REPORT

Standard beats size in Europe's offshore wind

Timely and affordable rollout contingent on turbine standardization

Roland Berger

Management summary

Offshore wind (OW) is a key pillar of Europe's energy transition. It is crucial to reaching climate targets, achieving energy independence, and creating earning capacity in the region's future economy. Europe's ambitious OW rollout requires a threefold increase in supply chain capacity. But a perfect storm of inflation, interest hikes and supply chain bottlenecks has escalated costs by 40% since 2022. Achieving the rollout targets in a timely, affordable way is a herculean task for the European OW industry, one that necessitates the development of a robust and fully industrialized supply chain.

Today, the OW supply chain is organized around a race for size: who can develop the tallest, biggest, highest-capacity turbines. In the past, larger turbines contributed significantly to cost reductions. But the cost benefits of even larger turbines are diminishing. In fact, today's race to produce ever-larger turbines is now causing costs to increase, and hampering capacity rollout, due to ever-shorter product life cycles and uncertainty about future turbine sizes.

This "rat race" is fueled by a vicious cycle in the sector:

1. Governments are trying to reduce costs, in some countries through competitive auctions, which only leads to local, short-term cost pressure on the supply chain, not to longer-term, structural cost reduction.
2. Project developers are keen to be the first to use the newest, largest turbine models to win tender bids and maintain their profitability.
3. Turbine OEMs expect larger market share and/or higher margins from value pricing for ever-larger turbines, and are shortening product life cycles to accelerate introductions, but this is leading to performance issues.
4. Component and foundation manufacturers, installers and ports need reliable forecasts of future quantities and specifications to invest in R&D, capacity extensions and industrialization, but the uncertainties are making such investments too risky.

Governments must enforce a standard turbine size for a considerable period to allow the supply chain to break out of this cycle. A standard size now will create certainty for investments and industrialization, and support the capacity boost we need. For the longer term, a standardization roadmap will pave the way towards even larger and/or smarter turbines. Only with a standard turbine size will the European OW industry become truly future-proof.

Cover: 1063893770/iStock

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Fast facts

120 GW

Ambition of the North Sea countries in the Ostende Declaration: 120 GW offshore wind capacity in 2030

330 m

Tip height of a 15 MW offshore wind turbine above the sea floor

5,600

(15 MW) turbines to be installed by 2030

1

Key pillar of the energy transition

Europe's energy transition has a major stake in the successful, large-scale rollout of offshore wind (OW). Not only is it crucial to meeting Europe's climate targets, but it is also a pillar of the region's future energy independence and earning capacity.

Specifically, Europe's targets to reduce greenhouse gas emissions by 90% by 2040 and reach net zero by 2050 will heavily depend on OW. The Netherlands, for example, aims to supply ~46%[1] of the country's total energy demand with OW by 2050, and is targeting 72 GW in capacity in order to do so.

Ongoing geopolitical concerns, such as the Russian Federation's war against Ukraine and conflicts in the Middle East, are also underscoring the importance of disentangling Europe's energy systems from sources beyond its borders. OW is an ample energy resource that the region can harness with its own means.

The EU wants to bolster its industries in decarbonization technologies[2] so that they produce a large part of the home demand and also have a large market share outside of the region. Further strengthening the global leading position of the European OW industry will create sustainable earning capacity at home.

2

Herculean task ahead

Over the next seven years, Europe's OW industry must triple its supply chain capacity if the region is to make strides in its transition – a herculean task.

This is not to say it cannot be done. The European OW sector has achieved major progress over the last 20 years, pioneering new technologies and realizing a capacity ramp-up to 36 GW by the end of 2023. These efforts must not only continue; they must accelerate.

To reach Europe's greenhouse gas targets, heads of state from countries around the North Sea, together with the European OW industry, came together in 2023 and released the Ostend Declaration of the North Seas Energy Cooperation (NSEC), a very ambitious target to reach about 120 GW by 2030 and at least 300 GW by 2050. In the Offshore Renewable Industry Declaration, the industry committed to ramping up capacity additions from 7 GW/year in 2023 to 20 GW/year by the end of the decade.

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[1] Netbeheer Nederland (association of electricity and gas network operators in the Netherlands) estimates the share of OW in total energy generation in 2050 to rise between 41% and 54%, depending on four scenarios from the publication "The Energy System of the Future: The II3050 Scenarios" published in June 2023

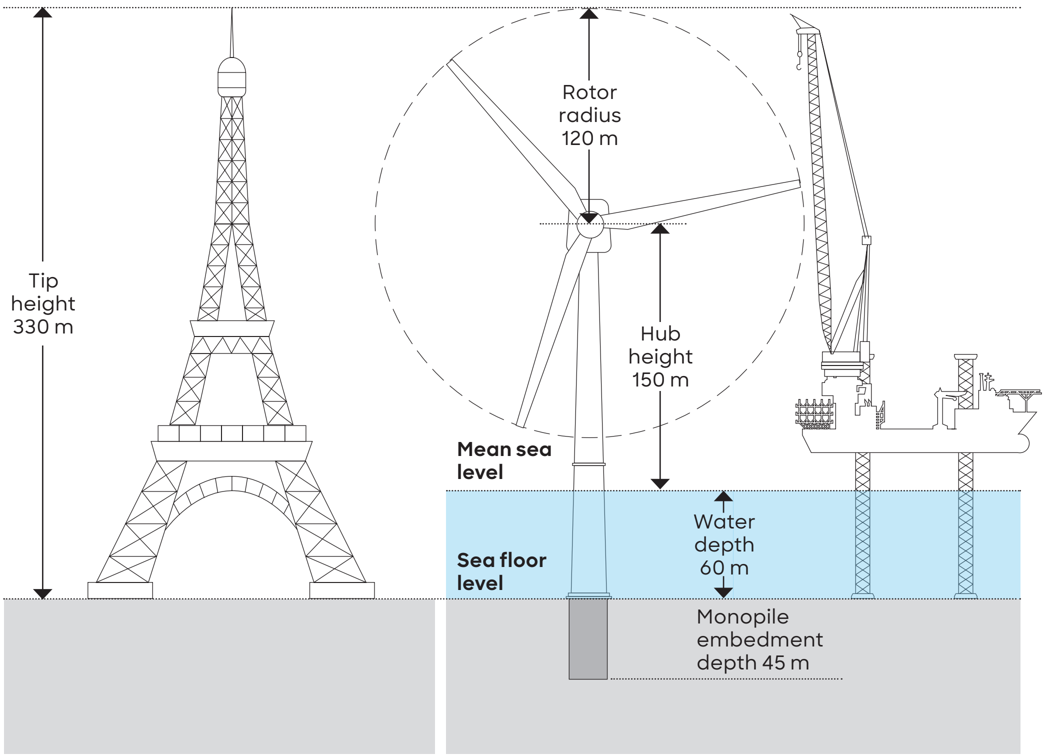
[2] The Net Zero Industry Act, adopted by the EU Parliament in April 2024, sets a target for Europe to produce 40% of its annual deployment needs in net-zero technologies by 2030, based on National Energy and Climate Plans (NECPs), and to capture 15% of the global market value for these technologies

To get from 36 GW to 120 GW in the next seven years, a total of 5,600 15 MW turbines must be added to the grid. This means 15 new installation vessels. To point out the magnitude of this endeavor: the dimensions of a turbine and its installation vessel are similar to those of the Eiffel Tower. The Eiffel Tower took 2.2 years to complete. It is true that since 1889 we have made huge advances in technology, engineering and industrialization, but not so far as to make the manufacture and installation of 5,600 turbines within a seven-year time frame a simple task. ▶ A

To put it another way, the NSEC target requires nearly a tripling of Europe's OW supply chain capacity, from 7 GW in annual capacity additions in 2023 to 20 GW by 2030. This means a massive ramp-up of steel, marshalling yards, installation vessels, and personnel. ▶ B

A Dimensions of a typical 15 MW turbine and installation vessel and (targeted) rollout pace

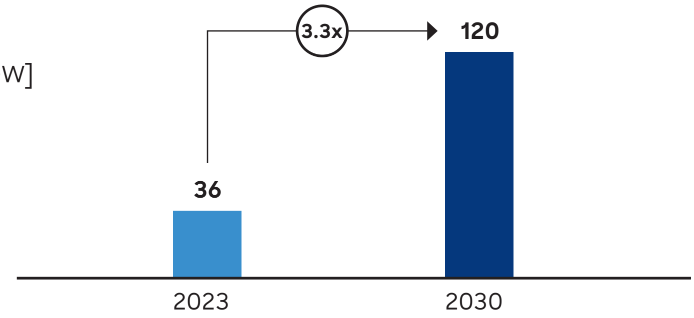
	Eiffel Tower	15 MW turbine	Installation vessel
Height	**330 m**	**330 m**	**326 m**
Rollout pace	**1 tower 2.2 years**	**5,600 turbines 7 years**	**15 vessels 7 years**



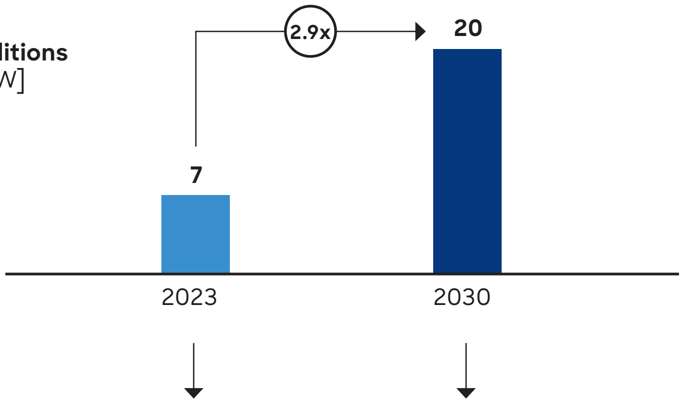
Source: IEA, NSEC, WindEurope, Company websites

B European OW supply chain ramp-up, 2023-2030

Installed OW capacity
2023 vs. 2030 target [GW]



Yearly OW capacity additions
2023 vs. 2030 target[1] [GW]



Key figures of the ramp-up

Turbines[2] [installed per day]	1.6	3.7
Monopiles[3] [Mtons of steel per year]	0.6	2.2
Marshalling yards[4] [# soccer fields]	385	2,100
Installation vessels[5] [#]	20	35
Personnel[6] ['000 FTE]	80	250

[1] 20 GW/year by the end of the decade taken from the Offshore Renewable Industry Declaration
[2] 12 MW and 15 MW average turbine sizes estimated for 2023 and 2030, respectively, by 4C Offshore
[3] Estimated steel needs for monopiles of 15 MW turbines based on SIF data
[4] Calculation based on 50 acres per 500 MW farm for 15 MW turbines (University of Delaware)
[5] Calculation based on Rystad's 2023 report on wind turbine installation vessels available for Europe in 2022, repurposing of vessels to O&M not taken into account
[6] FTE figures taken from the Offshore Renewable Industry Declaration

Source: 4C Offshore, SIF, Rystad, IEA, GWEC, University of Delaware, WindEurope, Roland Berger

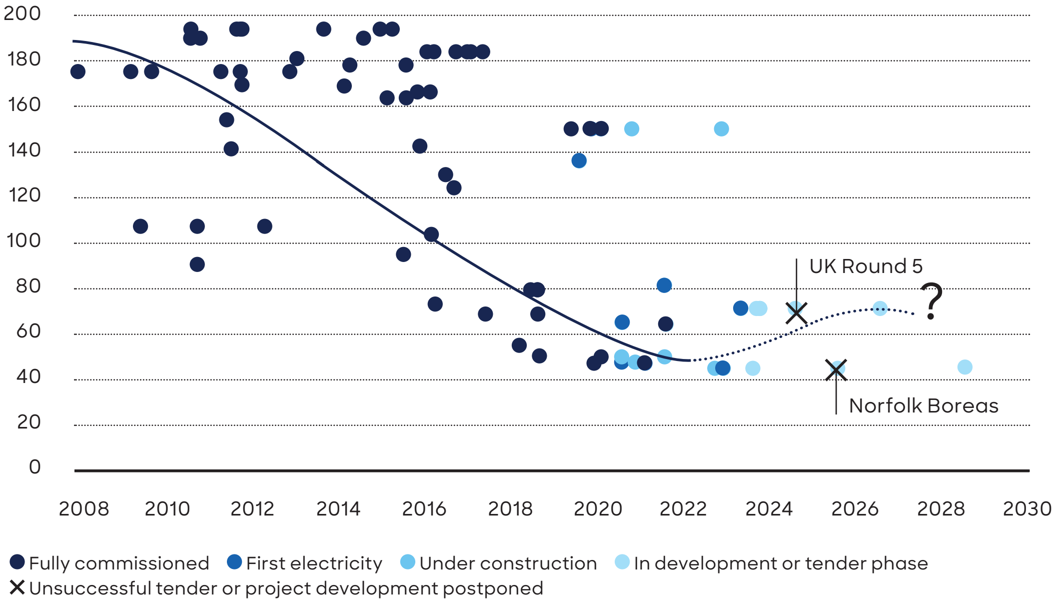
3

Robust supply chain to keep costs in check

The ramp-up of OW is necessary, but it is massive. The only sustainable way to keep costs in check during this ramp-up is to develop a robust and fully industrialized supply chain across the OW and adjacent sectors. The stronger the supply chain, the better it will withstand intrinsic cost pressures. For Europe's consumers, further cost reductions are a prerequisite to their support for the energy transition. For Europe's energy-intensive industries, further cost reductions are simply a question of survival. Over the last decade, we saw OW costs drop considerably in the strike prices in contracts for difference (CfDs) and feed-in tariffs (FiTs) of operational wind farms. But costs began to rise again in 2022 due to inflation – which hits raw material prices – interest rate hikes, and supply chain bottlenecks. The levelized cost of energy (LCOE) of wind farms in Europe has gone from ~50 to ~70 EUR/MWh,[3] and offshore grid connection costs are also expected to increase (e.g. from EUR 14 to 38/MWh[4] in the Netherlands). This cost reversal has already led to the postponement of the Norfolk Boreas wind farm and the failure of the 5th CfD allocation round in the UK. ▶ **C**

In the coming years, OW farms will move further from shore and into deeper waters. This will inevitably increase the costs of foundations, installation and grid connections. Once OW is responsible for a large share of electricity generation in a country, additional costs will also be incurred to balance its intermittency, e.g. through energy storage solutions like batteries and green hydrogen. The costs of OW must therefore be kept in check if we want to keep our energy system affordable. And to do that, we need a robust and fully industrialized supply chain that is on the same page.

C Strike prices of wind farms at date of financial close [EUR/MWh]



Note: Strike prices after conversion from local currencies to euro. No corrections made for e.g. inflation and scope of the project (e.g. incl. vs. excl. grid connection), water depth and distance to shore. Chart shows all offshore wind farms in NL, BE, UK, DE, PL and FR, tendered with feed-in tariff (FiT) or contract for difference (CfD), of at least 100 MW and at > 10 m water depth

Source: 4C Offshore

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[3] Based on "Offshore Wind Energy Market Study – Implications for Tenders IJmuiden Ver Gamma and Nederwiek I" from AFRY in April 2014, and on Vattenfall's 2023 announcement of a 40% rise in the Norfolk Boreas project costs

[4] Based on TenneT's 2023 announcement of EUR 14/MWh for five grid connections already operational, and the projected average cost over 2032–2057 of EUR 38/MWh for all grid connections to reach the Netherlands target of 21 GW by 2032

4

Rat race to ever-larger turbines

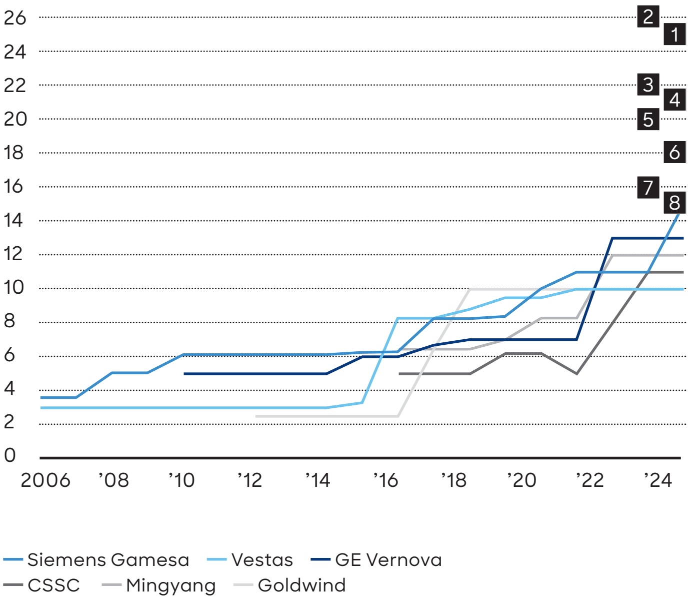
The OW industry has long been in a race towards bigger and better, especially when it comes to turbines. Up to now, size has mattered. The taller the turbines, the bigger the rotors, the more energy generated. And size is also how OEMs have been able to differentiate themselves and claim market share.

Today, turbines of 14-15 MW are installed at commercial wind farms. The largest operating prototypes are a 16 MW Mingyang and an 18 MW Dongfang. According to reports, Siemens will soon complete a 21 MW prototype at the Test Centre Østerild in Denmark. Several Chinese turbine OEMs have recently announced much larger turbines in their development pipelines, with a rotor diameter of more than 310 meters and swept area of 10.5 soccer fields. ▶D

This "rat race" is fueled by a vicious cycle in the sector. Governments want to accelerate OW capacity rollout, of course, to reach their climate targets, as well as lower energy costs for industry and consumers. As a result, some countries are organizing very competitive auctions, where project developers must place a financial bid for the license to build a wind farm - so-called negative bidding. This only leads to local, short-term cost pressure on the supply chain, not to longer-term, structural cost reduction. ▶E

D Turbine capacity per OEM [MW]

Commercially operational[1]



Not yet commercially operational

Announced

1 CSSC 25 MW
Shanghai Electric 25 MW
Goldwind 25 MW

Component rollout

2 Dongfang 26 MW
3 Goldwind 22 MW

Prototype

4 Siemens 21,5 MW
5 Mingyang 20 MW
6 Dongfang 18 MW
7 Goldwind 16 MW
8 Vestas 15 MW

[1] Minimum turbine capacity from projects with the following criteria: bottom-fixed, wind farm size above 30 MW, partial generation or fully commissioned

Source: 4C Offshore, Company websites, Press releases, Industry press articles

E Vicious cycle in the OW sector

1. Governments

Climate targets not met due to supply chain bottlenecks

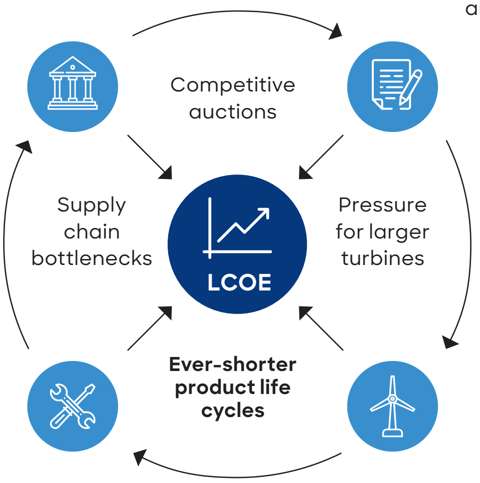
Energy not affordable for industry and consumers due to LCOE increases

2. Project developers

Lower margins due to pressure on revenues from negative bidding in auctions, and higher costs from supply chain bottlenecks

Projects postponed due to supply chain bottlenecks

Operational downtime from performance issues with new turbine models



3. Turbine OEMs

Competitive pressure to develop and launch ever-larger turbines

Accelerated pace of introduction of new turbine models

Performance issues with quickly launched new models

4. Component and foundation manufacturers, installers and ports

Inability to invest in R&D, capacity extensions and industrialization due to uncertainty around future turbine sizes

Source: Sector interviews

In turn, project developers are keen to lower the LCOE in order to maintain their profitability, as well as to place winning bids in new tenders by beating the competition with lower costs. Project developers therefore look to use the newest, largest turbine models, anticipating the potential savings they will bring.

Turbine OEMs are launching ever-larger turbines to keep up with their competition, as larger turbines potentially mean more market share or higher margins from value pricing. So product life cycles are shrinking fast as OEMs accelerate the pace of introductions, leading to performance issues at the early stages of wind farms. Ever shorter product life cycles also lead to limited uniformity in the installed base, which drives up maintenance costs for OEMs and project developers alike.

All of this is creating substantial uncertainty for component and foundation manufacturers, installers and ports, which need reliable forecasts on future quantities and specifications in order to make their investments. For example, component and foundation manufacturers in R&D, capacity extensions and their industrialization; installers in new installation vessels; and ports in new quays and marshalling yards. Not only is the size race making it impossible to know what the next turbines will look like – how large they will be – but also when they will even be introduced. These players are therefore starting to deem investments too risky, and we are seeing many postpone their plans. This is already leading to bottlenecks in the supply chain, and even a slowdown in innovation and industrialization, which in turn hampers capacity rollout and drives up the LCOE.

The rat race has taken an adverse turn. This can be particularly seen with turbine OEMs, which are not only struggling to stay profitable but are also struggling to ramp up capacity due to slower-than-expected headcount additions, production delays, and insufficient component quality. Such challenges have recently led to the postponement and cancelation of new turbine models, which in turn has caused the postponement and cancelation of new wind farms. The vicious cycle must end.

5

Diminishing returns on larger turbines

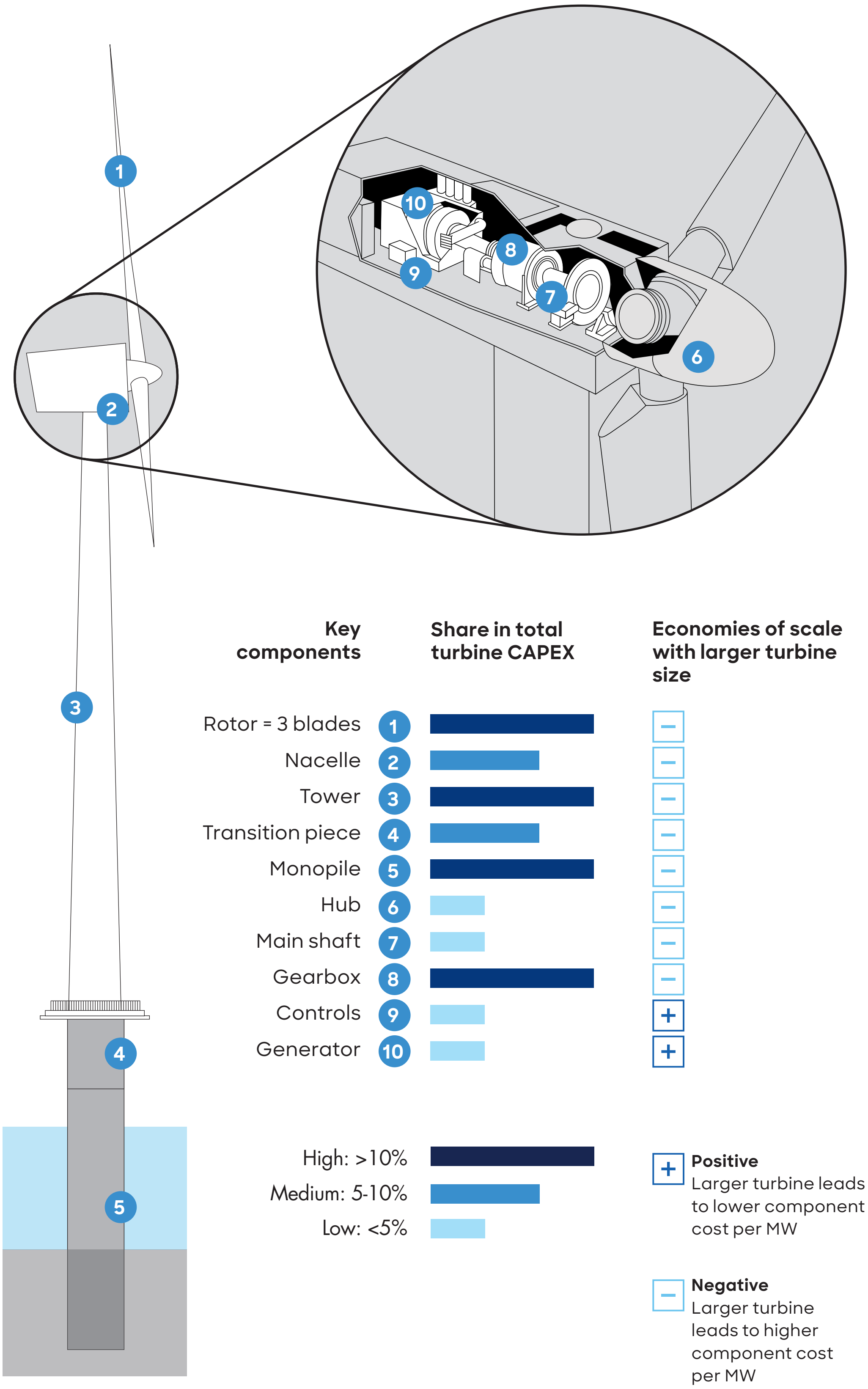
In the past, the development of larger turbines not only stimulated the sector, but also contributed significantly to reducing the LCOE. But it is clear that these benefits are now diminishing.

We are reaching the tipping point where incremental steps to larger turbines no longer yield positive returns. Up to now, larger rotors with higher turbine capacity in MW reduced costs by reducing the number of turbines necessary to reach a certain capacity. But obviously, larger turbines are more expensive, even in terms of MW capacity, as the most expensive components suffer from a negative economy of scale. ▶ F

Even though the cost per unit was much higher, fewer turbines still meant both lower CAPEX and OPEX due to savings in installation and O&M. These benefits, though, are starting to diminish. Due to the massive dimensions of current turbines, further incremental increases of turbine capacity are relatively lower than in the past, and thus lead to a relatively lower decrease of the number of turbines that are necessary for a wind farm of a given capacity. Therefore the cost benefit of larger turbines decreases. ▶ G

> **“ The OW industry must triple its capacity. Now is the time to lay the groundwork for a robust, future-proof supply chain, to ensure competitive cost of electricity and continued industrial activity in Europe.”**
>
> **Bram Albers, Partner at Roland Berger**

F Economies of scale in turbine from turbine size[1]



Key components		Share in total turbine CAPEX	Economies of scale with larger turbine size
Rotor = 3 blades	①	█	−
Nacelle	②	▓	−
Tower	③	█	−
Transition piece	④	▓	−
Monopile	⑤	█	−
Hub	⑥	░	−
Main shaft	⑦	░	−
Gearbox	⑧	█	−
Controls	⑨	░	+
Generator	⑩	░	+

High: >10% █

Medium: 5-10% ▓

Low: <5% ░

+ **Positive**
Larger turbine leads to lower component cost per MW

− **Negative**
Larger turbine leads to higher component cost per MW

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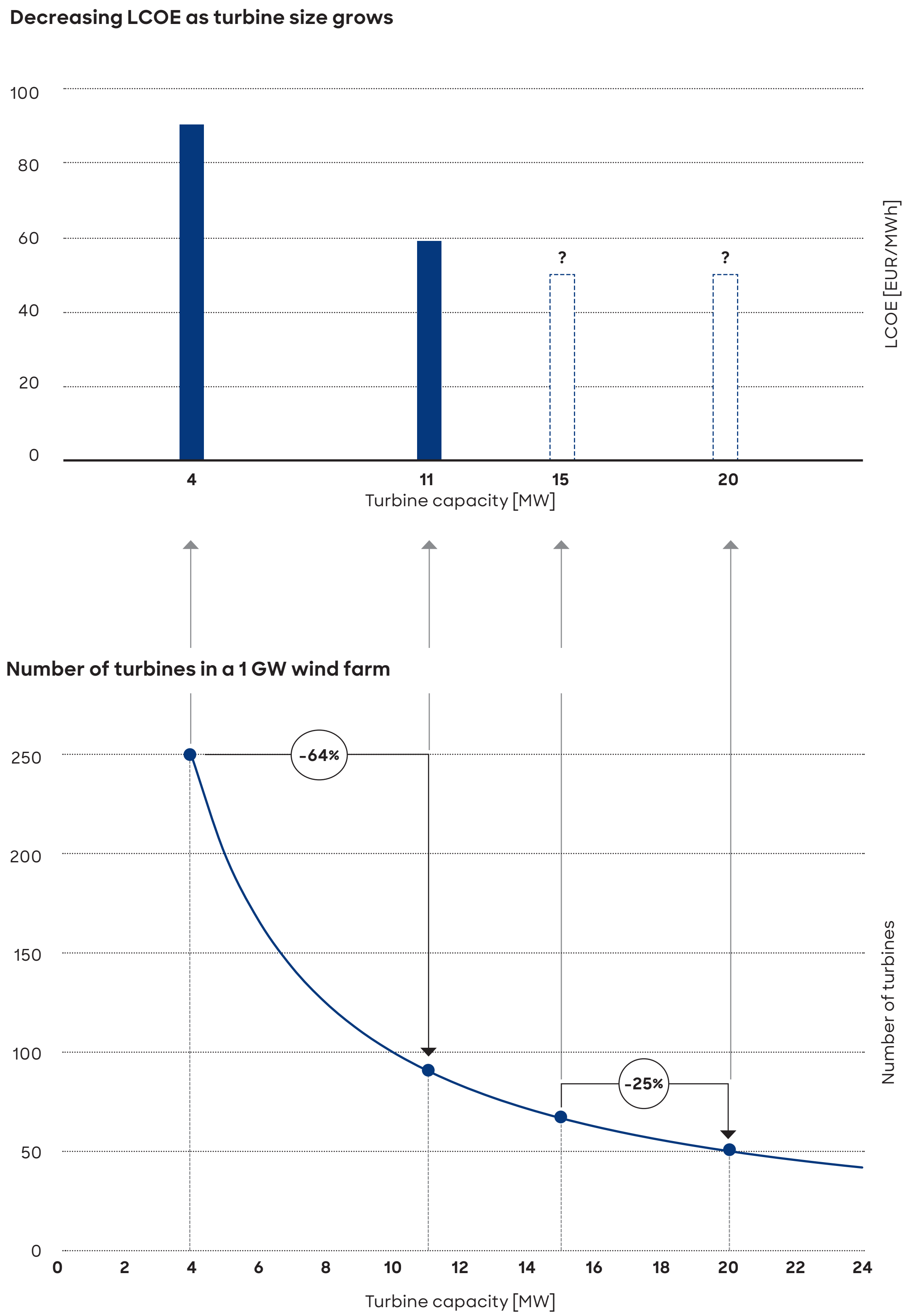
[1] "Pathways to Potential Cost Reductions for Offshore Wind Energy", TNO, BLIX, January 2021

Source: TNO, BLIX, Roland Berger

G Diminishing returns of even larger turbines



Source: Aegir Insights, Roland Berger

6

Setting a standard size

To halt the increasingly fruitless rat race towards bigger turbines, we need to set an industry standard for turbine size, and to do so for long enough that the European OW industry can break out of the vicious cycle and build the robust, industrialized supply chain it needs. The standard should be set at the dimensions of the generation of 14-15 MW turbines that are currently being delivered for commercial wind farms, so that OEMs can further optimize their current models and there will be no uncertainty about future turbines for a long period. Standardization will lead to longer product life cycles, and this will lead to:

- **Stronger learning effects**, and therefore higher efficiency, better product quality, and more certainty throughout the supply chain;
- **More predictability in the capacity rollout**, bringing about more certainty for investments in R&D, capacity extensions and their industrialization.

Figure H presents the benefits of a fixed turbine size – and therefore longer product life cycles – in detail. ▶ H

A report by DNV[5] published in 2022 confirmed that the cost benefits of longer product life cycles will far outweigh any potential cost benefits of the current rat race. Many analogies exist in other industries, which show that fixed standards have significantly accelerated capacity ramp-up and reduced costs. For example, during World War II, the United States realized a massive rollout of the Liberty cargo vessels through imposing a simple, easy-to-manufacture standard design. The ISO standards for shipping containers have realized huge cost savings in loading, unloading and transfer of cargo. ▶ I

A fixed size will still leave ample room in the supply chain for differentiation and competition, especially when it comes to aspects like turbine performance, installation techniques, circularity gains, cybersecurity and ecological protections. In fact, the extensive cost reductions that a standard size will generate across the supply chain, combined with the industry's proven capacity to work closely together on wind farm projects and longer-term innovations, will give Europe's industry a considerable boost competitively, not just at home but also across the international OW industry.

> " To halt the increasingly fruitless rat race towards bigger turbines, we need to set an industry standard for turbine size, and to do so for long enough that the European OW industry can build the robust, industrialized supply chain it needs."
>
> **Maarten de Vries, Senior Associate at Roland Berger**

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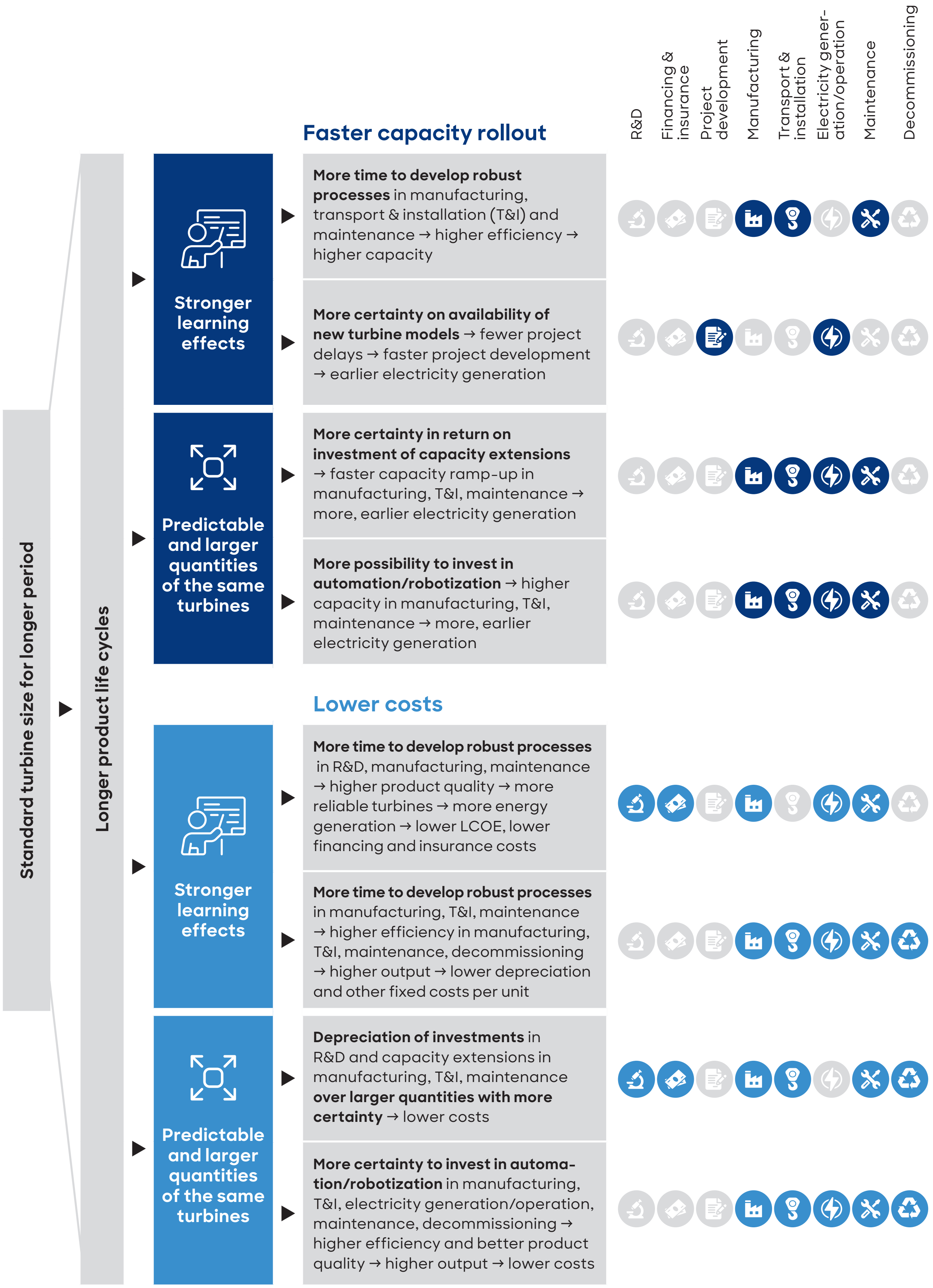
[5] "Optimal offshore wind turbine size and standardisation study", DNV for TKI Offshore Energy, April 2022

H Benefits of a fixed turbine size



Standard turbine size for longer period ▶ Longer product life cycles

Faster capacity rollout

		R&D	Financing & insurance	Project development	Manufacturing	Transport & installation	Electricity generation/operation	Maintenance	Decommissioning
Stronger learning effects	**More time to develop robust processes** in manufacturing, transport & installation (T&I) and maintenance → higher efficiency → higher capacity	○	○	○	●	●	○	●	○
	More certainty on availability of new turbine models → fewer project delays → faster project development → earlier electricity generation	○	○	●	○	○	●	○	○
Predictable and larger quantities of the same turbines	**More certainty in return on investment of capacity extensions** → faster capacity ramp-up in manufacturing, T&I, maintenance → more, earlier electricity generation	○	○	○	●	●	●	●	○
	More possibility to invest in automation/robotization → higher capacity in manufacturing, T&I, maintenance → more, earlier electricity generation	○	○	○	●	●	●	●	○

Lower costs

		R&D	Financing & insurance	Project development	Manufacturing	Transport & installation	Electricity generation/operation	Maintenance	Decommissioning
Stronger learning effects	**More time to develop robust processes** in R&D, manufacturing, maintenance → higher product quality → more reliable turbines → more energy generation → lower LCOE, lower financing and insurance costs	●	●	○	●	○	●	●	○
	More time to develop robust processes in manufacturing, T&I, maintenance → higher efficiency in manufacturing, T&I, maintenance, decommissioning → higher output → lower depreciation and other fixed costs per unit	○	○	○	●	●	●	●	●
Predictable and larger quantities of the same turbines	**Depreciation of investments** in R&D and capacity extensions in manufacturing, T&I, maintenance **over larger quantities with more certainty** → lower costs	●	●	○	●	●	○	●	●
	More certainty to invest in automation/robotization in manufacturing, T&I, electricity generation/operation, maintenance, decommissioning → higher efficiency and better product quality → higher output → lower costs	○	○	○	●	●	●	●	●

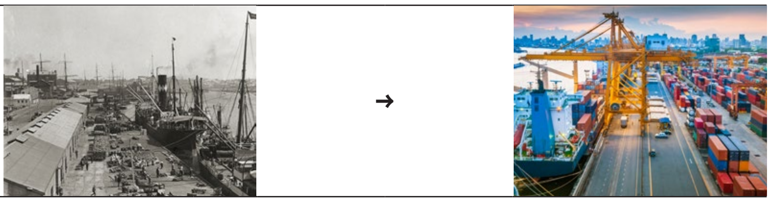
Source: Roland Berger

Analogies of fixed standards in other industries

Liberty ships in WWII

Industry	**Shipbuilding, maritime**
Building phases (illustration[2])	
Scope of standardization	Design and construction standardized to a simple, easy-to-manufacture design
Impact of standardization	**Efficiency:** Accelerated shipbuilding, enabling quicker mass production of 39 days/ship from 230 days/ship achieved in 2 years (1941-1943) **Costs:** Reduced costs per ship via economies of scale and reduction in complexity

Shipping containers

Industry	**Shipping/logistics**
Shipping container evolution[3+4] (illustration)	
Scope of standardization	Size, shape and construction standardized globally to enable mechanized loading (replacing labor-intensive work)
Impact of standardization	**Efficiency:** Streamlined loading, unloading and transfer processes, reducing container loading costs by 95% - From USD 5.86 per ton to USD 0.16 per ton **Interoperability:** Seamless transportation and incentivized global adoption of loading equipment

[1] Record production time in a Baltimore shipyard in 1943
[2] Images: Library of Congress, https://www.loc.gov
[3] State Library of South Australia
[4] iStock/primeimages

Source: Navalhistoria.com, ISO, IMO, Roland Berger

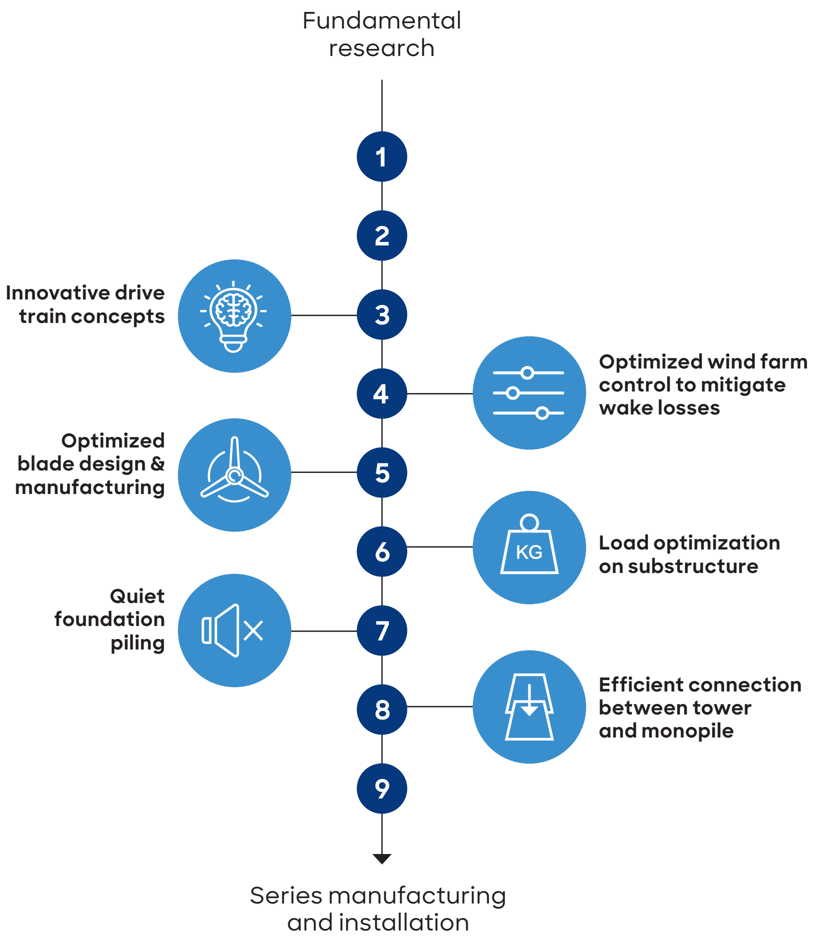
7

Standardization roadmap

Fixing a standard for turbine sizes at commercial wind farms in the coming years does not mean hitting the brakes on the development of larger turbines. Despite the diminishing returns of the current incremental steps, a much larger step – for example to 30 MW – may bring further LCOE reduction by reducing the number of turbines necessary to reach a certain capacity on a wind farm, also depending on other cost impacts throughout the supply chain.

Besides much larger turbines, many promising technological innovations can also lead to lower LCOE. These innovations are at different stages in the R&D pipeline. ▶ J

J Technology readiness levels of a selection of technological innovations that can reduce LCOE[1]



[1] "The Netherlands' Long-Term Offshore Wind R&D Agenda", TKI Offshore Energy, Roland Berger, 2019; "Pathways to Potential Cost Reductions for Offshore Wind Energy", TNO, BLIX, 2021

Source: TKI Offshore Energy, Roland Berger, BLIX, TNO

Innovative drivetrain concepts

Generators with superconducting magnets is one such example. These are electromagnets made from coils of superconducting wire. They are cooled to cryogenic temperatures during operation. In its superconducting state, the wire has no electrical resistance and therefore can conduct much larger electrical currents than ordinary wire. They result in a lower generator weight, which can enable a larger turbine size. And they eliminate the need for rare earth metals for permanent magnets. Other innovative drive train concepts could involve hydraulic gearboxes with high efficiencies and nearly no maintenance requirements.

Optimized wind farm control to mitigate wake losses

Large-scale aerodynamic interactions between turbines within wind farms are still not well understood. Simulations and physical models are necessary to get a better grip on these interactions in order to optimize control of the entire array of a wind farm, mitigate wake losses, and gain higher energy yields.

Optimized blade design and manufacturing

Modular blade designs can facilitate easier installation and lower production cost. Specific attention is also being paid to joining methods. The automation and robotization of blade manufacturing can lower CAPEX and increase manufacturing precision, lowering O&M costs. Circular product designs, taking into account end-of-life solutions, are also in development.

Load optimization on substructure

Optimization of wind turbine control aims to reduce (fatigue) loads to optimize the design and/or extend the lifetime of the turbine and its substructure.

Quiet foundation piling

Cost-efficient reduction of the ecological impact of noise from the hammering of monopiles, e.g. vibration and rotation piling, water jets.

Efficient connection between tower and foundation

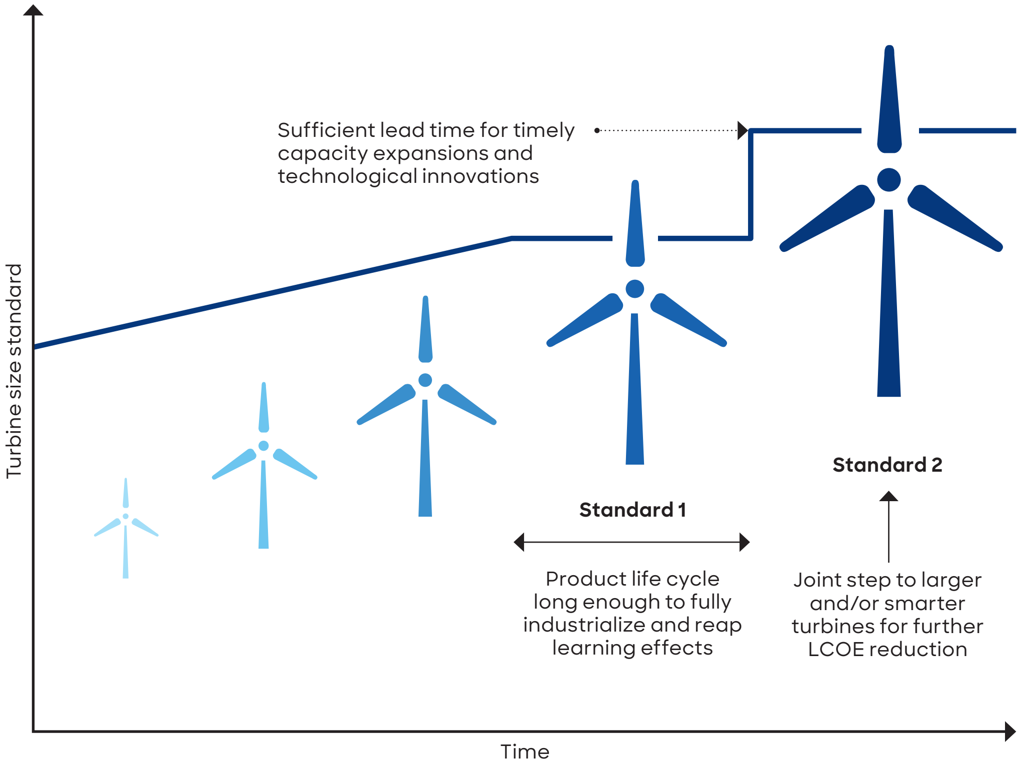
Novel approaches to connecting tower and support structures can make the installation process more efficient. Examples are slip joints and wedge-bolted connections.

To realize much larger turbines and technological innovations, the industry must plan a clear pathway ahead for the move to larger and/or smarter turbines; it must develop a standardization roadmap, as it were.

This roadmap will create predictability around the next step up and its timing. In this roadmap, the industry will align on the dimensions and timetable of the next standard, e.g. 30 MW for commercial deliveries in 2037, if that is found to be the next cost-effective step. This will give the supply chain the assurance and time it needs to plan for and invest in capacity extensions and their industrialization for the coming years while having ample time to plan ahead for the next step up. Predictability around future turbine sizes is also essential for the development and introduction of technological innovations. ▶K

K Turbine standardization roadmap

Predictable timetable for the step-wise increase of the turbine size standard will enable suppliers to **forecast requirements** accurately and make **informed investments in capacity extensions and technological innovations**



Source: Roland Berger

> **"For the longer term, the industry must develop a roadmap with a standard for much larger and/ or smarter turbines – to create certainty for the supply chain to invest in further ramp-up and innovation."**
>
> **Benno van Dongen, Senior Partner, Roland Berger**

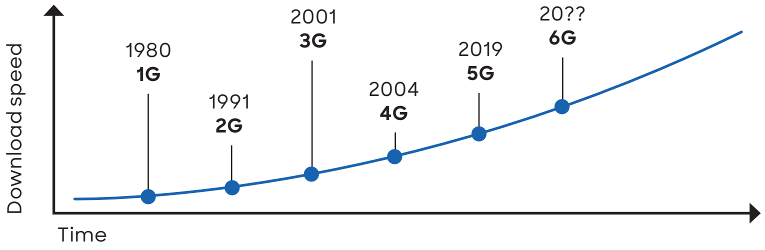
Again, we can turn to compelling analogies in other industries to demonstrate the benefits of standardization roadmaps. In mobile data communication, the International Telecommunication Union (ITU) sets the standard for mobile data communication, ensuring interoperability of networks and devices across the globe. ▶L

In semiconductors, Moore's law has measured the great strides made in performance. For instance Advanced Semiconductor Materials Lithography (ASML) continuously upgraded the photolithography technology in its manufacturing equipment to produce ever-higher-performing semiconductors. ASML has realized transitions to shorter lithography wavelengths that make higher resolutions of the electronic circuits on semiconductors possible. Each step forward required innovation in how the light was generated, from visible blue light to ASML's current extreme ultraviolet technology. ASML published roadmaps for those upgrades, so that the complex supply chain of its equipment (which can have more than 1,000 components) could rely on fixed specifications and timetables for its upgrades.

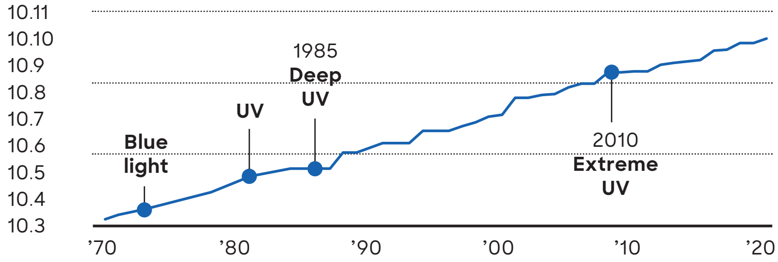
At first glance, it may seem odd to compare technological innovation in the offshore wind industry with that of the semiconductor industry. But the technology and engineering for massive turbines and their installation vessels is just as complex as that of semiconductors and the machines that produce them – the only difference is size: ever smaller for the circuits on semiconductors, ever larger for the turbines in offshore wind farms. Conceptually, there is no difference between a roadmap for a future upgrade in photolithography technology and a roadmap for the future size of offshore wind turbines.

L Analogies of standardization roadmaps in other industries

Mobile data speed

Industry	**Telecommunications, mobile technology**
Illustration **Evolution of mobile data speed**	
Scope of standardization	Global standards for mobile data communication speeds, including technical specifications The United Nations specialized agency for digital technology ITU sets the standards for telecommunication
Impact of standardization	**Interoperability:** Roadmap to ensure that devices and networks work across the globe, enhancing global communications **Innovation:** Improvement in data capacity, speed and reliability, leading to better user experience and adoption

Semiconductor performance and cost

Industry	**Semiconductors, photolithography technology**
Illustration **Number of transistors per microchip, lithography technology, 1971-2020**	
Scope of standardization	ASML's roadmap for development of more advanced photolithography technology for manufacturing equipment of semiconductors Roadmap was set by ASML for the entire supply chain
Impact of standardization	**Predictability:** Technology roadmap facilitating long-term planning of R&D efforts by component suppliers **Innovation:** Roadmap for technological innovation, so that the industry could deliver on Moore's law: the number of transistors on a microchip doubles about every two years with a minimal cost increase

Source: ASML, ITU, Roland Berger

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Action now

For some years, the European OW industry has been talking about setting a turbine standard. The Dutch OW industry association NedZero, in fact, proposes the "North Seas Standard" of a tip height at 1,000 feet (~305 meters) above sea level, for the next 10 years. However, to date, no European standard has yet been agreed upon.

The sector's vicious cycle is not going to break itself. It is time for governments to step in and enforce a standard. Several routes are possible, including:

- **EU standard through regulation**
- **NSEC standard (i.e. by the Ministers of Energy of the North Sea countries)**

The European OW industry must be consulted on the scope and dimensions of the standard, in other words whether the standard is in MWs or in maximum hub or tip height. Once set, national governments must enforce this standard in their tenders, and the European OW industry must set itself to developing a roadmap towards future turbine sizes.

Other standards can also be assessed for their added value and pursued, like for turbine components, monopile/mast connection systems, and vessel landings. Vestas and Siemens Gamesa, for example, are already leading the way with their standardization initiative for sea fastening, which involves the securing of towers, blades and nacelles onto installation vessels.

In offshore wind, size is no longer the thing that matters most. The supply chain must now work hard on further industrialization to achieve a timely and affordable rollout. Turbine standardization is a prerequisite for such industrialization. Only then will the European offshore wind industry become truly future-proof.

AUTHORS

Maarten de Vries
Senior Associate
Amsterdam
maarten.devries@rolandberger.com

Bram Albers
Partner
Amsterdam
bram.albers@rolandberger.com

Benno van Dongen
Senior Partner
Amsterdam
benno.vandongen@rolandberger.com

CONTRIBUTORS

Clément Audouin
Paris
clement.audouin@rolandberger.com

François Castelein
Brussels
francois.castelein@rolandberger.com

Emmanuel Fages
Paris
emmanuel.fages@rolandberger.com

Wim D'Hondt
Montreal
wim.dhondt@rolandberger.com

Manfred Hader
Hamburg
manfred.hader@rolandberger.com

Tim Longstaff
London
tim.longstaff@rolandberger.com

Urs Neumair
Munich
urs.neumair@rolandberger.com

Marc Sauthoff
Frankfurt
marc.sauthoff@rolandberger.com

Uwe Weichenhain
Hamburg
uwe.weichenhain@rolandberger.com

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Roland Berger BV
Strawinskylaan 581
1077 XX Amsterdam
The Netherlands
www.rolandberger.com

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