Wind power forum: Introductory talk

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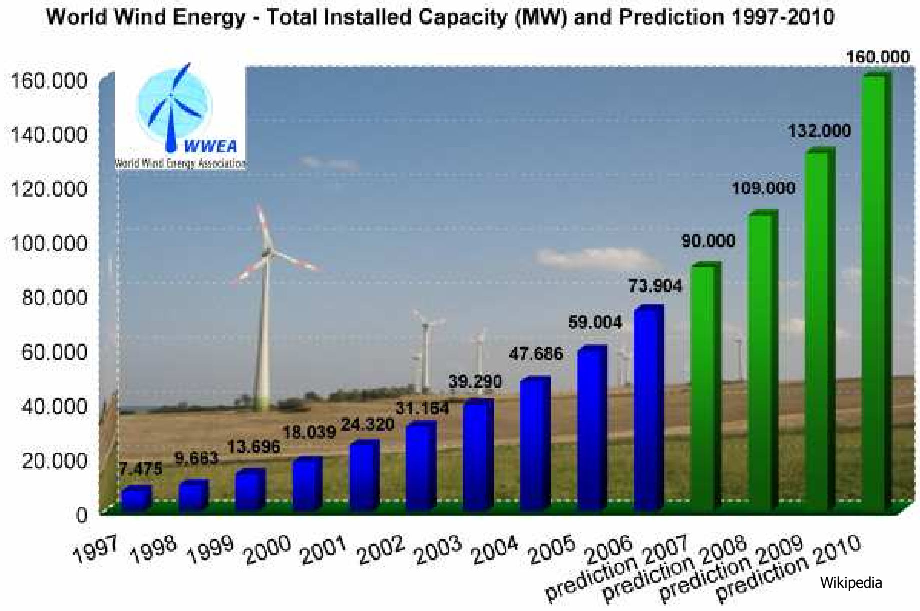
Wind power growth



Growth

- Growing at around 30% per year,
  but produces < 1% of word's electricity
- Countries with highest installed capacities:
  Germany (21 GW), Spain (12 GW),
  USA (12 GW), India (6 GW), Denmark (3 GW)
- Countries with highest fractional capacities:
- Denmark (18%), Spain (9%),Germany (7%)

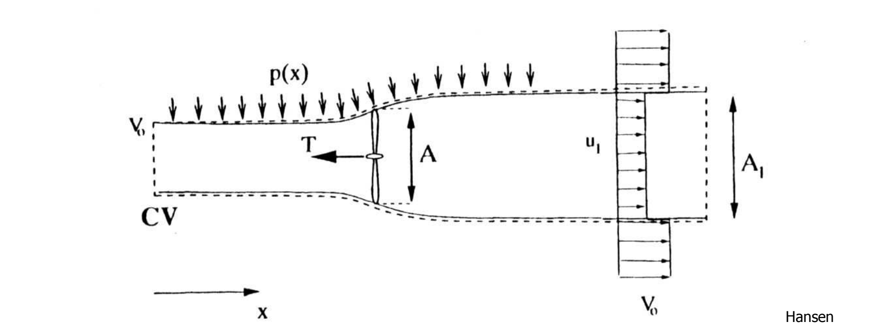
Cost

- 2004 cost is 1/5 of 1980s cost
- Electricity cost (USA) :
  Wind: $56/MWh vs. Fossil: $53/MWh
- Electricity cost (UK) :
  Wind: £30-40/MWh vs. New coal:
  £25-45/MWh vs. New nuclear: £40-70/MWh
- Installation cost: $1600/kw

Elementary wind turbine theory

Wind energy is kinetic energy per unit mass
The turbine slows the flow down

$$P = \dot{m} \times KE = \rho V A_{stream} \times \frac{V^2}{2} = C_p A_{rotor} \times \rho \frac{V^3}{2}$$



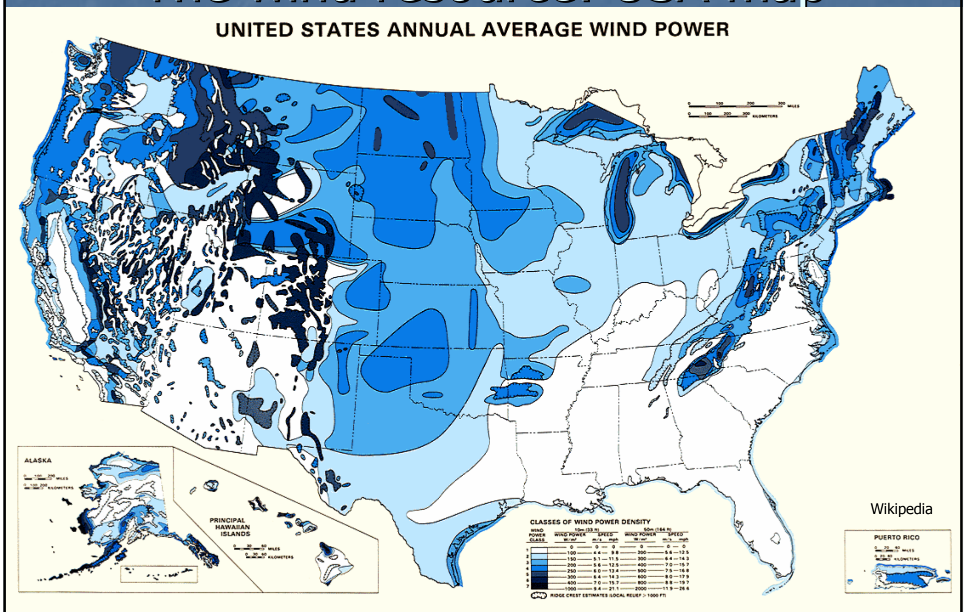
The Betz limit: *Cpmax* = 16/27 = 0.5926

The Betz limit

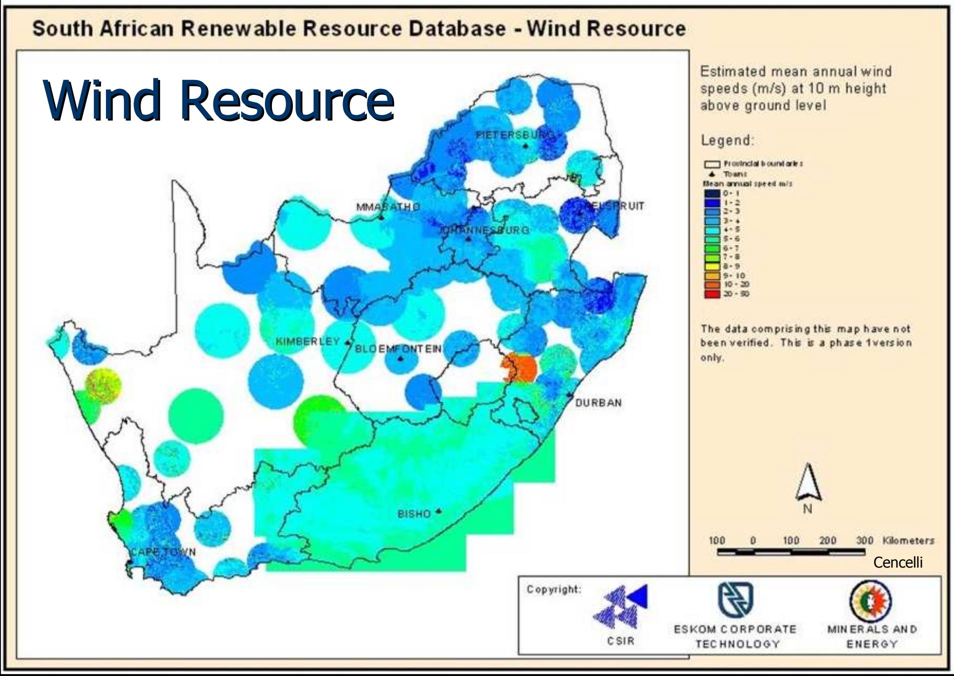
Flow and pressure drop for maximum power:

- It occurs when the wake velocity is:
  1/3 of the wind velocity
- The exit KE/unit mass in the wake is then:
  1/9 of the upstream value
- Velocity through the turbine is the average value:
  $(1 + 1/3)/2 = 2/3$ of upstream value
- The upstream flow area is then:
  2/3 of the turbine disc flow area
- Fraction of power extracted is:
  $2/3 \times (1-1/9) = 2/3 \times 8/9 = 16/27 = 0.5926$

The wind resource: USA map



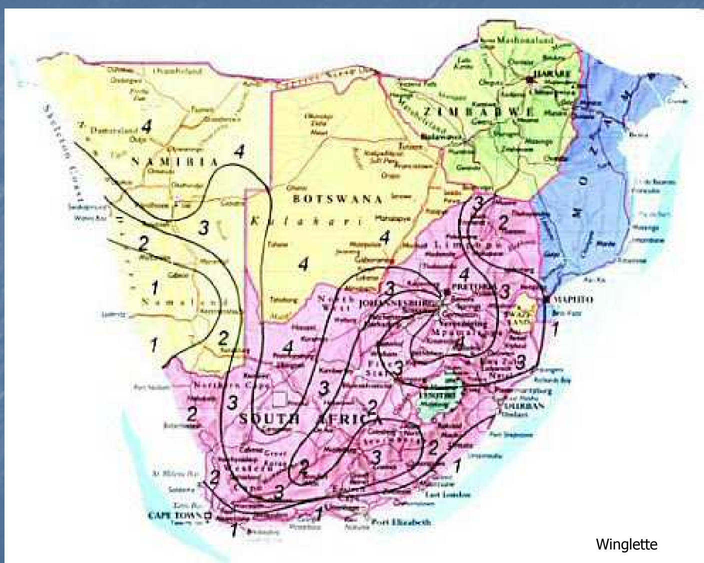
Wind Resource



Map of wind power zones

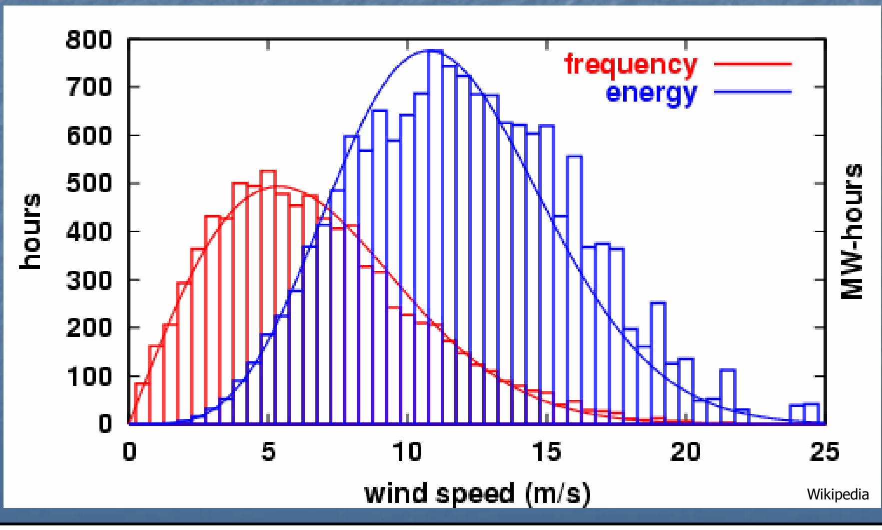
Power production Of 3 kW Winglette wind turbine at 18 m rotor height

Zone	Power (kWh/day)
1.	26.6
2.	16.2
3.	12.0
4.	10.2

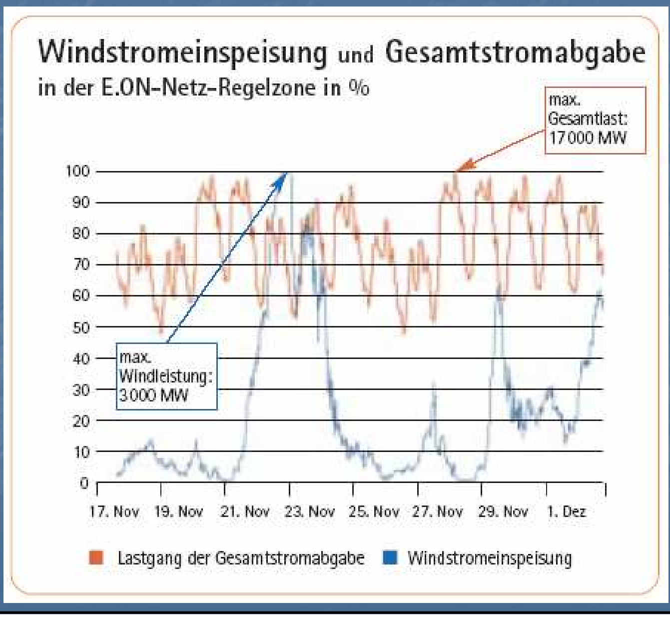


Typical wind time and energy frequency distributions

The wind blows wherever it pleases. (John 3:8)



Intermittency and variability



Siting issues

- Average wind strength:
  > 16 km/h (4.5 m/s)
- Wind steadiness and availability
- Proximity to users
- Altitude, temperature Topography
- Effect of turbines on each other
- Environmental impact

Onshore, nearshore or offshore

Onshore:

- Micrositing, e.g. on ridge lines
- Aesthetics and tourism
- Ecology, e.g. bird and bat life

Nearshore:

- Up to 3km from coast
- Good wind and high air density

Offshore:

- Turbines almost invisible from land
- Strong, steady winds with high speeds at low heights
- Costs of foundations and grid connection
- Maintenance in marine environment
- American great lakes

Large scale wind power

- Theoretical potential 40 times world's current electricity use
- By 2010 160 GW expected to be installed
- China: 30 GW by 2020
- Germany: 6% → 12%
- Denmark: 20% → 50%
- Feasibility of > 25% is not certain

Small scale wind power

- Wind mills have been used for centuries
- Wind pumps and generators, for decades
- Off-grid turbines require energy storage

Wikipedia

Conceptual design choices

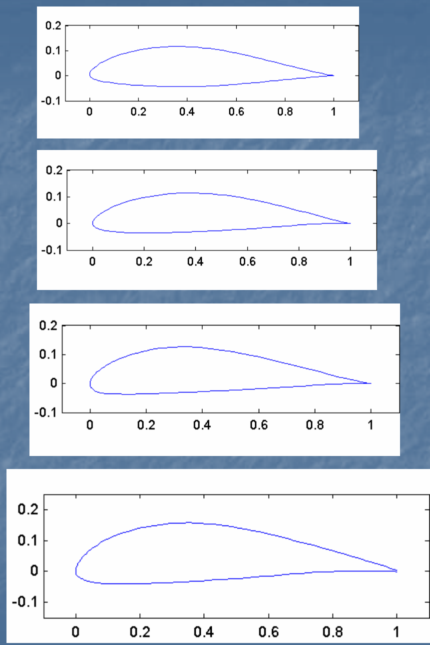
- Type
- Flow area – cost, power intermittency
- Turbine height - wind strength, loading
- Flow deflection – number, width of rotor blades
- Tip speed – noise, generator type

Wikipedia

Blade profiles developed at the Department of M&M Engineering at Stellenbosch by Nicola Cencelli

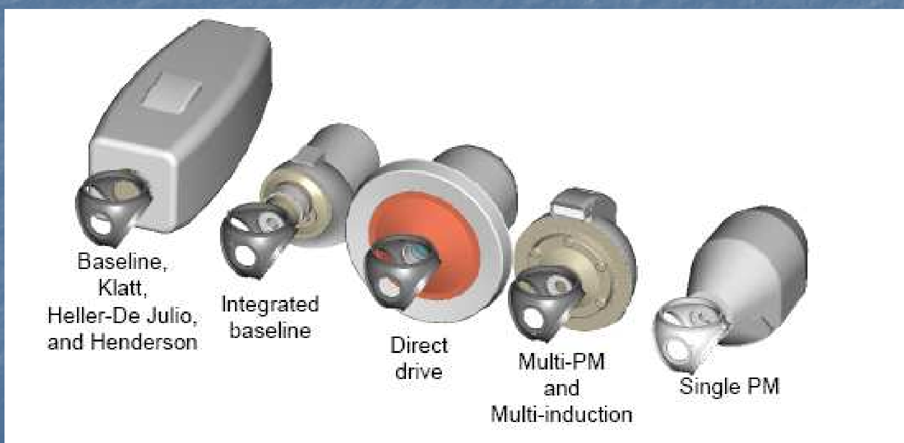
Issues:

Stall at prescribed C_L
Maximum C_L/C_D
Maximum C_L



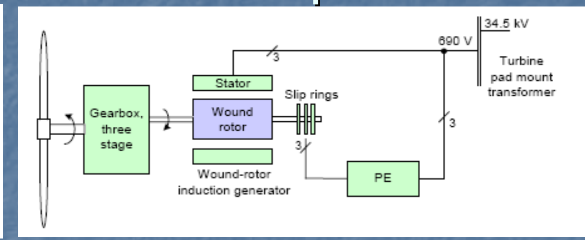
Cencelli

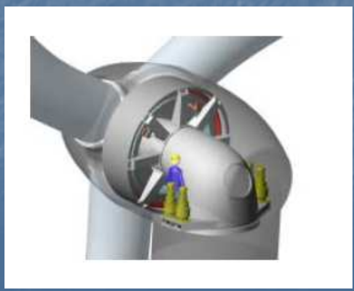
Comparative sizes of drive trains

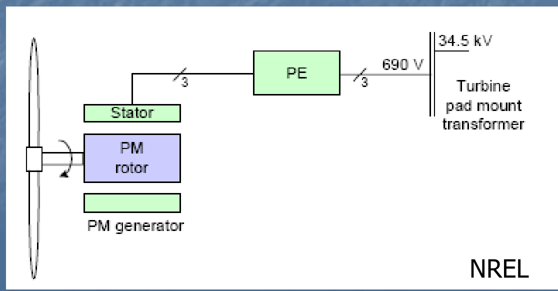


NREL

Power train layout: Prof Maarten Kamper







Feasibility and economics

- Wind energy is often directly subsidised
- Other energy sources are indirectly subsidised, e.g. environmental clean up.
- Capacity factor is relatively low (≈30%)
- Since almost all costs are capital costs, financing determines price of electricity

Ecology and aesthetics

- It uses only a small fraction of the air energy
- Birds are killed, but very few compared to buildings, house cats, traffic and pesticides
- Conventional farming is possible on wind farms, due to wide spacing between turbines
- Modern turbines are quiet (44 dB) or about the same as wind noise at 16 km/h
- Shadow flicker and aircraft warning lights

Pollution

- Electric power is only part of power use
- UN’s IPPC states that pollution mitigation can be more cheaply achieved by improvements in building, manufacturing and transport efficiency
- Wind turbine manufacture and transport require energy and fossil fuels
- Energy return on investment is a factor 20
- No direct long term pollution effects.
  Site use is reversible.

Conclusion

- Wind electrical energy has a role worldwide
- The Western Cape has a target of 15%

  (of 5500 MW) renewable electricity generation by 2015
- Western Cape has a feasible wind resource
- We hope to establish a wind energy research unit at UCT in cooperation with US