Living Lab 70 GW Offshore Wind

FACT SHEET

Understanding wind conditions to operate turbines efficiently and provide system services

System-oriented integration of offshore wind turbines

Wind speeds fluctuate on timescales ranging from seconds to hours and beyond, causing variable power generation and load peaks on wind turbines. Wind conditions at the heights of modern turbines or in the centre of a wind farm cannot currently be predicted with sufficient accuracy. In the Living Lab 70 GW Offshore Wind, they are measured through extensive offshore campaigns and reproduced in wind tunnel experiments. Based on this data, the power output and loads of wind turbines are analysed to develop advanced system-oriented control concepts. These concepts aim to adapt turbine operation not only to current wind conditions but also to current electricity demand, helping to stabilise transmission grids directly through energy generation.

- **The targeted offshore wind expansion in the North Sea is challenging.**
- **The planned power yield per marine area would be the highest worldwide.**

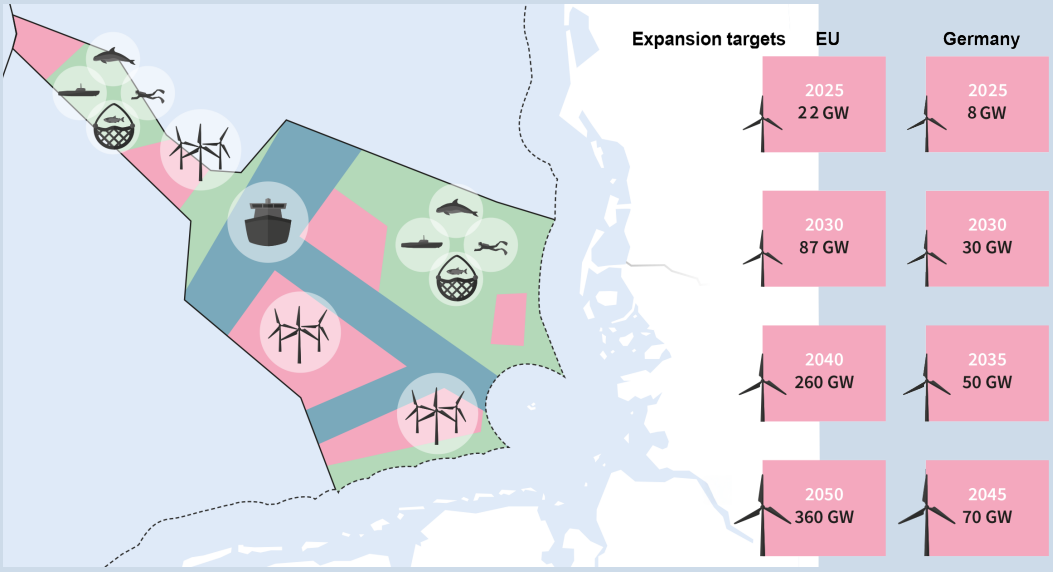
▸ Expansion of offshore wind energy in the North Sea: To achieve the target of 70 GW offshore wind capacity by 2045, innovative solutions are needed along the entire value chain. The Living Lab investigates how existing and future wind farms can be planned and operated sustainably and how marine space can be used optimally while considering competing interests such as fisheries, shipping and nature conservation.

▸ Wind turbines have grown larger with each generation, creating structural and aerodynamic challenges. Additional challenges arise from wake effects between individual turbines and entire wind farms. Weather conditions such as storms, high waves and icing can affect turbines and require innovative control concepts. Wind fluctuations and wake effects directly influence the electricity grid and therefore need to be considered increasingly when providing system services and ensuring grid stability.

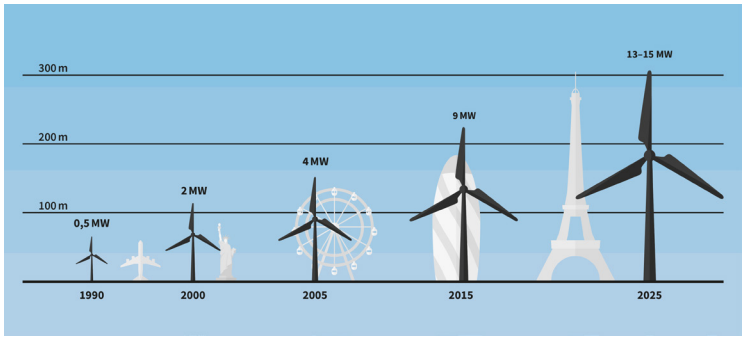
Wind parks in the German Bight

The colour-coded areas in the North Sea indicate different uses of the sea, such as nature conservation, fishing and shipping. The red areas are being considered for wind energy generation up to the year 2045.

On the right is a diagram showing the gradual expansion of offshore wind energy towards becoming Europe's green power station.



- **In the past, offshore wind turbines have become larger with each new generation, for economic reasons.**
- **Fluctuating wind speeds lead to variations in electricity generation.**



▸ Offshore wind energy contributes increasingly to electricity generation, while turbine size has almost tripled over the last 25 years. Modern turbines reach heights of more than 300 metres, making offshore wind energy economically viable despite harsh environmental conditions. Planning offshore wind farms is complex, ranging from long-term allocation of marine areas and compliance with environmental regulations to establishing offshore and onshore infrastructure. Fluctuating winds, extreme weather and variable grid feed-in make system integration more difficult. Larger turbines in denser wind farm layouts require new simulation models capable of representing changing flow conditions and loads.

- **Fluctuations in electricity feed-in can be reduced through the skilful control of wind farms.**

▸ To ensure grid stability, the power drawn from the wind must be adjusted to the grid's current power demand. To make this possible, control strategies are required that take into account both the electrical power balance and aerodynamic influences. This requires aerodynamic analyses and forecasts that describe the changes in power output resulting from wind events.

- **The requirements for the design and operation of modern offshore wind turbines are wide-ranging.**

▸ Improved wind forecasts, together with system-optimised control of wind turbines – i.e. control tailored to demand – could significantly reduce short-term fluctuations on a timescale ranging from seconds to hours and substantially improve grid stability. The control of the turbines also determines the loads that occur and can minimise shadowing effects. At present, however, there are still gaps in our understanding of the prevailing wind conditions at the great heights reached by modern wind turbines, as well as the complex interactions within a wind farm, the resulting loads on the turbines and the resulting power fluctuations.

- **Extensive offshore measurements generate a unique database.**
- **Laboratory tests and simulations enable the systematic development of innovations.**

▸ The Living Lab 70 GW Offshore Wind conducts large-scale offshore measurement campaigns in existing wind farms to establish the largest database to date on wind fields, turbine data and marine currents. The measured wind fields and turbine data are incorporated into models and reproduced in laboratory experiments such as wind tunnel tests. The goal is to improve the prediction of complex flow conditions and turbine loads and to develop control concepts based on this knowledge.

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