United States Department of Agriculture
Natural Resources Conservation Service

USDA NRCS

Renewable Energy
Wind Applications Primer

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Renewable Energy Definition

Renewable energy is naturally replenished energy generated from natural resources such as sunlight, wind, rain, tides, biomass, and geothermal heat.

What is Wind?

- Wind is a byproduct of solar energy resulting from uneven heating and cooling of the earth.
  - This creates atmospheric pressure gradients
  - Gradients force air movement from areas of high pressure to low pressure
- Approximately 2% of solar energy reaching the earth is converted to wind.

Wind or Solar

Wind Energy

- No nearby wind breaks
- Tower 75 – 200 feet tall
- 24-hour production?
- Wind speed range
- Geographical variations
- 17 – 38% availability
- 20 – 40% conversion efficiency
- 20-year life span

Solar Energy

- Unobstructed southern view
- Array perpendicular to sun
- Production 9 am to 3 pm
- Seasonal variations
- Geographical variations
- 10 – 25 % availability
- 10 – 15% conversion efficiency
- 25-year life span

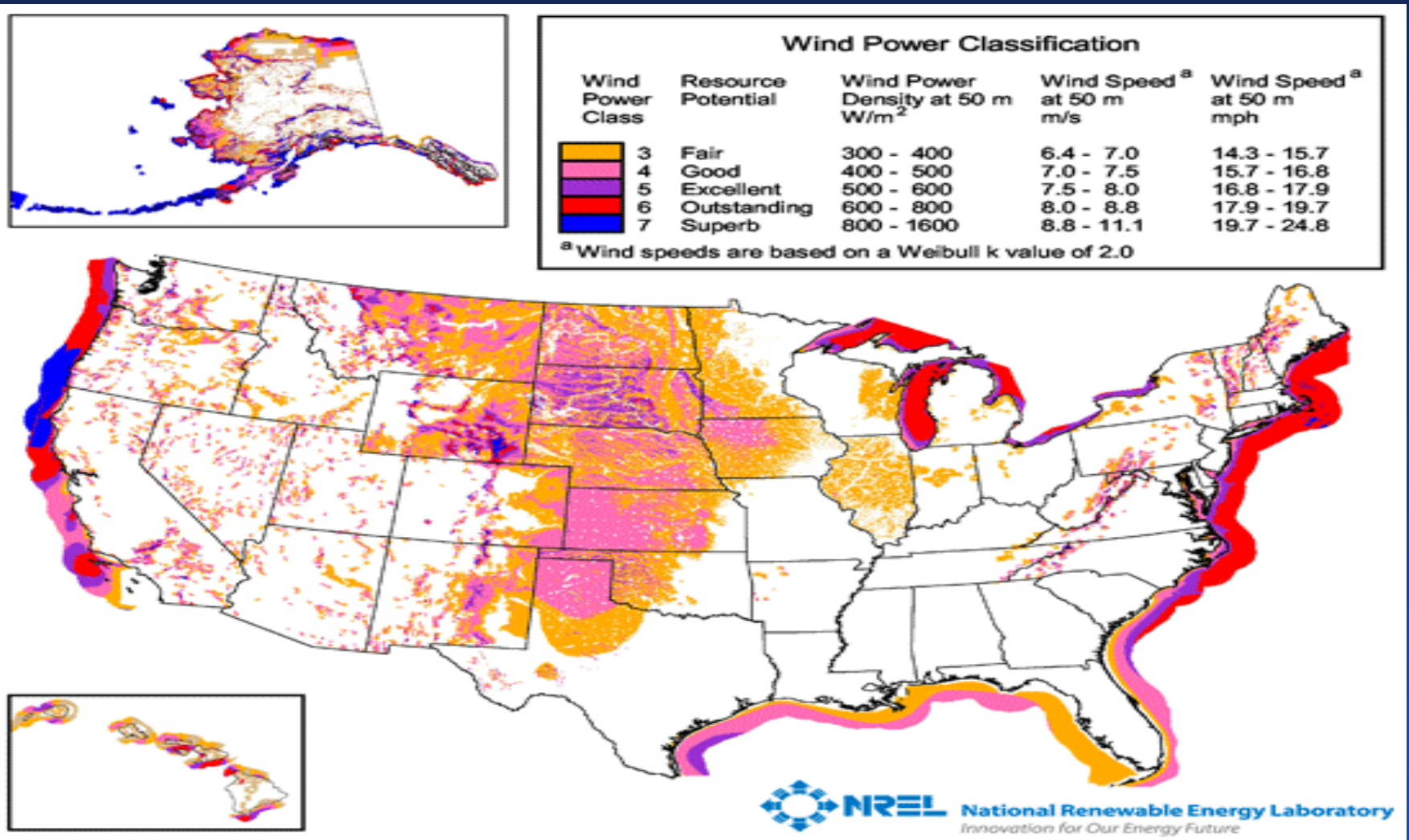
Applicable Conservation Practice Standards

- Pumping Plant (533)
- Watering Facility (614)
- Pipeline (516)
- Water Well (642)

Wind Energy Basics

- Site assessment
- Windmills (mechanical)
- Turbines (electrical)
  - Small-scale (< 1 kW)
  - Residential-scale (< 10 kW)
  - Utility-scale (> 10 kW)

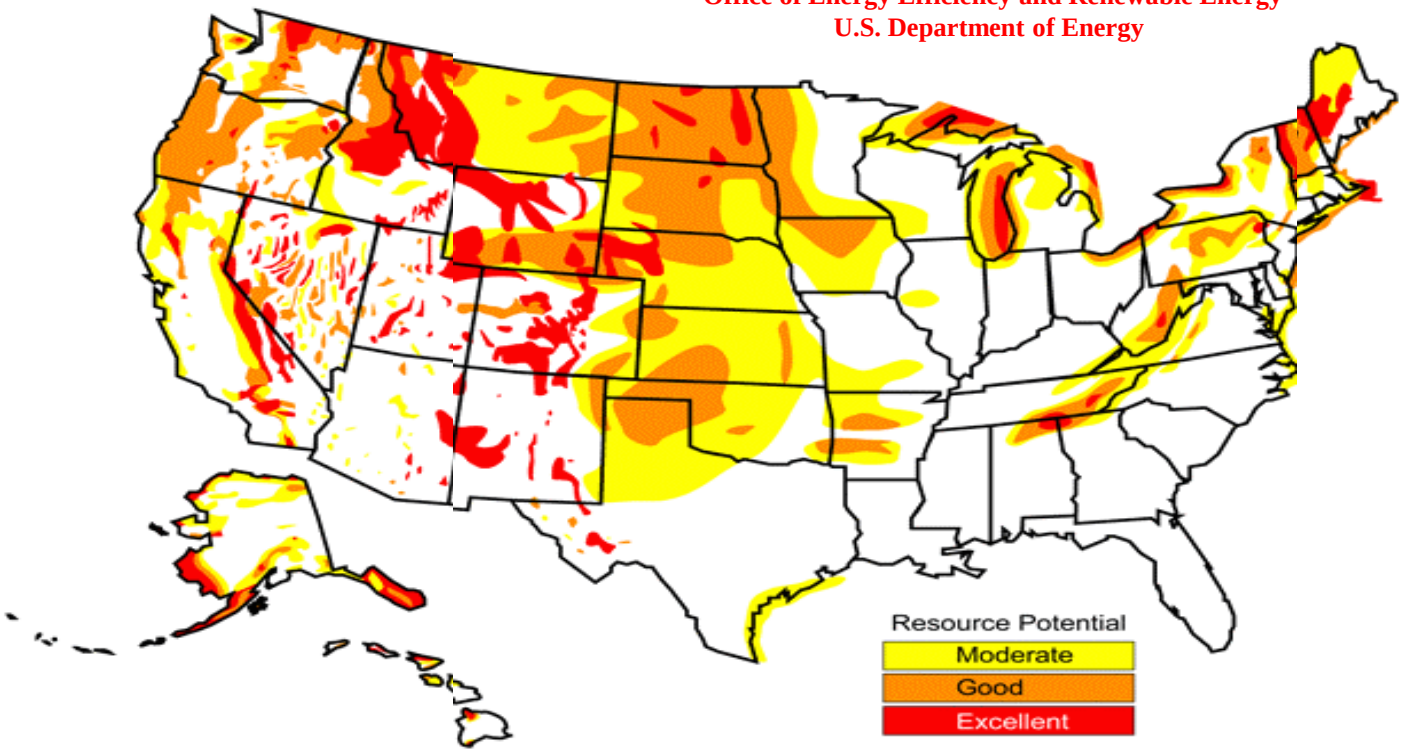
Wind Energy (continued)



Wind Resource Potential

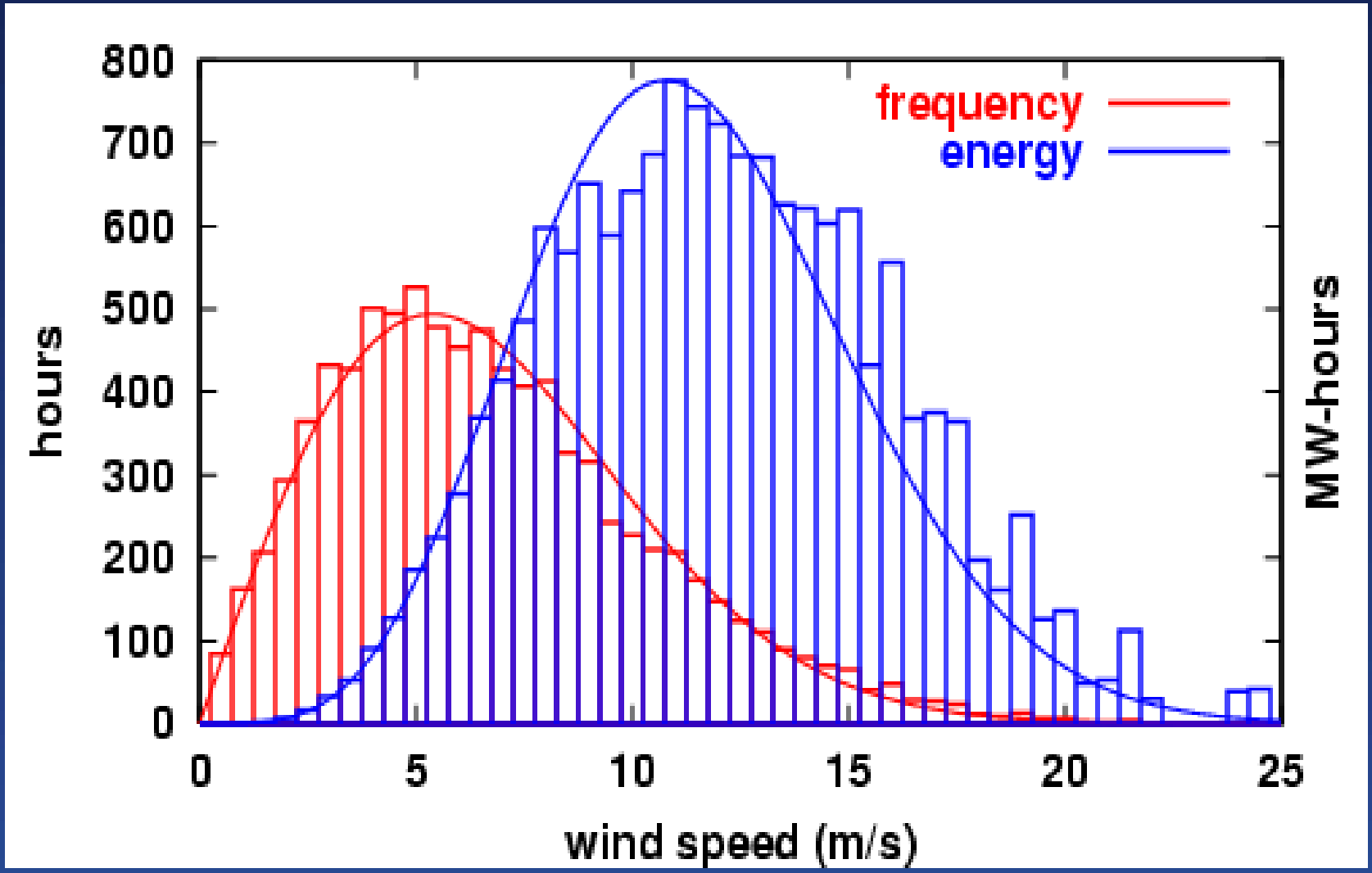
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Rank	State
1	North Dakota
2	Texas
3	Kansas
4	South Dakota
5	Montana
6	Nebraska
7	Wyoming
8	Oklahoma
9	Minnesota
10	Iowa
11	Colorado
12	New Mexico
13	Idaho
14	Michigan
15	New York
16	Illinois
17	California



http://www.windpoweringamerica.gov/wind_maps.asp for info by state.

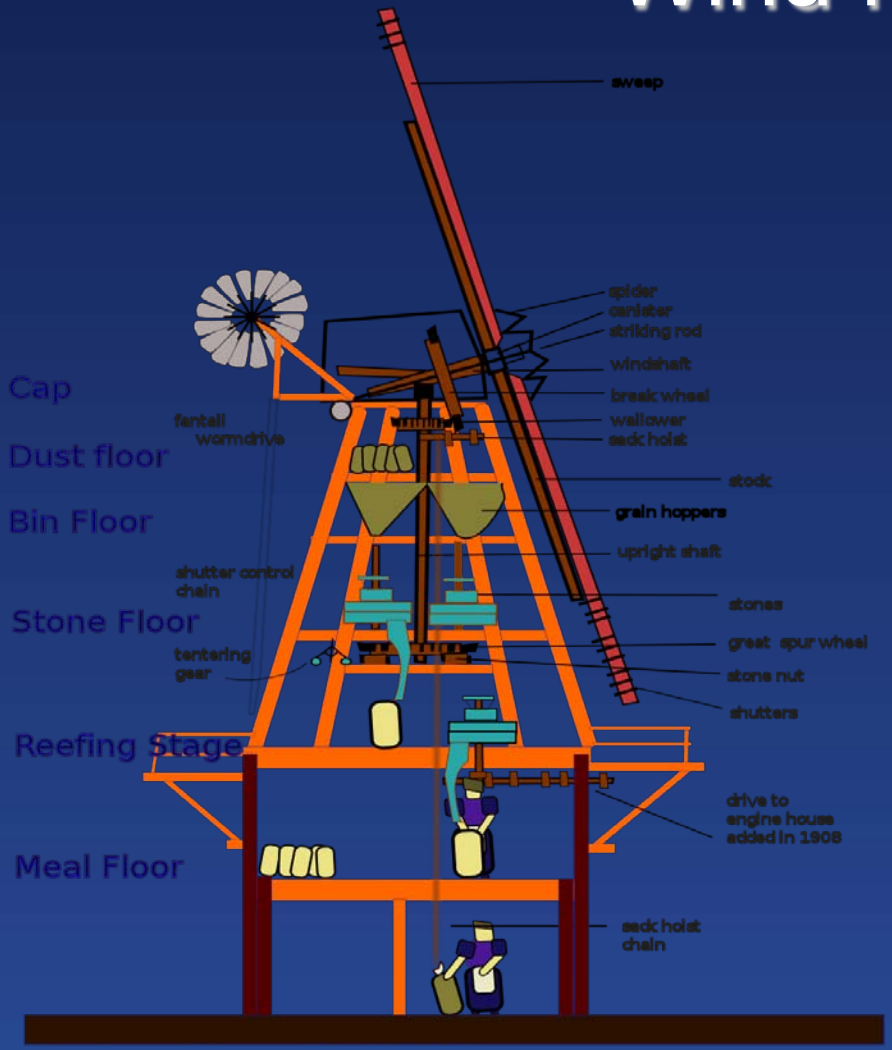
Wind Energy Distribution



Wind Resources

- For accurate assessment of complicated sites, wind speed and direction is typically monitored for 2-3 years at 10 and 50 meters (32 to 160 feet).
- Costs range from $3,000 - $10,000.

Wind Mills



Meopham Green, Kent 1820.

Wind Turbines

Small (≤10 kW)
- Farms
- Remote Applications

(e.g. water pumping, telecom sites, ice making)

Intermediate (10-250 kW)
- Village Power
- Hybrid Systems
- Distributed Power

Large (250 kW - 2+MW)
- Central Station Wind Farms
- Distributed Power

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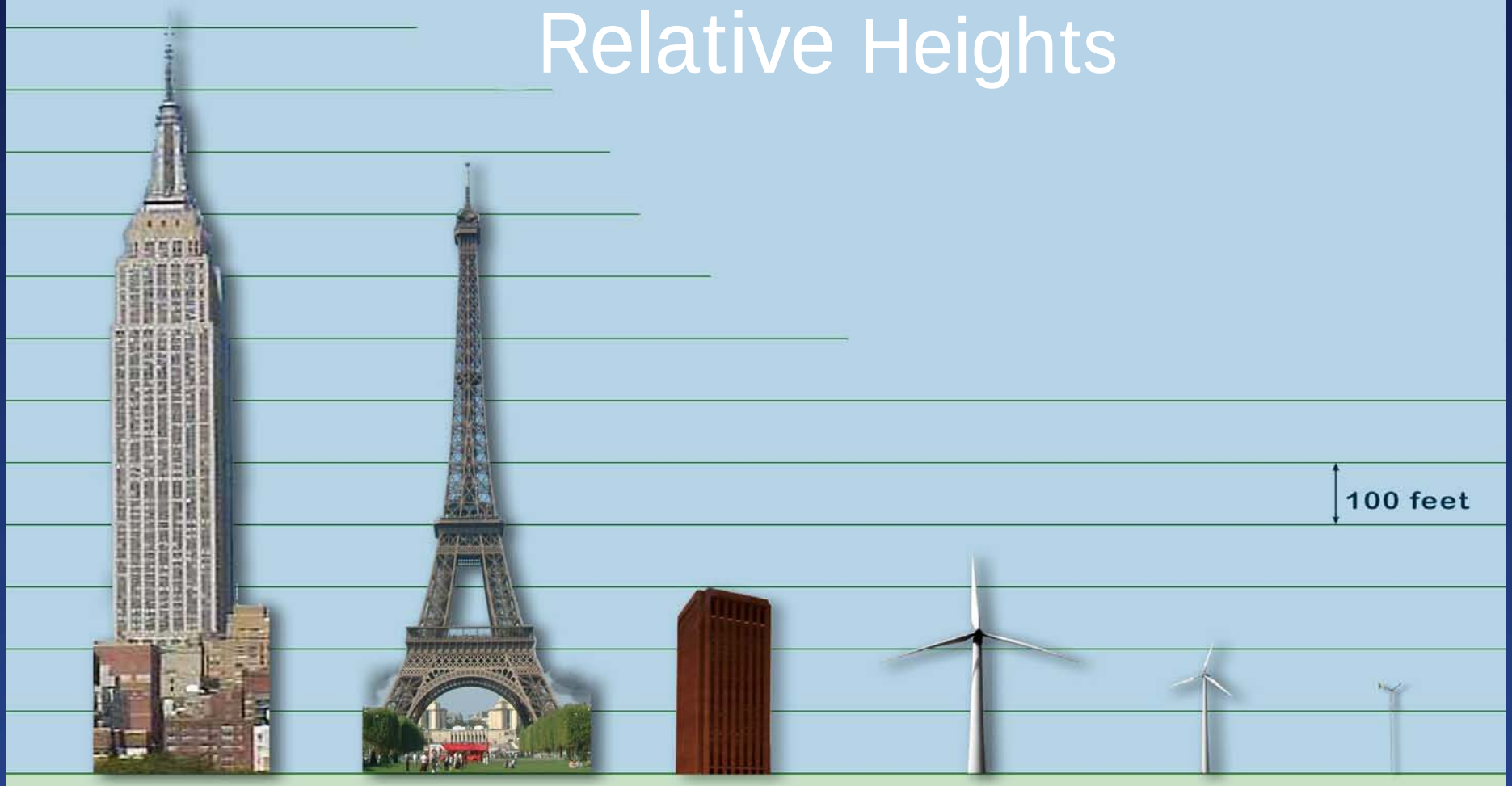
Relative Heights



Empire State 1250’	Eiffel Tower 986’	UMass Library 297’	1.5 MW Turbine 356’	Medium Turbine 212’	Farm Turbine 142’

Siting and Sizing Considerations

- Power Needs (energy audit)
- Wind Resources:
  - Speed and direction
  - Turbulence
- Design Considerations
- Operation & Maintenance
- Accessibility
- Regulations

Small Farm Applications

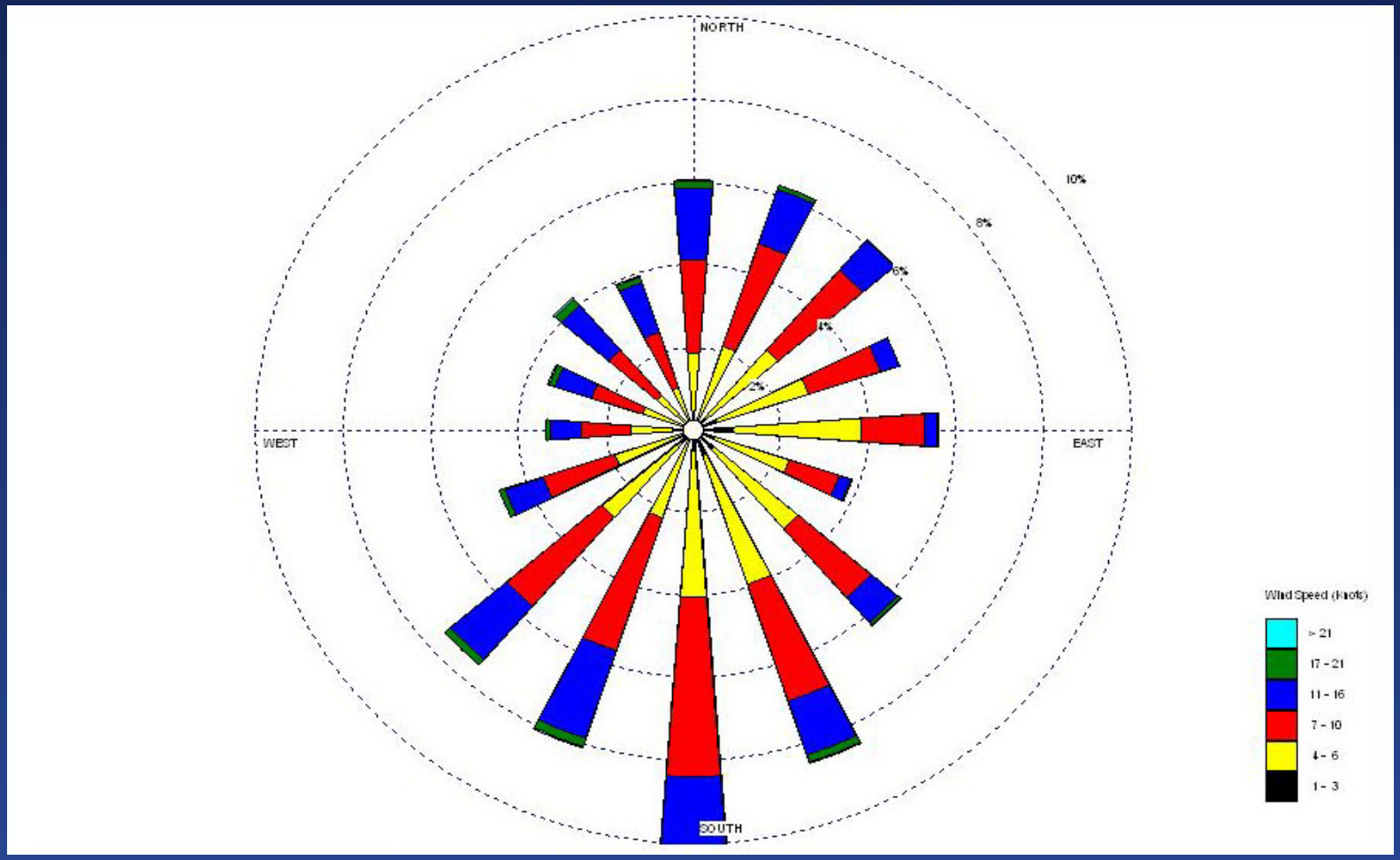
Livestock Watering

$2,000 - $3,000

Net Metering (home)

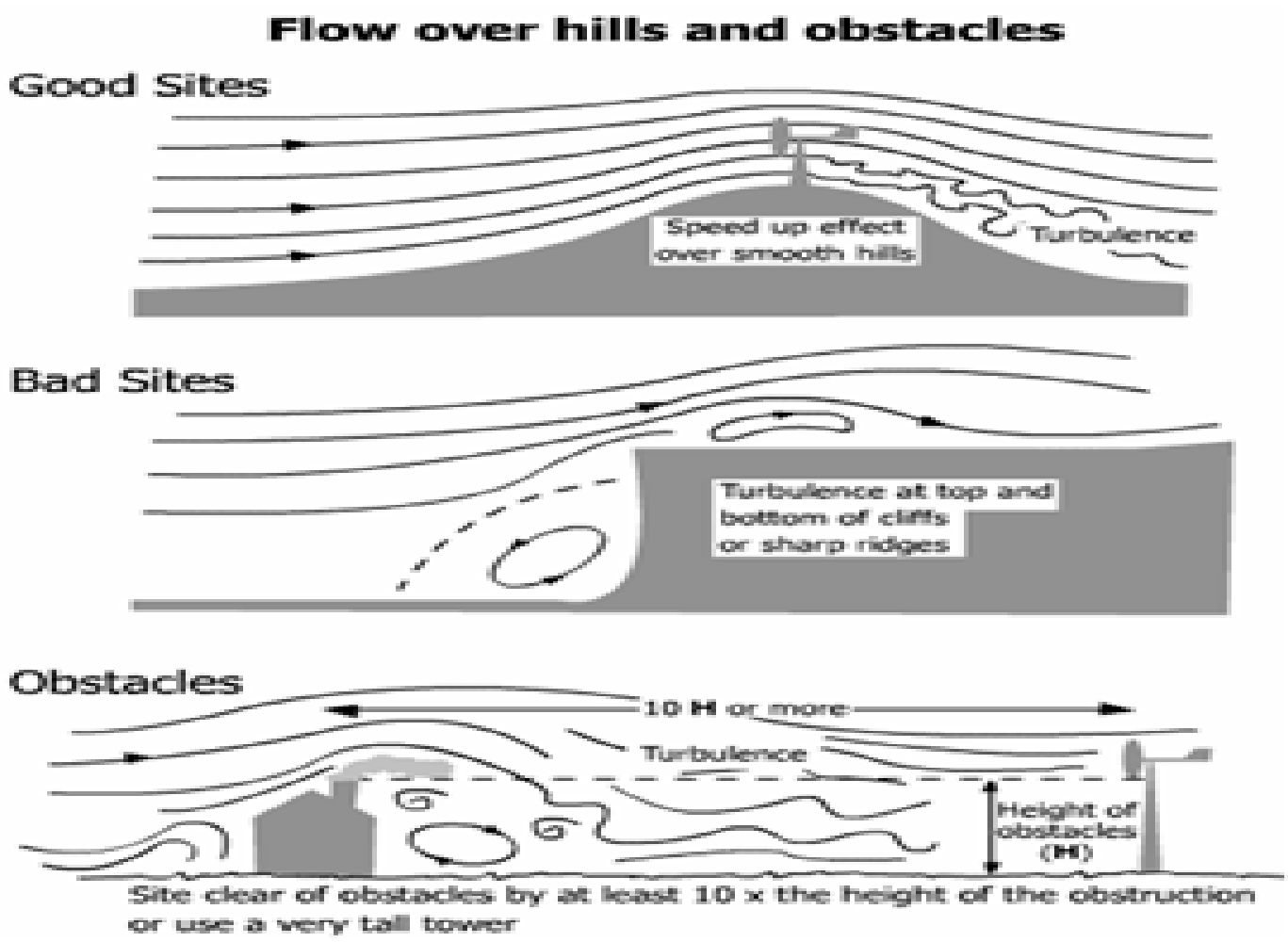
$30,000 – $40,000

Wind Resources



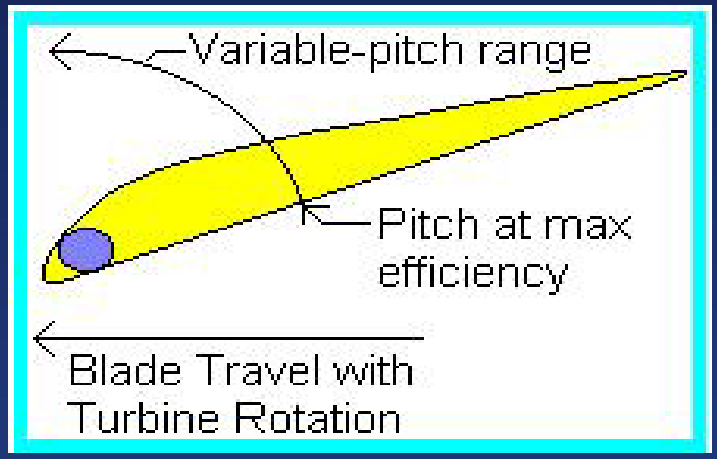
http://www.wcc.nrcs.usda.gov/climate/windrose.html

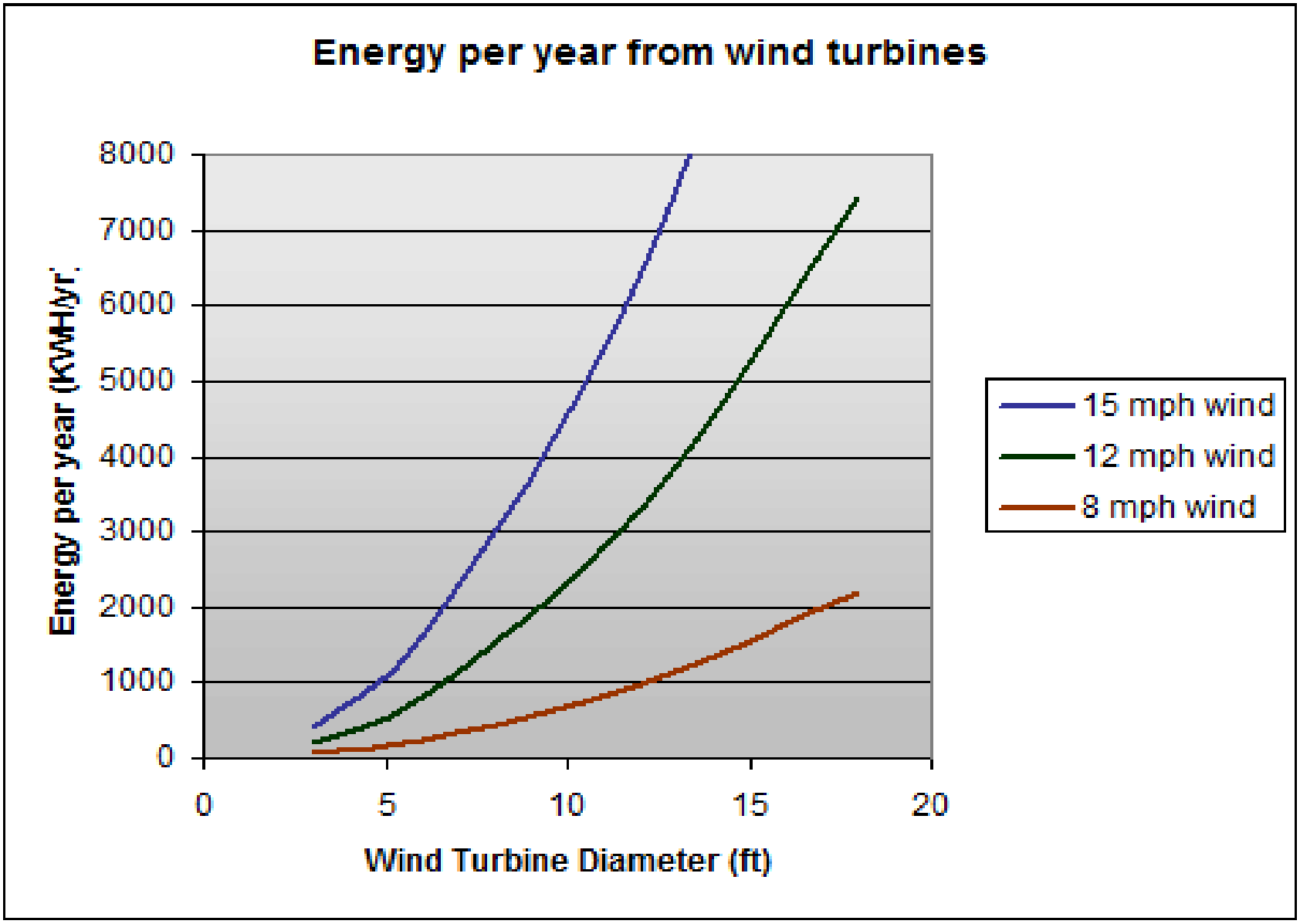
Wind Turbine Site Conditions

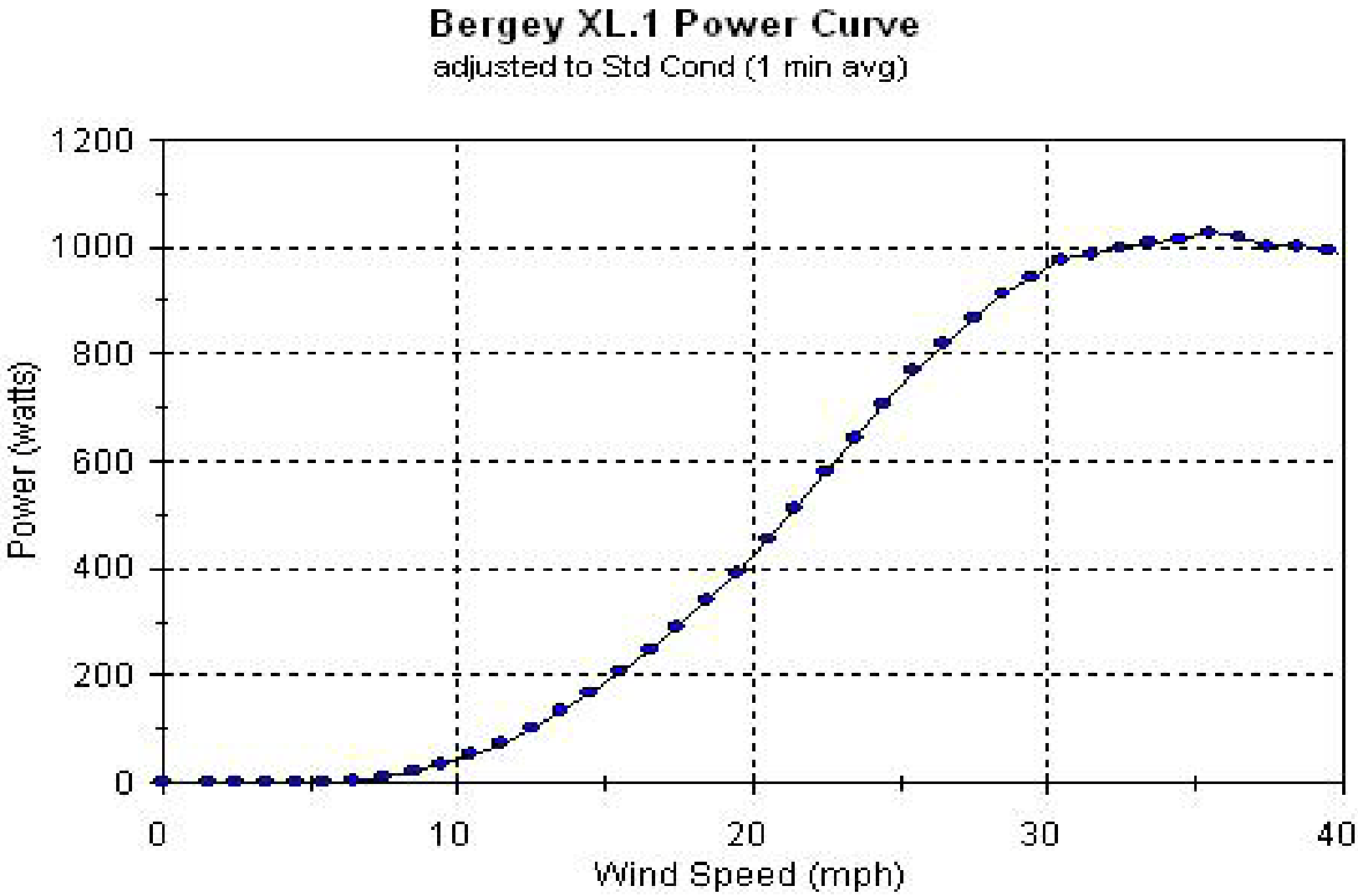


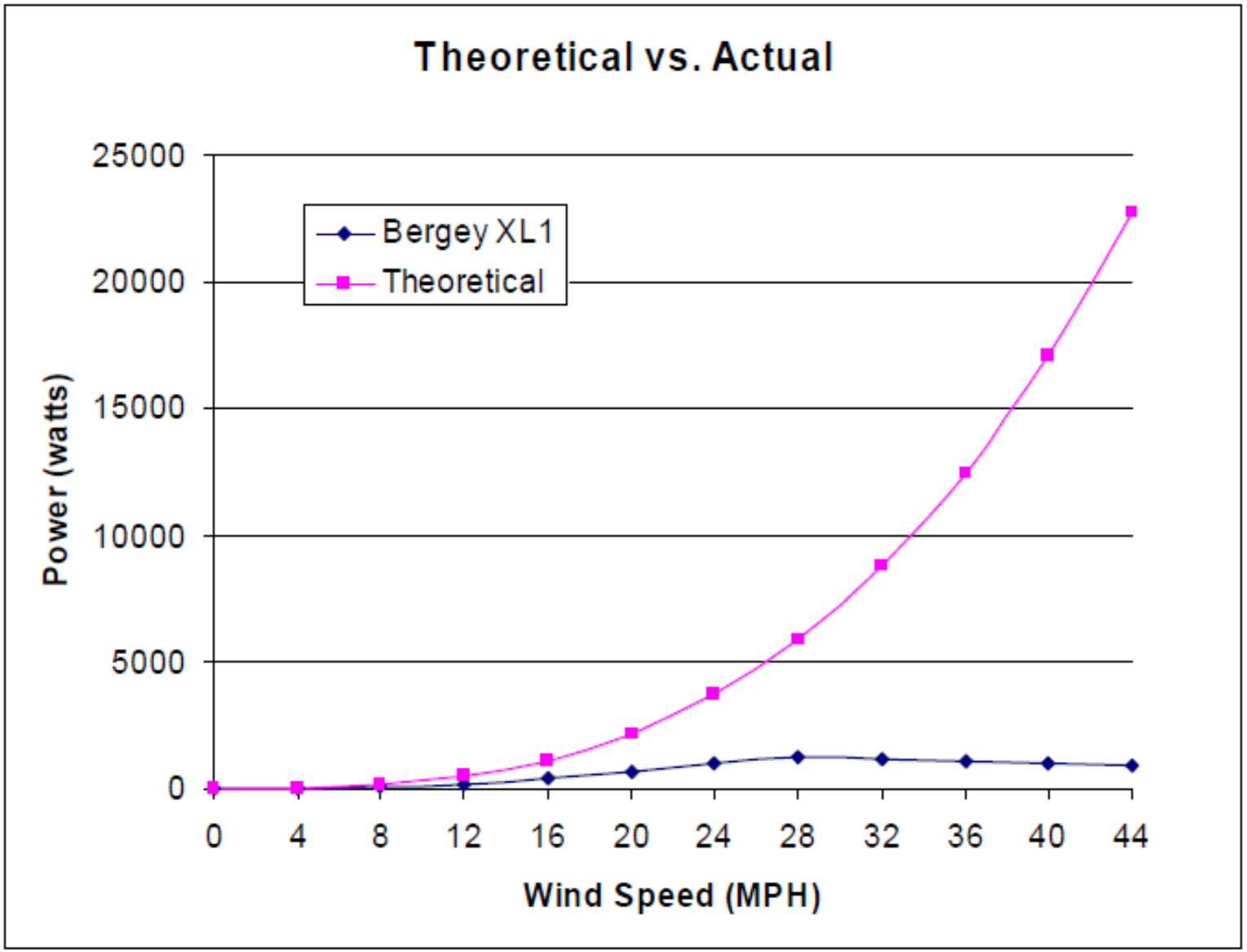
Design Considerations

- Air Density (ρ)
- Rotor Efficiency (C_p)
- Blade Area (A)
- Wind Speed (V)
- Power: $P = 1/2\ \rho\ C_p\ A^2\ V^3$
- For a given turbine, double the wind speed and the power output increases by a factor of eight.

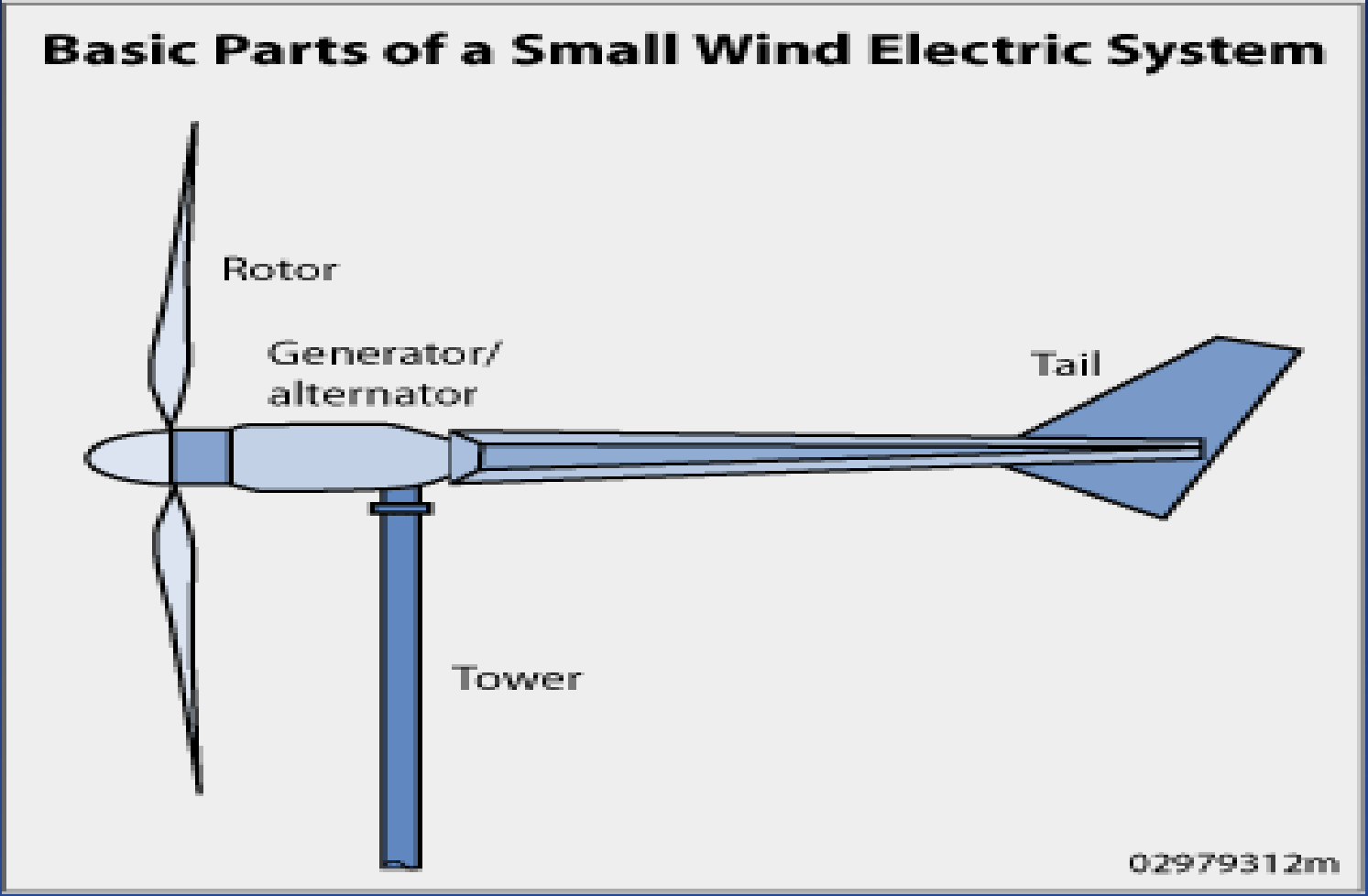



Energy per year from wind turbines
Energy per year (KWH/yr)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
Wind Turbine Diameter (ft)
15 mph wind
12 mph wind
8 mph wind

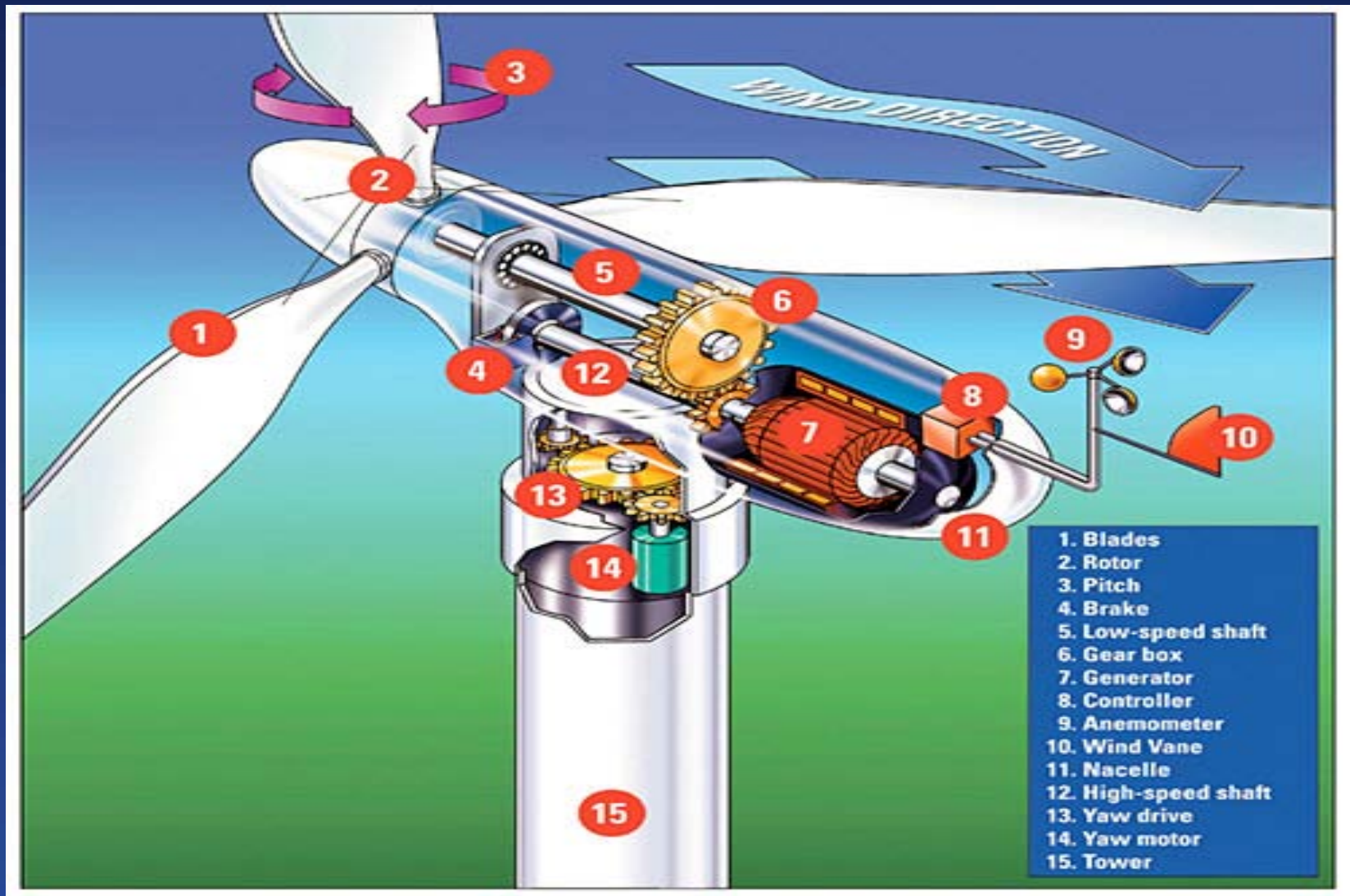

Bergey XL.1 Power Curve
adjusted to Std Cond (1 min avg)
Power (watts)
1200
1000
800
600
400
200
0
0
10
20
30
40
Wind Speed (mph)


Theoretical vs. Actual
25000
20000
15000
10000
5000
0
Power (watts)
Bergey XL1
Theoretical
0
4
8
12
16
20
24
28
32
36
40
44
Wind Speed (MPH)

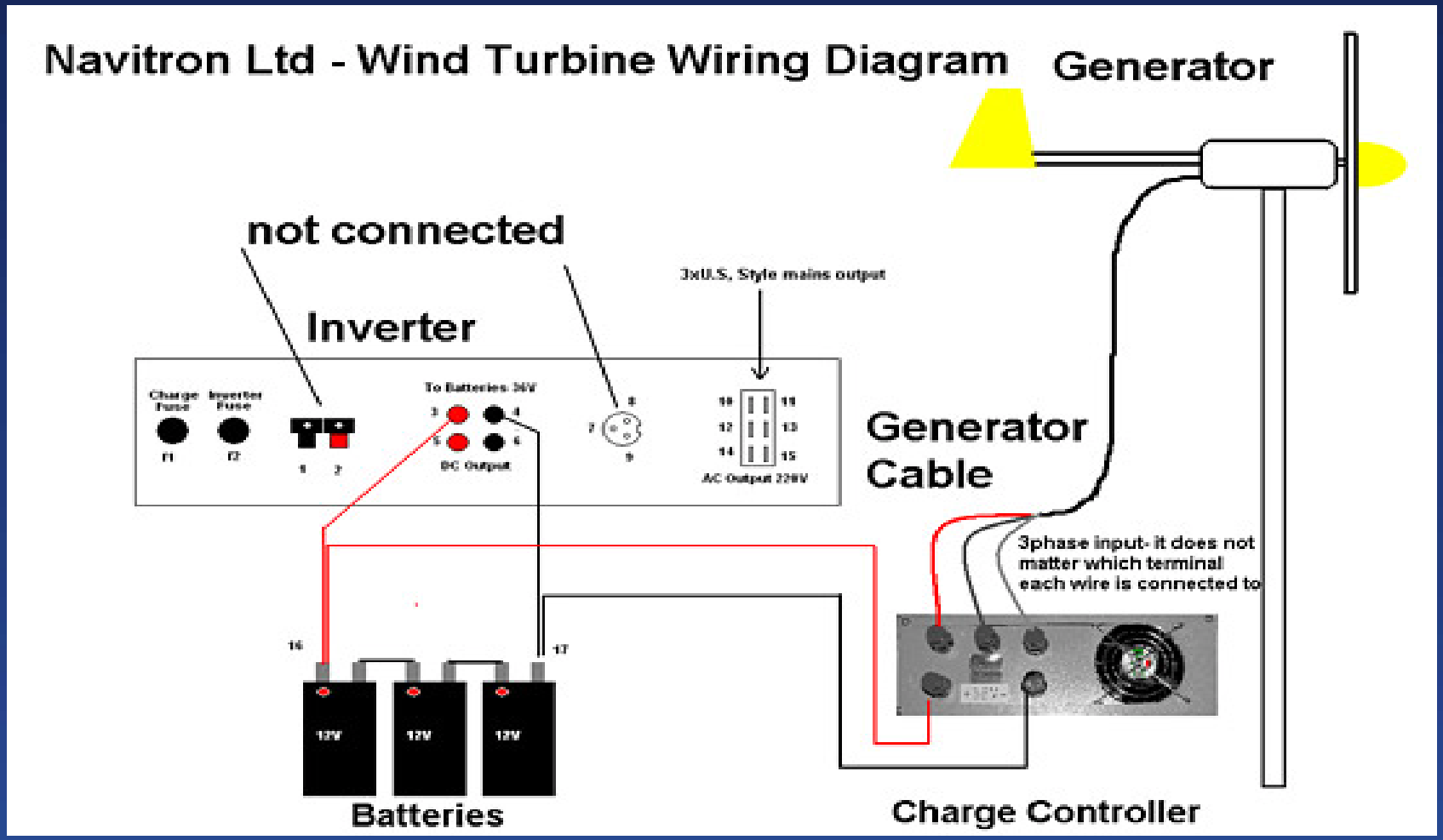
Wind Turbine



Wind Turbine Details



Wind Turbine System



O&M Costs

- Annual O & M 2-3% of Installed Cost
- Vary by Site and System Age
  - Insurance
  - Land costs
  - Repairs and replacements
  - Spare parts
  - Administration

Accessibility

- How far from the needed power should you site a turbine?
- How often will maintenance be required?
- How do you access the turbine?

Regulations

- Land use
- Zoning
- Setback requirements
- Environmental laws

Environmental Considerations

- Birds, bats, other wildlife
- Aesthetics
- Noise
- Health effects(?)

Environmental Benefits

- No SOx or NOx
- No particulates
- No mercury
- No CO2
- No water

Advantages and Disadvantages of Wind Energy

- **Advantages**
  - Environmentally friendly
  - Economically competitive with kinds of electrical generation
  - Favorable economic impacts
- **Disadvantages**
  - Highly variable
  - Complimentary power supply often necessary
  - Location specific

Installed Costs for Energy Systems (your prices will vary)

Wind Turbine

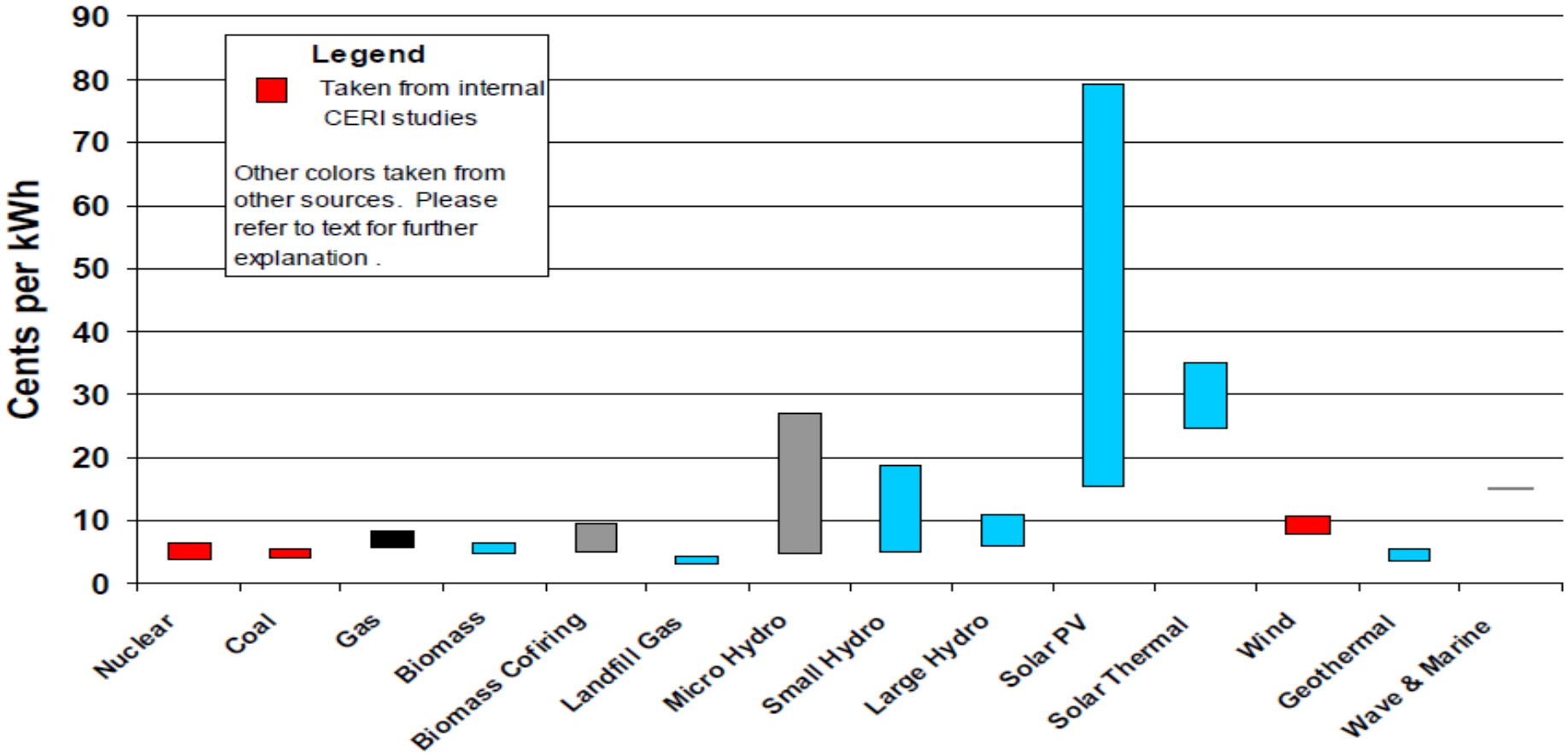
- 400 watt - $3.00/watt
- 1,000 watt - $3.50/watt
- 10,000 watt - $3.00/watt

Solar PV

- 400 watt - $2.50/watt
- 1,000 watt - $4.00/watt
- 6,000 watt - $4.00/watt

Relative Costs of Electricity Generation Technologies

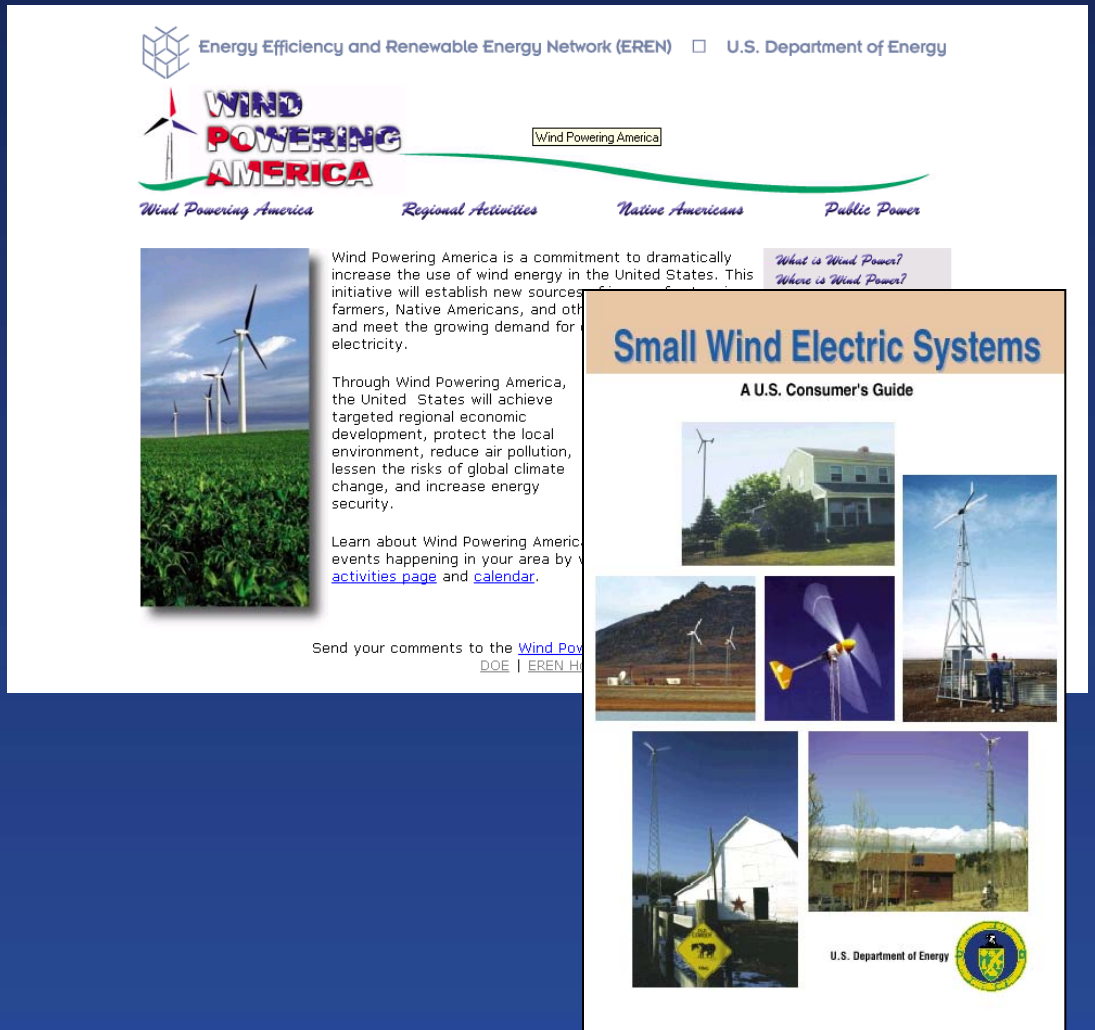
(2003 Canadian cents per kilowatt-hour)



Source: Canadian Energy Research Institute

Education Materials

- Workshops/events
- Wind coalitions
- Regional/State web sites
- Landowner guides
- Small wind guides
- State wind guides
- Wind calendar
- Technical support
- Earth Day materials
- Presentations
- Regional leveraging
- On-line tools



Database of Renewable Energy Incentives

www.dsireusa.org

- Each State-Financial Incentives from city/county/state/federal governments
- State Rules, Regulations and Policies
- Utility Incentives

Additional Information Resources

- NRCS wind energy assessment tool
  - http://www.ruralenergy.wisc.edu/
- National Sustainable Agricultural Information Service
  - http://attra.ncat.org - publications and tools.

Renewable Energy Opportunities

- Technologies are advancing rapidly
  - Decreasing costs
  - Increasing efficiency
- Finally, check the following web sites:
  - **National Renewable Energy Laboratory**
    - **http://www.nrel.gov/**
  - **Energy Efficiency & Renewable Energy**
    - **http://www.eere.energy.gov/**

Wind Energy Applications

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A Brief Overview of Wind Power in the U.S.A.

1. Early American settlers: European technology
2. Self regulating and pivoting blades for high winds: 1857
   - Provided year round water allowed much of the Great Plains to be settled between 1870 & 1920

A Brief Overview of Wind Power in the U.S.A.

3. Wind power to produce electricity
   - Rural Electrification Administration ended this phase
   - 1930's power for farmsteads
4. Today
   - Beginning in the 1970's
   - Uses modern aerodynamics learned from the aerospace industry

Uses of Wind Power

- Pump Water
  - Mechanical Windmill
- Produce Electric Power (and then pump water with the electricity)
  - Wind Turbine

Power Requirements

- Solar-PV water pumping systems less than 1.5 kW are more likely to be used in U.S. than wind powered water pumping systems due to:
  - a better match to water demand,
  - less maintenance requirements (e.g. fewer moving parts), and
  - a larger area of land with a good solar resource than with a good wind resource.
- As power requirements increase however, a wind only or a hybrid wind/solar water pumping system is desirable until the price per Watt for solar-PV modules can be decreased significantly and/or efficiency of Solar-PV modules can be improved significantly.

Conditions for Stand-Alone Wind System

- You live in an area with average annual wind speeds of at least 9 miles per hour (4.0 meters per second).
- A grid connection is not available or can only be made through an expensive extension. The cost of running a power line to a remote site to connect with the utility grid can be prohibitive, ranging from $15,000 to more than $50,000 per mile, depending on terrain.
- You acknowledge the intermittent nature of wind power and have a strategy for using intermittent resources to meet your power needs

Solar vs. Wind
Where to draw the line?

- In general, mechanical windmills and solar pumps are best for small quantities of water and low pumping heads.
- Wind-electric systems, such as 1.5 and 10 kW units, are better for large-scale livestock watering applications, small plot irrigation, and village water supply.

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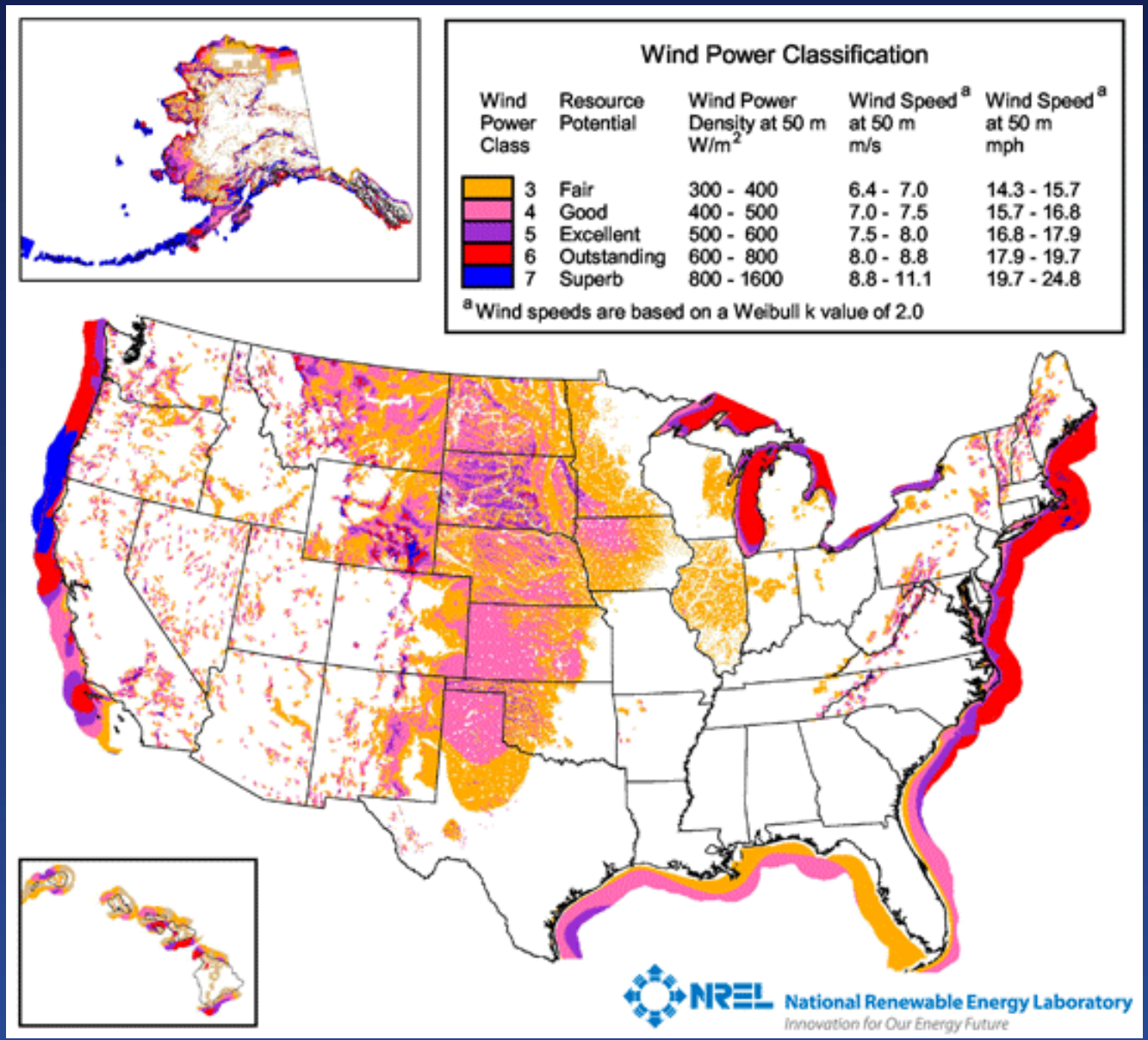
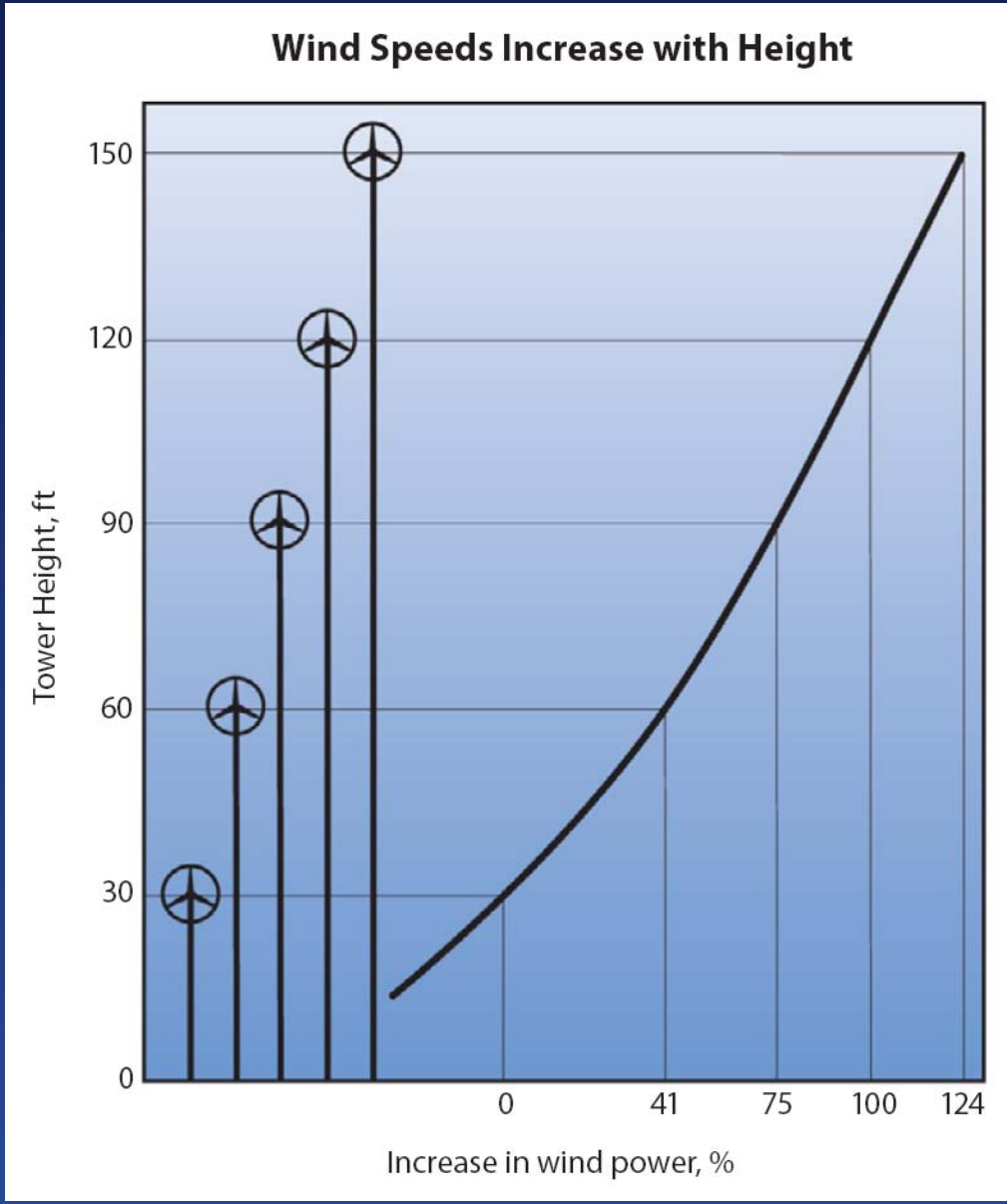
Making the Decision

- Analyzing the monthly water demand requirement;
- Conducting a resource assessment;
- Deciding whether a wind or solar water pumping system would be best.


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
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 National Renewable Energy Laboratory
Innovation for Our Energy Future


Wind Speeds Increase with Height
Tower Height, ft
150
120
90
60
30
0
0
41
75
100
124
Increase in wind power, %

Analyzing the monthly water demand requirement

- Need to know the height the water needs to be lifted
- Need to know the water demand

Water Use Information					
Type of Use	Seasonal Water Requirement (Gal./Day)				Comments (# or type of animals, type of irrigation, etc.)
	Summer	Fall	Winter	Spring	
Livestock					
Wildlife					
Irrigation					
Domestic/Potable					
Other					
Total Requirement					

Use a reservoir (e.g. large tank) if…

•Water supply systems with a water reservoir are used where ...

•• for short periods, the wind energy is insufficient to run the pump

•• there is a need for a back-up water source.

•As the turbine noise level increases with the wind speed, siting of the wind turbine near a residence is not recommended.

Mechanical Windmills

- Mechanical windmills are still in production and thousands are installed every year.
- The amazing thing is that the design of these windmills has not changed for over a hundred years. The reason is that they were so well designed in the first place.
- The major U.S. manufacturers are Aermotor (San Angelo, TX) and Dempster (Beatrice, NE).
- We have a list of manufacturers

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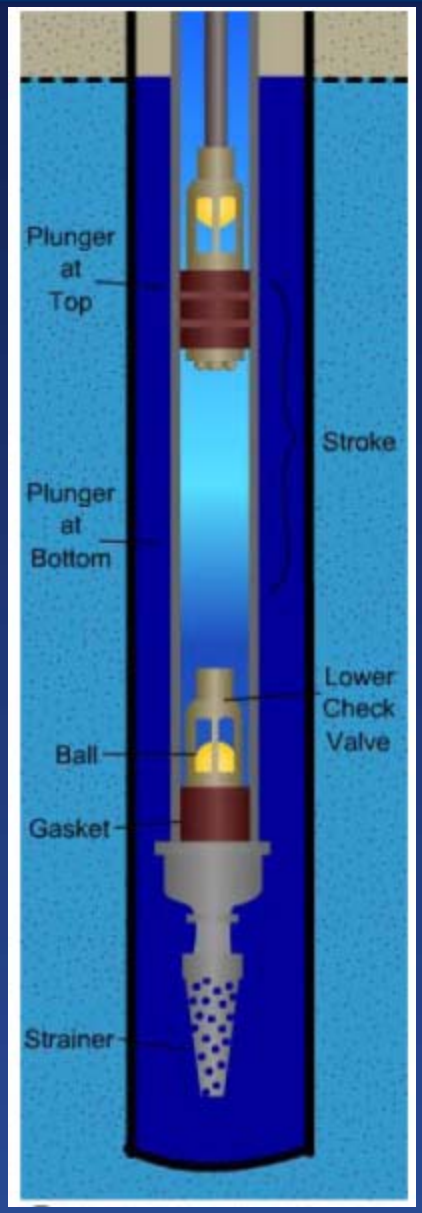
- Mechanical windmills use a positive displacement pump



Payment Schedule: Pumping Plant (533) Windmill

- $5,800

Typical Implementation Scenario

- Complete windmill system - 12 ft fan and head to pump 2 gpm for livestock watering.
- A pumping facility installed to transfer water for a conservation need, usually for livestock watering, filling ponds, ditches or wetlands; or pumping from wells, ponds, streams and other sources.

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Payment Schedule: Pumping Plant (533) Windmill with Tower

$1,022/mill-ft

Typical Implementation Scenario

- Complete windmill system with a new tower to pump livestock water, 30-foot tower (does not include well).
- A pumping facility installed to transfer water for a conservation need, including removing excess surface or ground water; filling ponds, ditches or wetlands; or pumping from wells, ponds, streams and other sources.

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Windmills vs Turbines

- Windmills work very well at low wind speeds, so they tend to give more reliable water supply than wind-electric systems.
- The wind-electric systems are more efficient over a wide range of wind speeds, they can pump higher volumes of water, and the wind turbine can be placed far from the well.

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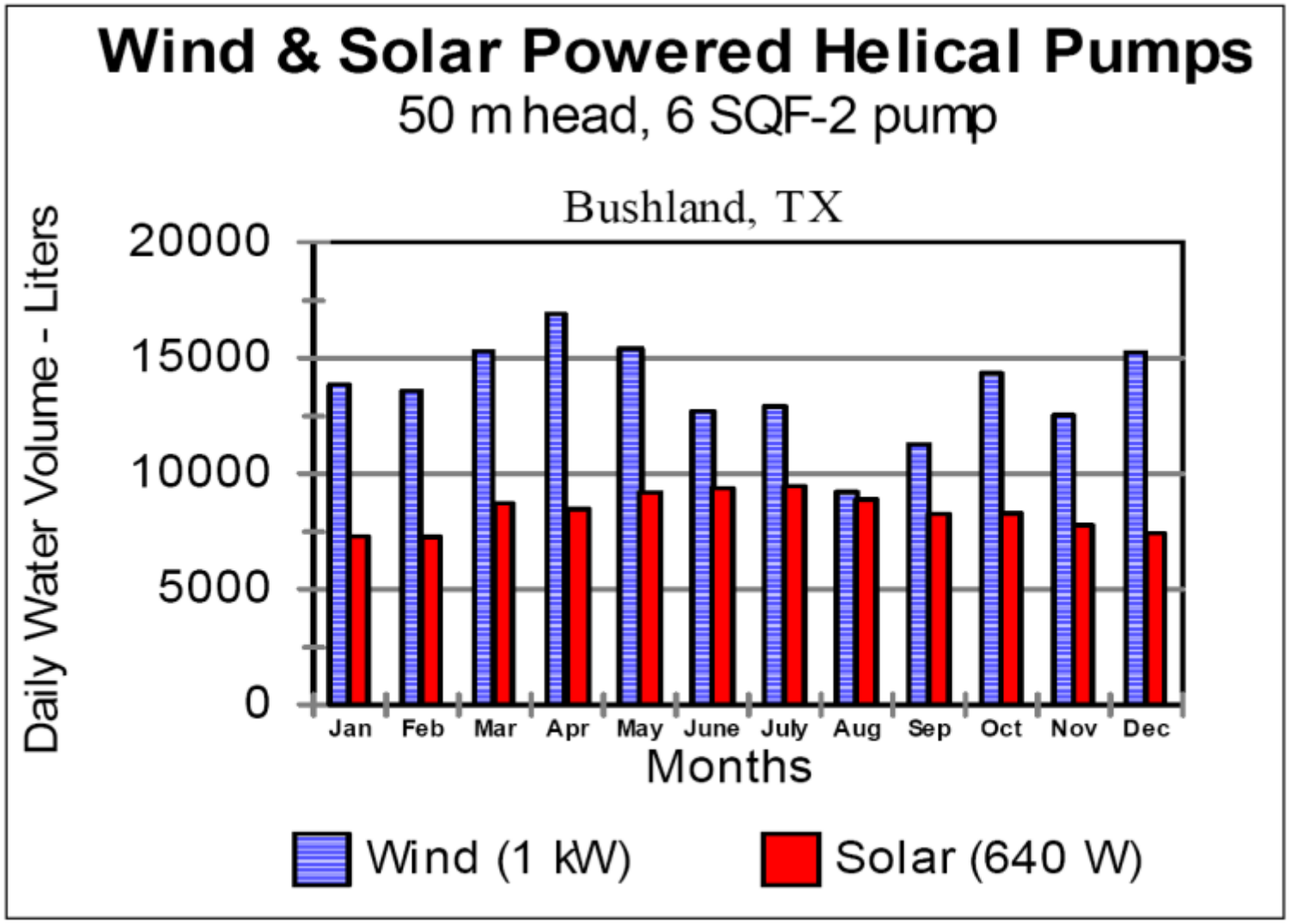


Figure 9. Daily comparisons of wind and solar powered water pumped at the 50 m pumping depth. Minimum volume is approximately 7,000 liters per day.

- 10 kW turbine vs.
- 1,800 kW turbine

	Richmond Wind Ranch	Wild Horse Wind Farm
Turbine	Bergey Excel	Vestas V80
Blade Length	11 feet	129 feet
Tower Height	100 feet	221 feet
Max Watt Output	10 KW	1,800 KW per turbine
Estimated Average Wind Speed	12 MPH	15 MPH
Estimated Annual KWhr	17 MWhrs	5,055 MWhrs per turbine
Households Powered[1]	1.3	421 per turbine

1. Based on an average annual household power consumption of 12 MWhrs.

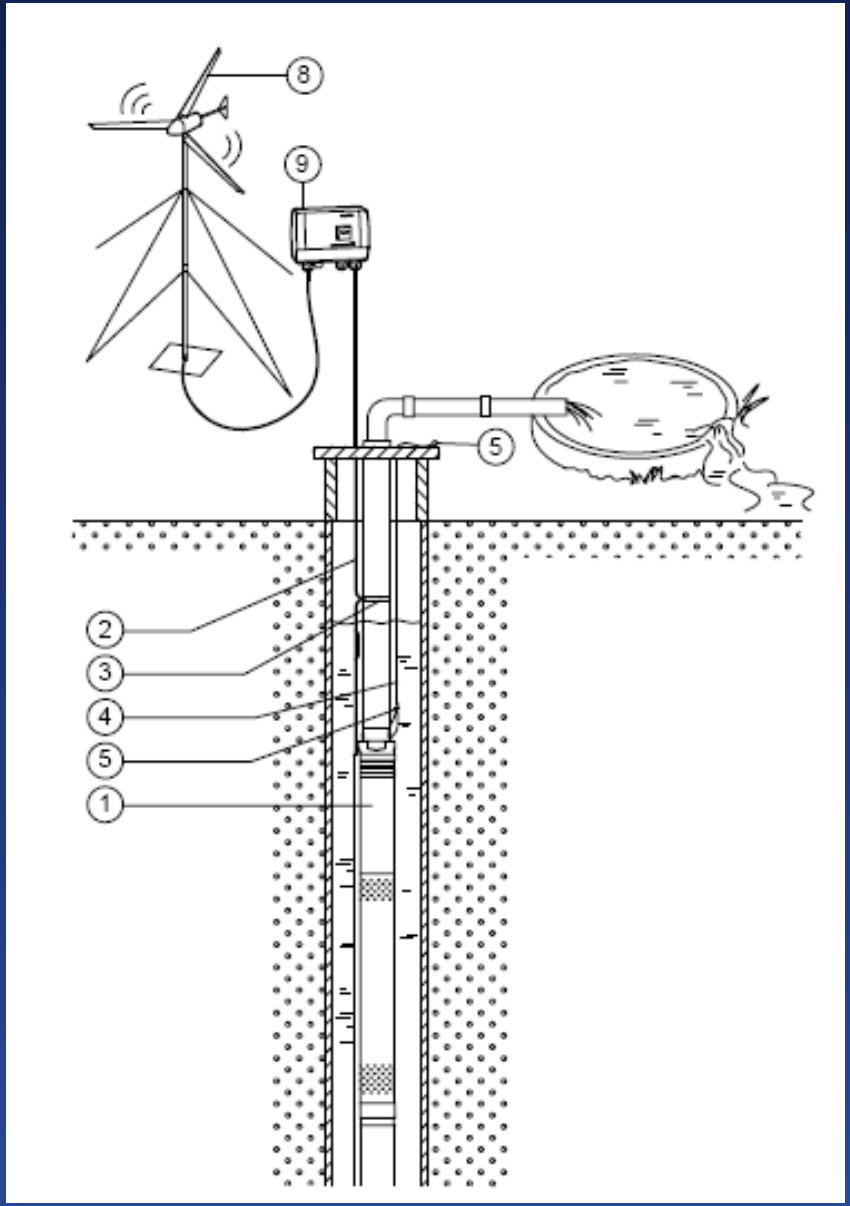
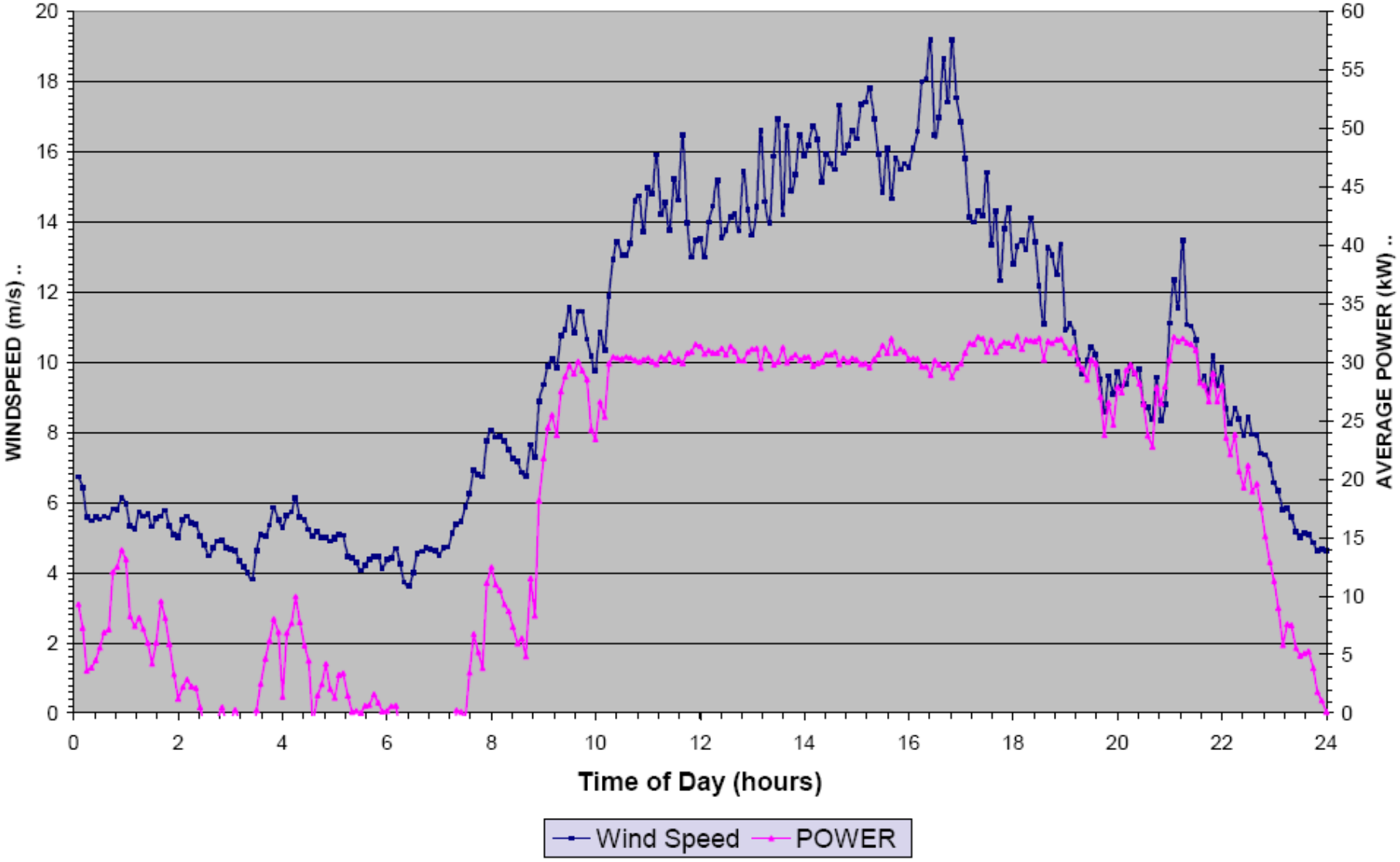

8
9
5
2
3
4
5
1

Figure 1. The 1000 W wind turbine installed on a 19.2 m tilt-up guyed pipe tower (Bushland, TX).


WINDSPEED (m/s) ..
AVERAGE POWER (kW) ..
Time of Day (hours)
0
2
4
6
8
10
12
14
16
18
20
22
24
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30
35
40
45
50
55
60
Wind Speed
POWER

One example: 900 Watt Wind Turbine

- From Oct. 2005 to Mar. 2008
- Lorentz helical pump was powered by wind energy at the USDA-ARS Conservation and Production Research Laboratory (CPRL) near Bushland, TX.

One example: 900 Watt Wind Turbine

- The wind turbine used was a Southwest Windpower (Flagstaff, AZ) Whisper 100 (2.1 m or 7 ft rotor diameter) which generated 3-phase variable voltage, variable frequency AC electricity.
- The wind powered version required an additional controller manufactured by Lorentz to rectify the electricity to DC before entering the primary controller.

Fig.4. 3-Way Switch and Controllers Used on Wind Powered Water Pumping System. (Bushland, TX).

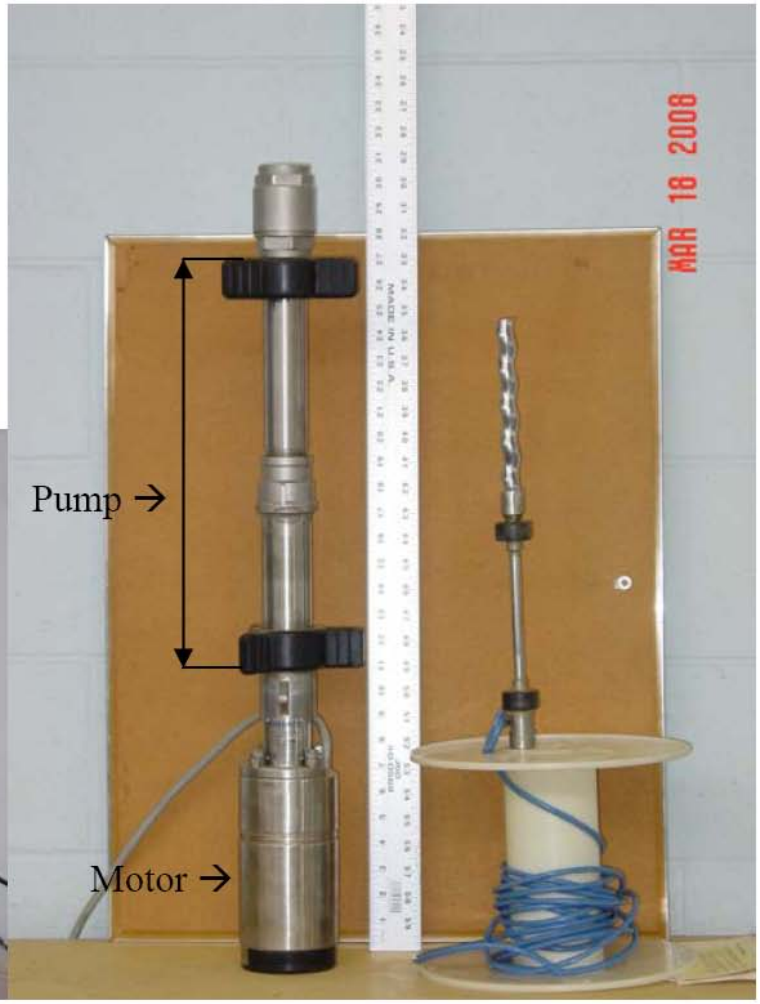


Fig. 5. Lorentz Helical Pump and Motor with Pump Shaft on Right (Bushland, TX).

One example: 900 Watt Wind Turbine

- For the Bushland, TX site, the wind powered helical pump system demonstrated the ability to pump enough water to meet the daily requirements of:
- 120 beef cattle at 50 m (164 ft) pumping depth
- 60 beef cattle at a 100 m (328 ft) pumping depth.

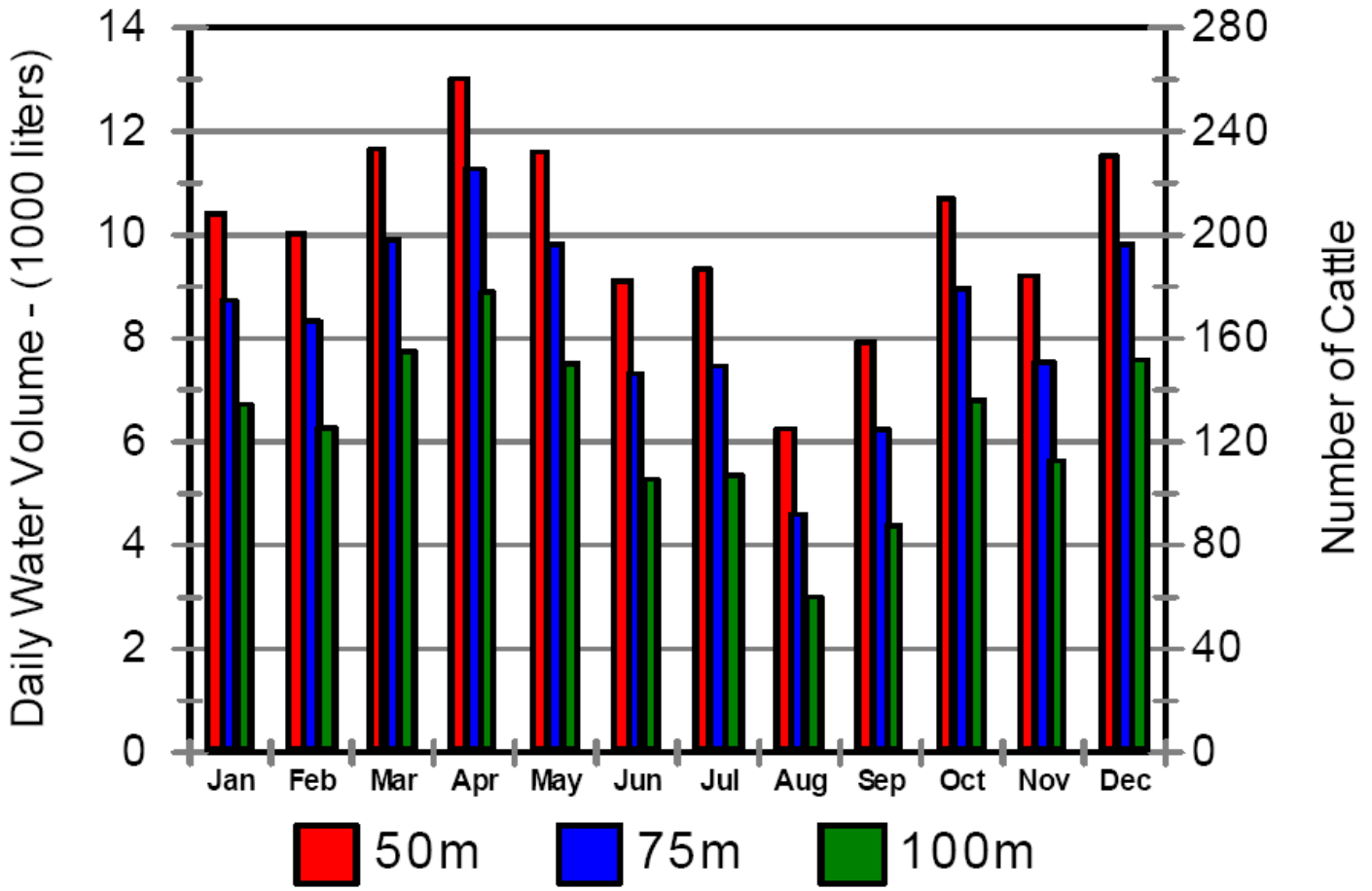
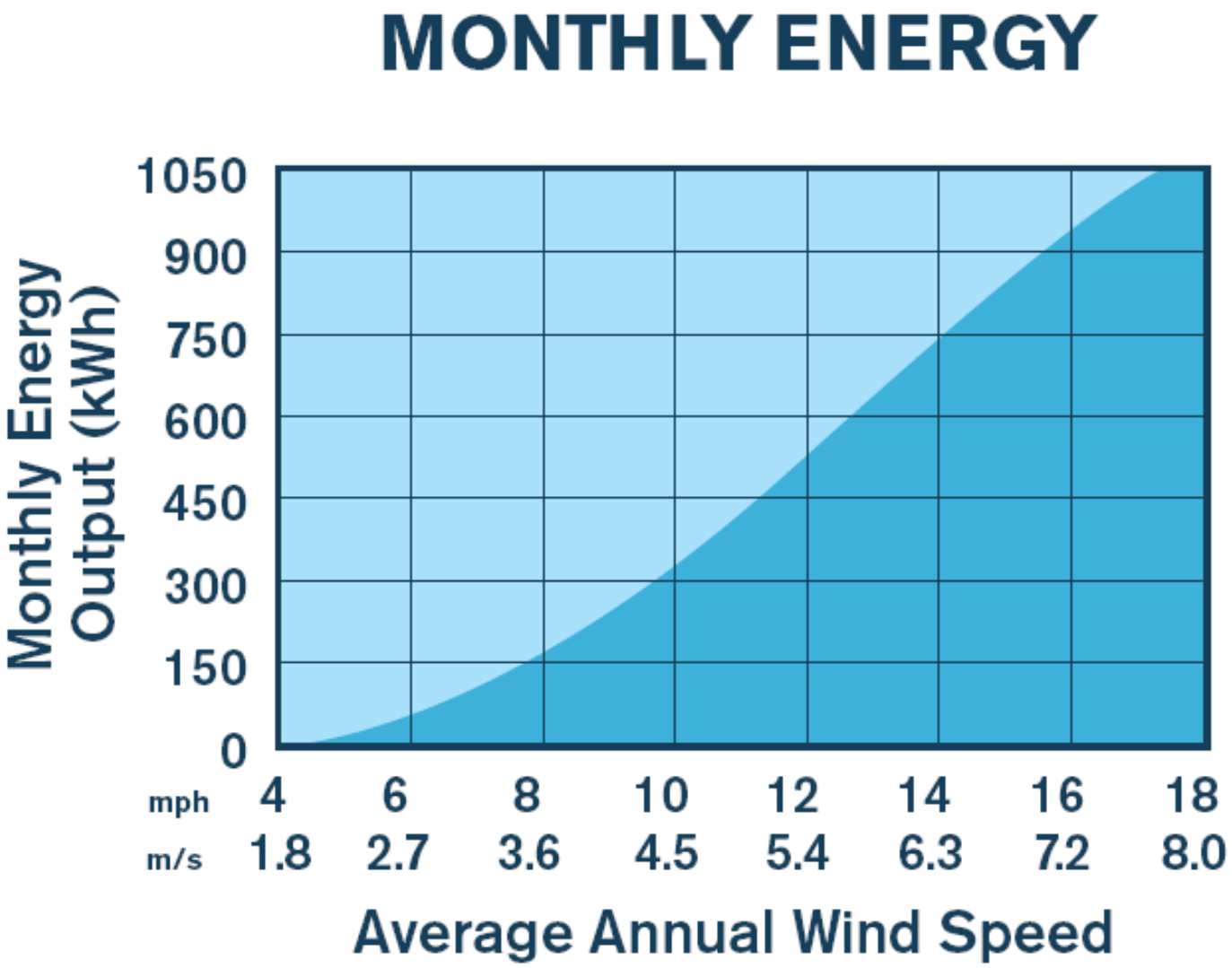


Fig. 12. Daily Water Volume of Lorentz HR07-2 Helical Pump Powered by SWWP Whisper 100.

3 kW Turbine


MONTHLY ENERGY
Monthly Energy Output (kWh)
1050
900
750
600
450
300
150
0
mph 4 6 8 10 12 14 16 18
m/s 1.8 2.7 3.6 4.5 5.4 6.3 7.2 8.0
Average Annual Wind Speed

Payment Schedule: Renewable Energy Production (716) Wind Turbine < 50 kW

$1,875/kW

Typical Implementation Scenario

- Wind turbine, < 50kW capacity, consisting of blades, rotor, generator, over-speed control mechanism, tower, and electrical control system
- A facility for producing energy from renewable resources

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Summary

- In general, mechanical windmills and solar pumps are best for small quantities of water and low pumping heads.
- Wind-electric systems, such as 1.5 and 10 kW units, are better for large-scale livestock watering applications, small plot irrigation, and village water supply.

Questions?