Danish Energy Agency

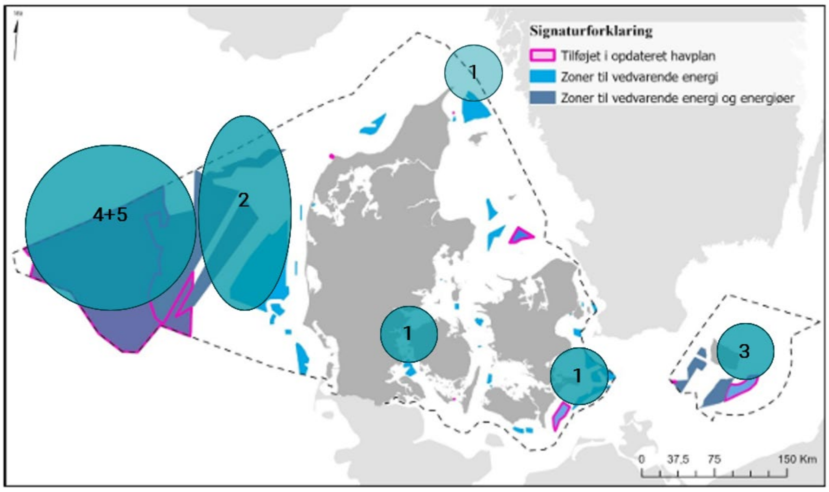
Technology Brief

Update of offshore wind in the Technology Catalogue (Feb 2025)

The Danish Energy Agency has published an updated Technology Catalogue chapter for offshore wind in February 2025.

The new version contains updates on AC grid connected wind farms, both with and without dedicated transformer stations for respectively offshore and nearshore wind farms.
In addition, the catalogue now also includes data for far offshore sites requiring a DC grid connection. Furthermore, quantitative assumptions on floating offshore wind farms both offshore (AC) and far offshore (DC) are presented.

There are thus now five datasheets for different representative cases, exemplified by areas in the Danish EEZ. Considering similar geographical characteristics such as comparable water depth and distance to shore, these data may also inform representative overall assumptions in other countries.



NB: The cases 1-5 are a non-exhaustive list of technical examples. Other technical solutions not investigated in this study may also be relevant, e.g. other foundation types depending among others on water depth and sea bottom conditions.

Supplementing the discrete datasheets and as in the previous edition of the Catalogue, the investment cost assumptions can be adjusted over varying water depths and distance to shore. This updated chapter edition simplifies the previous complexity of the cost formulas behind water depth and distance to shore and states clearly, over which range the variables can be adjusted.

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The newest edition has quantified the technoeconomic assumptions predominantly based on information on the latest Danish offshore wind farm that has reached Final Investment Decision, Thor developed by RWE, and supplemented with further interviews with industry stakeholders, held before and after the latest Danish auction close.
The current macroeconomic investment climate around offshore wind acts as an important factor for the updated estimations in the short term, compared to the previous edition that was analyzed in late 2021/early 2022.

- The investment cost (CAPEX) estimates for a representative Danish offshore wind farm with investment decision taken in 2025 has risen by ca. 30 pct. in real terms compared to data from the previous edition of the chapter. In the context of the Technology Catalogue, this is also due to the updated assumption of placing the representative site further offshore (twice the distance to shore) than in the previous edition.

- Expected turbine sizes are continuing to increase. Among others, rising competition between turbine manufacturers from different global regions has led to an upward adjustment of the long-term assumptions, now projecting representative turbines at 35 MW in 2050. Numbers in the short term to 2030 remain stable.

- Expected full-load hours of the analyzed wind farm cases are reduced by 5-10 pct. across years, due to an updated estimation that is relying more on observed full load hours of state-of-the-art projects, while still accounting for modelled results based on expected developments in technical design, such as turbine size and specific power rating.

Multiple reasons are driving these technoeconomic developments. Key factors such as increased inflation and elevated component and material costs in a material-heavy industry as offshore wind are the main reason for an increase in cost, along with bottlenecks caused by buildout targets in specific years.

Furthermore, the timing aspect plays a crucial role in the assessment of future cost. The Final Investment Decision (FID) of a given farm now lies earlier with respect to its commissioning date than in the previous edition. Since cost reductions based on learning effects are an important factor in the estimation of future costs, the now longer assessed lead times cause a longer delay in the cost reduction pathway.

The intention of the Technology Catalogue is to describe a site of a given year based on its FID (the year presented in the datasheet). With a commissioning date typically around 3.5 years later (construction time after FID stated in the datasheets), a farm with FID in H1 2025 will commence operation only in H2 2028. Due to stepwise changes in technology design for offshore wind, e.g. incremental turbine size increases, users of the data are discouraged to interpolate any numbers between the presented years.

Major changes in updated Technology Catalogue

Based on the latest publicly available data and interviews with the Danish wind industry, the updated Technology Catalogue chapter for offshore wind gives an up-to-date perspective on technical and economic assumptions behind the expected future development of offshore wind, based on the current macroeconomic climate.

Together with the surge of inflation rates in the wake of Covid-19 and the war in Ukraine, material and component cost have risen compared to a pre-crisis level.

Component and material cost in offshore wind
As the IEA shows in their Energy Technology Perspectives 2024 report[1], 84 pct. of the technology manufacturing cost for wind energy are linked to component and material costs. These refer to the costs of upstream components used in the production of components for offshore wind farms or the costs of materials used as inputs (e.g. steel for turbine towers). IEA shows that this is a significantly higher share than for other energy technologies such as solar PV or batteries. Other costs as development cost, labour cost or energy cost play a smaller role for offshore wind in comparison.

Commercial contracts between commercial partners within the offshore wind value chain have been affected to different extents. As component and material prices are gradually decreasing again from the previous peak, but as inflation is slower to return to a pre-crisis level, it is expected that the current investment climate remains affected.

Conditionally signed contracts within the value chain have a ripple effect over time, as Final Investment decision and the construction phase can happen several years after the contracts are negotiated. This is linked to the industry's increased need for profits after years of losses.

Figure 1 shows the assumed investment cost for a fixed bottom offshore wind farm with AC grid connection with FID in 2025. Cost for turbines and foundations (incl. their installation) account for ca. 2/3 of the overall CAPEX. The grid connection cost comprised by substation and cabling account for almost 30 pct. of the overall CAPEX.

IEA; Energy Technology Perspectives 2024[1] https://www.iea.org/reports/energy-technology-perspectives-2024

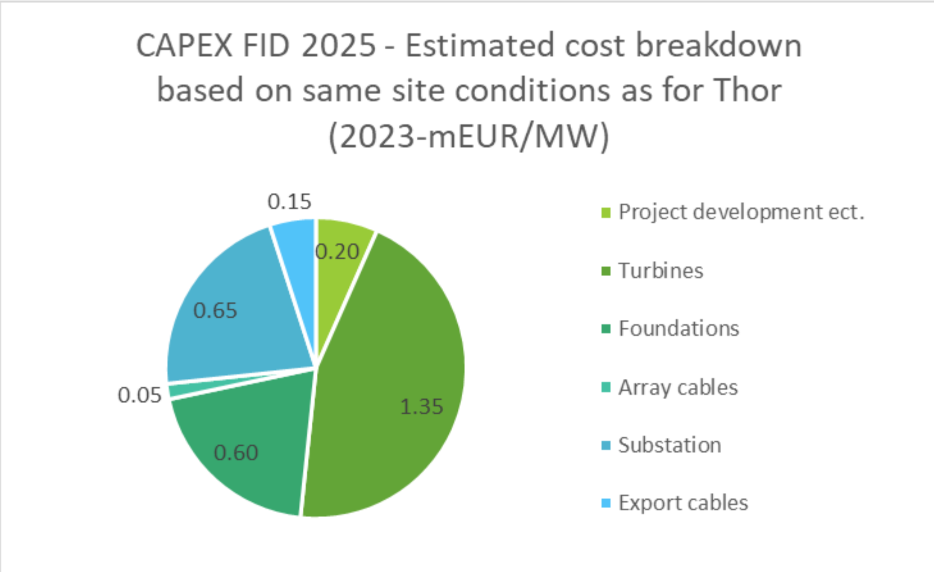

Figure 1: CAPEX per component and cost element for a fixed bottom AC grid-connected offshore wind farm (FID in 2025)

Figure 2 shows the assumed investment cost breakdown for 2025 plants. Due to the 2025 edition presenting offshore wind farms with a distance to shore twice as long as the previous edition, the share of grid connection is considerably higher. The residual shares of the primary cost elements of turbines and foundations remain stable, but elevated in absolute terms.

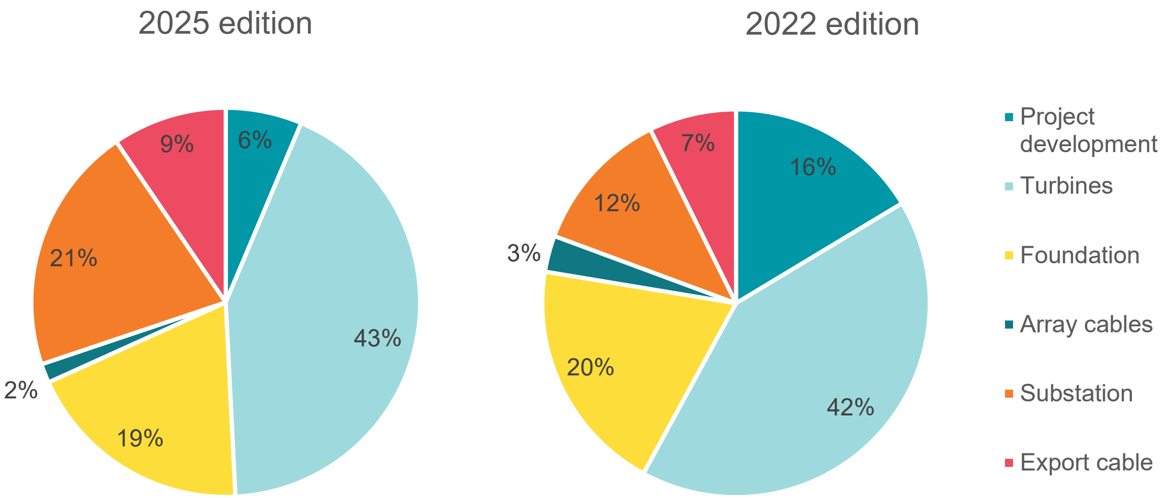

Figure 2: Cost breakdown for the AC grid connected offshore wind farm in 2025, comparing assumptions for 2025 and 2022 edition of the Technology catalogue

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Increased Levelized Cost of Electricity

The Levelized Cost of Electricity over time for an AC grid connected site in the North Sea are shown in **Figure 3**. Among other minor factors, updated assumptions on site geography, annual energy production, cost increases due to material commodity prices, and lead times shift the expected LCoE upwards. The expected levelized costs remain on an elevated level compared to the previous edition up to 2050.

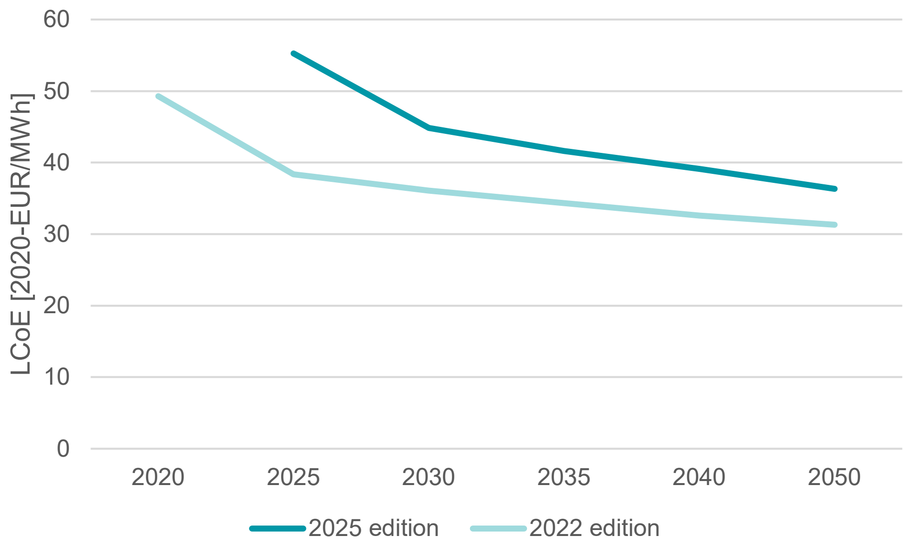

Figure 3: Levelized Cost of Electricity for AC grid-connected offshore wind, comparing results for 2025 and 2022 edition of the Technology Catalogue. 3.5 pct. WACC and technical lifetime assumed

Floating offshore wind is added to the Technology Catalogue

The updated Technology Catalogue now contains data on floating wind farms as well. Unlike onshore or bottom-fixed offshore wind, there are only a few full-scale floating wind projects in operation, making the estimations more uncertain in comparison to the residual data.

Figure 4 shows the CAPEX projections for all five examined cases, thus comparing bottom-fixed offshore wind with floating sites with same geographical characteristics. The figure shows that cost for floating wind remains higher than for a comparable bottom-fixed farm. It shows as well, however, that considerable learning is expected. In this regard, in the long-term projections the distance to shore is expected to be a more crucial driver for cost than the technology choice. With expected learnings, floating wind can play a viable role in other regions with deeper waters closer to shore, all else equal. Deployment of floating wind in several suitable markets across the globe is required to trigger this expected learning.

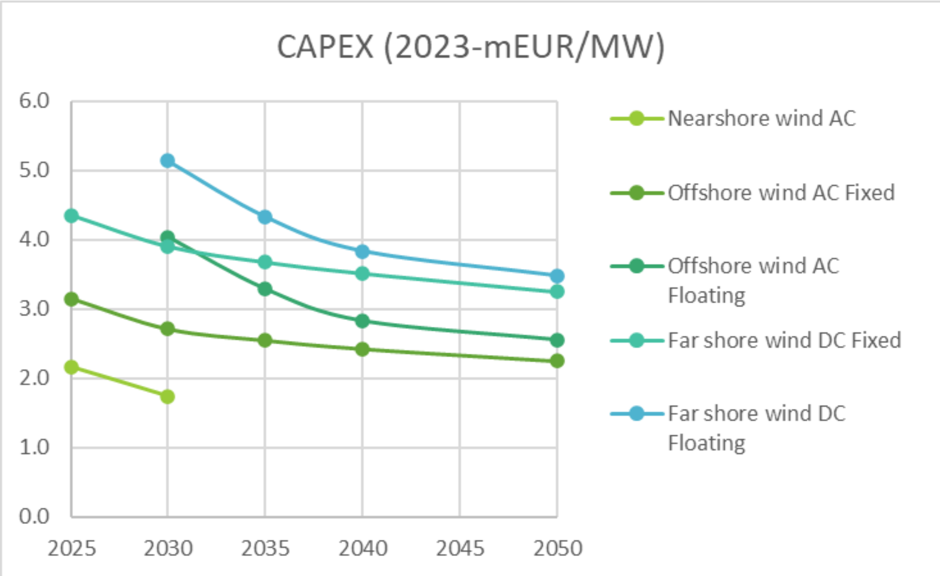

Figure 4: CAPEX projections for different fixed bottom and floating offshore wind cases

Perspectives for Denmark

Offshore wind cost has experienced a cost surge compared to the macroeconomic climate of the 2010's characterized by low interest rates and stable material and component commodity prices. Ongoing technological development and learning by manufacturing components and deploying farms is still expected to drive down offshore wind cost going forward. Based on the current macroeconomic climate that affects not only the Danish but also other offshore wind markets, this continued learning is now expected to happen from an elevated level, with Denmark still possessing some of the most attractive sites for deploying offshore wind. At the same time, inflation and commodity prices are expected to play a greater role in the assessment of cost reduction pathways than previously.