Small Wind – From the Box

Converting Wind Energy to Electricity

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Workshop Objectives

- **Introduction to Small Wind Turbine Technology**
  - Types of Turbines
  - Types of Towers
  - Basics of "How" Turbines Convert Energy to Power
- **Installation Options**
  - Overview of the checklist

Courtesy DOE/NREL: Credit Warren Gretz

Some Windmill History

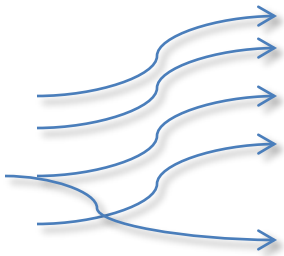
- Used in Persia in 200 B.C. & in the Roman Empire in 250 A.D.
- First practical vertical axle windmills, built in Afghanistan in the 7th century. Made of 6 to 12 sails covered in cloth, these windmills were used to grind corn and draw up water.
- Around WWI, Americans were producing 100,000 farm windmills per annum, most for water-pumping.
- The first windmill for U.S. electricity production was built in Cleveland, Ohio in 1888.
- By 1908 there were 72 wind-driven electric generators from 5 kW to 25 kW. The largest machines were on 24 m towers with four-bladed 23 m diameter rotors.

Courtesy of Jacobs Wind Electric Company, www.jacobswind.net

The Jacob's Brothers – Montana's Wind Pioneers

Wind is ENERGY

Wind is:



- Flow of air and/or gases that make up the Earth's atmosphere
- Driven by solar heating (sun) and Earth's rotation

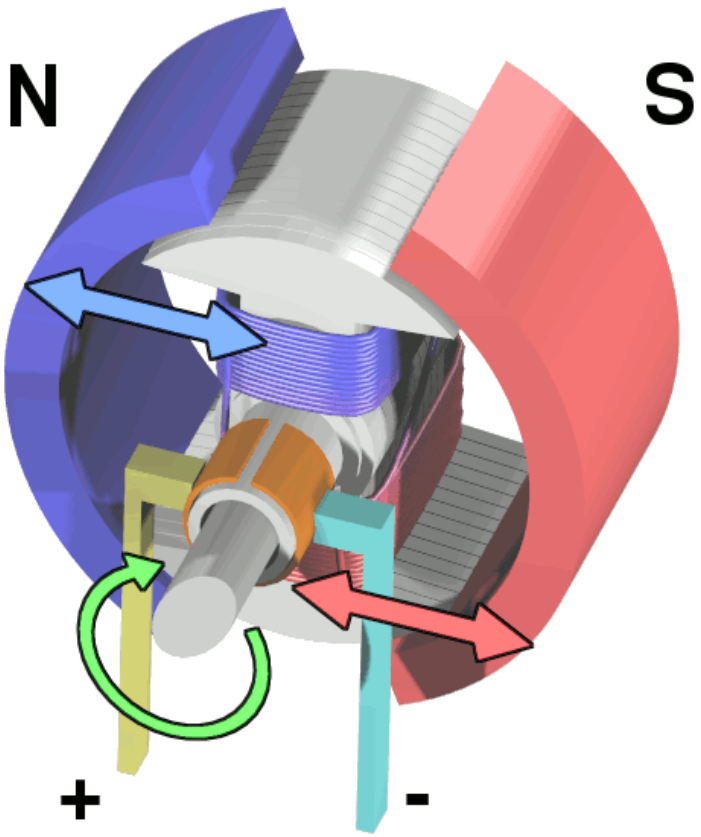
Because air contains mass (molecules of oxygen, nitrogen, argon, carbon dioxide, etc) and possesses velocity (movement) the wind has ENERGY!

$$P = \frac{1}{2}\rho v^3 \prod r^2$$

Power=(1/2) X (AIR DENSITY) X (VELOCITY)3 X (SWEPT AREA OF ROTOR)

Source: MSU Wind Application Center

Electrical Power Generation



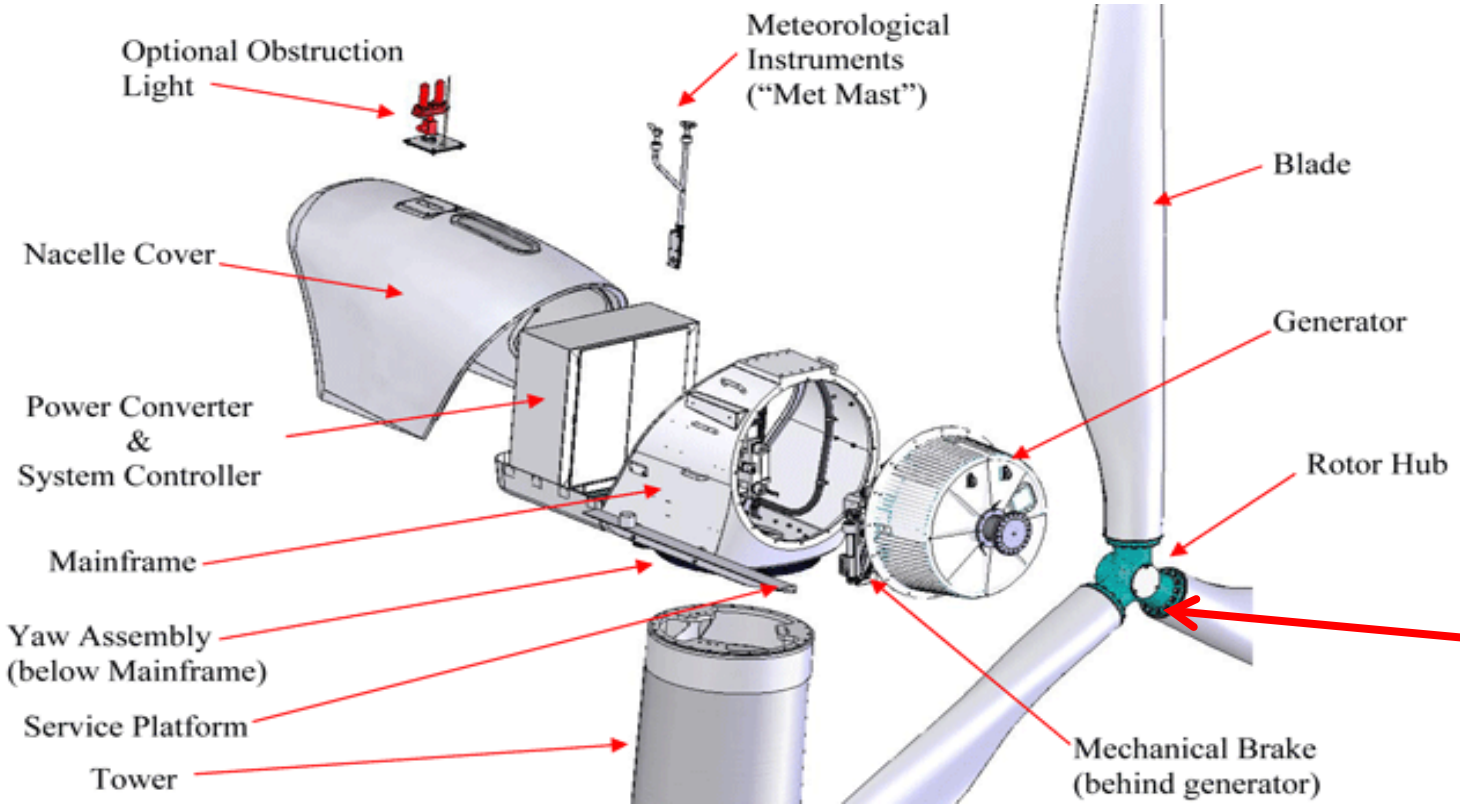
Courtesy of Wikimedia Commons

Most power used in the world is generated by converting rotational torque into electricity by using copper and magnets.

When the copper windings pass through the magnetic fields created by the magnets, electrical current is generated and sent to the battery

This concept is the basis for most electrical generators, including modern wind turbines.

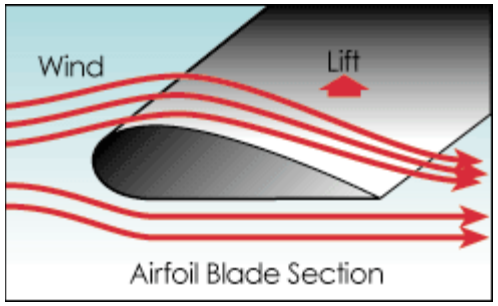
TURNING WIND ENERGY INTO ELECTRICITY



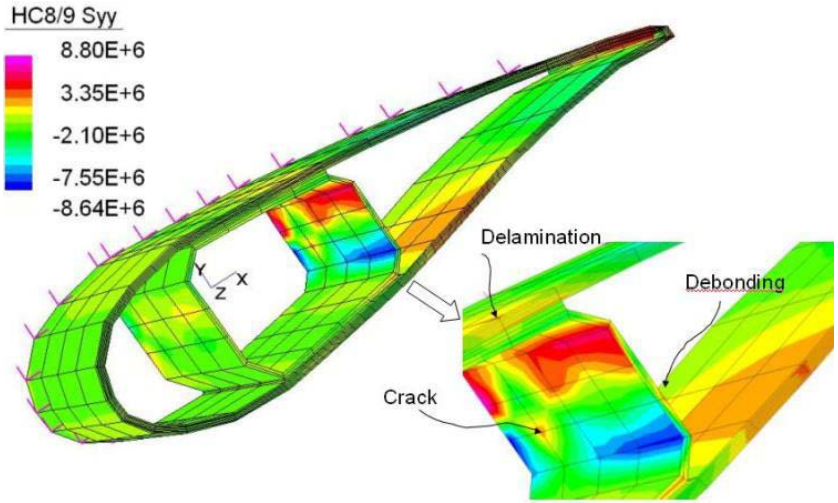
This is the "hub" or "hub height"

Turbine Blades → **Shaft and/or Gear Box** → **Generator** → **Wires & Distribution System** → **Electrical User**

Airfoil Shape



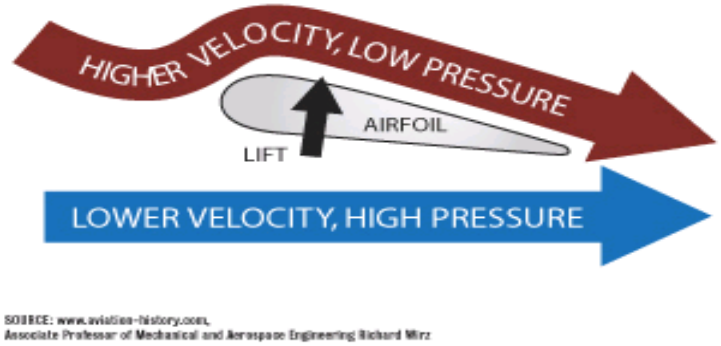
Just like the wings of an airplane, wind turbine blades use the airfoil shape to create lift and maximize efficiency.



Source: MSU Wind Application Center

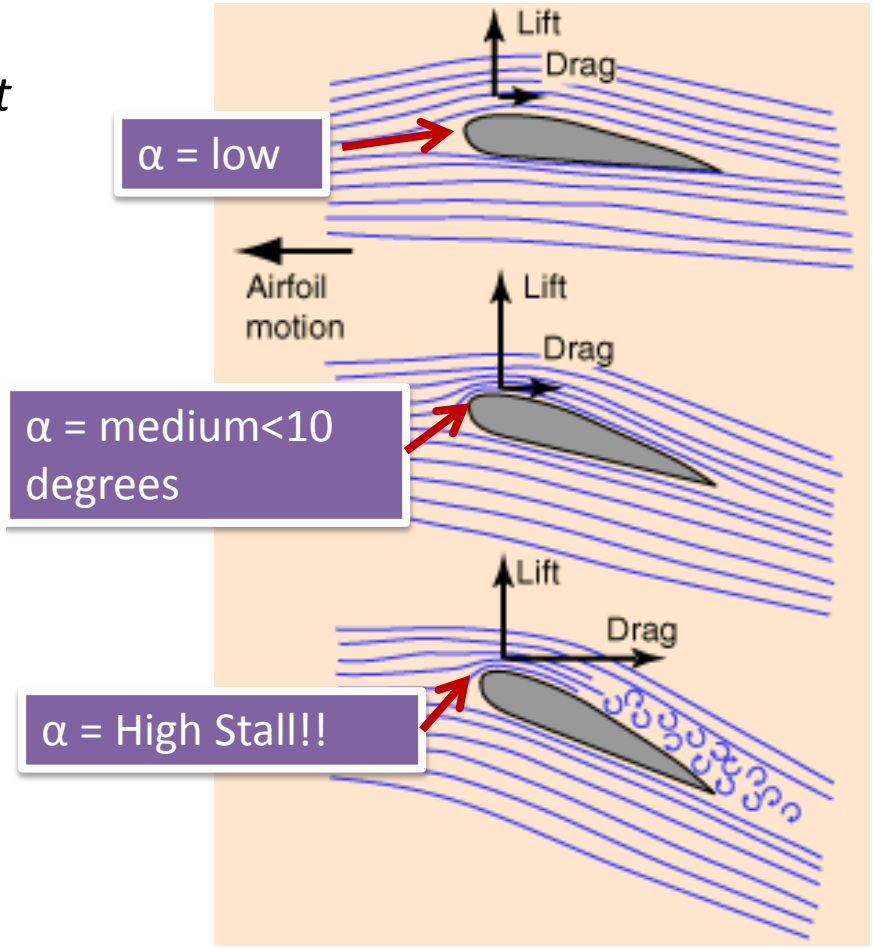
Lift & Drag Forces

- The *Lift Force is perpendicular to the direction of motion. We want to make this force <u>BIG</u>.*



SOURCE: www.aviation-history.com,
Associate Professor of Mechanical and Aerospace Engineering Richard Mirz

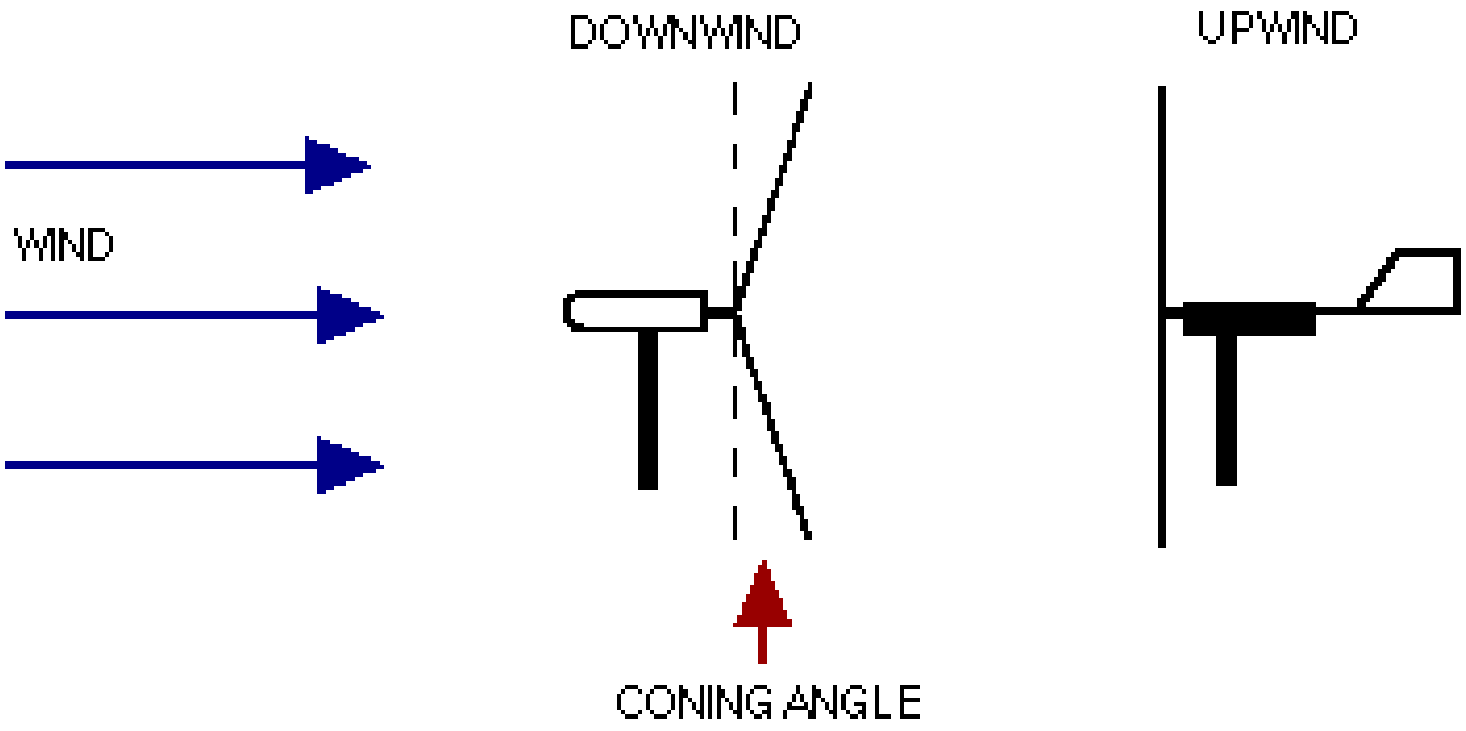
- The *Drag Force is parallel to the direction of motion. We want to make this force <u>small</u>.*



α = angle of attack

Source: MSU Wind Application Center

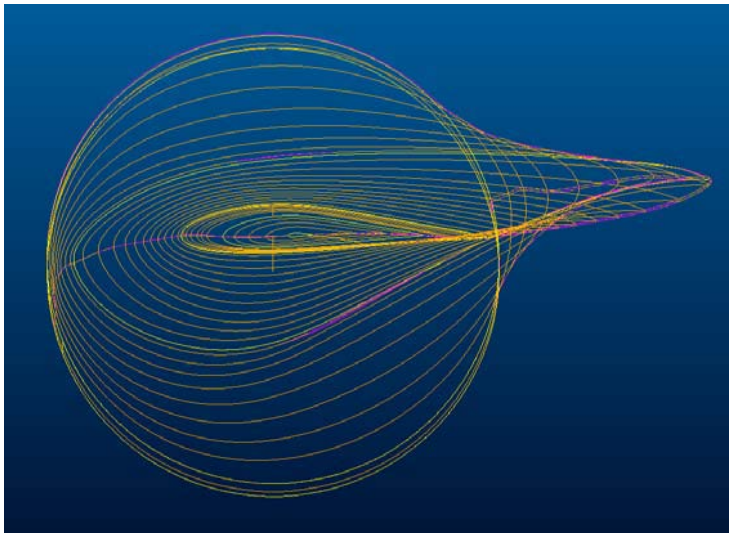
Downwind & Upwind



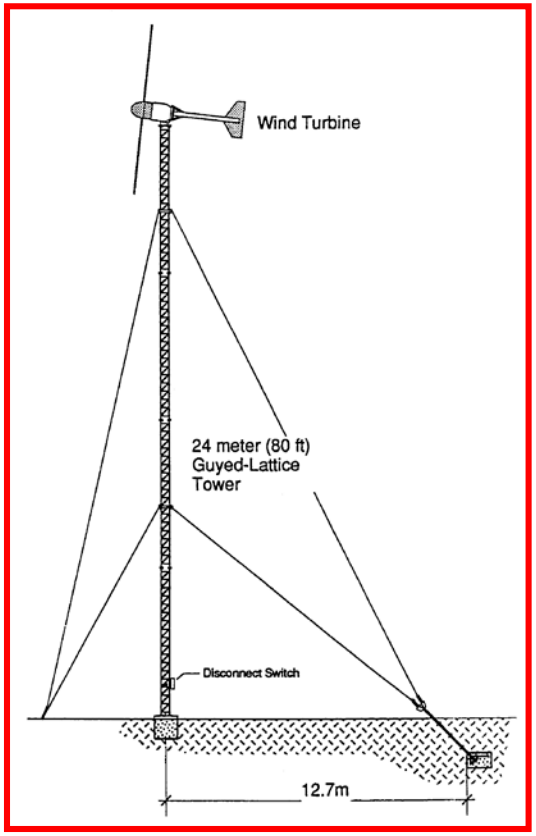
Courtesy: Alternative Energy Institute

Twist and Taper

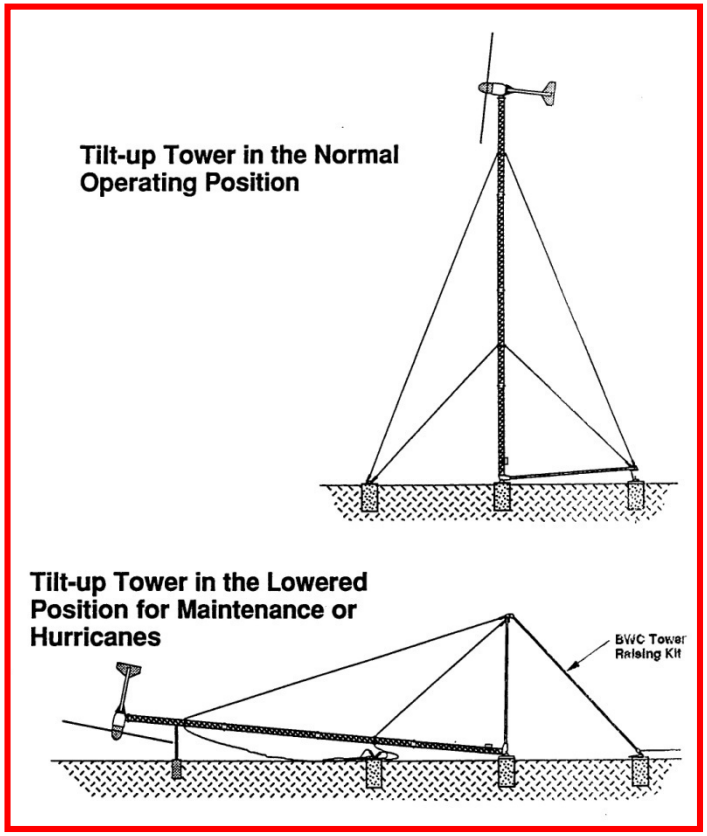
- Speed through the air of a point on the blade changes with distance from hub
- Therefore, tip speed ratio varies as well
- To optimize angle of attack all along blade, it must twist from root to tip



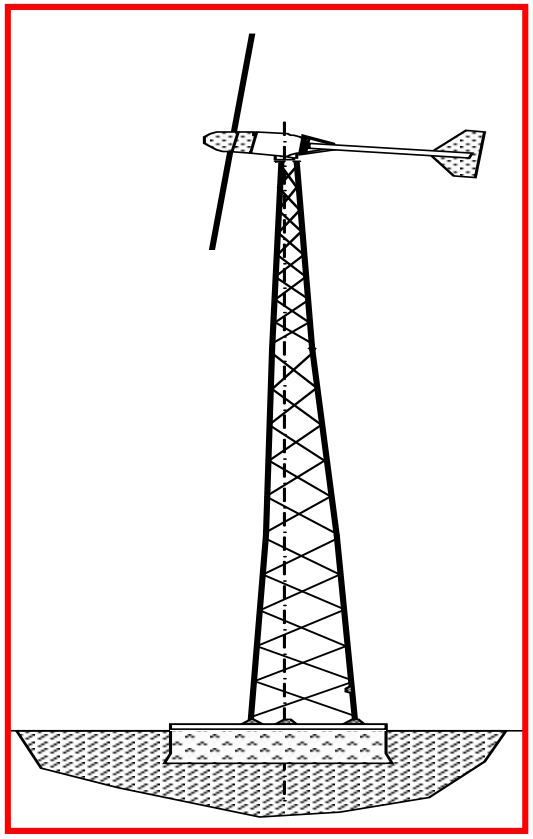
Small Wind Turbine Towers



Guyed-Latticed Tower



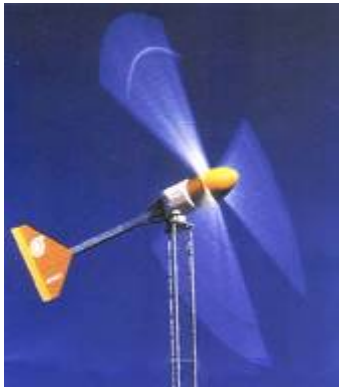
Tilt-up Tower



Latticed Tower

Horizontal Axis Wind Turbines

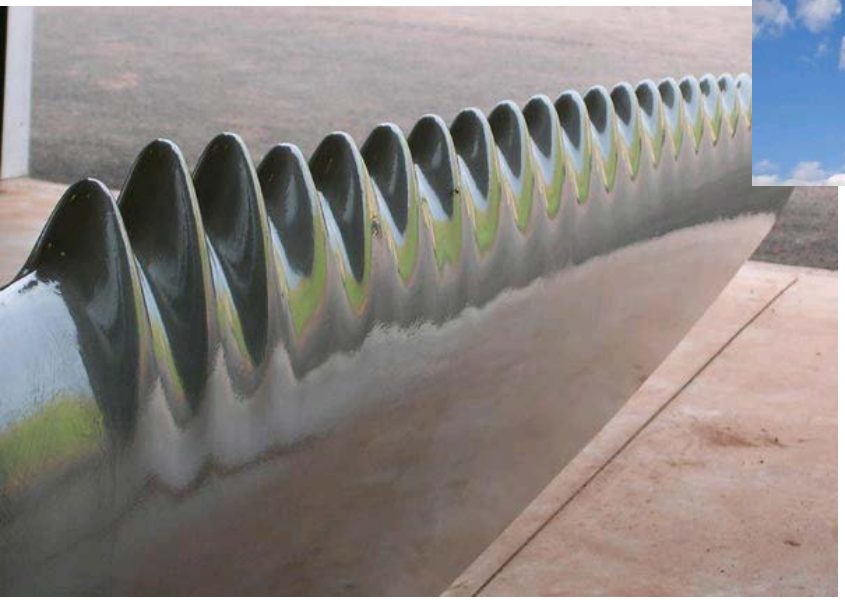
- Rotors are usually Up-wind of tower
- Some machines have down-wind rotors, but only commercially available ones are small turbines



Source: KidWind

HAWT Designs

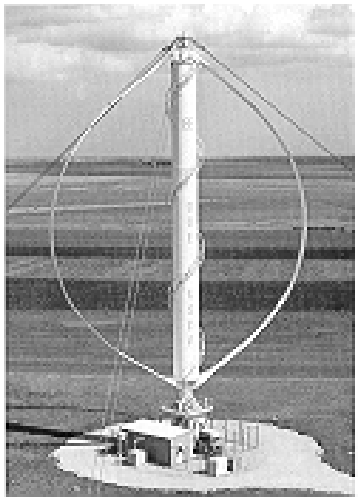
WhalePower
http://www.whalepower.com/drupal/?q=node/3



Airbreeze
http://airbreeze.com/

Skystream 3.7

Vertical Axis Turbines



Proponents of VAWTs Argue

- Omnidirectional
  - Accepts wind from any angle
- Components can be mounted at ground level
  - Ease of service
  - Lighter weight towers
- Can theoretically use less materials to capture the same amount of wind

Disadvantages

- Rotors generally near ground where wind poorer
- Centrifugal force stresses blades
- Poor self-starting capabilities
- Requires support at top of turbine rotor
- Requires entire rotor to be removed to replace bearings
- Overall poor performance and reliability
- Have never been commercially successful

Source: KidWind

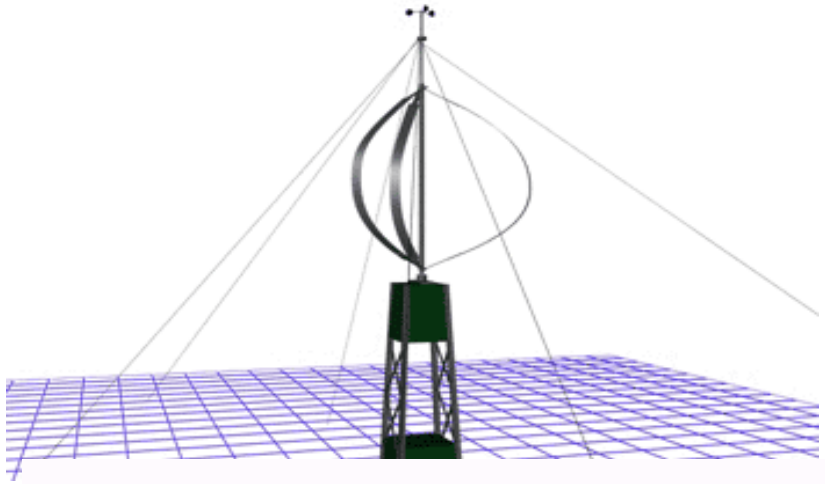
Lift vs Drag VAWTs

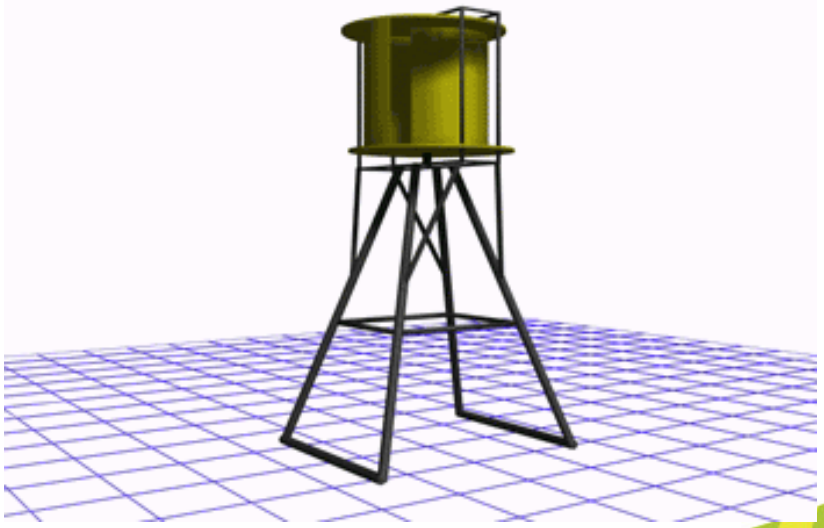
Lift Device "*Darrieus*"

- Low solidity, aerofoil blades
- More efficient than drag device

Drag Device "*Savonius*"

- High solidity, cup shapes are pushed by the wind
- At best can capture only 15% of wind energy





Source: KidWind

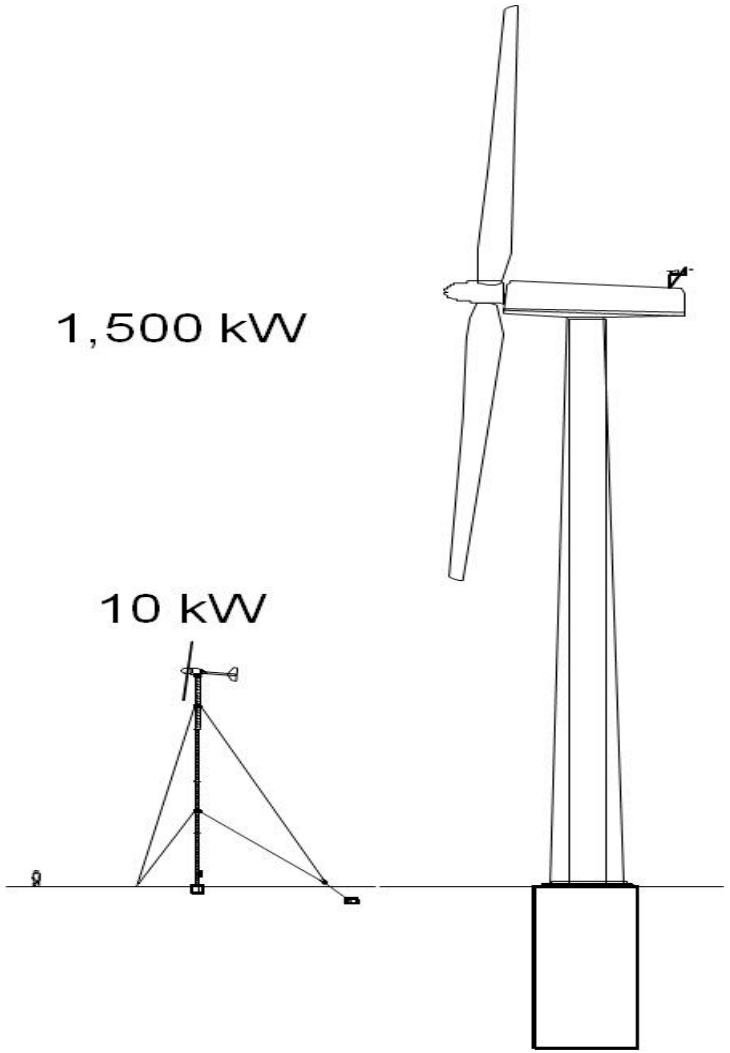
Windspire

Quietrevolution 5

Savonius

Small Wind Defined

- System size usually defined by the maximum system size allowed to connect to regulated utilities
  - In WY, systems under 25 kilowatts
- Cooperatives may have different size limits of turbines
- Most grid-connected home applications have system sizes of 3-10 kilowatts
- Utility-scale turbines are 1.5 to 2.5 MEGAwatts



Off-Grid Water Pumping

Courtesy NREL/DOE

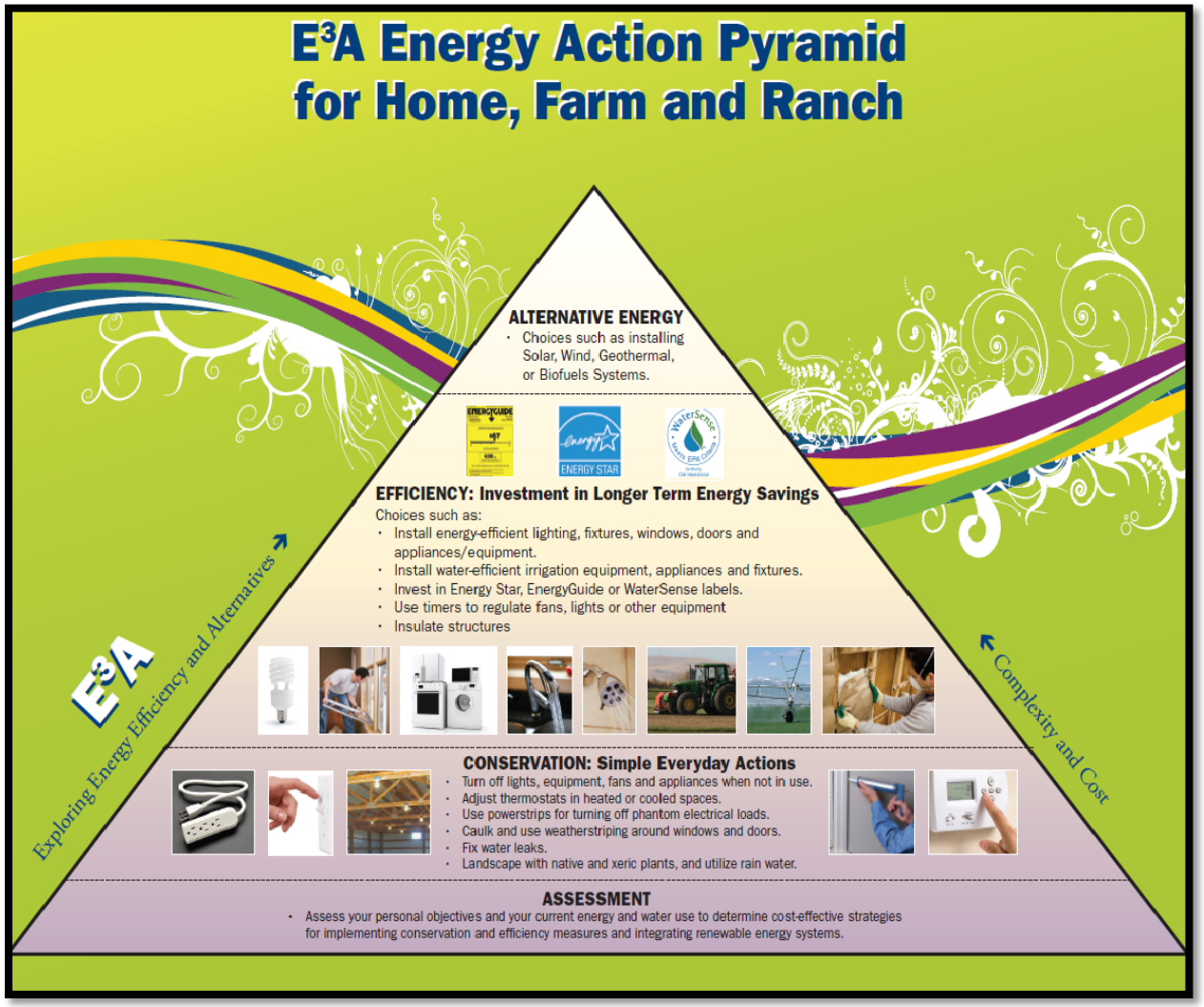
- Site is Candidate for Small Wind if:
  - Electricity is required more than ¼ mile from electrical line
  - Site has good wind resource
  - Water can be stored (rather than batteries, these systems store water to provide for times when wind is not blowing)

Question #1:
Am I willing to learn about small wind?

- Factors Complicating Small Wind
  - Wind is a variable resource
    - Nothing holds still!
  - Lack of industry standardization
    - Buyer-beware market
    - Choices
      - Educate yourself
      - Hire someone to educate you
      - Accept risk of performance that does not match expectations

Question #2

Have you considered energy conservation and efficiency?



Efficiency will (almost) always:

- Have a better return on investment
- Reduce the system size needed
- Improve the return on investment for your renewable system

ROUGH Estimate of Turbine Size

Calculate Your Load

- Total Kilowatts/8760 Hours Per Year
- Divide by 0.1 to 0.2

- Average WY 10,644/ 8760 = 1.22
- 1.22/.1 = 12.1
- 1.22/.2 = 6.1

This is a very rough way of finding the largest size turbine for your home.

Courtesy of Jacobs Wind Electric Company, www.jacobswind.net

Using a Buying Guide to Determine Size

Turbine	Excel-S
Manufacturer	Bergey Windpower
Specs	
Swept Area (sq. ft)	415.0
Warranty (years)	10
SWCC Certificaiton Application	Yes
Predicted Annual Energy Output (kWh)	
8 mph	5,000
9 mph	7,100
10 mph	9,600
11 mph	12,700
12 mph	15,900
13 mph	19,500
14 mph	23,300
This information is provided for reference only and does not indicate an endorsement of either Home Power Magazine nor Bergy Windpower.	
Source: Home Power Magazine Jun-Jul 2011 Edition	

- A more accurate method is to use a buying guide.
- Requires good assessment of wind speed

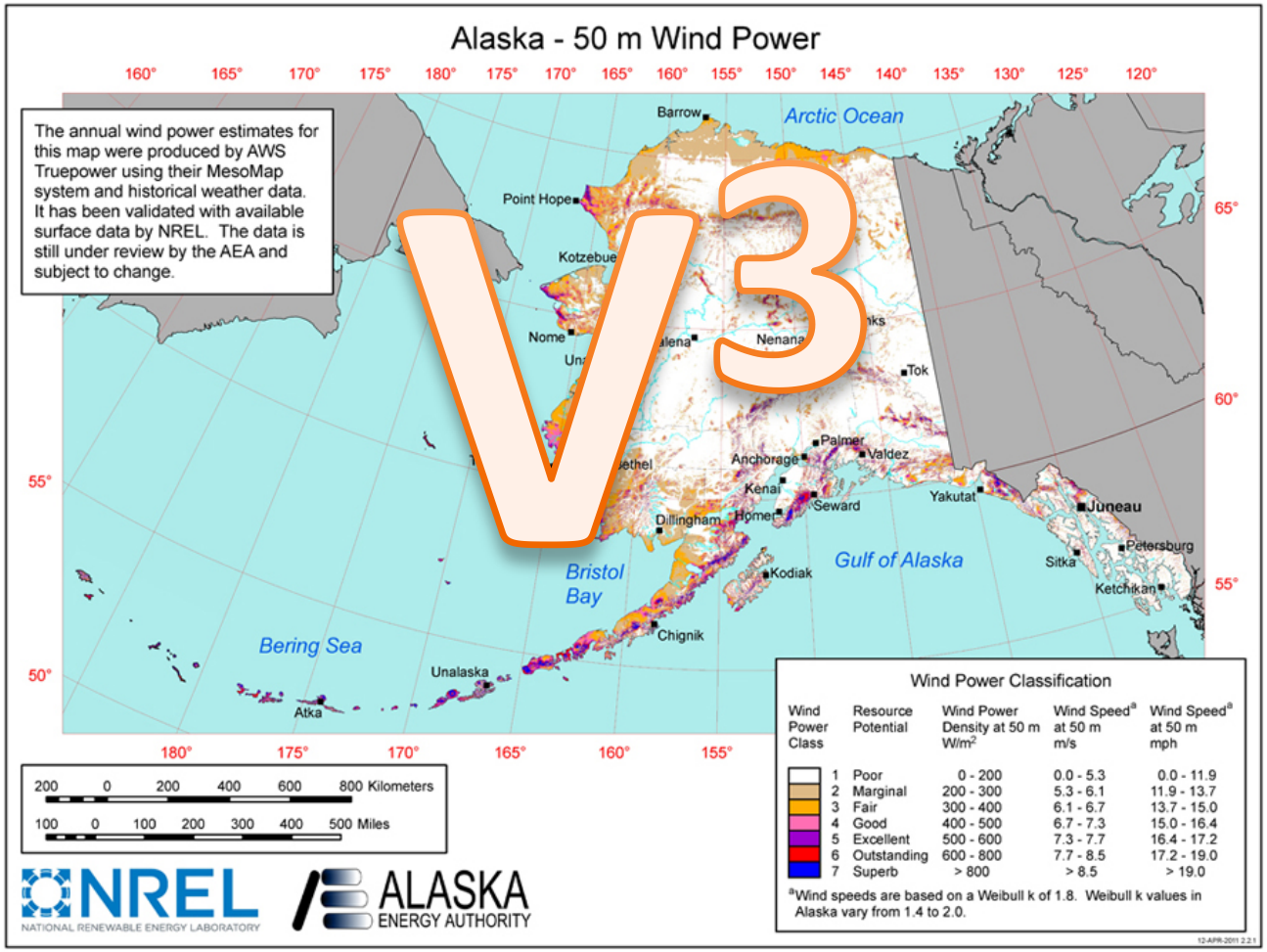
Question #3

Do you have a good wind resource?

Wind Varies by:

- Site
- Topography
- Weather
- Time of Day
- Time of Year (Seasonality)
- Year (Variances from year-to-year)

The AK Resource



Realities of Wind Assessment with Free Data

- **Free mapping tools often use publically available data and wind "modeling"**
  - Accuracy varies
  - Difficult to know which data was used
  - Difficult to know hub height of collection
  - Seasonality calculations can be off for mountainous regions
- **Provide a "guesstimate"**
- **Consultants or dealers <u>should</u> have access to better data**

Question #4

Are you comfortable with some uncertainty?

In small wind, we use best "guesses" for:

- Actual wind speed and characteristics at your site
- Actual turbine production
  - The next slides will discuss some of the challenges associated with determining energy output.

Annual Energy Output

- Best measure and most easily compared
- Determining calculations can be difficult for a consumer
  - Highly dependent on accurately pegging the average wind speed!
  - Many AEO provided by manufacturers in a range of average annual wind speeds of 8 to 14 mph
  - Some experts suggests that you multiply the AEO provided by 75% to account for overstatement of actual (NREL)

Question 5

Are you willing to invest in a tall tower?

- Hub height of turbine needs to be at least 30 feet above tallest obstacle within 500 feet.
  - BTW – Trees grow!
- Minimum tower height is 30 feet (~10 meters)
- Tower may cost 2-5 times the amount of the turbine
- Why a tall tower???
  - Must get above turbulent air
  - Wind shear = power production
  - “Putting a wind turbine on a short tower is like putting a solar panel in the shade.”

Question 6

Can you finance a small wind system?

- For grid-connected systems
  - Rough cost estimates of $4K-$8K per kilowatt
  - Assume average home at 10,116 kWh (off-setting almost all consumption) at $5K/kW = $50,000
- Off-grid systems are usually smaller, so total wind turbine costs are lower, but there are other system components and batteries that add to the total cost.

Turbine Cost Example

Bergey Excel-S (10kW)	
Turbine & Inverter	$31,700
Tower (100 ft Guyed)	$14,145
Wiring Kit	$1,615
Shipping	$1,500
Installation	$8,000
Other	$250
	$57,210

Question 7
Do you have available space?

- Minimum requirement is ½ acre around tower site
  - NREL recommends minimum of 2-3 acres for turbines of 10 kW or more
  - Many areas increase size requirements in ordinances from 1-5 acres (especially for larger systems)
- Perhaps a better question:
  - Do you have available space at the site that has a good wind resource??
- Think ahead – are new buildings being planned near your site? Trees???

Question 8

Is wind allowed in your area?

- Check zoning and ordinances (homeowners association covenants)
  - Some restrictions on height, noise, etc. may not be written for wind, but will apply
- Will utility allow net metering?
  - If so check system size and true up period
- What about your neighbors?

Question 9

Are you willing to maintain the system?

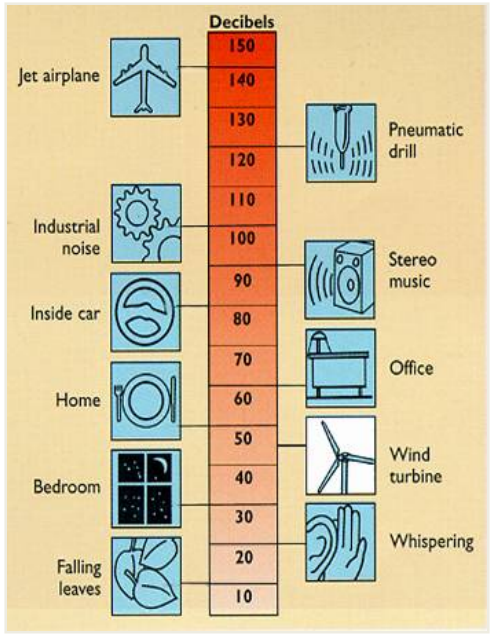
- Are you willing to climb the tower?
- Costs
  - Some estimates of $0.01 to $0.02 per kilowatt hour
  - More realistic based on replacement parts – 1-2% of installed cost per annum
- At least annual maintenance
  - Bearings
  - Blades
  - Tower foundation/guy wires
  - Any and all moving parts!

Question 10

Are you willing to live with wind?

- Ice Shedding
- Lightening
- Flicker
- Homeowners Insurance
- Property Taxes

Impacts of Wind Power



Noise

- Modern turbines are relatively quiet
- Rule of thumb – stay about 3x hub-height away from houses

Birds and Bats

Source: KidWind

Question Review

- If you answered “yes” to most of these questions, you may be a good candidate for small wind!
- If you answered “no” to:
  - Questions 3, 6, or 7, you are probably not a good candidate for small wind.
  - Questions 1, 2, 4, 5, 8, 9 or 10, you may wish to do more homework and research before you invest
- If you answered “uncertain” to most of these questions, you need to do more research before you can decide if wind is right for you.

Converting Wind to Electricity

Discussed:

- How electrical current is generated
- Types of turbines and blades
- Types of towers
- Overview of checklist

Check out the E3A Small Wind Series for more information on using small wind systems!

Courtesy of DOE/NREL: Credit Otto Van Geet