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Offshore Wind – Achieved Cost Reductions in Germany

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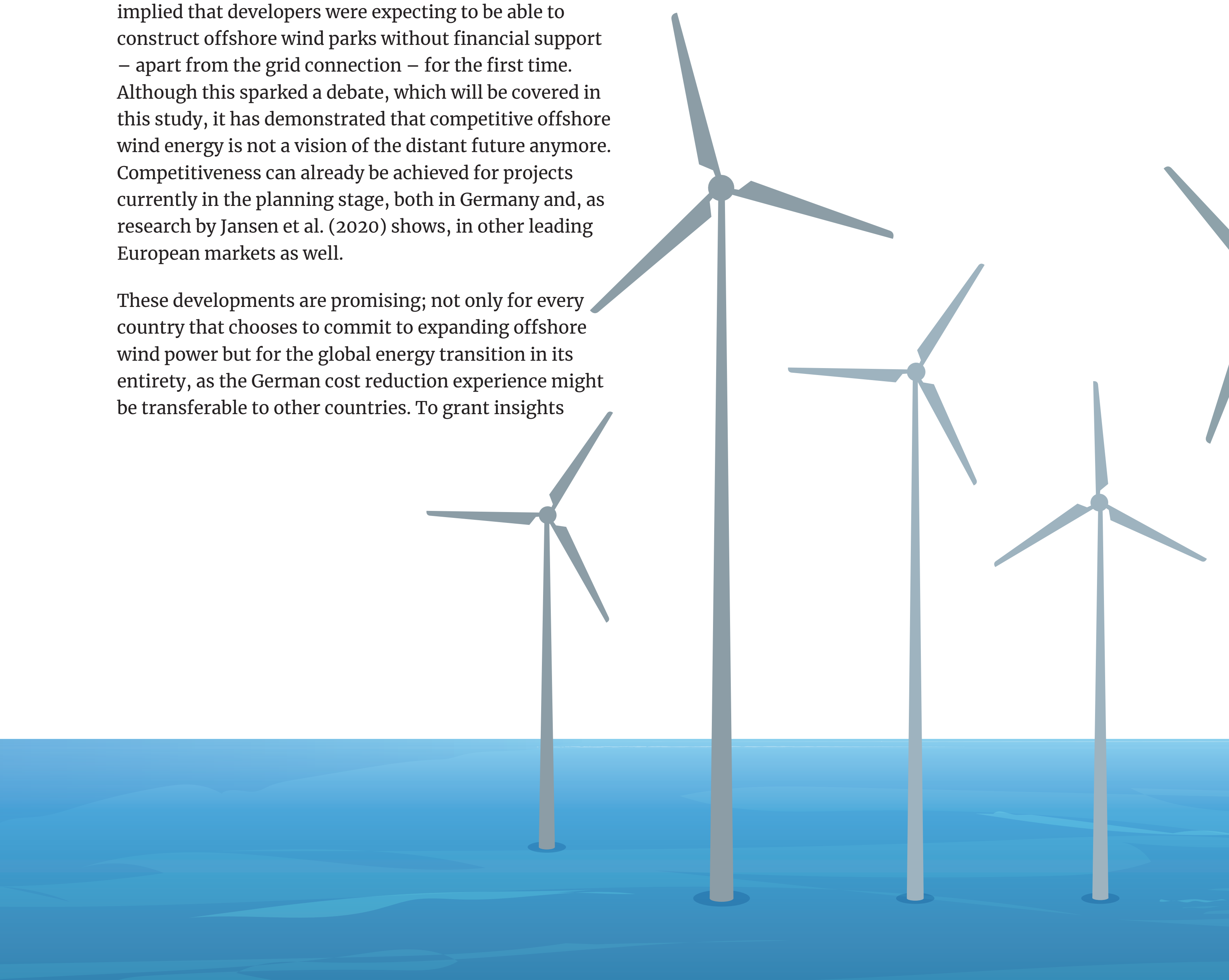
Introduction

Germany is, as of 2019, the second largest market for offshore wind power, with 28.5% of global capacity installed in German waters (Global Wind Energy Council 2020). After launching the first German offshore wind park Alpha Ventus in 2010, which also was the first wind park built under high-sea conditions in the world (Alpha Ventus 2020), the country has collected a range of experiences concerning offshore wind park development. Thanks to these experiences, Germany was able to greatly reduce the costs of offshore wind energy. These cost reductions then culminated in several zero-support bids being submitted at offshore auctions in 2017 and 2018. This event, which surprised many even though costs of offshore wind had been falling for some time, implied that developers were expecting to be able to construct offshore wind parks without financial support – apart from the grid connection – for the first time. Although this sparked a debate, which will be covered in this study, it has demonstrated that competitive offshore wind energy is not a vision of the distant future anymore. Competitiveness can already be achieved for projects currently in the planning stage, both in Germany and, as research by Jansen et al. (2020) shows, in other leading European markets as well.

These developments are promising; not only for every country that chooses to commit to expanding offshore wind power but for the global energy transition in its entirety, as the German cost reduction experience might be transferable to other countries. To grant insights into these experiences, the following study gives a brief overview of the achieved cost reductions in Germany and its drivers. It concludes with several lessons learned, which could be of interest for countries at the early stage of offshore wind development hoping to achieve similar cost reductions.

The following report is based on extensive desk research and interviews with industry experts from German associations and wind power companies. If information was obtained from an interview, it is marked as such, but the interviewees are, following their request, not explicitly cited. An overall list of interviewees is however appended to the report.



2. Cost Development Bottom-fixed Offshore

Currently, most offshore wind parks both in Germany and around the world are bottom-fixed, while the development of floating solutions is still in its infancy. Since the focus of this study is placed on achieved cost reductions, the main part will focus on bottom-fixed installations, while parallels and expected price development of floating solutions will be briefly discussed in the next chapter.

Chapter 2 focuses on recent developments regarding the cost development of (bottom-fixed) offshore in Germany. The chapter starts with a brief discussion of the submission of zero support bids at German offshore wind auctions, as this led to considerable attention at the time and is somewhat indicative of the impressive cost reductions that have been achieved. Afterwards, the general cost trend is described and placed in the European and global context. This is followed by a discussion of potential drivers and contributing factors, namely different parts of the cost structure, the political framework as well as the development of full load hours and output.

2.1 Zero-Support Bids

In April of 2017, an offshore wind auction in Germany called the attention of energy experts around the world when several companies submitted zero-support bids (Fraunhofer IWES 2017). This meant that firms were bidding to secure the right to develop offshore wind farms without financial support, at least beyond grid access (Müsgens and Riepin 2018). Such support had been the norm before and is in Germany provided by grid operators, ultimately paid for by consumers, and will be partly government subsidized starting in 2021. As the offshore wind was generally seen as more expensive compared to other forms of renewable energy production, such as photovoltaic or onshore wind, this was a truly remarkable development and started a debate about the underlying reasons. As experts were quick to point out, the German support system was not directly comparable to other support systems, e.g. in the United Kingdom or Denmark, which also differ substantially between themselves. The systems generally differ concerning details regarding the bidding process, for example, whether grid access is socialized, the level of reservation payments, and the duration until the beginning of project implementation. Characteristics of the German system, as well as strategic bidding, might therefore be reasons for the low bids (Koepp et al. 2019). Furthermore, it has been suggested that some companies had already undertaken considerable investments in these sites before bidding, which is why there was a greater motivation to secure the right to build (Industry Expert C 2020). A study from 2018 discussed these potential reasons and emphasised that the significant time between the bid and the start of construction, which allow companies to include expected technology improvements in their calculations, and a strategic behaviour to secure the option to build or grid access might have been underlying reasons for the zero-support bids (Müsgens and Riepin 2018). The significant time difference between bidding and project implementation might have furthermore allowed the companies to calculate rising electricity prices (Industry Expert C 2020). In addition, it has to be noted that the developers do not have to pay for grid access in Germany, as these costs are socialized and paid by the consumer through the electricity bill. Another factor behind the zero-support bids might have been the market power of some of the bidding companies. They might have used the bids as a signal to the market that they expected further cost decreases from their suppliers in the upcoming years (Industry Expert B 2020).

The litmus test for the zero-support bids will however be the question, whether the developers will follow through with building the proposed projects. A study by Jansen et al. (2020) states that the behaviour of companies already indicates that they are indeed planning to start construction. In addition, interviewed experts also believe that the projects will be built, namely because the zero support bids were not too surprising given prior cost trends in Europe (Industry Expert C 2020) and to avoid risking their reputation (Industry Expert B 2020). In addition, financial penalties will have to be paid in case the projects are not built.

However, it might for example be difficult to obtain financing for offshore wind parks which are entirely dependent on electricity market prices (Industry Expert B 2020). One solution in this regard is the usage of Corporate PPAs, effectively selling electricity to large corporate clients with a fixed price (Industry Expert C 2020), even though larger projects would potentially need several of them (Industry Expert A 2020).

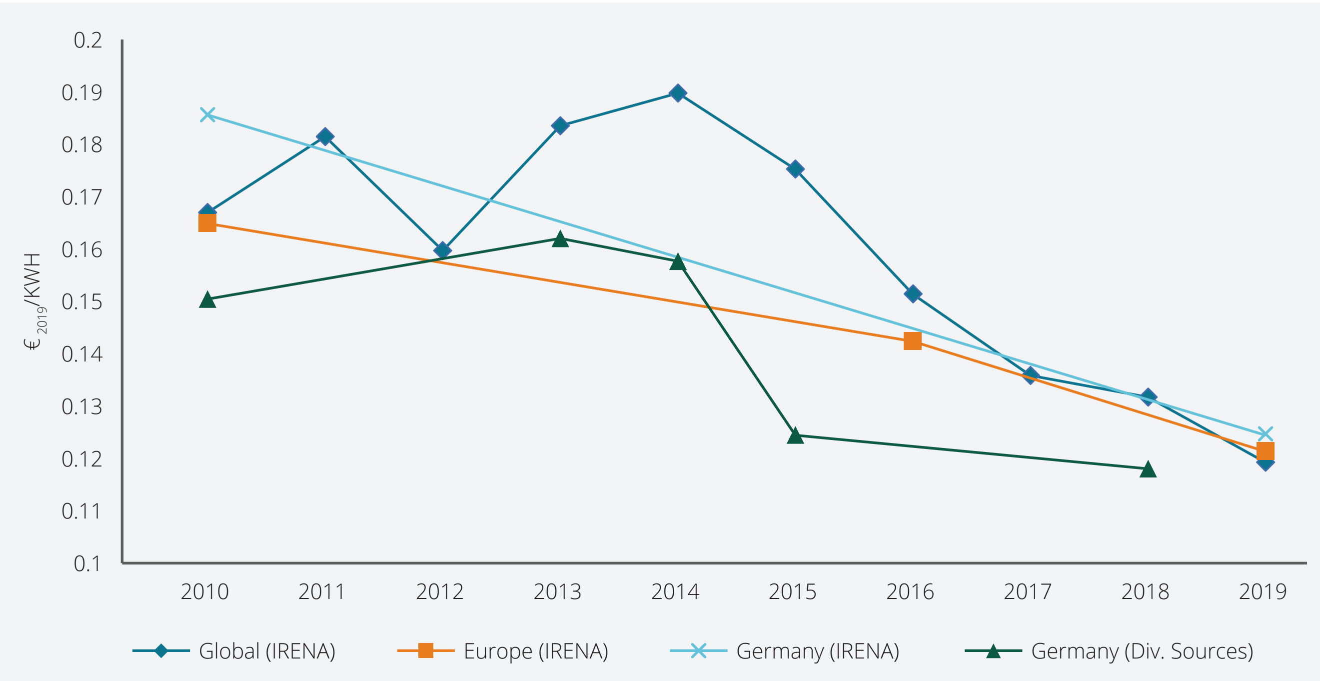
In the context of these risks, the zero support bids will only be validated by FIDs. Especially the largest of the zero-support bid projects, the 900 MW "He Dreiht" of EnBW, could in this regard be a crucial indicator. As of today, construction seems likely given that EnBW already has large-scale wind parks in operation nearby. More clarity can also be expected from the next round of auctions in Germany in 2021. Given the experiences, having additional zero-support bids in these auctions would add robustness to the cost signal that can be deducted from such bids and would furthermore underscore companies' commitment to build the wind parks.

A recently published study by Jansen et al. (2020) took a more detailed look at the developments of bids on offshore wind projects across major European offshore wind markets. The authors studied the rapid decrease in the Levelized Costs Of Electricity (LCOE)1, which are already lower than some 2050 predictions, and used auction bids to forecast harmonized and expected revenue developments over the next years. Even though these harmonized revenues are not the same as LCOE, they offer a similar overview of cost developments. Using this methodology, the authors were able to show that the revenues developers were expecting have already fallen below 5ct2019/kWh in perfectly competitive markets. They furthermore predicted that the effective subsidy will - across all analysed countries, not only in Germany – hit zero for projects with construction starting between 2024 and 2025. This means that "the era of subsidy free offshore wind turbines has begun" (Jansen et al. 2020). They furthermore predict similar developments for other regions and argue, "regions of Asia and North America [...] could expect some of the learning of Europe to play a key role in achieving similar results". This result was mirrored in the interviews conducted for this study. One expert commented that the cost development across Europe was already showing that there would most likely be zero support bids at some point, as LCOE were already as low as 10ct/KWh in auctions in Denmark in 2015 and even significantly below that in the Netherlands more recently (Industry Expert C 2020). The uniformity of such developments across different countries is mostly because a large part of the achieved cost reductions stem from technology improvements.

2.2 Development of offshore wind costs over time

Based on the findings presented in the last chapter, it can be assumed that Germany and other leading offshore wind markets in Europe have already reached a point at which offshore wind energy is price-competitive with

Figure 1: International Comparison LCOE Offshore Wind (€2019/kWh, projects in operation) (IRENA 2018, 2019, 2020; Kost et al. 2013; Kost et al. 2018; Koepp et al. 2019; DLR, IWES, IFNE 2010; Leipziger Institut für Energie 2014)



1 The levelized cost of electricity refers to the average income per unit of electricity that is required to develop, build, and run a power plant during an expected period of operation. (U.S. Energy Information Administration 2020)

fossil-fuelled energy production, even though projects crossing the zero-support line are still in the planning phase and have yet to be built. Nevertheless, scholars agree that the cost reductions in offshore wind have been impressive (Müsgens and Riepin 2018; Koepp et al. 2019; Jansen et al. 2020). Figure 1 shows the extent of these cost reductions, with LCOE decreasing to somewhere between 11 and 13 €ct2019/kWh across the globe in the last two years. These numbers apply to parks in operation in a given year; the LCOE of parks currently planned or in construction is already significantly lower. In individual auctions for parks that are currently under construction, the costs are even as low as 6 €ct/kWh, indicating that the LCOE will drop further for parks constructed during the next years (Industry Expert C 2020).

Yet, looking at the development, it becomes apparent that it has differed greatly between countries and regions. Firstly, it has to be noted that the development of the European LCOE is surprisingly similar to the global development, while the UK, Germany, Belgium and Denmark together accounted for 73% of total installed wind capacity in 2019 (Piria et al. 2020, based on IRENA), with China being the only non-European country with significant offshore wind capacity.

For Germany, two different LCOE development estimations are shown. The first one is based on data by IRENA, which only provides two data points, 2010 and 2019. These are however directly comparable to the other IRENA estimations concerning global development and the development of Europe. The second timeline for Germany is sourced from a range of different studies, which have estimated the LCOE of offshore wind in Germany over the years. Since different studies with different methodologies were used, this time series is not as comparable as the ones by IRENA, but – given the fact that the development over time is very similar in both cases – adds additional robustness to the IRENA results.

Looking at the IRENA value for 2010, German offshore wind power was significantly more expensive than in other regions. This might be because Germany started offshore wind expansion later than other large European markets (Industry Expert C 2020) and was therefore still at a very early stage of offshore development in 2010. Furthermore, the circumstances in Germany were more difficult, as even early parks were built relatively far away from the shore. Even today, German installations are significantly further away from shore vis-á-vis their European counterparts (Koepp et al. 2019) and are built in higher depths compared to most other leading offshore countries, except for Japan (IEA Wind TCP Task 26 2018). This increases overall costs, including for installation and grid connection, the latter of which is however not paid by the developer in Germany. Therefore, just based on such characteristics, the costs for German wind farms can be expected to be higher than in other countries. These factors also partly explain the results of a cross-country comparison by IEA Wind in 2018 (IEA Wind TCP Task 26 2018), which has found that Germany had the second highest offshore costs based on local conditions. These costs however decrease substantially once the political framework is considered, which in the study mostly refers to both the risks and costs related to grid connection as well as to the development and approval process, resulting in Germany having the second lowest costs for developers. This emphasizes the importance of the right political framework as far as offshore wind costs are concerned. Even with difficult geographical conditions, low costs are still achievable with the right political approach.

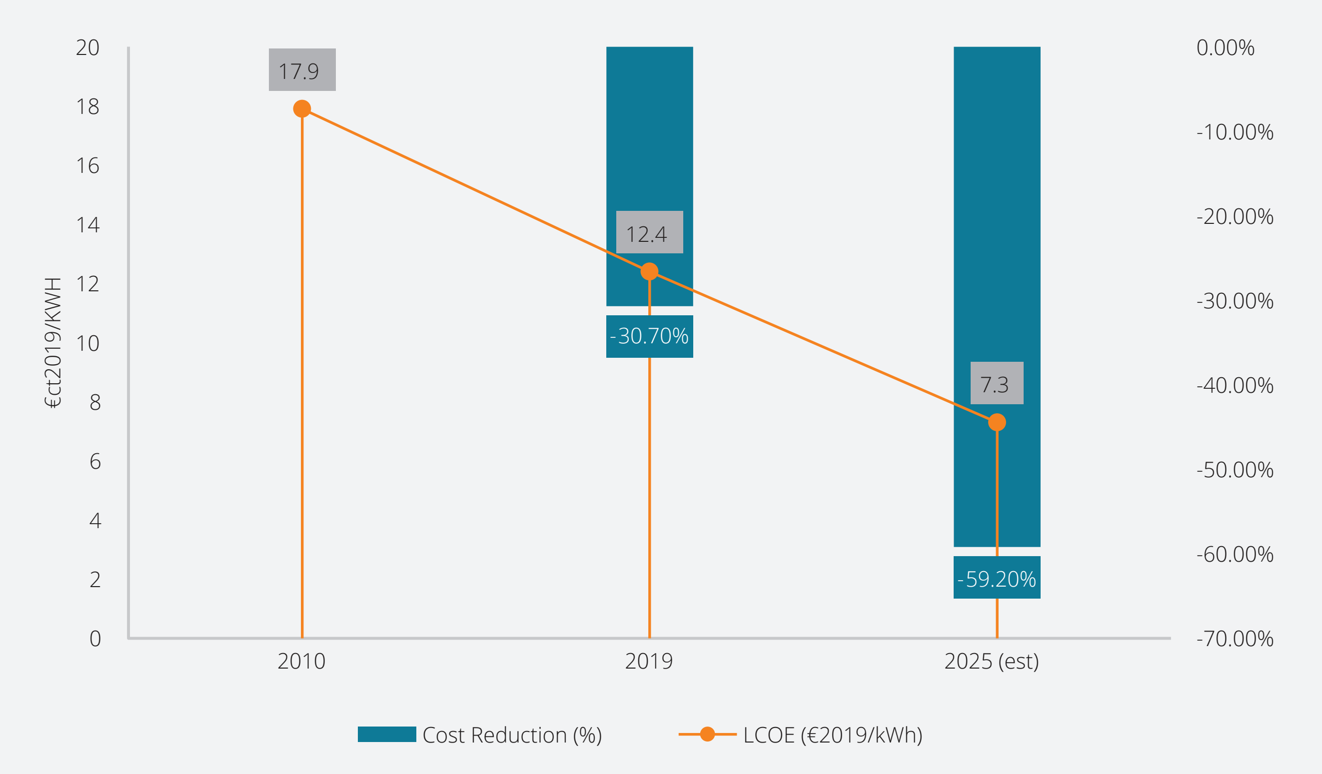
Although Germany started from such difficult conditions, both time series shows that the country managed to decrease prices at a faster rate than the European or global average, reaching a similar price level by 2019 – despite the unchanged difficult regional characteristics. Offshore wind thereby reached an average LCOE within or only very slightly above (depending on the source) the range for hard coal (Fraunhofer ISE 2018), making it competitive with dominant conventional power sources. Still, the potential for offshore wind energy is not yet reached. As the studies concerning the zero-bids presented above already indicate, experts and industry leaders expect the costs of offshore wind to drop even further. A recent study suggests that the technology still holds the largest cost reduction potentials and predicts a further drop from 12.4 €ct2019/kWh, which is their estimate for 2019, to 7.3 €ct2019/kWh in 2025 (Klobasa et al. 2019).

As shown in Figure 2, this would indicate that the costs of offshore wind in Germany, after already dropping by more than 30% since 2010, would fall just short of another 30% (based on 2010 values) until 2025, leading to an overall cost reduction of 59.2 % within 15 years in Germany. This shows not only that the German strategy has worked, and that subsidies and increased political support have allowed the technology to become competitive, but it also offers other countries an example of a pathway to cheap renewable energy.

2.3 Main Trends: Experience and Project Scale

When it comes to the main drivers of this remarkable cost reduction over the last years, two main trends are crucial, namely increasing experience in production along the value chain (en: former 2020) and, closely related, increasing project scale (Industry Expert C 2020). Increasing scale applies not only to the size of projects but is in part also related to technology improvements. Scale,

Figure 2: **Past and Projected Cost Reductions in Germany (Klobasa et al. 2019)**



as it relates to technology, will however, be discussed in the next chapter for the different cost components.

The first trend, namely experience in production, is particularly crucial, as it is directly related to a local, meaning in this context country-specific, learning curve. The experience of domestic developers as well as the build-up of domestic production capacity and related supply chains is directly related to the installed capacity in a country (Industry Expert A 2020), even though globally active developers might be able to transfer their experience.

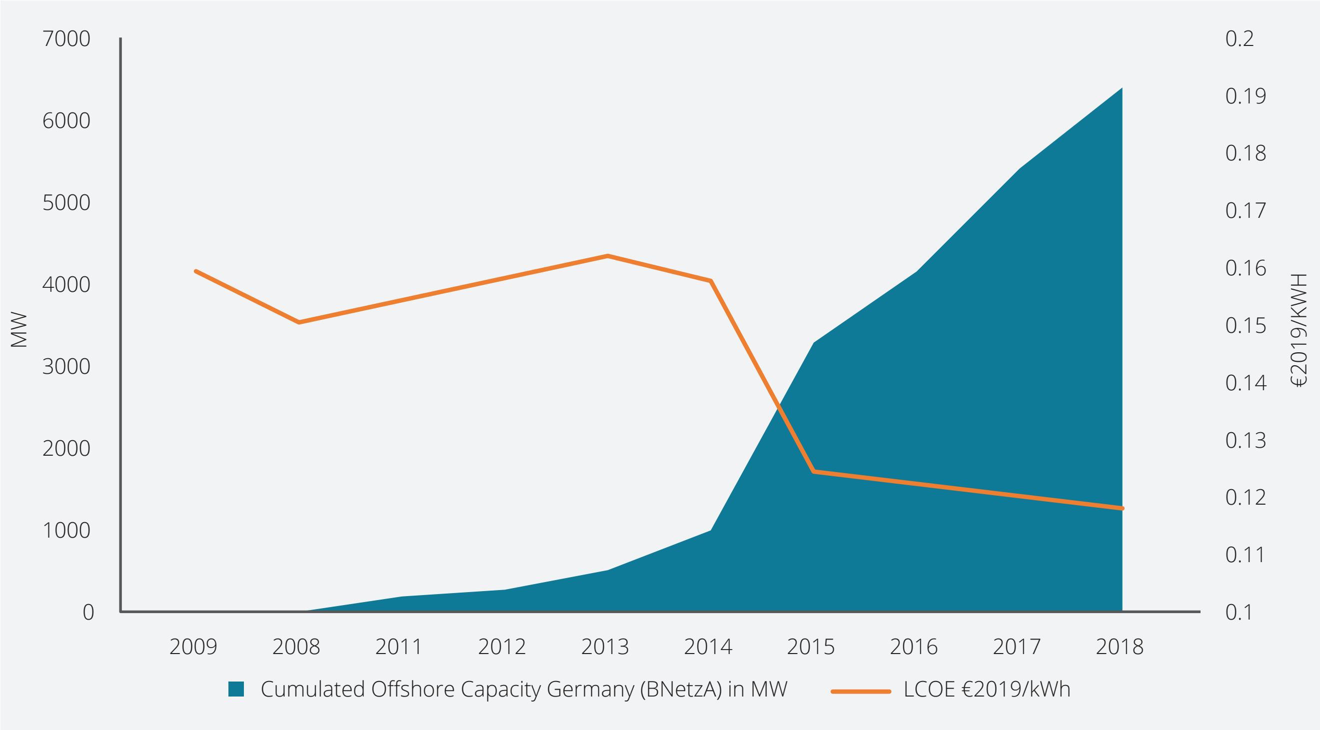
This implies that cost reductions achieved in a given country can only be partly transferred to other countries. They are only transferrable as far as they are related to universal technology improvements or experience gained by globally active developers. Cost reduction transfers in this sense are therefore dependent on the import of technology and know-how from abroad.

Therefore, a country that newly enters the offshore market needs to be aware of two points. Firstly, even though offshore costs might in the beginning not be as high as they were when first movers in Germany and Europe built offshore wind parks in the late 2000s, they will most likely still be substantially higher than current offshore costs in these countries (Industry Expert A 2020). Secondly, and that is the promising aspect, they can expect a similar learning curve as these countries (Jansen et al. 2020), which implies that, given the further technological progress, costs will most likely drop to significantly lower levels within the same time frame. However, the German experience shows that making the first move and continuing to build up capacity is crucial for this learning curve and corresponding cost reductions. As Figure 3 below shows, there is a clear correlation between the costs of offshore wind energy and the existing capacity in a country. This observation can also be made for other early offshore wind adopters and therefore holds a promise for every country willing to take a similar path.

Even more important than experience is project scale, which one interviewed expert described as the biggest driver of cost reductions in the past (Industry Expert C 2020). Even though one part of this process is related to increasing turbine size, which facilitates the build-up of high-capacity parks, the sheer size of the project also matters in itself. The underlying logic is that economies of scale impact every aspect of a project, also along the value chain (Industry Expert C 2020). In this context, having a large and integrated European market with strong offshore development has also benefitted cost reductions, as economies of scale could be achieved in the value chain.

One example of why the size of a project or even the format of the sites being auctioned matters is one of the zero-bid projects in Germany, namely the wind park "He Dreiht". This project is planned with an overall capacity of 900MW, which would make it the largest wind park in Germany to date. This fact alone might explain parts of the low costs that were achieved and allowed EnBW, the owner of the

Figure 3: **Learning and Scale - Cost Reductions and Capacity in Germany (Bundesnetzagentur 2020; Kost et al. 2013; Kost et al. 2018; Koepp et al. 2019; DLR, IWES, IFNE 2010; Leipziger Institut für Energie 2014)**



park, to hand in a zero support bid, especially since the company also has other wind parks nearby.

2.4 Cost Components

The costs of an offshore wind park are the sum of many different cost components, which are in turn determined by different factors. Even though most of them have been decreasing over time, the reasons behind these decreases are manifold and associated with different discussions regarding policy design. To allow for a more detailed discussion of the cost reduction in Germany and its ultimate drivers, it is, therefore, necessary to take a closer look at each of the different components. Following Hobohm et al. (2013), these are costs for financing, turbines or technology, installation, operation and maintenance, as well as risk and decommissioning reserves and other costs.

2.4.1 Financing Costs

For energy projects in general, investment, maintenance and fuel costs are the three main pillars of their overall cost structure. For offshore wind, as for most renewable energy sources, the latter is no issue at all – the wind blows free – while even maintenance costs are comparatively low. Investment costs for offshore wind however tend to be higher in relation to the expected output than investment costs for modern gas power plants or some other renewable power sources like onshore wind or utility scale PV, while still being lower than coal or nuclear (Lazard 2019). From a macroeconomic point of view, and setting technology developments aside, the development of investment costs vis-á-vis fuel prices (for the potential alternative, fossil fuelled power generation) is therefore important for the competitiveness of offshore wind compared to conventional energy sources.

Changing from a macroeconomic to a project perspective, it is important to emphasize that financing costs make up a significant portion of the overall costs of an individual park, which makes the interest rate and the availability of finance in general crucially important (Industry Expert C 2020). In this regard, the declining level of interest rates in Germany has supported the further expansion of offshore wind projects. Increasing trust in the technology was an important reason for the drop in interest rates specific to such projects, even though this is hard to separate from the overall declining trend (Industry Expert B 2020). At the beginning of offshore expansion in Germany, around the year 2010, the trust of investors and financial markets was low, as the technology was new and most companies had no record of accomplishment concerning the construction of offshore wind farms. However, with an increasing number of projects being successfully implemented and companies gaining more and more experience, this changed (Industry Expert A 2020). Now, financial markets generally provide strong liquidity for wind projects (WindEurope 2018), which led to cost reductions and improved the market position of offshore.

As the trust of investors tends to be low at the beginning of offshore wind expansion in a given country, measures supporting the availability and reducing the costs of financing can be of crucial importance. One solution for such issues is including established companies with a proven international record, as this sends positive signals to investors for a given project. On a more general level, the involvement of public banks can support financing at the early stages of market development. In Germany, the support by such public banks, for example by the German KfW (KfW 2020) or the EIB (EIB 2020) on the European level was of significant help. Their funding allowed for lower interest rates and thereby might have been crucial, especially in the early phase of market development (Industry Expert C 2020). In addition, other factors also contribute to financing costs. Especially policy design is crucial. A clear political framework, concise auction and bidding guidelines and a long-term policy roadmap can provide investors and developers with the necessary security and thereby drive down financing costs (Industry Expert C 2020).

As the market matures, financing becomes less of an issue. New questions arise once government support reaches low levels in mature markets. In such a case, for example in the case of the zero-support bids in Germany, projects are not protected against market fluctuations and low electricity prices anymore, increasing the risk for developers. Even though this is not yet of high relevance for new offshore markets, planning and considering different solutions for this issue might be advisable.

Since the German market has now largely matured, and coincidentally an overhaul of the existing support system was due for 2020, extensive debates on this issue have emerged in Germany over recent months. They interviewed industry experts as well as industry associations (see e.g. bdew 2020) favour systems with security measures against the risk of low prices, in particular, so-called two-sided Contracts-for-Difference (CfD), as a solution for this issue. Currently, Germany employs a floating market premium (gleitende Marktprämie), where the developer bids on a specific price and receives a subsidy if the market price falls below this bidding price. In a CfD system, companies would also receive compensation should the market price of electricity fall below the bidding price. Should the market price, however, raise above the bidding price level, additional earnings would be paid back to transmission grid operators. Such a support system effectively ensures a developer against risks associated with price fluctuations on the electricity market.

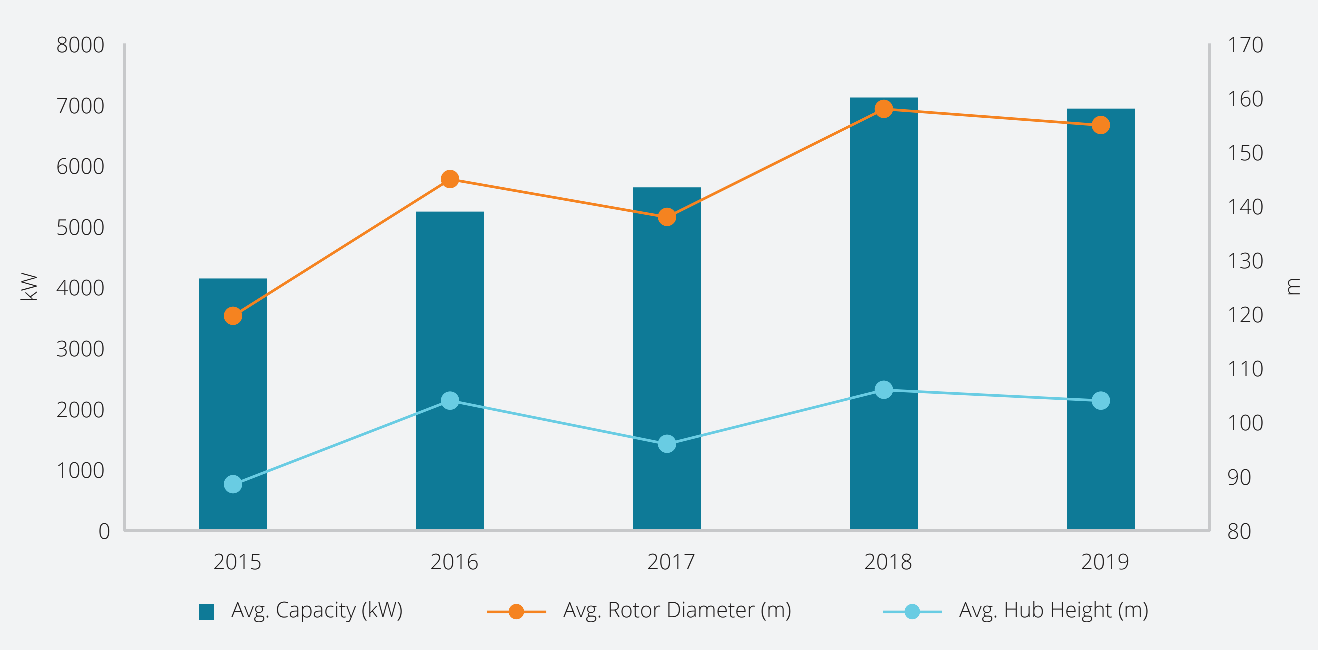
While this system is favoured by most industry and business associations that have lobbied for it extensively, the original draft of the German law in question, the Windenergie-auf-See-Gesetz (Wind-Energy-on-Sea-Act), did propose a different approach. Instead of offering CfDs, the proposal was to add second bidding round to the current bidding system. This second round would, in the case of several zero-bids, allow companies to effectively hand in negative bids, effectively paying for a part of the network access, which is provided by the transmission grid operator. Experts in favour of the proposed draft argued that the introduction of CfDs would hinder full market integration of offshore wind energy in the future, as it would protect them from market risks. Following this argumentation, this would extend the period during which offshore wind energy would still be dependent on support policies. Allowing negative bids would however offer a gradual way towards an end of subsidies (Maurer 2020). For now, the German government decided to study further, which approach would be better suited. A decision is set to be made in 2022.

Another solution for the issue related to higher financing costs due to exposure to market risks could be green corporate power-purchasing agreements (PPAs). As part of such agreements, developers sell electricity directly to large consumers at a fixed price and over a longer period. There is already a certain trend towards these arrangements (Industry Expert C 2020), especially for the wind industry (PwC 2020). They have the advantage of reducing cost risks on both sides and allow the consumer to include the fact that they are receiving green electricity from a given offshore wind farm in their marketing strategy. According to PwC (PwC 2020), the ability to meet corporate sustainability goals through PPAs is the most important driver of their popularity, while limiting exposure to energy price fluctuations and an improvement of a company's reputation also play a large role. Even though this is already a trend in the industry, a government might be well advised to incentivize such agreements, for example through certification or by including them as attractive compliance options for existing regulations, as they provide a solution for market-risk associated financing problems and can furthermore provide additional momentum for offshore wind development. Importantly, however, they only work within the current German framework of a floating market premium and would not be feasible under a CfD-scheme. Since they can be important tools to alleviate potential issues with higher financing costs, their possible usage can be regarded as an argument in favour of the approach currently employed in Germany.

2.4.2 Turbine Costs

The costs of the wind turbines themselves, including costs for the foundations and additional infrastructures, such as cables and the transformer substation, is the largest cost factor for the construction of a new wind

Figure 4: Scale Development of New Offshore Wind Turbines per Year in Germany (Deutsche WindGuard 2020)



park and amount to ca. 30%-50% of investment costs (CapEx) (Hobohm et al. 2013; Industry Expert B 2020). Turbines have however seen immense efficiency and capacity improvements. The development is so fast that developers usually plan a wind park five years in advance using turbines that only exist as prototypes (Industry Expert B 2020). In this regard, it is important that turbines, which are still in the development phase, can already be part of offshore tenders. Otherwise, parks will be planned with outdated technology, driving up costs (Industry Expert D 2020). This fast progress and increases in the scale and capacity of turbines drove down the relative costs of the turbines themselves. It furthermore greatly reduced the costs of foundations to the installed capacity since they do not change significantly with turbine size. Especially the latter is highly relevant since the costs for the foundation are one central reason why offshore wind parks tend to be more expensive than onshore ones (Friedrich 2015). In addition, larger turbines have allowed the construction of larger projects, which, as discussed in a later chapter, was also one of the drivers of cost reductions (Industry Expert C 2020). As depicted in Figure 4 below, the average turbine capacity in Germany, along with height and rotor diameter has increased over the years.

Turbines with capacities between 6 and 8 MW were standard in the past, hence the average capacity of around 7 MW in 2019, as depicted in the graph above. However, there are already models with higher capacity, MHI Vestas for example launched a 9.5 MW model in 2017 (Windkraft-Journal 2017) and currently installed parks usually operate with a turbine capacity of 8 to 10 MW (Industry Expert A2020). This trend is furthermore expected to continue in the future. GE presented a 12 MW turbine in 2019, which it plans to launch in 2021 (General Electric 2020), and Siemens Gamesa Renewable Energy recently presented their new 14 MW turbine, which is expected to come to the market in 2024 (Erneuerbare Energien 2020). Even though such large turbines are not suitable for every site, their usage will most likely contribute to a further reduction in offshore energy costs (Fraunhofer IWES 2017) and, as discussed above, offer some potential for transferrable cost reduction. This however also depends on the production scale of the new high-capacity turbines and the related learning curves (Hobohm et al. 2013).

Regarding the political framework, one aspect was furthermore crucial in driving the turbine-related cost reductions in Germany, namely the integrated European market and uniform certification of turbines following the IIC standard. Even though minor changes or additions to the standard might be necessary for other markets, following uniform certifications is important in reducing turbine costs and each deviation from such standards is costly (Industry Expert D 2020).

2.4.3 Installation Costs

Even though the costs of installation of the park are not as pronounced as the technology costs, they still account for approximately 10% of CapEx (Hobohm et al. 2013). The installation costs also experienced a substantial decline over recent years. While converted oil and other ships were for example used for turbine installation in the past, purpose-built special ships are the norm nowadays. This, along with further process improvements, has also contributed to the overall cost decrease (Industry Expert A 2020). In addition, it is now possible to install turbines even in winter, which has also decreased costs further

(Industry Expert B 2020). Another relevant factor is again the scale of turbines. Larger turbines require only slightly higher installation expenditures while providing much more capacity, which has additionally decreased relative installation costs (Klobasa et al. 2019). The same applies to additional infrastructure and, with certain limitations, can be extended the number of turbines in one single park.

2.4.4 Operation and Maintenance

The costs for operation and maintenance (OPEX) of the parks have also significantly decreased over time. This is partly due to technology and process optimization, but most importantly a consequence of wind park clustering (Industry Expert A 2020). While each park had its base for operation and maintenance in the past, parks nowadays tend to be grouped, which allows the maintenance of several parks from one base. Since adding one park to the responsibility of a base does not lead to large cost increases, this strategy has significantly reduced the overall costs. The same applies to the increasing scale of the parks themselves (Industry Expert B 2020). Further combination of maintenance infrastructure, also across companies might additionally decrease costs in the future (Hobohm et al. 2013).

2.4.5 Risk Reserve

Due to the experience of all involved actors along the value chain (Industry Expert B 2020) and a clear political framework, project risks have steadily decreased over time. While this has affected all aspects of project costs, especially financing costs as well as internal financing calculations of developers, it also directly reduced the need to include a large risk reserve in project planning. This is however only a minor part of overall project costs (Industry Expert A 2020).

2.4.6 Additional Costs

In addition to the previously mentioned cost components, there are also other minor costs, e.g. certification and approval costs or reserves for decommissioning. Even though there were some process improvements regarding the former, they have not changed much over time, which however is not crucial, as they are only marginal concerning overall costs. Another issue, which contributes only marginally to overall costs, is decommissioning reserves. Since they are roughly correlated with installation costs, they have also strongly decreased, at least on paper (Industry Expert B 2020), as no park has yet been decommissioned. But since decommissioning costs usually materialize far in the future, they are discounted and almost do not matter for current project costs (Industry Expert A 2020).

2.5 Political Framework

Apart from the different cost components of offshore wind, the political framework also plays a central role, as it provides the basis for the development of offshore projects. Experts emphasise that in this context, a long-term commitment to given policy choices is crucial (Industry Expert A 2020). In Germany, the government made commitments to pay developers a feed-in-tariff over 20 years from the start. This, in combination with the credibility of such a commitment by the German government, allowed developers long-term planning and decreased project-related risks, which would have otherwise driven investment costs and risk reserves. Changes in such a framework have to be implemented very carefully, as they can otherwise hurt the trust of investors in offshore wind projects or disrupt value chains, leaving companies without orders (Industry Expert A 2020). Spain for example radically changed their support system several times after its introduction, which disrupted the industry and severely affected market demand (European Environment Agency 2014). In addition, the design of support schemes and the tailoring of such schemes to the level of market development is also relevant for cost developments, as discussed above. Related to the stability of regulation is furthermore the reliability of infrastructure provision, in particular grid expansion. If grid expansion does not go hand in hand with offshore expansion, large projects might be delayed, increasing costs (Industry Expert D 2020).

A second important factor is the institutional quality of the relevant government agencies. According to the industry (Industry Expert A 2020), the level of professionalism in the German BSH (Federal Maritime and Hydrographic Agency) has been high from the start and processes have further improved which facilitated the construction of parks and reduced costs. It was also important that the responsibility for the exclusive economic zone more than 12 miles from the coast lies with the federal level BSH (BSH 2020).

After some early parks were built close to shore in German territorial/coastal waters, and therefore under a different and less concise legal regime, most parks were built in the German exclusive economic zone further away from the shore. Even though the larger distance increased costs overall, as discussed before, the fact that these parks were now built under a clear, federal-level legal framework decreased costs related to the approval process. However, the decision to build them further offshore was mainly due to the high number of natural protection zones in coastal waters. In addition, the BSH is in charge of spatial planning in the exclusive economic zone and is now even pre-developing sites for offshore wind parks. It thereby takes other interests and stakeholder groups into account and therefore facilitates the approval process and decreases risks of legal disputes, further reducing costs. Generally speaking, the clearer responsibilities are bundled, the lower costs are for developers. In that sense, it might be generally advisable to facilitate the planning and approval process as much as possible, ideally by providing a one-stop-solution (Industry Expert D 2020).

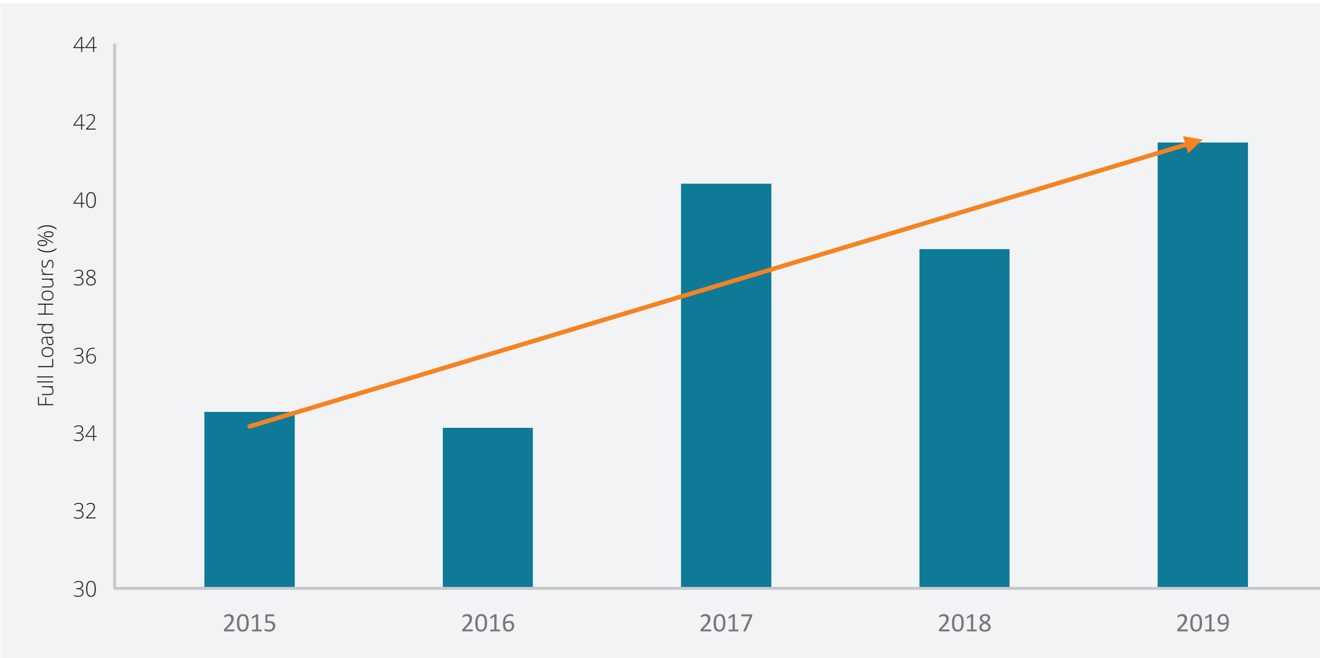
Lastly, a topic that was in part already touched on in the discussions regarding the design of support schemes is the design of auctions or other systems to select developers for offshore sites. In Germany, the price is the sole important factor in this regard, imposing no local content requirements. This approach has led to positive experiences, as an overly rigid system might prohibit the most efficient approach to a given project (Industry Expert D 2020). The focus on prices sends a clear signal and motivates companies to focus planning on efficiency. If additional requirements are imposed, they must be considered very carefully. This means on one hand that they should focus on maintaining efficiency, for example by focusing on existing industrial strengths of a given market, for example regarding specific supplier industries. On the other hand, they should follow from cost-benefit deliberations, keeping in mind which goals are to be achieved, which costs will most likely be associated with certain policy choices or targeted segments along the value chain and how goals could be achieved with the lowest costs (Industry Expert D 2020).

2.6 Output and Full Load Hours

While direct costs for the development and implementation of an offshore wind farm are certainly highly relevant, increases in the output of wind farms also played a role in cost reductions. In this regard, optimization of full load hours is important to drive down costs for the electricity generated (Industry Expert B 2020). This is especially important for offshore wind as higher full load hours represent one of its central advantages compared to onshore wind. As seen in Figure 5 above, full load hours have increased over the last few years. Experts expect further increases in full-load hours over the coming years, contributing to additional cost reductions (Fraunhofer IWES 2017). While non-technology factors also play a role in this, such as the weather conditions, the overall trend is likely related to gradual improvements in technology, operations and wind park design. One factor is also the differentiation of turbines on the global market, which allows developers to choose the perfect size and capacity for a site (Industry Expert B 2020).

Even though these improvements do not play a major role at the moment, this might become more important in the future as there is still significant potential in this regard. Therefore, the focus of the industry starts to shift from decreasing construction costs to increasing output. This might be achieved by reducing downtime, for example by scheduling maintenance at times of low wind, and by using modern technology, such as predictive analytics to do so (Industry Expert A 2020). However, one particular issue in Germany is the lack of space for offshore wind development. Even though this is not a problem at the moment, a recent report by Agora Energiewende et al. (2020) suggests that full load hours in Germany could significantly decrease in the future due to shadowing effects. This is however an issue with low relevance for many other countries, especially for ones with ample access to the suitable sea area.

Figure 5: Full Load Hours (%) in Germany (Fraunhofer ISE 2020)



3. Cost Development of Floating Offshore

The situation for floating offshore solutions is substantially different from the situation of bottom fixed ones. While the latter has been established in the German and global market for more than ten years now and have experienced astonishing cost reductions, the former are still in the development stage. Currently, only one floating offshore park is commercially operated, namely the Hywind Scotland park by Equinor (Equinor 2020). This park only has a capacity of 30 MW, which makes it a comparatively ambitious demonstration project rather than an commercially interesting park.

Due to these circumstances, the leading question concerning floating offshore is whether the technology will experience the same cost reductions over the next ten years as bottom-fixed offshore did. This can be assumed as many aspects of floating turbines are very similar, e.g. the same turbine technology can be used, which means that floating turbines can already profit from the strong cost reductions that were achieved in this regard. The actual development will however greatly depend on the number of such projects being implemented, as only this can start a learning curve (Industry Expert A 2020). Therefore, first movers are needed which are, just as in the case of the first bottom-fixed projects, willing to bear the extra costs. Experts assume that there might be some institutions willing to take such a step. Traditional oil companies, pushed towards greener energy by citizens as well as by their investors and that are already experienced in offshore construction, seem for example to be willing and able to finance such projects to become leaders in this new technology and to signal their commitment to green energy (Industry Expert A 2020).

It can be assumed that cost reductions will materialize faster than in the case of offshore wind, given the conditions outlined above. Nevertheless, the very high costs of floating offshore at the moment also imply that it might take until 2030 for the technology to become competitive with other energy sources. At the moment, floating LCOE are estimated at slightly above 20ct/kWh in Europe (WindEurope 2020), while the costs in Germany were estimated at 11,6ct/kWh for bottom-fixed offshore and 5,5ct/KWH for onshore wind in 2019 (Klobasa et al. 2019). According to industry estimations, the costs for floating offshore in Europe could reach the current level of bottom-fixed offshore by 2026 (WindEurope 2020).

These estimations and the experience with bottom-fixed offshore show that investing in such a technology and supporting it on the way to market readiness is a worthwhile endeavour. And since cost reductions for offshore have so far materialized significantly faster than expected even a few years ago, there is a possibility that this also occurs in the case of floating solutions.

4. Lessons Learned

Several lessons learned can be derived from the German experience concerning cost reductions in offshore wind. These lessons could be of special importance to countries currently planning to expand their offshore wind market.

Implement an ambitious long-term strategy for offshore wind development

Especially at the early stages of market development, at a point where financial markets and investors do not yet have significant trust in the technology and developers still have to gain more experience, credible and long-term government commitment to the offshore wind market can be vital. This goes both for the general commitment to offshore wind as well as for the commitment to clear policy choices, e.g. regarding subsidies and grid access. Regarding the former, credible long-term capacity targets in combination with comprehensive plans for achieving them can send a signal to the industry that it makes economic sense to commit to this new market. Just as important is that these targets are ambitious, as scale effects are crucial in the offshore wind industry. Only if a sufficient market size can be expected, the establishment of a local value chain becomes profitable and companies have an incentive to enter the market. This in turn decreases costs and accelerates the learning curve. Regarding the latter, a credible commitment to given policy choices and subsidies was crucial in Germany, as it allowed developers to secure planning and thereby decreased the risks involved. This had effects on all aspects, in particular on financing costs and the necessary risk reserve. It also allowed more companies to enter the market, thereby increasing competition, and reducing costs further.

In addition, infrastructure development should also follow the same stable long-term strategy. Especially grid expansion should be planned and implemented alongside offshore wind power expansion to avoid disruptions and additional costs in the process.

Stay committed to existing regulations

Although this lesson is in a way an extension of the first one, it is crucial to emphasise that sudden changes to the regulatory environment can disrupt the industry and in the worst case reset the national learning curve. Changes in the regulatory environment and especially in the support scheme might be necessary as potential cost drivers vary depending on the level of market development, as described below. Nevertheless, such changes should be part of a long- or medium-term roadmap and communicated ahead of time.

Doing so and implementing them gradually can avoid disruptions and therefore can lower overall costs. Since there is only limited export potential for related products, the local value chain and the survival of domestic companies depend highly on a constant stream of orders.

Tailor the policy and support roadmap to different stages of market development

There are different ways in which policies can be tailored to market development to make sure projects are implemented and costs, in particular for financing, are reduced. In an early phase, domestic companies tend to have a limited offshore record and the financial market is not yet familiar with offshore wind. The experience in Germany has shown that comparatively strong support might therefore be needed in the beginning, both in the form of clear and reliable subsidies and in the form of financing support by public banks. In addition, the involvement of companies with a strong overall offshore record should be prioritized through auction design. If such companies do not yet exist in the domestic market, encouraging for instance joint ventures between experienced international firms and local companies might be an option to lower costs. As the market matures, these measures can gradually be reduced. In mature markets, especially once costs are down to a significant extent, project-related risks and potentially unstable electricity prices become the main challenge. By signing long term power purchase agreements offshore wind developers can tackle this risk. The government could encourage power-consuming companies to enter long-term power purchasing agreements with offshore wind parks.

Another option, which is favoured by a big part of the industry, is government support via two-sided contracts-for-difference, which reduce the risk of price fluctuations for project developers but exclude the opportunity to make use of PPAs. This option does however hinder market integration of offshore wind energy and burdens the electricity consumer/taxpayer with the electricity price risk.

Design tenders and auctions with cost reductions in mind

As mentioned above, the focus on prices as the sole determinant of offshore wind auction winners in combination with an open and integrated European offshore market has proven effective at increasing competition and delivering low-cost offshore wind energy in Germany. Having only a few requirements allows companies to find the most cost-efficient way to building an offshore farm. Therefore, policy makers have to choose between imposing additional requirements and achieving low-cost offshore wind, as the former most likely drives cost upwards. This is, even more, the case if such requirements favour companies with no strong record of accomplishment, which increases costs at every step of the value chain.

Facilitate the regulatory process concerning offshore development

During the early phase of offshore wind development in Germany, wind parks were built under a less concise legal framework, which significantly increased the required effort and therefore the costs of these early parks. Based on this German experience, having a centralized and highly professional government agency on the federal level in charge of all aspects of offshore wind farm development can facilitate processes and reduce costs. Furthermore, if such an agency, like the German BSH, does detailed spatial planning and stakeholder dialogue, costs stemming from later conflicts with other stakeholders and associated risks can be greatly reduced.

Encourage clustering of offshore wind parks

If offshore wind parks are clustered and a certain level of cooperation between developers of different nearby parks is allowed or even encouraged, costs for the development of necessary infrastructures, such as grid connection, can be reduced. In addition, such a clustering might also facilitate operation and maintenance. This is especially the case if support infrastructure, such as specialized offshore ports of factories producing parts for the turbines are also clustered close to offshore wind parks.

Be patient and make the necessary investments

Even though the cost reductions in leading European offshore markets, such as Germany, have been impressive, they are largely dependent on local learning curves. A country entering the offshore wind market can therefore not expect that the costs of the first parks will be as low as they are in Germany right now. However, if the expertise of leading international companies is used, some technologies, e.g. turbines, can be imported and the experience of international developers as well as their credibility on financial markets can be employed. If this is done, a part of the achieved cost reductions on the European market can be transferred, even though the actual costs still depend on local conditions and the technologies used.

Just like in the German case it can be expected that costs will eventually fall significantly when the first parks are constructed. Once financial markets and investors have gained confidence in the technology and developers, a local value chain has been set up and processes have been improved, costs for local projects will likely decrease similarly to the German development, if not faster. To get to this point, first movers are needed who are willing to invest at initially higher prices. Only waiting for further improvements in the global technology level will not lead to sufficient cost reductions. Instead, having a clear and ambitious policy roadmap as well as encouraging investment in value chains can lead to fast cost reductions.

The same is true, and even more important, for floating solutions. Since the technology is still in its infancy, even more experience and scale-up is needed to achieve cost reductions. However, given the similarities between floating and bottom-fixed turbines, fast cost reductions also seem likely.

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Annex

6.1 List of Interviewees

Name (alphabetical order, does not correspond with naming of sources)	Position	Date of the Interview
Dr. Amt, Gunther	Finance Director Kaskasi Wind Farm, RWE Renewables	17.11.2020
Herzig, Gunnar	Managing Director, World Forum Offshore Wind	20.10.2020
Tschierschke, Gero	Head of APAC New Markets - Offshore Regional Development, Siemens Gamesa	27.11.2020
Wagner, Andreas	Managing Director, Offshore Wind Foundation	20.11.2020

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