Benha University

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Faculty of Engineering at Shoubra
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Postgraduate (Pre-master) Course

Generation of Electrical Power from Renewable Resources

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Syllabus

1. • ***INTRODUCTION.***
2. • ***SOLAR PHOTOVOLTAIC POWER SYSTEM.***
3. • ***SOLAR THERMAL POWER SYSTEM.***
4. • ***WIND POWER SYSTEM.***
5. • ***ENERGY STORAGE SYSTEMS.***
6. • ***STAND-ALONE SYSTEM.***
7. • ***GRID-CONNECTED SYSTEM.***

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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

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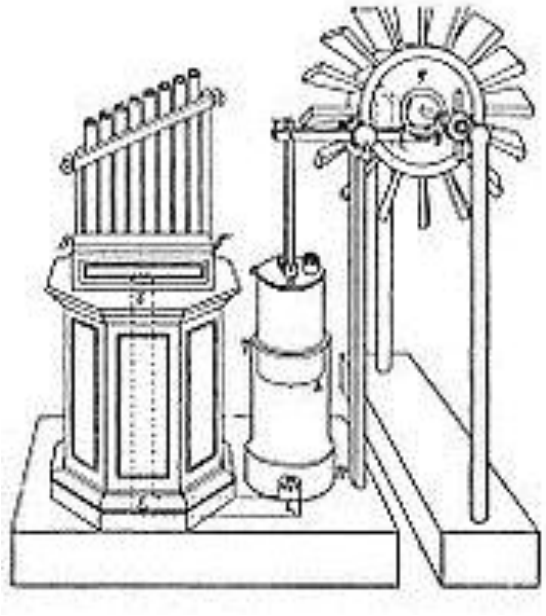
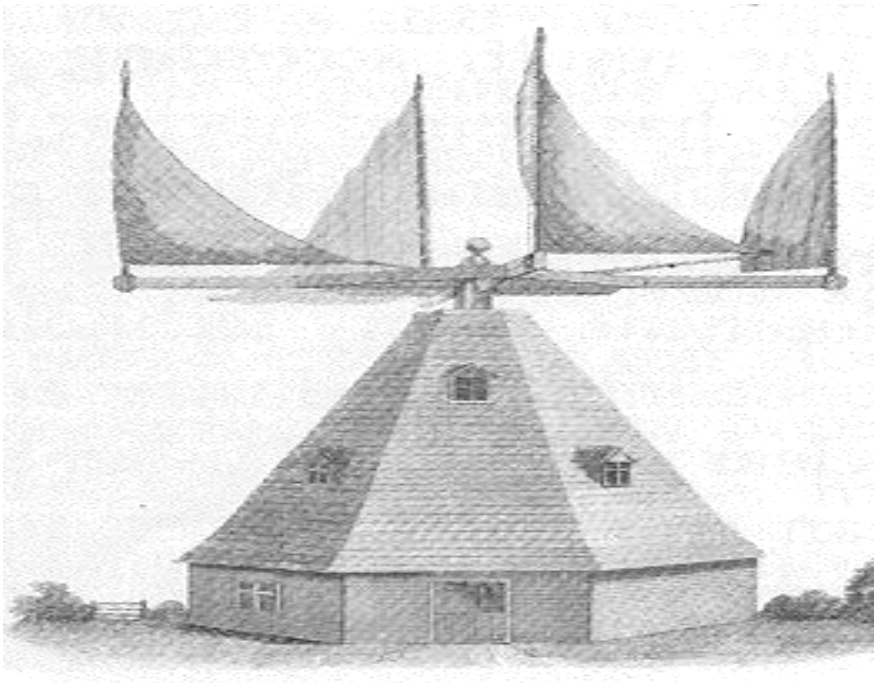
- The wind wheel of the Greek engineer Heron of Alexandria in the first century is the earliest known instance of using a wind-driven wheel to power a machine.
- Another early example of a wind-driven wheel was the prayer wheel, which has been used in Tibet and China since the fourth century.

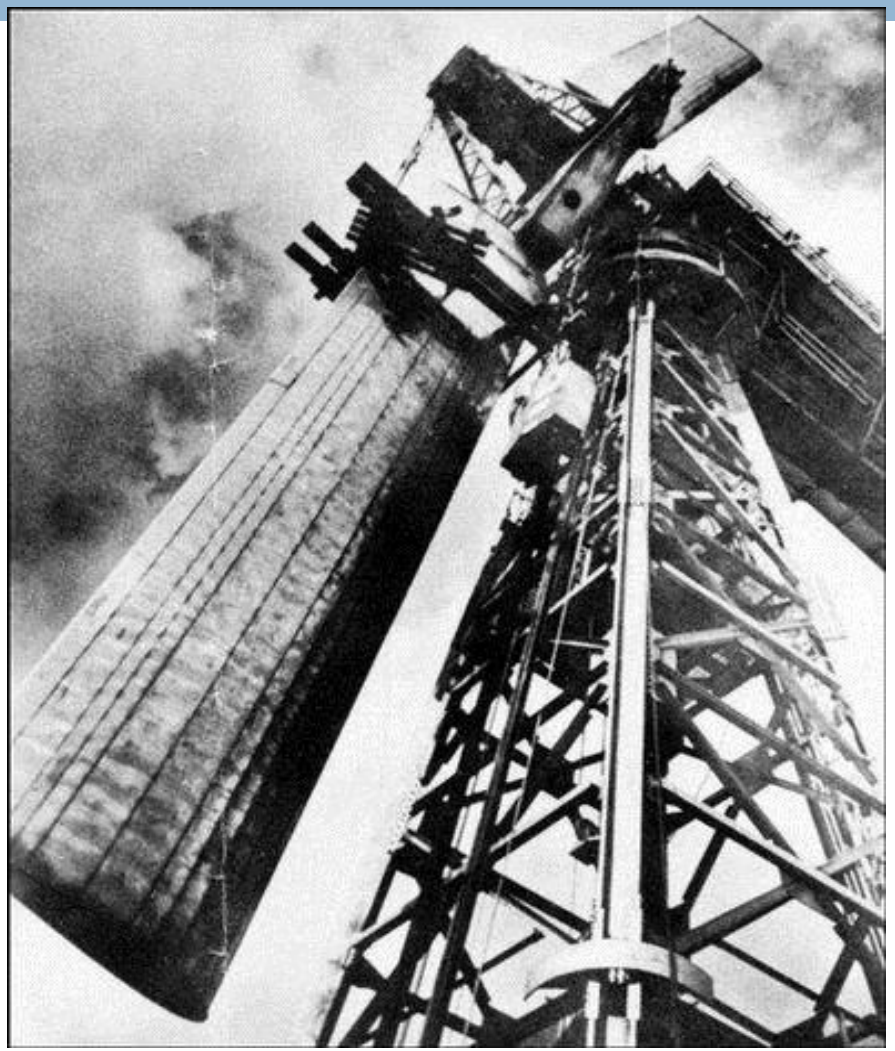


Heron's wind wheel



Grandpa's Knob

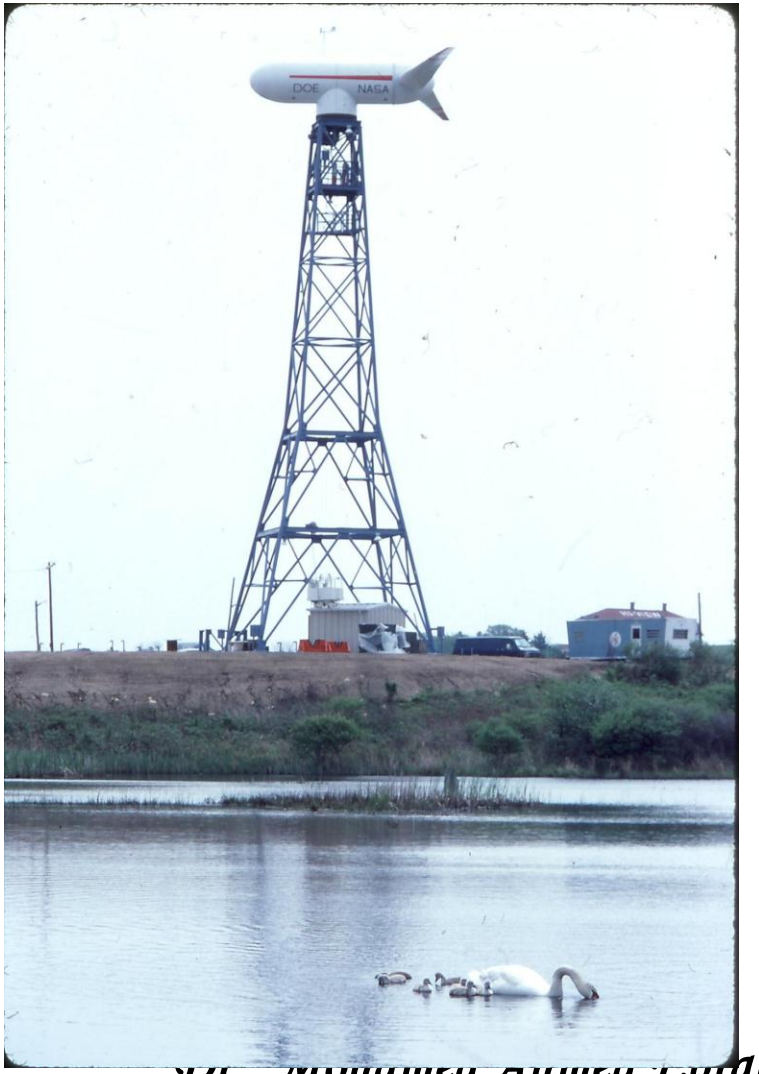
- Smith Putnam Machine
- 1941
- Rutland, Vermont
- 1.25 MW
- 53 meters (largest turbine for 40 years)
- Structural steel
- Lost blade in 1945



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)



Mod 1 (2 MW)

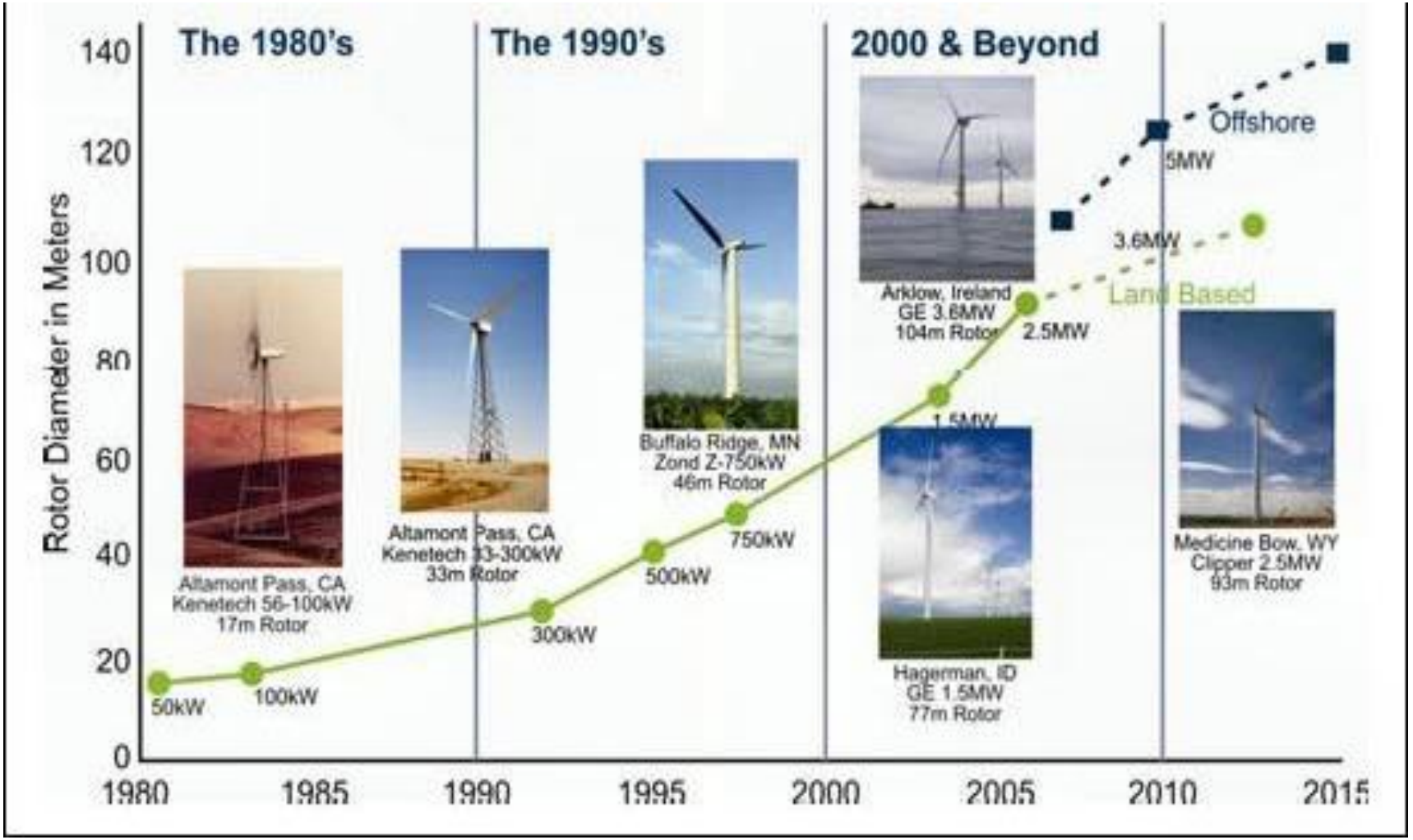

DOE NASA


DOE NASA
DOE/NASA 2000kW EXPERIMENTAL WIND TURBINE

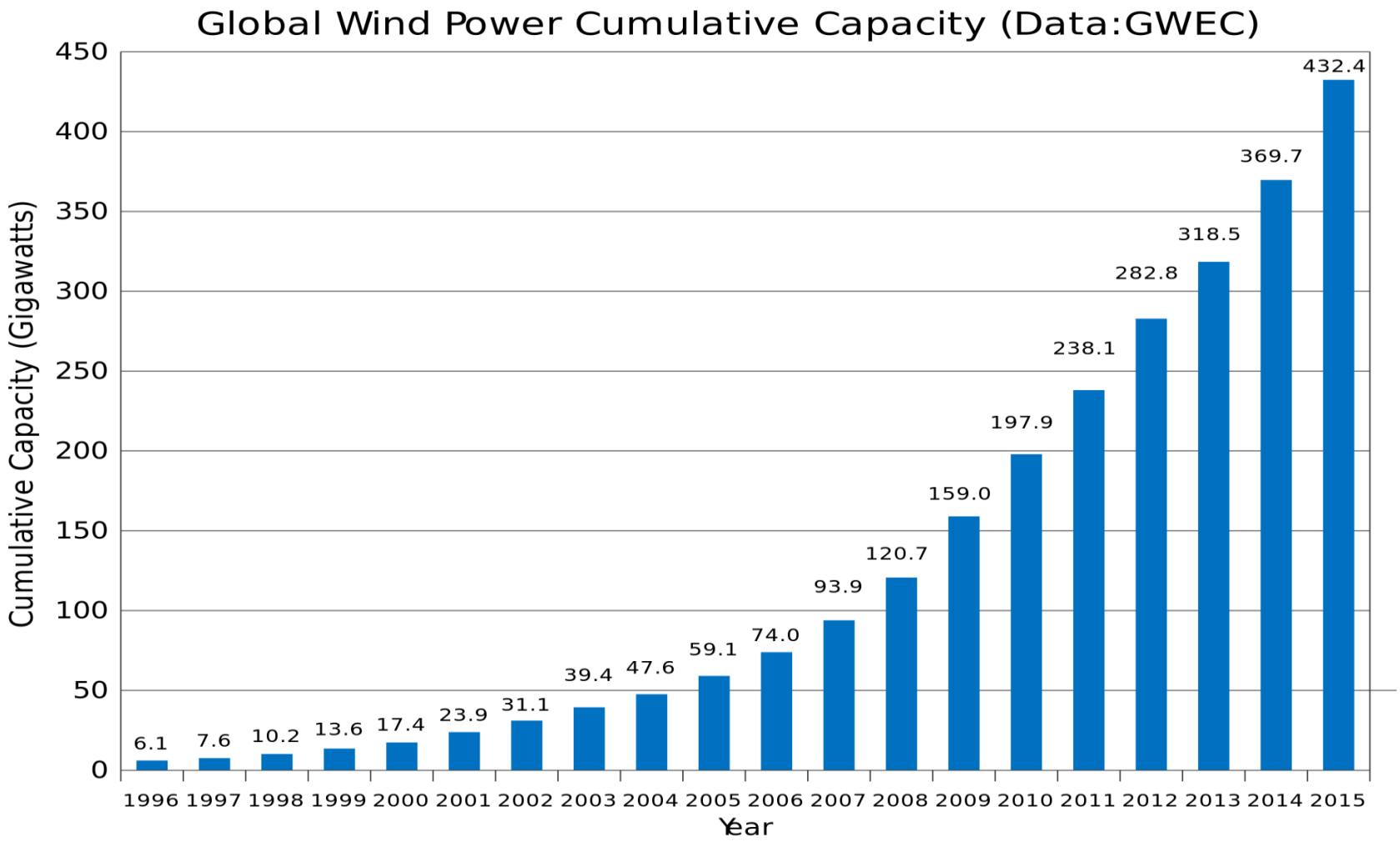
Mod 5b (3.2 MW)


BOEING
ENGINEERING &
CONSTRUCTION
MOD 5B WIND TURBINE SYSTEM

Evolution of Commercial Wind Technology



World Growth Market



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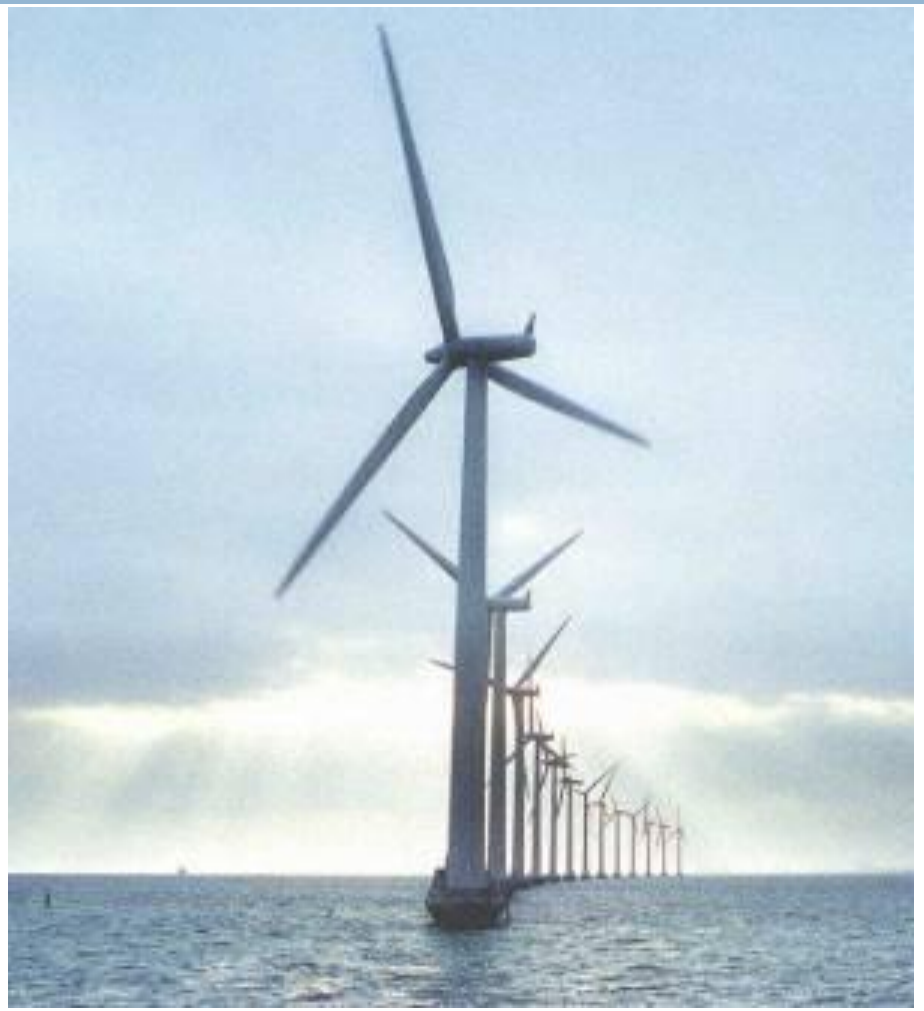
Current Trends

- 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

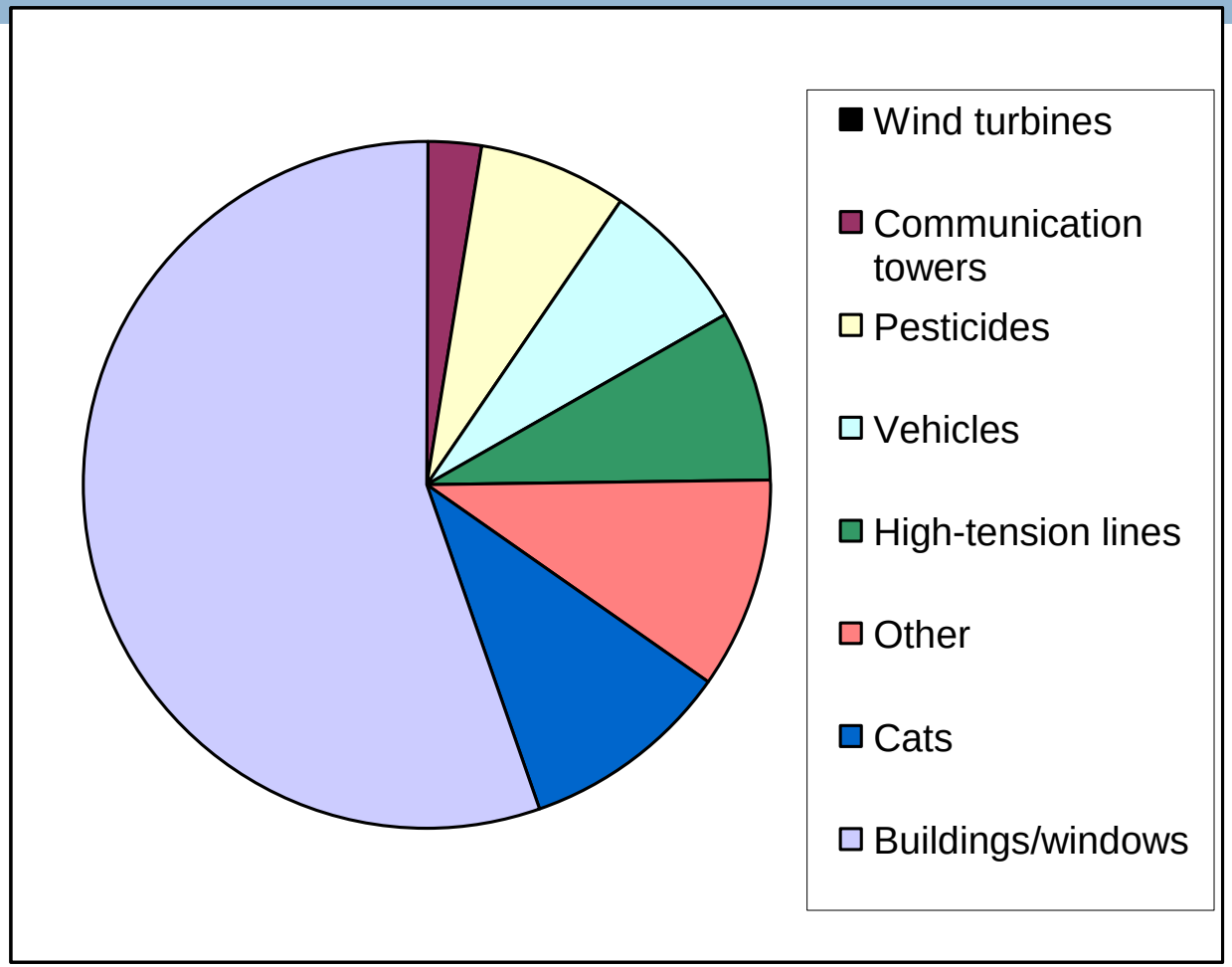
- What are your most burning questions about wind energy?

- 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=

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

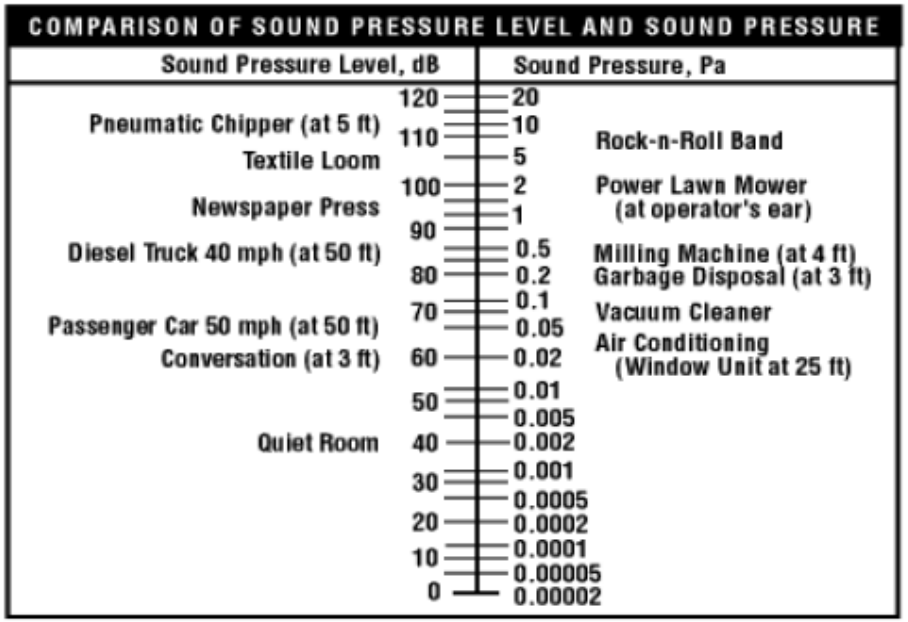
Lifetime environmental impact

- Manufacturing wind turbines and building wind plants does not create large emissions of carbon dioxide.
- When these operations are included, wind energy's CO_2 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

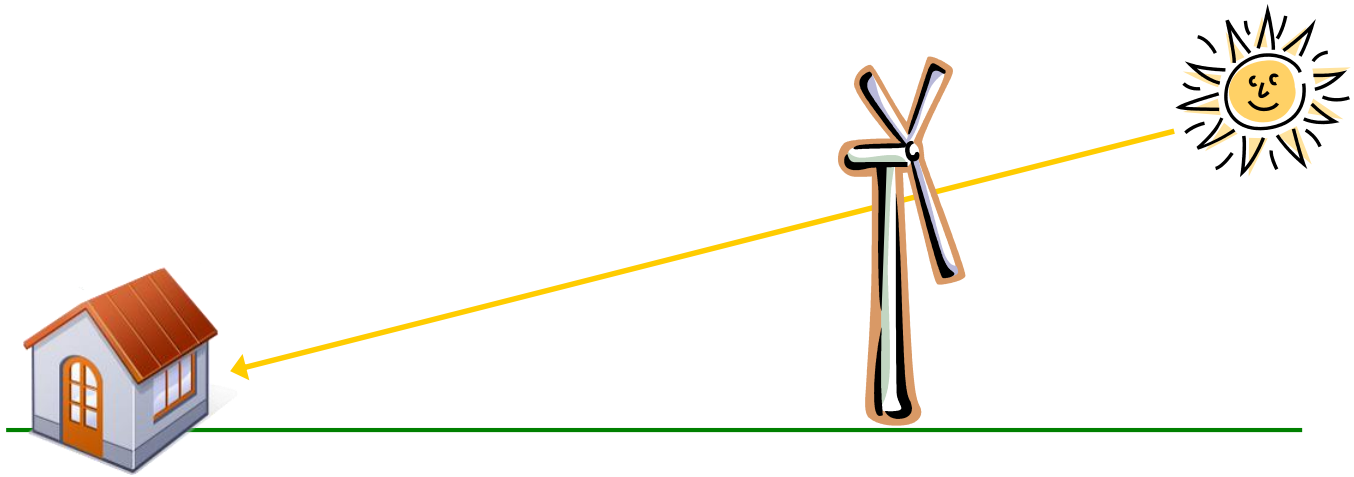
- Noise used to be a very serious problem for the wind energy industry.
  - annoying from as much as a mile away
- Aerodynamics and soundproofing have been improved significantly.
- Wind turbines operate when the wind is blowing, which tends to be louder than turbine noise.
- A modern operating wind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



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

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.



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Electrical power quality

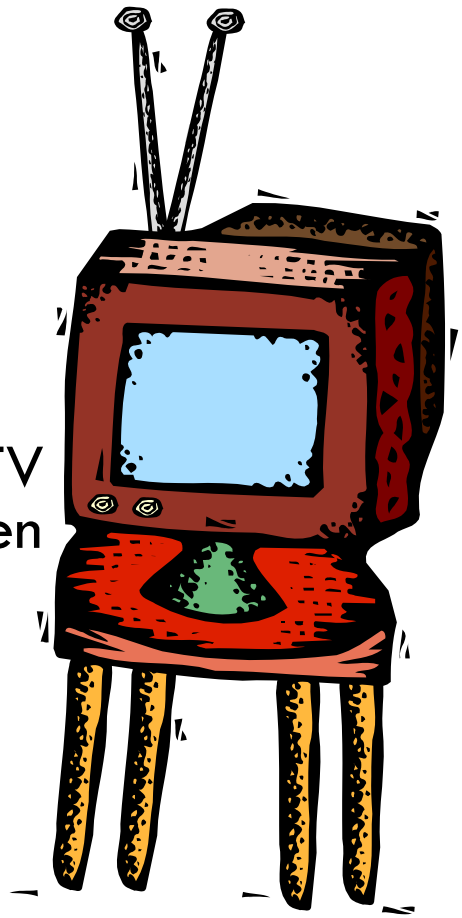
- Generally not a concern for low “penetration”
- Weak grids and grid reinforcement
  - Problems may occur if a turbine is connected to a weak electrical grid, which can be reinforced.
  - Power quality problems caused by wind farms are the exact mirror-image of connecting a large electricity user, (e.g. 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



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Sizes and Applications

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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

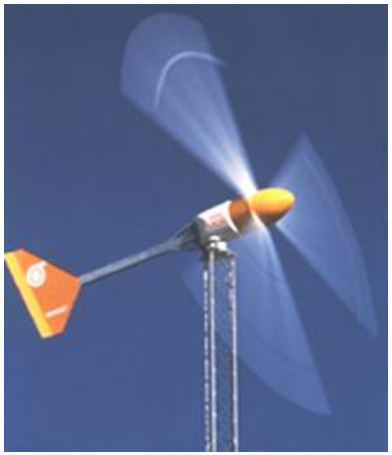
Large and Small Wind Turbines

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

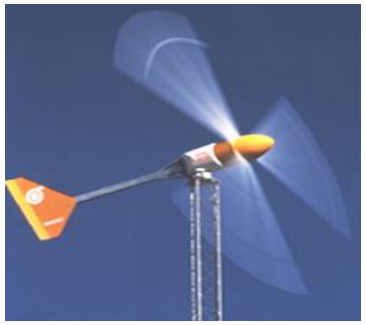
Small Turbines (0.3-100 kW)

- 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

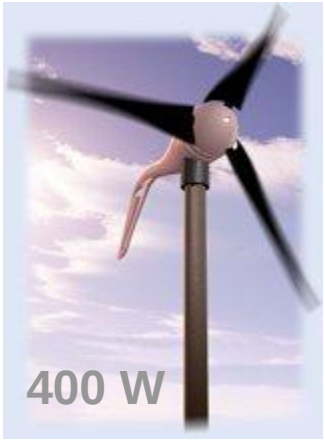


Small Wind Turbines

- 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



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

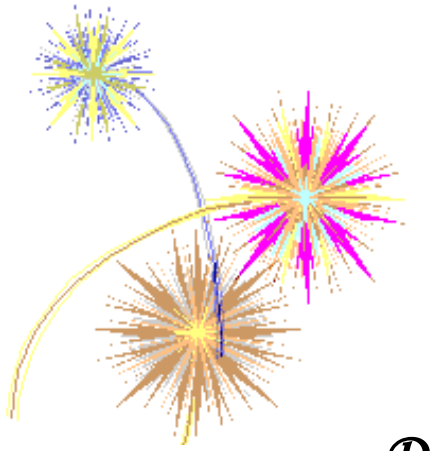
Hull, Massachusetts

- 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

Thank You
For Your Attention



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