The falling cost and future growth of offshore wind energy

Peter Geddes
Head of WTG installation

Ørsted

25th September 2018

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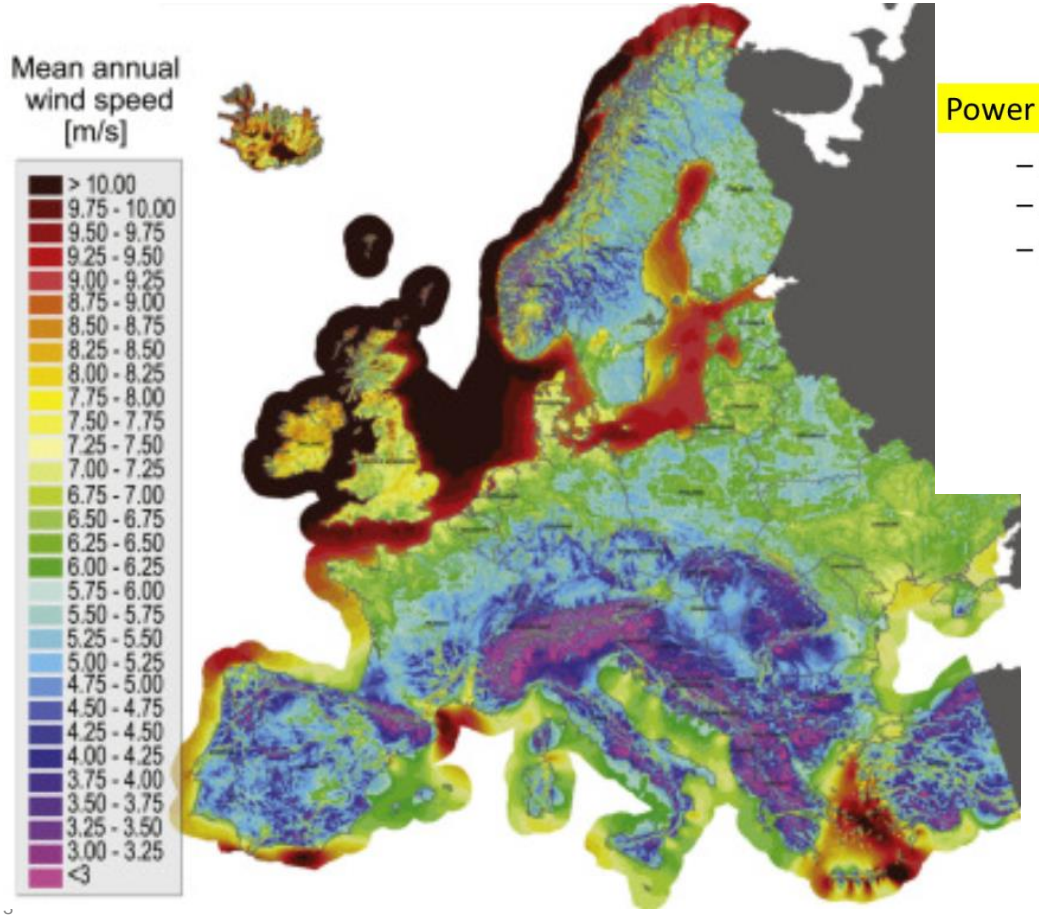
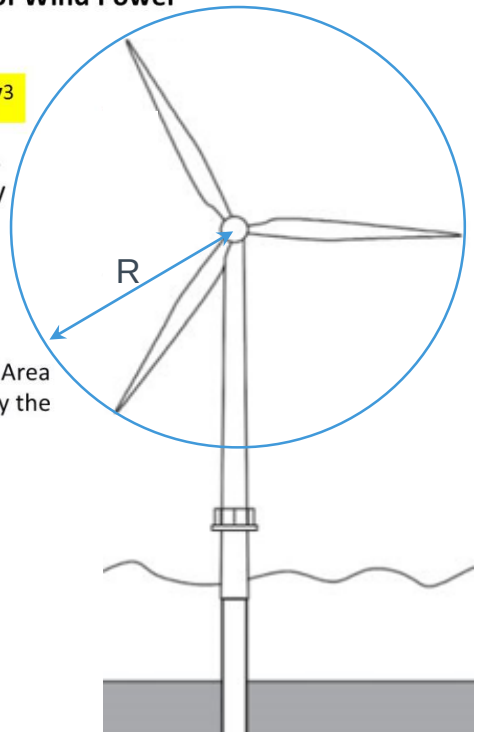
Wind energy potential



Calculation of Wind Power

Power in the Wind = $\frac{1}{2}\rho AV^3$

- Effect of swept area, A
- Effect of wind speed, V
- Effect of air density, ρ



Swept Area: $A = \pi R^2$ Area of the circle swept by the rotor (m^2).

CONCLUSION: Higher average windspeed = more energy capture over the year and better economic returns (if all else equal)

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Why offshore wind?

- Environmentally benign
- Scalable – opportunity to industrialise
- Huge potential
- Efficient – higher capacity factors than other pure renewables
- Economies of scale
- Political – security of supply
- Visual impact
- **= opportunity to help reduce CO2 emissions rapidly**

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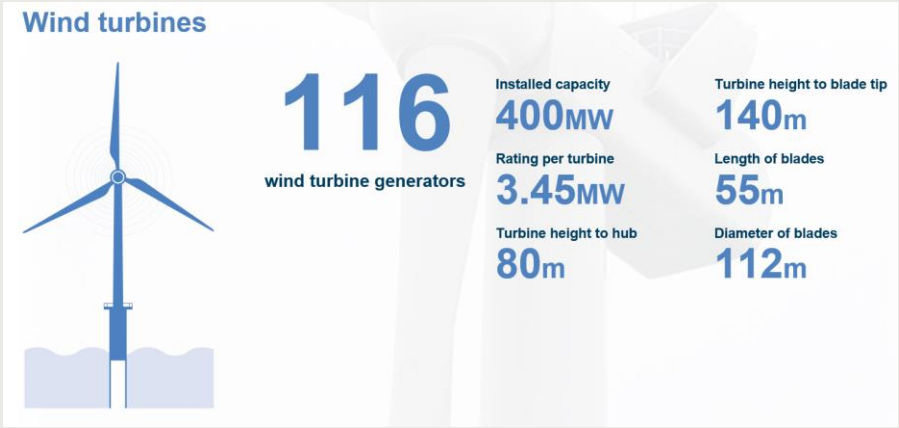
RAMPION OFFSHORE WIND FARM
nearest to Sussex University (EON Majority owner)

- **Video – Rampion (EON) wind farm, Sussex**
- **https://www.youtube.com/watch?v=0czp1NS306U**

- **Video - West of Duddon sands inauguration**
- **https://www.youtube.com/watch?v=W9l6Mw9qZis**

- **Video – Walney extension**
- **https://www.youtube.com/watch?v=rbnlJOEQ9Hc**



The Rampion offshore wind farm is located in the English Channel, off the Sussex coast and extends from approximately 13km to 20km offshore, occupying an irregular elongated area, approximately 19km in an east to west direction and approximately 7km in the north to south direction. The site has an overall area of 72km^2

A schematic of typical offshore wind farm elements

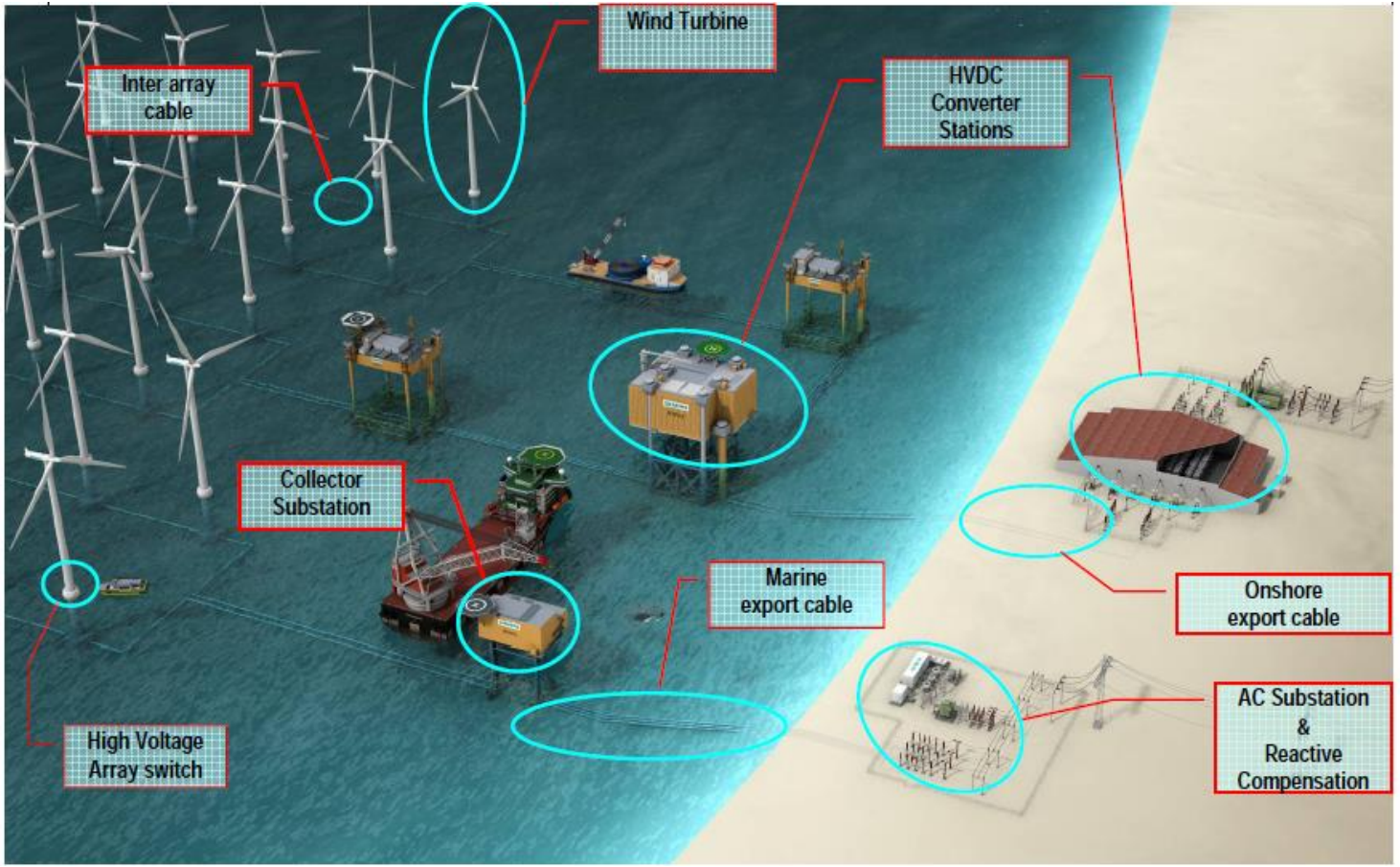


Image courtesy Siemens

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Substations

- London array substation

Offshore Cables

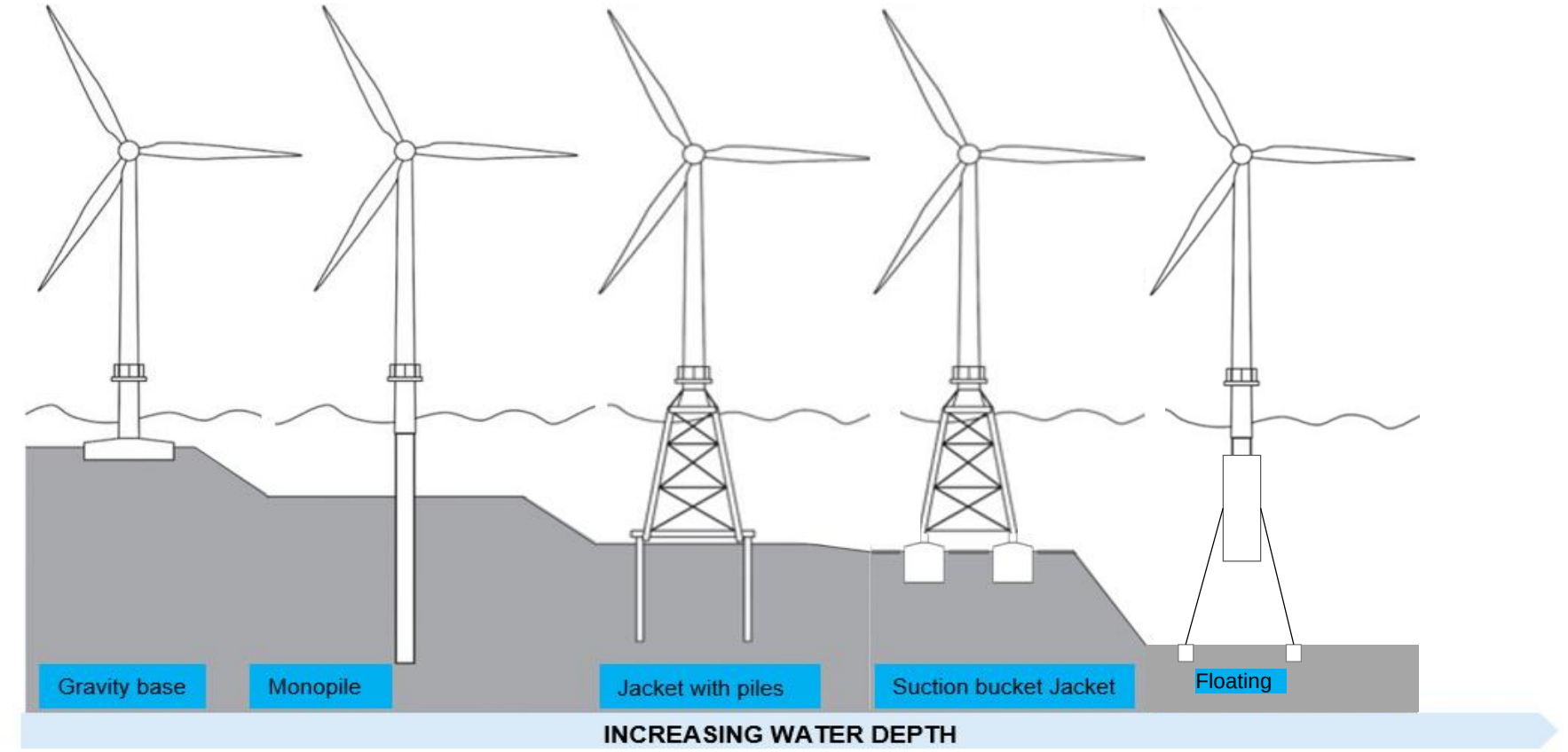
- Armoured mostly for handling to prevent damage to the cores

Export cables

Array cables

Examples of cable installation vessels

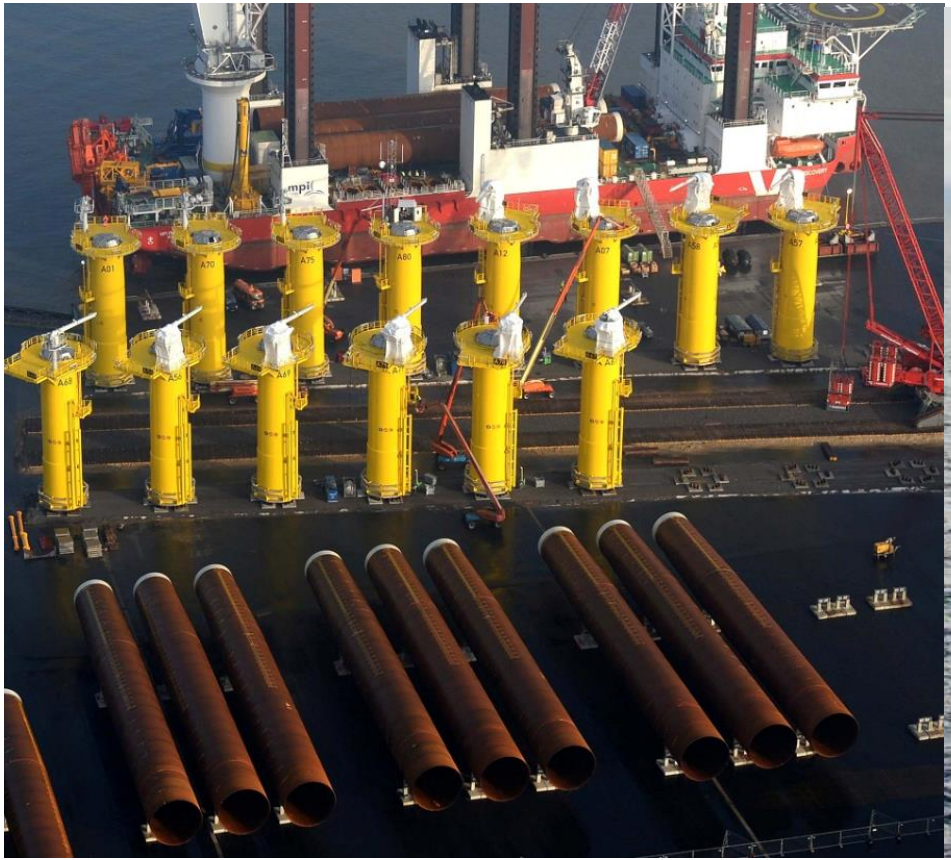
Foundations – Design choice mainly influenced by water depth, also soil type and turbine size



Gravity base foundation

Monopile installation with Jack up barge

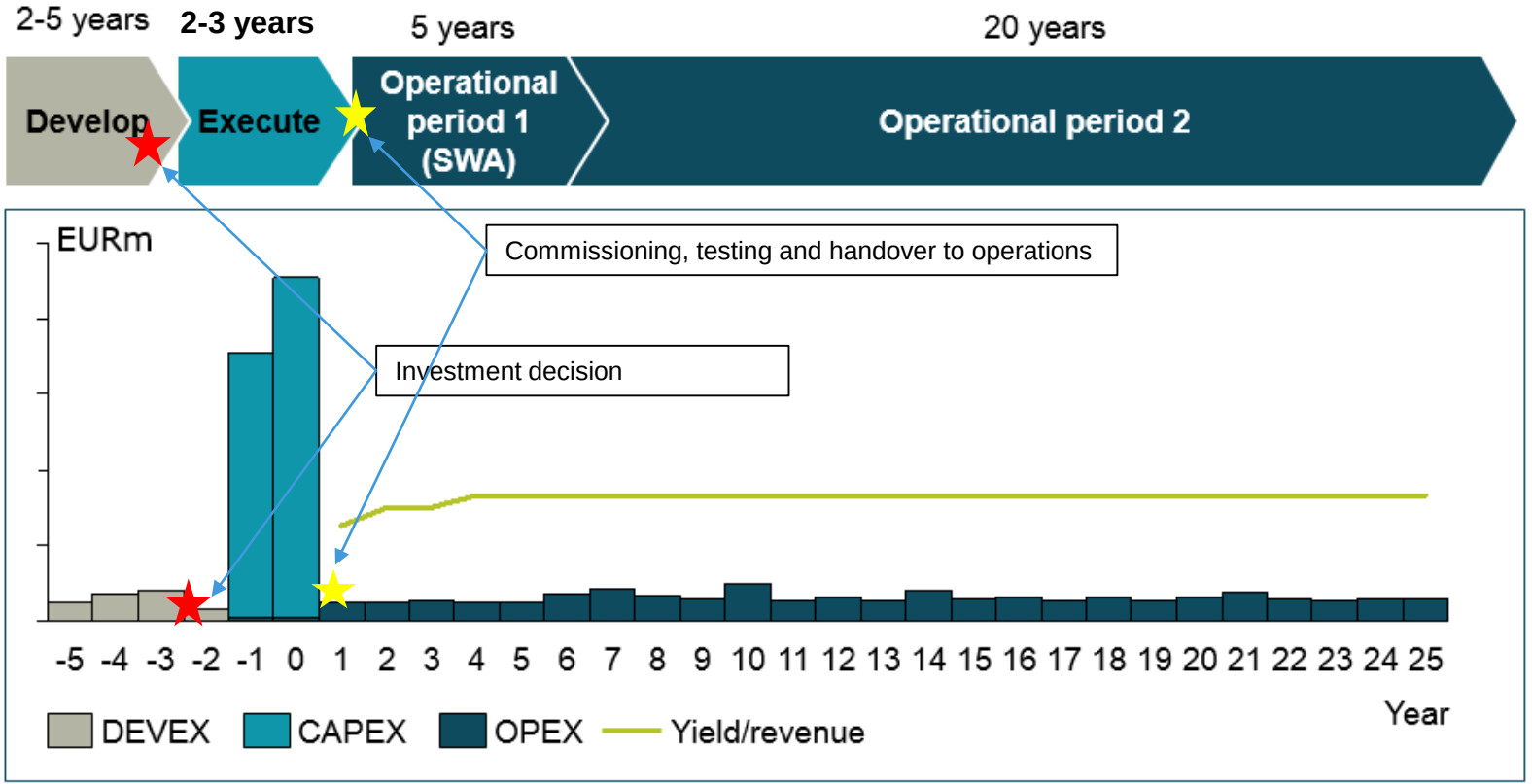
Various techniques including soft starts and noise reducing screens are necessary to protect marine mammals, and have been implemented



Jacket foundations

Evolutionary steps - Operations

Wind farm investment timeline



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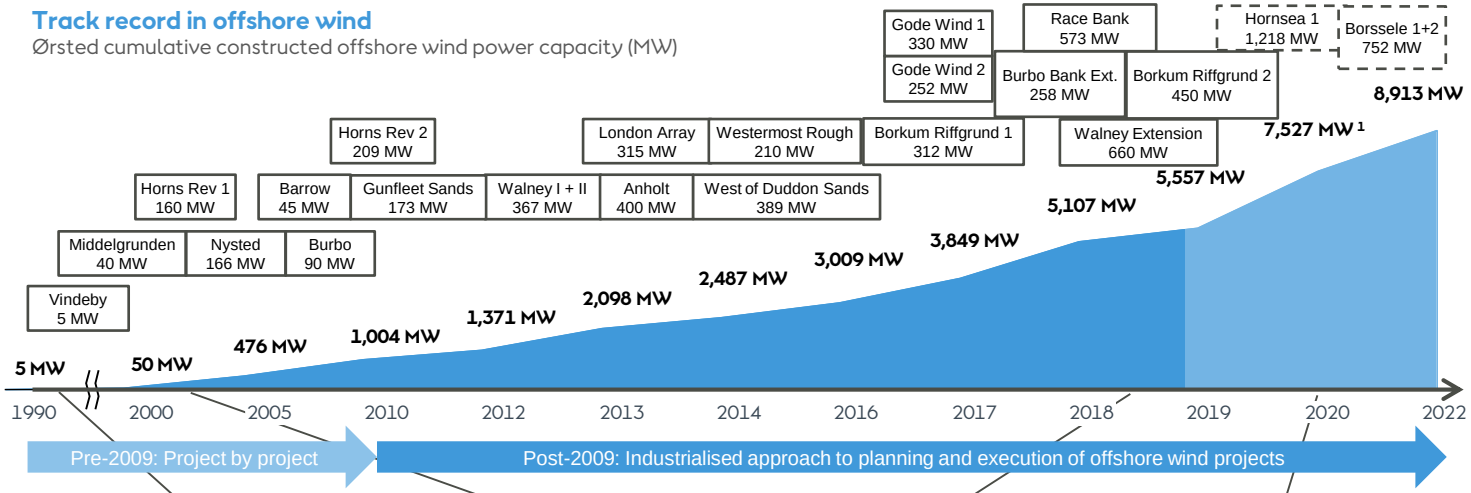
Ørsted pioneered the offshore wind industry

Track record in offshore wind

Ørsted cumulative constructed offshore wind power capacity (MW)



Vindeby	Horns Rev 1	Walney Extension	Hornsea 1
First offshore wind farm in the world	First large scale offshore wind farm in the world	The largest operational offshore wind farm in the world	The world's largest offshore wind farm once constructed
			
5 MW	160 MW	659 MW	1,218 MW
Turbine capacity: 0.45 MW	Turbine capacity: 2 MW	Turbine capacity: 7-8.25MW	Turbine capacity: 7 MW
Nr. of turbines: 11	Nr. of turbines: 80	Nr. of turbines: 87	Nr. of turbines: 174
Rotor diameter: 35 m	Rotor diameter: 80 m	Rotor diameter: 154-164m	Rotor diameter: 154 m
Distance to shore: 1.8 km	Distance to shore: 18 km	Distance to shore: 19 km	Distance to shore: 120 km

Note 1: Ørsted will, in accordance with the Dutch tender regulation, build Borssele 1 and 2 within four years f

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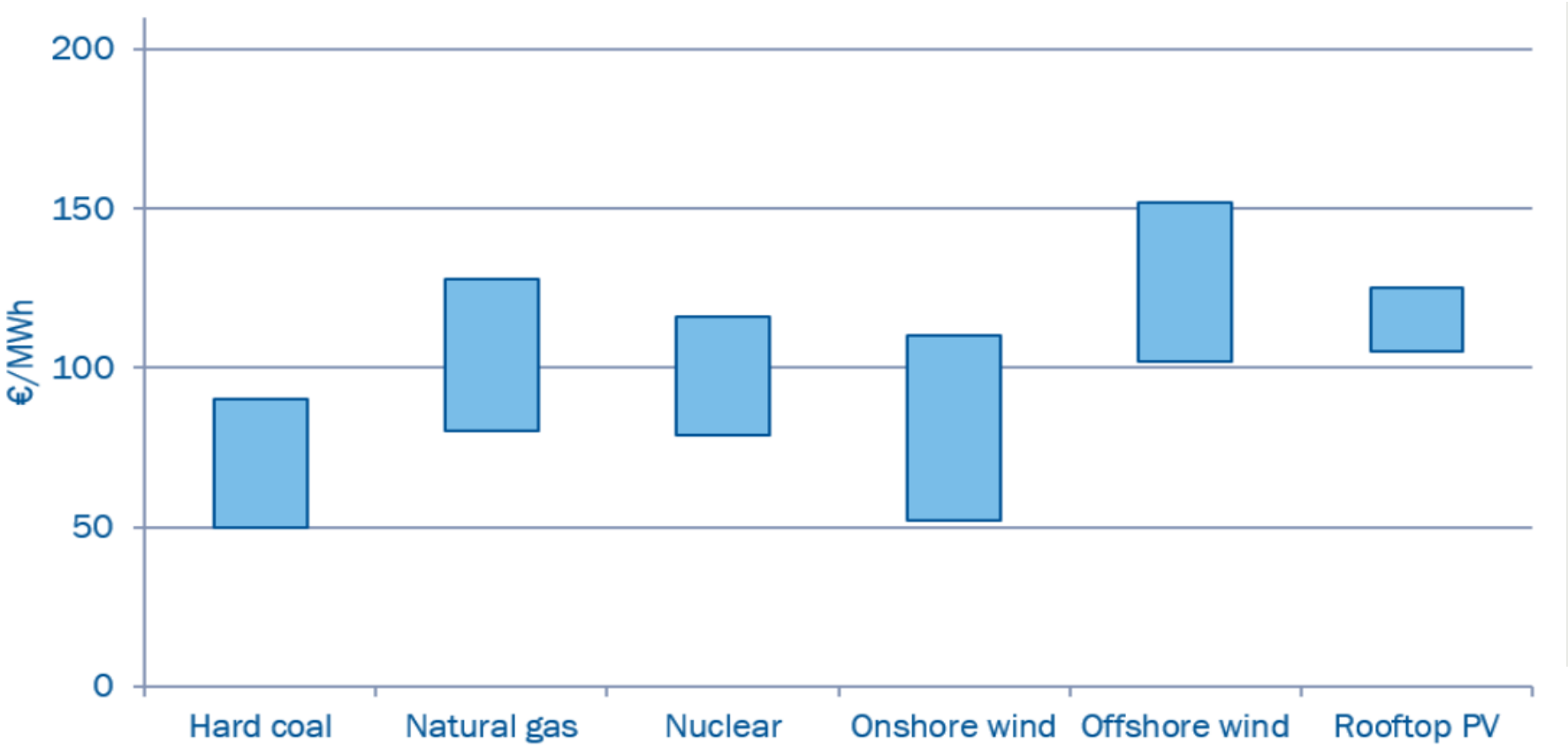
Levelised Cost of Electricity (LCOE) of major power generation technologies in Europe (2015 study)



SOURCE EUROPEAN COMMISSION 2015 / WindEurope

Dramatic headlines…

NewsFLASH

Dong wins Dutch offshore double at Borssele 1&2

700MW project to be built for 'highly competitive' €72.70 per MWh

www.renews.biz

NewsFLASH

Vattenfall record low bid wins 600MW Kriegers Flak

€50/MWh secures rights to build Baltic Sea wind farm by end-2021

www.renews.biz

NewsFLASH

EnBW, Dong secure German spoils

Four North Sea projects secure contracts, average price €44/MWh

www.renews.biz

NewsFLASH

UK awards 3.2GW offshore

Hornsea 2, Moray 1 and Triton all secure CfDs, lowest winning bid of £57.50/MWh

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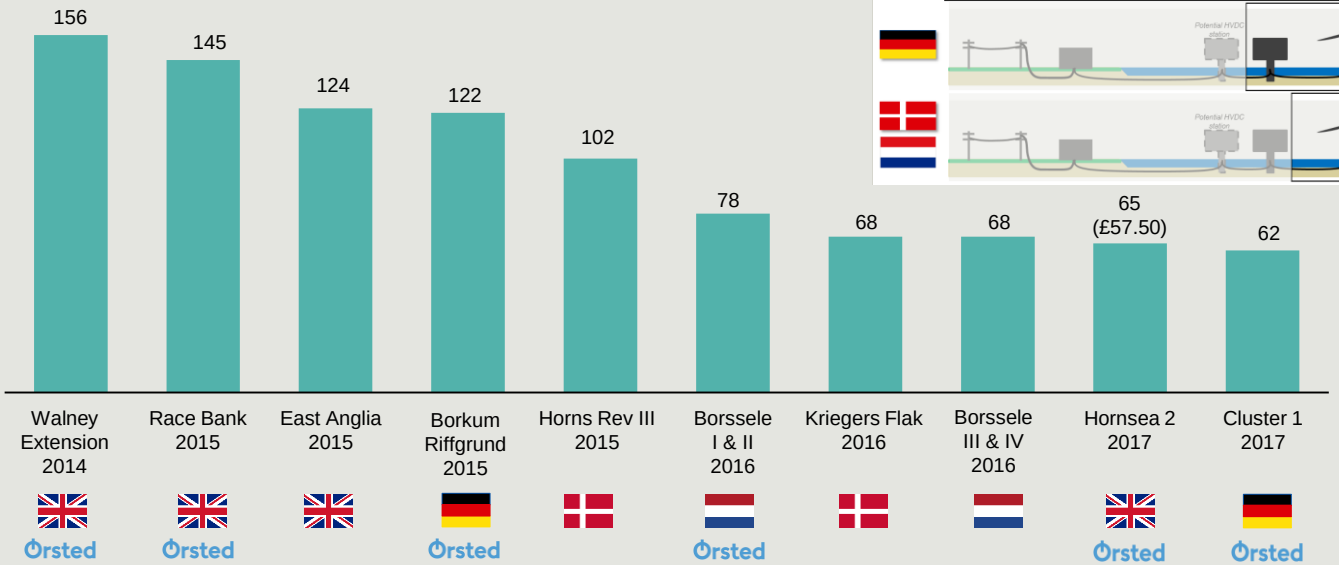
Offshore wind has demonstrated rapidly declining cost over short timescales

Levelised costs for society of electricity, incl. transmission costs
EUR/MWh[1], 2016-prices, bid announcement year



Different national scope leads to differences in the cost of electricity from offshore wind

Sources: DECC; Danish Energy Agency; Energinet.dk; NEV (Dutch Energy Scenarios), Bundesnetzagentur
1. Levelised revenue (price) of electricity over the lifetime of the project used as proxy for the levelised cost to society

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Ability to face new challenges with progressive projects whilst reducing the cost of generation

Multiple levers to drive down cost in offshore wind

1 Scale

- Turbines and rotor size
- Sites
- Vessel size
- Cable capacity

✓

2 Innovation

- Foundation design (e.g. monopiles)
- Electrical

✓

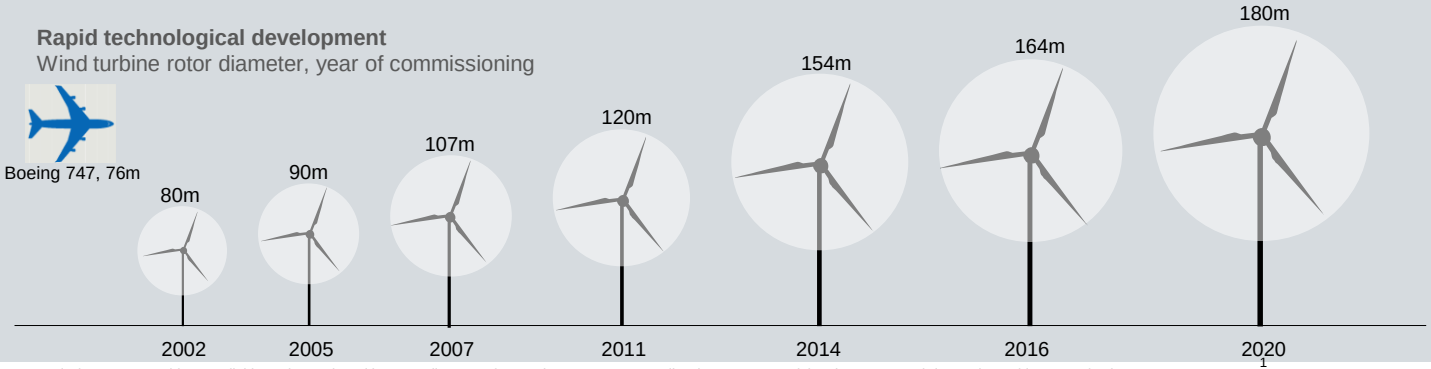
3 Industrialisation

- Transition from single supply to multiple global suppliers

✓

Rapid technological development

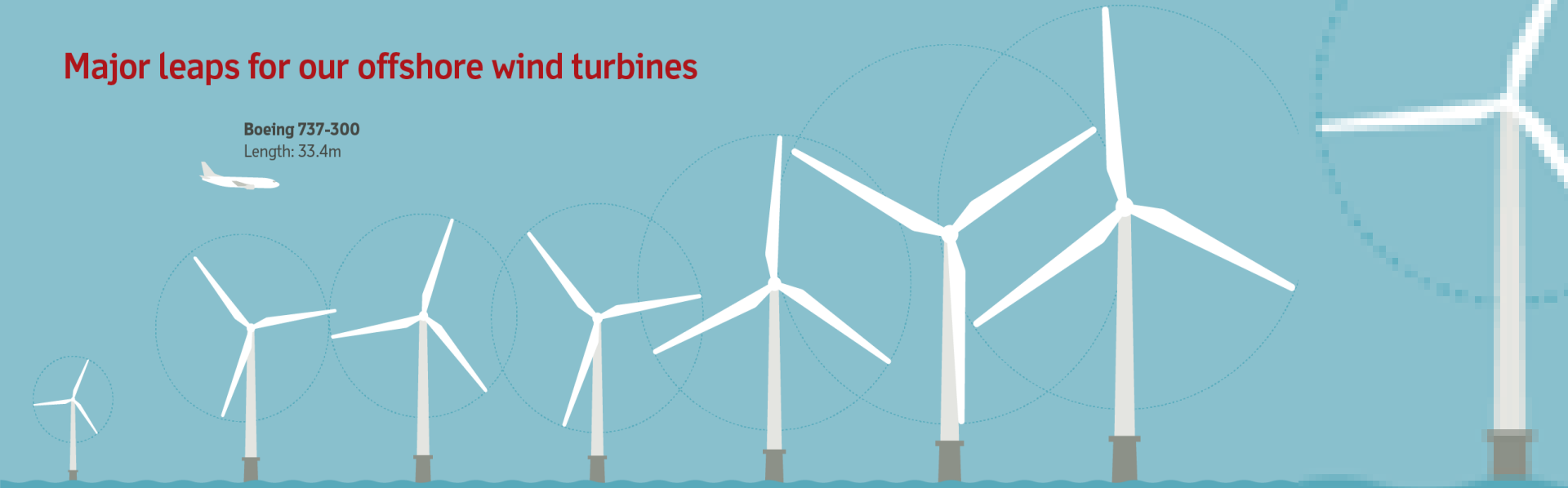
Wind turbine rotor diameter, year of commissioning



1. Currently there are no turbines available on the market with a rotor diameter of 180m, however some suppliers have announced that they expect to bring such a turbine to market in 2020.

INNOVATION is ENABLING LARGER TURBINES

Major leaps for our offshore wind turbines



Vindeby
Year: 1991
Diameter: 35m
Tower Height: 35m
Turbine: 0.45MW
Total output: 4.95MW

Middelgrund
Year: 2000
Diameter: 76m
Tower Height: 64m
Turbine: 2MW
Total output: 40MW

Nysted
Year: 2003
Diameter: 82,4m
Tower Height: 69m
Turbine: 2.3MW
Total output: 166MW

Horns Rev 2
Year: 2009
Diameter: 93m
Tower Height: 68m
Turbine: 2.3MW
Total output: 209MW

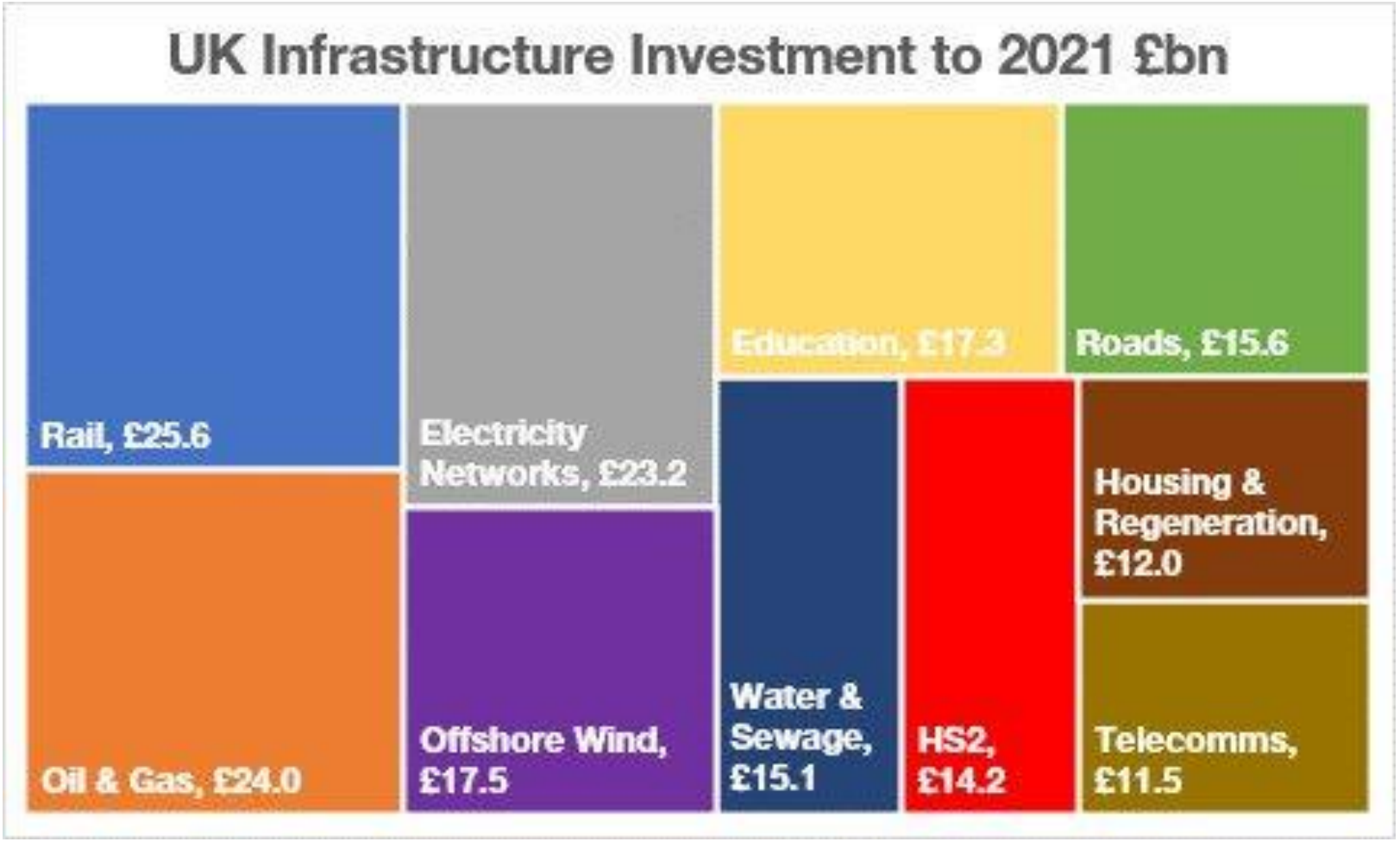
Anholt
Year: 2012
Diameter: 120m
Tower Height : 82m
Turbine: 3.6MW
Total output: 400MW

Westermost Rough
Year: 2014
Diameter: 154m
Tower Height: 102m
Turbine: 6MW
(Godewind: 582MW)

Walney Extension
Year: 2018
Diameter:164m
Hub height 105m
Turbine: 8MW
Total Output: 660MW

Next gen prototype
Year online: 2021?
Diameter: 203+m?
Hub height: 140m?
Turbine: 12MW?
Manufacturer GEwind

INDUSTRIALISATION:
for example increasing efficiency of installation of WTGs
from 2003 to today


UK Infrastructure Investment to 2021 £bn
Rail, £25.6
Electricity Networks, £23.2
Education, £17.3
Roads, £15.6
Oil & Gas, £24.0
Offshore Wind, £17.5
Water & Sewage, £15.1
HS2, £14.2
Housing & Regeneration, £12.0
Telecomms, £11.5

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Conclusion

- Cost high now but falling rapidly
- Raw potential is greater than our current needs
- Environmentally benign
- The technology lends itself to large scale deployment
- The industry has matured substantially in the last 20 years
- Industrialisation and innovation will enable the necessary cost reductions to be realised
- The industry is geared up to go on building into the 2020's and beyond…

References and links

- www.Ørsted.com
- UK renewables association
- https://www.renewableuk.com/page/UKWEDhome

Global renewables data: REN21

- http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_final_.pdf

International renewables energy association

- http://resourceirena.irena.org/

European wind energy association

- https://windeurope.org/

Danish wind energy association – technology – excellent resource on how wind energy works: European commission

- http://xn--drmstrre-64ad.dk/wp-content/wind/miller/windpower%20web/en/tour/wres/index.htm

European commission

https://ec.europa.eu/energy/sites/ener/files/documents/ECOFYS%202014%20Subsidies%20and%20costs%20of%20EU%20energy_11_Nov.pdf

Appendix

Spare slides

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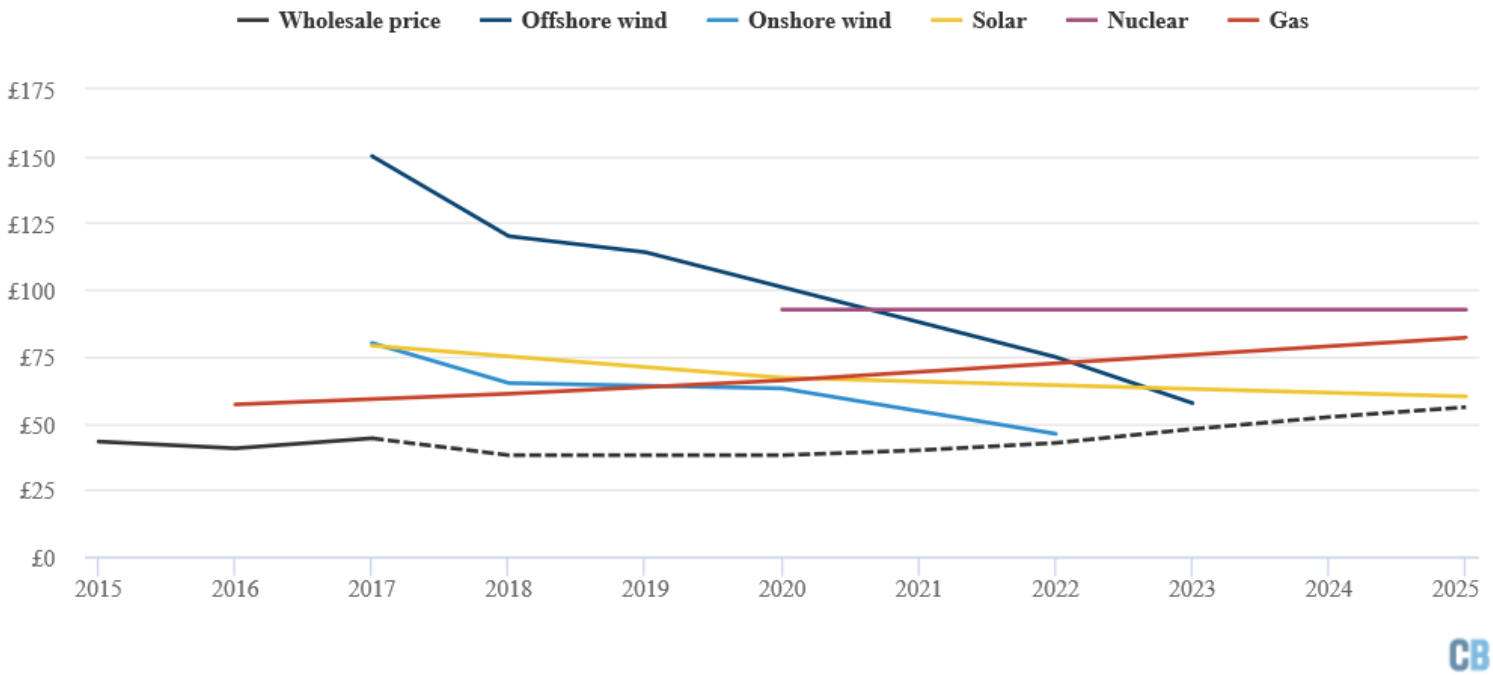
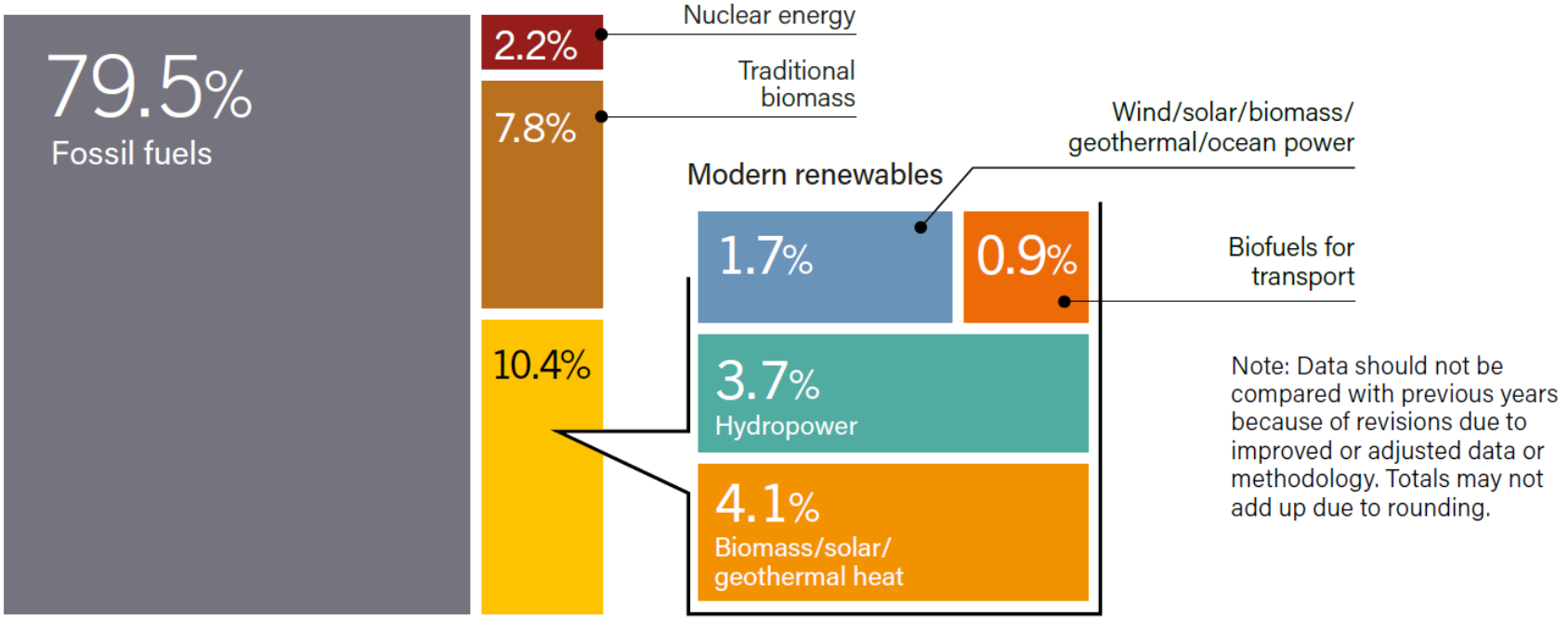
UK electricity costs



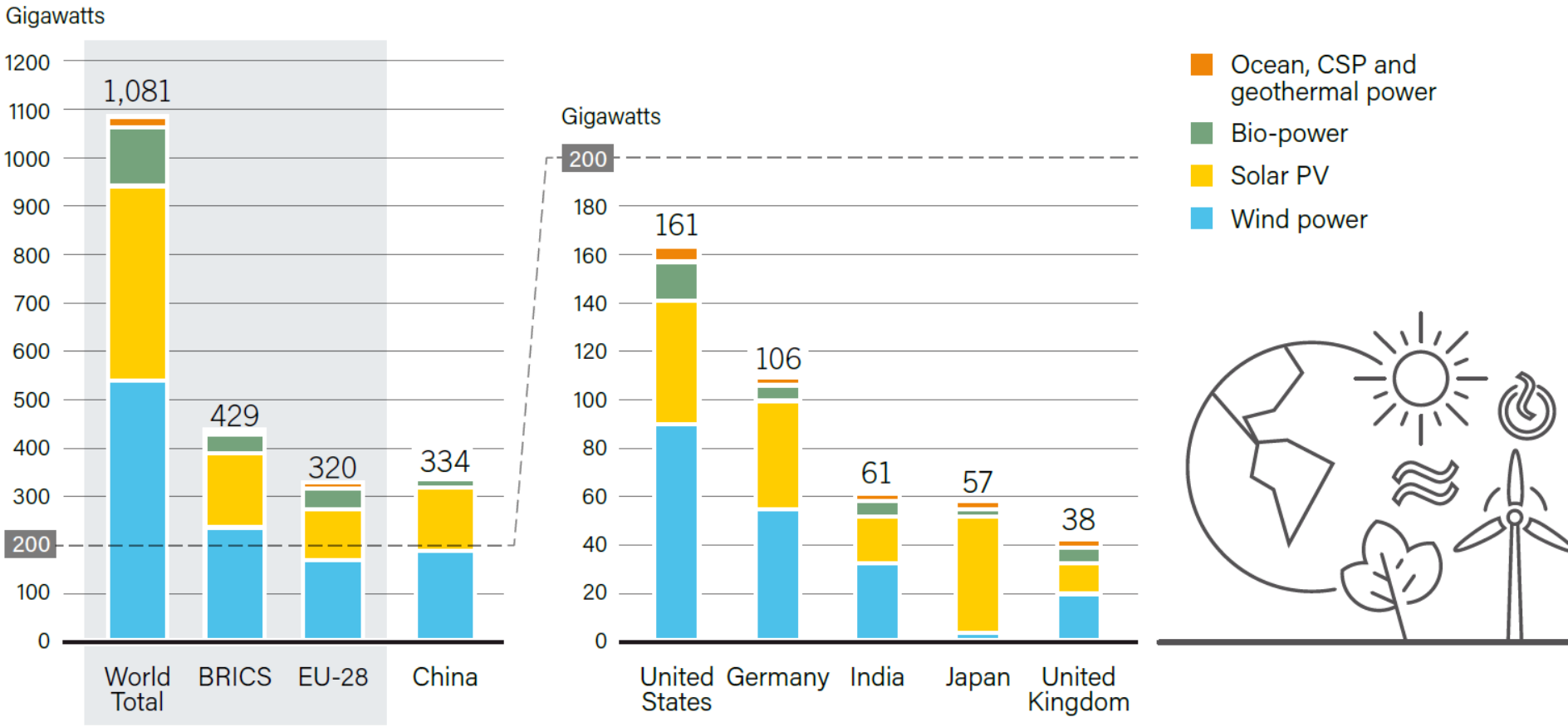
Costs of UK electricity generation, £/MWh. Wholesale prices are actual (solid black line) and projected, (dashed line). Technology costs reflect awarded contracts and projections, see notes below for more details. Sources: BEIS projections, CfD auction results and Baringa Partners. Chart by Carbon Brief using Highcharts.

FIGURE 1. Estimated Renewable Share of Total Final Energy Consumption, 2016



SOURCE: REN21-2018 edition

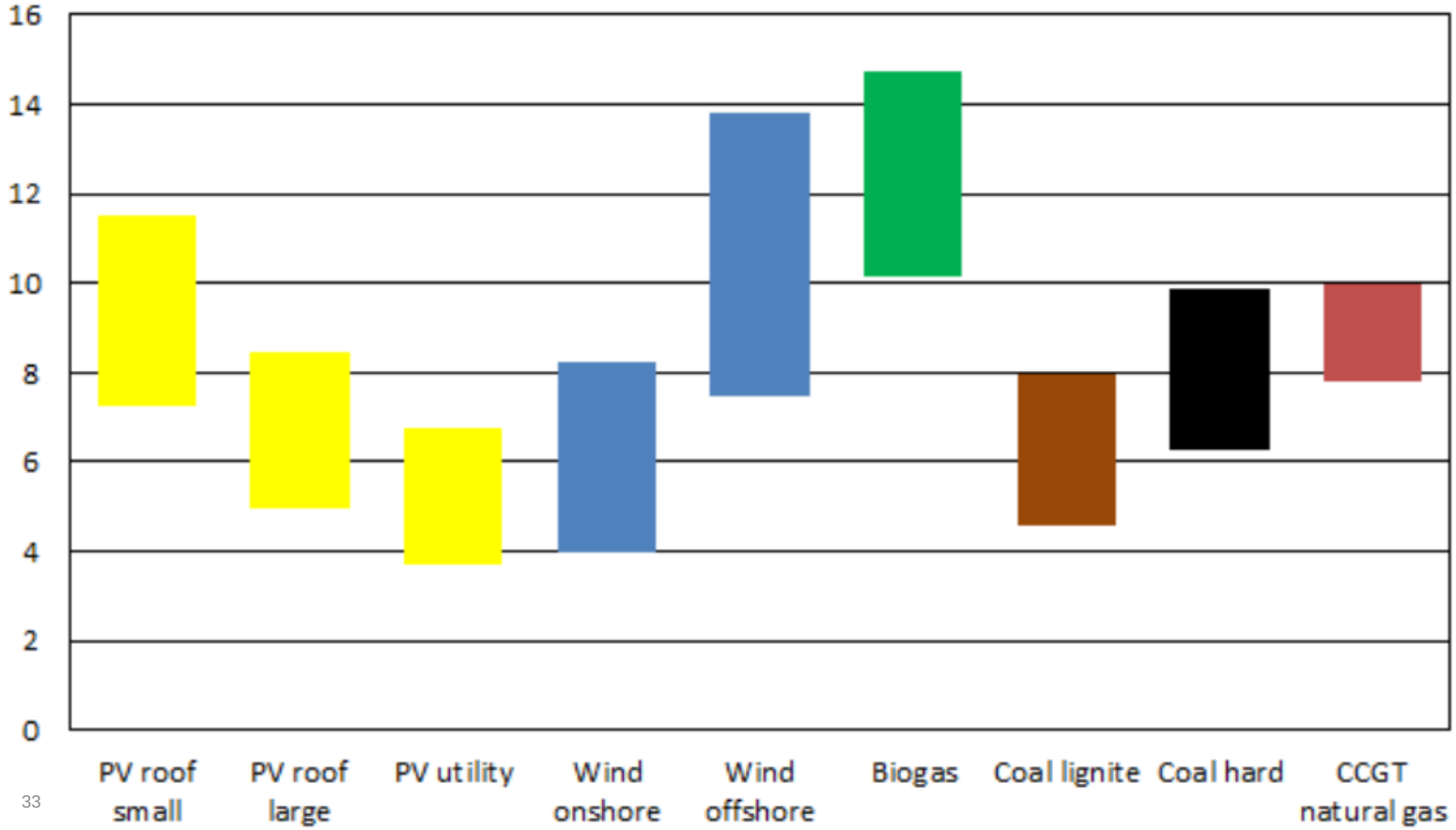
FIGURE 7. Renewable Power Capacities* in World, EU-28, and Top 6 Countries, 2017



Note: BRICS = Brazil, the Russian Federation, India, China and South Africa. *Not including hydropower.

Levelized cost of electricity for Germany

in EuroCent/kWh, source: Fraunhofer ISE; March 2018



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How much is enough? Raw potential wind power

Table 1. Annual wind energy potential, CO_2 emissions, and current electricity consumption for the top 10 CO_2 emitting countries

No	Country	CO_2 emission (million tonnes CO_2)	Elec. Consumption (TWh)	Potential Wind Energy (TWh)		
				Onshore	**Offshore**	**Total**
1	United States	5956.98	3815.9	74000	14000	89000
2	China	5607.09	2398.5	39000	4600	44000
3	Russia	1696.00	779.6	120000	23000	140000
4	Japan	1230.36	974.1	570	2700	3200
5	India	1165.72	488.8	2900	1100	4000
6	Germany	844.17	545.7	3200	940	4100
7	Canada	631.26	540.5	78000	21000	99000
8	United Kingdom	577.17	348.6	4400	6200	11000
9	South Korea	499.63	352.2	130	990	1100
10	Italy	466.64	307.5	250	160	410

- **Lu, Xi, Michael B. McElroy, and Juha Kiviluoma. 2009 https://dash.harvard.edu/handle/1/5029362**

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