Wind Power

Presentation by:

Victor Austin

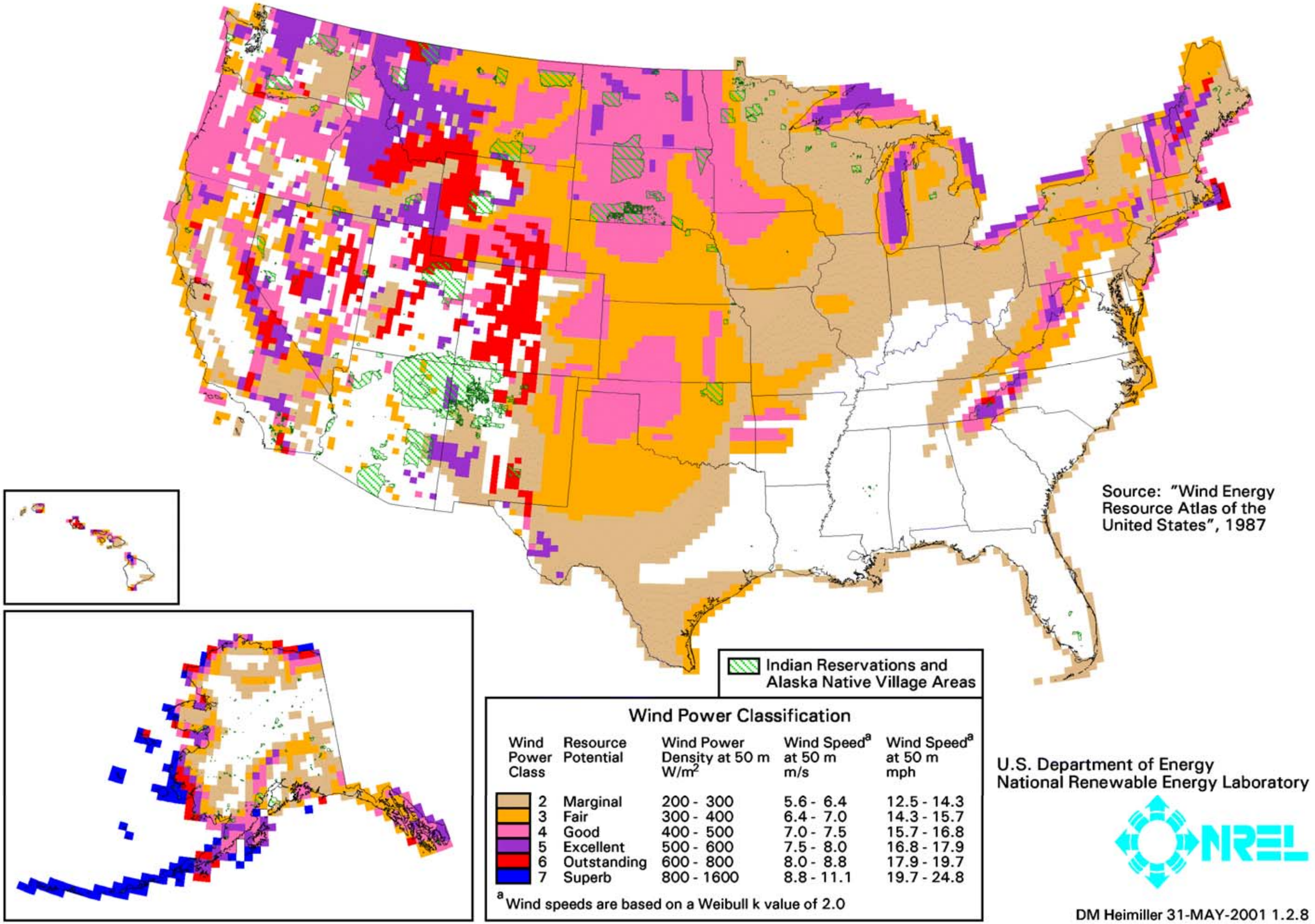
Midwest Renewable Energy Corporation

Outline

- The Wind Resource
- Turbine Design
- US Wind Industry
- Wind Farm Development
- The Future

The Wind Resource

United States - Wind Resource Map



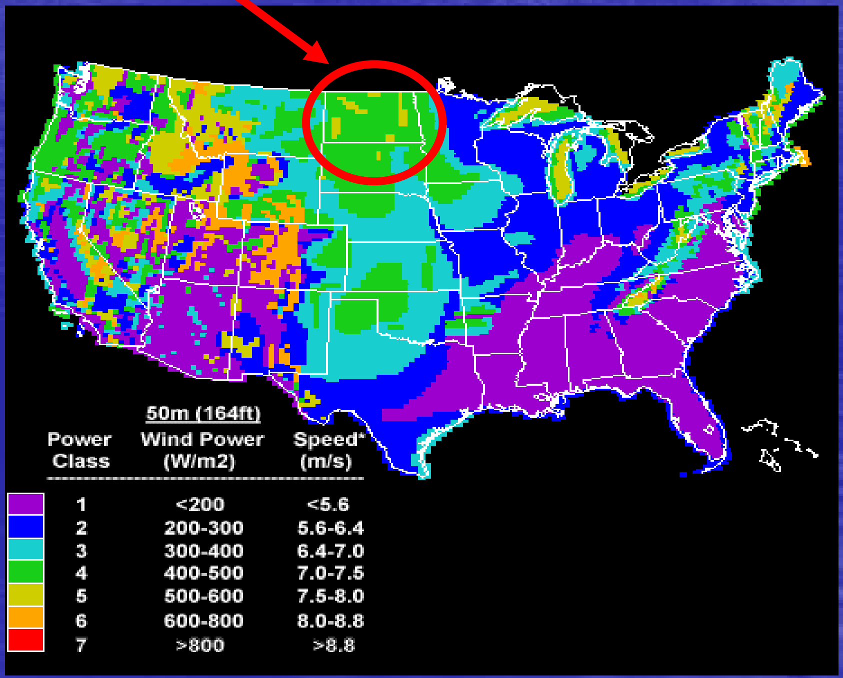
North Dakota: The "Saudi Arabia" of Wind

- Enough wind potential to supply 1/3 of the electricity consumption of the lower 48 states.
- No major load centers – need to transmit power to remote locations
- Potential to become an clean fuel supplier to Minneapolis & Chicago:

    Electricity (through power transmission lines)

    Hydrogen (through pipelines)

Wind Resources & Infrastructure Challenges



Power in the Wind

Power = Work / t

= Kinetic Energy / t

$= \frac{1}{2} m V^2 / t$

$= \frac{1}{2} (\rho A d) V^2 / t$

$= \frac{1}{2} \rho A V^2 (d/t)$

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

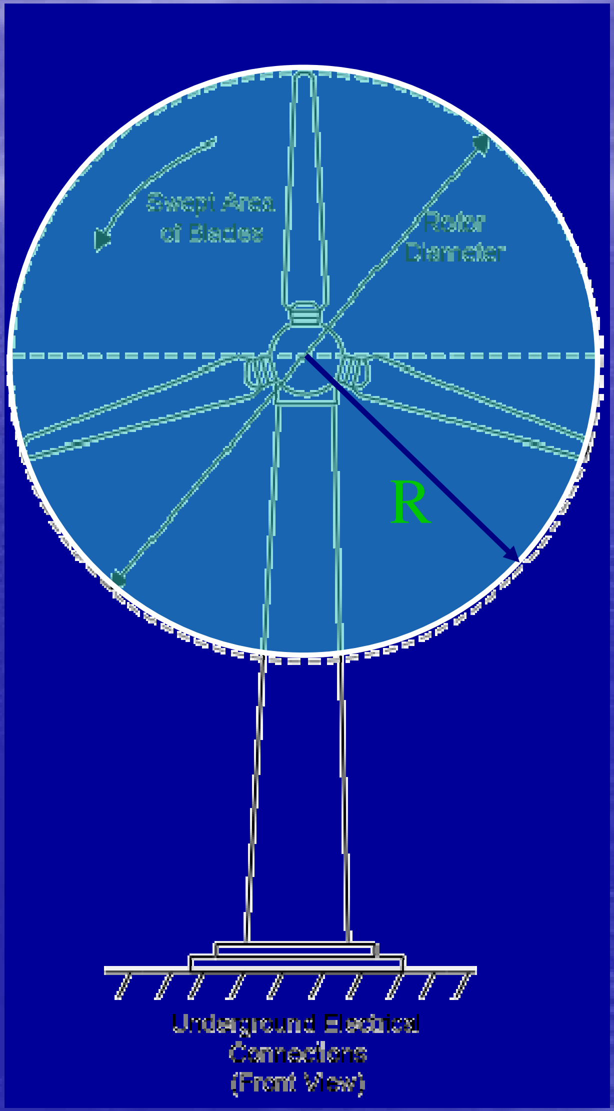
$d/t = V$

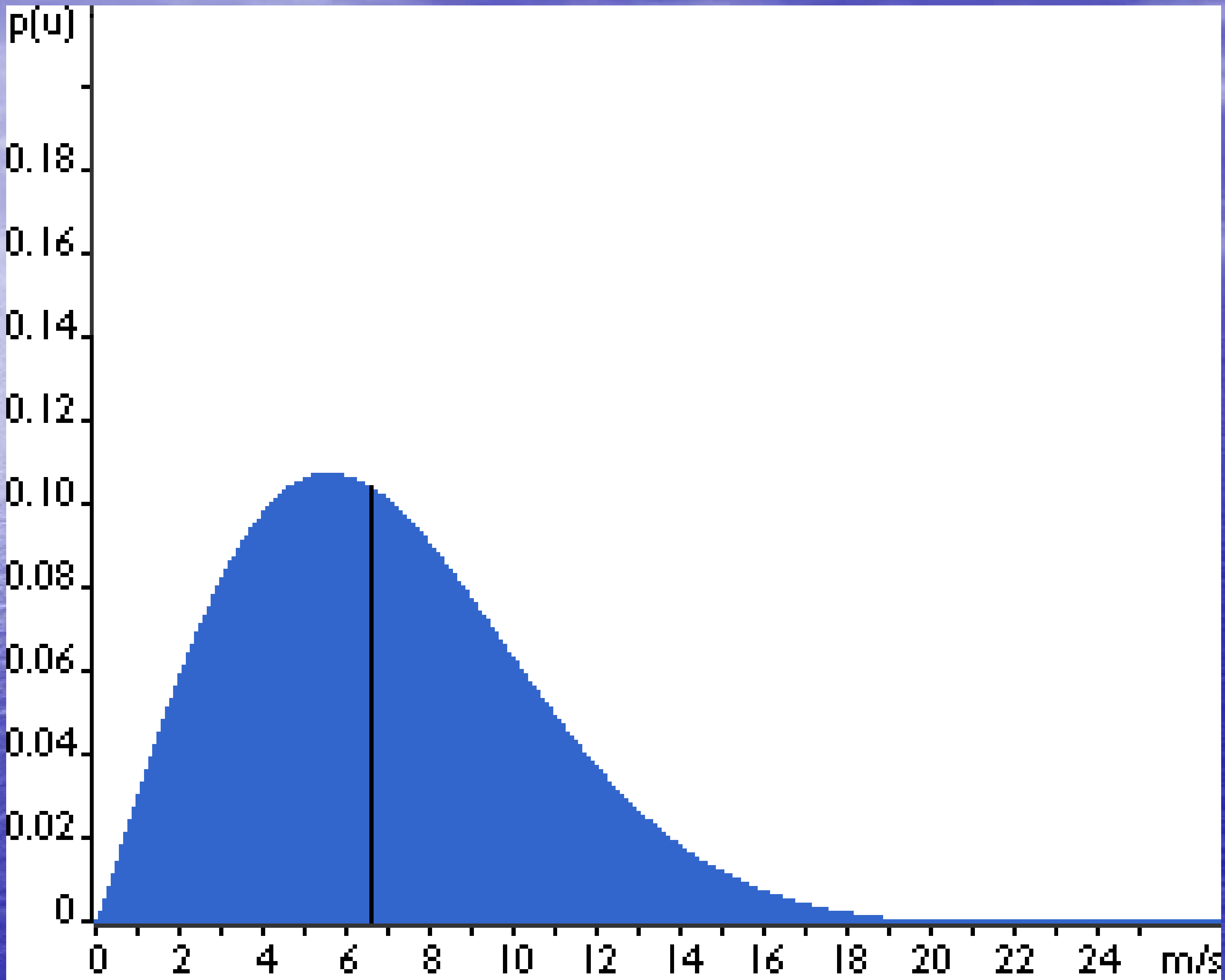
Power in the Wind = $\frac{1}{2} \rho A V^3$

Maximum Power

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

- Swept Area – $A = \pi R^2$ (m^2) Area of the circle swept by the rotor.
- Power from a Wind Turbine Rotor $= C_p \frac{1}{2}\rho AV^3$
- Betz limit (air can not be slowed to zero) $C_p < 59\%$
- Generator Losses




p(u)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
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0.02
0
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2
4
6
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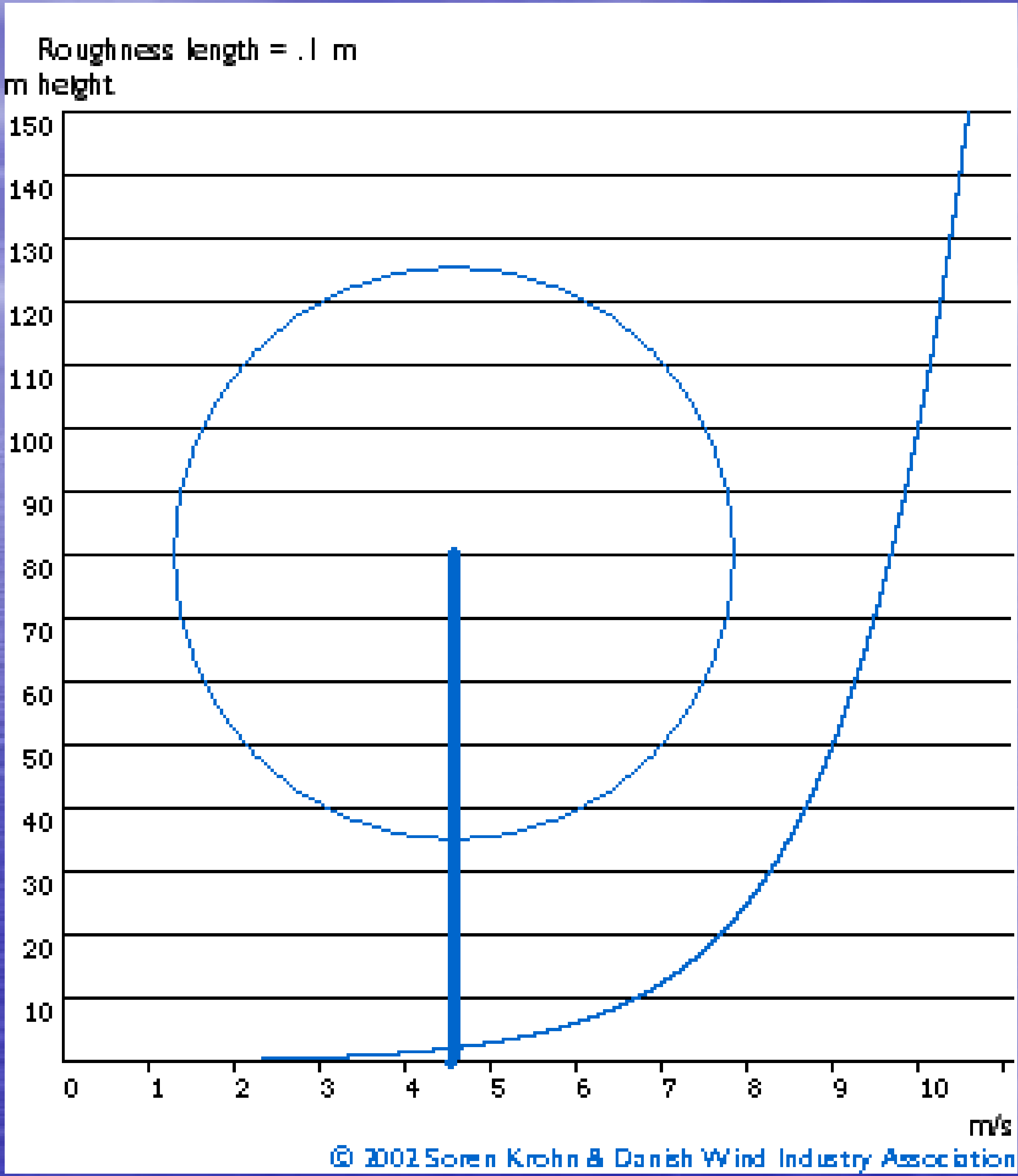
18
20
22
24
m/s


Roughness length = .1 m
m height
150
140
130
120
110
100
90
80
70
60
50
40
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0
1
2
3
4
5
6
7
8
9
10
m/s
© 2002 Soren Krohn & Danish Wind Industry Association

Turbine Design

Sizes and Applications

Small (≤10 kW)

- Homes
- Farms
- Remote Applications

(e.g. water pumping, telecom sites, icemaking)

Intermediate

(10-250 kW)

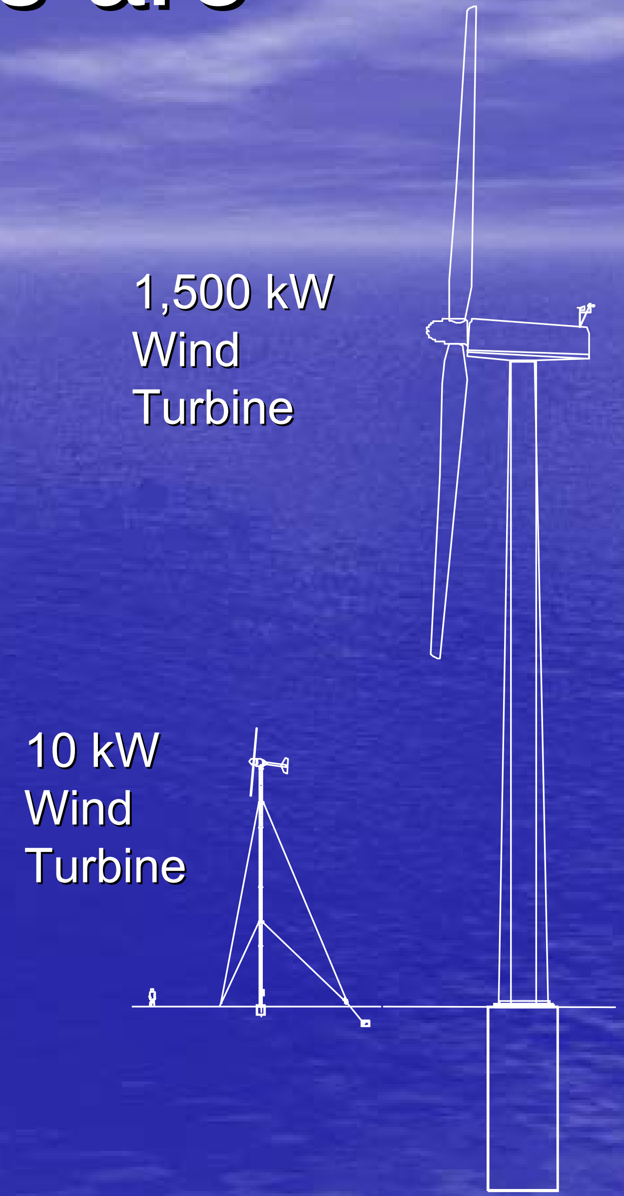
- Village Power
- Hybrid Systems
- Distributed Power

Large (250 kW - 2+MW)

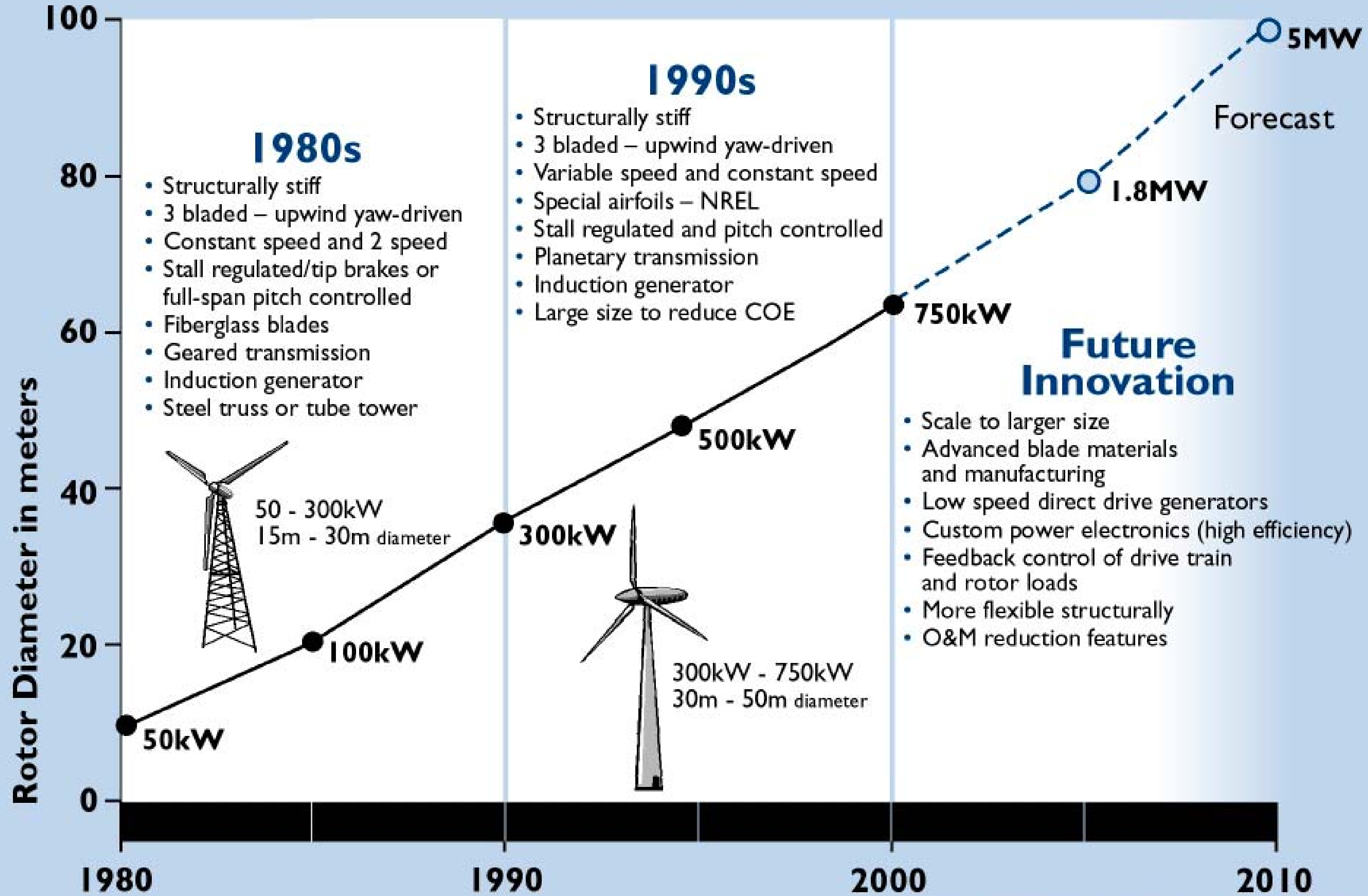
- Central Station Wind Farms
- Distributed Power

Small Wind Turbines are Different

- Large Turbines (600-1800 kW)
  - Installed in Windfarms, 10 - 100 MW
  - Provide Low Cost Power to the Grid
  - < $1,000/kW
  - Require 6 m/s (13 mph) Average Wind
- Small Turbines (0.3-50 kW)
  - Installed Off-Grid or at On-Grid Facilities
  - $2,000-6,000/kW
  - Designed for Reliability / Low Maintenance
  - Require 4 m/s (9 mph) Average

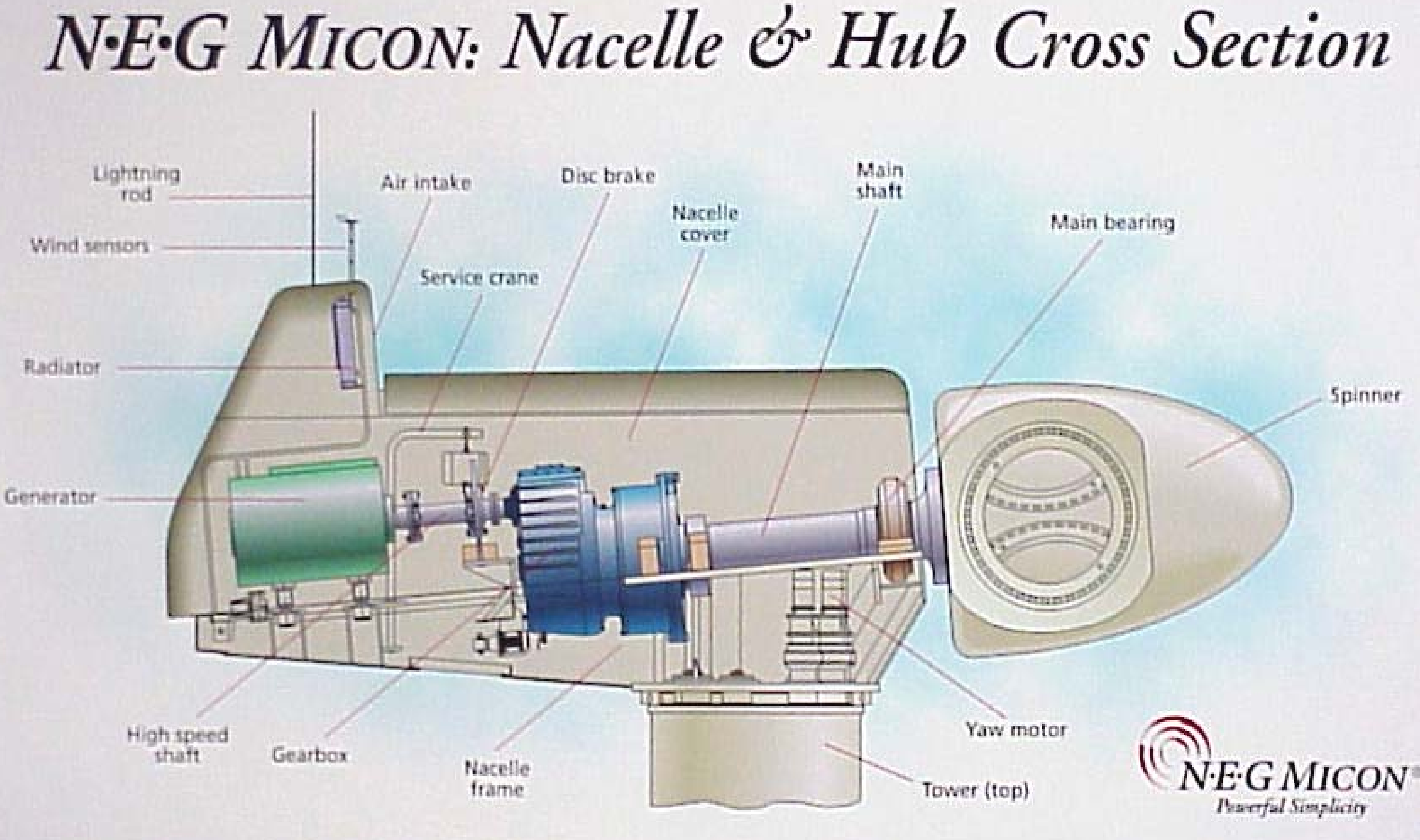


The Evolution of Commercial U.S. Wind Technology



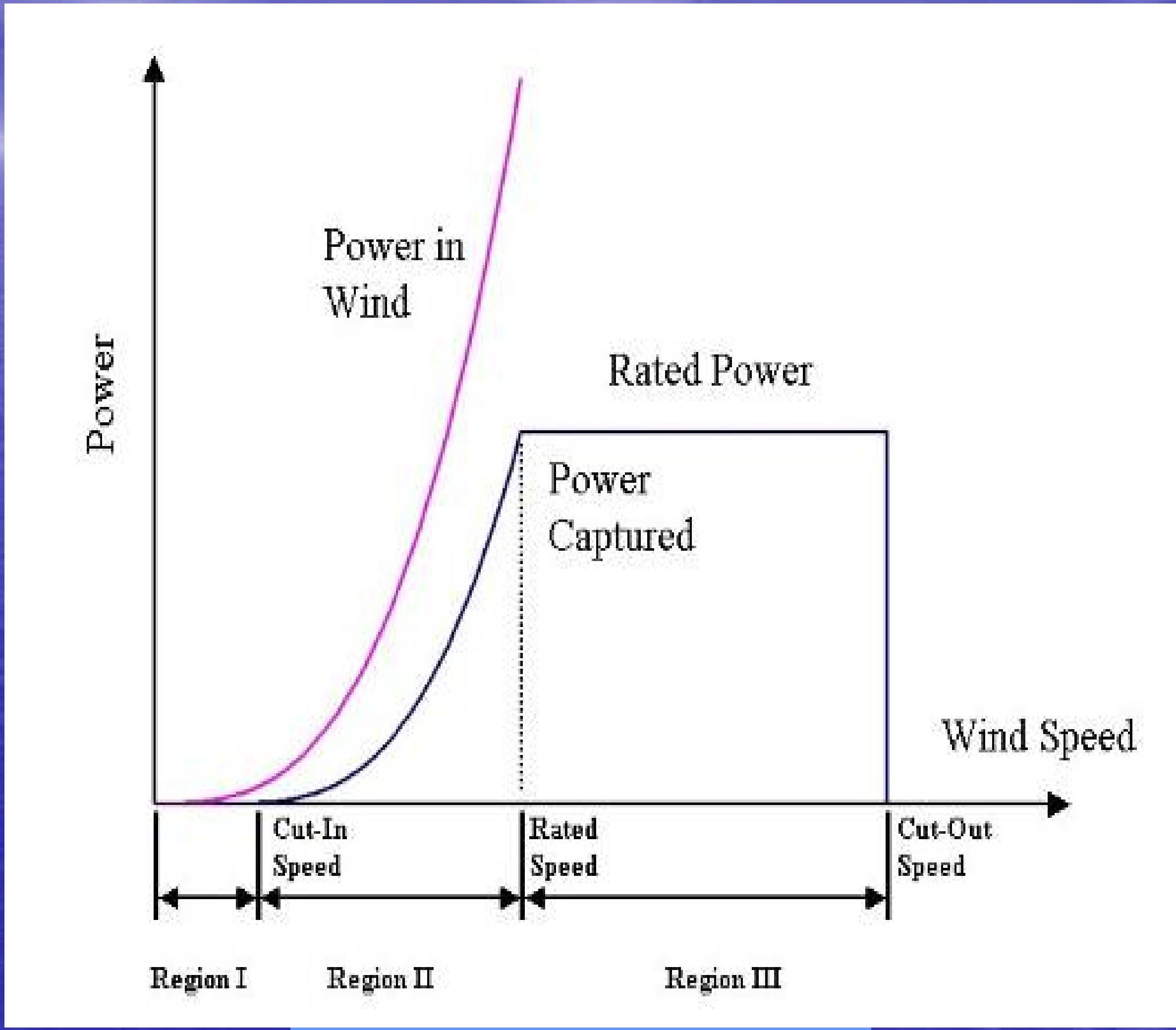
Source: Thresher & Dodge, Wind Energy Journal 1998

HOW A TURBINE CHANGES WIND ENERGY TO ELECTRICITY

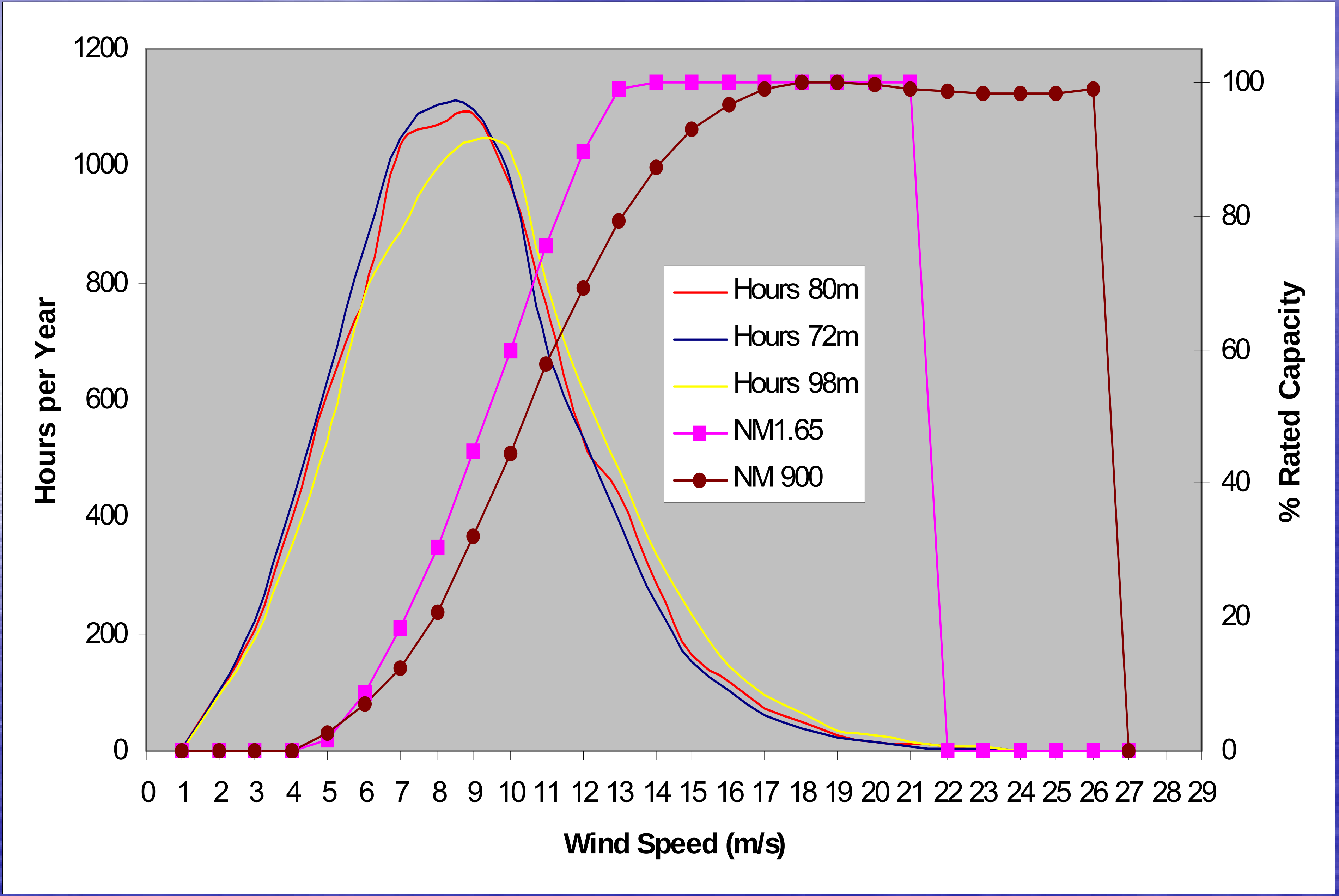


Energy Production Terms

- *Power in the Wind* = $1/2\rho AV^3$
- *Betz Limit* - 59% Max
- *Power Coefficient* - C_p
- *Rated Power* – Maximum power generator can produce.
- *Capacity factor*
  - Actual energy/maximum energy
- *Cut-in* wind speed where energy production begins
- *Cut-out* wind speed where energy production ends.



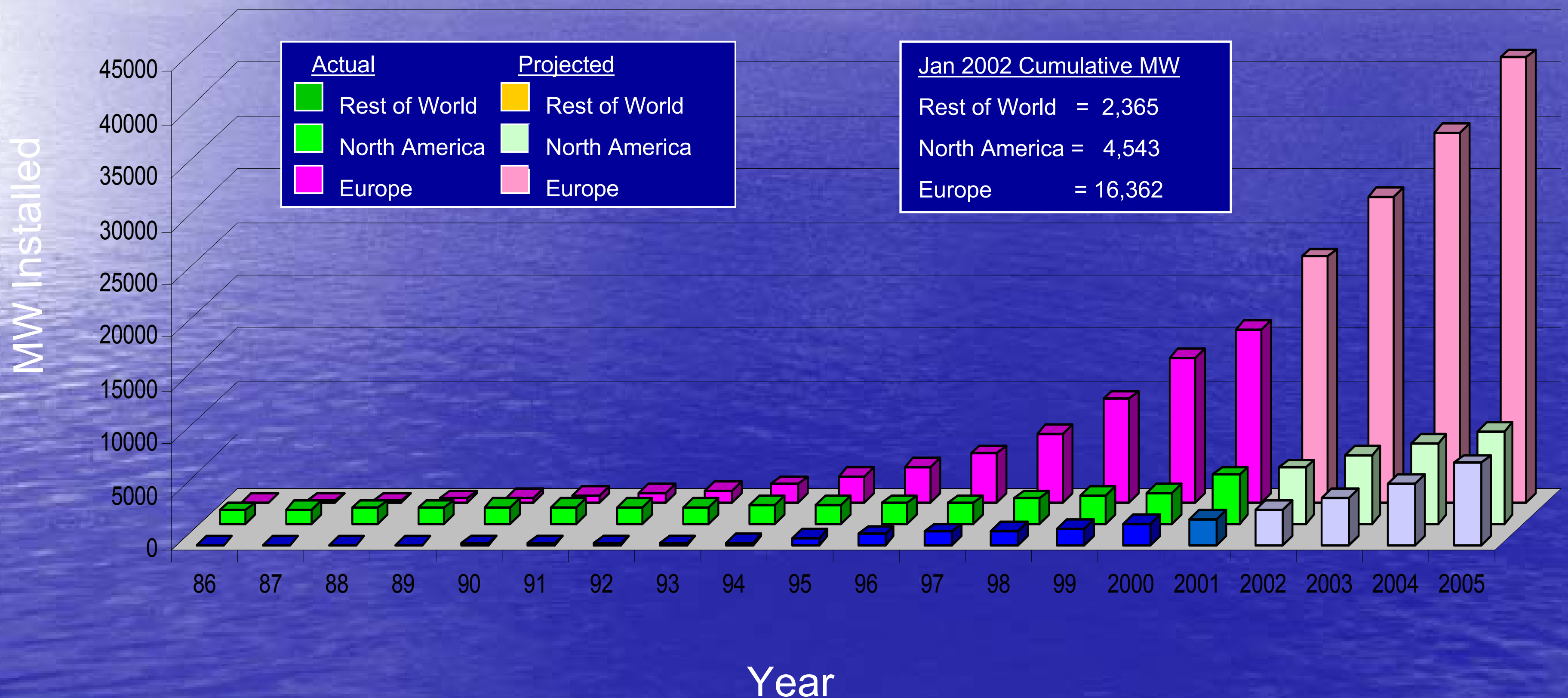
Typical Power Curve



1200
1000
800
600
400
200
0
Hours per Year
100
80
60
40
20
0
% Rated Capacity
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Wind Speed (m/s)
Hours 80m
Hours 72m
Hours 98m
NM1.65
NM 900

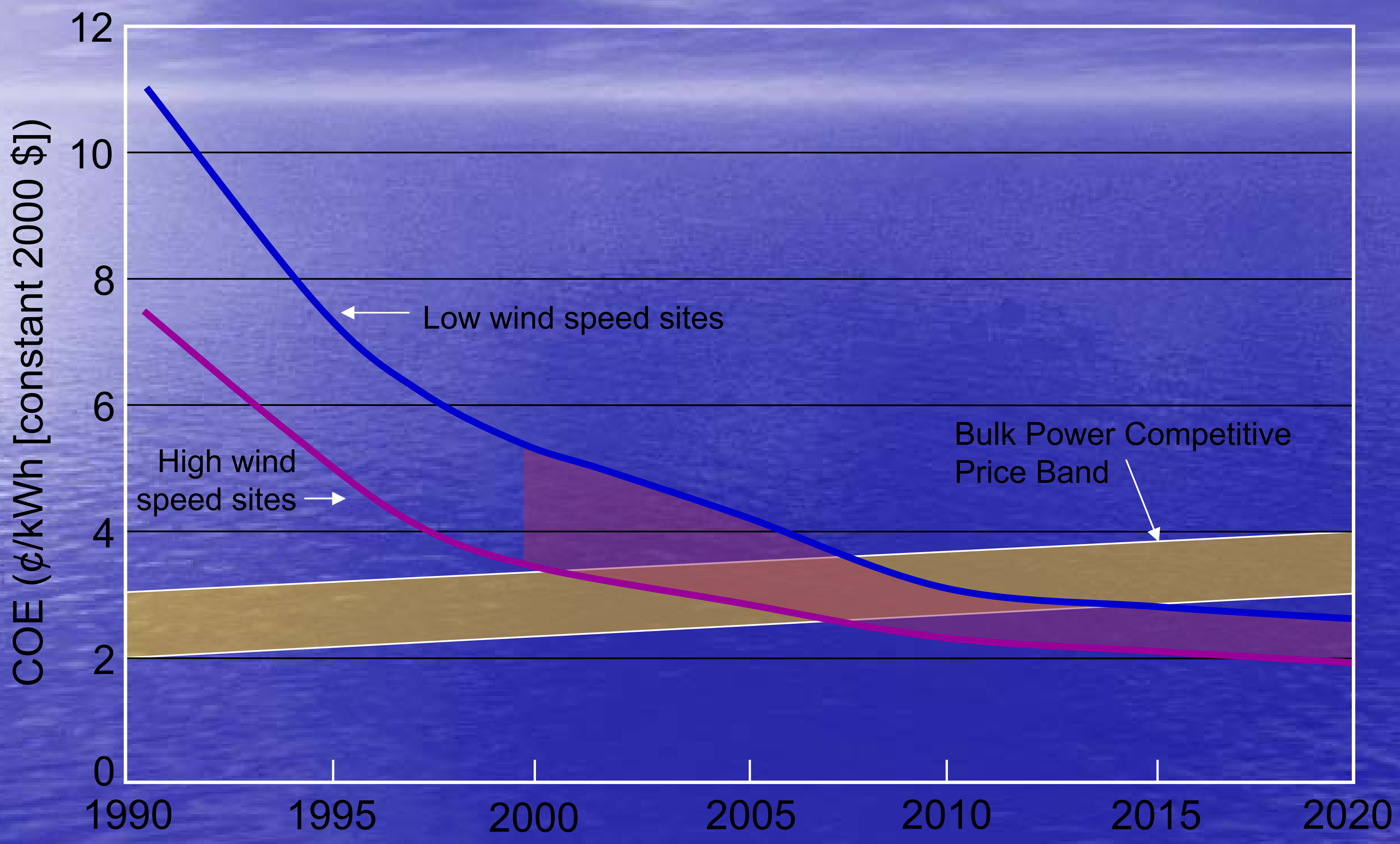
US Wind Industry

Growth of Wind Energy Capacity Worldwide



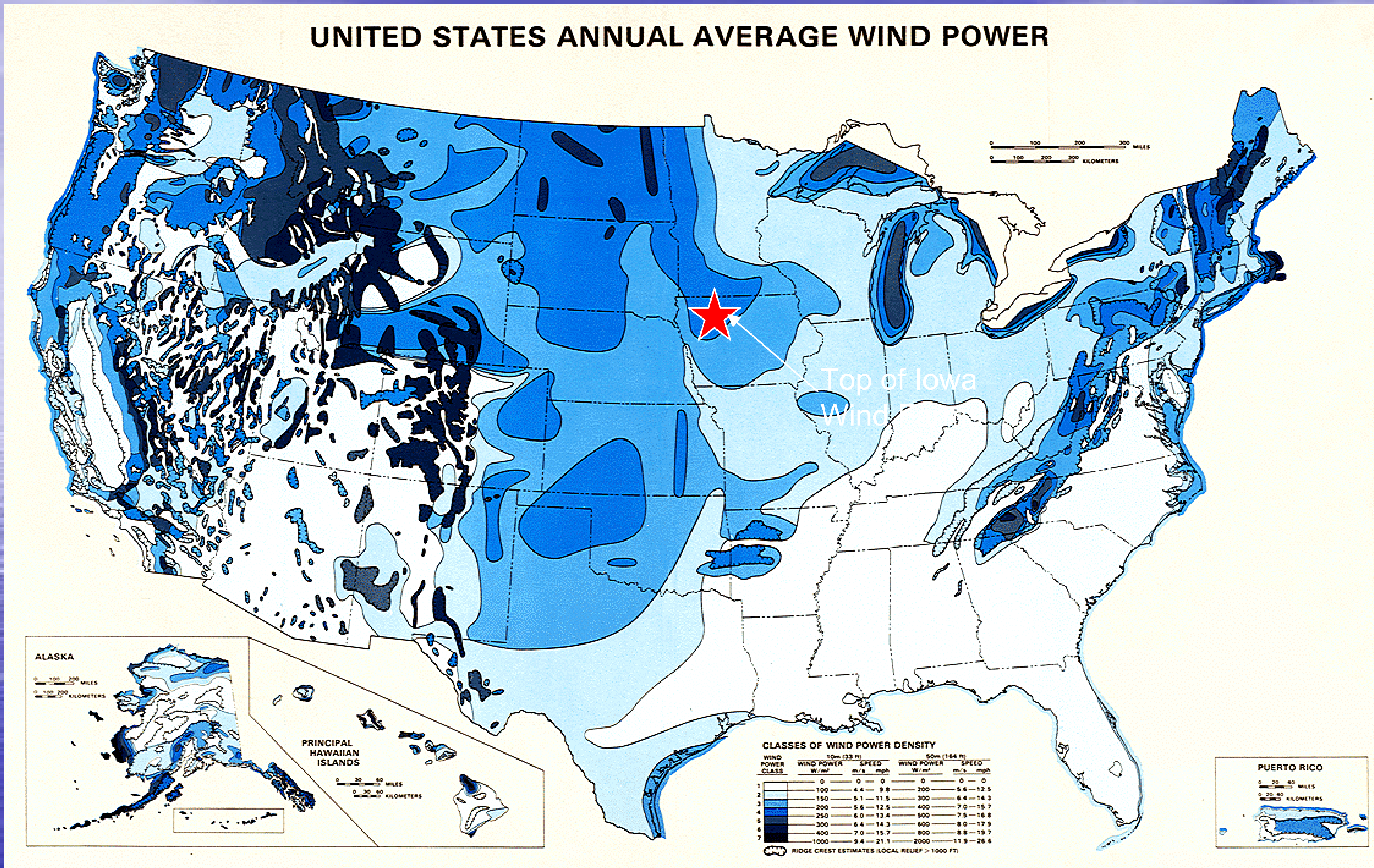
Sources: BTM Consult Aps, March 2001
Windpower Monthly, January 2002

Wind Cost of Energy

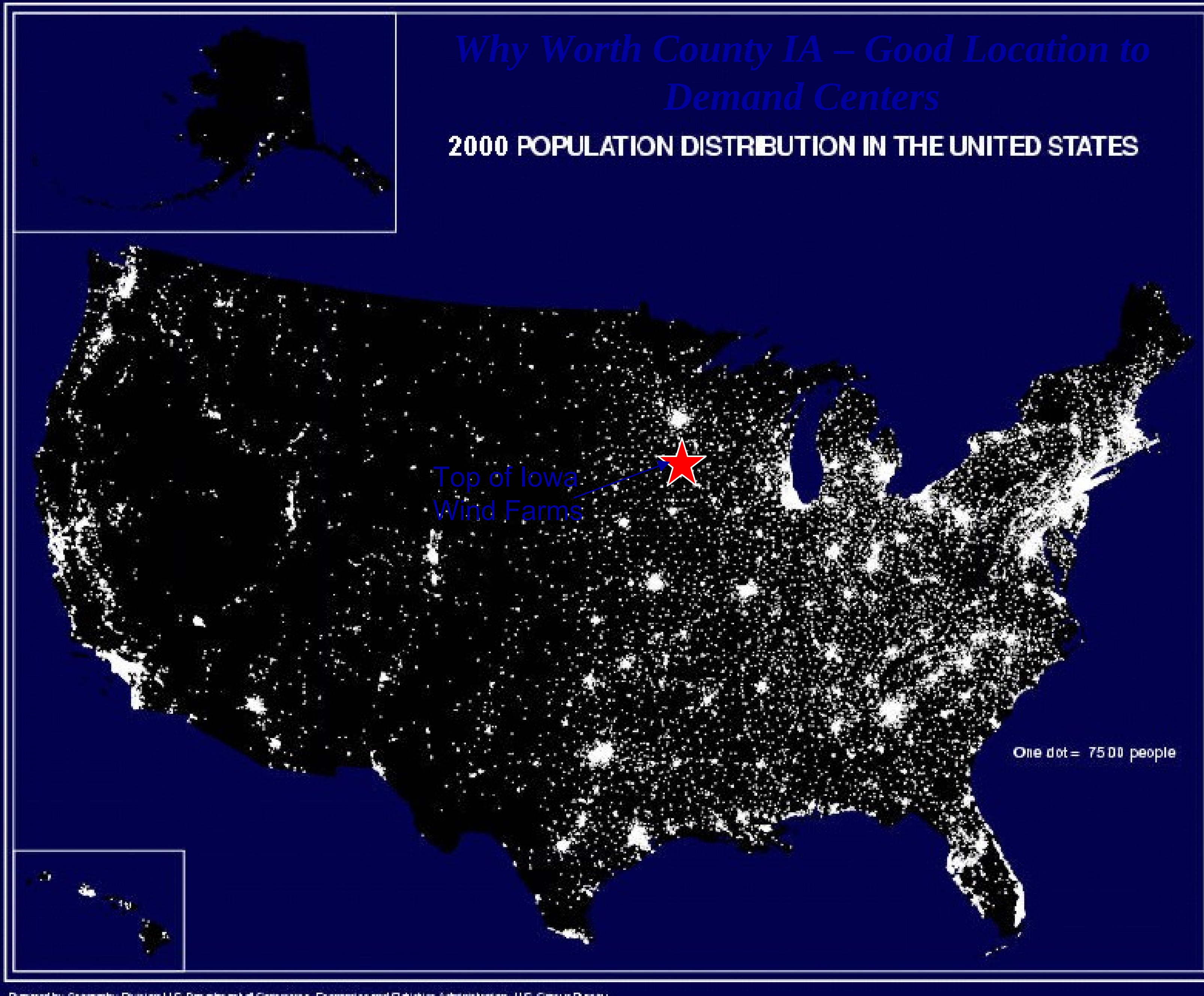


Wind Farm Development: Driving Factors

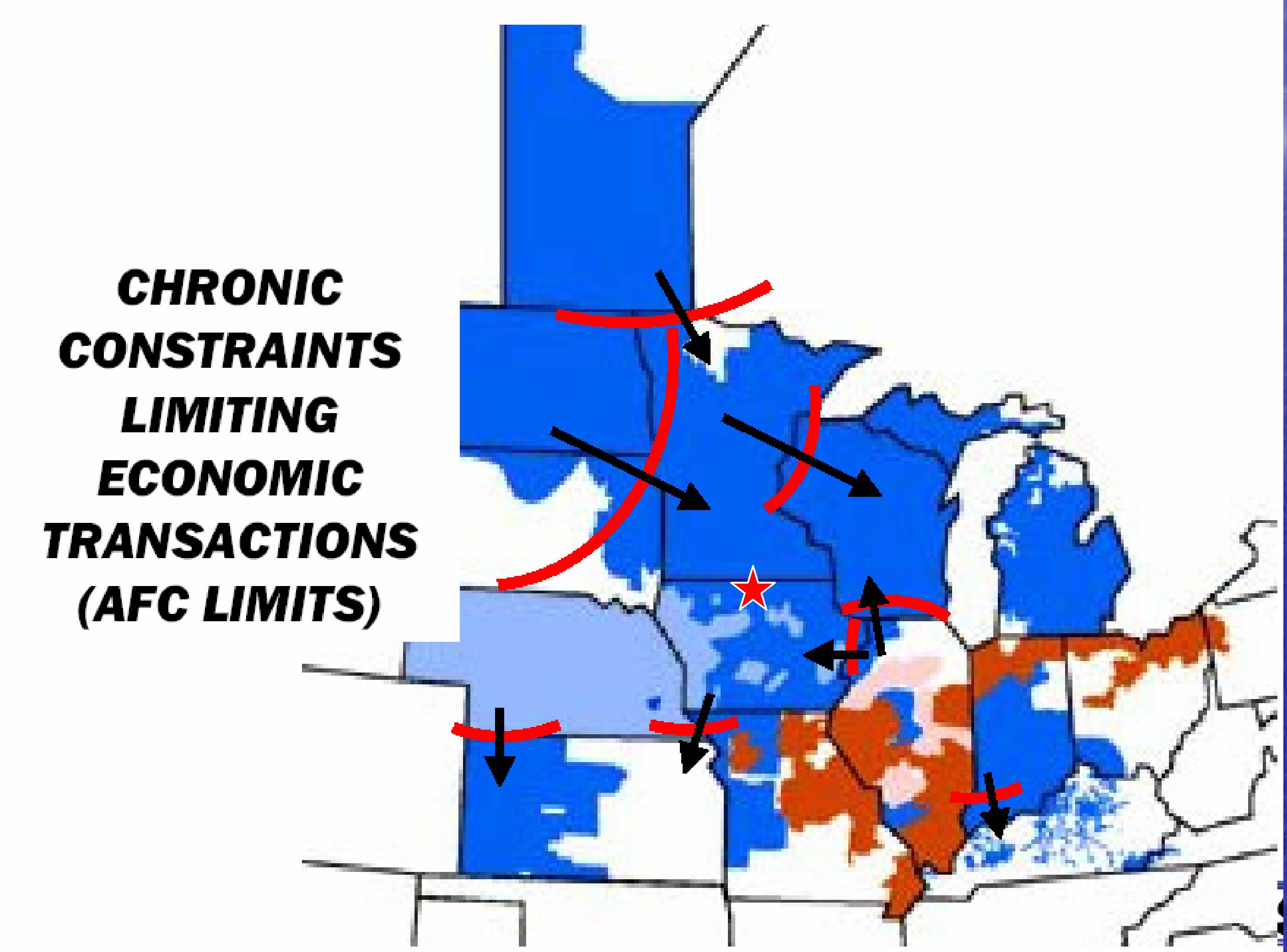
- Wind Resource
- Proximity to Transmission Lines/Substations with excess capacity
- State Policy Provisions
  - property/sales tax,
  - permitting and review,
  - subsidies and incentives
  - renewable power purchase mandates
- Utility green power programs and customer demand
- Federal Policy
  - renewal of production tax credit
  - potential purchase mandates


UNITED STATES ANNUAL AVERAGE WIND POWER
Top of Iowa Wind
ALASKA
PRINCIPAL HAWAIIAN ISLANDS
CLASSES OF WIND POWER DENSITY
WIND POWER CLASS
PUERTO RICO

Why Worth County IA – Good Location to Demand Centers

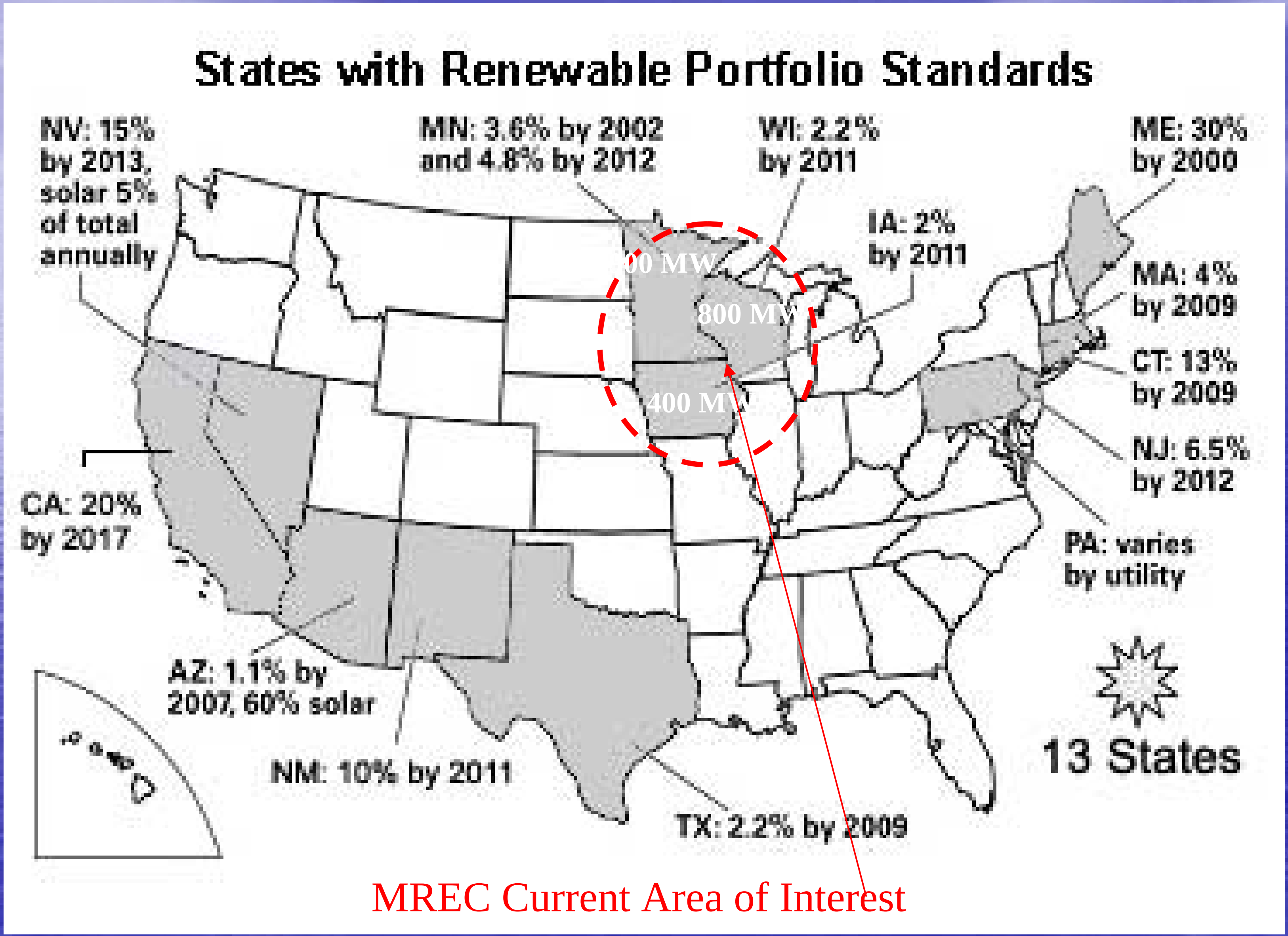


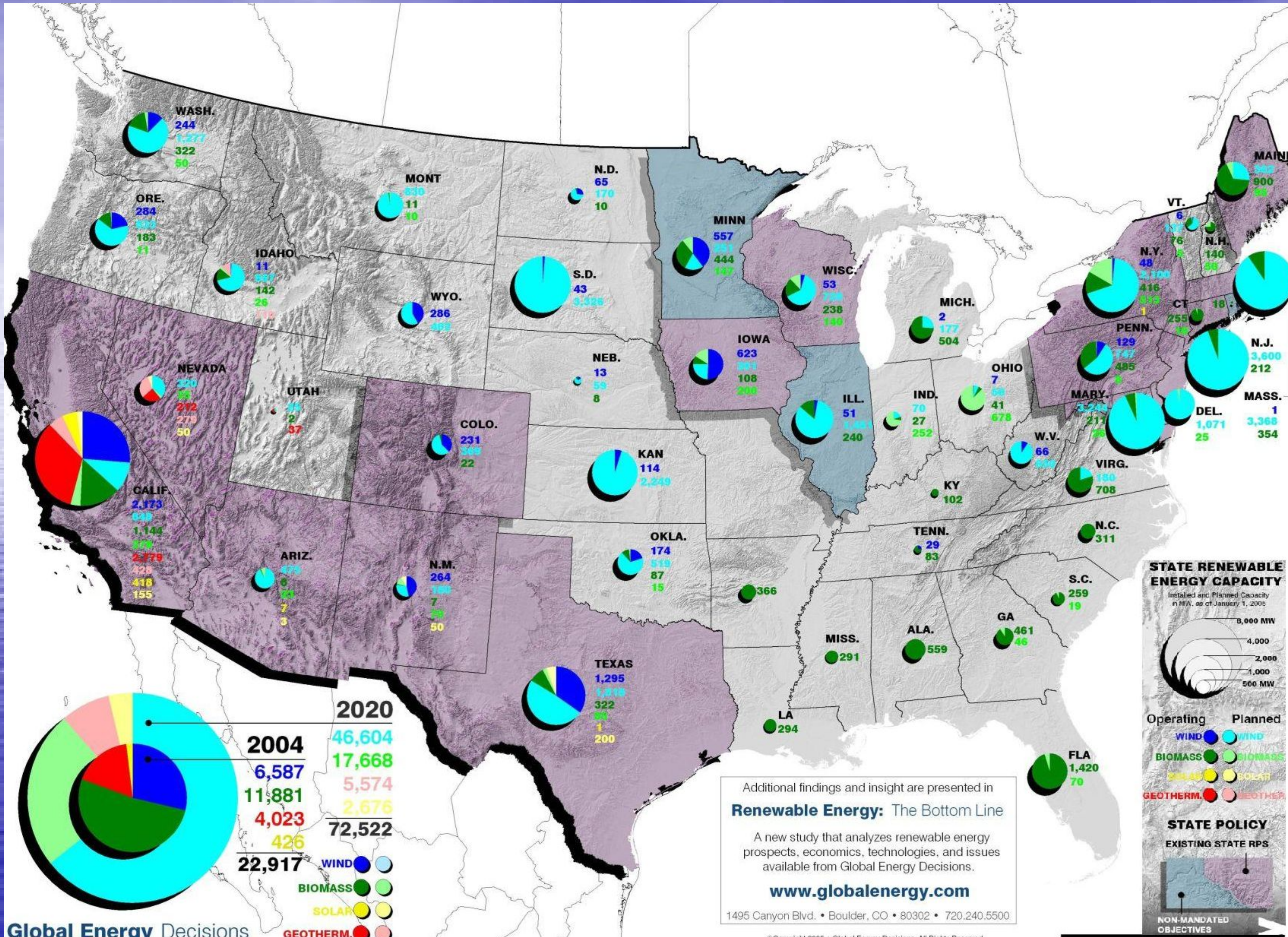
Why Worth County IA – About the best Non-Firm Transmission available



★ Top of Iowa Wind Farms

Mandated Market Demand




WASH.
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ORE.
284
183
MONT
11
10
N.D.
65
170
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IDAHO
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26
WYO.
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S.D.
43
MINN
557
444
WISC.
53
238
MICH.
2
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504
MAINE
900
VT.
6
76
N.H.
140
N.Y.
48
416
CT
255
18
PENN.
129
N.J.
3,600
212
NEVADA
UTAH
2
37
COLO.
231
22
NEB.
13
59
8
IOWA
623
108
ILL.
51
240
IND.
70
27
252
OHIO
7
41
678
MARY.
DEL.
1,071
25
MASS.
1
3,368
354
CALIF.
KAN
114
W.V.
66
VIRG.
708
KY
102
OKLA.
174
87
15
ARIZ.
N.M.
264
50
TENN.
29
83
N.C.
311
366
S.C.
259
19
GA
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46
MISS.
291
ALA.
559
TEXAS
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322
200
LA
294
FLA
1,420
70
2020
46,604
17,668
5,574
2,676
72,522
2004
6,587
11,881
4,023
426
22,917
WIND
BIOMASS
SOLAR
GEOTHERM.
Global Energy Decisions
STATE RENEWABLE ENERGY CAPACITY
8,000 MW
4,000
2,000
1,000
500 MW
Operating
Planned
STATE POLICY
EXISTING STATE RPS
NON-MANDATED OBJECTIVES
Additional findings and insight are presented in
Renewable Energy: The Bottom Line
A new study that analyzes renewable energy prospects, economics, technologies, and issues available from Global Energy Decisions.
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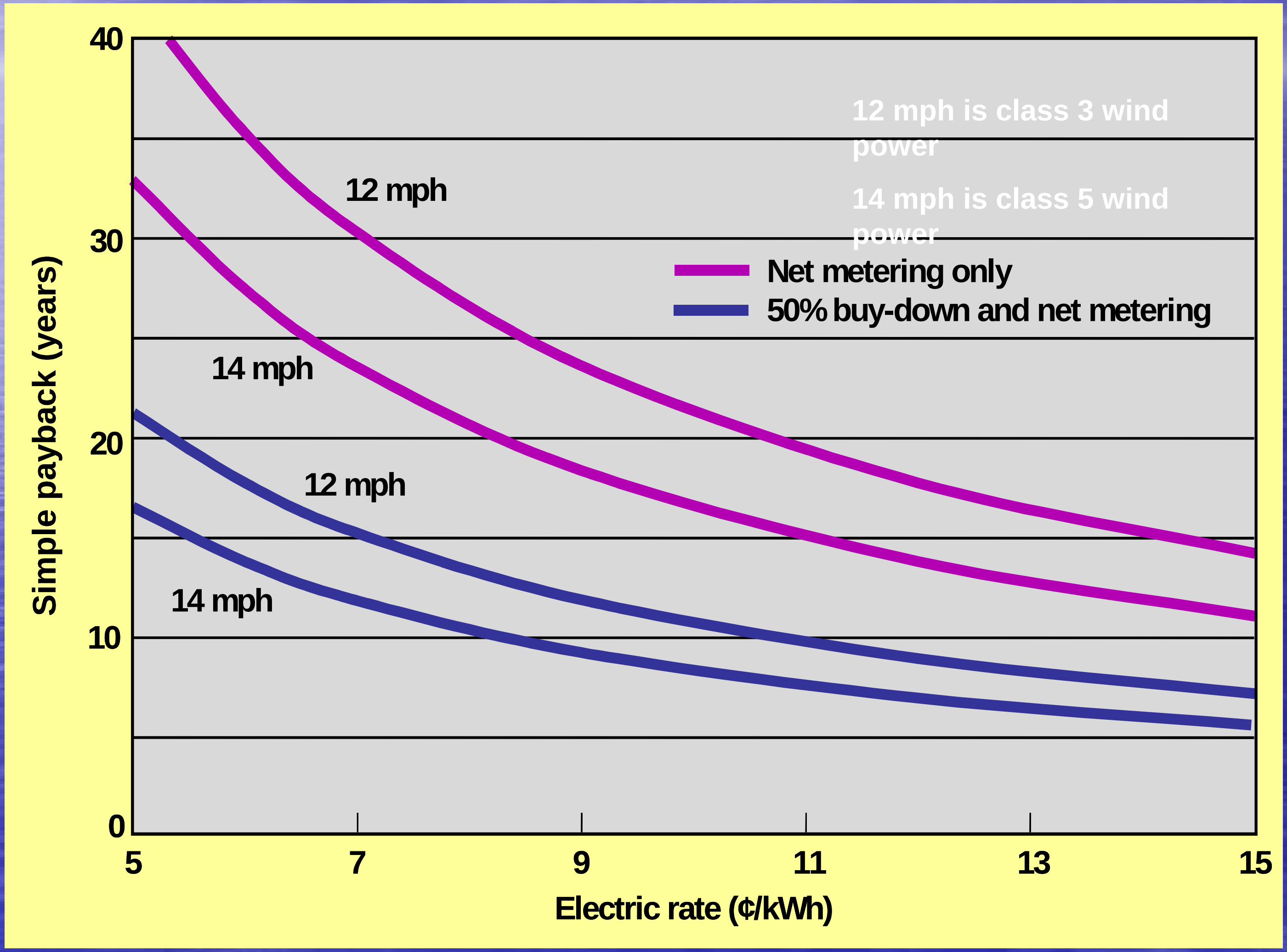
Payback



40
30
20
10
0
Simple payback (years)
12 mph is class 3 wind power
14 mph is class 5 wind power
12 mph
14 mph
12 mph
14 mph
Net metering only
50% buy-down and net metering
5
7
9
11
13
15
Electric rate (¢/kWh)

Economic Development Opportunities

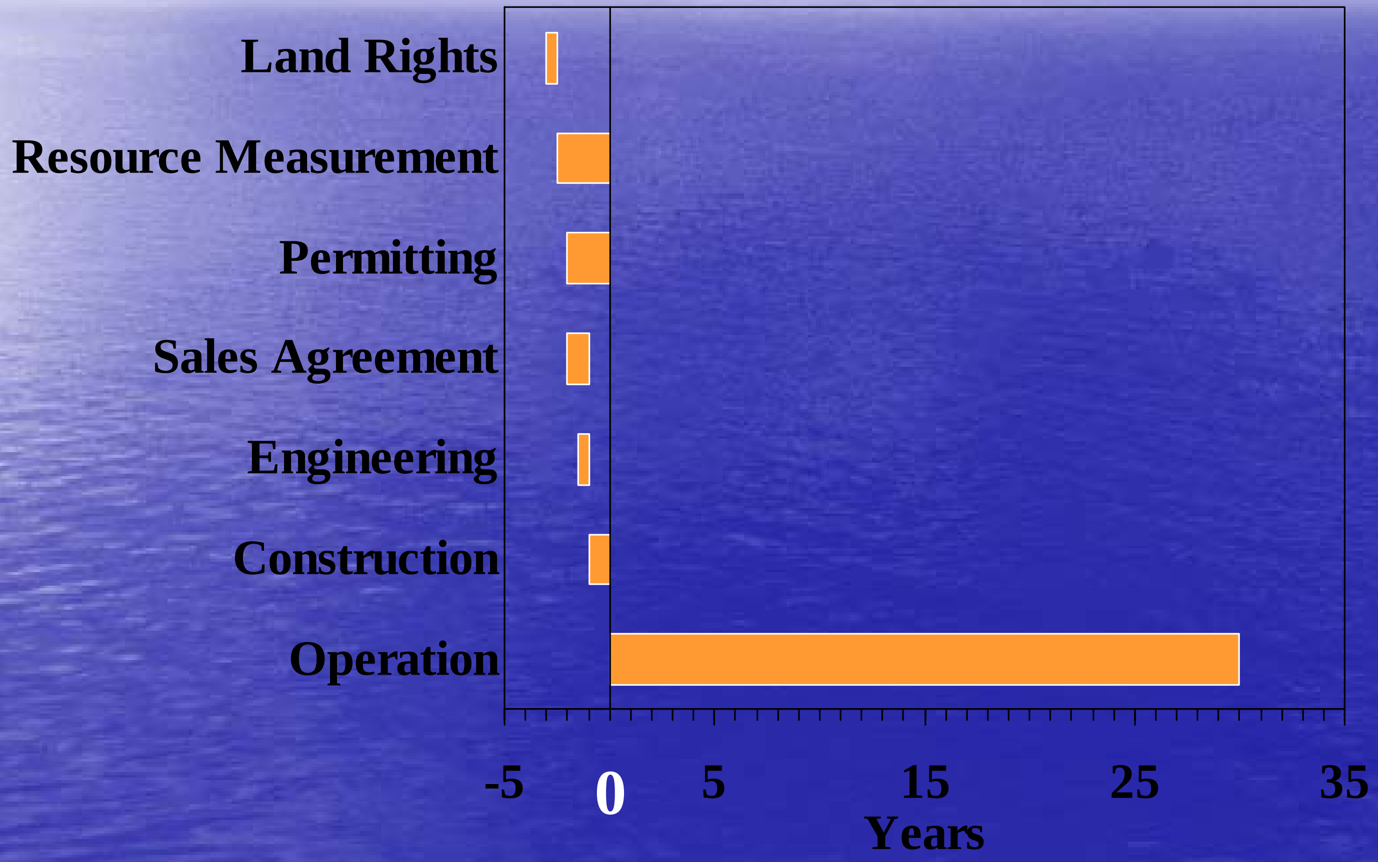
- Land Lease Payments: 2-3% of gross revenue $2500-4000/MW/year
- Local property tax revenue: 100 MW brings in on the order of $1 million/yr
- 1-2 jobs/MW during construction
- 2-5 permanent O&M jobs per 50-100 MW,
- Local construction and service industry: concrete, towers usually done locally
- Investment as Equity Owners: production tax credit, accelerated depreciation
- Manufacturing and Assembly plants expanding in U.S. (Micon in IL, LM Glasfiber in ND)

Wind Farm Development

Development Process:

- **Site prospecting**
  - Simultaneously taking first cut at everything
- **Land rights (leases, easements)**
- **Site investigation**
  - Wind measurement, analysis (2 years unless strongly correlations)
  - Environmental study
    - Sound, avian, viewshed, other issues (lightning, erosion, other flora, fauna)
  - Cultural issues (artifacts, land use, religious concerns, historic structures)
  - Geotechnical
- **Permitting**
- **PPA negotiation**
- **Engineering**
- **Financing**
- **Construction and Operation**

Project Development Cycle



BUILDING A WIND FARM

Build Accesses & Dig Foundation Holes

BUILDING A WIND FARM

Bury Underground Cable & Build Substation

BUILDING A WIND FARM

Install Foundations

BUILDING A WIND FARM

Deliver Turbines

BUILDING A WIND FARM

Install First Section

BUILDING A WIND FARM

Install Second Section

BUILDING A WIND FARM

Install Third Section & Nacelle

BUILDING A WIND FARM

Install Rotor

BUILDING A WIND FARM

Install Rotor

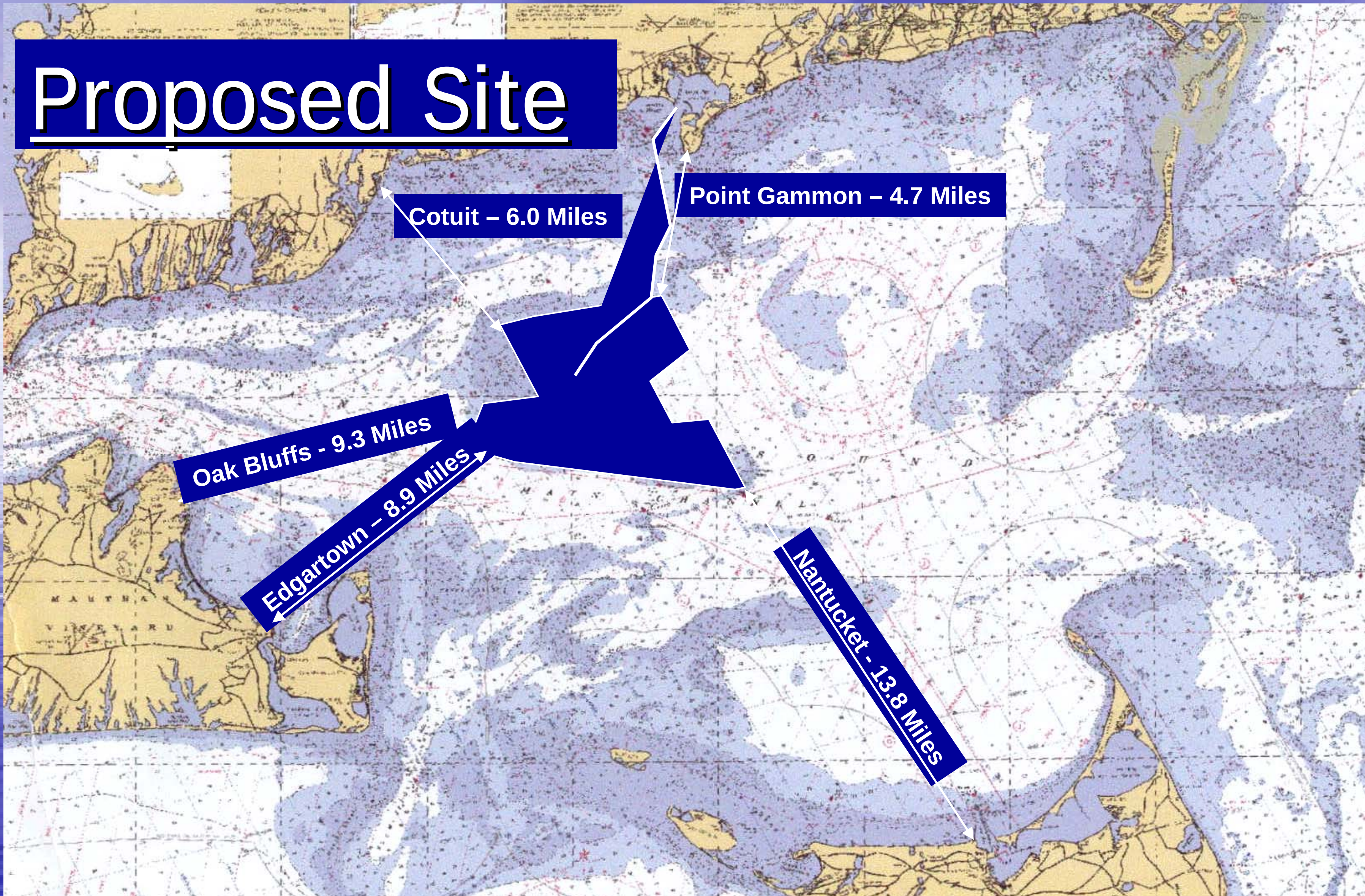
The Future

- With an eye for Florida

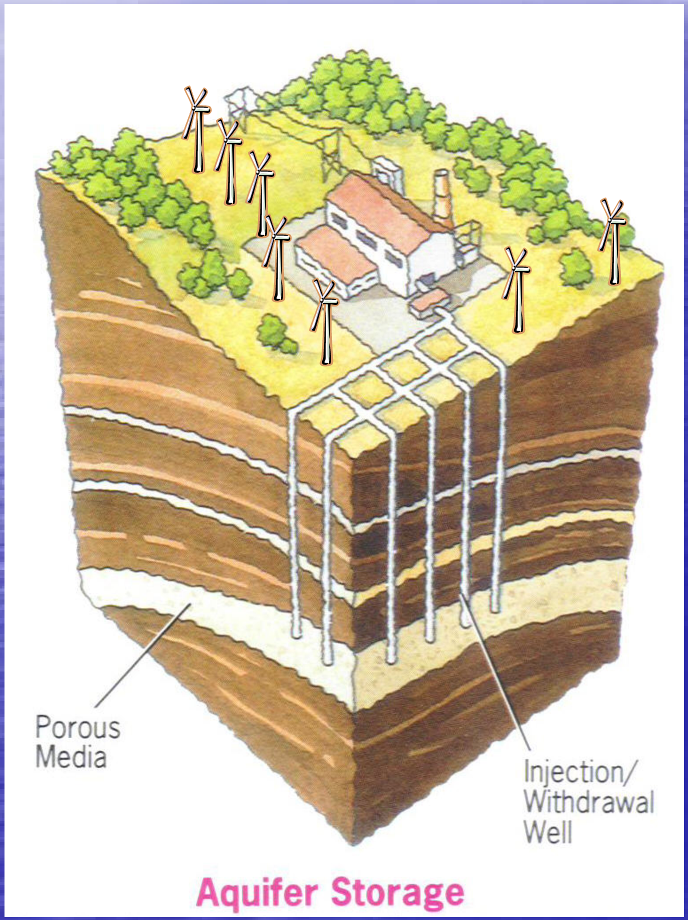
Utgrunden offshore project

Middlegrunden offshore project

Proposed Site



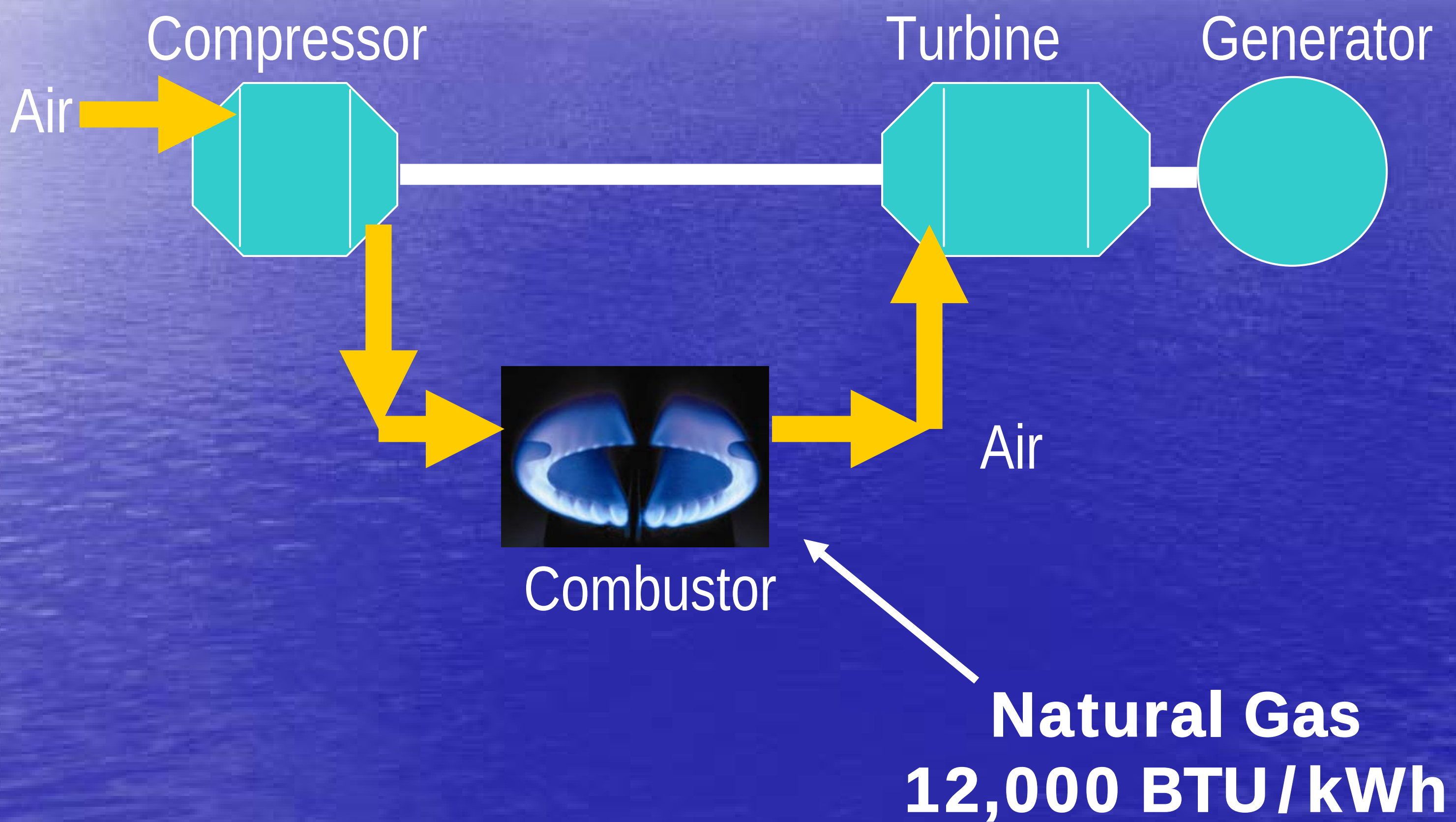
The Iowa Stored Energy Plant (ISEP)



3 Proven Technologies

1. Renewable wind energy
2. Aquifer storage of gas
3. Combustion turbine

3. Combustion turbine (simple cycle)



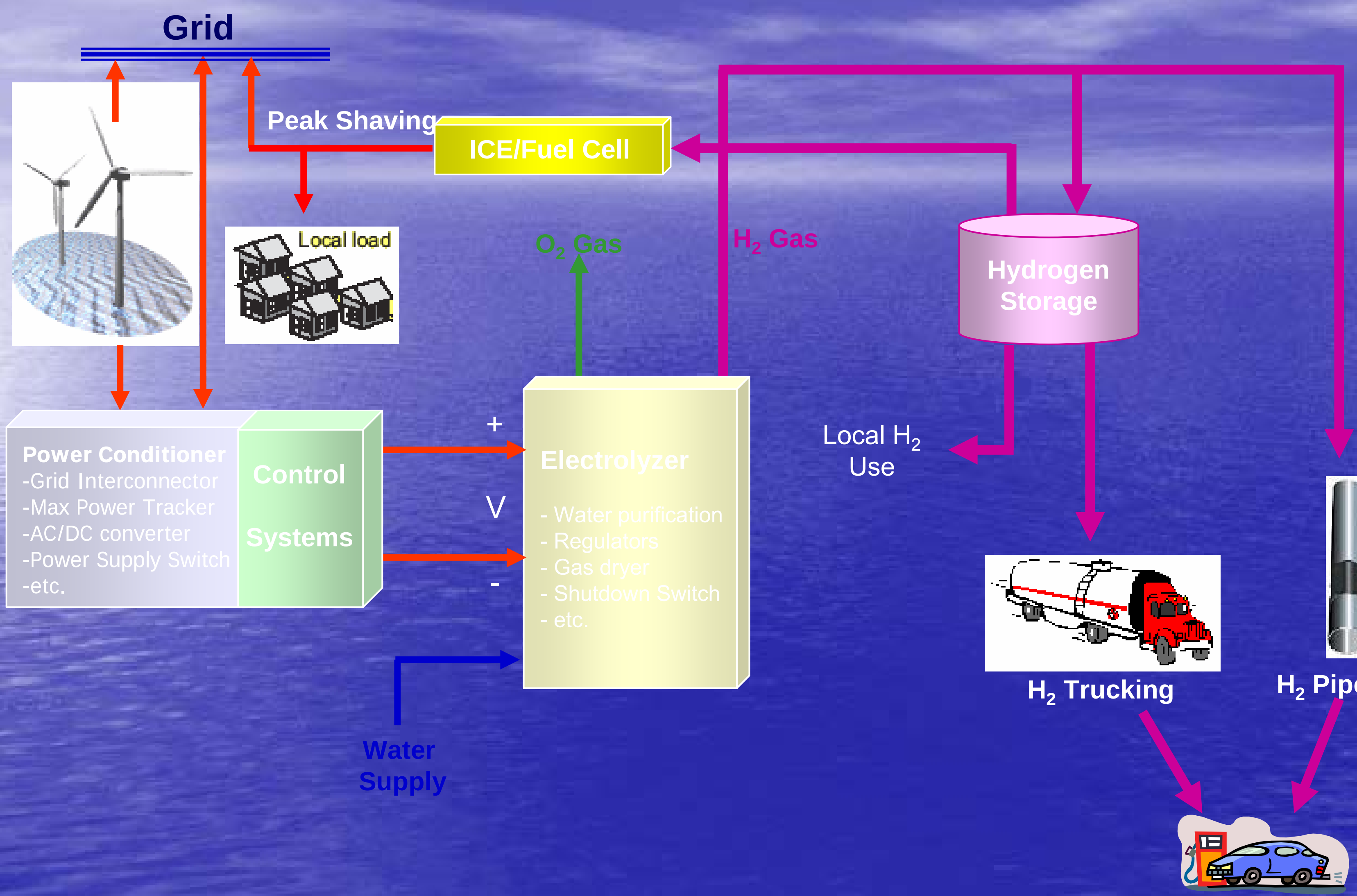
The Alabama CAES plant

Alabama Electric Cooperative

McIntosh Power Plant

Aerial View

Wind-Hydrogen System Concept



Wind-Hydrogen Forms a Green Energy Cycle and is Technically Feasible

Offshore Wind - Onshore H_2 Production (Long Island)