Ocean renewable energy

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Overview

- Ocean/offshore energy
- Origins and potential of ocean renewable energy
- Ocean wave energy systems:
  - Pelamis & other wave harvesting systems
  - Tidal energy power devices
  - Temp. gradient & other systems
- Offshore wind energy:
  - Fixed structure installations
  - Floating wind turbines
- Environmental issues

What is ocean energy (or power)?

- Energy possessed by ocean waves, tides, salinity & ocean temp. gradients
- Idea is to convent kinetic energy or temp. differences in power or for desalination purposes
- Ocean energy is usually close to populated centers eg, NY, Netherlands, Germany, etc.

Origins of ocean renewable energy

- Marine energy originates from sun & tidal energy from the moon & sun gravitational attraction
- Winds generate waves & trigger currents at ~3% of wind speed
- Water waves are concentrated form of wind energy
- Ocean winds are generated by temp. fluctuations from incoming sunlight

Energy potential of oceans

- World electricity generation: 23,322 TWh/yr (2013) [IEA, 2015]
- By comparison potential energy of oceans is ~250mbpd
- Ocean energy is less variable compared to solar energy
- Harvesting 0.1% of ocean energy = 5x world's energy demand
- ~50% of world's power needs can be met by ocean energy

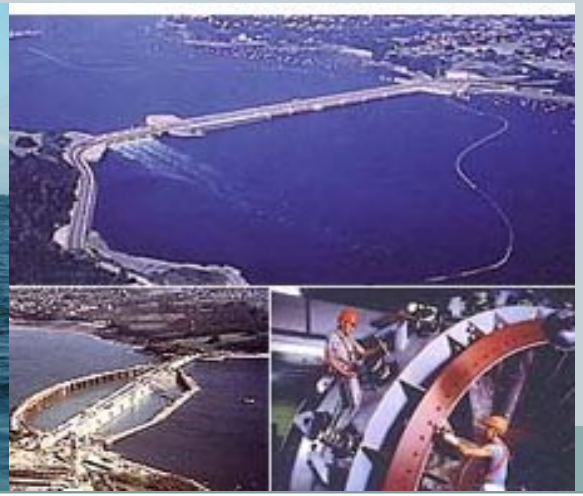
Global potential

Form	Annual generation
Tidal energy	>300 TWh
Marine current power	>800 TWh
Osmotic power Salinity gradient	2,000 TWh
Ocean thermal energy Thermal gradient	10,000 TWh
Wave energy	8,000–80,000 TWh

Source: IEA-OES, Annual Report 2007[3]

Ocean wave energy systems

- The dilute energy density of ocean waves requires large number of small harvesting devises
- Damage to equipment from sea has discouraged development of wave harvesting devices
- Installations need to be robust; payback period is long

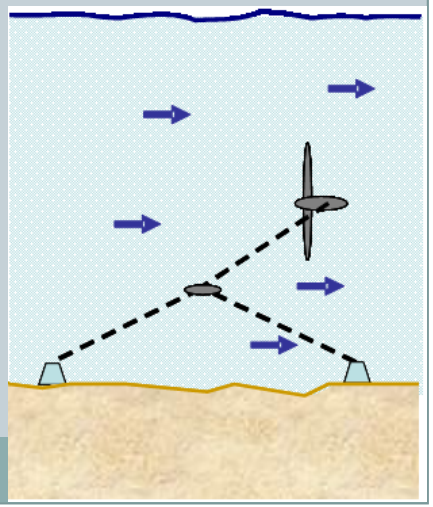


Pelamis system

- Pelamis attenuator: 121m long, 3.5m in diameter
- Movable hydraulic operators
- Suffers from structural issues

Tidal power systems

- Exploit exploits movement in water masses
- Major systems comprise:
  - Bottom mounted turbines
  - Cable tethered systems
- Bulky, installation issues, reliability concerns



Wave harvesting device made in Cyprus

- Video

Onshore and offshore wind energy

Sources

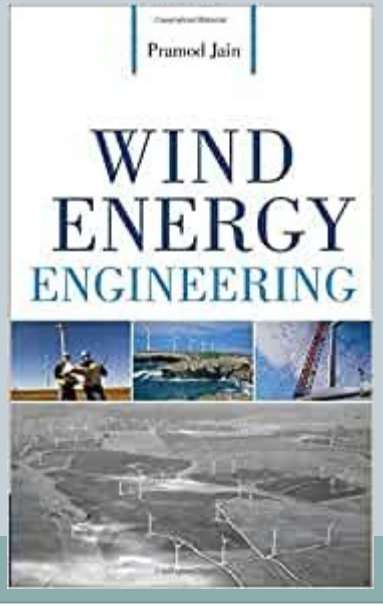
- How do offshore wind turbines work?

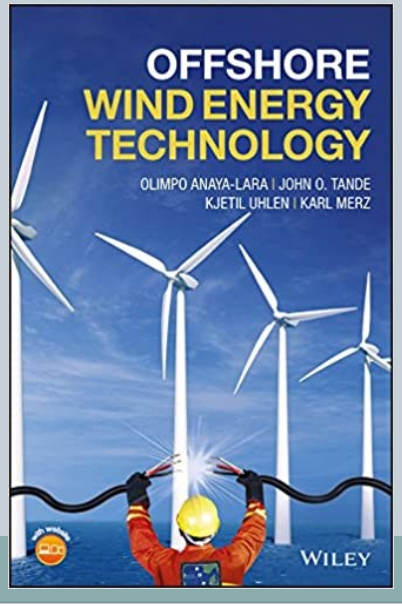
https://www.youtube.com/watch?v=HqCVgRbPQcg

- Overview of Floating Offshore Wind: https://bit.ly/3anOryr

Jain Pramod "*Wind energy engineering*," 2010, McGraw Hill

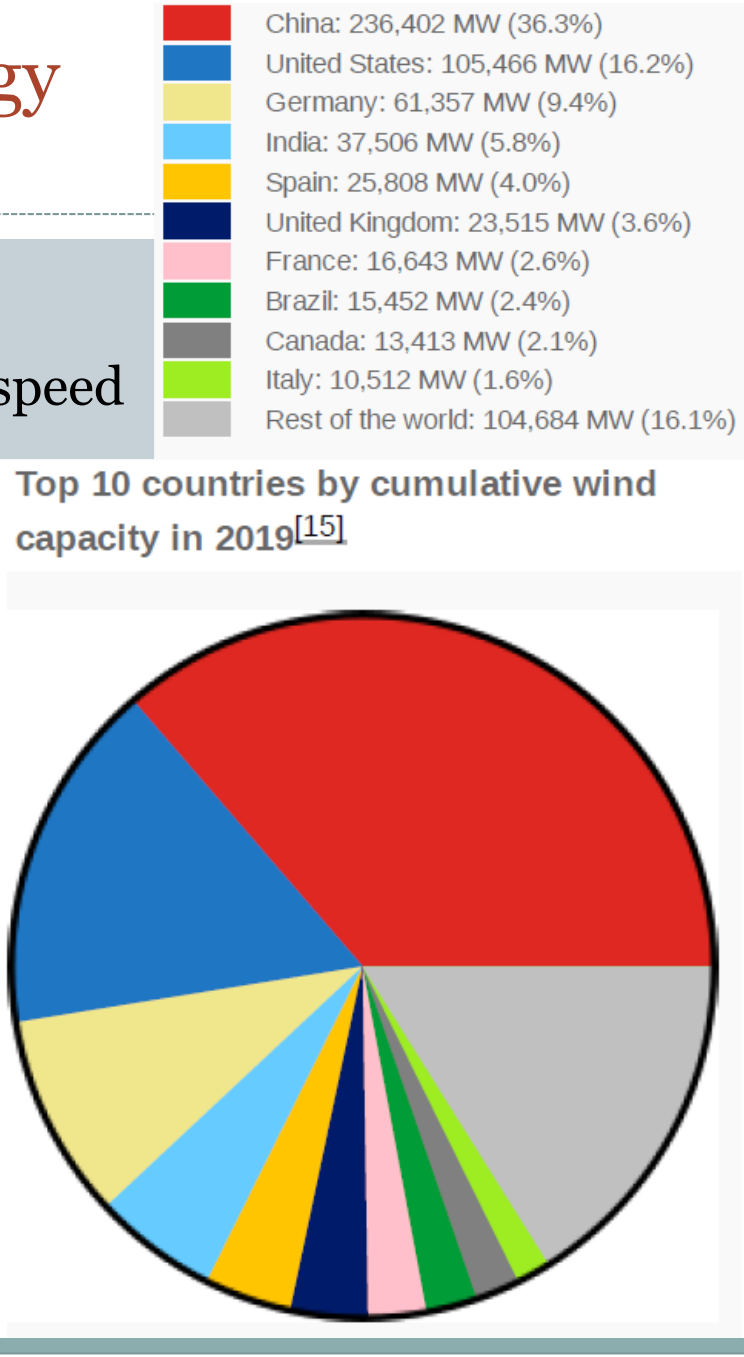
- John Olav Tande, Olimpo Anaya-Lara, Kjetil Uhlen, Karl Merz "*Offshore Wind Energy Technology,*" 2018, John Wiley





Wind energy

- End 2019: installed capacity was 651 GW
- Wind power costs are a function of wind speed
- Benefits of wind energy:
  - Onshore wind more cost effective than PVs
  - Environmental aspects
  - Emissions need consider embodied carbon
  - Save space if farms are offshore
  - Enhance energy security
  - Consistent generation from year-to-year
- Downsides:
  - Offshore wind turbine maintenance
  - Wind variability or intermittency
  - Need for expensive transmission lines
  - Produce economically; speeds >6.5m/s @ 50m
  - Noise
  - Kill birds
  - Aesthetics (NIMBY)



Wind energy

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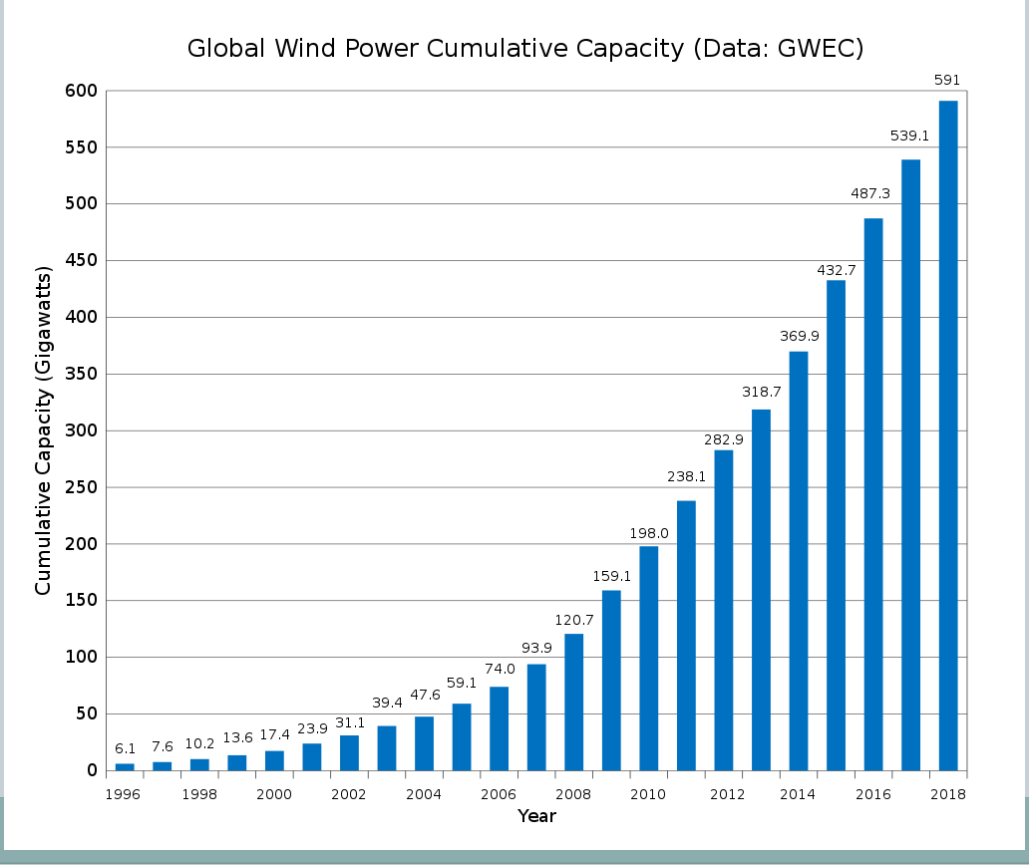
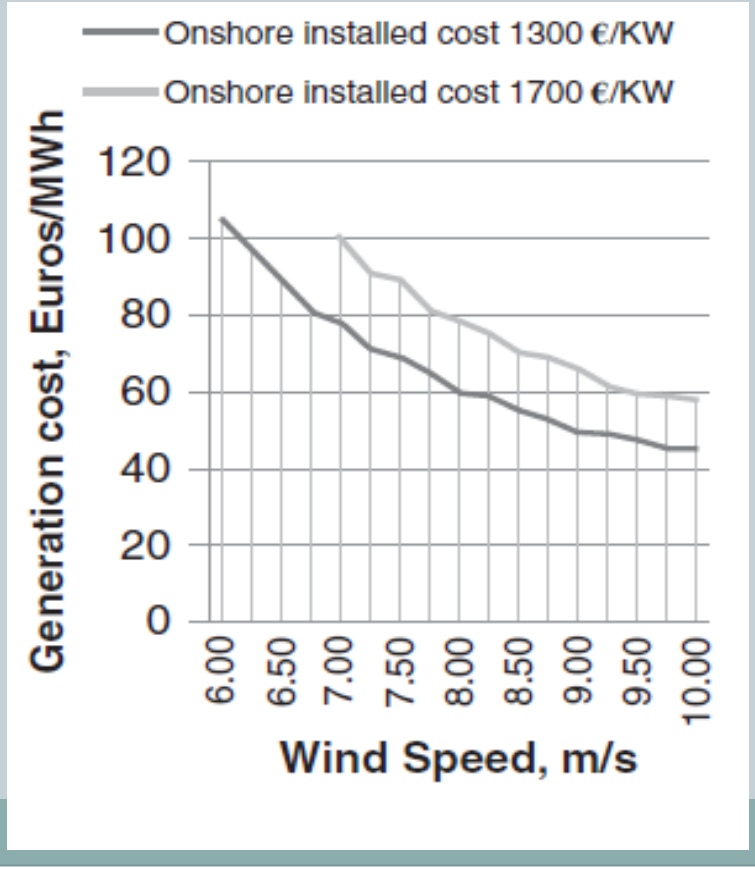
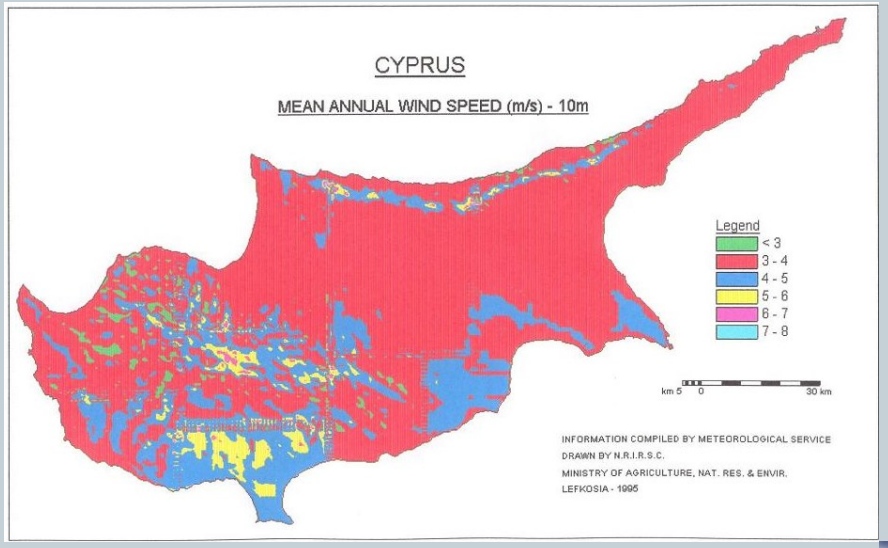


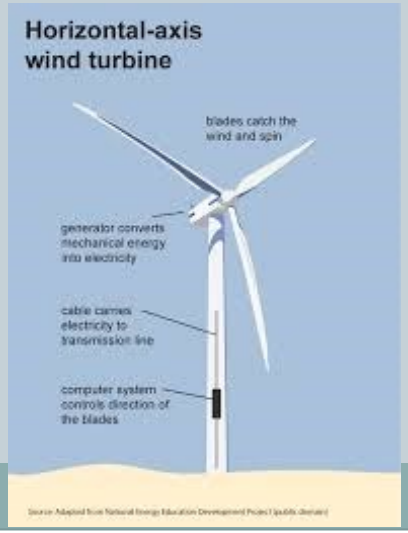
Milborrow, D (2010)



Cyprus is not particularly windy

- Large wind turbines require 3-4m/s (11-14.5 km/h)
- Upper velocity limit of wind turbines: 24m/s (88 km/h)

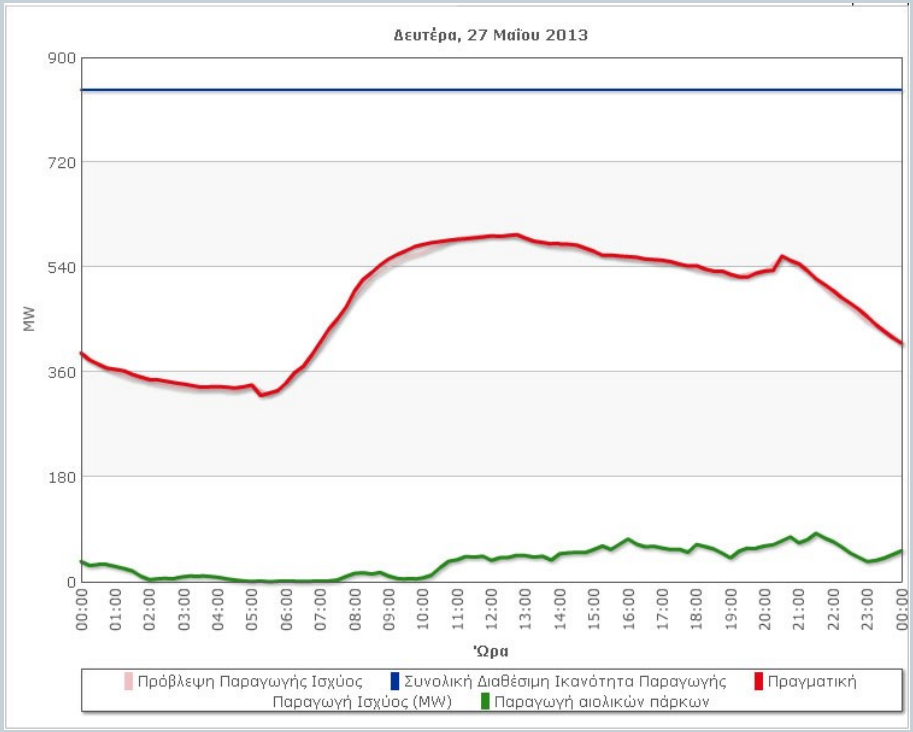




Wind farms: benefits & challenges

- Lower cost electricity than PVs
- Need for conventional power plant capacity

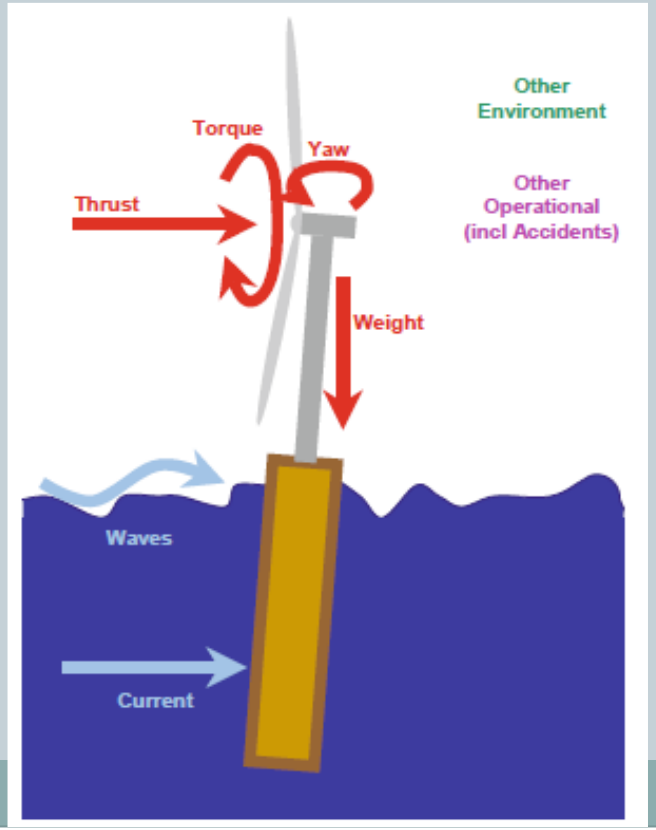
Source: Transmission System Operator



Koshi wind park

Offshore wind energy

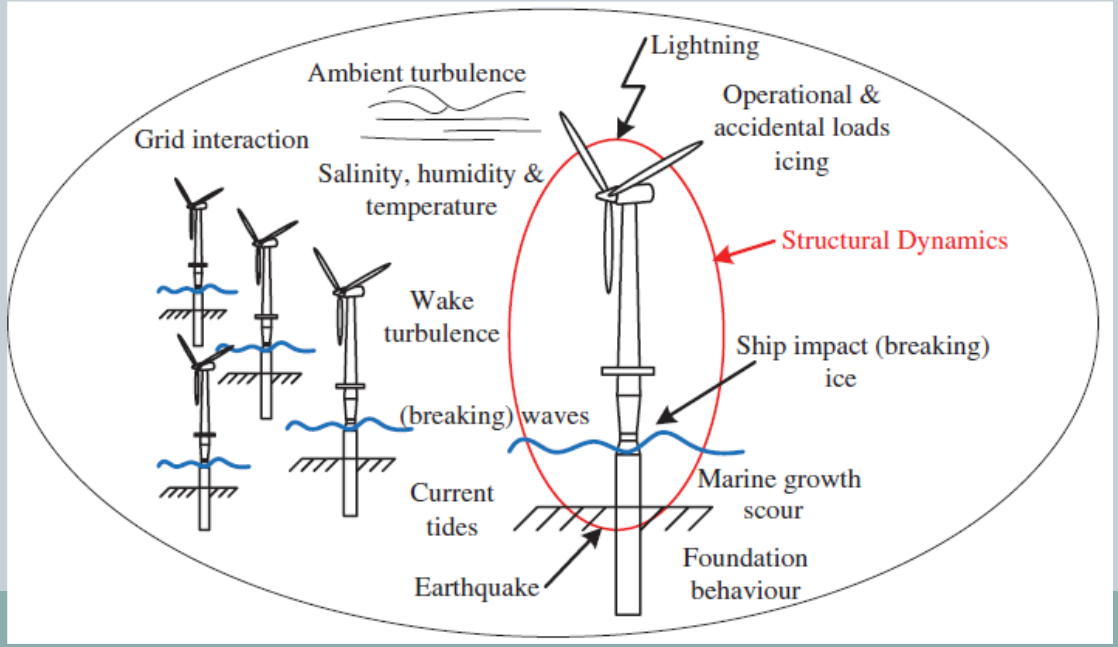
- 1991: 1st offshore wind farm erected in Vindeby (Denmark) 11×450kW
- Onshore permission restrictions, have given impetus to offshore wind
- Need for offshore wind turbines to be very reliable
- Loads on wind turbine:
  - Wind
  - Waves
  - Sea currents and
  - Sometimes, floating ice.
- Major challenges:
  - Secure contracts for the sale for electricity (revenue stream) to make project viable
  - Stability issues of having the generator mounted at the top of the tower
  - Rotating blades also raise stability issues



Loads on a fixed wind turbine

- Structural loads due to wind, waves and currents
- Tectonic
- Ice loads
- Accidental (ship)
- Lightning

(Fischer, 2006)



Offshore turbines are getting bigger

- Reasons:
  - Generate more electricity
  - Lower per unit electricity costs
  - Fewer constraints on transportation of components & assembly equipment
  - Offshore towers are shorter than onshore for same power due to lower wind shear

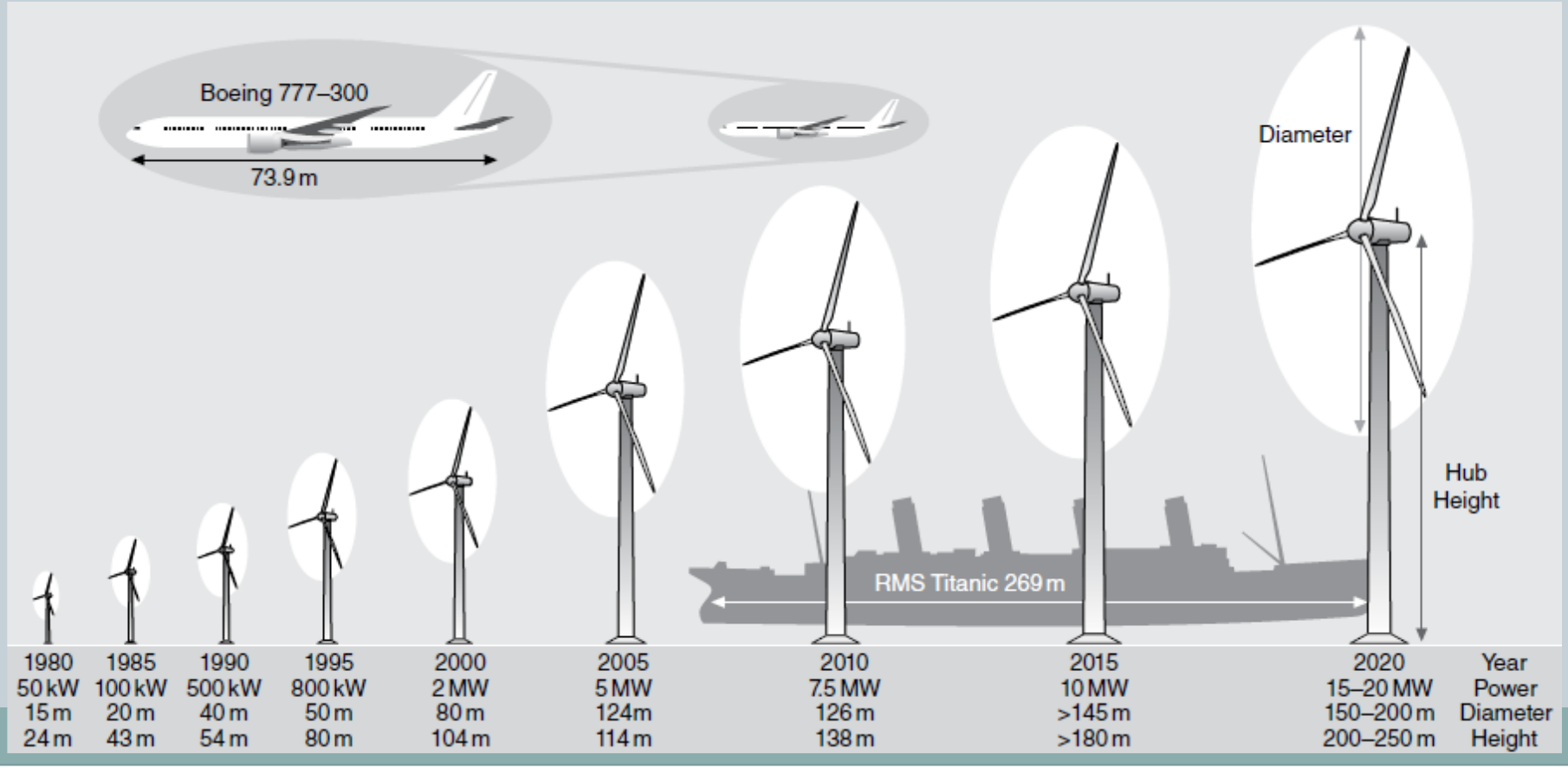



Project	Scroby Sands	Rødsand II	Robin Rigg	Alpha Ventus
Turbine type	Type C	Type D	Type C	Type C, D
Hub height	60 m	68 m	80 m	90 m
Rotor diameter	80 m	93 m	90 m	126 m / 116 m
Capacity	2 MW	2.3 MW	3 MW	5 MW
Number of turbines	30	90	60	12

Size of offshore wind turbines

- Offshore wind turbines are bigger than onshore

Olimpo Anaya-Lara (2018)



Hywind Scotland 30-MW floating wind farm

Statoil, 2015

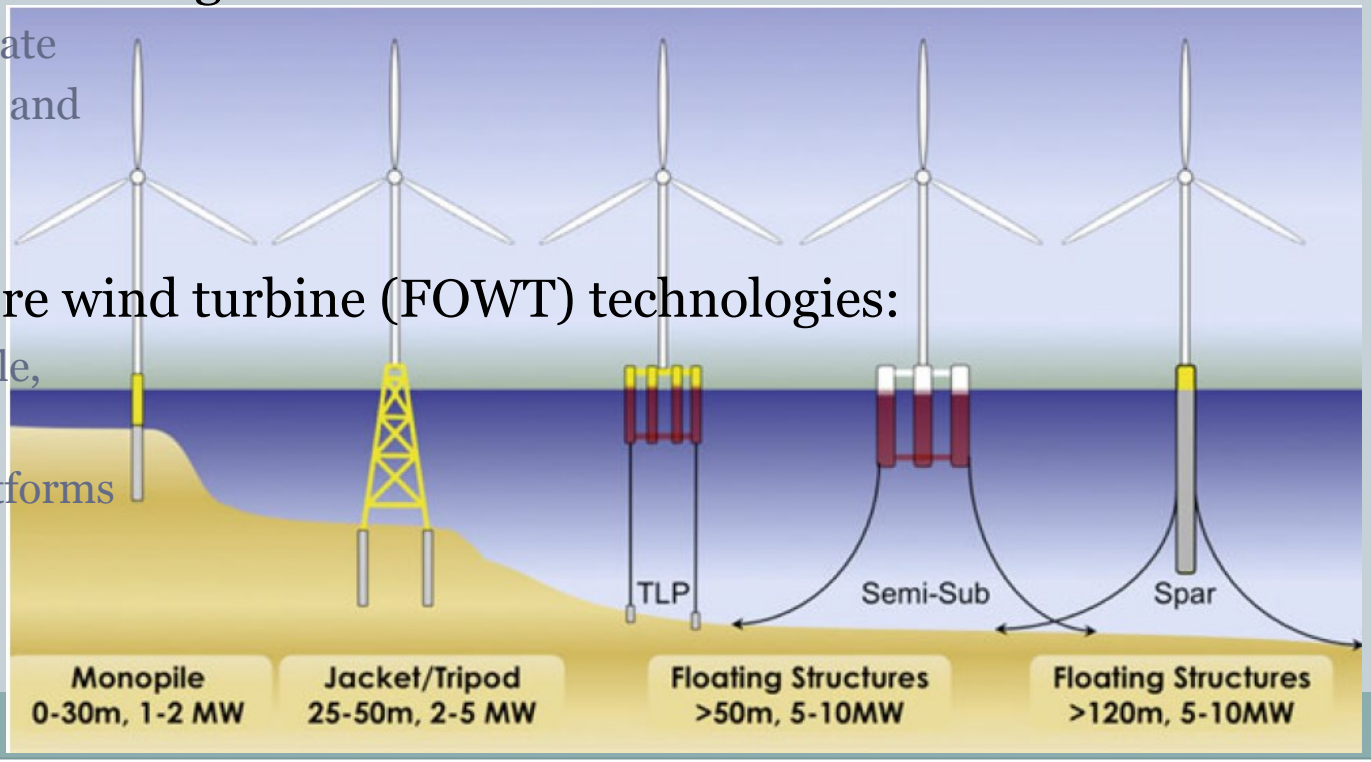
Hywind offshore wind farm

- Wind farm provides enough power to run 36,000 households.
- Farm consists of five(5)×6 MW turbines
- Total installed capacity = 30 MW
- Transmission voltage = 33 kV
- Rotor diameter of 154 m & overall height of 253 m.
- Pilot farm covers ~4 km^2 in water depths btw 95—129m.
- Avg wind speed in North sea is ≈10 m/s & avg wave height of 1.8m.
- Export cable length of 30 km.

Fixed and floating offshore turbines

- Fixed wind turbine limited to <50m water depth:
  - Fixed monopile foundations
  - Space frame jacket
  - Tripod structure
- Need to restrain floating wind turbines since:
  - Turbine to operate
  - Station keeping and
  - Safety concerns
- Floating offshore wind turbine (FOWT) technologies:
  - Semisubmersible,
  - Spar and
  - Tension leg platforms

Principle Power



Floating offshore wind turbines

Cruz (2016)

Table 1 Assessment of floating platform classes

	Spar	TLP	Semi-Sub
			
Stability	Ballast	Moorings	Hydrostatics
Min depth [a]	Deeper	Shallower	Shallower
Periods	Good	Good	Acceptable
Cost	Uncertain	Uncertain	Uncertain
Yaw and torque	Acceptable	Probably good	Good
Fabrication	Potentially simple structure	More complex structure	More complex structure
Installation	More complex operation	More complex operation	Good

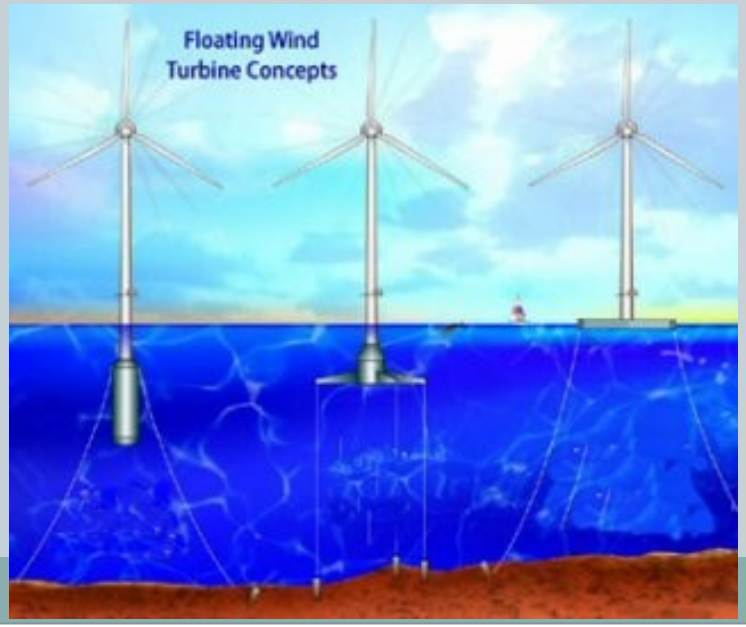
[a]However greater depths will typically allow a better performing and lower cost design to be deployed

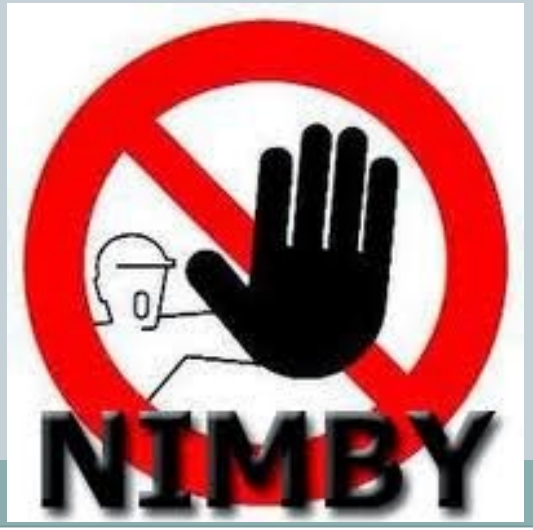
World's largest offshore wind farm

- https://www.youtube.com/watch?v=TgRPjCQn7Tw

Environmental issues

- Some of the environmental criticisms comprise:
  - Fish may be hit by tidal turbine blades
  - Submarine noise emitted from energy systems
  - Marine energy installations can potentially influence the behaviour of marine mammals, fish & seabirds
  - Possible effect on sediment transport and water quality
  - Aesthetic matters e.g., NIMBY





Thanks for your attention!