

# **Wind Power: A Sustainable Solution**

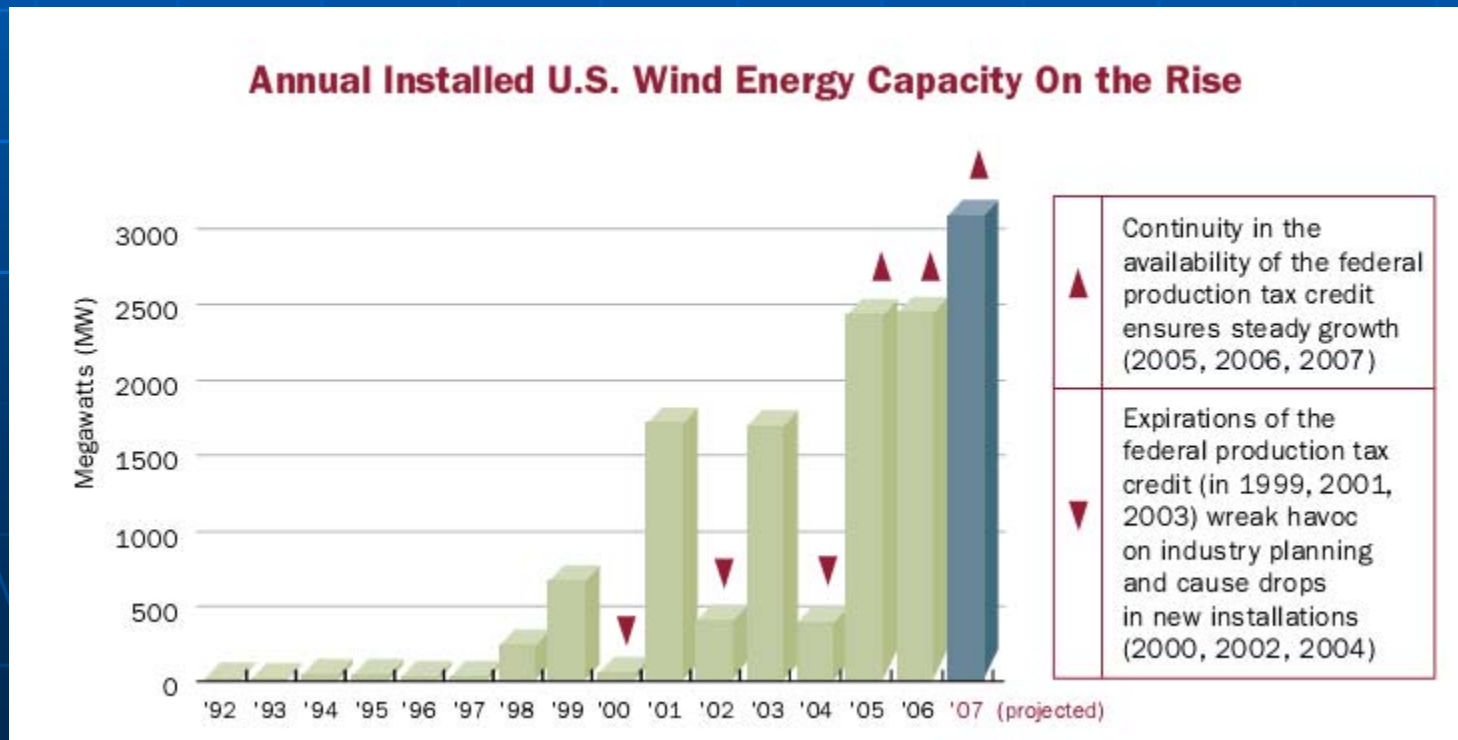
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# Wind Power: A Sustainable Solution

- **Statistics**
- **How does wind energy work?**
- **Advantages / Disadvantages of Wind Turbines**
- **Availability**
- **Cost**
- **Designs**
- **Public Opinion**
- **Current Projects**

# Wind Power: A Sustainable Solution

- 2007 : 45% growth
- 5,200 MW installed
- Generating 16 billion kWh (AWEA)



# How Does Wind Energy Work?

- Wind

- Produced via uneven heating of the earth

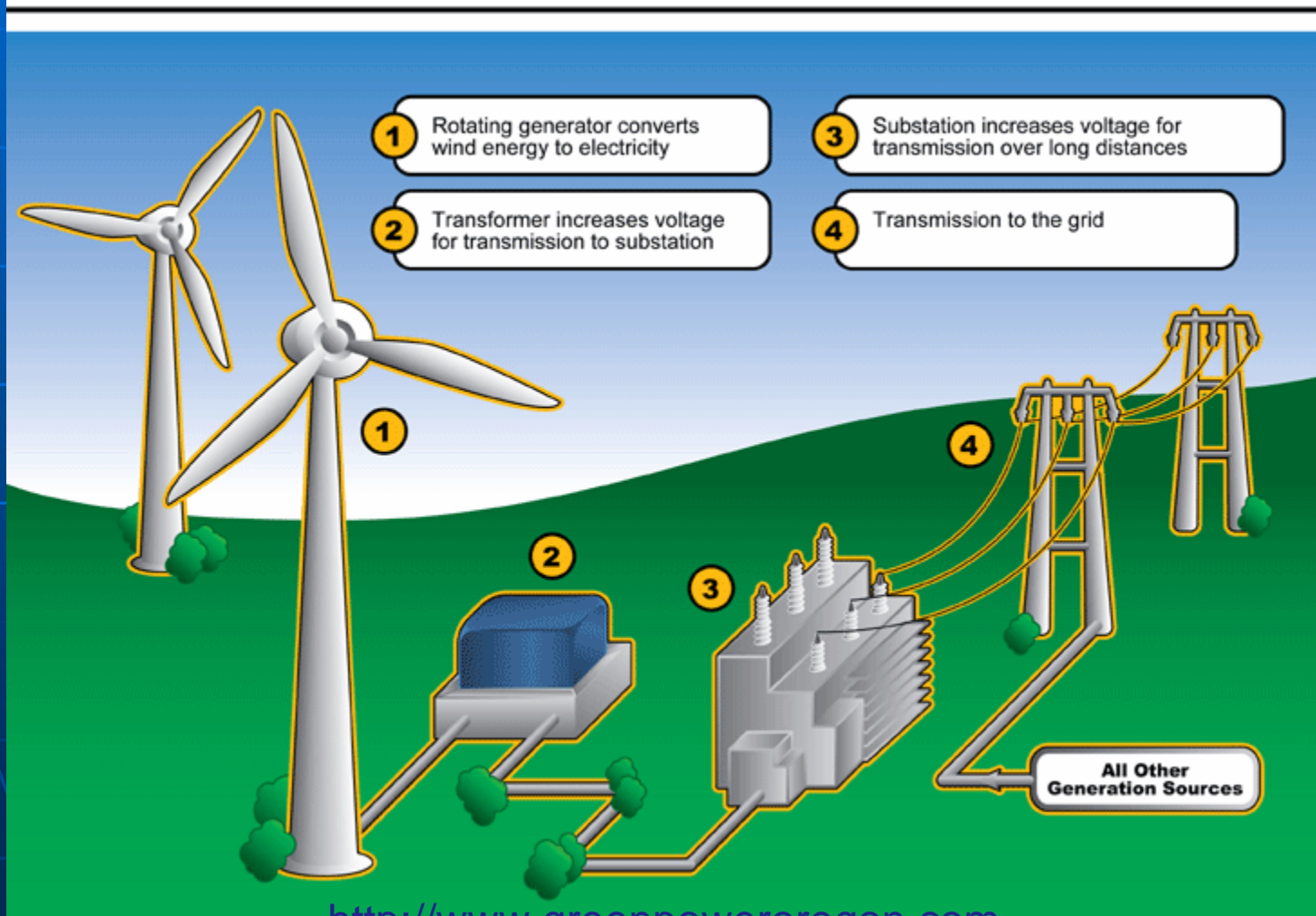
- Kinetic Energy → Mechanical / Electrical Energy

- Turbine
- Wind turns blade → spins shaft → generator

- [http://www1.eere.energy.gov/windandhydro/wind\\_animation.html](http://www1.eere.energy.gov/windandhydro/wind_animation.html)

# How Wind Turbines Work

## WIND



# Schematic of Wind Turbine



**Yaw drive:** ensures the turbine is producing the maximum amount of power by keeping rotor facing the wind (for horizontal axis turbines)

# Advantages of Wind Energy

- Renewable
- Emits no pollutants
- No foreign dependence
- Wind is free & plentiful
- Cost effective
- Take up less space than conventional power plants



# Disadvantages of Wind Power

- Wind variance
- Can be noisy (?)
- Ugly (?)
- Low capacity factor
- Wildlife (?)
  - Birds / bats





# Noise (?)

Sound Pressure Level, dB	Sound Pressure, Pa
120	20
110	10
100	2
90	1
80	0.2
70	0.05
60	0.02
50	0.01
40	0.002
30	0.001
20	0.0002
10	0.0001
0	0.00002

Sound Pressure Level, dB	Sound Pressure, Pa	Source
120	20	Pneumatic Chipper (at 5 ft)
110	10	Rock-n-Roll Band
100	2	Textile Loom
100	2	Power Lawn Mower (at operator's ear)
90	1	Newspaper Press
80	0.2	Milling Machine (at 4 ft)
80	0.2	Garbage Disposal (at 3 ft)
70	0.05	Vacuum Cleaner
60	0.02	Air Conditioning (Window Unit at 25 ft)
50	0.01	Passenger Car 50 mph (at 50 ft)
40	0.002	Quiet Room
30	0.001	Conversation (at 3 ft)
20	0.0002	
10	0.0001	
0	0.00002	

- Dependent upon ambient conditions
- New technology
  - Older = louder
- Higher speeds → less noise
  - Masked by sound of wind

# What About the BIRDS?!

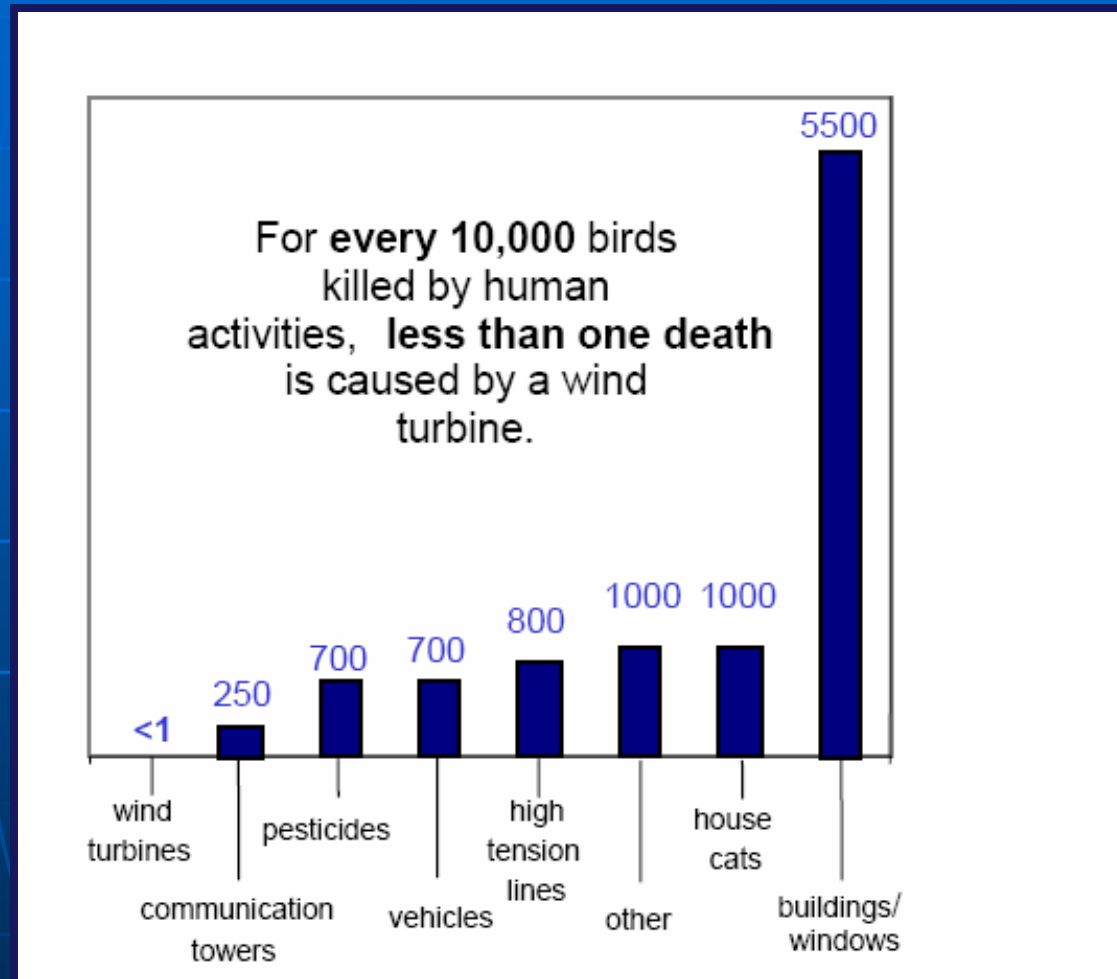


## FACTS:

- Bird kills per MW = 1-6 / yr (AWEA)
- US: 16,818 MW / yr
- ~59,000 Bird /yr killed by wind turbines
  - **.003% of bird kills**
- **Cats** : 1 billion bird deaths / yr

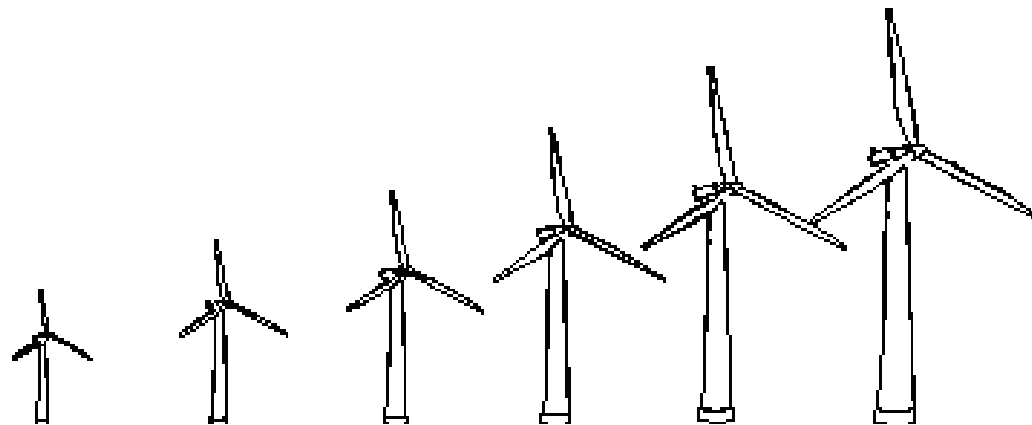


# Birds



Data source: Erickson et al., 2002, Summary of Anthropogenic Causes of Bird Mortality.

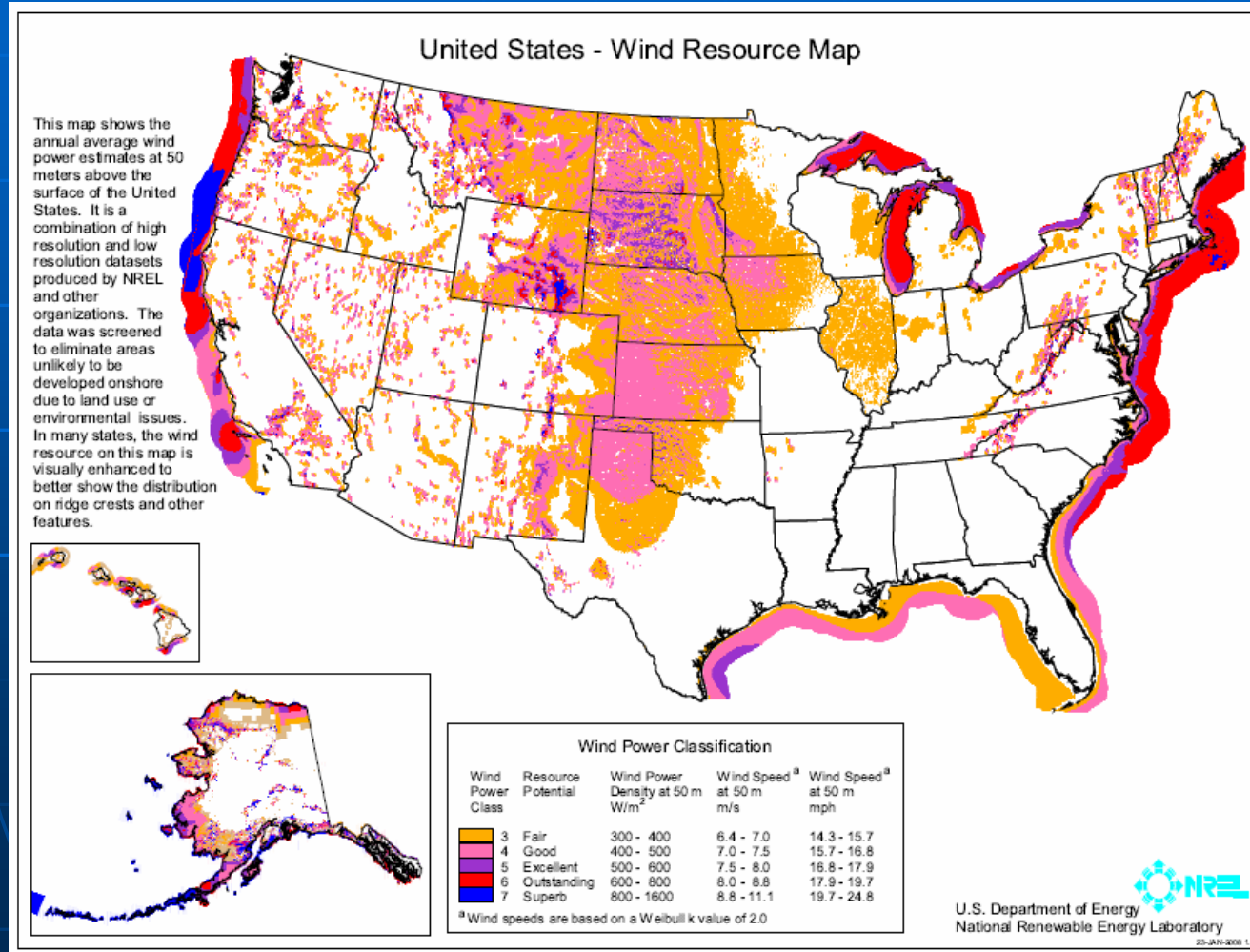
# Size vs. Output



	1981	1985	1990	1996	1999	2000
<b>Rotor (meters)</b>	10	17	27	40	50	71
<b>Rating (KW)</b>	25	100	225	550	750	1,650
<b>Annual MWh</b>	45	220	550	1,480	2,200	5,600

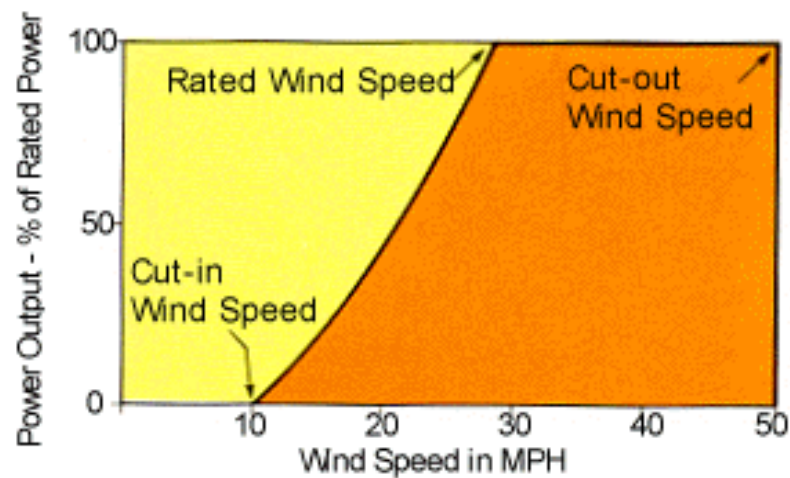
(Awea)

# Wind Resource Map



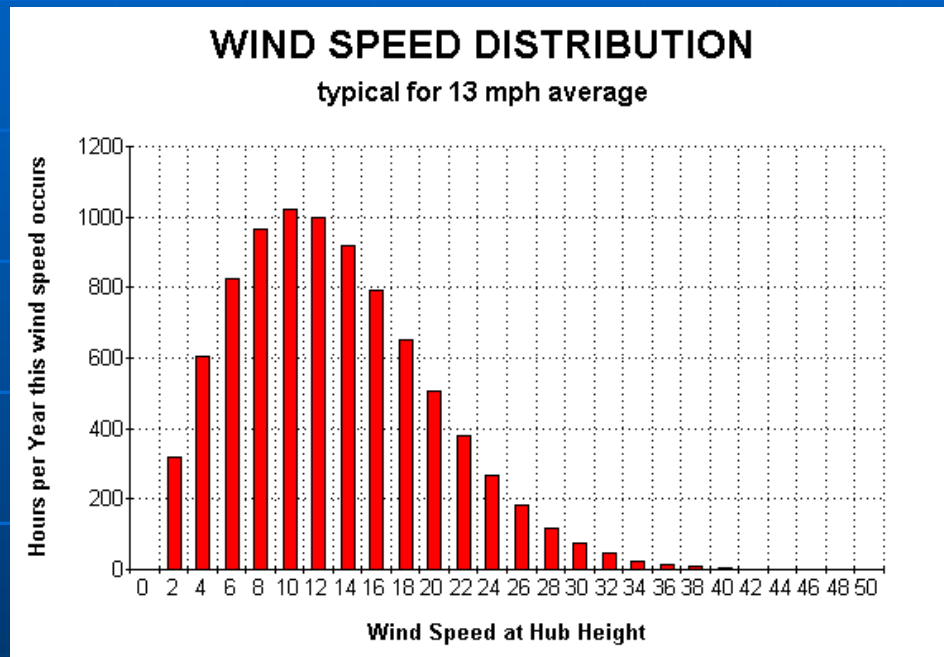
# Power Curve

- Power output  $f(\text{wind speed})$
- Power available in the wind increases eight times for every doubling of wind speed



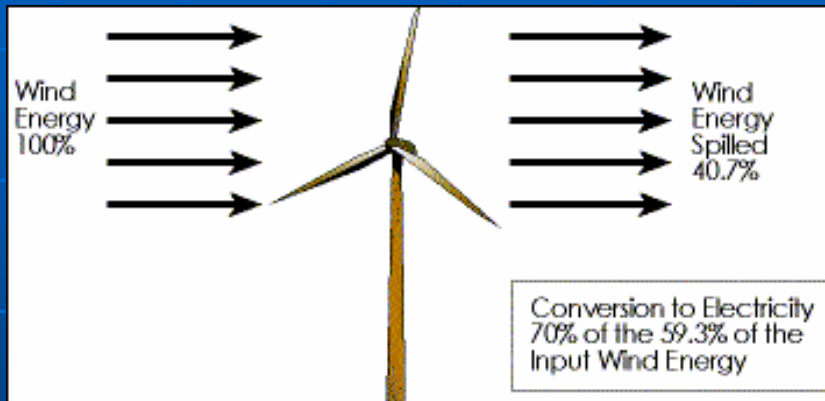
*Idealized Power Curve for a Wind Turbine*

# Wind Speed Distribution



- Weibull Distribution
- Low and moderate winds very common
- Strong gales - relatively rare

# Find Power Generated by Turbine

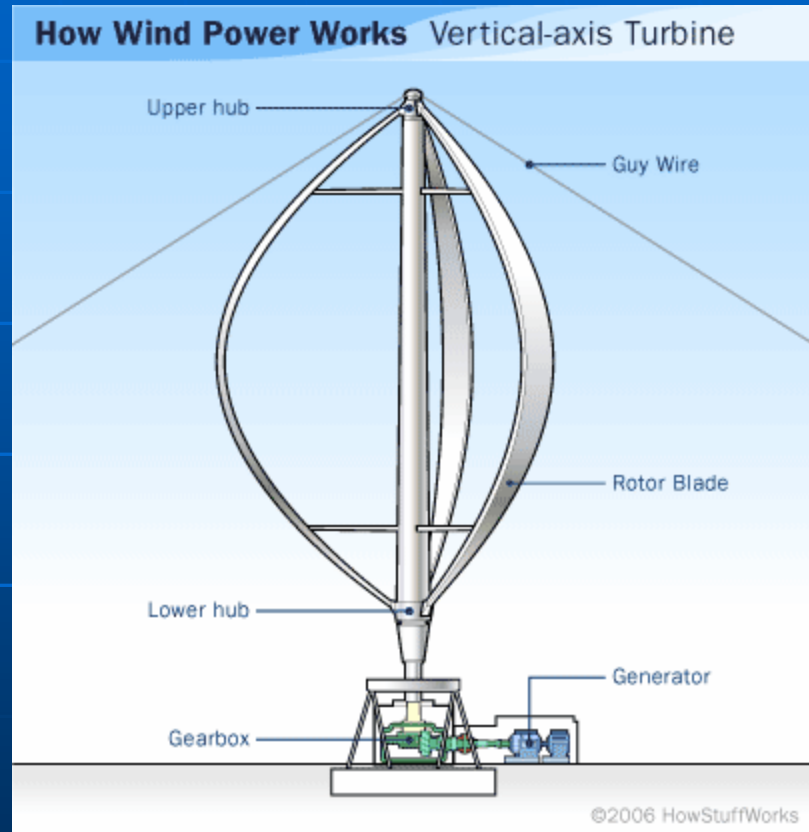


- Power generated:
  - Diameter of rotors
  - Efficiency
    - Betz Limit
    - Max power = .59
- Hours @ windspeed \* power generated at windspeed = Watt hrs
- Capacity factor

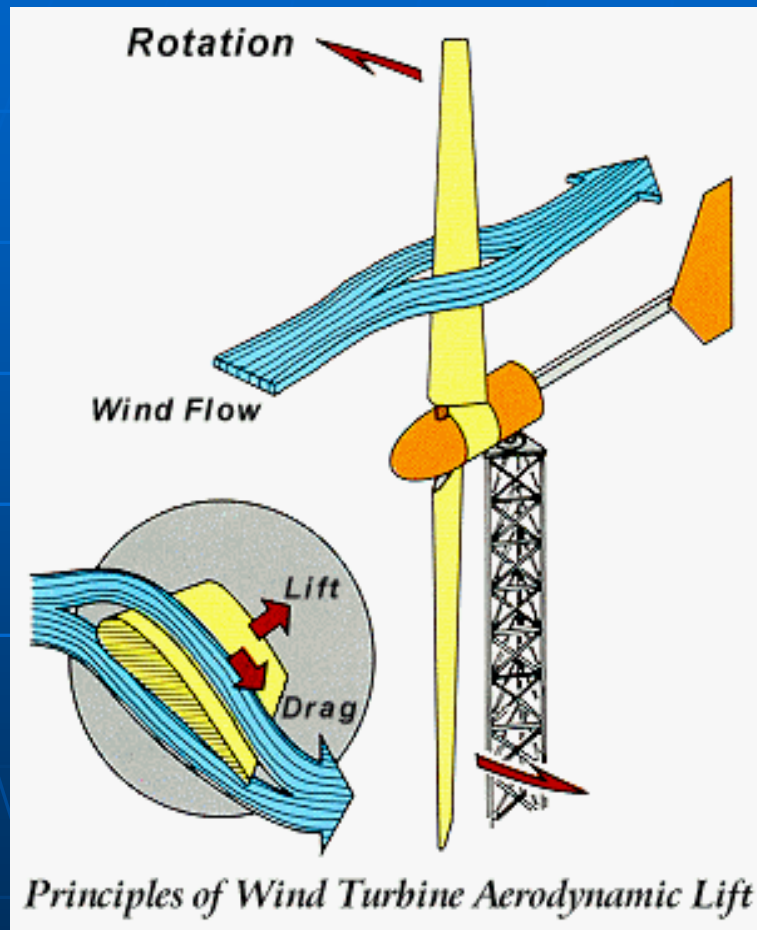


# Vertical Axis

- Darrieus
  - Always aligned with wind, unlike horizontal
  - Centrifugal stress
    - Cause wear
  - More expensive material
  - Rarely used



# Horizontal Axis



- Utilize lift
- Wind generates force perpendicular to direction it is blowing

# Public Opinions

- Pretty
- "What sound?"
- Good source of energy
- Ugly
- Noisy
- Better forms out there
- Hurt birds

# Cost

- The costs for a commercial scale wind turbine in 2007 ranged from \$1.2 million to \$2.6 million, per MW of nameplate capacity installed
- 10-kw grid connected residential scale
  - \$55,000 to install
- 12 cents / kWh with 10mph wind speed

# Atlantic City Wind Farm



**Five 1.5 MW Turbines**

[www.njwind.com](http://www.njwind.com)

# WindShare

- Ontario
- 10MW wind farm
- involves citizens as Co-op members
- Locally owned
- Revenue for the community



