U.S. Wind Resources and Technology

Wind Energy and Rural Economic Development in North Dakota

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New United States Wind Power Projects 6/98 - 6/99

Update 9/8/99

Legend

Name/Location MW Capacity
Developer
Utility
Manufacturer Status

Green — Repower

U.S. Manufacturers

Chandler 1.98 MW
Great River Energy
Vestas

Lake Benton I 107.25 MW
Enron Wind Corporation
Northern States Power
Zond

Woodstock 10.20 MW
Woodstock Windfarms
Northern States Power
Vestas

Lakota Ridge 11.25 MW
Northern Alternative Energy
Northern States Power
Micon

Moorhead 0.75 MW
Moorhead Public Service
Micon

Shaokatan 11.88 MW
Northern Alternative Energy
Northern States Power
Vestas

Lake Benton II 103.50 MW
Enron Wind Corporation
Northern States Power
Zond

Byron 1.32 MW
Wisconsin Electric
Vestas

Lincoln 9.24 MW
Wisconsin Public Service
Vestas

Rosiere 11.22 MW
Madison Gas & Electric
Vestas

Foote Creek Rim 41.40 MW
SeaWest
PacifiCorp/EWEB/BPA
Mitsubishi

Foote Creek Rim 24.75 MW
SeaWest
PSCo
NEG Micon

Vansycle Ridge 24.90 MW
FPL Energy
Portland General Electric
Vestas

NDWGP 1.50 MW
Enron Wind Corporation
Nebraska Public Power District
Zond

Lincoln 0.66 MW
Vestas
Lincoln Electric System
Vestas

Enron Earth Smart/S.G. 16.50 MW
Enron Wind Corporation
Enron Energy Corporation
Zond

Oak Creek/Tehachapi 23.90 MW
Oak Creek
Southern California Edison
NEG Micon Repower

Cameron Ridge/Tehachapi 56.00 MW
FPL Energy
Southern California Edison
NEG Micon Repower

Pacific Crest/Tehachapi 45.54 MW
FPL Energy
Southern California Edison
Vestas Repower

Victory Gardens/Tehachapi 6.75 MW
Enron Wind Corporation
Southern California Edison
Zond Repower

San Clemente Island 0.68 MW
U.S. Navy
NEG Micon

Cabazon/San Gorgonio 39.75 MW
Enron Wind Corporation
Southern California Edison
Zond Repower

Westwind/San Gorgonio 47.25 MW
SeaWest
Southern California Edison
NEG Micon Repower

Westwind-PacifiCorp/S.G. 1.50 MW
SeaWest
SCE/PacifiCorp/GMER
NEG Micon Repower

Energy Unlimited/San Gorgonio 4.00 MW
Energy Unlimited
Southern California Edison
Nordex Repower

Storm Lake I 112.50 MW
Enron Wind Corporation
MidAmerican Energy Company
Zond

Storm Lake II 80.25 MW
Enron Wind Corporation
Alliant
Zond

IDWGP 2.25 MW
Algona Municipal Utilities
Consortium
Zond

Joice 0.30 MW
Alliant
Nordex

Nevada High School 0.50 MW
Minnesota Windpower
Alliant
Wind World

Akron-Westfield 0.60 MW
Alliant
Vestas

Storm Lake II 1.50 MW
Enron Wind Corporation
Waverly Light & Power
Zond

Forest City 0.60 MW
Alliant
Nordex

Cerro Gordo 42.00 MW
FPL Energy
Alliant
NEG Micon

St. Marys 1.50 MW
Enron Wind Corp.
Western Resources
Zond

Ponnequin (EUI) 5.10 MW
Energy Unlimited
PSCo
NEG Micon

Ponnequin (PSCo) 16.50 MW
DisGen
PSCo
NEG Micon

Delaware Mts. 30.00 MW
American National Wind Power
Reliant Energy HL&P/LCRA
Zond

SW Mesa/McCamey 75.00 MW
FPL Energy/FORAS
Central and South West
NEG Micon

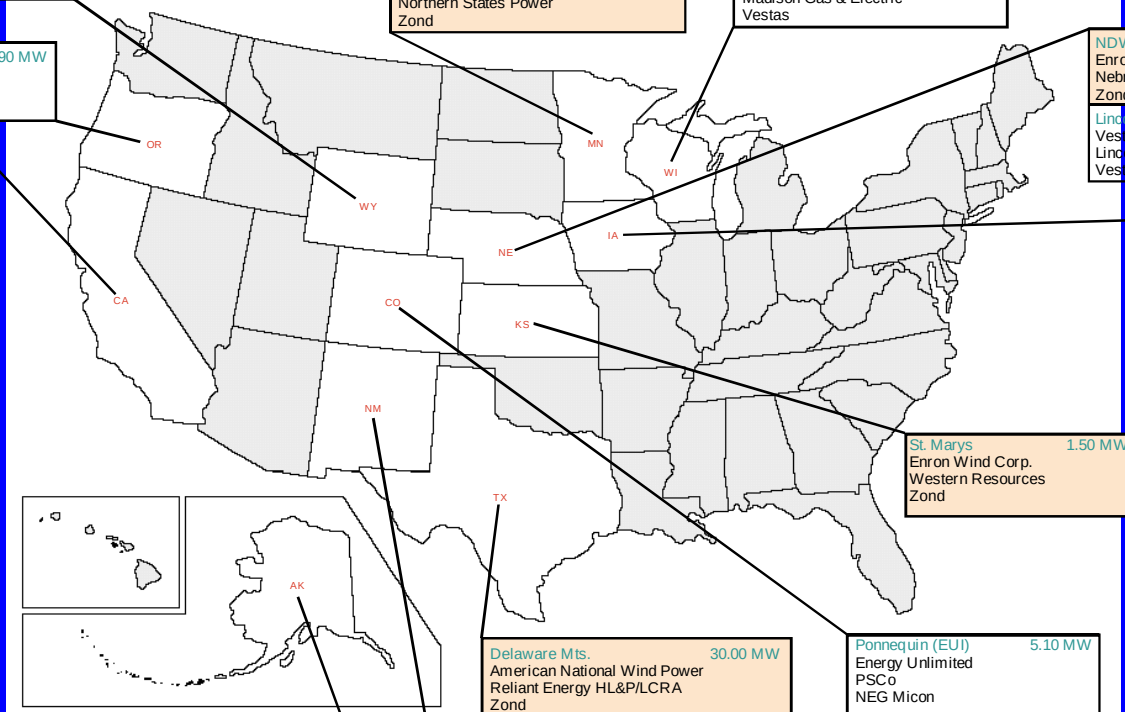
Big Spring/Howard County 34.32 MW
York Research
TU Electric
Vestas

Big Spring/Howard County 6.60 MW
York Research
TU Electric
Vestas

Kotzebue 0.35 MW
Kotzebue Electric Association
Kotzebue Electric Association
Atlantic Orient Corporation

Saint Paul Island 0.23 MW
Northern Power Systems
Tanadgusix Corporation
Vestas

Clovis 0.66 MW
Texas Wind Power
Southwestern Public Service
Vestas



Comparison of Large and Small Wind Turbines

Characteristics	Large Turbines	Small Turbines
Typical Unit Size	30 kW to 1,500 kW 40 m dia. at 500 kW 65 m dia. at 1,500 kW	100 W to 40 kW 3 m dia. at 1 kW 7 m dia. at 10 kW
Basic Technology	Complex Variable speed emerging Gear box Various generators Active Controls Cut-out in high winds Active yaw drive Free-standing towers	Simple, 2-4 moving parts Variable speed standard Direct drive P.M. alternator Passive Controls Furling in high winds Passive yaw with tail vane Guyed towers
Viable Wind Resource	5.8 m/s (13.0 mph)	4.0 m/s (7.8 mph)
Typical Turbine Cost	$1,000 - 1,500 / kW	$1,500 - 6,000 / kW
Maintenance	Attended by professional staff	Inspection every 6 months

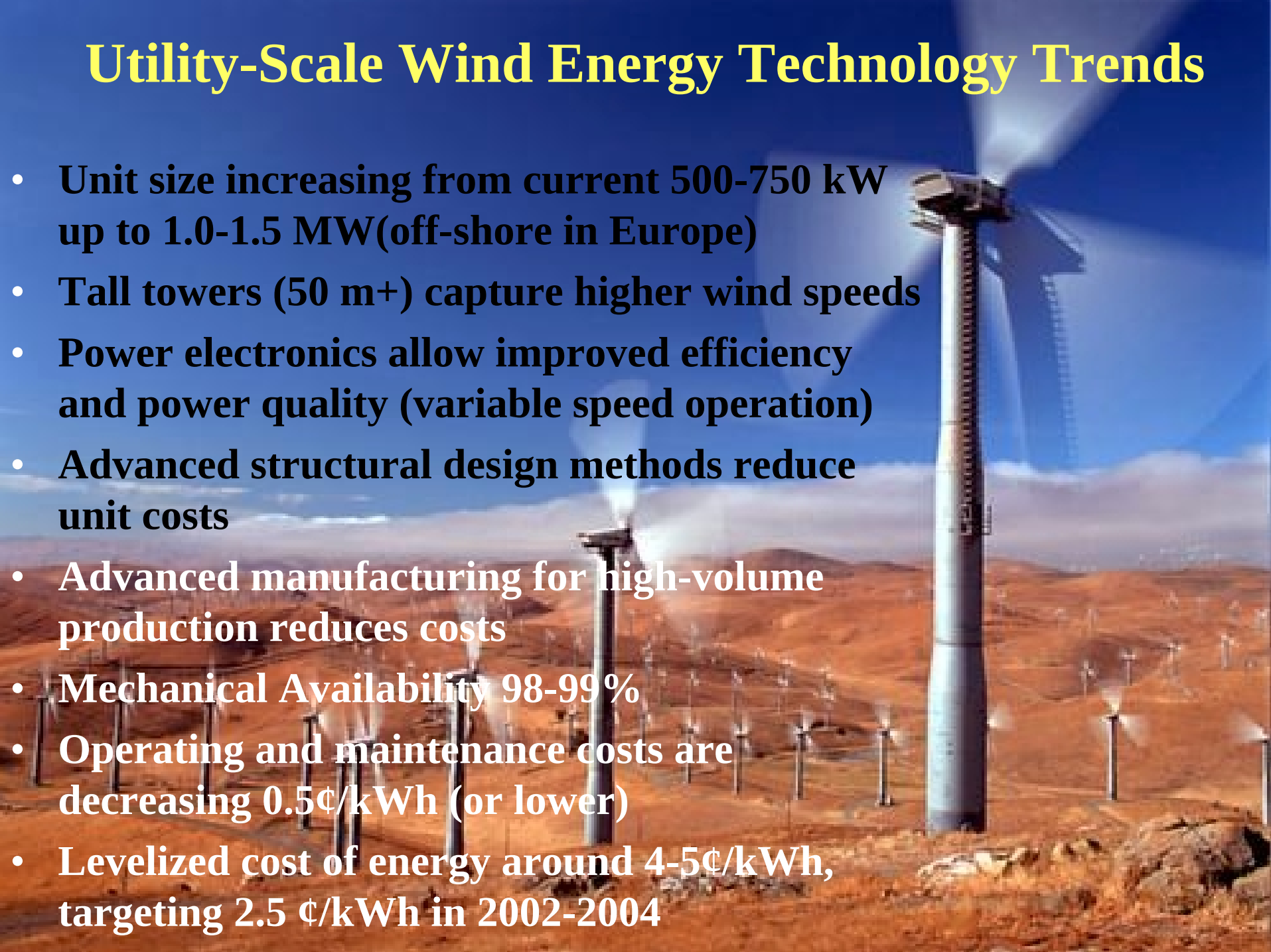
Comparison of Large and Small Wind Turbines

Characteristic	Large Turbines	Small Turbines
Energy Competition	Coal, Oil, Natural Gas Nuclear, Hydro	Diesel, Grid Extension Kerosene, Batteries
Typical Applications	Bulk Power Grid Connected	Village / Remote Power Not Grid Connected
Typical Implementation	10 - 300 Units in a Windfarm	1 or more Units for a home, school, farm or village
Other Applications	Distributed Applications, and larger Mini-grids	Water Pumping Telecommunications (battery-charging stations, ice-making, desalination, water purification)
Primary Design Goal	Minimize Cost of Energy	Maximize Reliability

Applications Status

- Small turbines are used for domestic net-billing and world-wide off-grid applications
- Most of 3000 MW in Germany and 1500 MW in Denmark are single turbines or clusters connected to distribution lines
- Majority of 2500 MW in U.S. are large windfarms connected to transmission system
- Some U.S. utilities have been trying distributed deployment

Utility-Scale Wind Energy Technology Trends

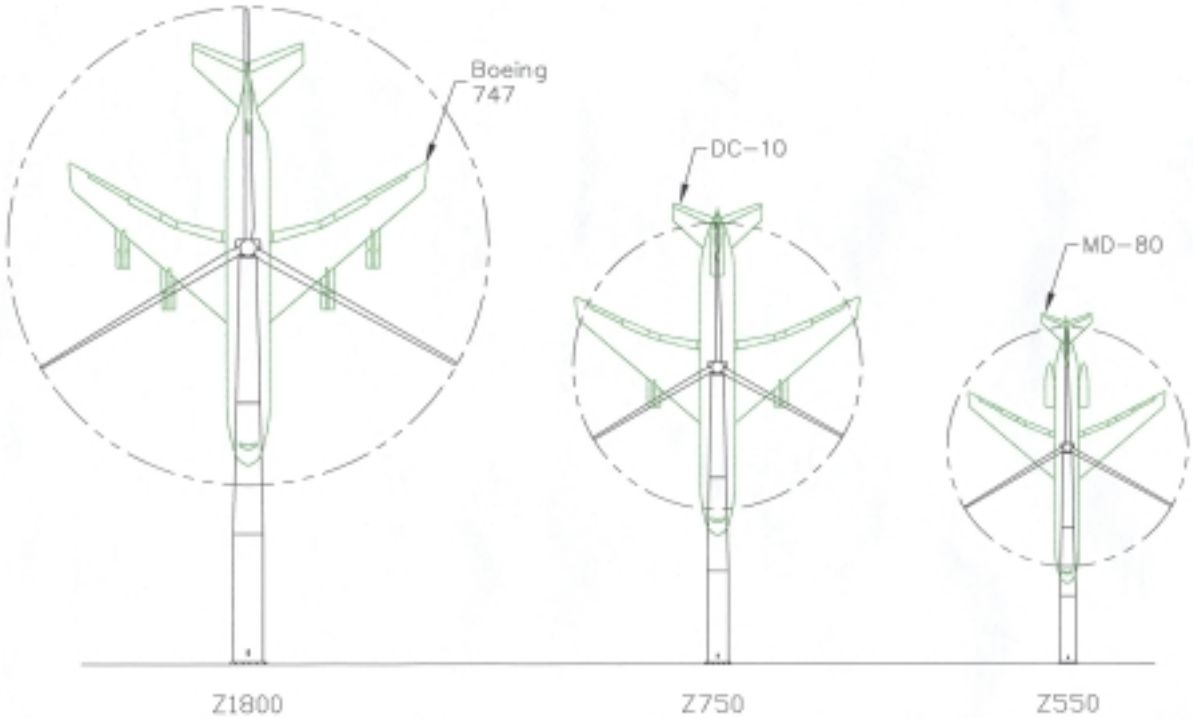


- Unit size increasing from current 500-750 kW up to 1.0-1.5 MW(off-shore in Europe)
- Tall towers (50 m+) capture higher wind speeds
- Power electronics allow improved efficiency and power quality (variable speed operation)
- Advanced structural design methods reduce unit costs
- Advanced manufacturing for high-volume production reduces costs
- Mechanical Availability 98-99%
- Operating and maintenance costs are decreasing 0.5¢/kWh (or lower)
- Levelized cost of energy around 4-5¢/kWh, targeting 2.5 ¢/kWh in 2002-2004

Z1800/NGT-POC

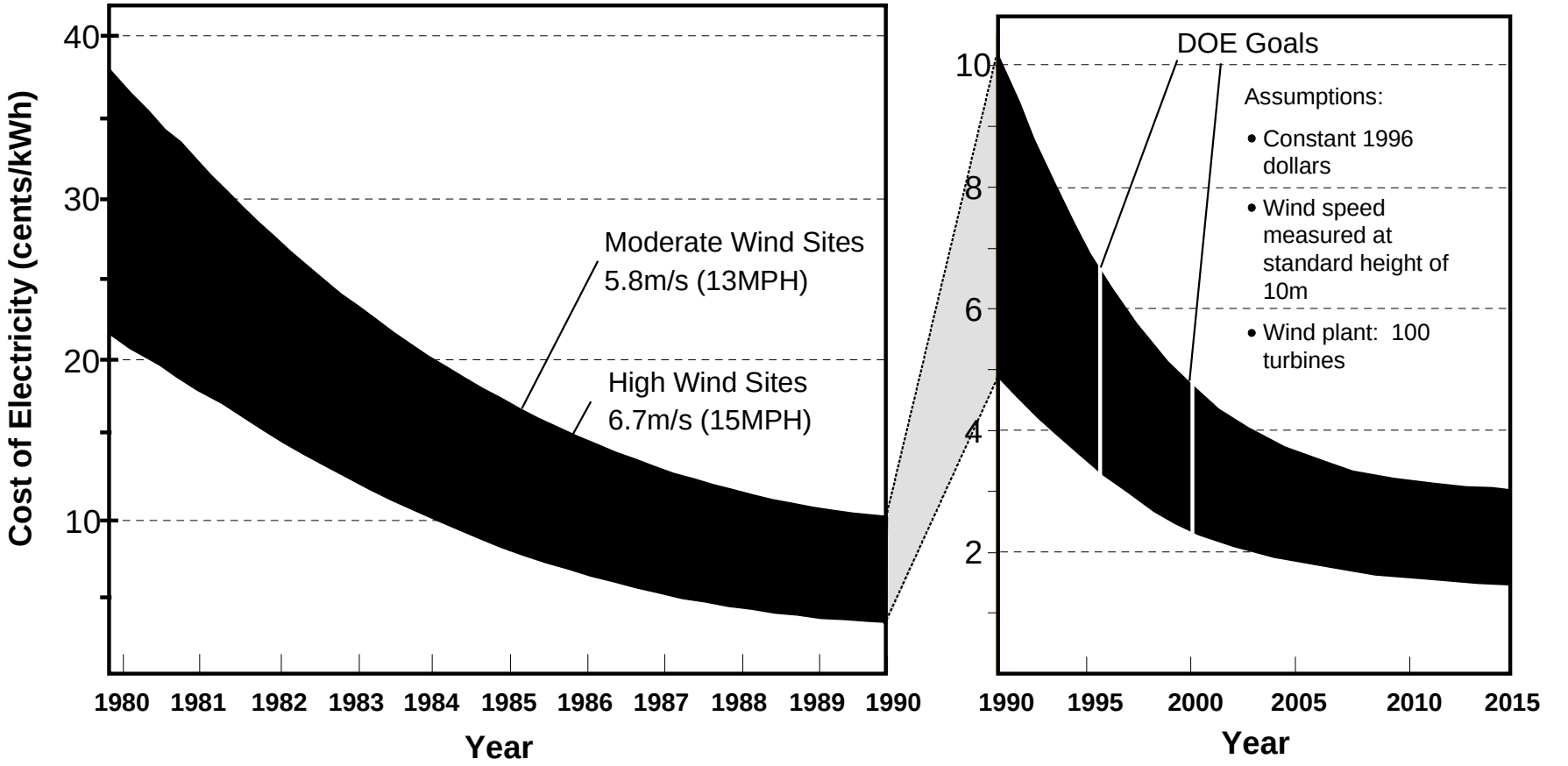
1.8 MW Power Rating
80.5m (264 ft) Diameter Rotor
80m (262 ft) Tower Height

Towers are not properly scaled. Z1800 tower is planned to be 85 meters, possibly above a 15 meter concrete base.



Zond

Cost Reduction Trend



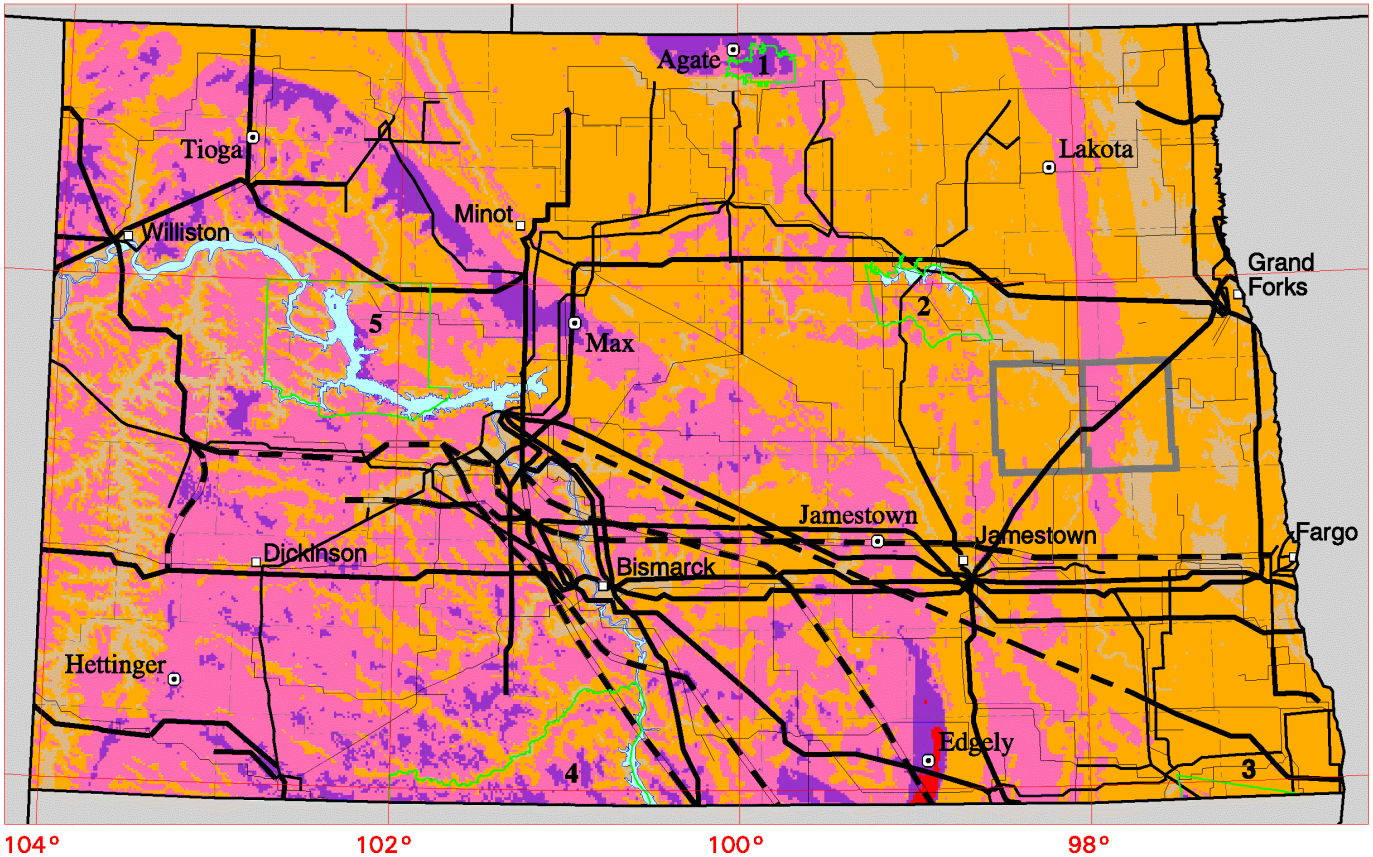
Market Obstacles

- Transmission
- Utility Risk -Uncertain Regulations and New Business Environment
- Intermittent Output
- Emerging Technology
- Siting: Avian, Land-use, Noise, Aesthetics

Market Trends and Opportunities

- **Restructuring (federal and state)**
  - **customer preference for clean power (early indicators in CA, MA, PN)** ***Rules Matter - labeling, stranded cost recovery, and mandated rate reductions***
  - **system benefits charges (12 states with renewable provisions)**
  - **renewable portfolio standards (8 states)**
  - **estimated impact of enacted SBC's and RPS's: 4800 MW by 2010**
- **Green products in regulated monopoly (20 states, over 57 MW new wind installed to date)**
- **Net metering in over 30 states, various specific provisions**
- **Existing nuclear and coal plant retirements**
- **Future environmental regulations: toxics, global climate change**

North Dakota - 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
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

WAPA Study Site
City or Town

Empowerment Zone

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

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

Conclusions and Issues

- Costs are dropping, but economic development and environmentally motivated public policies make the deployment difference
- Technologies are well established in a variety of world market places
- Opportunity exists for farmer income through land rents or turbine ownership
- Transmission limits need cooperative solutions
- Financing mechanisms are not in place for distributed deployment of larger machines (local ownership)