Wind energy

Energy Centre summer school in Energy Economics
18-21 February 2019

Kiti Suomalainen
k.suomalainen@auckland.ac.nz
Outline

The resource

The technology

Wind energy in the world

Wind research at the Energy Centre
Wind resource in New Zealand
Historical milestones I

**Middle Ages**
- Iran/Afghanistan (7th/9th century): grinding corn and pumping water
- Middle East, Central Asia, China, India, Sicily (by 1000 AD): seawater pumping for making salt
- North-western Europe (1180s on): grinding flour

**19th century**
- Denmark: 2500 windmills for pumps, mills
- American mid-west: ca 6 million small windmills for irrigation
- Scotland, 1887: Prof James Blyth built the first windmill for production on electricity, used for providing lighting in his holiday cottage
- Ohio, 1888: Charles F. Brush’s 17m rotor diameter wind turbine, 12 kW, used to charge batteries or operate up to 100 (inefficient!) light bulbs
20th century

- 1900-1973: wind generators widespread, but competed against fossil fuel plants and centrally generated electricity
  - USSR, 1931: 100kW, 30m diameter (d)
  - UK, early 1950s: 100kW, 24m (d)
  - Denmark, 1956: 200kW, 24m (d)
  - France, 1963: 1.1MW, 35m (d)
- 1973-onwards: oil price crisis spurred investigation of non-petroleum energy sources
  - USA, 1987: 2.5MW, 97.5m (d)
  - USA, 1981: 3MW horizontal axis, hydraulic transmission instead of yaw drive
  - Canada, 1984: 4MW Darrieus wind turbine
  - Large turbines constructed with 1, 2 or 3 blades (prototypes)
  - Smaller, often simpler turbines available for commercial sale
Modern wind turbines

The Danish concept:
• 3-bladed, stall-regulated rotor, fixed speed became dominant model in 1980s, less than 200kW rated power

More recent developments:
• 2-3MW(3-8MW)/97-117m(112-164m) diameter onshore (offshore)
• Rotor speed: Fixed speed / Variable speed
• Blade control: Full-span control of the blades (pitch regulated)
• Advanced materials: blades lighter -> can be made longer
• Drive train: Direct-drive concept vs. gearbox + high speed generator
Offshore technologies

Main issues for offshore wind power
- Going deeper, farther from coast – foundations & interconnections
- Reliability – high cost of maintenance!
- Need for mainstreaming installation processes (currently few specialised vessels)

Existing foundation types

Emerging foundation solutions

Breakdown of offshore O&M costs and downtime per component, 2011

- Other wind farm
- Other turbine
- Support structure (inc. tower)
- Array cable
- Blades
- Generator (HS)
- Gearbox and main shaft
- Hub and pitch system
- Turbine electrical
Hywind Scotland: world’s first floating wind farm
World’s largest wind farms

The London Array (630 MW)
World’s largest offshore wind farm, 20km off the coast of Kent and Essex, England (right, both)

The Gansu Wind Farm Project (6000 MW).
The project is one of six national wind power megaprojects approved by the Chinese government. It is expected to grow to 20,000 MW by 2020 (below)
World’s largest wind farm

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Wind turbine costs

Total installed cost reduction

## LCoE of wind

### Wind Power Onshore

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<th>Region</th>
<th>Levelised Cost of Energy → USD/kWh</th>
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Source: REN21, 2018
Wind energy in the world

Asia was the largest regional market for wind power for the ninth consecutive year.

Source: REN21, 2018
Offshore wind energy in the world

Gigawatts

- North America
- Asia
- Europe

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Wind power in the electricity mix

Source: Berkeley Lab estimates based on data from Navigant, EIA, and elsewhere
Wind research at the Energy Centre: Wind, hydro and demand correlation

New Zealand's electricity prices are quite vulnerable to the natural fluctuations of hydro power availability.

The system must rely on other, generally more expensive, energy sources.

Can wind help?

Existing and potential wind development sites

SI hydro

NI hydro
Wind-hydro correlation

SI wind & SI hydro storage

SI wind & NI hydro storage

NI wind & SI hydro storage

NI wind & NI hydro storage
Wind-demand correlation

STH1

NTH3

Seasonal pattern

Existing and potential wind development sites
Wind and hydro correlations with demand and prices

- Well-suited during months of low SI hydro
- Suitable for balancing SI hydro in general
- Well correlated with NI demand (& NTHs, CNIs with prices!)
‘The old “Chance”, as man of war, merchantman, and whaler, for over one hundred years. In her last resting place. Bluff. N.S. 1902.’