Wind energy

Energy Centre summer school in Energy Economics

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THE UNIVERSITY OF AUCKLAND
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Outline

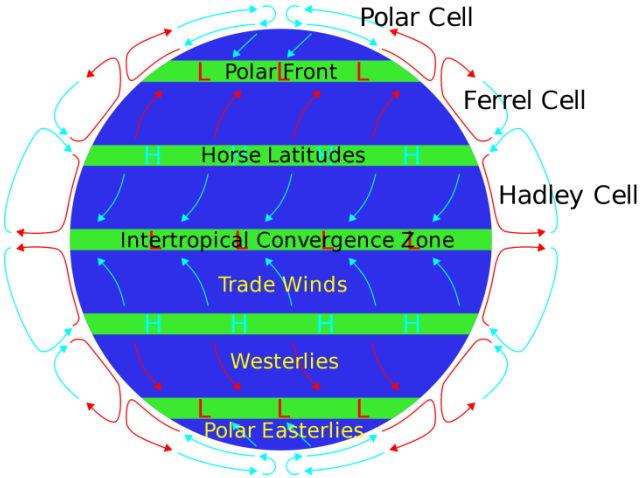
The resource

The technology

Wind energy in the world

Research at the Energy Centre

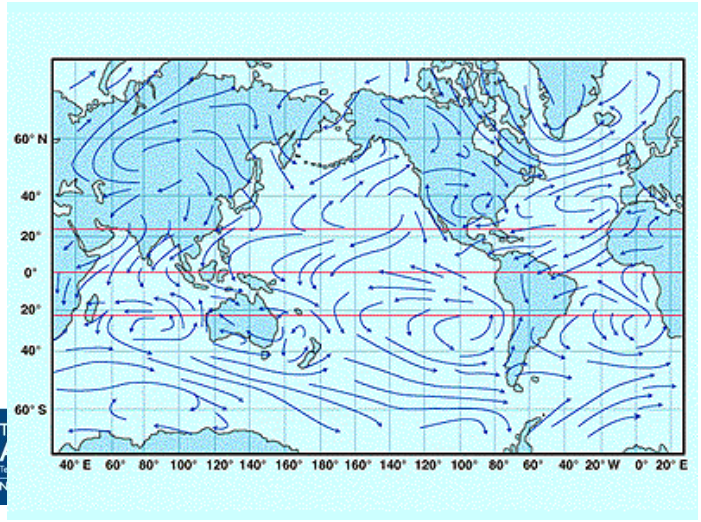
The source of wind



Wind is caused by the uneven heating of the Earth's surface by solar radiation.

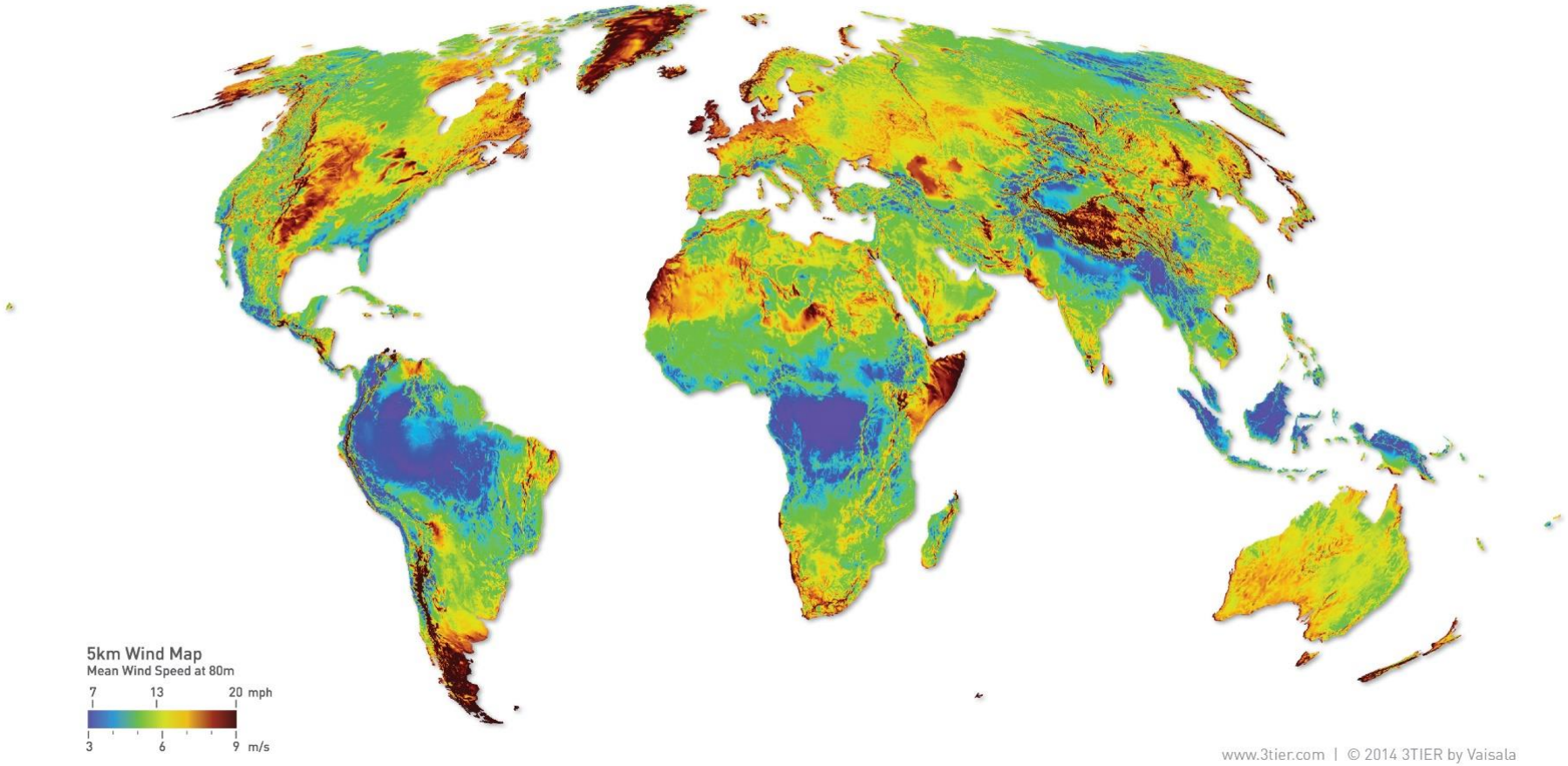
Depends on:

- Latitude
- Season (summer, winter)
- Time of day (day, night)
- Type of surface (sea, land)
- Presence of clouds

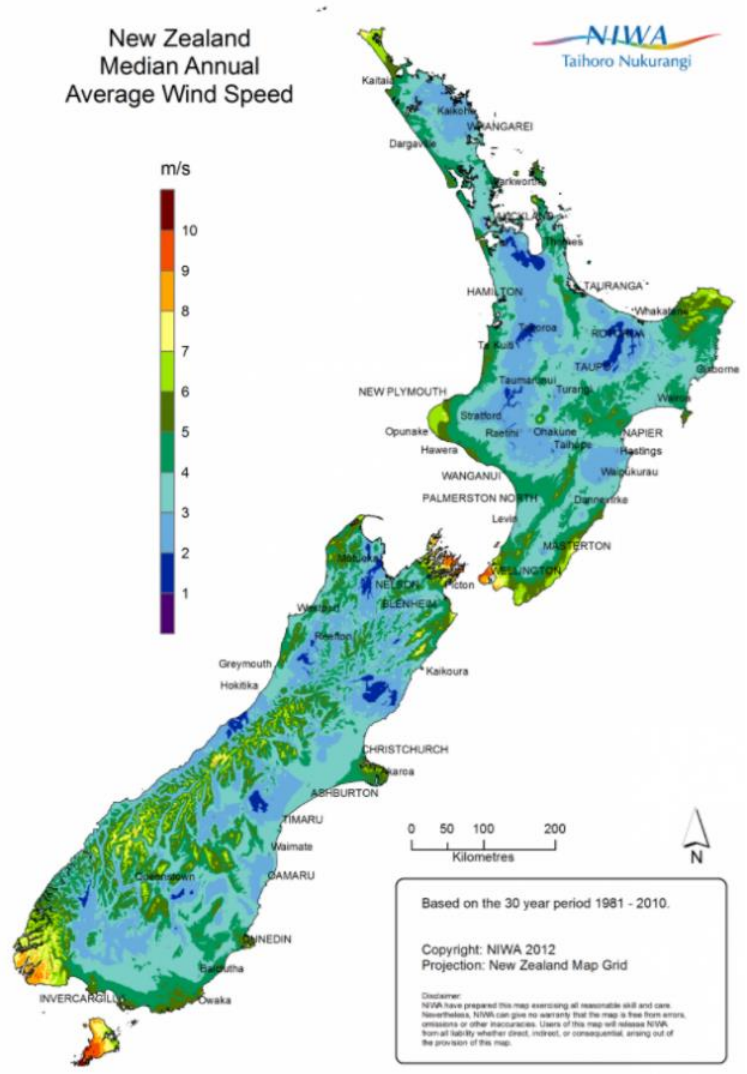


Large-scale modifications to the global wind patterns caused by continents and large islands.

Global Mean Wind Speed at 80m



Wind resource in New Zealand



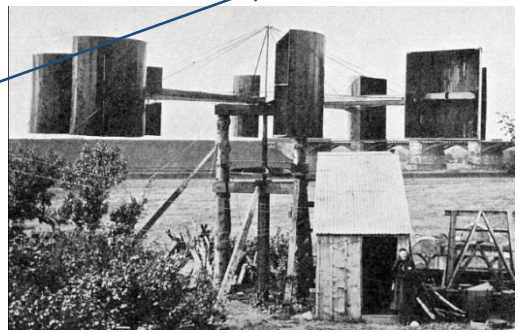
Historical milestones I

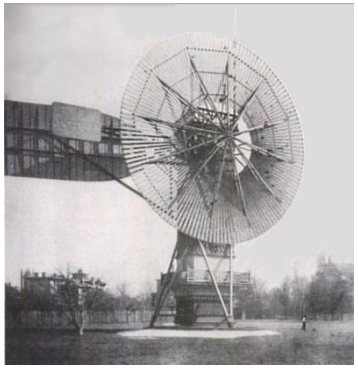
<u>Middle Ages</u>

- 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

<u>19th century</u>

- 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

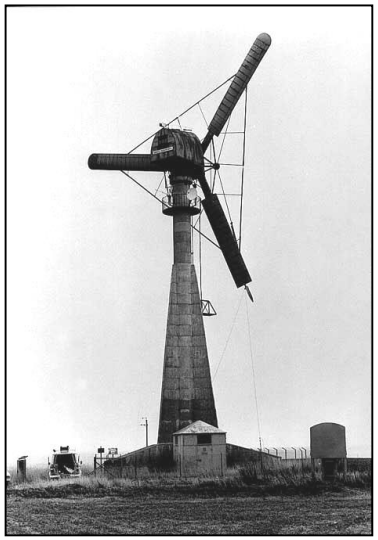




Historical milestones II

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



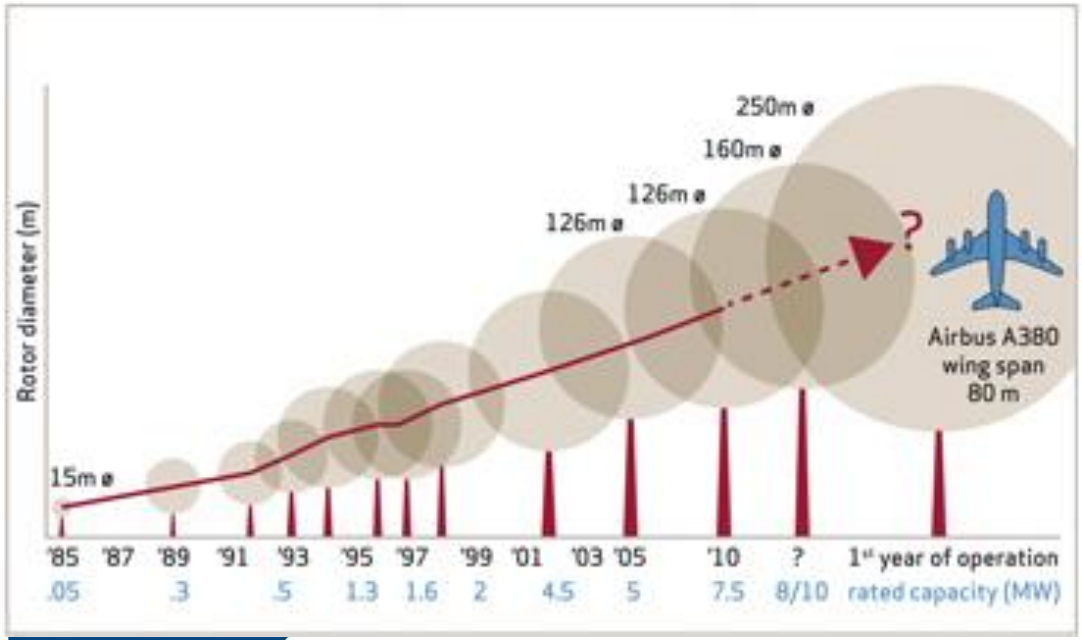
Modern wind turbines

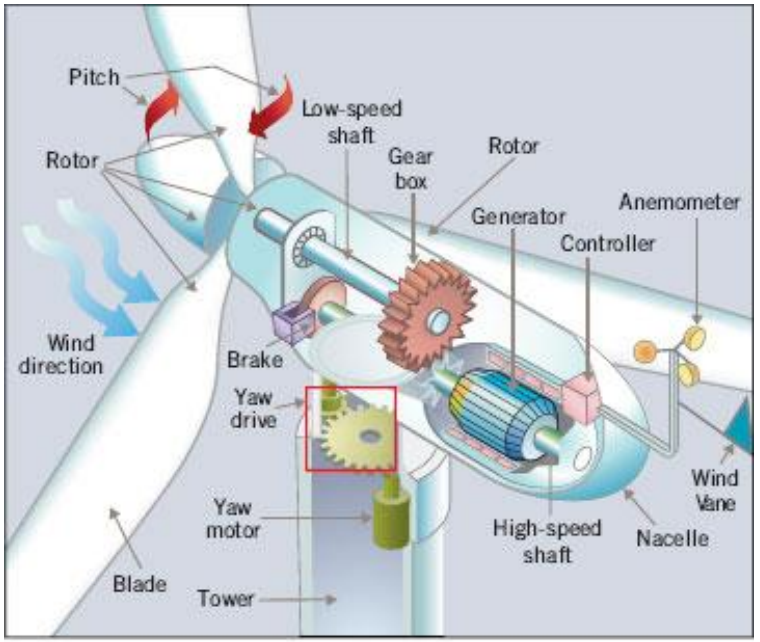
The Danish concept:

- 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

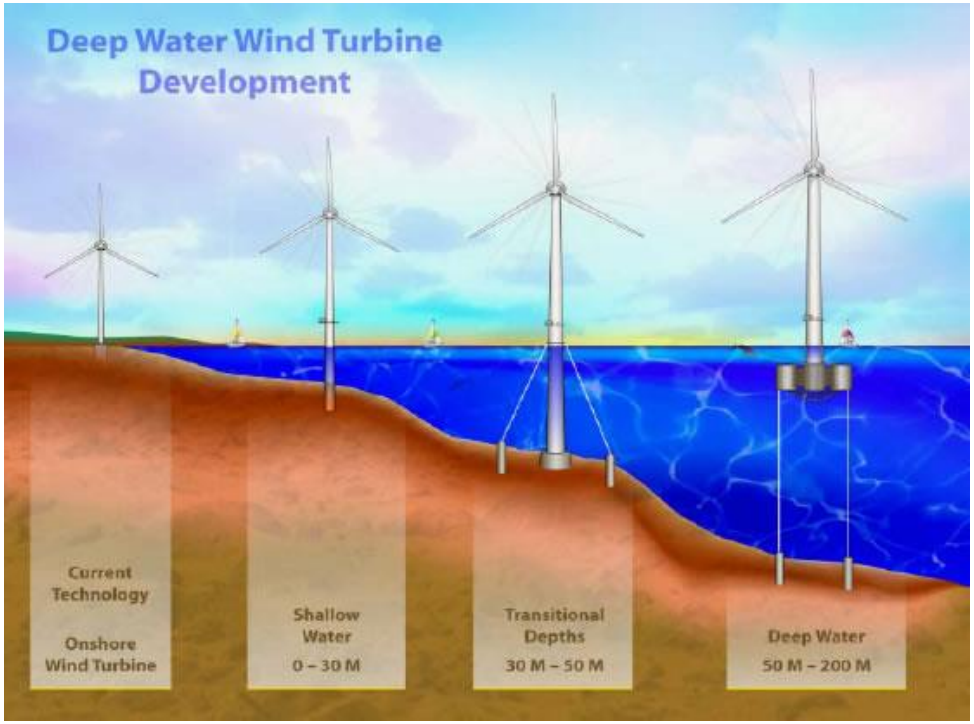


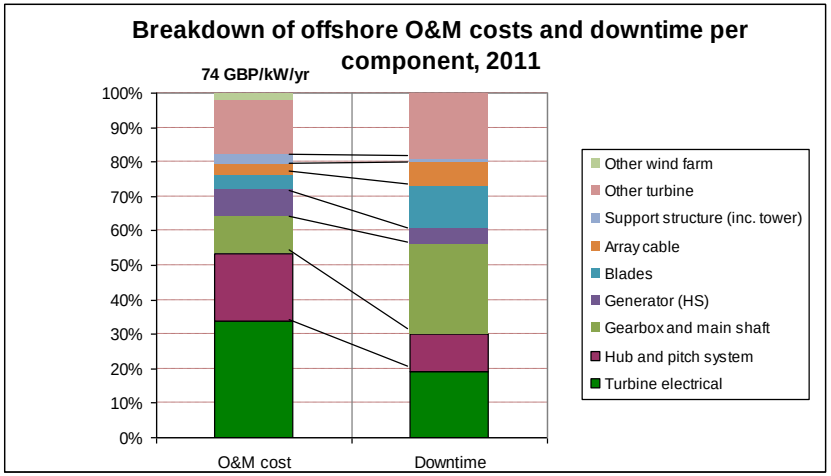


Offshore technologies

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)





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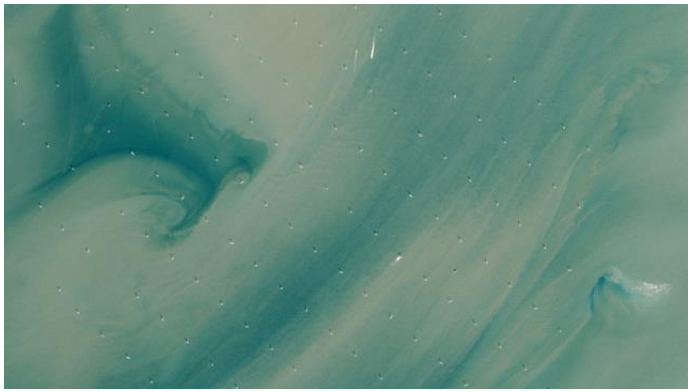
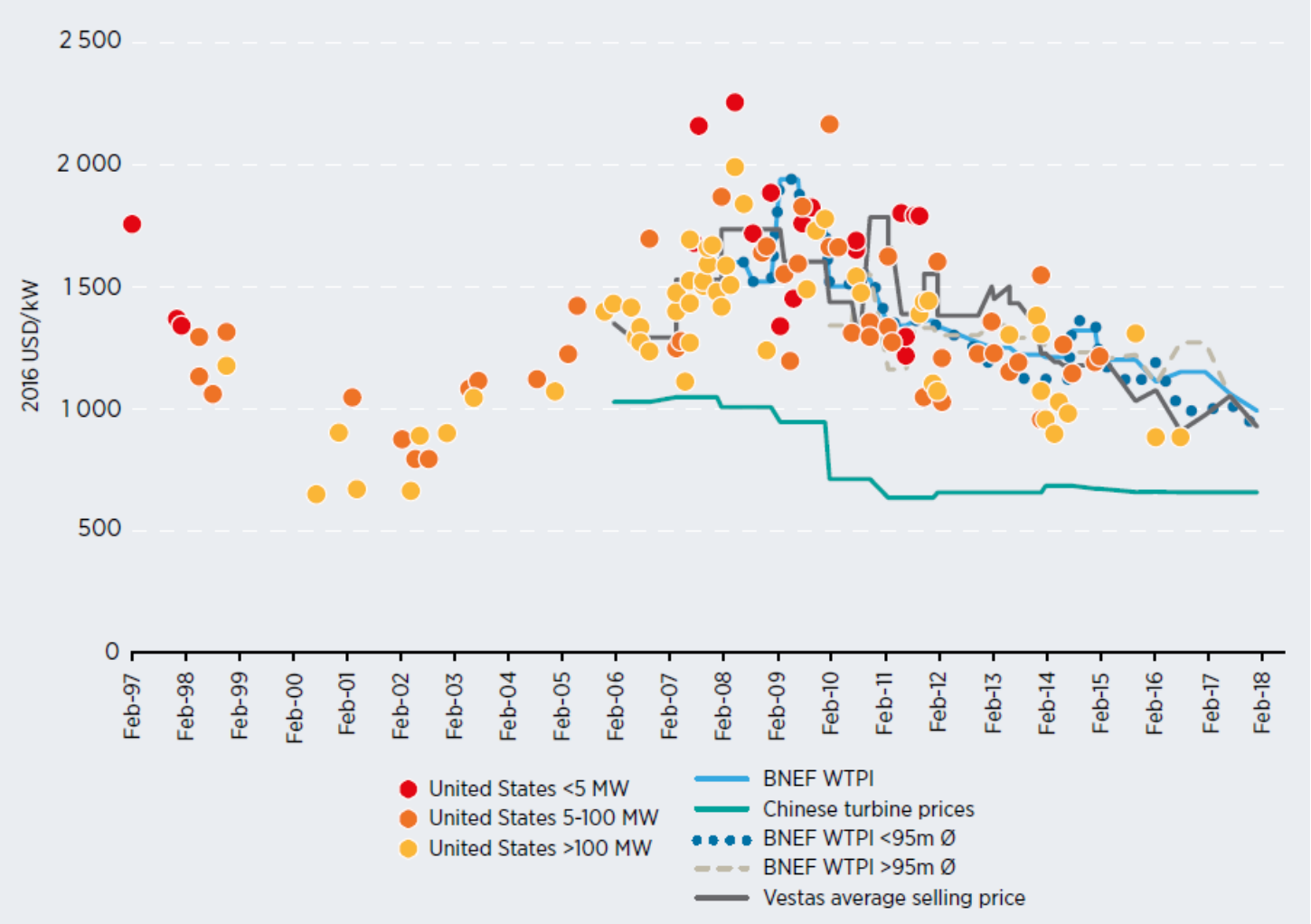
World’s largest wind farms

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)

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



Wind turbine costs

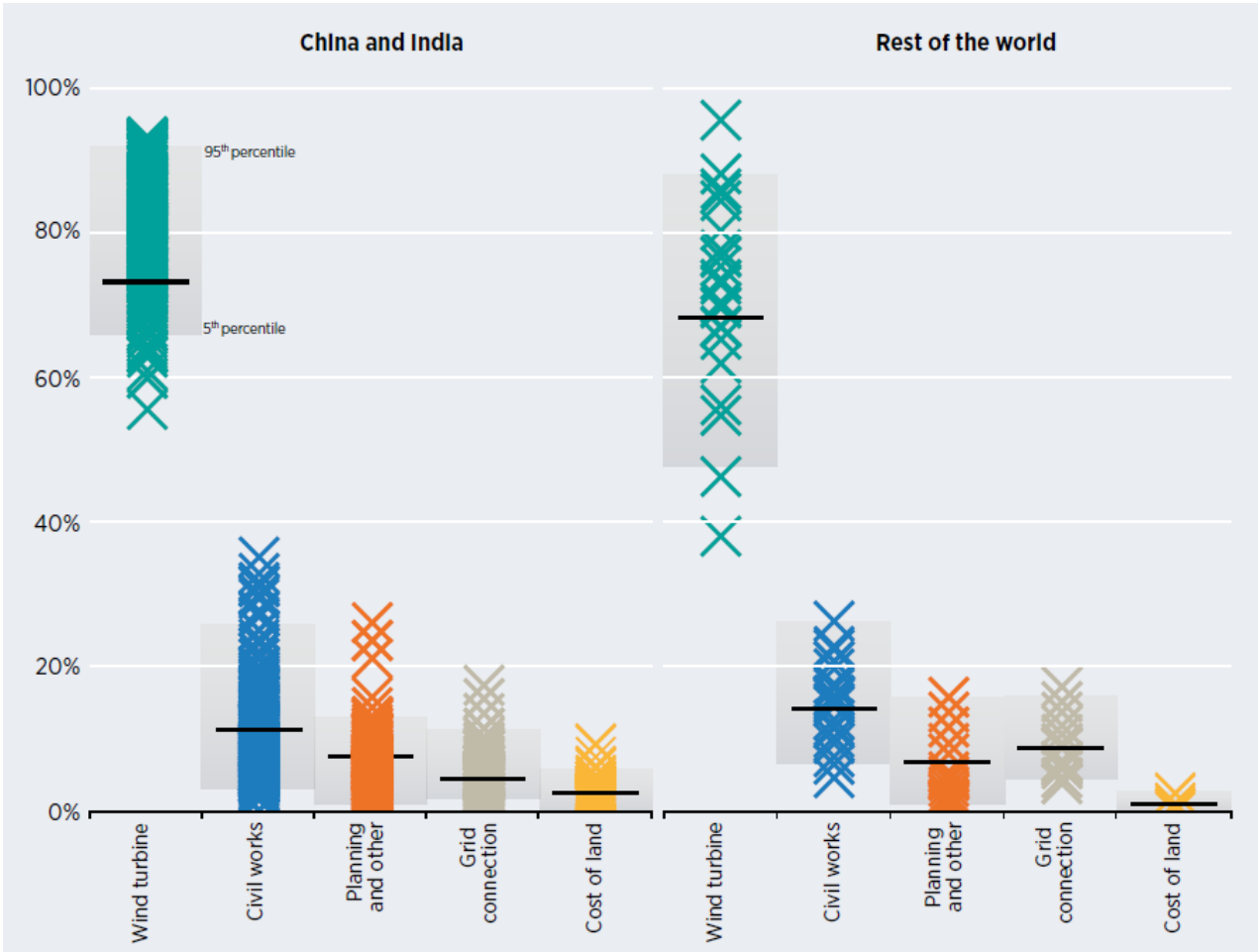


Source: IRENA, 2017.

Total installed cost reduction

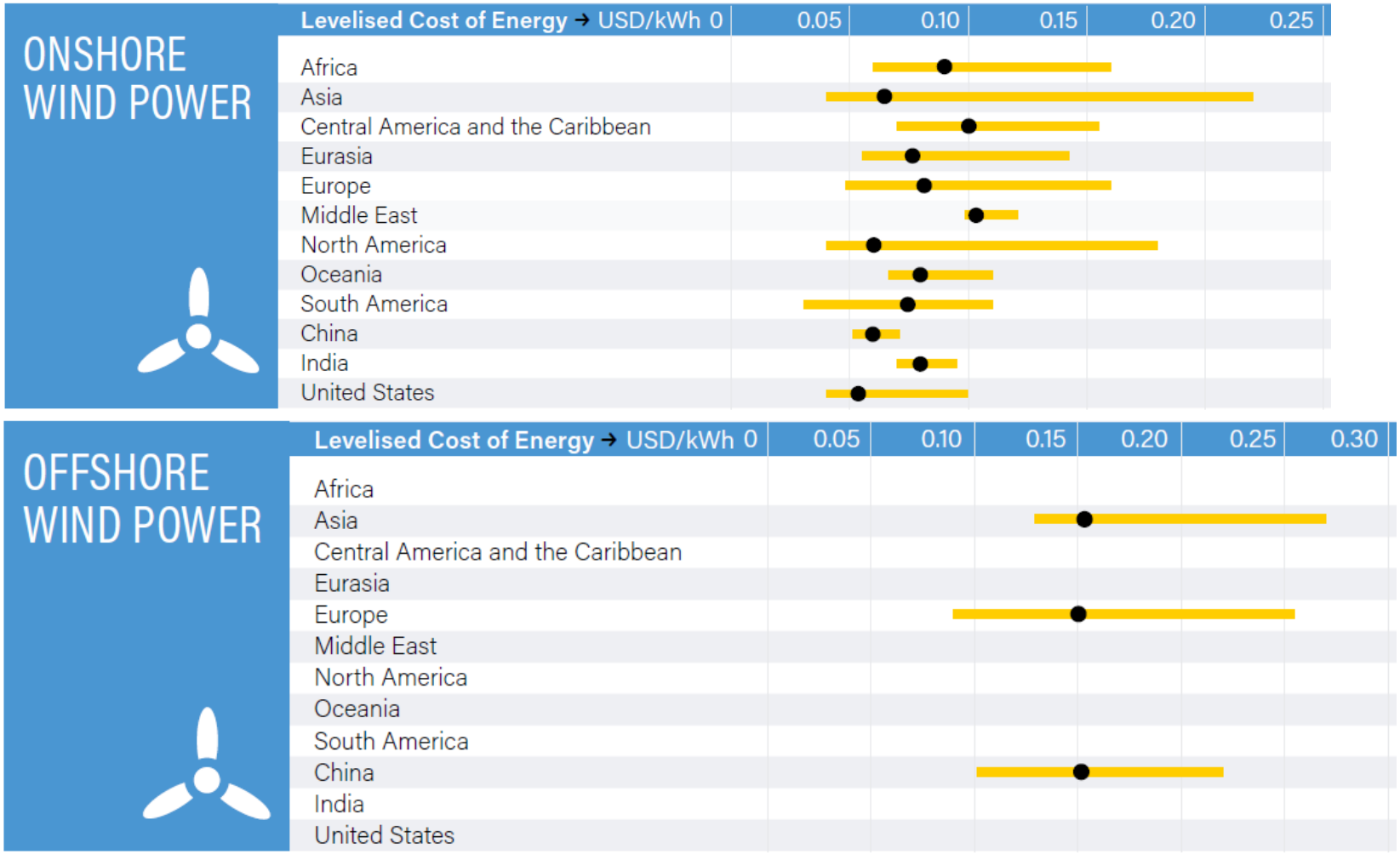
Source: IRENA, 2017.

Average share of onshore wind total installed costs



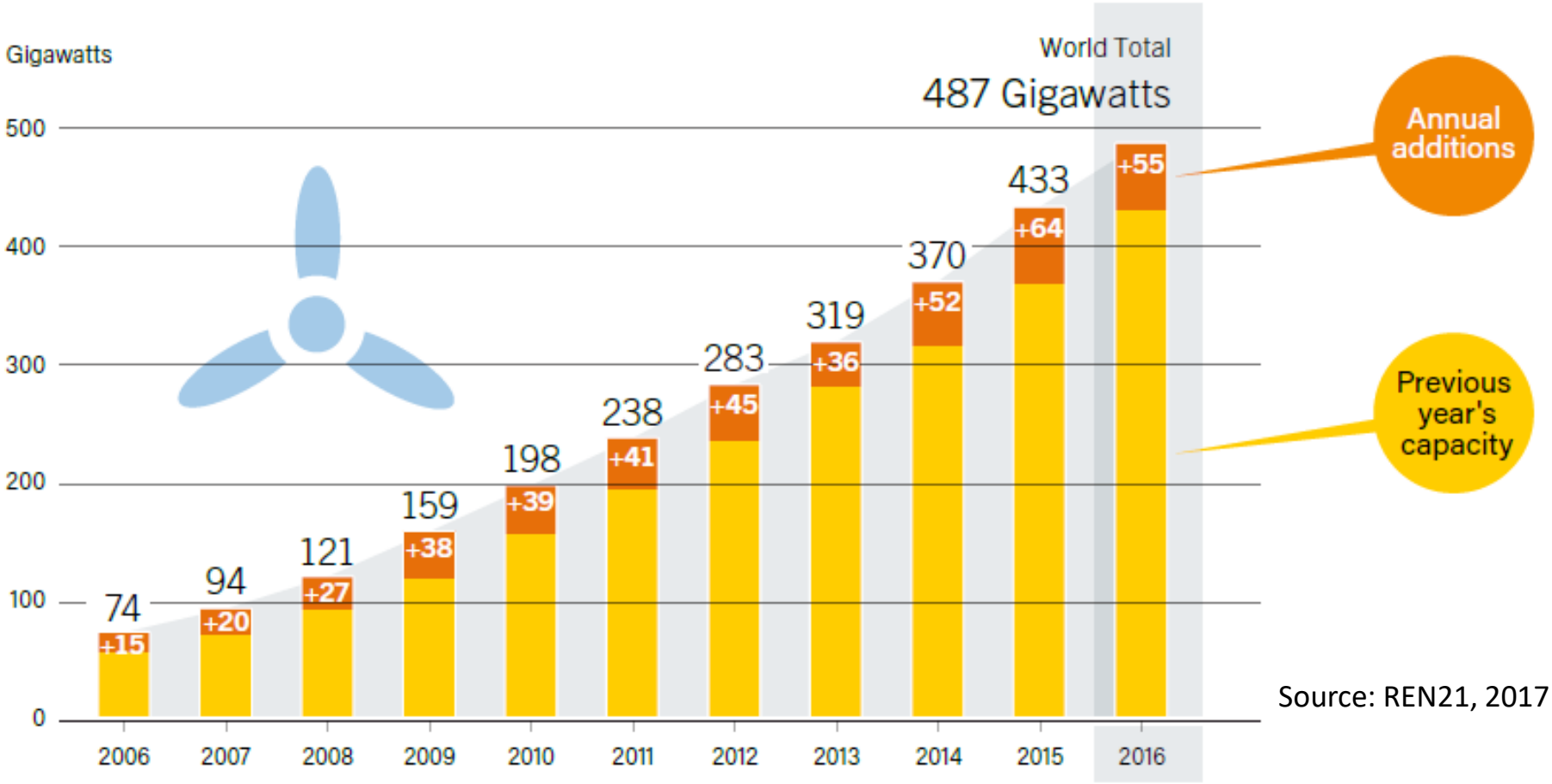
Source: IRENA, 2017.

LCoE of wind



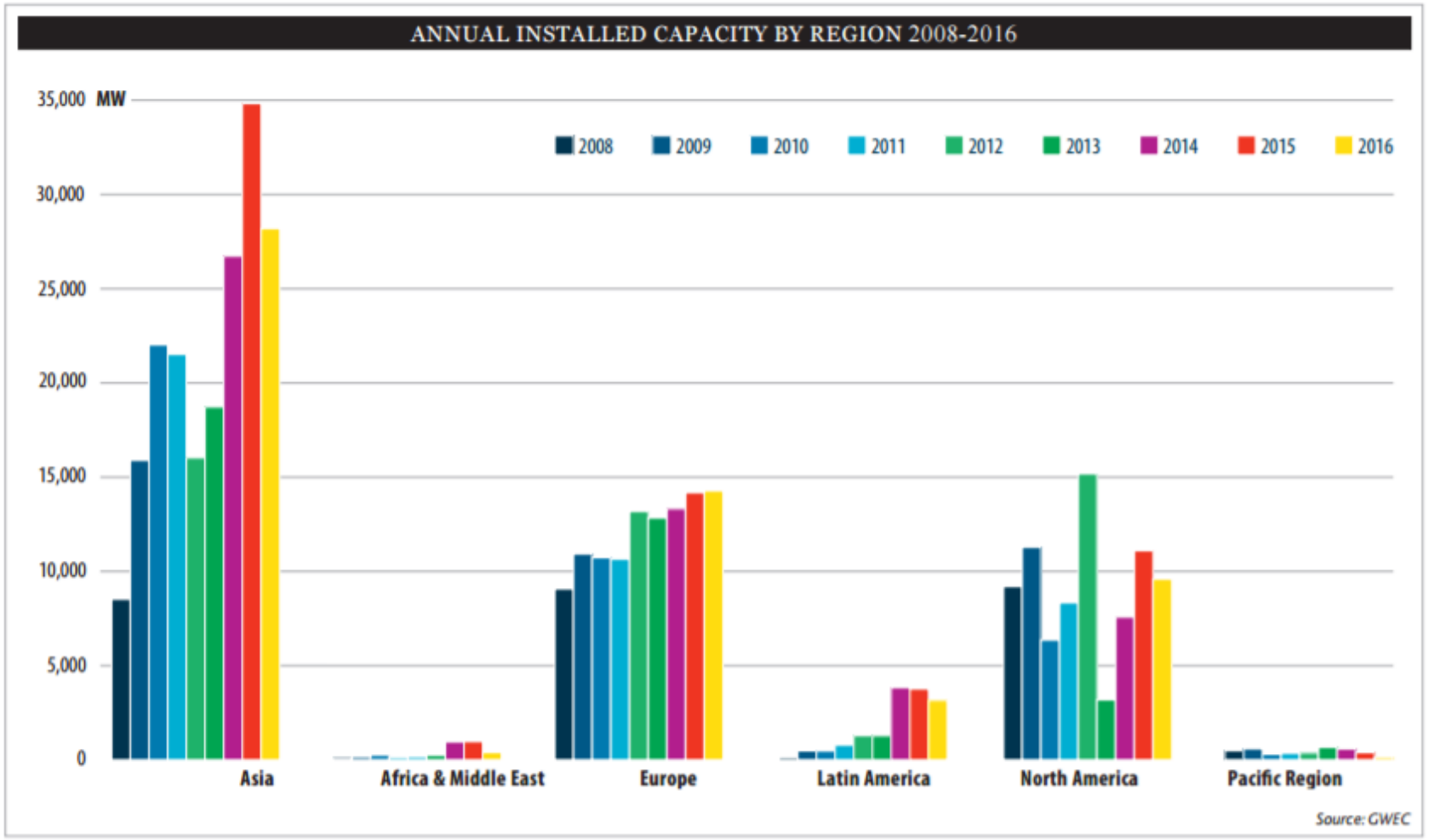
Source: REN21, 2017

Wind energy in the world

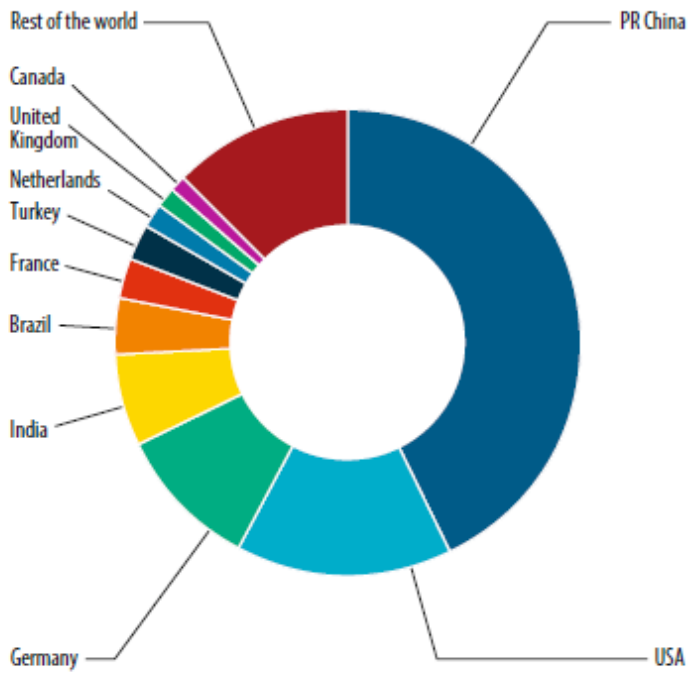


Source: REN21, 2017

Wind energy by region



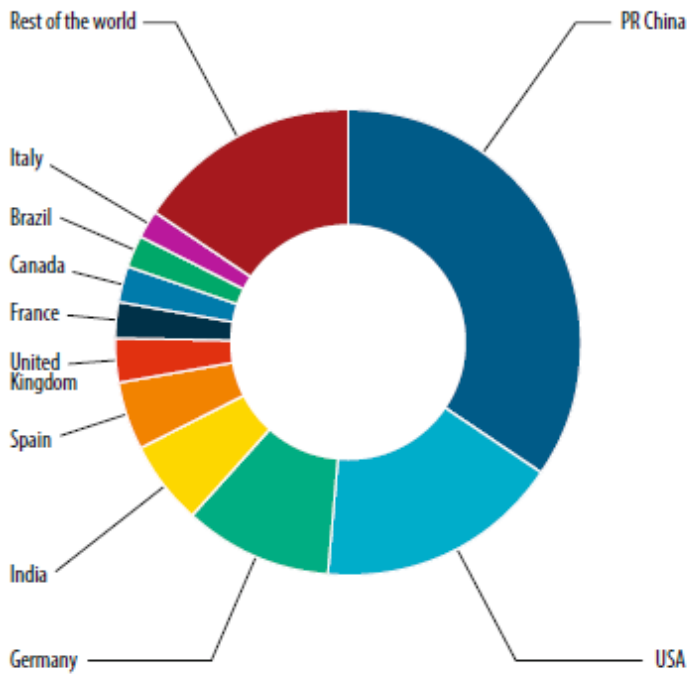
TOP 10 NEW INSTALLED CAPACITY JAN-DEC 2016



Country	MW	% Share
PR China	23,370	42.8
USA	8,203	15.0
Germany	5,443	10.0
India	3,612	6.6
Brazil*	2,014	3.7
France	1,561	2.9
Turkey	1,387	2.5
Netherlands	887	1.6
United Kingdom	736	1.3
Canada	702	1.3
Rest of the world	6,727	12.3
Total TOP 10	**47,915**	**88**
World Total	**54,642**	**100**

Source: GWEC

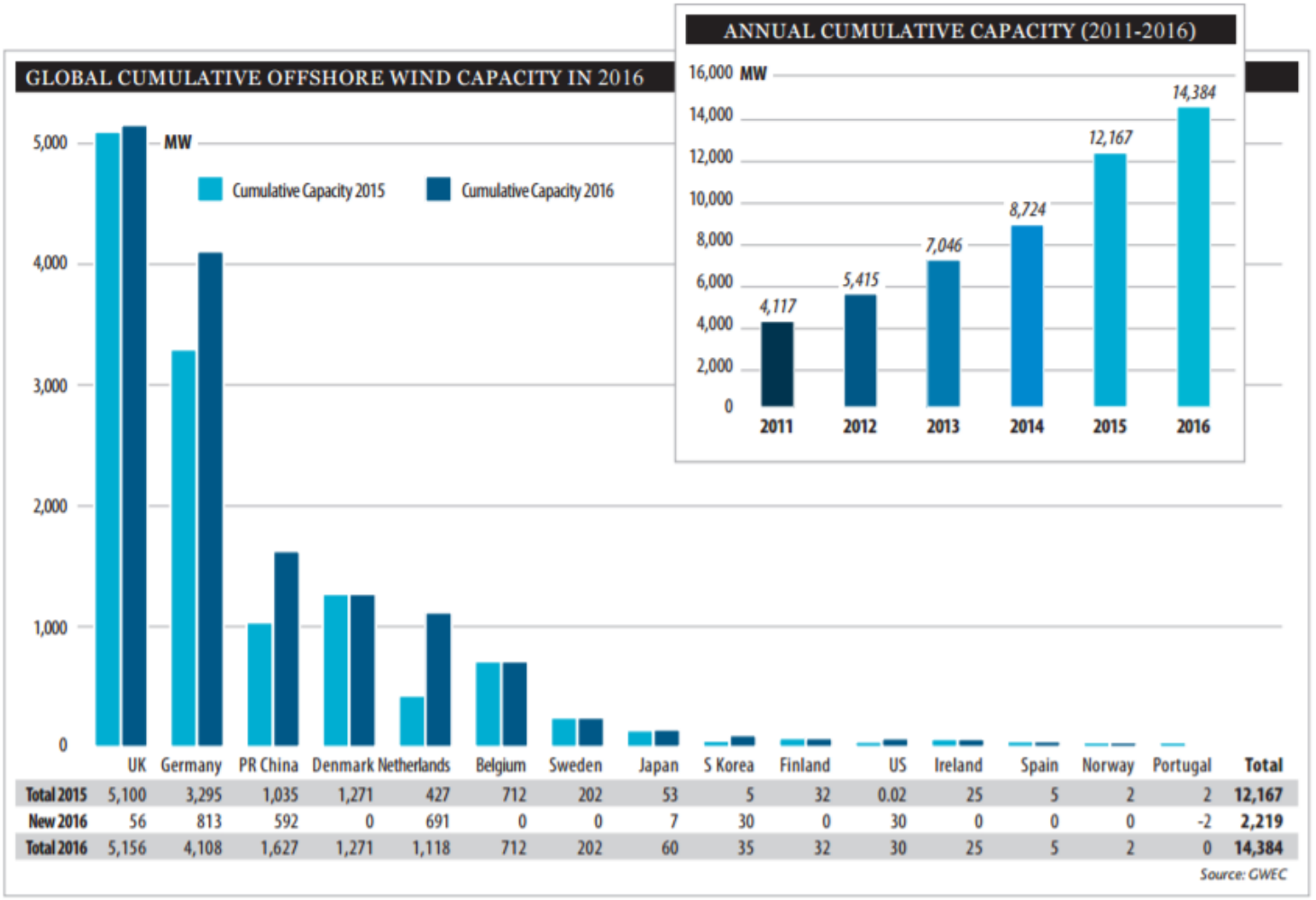
TOP 10 CUMULATIVE CAPACITY DEC 2016



Country	MW	% Share
PR China	168,732	34.7
USA	82,184	16.9
Germany	50,018	10.3
India	28,700	5.9
Spain	23,074	4.7
United Kingdom	14,543	3.0
France	12,066	2.5
Canada	11,900	2.4
Brazil*	10,740	2.2
Italy	9,257	1.9
Rest of the world	75,576	15.5
Total TOP 10	**411,214**	**84**
World Total	**486,790**	**100**

Source: GWEC

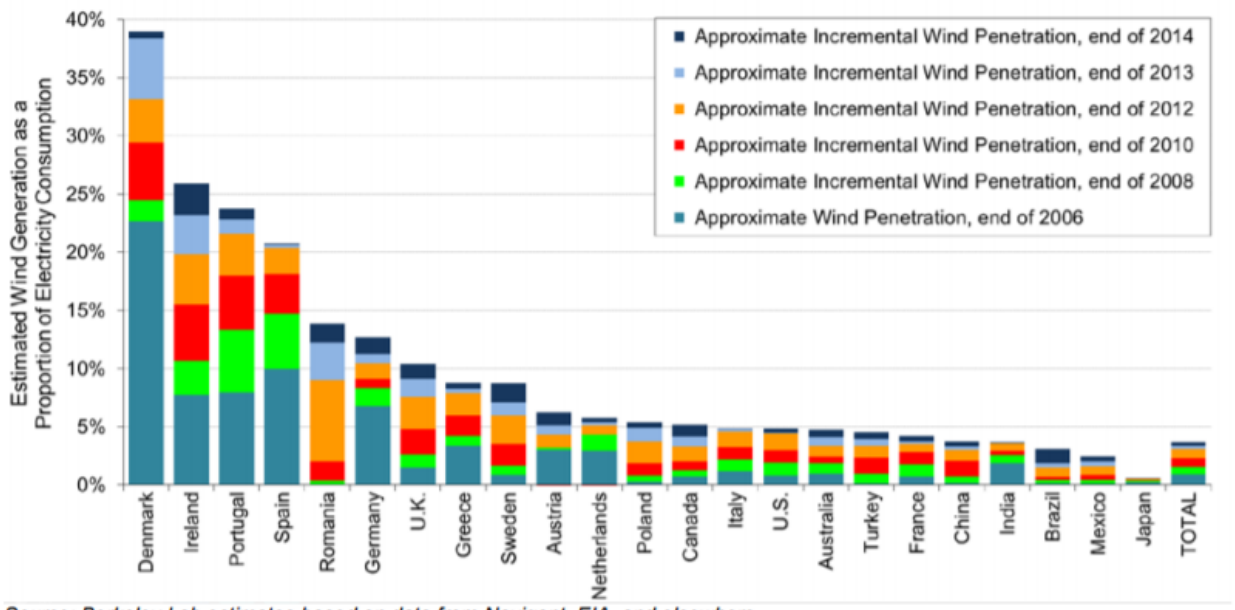
Offshore wind energy by country



	UK	Germany	PR China	Denmark	Netherlands	Belgium	Sweden	Japan	S Korea	Finland	US	Ireland	Spain	Norway	Portugal	Total
Total 2015	5,100	3,295	1,035	1,271	427	712	202	53	5	32	0.02	25	5	2	2	**12,167**
New 2016	56	813	592	0	691	0	0	7	30	0	30	0	0	0	-2	**2,219**
Total 2016	5,156	4,108	1,627	1,271	1,118	712	202	60	35	32	30	25	5	2	0	**14,384**

Source: GWEC

Wind power in the electricity mix



Source: Berkeley Lab estimates based on data from Navigant, EIA, and elsewhere

Country (top ten producers)	% of wind in total domestic electricity generation
Spain	17.6
Germany	12.2
United Kingdom	11.9
Sweden	10.0
United States	4.5
Canada	3.9
France	3.7
Brazil	3.7
People's Rep. of China	3.2
India	3.1
Rest of the world[1]	2.0
World	**3.4**

Source: IEA, 2017
Data from 2015.

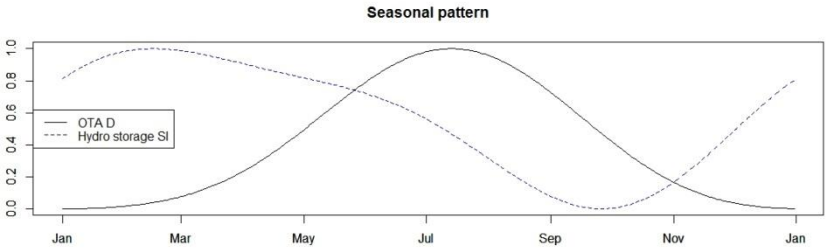
Wind research at the Energy Centre: Wind, hydro and demand correlation

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

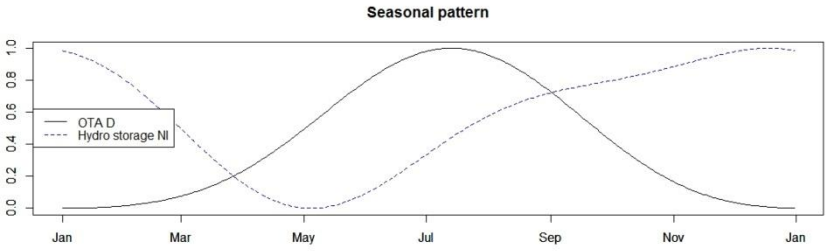
The system must rely on other, generally more expensive, energy sources.

Can wind help?

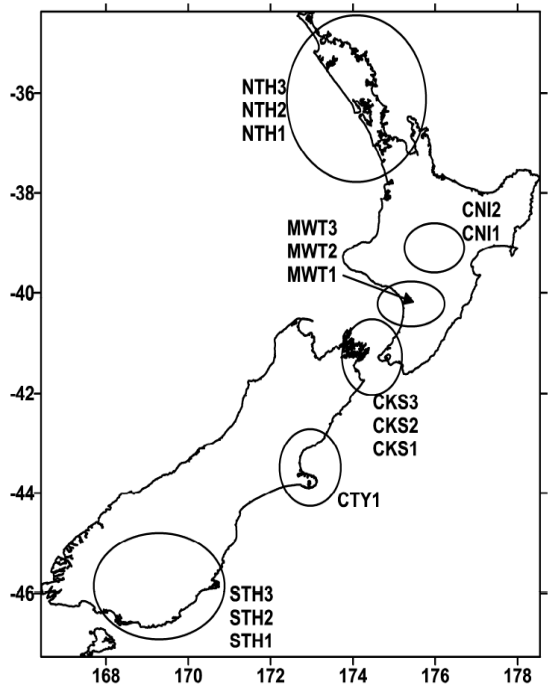
SI hydro



NI hydro



Existing and potential wind development sites



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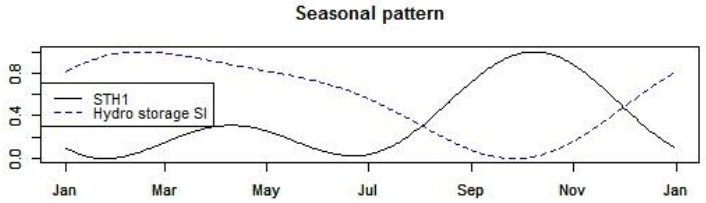
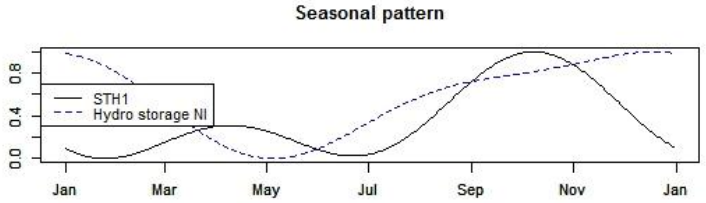
Wind-hydro correlation

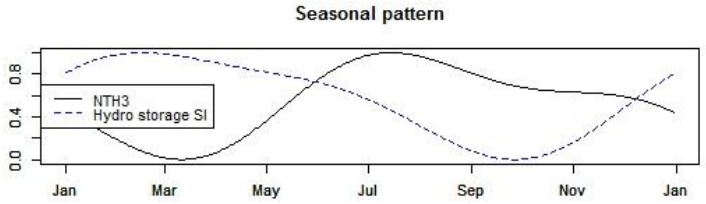
STH1 & SI hydro storage



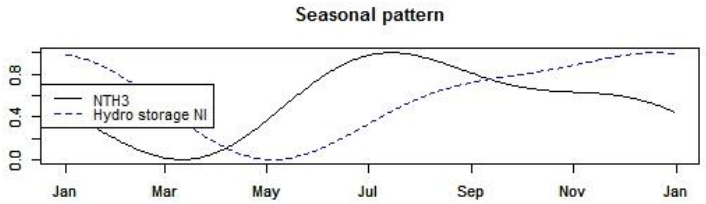
STH1 & NI hydro storage

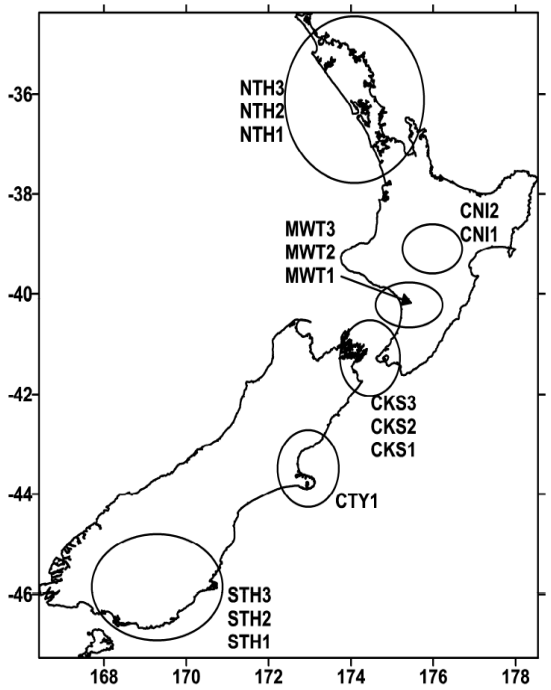


NTH3 & SI hydro storage



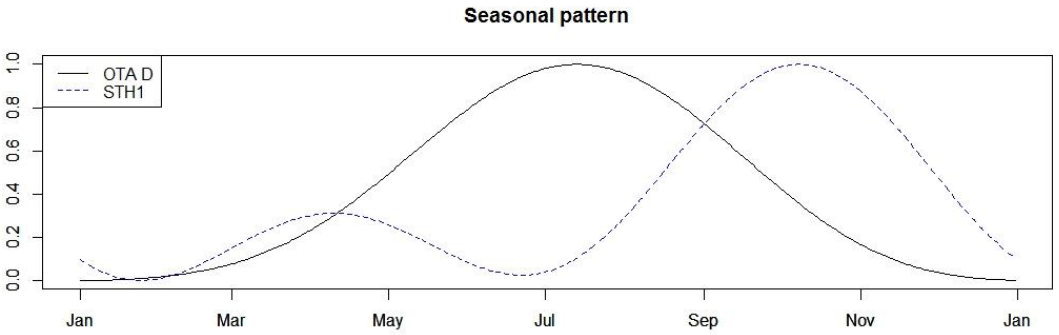
NTH3 & NI hydro storage



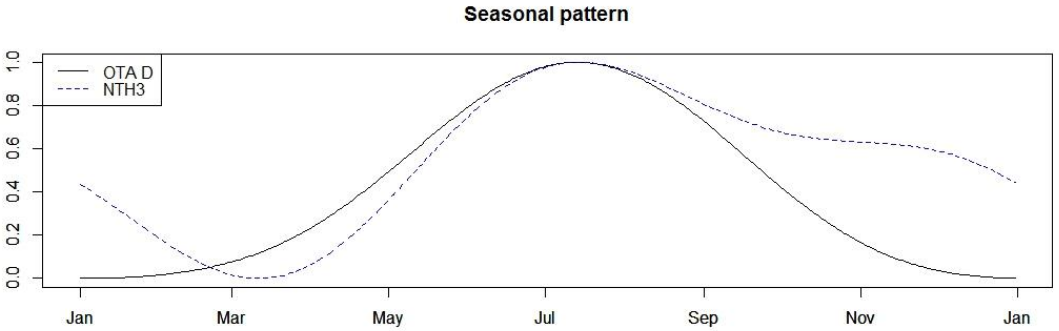


Wind-demand correlation

STH1



NTH3



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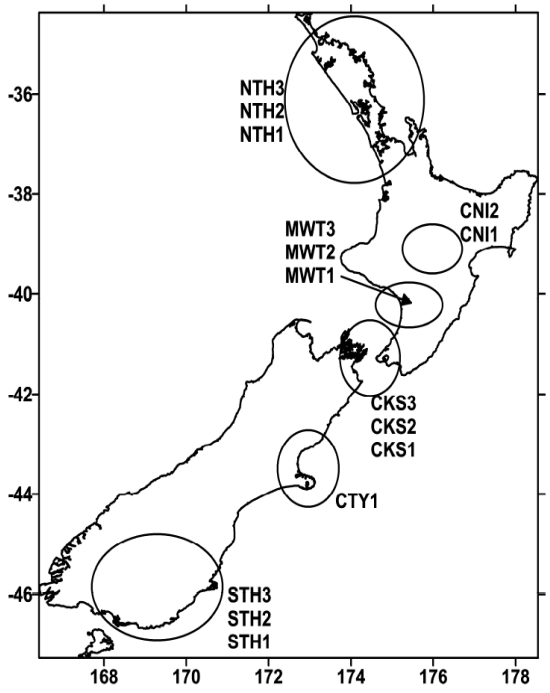
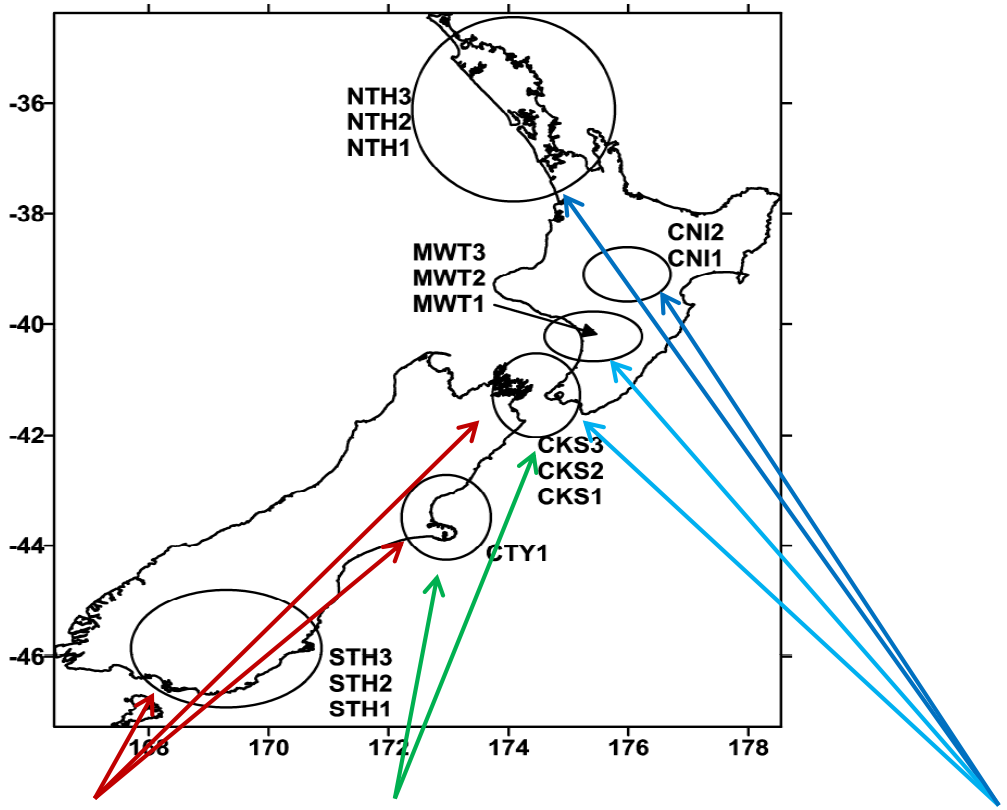


Wind and hydro correlations with demand and prices



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.'

Thank you

Questions?