CISMADVANCED SCHOOL, Udine, Italy, 2025

ADVANCES IN WIND ENERGY STRUCTURES:

Current trends on the use of AI to advance wind energy infrastructures

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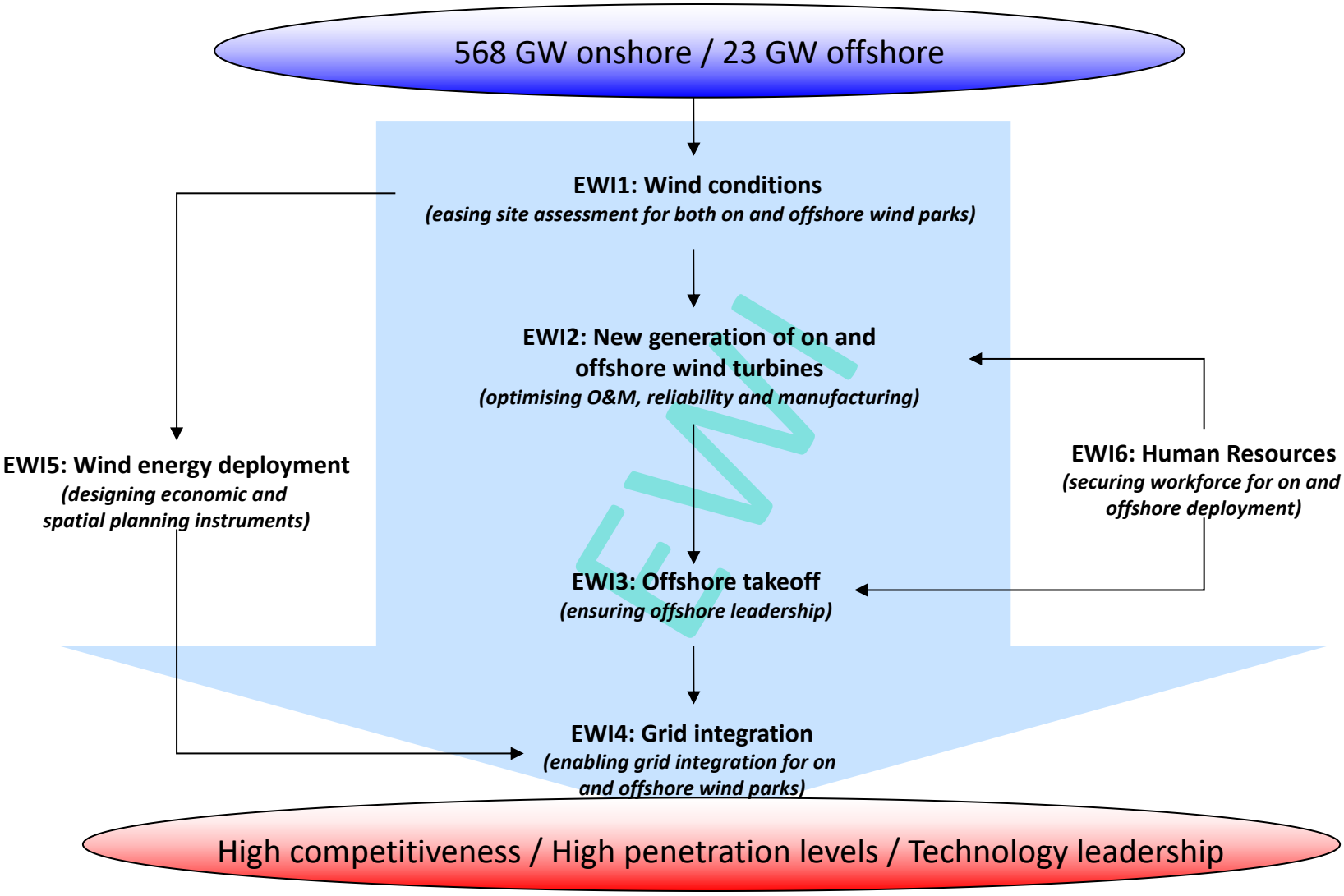
CONTENTS

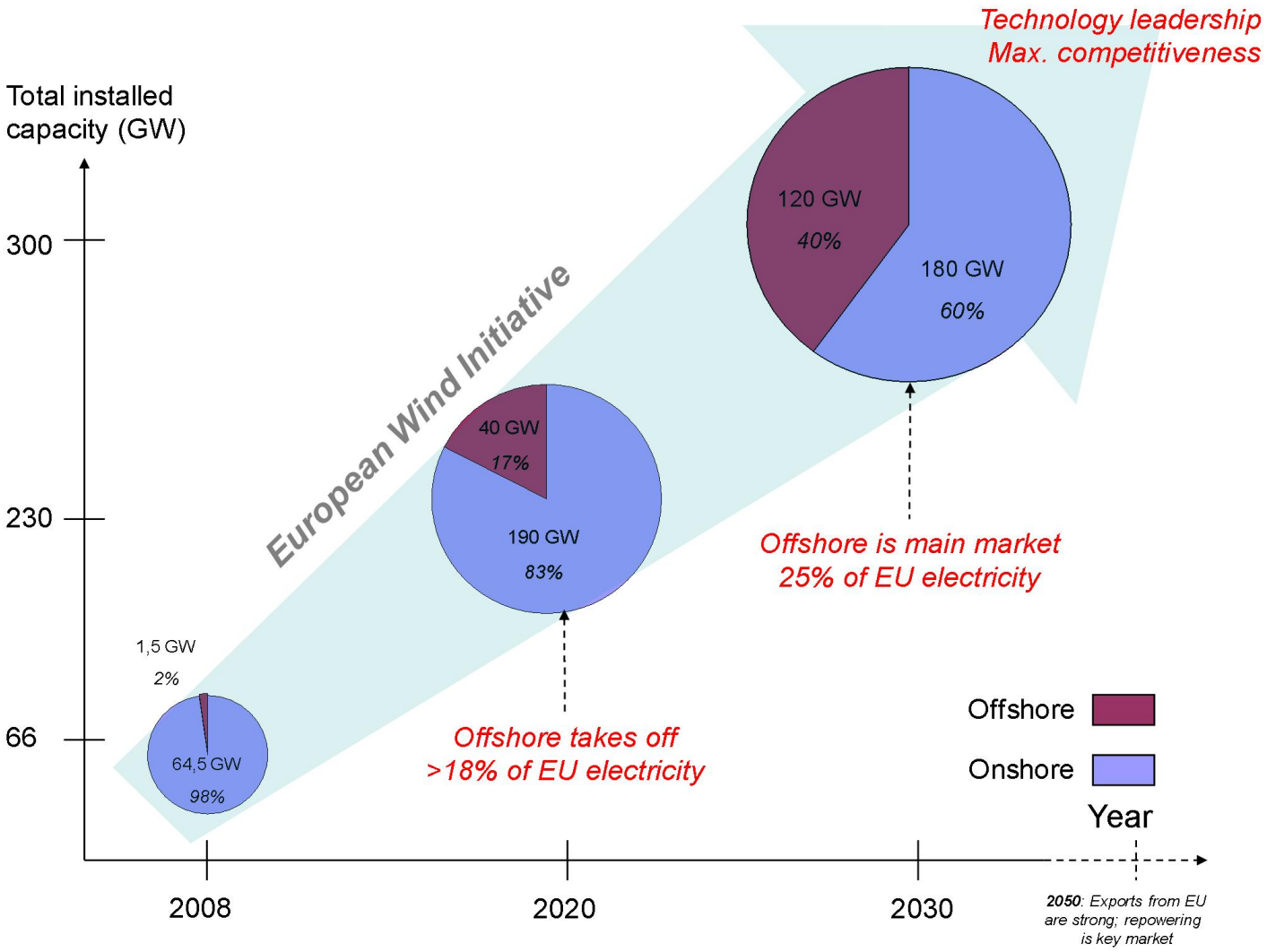
European Wind Initiative

- To make wind energy the most competitive energy source on the market during the decade 2020-2030, and as a first step decreasing the wind energy costs by at least 20% by 2020

- To enable the required large-scale deployment and grid integration of wind energy offshore and onshore with the aim of reaching wind penetration levels beyond 20% of European electricity consumption in the early 2020's

- Ensuring the European technology leadership on- and offshore, and developing large offshore wind turbines, including exploring concepts up to 20 MW.


568 GW onshore / 23 GW offshore
EWI1: Wind conditions
(easing site assessment for both on and offshore wind parks)
EWI2: New generation of on and offshore wind turbines
(optimising O&M, reliability and manufacturing)
EWI5: Wind energy deployment
(designing economic and spatial planning instruments)
EWI6: Human Resources
(securing workforce for on and offshore deployment)
EWI3: Offshore takeoff
(ensuring offshore leadership)
EWI4: Grid integration
(enabling grid integration for on and offshore wind parks)
High competitiveness / High penetration levels / Technology leadership


Technology leadership
Max. competitiveness
Total installed capacity (GW)
300
230
66
120 GW
40%
180 GW
60%
European Wind Initiative
40 GW
17%
190 GW
83%
1,5 GW
2%
64,5 GW
98%
Offshore is main market
25% of EU electricity
Offshore takes off
>18% of EU electricity
Offshore
Onshore
Year
2008
2020
2030
2050: Exports from EU are strong; repowering is key market

- Installed and planned wind power

Summary of Strategic Research Agenda

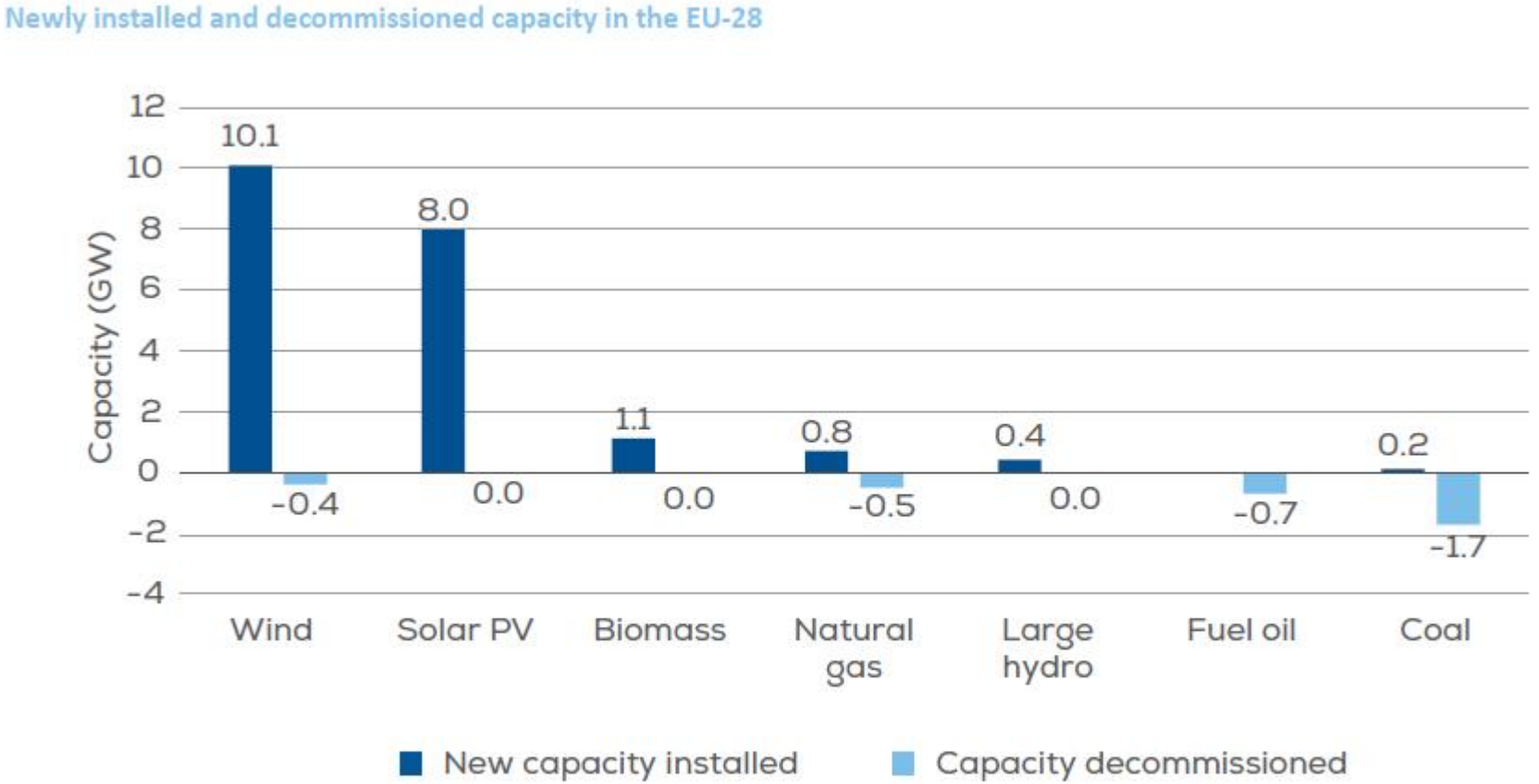
- **Short term targets**: within 2020 to reduce the greenhouse gas emission by 20% and ensure 20% of renewable energy sources in the EU.
- **Long term targets:** decarbonization. To reduce by 60–80% the greenhouse gas emission.

To meet the 2020 targets, among many other research lines, for the EC it is imperative to:

Double the power generation capacity of the largest wind turbines, with offshore wind as the lead application

- Installed and planned wind power

Wind still leads EU power sector (2018)



Source: Platts, SolarPowerEurope, WindEurope

- Installed and planned wind power

Wind power capacity in 2018

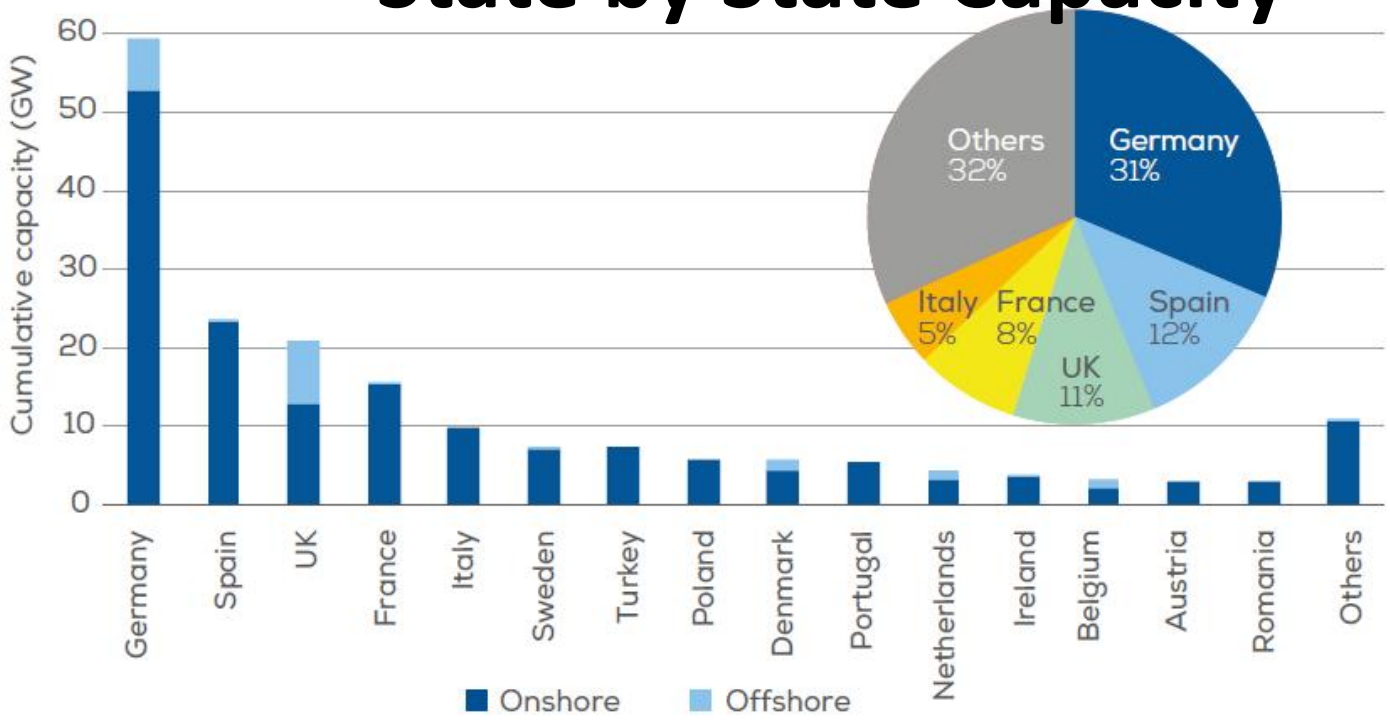
	Installed in 2018 [GW]	End 2018 (cumulative) [GW]
Total EU-28	11.7	189
Of which Offshore	2.7	19

With 362 TWh generated in 2018, wind power covered 14% of the EU's electricity demand!

- Installed and planned wind power

Cumulative onshore and offshore installations by country

State by State Capacity



Offshore	6.4	-	8.2	-	-	0.2	-	-	1.3	-	1.1	-	1.2	-	-	0.1
Onshore	52.9	23.5	12.8	15.3	10.0	7.2	7.4	5.9	4.4	5.4	3.4	3.5	2.2	3.0	3.0	10.8
Total	**59.3**	**23.5**	**21.0**	**15.3**	**10.0**	**7.4**	**7.4**	**5.9**	**5.7**	**5.4**	**4.5**	**3.5**	**3.4**	**3.0**	**3.0**	**10.9**

Source: WindEurope

- Installed and planned wind power

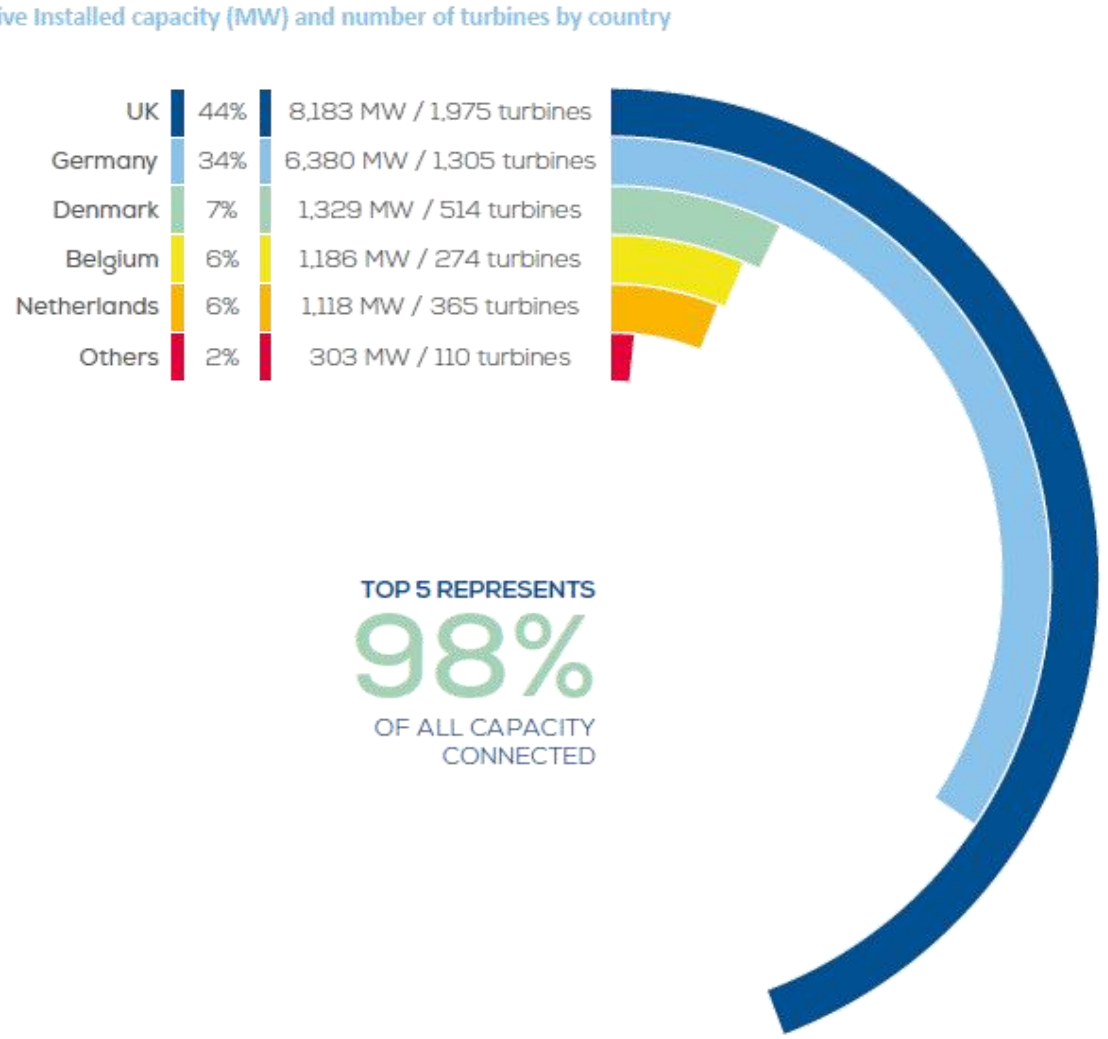
Planned capacity up to 2020

In March 2009 the EWEA target for total installations by 2020 has been increased from **180 GW to 230 GW**, of which **40 GW** will be **offshore**.

This means 14-18% of the EU electricity demand (60% of EU households)

- Installed and planned wind power

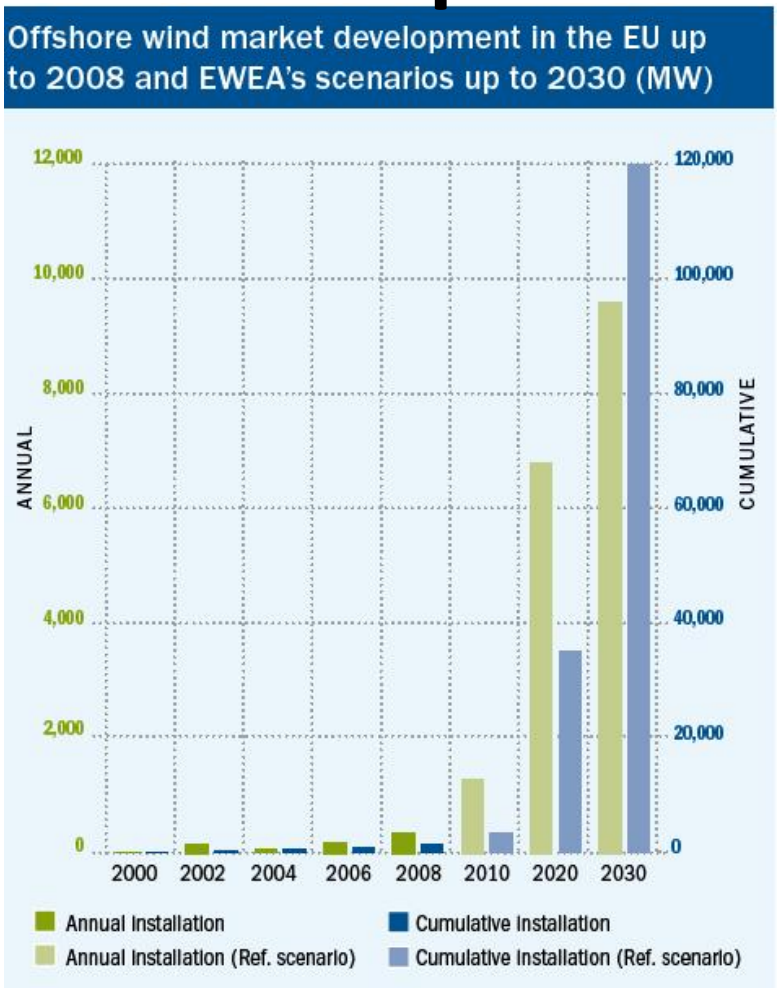
Offshore at the end 2018



Source: WindEurope

- Installed and planned wind power

Development of offshore installations



- **by 2010:**
  3.5 GW predicted in March 2009
  3 GW actually at the end of 2010
- **by 2020:**
  40 GW predicted in March 2009
  23.5 GW corrected in July 2014
  19 GW at the end of 2018 ...
- **by 2030:**
  120 GW predicted in March 2009
  66 GW corrected in August 2015

- Installed and planned wind power

Offshore and SRA

More than 10 % of total demand within 2030

(Ref. Ch. 3 Strategic Research Agenda)

2030 Priorities:

Offshore Wind Power Meteorology:

- Development of a fully integrated wind/waves/current interaction models

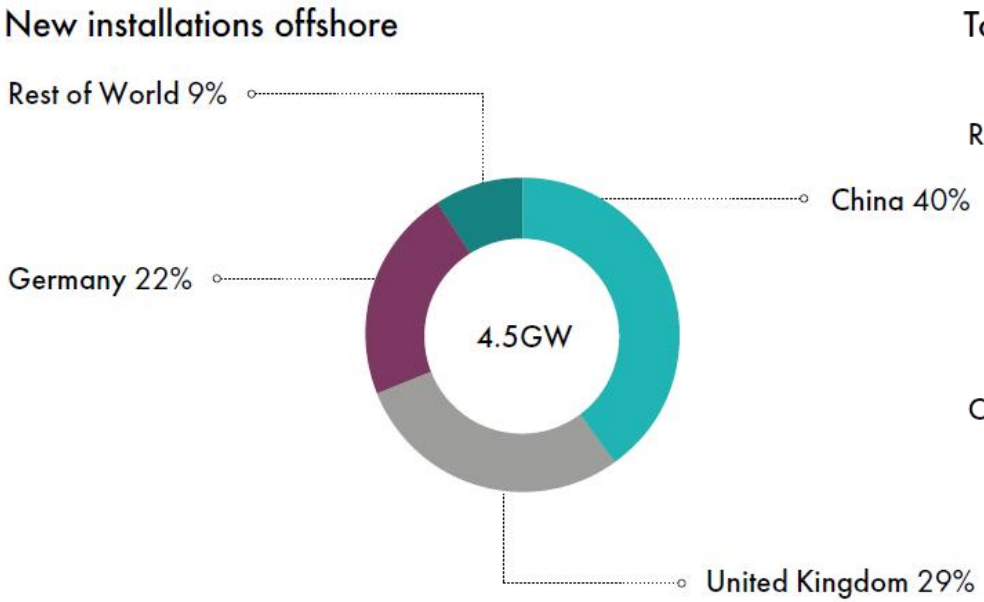
Substructures: (25% of the whole offshore investment!)

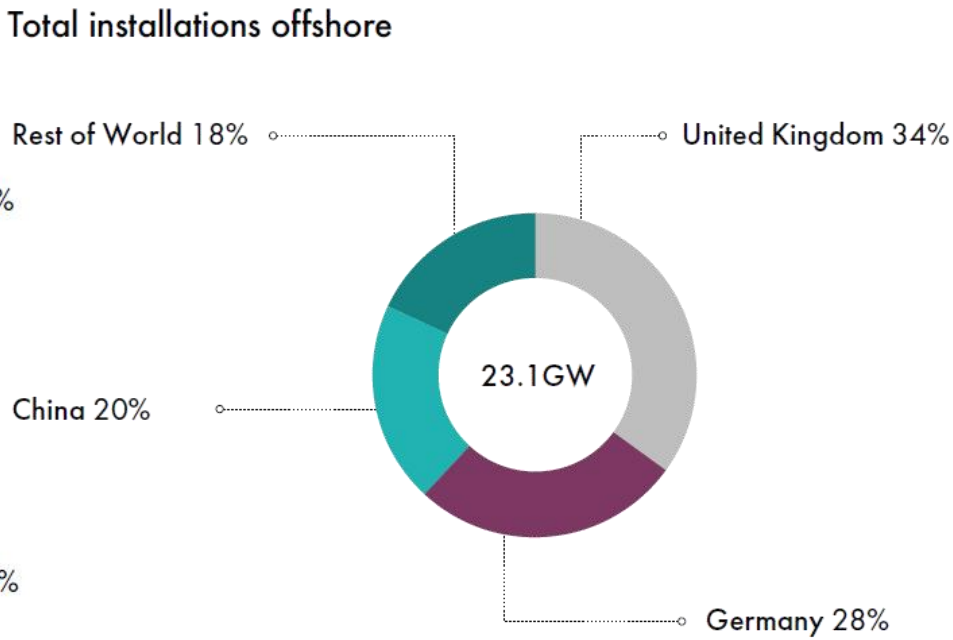
- Development of new substructure concepts
- Develop improved designs to extend the life of structures, to reduce costs and to incorporate risk based life–cycle approaches.

Consider: forces (and somehow costs) increase by the square of wind/water velocity!!

- Installed and planned wind power

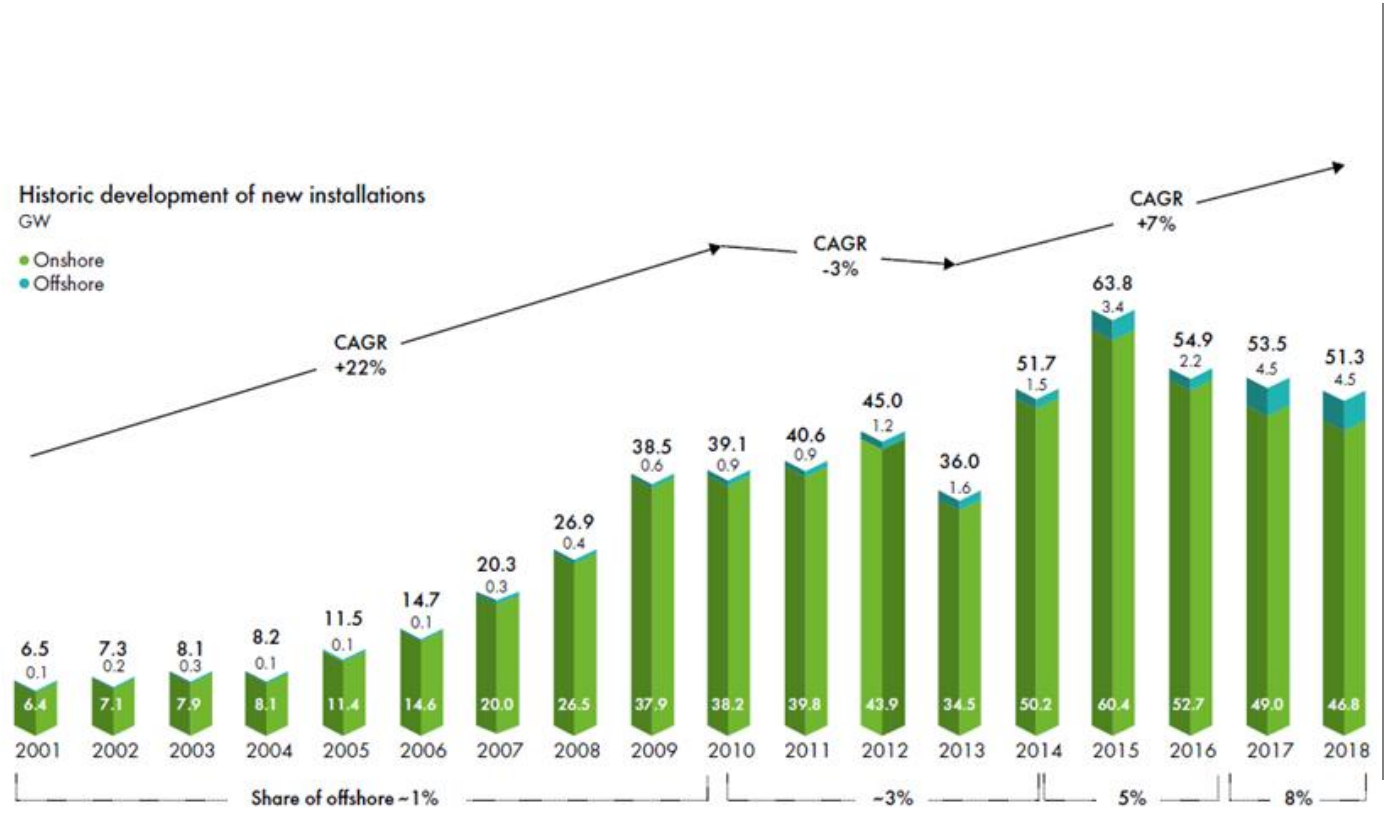
The worldwide situation – regions

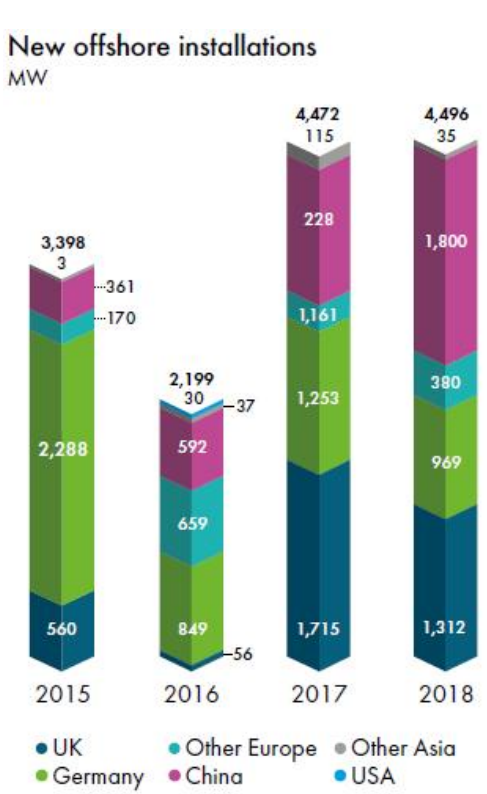




- Installed and planned wind power

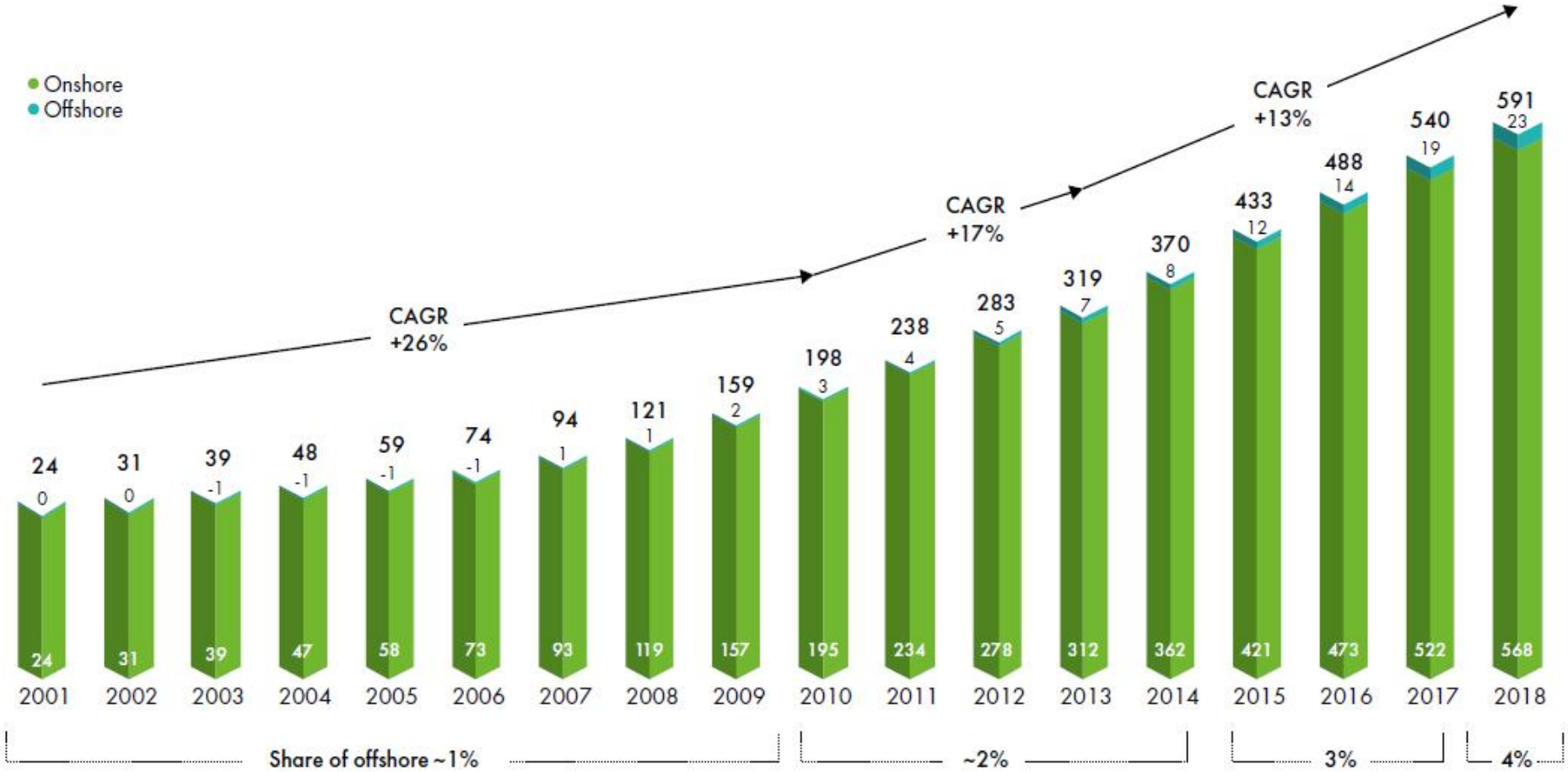
The worldwide situation – new installations





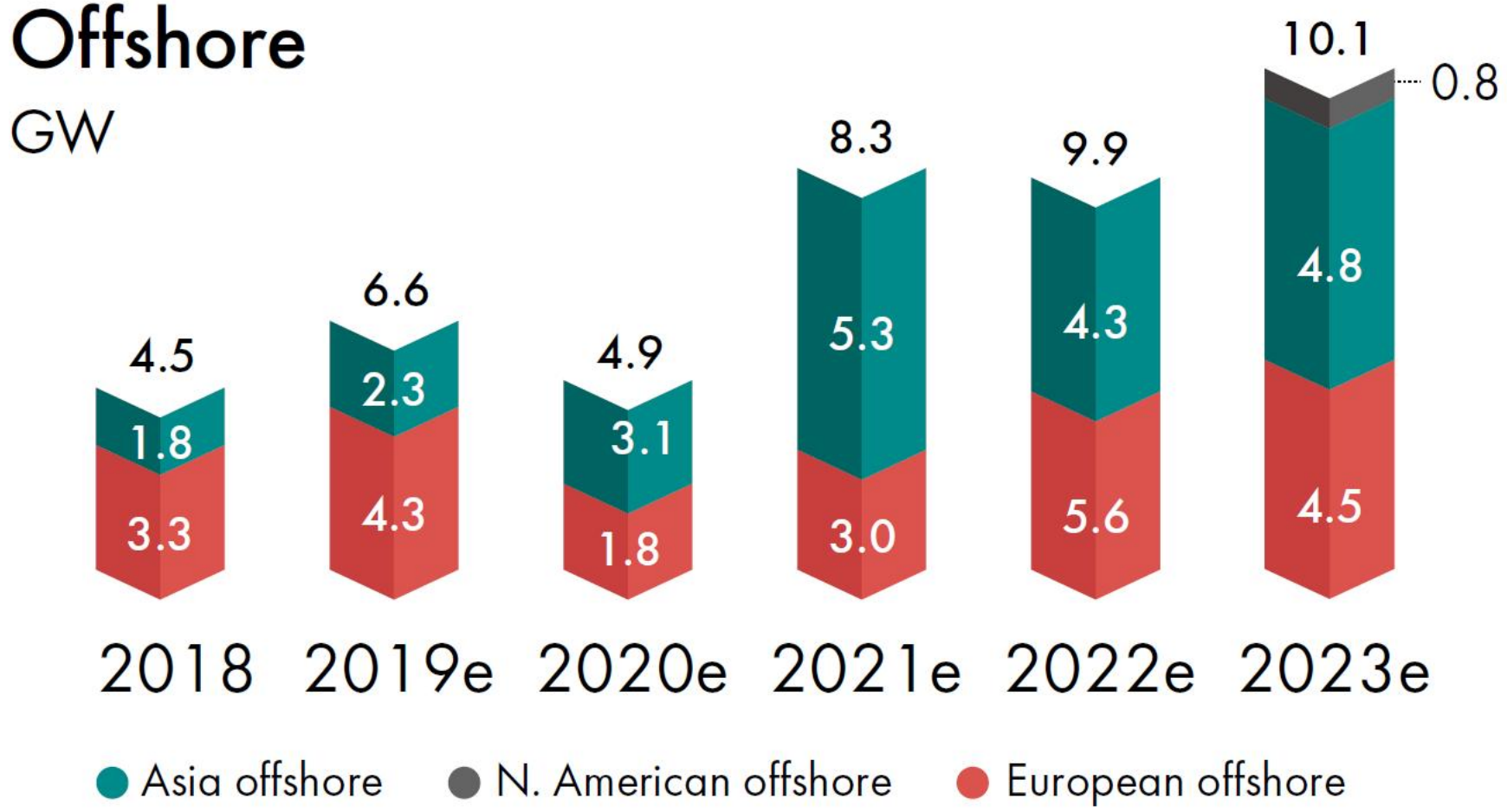
- Installed and planned wind power

The worldwide situation – total installations



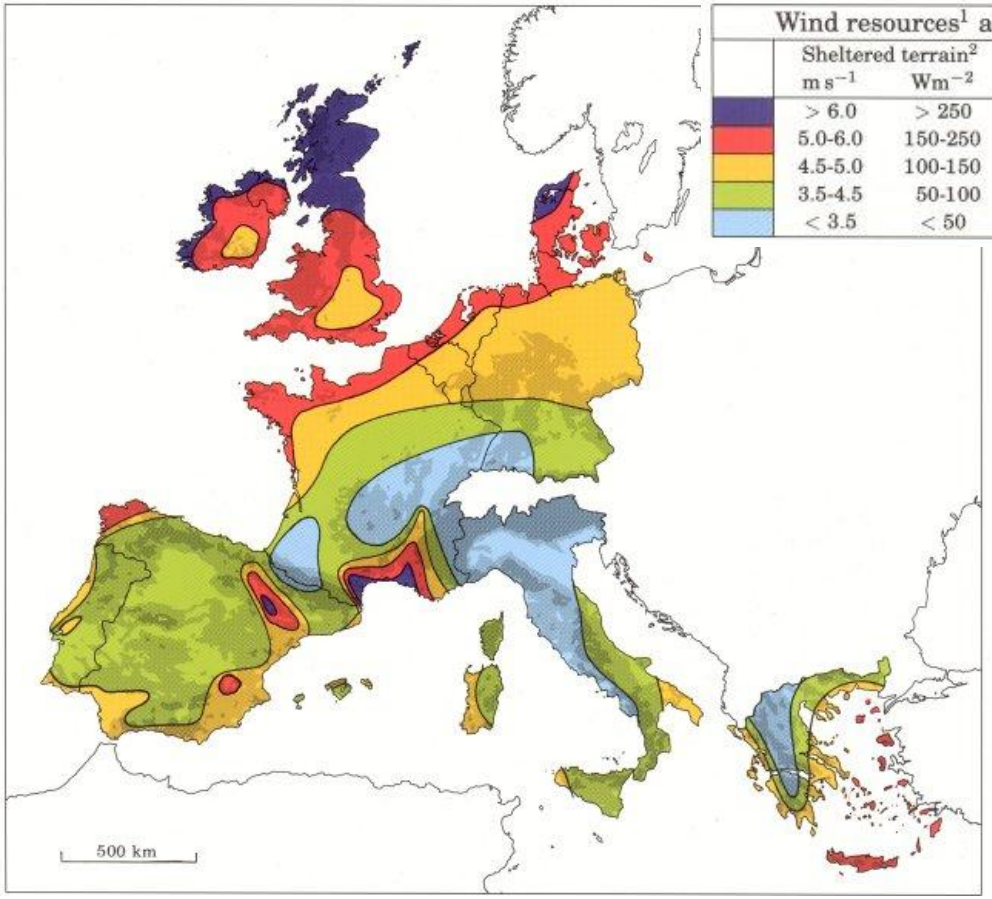
- Installed and planned wind power

The worldwide situation – outlook to 2023



- Potential

The European onshore potential



Wind resources[1] at 50 metres above ground level for five different topographic conditions

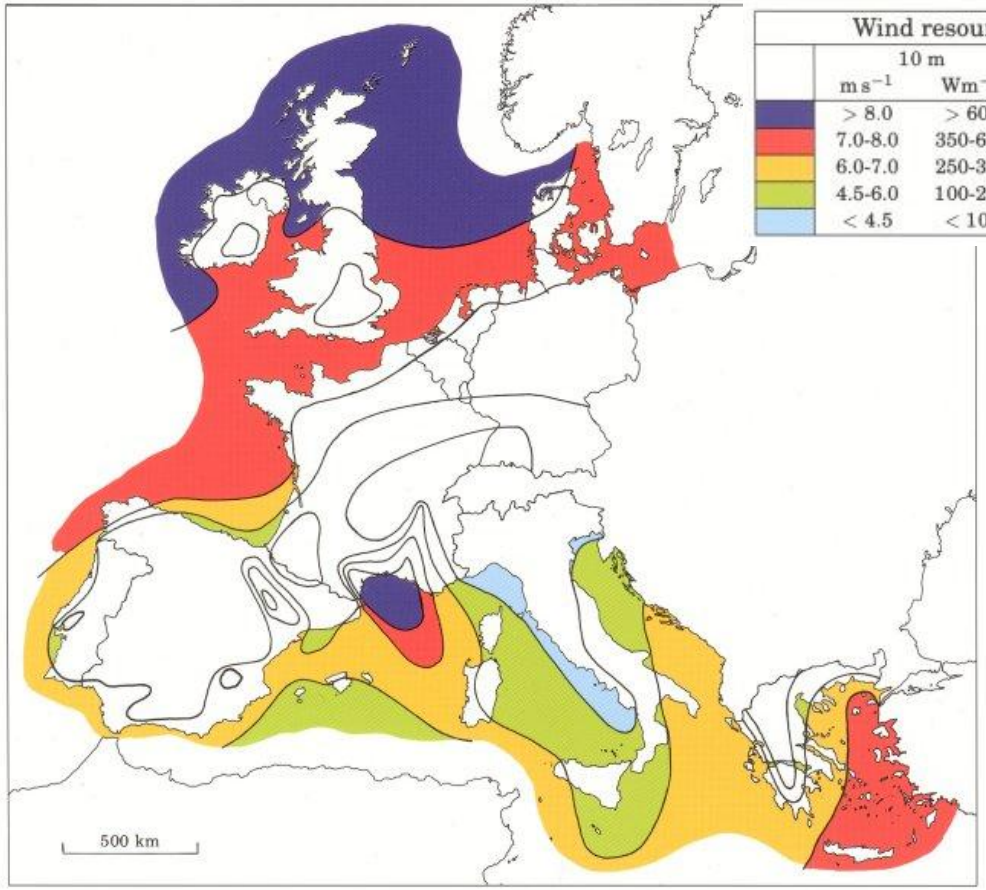
	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Minimum cost-effective wind speed = 4 m/s

Source: *European Wind Atlas*. Copyright © 1989 by Risø National Laboratory, Roskilde, Denmark.

- Potential

The European offshore potential



Wind resources over open sea (more than 10 km offshore) for five standard heights										
	10 m		25 m		50 m		100 m		200 m	
	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}
	> 8.0	> 600	> 8.5	> 700	> 9.0	> 800	> 10.0	> 1100	> 11.0	> 1500
	7.0-8.0	350-600	7.5-8.5	450-700	8.0-9.0	600-800	8.5-10.0	650-1100	9.5-11.0	900-1500
	6.0-7.0	250-300	6.5-7.5	300-450	7.0-8.0	400-600	7.5- 8.5	450- 650	8.0- 9.5	600- 900
	4.5-6.0	100-250	5.0-6.5	150-300	5.5-7.0	200-400	6.0- 7.5	250- 450	6.5- 8.0	300- 600
	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 6.0	< 250	< 6.5	< 300

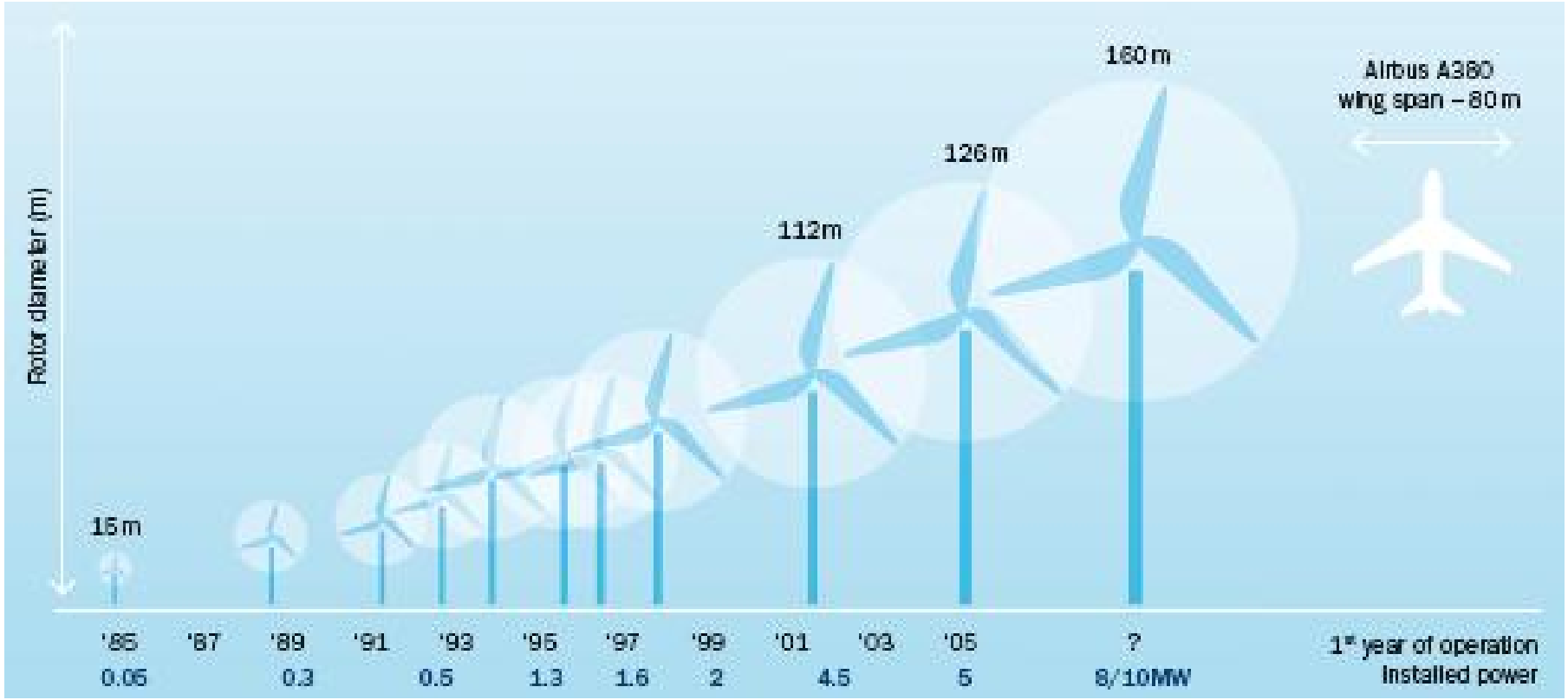
Minimum cost-effective wind speed = 4 m/s

Source: *European Wind Atlas*. Copyright © 1989 by Risø National Laboratory, Roskilde, Denmark.

- Technologies

The technological challenge

A (offshore) wind turbine is a very sophisticated system, combination of components and sub-systems that have to be designed in an interdisciplinary and integrated manner. In addition, the size and complexity of wind turbines is increasing rapidly over time:



- Technologies

- 10 MW offshore wind turbine
- Rotor diameter of 164 metres
- 80 m blades, the equivalent of nine double decker London buses
- Each blade weighs 35 tonnes
- Swept area of 21,124 m2, larger than the London Eye
- One turbine can power 5,977 German homes
- Available for sale now
- Can be delivered for commercial installation beginning in 2021

Thank You for Your attention

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