Offshore wind at a crossroads

Reviving the industry to secure Europe's energy future

→ An analysis of the state of offshore wind in Europe

Disclaimer

This paper focuses on the urgent need to revitalise Europe's offshore wind industry and the policy and industry actions required to unlock investment, stabilise costs, and accelerate deployment. While offshore wind is a critical pillar of Europe's energy transition, we acknowledge that other factors – such as demand-side measures, grid infrastructure, energy storage, and broader market dynamics – also play a fundamental role in shaping a sustainable and resilient energy system.

These topics, while essential, fall outside the primary scope of this paper. The analysis centres on supply-side challenges and solutions specific to offshore wind, recognising that an integrated approach, including improvements in grid capacity, interconnection, and energy demand management, is necessary to fully realise Europe's clean energy ambitions.

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Ørsted acknowledges the support from Bain & Company in developing the underlying fact-base and analyses based on external sources.

Offshore wind in Europe at a crossroads

In the coming months and years, Europe must secure its energy future by ensuring affordability, decarbonisation, competitiveness, independence from weaponised energy imports, and strategic autonomy. Achieving these goals requires a safe, sustainable, and reliable energy system – one that meets rising electricity demand through a diverse mix of clean energy technologies.

Offshore wind is essential to this transition. It reduces reliance on fossil fuel imports, stabilises energy prices, strengthens energy security and resilience, and delivers large-scale, cost-efficient green power. At the same time, it drives climate action while creating and sustaining European jobs.

For all these benefits, offshore wind is set to remain a key building block in governmental energy plans, and current energy system projections expect offshore wind to cover 20 % or more of Europe's electricity needs by 2050. But while the expansion of offshore wind may be needed, it won't happen by itself. The offshore wind industry stands at a crossroads.

In this report, we identify the risk of stagnation within the European offshore wind industry due to a vicious cycle ignited by inflationary pressures, higher interest rates, bottlenecks in supply chains, and higher risks on future revenue. This, in turn, has had a negative impact on projects' commercial viability, thus reducing investments from the supply chain and developers, slowing down the growth of capacity in the supply chain, leading to further bottlenecks – and further increasing costs.

The common currency here is uncertainty. Uncertainty about future electricity demand and, by extension, future electricity prices. Uncertainty among investors about the bankability of the projects at hand. Uncertainty in the industry about which targets will translate into actual turbines at sea. Uncertainty about the future capacity of the supply chain.

Collectively, this has created an imbalance between risks and rewards; and imbalance that now requires a reality check and re-calibration among governments and industry. Governments are discovering that trying to monetise offshore wind through high upfront concession payments and high seabed prices has put off developers. Meanwhile, the industry realises that persistent calls for more volume and complex auction criteria have not held the solutions to the most pressing challenges at hand.

Against this backdrop, this report points to a way forward for offshore wind, one that can revive the industry and secure Europe's energy future.

We believe that governments and industry will benefit mutually from a joint commitment for offshore wind. Regaining momentum for offshore wind is a mutual interest and obligation. It is easy to think of the current impasse as a problem mainly for the private sector. However, if not properly addressed, including at political and regulatory levels, all of society will lose out.

Energy security, climate ambitions, and economic growth opportunities will be missed – and the deflationary effects on energy prices will not materialise. Policies and regulations must be aligned with and support the industry's efforts to sustainably scale and create long-lasting value.

Responsibility lies with governments to provide predictability and certainty through contracts for difference (CfDs), to ensure the consistency of the build-out through sequential commissioning over time, and to coordinate with one another to maximise the value of offshore wind across the continent. In return, the industry can attract capital for necessary investment, secure enough capacity to deliver the necessary assets and technology, and deliver cost reductions by bringing down the cost of capital and committing to an accelerated learning curve.

This is no easy fix. But our analysis shows that if governments can commit to commissioning at least 10 GW of viable CfD capacity, alongside around 5 GW of flexible merchant capacity, every year from 2031 to 2040, then the industry will be able to secure sufficient capacity to reduce costs by around 30 % by 2040.

It should be noted that this formula alone is not enough to create a new equilibrium for offshore wind and secure Europe's energy future. That will require demand for electricity to be stimulated and facilitated through electrification and anticipatory investments in power grids.

We at Ørsted are ready to do our part together with the rest of the industry. We look forward to continuing our collaboration with governments across the continent to deliver a safe, sustainable, affordable energy future for countries, companies, and communities in Europe.

Rasmus Errboe
CEO, Ørsted

Executive summary

The case for offshore wind: Europe's energy future

The European energy landscape is rapidly changing. Energy prices have increased, energy imports remain high, and over 90 % of Europe's carbon emissions come from energy. The path forward is clear: Europe must build an energy system that is affordable, secure, and clean – ensuring competitiveness through affordable energy, enhancing energy security by reducing imports, and minimising climate impact with clean energy sources. This can only be achieved through a massive and unprecedented surge in electricity demand and require extensive build-out of clean electricity generation.

Affordable energy

Energy costs are important to industrial competitiveness, with affordable and predictable prices being essential for success. Manufacturing industries, for example, generate EUR 2.2 trillion in annual gross value added and employ 30 million people in the European Union.[1] However, high and volatile energy prices, partially resulting from high dependence on gas imports from Russia, have contributed to an erosion of Europe's global competitiveness in these industries. This has led to a 10-15 % drop in production between 2021 and 2024, and the loss of nearly 1 million manufacturing jobs since 2019.[2, 3]

If high energy costs and uncertainty persist, industries might relocate to regions outside Europe with more stable and lower input costs, putting the future of European industry at risk.

> "EU firms have been experiencing competitiveness losses owing to increased input costs, exacerbated by elevated energy prices in Europe compared to other regions."
>
> Mario Draghi, 2024[4]

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An affordable energy system also delivers societal benefits for households and small businesses, strengthening local economic resilience.

Key policy objectives for Europe's future energy system

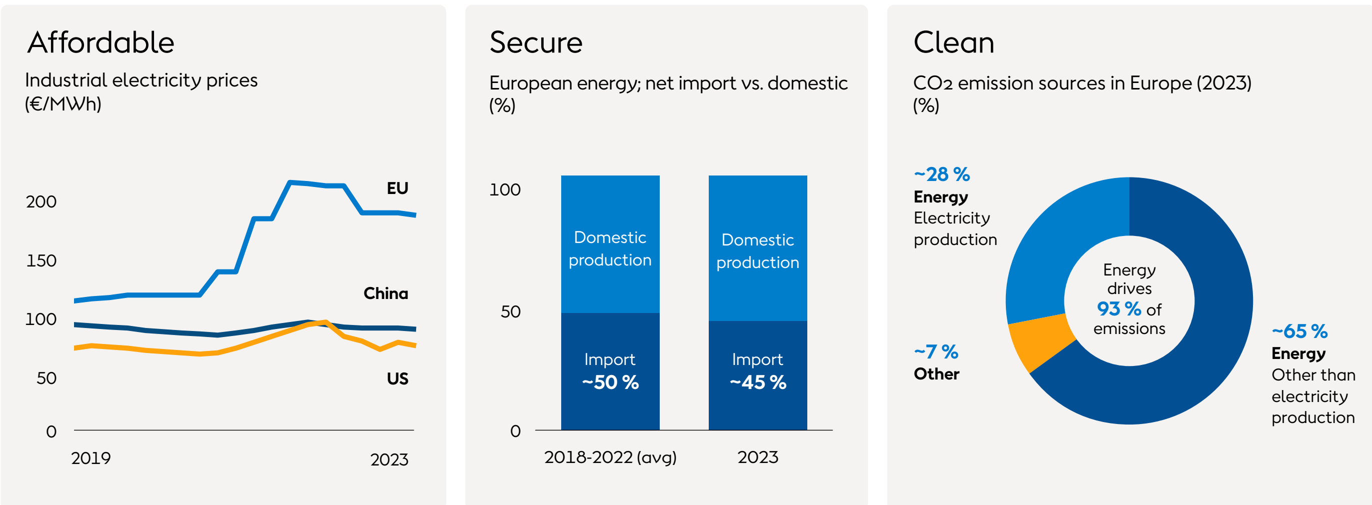


Figure 1: Note: Europe here consists of European members of the OECD with Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, North Macedonia, Georgia, Gibraltar, Latvia, Lithuania, Malta, Montenegro, North Macedonia, Romania, and Serbia; Imports refer to European energy net imports (imports minus exports) per year, broken down into ~6,600 TWh oil, ~3,300 TWh gas, ~1,300 TWh coal in 2018-2022 (average), and ~6,500 TWh oil, ~2,700 TWh gas, ~900 TWh coal in 2023; carbon emissions for all European countries, please reference Greenhouse Gas Emissions from Energy database documentation for a full country overview; 'Other' in carbon emissions pertains to commercial and public services, agriculture/forestry, fishing, other energy industries, and other non-specified industries. Source: The future of European Competitiveness (2024), Energy Institute Statistical Review of World Energy (2024), IEA World Energy Outlook (2024), ENTSO-E TYNDP (2024), IEA Greenhouse Gas Emissions from Energy (2022).

1 Eurostat (2024), 'Key figures on European business', based on 2021 data.
2 European Trade Union Confederation (2024).
3 Mario Draghi (2024), 'The future of European competitiveness'.
4 Mario Draghi (2024), 'The future of European competitiveness'.

Secure energy

The weaponisation of energy during the Russian-driven energy crisis has exposed the consequences of Europe's heavy reliance on energy imports. Average gas prices peaked in 2022 at over 400 % above pre-COVID levels – the most extreme energy shock in history – and hovered at over 50 % above pre-COVID levels in 2024.[5,6] Import dependency brings volatility, with fossil fuel prices fluctuating due to geopolitical tensions and supply issues. This unpredictability hinders long-term investment and highlights the need for resilient, domestic energy solutions.[7]

A secure energy system with minimum disruptions is essential for economic stability. Reliance on foreign fossil fuels, particularly natural gas, has left Europe vulnerable to price fluctuations, including from external shocks.

Clean energy

The urgency for rapid decarbonisation is accelerating, with global warming now happening more than 50 % faster than in 1970-2010, pushing temperatures beyond any level seen in the last 11,700 years.[8]

Combatting climate change and achieving EU climate targets require a large-scale expansion of carbon-free electricity.

Currently, over 90 % of Europe's carbon emissions stem from energy production or consumption, contributing 3.8 gigatonnes annually.[9] Transitioning to a system powered by renewable energy will drive Europe toward a sustainable, low-carbon future. Doing so in a way that also delivers on affordability and security objectives will set an example for a winning strategy for the world.

Europe's energy solution

Achieving an affordable, secure, and clean energy system in Europe hinges on large-scale electrification. Electricity demand in the EU is projected to nearly double – or even more than double – increasing from ~2,700 TWh in 2023 to between 4,900 and 6,800 TWh by 2050.[10] This surge will largely be driven by transportation and industry – two sectors that are key to Europe's economic output and among the largest contributors to its carbon footprint.[11]

Meeting these objectives requires strong government policies to accelerate electrification, drive technological advancements, foster new clean product markets, and support the expansion of clean electricity generation and infrastructure. Policy tools must ensure that the transition is both feasible and cost-effective, while supporting industrial competitiveness.

5 Fatih Birol, World Economic Forum Davos (2023).
6 Energy Institute Statistical Review of World Energy (2024); averages calculated basis TTF inception in 2005.
7 Mario Draghi (2024), 'The future of European competitiveness'.
8 Hansen, J. E. et al. (2025) 'Global Warming Has Accelerated: Are the United Nations and the Public Well-Informed?', Environment: Science and Policy for Sustainable Development, 67(1), pp. 6–44.
9 Energy Institute Statistical Review of World Energy (2024).
10 IEA World Energy Outlook (2024). Range reflects uncertainty in demographic, economic and technological development.
11 IEA World Energy Outlook (2024).-

The differing paces of electrification, clean energy deployment, and infrastructure expansion — driven by technical and economic factors — pose investment risks. There is a risk that electricity supply may not meet growing demand, or that power generation may lack sufficient demand at the time of commissioning, and that inadequate infrastructure may hinder connectivity. These risks increase with investment lead times. Long lead times associated with transmission grid investments mean projects must be planned in anticipation of future supply and demand. Similarly, offshore wind — characterised by extended development timelines — faces heightened exposure to demand uncertainty.

Offshore wind is key to any future cost-efficient transition scenarios catering for affordable, secure, and clean energy. Across analyst forecast scenarios of Europe's future energy mix, renewable energy will reach 70-90 %, and offshore wind is set to deliver between 20 and 26 % of future electricity generation.

This translates into a projection range of ~350-450 GW of offshore wind capacity by 2050. This range is driven by variation in major drivers, such as expected future electricity demand levels, ambition level of government policies (including carbon pricing and phase-out of imported fossil fuels), prioritisation between carbon free technologies, the limits of public acceptance of onshore assets, fossil fuel prices, and the magnitude of energy imports. This will help to work towards the accumulated ~500 GW offshore capacity ambitions set by the EU, the UK, and Norway (Figure 2).

European electricity generation mix projection in 2050

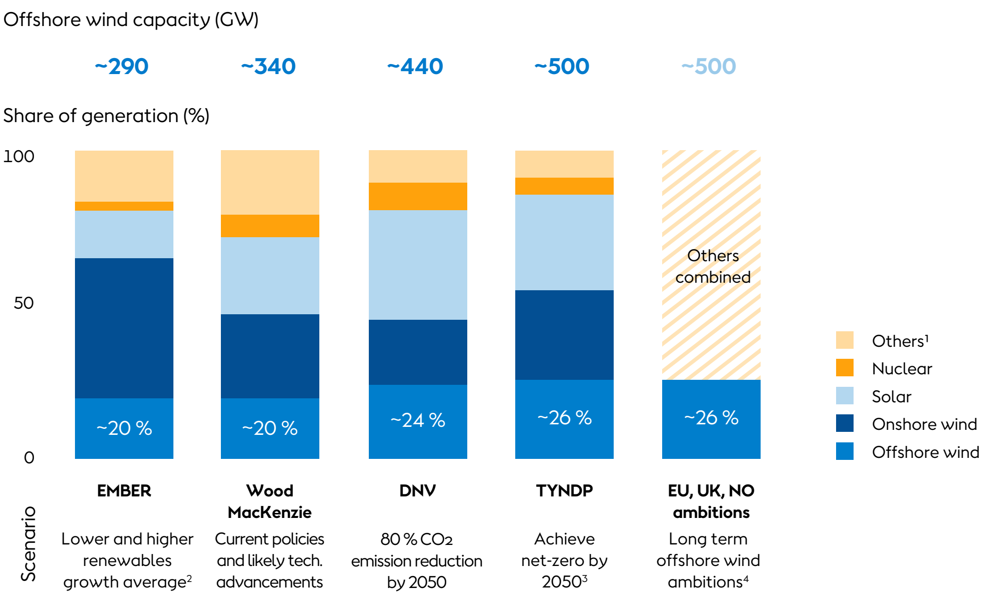


Figure 2: Note: 1) Includes hydropower, biomass, gas and others; 2) Lower renewables growth based on Alternative Hydrogen Supply and Nuclear Plus scenarios, while higher renewables growth based on Higher Fossil Fuel Prices, Limited New Gas, and No Gas + CCS scenarios; 3) Generation mix from TYNDP in Europe is extrapolated using TYNDP's projected capacity of various energy sources in Europe vs. EU; 4) Offshore wind capacity ambitions calculated by non-binding goals for the EU (~360GW), estimated UK offshore wind capacity in Future Energy Scenarios: ESO Pathways to Net Zero (~100 GW) , and communicated Norwegian capacity ambitions (~30GW), converted into the future generation mix. Source: Wood Mackenzie (2024), DNV (2024), TYNDP by ENTSO-E (2024), EMBER (2022), EU Commission, UK National Energy System Operator, Norway-EU Green Alliance, IEA World Energy Outlook (2024): Announced Pledges Scenario.

The role of offshore wind

Succeeding with the transformation of European energy use will require an 'all-the-above' strategy, starting with electrification and successfully mobilising all clean energy solutions and the grid to connect supply and demand. But the various electricity generation solutions also possess individual characteristics, and offshore wind especially contributes to the overall energy system with features that strengthens resilience.

Offshore wind has a higher capacity factor than onshore wind, and a complementary generation profile to solar PV, making it a valuable component in the clean energy system, providing grid stability and effectiveness in the system.[12] Practical constraints — such as limited space, time, cost, and resources — on the expansion of alternative renewables and nuclear energy mean that offshore wind is expected to account for at least 20 % of future electricity generation in most scenarios.

Taking into account generation timing and grid reliability, the IEA estimates that offshore wind in Europe — from a holistic system perspective captured by the value-adjusted levelised cost of electricity — is expected to match solar and onshore wind beyond 2030.[13] Additionally, because offshore wind farms are usually located far from residential areas, they often face fewer local acceptance challenges compared to onshore installations.

The combined share of renewables (offshore wind, onshore wind, and solar PV) in the European power mix is expected to increase from 25 % today to over 75 % by 2040.[14] Given this, the average cost of electricity generation in Europe is projected to decrease by 30-35 %, reaching around EUR 60 per MWh.[15] At the same time, significant investments in grids and flexibility will be required to enable this high share of renewable

Comparison of energy sources across critical system value criteria

Energy source	LCoE[1]	Production availability[2]	CO_2 footprint	Foreign reliance Fuel import
Offshore wind	59-83	High-Medium	Low	Low
Onshore wind	35-46	Medium	Low	Low
Solar PV	32-55	Low	Low	Low
Nuclear	163-279	High	Low	Medium
Natural gas	156-198	High	High	High
Coal	226-342	High	Very high	Medium

- **Offshore wind LCoE lower than fossil sources and nuclear** but slightly higher than onshore renewable
- **Offshore wind's** integration into the renewable power **mix optimises electricity system cost**
- Seasonal generation profile of **offshore wind complements solar PV**
- With a European supply chain, offshore wind is a **highly independent power source**

Figure 3: Note: 2040 values with relative performance in low-very high, North-Sea focus including UK, France, Belgium, Netherlands, Germany, Denmark, Norway; 1) Weighted-average of countries' LCoE, €/MWh – 2040 ranged by low to high estimates; 2) Production availability reflects how reliably a power source can deliver electricity on demand, factoring in dispatchability, resource variability, and operational constraints. Source: Wood Mackenzie Europe levelised cost of electricity (2024), IEA Energy Outlook (2024), IEA Offshore Wind Outlook (2019).

12 IEA Offshore Wind Outlook (2019).
13 IEA World Energy Outlook (2024).
14 Wood Mackenzie (2024) for EU power mix in 2024 & LCoE, ENTSO-E TYNDP (2024) for EU power mix in 2040.
15 Wood Mackenzie (2024) for EU power mix in 2024 & LCoE, ENTSO-E TYNDP (2024) for EU power mix in 2040.

Offshore wind at a crossroads

Europe's offshore wind industry stands at a crossroads, grappling with increased risks, declining project viability, and lower than needed investments across the supply chain. As supply chain disruptions and political uncertainties cast shadows over the ambitious renewable energy targets, the sector's future hinges on overcoming these critical hurdles

From 2015 to 2020, the cost of electricity production from offshore wind in Northern Europe fell by ~70 % (Figure 4), making it one of the most competitive technologies available. This sharp decline in cost contributed to driving increased offshore wind ambitions and political goals across Europe.

There have been multiple drivers behind this massive cost reduction: low-interest rate environment, favourable raw material costs, and significant advancements in technology with larger wind turbines as the major contributors. The reduction was also driven by transitioning from feed-in-tariffs to centralised offshore wind auctions, where developers would compete for individual projects.[16] Developers' appetite was much bigger than the number of auctions, which led to fierce competition[17] Over time, this led to structural changes in auction regimes. Regulators in some countries saw a transition from paying out subsidies, over projects being auctioned subsidy-free, and finally to auctions containing EUR multi-billion concession payments.[18]

In 2021, the conditions started to shift dramatically, kick-starting a ~50 % increase in LCoE over the following three years (Figure 4). This increase was initiated by high input costs, sliding into abrupt interest rates increases and supply chain challenges, with tender regimes leading to higher risks and, consequently, a higher project cost of capital.

Historical offshore wind levelised cost of electricity (LCoE)

Offshore wind real LCoE by FID date,
Northern Europe €/MWh

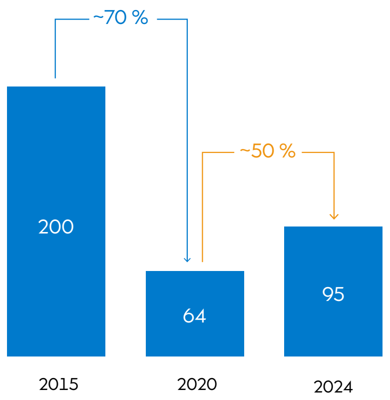


Figure 4: Note: LCoE in real terms, assumed exchange US$ 1 = €0.96; Northern European LCoE based on average from Denmark, Germany, Netherlands, United Kingdom. Source: BNEF historical data.

Looking ahead, without action, the offshore wind industry risks continuing the vicious cycle (Figure 5).

High input costs and interest rates

Soaring input costs and rising interest rates have reversed years of declining offshore wind costs. Capital expenditure to build new offshore wind farms relative to capacity (CAPEX/MW), including

The challenges affecting offshore wind

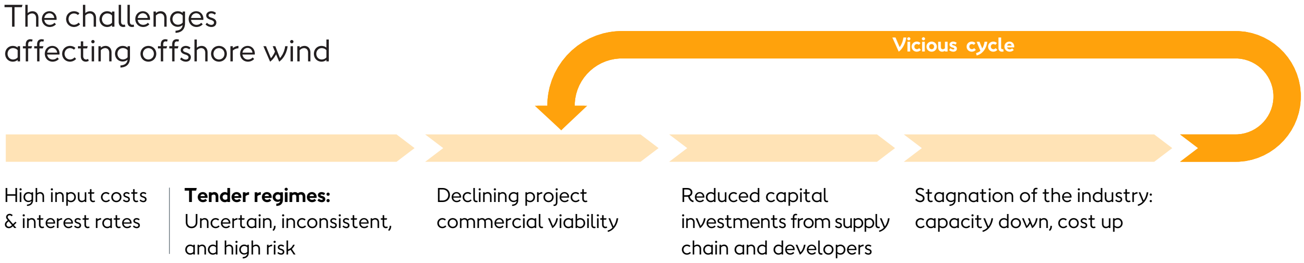


Figure 5.

16 WindEurope (2016), 'Germany EEG reform a mixed bag for wind energy'.
17, 18 Reuters (2024), 'Failed offshore auction highlights how Denmark missed winds of change'.

wind turbines, cables, and installations, has increased in recent years. For example, between 2019 to 2024, offshore CAPEX/MW has been assessed to increase an average of 18 % in the UK, Germany, The Netherlands, and Denmark.[19] In parallel, interest rates in Europe have increased from ~0 % between 2015 and 2020 to ~4 % in 2023, making financing significantly more expensive.[20] The impact of cost increases is further compounded by the time lag between government auction decisions and procurement contracts, straining project budgets across the value chain.

Tender regimes: high risk & cost of capital

Uncertainty about future electricity demand, and therefore electricity prices, has increased in Europe, raising revenue risks for merchant offshore wind projects. This, in turn, drives up the cost of capital and, consequently, the cost of electricity production (LCoE).

Electrification is central to achieving Europe's climate and industrial policy commitments, requiring a fundamental shift in energy consumption. This transformation — spanning industrial processes, electric vehicles, heating and cooling, and hydrogen production — is expected to drive a substantial increase in electricity demand. However, significant uncertainty remains regarding the annual volume required by 2050, with a ~1,900 TWh or ~40 % difference across credible forecast scenarios (Figure 6). And not least the pathway there, which will largely be determined by policy measures.

This future demand uncertainty in part drives electricity price uncertainty. In the UK and Germany, the projected average electricity price range for 2040 has expanded by ~230 % and ~200 % in the 2024 forecast compared to 2022 (Figure 7).[21]

Merchant projects, where electricity output is sold at market price, are fully exposed to the rising price risk. In contrast, revenue guarantees, like government-backed contracts for difference (CfDs), provide projects with price certainty, eliminating the risk throughout the contract period. (See further in Chapter 3 and the Q&A chapter, Question 1). The share of merchant project capacity in announced offshore wind auctions is growing. In the next 5 years ('26-'30), ~35% of expected commissioned capacity looks to be merchant exposed fully to price risks. Based on current outlooks this share will rise to be closer to 50 % in the following five years ('31-'35).[22]

Forecasted electricity demand levels in EU

EU electricity demand forecast.
000 TWh

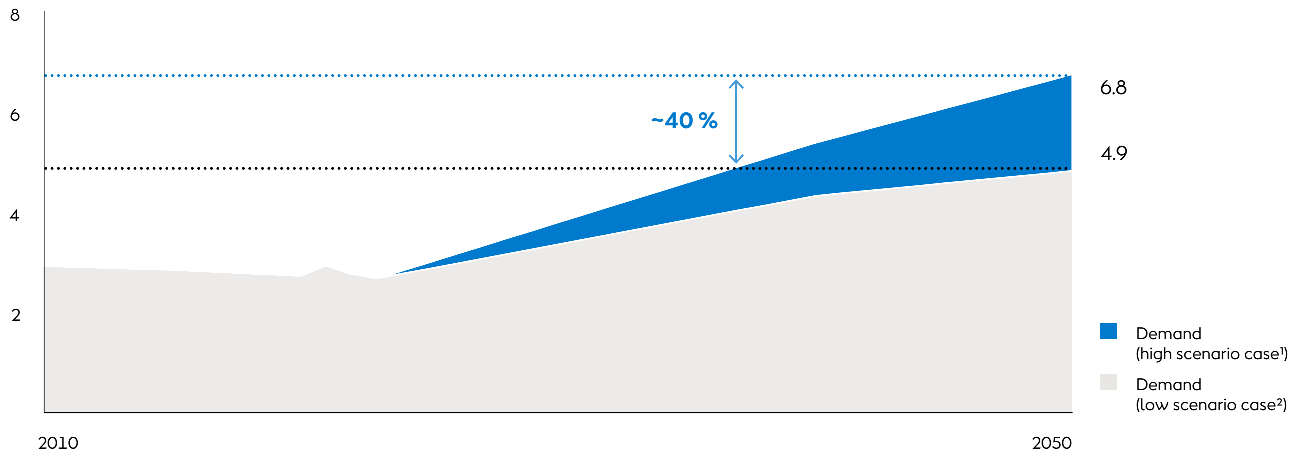


Figure 6: Note: Demand based on direct and indirect consumption, Forecasts based on 2024 TYNDP by ENTSO-E (Distributed Energy & Global Ambition scenarios) and IEA World Energy Outlook (Stated Policies & Announced Pledges scenarios); 1) Based on TYNDP model, Distributed Energy scenario; 2) Based on IEA model, Stated Policies scenario. Source: 2024 TYNDP by ENTSO-E and 2024 IEA World Energy Outlook.

19 BNEF LCoE (2024).
20 Euro Interbank Offered Rate (Euribor) rates.
21 UK Department for Energy Security and Net Zero, die vbw – Vereinigung der Bayerischen Wirtschaft e. V.
22 WindEurope (2025) Auction & Tenders, 4C Offshore, government announcements.

The weighted average cost of capital (WACC) for offshore wind projects in Europe has risen by approximately 3-4 percentage points from 2020 to 2024.[23] Higher interest rates account for a 1.5-2.5 percentage point increase, and a higher share of projects being tendered and developed under merchant models, exposed to revenue risk, accounts for an additional ~1.5 percentage point increase. Isolating merchant projects, that increase is ~2 percentage points.[24] In total, the 3-4 percentage points increase in WACC is consistent with a cost (LCoE) increase of around 30 %.

Unpredictable government policies play a key role in shaping the supply/demand balance, which in turn affects future electricity prices and contributes to the growing risk. For instance, on the demand side, direct electrification in the industry sector can potentially increase demand by ~1,000 TWh in the EU per year by 2050, about 30 % of total electricity demand today.[25] To unlock this potential, policies to stimulate electrification will be necessary, such as the EU Industrial Emissions Directive, the Net-Zero Industry Act, and the initiatives under the Clean Industrial Deal.[26,27,28] On the supply side, policies, such as renewable energy targets and the European Wind Power Action Plan, can potentially trigger an additional supply of ~1,800 TWh per year in the EU by 2050 from both offshore and onshore wind.[29] This is more than 60 % of current supply.[30] Albeit the future supply/demand balance is largely policy-driven, offshore wind developers bear this risk in merchant projects, leading to higher cost of capital and thus higher LCoE. Considering the pivotal role of policies in influencing the cost of capital, it will be cheaper for consumers and societies to share some of the policy-dependant risks that investors face.

Declining project commercial viability

Rising costs and a higher WACC due to increased revenue risk are making project economics unsustainable. This puts awarded projects at risk, causing unsuccessful auctions and leading to historically low participation in auctions. It often takes one to two years from winning an auction to signing all supplier contracts. With the changing pace of cost and electricity prices, developers are taking huge risks in auctions. In doing so, they are exposing themselves to cost increases and price uncertainties that can erode returns even before they get to a final investment decision. If the investment doesn't work out, developers must pay EUR multi-million fines for cancelling their contracts with both suppliers and states. While the heavy frontloading of government tenders reflects a commendable sense of urgency, their different frameworks and varying degrees of optionality creates additional complexity and risk for developers.

For example, the communicated tender pipeline includes 37 GW to be tendered in 2025 alone, more than the total offshore wind capacity in Europe today, followed by 19 GW and 18 GW in the following years.[31] This requires significant resources for developers and the supply chain to navigate overlapping tender rounds, complicating project coordination and deployment. This also significantly increases risk, as developers will need to bid on numerous tenders, without a clear indication of how many successful bids will occur – and consequently their capital commitment. For the supply chain, this uncertainty does not create a line of sight on what demand for wind turbines, foundations, cables, etc. will be.

In addition, tender designs are not reflective of the changing industry environment. Design elements such as high concession payments, optionality, extensive qualitative criteria, and tight timelines can significantly escalate project costs, worsening project commercial viability. Governments are continuing to seek revenues from seabed leases and concession payments, sometimes exceeding EUR 2–3 billion, yet the industry environment has changed.[32] Through these design elements, tendering authorities add additional cost and risk on already stretched project economics, making offshore wind more costly.

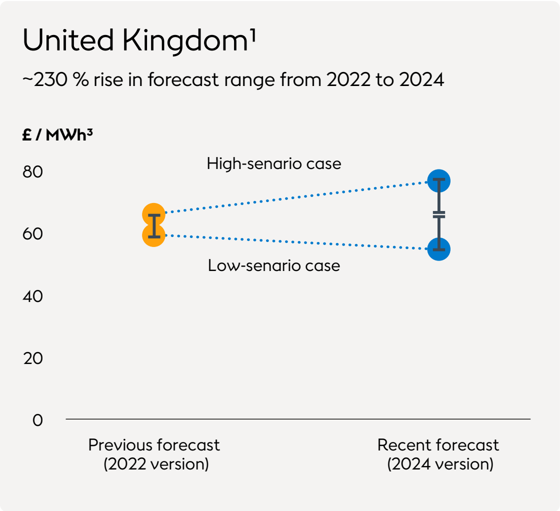
Engie has stated that it will not register for the Dutch tender which opens in September 2025, unless postponed or adjusted, as:

> "It is not responsible to make a bid under these conditions."
>
> Harry Talen, CEO, Engie Nederland, 2025[33]

These rising risks are in turn impacting project-internal rates of return (IRRs) of developers. Over the previous decade, the offshore wind project IRRs have gradually declined in line with the reduced project risk. More recently, project returns have leveled out, while financing costs and risk-free rates (e.g. the German 10-year bond) on the other hand have been rising.[34] This combination of lower returns and higher capital costs is making offshore wind investments less attractive and highlights a misalignment between project economics and evolving financial realities (Figure 8).

23 LSEG Data & Analytics, estimated from WACC of top European offshore wind developer companies.
24 Offshore wind investment banking expert interviews. Further explained in Question 1. in Q&A.
25 Based on EU region. IEA World Energy Outlook (2024) and ENTSO-E TYNDP (2024) for potential demand increase.
26 European Commission (2024), 'Industrial and Livestock Rearing Emissions'.
27 European Commission (2024), 'The Net-Zero Industry Act: Accelerating the transition to climate neutrality'.
28 European Commission (2024), 'Clean Industrial Deal'.
29,30 European Commission (2023), 'European Wind Action Plan'. IEA World Energy Outlook (2024) and ENTSO-E TYNDP (2024) for potential supply increase.
31 WindEurope, government announcements, 4C Offshore.
32 Bundesnetzagentur, RVO, NREL, CEIC, Lit. search.
33 Energeia (2025), 'Tender for offshore wind farms threatens to fail'.
34 Bloomberg, Morgan Stanley (2025), 'European Utilities 2025 in 25 Slides'.

2040 average wholesale electricity price forecast uncertainty



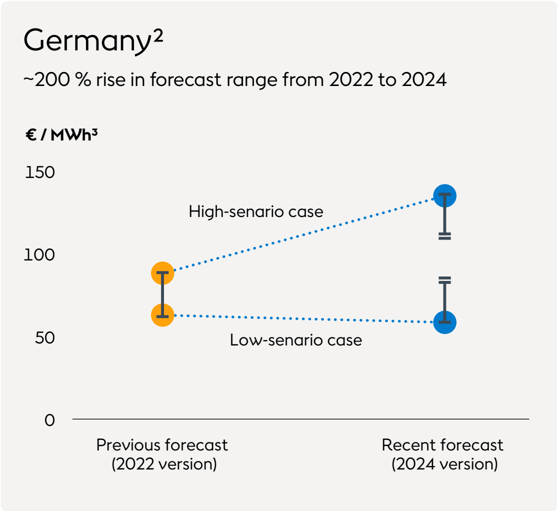


Figure 7: Note: Real price based on price level in 2022 (inflation-adjusted); 1) Based on Reference, Low fossil fuel prices, High fossil fuel prices, Low GDP growth, High GDP growth, and Existing measures scenarios; 2) Based on upper, middle, and lower price path scenarios. Source: Department for Energy Security and Net Zero UK, die vbw – Vereinigung der Bayerischen Wirtschaft e. V.

Comparison of offshore wind project and German 10-year bond returns over time

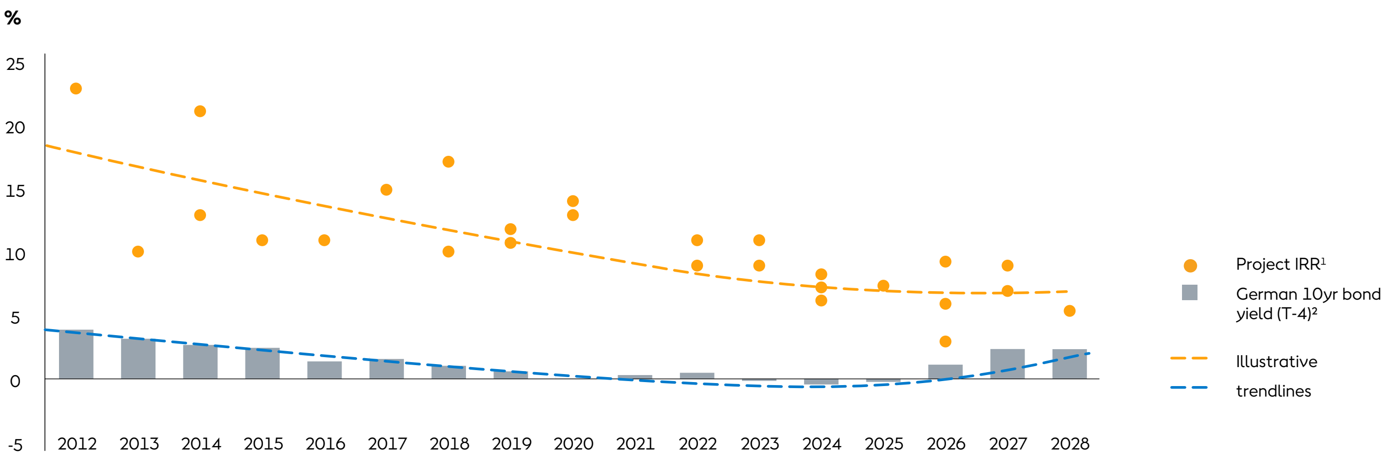


Figure 8: Note: (1) Morgan Stanley estimates of project IRRs of key European offshore wind developers; (2) "T-4" meaning bond yield is taken from four years prior to align to the project's final investment decision (FID), generally about four years before COD. Source: Morgan Stanley (March 2024).

Reduced investment from OEMs and developers

As project viability declines, and pipelines are put into question, the resulting uncertainty is driving capital away from the industry. Original equipment manufacturers (OEMs) along the supply chain are announcing delayed or cancelled investments, such as scaling back 18 MW turbine production plans and restructuring facilities to shift production from offshore to onshore wind.[35,36] This has ripple effects across the sector, delaying critical investments and potentially exacerbating existing supply chain bottlenecks and further driving up input cost. The supply chain, burnt by recent experience of oversupply and innovation cycle misalignment to financial returns, are cautious to invest and are seeking to regain margins.

> "We've been very clear for quite a given time that we're not taking new offshore wind orders until they're with materially different economics than the economics that we see today."
>
> Scott Strazik, CEO, GE Vernova, 2024

On the project developer side, we see utilities reducing offshore targets, stepping out of markets and buying back shares,[37,38] while oil and gas players are refocusing on their core businesses.[39]

Stagnation of the industry

Swift and decisive action is needed to avoid the risk that the industry enters a downwards spiral. Without such action, even awarded European projects may face cancellation, mirroring setbacks seen in the United States. Currently, there are ~155 GW of projects in the pipeline that have either been tendered or are planned to be tendered for delivery by 2040.[40] However, project economics are under pressure due to this vicious cycle — as evidenced by recent unsuccessful auctions or paused tenders in the UK, Denmark, Lithuania, and Estonia — and final investment decisions (FIDs) are increasingly delayed.[41,42,43,44] Investor sentiment echoes these concerns, with shareholders and analysts ascribing lower valuations to projects due to "impairments, continued construction risk, and the uncertain long-term outlook".[45]

Both merchant projects and some CfD-backed projects under development or already tendered might still face severe challenges. In key merchant markets like Germany, the Netherlands, and Denmark[46] — slated to contribute 34 GW, 18 GW and 7 GW, respectively[47] — many awarded projects could be at risk, unless tender design or market frameworks undergo fundamental changes. The recent unsuccessful merchant tender with zero bids in Denmark demonstrates these challenges.

Investors typically demand a capture price of at least EUR 90 per MWh to cover their LCoE, especially when including concession fees.[48] Achieving such price levels will rely on persistently high wholesale electricity prices or, alternatively, corporates willing to enter power purchase agreements (PPAs) at these capture prices levels, which can have broader economic drawbacks.

Even CfD-backed projects may be challenged if future CfD tender ceiling prices are set too low to cover project LCoE, or if the framework for already awarded capacity fails to account for cost inflation and market realities, the economic viability of these projects may be compromised. Consequently, several European countries risk CfD-backed capacity failing to materialise.

Build-out profile – bumpy and uncertain

Around 54 GW of the communicated European offshore wind capacity from 2029 is either merchant projects or estimated to be CfD-backed projects with a ceiling price below the LCoE levels expected in the projects' respective markets. This is equivalent to approximately 45 % of capacity commissioned from 2029 onwards being at risk of commercial unviability (Figure 9). The remaining capacity, allocated with CfDs that are assessed to be at par with LCoE, has a higher likelihood of being built, but final investment decision and successful execution is still not guaranteed for all capacity.

The announced build-out plan is also not evenly distributed across years. Taking the communicated and expected capacity pipeline in the announced tenders, the annual build-out jumps from 9 GW in 2029 to over 20 GW between 2030 and 2032 and falls to 12 GW in 2033 (Figure 9), hampering the supply chain's ability to invest, deliver, and scale up.

35 GE Vernova SEC filing (February 2024).
36 Reuters, (2024), 'Vestas to cut 300 jobs at British wind turbine plant'.
37 Ørsted announcement on business plan adjustment (February 2025).
38 RWE press release on 'Growing Green' strategy (November 2023).
39 BBC, (2025), 'BP shuns renewables in return to oil and gas'.
40 4C Offshore (2024), WindEurope, government announcements. See Figure 9, where 155 GW is sum of future communicated offshore wind capacity additions.
41 BBC (2023), 'No bids for offshore wind in government auction'.
42 WindEurope (2024), 'No offshore bids in Denmark – disappointing but sadly not surprising'.
43 Enerdata (2024), 'Estonia relaunches a tender to procure up to 1.2 GW of offshore wind'.
44 Offshore WIND (2025), 'Lithuania Puts Second Offshore Wind Tender on Hold'.
45 HSBC Ørsted analyst report (February 2024).
46 Based on trajectory of announced tenders.
47 4C Offshore (2024), WindEurope, government announcements.
48 Wood Mackenzie (2024) for Europe levelised cost of electricity (LCoE) 2024 data - average sensitivity, cost of debt & equity; Market participant interviews; Bundesnetzagentur; Netherlands Enterprise Agency (RVO); Danish Energy Agency

The lack of line of sigh forces suppliers into a stop-and-go cycle, preventing long-term investments in capacity and innovation. This uncertainty makes it difficult for companies to commit to large-scale offshore wind projects without clearer economic viability, leading some suppliers to pause new orders entirely.

The high level of uncertainty of auctioned and planned auction capacity could be compounded by supply chain constraints. The European supply chain is currently equipped to produce only about 10 GW of offshore wind capacity per year, primarily based on blades and nacelles being the limiting factor, while bottlenecks across other supply chain elements and profitability challenges could limit actual output further.[49,50,51]

Scaling up from this baseline, which has also served markets outside of Europe, poses significant challenges, particularly if suppliers see credible demand as short-lived. If the supply chain does not scale as required, costs may plateau or even increase from current levels, moving more projects into a higher LCoE range and risking more project capacity than shown below.

The offshore wind industry is facing this complex interplay of challenges which, while individually easier to manage, collectively form a maze of risk and complexity, which is aggravated by the fact that offshore wind is a long-cycle business – capital investments by the supply chain and bids made by offshore wind developers must be made several years before steel can hit the water. As a result, the outlook for the offshore wind industry threatens Europe's energy transition, and the vicious circle must be turned to avoid further setbacks.

Communicated offshore wind capacity additions in Europe[1,2]

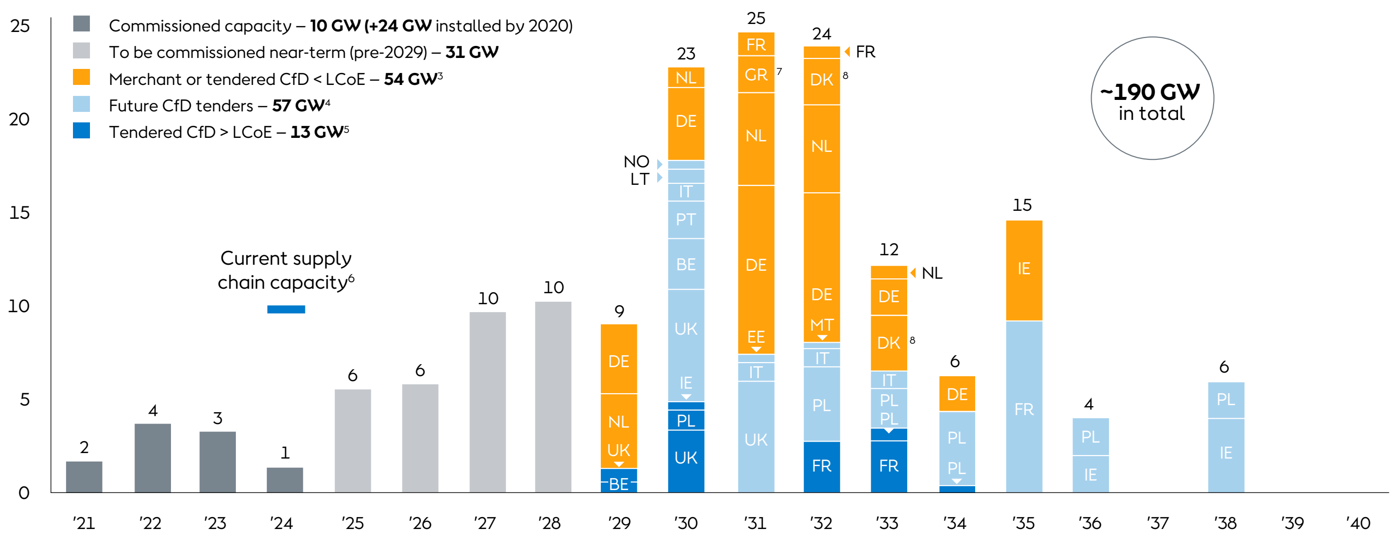


Figure 9: Note: 1) Only tenders with an auction year are included, while those without a commissioning year are assumed to be 5 years after tender year; 2) Projects under development and future tender auctions pipeline consists of Germany (34 GW), United Kingdom (28GW), France (19 GW), Poland (18GW), Netherlands (18 GW), Ireland (17 GW), Denmark (7 GW), Italy (4 GW), Belgium (4 GW), Greece (2 GW), Norway (2 GW), Portugal (2 GW), Lithuania (0.7 GW), Estonia (0.5 GW), Malta (0.4 GW); 3) Projects that have, or are expected to have, a merchant revenue mechanism, or already tendered CfD projects whose LCoE is estimated as being at least 5% higher than their respective ceiling prices; 4) Projects that are expected to have a CfD revenue mechanism; 5) Already tendered CfD projects, whose LCoE is estimated as being lower than their respective ceiling prices; 6) Supply chain capacity based on capacity limitation on production of blades and nacelles in Europe, 2024; 7) Uncertain communicated revenue mechanism, classified as merchant; 8) In April 2024, Denmark launched a 6 GW offshore wind tender alongside a planned 3 GW tender for the North Sea Energy Island. The 6 GW tender was later cancelled after the first phase failed to attract bids. A new 2025 tender is estimated to offer 2–3 GW for commissioning in 2032. Bornholm's 3 GW capacity is estimated to be delayed by a year, while the North Sea Energy Island is presumed to not proceed. Source: 4C Offshore, WindEurope, government announcements, IEA Renewables 2024, Wood Mackenzie – Europe levelised cost of electricity (LCoE) 2024.

49 IEA Renewables 2024.
50 WindEurope (2024), 'North Seas countries set out clear vision on wind supply chain and grid build-out'.
51 Shoreline (2025), 'Headwinds: Offshore supply chain can boost profits despite challenging time ahead'.

A proposal for a joint commitment

Europe needs affordable, secure, and clean electricity. This will be very difficult to achieve without large volumes of offshore wind. On top of that, the offshore wind industry is also a potential engine for technology leadership, growth, and job creation. But in the current state, there are more factors driving the industry towards stagnation rather than industrialisation. The risks are simply too high.

For offshore wind to take its place in the European energy transition, the current vicious cycle must be propelled into a virtuous cycle. This, in turn, will bring offshore wind back on the technology learning curve that drives industrialisation and excellence and thereby cost reductions. Addressing the increasing risk of offshore wind investments, including revenue risk, through targeted policy action is pivotal. This requires risk sharing and certainty of a consistent and sufficiently large pipeline of projects.

This will provide the industry with larger investment confidence, ensuring supply chain capacity expansion and that offshore wind projects are delivered at scale (Figure 10).

Close collaboration between industry and governments has, and should continue, to underpin the industry's success. Offshore wind matured in the positive interplay between government ambition and support, with industry investing and innovating to deliver lasting value to both rate payers and the broader European community.

To reverse the current vicious cycle into a virtuous one, forward-looking policies and an industry that is up to the challenge are needed. This requires a new government-industry partnership with a joint commitment to create certainty, and consistency.

Governments across Europe should commit to auction out at least 100 GW of viable CfD capacity in an auction framework that optimises and de-risks build-out, to be commissioned sequentially each year for 10 years, from 2031 to 2040, plus ~5 GW annually of flexible merchant capacity.[52]

The vicious and virtuous cycle

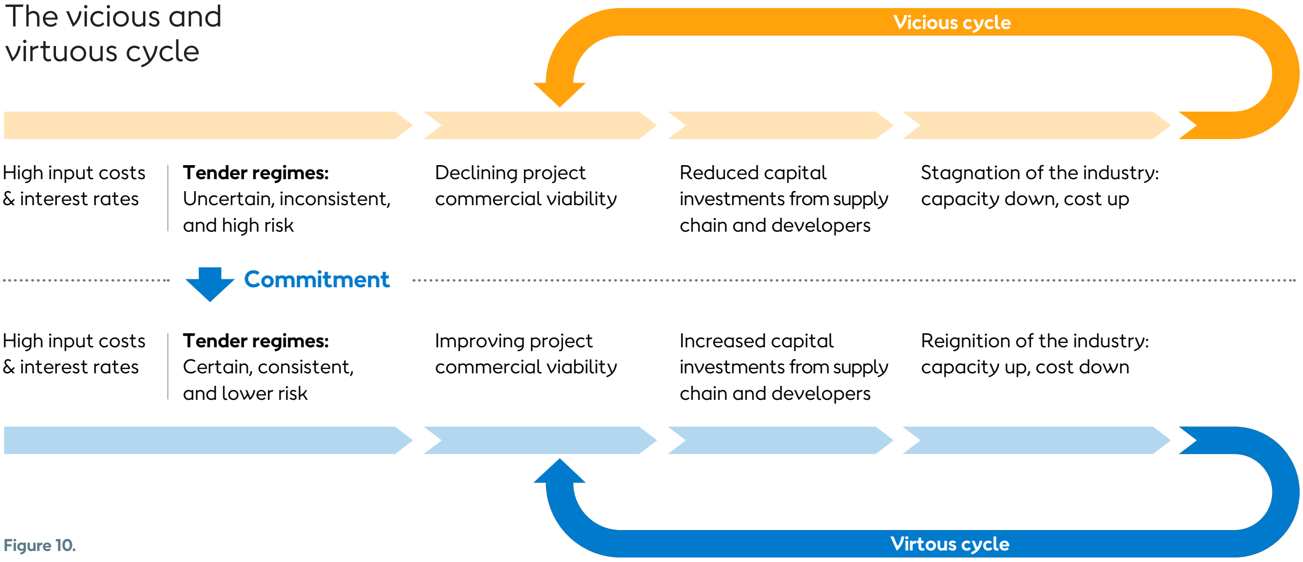


Figure 10.

52 Average capital expenditure investment for an additional 1 MW capacity commissioned in 2031-2040 under the joint commitment is estimated at EUR ~3.2 million. This is based on the middle of an LCoE range of EUR 90-100 and an LCoE reduction of 30 % towards 2040. When applied to 100 GW commissioned capacity, total capital expenditure required is EUR ~320 billion. The capital expenditure baseline is extracted from Wood Mackenzie from average North Sea countries: the UK, Germany, the Netherlands, and Denmark (2028 commissioning year).

Capacity commissioned under the joint commitment

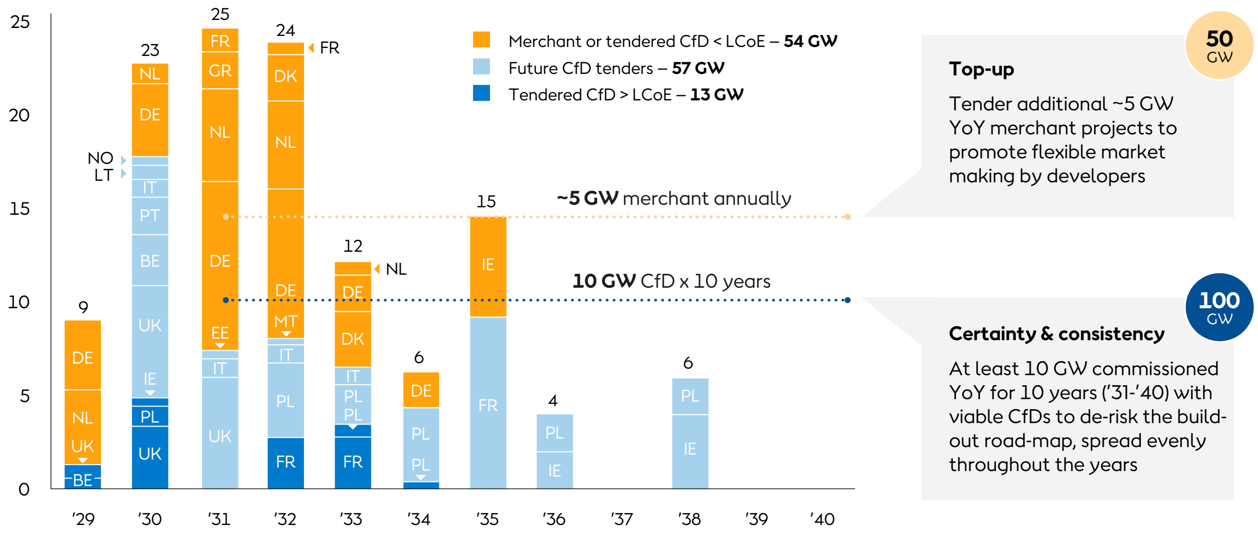


Figure 11: Note: Same methodology and sources as Figure 9.
Please refer to notes under Figure 9 for details.

When needed, governments should aim higher than 10 GW per year to make sure the electricity supply can meet future growing demand, where ~15 GW per year from post-2030 onwards could deliver ~240 GW for Europe in 2040 (see further in the Q&A chapter, Question 3).

This commitment requires strong collaboration across European governments to provide the certainty in capacity and reduce the revenue risk required for the industry to scale while promoting flexible market-making by developers. The tripartite framework proposed in the Affordable Energy Action Plan could serve as the vehicle for developing the trust and commitment needed to underpin such collaboration.

> The industry will based on this commit to mobilising the large investments needed[52] to meet the necessary offshore wind capacity and bring offshore wind to a better financing position and onto an accelerated learning curve, which together should reduce cost on a LCoE basis by ~30 % by 2040.[53]

The proposed joint commitment could guarantee a foundation of certainty, consistency, and predictability under the market, securing a sufficiently large de-risked pipeline of projects and moving away from the current uncoordinated and uncertain commissioning schedule (Figure 11).

Regaining momentum for offshore wind is both a mutual interest and a mutual obligation. Policy and regulation must be aligned with and support the industry's efforts to sustainably scale and create long-lasting value. Beyond reigniting the industry, the joint commitment will bring broader economic benefits for Europe. The joint commitment will have deflationary effects on energy prices, help to boost competitiveness, protect and generate employment, strengthen European energy independence, and cut carbon emissions (Figure 12).

Government commitments

Looking back, many governments have laid the foundation for the offshore wind industry, integrating a range of supportive measures.

The government commitments need to provide two key elements: i) risk- and reward-sharing through a CfD revenue model, and ii) an even, long-term, and investable capacity build-out profile.

Looking forward, some governments have already announced firm tenders for CfD-backed projects, other governments have only announced intentions to tender CfD-backed projects, and some governments are expecting merchant projects to fulfil their targets for offshore wind. The outlook in Figure 11 clearly shows that there will be a bottleneck of anticipated commissioned projects from 2030 to 2033. This puts focus on why a coordinated approach is key to the ramp-up of the supply chain.

53 Compared to merchant projects.

Broader benefits of the joint commitment for Europe

Affordability

Contribute to ~30 % lower electricity generation costs in 2040 in a system with higher share of renewables than today[1]

Competitiveness

Support European competitiveness to sustain the EUR 2.2 trillion gross value added by manufacturing industries

Employment

Help safeguard the ~30 million jobs in industrial sectors today, and create ~300,000 new offshore wind jobs[2]

Independence

Replace EUR ~70 billion/year in fossil fuel imports by 2040[3], equalling ~20 % of current imports[4]

Clean energy

Cut carbon emissions by ~500 million tons per year by 2040[5], equal to ~15 % of current European emissions[4]

Figure 12: Affordability, energy independence, security, and clean energy benefits based on growth in EU offshore wind generation between 2023 and 2040; 1) Based on increasing offshore/onshore wind and solar in EU vs. 2024 levels with full levelised cost of electricity (LCoE) used for renewables, while LCoE without CAPEX used for thermal power (coal, gas and nuclear), data from Wood Mackenzie; 2) Jobs created by 2050 estimated by Elia Group; 3) Based on EU fossil fuel import (oil, natural gas, and coal), except from the UK and Norway; 4) Based on 2023 figures; 5) Based on carbon emissions from oil, natural gas, and coal consumption in Europe. Source: The future of European Competitiveness (2024), Elia Group (2024) 'Going Like The Wind', EU trade statistics, Wood Mackenzie offshore wind projection (2024), IEA World Energy Outlook (2024), 'International comparison of energy efficiency of fossil power generation' by W.H.J. Graus, M. Voogt, E. Worrell (2007) for efficiency factor of fossil fuel.

Risk and reward sharing

A two-sided, inflation-indexed CfD mechanism for at least 10 GW of capacity each year is needed to reverse the current negative trend of uncertainty. The CfD's risk- and-reward-sharing model guarantees predictable revenue for developers, ensuring new capacity gets built, and therefore contributes to stabilising electricity prices, ultimately prevents excessive electricity prices. Furthermore, CfDs provide long-term certainty for supply chain investors, including OEMs, and project developers to plan and invest with confidence.

The CfD should be awarded through a competitive bidding process to ensure the strike price is as efficient for countries as possible, encouraging developers to strive to lower LCoE as much as possible.

Under the CfD framework, revenue risk is allocated to governments for the duration of the contract, while developers retain ownership of all other project risks. This ensures that risks are better distributed between their natural owners, leading to the most efficient risk management across the value chain. At the expiration of the contract, usually after 15-20 years[54], the revenue risk is returned to developers for the remainder of the wind farm's lifetime.

The market for corporate power purchase agreement (PPAs) has the potential to provide the same benefits in terms of hedging price risks; however, the PPA market is at the moment too small to meet the pipeline of offshore wind projects[55], and there is in many cases a mismatch between the cost of offshore wind and the price companies are willing to pay.

This further emphasises the necessity of CfDs to drive new capacity build-outs to meet Europe's need for offshore wind capacity until the PPA market develops further, and there is alignment between costs and willingness to pay.

See further details of the CfD mechanism, benefits, and impact in the Q&A chapter, Question 1.

As electricity demand rises to meet policy goals, expanding renewable energy supply is essential. Governments can minimise the risk of CfD payouts by ensuring offshore wind expansion aligns with demand growth through targeted electrification measures, fostering a balanced and sustainable market. A robust EU 2040 framework will be crucial in this regard. Both including a robust target for the build-out of renewable energy, but crucially also including measures to underpin the replacement of fossil fuels by electricity-based solutions in industry, households, and transport.

In parallel, enhanced regional cooperation and optimised tender frameworks will maximise the societal value of CfDs. Key elements include harmonised pre-qualification criteria across markets, centralised site selection, qualitative standards, price-based auctions, flexible project timelines, and transparent grid connectivity (see further details in the Q&A chapter, Question 2).

The financial implications of offering the proposed 100 GW of offshore wind with CfDs are highly dependent on governments' ability to balance electricity demand policies with electricity supply policies. This can be illustrated by assuming CfD levels at expected LCoE and comparing to expected power prices. In a high power price scenario, the CfD could provide a total government revenue of EUR 0.5 million a year per GW, and in a low case scenario, the CfD could incur a total government cost of EUR 80 million a year per GW.[56]

54 WindEurope, Auctions and Tenders (2005-2024).
55 Wind Europe PPA data (2024), capacity contracted in 2023 and 2024.
56 Low-high capture price forecast based on forecast based on a selection of external benchmarks. LCoE assumed at EUR 95/MWh and cost reduction of 30 % towards 2040 – half of the reduction is assumed from lower WACC by 2 %-points and is assumed at full effect from the start of 2031, the other half is assumed learning at a learning rate of 9 % LCoE improvement per doubling of total capacity (Europe only). CfD tenure assumed at 15 years. Capacity factor applied is 51 %.

Even and investable capacity profile
The targeted capacity should be allocated in tenders for sequential commissioning, allowing developers and the supply chain to deliver on a portfolio of projects consistently over time. This ensures predictability and certainty for the whole supply chain, encouraging further investments, and lowering LCoE levels. Policy makers should collaborate across Europe on tender schedules and, more importantly, commissioning years across countries to ensure this, articulated in an offshore wind capacity roadmap. The European Commission should make itself available to convene such collaboration and alignment, also including the UK and Norway. In the process of establishing the roadmap and need for offshore wind in the 2030s, governments would need to consider their longer-term energy and climate targets, projected electricity demand and electrification targets, and country-specific need for phasing out fossil fuels. The result could be that more than 10 GW per year of CfD-backed projects are needed, and that would work fine in an interplay with the anticipated merchant tender volumes, keeping in mind that Europe needs 13-19 GW annually from 2031 to reach 350-450 GW in 2050.

The smoothening of tendered capacity will have additional benefits for governments. Where frontloading of tendered capacity creates a risk of lower competition among developers, who prepare bids for numerous tenders,, an even sequential capacity profile reduces this risk. It also enables governments to achieve lower CfD prices in new auctions over time, as the expected LCoE reductions take place.

The joint planning framework should leave sufficient flexibility on commissioning dates to allow for optimal supply chain utilisation and to mitigate the risk of weather-dependent delays to installation campaigns. While also understanding that wide time gaps between timing of tenders, timing of final investment decisions, and final commissioning also add uncertainty when contracting with the supply chain.

In addition, governments should work closely together to optimise cross-border transmission and maritime spatial planning. For example, strategic planning to share offshore wind resources across jurisdictions and reduce wake effects can improve efficiency and protect output capacity. This collaboration could contribute towards significantly lower overall energy system costs (see further details in the Q&A chapter, Question 7).

Industry commitments
The joint commitment will give the offshore wind industry i) a reduced exposure to revenue risk compared to merchant projects, enabling better bankability and a lower cost of capital, which has an immediate effect on costs, and ii) the certainty and predictability to invest, innovate, and industrialise, accelerating the industry learning curve, which has a longer-term impact towards 2040. This will put the industry back in a positive cycle, bringing offshore wind back on a healthy learning curve and reducing the levelised cost of electricity (LCoE) by ~30 % down to EUR 60-70 per MWh by 2040 (Figure 13).[57]

Offshore wind LCoE 2040 cost reduction trajectory, with impacts of the joint commitment

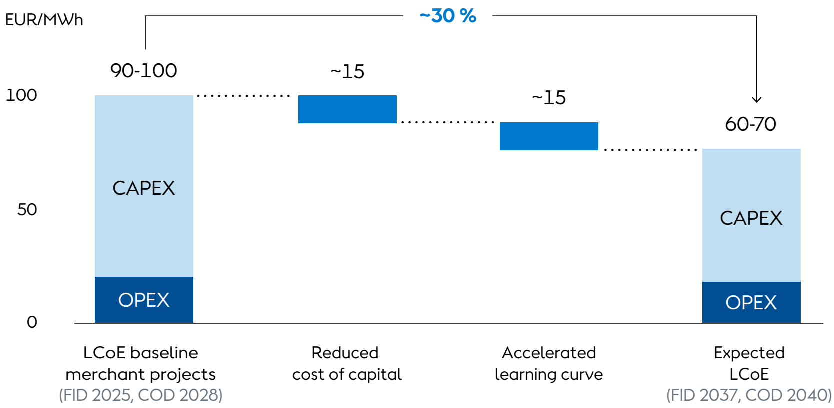


Figure 13: Note: Fixed 2024 prices; LCoE is based on a standard calculation method showing producer's cost of electricity and does not represent a business case perspective or the strike price level in an auction. The methodology and assumptions are described in the Q&A chapter, Question 6, page 32-33.
Source: Wood Mackenzie (Europe levelised cost of electricity (LCoE) 2024 data – average sensitivity) for CAPEX, OPEX, cost of debt, cost of equity, and capacity factor; Offshore wind investment banking expert interviews.

57 The ~30 % reduction is in fixed real 2024 prices. See details in the Q&A chapter, Question 6.

Cost of capital reduction
The firm CfD revenue stabilisation mechanism will reduce price and therefore revenue risk for developers compared to a merchant price risk case, in turn reducing the cost of capital and LCoE. The price and revenue certainty provided by CfDs is estimated to reduce project-weighted average cost of capital (WACC) by approximately 2 percentage points. With CfDs, developers can attain better financing positions and improve bankability for their projects due to the reduced project revenue risk (see further CfD details in Critical Question 1). Consequently, the cost of capital reduction from CfDs results in a lower LCoE of an offshore wind project in Europe by ~15 %, equivalent to EUR ~15 per MWh in the base case established with reference to merchant projects.

Accelerated learning curve
Committed, transparent volumes tendered annually with a clear linear cadence will ensure a clear investment signal for the industry to invest in the supply chain capacity and capabilities required to deliver volumes out to 2040. This long-term visibility and capacity delivery sets the offshore wind industry on the path to reducing LCoE by ~15 %, equivalent to EUR ~15 per MWh, specifically via industry learning and industry standardisation and industrialisation (see further learning rate details in the Q&A chapter, Question 6).

Collaboration across the offshore wind supply chain is essential to unlocking efficiencies, reducing costs, and building long-term industry resilience. By aligning early and working together across projects, developers and suppliers can accelerate the standardisation and industrialisation of key components and processes — areas often hampered by fragmented demand and bespoke project designs. Standardisation enables modular, high-volume manufacturing and repeatable installation methods, streamlining design, shortening lead times, and improving supply chain coordination.

A predictable pipeline — underpinned by government-backed CfDs — further supports these efficiencies by providing the volume certainty needed to invest in scalable solutions. Realising these standardisation and industrialisation benefits depends on coordinated efforts across a number of areas, including:

- **Engage the supply chain** early to optimise production and minimise costly redesigns.
- **Simplify design** to avoid unnecessary customisation by project, speeding up deployment.
- **Harmonise engineering** and regulatory standards to reduce complexity and costs.
- **Optimise procurement** through bundled orders achieve economies of scale.

Q&A behind key elements of the proposed joint commitment

The challenges are urgent, and a swift, strong solution is required. We propose that the industry and governments collaborate to outline a clear plan to reverse the current trajectory of offshore wind.

1 Why should at least 10 GW of commissioned capacity be backed by CfDs?

2 What are the key design elements for CfDs and tenders to de-risk offshore wind?

3 What capacity is required to meet Europe's offshore wind demand and sustain its supply chain?

4 Why is an even and investable capacity profile required for the industry?

5 How does the proposal compare to the announced tenders and projected capacity build-out?

6 How do the proposed elements impact offshore wind LCoE?

7 What is the potential impact of coordinated transmission and maritime spatial planning?

1 Why should at least 10 GW of commissioned capacity be backed by CfDs?

The joint commitment should call for at least 10 GW of commissioned capacity each year, for 10 years, to be backed by double-sided contracts for difference (CfDs). This section details what a CfD is, how CfDs benefit society and de-risk projects, and why governments are best suited to own offshore wind price-related risks through CfDs. Additionally, this section outlines the potential role power purchase agreements (PPA) have in the market.

What is a contract for difference?

A contract for difference (CfD) is a revenue mechanism used in the energy market to stabilise prices for generators while ensuring value for society. Under a two-way CfD, an agreed strike price is set between the government and the energy generator. If the market price rises above the strike price, the generator repays the surplus to the government. Conversely, if the market price falls below the strike price, the government or a designated counterparty covers the shortfall.

This ensures predictable income for generators while capping excess earnings when market prices are high, making it an effective risk- and reward-sharing model (Figure 14).

Simultaneously, a CfD fosters a stable investment environment, as advocated by EU regulations, enabling offshore wind to scale efficiently without long-term reliance on public funding. Given this, CfDs radically increase the likelihood that offshore wind projects are delivered, supporting the timely deployment of much-needed renewable energy capacity.

CfD risk- and reward sharing mechanism[58]

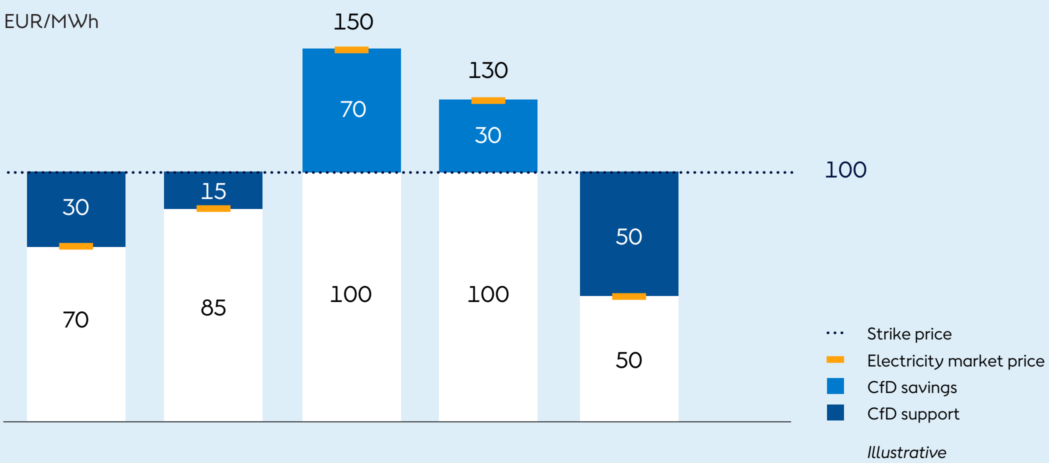


Figure 14.

58 Regulation of the European Parliament and of the Council amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design (7.05.2024).

Different electricity volume expansion pathways and the impacts on prices

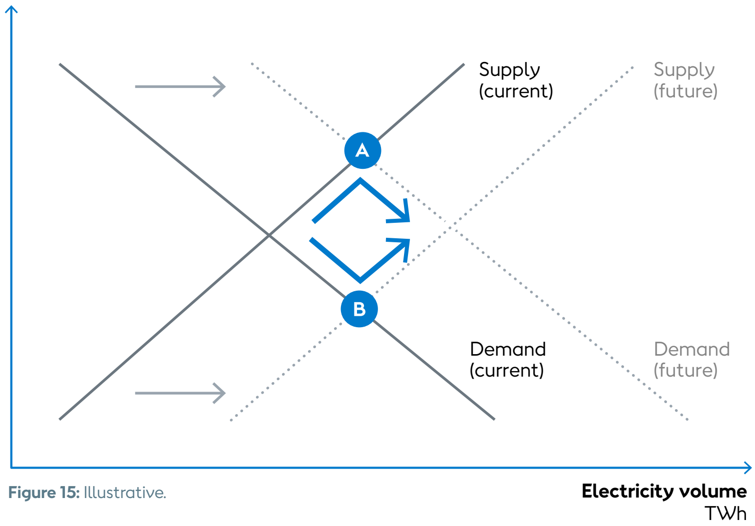


Figure 15: Illustrative.

Two different pathways for European electricity volume expansion

A With electricity price increase

- New build-outs are pure merchant revenue model
- Offshore wind is built only when business cases become commercially viable following demand growth, which drives up prices
- Long lead time of offshore wind build-outs sustains high price level

B Without electricity price increase

- New build-outs are CfD-backed with revenue stabilisation guarantee
- Build-outs anticipating future demand growth prevents price increases
- Lower electricity prices stimulate demand, allowing for faster electrification

How do CfDs benefit society?

Contracts for difference drive renewable capacity development, delivering clean electricity to consumers while protecting against high energy prices. Unlike merchant projects, rely on rising market prices, which can harm European competitiveness and slow electrification, CfDs enable proactive investment in new capacity. Given the risk of price increases if supply fails to keep pace with growing demand, CfDs provide a strong value proposition by securing long-term electricity supply and stabilising future energy costs for society (Figure 15).

Also in the short term, a CfD serves as an insurance against price spikes for society. During periods of energy shortages, when electricity prices surge, CfDs can mitigate excessive costs to society by requiring generators to return surplus revenue to the state.

How do CfDs de-risk projects and reduce cost of capital?

By stabilising future project revenue, CfDs lower the project-weighted average cost of capital (WACC). Today, a CfD will reduce the WACC of a European offshore wind project by approximately 2 percentage points through:

1. improved bankability and access to cheaper debt
2. lower risk premiums as a result of reduced volatility of cash flows.

1. Improved bankability (more attainable debt financing). Revenue-guaranteed projects, including CfD-backed projects, can access cheaper and more readily available financing structures compared to projects without revenue guarantees (merchant projects). Given their lower exposure to price risk, CfD-backed projects can access a higher proportion of debt financing (70-80 %) to cover project capital expenditure, which carries a noticeably lower cost of capital than equity financing (Figure 16). CfD-backed projects usually qualify for project financing, which enables them to secure a substantial share of debt with the project's predictable cash flows. In contrast, merchant projects typically cannot access the same level of debt financing due to more volatile revenues.[59]

2. Lower risk premiums: Compared to merchant projects, CfD projects benefit from lower debt and equity risk premiums. The revenue certainty of CfD projects reduces the returns required by debt and equity holders, thereby lowering financing costs. Furthermore, merchant project debt often includes restrictions that increase risks borne by equity investors, thereby raising the cost of equity. For instance, with the same debt level, merchant developers must hold larger reserve funds, limiting cash available for investment into new opportunities or dividends.[60]

59 Offshore wind investment banking expert interviews.
60 Offshore wind investment banking expert interviews.

These two impacts together reduce the WACC of a CfD project by ~2 percentage points relative to a merchant reference project (Figure 16), improving project commercial viability.

Why should governments bear offshore wind price risks via CfDs?

Governments are best suited to own a significant portion of price risk in offshore wind as policy measures play a key role in shaping prices. Future electricity price uncertainty arises from variations in electrification rates and renewable energy deployment, driven largely by government decisions. Depending on government policies and their implementation, the electricity volume in the European Union is projected to vary within a ~1,900 TWh range.[61]

On the demand side, rapid electrification — driven by electric vehicles, heat pumps, and industrial demand — is significantly impacted by government policy decisions (Figure 17). However, the anticipated increase in electricity demand resulting from these policies has yet to materialise, making it highly risky to use as a base for investment decisions.[62] This is particularly true for large energy infrastructure projects with long lead times, such as offshore wind.

On the supply side, government policies play a decisive role in driving supply investments and deployments. Key initiatives, including the EU solar energy strategy and the European Wind Power Action Plan, have the potential to drive ~2,500 TWh of potential energy supply growth (Figure 18). Both were introduced as part of the EU's broader response to the energy crisis triggered by Russia's invasion of Ukraine, and aim to reduce reliance on foreign fossil fuels.

CfDs efficiently allocate price risk to governments, given their pivotal role in shaping future electricity demand and supply dynamics. The transmission grid that will connect supply and demand will also need to scale up massively, it has long lead times, and it is also largely developed through political measures and initiatives. While offshore wind developers may have been willing to assume this risk for a few projects, the unprecedented growth in demand and the significant transformation required in the electricity supply mix create new challenges. As the primary drivers of price risk uncertainty are determined by policy measures, governments are the best owners of that risk. With CfDs, governments provide a framework for the offshore wind industry to de-risk investments and accelerate deployment, even amid demand and supply uncertainties. If governments are not willing to take the risk of entering into a CfD, the consequence may be that projects do not get built.

What is the role of the PPA market and its coexistence with CfDs?

With the joint commitment, 10 GW of commissioned capacity is to be supported through CfDs. On top, developers can sell additional capacity to non-government entities, including through power purchase agreements (PPAs). PPAs provide price certainty, like CfDs, enabling developers to sell electricity at a predetermined fixed price to corporate buyers. By securing long-term revenue streams, PPAs improve project bankability and serve as a commercial tool to reducing risk exposure in merchant markets. If the regulatory regime allows for it, developers can also adopt a hybrid revenue model, combining fixed-price CfDs or PPAs with merchant exposure in a project, to capture the upside potential of favourable market conditions.

With this non-CfD-backed capacity, developers can help grow the PPA market for offshore wind from its current scale of ~1.7 GW annual capacity contracted.[63] Currently, the European renewable PPA market is still underdeveloped to serve as a standalone revenue guarantee. A larger PPA market will help reduce reliance on government-supported schemes, fostering a more resilient renewable energy sector.

Financing structure and WACC of offshore wind projects

(According to Wood Mackenzie and expert interviews)

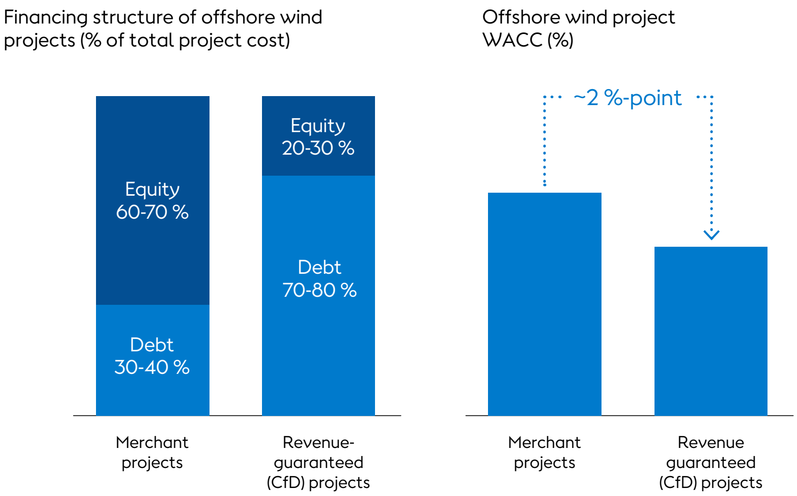


Figure 16: Source: Wood Mackenzie, offshore wind investment banking expert interviews.

61 TYNDP (2024), IEA World Energy Outlook (2024).
62 IEA World Energy Outlook (2024).
63 Wind Europe PPA data (capacity contracted in 2023 and 2024.

Scaling up PPAs could be enhanced by improving market accessibility with government-private sector collaboration. This includes measures such as establishing CfD-to-PPA transition flexibility (as seen in offshore wind in Taiwan and Belgium) and PPA credit guarantees by government authorities for smaller corporate offtakers (as in offshore wind in Taiwan).[64,65] With CfD-to-PPA flexibility, developers can transition from CfDs to PPAs when market conditions allow for it, balancing revenue certainty with market-driven opportunities. Additionally, the PPA credit guarantee will reduce default risks for smaller corporate buyers, making PPAs more accessible to a broader range of businesses. Of course, a PPA model is only viable if developers can secure a buyer willing to contract at a price that aligns with the project LCoE.

Key government policies impacting electricity demand

Demand	Key government policies	Potential electricity demand
Transport	**The EU hydrogen strategy** aims to deploy renewable hydrogen at large scale by 2050 in various areas, including aviation & shipping	~800 TWh
	The Renewable Energy Directive III targets renewable energy share of 29 % in transport by 2030	~500 TWh
Industry	**The Industrial Emissions Directive** prevents and controls emissions from a wide range of industrial activities, including steel, cement **The Net-Zero Industry Act** sets a net-zero manufacturing capacity goal at 40 % of deployment needs	~1,000 TWh
	The EU hydrogen strategy plans a large-scale hydrogen deployment in hard-to-decarbonise industrial sectors	~600 TWh
Buildings	**The Energy Performance of Buildings Directive** impacts demand, by promoting electrification in heating and energy efficient measures, and including steel and cement	~200 TWh

Figure 17: Source: European Commission (2020), 'A hydrogen strategy for a climate-neutral Europe'; European Environment Agency (2024), 'Use of renewable energy for transport in Europe'; European Commission (2024), 'Industrial and Livestock Rearing Emissions'; European Commission (2024), 'The Net-Zero Industry Act: Accelerating the transition to climate neutrality'; European Commission (2024), 'Energy Performance of Buildings Directive'.

Key government policies impacting electricity supply

Supply	Key government policies	Potential electricity supply
Solar PV	**The EU solar energy strategy** aims to accelerate solar technology deployment in commercial and residential buildings	~700 TWh
Offshore & onshore wind	**The European Wind Action Plan** focuses on boosting wind power deployment through a few key actions, including streamlining permitting processes and grid integration	~1,800 TWh

Figure 18: Source: European Commission (2024), 'PV on rooftops and beyond can surpass targets while preserving the environment'; European Commission (2023), 'European Wind Power Action Plan'.

64 Fitch Ratings, (2024) 'Taiwan's Renewable Power Credit Guarantee to Mitigate Offtaker Risk'; and Watson Farley & Williams, (2020) 'Corporate PPAs – Powering Ahead in Taiwan'.
65 Ministry o-f Energy Belgium, (2023) 'Belgian Offshore Wind Energy Tender & Corporate PPAs'.

2 What are the key design elements for CfDs and tenders to de-risk offshore wind?

The proposed commitment involves a two-way, inflation-indexed contract for difference (CfD) as the best revenue mechanism for offshore wind. This section explores how a two-way, inflation-linked CfD reduces risk, encourages competitive pricing, and ensures revenue stability. It then outlines the key elements of a transparent tender process — pre-qualification, centralised site selection, auction mechanisms, flexible timelines, and clear grid connectivity — that together create a reliable, bankable pipeline for offshore wind projects.

Why is a two-way, inflation-indexed CfD Optimal?

The proposed two-way, inflation-indexed CfD framework provides a stable strike price that shields offshore wind generators from low market prices. At the same time, the mechanism ensures that any surplus revenue — when market prices exceed the strike — is returned to the state. EU regulations support such schemes to promote renewable electricity without distorting market dynamics. A well-designed two-way CfD:

- Minimises LCoE through competitive bidding: Developers compete on the strike price, driving down costs and ensuring that only the most efficient projects are selected.
- **Reduces financing costs:** With a guaranteed revenue stream, developers benefit from improved bankability and a lower weighted average cost of capital.
- **Returns value to society from high prices:** Payments received by the governments in instances of high prices is returned to public coffers and can be used to compensate consumers directly and indirectly.
- **Provides real revenue stability:** Linking to inflation ensures the contract strike price keeps pace with rising costs over time and prevents erosion of real value.

In addition, depending on local market conditions, production-independent CfD variants may also be considered, provided they continue to reward efficiency and comply with EU standards.

What is required to design an effective tender framework?

Tender elements should be designed to optimise project costs and enhance transparency for developers during bidding. EU regulations require tenders to support a high project realisation rate by ensuring non-discriminatory and transparent qualification criteria, allowing for flexibility and innovation.[66] It should ensure that projects get built at the lowest possible cost. Specifically, the following elements should be addressed to remove associated costs and risks of a tender framework:

- **Pre-qualification criteria** should require bidders to demonstrate financial capability, stability, commercial viability, and proven technical competence. Bidders should demonstrate access to sufficient capital, a track record of delivering offshore wind projects of comparable scale and complexity, proven technology, and proven access to a robust and scalable supply chain.
- **Site selection** should be centralised by governments and include pre-investigated feasibility assessments for offshore wind build-out. This should prevent speculative bidding on the site status and ensure a fair, competitive process.
- **Minimum qualitative criteria** should be deployed to enhance bidding transparency. Beyond required qualitative criteria meeting the EU standards for robust and viable projects, the tender design should avoid elements that hinder transparency and innovation.

66 EU auction design for renewable energy, 13.5.2024.

- **Auction mechanisms** should leverage revenue mechanisms excluding concession payments. Concession payments increase LCoE and encourage aggressive financial assumptions from developers, ultimately increasing project risk.[67] Conversely, a two-way CfD is a revenue mechanism that ensures outsized profits are distributed to society.

- **Timeline and project delivery** should provide flexibility with a two-to-three-year delivery window upon grid connection finalisation. This commitment to deliver should be based on fair penalties and non-performance schemes. Penalties should be of a reasonable amount and structured as a staircase to ensure harsher penalties do not apply for minimal delay. This enables supply chain coordination and provides weather-related flexibility while maintaining a firm commitment to project completion.

- **Grid connectivity** should follow a centralised approach with a clear build-out plan published at auction launch. This serves to provide clarity on connection points, capacity availability, and infrastructure timelines. Letting developers be in charge of the transmission scope reduces cost and complexity and should be considered in tender designs.

What is an effective tender framework for merchant offshore wind projects?

Merchant tenders can partly follow the same framework as CfD tenders; however, the auction mechanism and some design elements need to be different.

The described framework above regarding pre-qualification criteria, sites selection, and minimum qualitative criteria would largely still be applicable to merchant projects. The merchant tender framework should also include the following:

- **Frequent seabed leases** to encourage market participation and maintain competitive pressure, while at the same time ensuring a sufficient number of areas.

- **Site investigations** conducted by the developer, not the government. Successful bidders gain the exclusive right to conduct preliminary investigations within their allocated area and explore project design options according to their preferences. Sites should still be selected by governments to minimise conflicts, avoid spatial overlaps, and mitigate wake effects.

- **More flexibility** in timeline, project delivery, and project design. The specific project capacity and corresponding grid connection capacity would not be predefined, allowing for greater adaptability.

- **Auction based on highest annual lease payments** that starts at the preliminary investigation phase and ends at COD.

- **Revenue-sharing model** per produced MWh (for instance a given share of revenues above a certain price or revenue level) could be added during the concession period and operational phase after the ceased lease payment.

67 TYNDP (2024), European offshore network transmission infrastructure needs.

3 What capacity is required to meet Europe's offshore wind demand and sustain its supply chain?

The proposed joint commitment entails at least 10 GW of capacity commissioned each year with a firm commitment via viable CfDs to be commissioned from 2031 to 2040, with a flexible 'top up' of ~5 GW per year of merchant project. This section explains how these capacity amounts contribute to the long-term needs of Europe towards 2050, recognising that the long-term needs are dependent on electrification and general electricity demand.

To keep Europe on track to reach 350–450 GW by 2050 and maintain a stable offshore wind pipeline, between 13 and 19 GW must be commissioned annually from 2031 towards 2050 (Figure 19).

The key focus right now is the period up to 2040 because as the offshore wind industry is a long-cycle industry, decisions today impact the next decade. Even reaching the low case of ~220 GW of offshore wind in 2040 requires a significant ramp-up of the supply chain capacity, given that it is also delivering for export to international markets (Figure 19).

On the current investment trends, the supply chain needed to meet the very front-loaded government demand in the early 2030s cannot and will not materialise. The complexity of this is magnified for offshore wind by its long development cycles and multi-year execution build-out. With effective coordination, the offshore wind industry can deliver large volumes of rapid-to-deploy home-grown energy year by year and an internally competitive supply chain.

Europe is currently equipped to produce only about 10 GW of offshore wind capacity per year.[68] This is primarily based a on production constraint of blades and nacelles. However, this stated capacity does not represent a firm full-cycle capability across the entire sector and all input factors, as bottlenecks across other supply chain elements and profitability challenges could further limit actual output.[69,70,71]

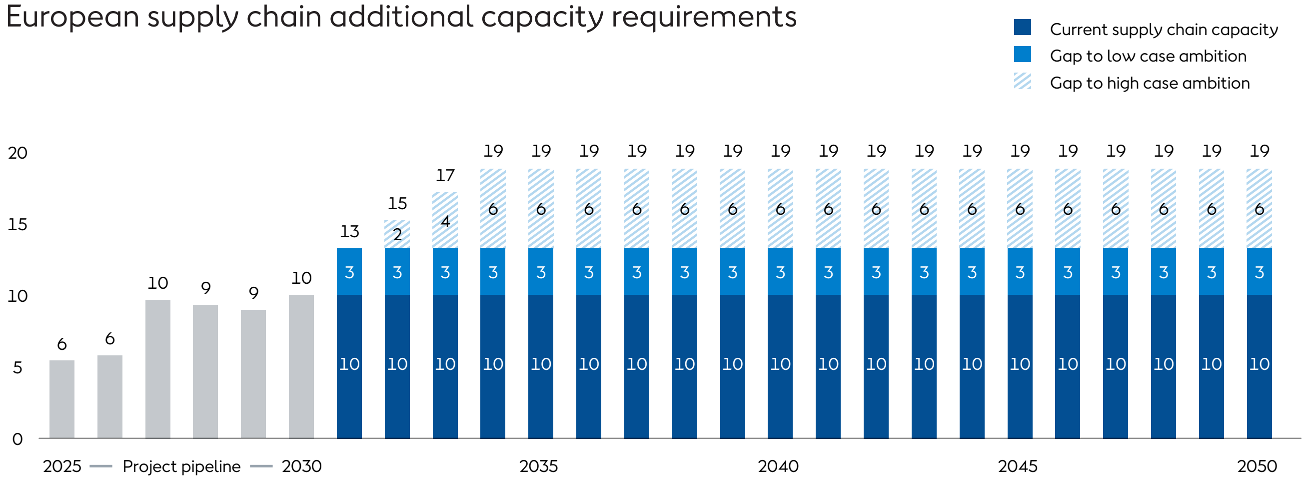
To grow the supply chain to deliver on the longer-term needs of 350-450 GW in Europe in 2050 and ensure the European supply chains remain competitive internationally and can drive further investments in Europe for other global markets, an annual commissioning rate of between 13 and 19 GW in the 2030s becomes critical to:

- **Provide the line of sight that justifies large-scale investments** in factories, vessels, and training programmes — particularly for those sub-supply segments lagging behind nominal wind turbine capacity.
- **Strengthen supply chain economics**, so struggling OEMs and sub-suppliers can improve margins and confidently expand output.
- **Avoid persistent shortfalls** that stall Europe's progress toward its 2050 targets, especially given the learning curve benefits unlocked by continuous deployment at scale.

Upholding and expanding upon today's nominal baseline will not happen organically — firm, predictable volume commitments beyond 10 GW are needed to spur fresh investment and coordinated growth across all supply chain tiers. Without a stable, bankable pipeline above 13 GW per year, manufacturers remain cautious, the flow of critical components can be interrupted, and the entire build-out risks delays and cost overruns.

68 IEA Renewables (2024)
69 IEA Renewables (2024)
70 WindEurope (2024), 'North Seas countries set out clear vision on wind supply chain and grid build-out'
71 Shoreline (2025), 'Headwinds: Offshore supply chain can boost profits despite challenging time ahead'

European supply chain additional capacity requirements



	2025					2030					2035					2040					2045					2050
Accumulated capacity – low case	41	46	56	65	75	85	98	111	124	138	151	164	177	191	204	217	230	244	257	270	283	297	310	323	336	350
Accumulated capacity – high case	41	46	56	65	75	85	98	113	130	149	168	187	206	224	243	262	281	300	318	337	356	375	394	412	431	450

Figure 19: Note: The high-case and low-case scenarios are based on projections of European offshore wind capacity in 2050, estimated to range between 350 and 450 GW considering scenarios from Wood Mackenzie (2024), DNV (2024) and TYNDP (2024), and offshore wind capacity ambitions of EU, NO and the UK. Source: 4C Offshore (Ongoing projects), IEA Renewables 2024 (supply chain capacity).

4 Why is an even and investable capacity profile required for the industry?

The joint commitment should entail governments to distribute commissioned capacity evenly year by year through cross-border planning. This section emphasises the importance of a smooth build-out and of providing the offshore wind industry with a clear line of sight.

An approach where projects are tendered for commissioning in a steady, structured sequence creates a predictable framework for offshore wind expansion. This ensures efficient resource allocation, streamlined planning, and timely execution.

Currently, offshore wind tender commissioning dates are fragmented and inconsistent, with capacity allocated in a highly front-end-loaded manner. For example, 23 to 25 GW is communicated to come online per year between 2030 and 2032, more than two times the capacity the existing supply chain can deliver each year.[72] Europe can currently produce only ~10 GW of offshore wind capacity annually, making it extremely challenging to fulfil these front-loaded allocations.[73] Such a surge places immediate pressure on manufacturing, vessel availability, workforce deployment, and grid infrastructure, increasing the risk of delays, cost overruns, and potential project cancellations. Developers must also navigate overlapping tender rounds, which further complicates project coordination and can slow deployment.

The commitment calls for at least 10 GW of firm CfD-backed commissioned capacity each year for at least a ten year period to create a foundation for the industry and create a stable base for the supply chain.. A stable, incremental build-out of this base capacity supports efficient supply chain utilisation and long-term cost reduction.

Predictability of capacity can help spread workload and resource needs more evenly, allowing each part of the supply chain to operate continuously and at scale. Additionally, consistent and predictable volumes encourage investment in new production lines, advanced equipment, and workforce training, as players are more confident that they will see returns from their investments.

A well-sequenced pipeline also bolsters investor confidence, because clear sightlines on future projects reduce uncertainty and facilitate more attractive financing terms. This is vital for ensuring that large-scale offshore wind expansions can proceed smoothly and cost-effectively, without subjecting developers, suppliers, and financiers to disruptive peaks in demand. The resulting continuity enables strategic investments that strengthen production stability, sustain the workforce, and build overall resilience in the industry.

Steady capacity allocations represent a more manageable and predictable pathway towards Europe's long-term offshore wind ambitions. By adopting a cross-border collaborative approach, the sector can maintain momentum, avoid resource bottlenecks, and capture the benefits of learning-curve effects that drive further reductions in LCoE. Through balanced, year-by-year commissioning, offshore wind can scale without creating harmful cycles of oversupply or underinvestment, ultimately ensuring that clean energy ambitions are met on time and at a lower cost.

72 4C Offshore (2024), WindEurope, government announcements. See Figure 9, for communicated annual capacity additions.
73 IEA Renewables (2024).

5 How does the proposal compare to the announced tenders and projected capacity build-out?

The joint commitment should call for governments to collaborate to reinvigorate the European offshore wind industry, build-out the project pipeline, and meet future electricity demand. This section details the ask of the proposed joint commitment as compared to the announced tenders and the projected capacity build-out from these tenders.

European governments have communicated 123 GW of tendered capacity to be commissioned between 2029 and 2040 (Figure 20). This volume is enough to cover the initial ask under the commitment of 100 GW of CfD-backed capacity as well as the capacity commissioned prior to the commitment coming into effect (2029-30). However, to stay on track to deliver ~400 GW by 2050 (midpoint of the 350-450 GW target range), a 'top up' of ~50 GW build-out capacity is needed. This would require additional capacity to be tendered by governments for commissioning before 2040.

Importantly, at least 54 GW (~45 %) of the communicated capacity is uncertain due to reliance on merchant revenue models or CfDs with ceiling prices below expected LCoE (Figure 20). Therefore, the commitment also calls for at least 100 GW of commissioned capacity to be firm CfD-backed capacity to address these concerns. This requires governments to revisit existing and planned capacity tenders to introduce a viable CfD design.

Countries have set ambitious targets and already announced significant volume.

However, progress remains uneven due to fragmented tender structures, uncoordinated timelines, and a lack of transparency regarding commissioning dates to avoid bottlenecks. Additionally, uncertainty around future revenue support mechanisms complicates long-term planning. To address these challenges and drive effective implementation, governments should:

- **Enhance transparency:** Clearly communicate commissioning dates to reduce uncertainty and improve planning.
- **Scale up commitment volume:** Consider increasing the volume of commitments, including additional CfDs, to leverage economies of scale, attract more investment, and increase overall project delivery certainty.
- **Improve reliability of volume commitments:** Allocate funding or implement other measures to provide the trust in the commitment needed for the supply chain to scale.
- **Co-ordinate the build-out:** Harmonise tender schedules and commission dates across nations, ensuring that supply chain investments are supported by consistent, long-term demand.

Capacity commissioned with the proposed joint commitment

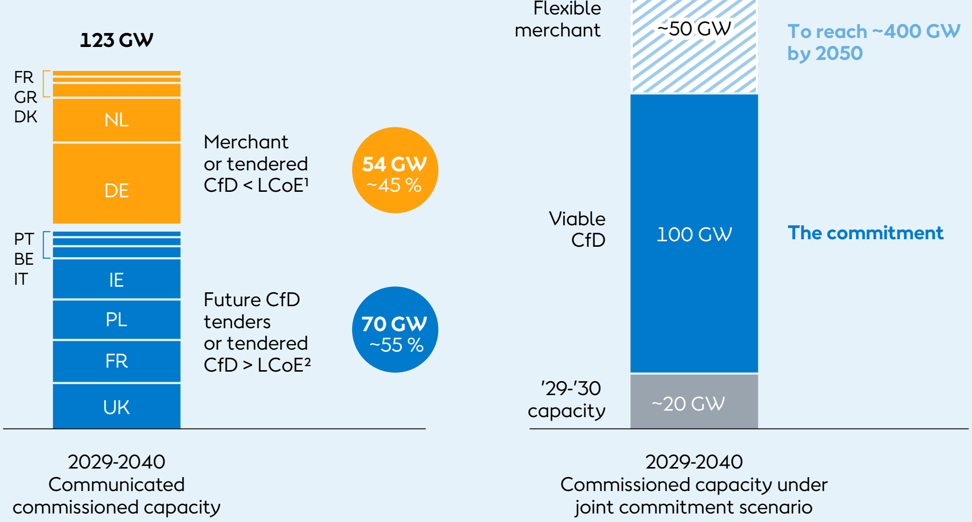


Figure 20: Note: Same methodology and sources as Figure 9. Please refer to notes under Figure 9 for details.

6 How do the proposed elements impact offshore wind LCoE?

The joint commitment will, under the right conditions, lead to a reduction of levelised cost of electricity (LCoE) by ~30 %. This is driven by both cost of capital reduction and industry development through learning, committed volumes, standardisation, and industrialisation.

What is LCoE and how can it be used to assess the cost impact of the elements under the commitment

To measure the impact on the cost of offshore wind the generic tool of levelised cost of electricity (LCoE) is used. This is a measure of the average net present cost of electricity generation for in this case offshore wind over its lifetime. It is used for investment planning and to compare different technologies of electricity generation on a consistent basis. The cost of electricity production depends on costs during the expected lifetime of an offshore wind project and the amount of electricity the project is expected to produce over its lifetime. Thereby the LCoE shows the average cost in currency per electricity unit, for example, EUR per megawatt-hour.

In assessing the impact of the two elements – cost of capital reduction and learning curve – cost reductions a baseline needs to be established. Here a 'standard wind farm' project located in the North Sea with a merchant risk profile is defined (see the box below) and calculated to have a baseline LCoE on 90-100 EUR/MWh.

Impact of WACC on offshore wind LCoE

Levelised cost of electricity (LCoE), indexed to 100 at 0 % WACC

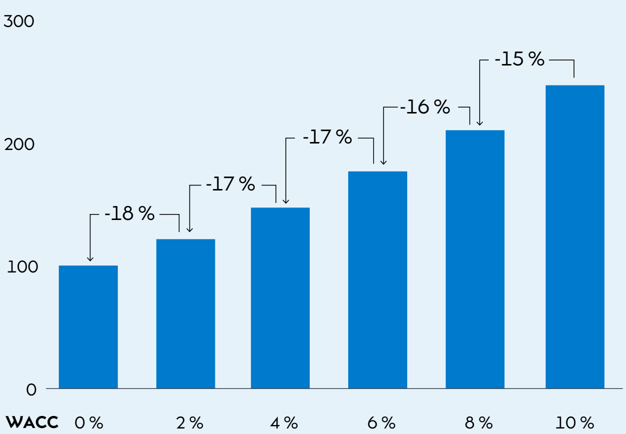


Figure 21: Note: Assuming same CapEx and OpEx in all cases
Source: Wood Mackenzie, same data as in the reference case described in the box on page 33.

How does cost of capital reductions impact LCoE?

The cost of capital or weighted average cost of capital (WACC) has a substantial impact on the LCoE for offshore wind projects. WACC combines the level of interest and return expectations on investment. It indicates how much offshore wind developers must pay in loans/debt and equity costs. The WACC impact on LCoE is pivotal to making offshore wind projects more financially viable. A decrease in WACC of 2 percentage points leads to an LCoE reduction of between 15 % and 18 % on average (Figure 21).

Price and revenue certainty provided by CfDs will lower the project-weighted average cost of capital (WACC) by approximately 2 percentage points. With CfDs, developers can attain better financing positions and improve bankability for their projects due to the reduced project revenue risk (see further CfD details in the Q&A chapter, Question 1). Consequently, the cost of capital reduction from CfDs results in a lower LCoE for an offshore wind project in Europe of EUR ~15 per MWh, equivalent to a ~15 % decrease, compared to merchant projects (Figure 22).

How does capacity delivery with accelerated learning curve impact LCoE?

With significant and guaranteed capacity expansion, the offshore wind industry will be able to accelerate the impact of the learning curve effect. The at least 10 GW of de-risked annual committed capacity and 'top up' of ~5 GW annual capacity will kick-start the sector and provide certain volumes. This kick-start will reinforce long-term industry growth and enable greater learnings across development, manufacturing, installation, operations, and maintenance. Together these effects result in a ~15% decrease in LCoE for offshore wind in Europe, equivalent to ~15 EUR per MWh in the reference calculation (Figure 22).

The assumed learning rate for the offshore wind industry is 8–10 %. This learning rate has been calculated based on historical and forecasted industry cost and capacity developments. This is derived from observed cost reductions as installed capacity has been scaled, using historical data.[74] Historical trends have been validated against forecasted cost and capacity trajectories, ensuring consistency with future projections. Additionally, the assumed learning rates have been compared with published estimates for offshore wind to further support their robustness.[75,76]

74 4C Offshore.
75 4C Offshore, Wood Mackenzie.
76 IEA, Danish Energy Agency, International Renewable Energy Agency (IRENA).

LCoE cost reduction to 2040

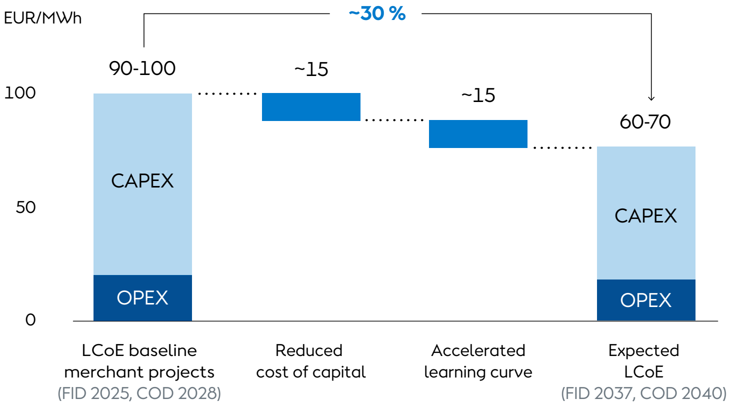


Figure 22: Note: Fixed 2024 prices. The LCoE is based on a standard calculation method showing producer's cost of electricity and does not represent a business case perspective or the strike price level in an auction. Impact from the CfD revenue stabilisation based on WACC reduction of ~2pp compared to merchant projects and projects with similar high-risk profiles that also carries an elevated cost of capital. Source: See box below.

What is the learning rate applied to the offshore wind industry?

The learning curve effect refers to the observed pattern where efficiency, skills, and performance improve as experience is gained through repeated production or tasks. As deployment increases, industries streamline manufacturing, enhance installation techniques, and optimise supply chains, driving cost reductions – a process known as the learning curve effect.

The learning rate quantifies this improvement. It is typically expressed as a percentage, representing a reduction in cost each time cumulative production doubles. With every doubling of offshore wind capacity, the industry moves further along the learning curve, reducing the cost to deliver offshore wind by 8–10 % – this is the learning curve effect.

Learning rates are typically studied in the context of manufacturing, where capital cost declines are more directly observable, compared to operations and maintenance. Given this, there is less available research on learning effects in OPEX. However, the Danish Energy Agency assumes that OPEX learning rates for offshore wind — particularly for wind turbines and foundations — are similar to those for CAPEX. Therefore, 8–10 % has been applied across both expenditure categories. While OPEX cost reductions are less well-documented, improvements in digitalisation, automation, remote monitoring, and predictive maintenance are expected to drive efficiency gains over time.

What is the learning rate applied to other industries?

Learning rates vary across energy technologies based on maturity, capital intensity, and innovation. Solar PV is assessed to be at 18–21 %, driven by material advances and large-scale manufacturing.[77] Fuel cells follow at 18 %, while industrial carbon capture and storage (CCS) reaches 11–12 % through process integration, whereas fossil fuel-based CCS lags is expected to be 2.1–2.2 %.[78]

Heavy industries like aerospace, shipbuilding, and rail transport industries typically exhibit 10–20 % learning rates through automation, standardisation, and process optimisation.[79] Applying best practices, such as modular manufacturing and digital optimisation, can help emerging energy technologies accelerate efficiency gains and reduce costs. Given the learning rate of other industries, there is reason to believe that the actual learning rate for offshore wind could surpass the assumed 8–10 %, leading to even greater cost reductions and efficiency gains, further strengthening offshore wind's role in the energy transition.

LCoE estimation is based on standard discounted cash flow model based on capital expenditures (CapEx), operational expenditures (OpEx), and electricity output generated over the project lifetime. Cost is based on real terms in 2024.

Major inputs of the LCoE estimation are as follows:

1. **Key timeframes:** Construction phase is set to 3 years before the commissioning year with equal split of annual CapEx outflow. The wind farm operates for 30 years, incurring constant OpEx and generating constant MWh output throughout the lifetime.

2. **Comparison:** The baseline is based on a project commissioned in 2028 (Final Investment Decision or FID in 2025) and expected LCoE is based on commissioning year of 2040 (FID in 2037).

3. **CapEx and OPEX baseline:** CapEx is set to ~EUR 3.7M per MW and OpEx is set to ~EUR 87k per MW per year, excluding taxes, from the average of the North Sea countries UK, Germany, the Netherlands and Denmark from 2028 commissioning year, with the expected mix of local and foreign inputs.[80]

4. **Capacity factor:** Capacity factor is set at 51 % applied throughout the project lifetime on both base case and future case.[80]

5. **LCoE impact from future capacity volumes (accelerated learning rate):** ~EUR 15/MWh LCoE decrease based on a ~9 % learning rate for offshore wind derived from data from 4C Offshore, Wood Mackenzie, and IRENA combined with offshore wind capacity growth between the FID years 2025 & 2037 with a linear trend toward 400 GW by 2050. This results in ~19 % cost reduction on CapEx and OpEx for a project commissioned by 2040.

6. **The impact on LCoE is in an 'all other things being equal' scenario**, including assuming healthy competition in the supply chain and among project developers to drive the industrialisation efficiencies.

77, 78 Danish Energy Agency (February 2025), Technology data catalogue for electricity and district heating.
79 US Environmental Protection Agency (2016), Cost reduction through learning in manufacturing industries and in the manufacture of mobile sources.
80 Wood Mackenzie, 'Europe levelised cost of electricity (LCoE) 2024 data'.

7 What is the potential impact of co-ordinated transmission and maritime spatial planning?

The proposed joint commitment entails that governments and industry collaborate to coordinate not only the timing of offshore wind auctions but also the cross-border offshore transmission and maritime spatial planning. In this section, we outline the key mechanisms and projected outcomes of enhancing transmission infrastructure with hybrid interconnectors and applying optimised maritime spatial planning.

Governments can maximise impact and make sure to harvest further cost reductions by creating a cross-border framework that increases the cost efficiency of offshore wind build-out. This includes aligning cross-border transmission infrastructure with hybrid interconnectors and implementing regional maritime spatial planning. Through coordinated planning across jurisdictions, efficient site allocation is ensured, while integrated cross-border transmission boosts grid flexibility, streamlines energy trading, and enhances market efficiency — facilitating the seamless flow of energy.

Thema Analysis has performed an analysis[81] to identify the system value of increased cross-border collaboration. The study concludes that the key benefits of this coordinated approach compared to a radial only (no hybrid interconnection) approach include the following:

- Cross-border offshore transmission, when integrated with hybrid interconnectors and optimised maritime spatial planning, can reduce consumer power prices by on average EUR 3 per MWh, yielding annual consumer savings of EUR 15 billion in Europe[82,83]
- Expansion of regional collaboration can increase incremental capacity across Europe, with potential increases of 30–40 GW in the North and Baltic Seas until 2050 alone.[84]

What are the economic savings from coordinated offshore transmission and maritime spacial planning?

Cross-border offshore transmission, when strategically integrated with optimised maritime spatial planning, has the potential to significantly reduce overall consumer electricity prices.

By pooling offshore wind resources across multiple jurisdictions, the system can take advantage of geographical diversity, reducing curtailment and maximising efficiency. This can serve to ensure electricity is available in areas where demand is highest, for example inland Germany being supplied by offshore wind farms situated in Danish waters. The combination of optimised maritime spatial planning and improved grid connection strategies will result in a relatively lower LCoE for offshore wind when compared to a radial only strategy.

By strategically placing wind farms and coordinating grid infrastructure, unnecessary transmission losses and inefficiencies can be minimised. This approach is also expected to reduce LCoE by 5 % on average, helping to ensure that offshore wind is built out as cost-efficiently as possible.

How much more offshore wind capacity can be unlocked with coordinated offshore transmission and maritime spacial planning?

The expansion of cross-border offshore transmission through regional collaboration can not only enable a capacity increase of 20–30 GW in the North and Baltic Seas by 2050, but it can also create a more attractive investment environment when compared to a radial only scenario. By alleviating grid bottlenecks and ensuring efficient, reliable electricity delivery, these coordinated measures reduce technical and regulatory barriers and lower project costs.

As a result, developers are more inclined to invest in new capacity, confident that improved transmission infrastructure and strategic planning will support a large-scale, cost-effective offshore wind expansion and enhance overall energy security.

81 Analysis commissioned by Ørsted. Results to be made public during 2025.
82 IEA World Energy Outlook (2024) for 2050 electricity demand projection.
83 THEMA Analysis.
84 THEMA Analysis.

Proximity of planned SN-10 site's impact on neighbouring areas[85]

Strategic maritime spatial planning and cross-border offshore wind farm coordination can mitigate wake effects, preserve efficiency, and sustain high energy outputs. By taking a more integrated approach, countries can extend the long-term viability of offshore wind projects while minimising energy losses.

For instance, in the North Sea, Germany's N-6 to N-13 sites (which were tendered in recent years) experience notable wake impacts from neighbouring wind farms. As projects expand, measurable production losses occur—planned SN-10 areas alone are expected to reduce the energy output of nearby sites (N9, N11 and N12) by 5–15 % (Figure 23).

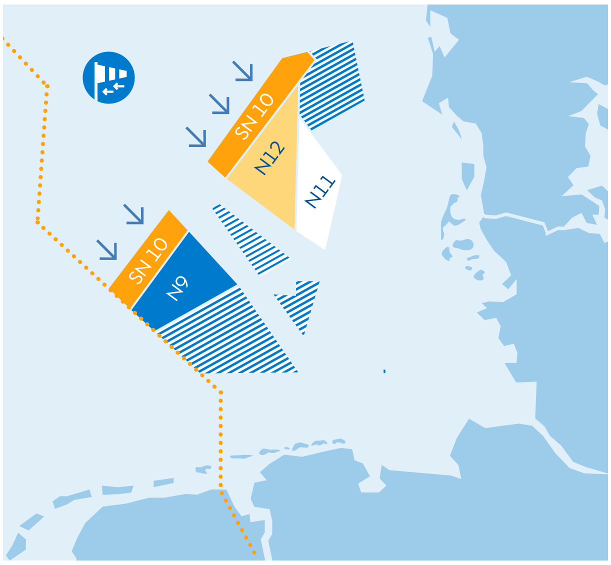


Figure 23..

85 Fraunhofer study (2023).

About Ørsted

Ørsted is the global leader in offshore wind power and is one of the largest renewable energy companies in the world.

Within a decade, we transformed from being one of Europe's most fossil fuel-intensive utilities to being ranked as one of the most sustainable energy companies in the world. Today, we're guided by a clear vision: to create a world that runs entirely on green energy.

We provide countries, companies, and communities with sustainable, reliable, and cost-competitive energy solutions, including offshore and onshore wind, solar PV, energy storage, and bioenergy facilities. In total, we own or operate over 18 GW of renewable energy capacity across North America, Europe, and Asia Pacific.

We built the world's first offshore wind farm and currently operate the world's largest. Our current installed offshore wind capacity of around 10 GW will nearly double within the next three years through our ambitious construction programme.

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