Wind Resource Assessment

D. Elliott, M. Schwartz, G Scott, S Haymes, D Heimiller, R George
National Renewable Energy Laboratory
Golden, Colorado

WEATS
August 9, 2006
NREL Golden, Colorado

WIND POWER RELATIONSHIPS

$$P = \frac{1}{2} \rho A V^3$$

- P → AVAILABLE POWER
- ρ → AIR DENSITY
- A → SWEPT AREA
- V^3 → WIND VELOCITY CUBED

EXAMPLE: SAME TURBINE, SEA LEVEL, DIFFERENT SITE

$$P = KV^3$$

WIND VELOCITY = v $\quad P_1 = Kv^3$

WIND VELOCITY = $2v$ $\quad P_2 = 8Kv^3$

$$P_2 = 8P_1$$

EXAMPLE: DIFFERENT TURBINE, SEA LEVEL, SAME SITE

$$P = CD^2$$

ROTOR DIAMETER = d $\quad P_1 = Cd^2$

ROTOR DIAMETER = $2d$ $\quad P_2 = 4Cd^2$

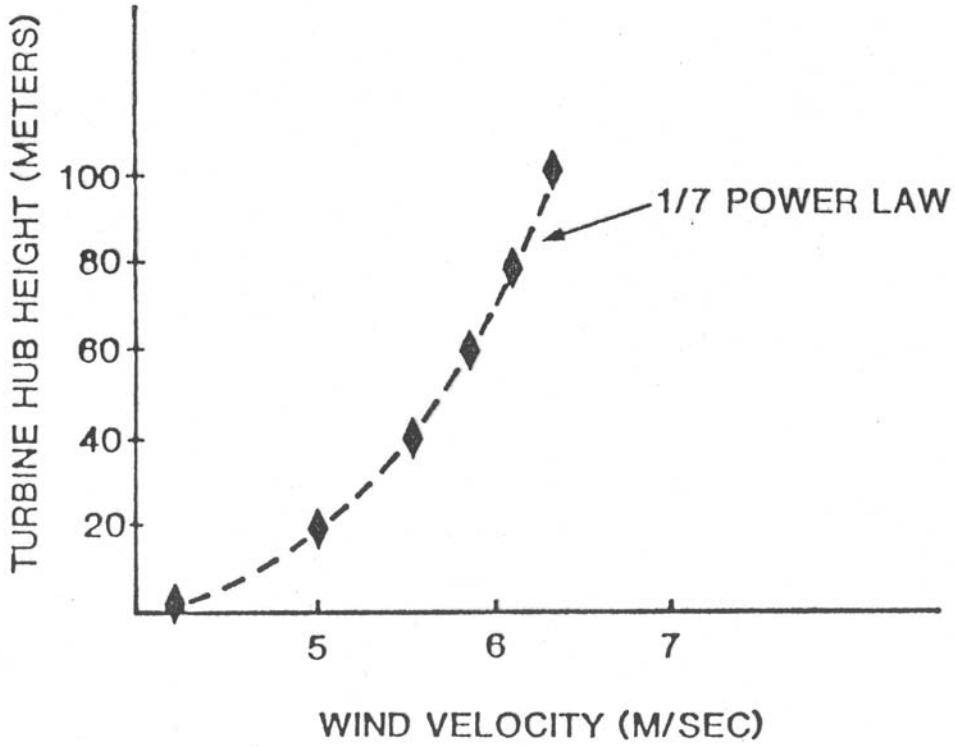
$$P_2 = 4P_1$$

NREL

WIND VELOCITY VERSUS ALTITUDE

$$\frac{V}{V_o} = \left(\frac{H}{H_o}\right)^n$$

WHERE: V_o = REFERENCE WIND VELOCITY
H_o = REFERENCE HEIGHT
n = DEPENDENT EXPONENT



Comparison of Annual Average Wind Power at Four Sites with Identical Annual Average Wind Speeds at 10 m

Site	Annual Average Wind Speed, m/s (mph)	Annual Average Wind Power Density, W/m²	Wind Power Power Class
Constant Wind Speed (hypothetical)	6.3 (14)	150	2-3
Culebra, Puerto Rico	6.3 (14)	220	4
Tiana Beach, New York	6.3 (14)	285	5
San Gorgonio, California	6.3 (14)	365	6

S9106046.5

NREL

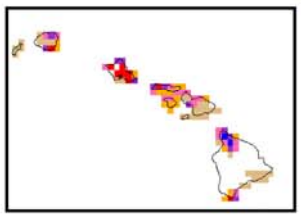
Wind Power Classification

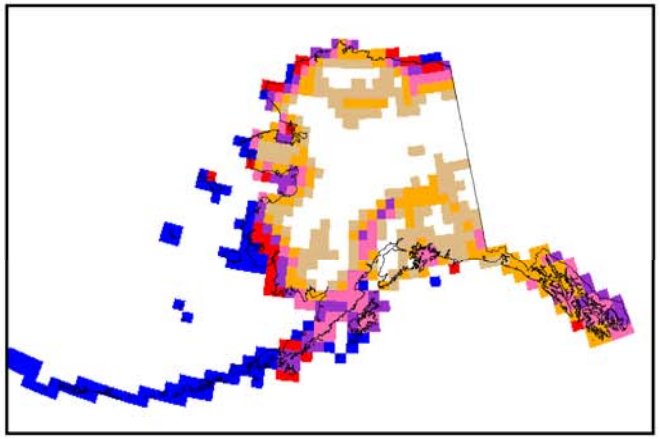
Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

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

NREL

United States - Wind Resource Map





Source: "Wind Energy Resource Atlas of the United States", 1987

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
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 - 1600	8.8 - 11.1	19.7 - 24.8

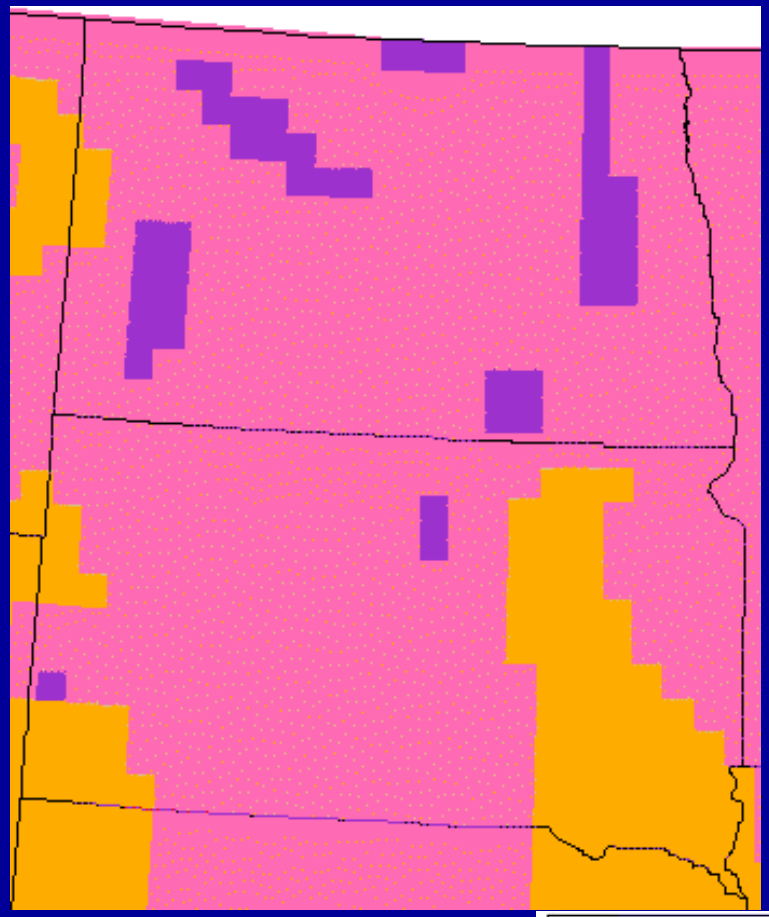
[a] Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory

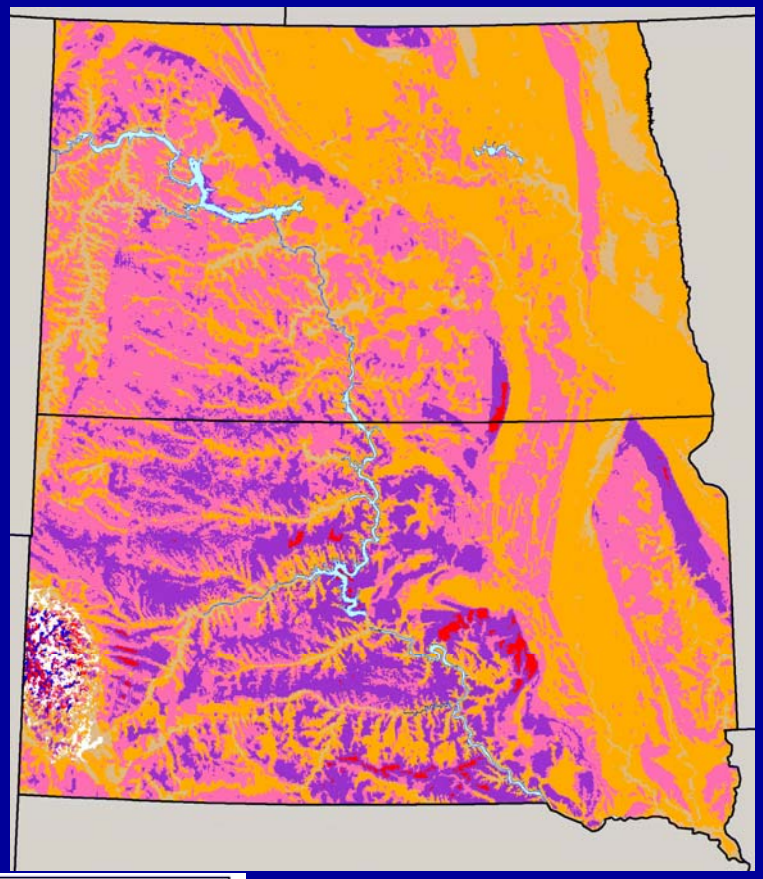
NREL

20-MAR-2000 1.1.5

Comparison of Digital Wind Map from 1987 U.S. Wind Atlas and New (2000) High-Resolution (1-km^2) Wind Map North and South Dakota



1987



2000

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
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 - 1600	8.8 - 11.1	19.7 - 24.8

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

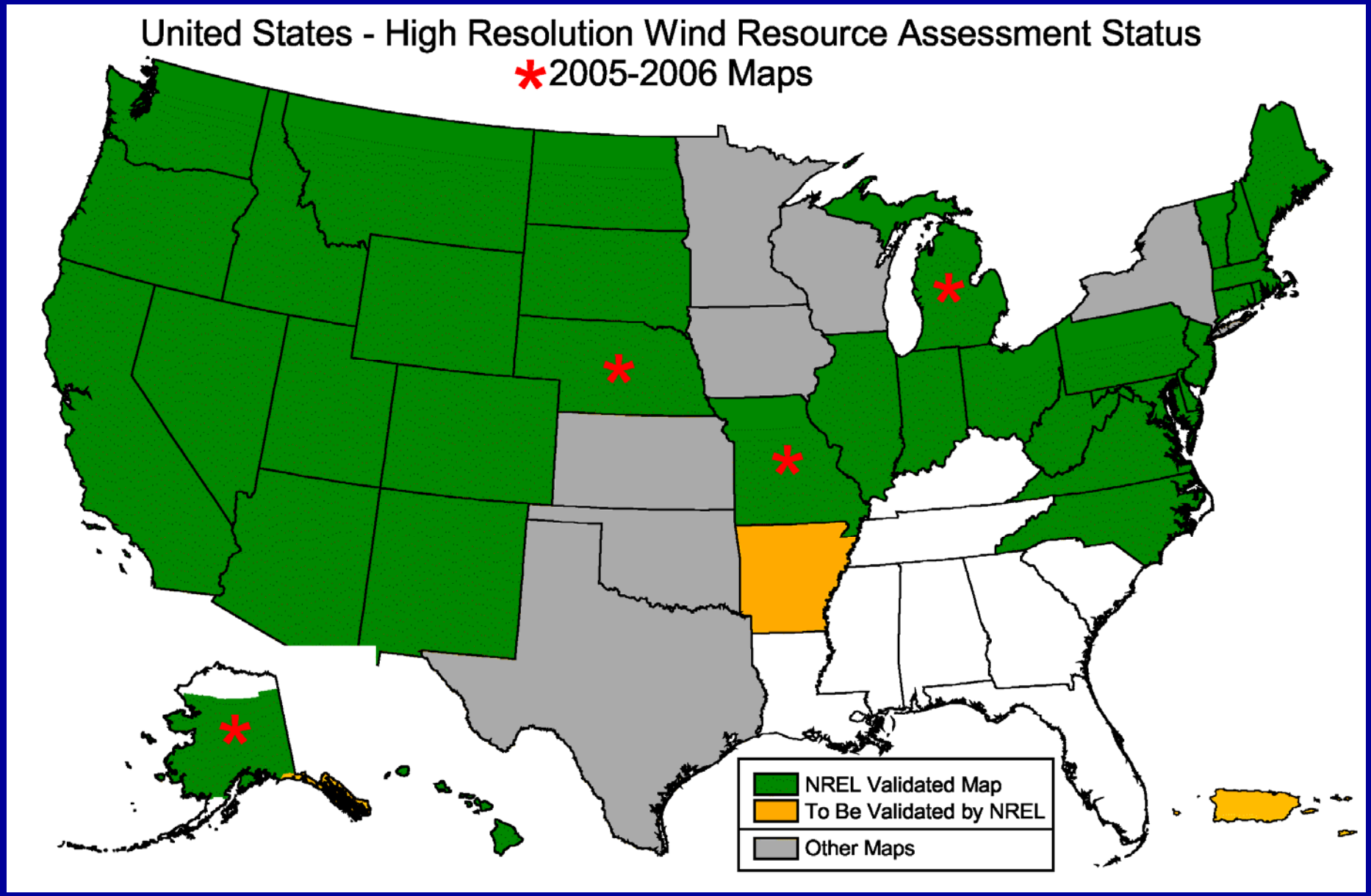
Wind Mapping Approach

- Computerized mapping approach using Geographical Information System (GIS) software (ArcInfo® and ArcView®)
- Designed for regional wind mapping (not micrositing)
- Combination of analytical, numerical, and empirical methods
- Does not depend on high-quality surface wind observations (but it helps)
- Produces high resolution (1 km^2 or finer) wind power maps

Validation of Wind Maps

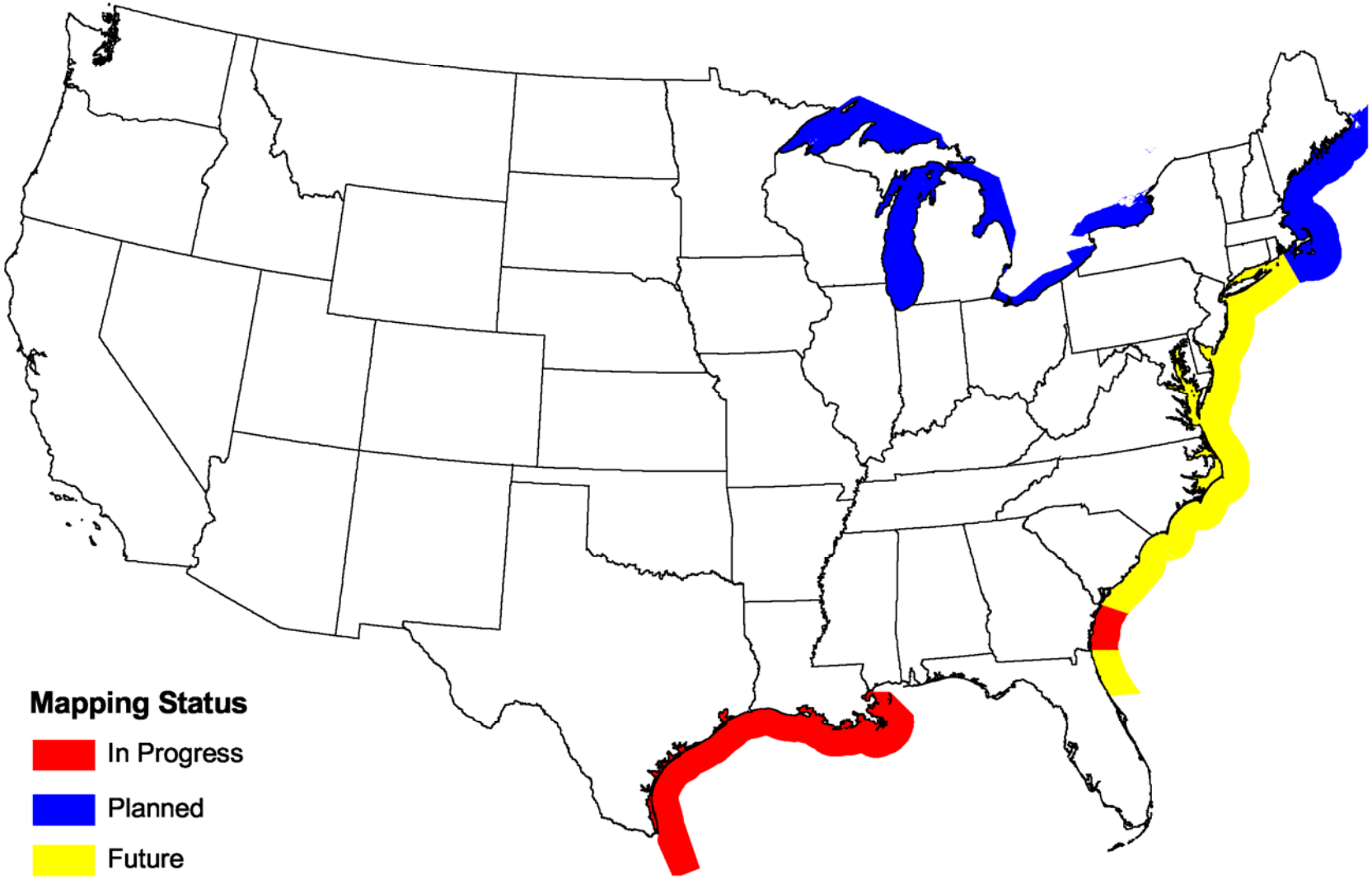
- Collaborative process among AWS TrueWind, NREL, and consulting experts
- Validators -- NREL and expert consultants
  - use own methods and data
  - provide both quantitative scores and qualitative comments
  - provide validation results to NREL/AWS TrueWind
- AWS TrueWind
  - produces preliminary map for validators
  - reviews validation results to improve map
  - produces final validated map

NREL



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

Offshore Wind Mapping Regions

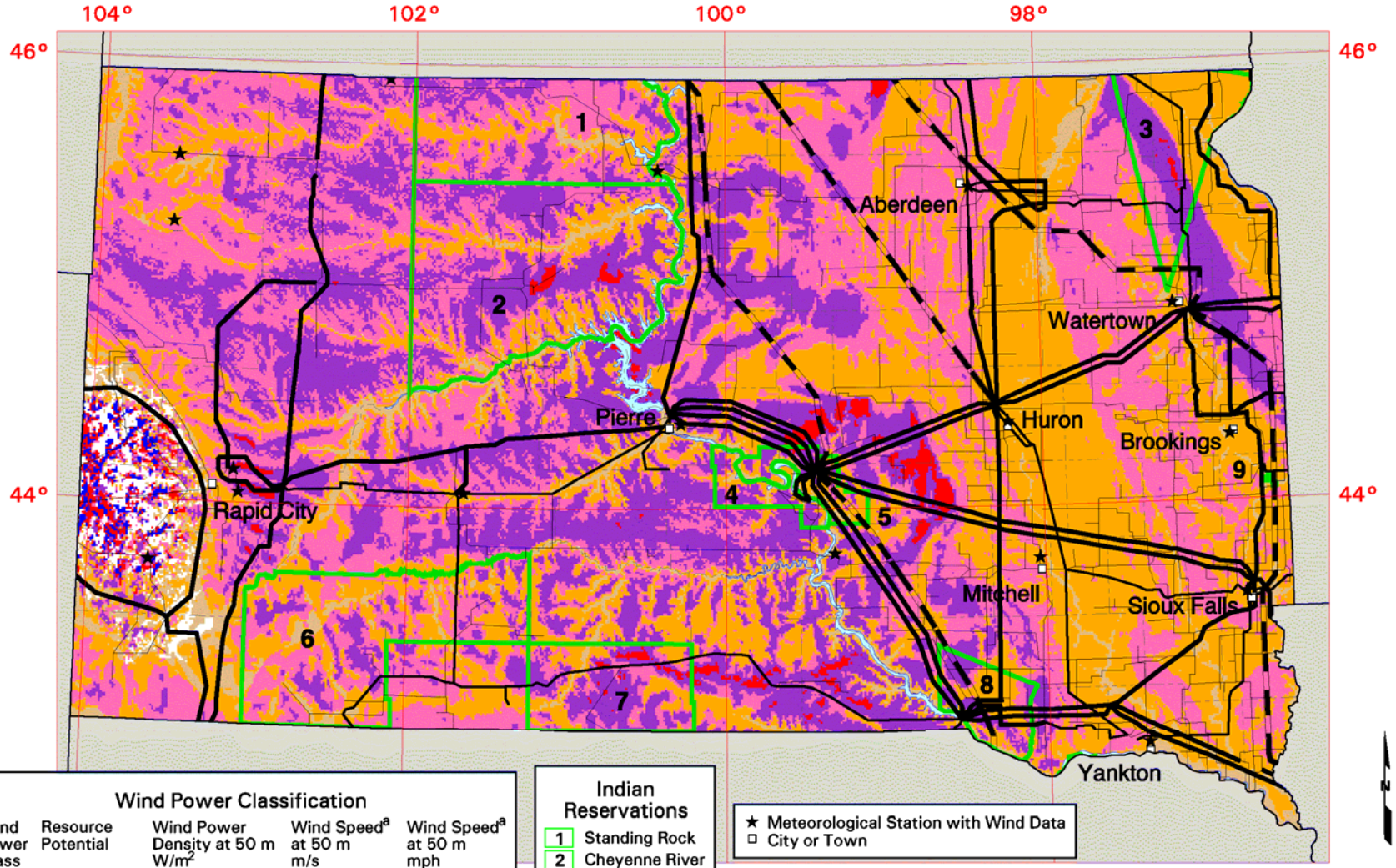


U.S. Department of Energy
National Renewable Energy Laboratory

NREL

03-MAY-2006 3.1.1

South Dakota - Wind Resource Map



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
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 - 1600	8.8 - 11.1	19.7 - 24.8

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

Indian Reservations

1 Standing Rock
2 Cheyenne River
3 Lake Traverse
4 Lower Brule
5 Crow Creek
6 Pine Ridge
7 Rosebud
8 Yankton
9 Flandreau

★ Meteorological Station with Wind Data
□ City or Town

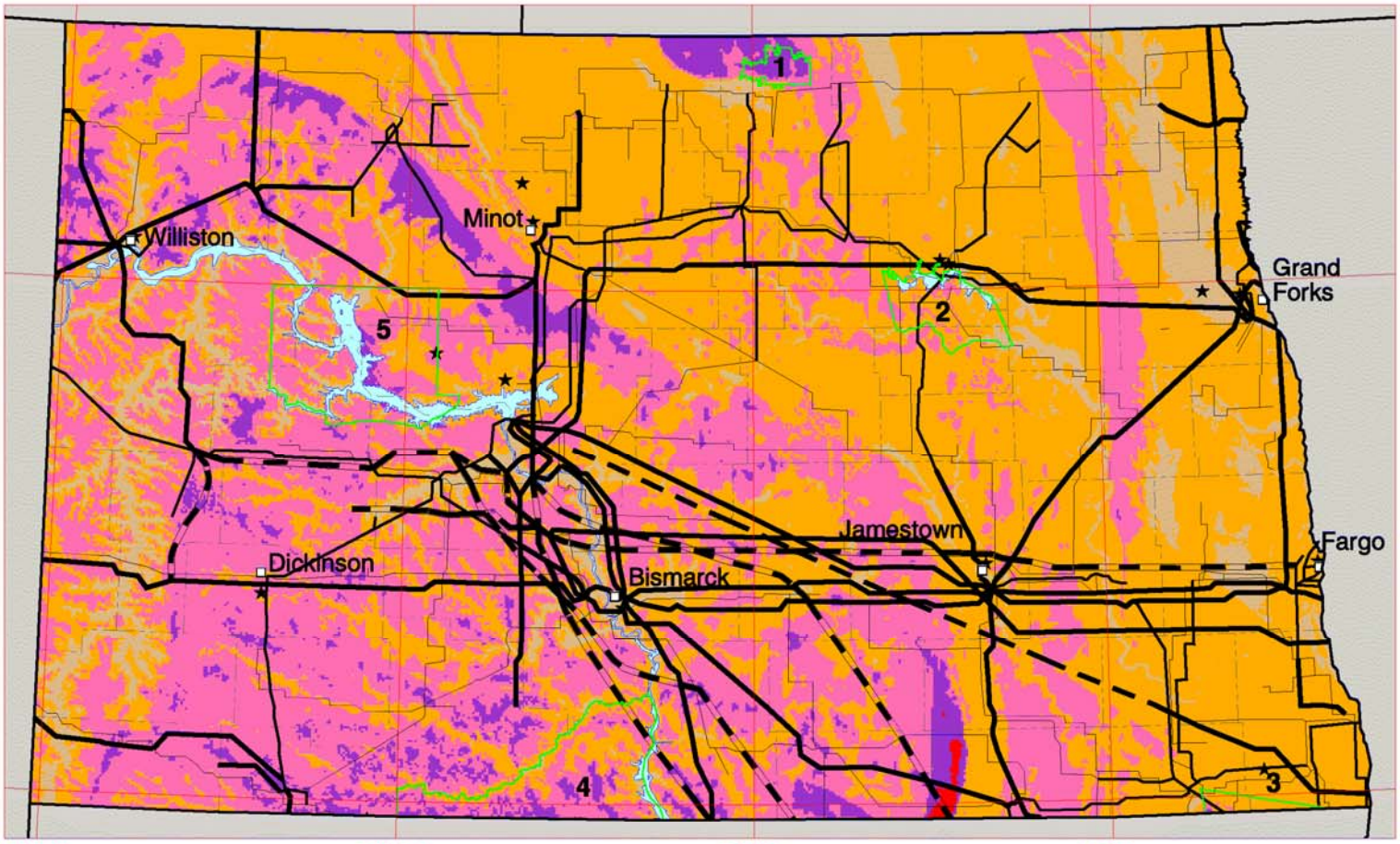
Transmission Line Voltage

69 Kilovolts
115 Kilovolts
230 Kilovolts
345 Kilovolts

50 0 50 100 Kilometers
25 0 25 50 75 Miles

U.S. Department of Energy
National Renewable Energy Laboratory

North Dakota - Wind Resource Map



40 0 40 80 120 160 Kilometers
25 0 25 50 75 100 Miles

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
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

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

★ Meteorological Station with Wind Data
□ City or Town

Transmission Line Voltage

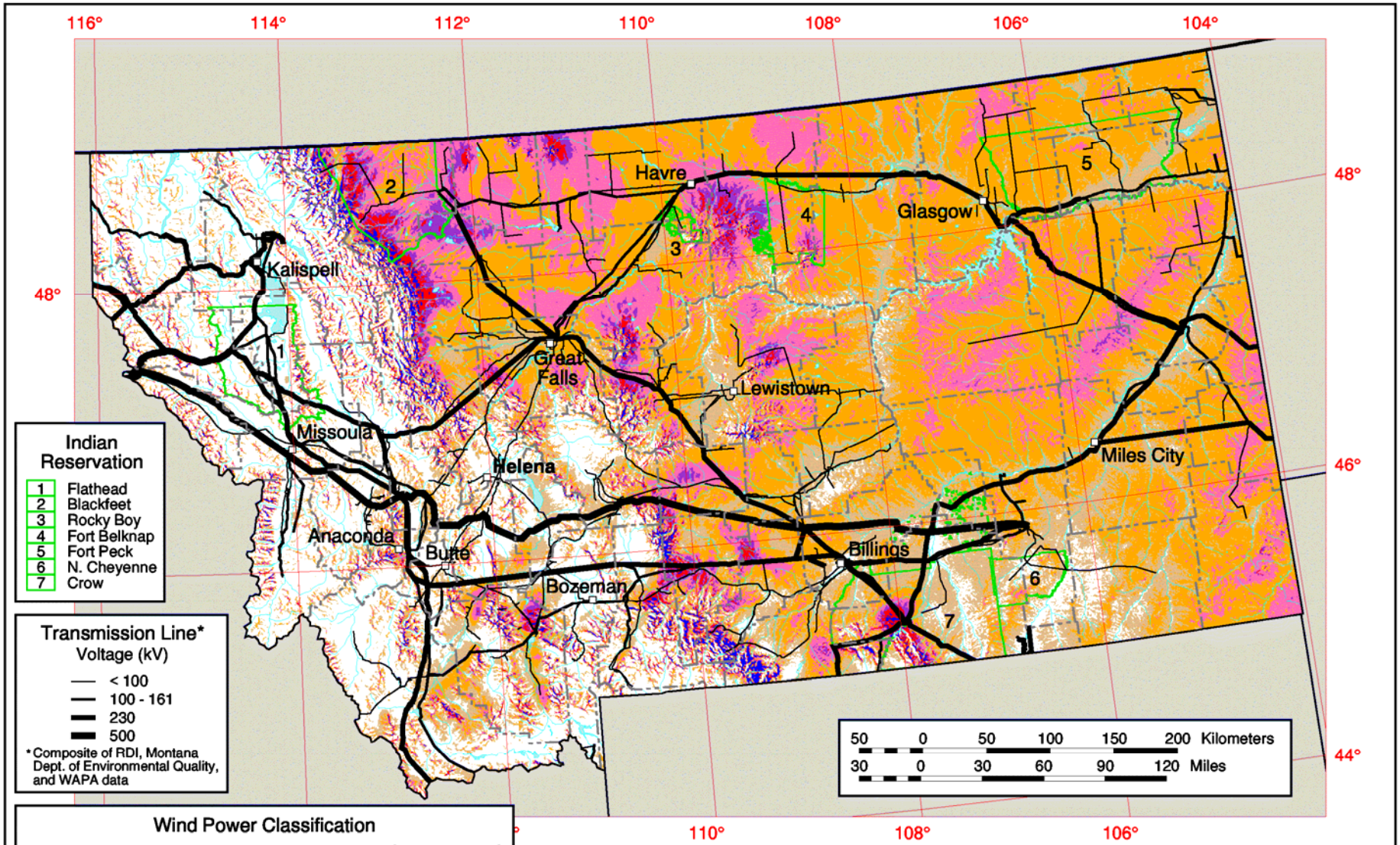
- 69 Kilovolts
- 115 Kilovolts
- 230 Kilovolts
- 345 Kilovolts
- Under Construction

Indian Reservations

1. Turtle Mountain
2. Devil's Lake Sioux
3. Lake Traverse
4. Standing Rock
5. Fort Berthold

U.S. Department of Energy
National Renewable Energy Laboratory

NREL



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 approximate and based on a Weibull k value of 2.0

Montana
Wind Power Resource Estimates

The wind power resource estimates were produced by TrueWind Solutions using their Mesomap system and historical weather data. This map has been validated with available surface data by the National Renewable Energy Laboratory and wind energy meteorological consultants.

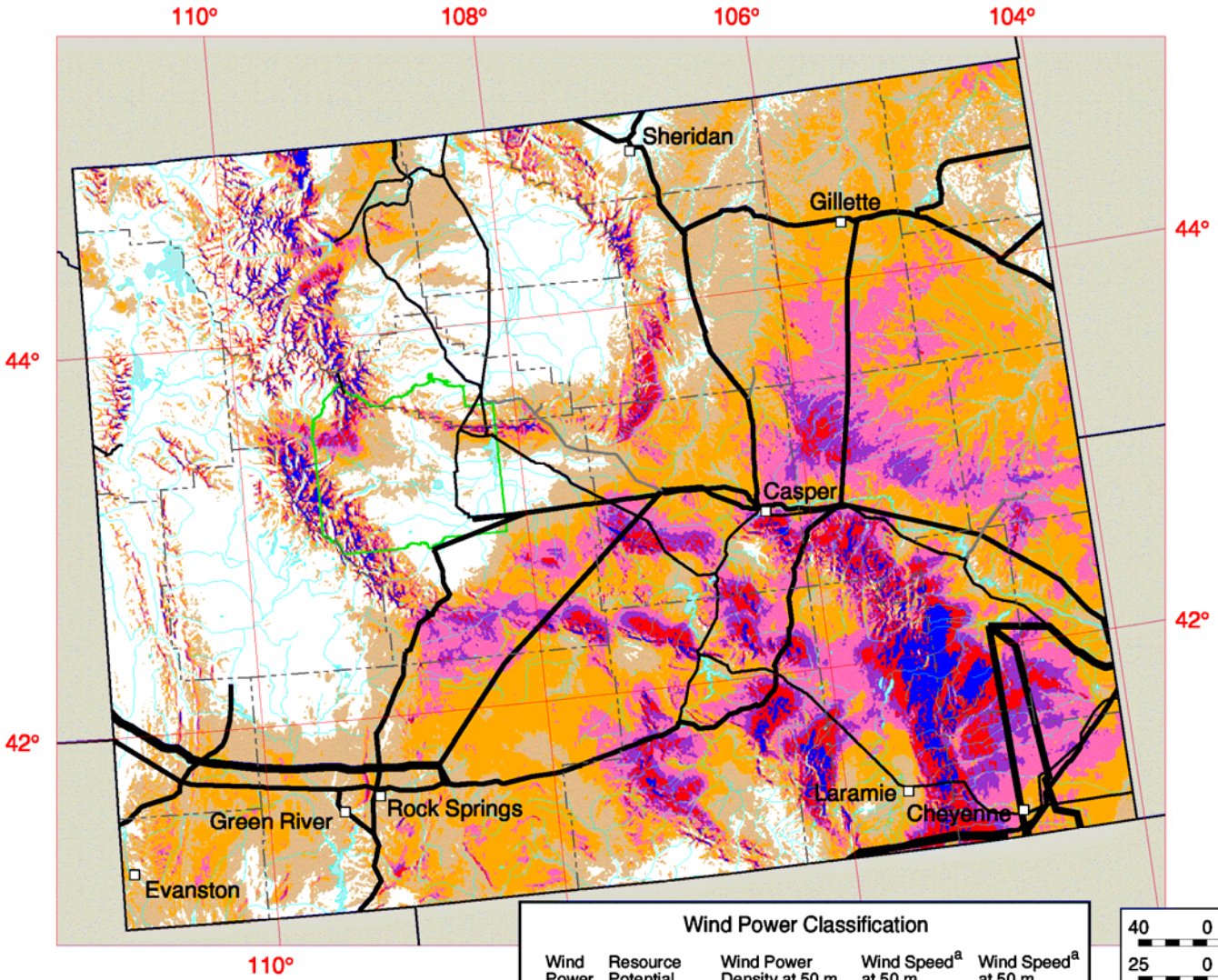
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

15-MAR-2002 1.1.1

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

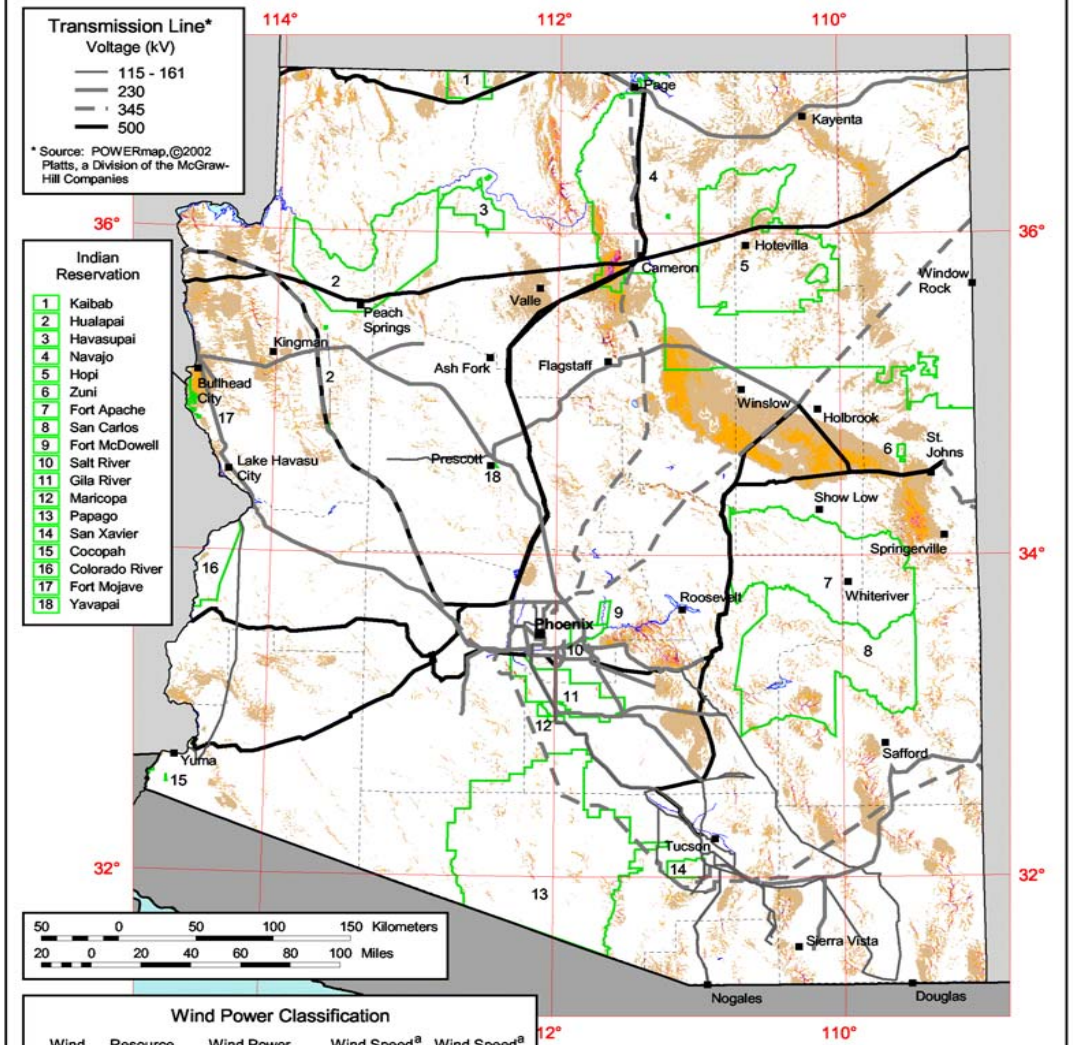
The wind power resource data for this map was produced by TrueWind Solutions using the Mesomap system and historical weather data. It has been validated with available surface data by the National Renewable Energy Laboratory and wind energy meteorological consultants.

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

06-JUN-2002 2.1.2

Arizona - 50 m Wind Power



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 - 5.5	0.0 - 12.3
2	Marginal	200 - 300	5.5 - 6.3	12.3 - 14.1
3	Fair	300 - 400	6.3 - 7.0	14.1 - 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

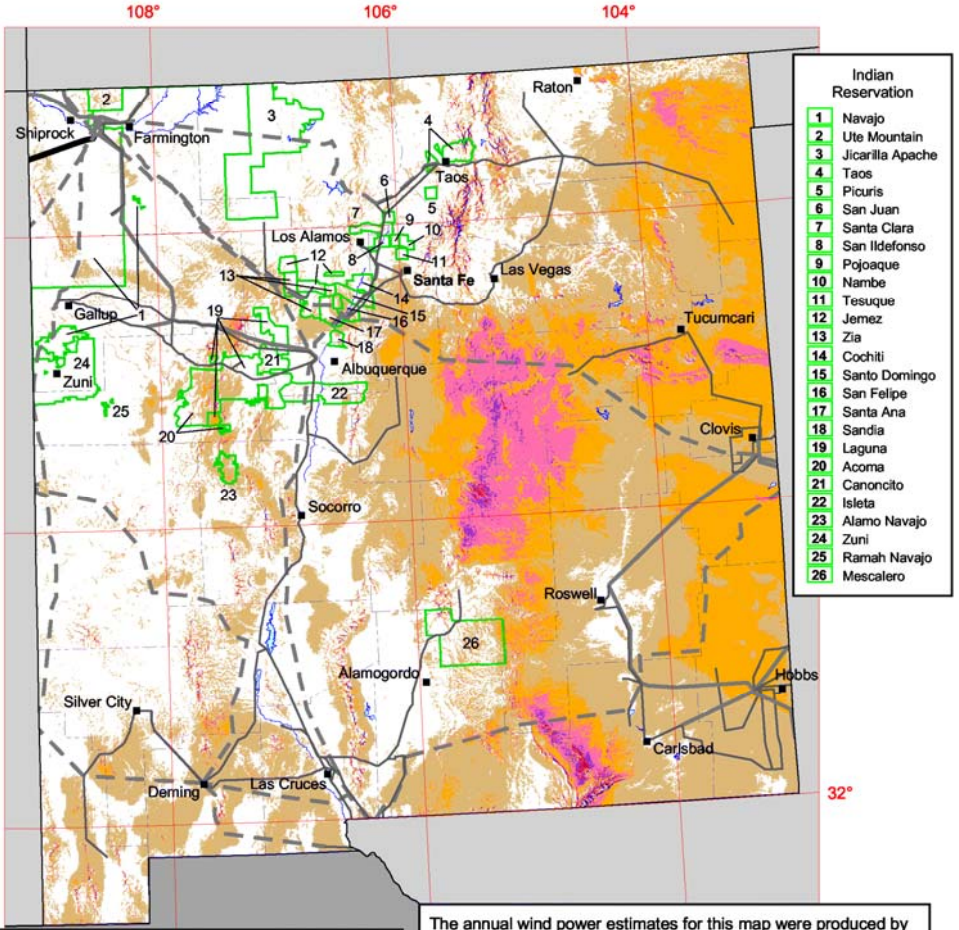
[a] Wind speeds are based on a Weibull k of 1.8 at 1000 m elevation.

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.

U.S. Department of Energy
National Renewable Energy Laboratory

31-JUL-2003 1.1.1

New Mexico - Wind Resource at 50 m



Indian Reservation

1	Navajo
2	Ute Mountain
3	Jicarilla Apache
4	Taos
5	Picuris
6	San Juan
7	Santa Clara
8	San Ildefonso
9	Pojoaque
10	Nambe
11	Tesuque
12	Jemez
13	Zia
14	Cochiti
15	Santo Domingo
16	San Felipe
17	Santa Ana
18	Sandia
19	Laguna
20	Acoma
21	Canoncito
22	Isleta
23	Alamo Navajo
24	Zuni
25	Ramah Navajo
26	Mescalero

50 0 50 100 150 200 Kilometers
30 0 30 60 90 120 Miles

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	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

Transmission Line*

Voltage (kV)

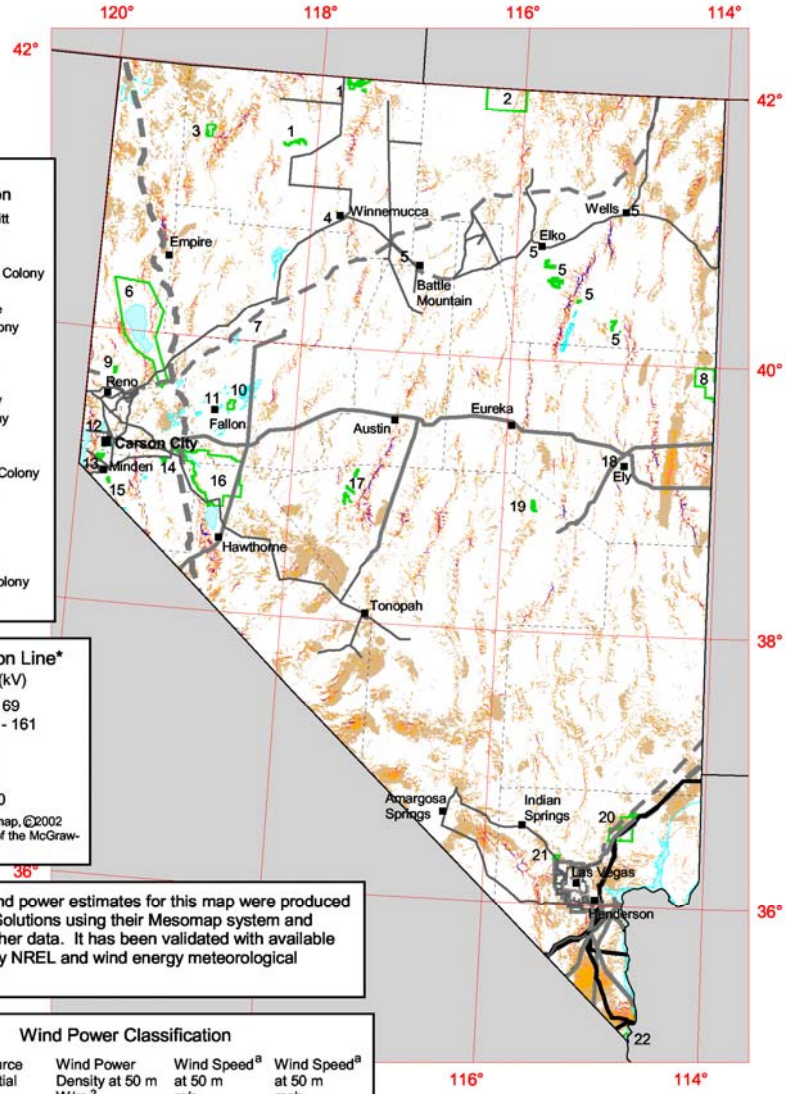
- 115 - 138
- 230
- 345
- 500

* Source: POWERmap,©2002 Platts, a Division of the McGraw-Hill Companies

U.S. Department of Energy
National Renewable Energy Laboratory

12-MAY-2003 1.2.1

Nevada - 50 m Wind Power



Indian Reservation

1 Fort McDermitt
2 Duck Valley
3 Summit Lake
4 Winnemucca Colony
5 Te-Moak
6 Pyramid Lake
7 Lovelock Colony
8 Goshute
9 Reno-Sparks
10 Fallon
11 Fallon Colony
12 Carson Colony
13 Washoe
14 Yerington
15 Dresslerville Colony
16 Walker River
17 Yomba
18 Ely Colony
19 Duckwater
20 Moapa River
21 Las Vegas Colony
22 Fort Mojave

Transmission Line*

Voltage (kV)

55 - 69
115 - 161
230
345
500
1000

* Source: POWERmap, ©2002 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	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 - 7.1	14.3 - 15.9
4	Good	400 - 500	7.1 - 7.6	15.9 - 17.0
5	Excellent	500 - 600	7.6 - 8.1	17.0 - 18.1
6	Outstanding	600 - 800	8.1 - 8.9	18.1 - 19.9
7	Superb	> 800	> 8.9	> 19.9

[a] Wind speeds are based on a Weibull k of 1.8 at 1500 m elevation.

50 0 50 100 150 200 Kilometers

50 0 50 100 Miles

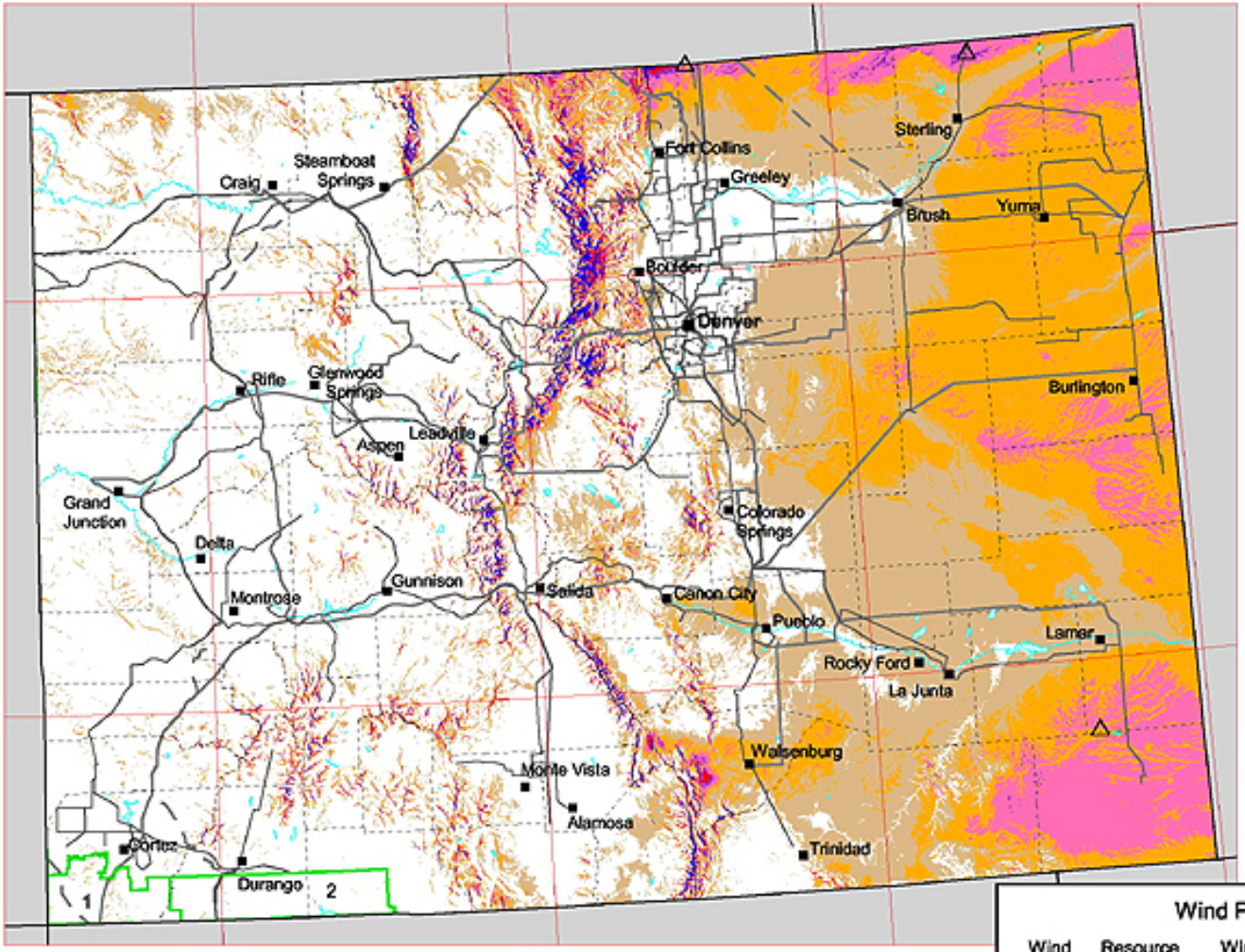
Nevada State Office of Energy

U.S. Department of Energy
National Renewable Energy Laboratory

26-SEP-2003-3.1.1

Colorado

50 m Wind Power



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.

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
1	Poor	0 - 200	0.0 - 5.9	0.0 - 13.2
2	Marginal	200 - 300	5.9 - 6.7	13.2 - 15.0
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

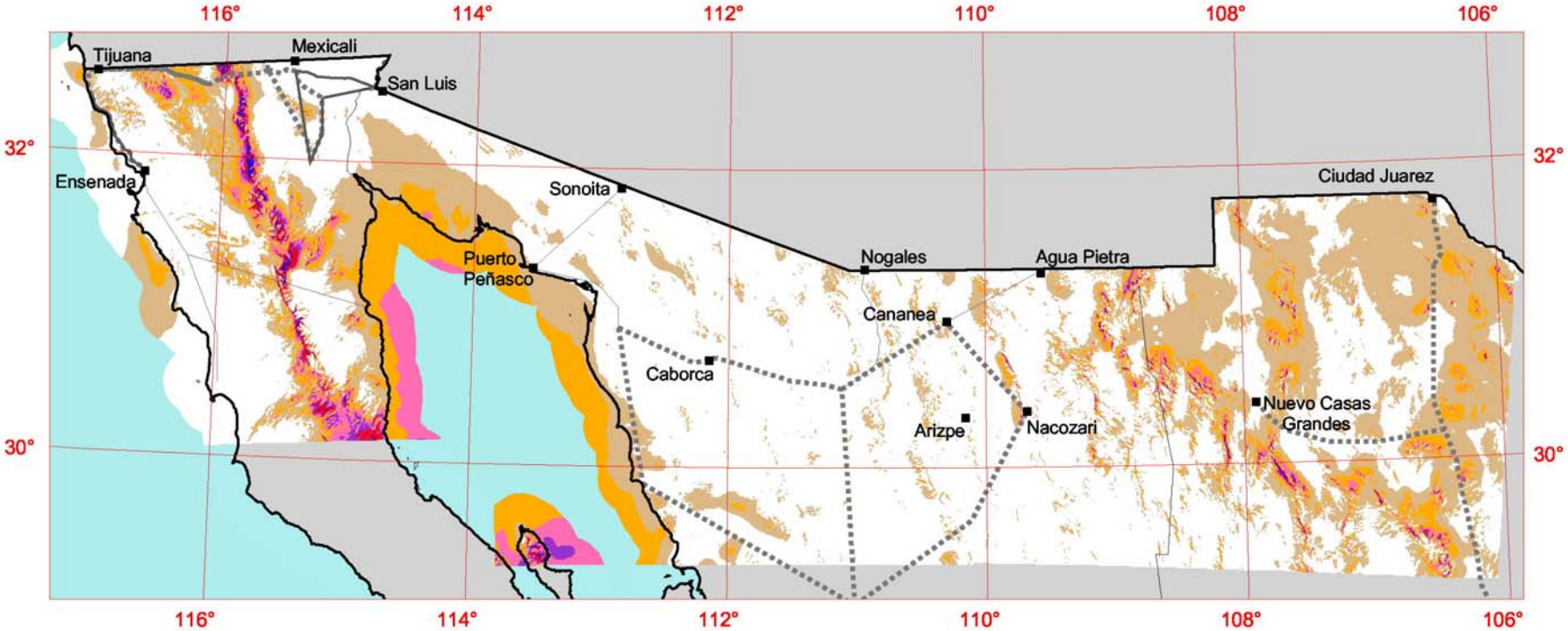
Indian Reservation
1 Ute Mountain
2 Southern Ute

U.S. Department of Energy
National Renewable Energy Laboratory

Colorado Governor's Office of Energy Management and Conservation

26-MAR-2004 2.1.4

Northwestern Mexico Border Areas - 50 m Wind Power



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 of 2.0 at sea level.

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.

Transmission Line*

Voltage (kV)

- 69
- 115 - 161
- 230
- 345

* Source: POWERmap, ©2003 Platts, a Division of the McGraw-Hill Companies

50 0 50 100 150 200 250 Kilometers

50 0 50 100 150 Miles

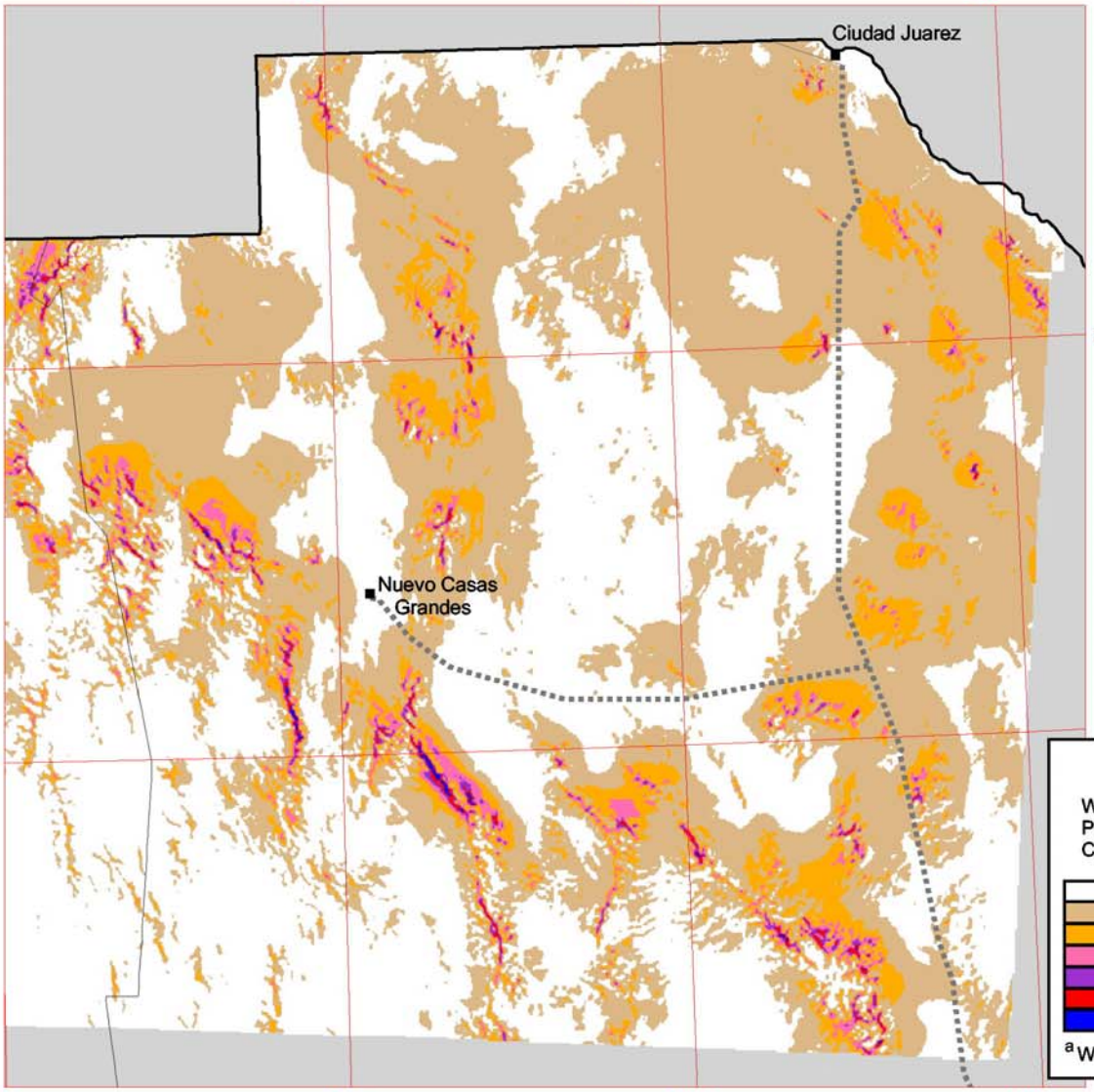
U.S. Department of Energy
National Renewable Energy Laboratory

11-FEB-2004 1.1.1

Western Chihuahua

Border Region

50 m Wind Power



Transmission Line*
Voltage (kV)

- 69
- 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.

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 of 2.0 at sea level.

20 0 20 40 60 80 100 120 Kilometers

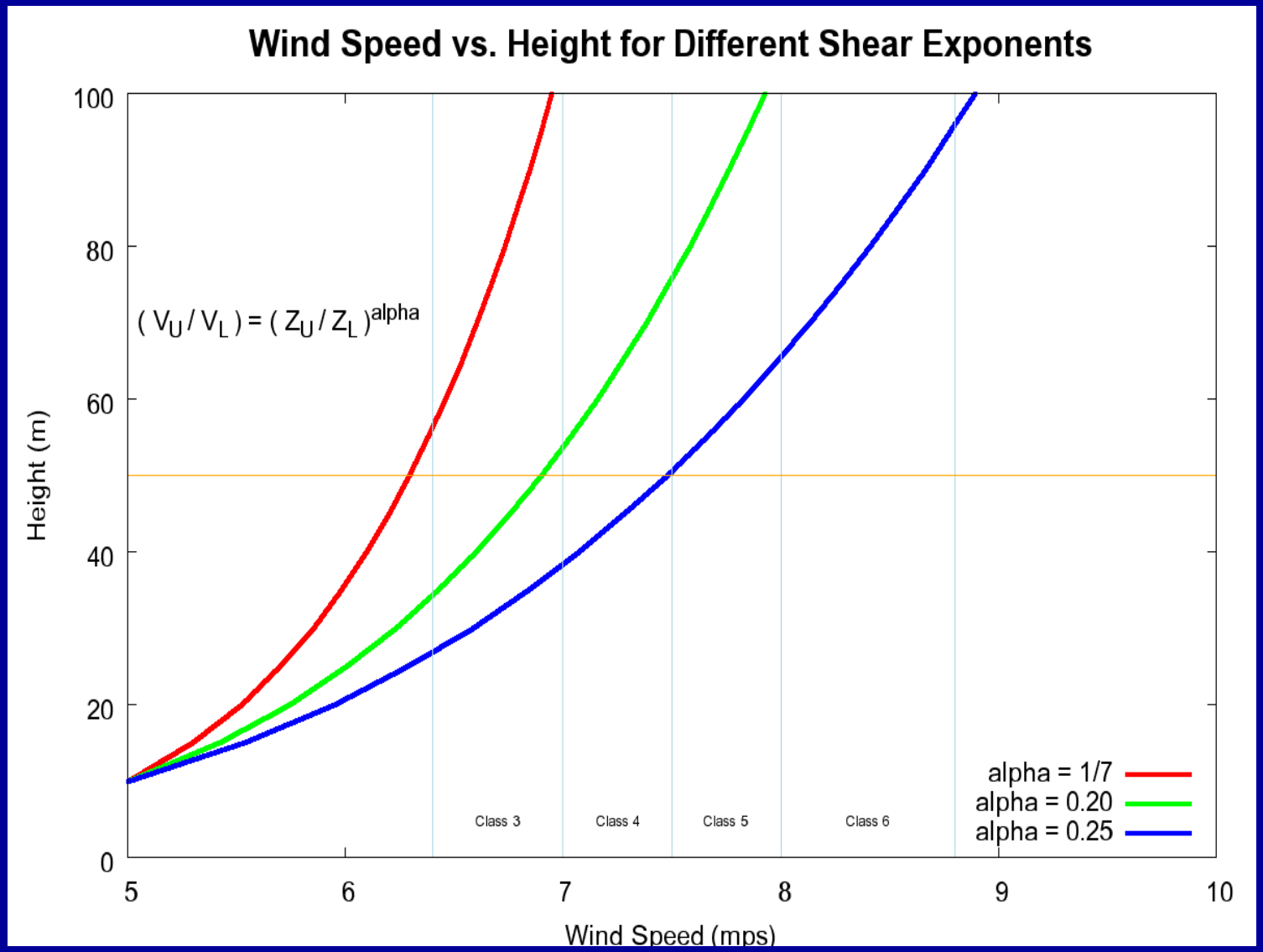
20 0 20 40 60 Miles

U.S. Department of Energy
National Renewable Energy Laboratory

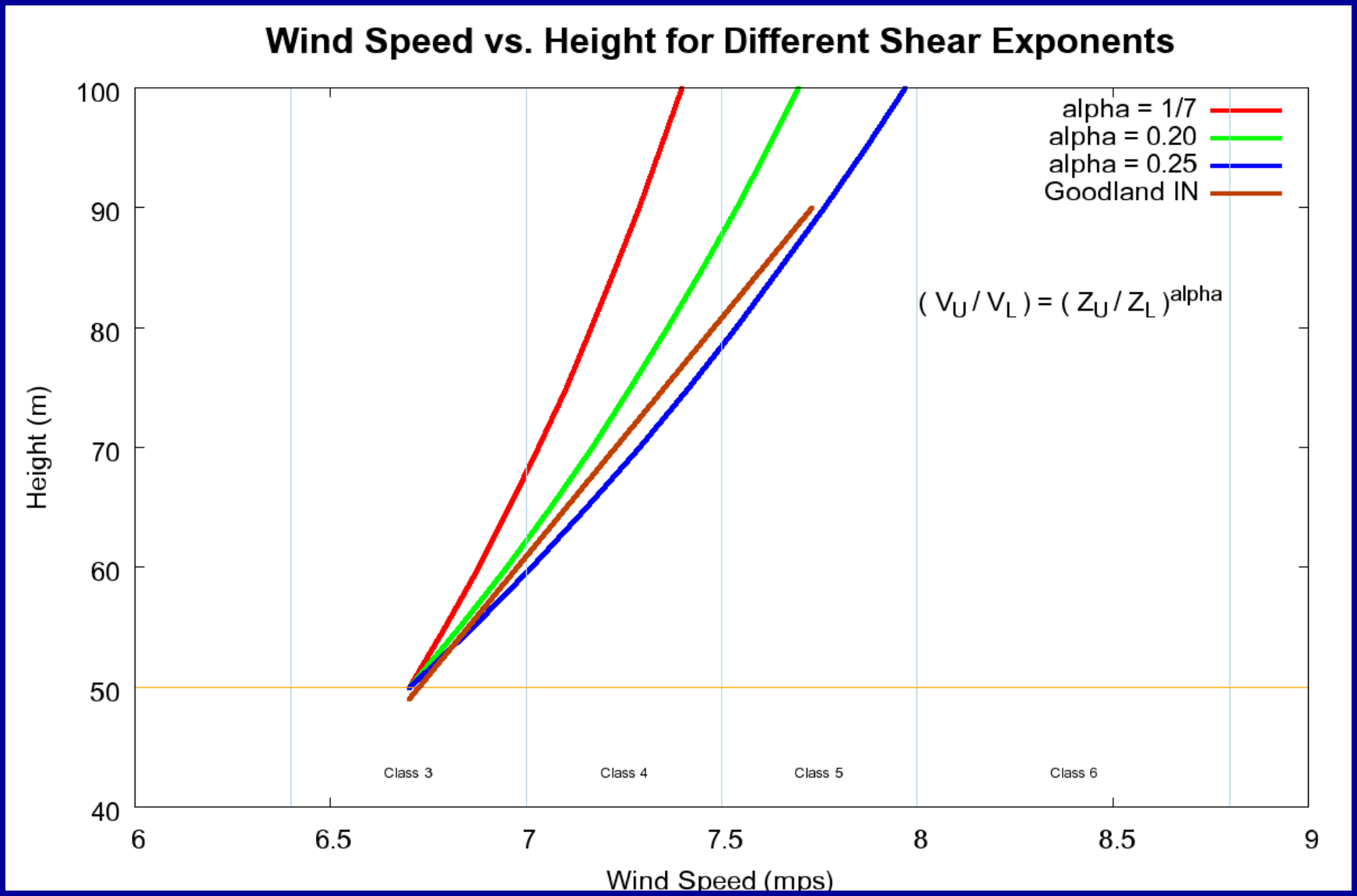
06-FEB-2004 1.1.3

Tall Tower site on the Great Plains.

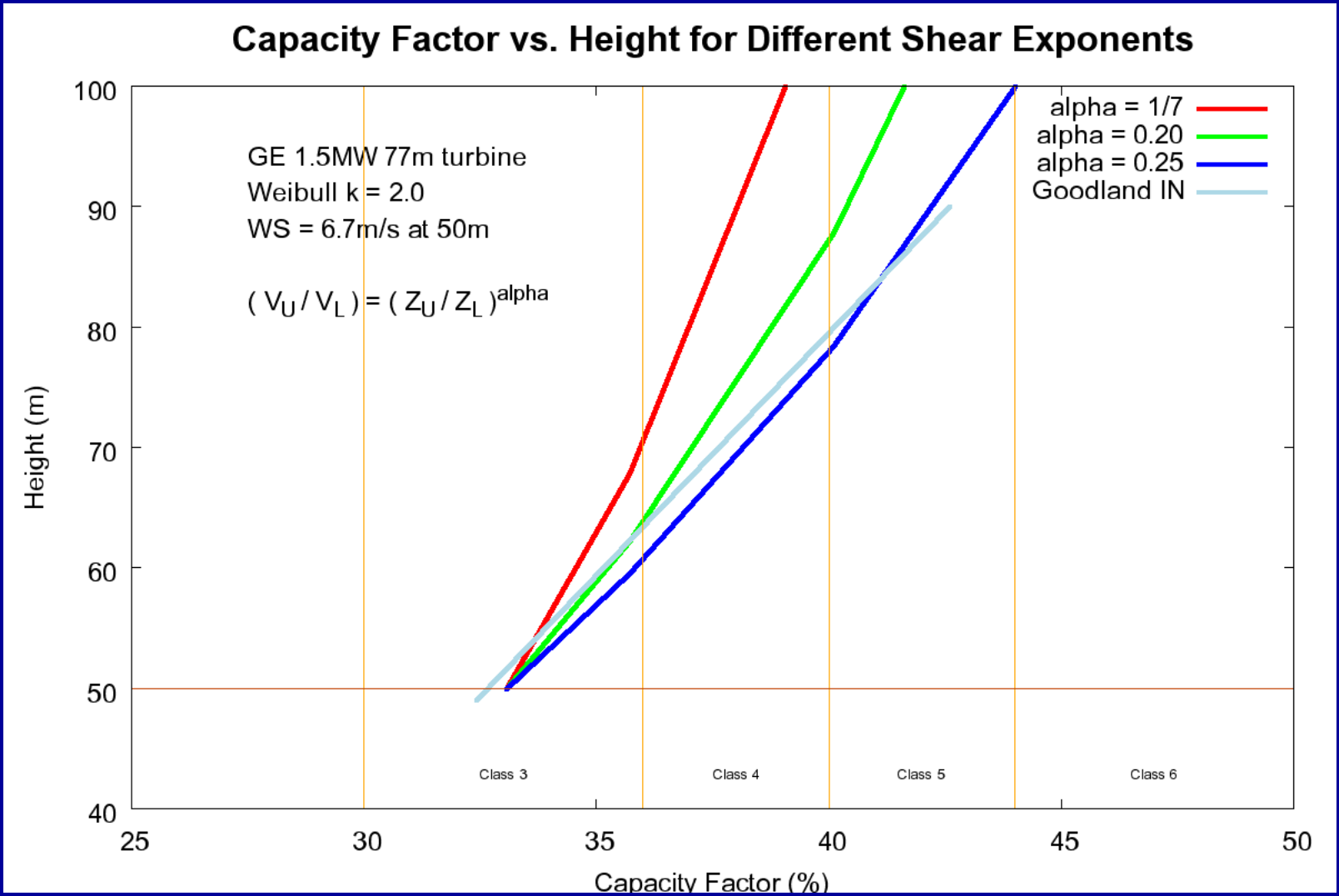
Communication towers are frequently used for measuring wind energy characteristics at heights up to 100 m or above.



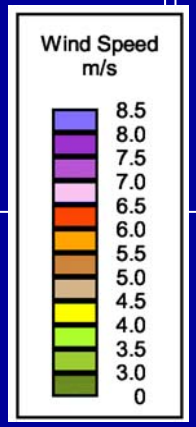
Annual average shear exponents can vary from 1/7 to 0.25, causing considerable uncertainty in vertical extrapolations of wind resource



- Even if 50-m wind resource is known, potential variations in shear exponents cause considerable uncertainty in wind resource at heights of 80-100 m
- Measured shear exponent at Goodland is 0.235, with much higher wind resource at 90 m than estimated by 1/7 shear estimate



- High wind shear locations can have considerably higher capacity factors at 80-100 m than low shear locations, given similar capacity factors at 50 m
- Goodland's capacity factor of 42.5% at 90 m is considerably higher than would be estimated by using typical shears of 1/7 to 0.2

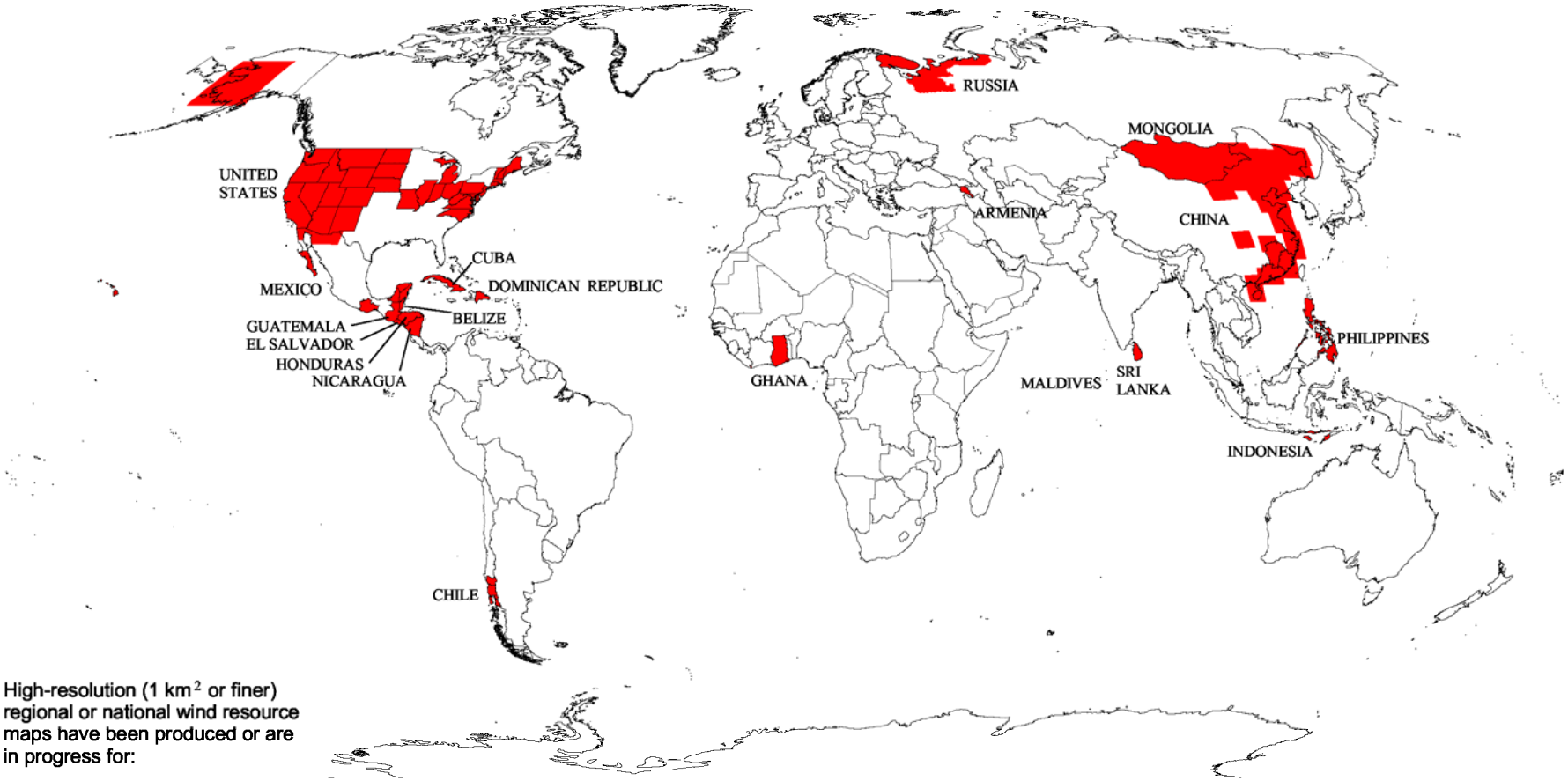


Wind Potential (Installed Capacity) for 12% Power Loss Scenario
30-36% Capacity Factor: 42 GW

Total: 42 GW

Wind Potential (Installed Capacity) for 12% Power Loss Scenario
30-36% Capacity Factor: 161 GW
36-41% Capacity Factor: 37 GW
Total: 198 GW

NREL's High Resolution Wind Mapping and Validation Projects



High-resolution (1 km^2 or finer) regional or national wind resource maps have been produced or are in progress for:

- Armenia
- Chile - specific areas
- China - specific areas
- Dominican Republic
- Indonesia - specific areas
- Maldives
- Mexico - specific areas
- Mongolia
- Philippines
- Russia - specific areas
- Sri Lanka
- United States - specific areas

A United Nations Environment Programme (UNEP) project is mapping additional regions of the world:

Africa:
- Ghana

Asia:
- China (specific areas)

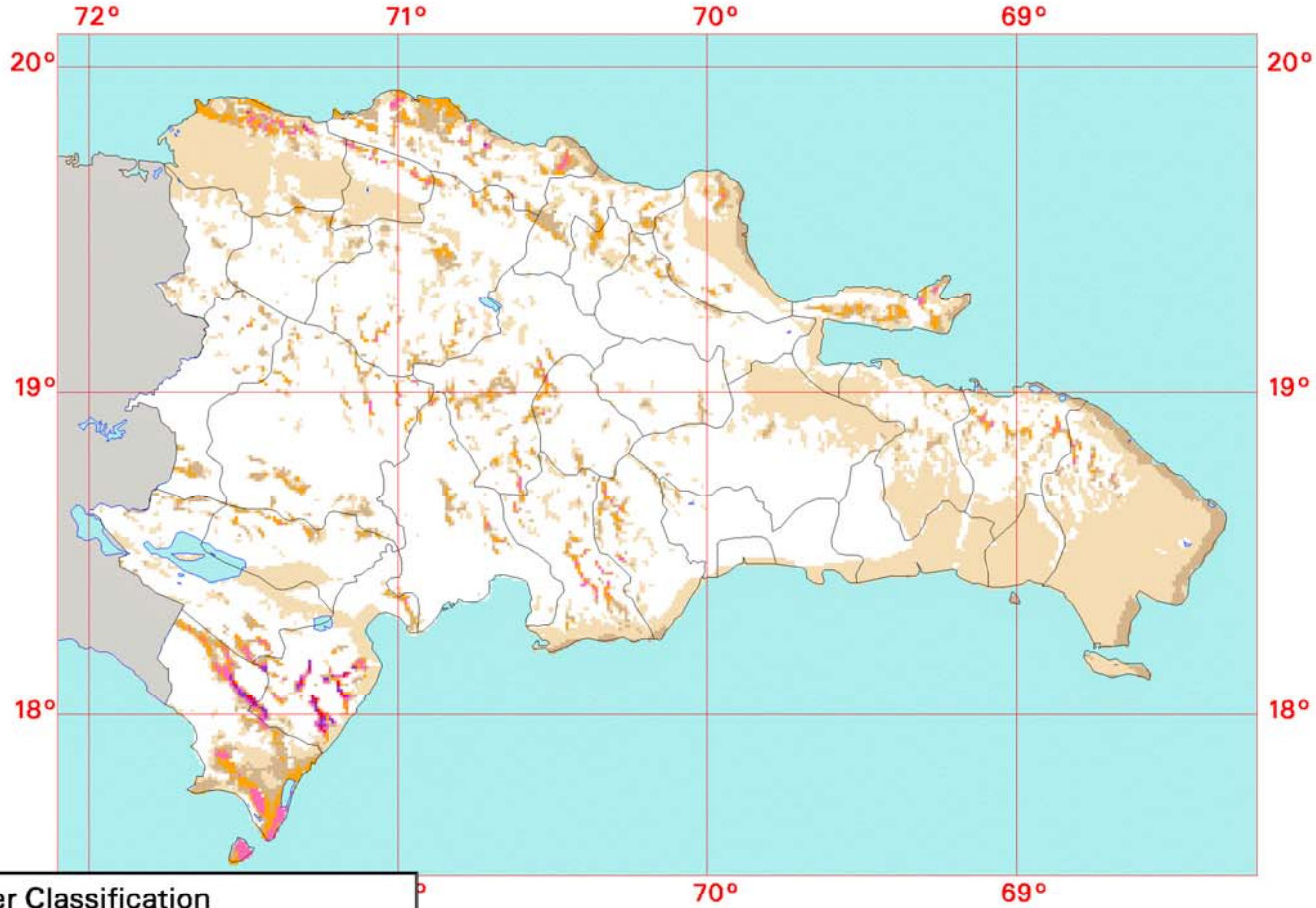
Central America and the Caribbean:
- Belize, Cuba, El Salvador, Guatemala, Honduras, and Nicaragua

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

26-APR-2004 3.7.1

Dominican Republic - Most Favorable Wind Resource Areas



Wind Power Classification

Resource Potential: Utility	Resource Potential: Rural	Wind Power Density at 30 m W/m^2	Wind Speed[a] at 30 m m/s
Marginal	Moderate	100 - 200	4.9 - 6.1
Moderate	Good	200 - 300	6.1 - 7.0
Good	Excellent	300 - 400	7.0 - 7.7
Excellent		400 - 600	7.7 - 8.9
		600 - 800	8.9 - 9.8
		800 - 1000	9.8 - 10.5

[a] Wind speeds are based on a Weibull k value of 3.0

The wind resource classification is specific for both utility scale and rural applications and applies to areas with low surface roughness.

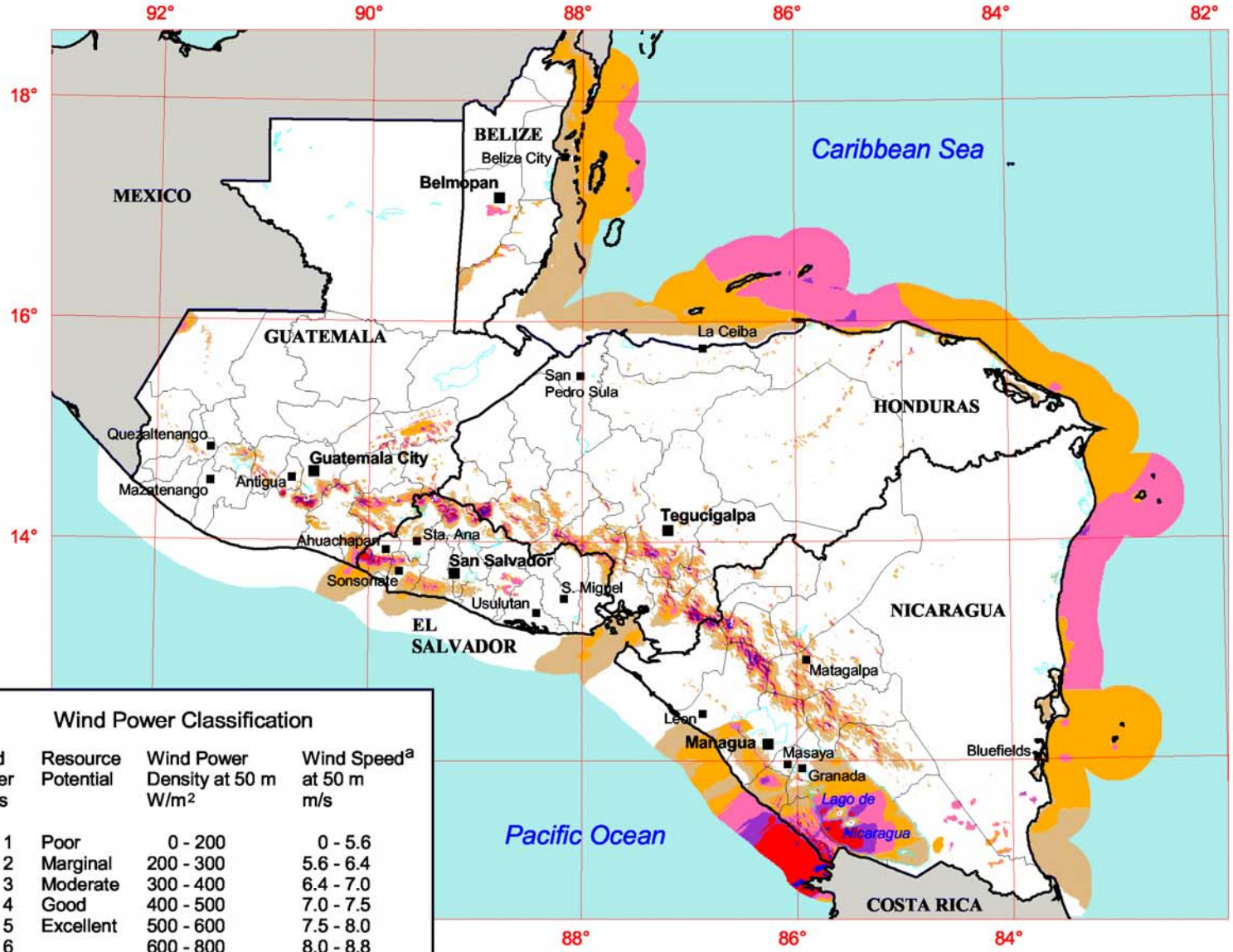
20 10 0 20 40 60 80 100 Kilometers

US Dept. of Energy - National Renewable Energy Laboratory

NREL contacts:
Dennis Elliott
Marc Schwartz

SR Haymes 30-APR-1999 5.1

Central America - 50 m Wind Power



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s
1	Poor	0 - 200	0 - 5.6
2	Marginal	200 - 300	5.6 - 6.4
3	Moderate	300 - 400	6.4 - 7.0
4	Good	400 - 500	7.0 - 7.5
5	Excellent	500 - 600	7.5 - 8.0
6		600 - 800	8.0 - 8.8
7		> 800	> 8.8

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

Solar and Wind Energy Resource Assessment

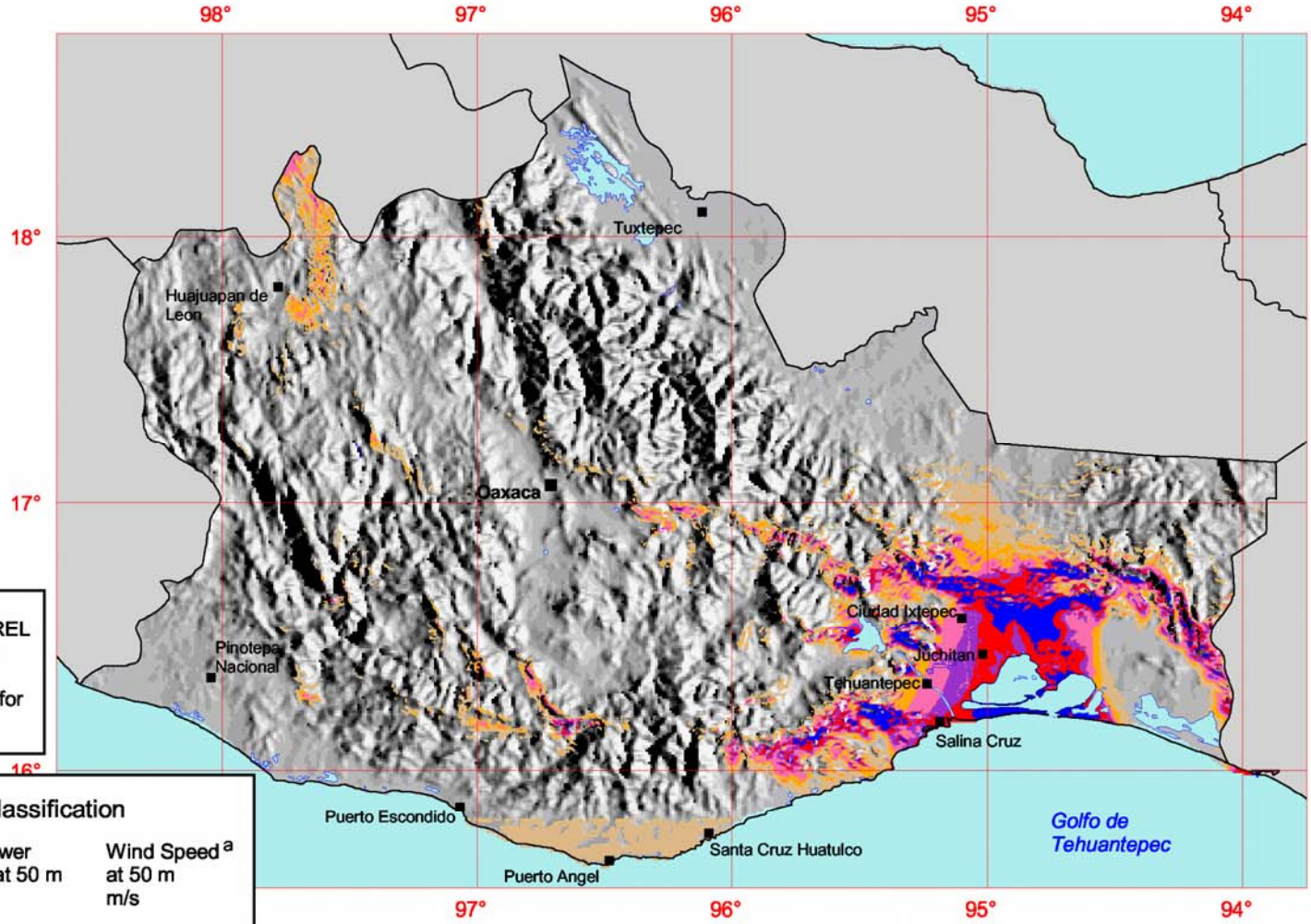
United Nations Environment Programme

Global Environment Facility

U.S. Department of Energy
National Renewable Energy Laboratory

12-MAY-2004 1.1.11

Oaxaca - Wind Resource Map



This map was produced by NREL with technical assistance from TrueWind Solutions and with funding from the U.S. Agency for International Development.

Wind Power Classification

Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed [a] at 50 m m/s
Poor	0 - 200	0 - 5.3
Marginal	200 - 300	5.3 - 6.1
Moderate	300 - 400	6.1 - 6.7
Good	400 - 500	6.7 - 7.3
Excellent	500 - 600	7.3 - 7.7
	600 - 800	7.7- 8.5
	> 800	> 8.5

[a] Wind speeds are based on a Weibull k value of 1.8

Legend

■ Town or ■ **Capital**

50 0 50 100 150 Kilometers

U.S. Agency for International Development

U.S. Department of Energy
National Renewable Energy Laboratory

12-MAY-2003 1.6.2

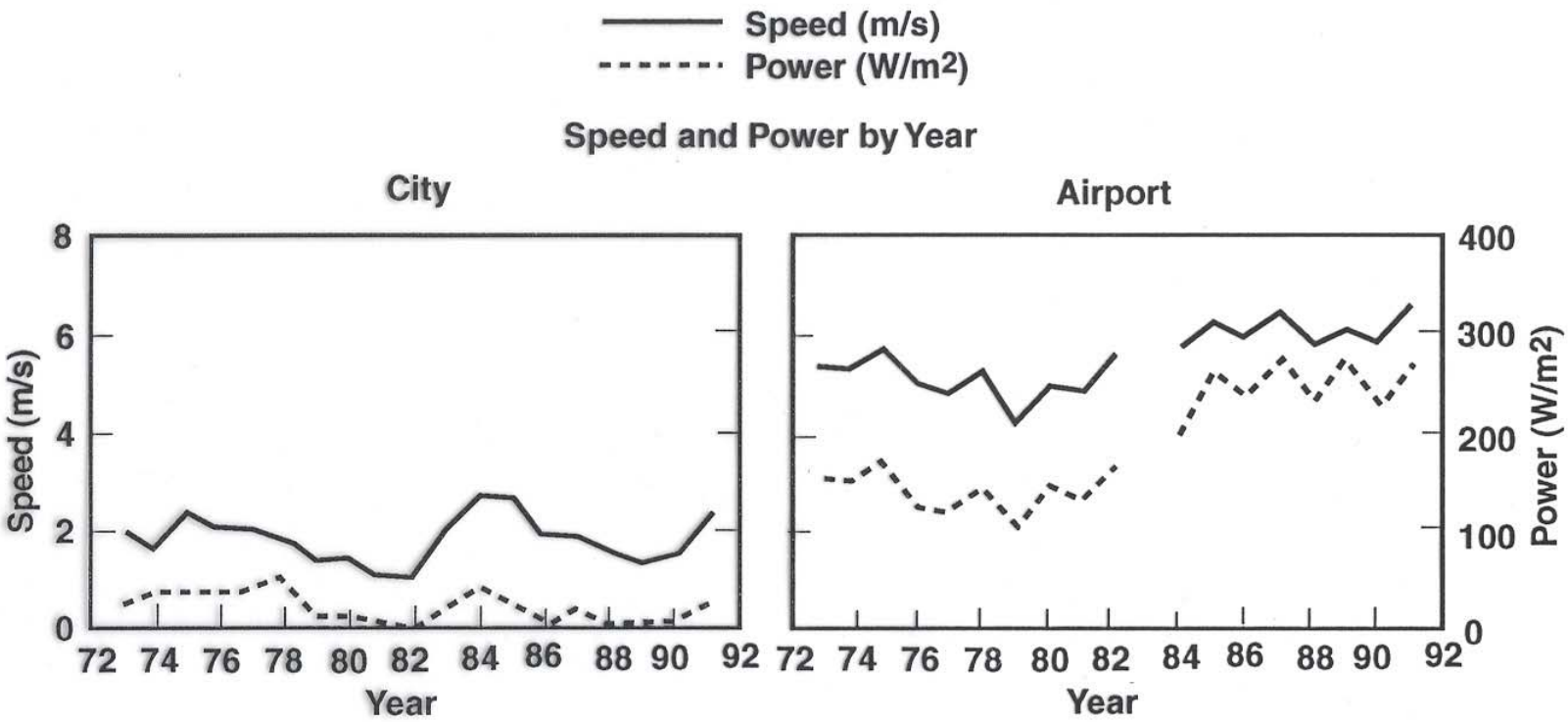
Major Global Data Sets used by NREL for Wind Resource Assessment

Data Set	Type of Information	Source	Period of Record
Surface Station Data	Surface observations at 20000 stations	NOAA/NCDC	1973-2003
Upper Air Station Data	Rawinsonde and pibal observations at 1800 stations	NCAR	1973-2003
Satellite-derived Ocean Wind Data	10-m ocean wind speeds gridded to 0.25 deg	NASA/JPL	1988-2002
Marine Climatic Atlas of the World	Gridded (1.0 deg) statistics of historical ship wind observations	NOAA/NCDC	1854-1969
Reanalysis Upper Air Data	Model-derived gridded (~200km) upper air data	NCAR	1958-2003
Global Upper Air Climatic Atlas	Model-derived gridded (2.5 deg) upper air statistics	NOAA/NCDC	1980-1991
Digital Geographic Data	Political, hydrography, etc.	ESRI	
Digital Terrain Data	Elevation – 1 km resolution	USGS/EROS	
Digital Land Cover Data	Land use/cover and tree cover density – 1 km resolution	NASA/USGS	

Surface Wind Data from Meteorological Stations

- Problems in many regions of the world:
  - Measurements often reduced by buildings and nearby obstructions
  - Equipment not properly maintained
  - Measurements heights and station history not documented
- Wind energy resource has been underestimated in many regions due to these problems

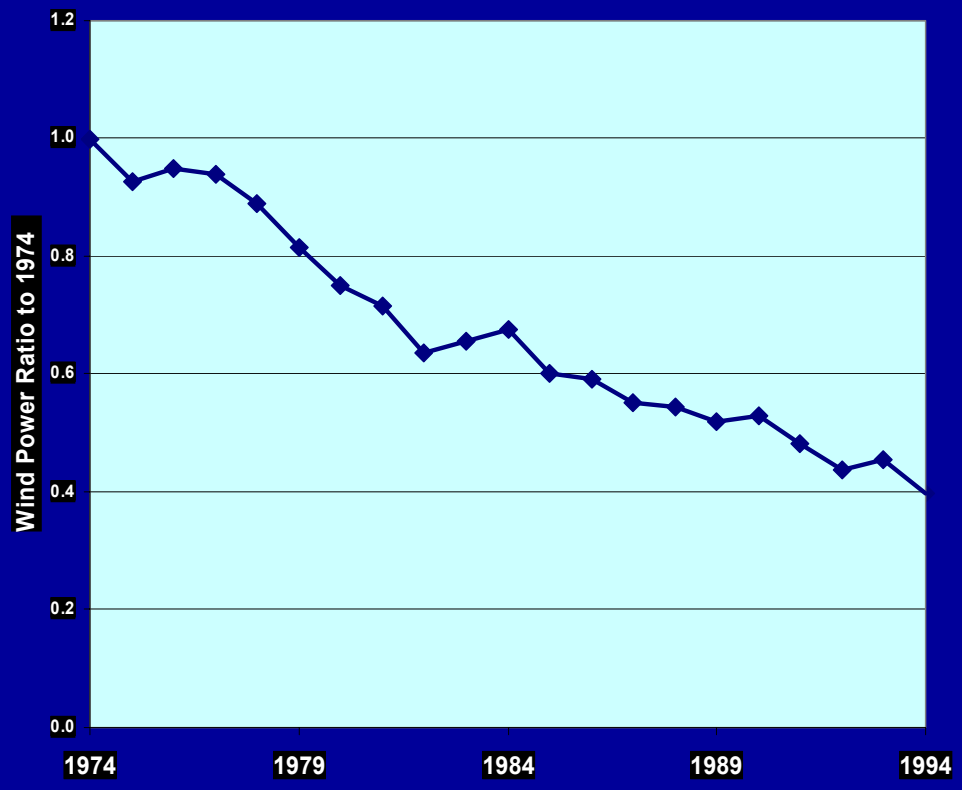
Chetumal, Mexico
Yucatan Peninsula - East Coast



	Period	Speed (m/s)	Power (W/m2)
City	1973-91	1.9	22
Airport	1984-91	6.1	245

“Disappearing Wind” Syndrome

- >90% of meteorological stations in southeast China indicate “disappearing wind”



- Data from 1974 to 1994 for 79 meteorological stations
- Apparent wind power decreases by 60% over 20 years
- Decrease caused by new construction around meteorological stations, which reduces the measured wind speeds

Anemometer Siting

Wind Resource Assessment

- **Main objective is to identify potentially windy areas that also possess other desirable qualities for wind project development**

- **Steps in the siting process:**
  - » **Identification of potential wind development areas**
  - » **Inspection and ranking of candidate sites**
  - » **Selection of actual tower location(s) within the candidate sites**

Wind Resource Assessment Steps

- Preliminary area identification
- Ranking of candidate sites
- Selection of tower location(s)
- Development of a monitoring plan
- Quality assurance

Preliminary Area Identification

- **Objective is to determine or verify whether sufficient wind resources exist within an area to justify further site-specific investigation**
  - » use of existing wind data
  - » topographic indicators
  - » field surveys
    - – flagged trees
    - – accessibility
    - – land use
    - – obstructions
    - – available land area

Ranking of Candidate Sites

- Objective is to compare areas to distinguish relative development potential

- In addition to accessibility, land use, obstructions, and available land area, siting criteria could include:
  - » proximity to transmission lines
  - » potential impact on local aesthetics
  - » cellular phone service reliability for data transfers
  - » potential avian interactions

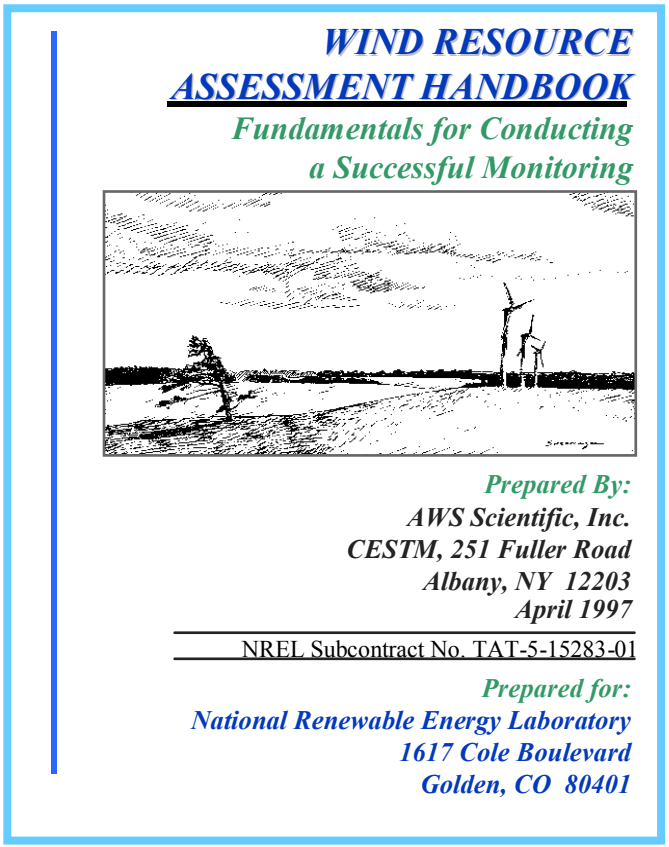
Selection of Tower Location(s)

- Objectives of this step in the siting process are to:
  - » obtain representative data for estimating the performance and/or economic viability of selected turbines, and
  - » screen for potential wind turbine installation sites

Tower Placement Guidelines

- Select an open area free of obstructions
- Select a location that is representative of the majority of the site
  - » in complex terrain, multiple towers may be required
- Other issues
  - » permitting
  - » lease agreements

For Further Information



WIND RESOURCE ASSESSMENT HANDBOOK

Fundamentals for Conducting a Successful Monitoring

Prepared By:
AWS Scientific, Inc.
CESTM, 251 Fuller Road
Albany, NY 12203
April 1997

NREL Subcontract No. TAT-5-15283-01

Prepared for:
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401

Web Site

- **http://www.nrel.gov/wind/wind_pubs.html**

aws scientific