Wind Turbine Design

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Why Wind?

- Reduces water consumption
- Reduces production of CO2
  - median value of between 12 and 11 (gCO_2eq/kWh) (IPCC)
    - Comparable to nuclear and
    - hydropower
- Does not produce a significant amount of sulfur dioxide, mercury, etc.

Table 2.
Water consumption of conventional power plant and renewable energy based sources [21] and [22].

Technology	gal/kWh	l/kWh
Nuclear	0.62	2.30
Coal	0.49	1.90
Oil	0.43	1.60
Combined cycle gas	0.25	0.95
Wind	0.001	0.004
Solar	0.030	0.110

Table options

[1]

Wind Power Statistics

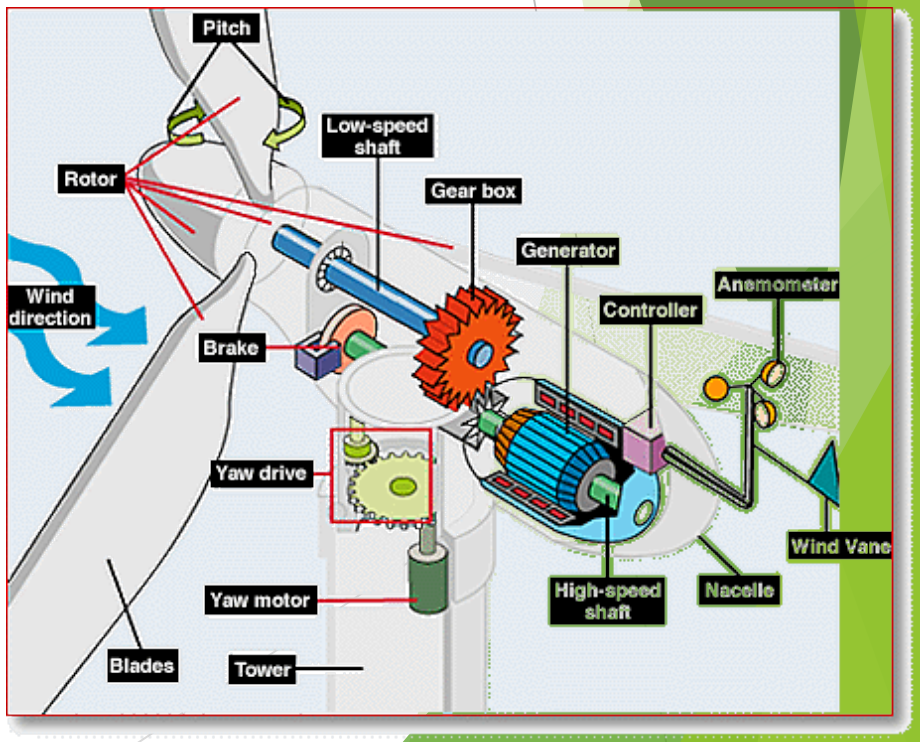
- Wind energy produced in United States: 16,000,000,000 kWh per year (enough for 1.6 million homes)
- Wind farms generate 17-39 times more power than they consume
- Yearly emissions saved from 1MW of wind vs conventional sources:
  - 1,500 tons carbon dioxide
  - 6.5 tons sulfur dioxide
  - 3.2 tons nitrogen oxide
  - 60 pounds mercury
- Installed cost of wind energy: 2-6 cents/kWh

Basics of Energy Production

- Blades lift and rotate as wind passes over them (30rpm)
- Gear box converts low rpm of blades to higher rpm needed for generator
- Induction generator produces 60 Hz AC
- Controllers keep turbine on only

  at winds between 8 and 55 mph
- System keeps turbines oriented at optimal

  position to wind (pitch, yaw)



[4]

Brief History of Design

- 1887 – First windmill for electricity built in Glasgow (144 blades)
- 1931 – First Darrieus (vertical axis) wind turbine
- 1941 – First MW turbine connected and operational
- 1956 – Gedser wind turbine: innovative 3 blade design
- 1970s to 1980s – United States/NASA research and develop large commercial turbines

Horizontal Axis Image

[6]

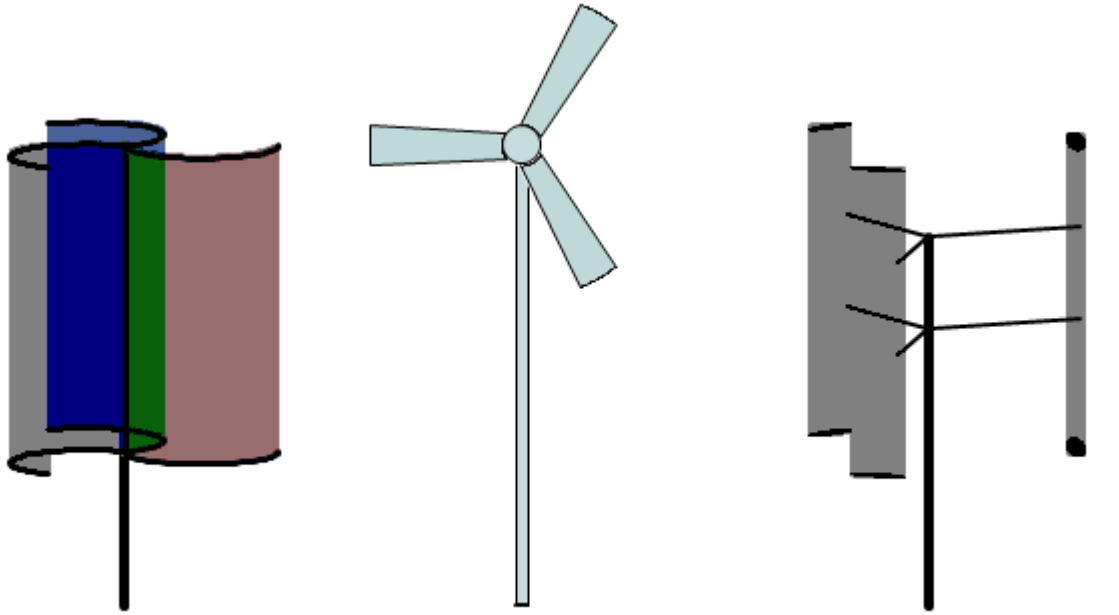
[7]

Horizontal Axis

- Axis runs parallel to ground
- All major big wind companies use horizontal axis
- High efficiency through aerodynamic blades (high power from low wind)
- Typically require annual average wind speeds of ~11mph
- Range from 60 to 90m tall, blades from 20 to 40m.
- Tower height continues to increase, generating more power
- Requires sensors to calibrate wind direction

Vertical Axis Image

[7]



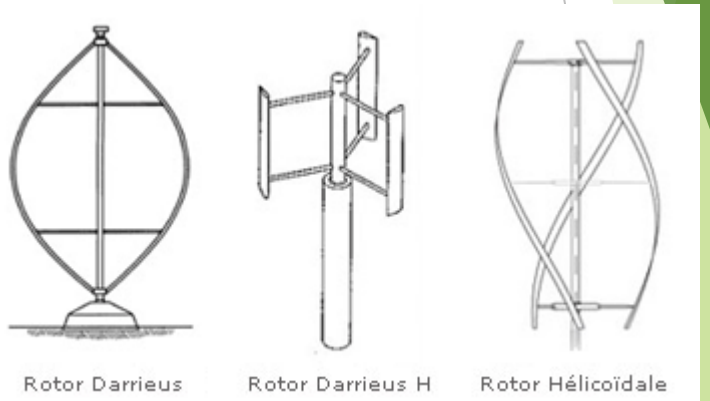
http://celloexpressions.com/ts/dynamic-documentation/intro/

Vertical Axis

- Axis of spin perpendicular to ground
- Primarily for residential applications or other small wind usages
- Captures wind from any direction
- Can work well under intense wind speeds
- Easier to maintain
- Less efficient than horizontal

Darrieus

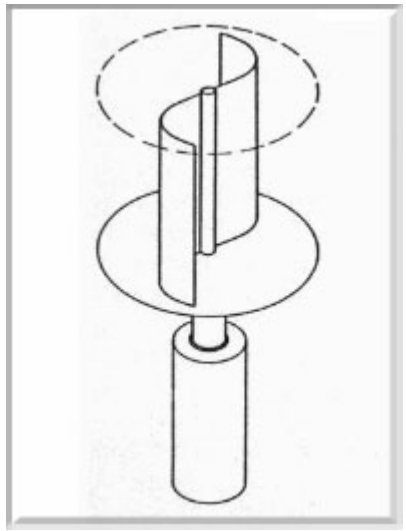
- Curved aerofoil blades mounted on vertical rotating shaft
- Works by adding wind to already spinning blades
- Good efficiency comparative to other vertical axis
- High stress due to moving masses far away from center
- Require mechanical brakes
- Angle of attack issues
- Cannot be self-started easily



[8]

Savonius

- Consists of curved aerofoils in scoop shapes
- Utilizes drag
- More reliable than Darrieus wind turbines
- Less efficient
- Three or more scoops is self starting



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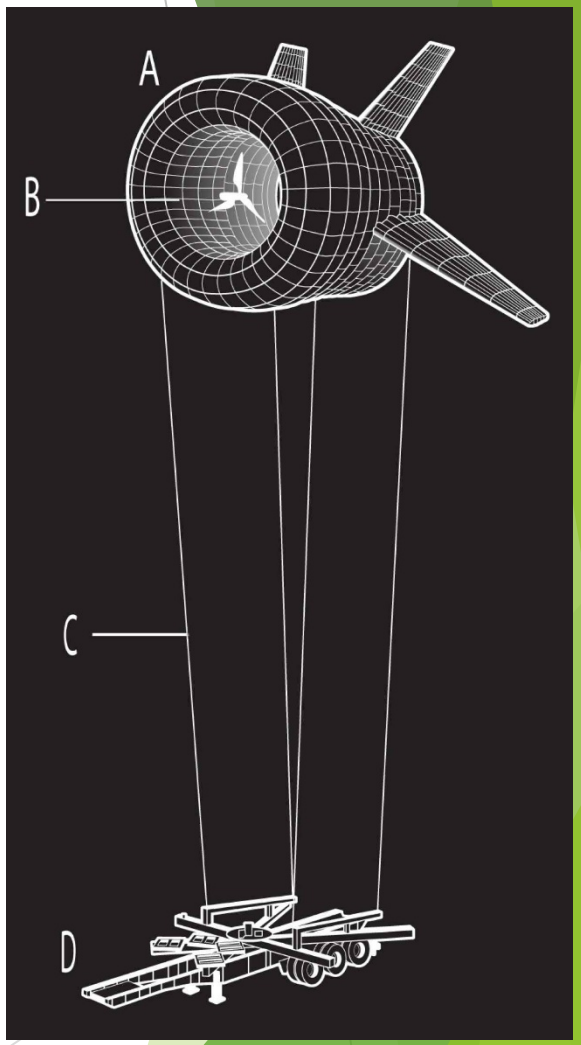
High Altitude Wind Power

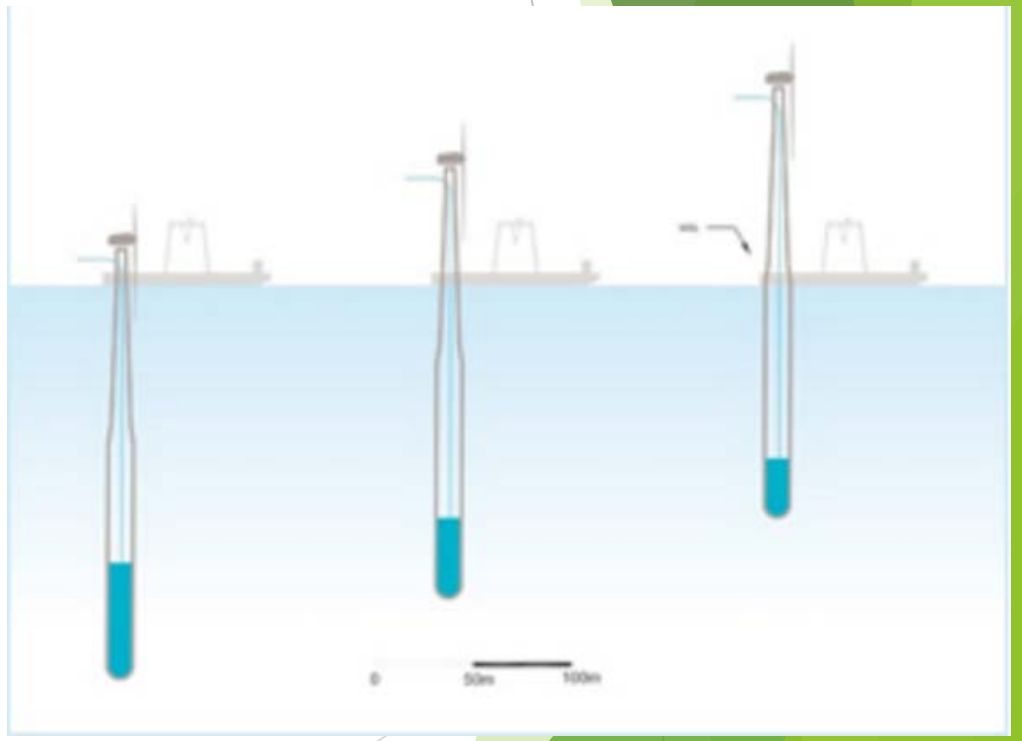
- Proposed technologies for harnessing wind at high altitudes
- Wind velocity increases with altitude
- Methods of collection: kites, gliders, blimps, kytoons
- Problems/risks: lightning, air traffic, electrical safety, tethering/mooring



[10]

Floating Wind Turbine

- Offshore floating turbine structure
- Able to be mounted far from shore
- Stronger winds away from shoreline due to topography
- Reduces visual pollution



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