



Benha University

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Undergraduate Course

Renewable Energy Systems

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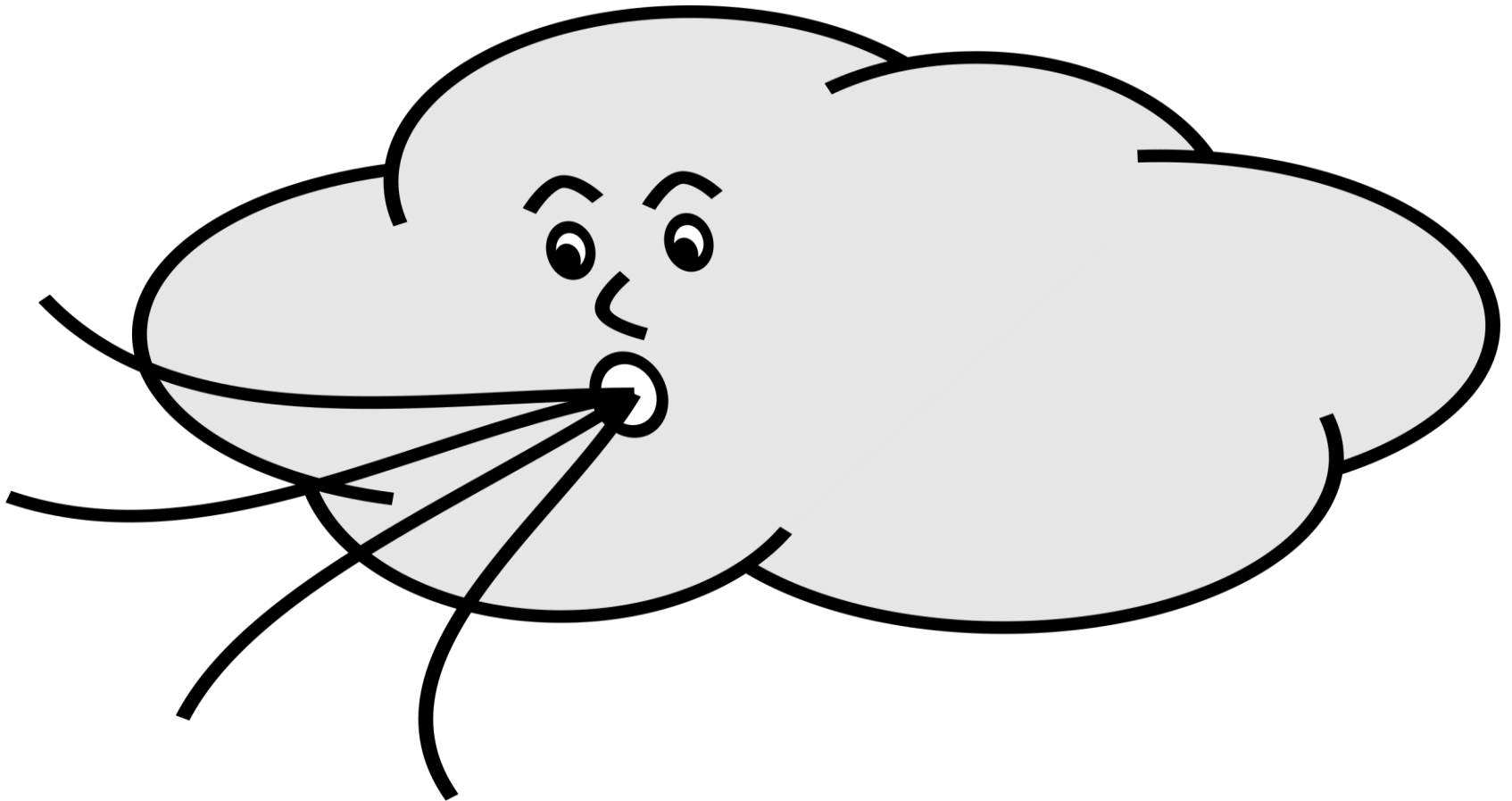


Lecture (4)



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Wind energy?



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When was it used?

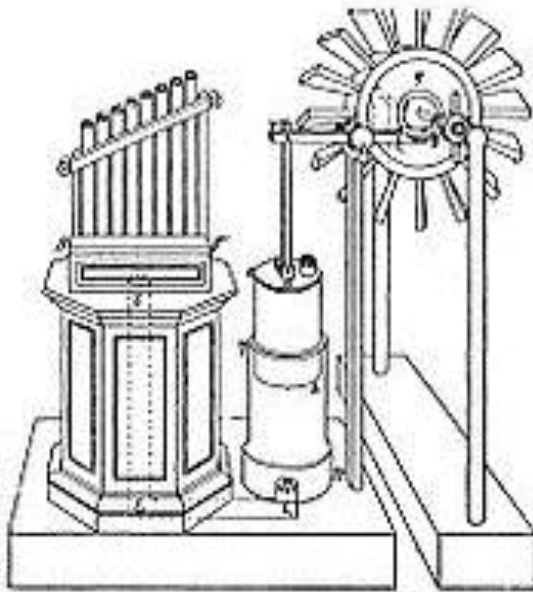
Historical overview

- Wind has been used by people for over 3000 years for grinding grain and pumping water
- Windmills were an important part of life for many communities beginning around 1200 BC.
- Wind was first used for electricity generation in the late 19th century.

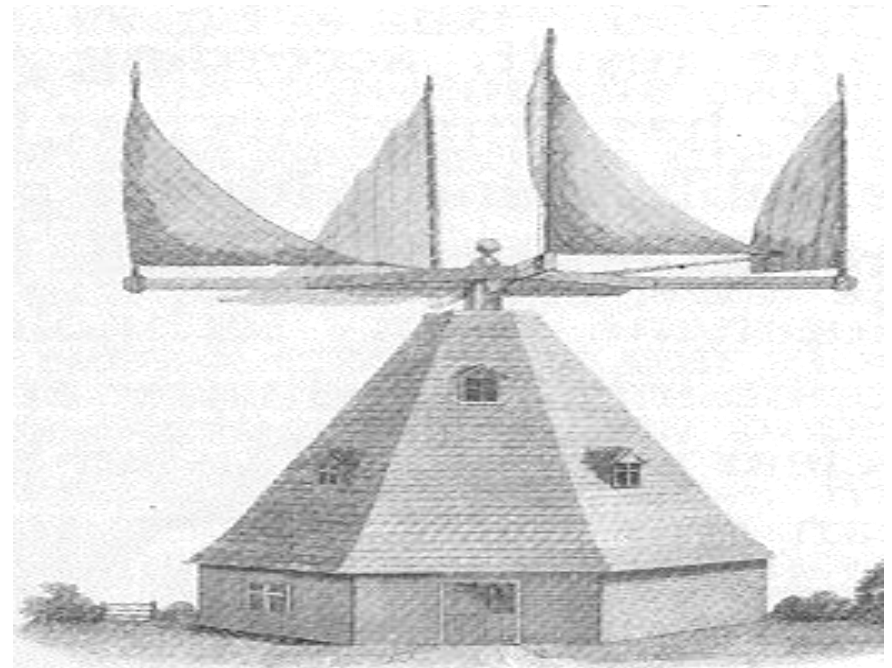


Wind Energy History and Trends

- ❑ The wind wheel of the Greek engineer Heron of Alexandria in the first century is the earliest known instance of using a wind-driven wheel to power a machine.
- ❑ Another early example of a wind-driven wheel was the prayer wheel, which has been used in Tibet and China since the fourth century.



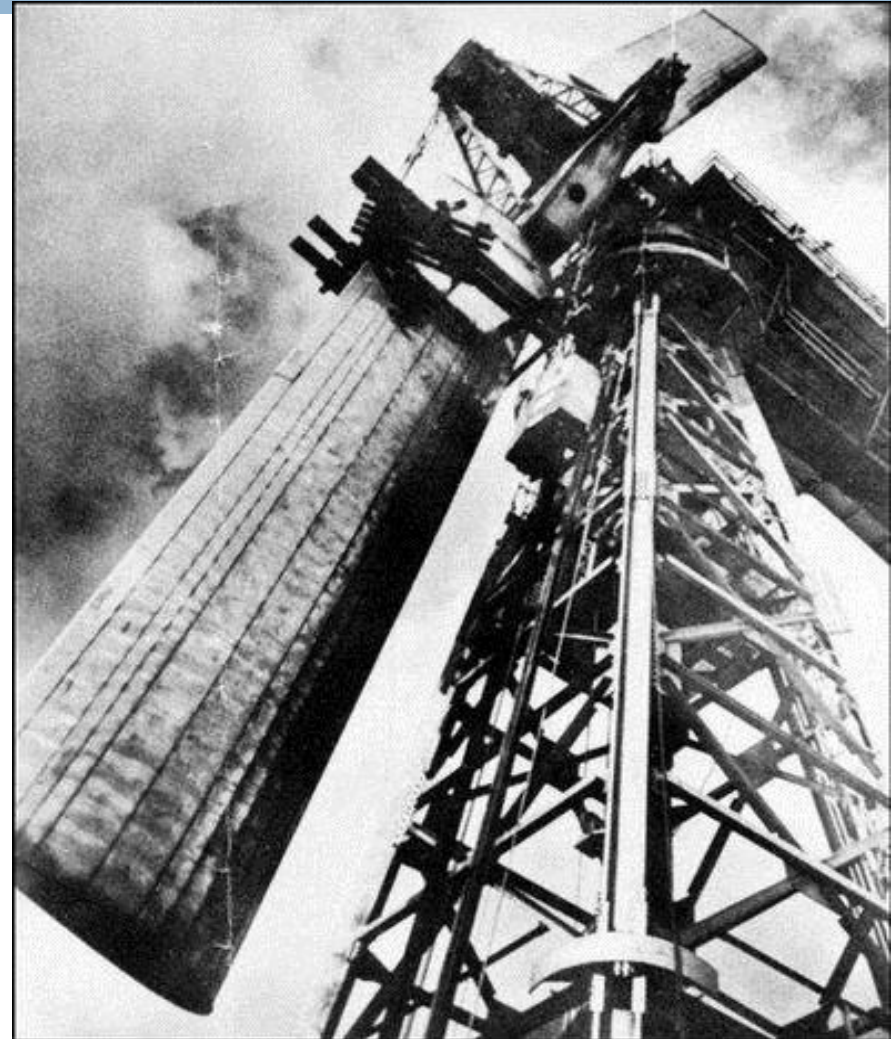
Heron's wind wheel



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Grandpa's Knob

- Smith Putnam Machine
- 1941
- Rutland, Vermont
- 1.25 MW
- 53 meters (largest turbine for 40 years)
- Structural steel
- Lost blade in 1945



What is the Wind energy?

- Wind is the movement of air from an area of high pressure to an area of low pressure.
- The energy of wind is harnessed with wind turbine, they are usually grouped in the wind farms.
- Constant, such as offshore and high altitude sites, are preferred locations of wind farm.
- Wind energy is believed to be five times total current global energy production.





Continue

There are three types of wind farms:

1. Onshore farms (often near water).
2. Nearshore farms (on land or on sea within several km of a coast).
3. Offshore farms (parks ten km or more from land).

Advantages of Wind Energy

1. Wind energy is a clean fuel source, and doesn't pollute the air like power plants.
2. It is a domestic source of energy.
3. The wind is free and with modern technology it can be captured efficiently.
4. Once the wind turbine is built the energy it produces does not cause green house gases or other pollutants.
5. Although wind turbines can be very tall each takes up only a small plot of land. This means that the land below can still be used.



Continue

6. Remote areas that are not connected to the electricity power grid can use wind turbines to produce their own supply.
7. Wind turbines are available in a range of sizes which means a vast range of people and businesses can use them.

Disadvantages of Wind Energy

1. Installation is expensive.
2. Threat to wildlife.
3. Noise pollution.
4. Visual pollution.

Wind Energy Application

1. Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or combined with a photovoltaic (solar cell) system.
2. Several electricity providers today use wind plants to supply power to their customers.
3. Stand-alone wind turbines are typically used for water pumping or communications.
4. Small wind systems also have potential as distributed energy resources.

How Wind Energy Works?

- Most wind energy comes from turbines that can be as tall as a 20-story building and have three 200-foot (60-meter)-long blades.
- The wind spins the blades, which turn a shaft connected to a generator that produces electricity.
- The biggest wind turbines generate enough electricity in a year (about 12 megawatt-hours).
- Wind farms have tens and sometimes hundreds of these turbines lined up together in particularly windy spots.
- Smaller turbines erected in a backyard can produce enough electricity for a single home or small

Increased incentives

- Rise in oil prices in early 1970s prompted government research and incentives
- Key players:
 - ▣ Rocky Flats – Small HAWTs < 100 kW
 - ▣ NASA Lewis – Large HAWTs > 100 kW
 - ▣ Sandia Labs – VAWTs
- Result: the “Mod” series
 - ▣ Mod 0 – Plum Brook, Ohio
 - ▣ Mod 1 – Boone, North Carolina
 - ▣ Mod 2 – Washington, Calif, & Wyoming

Mod 0 (200 kW)



November 11



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Mod 1 (2 MW)



November 17



DOE/NASA 2000kW EXPERIMENTAL WIND TURBINE

Mod 5b (3.2 MW)

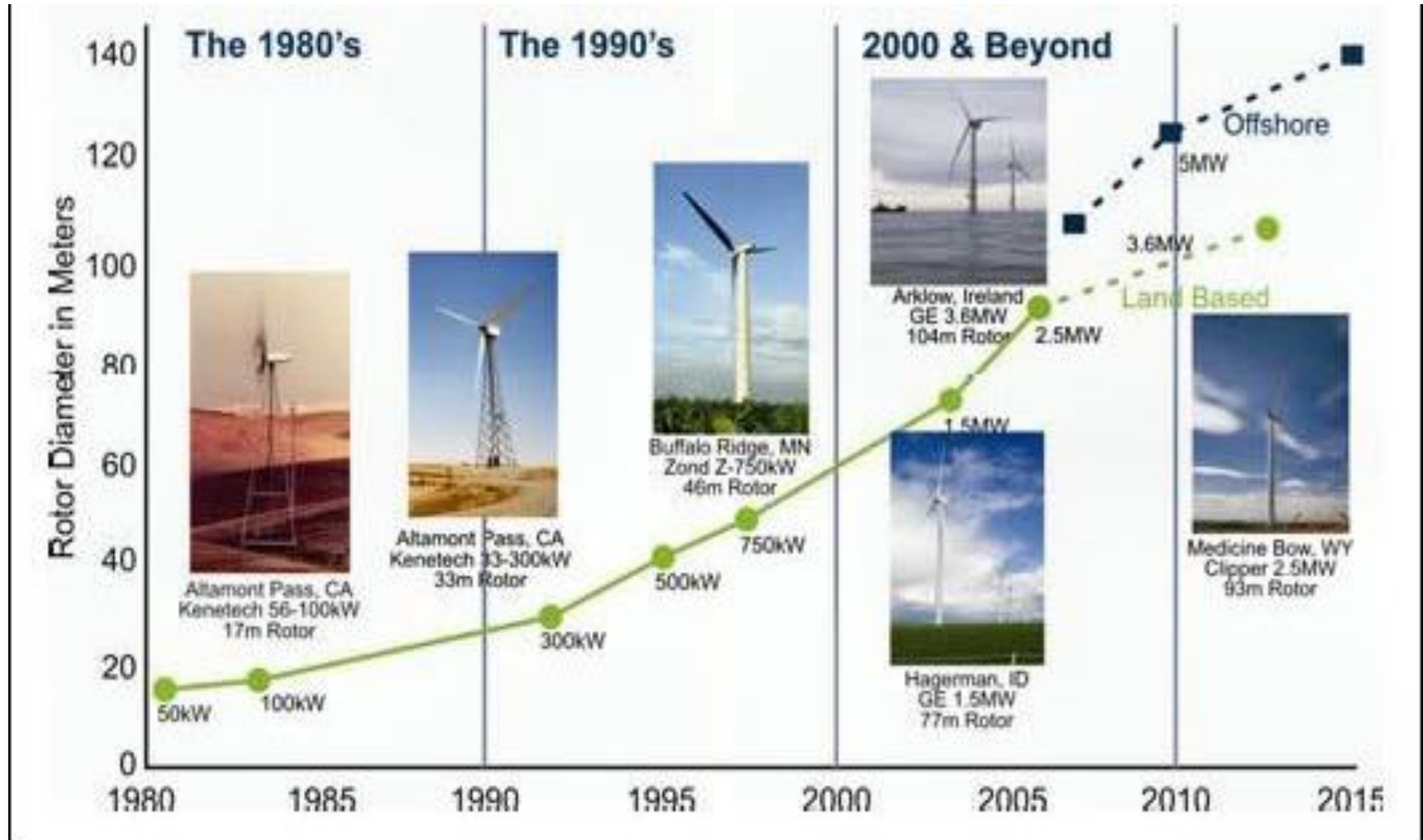


November 17

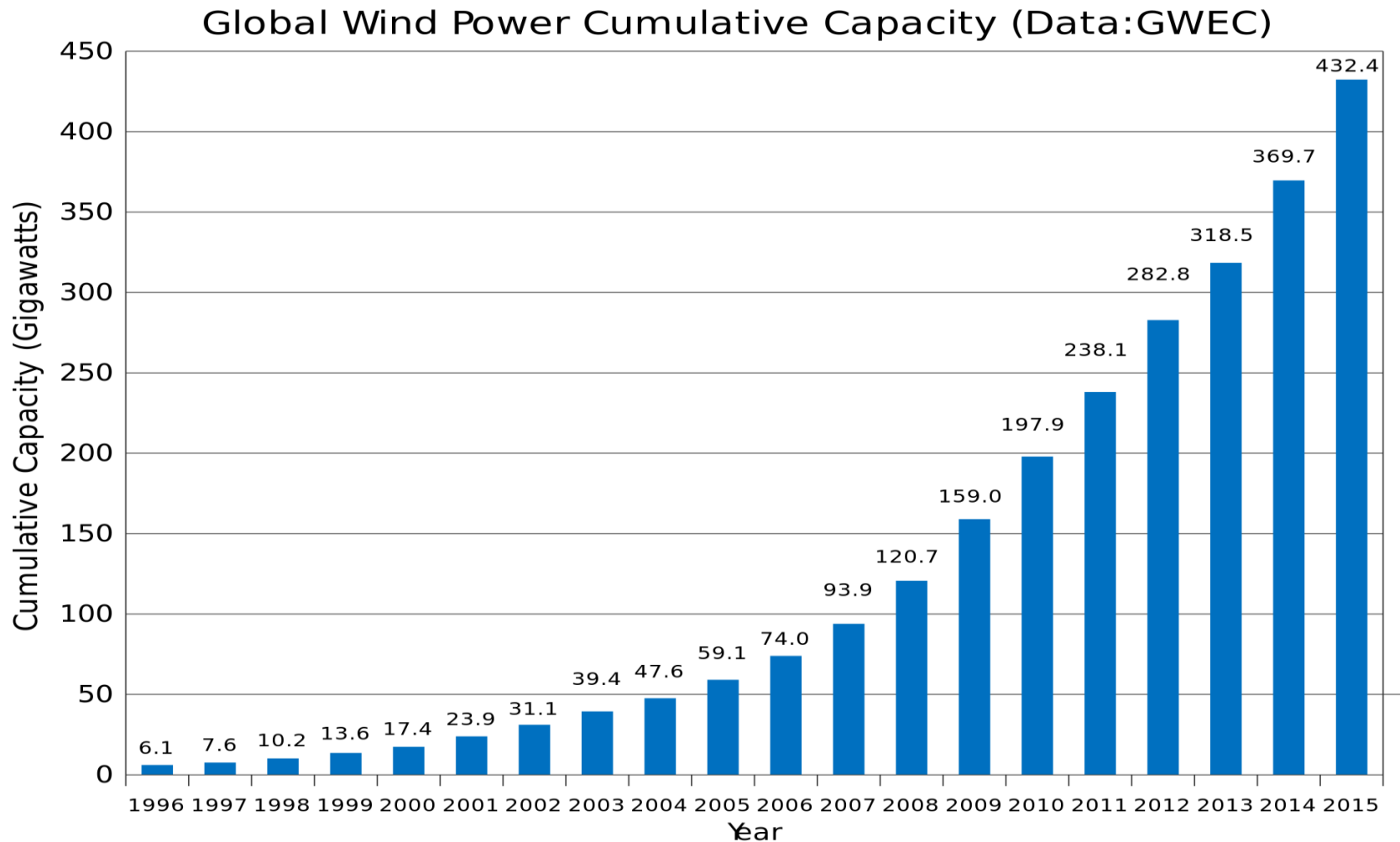


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Evolution of Commercial Wind Technology



World Growth Market



Current Trends

- Move towards ever larger machines
- Offshore
- More financial players
- More countries
- Low wind speed turbines (U.S.)
- Green energy and green tags



Offshore Wind

- Why offshore?
 - ▣ Close to load centers (avoids transmission)
 - ▣ On-shore NIMBY
 - ▣ Better wind resource
- U.S. issues
 - ▣ Less shallow water than Europe
 - ▣ More extreme wave and hurricane design conditions
 - ▣ Ice in great lakes





Fact or Fiction?

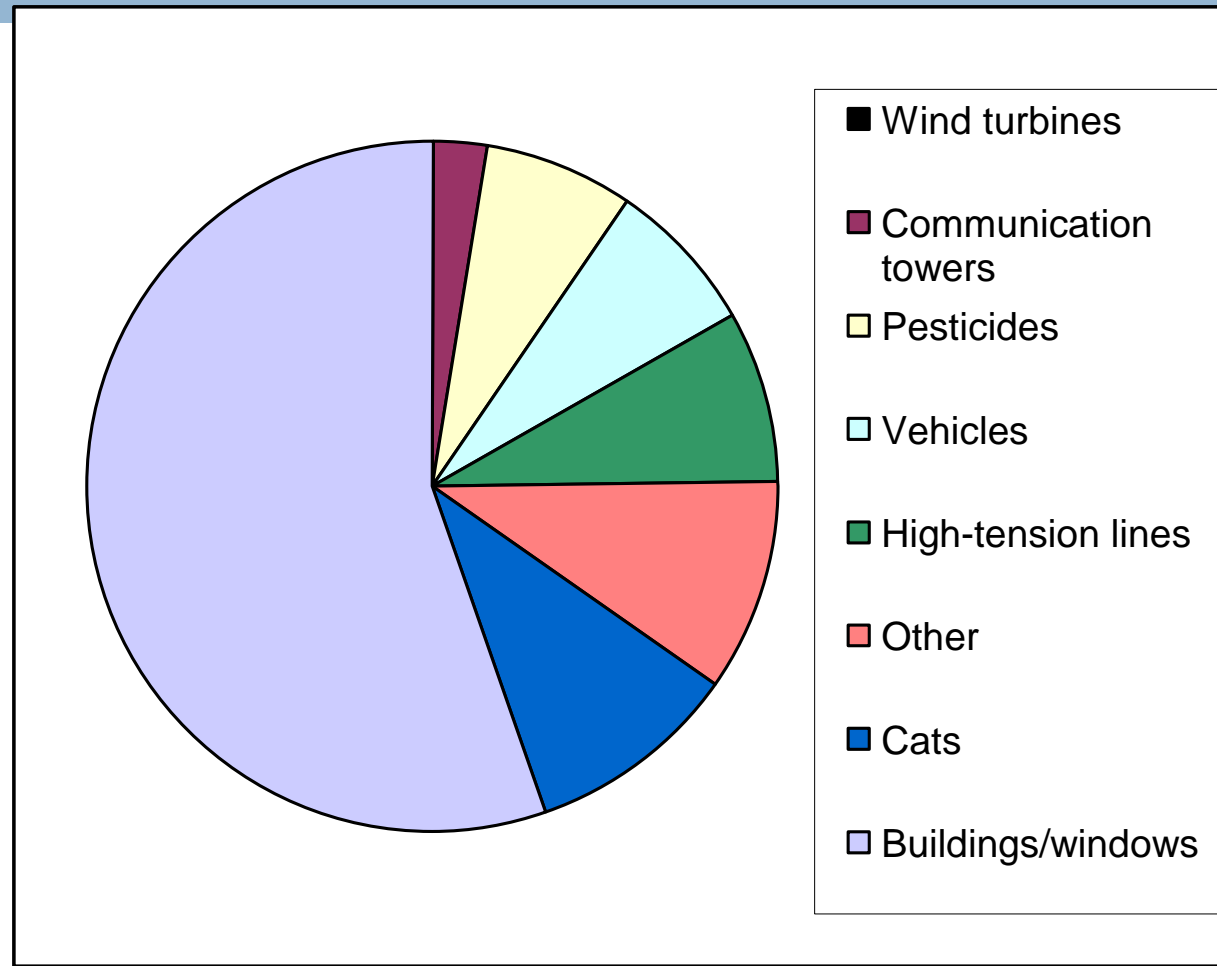
Burning questions

- What are your most burning questions about wind energy?
- Break into small groups and come up with two biggest questions per group.

Predicted Questions

- What's the real story with bird kills?
 - ▣ What about bats?
- What happens to my electricity when the wind doesn't blow?
- How noisy are wind turbines?
- Do wind turbines interfere with electrical power quality or TV and radio transmissions?

Human-related bird kills



http://www.awea.org/faq/wwt_environment.html#Bird%20and%20bat%20kills%20and%20other%20effects

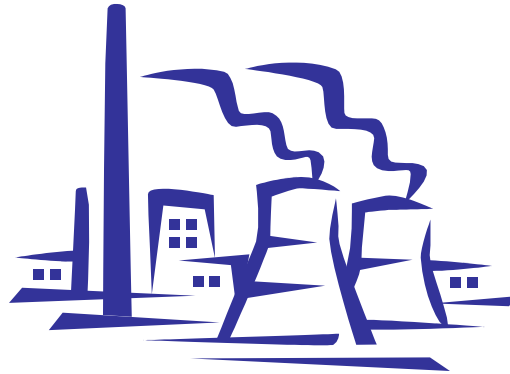
Bat Kills

- Bat fatality at wind turbines has been documented worldwide in the U.S., Australia, Canada, Germany, Spain, and Sweden.
- Bat fatalities have been reported at nearly all wind energy facilities in the U.S.
 - ▣ annual mortality estimated at <2 to nearly 50 bats/turbine/year
- Bat mortality appears to be highest in or near forests and lowest in open grassland or farmland away from forests.
- Bats rarely strike fixed objects.
- Source: Bat Conservation International
(<http://www.batcon.org/home/index.asp?idPage=55&idSubPage=52>)



When the wind doesn't blow...

- **Do fossil-fired generating units have to be kept running on a standby basis in case the wind dies down?**



- No. Wind speeds rise and fall gradually and the system operator has time to move other plants on and off line as needed.
- A 100-MW wind plant requires about 2 MW of conventional capacity to compensate for changes in wind.
- Wind can reliably provide 20% or more of our electricity.

http://www.awea.org/faq/wwt_environment.html#Bird%20and%20bat%20kills%20and%20other%20effects

Lifetime environmental impact

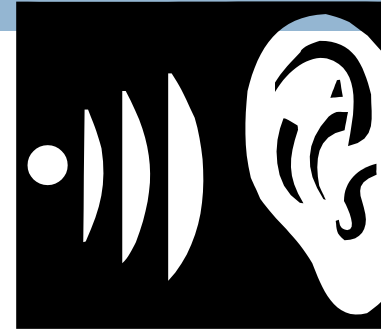
- Manufacturing wind turbines and building wind plants does not create large emissions of carbon dioxide.
- When these operations are included, wind energy's CO₂ emissions are quite small:
 - ▣ about 1% of coal, or
 - ▣ about 2% of natural gas (per unit of electricity generated).



http://www.awea.org/faq/wwt_environment.html#Bird%20and%20bat%20kills%20and%20other%20effects

Noise

- Noise used to be a very serious problem for the wind energy industry.
 - ▣ annoying from as much as a mile away
- Aerodynamics and soundproofing have been improved significantly.
- Wind turbines operate when the wind is blowing, which tends to be louder than turbine noise.
- A modern operating wind farm at a distance of 750 to 1,000 feet is no noisier than a kitchen refrigerator or a moderately quiet room.



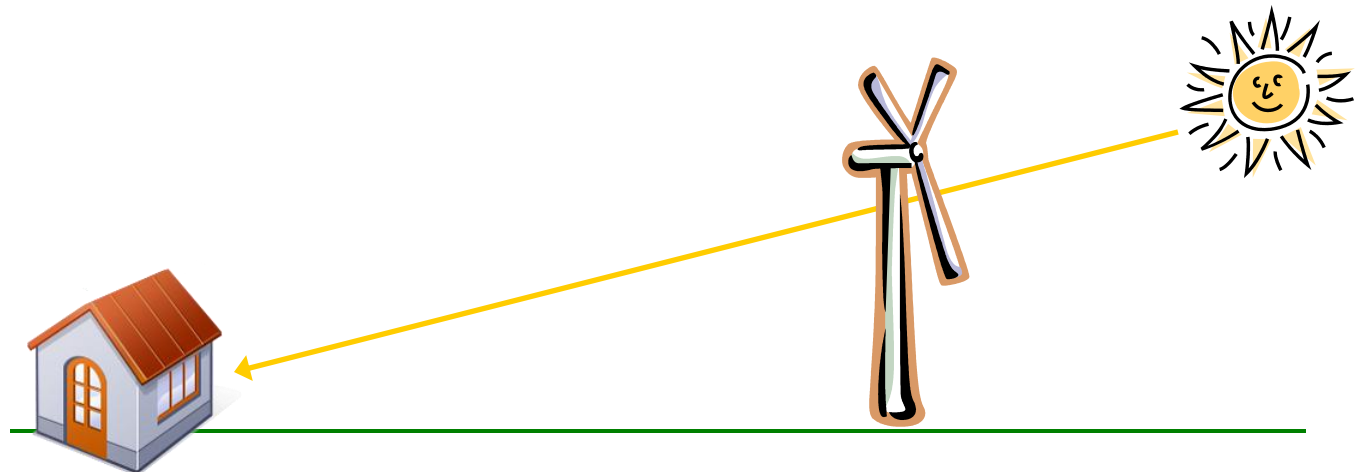
COMPARISON OF SOUND PRESSURE LEVEL AND SOUND PRESSURE		
Sound Pressure Level, dB		Sound Pressure, Pa
	120	20
Pneumatic Chipper (at 5 ft)	110	10
Textile Loom	100	5
Newspaper Press	90	2
Diesel Truck 40 mph (at 50 ft)	80	1
Passenger Car 50 mph (at 50 ft)	70	0.5
Conversation (at 3 ft)	60	0.2
	50	0.1
	40	0.05
Quiet Room	30	0.02
	20	0.01
	10	0.005
	0	0.002
		0.001
		0.0005
		0.0002
		0.0001
		0.00005
		0.00002

http://www.awea.org/pubs/factsheets/WE_Noise.pdf

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Shadow flicker

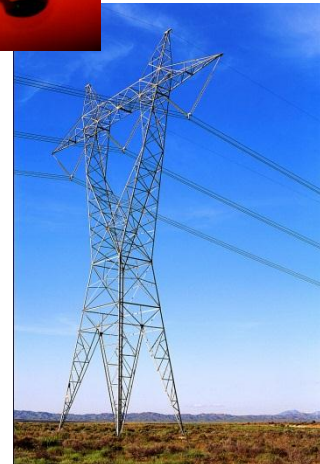
- A wind turbine's moving blades can cast a moving shadow on a nearby residence, depending on the time of the year and time of day.
- Normally, it should not be a problem in the U.S., because at U.S. latitudes (except in Alaska) the sun's angle is not very low in the sky.



http://www.awea.org/faq/wwt_environment.html#Bird%20and%20bat%20kills%20and%20other%20effects

Electrical power quality

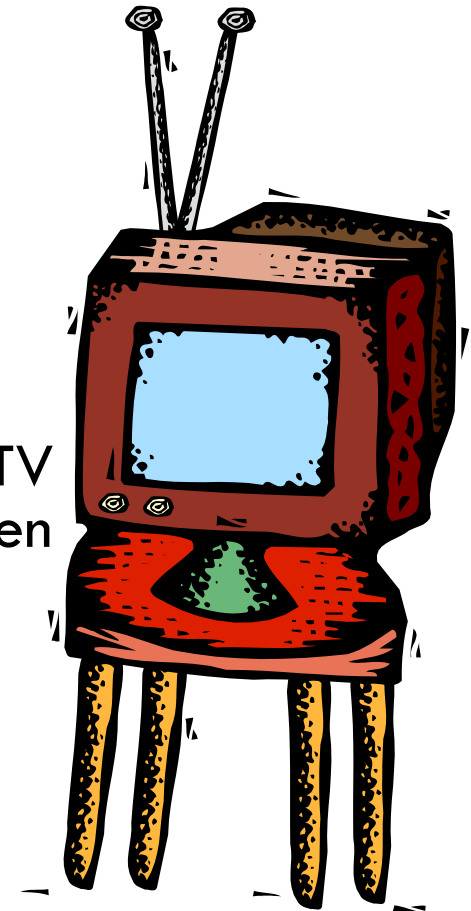
- Generally not a concern for low “penetration”
- Weak grids and grid reinforcement
 - ▣ Problems may occur if a turbine is connected to a weak electrical grid, which can be reinforced.
 - ▣ Power quality problems caused by wind farms are the exact mirror-image of connecting a large electricity user, (e.g. a factory with large electrical motors) to the grid.
- Electrical flicker
 - ▣ Flicker = short lived voltage variations in the electrical grid which may cause light bulbs to flicker.
 - ▣ Flicker may occur if a wind turbine is connected to a weak grid.
 - ▣ Flicker can be reduced with proper turbine design.



<http://www.windpower.org/en/tour/grid/rein.htm>

TV and radio reception

- Modern small (residential) wind turbines will not interfere with communication signals.
 - ▣ The materials used to make such machines are non-metallic (composites, plastic, wood).
 - ▣ Small turbines are too small to create electromagnetic interference (EMI) by "chopping up" a signal.
- Large wind turbines can interfere with radio or TV signals if a turbine is in the "line of sight" between a receiver and the signal source. Alleviate the problem by:
 - ▣ improving the receiver's antenna
 - ▣ installing relays to transmit the signal around the wind farm





Sizes and Applications

Sizes and Applications



Small (≤ 10 kW)

- Homes
- Farms
- Remote Applications
(e.g. water pumping, telecom sites, icemaking)



Intermediate (10-250 kW)

- Village Power
- Hybrid Systems
- Distributed Power



Large (660 kW - 2+MW)

- Central Station Wind Farms
- Distributed Power
- Community Wind

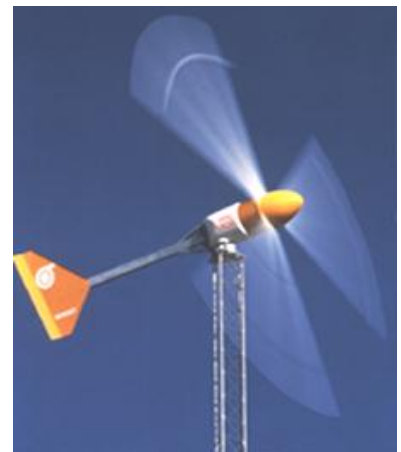
Large and Small Wind Turbines

Large Turbines (600-2000 kW)

- Installed in “Windfarm” arrays totaling 1 - 100 MW
- \$1,300/kW
- Designed for low cost of energy (COE)
- Requires 6 m/s (13 mph) average wind speed
- Value of Energy: \$0.02 - \$0.06 per kWh

Small Turbines (0.3-100 kW)

- Installed in “rural residential” on-grid and off-grid applications
- \$2,500-\$8,000/kW
- Designed for reliability / low maintenance
- Requires 4 m/s (9 mph) average wind speed
- Value of energy: \$0.06 - \$0.26 per kWh



Small Wind Turbines

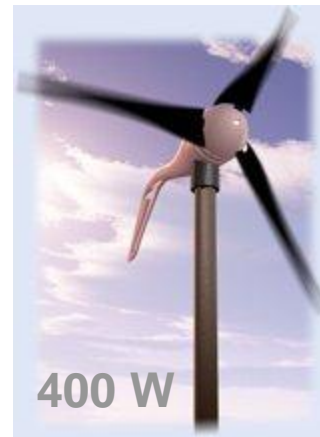
- Blades: Fiber-reinforced plastics, fixed pitch, either twisted/tapered, or straight (pultruded)
- Generator: Direct-drive permanent magnet alternator, no brushes, 3-phase AC, variable-speed operation
- Designed for:
 - Simplicity, reliability
 - Few moving parts
 - Little regular maintenance required



10 kW



50 kW



400 W



900 W

On-Grid Home with Wind System

- Tehachapi, CA
- Bergey Excel wind turbine, 23 ft rotor, 10 kW
- Total installed cost was \$34,122 in October 1999
- California Buy-Down Program, \$16,871 cash rebate
- Estimated payback: 8 years



On-Grid Farm with Wind System

- Southwestern Kansas
- Bergey Windpower Excel wind turbine: 10 kW, 23 ft rotor, 100 ft tower
- ~21,000 kWh/year generation, utility bill savings ~\$2,800/year
- Installed in early 1980s, ~\$20,000, received federal tax credit
- Maintenance costs \$50/year



Orland, Maine

- Turbine Size: 50 kW
- Turbine Manufacturer: Atlantic Orient Corp. (AOC)
- Radius: 7.5 m
- Developer/owner: G.M. Allen & Sons Blueberry Processing Plant



Selawik, Alaska

- 4 x 50 kW Wind Turbines
- Turbine Manufacturer: AOC
- Developer/Owner: Alaska Village Electric Corp.
- Capacity: 200 kW



Hull, Massachusetts

- Turbine Size: 660 kW
- Turbine Manufacturer: Vestas
- Developer/Owner: Hull Municipal Lighting Plant
- Capacity: 0.66 MW



Ponnequin, Colorado



- Turbine Manufacturer: Vestas, NEG Micon
- Developer/owner: DisGen/Xcel Energy
- Turbine Size: 660-750 kW
- Capacity: 31.5 MW
- Commissioned: 1999