Overcoming Turbulence in the Offshore Wind Sector

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Energy Transitions Commission

Insights Briefing

The Energy Transitions Commission (ETC) is a global coalition of leaders from across the energy landscape committed to achieving net-zero emissions by mid-century, in line with the Paris climate objective of limiting global warming to well below 2°C and ideally to 1.5°C.

Our Commissioners come from a range of organisations – energy producers, energy-intensive industries, technology providers, finance players and environmental NGOs – which operate across developed and developing countries and play different roles in the energy transition. This diversity of viewpoints informs our work: our analyses are developed with a systems perspective through extensive exchanges with experts and practitioners. The ETC is chaired by Lord Adair Turner who works with the ETC team, led by Ita Kettleborough (Director), and Mike Hemsley (Deputy Director).

The ETC's *Overcoming Turbulence in the Offshore Wind Sector* briefing was developed in consultation with ETC Members, but it should not be taken as members agreeing with every finding or recommendation.

The ETC team would like to thank the ETC members, member experts and the ETC's broader network of external experts for their active participation in the development of this insights briefing.

The ETC Commissioners not only agree on the importance of reaching net-zero carbon emissions from the energy and industrial systems by mid-century but also share a broad vision of how the transition can be achieved. The fact that this agreement is possible between leaders from companies and organisations with different perspectives on and interests in the energy system should give decision-makers across the world confidence that it is possible simultaneously to grow the global economy and to limit global warming to well below 2°C. Many of the key actions to achieve these goals are clear and can be pursued without delay.

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Front cover and Report design: Ellie Pinney.

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Introduction

To limit global warming to well below 2°C, and ideally to 1.5°C, the world will need to cut net greenhouse gas emissions to zero by around mid-century. Widespread electrification of transport, buildings and industry, combined with power sector decarbonisation, will be by far the most important lever to achieve this emission reduction. Total global direct electricity use will need to grow over two times by 2050, with significant additional electricity generation required for green hydrogen production. Rapid deployment of wind and solar power capacity is, therefore, essential.[1] To achieve a net-zero global economy, annual generation from wind could increase ten-fold, from 2,000 TWh in 2022 to over 20,000 TWh in 2050, and solar power generation growing from 1,000 TWh to approximately 30,000 TWh.[2] This would require over 20 TW of solar capacity, and over 8 TW of wind.

Within this scale-up, offshore wind can and must play a vital role. Offshore wind can both produce energy when the sun is not shining and typically achieves a far higher capacity factor than onshore wind;[3] it is also not subject to the same land constraints as onshore wind and solar.[4,5] Costs and prices bid at auctions for offshore wind have fallen rapidly between 2015 to 2020 (e.g., by around 65% in the UK), and by the end of 2023, 74 GW of offshore wind farms had been constructed across Europe, Asia and the US, capable of producing over 250 TWh of electricity per year (enough for around 90 million households). European countries together have set targets to reach 140 GW of installed offshore wind capacity by 2030.[6] And the eventual potential is much greater still: in its special report on offshore wind in 2019, the International Energy Agency (IEA) showed that offshore wind has the potential to generate more than 420,000 TWh per year worldwide. This is more than 14 times global electricity generation today.[7] More countries each year are exploring development of offshore wind, with deployment targets increasing across the globe.[8]

However, in 2023, progress was stalled in several major countries. Offshore wind costs have rapidly increased, developers have walked away from projects, and auctions have been undersubscribed. There is a growing perception that offshore wind is in "crisis" [Exhibit 1.1].

This Insights Briefing explores these claims by examining in turn:

- Recent developments in the offshore wind industry – project cancellations, auction processes and cost increases.
- The drivers of recent cost increases, and how long they could persist.
- Long term expectations for offshore wind costs.
- Key actions that can relaunch the confidence cycle and bring down costs.

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1 ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels*.

2 Additional potential wind and solar generation for green hydrogen may be required for low-carbon hydrogen. See ETC (2023), *Fossil Fuels in Transition: Technical Annex*.

3 For example, in Europe or North America, offshore wind load factors are typically highest in winter, when solar output is lowest. The capacity factor is a utilisation factor which compares a plant's real electricity output over time to its maximum output if it ran constantly at full power. Capacity factors for offshore wind vary depending on the size and design of the turbine, but global averages of existing turbines are around 42% which would mean that on average the turbine generates electricity at full capacity for 3670 of the 8760 hours in a year.

4 Further, offshore wind is deployed off coastal areas, where 40% of global population is based and 12 of the 15 most populous cities are located. See UNEP Topics "Oceans, seas and coasts", Available at: https://www.unep.org/topics/ocean-seas-and-coasts [Accessed April 2024].

5 Whilst seabed space is not subject to the exact same restrictions as land use, in many countries seabed space is often constrained in a similar manner with multiple users and stakeholders, including shipping, fisheries, nature reserves, military zones, etc.

6 The Ostend Declaration targets 120 GW by 2030 in the North Seas, and the Marienborg Declaration targets an additional 19 GW by 2030 in the Baltic Sea. See Ostend Declaration of Energy Ministers (2022), *The North Seas as Europe's Green Power Plant*; The Baltic Sea Energy Security Summit (2022), *The Marienborg Declaration*.

7 IEA (2019), *Offshore Wind Outlook 2019*.

8 Outside of Europe, the US and China offshore wind projects are actively being planned in Australia, New Zealand, Japan, South Korea, Taiwan Vietnam, India, Canada, Brazil, Colombia and South Africa. See GWEC (2023), *Global Offshore Wind Report 2023*.

Growing perceptions of an "offshore wind crisis" in certain markets

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Until 2022, the offshore wind industry seemed to be flourishing. Annual deployment had increased from less than 1 GW per year installed in the 2000s, to 5 GW per year in 2020, with the IEA projecting an increase to 80 GW per year by 2030.[9] Cumulative installed capacity grew from 12 GW in 2015 to 74 GW by 2023 [Exhibit 1.2].

Prices bid at auctions were on a strong downward path. In 2015, the UK's first CfD auction for offshore wind saw 1 GW of capacity awarded at strike prices of £102/MWh[10,11] [Exhibit 1.3]. Each subsequent auction round saw increasing GW awarded at lower prices: in 2022, 7 GW was awarded at a strike price of just £37/MWh (in 2012 prices).

Estimates of levelised cost of electricity (LCOE) also saw significant decline. BNEF estimated in 2023 that the LCOE for offshore wind in China had fallen from $126/MWh in 2015 to $74/MWh in 2022; while in Germany the estimated decline was from $205/MWh to $112/MWh [Exhibit 1.3].[12]

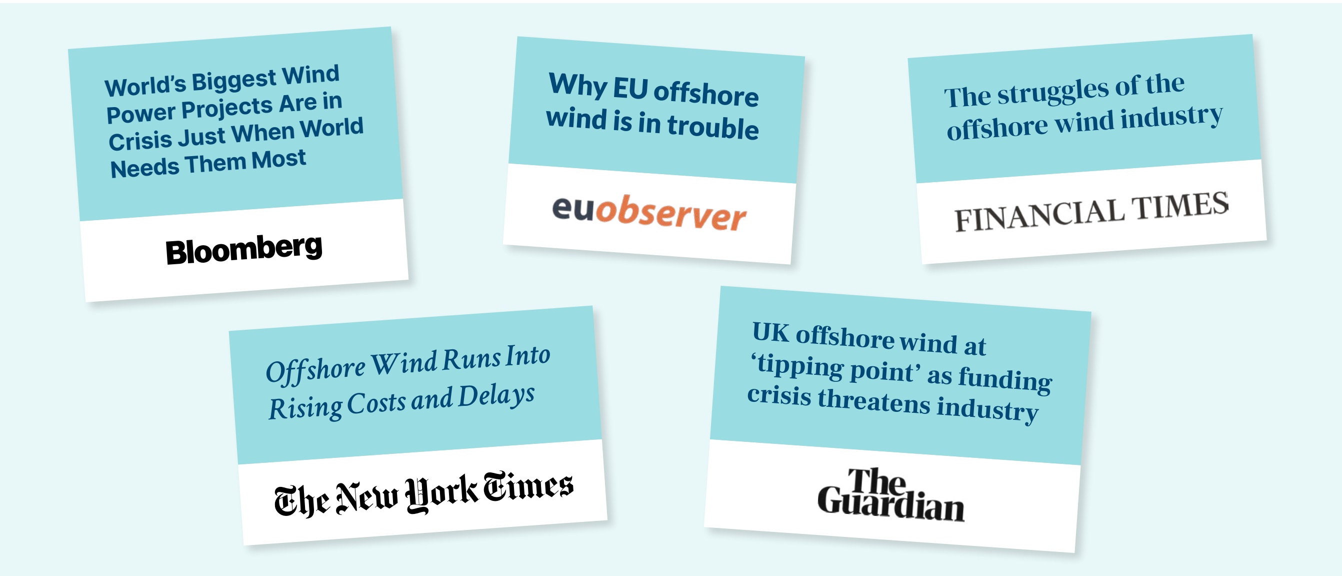
Since 2022, these favourable trends have halted and reversed in some countries, in particular the UK and the US. Estimated LCOEs have risen, with some auctions undersubscribed. The development of the supply chain has been impaired by uncertainty about whether favourable pre-2022 trends will return.

This chapter assesses latest trends in offshore wind costs and deployment in different countries, looking in turn at:

- The significant problems which have emerged in the UK and US.
- The more mixed picture in European countries as well as Japan and South Korea.
- The counter example of rapid growth in China.
- Latest projections of global and regional growth relative to what is required to achieve net-zero global emissions by mid-century.

Perceptions of a "crisis" in the offshore wind industry

Exhibit 1.1



[9] IEA (2021), *Net Zero by 2050, A Roadmap for the Global Energy Sector*.

[10] A contract for difference (CfD) is a financial instrument used to hedge the price of risk of electricity generation projects. A CfD auction is a competitive bidding process used to determine the strike price for a CfD. The strike price is the price per MWh of electricity the generator will receive from the CfD provider for the duration of the contract.

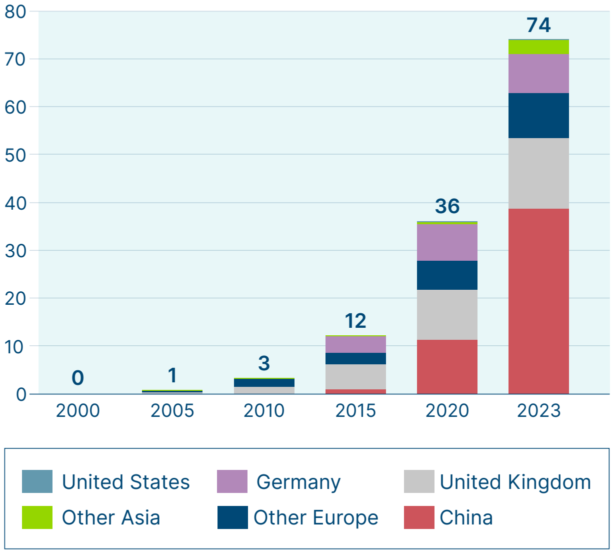
[11] UK auction prices are expressed in 2012 real price values, reflecting the cost of generating electricity in 2012 excluding the effects of inflation. These values are generally used for standardisation and comparison, risk management, and long-term planning.

[12] BNEF (2023), *2H 2023 LCOE: Data Viewer Tool*.

Offshore wind deployments have been increasing with ambitious targets set

Exhibit 1.2

Offshore wind deployments have been increasing
Cumulative GW capacity



Ambitious targets and projections have been set

European and UK commitments to massive offshore wind development:

- EU announced targets in 2020 of 60 GW by 2030 and 300 GW by 2050.
- UK targets of 50 GW by 2030 & CCC targets of 125 GW by 2050.

Auctions across EU have seen offshore wind contracts increase in scale, with falling but now stabilized prices.

CCC projections of very low costs:

Scenarios ranging from £25/MWh – £35/MWh possible by 2050.

IEA forecasted huge offshore potential in its 2020 Net-Zero roadmap with annual global deployment increasing:

5 GW in 2020 → 80 GW in 2030

Source: BNEF (2024), *Global Installed Capacity*; EU Commission (2020), *An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future*; HM Government (2023), *Offshore wind net zero investment roadmap*; CCC (2020), *The Sixth Carbon Budget Electricity generation*; IEA (2021), *Net Zero by 2050, A Roadmap for the Global Energy Sector*.

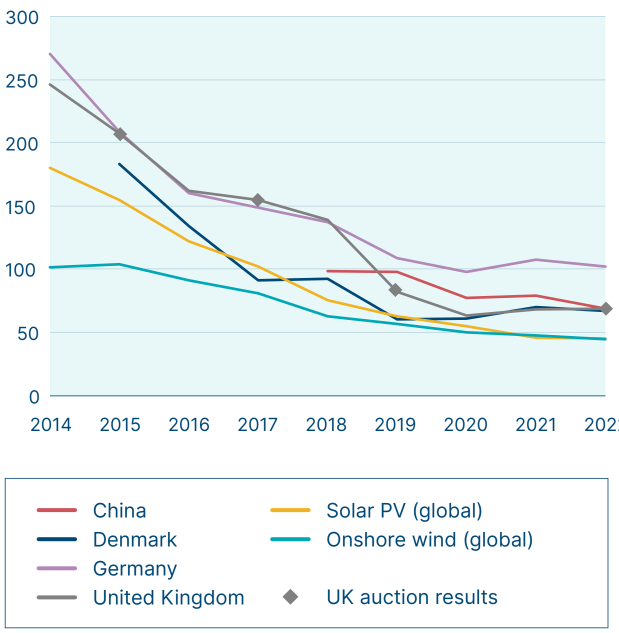
Note: “Other Asia” includes India, Japan, South Korea, Taiwan and Vietnam; “Other Europe” includes Belgium, Denmark, Finland, France, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Spain and Sweden.

Offshore wind costs have been declining

Exhibit 1.3

UK CfD auction offshore capacity awarded and price
GW, £/MWh (2012 prices)

Offshore wind LCOE estimates have been declining
LCOEs, $/MWh (2022 prices)



Source: Carbon Brief (2022), *Analysis: Record-low price for UK offshore wind is nine times cheaper than gas;* BNEF (2023), *2H 2023 LCOE: Data Viewer Tool.*

Note: UK LCOEs are highlighted in right chart in 2022 prices which are the equivalent power contracts awarded in the left chart in 2012 prices.

1.1 Significant problems in the UK and US

United Kingdom

The UK has been a world leader in offshore wind development, with China only recently overtaking it in the total capacity installed. Its innovative Contracts for Difference (CfD) scheme led to the first government contracts for offshore wind being auctioned,[13] and each auction round from 2015 to 2022 saw an increase in contracted capacity with 1 GW in 2015, 3 GW in 2017, 5.5 GW in 2019 and 7 GW in 2022. Contract prices per MWh fell by 65% from 2015 to 2022 [Exhibit 1.3]. Building on this success, the UK announced in 2022 a target of 50 GW of offshore capacity by 2030.[14]

But, significant problems emerged in 2023. High inflation and supply chain bottlenecks in the period of post COVID-19 recovery, exacerbated by the effect of the Ukraine war, drove up offshore wind turbine and installation costs, while increased interest rates resulted in a higher cost of capital. Industry warned that LCOEs had risen by as much as 40% between 2022–23,[15] but the maximum allowable strike price within the fifth auction round was increased by only 15% (from £37/MWh to £44/MWh in 2012 prices). This resulted in both:

- **No bids being submitted in the 2023 fifth CfD round** [Exhibit 1.4][16] as developers were not able to commit to deliver electricity at or below the maximum allowed bid price.[17]
- **Project postponements** with some projects which secured contracts in the 2022 fourth CfD round auctions (at record low prices of £37/MWh in 2012 prices) could not proceed under the previously agreed terms. Vattenfall's 1.4 GW Norfolk Boreas project (which could have produced 6.5 TWh per year) had the CfD contract cancelled, and other developers have warned that other projects may be at risk.[18,19]

For the UK to reach its 50 GW of offshore wind by 2030 target, it must now contract at least 10 GW in each of the next two CfD auctions, and ensure these projects are seen through to completion.[20] Regaining momentum is essential.

Since these developments, the UK government decided to bolster the next CfD round, Auction Round 6 (AR6), to be held in 2024 – introducing an increased administrative strike price of £73/MWh (2012 prices) for fixed-bottom and £176/MWh for floating, and assigning a £800 million pot for fixed and £105 million for floating (all 2012 prices). Despite reforms of the scheme for AR6, industry expectation is that it is will be hard to deliver more than the 7 GW originally procured in Auction Round 4 (AR4), putting the 2030 target at risk.[21]

United States

Despite having less than 100 MW of offshore capacity installed as of 2023, the US has ambitious targets to install 30 GW of offshore wind by 2030. These targets are now in doubt. Of total contracts awarded up to April 2024, almost 60% have been cancelled or look on course for termination [Exhibit 1.4].

Rising inflation and supply chain bottlenecks, plus higher interest rates, increased estimated LCOEs by around 60% between 2021–2023.[22] These cost impacts were exacerbated by strict local content requirements which restricted cheaper imports from more established supply chains abroad; and the impact of rising inflation

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[13] Contracts were also previously awarded to offshore wind under the Renewables Obligation, a credit based scheme that preceded CfDs. See Our World in Data (2020), *Why did renewables become so cheap so fast?*

[14] Carbon Brief (2022), *Analysis: Record-low price for UK offshore wind is nine times cheaper than gas*.

[15] ECIU (2023), *Offshore wind: All at sea?*

[16] Carbon Brief (2023), *Analysis: UK renewables still cheaper than gas, despite auction setback for offshore wind*.

[17] The UK government also hosted a separate auction for floating offshore wind, which had a higher price cap of £116 per MWh (2012 prices); this price cap was also unfortunately set too low, and also did not receive any accepted bids. See Gov.uk (2023), *Boost for offshore wind as government raises maximum prices*.

[18] Reuters (2023), *Vattenfall says it is stopping British Norfolk Boreas offshore wind farm*.

[19] As of December 2023, this project and Vattenfall's two other projects in the Norfolk Offshore Wind Zone totalling 4.2 GW, were acquired by RWE for almost £1 billion. The new owner says it will resume development of the paused Norfolk Boreas wind farm, demonstrating renewed industry confidence. See BBC (2023), *Norfolk offshore wind farms sold to RWE for £1bn*.

[20] To achieve the 50 GW by 2030 target an additional 21 GW of offshore wind needs to be delivered beyond the current pipeline. Given that it takes around five years from receipt of a CfD contract to a new offshore wind farm producing electricity for the first time, only CfD contracts awarded in the next two round (AR6 and AR7) can realistically contribute to the target by 2030. See Energy UK (2024), *Energy UK explains: Allocation Round 6 and the UK's energy security goals*.

[21] Ibid.

[22] BNEF (2023), *Levelised Cost of Electricity 2H 2023*.

on project economics was exacerbated by the fact that the US contracts (unlike the UK contracts) did not allow for price indexation to inflation. These factors resulted in a combination of:

- **Project cancellations** – In total, projects equivalent to 13 GW of contracted capacity across New Jersey, New York, Massachusetts and Connecticut have now been cancelled.[23] Recently cancelled contracts include 4 GW of New York projects, which were only contracted in October 2023.[24]
- **Renegotiation attempts** – A further 1.5 GW of capacity across the same markets is currently undergoing contract renegotiations.[25]
- **Rejection of new bids** – A Rhode Island auction refrained from awarding any contracts in a 1 GW solicitation on July 18th 2023. The state said that the only bid price it received was too high.[26]

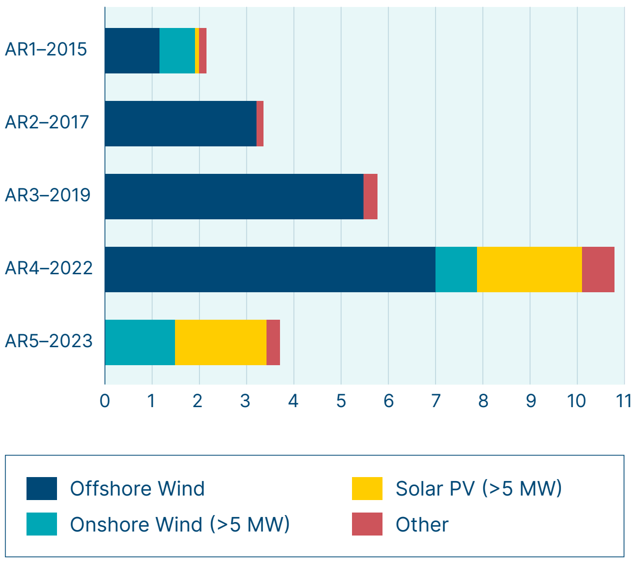
Efforts to boost the prospects of offshore wind in the US have been mixed in late 2023/early 2024. New York hosted expedited auctions and awarded 4 GW of capacity in October 2023 between three projects seeking to use GE Vernova's new Haliade-X 18 MW turbine. GE Vernova has now opted not to produce the 18 MW turbines, choosing to focus on a 15.5 MW variant instead. The three associated projects have now been cancelled by the state government, citing "material modifications" to the projects.[27] New Jersey contracted 3.7 GW of additional capacity in January 2024, which is set to commission in 2031.[28]

In February 2024, New York reallocated power contracts to Ørsted's and Equinor's approximately 1 GW projects through an expedited solicitation. These contracts used higher power prices ($150 per MWh compared to $110 per MWh awarded in 2019), inflation indexes and transmission cost sharing to re-establish offshore wind growth in North East US which should help preserve plans for local supply chains.[29]

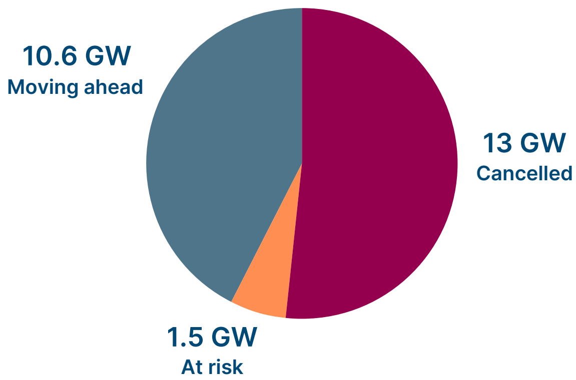
The US and UK have faced significant issues contracting and retaining capacity

Exhibit 1.4

UK failed to clear any offshore wind in 2023 auction for the first time
GW contracted capacity



Sixty percent of offshore wind under contract is at risk or has been cancelled as of April 2024
GW contracted capacity



Source: BNEF (2024), *US Offshore Wind Cancellation Mania Leaves Few Standing*; Utility Dive (2024), *New York nixes 3 offshore wind projects, notes GE Vernova move to abandon 18-MW turbine*; Carbon Brief (2023), *Analysis: UK renewables still cheaper than gas, despite auction setback for offshore wind*.

Note: AR = Allocation Round; "Other" includes advanced conversion technology, energy from waste with CHP, dedicated biomass with CHP, remote island wind (>5 MW), floating offshore wind and tidal stream.

[23] BNEF (2023), *BNEF Offshore Wind Market Outlook 2H 2023, Ramp up Delayed*.

[24] Utility Dive (2024), *New York nixes 3 offshore wind projects, notes GE Vernova move to abandon 18-MW turbine*.

[25] BNEF (2024), *New Jersey's Biggest Offshore Wind Award Is Its Priciest*.

[26] Windpower Monthly (2023), *Rhode Island utility rejects Revolution Wind 2 PPA on cost grounds*.

[27] Utility Dive (2024), *New York nixes 3 offshore wind projects, notes GE Vernova move to abandon 18-MW turbine*.

[28] BNEF (2024), *New Jersey's Biggest Offshore Wind Award Is Its Priciest*.

[29] Reuters (2024), *New York auction highlights jump in US offshore wind prices*.

1.2 Mixed picture in other markets

Whilst supply chain constraints and higher prices have hit most offshore wind markets outside of China (see Chapter 3.3), the impact in several countries has been less severe than in the UK and US.

Germany and the Netherlands are seeking to build on well-established markets, with cumulative capacities of 8 GW and 3 GW respectively as of 2022, and 2030 targets of 30 GW in Germany and 21 GW in the Netherlands.[30] Ireland is a new entrant to offshore wind generation, with no current installed capacity but a 5 GW target for 2030. All three European countries, as well as emerging markets Japan and South Korea, managed to contract significant new capacity in 2023.

Germany had its largest offshore wind auction to date in July 2023, with 7 GW of new capacity awarded. This auction entailed "uncapped negative bidding" for a right-to-deliver electricity at uncertain future prices, rather than a CfD structure to set a guaranteed future price [Box A]. It saw oil majors Total and BP bidding high prices compared to their competition.[31]

The Netherlands hosted two successful auctions at the end of 2022, also utilising "negative bidding" for rights-to-deliver, with winners partially prioritised based on "non-price criteria" including demonstration that bidders can mitigate or restore the impact of the offshore wind farm on maritime biodiversity.[32] The Netherlands also have a record tender of 4 GW planned to be auctioned in 2024, where financial payments to the government must start during construction and be paid for 40 years at a much higher rate than prior auctions.[33]

Ireland secured its first offshore wind capacity in May 2023 auction via a CfD, at an average strike price of €86 per MWh for 20 years (2023 prices, with returns indexed to EU consumer price index inflation). The Irish government described these results as "hugely competitive" for an emerging offshore wind market.[34]

Japan hosted auctions awarding 1.4 GW of capacity at the end of 2023, with projects awarded a 30-year seabed lease and a 20-year, non-inflation-linked subsidy contract. Two of the three projects awarded in this auction will effectively not rely on subsidies given that developers expect market prices to be much higher than the $21/MWh bid price.[35]

South Korea hosted auctions awarding 1.5 GW of capacity at the end of 2023, with projects awarded 20-year fixed-price subsidy contracts. The 2023 auctions removed previous local content requirements and Chinese turbines will be installed in Korea for the first time, with two of the four projects opting for these.[36]

30 BNEF (2024), *Global Installed Capacity*.

31 Clean Technica (2023), *Germany Successfully Auctions Off 7 GW Of Offshore Wind Projects, As Experts Warn About Uncapped Negative Bidding*.

32 Wind Europe (2022), *New Dutch offshore auctions focus heavily on non-price criteria*.

33 "Negative bidding" annual payments of up to €420 million per annum will be accepted in the 2024 auctions, up from €50 million maximum fee over the lifetime of the project from previous auctions. See Wind Power Monthly (2024), *Netherlands boosts 'negative bidding' in new offshore wind tender*.

34 Renewables Now (2023), *Ireland awards 3 GW of offshore wind at "hugely competitive" price*.

35 A third winning bid at $157/MWh is still likely to generate a significant portion of revenue from subsidies. See BNEF (2023), *Japan Offshore Wind Tender Leapfrogs to Subsidy-Free Era*.

36 BNEF (2024), *Korea Offshore Wind Auction Imperils Local Supply Chain*.

Box A Alternative subsidy and auction regimes in offshore wind markets

Offshore wind subsidy systems and auctions have played a crucial role in promoting the development of projects and historical cost reductions in the technology. The strength of auction-based mechanisms lie in their potential to facilitate cost competitiveness and real price discovery.[37] They also allow more transparency and revenue certainty for project developers, mitigating risk and potentially allowing for easier project financing.

Approaches have evolved over the years and different countries have adopted different regimes. Contract mechanisms have been iterated on in recent years and countries have adopted varying types:

1) Fixed Price Mechanisms – designated price per unit output

Early renewable deployments tended to be supported by Feed-in-Tariffs (FiTs) which gave renewables developers a certain fixed price for electricity delivered, with the price determined by government. This approach involved an explicit subsidy since the prices set were significantly above the price of fossil-based electricity supply.

2) Explicit subsidies relative to floating electricity price

Such as delivered via the UK Renewables Obligation (RO) scheme in place in the UK between 2002 to 2017. The RO was a green certificate scheme which obligated energy suppliers (i.e. the companies selling electricity to end consumers) to source a certain percentage of their electricity from renewable sources, and resulted in additional revenue for certificates generated to developers on top of the revenue they received by selling electricity in the wholesale market. In the UK, the RO system was replaced by a two-way CfD mechanism between 2014–2017.

3) Contracts for Difference Auctions (CfD) – competitive process to agree price per unit output

CfDs were first introduced in the UK in 2014, and are usually competitively allocated via an auction.[38] In this process, developers submit bids that specify the price they require for the electricity generated by their projects. The government then awards contracts to projects with the lowest bid prices. CfDs should be and usually are "two-sided". This means that if the market price is below the strike price, the government pays the generator the difference between the strike price and the market reference price, but if the wholesale price is above the strike price, the generator pays the difference to a counterparty who returns money to consumers.

CfDs give developers price certainty, but provided they are "two-sided", they do not necessarily entail a subsidy. The revenue certainty reduces risks (and the cost of capital) for the developer and allows significant gearing of debt finance into the project, allowing developers to increase their project pipeline.[39] Other countries have since adopted two-sided CfDs for offshore wind deployment, including France and Ireland, and CfDs will be the default direct support mechanism in the EU as per the latest EU Electricity Market Design Reform.[40,41]

Another option under consideration is using a "Hurdle Rate CfD" where governments would agree that developers can build projects at a fixed price within a fixed delivery window.[42] Whilst there is a risk the set CfD level could become disconnected with project costs over time, this would allow developers to stack projects back-to-back to enable early, and scale engagement and contracting with the supply chain to help trigger investment in supply chain capacity to align with project development timelines. This would also provide certainty for developers to directly invest in and retain project development and deployment skills and capabilities as they roll in-house teams from one project to another rather than await uncertain outcomes of future auctions in respect of project timelines and CfD terms.[43]

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37 IRENA and CEM (2015), *Renewable Energy Auctions – A Guide to Design*.

38 IEA (2019), *Contract for Difference (CfD)*.

39 i.e. Some developers cannot borrow significantly more on their balance sheet, as it would impact their credit rating and therefore cost of capital, CfDs create a mechanism to bring in capital without raising corporate debt.

40 Power System Blueprint (2023), *Balancing act. Two-sided contracts for difference for a speedy, cost-efficient and equitable energy transition*.

41 European Council (2023), *Reform of electricity market design: Council and Parliament reach deal*.

42 For example, the UK Government could agree that any developer can build an offshore wind project for delivery by 2035 at a fixed price (e.g., the clearing price of the most recent competitive auction).

43 Offshore Wind Champion (2023), *Seizing our Opportunities*.

4) Auctions of rights-to-deliver (leading to "negative bidding")

In some countries, offshore wind markets have become so competitive that neither explicit subsidies nor guaranteed prices are required to entice interest. Indeed, if offshore wind is expected to be cheaper than fossil fuel based electricity, developers may be willing to pay governments for the right to develop and deliver. Some governments (recently Germany and the Netherlands)[44,45] have tried to extract this value through so called "negative bidding" auctions, where developers submit bids outlining what they are willing to pay to the government for a "right-to-deliver" offshore wind in a specified seabed. After securing this, the developer then has to secure offtakers, who will buy the power, either through a Power Purchase Agreement (PPA),[46] or selling their power on the merchant market.[47]

"Negative bidding" auctions can be cost effective for governments, but if they allow developers the option of not proceeding with the project, they create a risk that offshore wind growth targets will not be met. Thus, for instance, in 2023 German auctions "uncapped negative bidding"[48] was utilised to auction the right to develop 7 GW of offshore wind capacity on specific areas within the North and Baltic Sea beds. Winning bidders gained the development rights in return for total payments of $14 billion over the entire project lifetimes. But the bidders only have to pay 10% of the bid upfront, and the remaining 90% over the 20-year exploitation period, starting in 2028.[49] This auction methodology inherently introduces optionality into the contract, as developers could choose not to deliver on building their turbines after paying the entrance fee if electricity prices are not forecast to be high enough to meet their required payback.[50]

Whilst auctions are a critical route to market, offshore wind developers may choose instead to depend on corporate PPAs, or selling into the merchant market – or a combination of all of these. Auction structures should in general be designed to enable flexible combinations of these revenue streams.

Chapter 5 discusses the optimal approach to contract structure and auction design, including mechanisms to limit the risk of non-delivery.

44 Clean Technica (2023), *Germany Successfully Auctions Off 7 GW Of Offshore Wind Projects, As Experts Warn About Uncapped Negative Bidding*.

45 Wind Europe (2022), *New Dutch offshore auctions focus heavily on non-price criteria*.

46 A long-term supply contract of renewable power at a fixed price between a corporate consumer and a developer, giving the consumer certainty on the cost of power and origin.

47 Selling power to the merchant market on a short-term basis with no guarantee of a fixed price. This carries higher revenue risk as there is no fixed price contract, so a merchant price is betting on a higher selling price of electricity in the future.

48 There was no maximum cap beyond which developers were allowed to bid to secure right-to-deliver, "capped" negative auctions set this limit at a certain value, and developers willing to match this would compete on non-price factors. Notably, 90% of these funds are allocated to financing grid connection costs, with 5% devoted to protecting maritime biodiversity and 5% supporting environmentally-friendly fisheries. See Clean Technica (2023), *Germany Successfully Auctions Off 7 GW Of Offshore Wind Projects, As Experts Warn About Uncapped Negative Bidding*.

49 Rabobank (2023), *Offshore Wind Tender Design in Need of Overhaul to Meet Climate Ambitions*.

50 Patrick Pouyanne, the Chairman and CEO of Total Energies, claimed in 2023 that he sees the German tender as an "option" similar to an oil or gas license. Total Energies (2023), *Half Year 2023 TotalEnergies SE Earnings Call*.

1.3 Growth in China accelerating: problems in other markets not apparent

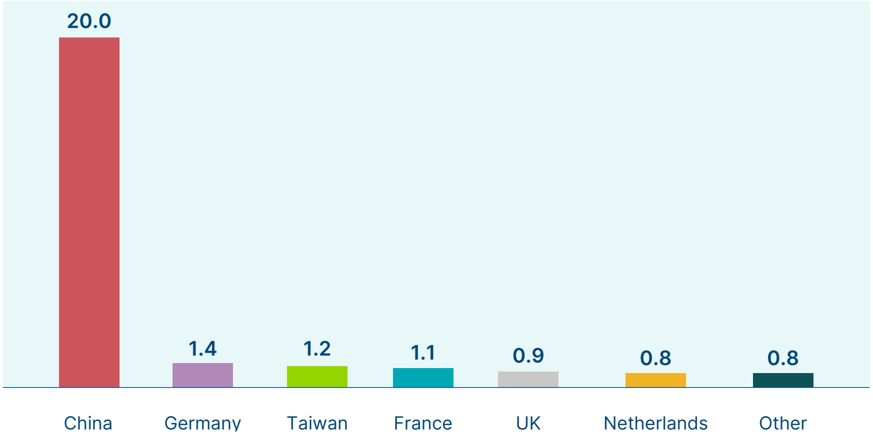
China's offshore wind capacity boomed from 1 GW in 2015 to 38 GW in 2023. The relative size of China's offshore wind sector compared to global capacity also increased significantly, representing less than 10% of global capacity (12 GW) in 2015 to over 50% of global capacity in 2023 (73 GW). In 2021, China connected 17 GW of new offshore wind capacity to their grid – greater than total global installations of offshore wind outside of China in the previous five years combined (2016–2020).[51] This dominance is forecast to continue, with China estimated to have a 2030 capacity of 124 GW, 48% of the global forecast of around 260 GW.[52] China's dominance in offshore wind follows a similar pattern to the growth in their installed solar capacity, which grew from 52 GW in 2015 (21% of 249 GW global capacity) to 700 GW in 2023 (42% of 1,670 GW global capacity).[53]

China has overcome supply chain, contractual and permitting issues that other countries are struggling with, enabling them to build at a rapid pace and scale (the reasons for this are explored in Chapter 4.3).[54] This has enabled China to have a record 20 GW of projects reach final investment decision (FID) in the 12 months to July 2023 [Exhibit 1.5]. This is despite national subsidies for offshore wind being phased out from 1st January 2022,[55] meaning that offshore wind now competes directly with coal for selling power to the grid in coastal regions.

Chinese projects reach final investment decision with ease

Exhibit 1.5

Offshore wind capacity secured financing, 12 months to July 2023
GW



The Chinese market has key advantages:

- Low cost of capital.
- High integration of supply chains from domestic production capacity for key materials.
- Strong downstream manufacturing and installation supply chains.
- Consistent schedule of auctions.

Chinese turbine costs **declined more than 40%** from 2020 to 2023.

Source: BNEF (2023), *Localizing Offshore Wind Supply Chains Threatens Growth*.

Note: "Other" includes Japan, South Korea, US and Vietnam. Charts refer to projects reaching FID.

51 GWEC (2024), *Global Wind Report 2024*

52 BNEF (2023), *Offshore Wind Market Outlook 2H 2023*.

53 BNEF (2024), *Global Installed Capacity*.

54 A new offshore wind project in Shandong province was approved, built, and commissioned in just two years, a record for offshore wind globally. See GWEC (2024), *Global Wind Report 2024*.

55 Nikkei Asia (2023), *China's offshore wind sector gears up for life after subsidies*.

1.4 Rapid growth likely but needs to be faster still

Latest projections from BNEF, built on detailed country by country analysis of contracted quantities and stated government and developer plans, suggest that total installed global offshore wind capacity could grow from 74 GW in 2023 to reach approximately 260 GW by 2030. Out to 2035, BNEF currently project another approximately 230 GW globally; with 275 GW of new additions between 2023–2035 outside of China [Exhibit 1.6].

Of the total 2023–2035 275 GW growth outside China, about 10% is already financed and under construction, 12% is contracted but subject to final investment decision, and 78% (about 215 GW) is yet to be contracted [Exhibit 1.7]. The policy actions discussed in Chapter 5 must seek to ensure that as much of the 12% as possible is now delivered despite the current risks, and that well designed contracting and other policies ensure that the 215 GW still to be contracted progresses smoothly and rapidly from auction to commissioning.

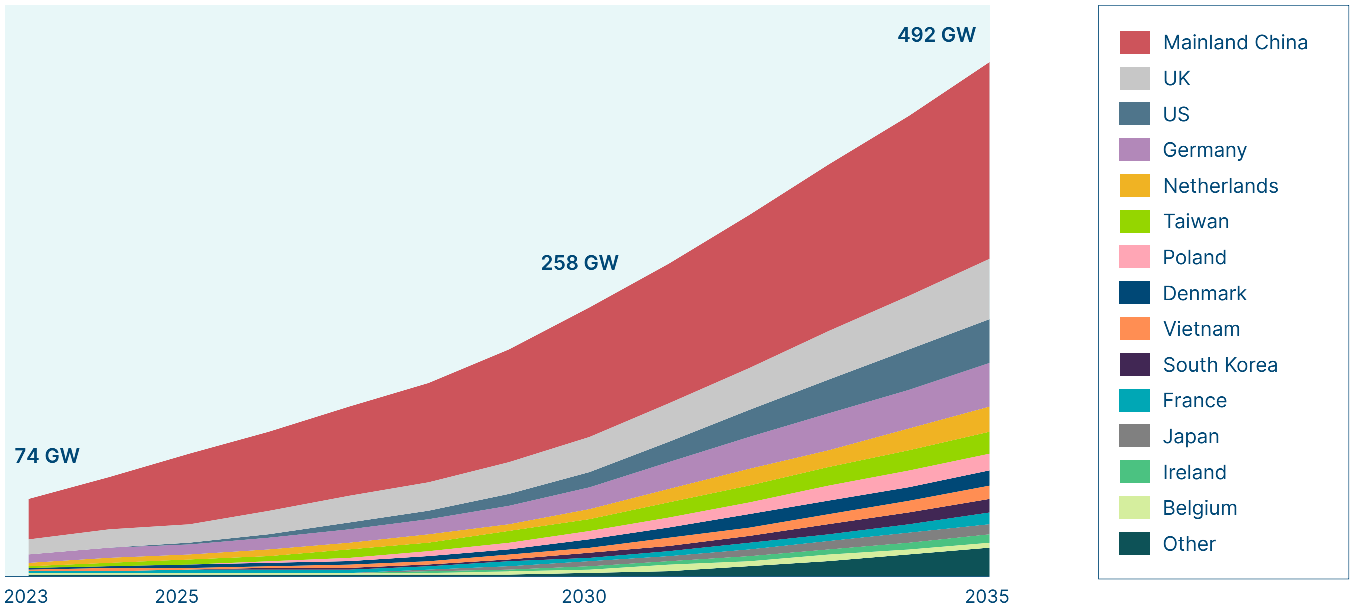
But even this pace of offshore deployment would for some countries fall short of government 2030 targets, and in aggregate would fall short of scenarios which describe the pace of different technology deployments required to put the world on a path towards net-zero emissions by 2050. Thus, BNEF's projected global installed capacity of 260 GW in 2030 falls 150 GW short of the figure they assume is needed in their net-zero scenario [Exhibit 1.8].

Policy reforms should aim to close as much of this gap as possible.

Strong growth projected in offshore wind installations

Exhibit 1.6

Outlook for global cumulative offshore wind installations, by market
GW



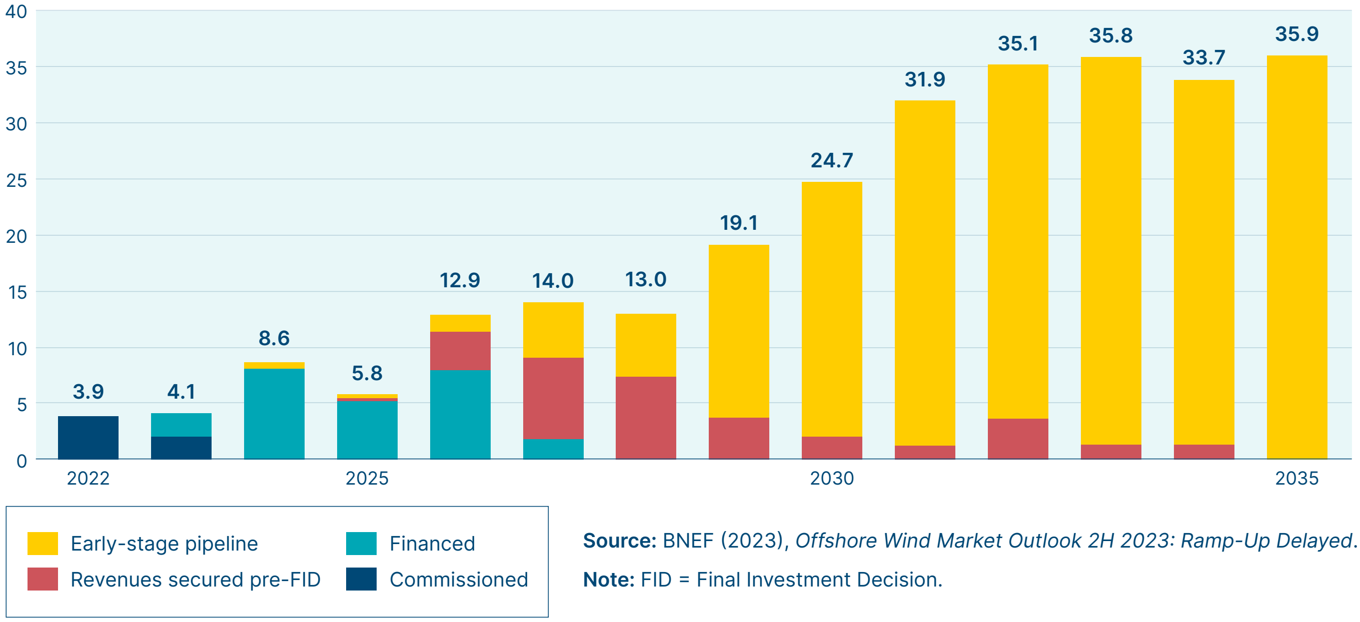
Source: BNEF (2023), *Offshore Wind Market Outlook 2H 2023: Ramp-Up Delayed*.

Note: "Other" includes India, Norway, Brazil, Sweden, Spain, Italy, Australia, Greece, Lithuania, Finland, Estonia, Latvia, Portugal and Colombia.

Strong growth projected in offshore wind installations

Exhibit 1.7

Annual offshore wind installations outside mainland China, by status
GW

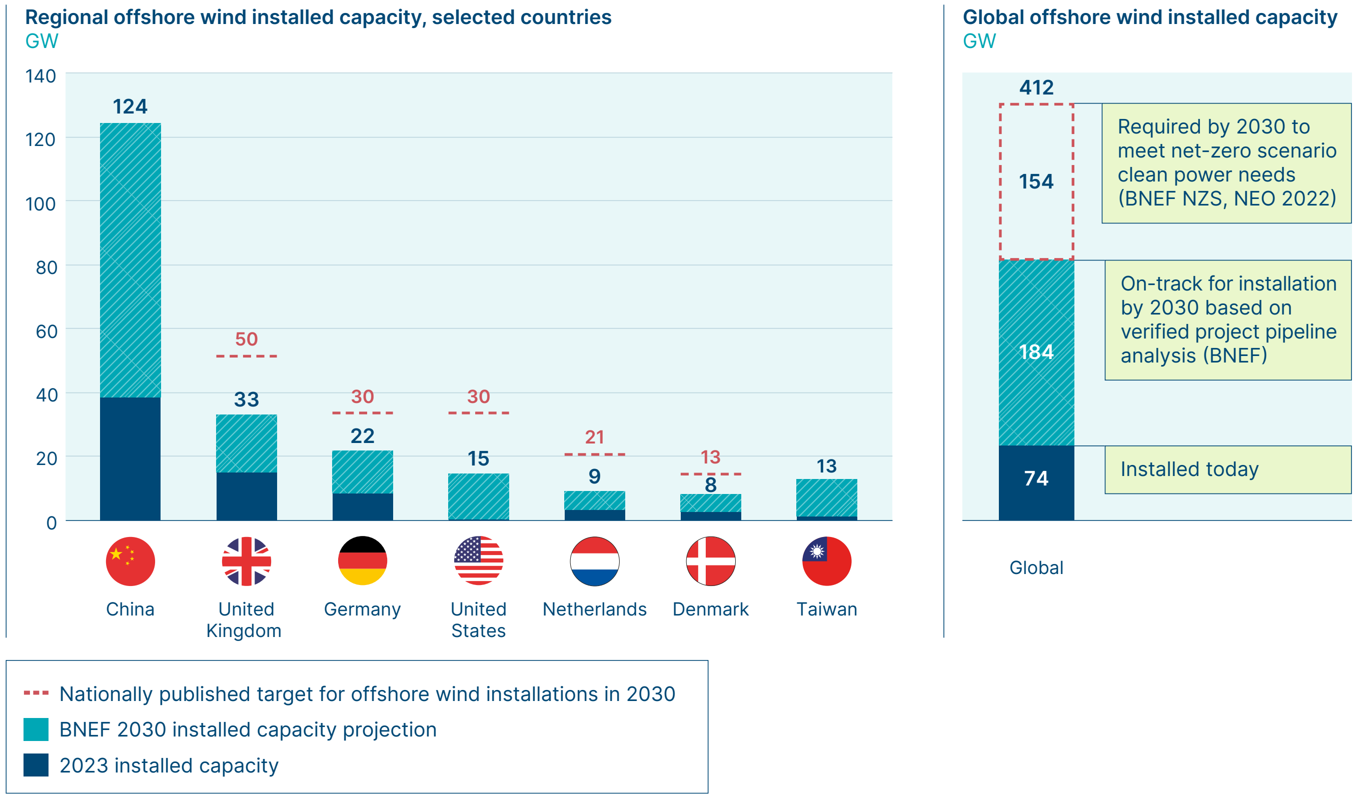


Source: BNEF (2023), *Offshore Wind Market Outlook 2H 2023: Ramp-Up Delayed*.

Note: FID = Final Investment Decision.

In most countries, forecast deployment levels are well behind targets

Exhibit 1.8



Source: BNEF (2023), *Offshore Wind Market Outlook 2H 2023*; BNEF (2023), *New Energy Outlook Data Viewer 2022*; HM Government (2023), *Offshore Wind Net Zero Investment Roadmap*; Reuters (2023), *Germany publishes plans to hit 30 GW offshore wind target in 2030*; Recharge (2023), *'Biggest power source by 2030' | Dutch cabinet approves doubling offshore wind target to 21GW*; Wind Europe (2023), *Pause to Danish Offshore wind scheme is absurd*; Taiwan commonwealth magazine (2030), *Taiwan offshore wind development faces headwinds*.

Note: BNEF 2023 projection based on verified project pipeline analysis, estimating for potential delays and cancellations; China: no nationally published target for offshore wind; Taiwan: is forecast to meet their 2030 target of 13 GW; Recent US cancellations are likely to impact projected 2030 pipeline.

Cost increases have occurred but these will likely prove temporary

2

As Section 1.1 showed, the cost of developing offshore wind has increased substantially in some markets between 2021 and 2023, with UK costs for some developers up 40%, and BNEF estimates of US LCOE up around 60%.[56]

Exhibit 2.1 shows BNEF's breakdown of offshore wind cost items in the US increasing from $77 per MWh in 2021 to an estimated $121 per MWh in 2023. The two main drivers of the increase are:

- An increase of $17 per MWh resulting from higher capex and opex costs. These increases reflected both economy-wide inflation and above-inflation price rises for specific inputs, such as steel and wind turbines.
- An increase of $27 per MWh arising from a higher cost of capital, due to higher nominal and real interest rates.

These different drivers of rising LCOE have different implications for the economic viability of current and future contracts:

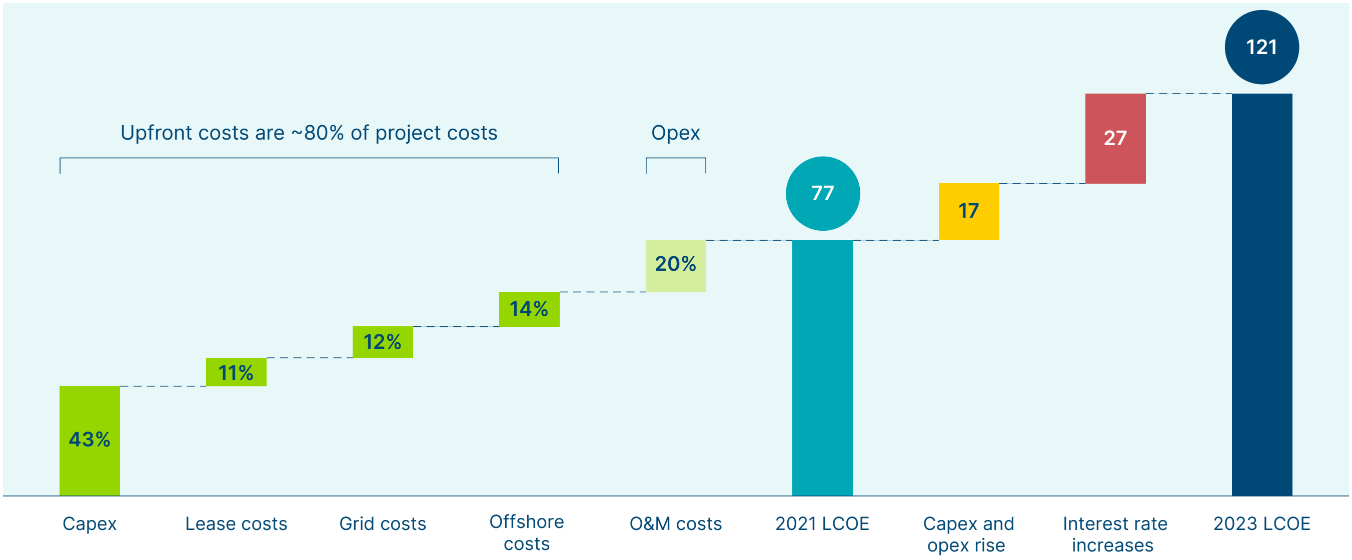
- Rises in general inflation and nominal but not real interest rates should, in principle, have no impact on the economic viability of already contracted projects – provided the contracts include price indexation in line with general inflation. But if, as is the case in the US, past contracts have not been price indexed, general inflation and nominal interest rate rises can make already contracted projects uneconomic.
- Rises in either real prices for specific inputs or real interest rates could make existing contracts uneconomic even if they were price index linked, and will imply higher real costs and auction prices in future if these the changes prove permanent.[57]

The crucial question is therefore whether real price increases in wind turbines and increases in real interest rates will prove temporary or permanent.

US offshore wind costs have increased substantially since 2021

Exhibit 2.1

US offshore wind LCOE progression from 2021–2023
$/MWh, nominal prices



Source: US Department of Energy (2022), *Offshore Wind Market Report: 2022 Edition*; BNEF (2023), *The $49 Million Fine That May End More US Wind Deals*.

Notes: 2021 LCOE assumes a 30% inflation tax credit, without this cost would be ~$100/MWh; the US have recently increased their inflation tax credit to 40%, which is excluded here for ease of reference, this would reduce 2023 LCOE by $7/MWh.

56 BNEF (2023), *Levelised Cost of Electricity 2H 2023*.

57 Contracts are generally indexed to a general price index (i.e. the Consumer Price Index in the UK); if real values of inputs rise by more than general inflation, project costs will increase.

2.1 Capex cost increases: temporary or real?

From 2016 to 2019, average wind turbine prices per MW (outside of China) fell by around 20%, from about $920,000 per MW to $720,000. This was despite a small increase in material input costs reflecting steady improvements in manufacturing efficiency, in part related to larger average turbine sizes. But from 2020 to 2022, this decline was completely reversed, with rising material costs – in particular from steel – accounting for almost all of the increase [Exhibit 2.2].

Global steel prices, and in particular, European steel prices, increased by around 200% between the end of 2020 and mid-2022 [Exhibit 2.3]. In addition, as economies recovered from COVID-19, supply chain bottlenecks resulted in increased shipping and installations costs.[58]

Between late 2022 and early 2024, however, global steel prices fell back much closer to 2019 levels, and are forecasted to hit 2019 levels some time in 2024.[59] Other key materials, including copper, aluminium and neodymium, may remain above their long-run averages even into 2024.[60] But since steel accounts for 90% of the material cost inputs, turbine prices should decline.

The pace of this decline may be slowed by increasing turbine manufacturer margins following three years of low, and in some cases, negative profitability.

Turbine Original Equipment Manufacturers (OEMs) have faced decreasing profitability since 2019, with the rise in turbine prices not fully reflecting rising costs.[61] All large Western turbine manufacturers (e.g., Vestas, Siemens Gamesa, GE Renewable Energy) declared negative or low profit margins in 2022. In aggregate, OEMs recorded €3.4 billion in losses between August 2020 and August 2022, including nearly €1.5 billion in the first quarter of 2022 alone.[62] In response, Siemens Gamesa and Vestas share prices fell 50% from their 2021 peak to 2023 troughs. This has led to OEMs stating they will “prioritise profit over growth” in the near future.[63] And while the recent EU Wind Action Plan has introduced measures to reduce OEM financing costs and shorten permitting times, some OEMs have still been wary of investing in new manufacturing capacity.[64,65]

Overall however, after a period of adjustment it seems likely that a significant share of the increase in turbine and installation costs which occurred between 2020–23 will prove temporary, with some manufacturers already having returned to profitability in 2023.[66]

58 BNEF (2023), *Wind Turbine Price Index 2H 2023: Elevated Levels Linger*.

59 BNEF (2023), *Industrial metals outlook 2H 2023: Heading into the Storm*.

60 Ibid.

61 Wood Mackenzie (2023), *Cross currents: Charting a sustainable course for offshore wind*.

62 Wood Mackenzie (2022), *Wind industry faces a perfect storm of profit pressures*.

63 Wood Mackensie (2023), *Western wind turbine manufacturers are prioritising profit over volume, opening the door for Chinese market share growth*.

64 Though the “Innovation Fund”, de-risking guarantees provided by the European Investment Bank and flexibility provided by the amended Temporary State aid Crisis and Transition Framework. See European Commission (2023), *Commission sets out immediate actions to support the European wind power industry*.

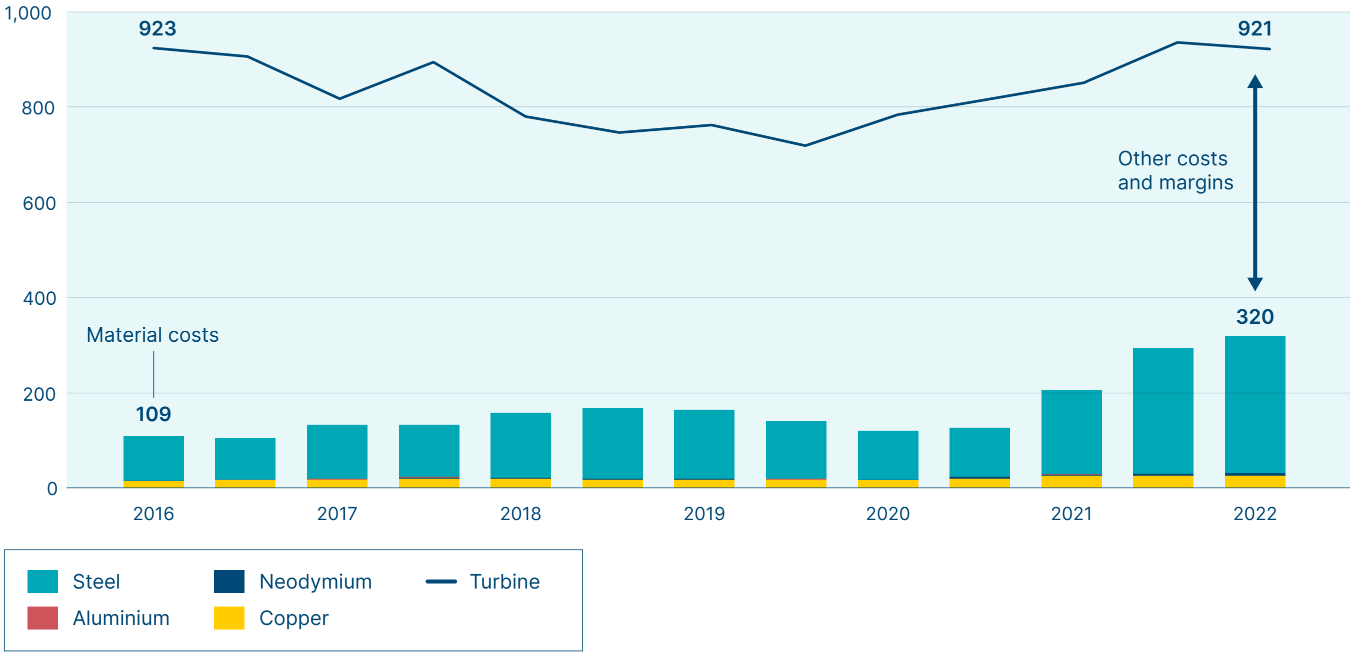
65 Reuters (2023), *EU turbine factory growth hangs on permitting action*.

66 Vestas have since returned to profitability with a record intake of 18.4GW in 2023, driven by strong growth in offshore and onshore turbines, particularly in the US. Vestas (2024), *Vestas Annual Report 2023 – A return to profitability*.

Rising steel costs contributed to driving up turbine price

Exhibit 2.2

Metal and total wind turbine price
Thousand $/MW

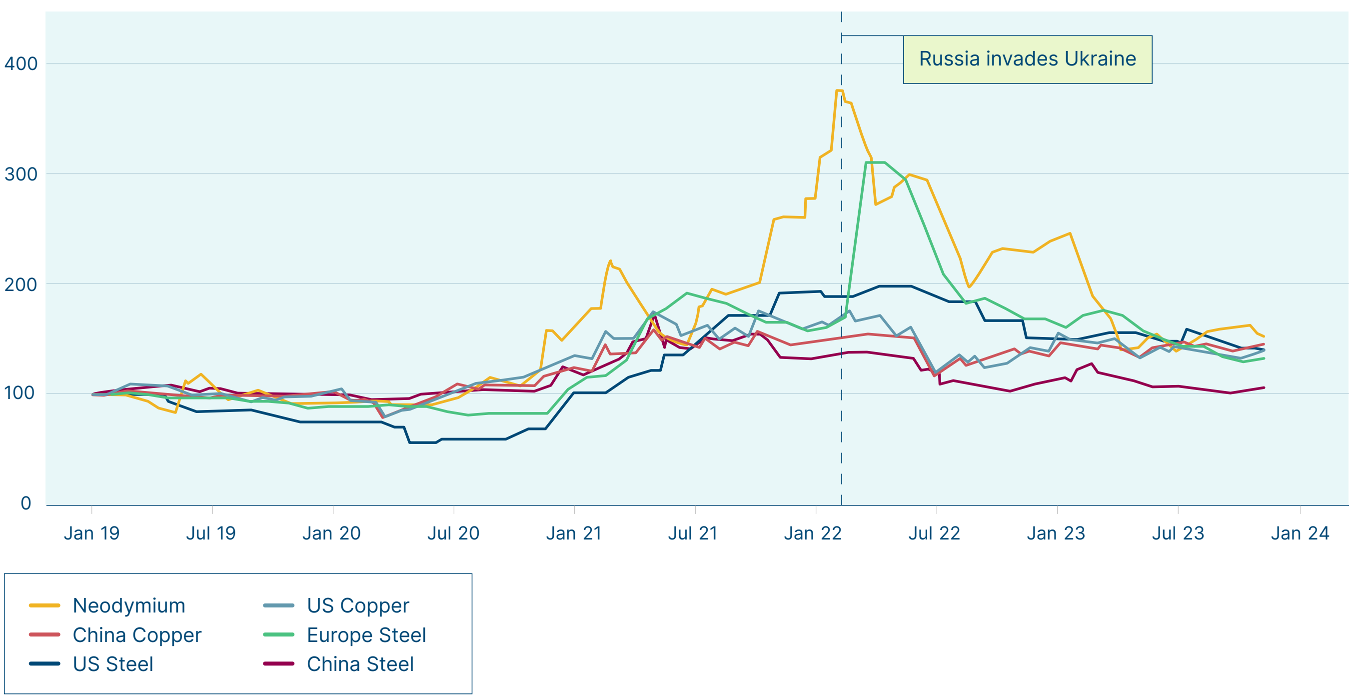


Source: BNEF (2023), *Transition metals outlook*.

Rising steel costs contributed to driving up turbine price

Exhibit 2.3

Raw material prices
Indexed to January 2019, %



Source: BNEF (2023), *Wind Turbine Price Index 2H 2023: Elevated Levels Linger*.

2.2 Interest rate increases: temporary or permanent?

After averaging approximately 2% inflation since 2010, the world experienced significant widespread inflation across 2021 and 2022. UK monthly inflation increased from 0.6% in December 2021 to 11.1% in October 2022;[67] whilst EU and US annual inflation in October 22 reached 11.5% and 7.7%, respectively.[68,69]

Central bank interest rates were increased across the world in an attempt to get inflation back to target. In the UK, the Bank Rate was gradually stepped up from 0.1% in December 2021 to 5.25% in August 2023 [Exhibit 2.4], with US and EU central bank interest rates increasing similarly. Interest rates had just started to increase during the UK's CfD round 4 bidding window, so the impact of interest rate increases had barely started to take effect. Projects that bid in this April/June 2022 round, and which had to place supply chain orders in the following year, faced a very significant increase in their cost of capital.

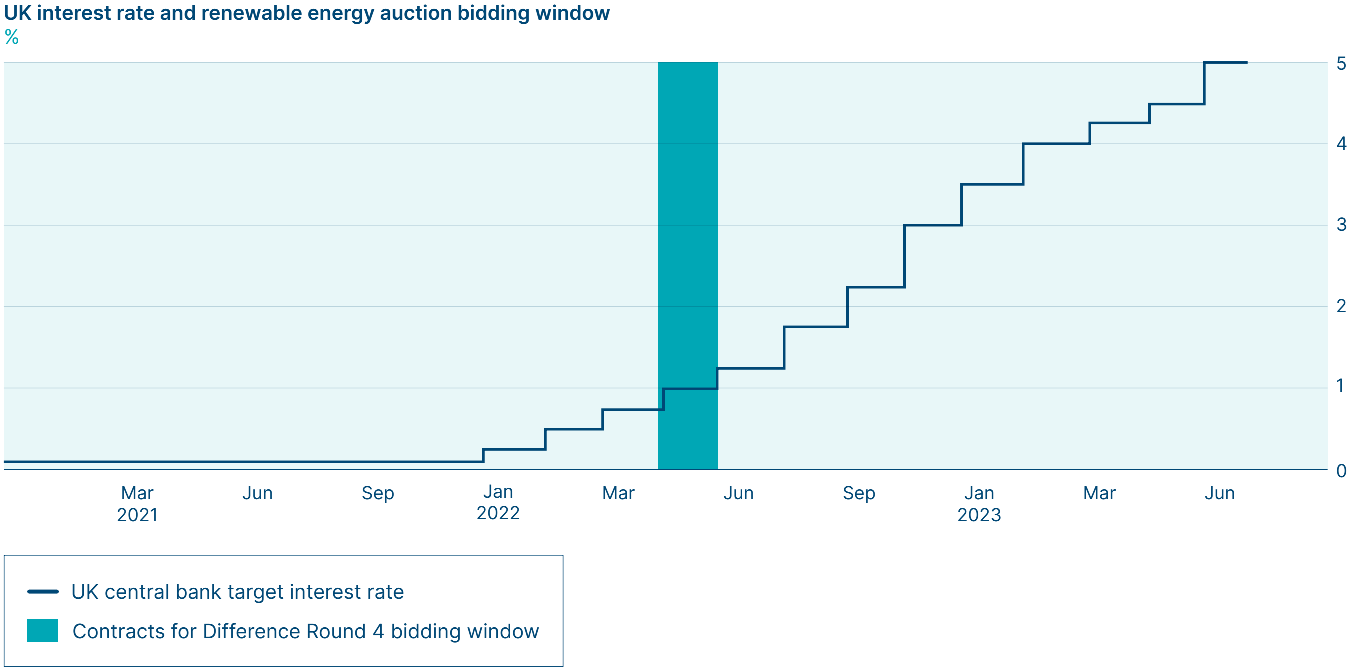
Yield curves[70] suggest that nominal interest rates may stay high for a considerable time and not return to pre-crisis near-zero levels.[71] In principle, however, nominal rises in interest rates should not be a problem as long as output prices in contracts are inflation linked. The increased price received by developers should cover the increase in borrowing costs.

Higher real interest rates however, could have a longer-term impact on both the profitability of recently agreed contracts and future levelised costs.[72]

For much of the 2010s, real interest rates in the major developing economies were close to zero and in some cases negative, but real yields on long-term government index-linked bonds have increased to around 2%,

UK interest rate and renewable energy auction bidding window

Exhibit 2.4



Source: BNEF (2023), *Rising costs dampening offshore wind outlook*.

67 ONS (2023), *Consumer price inflation, UK: October 2023*.

68 Eurostat (2022), *Euroindicators 130/2022 – 17 November 2022*.

69 US Bureau of Labour Statistics (2022), *Consumer prices up 7.7 percent over year ended October 2022*.

70 Graphical representations of the yields available for bonds of equal credit quality and different maturity dates which measure bond investors' feelings about risk.

71 Bank of England (2023), *Monetary Policy Report – November 2023*.

72 A real interest rate is the difference between the nominal interest rate and the inflation rate.

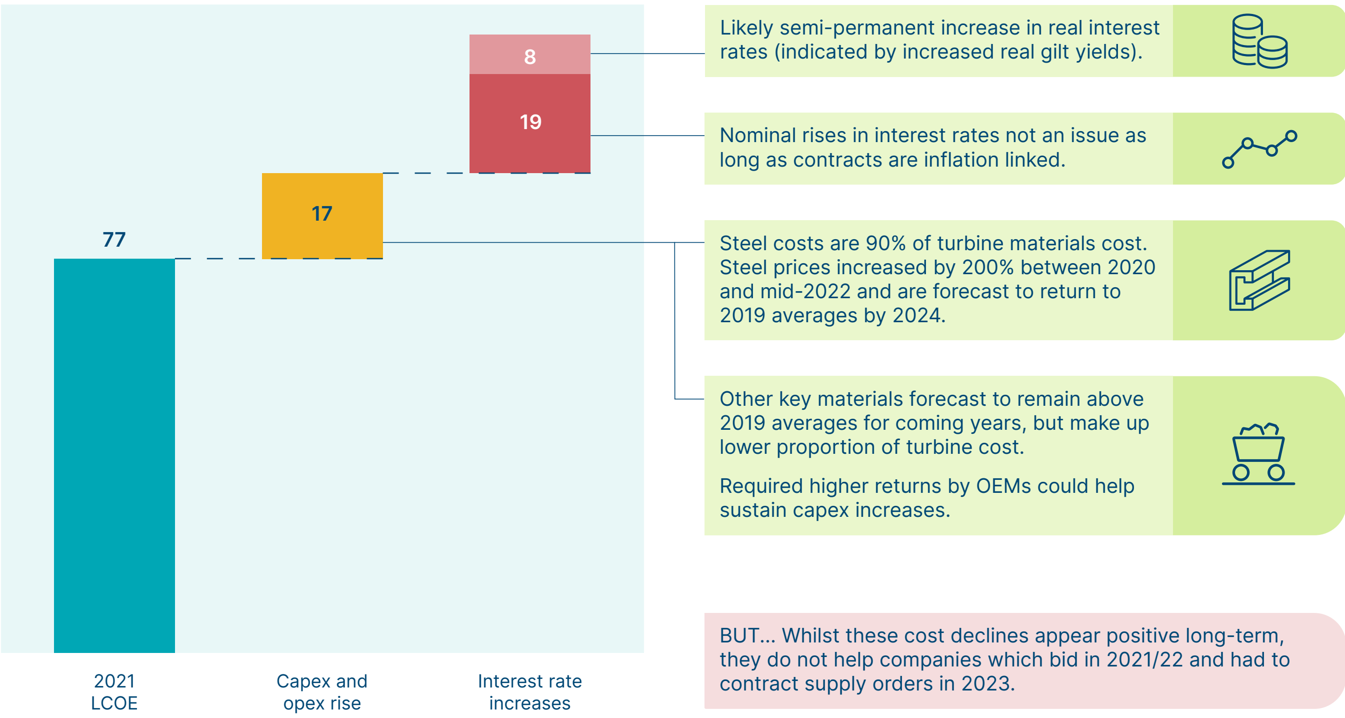
implying a significantly higher real cost of capital than before 2020.[73] There is a debate amongst economists about how real interest rates might evolve in future; it is worth noting that real yields remain very low compared to pre-2008 levels, particularly compared with the 1980s when they were around 4%.[74] A reasonable assumption, however, is that the ~2% increase will be sustained over medium-term; this could add ~15% ($8 per MWh)[75] to levelised costs for the foreseeable future.[76]

In summary, the majority of the cost increases shown in Exhibit 2.1 will likely prove temporary, but with the real interest effect likely to prove semi-permanent [Exhibit 2.5]. This is promising for future offshore wind projects, but does not help companies which bid into auctions in 2021/22 and had to contract supply orders in 2023, particularly those that bid into auctions that are not linked to inflation. A permanent rise in real interest rates could see less money flowing into the sector at a time of growing need. As argued in the ETC's 2023 *Financing the Transition* report, publicly-owned country and regional-level infrastructure banks should consider whether there is a case for low cost loans to support the sector.[77]

The largest cost effects will prove temporary, but somewhat higher prices could persist over the medium term

Exhibit 2.5

US offshore wind LCOE progression from 2021–2023
$/MWh, 2021 nominal prices



Source: Systemiq analysis for the ETC; BNEF (2023), *The $49 Million Fine That May End More US Wind Deals*; BNEF (2023), *Transition metals outlook*; BNEF (2023), *Industrial Metals Outlook 2H 2023: Heading Into the Storm*.

Note: Real cost effects estimated by modelling a 2% real interest rate rise, from 5% to 7% based on a project cost of $1.8 bn for a 1 GW wind farm with 30% equity, 70% debt. Nominal increases are the net of BNEF interest rate increases minus the real effect.

73 UK Debt Management Office (2023), *Real gilt yields 2022–23*.

74 Investors Chronicle (2019), *A brief history of interest rates*.

75 Real cost effects estimated by modelling a 2% real interest rate rise, from 5% to 7% based on a project cost of $1.8 bn for a 1GW wind farm with 30% equity, 70% debt.

76 Whilst these costs also hit fossil fuel investments, renewables projects are hit harder as capex is a higher % of overall project cost.

77 ETC (2023), *Financing the Transition: How to Make the Money Flow for a Net-Zero Economy*.

Costs are already competitive in certain markets with promising future prospects

3

Despite the setbacks in some markets in the last three years, offshore wind remains a vital and potentially cost-effective technology with huge potential in many regions.

Following significant cost declines over the last 15 years, it is now competitive with fossil fuels and other renewable resources in most regions. The remainder of this chapter will discuss the present position and future prospects of offshore wind's cost effectiveness, including:

- Significant cost declines have made offshore wind cost competitive.
- Further significant cost declines should be possible in future.
- Experience in China illustrates that such cost reductions can be achieved.

3.1 Significant cost declines have made offshore wind cost competitive

Despite challenges in the US, UK, and some other markets in 2021–23, the long-term global trend is that average LCOEs for offshore wind have declined dramatically since 2013 [Exhibit 3.1]. As a result, offshore wind is close to competitive with fossil fuel generation in Europe and China, though still falling short in the US. Exhibit 3.2 summarises the current situation:

- In the EU, offshore wind at €70–90 per MWh can compete with electricity from gas generation at €60 per MWh after allowing for the impact of the EU carbon price, which adds around €30 per MWh to gas-based electricity prices.[78]
- In China, current estimates of levelised costs of electricity from offshore wind of $63 per MWh are cost competitive with estimates of coal at $76 per MWh, and very close to the cost of coal even if carbon price values and expectations are excluded, at $61 per MWh.[79]
- In the US, however, cheap gas supplies, and high costs for offshore wind mean that strengthening policies will be essential to maintain deployment.

Compared with other renewable resources, in particular with solar and onshore wind, offshore wind costs are significantly higher and likely to remain so given the huge potential for solar cost reductions and the greater engineering complexity of offshore compared to onshore wind installation. But the high capacity factors achieved in offshore wind – 60%, and in some cases rising, compared with 20% for solar – mean that the impact on total system cost is more favourable than the comparison in Exhibit 3.2 suggests.[80]

Offshore wind also offers other benefits, including:

- Complementary generation patterns with solar, as power is generated more consistently during the day and night as well as more in winter in Europe and North America. This helps to bridge gaps when solar output dips.
- Compared to land-based wind and solar farms, the physical space into which offshore wind can expand is less constrained, and close to coasts, where most people live. Deep-water areas with strong consistent winds are abundant, especially when considering the potential for floating wind. This overcomes some land use challenges associated with other renewables.[81]

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78 Combined Cycle Gas Turbines (CCGT) typically have a 50% efficiency rate of turning fuel into power, this means a gas price of €30/MWh must be divided by 50% to provide a gas for power cost of €60/MWh. A €30/MWh carbon cost has been added in line with average EU Emissions Trading Scheme values across 2023. See Ember (2023), *Carbon Price Tracker*.

79 Current carbon price for China of $8.12/mt$CO_2$e results in a carbon price per MWh of around $7/MWh assuming a coal emissivity factor of 800g CO_2e/kWh. Carbon prices are expected to rise in the future as China seeks to decarbonise the power sector, which results in higher estimates of levelised cost. See S&P Global (2023), *China relaxes compliance carbon market rules for coal-fired power plants*; UN Economic Commission for Europe (2022), *Carbon Neutrality in the UNECE Region*.

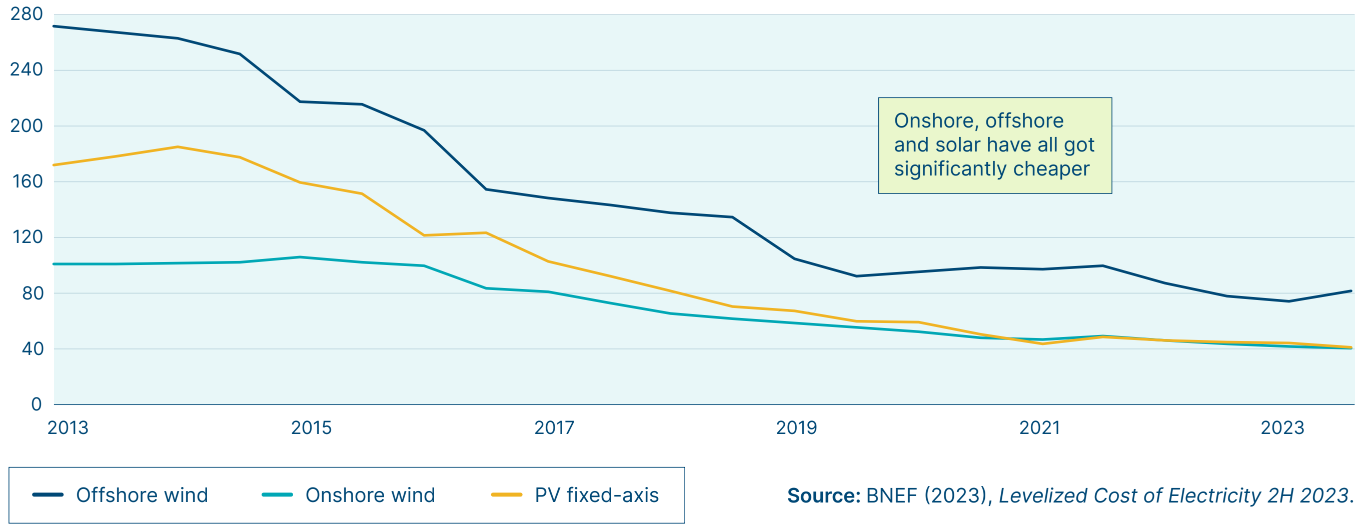
80 Highest capacity offshore turbine is GE Renewable Energy's 12 MW 63% capacity factor Haliade-X turbine. However it should be noted that wake effects and grid losses often reduce the realised capacity factor. See GE (2024), *Haliade-X offshore wind turbine*.

81 There is a downside in "wake effects", which can reduce the availability of downstream wind resources of other wind farms by as much as 20% within 50 km. These are most apparent if developers attempt to squeeze as many turbines as possible into allotted zones. See University of Bergen (2023), *Gone with the wind? Wind farm-induced wakes and regulatory gaps*.

Global renewables are on a downward price trend, despite recent offshore wind uptick

Exhibit 3.1

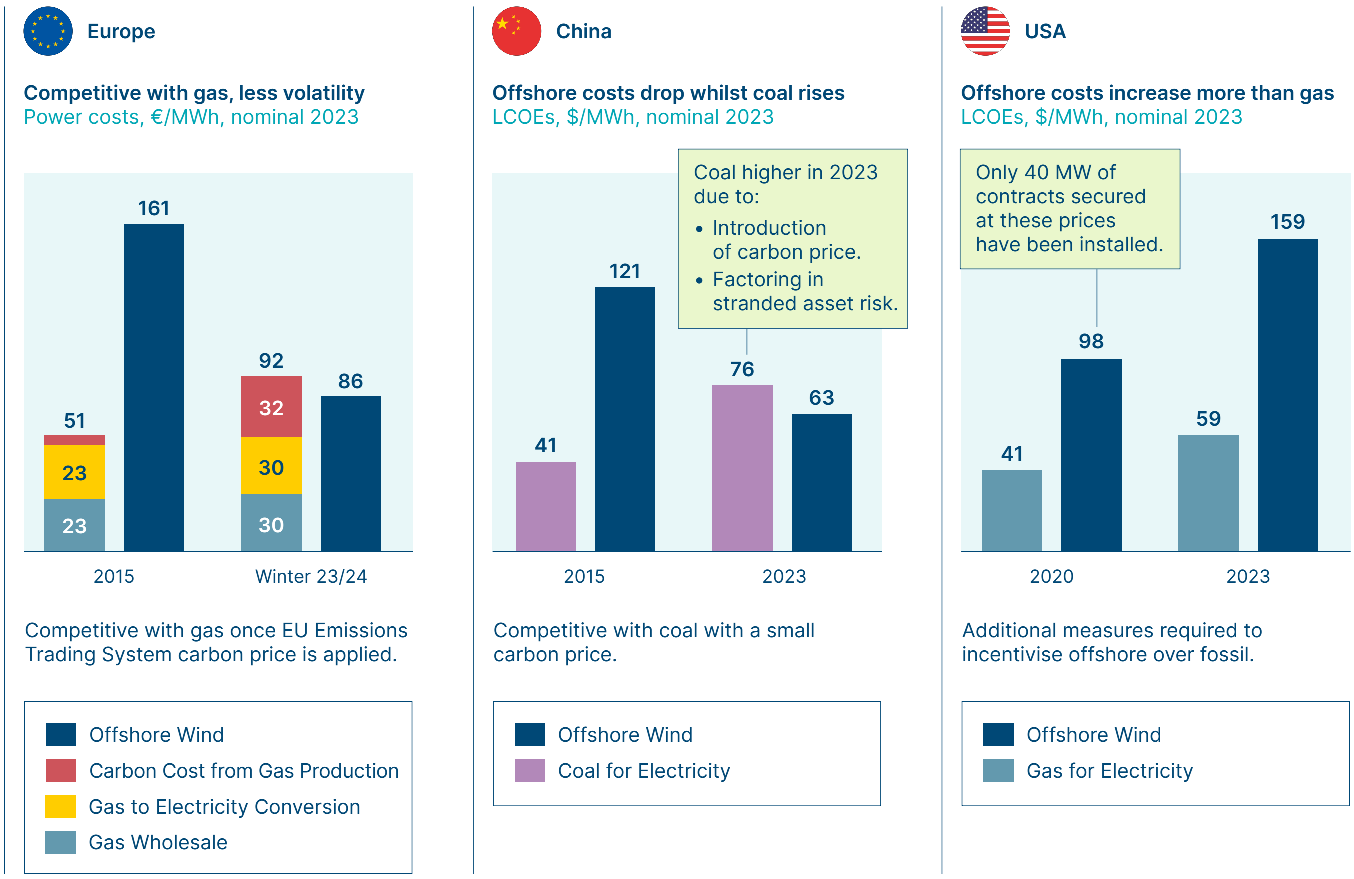
Global renewable LCOEs on downward trend
$/MWh, real 2022



Source: BNEF (2023), *Levelized Cost of Electricity 2H 2023.*

Offshore wind is competitive with fossil in certain markets

Exhibit 3.2



Source: Carbon Brief (2022), *Analysis: Record-low price for UK offshore wind is nine times cheaper than gas*; Wind Europe (2023), *Ireland makes history with its first offshore wind auction;* Sandbag (2024), *Carbon price viewer*; Trading Economics (2024), *EU Natural Gas*; BNEF (2023), *2H 2023 LCOE Update*.

Note: UK CfD results used for Europe 2015, with EU carbon price contributing €4/MWh; Ireland CfD results used for 2023; Established markets should be able to secure cheaper contracts than this emerging market; Gas to electricity conversion is based on an approximate 50% efficiency rate of a Combined-Cycle Gas Turbine.

3.2 Further significant cost declines should be achievable

The cost reductions shown on Exhibit 3.2 occurred from experience and learning curve effects, as offshore deployment reached significant scale. In addition, capacity increases in new turbines were a key driver of cost reduction [Exhibit 3.3].

Many expert analysts have therefore assumed that as the total industry scale continues to increase and large numbers of large turbines are manufactured, further significant reductions should be achievable. In 2020, the UK Climate Change Committee (CCC) suggested that an optimistic but feasible "widespread innovation" scenario could see the UK offshore wind LCOE falling to £25 per MWh in 2050 (2019 prices).[82]

To assess the potential for future cost reductions, it is useful to consider the very different pace of cost reduction which has been achieved in different technologies relevant to the energy transition [Exhibit 3.4]:

- At one end of the spectrum, we find solar PV and batteries for electric vehicles. These are technologies that are manufactured in millions of units and which have achieved 85–95% cost reductions over the last 12 years.[83]
- At the other end, estimated costs for Carbon capture, utilisation and storage (CCUS) have not declined significantly, while nuclear costs have actually increased during that same period. H_2 electrolysers have also increased in cost in recent months.[84]

The underlying causes of this divergence are increasingly clear:

- Rapid cost reductions occur in technologies which are susceptible to mass factory-based manufacture of huge volumes of standardised units and which can be transported cheaply in standardised containers.
- Slow, zero or even negative cost reductions are seen in technologies which require complex bespoke engineering and complex supply chains.

Along this spectrum, offshore wind is somewhere in the middle. In principle, large volumes of turbines can be produced to standardised designs (though units will be in the hundreds or thousands, not millions), with most of the key elements manufactured in automated factories, rather than on site. But some aspects of installation are bespoke to specific locations and transport requires specially designed cranes and ships capable of handling the largest turbine sizes.[85]

A key question is therefore how far can well-designed government policy and industry practice help achieve significant further cost reductions, even if these will never be as rapid as those seen in solar PV.

One crucial factor is relatively fragmented markets for wind turbines. We have gone from very few countries developing offshore wind in the early 2010s, to multiple countries now across three continents. However, the market is still fragmented, with manufacturing often concentrated at the individual country, not regional level, due to both local content requirements and the fact that the physical assembly of the large turbines needs to be close to the installation point. Long-term manufacturing investments require a stable pipeline in the country/region in order to be paid off, requiring both time and sustained effort from what has been a limited pool of manufacturers to date. Large and stable project pipelines at the country/regional level can help overcome market fragmentation issues, whilst local content requirements must be carefully balanced against the need to achieve economies of scale at a multiple-country/regional level.

Another crucial factor is turbine size. On the one hand, larger turbines automatically improve economics since more power can be provided from a single installation, and windspeeds tend to be more constant the higher the hub height and swept area. But continued progress to ever larger turbine sizes has also created technical and volume or business case risk; it has reduced the number of identical turbines being produced and brings with it significant transportation and installation complexity, requiring specialised vessels and equipment which are in short supply.[86]

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[82] CCC (2020), *The Sixth Carbon Budget Electricity Generation*.

[83] Nat Bullard (2024), *Decarbonisation: Stocks and flows, abundance and scarcity, net zero*.

[84] BNEF (2023), *2H 2023 LCOE Update*.

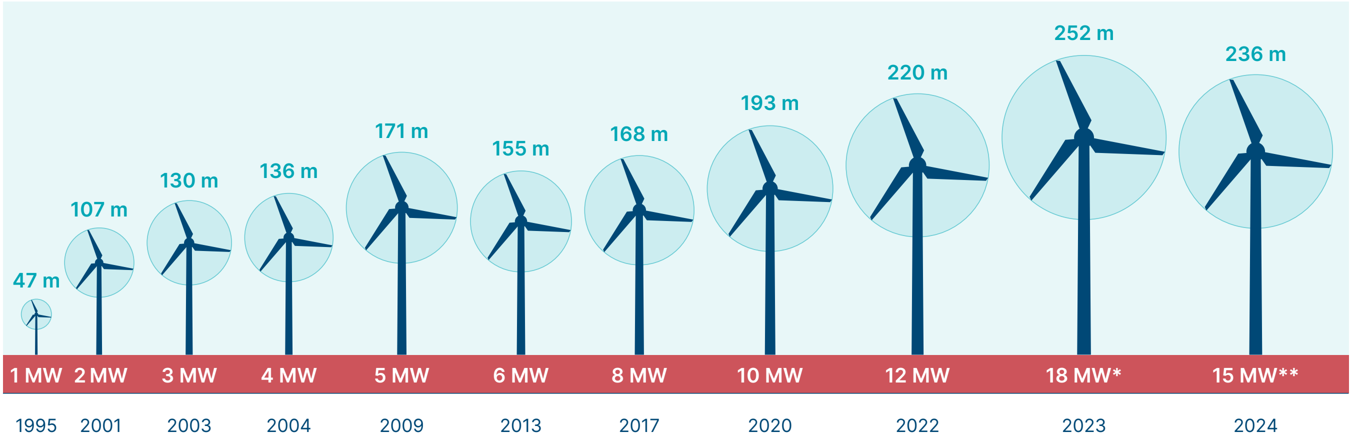
[85] Designing monopile or jacket foundations for specific sea-bed sites and having appropriate grid design are also significant cost and time drivers.

[86] It is worth noting that to some extent this issue exists in all manufacturing industries, i.e. producing the same model of car for ten years would increase the economies of scale and reduce production costs; but would not encourage significant progress towards a more efficient car.

Turbine sizes have continued to grow throughout the years

Exhibit 3.3

Development of wind turbine sizes
Size on year of entry into operation, MW



Source: DNV (2020), *Offshore wind power expands globally*; Expert interviews with wind turbine manufacturers.

Note: In contrast solar panels have stayed largely the same size, and are shipped in containers which have remained around 2.5m in height since the 1960s; * 18 MW turbines have been installed exclusively in China starting in 2023; ** Western turbine manufacturers will install 15 MW turbines at scale starting in 2024.

The technologies which are reducing in cost fastest are those most susceptible to mass production and easy deployment

Exhibit 3.4

FAST PROGRESS

Solar PV, EVs and batteries	• Mass produced in large-scale, replicable factories. • Easily transported. • Easily deployed / installed.
Heat pumps	• Mass produced in large factories. • Easily transported. • Complex installation.
Onshore wind	• Turbines supply chains relatively complex, scale of production orders of magnitude smaller than PV/batteries. • Higher degree of customisation for projects. • Transport and installation more complex.
Offshore wind	• Scale of production smaller than onshore due to nascent global market. • Harder to transport than onshore wind as must be installed at sea by specialised vessels into seabed foundations.
Electrolyser and green H_2	• Can be mass produced, but balance of system costs and specific project complexities important.
CCUS	• Customised engineering design and deployment.
Large scale nuclear	• Hugely complex large-scale systems.

SLOW PROGRESS

Box B Benefits and drawbacks of larger turbines

Benefits of larger turbines:

1. **Increased energy production:** Larger turbines have longer blades, which means they can sweep a greater area and capture more wind, especially as wind speeds tend to be greater and more constant at higher hub heights. This translates to significantly more electricity generation compared to smaller turbines, especially in areas with strong, consistent winds. For instance, a turbine with a 20% greater diameter will generate 45% more energy.[87]
2. **More efficient use of space and foundations:** Since larger turbines produce more power individually, fewer total turbines are needed to achieve a specific energy output. This can optimise the use of space in offshore wind farms, which may be important for managing costs and environmental impact. Importantly, larger turbines require fewer foundations and cables for a given farm capacity, which can fundamentally improve the economics of a project and result in more efficient costs per MW.
3. **Potential to generate power at lower wind speeds:** Larger turbines can capture more energy at lower wind speeds. This could open up more areas for offshore wind development, including places that previously weren't considered viable due to less forceful winds.
4. **Fewer wind turbines to service:** Larger turbines require a similar amount of time to service as smaller turbines, so fewer turbines result in cheaper operational expenditure. As operation and maintenance make up ~20% of overall turbine LCOE, this can be a significant cost saving.[88]

Drawbacks of moving to larger turbines too quickly:

1. **Higher development costs per turbine platform and lower shelf life of products:** This leads to OEMs struggling to recover R&D and investment costs, with all Western OEMs having declared negative or low profit margins in the past year and now making the decision to prioritise profit over quantity.[89]
2. **The rate of product growth makes it harder to industrialise:** It is harder to effectively drive down costs through scaling production lines and factory sizes if OEMs are not able to focus on a given turbine size for a meaningful time period.
3. **Severe knock-on effects to wider supply chain and supporting infrastructure:** The size of offshore wind turbines fundamentally influences design within the wider supply chain and supporting infrastructure. The complex global supply chain finds it harder to plan for the future if the goal posts on turbine size are always moved. It can take 3–5 years for ports and new installation vessels to be built to specification, and investors have shown hesitancy to invest if they don't know how big these assets should be.
4. **Lack of learning from operation in the field makes it harder to inform engineering of a stable product:** This leads to potential quality issues as products do not benefit from years of continuous testing and incremental improvement.

[87] Additionally, a turbine in a 15 mph wind can generate twice the energy of a 12 mph turbine. Power available from wind is proportional to the cube of its speed – twice the wind speed gives eight times the power. Power roughly doubles when moving from the cube of 12 mph to 15 mph. See IRENA, *Wind Power.* Available at: https://www.irena.org/Energy-Transition/Technology/Wind-energy [Accessed March 2024].

[88] US Department of Energy (2022), *Offshore Wind Market Report: 2022 Edition.*

[89] Wood Mackenzie (2023), *Western wind turbine manufacturers are prioritising profit over volume, opening the door for Chinese market share growth.*

3.3 Experience in China shows that cost reductions are being achieved

Despite the challenges faced in the industrialisation of producing ever larger wind turbines whilst keeping costs down, China has proved that this is possible if there is a large enough pipeline and access to low-cost capital. Whilst prices in most markets outside China increased after 2020, Chinese turbine prices fell by more than 50% over this time period [Exhibit 3.5]. This demonstrates that in principle and with the right supporting policies, other turbine manufacturers should be able to achieve further cost declines over time. It might also suggest a larger role for Chinese exports in the near future.

Among the key factors which explain this cost reduction are some which other countries will find difficult to replicate – in particular a low cost of capital, driven by financial policies which trap China's high savings primarily within the country. But others should, in principle, be replicable elsewhere, including:

- Consistent high demand created by a clear schedule of auctions providing confidence for the supply chain to expand.
- The emergence of a comprehensive supply chain, encompassing turbine components and through to transport infrastructure, including truck, vessel and port capabilities.
- Continued focus on developing very large turbines, but within the context of total volume growth sufficiently large to ensure that each design is manufactured on significant scale [Exhibit 3.5].

This Chinese cost advantage may result in a significantly expanded role for imports of Chinese turbines into other markets. EU wind turbine component imports have grown rapidly in recent years, nearly quadrupling from $122 million in 2018, to $483 million in 2022, with 60% of these components imported from China.[90] But historically, the EU has not been dependent on importing complete Chinese wind turbines, as international trade in turbines has been constrained by high weight-to-value ratios, transportation costs and local content requirements.

It is worth noting that the European wind industry challenges how replicable Chinese costs decreases would be over the short term.[91] The European Commission as of April 2024 has committed to investigate subsidies received by Chinese suppliers of wind turbines destined for Europe, in the Bloc's latest move to shield domestic firms from cheap clean technology products; following the same course of action as with electric vehicles.[92]

Chinese manufacturers are now increasing efforts to enter international turbine markets. And there are now examples outside China of turbines being exported long distances, including GE transporting 6 MW turbines from Europe to Rhode island, USA.[93] Experts suggest that such a journey can add 20% to the overall cost,[94] but given the huge manufacturing cost differential, this still implies that exported Chinese wind turbines could play a major role in the coming years.

There is a legitimate desire in the US and across Europe to develop local supply chains rather than relying heavily on imports, driven by policies such as local content requirements; these however can increase costs. Such policies should ideally be designed in ways which enable turbine prices to continue their historic decline, replicating the favourable features of the Chinese supply chain where possible in other countries, rather than simply increasing costs via tariffs. The most simple and effective way to move towards Chinese cost reductions is to grow the market and benefit from economies of scale.

Closer collaboration between countries to bring down technology costs can be a useful means of replicating the success of China. As of April 2024 Japan has agreed a partnership with the US to help reduce the cost of floating offshore wind projects, working to accelerate developments in engineering and manufacturing processes in line with the US aim of cutting the cost of floating wind installations in deep waters by more than 70% to $45/MWh over the next decade.[95]

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90 BNEF (2023), *The EU's wind turbine imports are quietly creeping up*.

91 Wind Europe (2023), *Wind Power Package: game-changer for Europe's energy security*.

92 Reuters (2024), *EU to investigate Chinese wind turbine suppliers*.

93 Heavy Lift PFI (2016), *GE delivers to Block Island*.

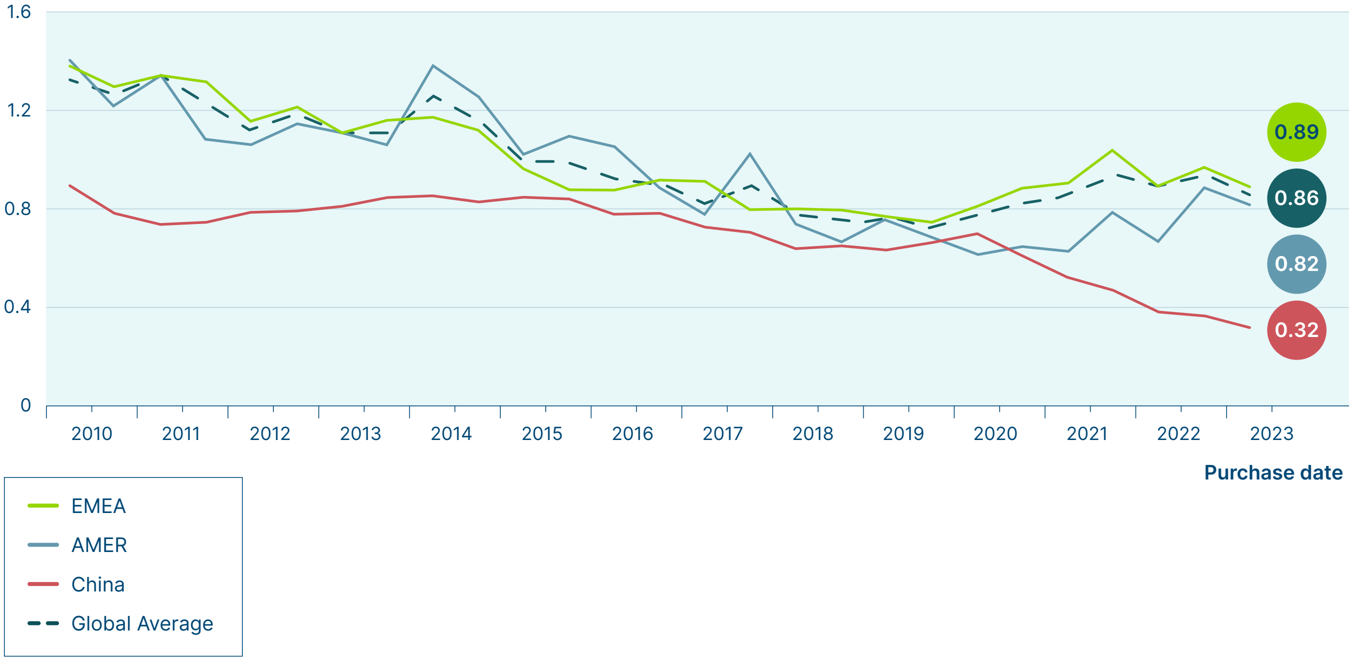
94 ETC interviews with offshore wind supply chain experts.

95 Reuters (2024), *Japan to collaborate with US on cutting floating offshore wind costs*.

Chinese turbine prices have declined despite price increases in other geographies

Exhibit 3.5

Turbine prices are starting to decrease
$ million/MW, nominal

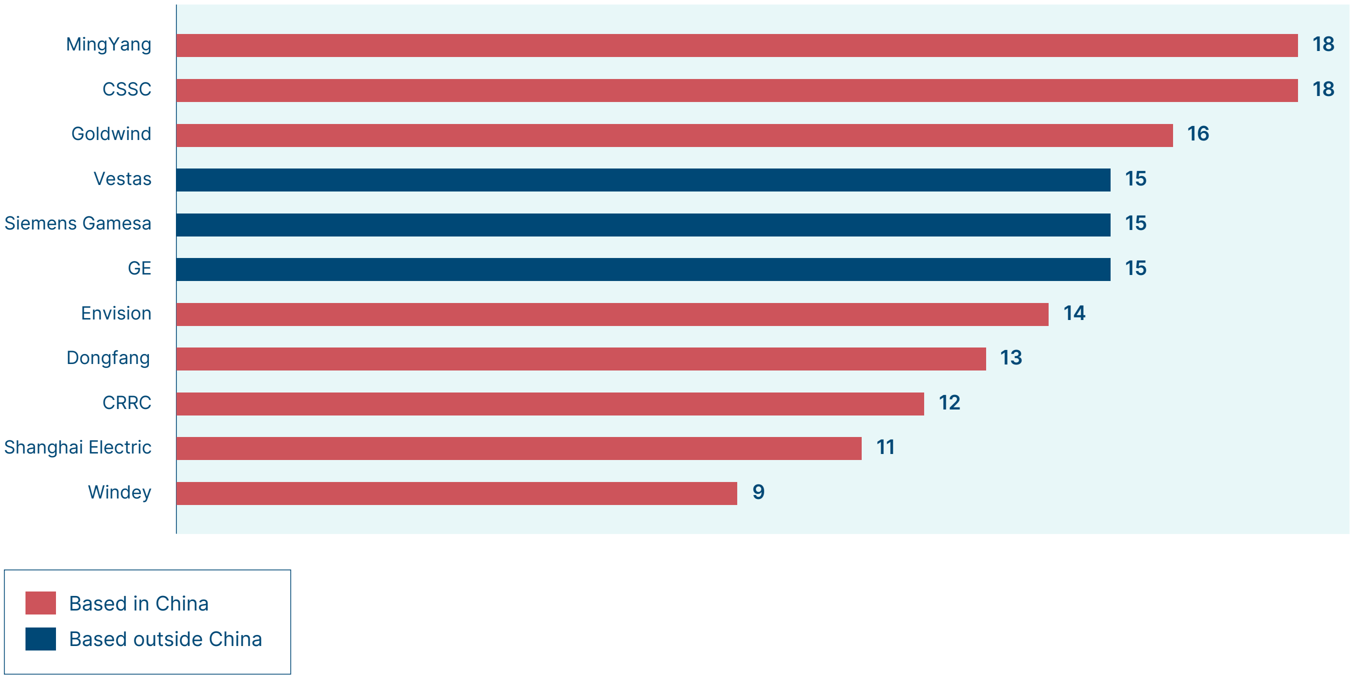


Source: BNEF (2023), *Wind power majors get price reprieve after bruising year*.

Chinese manufacturers now lead the world in turbine capacity

Exhibit 3.6

Highest-capacity offshore wind turbines, by manufacturer
Turbine capacity, MW



Source: BNEF (2023), *Wind power majors get price reprieve after bruising year*.

Five key recommendations to relaunch the confidence cycle and bring down costs

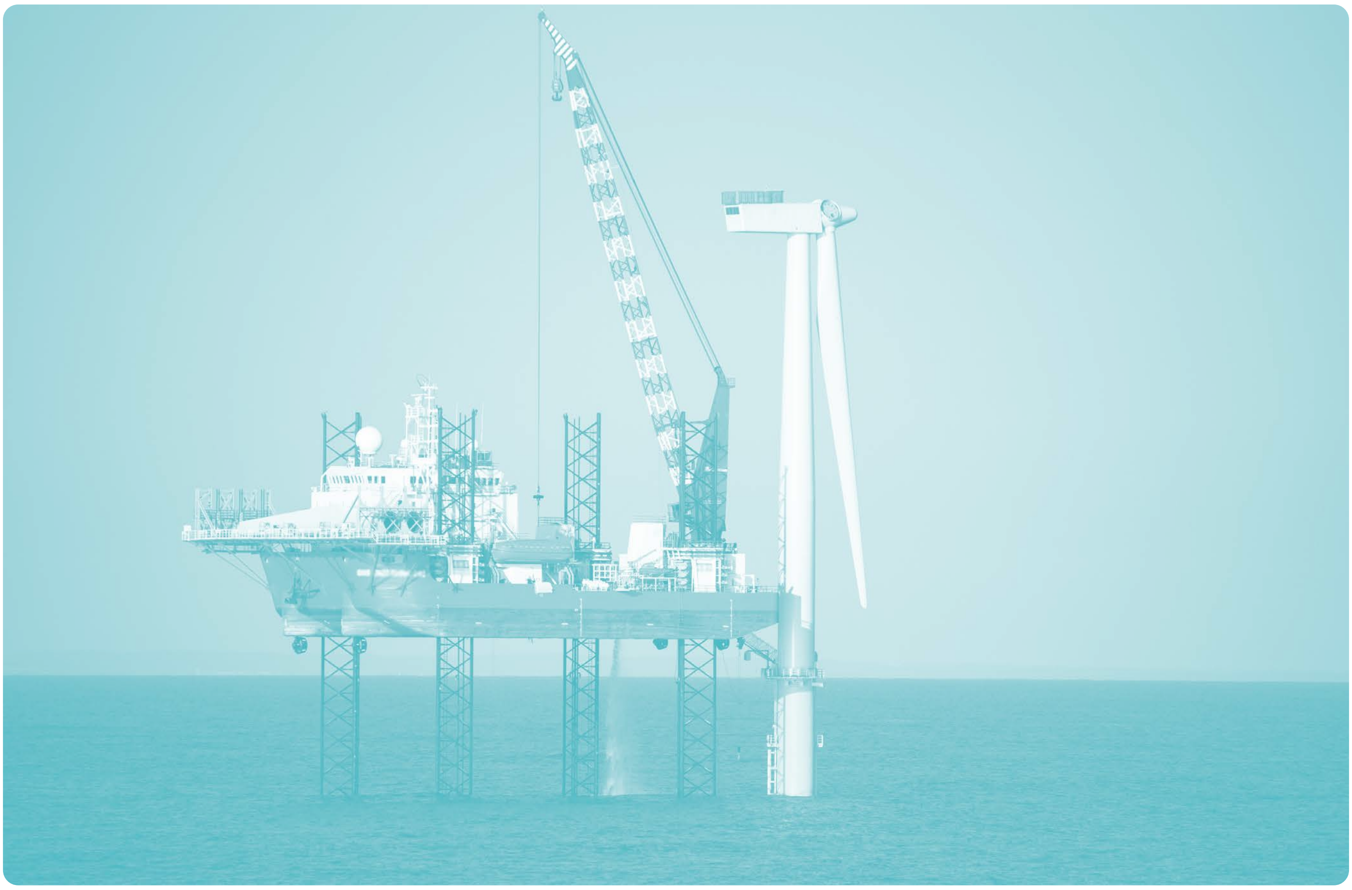
4

China has demonstrated that forecasts of much lower costs for offshore wind are credible. The scale of the market has helped drive down costs: in 2023, China installed 8 GW of offshore wind, compared to only 4 GW in the rest of the world.[96] These deployment volumes have helped to provide certainty to the supply chain, allowing greater standardisation and lower costs, and in effect bring offshore wind manufacturing closer to solar in our Exhibit 3.4 framework.

For other geographies to repeat the success of China, considerations around enabling certainty over deployment volumes and overcoming supply chain bottlenecks will be critical. Policies and processes should be designed to bring confidence to the supply side (component manufacturers, turbine OEMs, transport equipment, ships, and ports) to invest in key facilities and scale output.

Five key recommendations to relaunch the offshore wind confidence cycle and bring down costs will be outlined in this chapter:

- Set strategic planning, targets, and a constant flow of auctions.
- Contract and auction design to incentivise completion and removal of optionality.
- Streamline planning, permitting, and grid connection processes; and reinforce power grids.
- Encourage harmonisation of turbine components and sizes.
- Address specific supply chain bottlenecks.



[96] BNEF (2024), *Global Installed Capacity*.

4.1 Strategic planning, targets, and constant flow of auctions

For the offshore wind supply chain to confidently invest in scaling up, certainty about the future project pipeline and scale of deployment is required. Whilst governments have been setting ambitious targets, most countries are forecast to fall short of these [Exhibit 8], and there is a distinct lack of installation targets beyond 2030.

A clear strategic vision for power system growth and simultaneous decarbonisation up to and beyond 2030 is vital. Where relevant, country visions must include capacity deployment targets for offshore wind (GW). To deliver the targets, a strong set of supporting policies is required (e.g., a clear schedule of well-designed auctions).

Key actions

Creation of a strategic plan with clear targets for large volumes of capacity and consistent schedules of auction.

At the country level, the UK and Germany have set clear targets, aiming for 50 GW and 30 GW deployment respectively by 2030. On cross-border terms, the North Seas Energy Cooperation (NSEC) group have made the first steps towards this goal in North-Western Europe, with targets set for 120 GW of offshore wind by 2030, rising to 300 GW by 2050.[97] However, whilst a good first step, closer cross-border cooperation and clear signals to industry on progress will be required to make the North Seas into the "power plant of Europe".[98] It will also be important that there is a strategic grid plan to keep overall system costs down, reduce infrastructure needs, and reduce impacts on communities and environment.

To deliver on the targets, a sustained schedule of auctions is critical. At a country level, auctions should be publicised far in advance. Where possible, auctions should be held on a regular schedule, as in the UK's annual rhythm.[99] Where countries have cancelled existing auction results, replacement expedited wind solicitations should be hosted to backfill cancelled projects, as in New York, to quickly bring back confidence to the supply chain.[100]

Dedicated auctions to address gaps in generation profiles, either by technology (e.g., offshore/floating wind) or for delivery in specific time blocks or times of year.

Offshore wind can also deliver two key benefits to the system, which should be incorporated into auction design or within system plans:

- A complementary daily generation pattern (e.g., offshore wind can also produce at night and more in winter than in summer, while solar has a diurnal generation pattern). As a result, there should be dedicated auctions either for specific time blocks (e.g., night time or winter electricity delivery), or for offshore wind which can generate in time blocks complementary to solar.
- The provision of renewable generation which is not subject to land availability constraints. Floating offshore wind has even fewer land constraints as it doesn't require as shallow shores. As this is a new technology, dedicated floating offshore auctions should be hosted in the coming years, accepting higher current prices for this in the short-term as the technology begins to scale and decline in price.[101]

Recommendations

Governments and international bodies should:

- Develop a strategic plan for deployment of offshore wind and its offshore and onshore grid infrastructure, including Marine Spatial Planning at the basin level.
- Maintain clear targets for large volumes of capacity and consistent schedules of auctions.

Governments should:

- Host dedicated auctions to address gaps in generation profiles, either by technology (e.g., offshore/floating wind) or for delivery in specific time blocks or times of year.

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97 Netherlands Enterprise Agency (2023), *Research shows more port capacity needed to achieve 2030 offshore wind energy targets*.

98 Energy Ministers from the ten NSEC countries in November 2023 launched an 'NSEC Action Agenda' which sets out necessary actions in grid development, market design, financing, auction design, nature protection and offshore energy security. See North Seas Energy Cooperation (2023), *North Seas Energy Cooperation Action Agenda 2023–2024*.

99 Gov.UK (2022), *Government hits accelerator on low-cost renewable power*.

100 BNEF (2023), *Rising Costs Dampening Offshore Wind Outlook*.

101 Less than 300 MW of floating offshore wind has been deployed as of the start of 2024, compared with 74 GW of fixed-bottom offshore wind. Installed turbines tend to be smaller, at ~8 MW compared with 10–15 MW as of 2024.

4.2 Contract and auction design to incentivise completion and removal of optionality

Offshore wind supply chains require certainty that the auctioned volume of offshore wind capacity will be delivered. In 2023, this was called into question due to contract cancellations and built-in optionality of contracts.

- A number of contract cancellations for offshore wind capacity were recorded in the US and UK [Chapter 1.1], sending signals to the supply chain that a contract awarded will not necessarily equate to future demand. One direct result was the termination of a $200 million dollar Siemens Gamesa wind turbine blade factory due to be built in Virginia, US.[102]
- Embedded optionality has recently become a key feature in auction and contract design in the Netherlands and Germany [Chapter 1.2]. These auctions, based on a "right-to-deliver",[103] require most payments from developers to governments to start only when construction starts, with payment timelines of between 20–40 years.[104] If developers cannot secure supply contracts at a suitable price, projects may be abandoned, with limited cost to the developers, leaving the promised wind capacity unfulfilled and undermining the confidence of the supply chain.

Key actions

Ensuring contracts are delivered to completion through inflation indexing.

Contract design issues were a core reason for the perception of a crisis in 2023. In absence of inflation indexation, when developers came to order their turbines a year or more after bidding, costs had risen – meaning the auction price that was bid no longer provided a robust business case [Exhibit 4.1]. This led to a high number of cancellations. Most cancelled projects were in the US, which had very limited or no inflation-linking until recently.[105] As a counterpoint, the UK embeds inflation adjustments to CfD contracts (linked to the Consumer Price Index) and experienced fewer cancellations despite similar price increases.[106]

US projects are also generally more at risk from inflation than other geographies as offtake agreements can be secured early (shortly after sea-bed lease) whereas many more permitting stages are required before contract award in most other geographies. In some cases, projects have to wait eight years between contract award and finalising their supply chain orders – leaving a much longer amount of time at risk than other markets (for example, Exhibit 4.1 demonstrates the UK lag is typically around one year).[107]

Going forward, government-backed contracts should be designed with some form of inflation indexation as a standard. However, whilst reducing risks to developers, this shifts the burden of risk to the offtaker, so the exact mechanism for inflation adjustment should be carefully considered. In order of least developer risk, some options are:

- Price escalators linked to consumer price inflation and supply chain cost increases.[108]
- Price escalators linked to consumer price inflation.[109]
- One-time adjustments to offtake price.[110]
- Fixed price escalators.[111]
- No inflation adjustment mechanism.[112]

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102 RENEWS (2024), *Siemens Gamesa scraps US blade facility*.

103 Where developers pay governments for the right to develop and deliver a project in a certain seabed, see Box A.

104 Rabobank (2023), *Offshore Wind Tender Design in Need of Overhaul to Meet Climate Ambitions*.

105 Most contracts had no inflation adjustment mechanism, whilst a small number had fixed price escalators between 1.5–3% annually, rather than linked to CPI. See BNEF (2022), *2H 2022 Offshore Wind Market Outlook: Targets Out of Reach*.

106 Department for Energy Security and Net Zero (2023), *Contracts for Difference for Low Carbon Electricity Generation*.

107 BNEF (2023), *New York Hits Offshore Wind Reset, But at a Steep Price*.

108 Recently used in Ireland's 2023 3 GW auction, where the strike price on commencement date would be amended by the change in price of steel with a 10% weighting, with the remainder based on change in EU CPI. Post commencement projects receive annual uplifts based on EU CPI; see Government of Ireland (2023) *Terms and Conditions for the First Offshore Wind RESS Competition*.

109 Commonly used in UK CfD auctions, with price per MW increasing annually in line with UK CPI. House of Commons Library (2023), *Contracts for Difference Scheme*.

110 A one-off adjustment to offtake price based on movements in indexes from the time of bid submission to the time they receive their final federal permits, no further inflation adjustments. Introduced in the October 2023 in the New York round 3 auction to overcome issues faced in prior solicitations, and likely the option used in future wider US auctions. See BNEF (2023), *New York Hits Offshore Wind Reset, But at a Steep Price*.

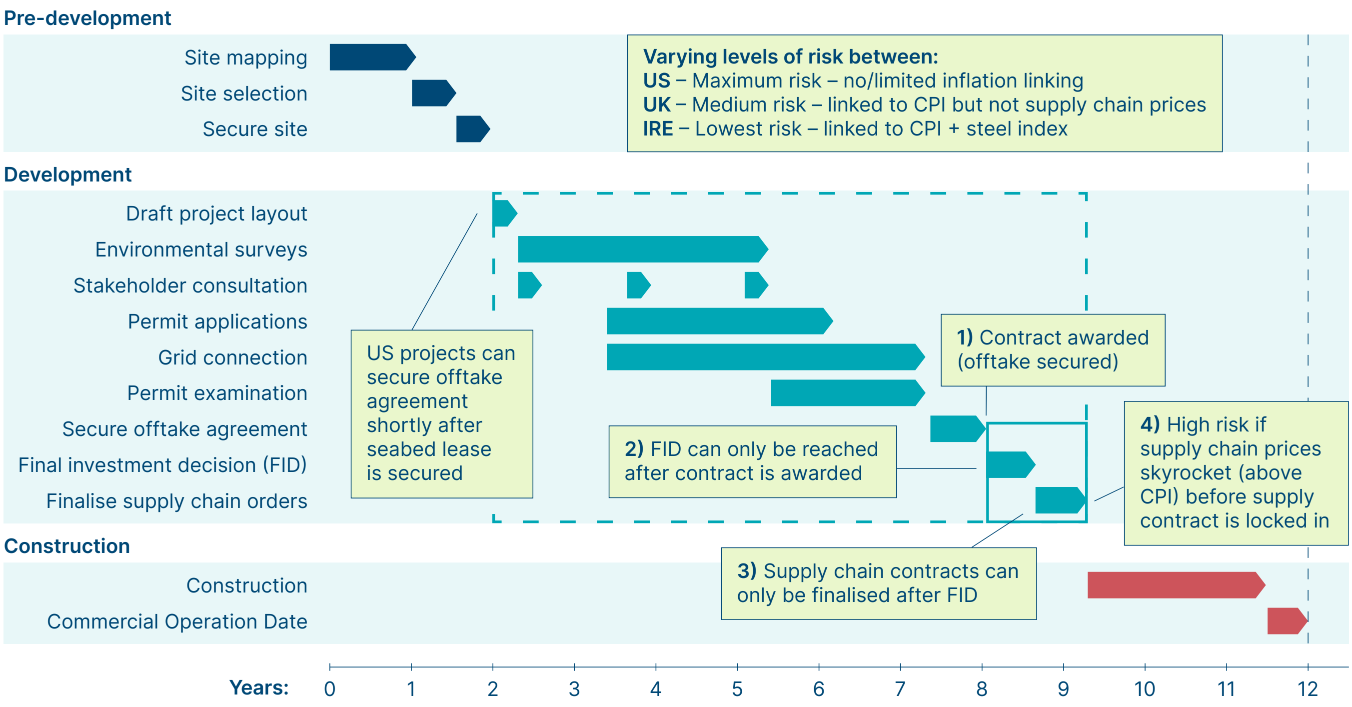
111 An escalator fixed at a given percentage over the contract term. Empire Wind 1 secured a contract in New Yorks first auction round with a fixed escalator of 2% over the 25-year contract term. This contract was initially cancelled and has been re-awarded to Empire Wind 1 at a higher price. See BNEF (2024), *Pricey New York Deals May Turn Tide for US Offshore Wind*.

112 The option with developers most at risk. Used in many US auctions which have since requested renegotiations or have been cancelled. See BNEF (2023), *New York Hits Offshore Wind Reset, But at a Steep Price*.

Offshore projects face varying inflationary capex risks after contract award before finalising supply chain orders

Exhibit 4.1

Renewable project development stages – illustrative example for offshore wind in UK



Source: ETC (2023), *Streamlining planning and permitting to accelerate wind and solar deployment*.

Removal of optionality affecting delivery of government backed contracts.

It is important that governments design tenders to limit developer option to cancel or pull out. This can be achieved, for example, by utilising a CfD scheme obligating the developer to build the wind farm and sell power at the price agreed in the contract, by issuing fines for non-delivery of contracts, by requiring sufficient equity commitments from parent companies, or in the case of a "right-to-deliver" auction, by requiring a substantial up-front payment.[113]

Across the spectrum of contract design, there are some forms which embed more safety against non-delivery risk. Two-sided CfD auctions provide more safety against non-delivery risk – following an auction, developers have confidence in the revenues they will receive once they start to generate electricity. Alternatively, right-to-deliver auctions generally carry more risk – these auctions require up front payments (in some instances of 10% of overall project bid)[114] but do not offer a fixed revenue for each unit of power generated, which is generally agreed at a later date either via a PPA or by the developer selling power directly into the merchant market [Box A]. This comes with substantial revenue and project realisation risk, and the project may be abandoned at limited further cost to developers.[115] Right-to-deliver auctions could also be combined with a series of milestones demonstrating project development progress to give increasing confidence of contract delivery towards completion date. Failure to meet such milestones could result in governments reauctioning that capacity.

Whilst limiting the optionality of developers to pull out of government-backed contracts, it is important not to fully limit the flexibility to raise revenue via different streams, including corporate PPAs and through merchant exposure. Hybrid options which combine CfDs with other non-CfD forms of revenue are a key part of the market.

113 However, it should be noted that requiring high upfront payments could cause higher barriers to entry and distort the market towards firms with large balance sheets. This may dissuade new entrants or established developers with smaller balance sheets.

114 Rabobank (2023), *Offshore Wind Tender Design in Need of Overhaul to Meet Climate Ambitions*.

115 Whilst two-sided CfDs protect against revenue risk, they are not a "silver bullet" to ensure deliverability, as costs can still increase after agreements are signed. Appropriate indexation can hedge against these risks.

However, making it harder for developers to pull out of contracts will increase developer risk and thus the expected returns required to deliver offshore wind projects. Governments should accept paying slightly higher prices for offshore wind power to account for measures to remove optionality, given the benefits to increasing supply chain certainty.

Ensure auction design optimises for long-term systems benefits, as opposed to short-term tax revenues for governments.

Some current auction mechanisms can hurt efforts to standardise. In auctions designed to boost government revenues, developers can become pitted against one another in a "race to the bottom" to offer the lowest bid. In the US, this may be through expensive seabed leases, whereas in wider Europe, this is often experienced through high price-capped or uncapped right-to-deliver auctions (known as "negative bidding" – see Box A). This can also be seen in two-sided CfD auctions which solely award the contract based on lowest price.

Competition has been good for driving down costs to date, but with auctions typically awarding limited volumes of capacity it can also inflate costs through competition for a finite supply chain – rather than supporting expanded supply chain capacity. These processes have contributed to the negative profit margins seen by OEMs explored in Chapter 2.1. If Western countries want to prioritise building or keeping their domestic supply chains – a wider system benefit – they should consider turning away from, or place a cap on, negative bidding auctions. The EU Commission has recognised this issue and has committed to launching a dialogue with Member States to discuss whether such bidding structures can be avoided, potentially through use of additional non-price criteria.[116]

Overall, placing a cap on negative bidding auctions could deliver several benefits, such as restricting artificially low pricing, which may not reflect true costs and could otherwise result in higher electricity prices for consumers or unfulfilled projects if the supply chain cannot service bids at these prices; promoting fair competition between developers; and ensuring the long-term viability of the industry in terms of credibility with investors and retention of established firms.

Increased auction price caps for upcoming auctions where necessary.

One key benefit of auctions is price discovery. Therefore, while one round of unfulfilled auctions with a lower than required price cap is not a fundamental issue for the technology, repeated unfulfilled auctions with low price caps would demonstrate a lack of understanding from governments of price increases faced by the industry, and would delay investment and project delivery. Price caps, therefore, should reflect reasonable expectations of industry costs.

In late 2023, both the UK and the US realised that prior price caps were too low. UK offshore wind prices are set to be raised 66% for the 2024 CfD auctions, to £73/MWh in 2012 prices or around £100/MWh in today's prices, close to the 2023 wholesale UK power price.[117] It is likely that prices secured at this auction will be well below the £100/MWh threshold, especially given Ireland's recent solicitation of 3 GW at €86/MWh.[118] New York's recent auctions were also 20% higher than previous solicitations, whilst also offering further protections of a one-off inflation adjustment mechanism.[119] Responding to unfulfilled auctions by increasing price caps provides increased certainty to the supply chain that project delivery will resume, even through periods of price inflation.

If auction price caps are to remain fixed, one alternative solution could be to extend the contract length offered to developers, with some experts noting that an increase in UK CfD terms from 15 to 20 years, along with tweaks to capital allowances to support net-zero investment, could reduce CfD prices in the UK by up to £10/MWh.[120]

Recommendations

Governments and offtakers must:

- Encourage contract delivery through (some form of) inflation adjustment.

Governments should:

- Explore removing optionality from contracts where possible (accepting somewhat higher prices).
- Ensure auction design optimises for long-term system benefits, as opposed to short-term tax revenues for governments.
- Consider an increase in auction price caps for upcoming auctions where necessary to encourage deployment.

Governments could:

- Make amendments to the offered contract length to provide greater certainty and lower strike prices.

116 EU Commission (2023), *European Wind Power Action Plan*.

117 Financial Times (2023), *UK government to increase offshore wind subsidies by 66%*.

118 As an emerging market with no currently installed capacity, prices in Ireland have not yet had time to benefit from learning curves and economies of scale. See: Renewables Now (2023), *Ireland awards 3 GW of offshore wind at "hugely competitive" price*.

119 BNEF (2023), *New York Hits Offshore Wind Reset, But at a Steep Price*.

120 ETC expert interviews with offshore wind developers.

4.3 Streamline planning, permitting and grid connection processes and reinforce grid

Reducing risk to the offshore wind sector can be achieved by minimising time spent in planning and permitting, and ensuring projects are entitled to and can secure a timely grid connection. The typical time for an offshore wind project to move from pre-development to completion is around 12 years, as highlighted in Exhibit 4.1.[121]

Key actions

Streamline planning and permitting.

Project development time for offshore wind can be cut in half by streamlining planning and permitting processes, from an indicative time of 12 years (as in the UK) to 5.5 years. The streamlined times are achievable in any geography, whilst maintaining or strengthening environmental and social standards. The ETC has provided detailed analysis of the key actions to take to streamline these processes.[122]

Design grid buildout in a manner which minimises transmission bottlenecks to offshore wind.

Offshore wind is inherently reliant on transmission infrastructure capacity into the mainland. It is therefore vitally important that transmission infrastructure is planned and built out with future offshore wind capacity in mind, to minimise bottlenecks. This is particularly important for Europe, where offshore wind is concentrated in the north of countries, and requires transmission to southern demand centres (i.e. the North Sea above Germany and the UK). More than 95% of wind congestion events in the UK are experienced by wind farms located in Scotland, despite hosting only 40% of the UK's wind capacity. In absence of a renewed focus on transmission, Carbon Tracker forecast that the wind congestion in Scotland will increase five-fold by 2030, resulting in 20% of Scottish wind output being curtailed, equivalent to the annual electricity production of a 6 GW wind farm at a cost of £3.5 billion per year.[123]

Countries should therefore seek to conduct the strategic planning mapping outlined in Chapter 4.1 and design the build of their offshore and onshore transmission networks with a Holistic Network Design. They should consider integrated designs that support the large-scale delivery of electricity generated from offshore wind – taking the power to where it is needed across the country, linking offshore wind farms to each other, and reinforcing connection points in the most cost effective manner.[124]

Where grids are continent level (i.e. China), country-level strategic planning should be sufficient to build out optimal grid infrastructure for offshore wind. However, for sub-continent level grids (i.e. Europe or South-East Asia) it is vitally important to plan and build out offshore transmission infrastructure together, share costs, benefit from economies of scale, and ensure that infrastructure is built where it will be most effective. The Ostend Declaration will jointly develop the North Seas as the "Green Power Plant of Europe", an offshore renewable energy system connecting countries with a particular focus on joint hybrid/multi-purpose and cross-border offshore projects and hubs, offshore wind and renewable hydrogen production at massive scale as well as electricity and hydrogen interconnectors and national projects.[125] This level of regional coordination will be essential to limit transmission bottlenecks.

Streamline grid connection processes.

As well as reinforcing the grid, it is essential to streamline the processes associated with obtaining a grid connection. Power auctions should also contain a "right-to-connect" to the grid, so that winning companies know that they have secured a grid connection alongside a power permit and when this will be connected. This is the case in Germany, however connection times there have been continually pushed back,[126] and the Netherlands, where costs to connect offshore wind have soared in 2023.[127] Further actions are required by national governments to prioritise the development of transmission networks and overcome supply chain challenges associated with this.

Recommendations

Governments must:

- Streamline planning and permitting.
- Reinforce transmission networks to enable increased offshore wind deployment.
- Streamline grid connection processes.

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121 An indicative example for the UK is shown, with the range of project development time for most countries outside of China between 10–15 years.

122 See ETC (2023), *Streamlining planning and permitting for accelerated wind and solar deployment*.

123 Carbon Tracker (2023), *Gone with the wind*.

124 See: National Grid ESO (2022), *Pathway to 2030 A holistic network design to support offshore wind deployment for net zero*.

125 Wind Europe (2022), *Ostend Declaration*.

126 OffshoreWind.Biz (2024), *Germany Facing Offshore Wind Grid Expansion Delays*.

127 Plans for an offshore Dutch grid were revealed to have increased by more than a third over initial estimates to €35.5bn. See Recharge (2023), *$10bn costs hike shock hits Dutch offshore wind grid plans*.

4.4 Encourage harmonisation of turbine components and sizes

The entire offshore wind supply chain requires clarity on the size of turbines which will be installed in the future. Chapter 3.2 detailed that turbines have been increasing in size most years, which has been beneficial in increasing power output of turbines, but has brought great uncertainty to the supply chain in terms of designing the size of their factories, transport equipment and ports.

Some standardisation of wind turbine development could make investing in new product development more attractive, reduce quality issues through in-field learning, enable factories to benefit from economies of scale, and provide clarity and reassurance to the wider supply chain [Box B]. For these reasons, there are some voices from industry calling for a slowing or more structured progression, of the race towards larger turbines.

Key actions

Harmonising regulation and non-price criteria across regional markets.

Offshore wind is much more of a bespoke industry than solar, with thousands of offshore turbines manufactured each year compared to hundreds of millions of solar modules. Standardisation in this industry should therefore not be seen from a "mass manufacturing" angle, but more from a project level i.e. how can one manufacturer build most efficiently for six projects in nearby countries.

Standardisation of regulation is critical. Standardisation of offshore wind transport interfaces to create uniform specifications for how components of offshore wind farms are transported and assembled across European projects could save millions of euros across the industry. This would involve harmonising dimensions and connection points of components, so that they can be efficiently loaded, transported, and lifted onto offshore platforms. This would enable reuse of tools for various projects across different manufacturers.

Standardisation also applies to auction criteria, especially in light of the new EU Wind Power Action Plan guidance for non-price criteria.[128] The rush towards ever larger turbines could be mitigated through increased use of non-price criteria in auction mechanisms, with less of a role for competition on cost (i.e. projects favoured which more easily integrate with local power generation and transport/installation systems, have high sustainability, and a good developer track record for delivery). For maximum efficiency, auction criteria could also be harmonised across EU markets, so that when building factories, turbine OEMs can know that a factory built to manufacture turbines for one country will be designed to the correct specifications for other countries. A wider pipeline of projects could then be serviced through the same manufacturing processes.

Some caution should be taken however, as non-price criteria in auctions can introduce a subjective element in bid assessment, raise complexity, reduce the transparency of selection process, and increase project costs for developers as they try to fulfil the requirements. It is therefore important to consider the level of specificity and subjectivity of any non-price criteria proposed. The EU Wind Power Action Plan suggests that applying some criteria as qualification metrics (including data and cybersecurity, environmental protection and ability to deliver) could alleviate some of these issues.[129]

Developing guidelines on turbine heights.

Some commentators have called for regulators to step in and impose a simple "cap" on rotor size (tip height) eligible to bid into upcoming auctions. The Netherlands Wind Energy Association have proposed a "North Seas Standard" of 1,000 feet (305 metres) above mean sea level, as a value that industry and regulators could rally around. Partially because international rules for aviation already require planes to stay above 1,000 feet.[130] They propose that these limits should be in place for the next 10 years, with 14 MW minimum installed capacity installed per foundation, and believe that turbines developed under this standard could reach at least a capacity of 20 MW within the specified caps.

However, these types of height restriction could prove challenging to implement comprehensively. Firstly, it creates a coordination challenge to align multiple offshore wind regulators simultaneously. Secondly, regulators may not be best placed to adjudicate on where the "right" threshold should be set, risking an arbitrary constraint holding back future innovation and therefore future cost reductions.

Even if regulatory harmonisation on height is not possible or desirable, engagement between governments, regulators, and industry to increase visibility of future turbine heights would be useful to allow the supply chain to plan for the future.

The role of "paper turbines" in auctions.

Most auctions today do not limit bids to only include turbines which have already demonstrated a successful prototype. This can often result in winning bids being based on "paper turbines" – a product which only exists on paper and has not yet been fully developed and tested as a prototype. Utilising "paper turbines" in

128 European Commission (2023), *European Wind Power Action Plan*.

129 Ibid.

130 NWEA (2023), *The North Seas Standard: enable growth with wind turbine standardisation*.

auction bids introduces risk and potential delay to the development process, as new turbines have to then be successfully designed to prototype standard and certified, before factories are created for mass production.[131] The rest of the balance of plant must also be scaled up, including foundation design, port infrastructure and vessel design. Arguments against excluding "paper turbines" suggest it will hamper innovation and the speed of turbine improvements – it typically takes 3–5 years between contract award and first generation, during which new turbine technology may come online.[132] Turbine manufacturers may require orders for larger turbines to provide the capital necessary for new factories to start production.

Some industry voices are calling for governments to consider a binding technology commitment as a pre-qualification requirement in auction requests. This commitment would require the developer to provide authentic assumptions and plans for a product, ideally in a prototype state or with a clear path toward certification.

As for the role of "paper turbines" in auctions – the key responsibility should reside with developers to only assume turbine availability on the basis of firm information from the suppliers. The recommendations about reducing optionality referred to in Chapter 4.2, should help ensure that "paper turbine" assumptions are not used in an unrealistic fashion.

Recommendations

Governments should:

- Explore harmonising regulation and non-price criteria across markets where possible.

Governments could:

- Explore developing guidelines on turbine heights together with the industry and supply chain players.

131 In 2023, GE Vernova were contracted to deliver new 18 MW turbines which had not been successfully rolled out at scale for New York projects totalling 4 GW. These plans were changed in 2024, With GE scraping the plans for the larger variant and focusing on 15.5 MW "workhorse" turbines instead, resulting in the New York projects being cancelled. Utility Dive (2024), *New York nixes 3 offshore wind projects, notes GE Vernova move to abandon 18-MW turbine*.

132 Although in the US this could be up to 10 years, see Chapter 4.2.

4.5 Address specific supply chain bottlenecks

Even if the aforementioned recommendations are completed, each area of the supply chain will still be wary that other aspects of the supply chain can become a bottleneck. A strong supply chain requires coordination across all supply chain members (including transport and installation capacity, materials and components capacity), with all members receiving sufficient incentive to expand production.

Key actions

Targeted action to address critical supply chains gaps.

There are a limited number of trucks, cranes, ports and installation vessels that are suitable to transport massive offshore wind turbines. This transportation infrastructure also needs to be upgraded each time a larger turbine is created. Coordination across all key stakeholders is required to ensure that transport and installation equipment scales in line with turbine sizes, and is ready at the scale required when needed for deployment.

In some instances ports, or crane/vessel manufacturers may struggle to invest in larger transportation equipment (i.e. to carry turbines at 20 MW or greater) due to a perceived lack of demand. In this case targeted government guarantees or subsidies in the short term may be required to make the business case viable.

Ensure vessel regulatory regimes are fit for purpose.

In some countries maritime laws prohibit foreign-owned ships conducting business in domestic ports. This can make it very challenging to ensure that there is an adequate specialist fleet to install offshore wind turbines at the scale required. In the US, for example, the Jones Act – a 100-year-old maritime law which says only US-flagged ships can move cargo from one point to another – prohibits any international vessels from installing wind turbines in US waters,[133] leaving no compliant vessels as of February 2024.[134] Countries must assess their maritime regulatory regimes to ensure they are fit for purpose and do not create extra bottlenecks in the system.

Adopt strategies to diversify supply through joint ventures where critical bottlenecks occur.

In some instances, bottlenecks may occur where domestic manufacturing or manufacturing from friendly countries, cannot fulfil the demand for critical components. In these circumstances, it may be preferable for the US/European firms to sign carefully structured joint venture agreements with companies from APAC markets to benefit from their experience in low-cost manufacturing and help scale the supply chain.[135]

Recommendations

Governments should:

- Take targeted action to address critical skills and supply chains gaps.
- Ensure vessel regulatory regimes are fit for purpose.

Governments could:

- Adopt strategies to diversify supply through joint ventures where critical bottlenecks occur.

[133] Spectrum News (2023), *The Jones Act: How a 100-year-old law complicates offshore wind projects*.

[134] Offshorewind.biz (2023), *Dominion Confirms First US Wind Turbine Installation Vessel Will Be Completed Later than Planned*.

[135] Where components are often cheaper or more readily available.

Five key recommendations to relaunch the confidence cycle and drive down costs

Exhibit 4.2

	Key recommendation	Specific examples	Why?
1	Strategic planning, targets and constant flow of auctions.	• **Set strategic GW targets**, as part of integrated strategic vision of the power system (i.e. German 30 GW by 2030 target). • **Maintain clear schedule of auctions** (annual auctions to be used where possible). • **Host dedicated auctions** to address gaps in generation profiles, either by technology (e.g., offshore/floating wind) or for delivery in specific time blocks or times of year.	• Provides **certainty that the scale of the overall business will be large.** • Firms can **invest with confidence** that there will be a large offshore wind market beyond 2030.
2	Contract and auction design to incentivise completion and removal of optionality.	• **Implement inflation adjustment mechanism(s)** and ensure any price caps set are responsive to market dynamics. • **Remove optionality** from government-backed contracts, limiting developer option to cancel or pull out, accepting somewhat higher prices. • **Ensure auction design optimises for long term systems benefits**, as opposed to short-term tax revenues for governments.	• **Reduces risk of sudden setbacks to volume** (i.e. as seen in the US). • Increases confidence **contracts lead to quick supply chain orders**.
3	Streamline planning, permitting, and grid connection processes; and reinforce power grid.	• **Streamline planning and permitting** (taking actions to address regulatory, administrative & societal support challenges). • **Reinforce transmission networks** to enable increased offshore wind deployment. • **Accelerate grid connection processes**.	• Ensures more r**apid translation of auctions into orders**. • **Reduces uncertainty** which comes with the long length of time under permitting.
4	Encourage harmonisation of turbine components and sizes	• **Explore harmonising regulation and non-price criteria** across regional markets where possible. • **Consider developing guidelines** on turbine heights together with industry and supply chain.	• Enables benefits from **economies of scale**. • Provides **clearer signals to supply chain** to scale for a given size of turbine.
5	Address specific supply chain bottlenecks	• **Take targeted action to address critical supply chains gaps** (e.g. coordination to ensure transport system is equipped to move turbines across country). • **Balance local content requirements** with required pace and cost of deployment.	• Ensures specific bottlenecks **do not disrupt the overall development process.** • Provides **more confidence to other areas** of the supply chain.

Conclusion

The future of offshore wind

Despite the glancing blow dealt to the offshore wind industry in 2023, the sector remains competitive with gas and is a vital technology for the energy transition. The sector was particularly affected by the COVID-19 pandemic, where disruptions pushed up the cost of commodities, labour and borrowing. Rigid contract structures led to a number of project cancellations and contributed to the perception of an industry in crisis. However, while some higher prices could persist over the medium term, the largest of the cost effects should prove temporary as key costs, including steel and capital on a longer timeline, return to lower levels in the near future.

There is great potential for this industry to thrive. China has demonstrated that massive cost declines are possible when the industry and wider supply chain have clarity and confidence. If clear actions are taken to relaunch the confidence cycle and drive down costs beyond previous levels, deployment will increase and offshore wind can fulfil its role as a vital part of the energy transition.

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