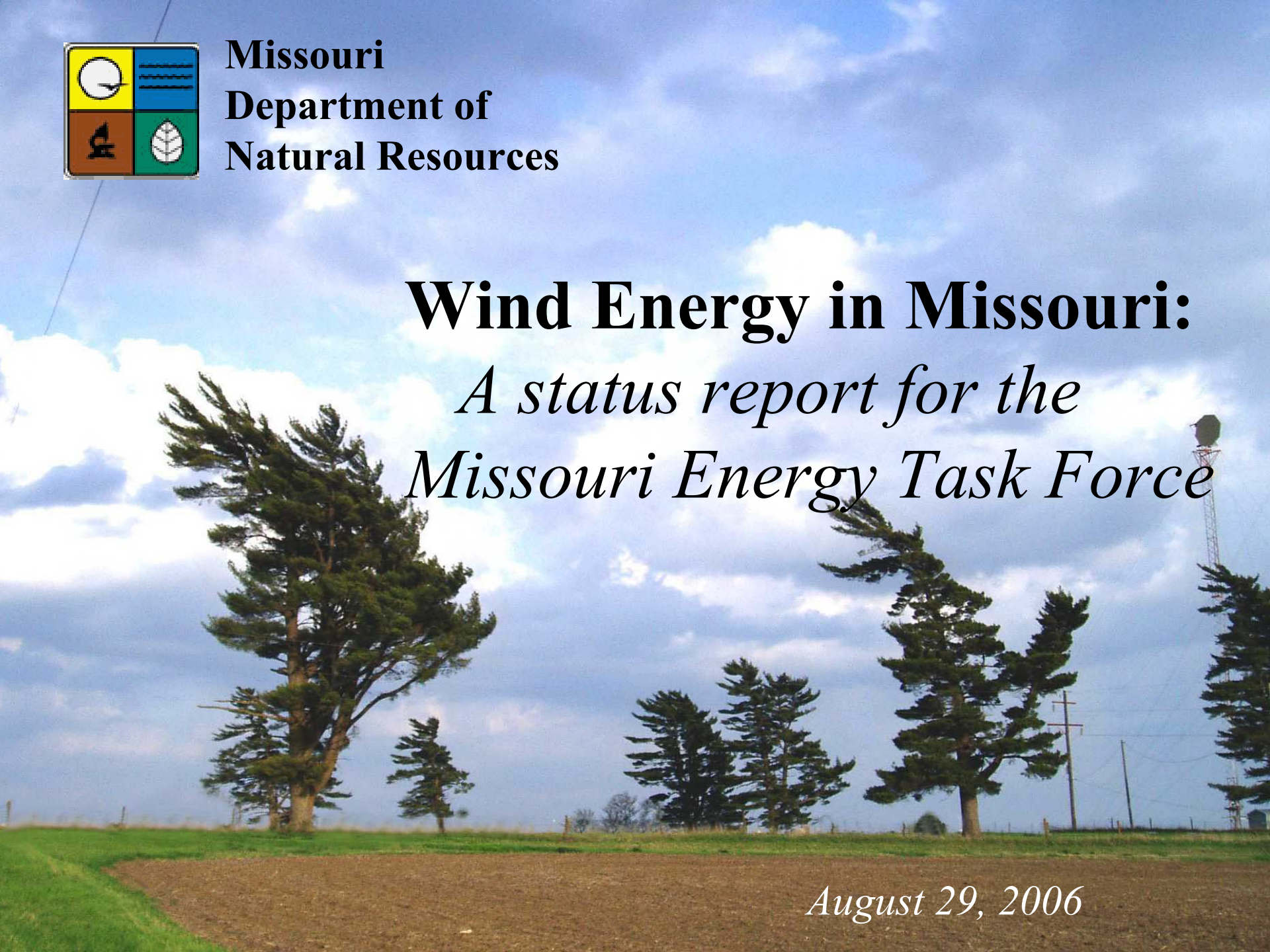


Missouri
Department of
Natural Resources

Wind Energy in Missouri:

A status report for the Missouri Energy Task Force

August 29, 2006

Overview

1) Wind Energy Basics

2) Mapping the resource

3) Refinements in wind technology

4) Missouri wind farms

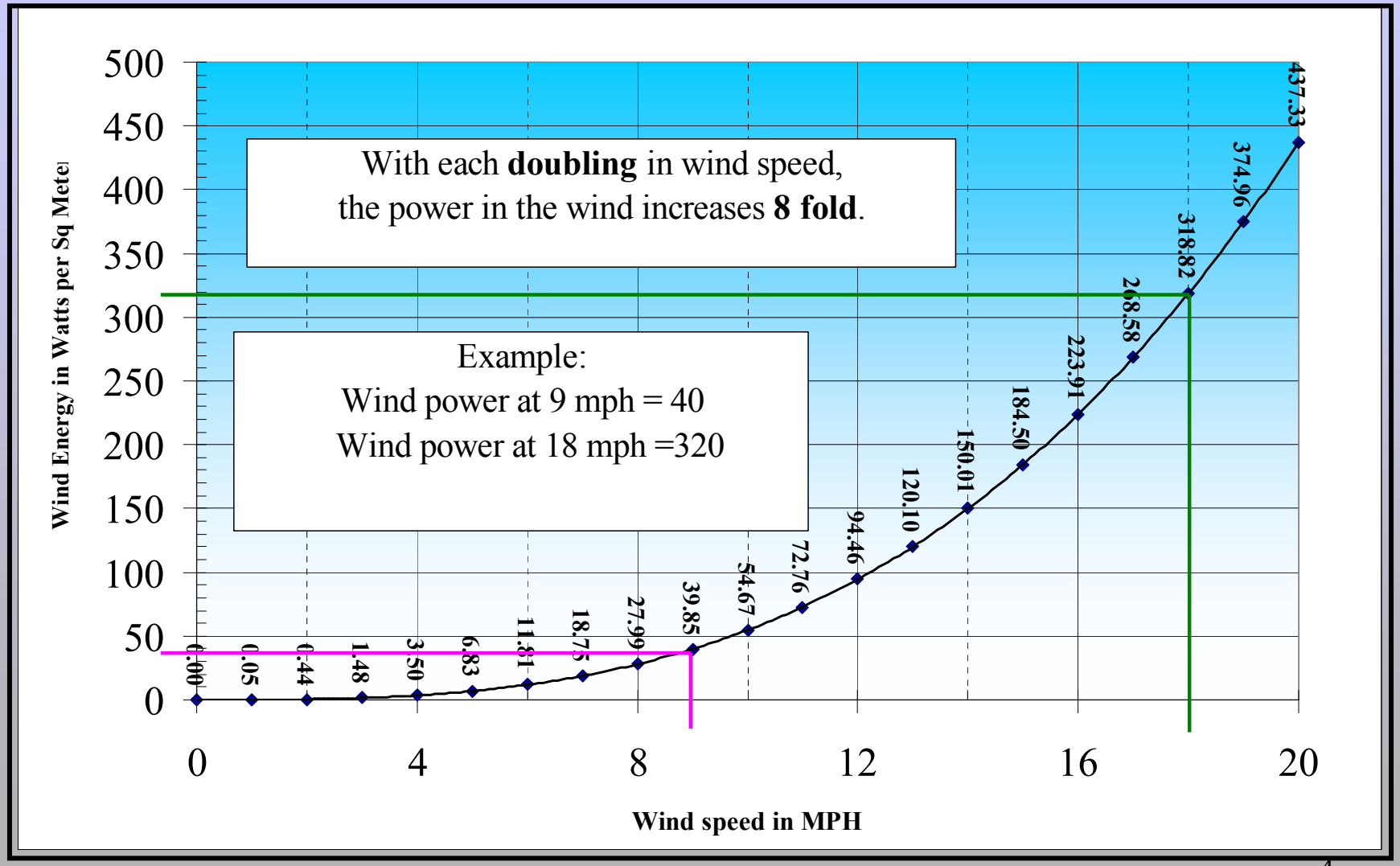
5) Tall Tower wind measurement

6) Utilities buy wind power in the Midwest

Wind Energy Basics

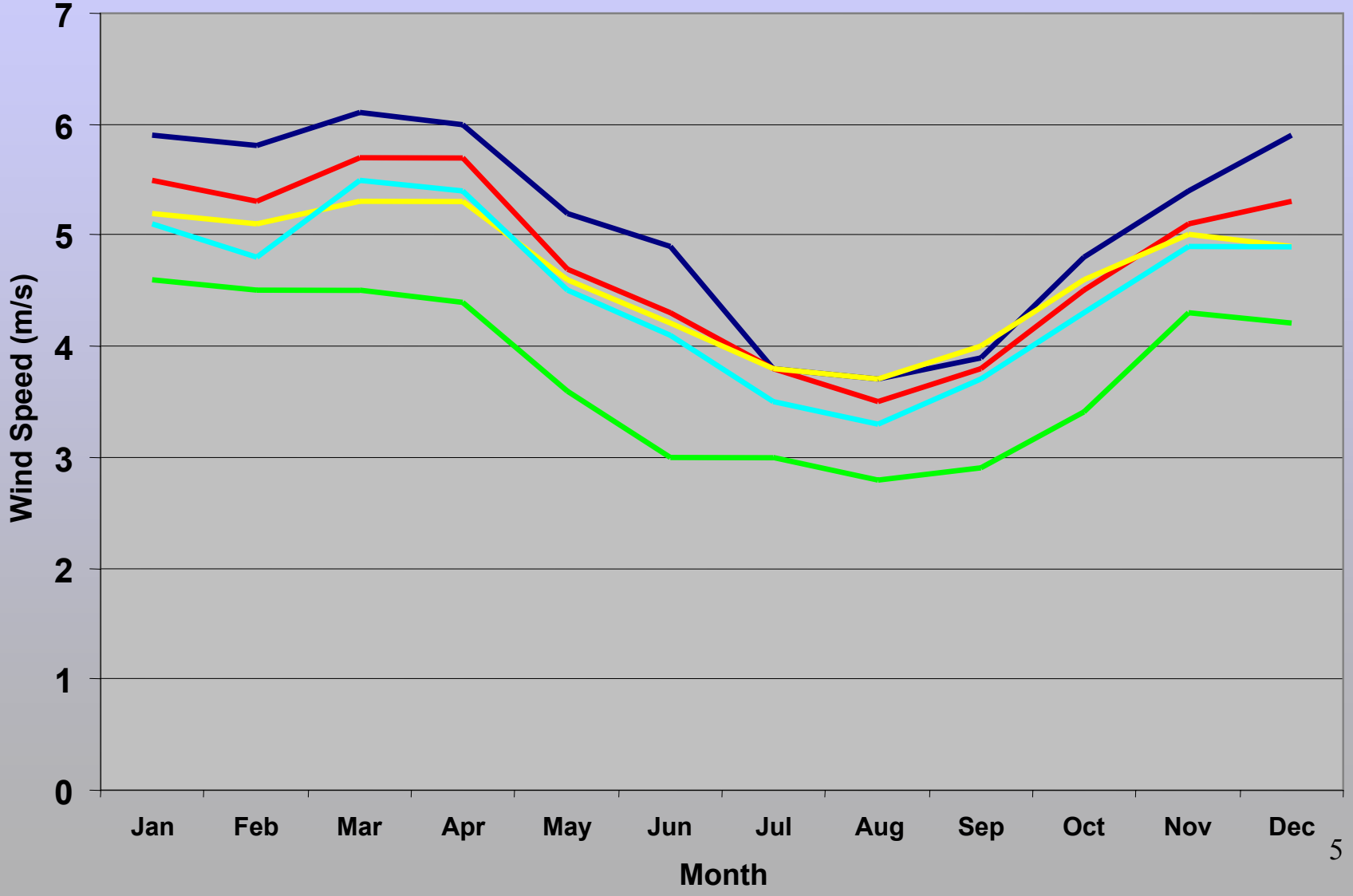
Photo: National Renewable Energy Lab

Wind energy vs. specific wind speeds



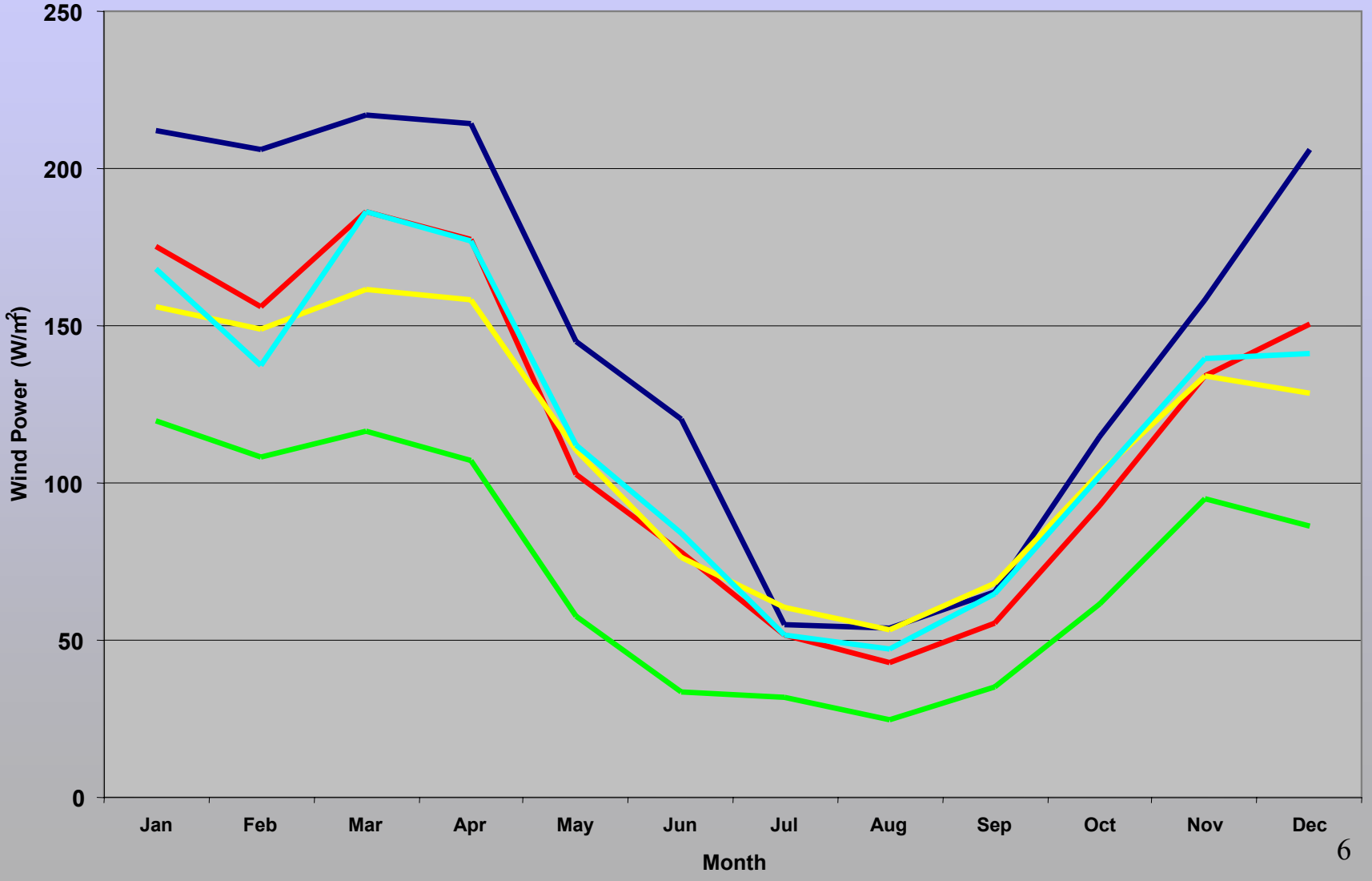
NREL

Wind SPEED by Month
Measurement Height 6 to 10m

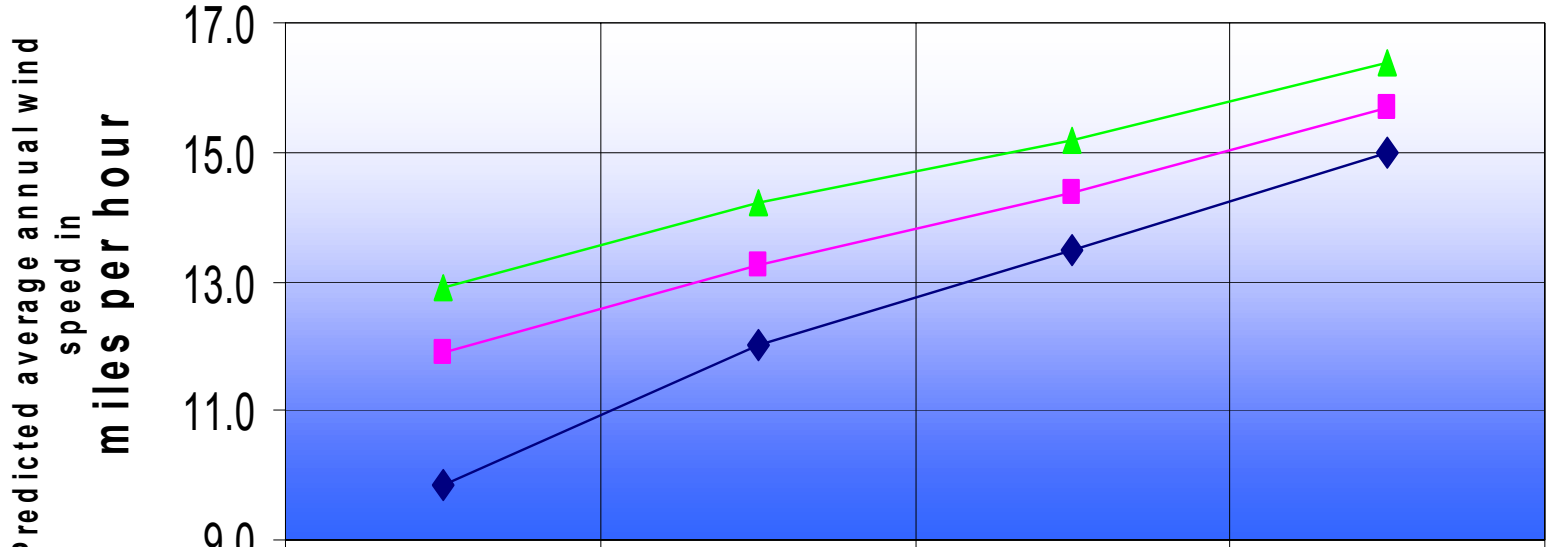


NREL

Wind POWER by Month
Measurement Height 6 to 10m



Wind speed increases with distance above ground level



	30 m Speed	50 M Speed	70 M Speed	100 M Speed
Low ground	9.8	12.0	13.5	15.0
Hillside	11.9	13.2	14.4	15.7
Top of ridge	12.9	14.2	15.2	16.4

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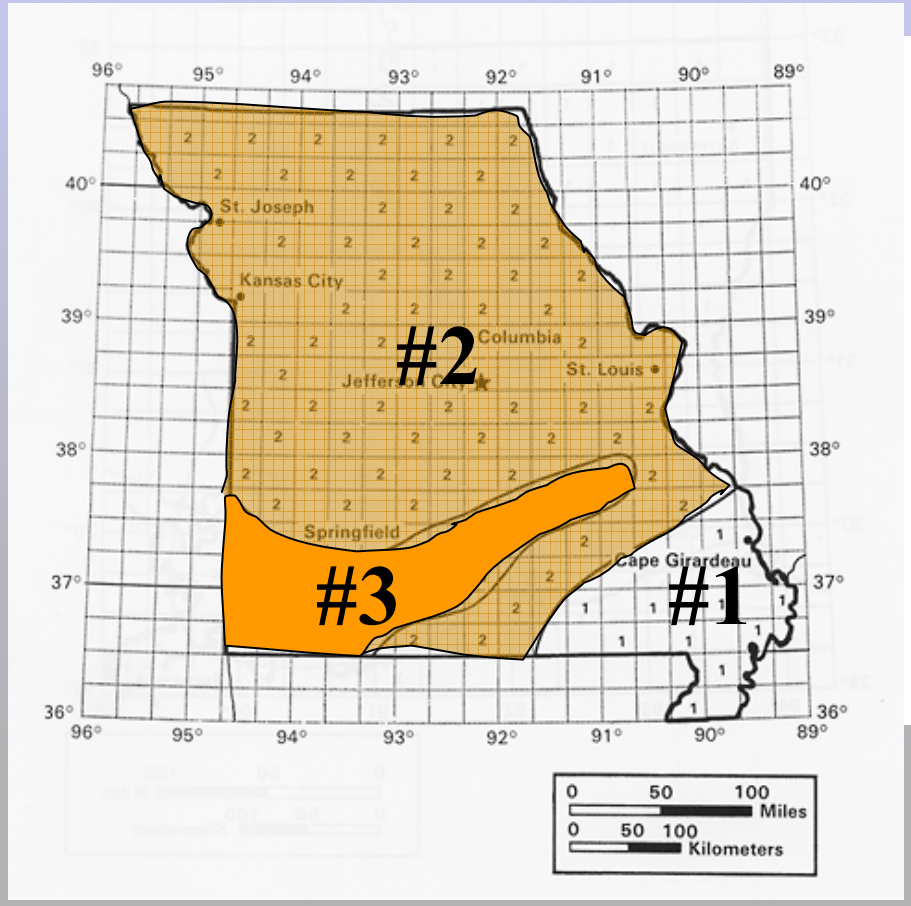
What does a high resolution wind map reveal?

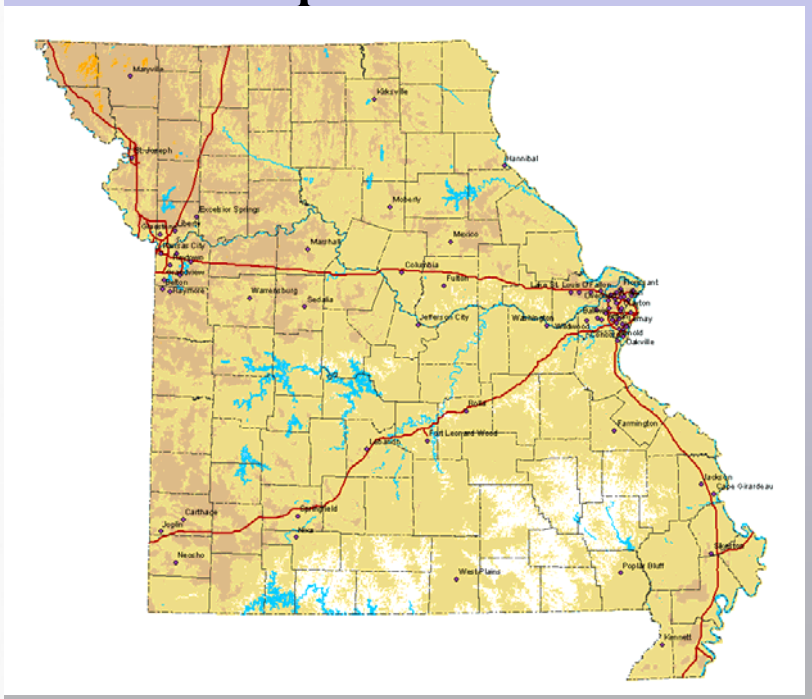
- Location of resource, focus wind prospecting
- Smaller data cells, estimates are more site-specific
- Estimates for multiple levels, and values
    - * Wind speed at 30, 50, 70 and 100 meters
    - * Wind power at 50 and 100 meters
- Interactive GIS map features
- Data query for individual map pixels
- Available on Missouri Department of Natural Resources' Energy Center's webpage http://www.dnr.mo.gov/energy/

Missouri's wind resources - what does a high resolution wind map reveal?

1987



New High-resolution maps in 2003



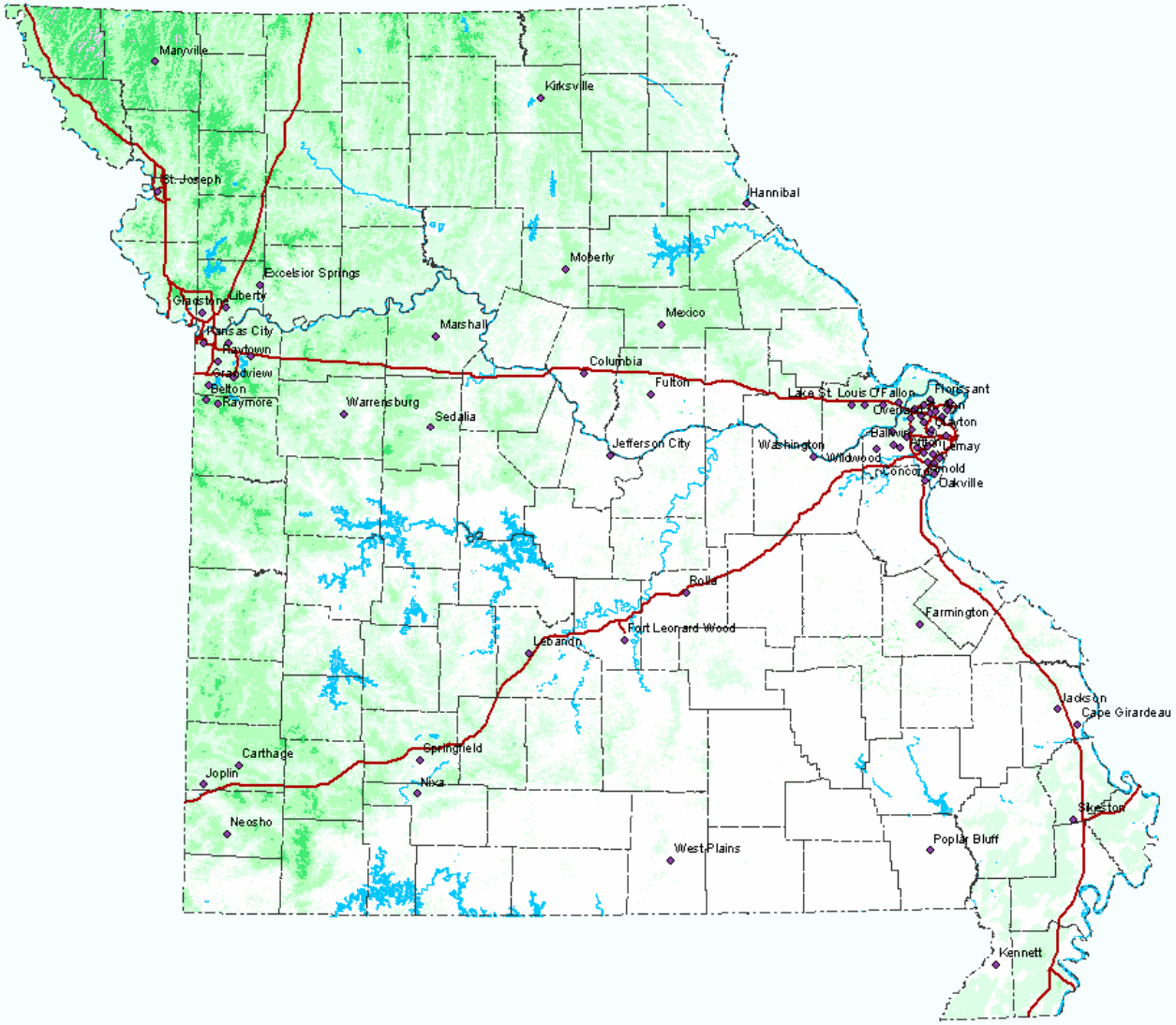
Wind energy at 50 meters

MO_FinalArcReader_v83_31Jan05 - ArcReader

File Edit View Tools Window Help

1:2,500,000

50 Meter wind speed



Layers

- Annual Wind Rose
  - Tabular Data/Hyperlink
  - Tabular Data
- Seasonal Wind Rose
  - Tabular Data
- City
- County Boundary
- Interstate Highway
- Road
- Railroad
- Stream/River
- Populated Place
- Federal Land
- State / Local Park
- Water Body
- Neighboring State
- Mean Speed at 30 m
- Mean Speed at 50 m

mph	m/s
< 12.3	< 5.5
12.3 - 13.4	5.5 - 6.0
13.4 - 14.5	6.0 - 6.5
14.5 - 15.7	6.5 - 7.0
15.7 - 16.8	7.0 - 7.5
16.8 - 17.9	7.5 - 8.0
17.9 - 19.0	8.0 - 8.5
19.0 - 20.1	8.5 - 9.0
20.1 - 21.3	9.0 - 9.5
> 21.3	> 9.5

- Mean Speed at 70 m
- Mean Speed at 100 m
- Power Density at 50 m
- Power Density at 100 m
- Surface Roughness
- Topography

377483.80 4169567.75 Meter

MO_FinalArcReader_v83_31Jan05 - ArcReader

File Edit View Tools Window Help

1:2,500,000

Layers
- Annual Wind Rose
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- Power Density at 100 m
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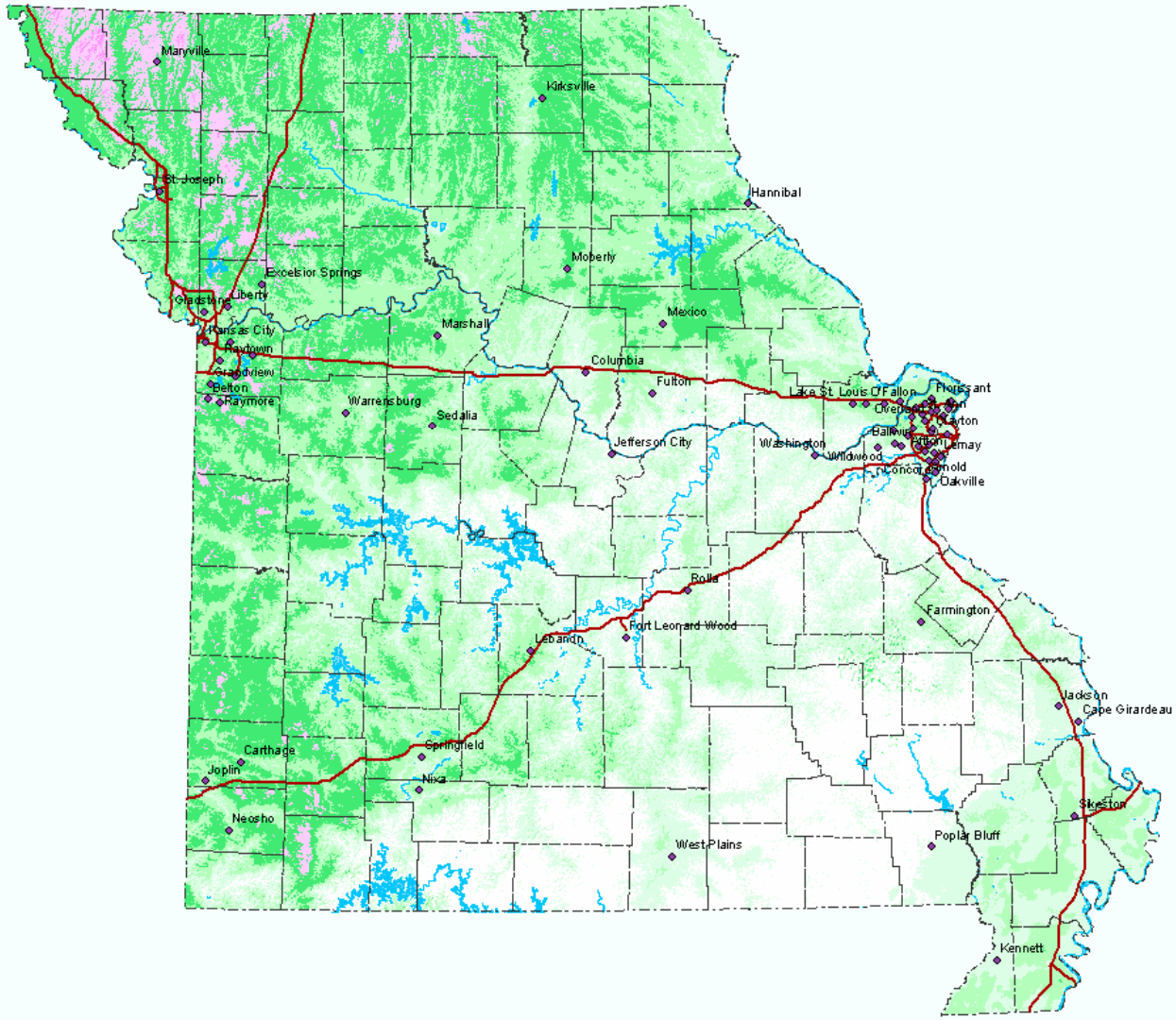
70 Meter wind speed



583197.76 4102098.87 Meter

MO_FinalArcReader_v83_31Jan05 - ArcReader

File Edit View Tools Window Help

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Layers
- Annual Wind Rose
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- Power Density at 100 m
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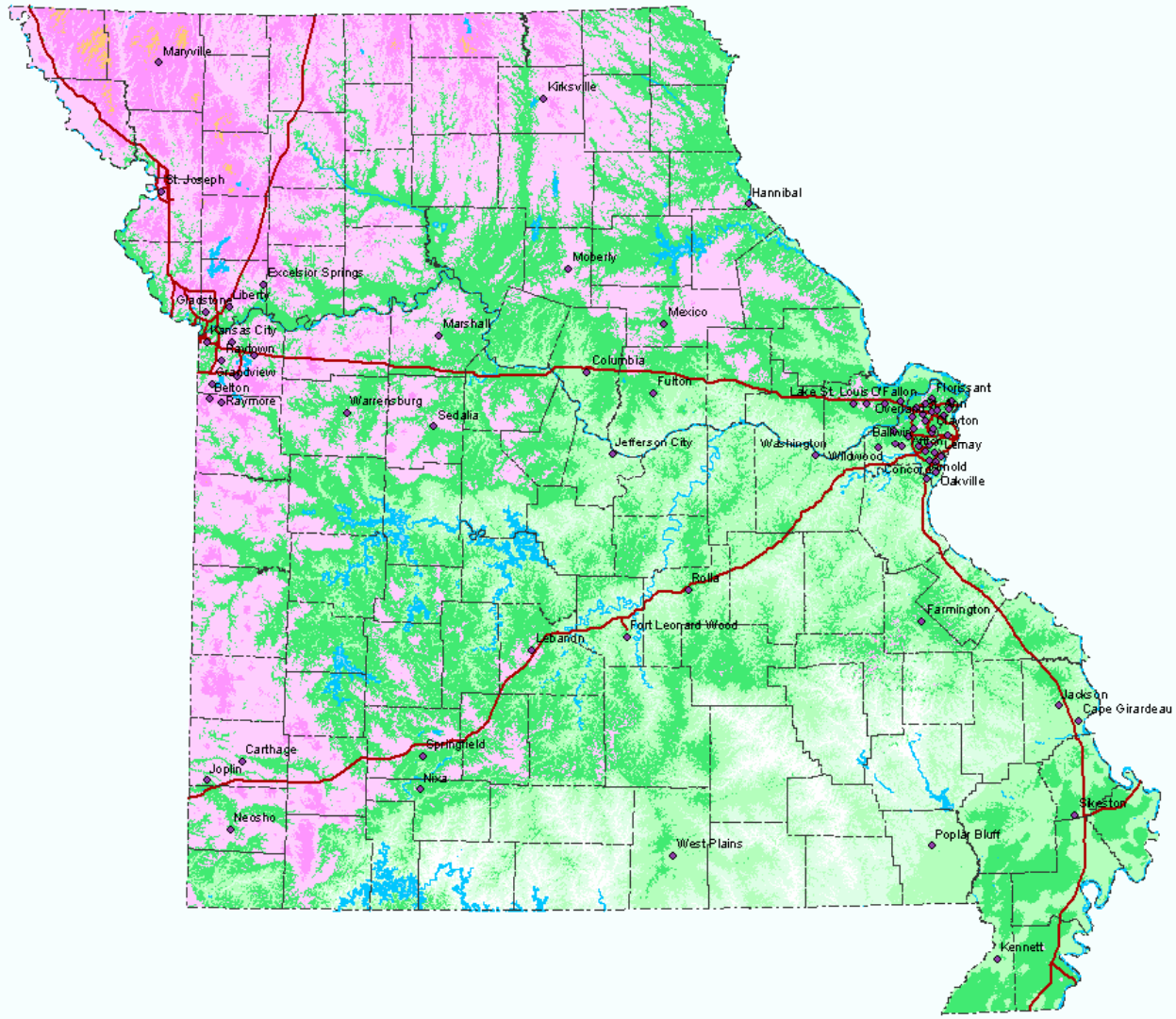
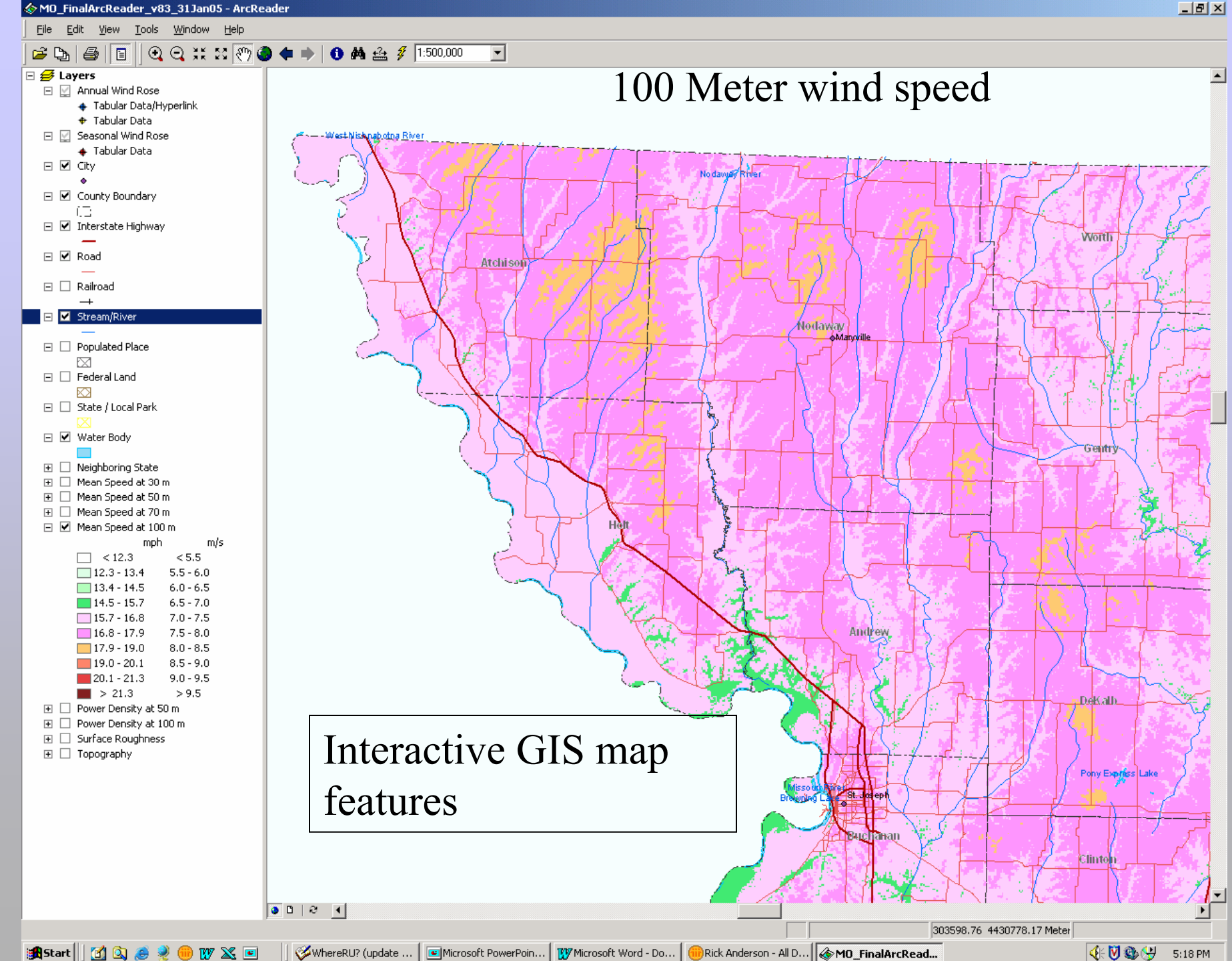
- Topography

100 Meter wind speed



526312.22 4182135.49 Meter

Start | WhereRU? (update ... | Microsoft PowerPoin... | Microsoft Word - Do... | Rick Anderson - All D... | MO_FinalArcRead... | 5:14 PM


MO_FinalArcReader_v83_31Jan05 - ArcReader
File Edit View Tools Window Help
1:500,000
Layers
Annual Wind Rose
Tabular Data/Hyperlink
Tabular Data
Seasonal Wind Rose
Tabular Data
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County Boundary
Interstate Highway
Road
Railroad
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Populated Place
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State / Local Park
Water Body
Neighboring State
Mean Speed at 30 m
Mean Speed at 50 m
Mean Speed at 70 m
Mean Speed at 100 m
mph m/s
< 12.3 < 5.5
12.3 - 13.4 5.5 - 6.0
13.4 - 14.5 6.0 - 6.5
14.5 - 15.7 6.5 - 7.0
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17.9 - 19.0 8.0 - 8.5
19.0 - 20.1 8.5 - 9.0
20.1 - 21.3 9.0 - 9.5
> 21.3 > 9.5
Power Density at 50 m
Power Density at 100 m
Surface Roughness
Topography
100 Meter wind speed
West Nishnabotna River
Nodaway River
Atchison
Nodaway
Maryville
Worth
Gentry
Holt
Andrew
DeKalb
Pony Express Lake
Missouri River
Brewing Lake
St. Joseph
Buchanan
Clinton
Interactive GIS map features
303598.76 4430778.17 Meter
Start
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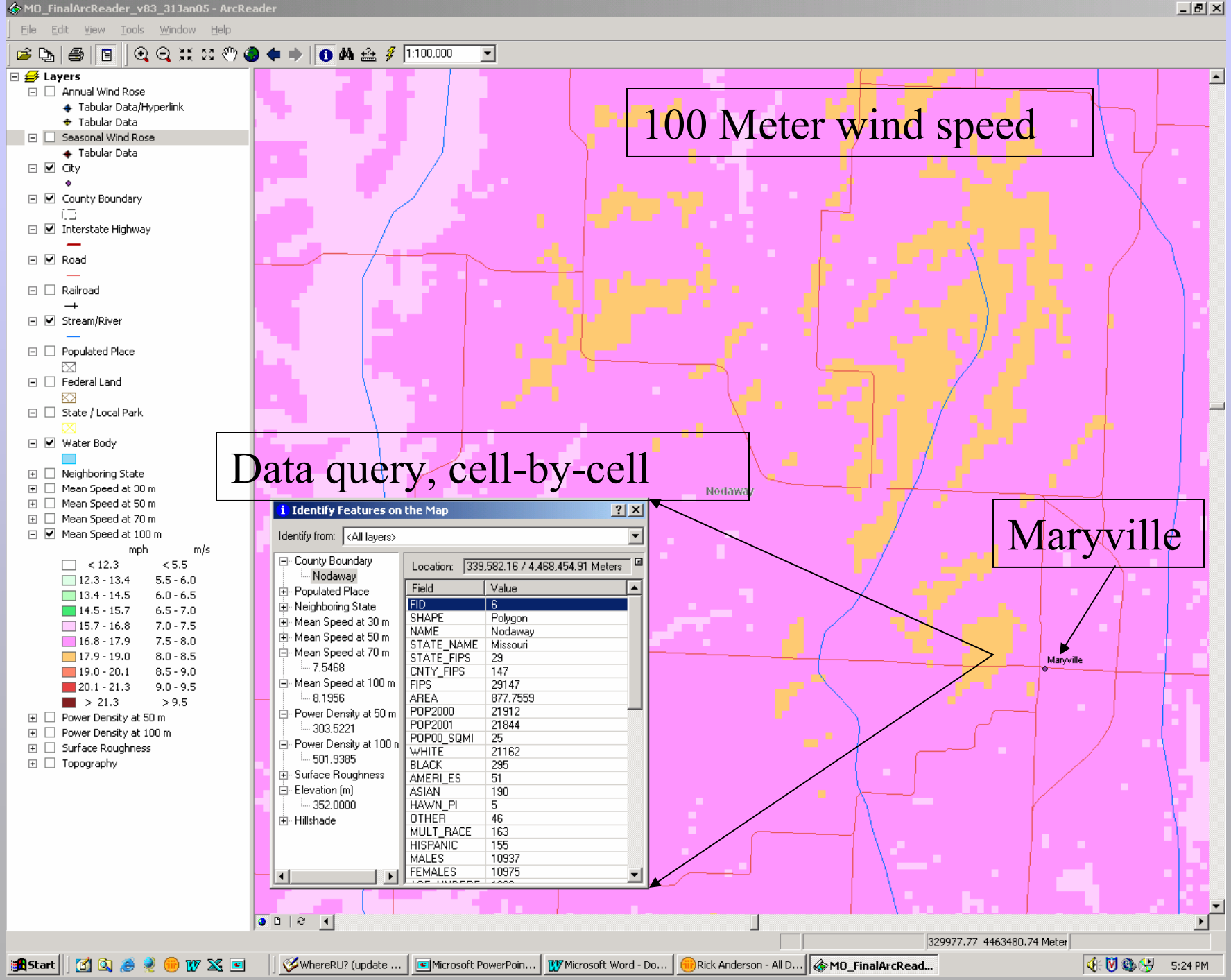
Microsoft PowerPoin...
Microsoft Word - Do...
Rick Anderson - All D...
MO_FinalArcRead...
5:18 PM


MO_FinalArcReader_v83_31Jan05 - ArcReader
File Edit View Tools Window Help
1:100,000
Layers
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Tabular Data
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19.0 - 20.1 8.5 - 9.0
20.1 - 21.3 9.0 - 9.5
> 21.3 > 9.5
Power Density at 50 m
Power Density at 100 m
Surface Roughness
Topography
100 Meter wind speed
Data query, cell-by-cell
Nodaway
Maryville
Identify Features on the Map
Identify from: <All layers>
County Boundary
Nodaway
Populated Place
Neighboring State
Mean Speed at 30 m
Mean Speed at 50 m
Mean Speed at 70 m
7.5468
Mean Speed at 100 m
8.1956
Power Density at 50 m
303.5221
Power Density at 100 n
501.9385
Surface Roughness
Elevation (m)
352.0000
Hillshade
Location: 339,582.16 / 4,468,454.91 Meters
Field Value
FID 6
SHAPE Polygon
NAME Nodaway
STATE_NAME Missouri
STATE_FIPS 29
CNTY_FIPS 147
FIPS 29147
AREA 877.7559
POP2000 21912
POP2001 21844
POP00_SQMI 25
WHITE 21162
BLACK 295
AMERI_ES 51
ASIAN 190
HAWN_PI 5
OTHER 46
MULT_RACE 163
HISPANIC 155
MALES 10937
FEMALES 10975
329977.77 4463480.74 Meter
Start
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5:24 PM

1) Wind Energy Basics

2) Mapping the resource

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4) Missouri wind farms

5) Tall Tower wind measurement

6) Utilities buy wind power in the Midwest

Big towers to reach bigger winds

Ever-taller towers, with larger turbines
and larger rotors.

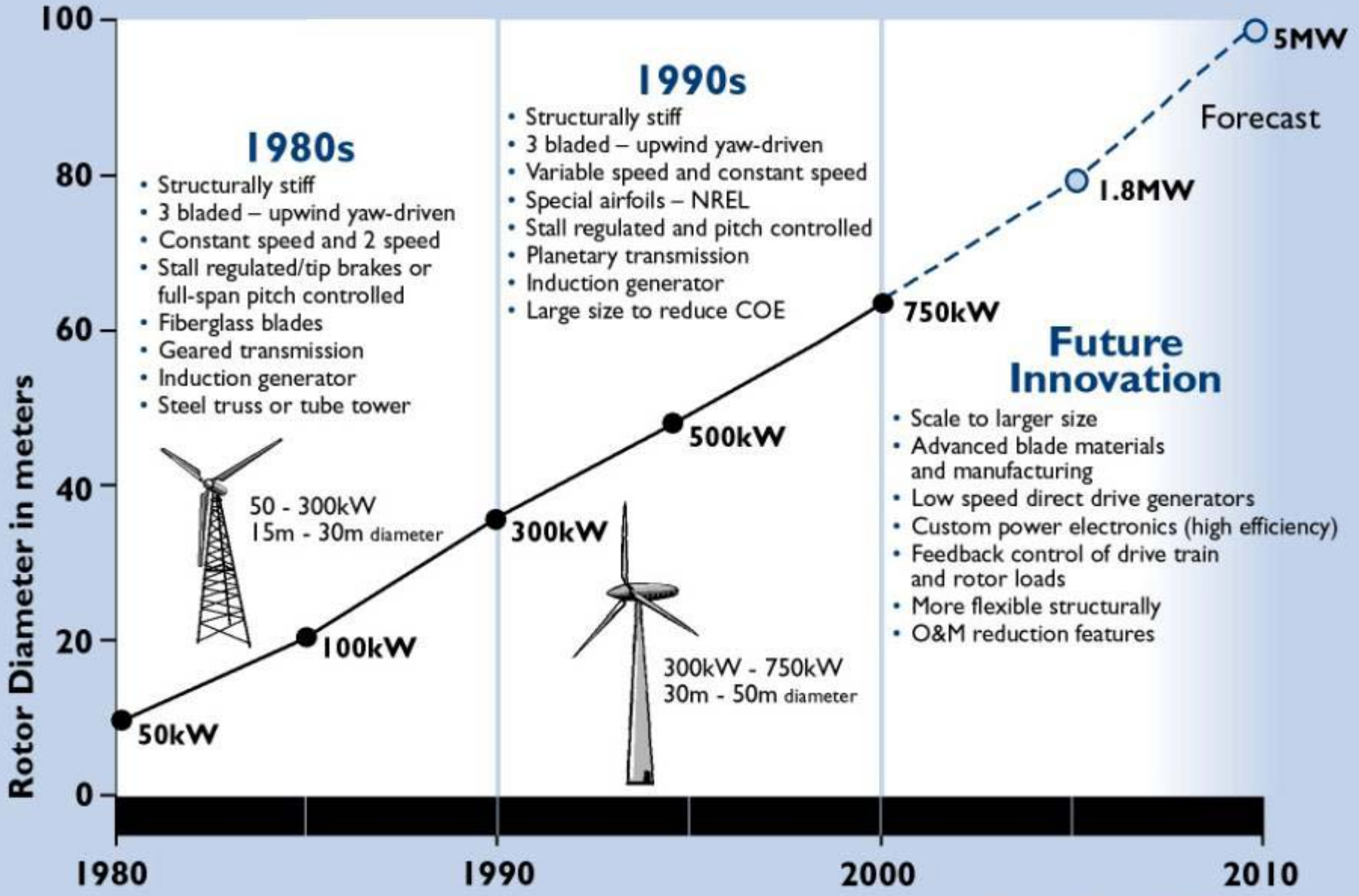
Improved rotors

Refinements in shape, weight, and durability

Design innovations

Modular generators, new gearbox designs,
‘Downwind’ rotors

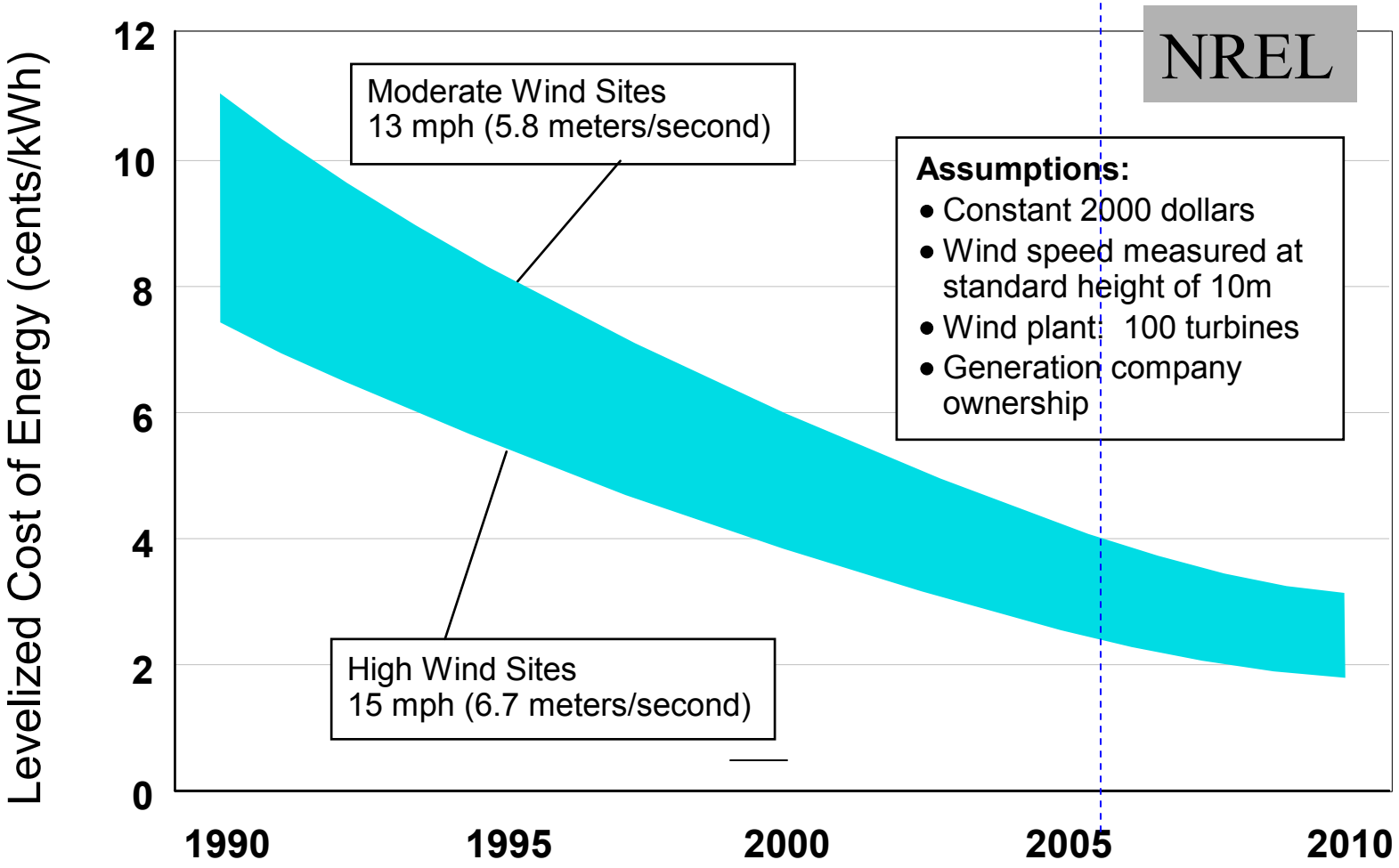
The Evolution of Commercial U.S. Wind Technology



Source: Thresher & Dodge, Wind Energy Journal 1998

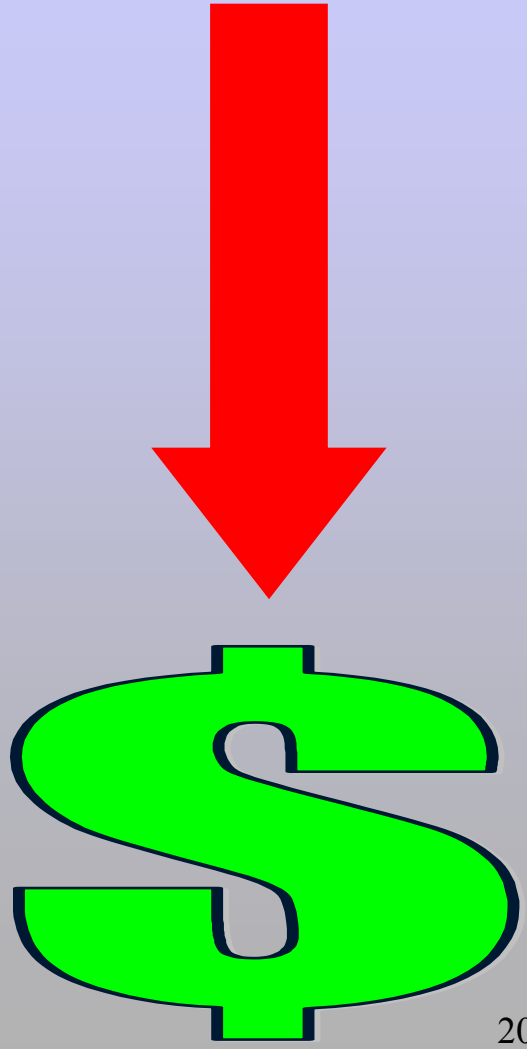
Cost of Energy for Large Wind Farms

Trends in cost per kilowatt hour - improving



Wind Costs

- **Tech advances → wind energy costs substantially down**
- **Wind generation costs: 3-6¢ kWh in high wind resource areas**
- **2001 Cost forecast → 50% drop by 2010**
- **Cost competitive with new fossil fuel generation, Esp. natural gas turbines**
- **Investor owned utilities considering wind generation capacity**
- **Increased wind generation may moderate natural gas demand & costs**



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Wind Energy Development

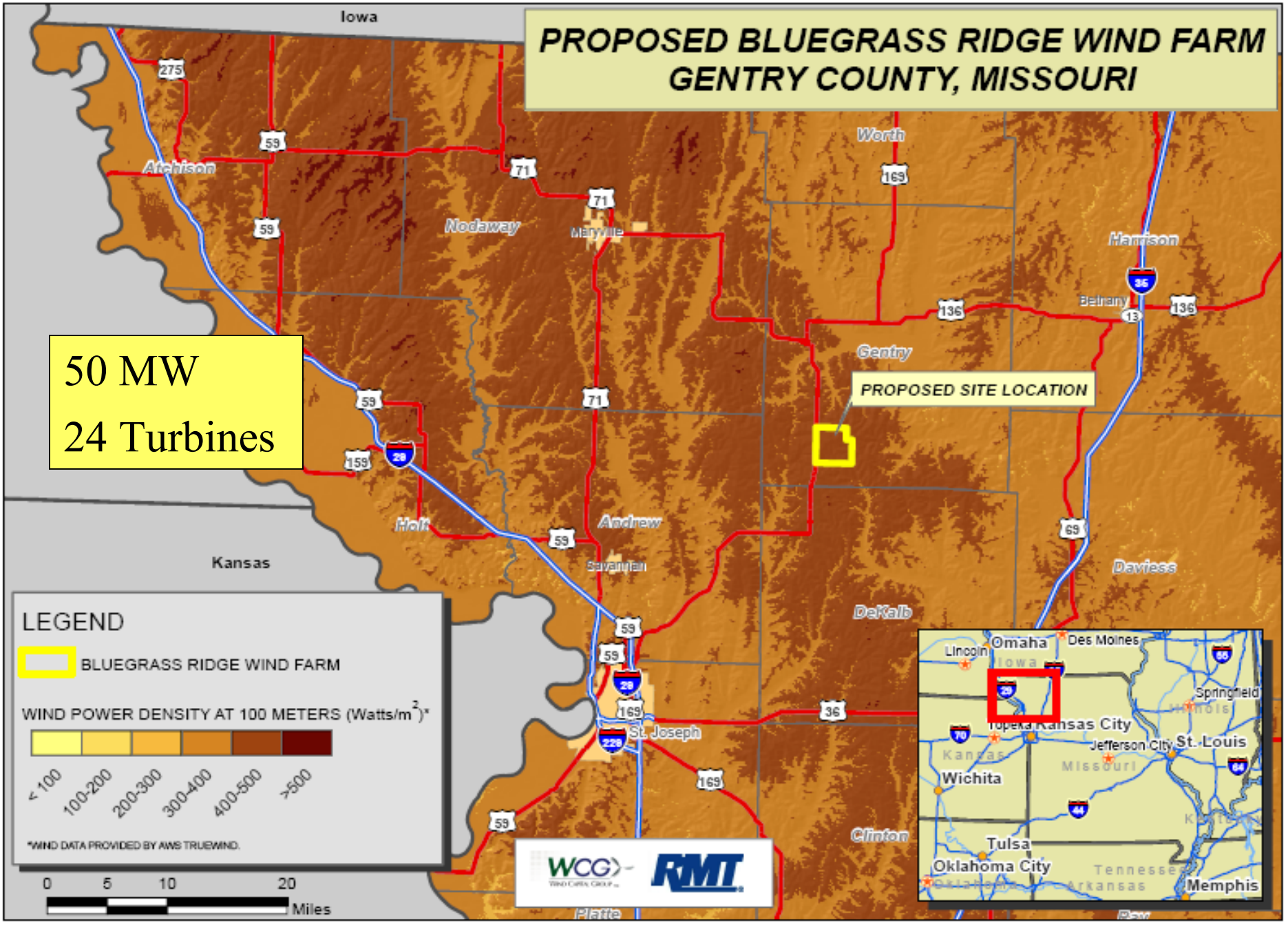
- Good wind resource is essential to have an economically viable project
- Access to electrical grid is essential
- Numerous complex legal, financial, and organizational issues each developer must resolve
- Cannot develop wind resource without a market for the energy (Power Purchase Agreement)

Wind Power Business Models

- Land Lease by Developer
- Community owned projects
- Farmer-Owned Cooperative

Economic Development Opportunities

- Economic impact affected by level of local ownership
- Land Lease Payments
- Local property tax revenue
- 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


PROPOSED BLUEGRASS RIDGE WIND FARM
GENTRY COUNTY, MISSOURI
50 MW
24 Turbines
PROPOSED SITE LOCATION
Iowa
Kansas
Atchison
Nodaway
Maryville
Worth
Harrison
Gentry
Holt
Andrew
DeKalb
Daviess
Clinton
Platte
St. Joseph
Bethany
LEGEND
BLUEGRASS RIDGE WIND FARM
WIND POWER DENSITY AT 100 METERS (Watts/m²)*
<100
100-200
200-300
300-400
400-500
>500
*WIND DATA PROVIDED BY AWS TRUEWIND.
0 5 10 20
Miles
WCG
RMT
Omaha
Des Moines
Lincoln
Springfield
Kansas City
Topeka
Jefferson City
St. Louis
Wichita
Tulsa
Oklahoma City
Memphis

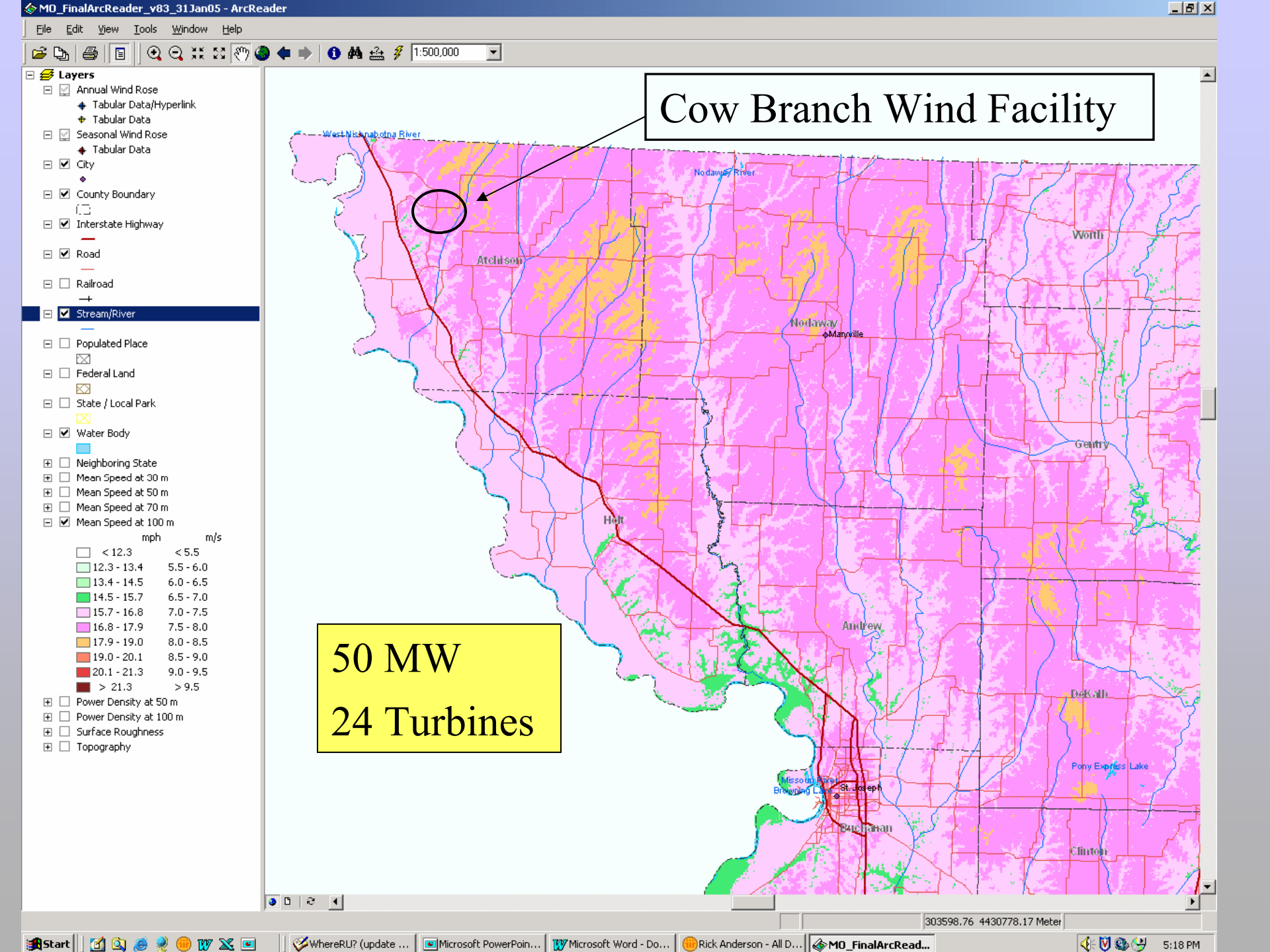
Bluegrass Ridge Wind Farm:

Tubular steel forms for tower's concrete foundation

Photo provided by the Wind Capital Group

July 2006

Photo provided by the Wind Capital Group


MO_FinalArcReader_v83_31Jan05 - ArcReader
File Edit View Tools Window Help
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Cow Branch Wind Facility
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Nodaway River
Atchison
Nodaway
Maryville
Worth
Gentry
Holt
Andrew
DeKalb
Pony Express Lake
St. Joseph
Buchanan
Clinton
50 MW
24 Turbines
303598.76 4430778.17 Meter
Start
WhereRU? (update ...
Microsoft PowerPoin...
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5:18 PM

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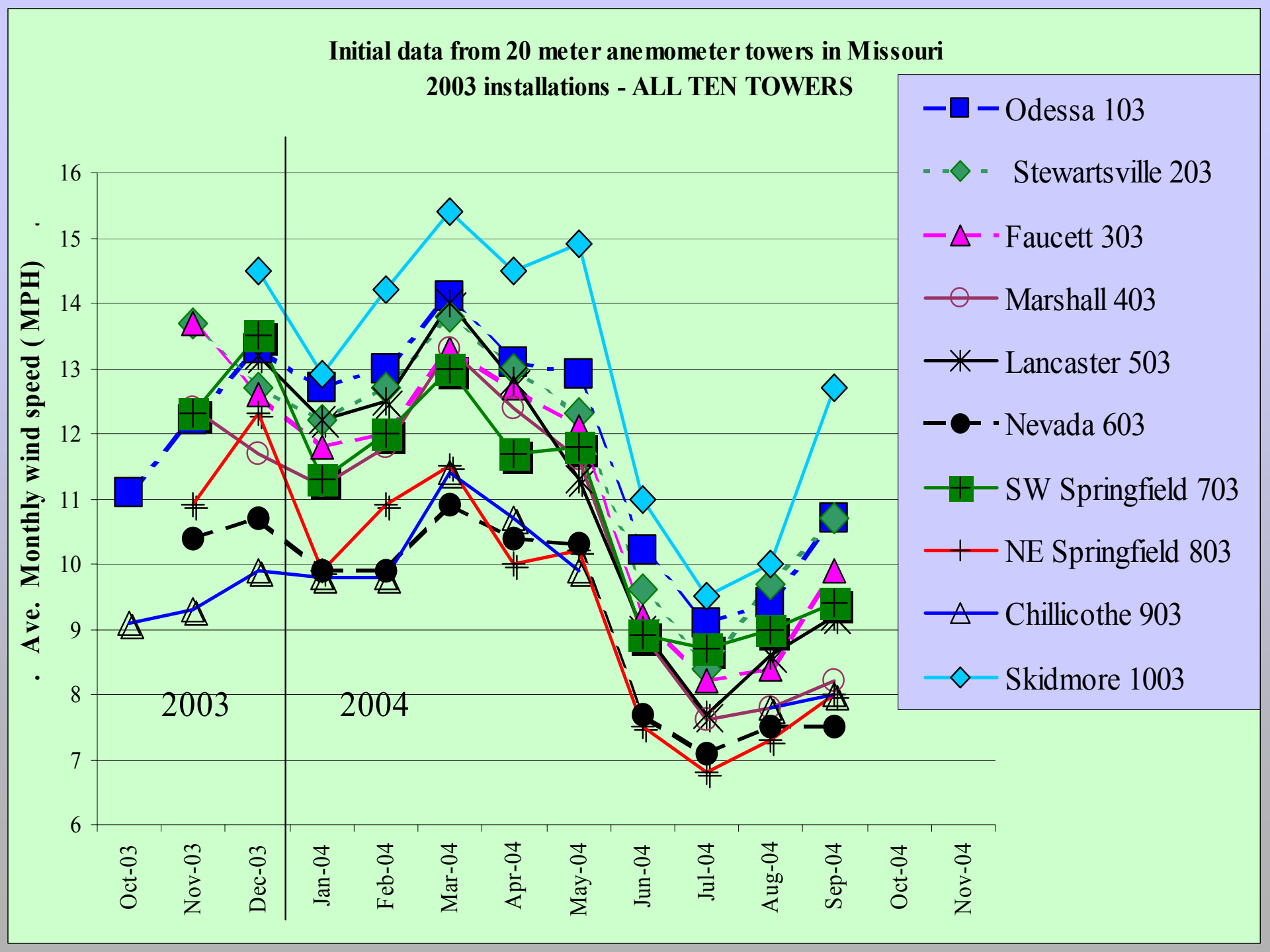
Missouri Anemometer Loan Project

- Assessment for on-farm scale systems
- Portable 20 meter towers
- 36 one year no-cost loans to landowners


Initial data from 20 meter anemometer towers in Missouri
2003 installations - ALL TEN TOWERS
Ave. Monthly wind speed (MPH)
16
15
14
13
12
11
10
9
8
7
6
2003
2004
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Odessa 103
Stewartsville 203
Faucett 303
Marshall 403
Lancaster 503
Nevada 603
SW Springfield 703
NE Springfield 803
Chillicothe 903
Skidmore 1003

Wind instrument boom on a communication tower

Photo: Green Energy Ohio

Tall Tower Wind Pattern Studies;

Wind energy sensors on communication towers

- Studies organized by Missouri Department Natural Resources, field work being conducted by UMC Atmospheric Sciences.
- Instruments being installed on 10 towers in northern & western Missouri during 2006. Installation now complete on 5 towers.
- Towers located in areas with predicted average annual wind speeds over 7 meters per second (15.7 mph) at 100 meters above ground level.
- Sensors at three levels, top level at least 100 meters, seek 150 meters when feasible.
- Data collection for one year.
- Seek to extend data collection period to three years to enhance data reliability

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Utility scale wind plans by utility

2001 Aquila, Gray County KS, 112 MW

2004 Columbia MO, citizen referendum, 15% from renewable energy by 2022.

2005 Empire E.D., Elk River KS, 150 MW

2006 AECI, Bluegrass Ridge MO 50 MW

2006 AECI, Cow Branch MO 50 MW

2006 KCPL, Spearville KS 100 MW

Photo: Gray County Wind Farm, Montezuma KS.


Thanks for your interest in Missouri's wind resources!


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Missouri Department of Natural Resources