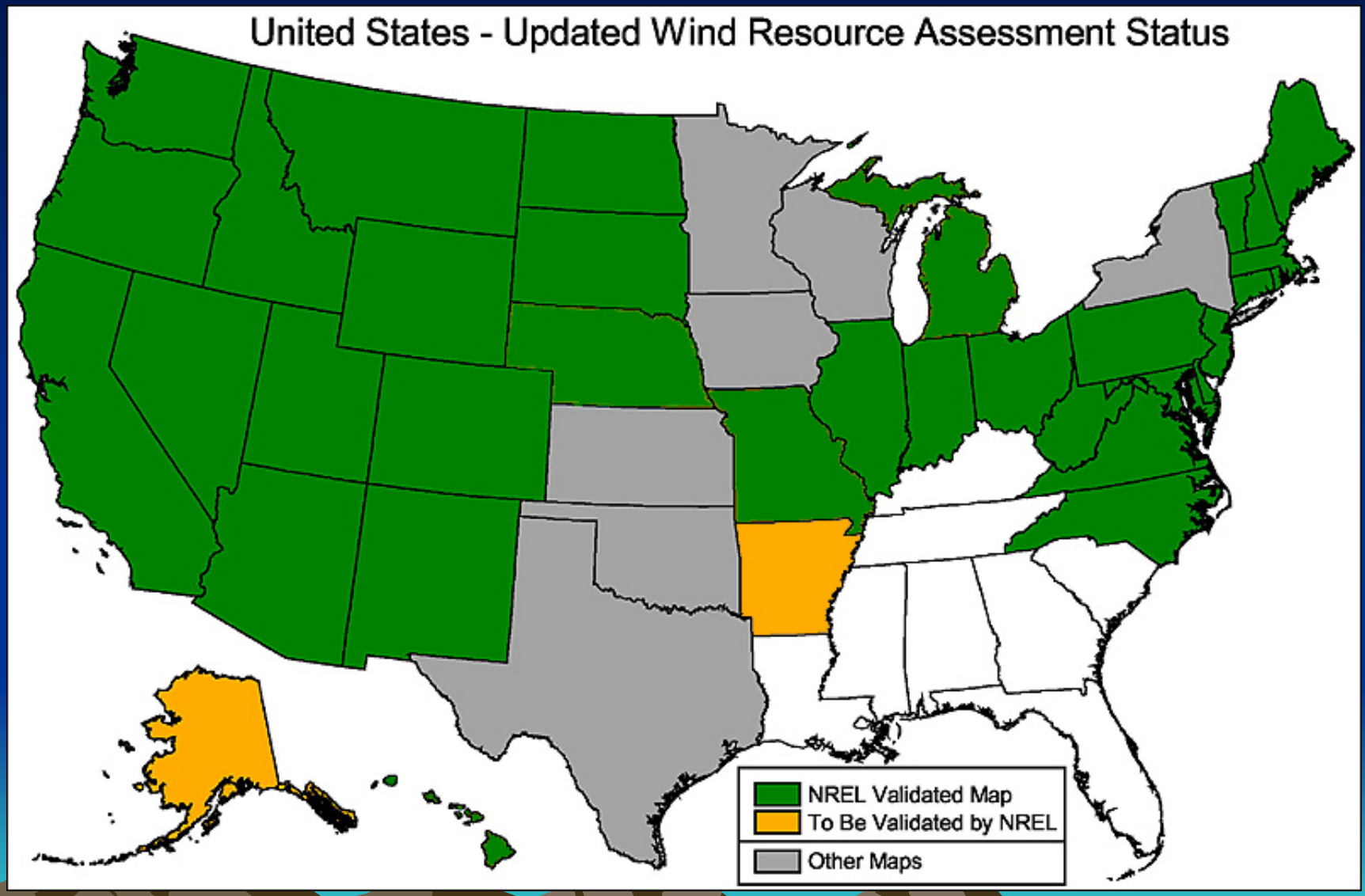


Are you still using your 1980s computer? What did it do for you?

- Got you started
- You did excellent work for the 1980s – my dissertation was done on an Mac SE 30
- You showed us your potential
- And a few us became breakout leaders

Where Are We Now?
Not in the 80s

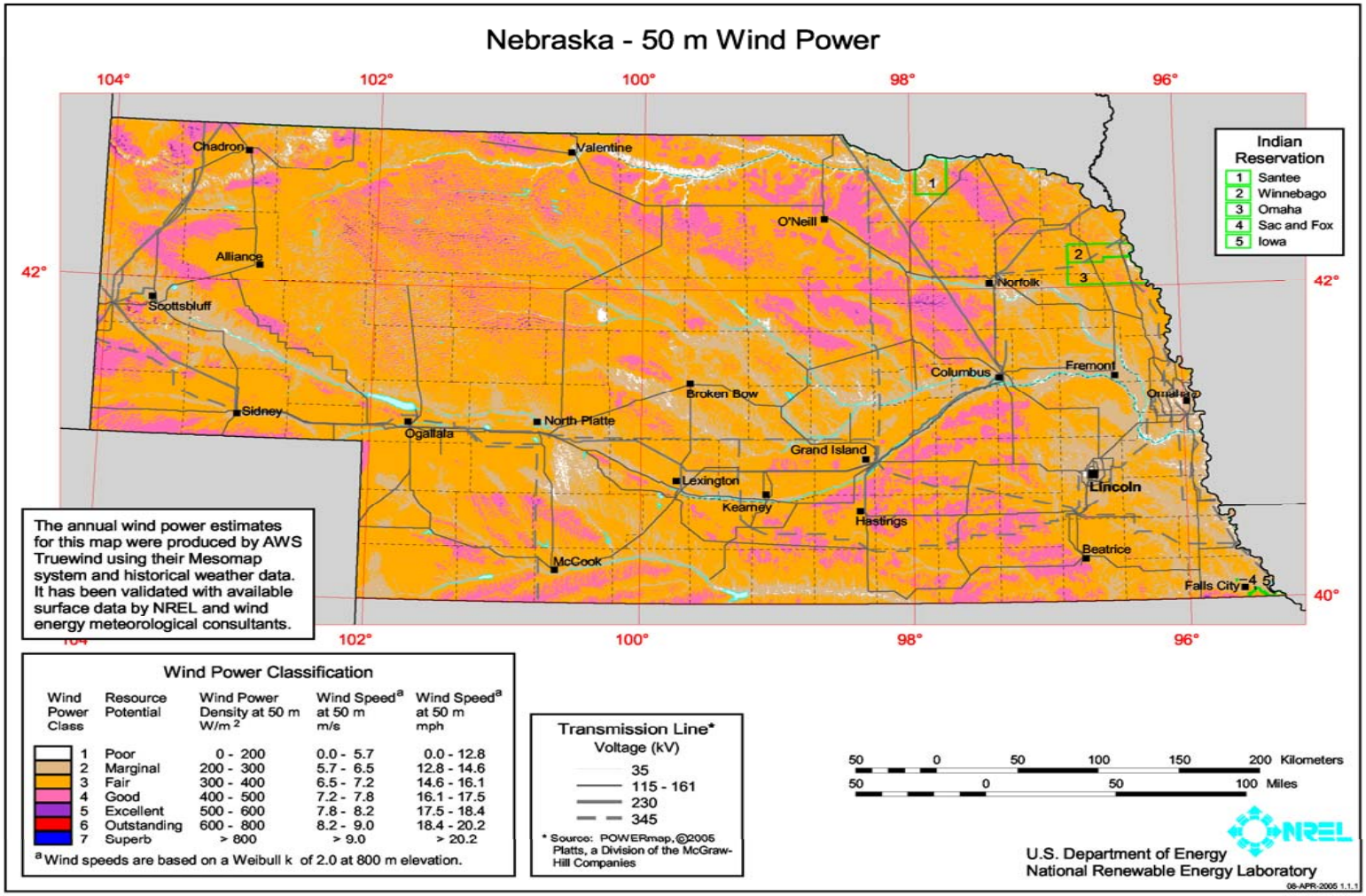
- www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp
- “windpoweringamerica” is one word
- State by state maps – much more detailed


United States - Updated Wind Resource Assessment Status
NREL Validated Map
To Be Validated by NREL
Other Maps

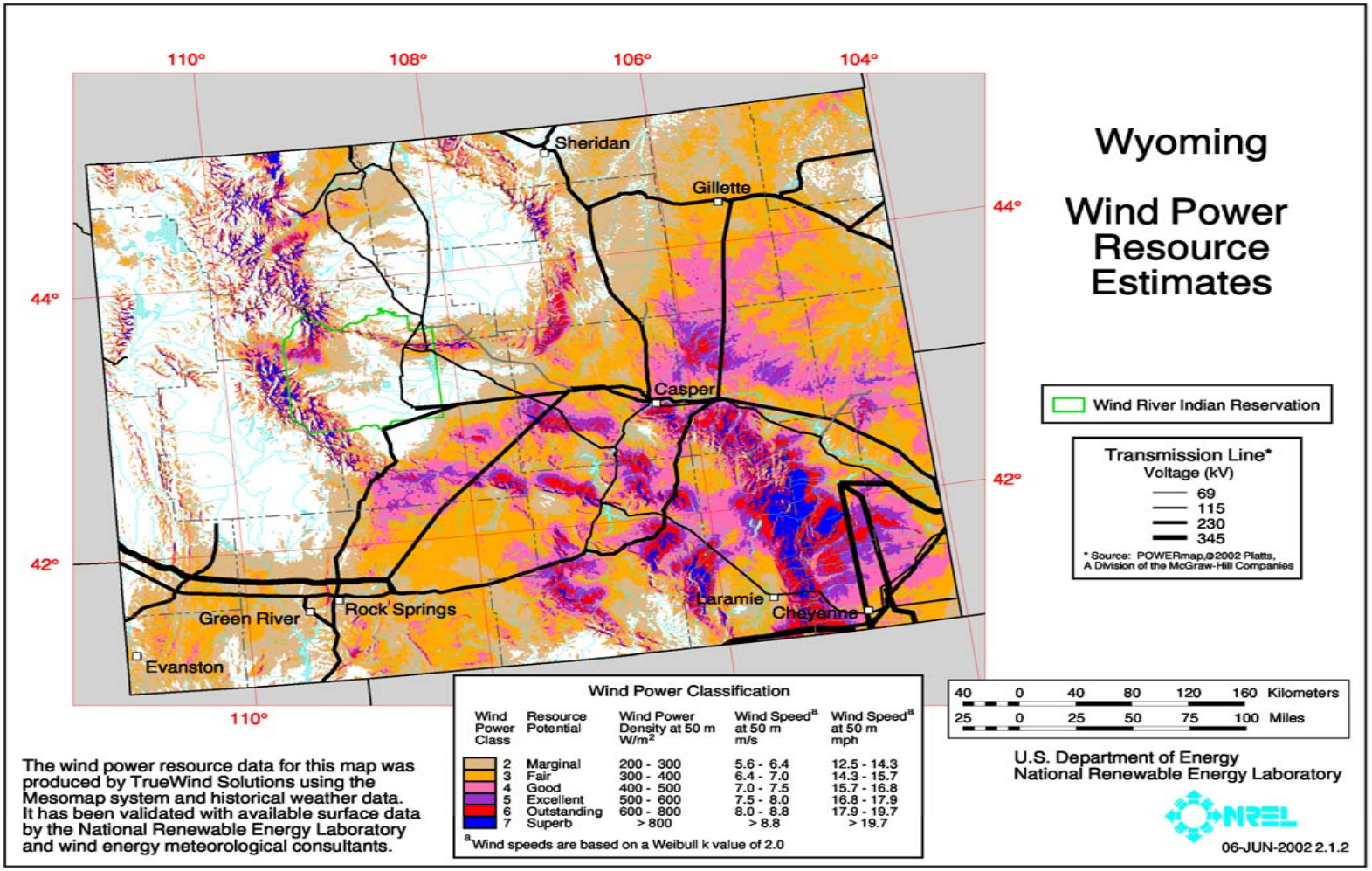
Caution

- A complete site specific wind energy resource assessment still needs to be done.
- The Take Home Message: A Complete Resource Assessment is Essential

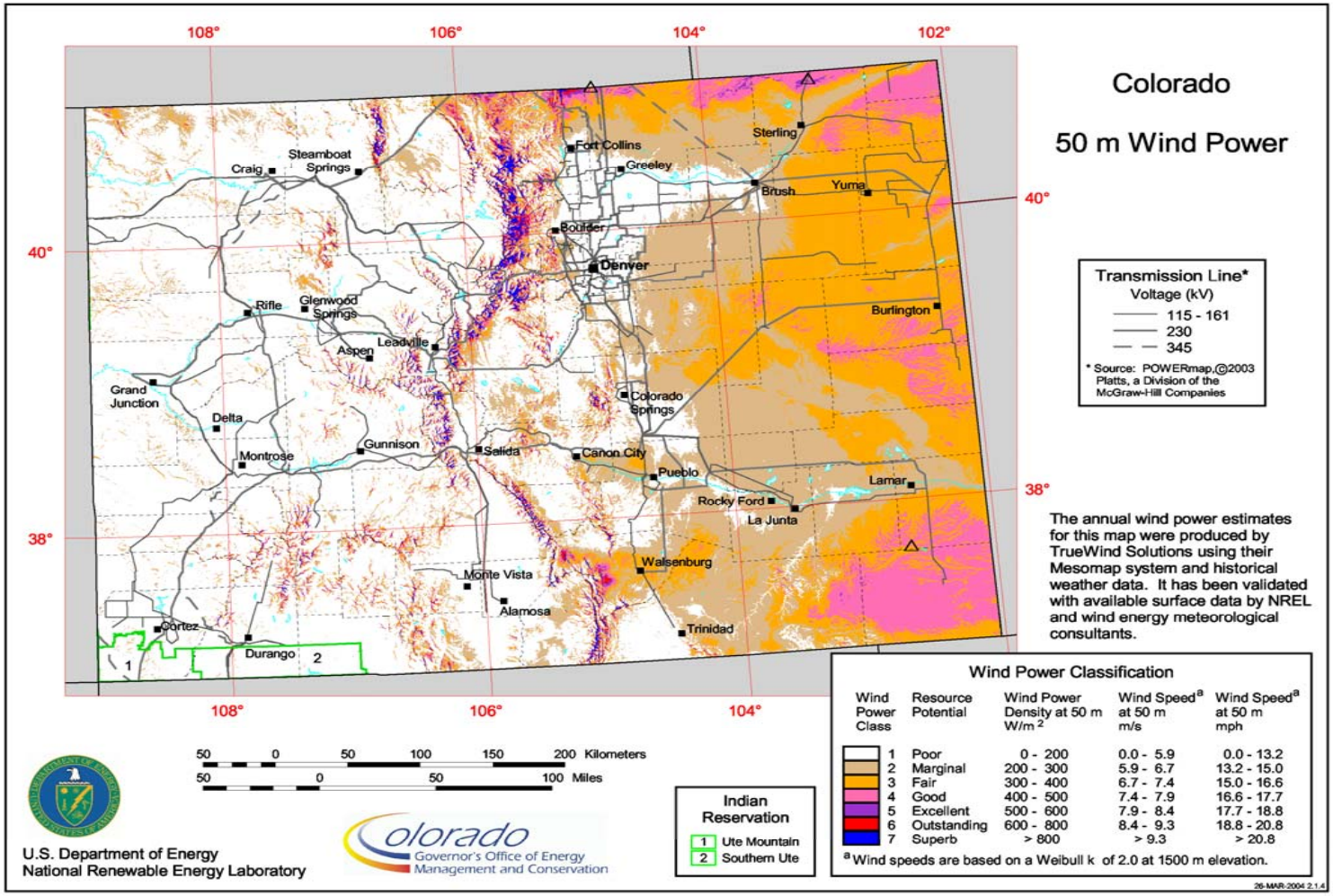
Nebraska


Nebraska - 50 m Wind Power
104°
102°
100°
98°
96°
42°
40°
Chadron
Valentine
O'Neill
Alliance
Scottsbluff
Norfolk
Columbus
Fremont
Broken Bow
Sidney
Ogallala
North Platte
Grand Island
Lexington
Kearney
Hastings
Lincoln
Beatrice
McCook
Falls City
Indian Reservation
1 Santee
2 Winnebago
3 Omaha
4 Sac and Fox
5 Iowa
The annual wind power estimates for this map were produced by AWS Truewind using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.
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
1 Poor 0 - 200 0.0 - 5.7 0.0 - 12.8
2 Marginal 200 - 300 5.7 - 6.5 12.8 - 14.6
3 Fair 300 - 400 6.5 - 7.2 14.6 - 16.1
4 Good 400 - 500 7.2 - 7.8 16.1 - 17.5
5 Excellent 500 - 600 7.8 - 8.2 17.5 - 18.4
6 Outstanding 600 - 800 8.2 - 9.0 18.4 - 20.2
7 Superb > 800 > 9.0 > 20.2
[a] Wind speeds are based on a Weibull k of 2.0 at 800 m elevation.
Transmission Line*
Voltage (kV)
35
115 - 161
230
345
* Source: POWERmap, ©2005 Platts, a Division of the McGraw-Hill Companies
50 0 50 100 150 200 Kilometers
50 0 50 100 Miles
U.S. Department of Energy
National Renewable Energy Laboratory
08-APR-2005 1.1.1

Wyoming


110°
108°
106°
104°
44°
42°
Sheridan
Gillette
Casper
Laramie
Cheyenne
Rock Springs
Green River
Evanston
Wyoming
Wind Power Resource Estimates
Wind River Indian Reservation
Transmission Line*
Voltage (kV)
69
115
230
345
* Source: POWERmap,@2002 Platts, A Division of the McGraw-Hill Companies
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
40 0 40 80 120 160 Kilometers
25 0 25 50 75 100 Miles
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
06-JUN-2002 2.1.2
The wind power resource data for this map was produced by TrueWind Solutions using the Mesomap system and historical weather data. It has been validated with available surface data by the National Renewable Energy Laboratory and wind energy meteorological consultants.

Colorado


Colorado
50 m Wind Power
108°
106°
104°
102°
40°
38°
Steamboat Springs
Craig
Fort Collins
Greeley
Sterling
Brush
Yuma
Boulder
Denver
Rifle
Glenwood Springs
Aspen
Leadville
Burlington
Grand Junction
Delta
Colorado Springs
Montrose
Gunnison
Salida
Canon City
Pueblo
Lamar
Rocky Ford
La Junta
Walsenburg
Monte Vista
Alamosa
Cortez
Durango
Trinidad
1
2
Transmission Line*
Voltage (kV)
115 - 161
230
345
* Source: POWERmap,@2003 Platts, a Division of the McGraw-Hill Companies
The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.
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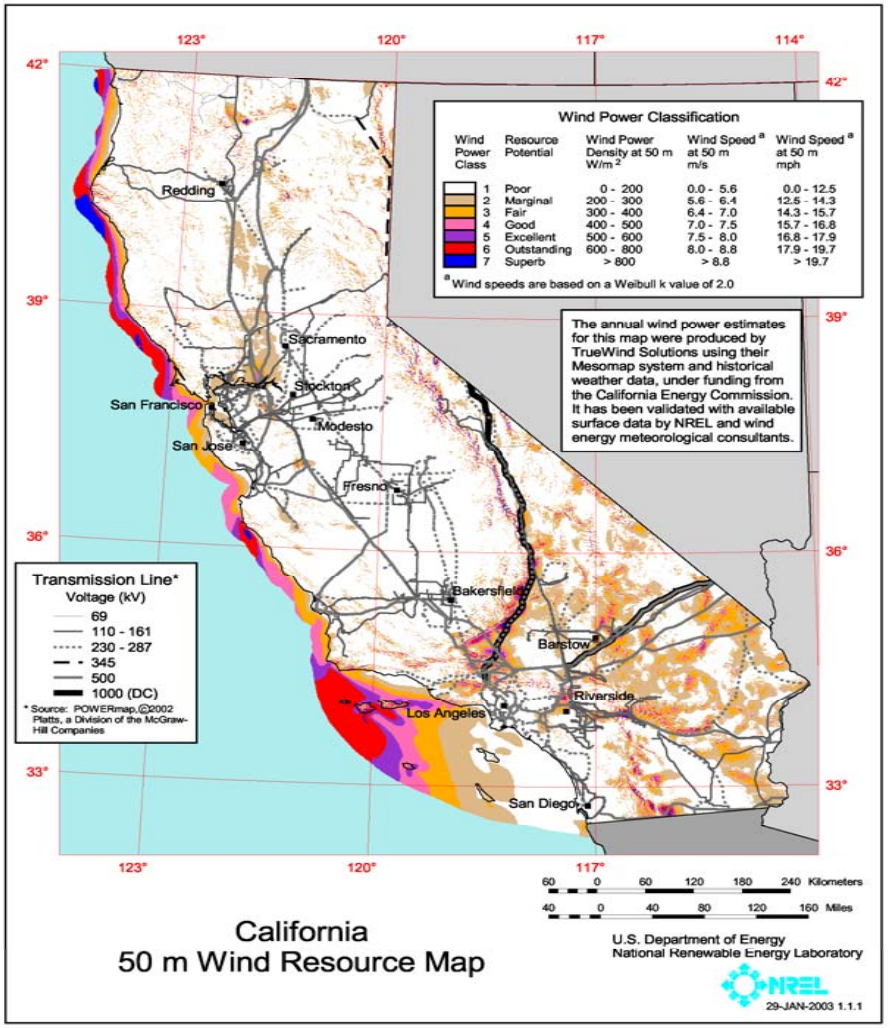
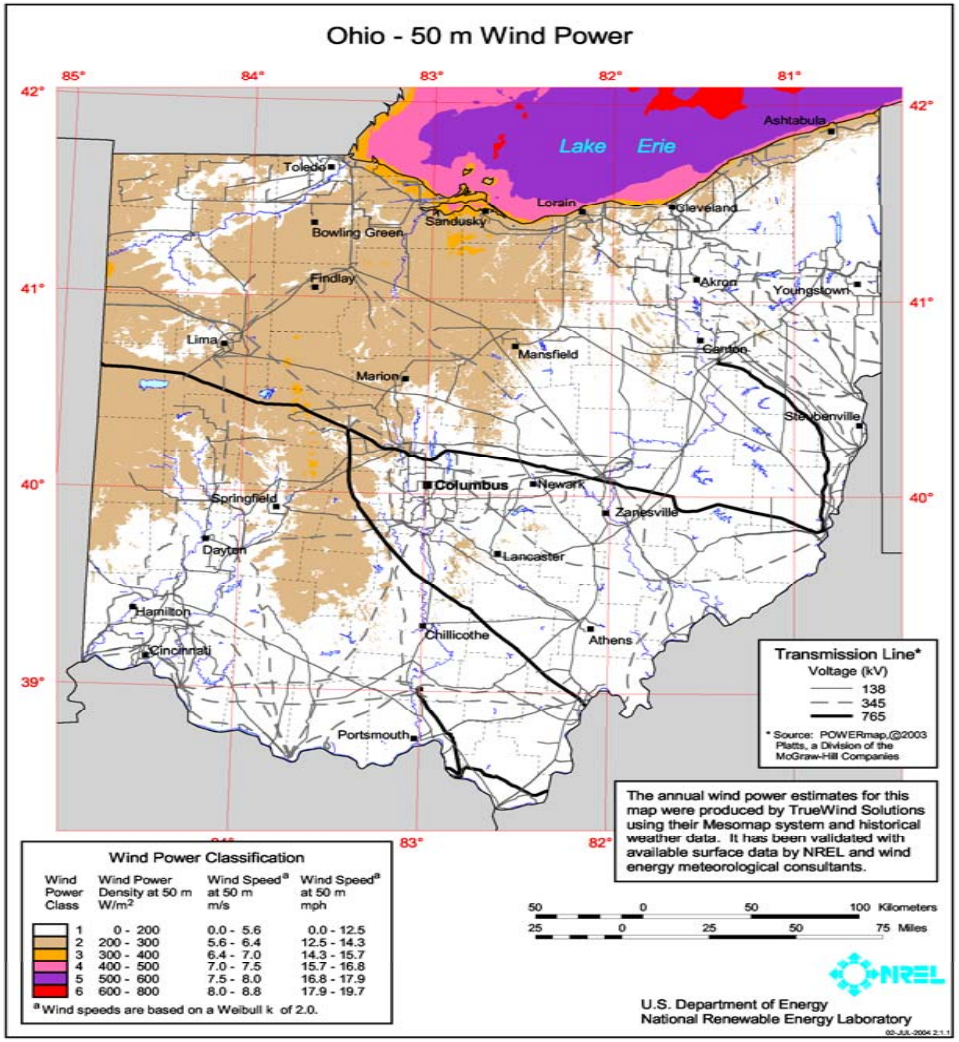
3 Fair 300 - 400 6.7 - 7.4 15.0 - 16.6
4 Good 400 - 500 7.4 - 7.9 16.6 - 17.7
5 Excellent 500 - 600 7.9 - 8.4 17.7 - 18.8
6 Outstanding 600 - 800 8.4 - 9.3 18.8 - 20.8
7 Superb > 800 > 9.3 > 20.8
[a] Wind speeds are based on a Weibull k of 2.0 at 1500 m elevation.
50 0 50 100 150 200 Kilometers
50 0 50 100 Miles
Indian Reservation
1 Ute Mountain
2 Southern Ute
U.S. Department of Energy
National Renewable Energy Laboratory
Colorado
Governor's Office of Energy Management and Conservation
26-MAR-2004 2.1.4

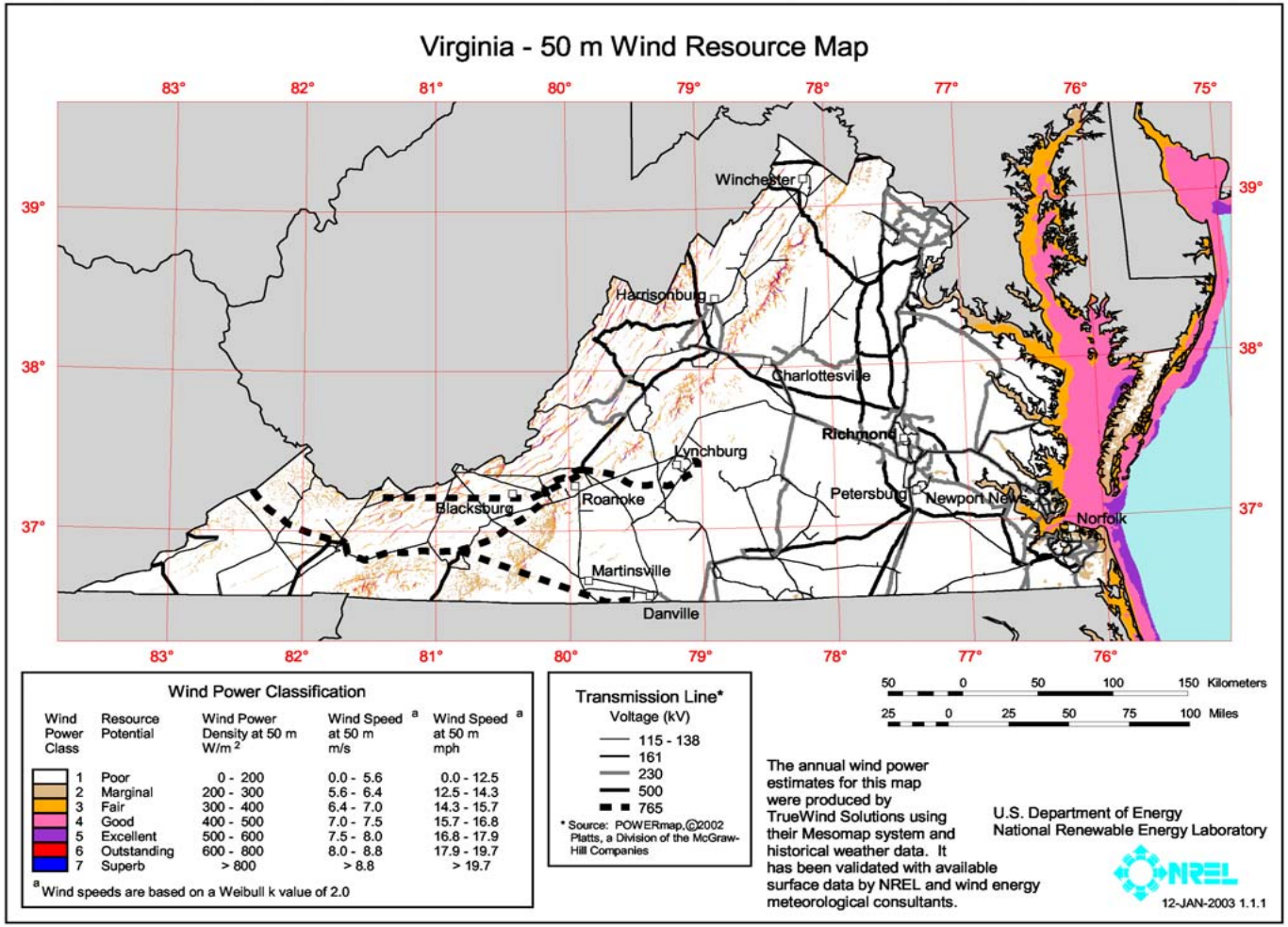
California


123°
120°
117°
114°
42°
39°
36°
33°
Redding
Sacramento
Stockton
San Francisco
Modesto
San Jose
Fresno
Bakersfield
Barstow
Riverside
Los Angeles
San Diego
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
1 Poor 0 - 200 0.0 - 5.6 0.0 - 12.5
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
The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data, under funding from the California Energy Commission. It has been validated with available surface data by NREL and wind energy meteorological consultants.
Transmission Line*
Voltage (kV)
69
110 - 161
230 - 287
345
500
1000 (DC)
* Source: POWERmap, ©2002 Platts, a Division of the McGraw-Hill Companies
60 0 60 120 180 240 Kilometers
40 0 40 80 120 160 Miles
California
50 m Wind Resource Map
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
29-JAN-2003 1.1.1

Ohio


Ohio - 50 m Wind Power
85°
84°
83°
82°
81°
42°
41°
40°
39°
Lake Erie
Ashtabula
Toledo
Lorain
Cleveland
Sandusky
Bowling Green
Findlay
Akron
Youngstown
Lima
Mansfield
Canton
Marion
Steubenville
Columbus
Newark
Springfield
Zanesville
Dayton
Lancaster
Hamilton
Chillicothe
Athens
Cincinnati
Portsmouth
Transmission Line*
Voltage (kV)
138
345
765
* Source: POWERmap,@2003 Platts, a Division of the McGraw-Hill Companies
The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.
Wind Power Classification
Wind Power Class
Wind Power Density at 50 m W/m²
Wind Speed[a] at 50 m m/s
Wind Speed[a] at 50 m mph
1 0 - 200 0.0 - 5.6 0.0 - 12.5
2 200 - 300 5.6 - 6.4 12.5 - 14.3
3 300 - 400 6.4 - 7.0 14.3 - 15.7
4 400 - 500 7.0 - 7.5 15.7 - 16.8
5 500 - 600 7.5 - 8.0 16.8 - 17.9
6 600 - 800 8.0 - 8.8 17.9 - 19.7
[a] Wind speeds are based on a Weibull k of 2.0.
50 0 50 100 Kilometers
25 0 25 50 75 Miles
NREL
U.S. Department of Energy
National Renewable Energy Laboratory

Virginia


Virginia - 50 m Wind Resource Map
83°
82°
81°
80°
79°
78°
77°
76°
75°
39°
38°
37°
Winchester
Harrisonburg
Charlottesville
Richmond
Lynchburg
Blacksburg
Roanoke
Petersburg
Newport News
Norfolk
Martinsville
Danville
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
1 Poor 0 - 200 0.0 - 5.6 0.0 - 12.5
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
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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
Transmission Line*
Voltage (kV)
115 - 138
161
230
500
765
* Source: POWERmap, ©2002 Platts, a Division of the McGraw-Hill Companies
50 0 50 100 150 Kilometers
25 0 25 50 75 100 Miles
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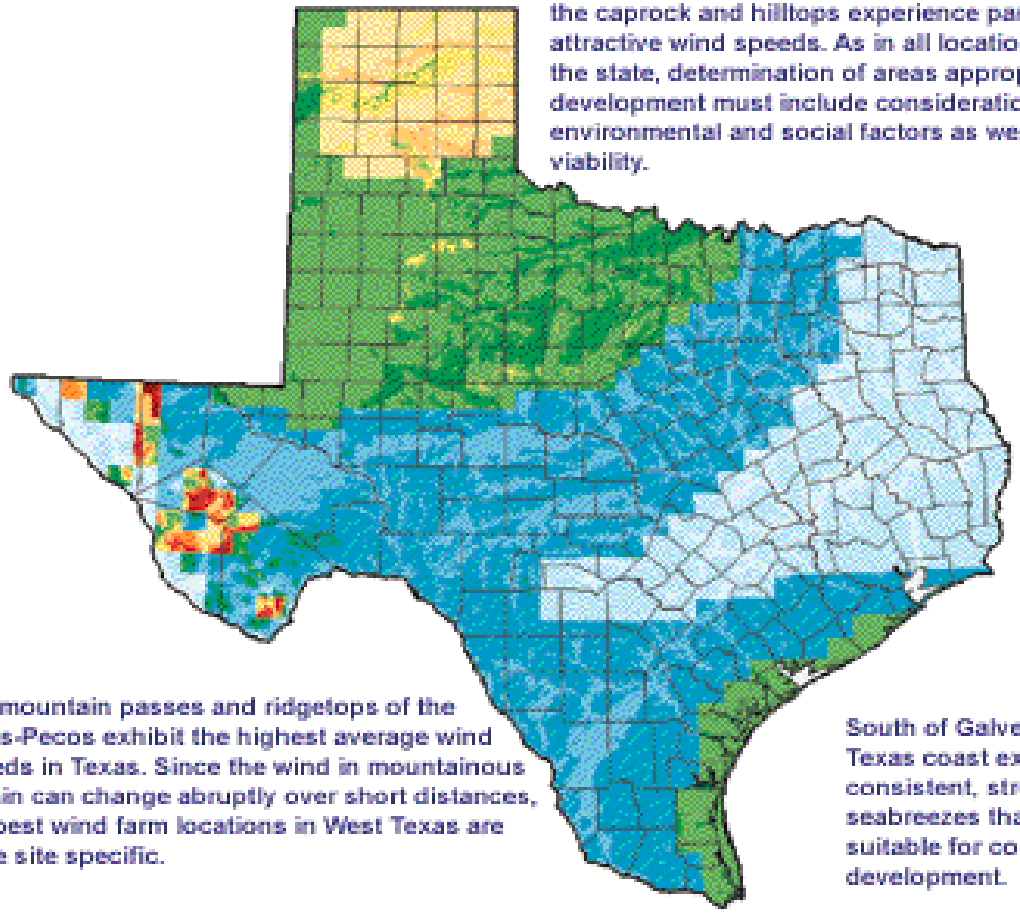
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
12-JAN-2003 1.1.1

Texas

The Panhandle contains the state's greatest expanse with high quality winds. Well-exposed locations atop the caprock and hilltops experience particularly attractive wind speeds. As in all locations throughout the state, determination of areas appropriate for development must include consideration of environmental and social factors as well as technical viability.



The mountain passes and ridgetops of the Trans-Pecos exhibit the highest average wind speeds in Texas. Since the wind in mountainous terrain can change abruptly over short distances, the best wind farm locations in West Texas are quite site specific.

South of Galveston, the Texas coast experiences consistent, strong seabreezes that may prove suitable for commercial development.

Georgia Research

- On Shore
  - Class 3 east of I-95
  - Sea Breeze
  - Afternoon Peaking

Probably holds true for the southeastern states in general – marginal to good along the coast for peaking power

Better wind energy potential in the southern mountains but the economic value of the vistas is more important

Meteorological Data Collection

- Now that we have a good idea where to look
  - Good wind energy potential based on wind energy resource potential maps
  - Connectivity Issues
  - Known environmental or social-political stoppers
- It is time to collect the data

Meteorological Data Collection

- Warning: Don’t fall into the trap that you are collecting data for the region and not for a particular site. I have seen too many regional wind energy resource data collection studies become site specific studies.

Meteorological Data Collection

- ***For the Most Recent Standards***
  - ***Standard Procedures for Meteorological Measurements at a Potential Wind Turbine Site - Standard 8.1***

  American Wind Energy Association (AWEA)

What Data Do You Need?

- Times have changed
  - Early 1990s: Hub height 35 m
  - Middle 1990s: Hub height 50 m
  - Late 1990s: Hub height 65 m
  - 2006: Hub height 80 m
  - Soon: Hub height 100 m

Reason for Increasing Hub Height

The wind speed generally increases with height

Historically micrometeorologists used the $1/7^{th}$ power law. It almost never works; the atmosphere is not that simple.

The 1/7th Power Law

$$[S_{(z)} / S_{(z_{ref})}] = [z / z_{ref}]^{a}$$

Where a = 1/7 (0.13)

Once wind developers started making actual measurements, they found that the assumed 1/7th generally underestimated the actual increase in wind speed with height in the plains.

The 1/7th Power Law

$$S_{(z)} = S_{(z_{ref})} [z / z_{ref}]^{0.13}$$

What Is the Expected Wind Speed and Increase in Power Potential at Various Heights if the 25 m Wind Speed is 10 mph?

- Early 1990s: Hub height 35 m → 10.4 mph (12 %)
- Middle 1990s: Hub height 50 m → 10.9 mph (30%)
- Late 1990s: Hub height 65 m → 11.3 mph (44%)
- 2006: Hub height 80 m → 11.6 mph (56%)
- Soon: Hub height 100 m → 12.0 mph (73%)

Assumed 1/7th power law

The Exponent is Site Specific

My Recommendation for Wind Speed and Direction Measurements

5 minute average wind speed and direction and peak wind speed at

- 10 m
- 25 m
- 50 m
- 80 m
- 100 m

Other Meteorological Elements

- Surface pressure
- Temperature and Humidity at least at 10 m and hub height (100 m)
- Solar Radiation (it is cheap and easy to gather this data, might be useful later)

Other Meteorological Issues

Surface roughness & shear
Escarpments
Variable winds
Turbulence
Wind obstacles
Wind shade
Wake
The park effect
The tunnel effect
The hill effect
Turbine siting

Other Meteorological Data Recommendations

- I am an atmospheric scientist – the more data the better
- Used Calibrated Instruments that are traceable back to a standard – regional resource assessments have a tendency to become site specific
- QC/QA the data daily – with cellular modems this should not be an issue any more – besides equipment failure, watch for instrument drift
- Have a maintenance budget and schedule, complete checks should be done at least twice a year; calibrations at least once a year
- Wind energy projects are investments of millions of dollars – don't skimp on data collection, use good equipment

Environmental Issues

- Wind Turbine are Ugly and Noisy
  - The choice is not wind turbines or no wind turbines
  - What is beauty?
  - Modern vs. ancient (1980s wind turbines)
- Wind Turbines Kill Raptors
  - Yes birds are killed by wind turbines, automobiles, buildings, etc.
  - Numbers killed have been greatly reduced
- Wind Turbines Do Not Offset Pollution because they only operate part of the time
  - Properly sited turbines will operate 65 to 80% of the time (AWEA)
  - No power plant is online 100% of the time
  - Redundancy in the system
  - Depends on the purpose, base power or peaking power

Economic Benefits for Rural America

Yes!

If the homework is done first!

Very location specific.

Follows the three most important rules in real estate …

Economic Benefits for Rural America

Can be combined with farming and ranching

- An additional, stable source of income
- Increases local tax base
- Home “grown” energy
- Modular, can grow over time and take advantage of improved technologies
- Stable Energy Prices – the input, wind, is free

Economic Benefits for Rural America

Landowners with wind development on their property receive $2,000 to $5,000 per turbine per year. US DOE

(web accessed 02/14/2006 www.eere.energy.gov/windandhydro/windpoweringamerica/ag_sector.asp)

Additional Web Resources

DOE: **Wind Energy Development and the Agricultural Community**

www.eere.energy.gov/windandhydro/windpoweringamerica/ag_sector.asp

Additional Web Resources

DOE: **National Renewable Energy Lab**

www.nrel.gov/wind/

Additional Web Resources

Farm Bureau

www.iowafarmbureau.com/windassessments/

Iowa Farm Bureau launches online wind energy assessments (Oct. 7, 2005)

Additional Web Resources

Alternative Energy Institute (1977)
West Texas A&M University

www.windenergy.org/index.htm

Excellent source of semi-technical to technical research reports and books.

Additional Web Resources

American Wind Energy Association

www.awea.org

Additional Web Resources

www.eere.energy.gov/windandhydro/windpoweringamerica/ag_sector.asp

www.nrel.gov/wind/

www.iowafarmbureau.com/windassessments/

www.windenergy.org/index.htm

www.awea.org


AERMOTOR