University of Nebraska Lincoln EXTENSION

Know how. Know **now.**

Enforcing Thru Education – Part 3

Small Wind Turbines On Buildings

By John Hay
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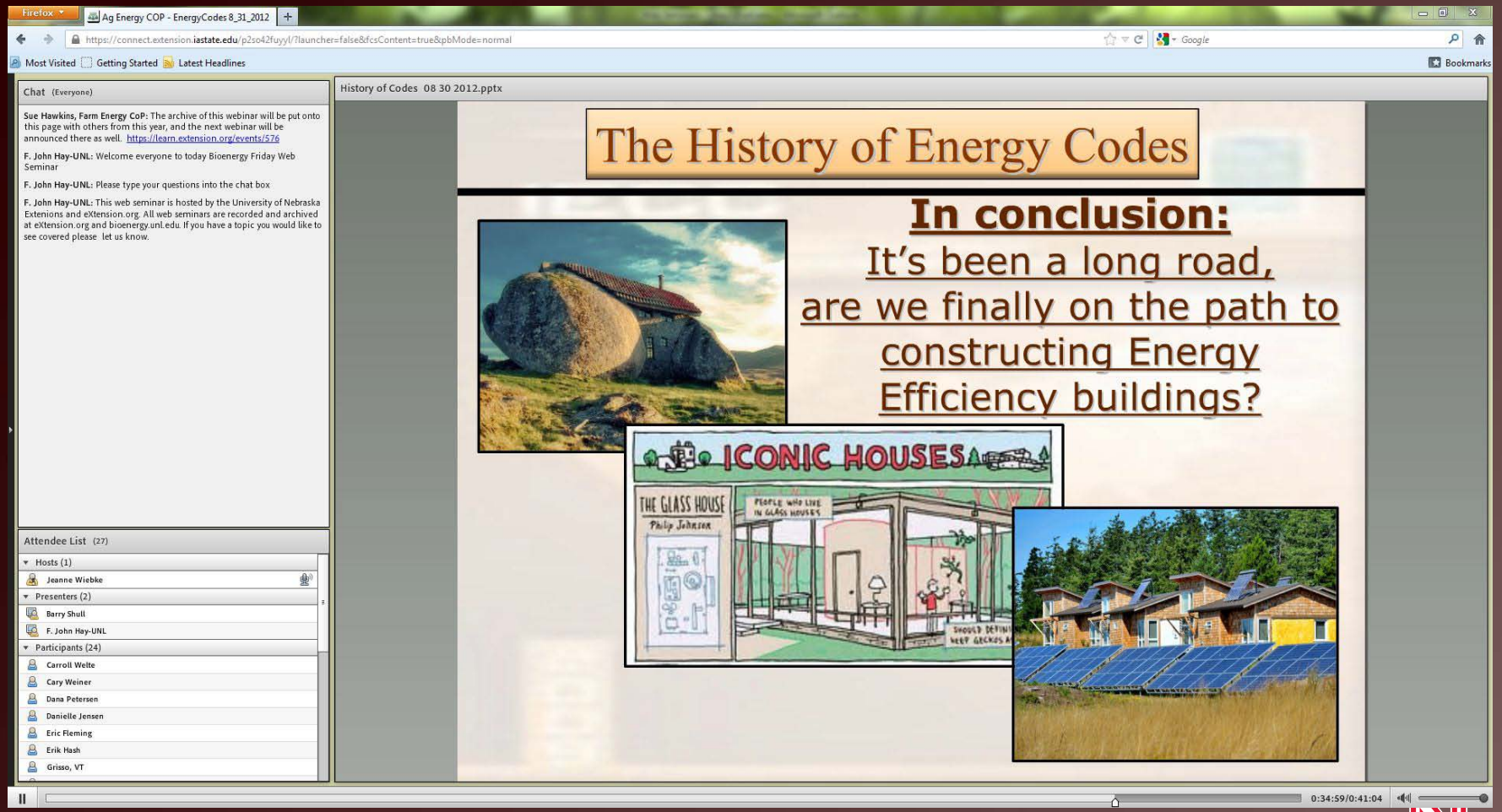
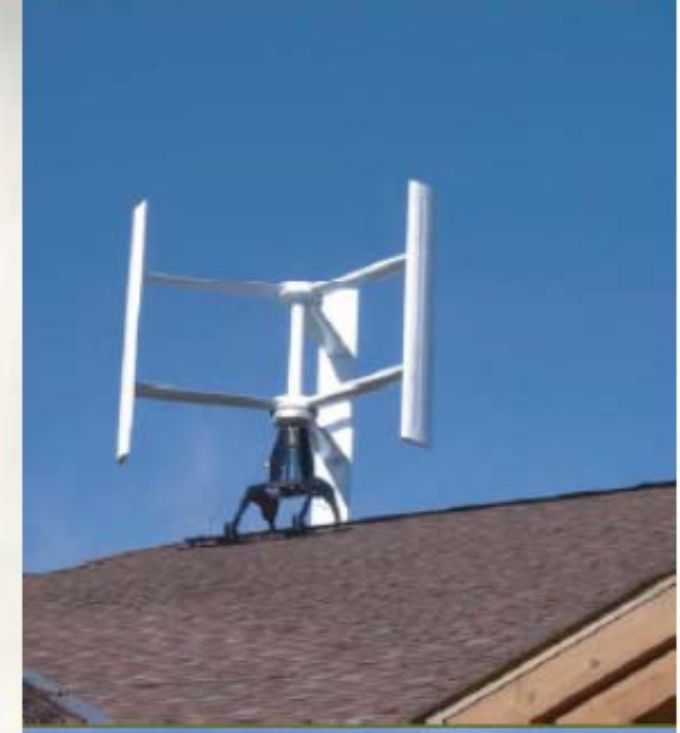
Biosystems Engineering

IANR

UNL – Extension






2008/

Thinking About Small Wind

- Physics
- Small wind turbines on roofs
- Small wind turbine certification

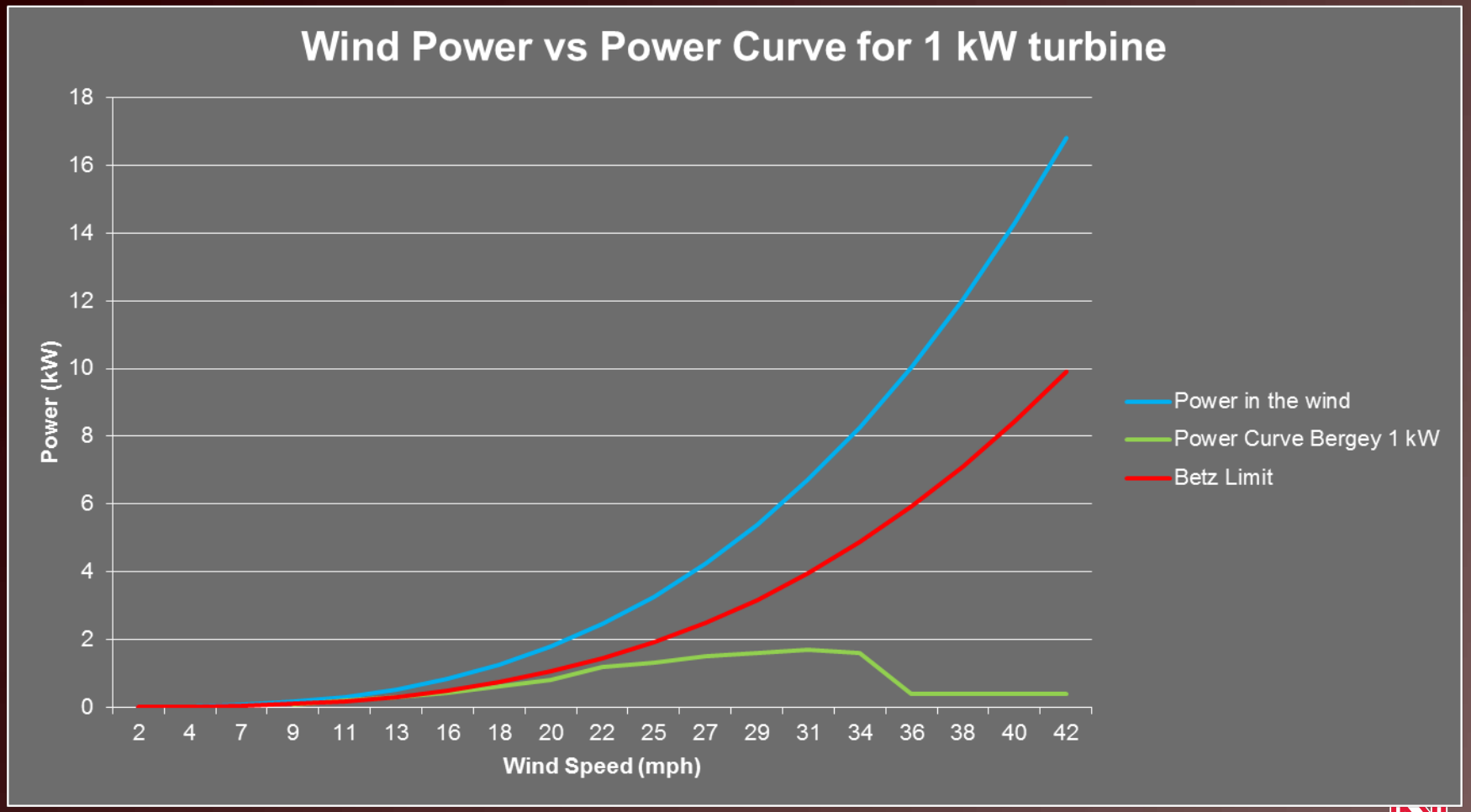
Calculation of Wind Power

- Power in the wind = $k\ {}^{1}/_{2}\ \rho\ A\ V^{3}$
  - Effect of wind speed, V
  - Effect of swept area, A
  - Effect of air density, ρ
  - Constant for units conversion, k

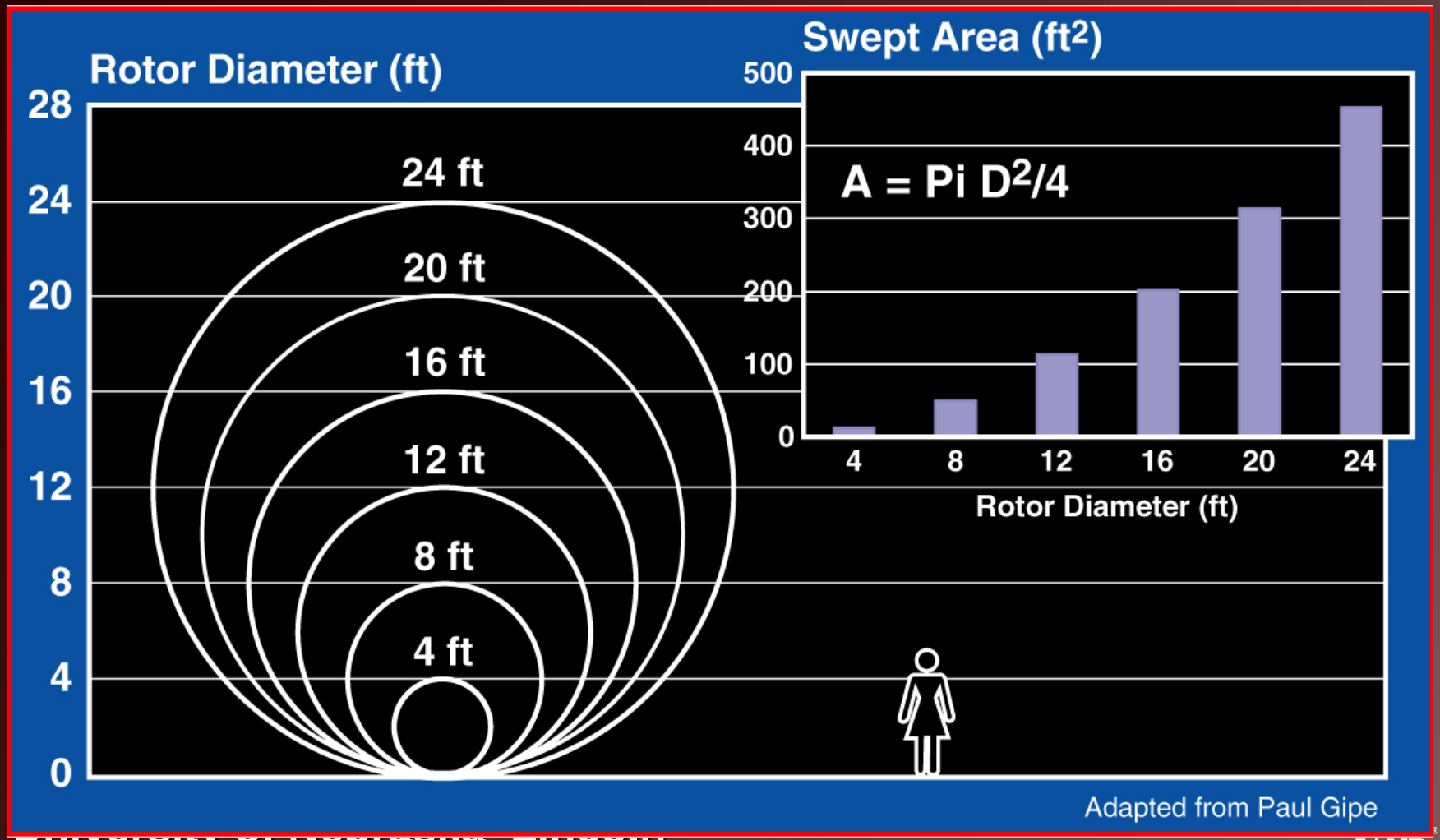
Calculation of Wind Turbine Power

- Power from a wind turbine = C_p k $^1/_2$ ρ A V^3
  - Effect of wind speed, V
  - Effect of rotor diameter on swept area
    A = Pi D^2 / 4
  - Effect of elevation and temperature on air density, ρ
  - Power coefficient (efficiency), C_p up to ~0.35 for small wind turbines (theoretical max, "Betz Limit" = 0.59)

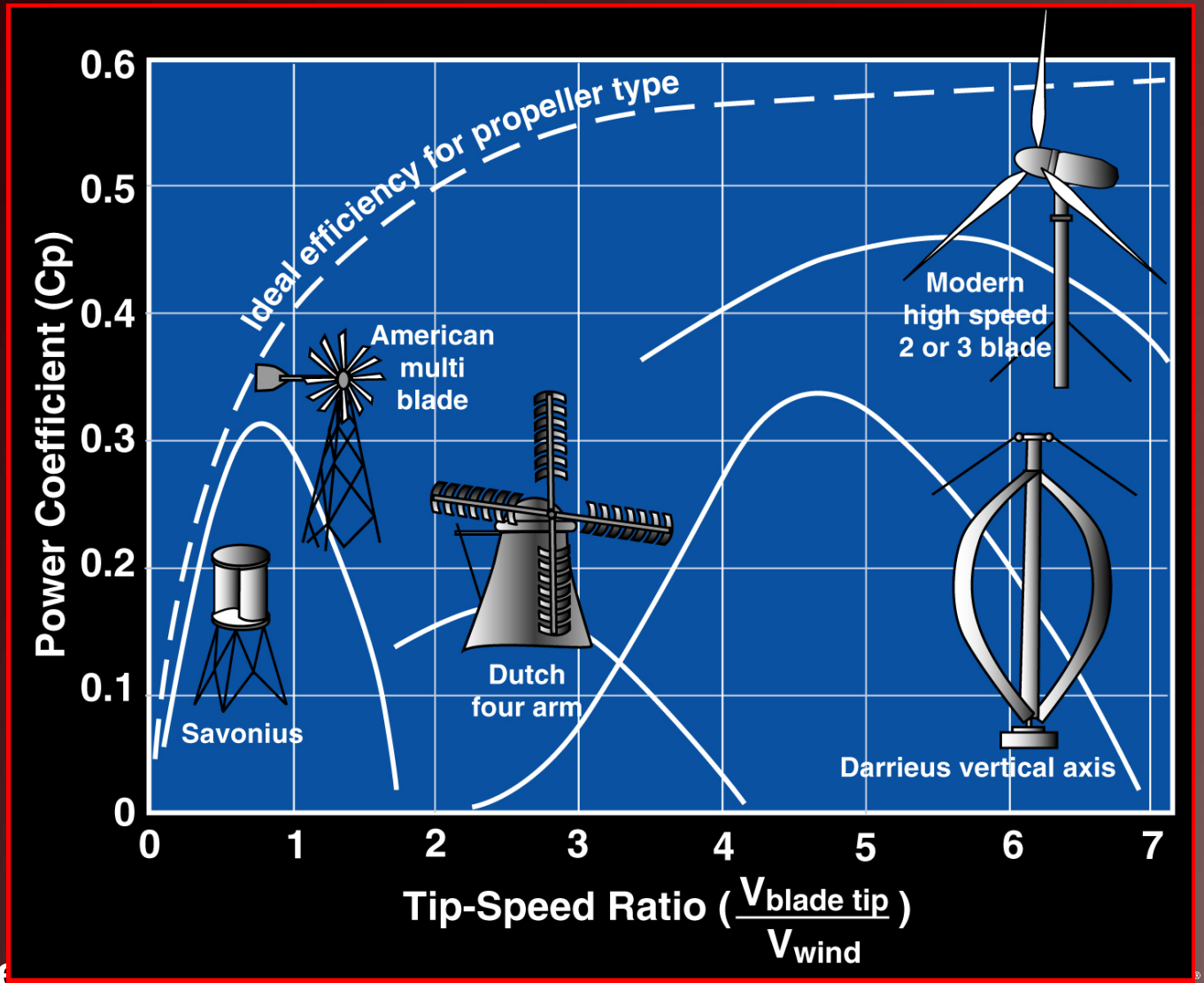
Wind Turbine Power



Relative Size of Small Wind Turbines



Wind Machine Types



Turbine Site

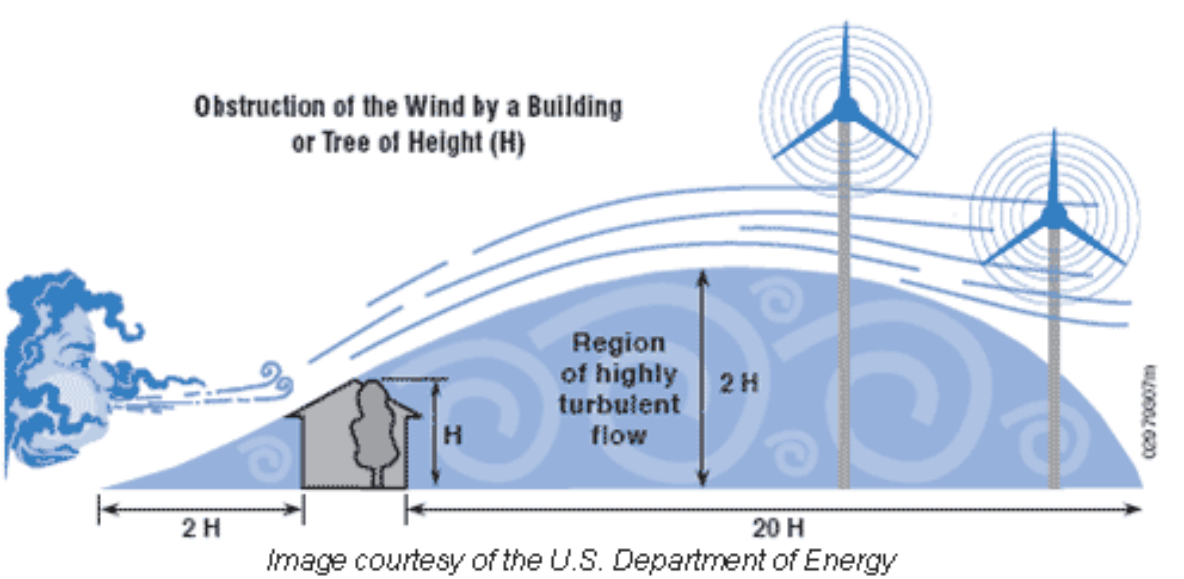
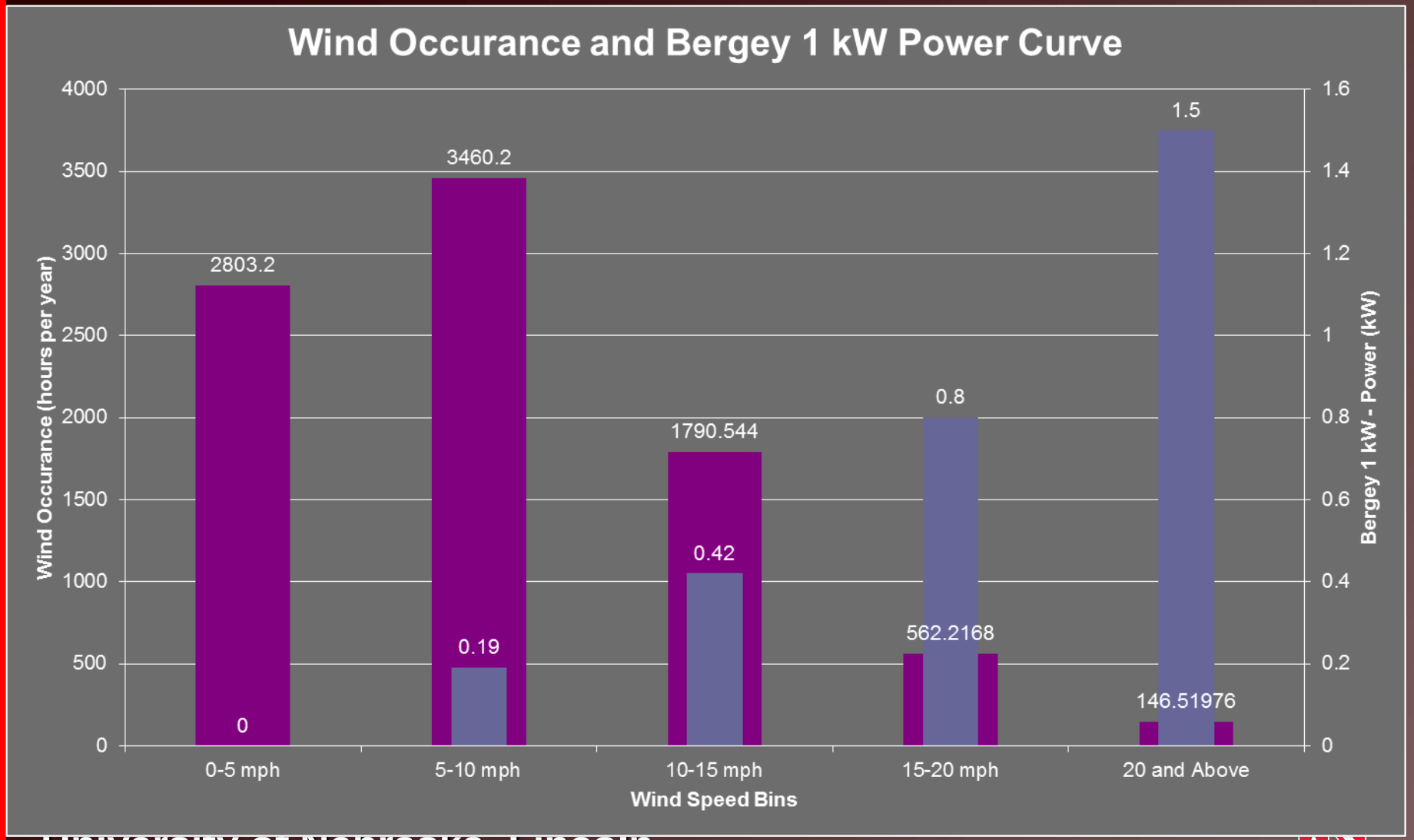
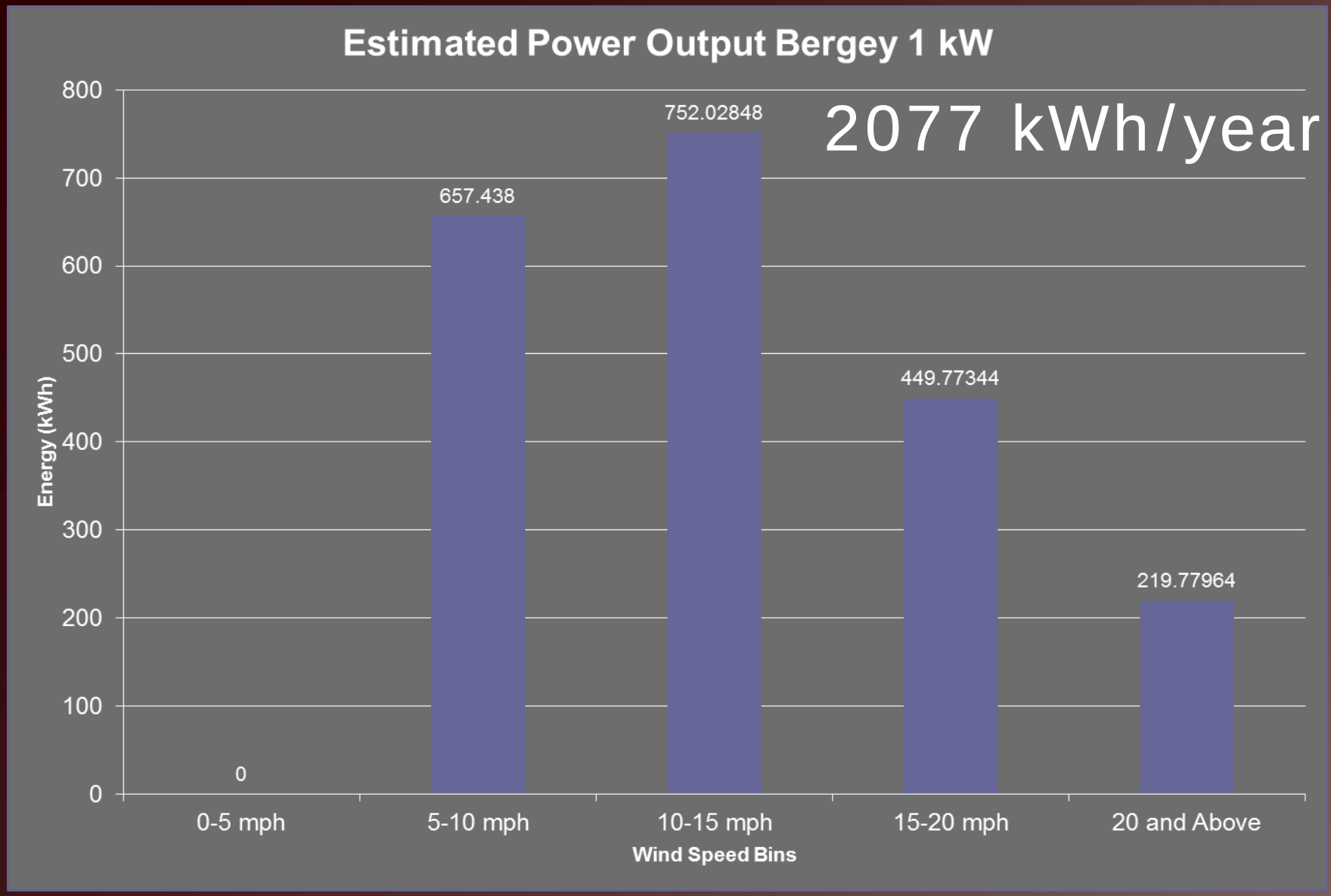


Image courtesy of the U.S. Department of Energy

Southwest Windpower

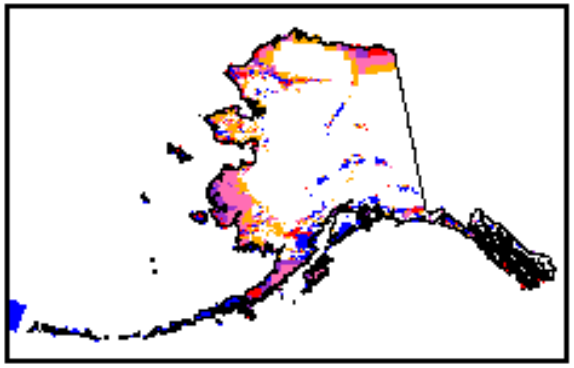

Wind Occurance and Bergey 1 kW Power Curve
Wind Occurance (hours per year)
Bergey 1 kW - Power (kW)
4000
3500
3000
2500
2000
1500
1000
500
0
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2803.2
0
3460.2
0.19
1790.544
0.42
0.8
562.2168
1.5
146.51976
0-5 mph
5-10 mph
10-15 mph
15-20 mph
20 and Above
Wind Speed Bins

Know how. Know **now.**



United States - Wind Resource Map

This map shows the annual average wind power estimates at 50 meters above the surface of the United States. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.

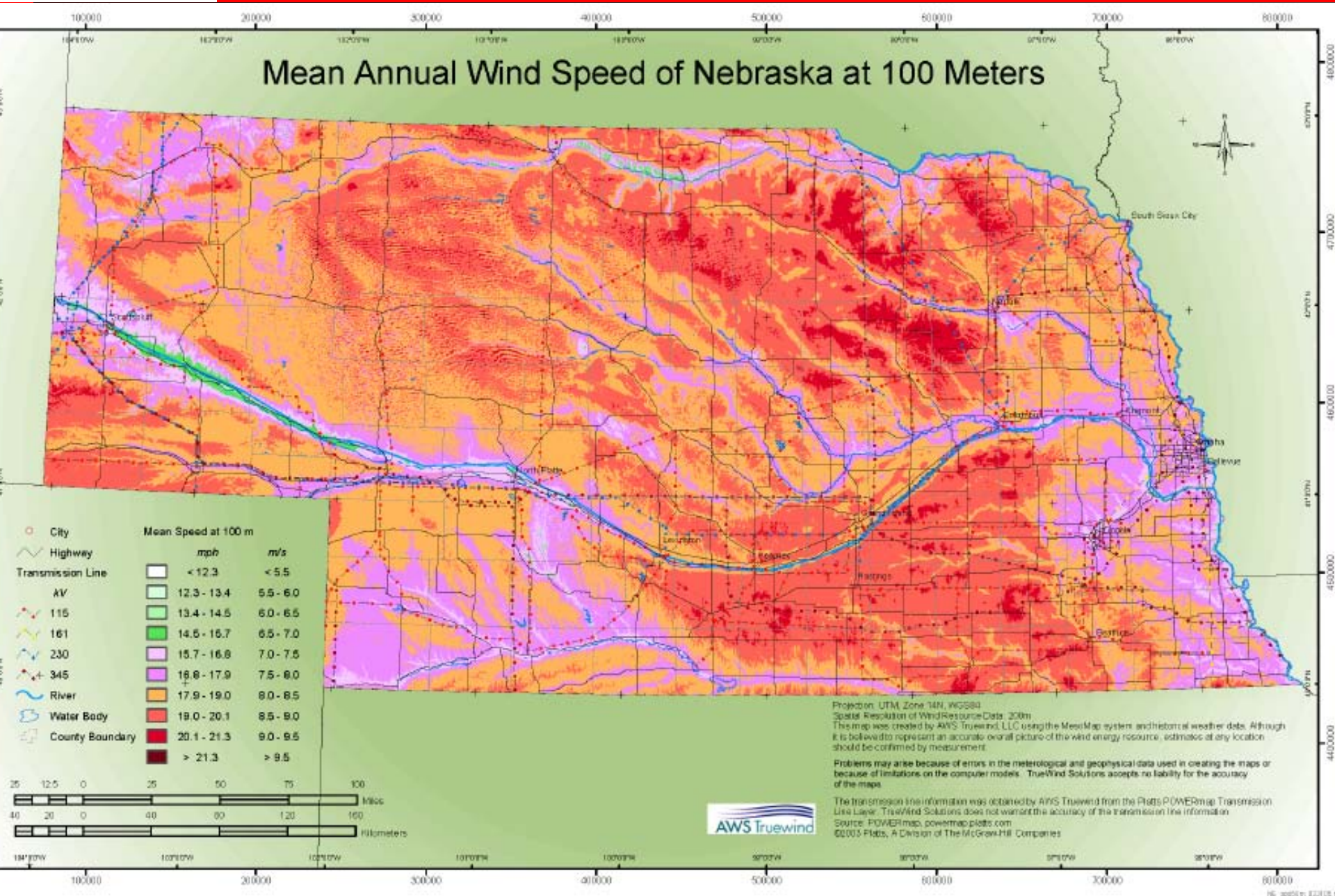


Wind Power Classification

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
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


Mean Annual Wind Speed of Nebraska at 100 Meters
City
Highway
Transmission Line
kV
115
161
230
345
River
Water Body
County Boundary
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
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
Miles
Kilometers
South Sioux City
North Platte
Lexington
Kearney
Hastings
Grand Island
Fremont
Omaha
Bellevue
Projection: UTM, Zone 14N, WGS84
Spatial Resolution of Wind Resource Data: 200m
This map was created by AWS Truewind, LLC using the MesoMap system and historical weather data. Although it is believed to represent an accurate overall picture of the wind energy resource, estimates at any location should be confirmed by measurement.
Problems may arise because of errors in the meterological and geophysical data used in creating the maps or because of limitations on the computer models. TrueWind Solutions accepts no liability for the accuracy of the maps.
The transmission line information was obtained by AWS Truewind from the Platts POWERmap Transmission Line Layer. TrueWind Solutions does not warrant the accuracy of the transmission line information.
Source: POWERmap, powermap.platts.com
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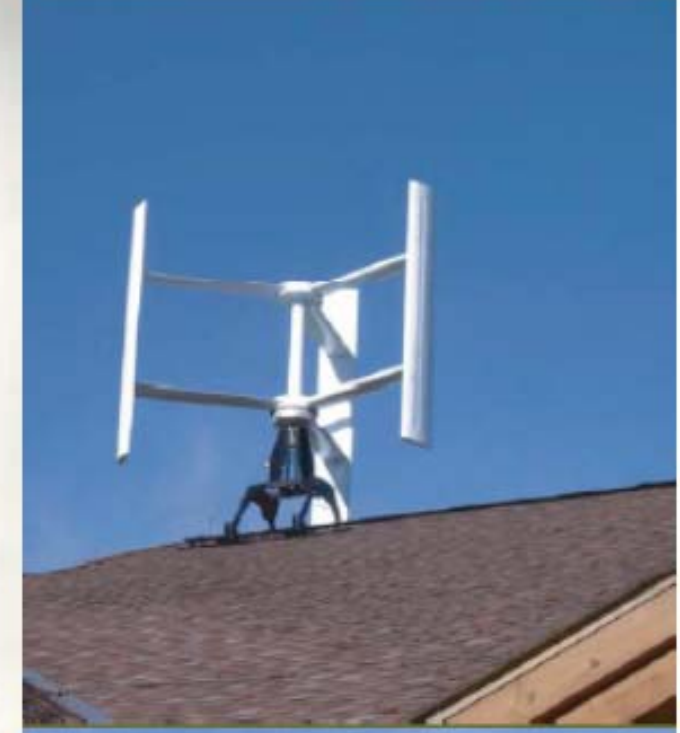
AWS Truewind




2008/

AeroVironment in Practice

- Government Services Center
  Duluth, MN
- Ribbon cutting 2-14-09
- $51,000 installation
- Peak output = 6 kW
- $8.5 per Watt installed
- Projected to save $1200/year

AeroVironment results

- 480 kWh/year = 1.3 kWh/ day for $51,000
- C of E = $5.31 / kWh
- At $0.12 / kWh, payback = 890 years

MGE Windside

- The installation
  - Fitchburg, WI
  - Installed 11-5-08
  - “urban turbine” demonstration
  - 10 kW at 35 mph
  - 30’ tower
  - “Starts generating at only 4 mph”
  - $40,000 installed

MGE Windside results

- CF for 10 kW
  = .0008%
- C of E =
  $28.57 / kWh
- At $40k installed,
  $0.12/kWh, and
  a 20 year life,
  the payback is
  4761 years

What do these designs all have in common?

1. Small swept area
2. Roof mounted or
3. Short towers
4. Unconventional rotor configuration
5. Eye candy photos
6. “Urban Turbines”
7. Claims!


Portland, Oregon


Thunder Bay, Ontario
PARKING

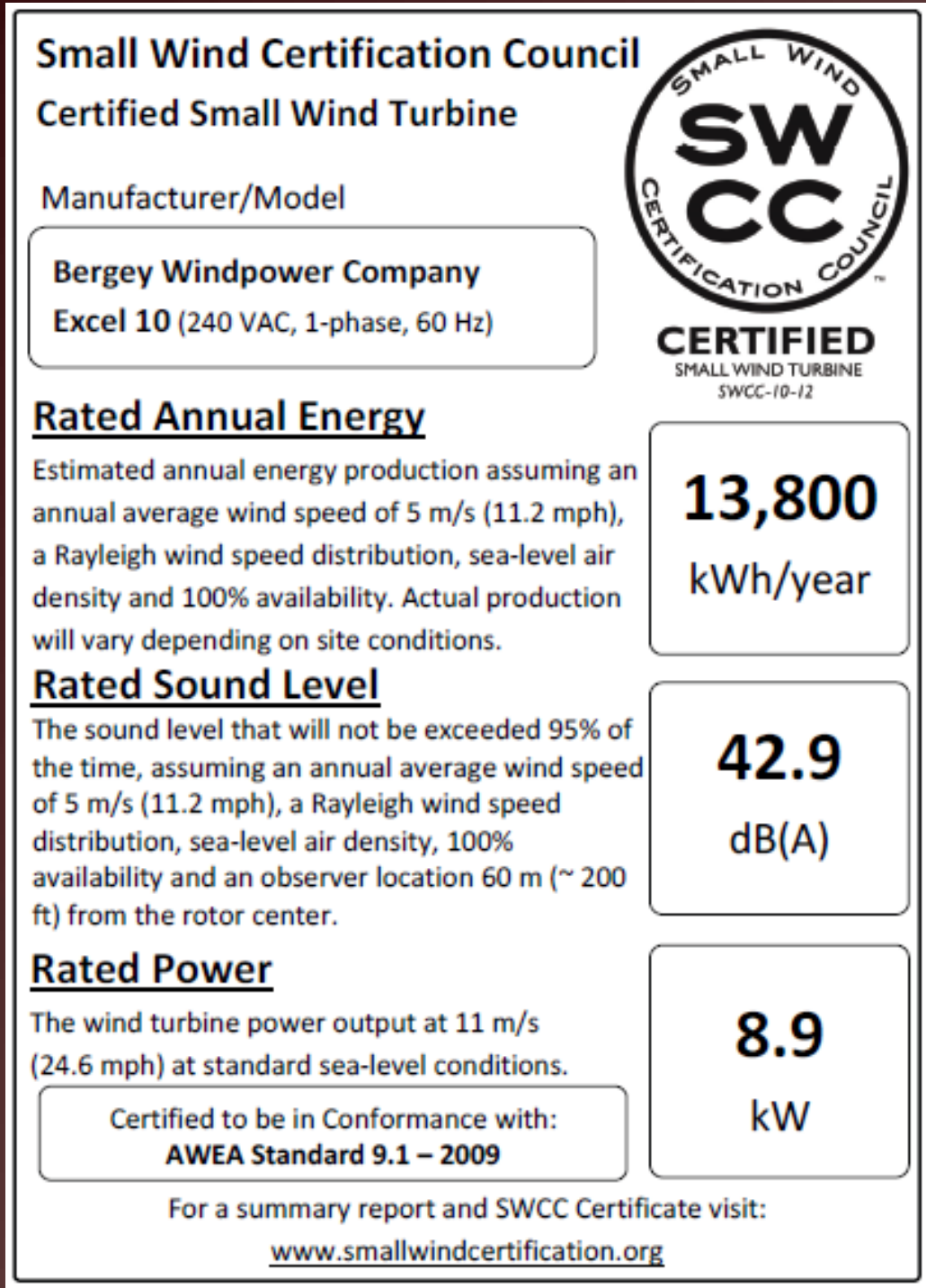

Lincoln, NE

Small Wind Certification Council

http://www.smallwindcertification.org

Public Deliverables

- Consumer Label
  - Single-number ratings
- Certificate
  - Available online to confirm validity
- Summary Report
  - Summary of testing
  - Power curve
  - Annual energy curve
  - Tabulated Data



Small Wind Certification Council

Certified Small Wind Turbine

Manufacturer/Model

Bergey Windpower Company
Excel 10 (240 VAC, 1-phase, 60 Hz)

SMALL WIND CERTIFICATION COUNCIL SWCC

CERTIFIED
SMALL WIND TURBINE
SWCC-10-12

Rated Annual Energy

Estimated annual energy production assuming an annual average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, sea-level air density and 100% availability. Actual production will vary depending on site conditions.

13,800 kWh/year

Rated Sound Level

The sound level that will not be exceeded 95% of the time, assuming an annual average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, sea-level air density, 100% availability and an observer location 60 m (~ 200 ft) from the rotor center.

42.9 dB(A)

Rated Power

The wind turbine power output at 11 m/s (24.6 mph) at standard sea-level conditions.

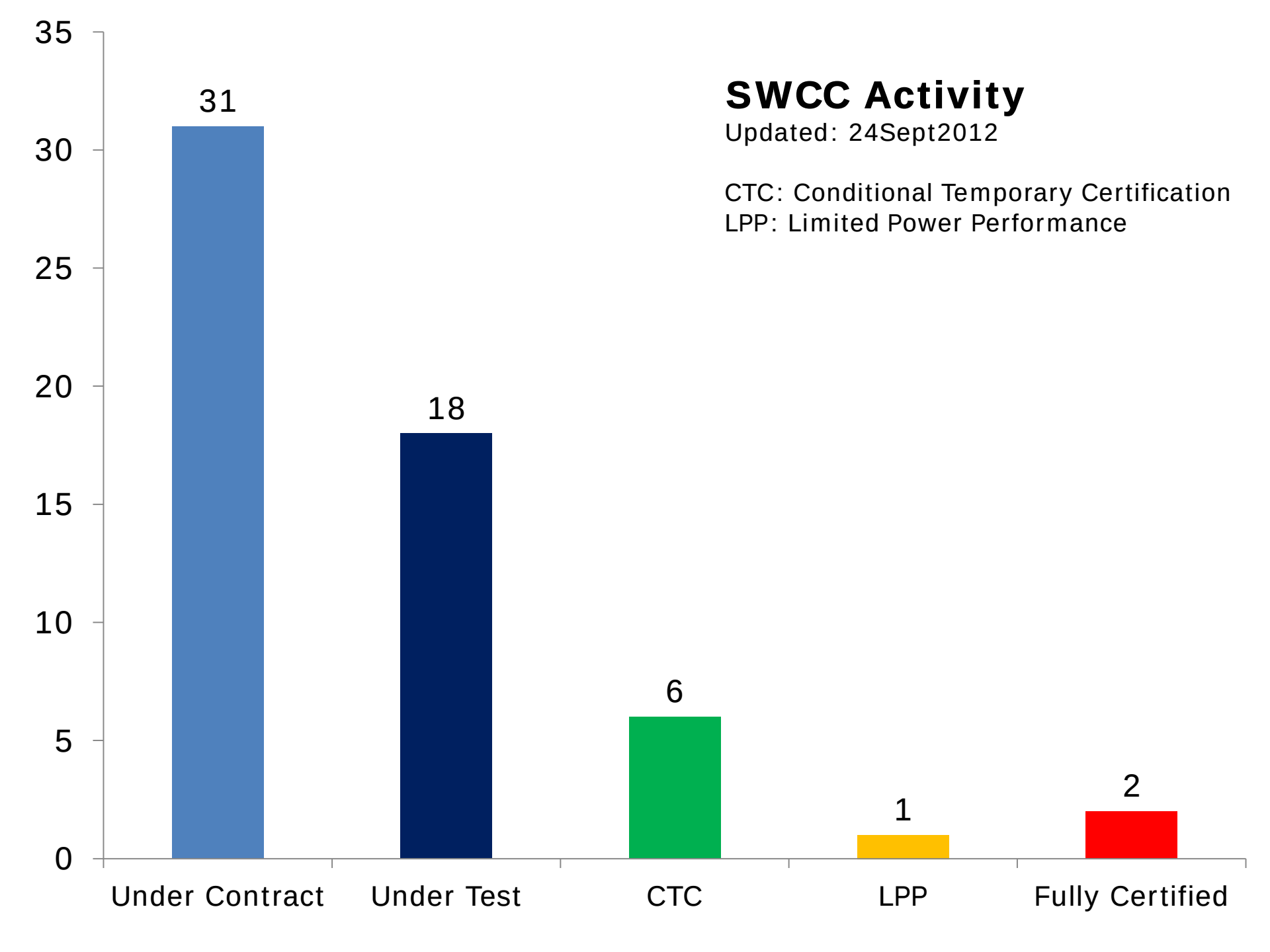
8.9 kW

Certified to be in Conformance with:
AWEA Standard 9.1 – 2009

For a summary report and SWCC Certificate visit:
www.smallwindcertification.org

Two Fully Certified Turbines

Applicant	Turbine	Rated Annual Energy @ 5m/s	Rated Sound Level	Rated Power @ 11 m/s	Certification Granted
Bergey Windpower Co.	Excel 10	13,800 kWh	42.9 dB(A)	8.9 kW	11/16/2011
Southwest Windpower	Skystream 3.7	3,420 kWh	41.2 dB(A)	2.1 kW	12/19/2011


SWCC Activity
Updated: 24Sept2012
CTC: Conditional Temporary Certification
LPP: Limited Power Performance
35
30
25
20
15
10
5
0
31
18
6
1
2
Under Contract
Under Test
CTC
LPP
Fully Certified

Thank you!

bioenergy.unl.edu

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