# Evolution of Wind Turbines

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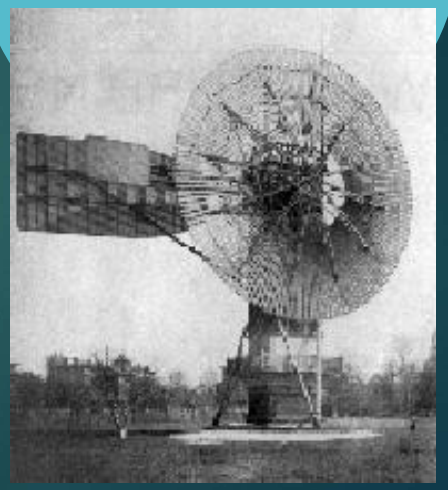
# The First Wind Turbines



- 200 B.C. - Windmills in Persia
- 1887 - 1st electricity-generating wind turbine, in Scotland
- 1888 - 1st large scale windmill, in Ohio
  - Turned a direct current generator at 500 rpm, 12 kW output
- End of WWI – Typical windmill
  - 25 kW output
  - Either fan-type or sail rotor configuration



http://ww.telosnet.com/wind/early.html
Price, Trevor J. (2004). "Blyth, James (1839–1906)". *Oxford Dictionary of National Biography* (online ed.). Oxford University Press. doi:10.1093/ref:odnb/100957.

# The Early 1900s



- 1920s - Turbines used modified propellers
  - Most small 1-3 kW devices
  - Used in rural areas to light farms and run appliances
  - Intermittent operation becomes problem
- 1930s-1940s – Becoming less effective
  - 1931 – 100kW forerunner of modern horizontal-axis wind generator in USSR (impractical)
  - 1941 – 1.25 MW Smith-Putnam, horizontal-axis design with two blades in Vermont (failed)

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# Rising of the Modern Wind Turbine



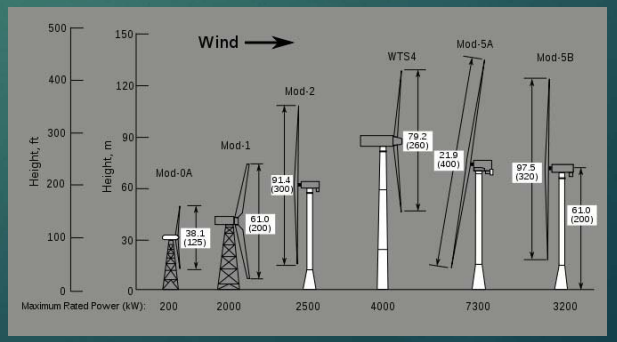
- 1956 – first modern wind turbine built in Denmark
  - 200kW Gedser wind turbine
  - Three-bladed upwind turbine with electromechanical yawing and asynchronous generator
- 1960s Wind turbines
  - Horizontal-axis made of airfoil-type fiberglass
  - Focused on shedding aerodynamic loads rather than withstanding them
  - Teeter hinge at the rotor blade

http://ww.telosnet.com/wind/early.html
http://www.powermag.com/changing-winds-the-evolving-wind-turbine/

# Golden Age of Wind Turbine Design, the 1970s and 1980s



- U.S. government (NASA) accelerates designing (13 different designs)
  - MOD-0 -> 100 kW machine (teetering problem)
  - MOD-1 -> 2 MW machine (Resonance and teetering problems)
  - MOD-2 -> 3 MW, 100m diameter machine
  - MOD-5B -> 3.2 MW, 100m diameter, first large scale variable speed drive train and a sectioned two-blade rotor
- 1987 – all major horizontal axis turbines go from rotating counter-clockwise to clockwise

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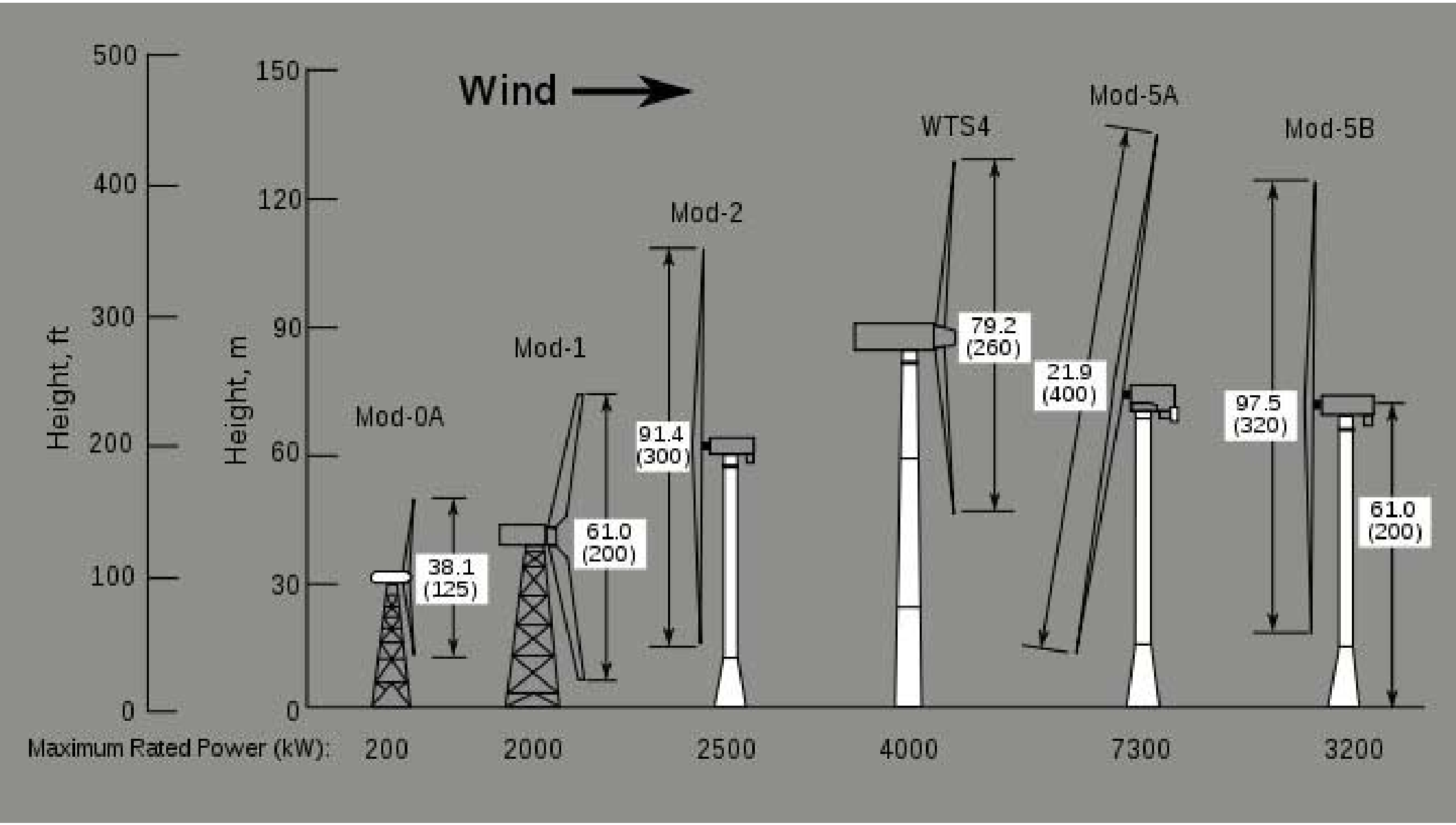
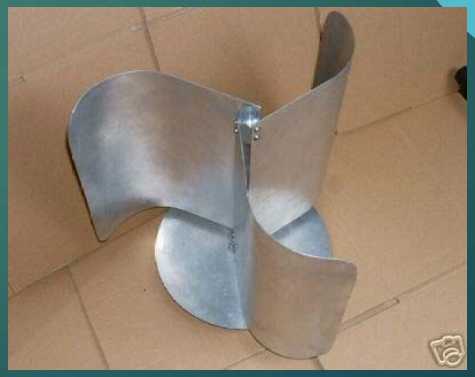

Wind
Height, ft
500
400
300
200
100
0
Height, m
150
120
90
60
30
0
Mod-0A
38.1
(125)
Mod-1
61.0
(200)
Mod-2
91.4
(300)
WTS4
79.2
(260)
Mod-5A
21.9
(400)
Mod-5B
97.5
(320)
61.0
(200)
Maximum Rated Power (kW):
200
2000
2500
4000
7300
3200

# Modern Wind Turbines: Vertical Axis Design



- Main rotor shaft arranged vertically
- Turbine does not need to be pointed at the wind
- Main components are located close to the ground
- Creates lots of torque -> helical twist in blades
- Lower reliability
- None operating today at utility scale
- Subtypes:
  - Darrieus wind turbine
  - Giromill wind turbine
  - Savonius wind turbine

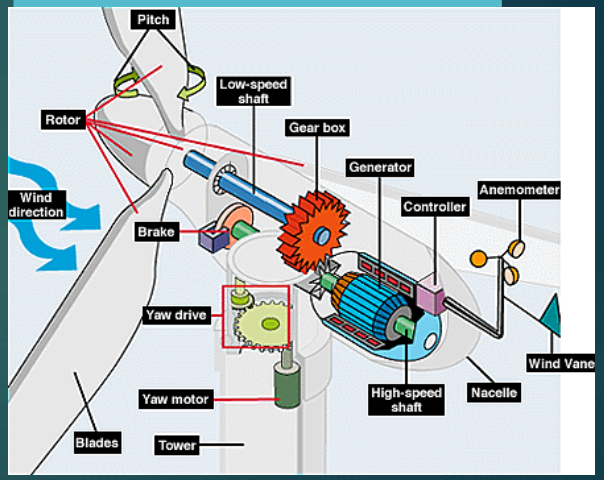


http://www.motherearthnews.com/renewable-energy/vertical-axis-wind-turbines-zmaz08fmzmcc.aspx
http://cleantechnica.com/2014/04/07/vertical-axis-wind-turbines-great-1890-also-rans-2014/

# Modern Wind Turbines: Horizontal Axis Design



- Main rotor shaft and electrical generator at the top of tower
- Must be pointed into wind (sensors to move turbine)
- Turbine position upwind of support tower
- Good reliability
- Most common are 1.5 MW
- Low torque ripple
- High efficiency
- Main components:
  - Rotor
  - Generator
  - Structural Support

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http://www.telegraph.co.uk/news/earth/energy/windpower/10548424/Wind-farm-test-case-could-seen-hundreds-of-turbines-near-historic-sites.html

# Wind Turbines of the Future: Dual Rotor Technology



- Problems addressed with current turbines:
  - Are big round structural pieces, not shaped like airfoil
  - Large base of blades disrupts wind causing wake behind them
- Solution:
  - Add a second, smaller rotor
  - Simulations point to up to 18% increase in energy harvest
- Next Step:
  - Find the best aerodynamic design for a duel-rotor turbine

http://www.alternative-energy-news.info/technology/wind-power/wind-turbines/

# Wind Turbines of the Future: Bladeless (Fuller) Wind Turbine

- Based on a patent issued by Nikola Tesla in 1913
- Only one rotating part: turbine-driveshaft (supported on magnetic bearings)
- Pro Green – safe for the environment
  - Entire machine is inside housing
- No visible movement (except to rotate towards wind) – military
- Cheap power – provides $0.12/kWh
- Should be capable of 10kW output
- Generating equipment at ground level

http://www.alternative-energy-news.info/bladeless-wind-turbine-inspired-by-nikola-tesla/

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