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Bidding for the Future: Efficient Auction Design during Financial Headwinds

A Comparative Study of UK and German Offshore Wind Auctions and Lessons for Norwegian Policymakers

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Abstract

Offshore wind is increasingly recognized as a viable source of renewable energy and has great potential for international decarbonization. However, current supply-chain bottlenecks, inflation and interest rates have increased industry costs. Consequently, investment risk is higher, and increased compensation is required. This study investigates the auction design of the two leading European offshore wind markets, to establish best practices and ultimately provide recommendations on how Norway should approach the new market conditions.

A comparative analysis finds that dynamic auctions have been successful in less mature markets, leading to price discovery and mitigating the winner's curse. Strict prequalification criteria and penalties ensure bidder competence and financial capability. This leads to higher effectiveness, efficiency, and realization. It mitigates bidder's real option strategies, while incentivizing auction participation. Shortening the application processes and state-covered grid connection reduces planning risks and lowers investment costs. Ceiling prices should consider technology costs and market conditions to ensure auction participation, project realization and limited support costs. Support mechanisms should include complimentary revenue streams for developers via commercial PPAs or merchant nose agreements. Germany has succeeded with a one-sided CfD and reduced capital expenditure, due to state-covered grid costs. This provides high upside potential and strategic real option value, compensating developers from new perceived risk. The UK, with a two-sided CfD and developer-covered grid costs, has seen failed auctions due to lack of compensation.

Considering the current macroeconomic climate and objective of cost efficiency, the Norwegian government is recommended to have a holistic approach to auction design. Timely announced, dynamic auctions will allow for price discovery and avoid the winner's curse. Facilitating electricity grid connection and shortening application processes will reduce uncertainty and planning risk. A two-sided CfD with a subsidy cap is advised, with increased, recalculated ceiling prices to internalize the current macroeconomic situation. Moreover, the government should include inflation-indexation of contracts, as well as complimentary revenue streams such as commercial PPAs. This may turn unprofitable projects into attractive prospects.

Acknowledgements

This master's thesis is written as part of our Master of Science in Economics and Business Administration at the Norwegian School of Economics (NHH), with specialization within Energy, Natural Resources & the Environment and Financial Economics. The topic of the study was chosen in collaboration with our supervisor Eirik Gaard Christensen, because of mutual interest in auction theory and its appliance to green technology and sustainable value creation. This thesis addresses the offshore wind industry challenges in recent macroeconomic conditions and proposes auction design recommendations to Norway for its first auctions. During this process, we have gained valuable insight into auction theory, as well as the financial and environmental applications and implications auctions have on successful deployment of Renewable Energy Sources.

We would like to express our gratitude to Fredrik Horn Hansen and Equinor, for their valuable input and in addressing current industry challenges. This has been instrumental for the results of this study.

Last, we want to thank our supervisor Eirik Gaard Christiansen, for his advice and input throughout this process. The support and guidance have been an important motivation and inspiration, and we hope the study will bring you some new insight as well.

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List of Abbreviations

AURES	Auctions for Renewable Energy Support
ASP	Administrative Strike Price
BNetzA	German Federal Network Agency (Bundesnetzagentur)
BSH	German Federal Maritime and Hydrographic Agency (Bundesamt für Seeschiffahrt und Hydrographie)
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
CEM	Clean Energy Ministerial
CfD	Contract for Difference
EIA	Environmental Impact Assessment
FiP	Feed-in Premium
FiT	Feed-in Tariff
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
kWh/MWh	Kilowatt / Megawatt-hours
LCCC	Low Carbon Contracts Company
LCOE	Levelized Cost of Energy
LCR	Local Content Rules
MW/GW	Megawatt / Gigawatt
NGESO	National Grid Systems Operator
NVE	The Norwegian Water Resources and Energy Directorate
OED	The Norwegian Ministry of Petroleum and Energy
PPA	Power Purchase Agreement
RES	Renewable Energy Sources
SCP	Supply Chain Plan
SME	Small & Medium size Enterprises
TSO	Transmission System Operator

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Applied Exchange Rate

EUR/NOK**:** 11,68

1. Introduction

An increasing world population requires more energy. To meet this growth sustainably, the demand for renewable energy sources (RES) is greater than ever. Historically, administrated support systems for RES have mainly been different types of price and support contracts. In recent years, auction systems have become the preferred allocation method for RES deployment. Its utilization rate has seen exponential growth in the last 20 years (del Río, 2018).

As a first attempt to incentivize and support development of renewable energy at lowest cost, the European Commission proposed a shift from administrative support to competitive tendering in 2015, and auctions have become the main support system for EU members ever since (Côté et al., 2022). Specifically, an auction-based support system involves bidders (developers), who compete for required level of support for a set amount of renewable energy (Đukan & Kitzing, 2021). Moreover, the European Commission argues that “A well-defined auction may lead to significant competition between bidders, leading to price discovery through displaying real costs of individual projects, promoters and technologies, in turn resulting in cost sufficient support levels – effectively limiting support need to a minimum” (Grashof et al., 2020).

Since 2012, both the UK and Germany have led industry development using the auction format successfully. However, considering recent changes in macroeconomic landscape, the two have experienced very different results in their most recent auction rounds.

Altogether, given the large potential of offshore wind, recommendations based on best practices derived from a comparative analysis of these two markets may be valuable for Norwegian policymakers. As such, this thesis presents information which could aid facilitation, expansion and efficient deployment of offshore wind through successful auction design, in today’s demanding macroeconomic and geopolitical climate.

1.1 Motivation for Research

1.1.1 Background

The market penetration of RES has been limited by its higher costs relative to conventional fossil energy sources. The implementation and supply of RES has depended on public support, which opens for debates on optimal policy to ensure cost-efficiency as well as security of supply. In terms of overall energy transition, Norway is committed through the Paris Agreement. Initially, all signing countries agreed to reduce their emissions by 40 % by 2030 to limit global warming to the two-degree goal. Norway has later increased this target in accordance with the EU to reduce net emissions by 55 % within 2030. In addition, the Norwegian Parliament has adopted a notion of climate neutrality by 2030 (Klima- og Miljødepartementet, 2023).

However, Norwegian deployment of renewable energy production is subject to the principle of short-term cost efficiency (Vasstrøm & Lysgård, 2021). In other words, requirements on short-term profitability are of higher importance than the need for a new industry. The increase of auctions used for RES deployment and for offshore wind in particular, serves as the background for the scope of this master thesis. By presenting a thorough overview of the individual components of auction design and the interplay between these in the context of offshore wind, it assesses the relationship between climate policy, auction design and cost-efficiency.

1.2 Research Question

Historic literature has reviewed and analysed offshore wind market policy, although few have taken into consideration the recent changes to geopolitical and macroeconomic climate. As such, there is a gap in research on design elements and policy mechanisms which can explain the current industry development and further promote offshore wind deployment. Norway has an ambitious target of 30 GW offshore wind capacity within 2030 and is currently developing the framework for its first auctions. Hence, learning from practices and experiences from other countries may be key to Norwegian success.

Consequently, this thesis aims to answer the following questions:

1. What are best practices in terms of design elements of auctions to promote development of offshore wind today?
2. Which recommendations can be made to Norwegian policymakers based on recent experiences in the UK and Germany?

This thesis, by answering these questions, aims to fill this gap in literature. Specifically, through a comparative study of the offshore wind auction systems in the UK and Germany, investigating their auction design elements using assessment criteria described in historic literature. This is to identify best practices for auction design for offshore wind. Subsequently, the findings serve as the foundation of recommendations made to Norwegian policymakers. Thus, potentially contributing to a more efficient transition to green energy.

2. Literature Review and Theoretical Framework

This chapter considers renewable auction theory, published works which investigate the elements that are part of auction system and design, as well as assessment criteria defining RES auction success.

2.1 Categories of Auction Design

The design elements in a RES auction may be classified into four different categories. First; auction demand, second; qualification requirements, third is the winner selection process, and fourth is seller's liability (IRENA, 2023).

2.1.1 Auction Demand

Demand determines what is to be procured, and under what conditions they are auctioned. This includes the auctioned volume, periodicity, long-term responsibility for demand-side commitments and the division between different technologies. More precisely, it can be technology-specific or technology-neutral auctions, even standalone or systematic auction formats which define how renewables are supposed to penetrate the power production mix.

2.1.2 Qualification Requirements

Qualification requirements seek to determine which suppliers are eligible to participate, for example through required documentation and conditions which must be met. These may be of technical or social nature, to confirm that the participant has the adequate capacity and competence. For example, the bidder's security of grid-access, the production site selection or chosen solutions to promote socio-economic development.

2.1.3 Winner Selection Process

The winner selection process plays an important part of an auction. It describes bidding and clearing rules as well as awarding contracts to winning bidders. For example, definition of the collection of supply-side information for the competitive process, i.e. the minimum competition requirements, including provisions, to ensure sufficient participation by multiple, competing bidders. Furthermore, it defines the winning criteria, dictating the ranking of bids and awarding of the winner, the clearing mechanism defining rules of contract allocation, based on marginal bids should supply not meet demand. Last, payment rules to establish the remuneration of the project developer winning the contract.

2.1.4 Investor Risks and Seller's Liabilities

This considers obligations and responsibilities in the auction documents. They include the commitment of contract signing, contract schedule, remuneration and financial risks, quantity liabilities, settlement rules including penalties for underperformance, delay and underbuilding as well as transmission delays (IRENA, 2017). For example, features such as indexation to inflation and denomination of contracts in a neutral currency such as the US Dollar, may protect developers from inflation and currency fluctuation risk.

2.2 Auction Design Elements

The following sections reviews the design of the renewable energy auctions from historic literature and describes the components of valuation for the participating bidders.

2.2.1 Private and Common Value in Auctions - The Winner's Curse

Valuation of the auctioned item is of highest relevance for auction participants when formulating their bids. In every valuation there is a degree of common value, comprised of factors known to all participants. In addition comes private value, which is independent for each bidder, and unknown to other participants. Common value means that the true value of the item after the auction (ex-post), is the same for each bidder. For example, if their costs are approximately equal, prior to an auction (ex-ante) the involved bidders form an estimate of true value of the item, which is updated upon gaining new information.

In auctions where the valuation only relies on private values, other participants' valuations are irrelevant for the auction outcome. For example, individual costs of development and operation of a wind farm may be lower for some than others. This is illustrated by a low winning bid. Thus, learning the valuation of other participants have no impact on the winner's private valuation ex-post.

However, in the case of offshore wind-auctions, it is likely that the item has both private and common elements, both on the cost and income side. The latter are also referred to as "affiliated values". These may be of relevance to the bidding behaviour and valuation of all bidders, as the bids will depend on the expected profit from the project. Such elements may include:

Factor Type	Income Side	Cost Side
Common	Price of Electricity Sales Volume (Market Conditions and Wind Conditions) Correlation between price and value Common Learning Effects	Grid Connection Cost Seabed Conditions Regulatory Uncertainty Factor Costs
Private	Portfolio Diversification Private Learning Effects	Firm-specific Technology and Cost-structure Bargaining Power in Factor Market

Table 1 - Private and Common Factors in RES Auctions

Strategic and financial factors for an offshore wind developer differ between the income and cost side. On the cost side, the cost structure and bargaining power in the factor market is important. High bargaining power with suppliers, as well efficient technology and cost-structure is likely to allow a developer to have a lower valuation, in this case requiring lower subsidies. On the income side, systematic risk may be mitigated through a high degree of portfolio diversification, meaning that revenue from the project will not be the sole source of revenue for the developer. Private learning effects, such as information on efficiency of operations or capacity factor of the plant may have implications on revenues from the specific project. In addition, such private learning effects may be transferrable to future projects.

Common values are based on publicly available information. These are for example, on the cost side, whether the grid connections will be covered by the state, the seabed conditions for installing the plant, regulatory uncertainty on concession process or taxation. On the income side, the contract price and expected market price of electricity decides the future revenue.

The main implication of private and common value factors on auctions considers the “winner’s curse”. It entails an outcome where the bidder with the most optimistic expected valuation of the project wins the auction. Winning the auction reveals that all other developers had a lower expected value, which leads the winner risking development and operation at a loss.

2.2.2 Criteria for Auction Selection

Auctions are split into two types of bid selection: Single-criteria and multi-criteria auctions. The first uses bid-price as the sole deciding factor for winner selection, whereas multi-criteria auctions include both quantitative and qualitative criteria such as Local Content Rules (LCR), project impact on local research and development, industry, and environment (del Río, 2018).

A price-only auction can ensure the most efficient deployment of projects measured by the lowest subsidy-bids as the winner, maximizing socioeconomical impact and minimizing support costs. However, having a price-centric auction can lead to issues such as geographical clustering, favouring major players. These may have substantial financial capacity, sufficient leverage concerning supplier bargaining and economies of scale, relative to small-medium sized developers. This, in turn, excludes local communities from the decision-making process (Fell, 2017). A common practice in most auctions are public hearings and conferences proposing auction format and specification on criteria and requirements for developers.

A multi-criteria auction could include:

1. Cost efficiency
2. Innovation and technological development
3. Financial strength, capacity and experience
4. Sustainable development and Environmental Impact Assessments (EIA)
5. Local community impact and job creation

The weight of each criteria displays the relative view of the auctioneer concerning their importance. In RES auctions these are likely to align with the policy goals of a nation, for example minimized support costs, energy security, or industry development.

2.2.3 Auction Formats

According to del Río (2018), the main distinction of auction formats in a Renewable Energy Source (RES) Auctions are:

1. Sealed-bid (Static) Auctions
2. Descending Clock (Dynamic) Auctions
3. Hybrid auctions

Sealed-Bid (Static) Auctions

In sealed-bid auctions, all bids are submitted simultaneously and undisclosed, resulting in no adjustments of bids based on information on other competitors' bid prices (Luiz A, 2011). The sealed-bid auctions are further categorized into single- or multi-item auctions. The first involves auctioning a single unit of a product to a single bidder, whereas the latter involves multiple units of a given product, and bids are submitted for parts of the total auctioned volume (del Río, 2018).

Support levels in sealed-bid auctions are set in a first price or a second price manner. In a first price, sealed-bid auction, the bidders do not receive information on other competitors' bids, as they are submitted simultaneously and undisclosed. Furthermore, the winning bidder receives the award price, which is set on the highest accepted bid. A potential drawback is that it incentivizes strategic bidding. In the case of an offshore-wind auction, additional strategic motivation may reduce the developer’s required compensation below the expected costs of development, such as first-mover advantages in the form of enhanced information on future auctions (Hoel-Holt, 2022).

A second-price, sealed-bid auction involves the winning bidder as the highest bidder, but the award price is the second highest bid (del Río, 2018). Consequently, given the assumption that the award price is proportional to project realization, a second-priced auction will have a lower probability of realization compared to a first-price auction (Kreiss et al., 2017). In such an auction, the optimal bidding strategy is to bid the participant’s own valuation, as it gains nothing from bidding above or below it.

Multi-item auctions differentiate between Pay-as-Bid and Pay-as-Cleared (uniform price), sealed-bid auctions. The first has bidders include price and quantity of the auctioned product they are willing to supply as part of their bid. Then, the auctioneer compiles all submitted bids, creating an aggregated supply-curve to be matched to the procured quantity. Then, the “clearing price” is given at the price at which the supply meets the demand of the auctioned products.

The main advantage of a sealed-bid, first price auction is that it reduces participation cost. The undisclosed bids are considered to increase competition in case of few competitors (Luiz A, 2011). However, it limits real price discovery, eventually leading to “the winner’s curse”. The lack of information on competitors’ bids induces an uncertainty which must be translated into a single bid and thus the competitor bids higher to make sure to win the auction. This cannot be revised upon gaining further information, and the winning bid could have been higher than necessary to win the auction.

Descending Clock (Dynamic) Auctions

Here, the auctioneer sets a high price, and bidders place their bids in form of quantity they are willing to supply at that price. Should quantity exceed the target demand, a new round of bids with a lower price follows. The final round is when supply matches demand at the “clearing price”, which winners receive for their supplied quantity. (Luiz A, 2011). Conversely, an ascending auction initiates with a low price, which increases by each round. As such, dynamic auctions allow for real price discovery, as bidders adjust their bid prices based on new information from earlier rounds of bidding. An open bidding format allows for fewer opportunities of corruption, and budget constraints may be adjusted or removed based on price adjustments over time and between rounds. Winning bidders do not disclose their reservation price due to price being set at the supply and demand equilibrium (del Río, 2018). The winning bid closes the auction when volume is filled, but the price does not necessarily equal the marginal cost of the bidder. Thus, the lowest possible price might not be discovered.

Hybrid Auctions

These are combinations of sealed-bid and ascending clock-auctions, to mitigate the drawbacks of each individual format. These types of auctions, with a descending-clock in a first round, and sealed-bid in the second round has been effective in historic RES-auctions (Azuela, 2014). Specifically, it identifies the market price of products with unknown demand and supply. The first round allows for price discovery, which is used to lower prices in the second. The number of bidders is reduced after the initial round. Then, to avoid collusion, it is considered better to use sealed-bid auctions to reduce the award price as much as possible.

Examples of hybrid auctions include the Netherlands and Germany. The Dutch example is based on a defined budget. It consists of a multi-bid, increasing-price auction round and a pre-defined FiP based on technology levels. The first round starts with the lowest price levels, and bidders state their supplied capacity volume at this price. The next round starts with a higher price, and the process continues in an ascending order, until the budget limit is reached. The government decides the price in each round, and collects the volume offered by the bidder. This is called a volume tender (Held et al., 2014).

A further example for RES allocation is the use of dynamic auctions in a hybrid matter. Here, the initial round is a sealed-bid auction, where the outcome sets the funding level. The following rounds use a uniform pricing method to evaluate bids and determine market price from a supply and demand equilibrium. If the price bids exceed the volume bids, then funding are awarded in ascending fashion from lowest to highest until the funding budget is reached. The uniform price is set from the highest accepted bid, which is then awarded to all winning bidders (Scherer, 2016). This has historically been practiced in Germany.

Collusion in Auctions

Collusion in an auction is when bidders coordinate to achieve an auction outcome more favourable to themselves. It can occur through cartel agreements, which are generally prohibited by law. Auction-wise, collusion is tacitly forbidden by intention signals through bidding behaviour. Explicit communication may be helpful for coordination but is not a necessity for collusion to happen. The risk of collusion depends on the auction type. Single-unit auctions are less vulnerable to collusion due to difficulties for bidders to share the auctioned item, such as in a multi-item auction. Ascending auctions are more vulnerable to collusion. In case bidders are colluding, and they decide to change their actions during the bidding process, this will be signalled at once because of the open format. Thus, any deviation from the colluding parties' agreement is easily visible compared to a sealed-bid auction.

2.2.4 Ceiling Prices

The ceiling price sets the maximum limit of subsidies. Any bid above this price is not accepted. This is done to limit support costs for governments and consumers in case of uncertain or limited competition. If a participant is not able to bid lower than the ceiling price, they cannot enter the auction. The ceiling price is set based on relevant factors. These can be previous contract prices, or market analysis and industry consultations. The estimates normally internalize the expected Levelized Cost of Energy (LCOE) for the project, i.e. the expected cost of development and operation over its lifetime (del Río, 2018).

One consideration is whether the ceiling price should be made public before the auction start. The action of setting a ceiling price will bear the risk of asymmetric information, similar to FiTs (del Río, 2018). A too high ceiling price risks inefficient outcomes as bids can be placed above a bidder's LCOE. At the same time, a too low ceiling price reduces competition due to lower participation levels. This, in turn, increases the risk of undersupply. Setting the optimal ceiling price reduces excessive levels of subsidies for projects. Further, it mitigates some risk of uncertainty and limited competition, or collusion between bidding parties. An alternative is to also set a minimum value, where a bid below set price is excluded. This has been practiced in Cyprus (Fokaides and Kylili, 2015).

Moreover, the ceiling price should be set at a level that allows for competitive price discovery. If set too low, it signals low subsidies available which likely leads to reduced auction participation. The advantage of disclosing a ceiling price prior to the auction, is that it prevents bidders from placing bids outside the ceiling price due to insufficient information. Furthermore, it increases planning security for bidders, increasing auction acceptance.

2.2.5 Auctioned Volume

The auctioned volume is set in three different ways:

1. Electricity Generation Target – where total energy generation is set for a total amount of MWh, where bids are awarded per kWh or MWh
2. Capacity Targets – This sets a fixed, total capacity of MW or GW
3. Budget Target – This includes a set, total volume to be auctioned, often a combination of option 1 and 2

The Electricity Generation Target and Budget Targets both ensure a high degree of certainty around policy costs, and the first provides grid integration and management benefits. The latter offers a precise estimate of generated electricity from the auctioned projects. However, the basis of the estimate may be difficult to establish. This can lead to uncertainty and risk for developers because of the variable nature of the renewable energy source input (del Río, 2018).

The most common international practices for RES auctions are capacity and budget targets. A budget target is practice in the UK, while the Polish government has set a maximum and minimum value of electricity produced. Denmark has previously pursued a FiT for a set generation capacity (del Río, 2018).

The auctioned volumes are often linked to a country's policy targets. Auction volume transparency seeks to incentivize auction competition. What is more, the risk of high support costs is lower when an auction attracts competition. Higher volumes mean higher risk and production costs, thus larger developers are attracted. It makes the threshold higher for smaller developers to enter the market, as they are not able to draw sufficient economies of scale without higher subsidies. An example of this was seen in South Africa, where the developers' matureness was overestimated. This lead to reduced competition and clearing prices close to the ceiling prices (Eberhard et al., 2017). Furthermore, some instances practice an auctioned volume higher than government policy targets, to achieve a sufficient deployment rate. Here, the risk of delay or non-delivery is internalized (de Vos, 2014).

2.2.6 Diversity

There are auction design elements that contributes to neutrality of participation or awarding of technologies, actors, geographic locations, and project sizes. In short, requirements for diversity in an auction context may reduce competition and increases market segmentation. Moreover, it encourages collusive behaviour from bidders, which results in higher auction prices and system costs. Consequently, the initial advantages of promoting diversity in auctions must be weighed against the objective of minimized support costs. This requires thorough analysis of technology and market skills of developers (del Río & Linares, 2014). In the case of cost equality of technologies, differentiation might not be necessary, as the deployment of the most cost-effective projects will be the outcome either way (Held et al., 2014).

Technological Diversity

Auctions may be technology-neutral or technology-specific. From a policy perspective, technological diversity leads to achievement of long-term strategic objectives on RES deployment and carbon footprint reduction. This is because it allows use of multiple resources, reducing the wind-fall profits for low-cost technologies, and aids industrial development and local supply chains. On the other hand, technology-neutral auctions focus on achieving short-term objectives in the most cost-efficient way. This design element depends on the auctioneers weighted short- and long-term strategic goals. The trade-off between cost-efficiency and long-term goals, and diversity criteria can fragment the auction process and reduce competition. This is due to higher barriers of eligibility for bidders, in turn leading to higher auction prices. Other ways to incentivize diversity are to include percentages required to meet diversity criteria such as demand for local content, i.e. local suppliers as part of the project. Another way is adding bonuses to support less mature and cost-efficient technologies (del Río & Linares, 2014).

Installation Size

Auctions are normally used for larger scale projects. Large companies are highly represented because of high transaction costs. This serves as barriers of entry for small-scale companies. Introducing size criteria to incentivize small-scale company participation in the auction will have negative implications in terms of cost-efficiency. This is due to less economies of scale and static efficiency. Smaller installation size does however help with actor diversity. Support mechanisms for small players reduce transaction costs in auctions and increase their ability to provide a winning bid (del Río & Linares, 2014).

Geographical Diversity

Prioritizing geographical diversity in auctions is empirically linked to lower allocative efficiency. However, it promotes social acceptance, avoids excessive subsidies for areas with high resource density and lowers grid restrictions. One solution is to link subsidies to location-specific wind levels. This avoids over-dimensioning of grid capacity (Held et al., 2014). Such site-specificity requires additional government resources but reduces risk of delays and non-delivery. This is because developers have a more accurate estimate of integration costs such as land agreements, grid connection and environmental permits (IRENA, 2017).

Actor diversity

Arguments against small developers' auction participation is their potential inability to access adequate, affordable financing. This indicates a higher need for subsidies or financial aid. The resulting lower static efficiency must be weighed against its advantages. Investor types vary in size, risk-preference, and outcome. Larger, commercial developers target large-scale investments and windfarms, while smaller, local actors focus on individual wind turbines. Thus, a combination of investors are required to achieve the full potential of RES (Ragwitz & Steinhilber, 2014). Actor diversity can be promoted in the auction design by i.e. introducing quotas or limiting maximum capacity per bidder (del Río & Linares, 2014).

2.2.7 Participation Conditions

The main purpose of including participation conditions such as pre-qualification criteria is to mitigate risk of non-realization. These ensure serious bidders and avoid those who submit bids they have no intention of honouring. This makes sure that the auction avoids winning bidders who do not complete the project and hamper long-term RES policy objectives. These measures are both financial and physical of nature (Kreiss et al., 2017).

Financial Pre-Qualifications

These are also known as security and are widely applied in RES-auctions. Specifically, the bidder must pay a deposit prior to entering the auction, or at the time of awarding the contract. The main idea behind such pre-qualifications is to ensure that bidders inhabit adequate financial capacity to realize the project and simultaneously serves as an enforcement mechanism to ensure project realization, as the bidder has “skin in the game”.

Physical Pre-Qualifications

These considerations must be fulfilled to ensure bid acceptance. Examples are experience within similar projects and technology, business plan and necessary construction and environmental permits. They serve as proof of the bidder’s seriousness of realization within the set criteria (del Río & Linares, 2014). In contrast to financial pre-qualification, the costs from physical pre-qualification are internalized from the developer’s side. This reduces uncertainty around a project’s future cost structure. A developer might have an estimate for construction costs for example. Yet, should the specific requirements be uncertain, the estimates might be inaccurate, which again impacts bid values.

These physical pre-qualifications will be useful for the bidder only in the event of project realization. If not, they may be considered sunk cost, for example in losing the contract or non-realization. In addition, comes LCR, which seeks to improve local economic development and supply chains. In auction practice, these rules can also serve as beauty contests. A critique of LCR is that high demands can lead to higher investor cost and risk, which in turn leads to lower auction efficiency when allocating resources (IRENA and CEM, 2015).

2.2.8 Penalties

Penalties in auctions also work to ensure project realization. In contrast to pre-qualification criteria, it does not rely on any bidder input. Penalties can be reduction of support levels, fees, a shorter support period, excluding bidders from future auctions or even termination of contracts (Kreiss et al., 2017).

In general, a lack of failure penalties combined with long lead time, can turn a Contract for Difference (CfD) into a "real option" for developers. This real option to abandon a project increases aggressive bidding and leads to the winner's curse. This could in turn increase the risk of non-realization, as bidders abandon the project and pay the penalty rather than realizing the unprofitable project. This is substantiated by Welisch et al. (2018) and their empirical studies, which proves that auctions with penalties mitigate inefficiency and incentivize project realization.

It must be a clear distinction between project failures resulting from events outside of a developer's control, and those who are not. Delays due to issues within the supply chain or logistic matters may be mitigated by the developer. On the other hand, if public consenting processes are problematic or delayed, the developer should be compensated rather than penalized. Nevertheless, not all cases are clear-cut, and some situations may be exploited by developers to avoid penalties, for example deliberate failure to comply with necessary permits to halt project development. This could be an example of a low-cost exit from a contract, should the developer experience the winner's curse.

Financial guarantees may be considered both as penalties and as prequalification criteria. An issued deposit as a security can be paid back to unsuccessful bidders after auctions or retained as penalty to winning bidders. Therefore, realization timelines must be carefully considered when setting the threshold for penalties. A too generous timeline may lead to over-optimism on uncertainties during project development. A too short timeline can put additional time-risk on developers and push bid prices.

Compliance rules should include the following components:

1. Bid bond, normally a percentage of total project cost to mitigate risk of developers avoiding signing a CfD or commercial Power Purchase Agreements (PPA) per terms of the bid
2. Project-completion bond, based on percentage of total project cost, to mitigate risk of non-realization
3. Penalty for delays, mitigating risk of setback at set stages of project development
4. Under-production penalties or tariff for over-production, to mitigate risk of project volume insufficiency or surplus

The rules should offer some flexibility to ease the burden on developers. For instance, if a developer produces a deficit one year due to slow winds, this deficit can be compensated by a surplus next year. If the required total is met over the two years, then the developer should not be penalized.

2.2.9 Support Conditions

An important aspect of auction design is the types of remuneration to the winner. Normally it is determined by capacity (total MW), or generation (MWh). Support levels can be set through instruments such as a Feed-in-Tariff (FiT) or Feed-in-Premium (FiP). Under a FiT, the volume is the determinator of remuneration – i.e. the contract price is fixed per MWh of generated electricity. A Power Purchase Agreement (PPA) is settled with utility providers as the obligatory purchasing counterparty.

PPAs are long-term agreements to purchase clean energy from a specific asset at a predetermined price between a renewable developer and a consumer, generally a company requiring high amounts of electricity – or between a developer and a supplier who then resells the energy. Signing of a PPA can be understood as the sale of the project and its environmental attributes. I.e., a commitment that allows a renewable developer to secure profitability and reduce revenue risk, or even obtain necessary funding for project investment and execution (Iberdrola, 2023).

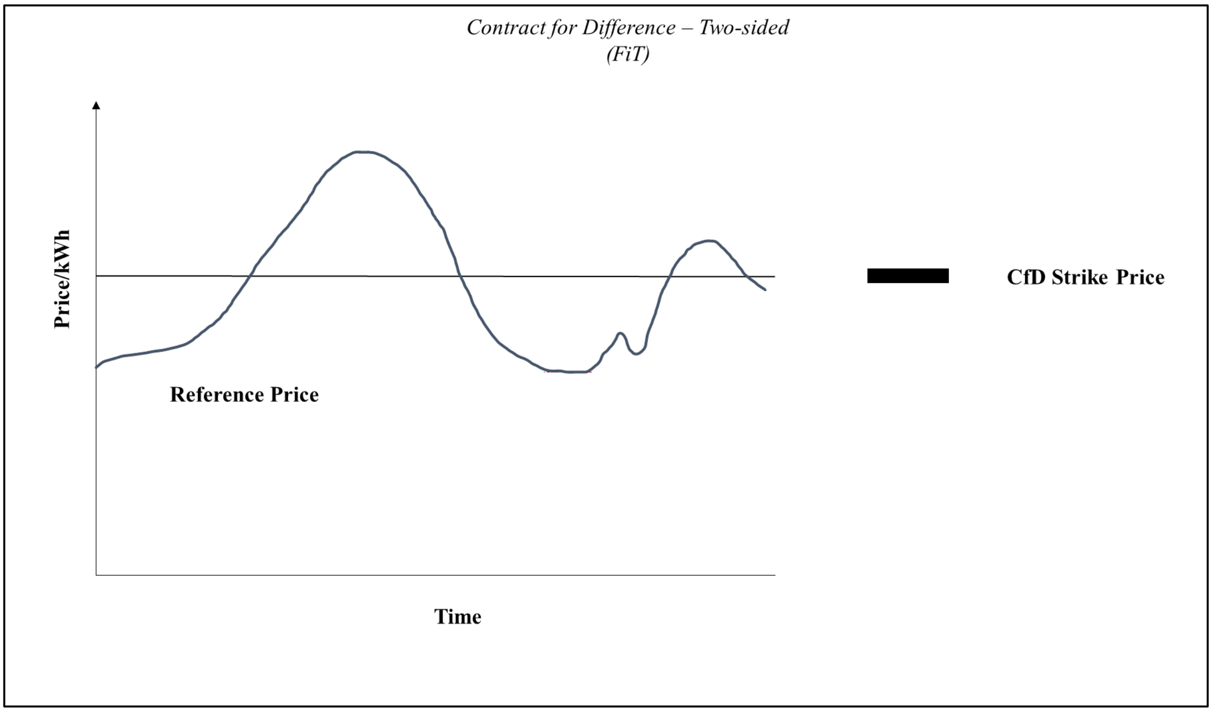

Figure 1 - Illustration of Contract for Difference, Feed-in-Tariff (FiT)

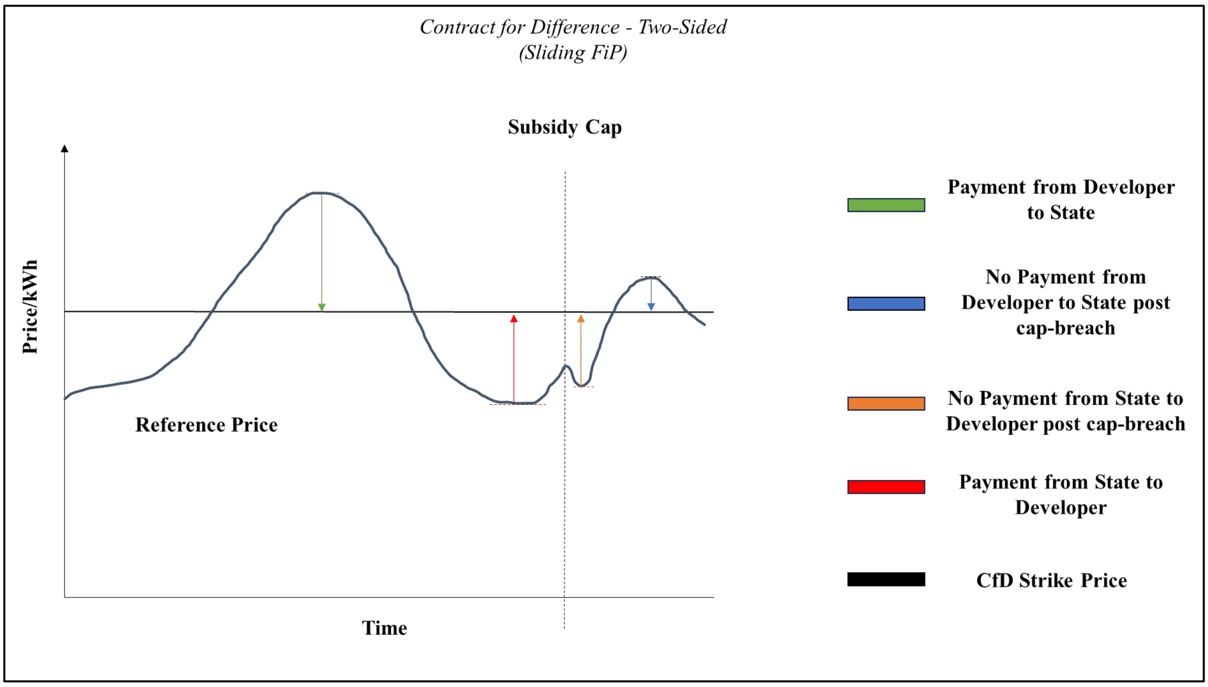

Figure 2 - Illustration of Contract for Difference with Subsidy Cap, Sliding Feed-in-Premium (FiP)

A FiP scheme includes a CfD. They come as fixed or sliding FiPs. A sliding FiP involves a two-sided CfD. In a two-sided CfD, the developer is entitled to a fixed payment, stated as the strike price in the contract. It closes the gap between the market price and auction strike price through a calculated reference price. The reference price is based on the average market price in each time-period, normally per month or annually. Any surplus from sales, in the event of reference prices being higher than the contract price is paid back to the auctioneer. Should the reference price be below the contracted strike price, the gap is remunerated by the auctioneer to the developer. In the case of a subsidy cap, the remuneration in times of a lower reference price compared to contract price will stop after the cap is reached, or the contract period is over. This form of contract provides a fixed revenue stream over the contracted period, shielding the counterparts from volatile market prices. In other words, it guarantees the producer a price floor and a subsidy roof for the potential compensation payment, limiting support costs for the auctioneer (IRENA, 2017).

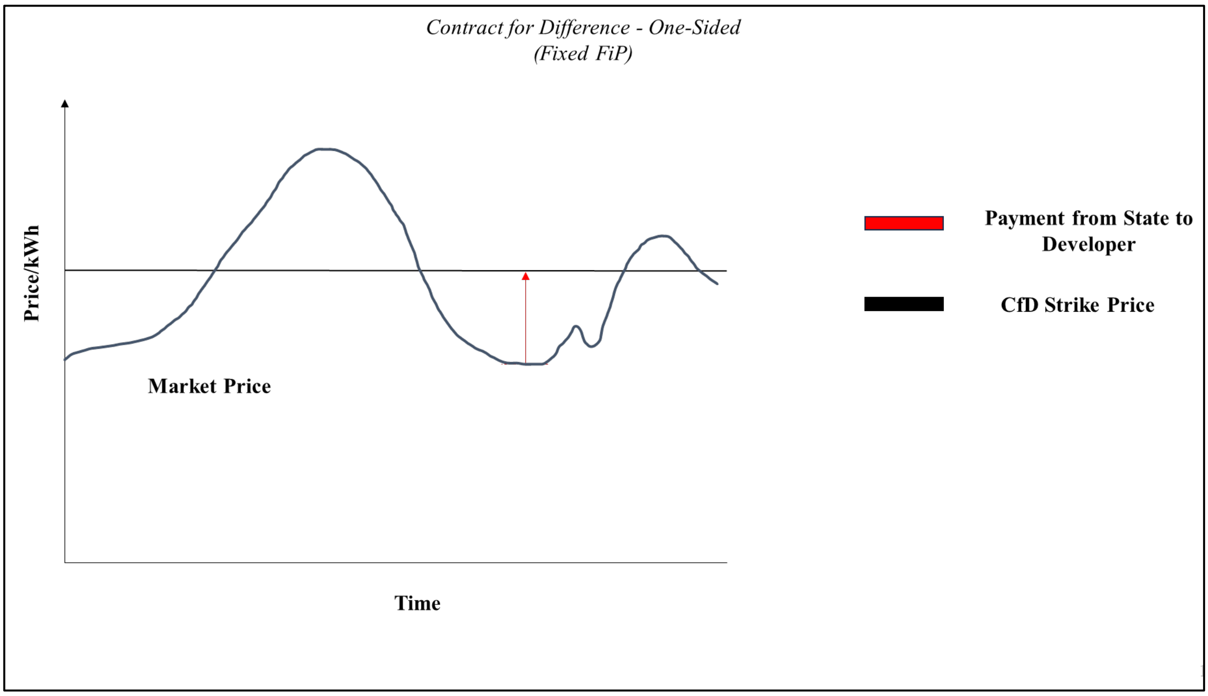

Figure 3 - Illustration of Contract for Difference, One-Sided - Fixed Feed-in-Premium

A fixed FiP scheme involves a one-sided CfD. Here, a price floor is given to the developer, which is the agreed strike price in the contract. However, here the developer has a potential upside in cases with a market price above the price floor, where any surplus is not needed to be repaid to the state. However, this market-based approach does bring more revenue risk, as the income depends on market prices rather than a guaranteed, fixed amount. (IRENA, 2017).

Other support conditions could also be implemented to increase attractiveness for bidders. For example, in the UK, developers are also allowed a “merchant nose”, i.e. postponing the start date of the CfD up to 12 months after operation start, allowing for sale to wholesale market electricity spot prices.

2.2.10 Realization Period

A realization period is included both in auctions and the contract period. It reduces the developer’s uncertainty on support duration, while minimizing support costs. Optimal realization period length balances efficiency and completion. A longer support period eases project financing and reduces subsidy requirements. However, it extends consumer burden. A shorter duration brings higher contract prices to recover investment cost over a shorter time span. Industry practice for determining the realization period is to calculate the break-even point of the project and adding a certain level of profitability. A high MWh remuneration does not necessarily imply a high support amount, as the support duration can be short. Moreover, shorter realization periods complicate financing for smaller developers. They are less able to apply economies of scale and cost efficiency to break-even in a shorter period compared to larger developers.

2.3 Assessment Criteria for RES Auctions

To determine the success of RES auctions, it is necessary to define assessment criteria for the various auction design elements. This thesis' criteria are based on historical work performed by members of the "AURES - Beyond 2020 project", information from policymakers, country-specific case studies in various energy policy journals (del Río, 2018) and public government. These are complemented by industry stakeholder correspondence (Horn Hansen, 2023). Specifically, this section describes these assessment criteria in greater detail.

2.3.1 Effectiveness

This criterion measures the percentage of target volume achieved in an auction. For RES deployment, it measures the installed capacity of renewable energy in MW, or the generated electricity, MWh, for a given period (normally one year). Important for the assessment is the variety in project size and capacity factor of the project, which depends on resource availability and developer capacities. RES auctions are considered effective if deployment reaches its targets, allowing for a small, negative deviation. High effectiveness relies on auction designs aligned with policy targets, while incentivizing project realization for winning developers.

Another way to measure effectiveness is based on electricity consumption. This requires analysis of energy demand fluctuations, as consumption is based on energy efficiency. The assessment of effectiveness considers electricity consumption relative to a country's potential for renewable energy generation. Last, effectiveness may be measured based on project realization rates, referring to the percentage of projects completed from awarded projects. Due to various risks, there has historically been non-realization in multiple countries (del Río & Linares, 2014).

2.3.2 Efficiency

Efficiency of renewable energy generation is defined as achieving the target with the lowest possible cost. This may be done in two ways; minimizing overall development cost for a given capacity (cost/MW) or minimizing cost of electricity generation (cost/MWh). This is defined as static (macroeconomic) efficiency. The counterpart is dynamic efficiency, relating to reduction in cost of future RES development. Schemes incentivizing a currently expensive technology can increase future static efficiency for that technology.

Static Efficiency

An auction achieves static efficiency by reaching the lowest cost of electricity generation, measured by comparing generation costs, indirect and direct costs combined. The first includes profile costs, balancing costs, grid costs and transaction costs. The second considers investment cost, i.e. cost of capital, interest cost from debt and equity as well as variable costs such as operation and maintenance cost (del Río & Linares, 2014). In other words, static efficiency is measured through the required subsidy for a specific project, also over time.

Dynamic Efficiency

This refers to how the auction facilitates technological progress and cost reduction for RES. By increasing dynamic efficiency, countries can impose more ambitious climate policies and accelerate green investments (del Río, 2018). This cost reduction is often reflected by lower requested subsidies, and higher deployment of new, innovative technology.

2.3.3 Minimizing Support Costs

Governments seek to reduce support costs, in turn decreasing costs for consumers and taxpayers. Historically, support costs have been high, and its impact on a microeconomic level must be evaluated in policy discussions concerning RES deployment (Steinhilber, 2012).

To define support costs, a supply-demand framework is used. Figure 4 describes support cost estimation and its elements. “MC” represents the marginal cost of renewable energy generation as a continuous, exponentially increasing curve, which indicates that cost increases proportionally with the auction quota target. This is highlighted in white. As quota target quantity “Q” is closer to be reached, more expensive technologies are awarded production volumes to fill the quota, increasing cost. P_{MC} describes production cost for the most expensive technology in the auction, while P_c denotes price of electricity. Consequently, the support cost is determined by the difference in cost between $P_c \ and \ P_{MC}$. Producer Surplus (PS), i.e. profits, is found as the difference between P_{MC} and MC, and will vary based on technology maturity and cost (Huber et al., 2007).

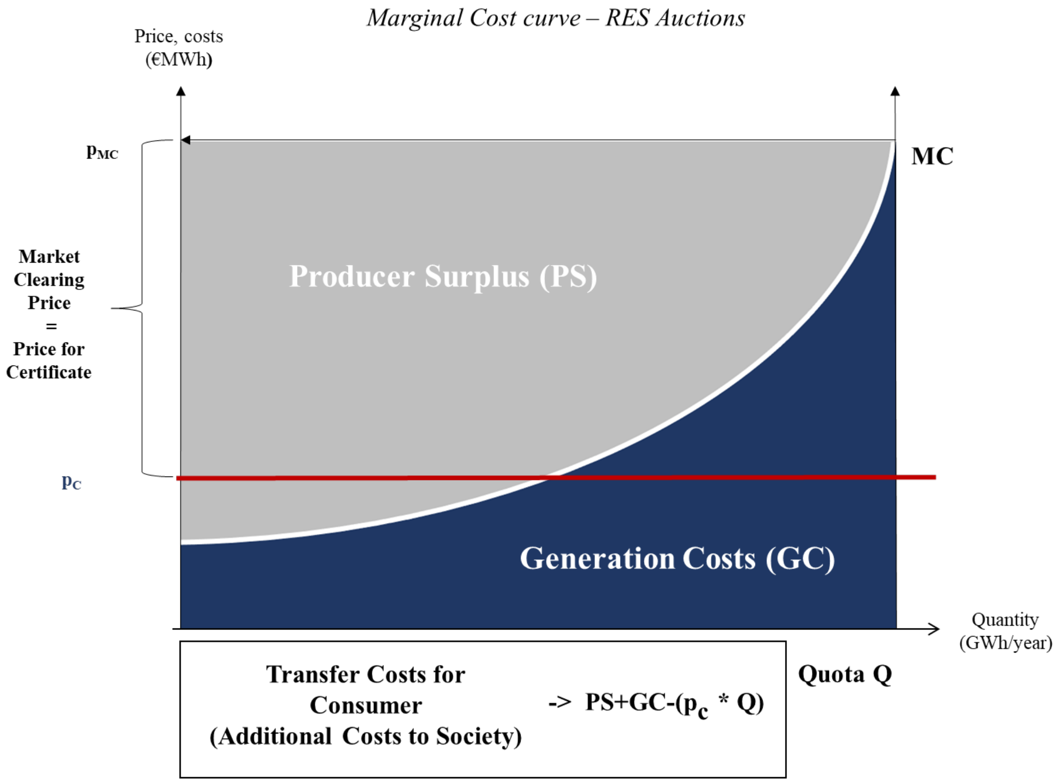

Figure 4 - Marginal Cost Curve for RES auctions (Huber et al, 2007)

Consumer costs are consequently the sum of generation and support costs for electricity production $(PS + GC - (P_C * Q))$, stating that support costs should be minimized. However, as it is a part of the producer surplus, which are necessary for payback of investment cost of RES projects, too low support levels will lead to undersupply due to unprofitability for producers. A too high support level will conversely benefit producers at the consumers' expense in the form of a high PS. Due to the impact on acceptance of energy policies from consumers and industries, the distributive effects from support schemes must be considered. An approach seeking to minimize support costs mitigates negative impact on consumers instead of generating the lowest energy production costs for the state (del Río & Linares, 2014). Minimization of support costs is achieved should total RES generation costs be as low as possible, and the auction should be designed to incentivize investors to choose sites, technologies contributing to this goal (Huber et al., 2007). In other words, an important trade-off must take place, based on policy targets.

2.3.4 Local Impact

RES deployment impacts the geographic region where it is installed. First, the socioeconomic impact considers employment and attracting foreign investments, leading to innovation and local industry development. Environmental impacts can be both positive and negative. The first considers reduction of climate emissions locally. The second involves negative events such as production noise, visual impact, and reduced access to agricultural land (del Río & Linares, 2014).

2.3.5 Socio-Political Feasibility

An additional criterion to consider for successful policy implementation is social acceptance. Varied ownership, social and financial support structures are key elements for RES development policies. Social acceptance can increase by raising awareness for RES and its positive synergies. This increase may in turn improve successful policy implementation.

2.3.6 Actor Diversity

The promotion of actor diversity must result in reduced developer risk. This concerns allocation, planning, non-compliance, qualification, and shared-ownership risk. The goal may be achieved through information transparency, and timely announcement of auction specifications, project requirements and schedules. It is also used as an assessment criterion. Diversity measures the number of winning bidders with local presence, combined with size diversity of the participating bidders. Diversity in the context of RES projects which have a visual and ecological impact, is often linked to the probability of social acceptance. This, in turn, is likely to be associated with future RES deployment growth in a country (Côté et al., 2022)

3. Data

This chapter includes a description of collection of data, and its characteristics. First, the type of data available is described along with its sources. Second, the necessary characteristics and overview of its contents is highlighted to provide a background for the analysis.

3.1 Data Collection

To answer the research questions, collection of reliable and relevant data is important. There are two types of data, primary and secondary. The first considers data which is collected by a researcher specifically for a type of research. Secondary data is collected for no particular purpose, or data collected for a different purpose than it is being researched for. The use of secondary data is mainly used to perform further analysis, for other reasons than the original purpose of the data. These types of data can be accessed through various sources. For example, many organizations store large amounts of data, either to support their own work or to create availability for further research by others. Data collection differ between the quantitative and qualitative methods. The first considers counting and mapping of events, while qualitative methods focus on description and relevance. Throughout the analysis, the quantitative data and findings highlights and illustrates the main arguments from qualitative findings and discussion, the latter serve as background for conclusion.

3.2 Data Characteristics

This paper’s analysis is based on both primary data and secondary data. The primary data is mainly derived from official websites of the governmental bodies responsible for the organisation and execution of RES auctions in Germany (Bundesnetzaggentur.de) and the UK (Gov.uk). This is complimented by correspondence with industry stakeholders such as Equinor employee Fredrik Horn Hansen, providing industry viewpoints on current RES challenges. The secondary data considers case study desk research from public databases, previous research reports on RES auctions and AURES.com, the European Union’s Renewable Energy Auction Research project. The latter include performed case studies as well as details on planned and past auction rounds in the European Union. This thesis relies on historic data from performed auctions in the selected markets. This includes auction results, auction systems and design elements. Thus, the chosen data sources are chosen to provide a foundation for the comparative analysis and assessment criteria.

4. Methodology

This chapter describes the research design and strategy used in this thesis, with emphasis on structure, reasoning and method, applied to the collected and aggregated data.

4.1 Research Design and Strategy

The research begins with an introduction of selected countries for analysis. It reviews the main characteristics of auction formats and the market situation in both countries. The next section includes a descriptive comparison of the auction systems' design elements. Following this comparison, the different design elements are analysed based on the introduced assessment criteria, to determine their relative performance. This qualitative analysis is complimented by quantitative methods to illustrate the main arguments. Finally, the findings from the comparative case study are summarized to identify best practices for offshore wind auctions and provide recommendations for Norwegian policymakers, considering the current geopolitical and macroeconomic climate and political goals.

The analysis of variables in the form of comparative analysis is considered as a valid method of answering questions such as "how" and "why" in real-life situations, in which the answers require an extensive description of that situation (Yin, 2014). Despite its popularity, this method has received critique in academic literature due to concerns of potential selection bias and generalization. Selection bias is not considered a concern in this research, as both selected countries are considered to have made significant progress within offshore wind development. Thus, they aid in identifying best practices for auction design, rather than illustrating general or average practices and trends. Both countries have experienced similar growth in the analysed period. To cope with generalization, the countries chosen have converging policies and auction use for development of an offshore wind industry.

Comparative analysis as a research method has been successfully used in previous studies on auction systems. Due to its empirical support on answering "how" and "why" in real-life situations, it is appropriate for this thesis. Strike prices from the auction results in multiple countries have been used to evaluate future cost of offshore wind projects in the papers from R. Domingo and Linares (2021). There is also research done on auction design in terms of optimal prequalification requirements and penalties using a comparative approach in multiple countries by Kreiss et al. (2017).

5. Comparison of UK & German Market

To set the background for the analysis, this chapter provides a thorough comparative overview of the auction systems and design elements in the United Kingdom and Germany.

5.1 Current UK Auction Framework

5.1.1 Auction Format

RES-auctions have historically been the main instrument for incentivizing renewable energy production and development of green technologies in the UK. The selection criteria have been price-only, in the form of a sealed, first price bidding process. The support format has been a sliding FiP i.e. a two-sided CfD scheme with a subsidy cap. This was first introduced as part of the 2013 Electricity Market Reform. In the UK, the CfD involves a private bilateral PPA between the government entity "the Low Carbon Contract Company" (LCCC) and the winning developer. As the contract is two-sided, the developer is compensated a fixed, annually inflation-indexed price, the "strike price" per MWh for a period of 15 years. The strike price seeks to reflect the investment and operating cost of the applied low-carbon technology, proxied by the LCOE.

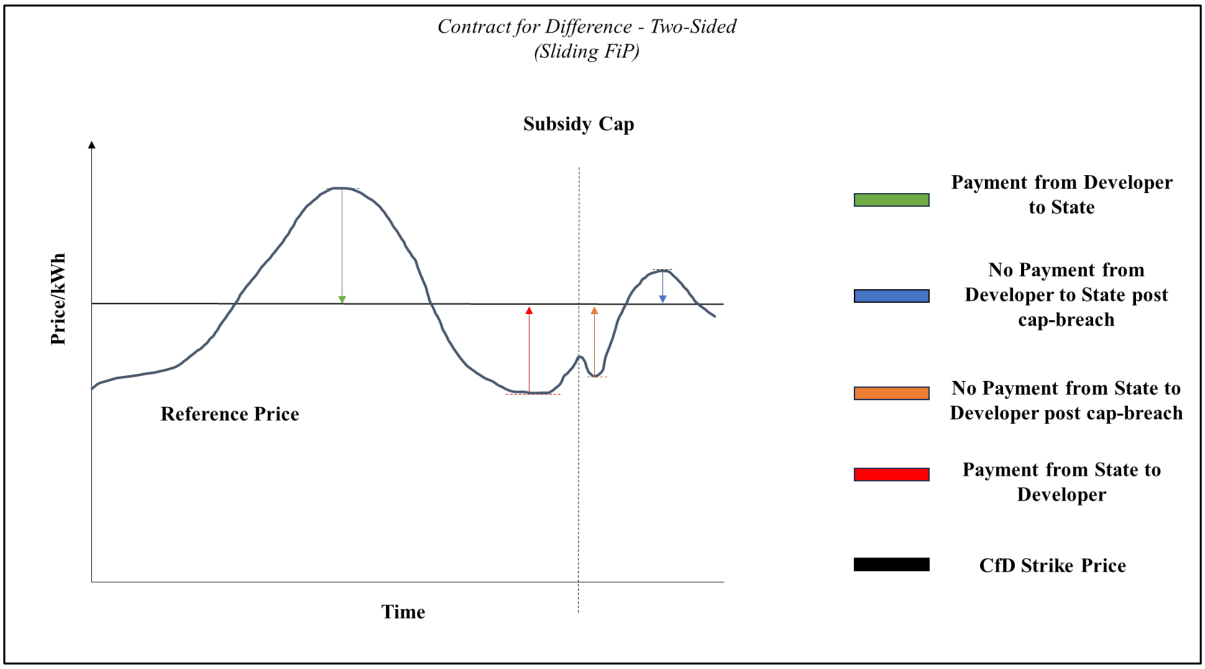

Figure 5 - Contract for Difference, Two-sided, Sliding Feed-in-Premium

The contract involves the winning bidder being paid the difference between the agreed reference price, (measure of average market price of electricity in the UK spot market, calculated using the day-ahead hourly price) and the strike price in the event of the reference price being lower than the contracted strike price. Then comes a repayment of the surplus profits to the LCCC should the reference price exceed the strike price (Kell et al., 2023).

5.1.2 UK RES Auction History

CfD auctions were initially designed to fit two technological categories in the UK, Pot 1 and 2. Pot 1 considered mature technologies, i.e., onshore wind and solar, while Pot 2 included less mature technologies, usually with a higher cost. It included advanced conversion technologies, biomass with combined heat and power, geothermal, tidal stream, wave, and offshore wind. As of 2015, the mature technologies were removed from the auctions, and the main allocation budget was targeted for Pot 2 technologies (Welisch & Poudineh, 2020). Since the full implementation of the CfD regime, there have been five competitive auction rounds to award CfDs in 2015, 2017, 2019, 2022 and 2023.

Auction Round (AR) 1 saw contracts awarded to two offshore wind projects with a combined capacity of 1.16 GW, with an average strike price of GBP 117.14/MWh. AR 2 auctioned 3.1 GW, with prices ranging from GBP 74.75/MWh for projects commissioning in the 2021/22 delivery year and reducing to GBP 57.50/MWh for the 2022/23 delivery year.

AR 3 saw the first “zero monetary budget impact” bids. This implies that contracts were awarded with CfD strike prices below wholesale power prices, providing substantial cost-savings for the state. These were at GBP 39.65/MWh for delivery in 2023/24 and GBP 41.611/MWh for delivery in 2024/25. In total, 5.46 GW was auctioned.

In AR 4, offshore wind was delegated to pot 3 and considered a mature technology, not directly in competition with any other land based energy source in pot 1 (Gov.uk, 2023). This resulted in almost 7 GW of new offshore wind projects being awarded CfDs. Projects secured a strike price of GBP 37.35/MWh for delivery in 2026/27.

AR 5 in 2023 saw Offshore Wind return to Pot 1, alongside Onshore Wind and solar. For the first time since the introduction of the CfD scheme, not a single megawatt of offshore wind secured government support. Although a disappointment for the industry, the outcome did not come as a surprise to many in the industry.

5.1.3 UK Auction Process

The UK auction process includes several bodies and the main entity in charge is the Department for Energy and Climate Change. Furthermore, through the Levy Control Framework, the national treasury is in control of the auction's budgetary implications. The National Grid Systems Operator (NGESO), the delivery body of the Electricity Market Reform, is responsible for carrying out the allocation process of the CfD auction. The NGESO invites participants to file their application for the available budget in the auctioned pot. The following figure describes the hierarchy and responsibilities of the CfD auction administration (Fitch-Roy & Woodman, 2016).

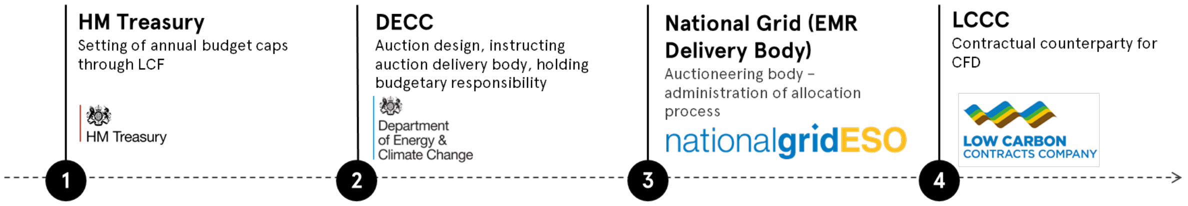

Figure 6 - UK Auction Process

The subsidy budget for an auction round is divided into the various pots via a budget notice, which indicates the max and minimum volume to be auctioned, or the total auction budget. The minimum capacity results in projects with the lowest bids being automatically accepted up to the minimum, given that the bid price is equal to or below the set ceiling price. The budget will dictate the number of accepted projects by assessing the budget impact of each project. Not setting a maximum capacity is considered to increase competition.

Developers submit bids specifying technology type, subsidy bid price, total capacity delivered, and the delivery year of the project. The NGESO ranks submitted projects in the same pot based on their bid price, regardless of delivery year. Developers may submit up to four, sealed, flexible bids by considering capacity, price and delivery year, with a maximum of two bids in each delivery year. Flexible bidding allows submission of several different capacities. By submitting multiple bids for varying proportions of their capacity and reducing the total budget impact of each bid, the bidders increase the probability of winning.

If the flexible bids of a project result in a budget breach, then the delivery year is closed. No other bids are then considered for that specific delivery year. Allocation can continue to the other delivery years until a new budget breach. Up until AR 4, a clearing price, i.e. a ceiling price, has been set for each individual delivery year breach.

From AR 4 and onwards, a budget breach in any delivery year results in the whole auction closing. As a result, only one clearing price is set across the auction. Should the total bids not result in a budget breach, then all bidders will be offered a CfD, non-competitively, at the Administrative Strike Price (ASP). The auctioneer sets the ASP, the maximum possible subsidy price awarded to a technology, i.e. the ceiling price. Should two bids be submitted with equal bid price, the accepted bid is decided by a tiebreaker, where the NGESO chooses at random.

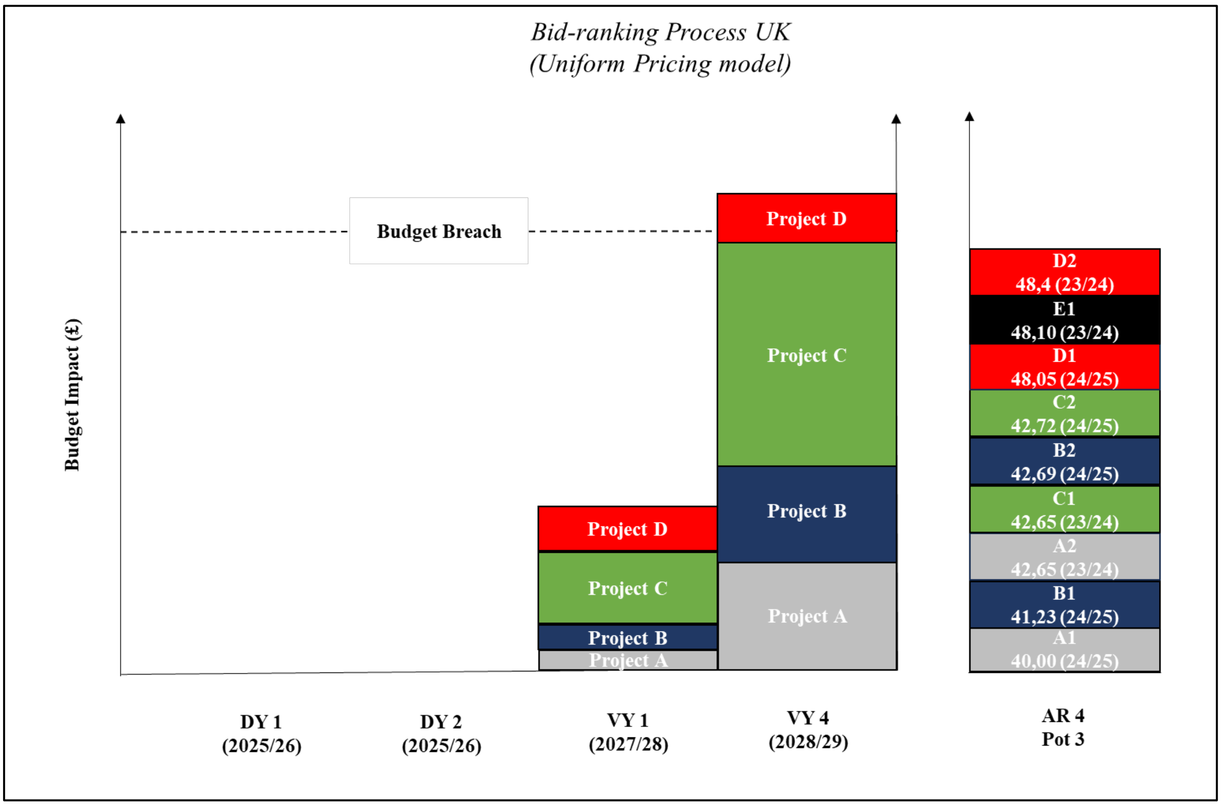

Figure 7 - UK Bid-Ranking Process

5.1.4 Market Situation and Policy

The UK commissioned its' first wind farm in 2012 and has since been in the forefront of industry development and produced capacity. Exhibiting 22 % of the total global capacity and the highest capacity in Europe of 14.8 GW, including a floating offshore wind capacity of 78 MW – the technology has become an established and proven part of the UK Energy mix (HM Government, 2023).

In 2019, the UK became the first major economy in the world to legislate a binding target of Net Zero Emission by 2050. Its initial ambition of 40 GW of offshore wind capacity by 2030 in 2021 was recently revised in the Net Zero Act to 50 GW. AR 5 in 2023 however, received zero bids, giving that target a setback. Despite 14.9 GW in operation and 12.5 GW under construction or awaiting final investment decisions, the country still requires 22.7 GW auctioned within the remaining 5 years of auctions to succeed.

The lack of bids has led to the UK revising the auction framework. The revision includes changes to annual auctions, de-risking measures regarding transmission integration costs and changes to the CfD scheme. For example, allowing PPAs with commercial counterparties. These changes internalize the rising costs and macroeconomic challenges faced by developers and the industry as a whole (HM Government, 2023).

5.2 German Auction Framework

5.2.1 Auction Format

Germany utilises pay-as-bid auctions with a Fixed FiP, i.e. a one-sided CfD. This involves an agreement of a non-inflation indexed strike price of cent/kWh, guaranteeing a certain price floor in case of a low wholesale market price. The contracts have a duration of up to 20 years, with possibility of extension up to 30 years. The contract start date is specified as the commissioning date of the project. Site lease includes grid integration and management costs, i.e., the bid does not internalize this, shifting a significant portion of the risk from the developer to the government. Also, the German grid fee is relayed on to the end consumer of electricity – further reducing cost and operational risk for the developer.

This design has led to developers being confident of project realization based on revenue from spot prices alone, and the sliding FiP format has resulted in no auctions without bids. Moreover, the last three auctions have seen bids requiring no subsidies, i.e. zero-subsidy bids. This has led to changes to the auction format – opening for second rounds of bids. The later round is an open, dynamic auction, allowing for negative bids, i.e. payment for the project. These display the developer's willingness to pay for the option to pursue the project, rather than support.

This negative bid is an uncapped financial bid. 90 % of the financial bid is funnelled to the Transmission System Operator (TSO) to contribute to electricity cost reduction. The TSO is the entity responsible for administrating and facilitating energy transfer and connection throughout the electricity grid on- and offshore. 5 % is earmarked for the federal budget for marine conservation and 5 % for the federal budget for fisheries. The payment is paid annually over 20 years, with the first instalment representing 10 % of the bid within 12 months of the contract being awarded. The last 90 % is then paid over the next 20 years. Bidders are required to provide a security deposit of EUR 200/kW for pre-investigated sites. 25 % of the security deposit is due by the bid deadline, and the remaining 75 % is due within three months of being awarded the contract. Furthermore, developers must meet set milestones and ensure commitments made for non-price criteria are met (Norton Rose Fullbright, 2023).

Subrogation Rights

Germany has had subrogation rights attached to some of the auctioned sites up until the pre-investigated auction of august 2023. It means that a developer has been pre-awarded the rights to a specific site before the auction. These rights stem from practices before the first auctions in 2017, and this was disclosed before the auction start. A developer with these rights can wait until the auction is closed, and then step-in by matching the winning bid and take over the operating lease. This practice will not continue in 2024. For the 2024 auctions, pre-investigated sites will be in the form of a static, sealed-bid first-price auction, while non-investigated sites will have a dynamic, price-only auction. The last use was in August 2023. RWE had won the rights for site N-6.6, which Vattenfall had subrogation rights for. Vattenfall exercised their right by matching RWE’s bid.

Although auctions for pre-investigated sites come with public site information, it is logical to assume that some degree of asymmetric information derives from these rights. To illustrate, should Vattenfall have had subrogation rights for a specific site for several years before it was auctioned, then having had this information would lead to them being better prepared. This information, in the form of learning effects, might have led Vattenfall to have an enhanced private valuation of the site, compared to RWE who initially won. This raises the question of whether RWE placed a lower bid than they would have if no subrogation rights were attached to the site, knowing that Vattenfall have more information. If Vattenfall had not exercised the right, it indicates that RWE had overpaid, thus suffering from the winner’s curse. If multiple bidders are interested in a site with subrogation rights, then this competition would drive up the price as a normal auction would.

If RWE were the sole bidder, however, then another question arises. As RWE were aware of the subrogation rights, the reason for the bid might not primarily be to win. They likely would not place any bids above their own calculated strike price, but rather to make sure that Vattenfall would have to pay extra for the site. Thus, “setting a trap”, reducing financial flexibility for its competitors.

5.2.2 Auction Process

The German auction process involves multiple steps and entities. First, the BMWK (Bundesministerium für Wirtschaft und Klimaschutz) i.e., the Federal Ministry for Economic Affairs and Climate Action, drafts the Offshore Wind Energy Act (WindSeeG) which is approved and amended by the German Parliament (Bundestag). They then pass on the responsibility to the "BNetzA".

The German "Bundesamt für Seeschifffahrt und Hydrographie" (BSH), which translates to the Federal Maritime and Hydrographic Agency, performs spatial planning and technical approval of offshore wind projects. The auctioneer is the German "Bundesnetzagentur" (BNetzA), i.e. the German Federal Network Agency. Their responsibility is that the auctions comply with the WindSeeG and the guidelines of the BSH. In short, the process of the German Auctions involves the BNetzA as the auctioning body, with the BSH as the investigator of the allocated sites.

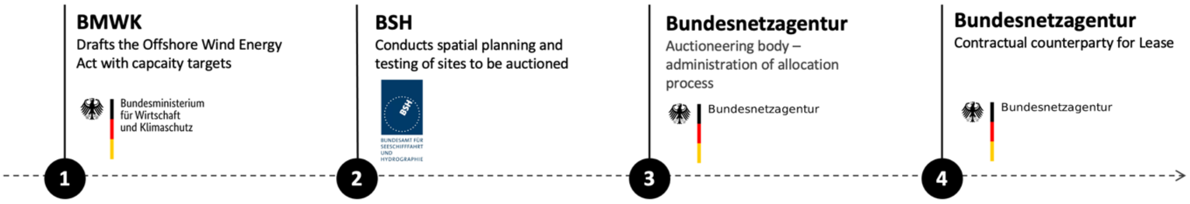

Figure 8 - German Auction Process

Prior to the first dynamic auction in 2023, the sealed-bid auctions for centrally pre-investigated sites were decided based on qualitative criteria after placement of zero-subsidy bids. In cases where the qualitative criteria were insufficient to make out a winning candidate, the winner was drawn randomly. This was done in 2021.

2023 saw the first sealed-bid auction with negative bid components. The criteria considered a financial bid weighted 60 % and project description on contribution to decarbonization, supplied volume, noise pollution and local impact and job creation weighing 40 % (4SeaOffshore, 2023). Penalties for non-compliance amount to EUR 100/kW for existing projects (N-3.8 and O-1.3) and EUR 200/kW for sites which have only been subject to preliminary investigation (N-3.7)

5.2.3 German RES Auction History

2017 saw the first tender auction for German offshore wind lease. All four sites were in the North Sea and pre-investigated. It allocated 1,490 of the budgeted 1,550 MW volume. Three of the four sites received zero-subsidy bids, and the last one had a strike price of EUR 0.06/kWh.

The second auction was in 2018, with a total budgeted MW of 1,610 MW distributed over six different sites. Two of the sites for the second auction round lie in the Baltic Sea, and four in the North Sea. All sites were pre-investigated. Four of the six sites received zero-subsidy bids, and two had bids under the EUR 0.12/kWh cap. The sliding FiP bids were EUR 0.064/kWh for a 476 MW site in the Baltic Sea, and EUR 0.983/kWh for a 131.75 MW site in the North Sea.

Germany has previously applied a ceiling price in the form of a subsidy cap at EUR 0.12 /kWh (in 2017 & 2018), and the highest subsidy asked this far has been EUR 0.983/kWh for the 131.75 MW “Gode Wind 4”, requested by Orsted in 2018 (F. Müsgens & I. Riepin, 2018).

The third auction was in 2021 and covered 958 MW capacity up for auction combined of three sites. All sites received zero-subsidy bids. Two of the sites are in the North Sea and one in the Baltic Sea. For this auction, the ceiling price was set at EUR 0.073/kWh (WindSeeG, 2023).

Auction four was in July 2023 and covered 7,000 MW capacity over four sites. This was the first auction to occur following a 2022 amendment of the WindSeeG, which opened for dynamic bidding process and the tendering of sites that were not centrally pre-investigated. Two rounds were completed, the first round saw actors bid on the amount of subsidy required, and those who placed zero-subsidy bids (EUR 0/kWh) qualified for the next round. The second involved negative bids. Areas were mapped by the BSH, but no further information was publicly available to the bidders. This structure introduced more asymmetric information during the bidding process, leading to record-setting EUR 12.6 Bn in combined negative bids placed by large oil corporations.

The fifth German auction took place in August 2023 and saw a return of the centrally pre-investigated site-system, and the last case of the subrogation right being exercised, used on only one site. It covered 1,800 MW combined over four sites located in the North Sea. All sites received zero-subsidy bids, and two received negative bids, totalling EUR 784 M.

5.2.4 Market Situation and Policy

2010 saw the first commercialized wind farm in Germany, and it has since become a key player in the industry. In 2023, it ranks third in total installation capacity by country, after China and the

United Kingdom. In 2021, Germany accounted for roughly 13 % of global capacity, the UK 22 % and China at 48 %. At the end of 2022, the German offshore wind market consisted of over 1,500 turbines generating 8.1 GW of operational capacity (Rehfeld, 2023). With current commissions the German offshore wind market is projected to increase to 13.8 GW by 2027 (Rehfeld, 2023).

The German WindSeeG was enacted as part of the Renewable Energy Resources Act of 2017. It seeks to increase the installed offshore wind capacity of Germany to a total of 15 GW between 2021 and 2030 in a cost-efficient manner. In December 2021 the WindSeeG was amended. Central changes were an increase in planned offshore wind capacity. The first change was an increase in capacity expansion targets of 15 GW to 30 GW in 2030. Per October 2023, the installed capacity target for 2035 is 40 GW, and minimum 70 GW by 2045.

The second change included a new tender procedure where BNetzA will auction non-investigated lots. As mentioned above, this opened for asymmetric information in auctions, where companies may enter with private valuation. This was expected to increase and speed up offshore wind development in the German Exclusive Economic Zone (EEZ).

5.3 Offshore Wind Projects as Real Options

In addition to financial analysis, developers must perform strategic analysis on uncertainties such as future technology cost reductions or developments in the electricity spot-market (Welisch & Poudineh, 2020). Considerations involve first-mover advantages such as securing important market shares or grid connection for later stages, combined with its implications on expected returns from current projects. The last consists of common and private factors, which are often beyond modelling, as data is rarely available due to commercial sensitivity. Yet, they have implications for the private valuation of projects.

As such, bidding behaviour in an offshore wind auction can be investigated through simplified, real option analysis (Bowman & Moskowitz, 2001). This captures the qualitative aspect of investment decision valuation through flexibility and strategic value. Developers' investment decisions are split into two parts: first an initial investment in the form of pre-qualification criteria. Later, with more information, a larger final investment decision in different phases of development of the awarded project is made (Welisch & Poudineh, 2020).

In general, the value of a real option is considered to increase given the following criteria:

1. Time: The period the owner of the option is allowed to wait and observe development of current trends
2. Volatility: The volatility (changes/fluctuations) of the factors with implications for project value. In this case, the technology cost and wholesale electricity prices, to the extent which the wait reduces uncertainty of these
3. Low discount rates: The present value of future cash flows is not significantly discounted relative to the cost of purchasing the option. The option is considered as pre-qualification measures such as posting a bid-bond or acquiring permits and necessary equipment
4. Low costs for project abandonment: In case of low penalty rates for non-delivery. The lower the penalty, the higher the option value

5.3.1 Example of Real Option Valuation of Offshore Wind Farm

A simplified example illustrates the value of a real option for a developer when deciding whether to make a zero-subsidy bid. Bidders submit at time T = 0, making a final investment decision at T = 1. There are two types of uncertainty. Technological uncertainty is resolved in time prior to the final investment decision. Market price uncertainty remains unresolved in time. The example includes two equally probable outcomes. With 50 % probability the technology available is cheap at time of construction, and with 50 % probability it is expensive or has not been significantly reduced over time. Similarly for the evolution of the market price of electricity, i.e. 50 % a high market price over the project's lifetime or 50 % likely that it will be low.

Investment Without Option to Abandon

If facing non-substantial penalties for non-delivery, bidders have a real option to construct under the CfD scheme or to default. This depends on technology costs in the delivery year of each respective phase. In the first example, the bidder does not have the option to abandon the project before making the final investment decision, or face substantial penalties for abandoning:

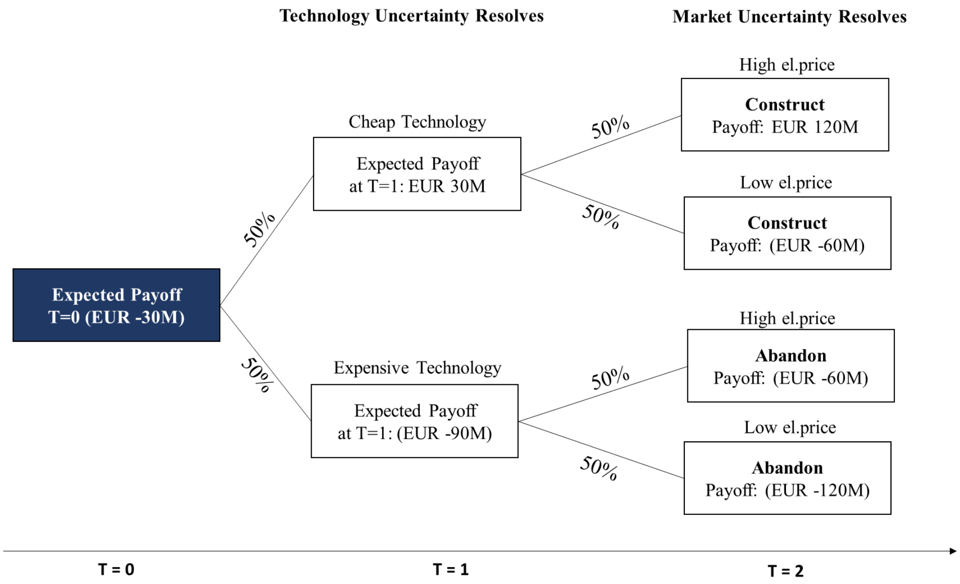

Figure 9 - Investment Decision Tree for Developers in OW auctions, no option to abandon

Assuming sunk costs for pre-qualification investment is EUR 30M in year 0, the developer faces a payoff of (EUR -30M). Should technology costs fall as expected, the investor gains a profit of EUR 30M. Do they stay high, the project will incur a loss of (EUR -90M). Should costs fall, the project is developed, if not, the investor defaults. This limits the loss to sunk costs from year 0 and the penalty. A developer can decide to invest for one phase at a loss and wait on cost development information before potentially constructing the second phase, or decide against it (Welisch & Poudineh, 2020). The latter would only be profitable should the technology costs fall, and the electricity prices be high for the lifetime of the project. In short, the expected payoff for a zero-subsidy bid would be (EUR -30M), indicating that the developer would not do so, and rather include a subsidy of at least EUR 30M to break-even.

Investment with Option to Abandon

If the developer does not face substantial penalties for non-realization, the decision-making process changes due to a new potential payoff. It may be less costly to abandon after final investment decision at T = 1 or at later phases T = (1 + n). Observed in Figure 10, the cost of abandoning the project in T = 1 is (EUR -27M) in the event of more costly technology. As such the optimal decision is to wait until T = 1 to make final investment decision. I.e., should the technology be more costly, the developer will prefer to pay the penalty and abandon the project at a cost of (EUR -27M), which is substantially lower compared to the expected payoff of (EUR -90M) in the scenario without the option to abandon.

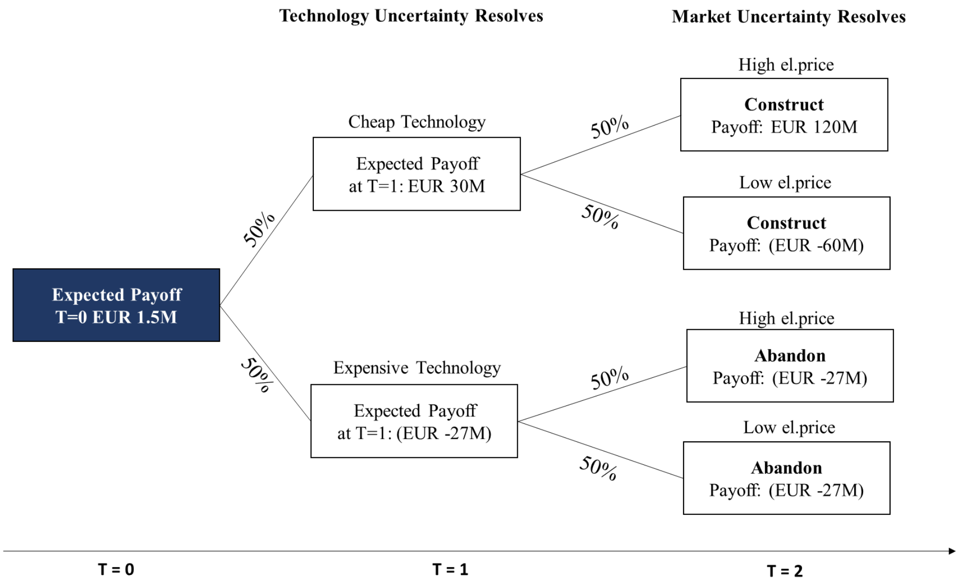

Figure 10 - Investment Decision tree for developers in OW auctions, with option to abandon

In short, the option to limit losses in case of expensive technology changes expected payoff at T = 0 from (EUR -90M) to (EUR -27M), resulting in change of overall expected payoff of a zero-subsidy bid from (EUR -30M) to EUR 1.5M. The expected payoff is now positive, which may explain the aggressive bidding behaviour and zero-subsidy bids in the German auctions.

Lessons and Takeaways

Without sufficient penalties or pre-qualification measures, bidders tend to bid more aggressively, as the repercussions of non-compliance are non-substantial (Welish & Poudineh, 2020). In other words, bidders do not get sufficiently penalized should they experience a "winners curse". Given that penalties for non-delivery increases over time, bidders will re-evaluate their options whenever a penalty milestone approaches, to validate their preferred option. These strategies are naturally expected to have impact on auction outcomes and project implementation rates. Underbidding strategies can be removed through sufficient penalties and prequalification requirements. This effectively makes the option to abandon too costly and reduces risk of non-realization (Marijke Welisch, 2018).

5.4 Comparison of Design Elements

As an integral part of the analysis, this section provides a comparison of the given design elements in each country's auction systems. The period considers auctions performed from 2017 until the year 2023, to enable a comparable analysis of both markets.

5.4.1 Selection Criteria

The UK has assessed and changed its auction format in different auction rounds, but during AR 1 - 5, the selection criteria have been price-only. This means that the bidder with the lowest price has been awarded the contract from the allocated auction budget. In 2023, the UK changed the frequency and format to annual auctions, to improve bidder's risk calculation and cost estimation through increased certainty on allocation round timing (Gov.uk, 2022).

In Germany, selection criteria have also been price-only. Since the first auction round there have been few subsidy bids and mostly zero-subsidy bids depending on the site in question. In 2021, multiple zero-subsidy bids were placed for the same site. The outcome was decided by draw. In 2023, allowing for negative bidding solved the issue of choosing the winner.

5.4.2 Auction Format

The UK applies a static, multi-unit auction where bidders submit multiple, sealed bids for each auctioned project. Further, the uniform pricing mechanism is used, i.e., the price of the highest winning bidders is set as the strike price (the contract price) for all winning bidders. In Germany two action formats have been used. Similar for both formats is that they follow a pay-as-bid system, whereas each site is bid on individually. The first three rounds in 2017, 2018 and 2021 were all sealed-bid, single-unit auctions with the sites for auction being pre-investigated. Here, the lowest subsidy bid, in most cases zero, has been the winning bid. The 2023 hybrid auction started with a sealed first-bid auction, where in the case of multiple zero-subsidy bids allowed a second, dynamic, rising-clock auction round where the highest bidder is awarded the site. This saw bidders paying for the option to build, rather than asking for subsidies.

The UK has announced changes to the auction design to increase transparency and optimize price discovery, adopting a rising clock auction in the future. The main advantage will consider publishing of pricing movements during each round, allowing transparency for developers to see whether other parties still are bidding for certain locations – much like the German format for non-investigated sites (The Crown Estate, 2023).

5.4.3 Ceiling Prices

The UK uses ceiling prices as the mechanism for capping support levels. The ceiling price is calculated based on estimated LCOE, set to reflect the level of investment needed to provide sufficient production of electricity through the given low-carbon technology. This ceiling price is called the ASP. The developers use this to negotiate two-sided CfDs, involving a PPA with the

LCCC, and counterparties often apply discounts when negotiating these PPAs to CfD holders, due to the low-risk revenue from the contract. It is also used as leverage when securing project financing from debtholders.

As Germany is operating with a one-sided CfD, the ceiling price has been limited to EUR 0.12/kWh for the 2017 and 2018 auctions (Bader & Kilgus, 2016). Per 2023, the highest subsidy asked is EUR 0.983/kWh for the 131.75 MW Gode Wind 4 requested by Orsted in 2018 (F. Müsgens & I. Riepin, 2018).

As a response to the failed AR 5 in 2023, the UK is set to increase the ASP by 66 % in AR 6. This is to acclimate current macroeconomic changes and cost-inflation throughout the industry, restoring trust in the auction system and boosting deployment (Millard, 2023).

5.4.4 Diversity

To describe the diversity of auction-winners, tables illustrating the awarded projects in different auction rounds, along with data on the awarded contract size, and winning developers is found below in Table 2 and 3. For illustrative purposes, parameters such as technological and geographical diversity have been excluded. This is because the scope of this analysis concerning solely offshore-wind projects, and thus all considered auctions are location and technology specific.

Year	Round	Project Name	Developer	Capacity (MW)	Round Total
2015	1	East Angolia - Phase 1 Wind Farm	Scottish Power Renewables	714	1162
		Neart Na Gaoithe OFW Farm	EDF/ESB	448	
2017	2	Triton Knoll OFW Farm	RWE/J-Power/Kansai Electric Power	857	3193
		Hornsea Project 2	Ørsted	1386	
		Moray OFW Farm (East)	CTG /DGE Ltd / Kansai Electric Power / Mitsubishi UFJ / Ocean Winds	950	
2019	3	Doggerbank Creyke A P1	SSE Renewables/Equinor/Eni Pletitude	1200	5466
		Doggerbank Creyke A P2	SSE Renewables/Equinor/Eni Pletitude	1200	
		Doggerbank Creyke A P3	SSE Renewables/Equinor/Eni Pletitude	1200	
		Forthwind	Forthwind Limited	12	
		Seagreen Phase 1	SSE Renewables/Total Energies	454	
		Sofia Offshore Wind Farm Phase 1	RWE Renewables	1400	
2021	4	EA3, Phase 1	East Anglia Three Limited	376	6994
		EA3, Phase 2	East Anglia Three Limited	491	
		EA3, Phase 3	East Anglia Three Limited	506	
		Hornsea Project Three Offshore Wind Farm	Orsted Hornsea Project Three (UK) Limited	2852	
		Inch Cape Phase 1	Inch Cape Offshore Limited	270	
		Inch Cape Phase 2	Inch Cape Offshore Limited	405	
		Inch Cape Phase 3	Inch Cape Offshore Limited	405	
		Moray West Offshore Wind Farm	Moray Offshore Windfarm (West) Limited	294	
		Norfolk Boreas (Phase 1)	Norfolk Boreas Limited	416	
		Norfolk Boreas (Phase 2)	Norfolk Boreas Limited	505	
		Norfolk Boreas (Phase 3)	Norfolk Boreas Limited	475	
2023	5	East Anglia One North	N/A	800	4000
		Seagreen 1A	N/A	500	
		Norfolk Vanguard	N/A	1800	
		East Anglia Two	N/A	900	

Table 2 - UK Allocated Projects Auction Round 1-5

Year	Round	Project Name	Developer	Capacity (MW)	Round Total
2017	1	He Dreiht	EnBW	900	1490
		OWP West	DONG (Orsted)	240	
		Borkum Riffgrund West 2	DONG (Orsted)	240	
		Gode Wind 3	DONG (Orsted)	110	
2018	2	Baltic Eagle	Iberdola	476	1610
		Gode Wind 4	Orsted	131,75	
		Wikinger Süd	Iberdola	10	
		Kaskasi	Innogy	325	
		Arcadis Ost 1	KNK Wind	247,25	
		Borkum Riffgrund West 1	Orsted	420	
2021	3	N-3.7	RWE Renewables Offshore Development GmbH	225	958
		N-3.8	EDF Offshore Nordsee 3.8 GmbH	433	
		O-1.3	RWE Renewables Offshore Development One GmbH	300	
2023	4	N-11.1	bp OFW Management 1 GmbH	2000	7000
		N-12.1	North Sea OFW N12-1 GmbH & Co. KG	2000	
		N-12.2	bp OFW Management 3 GmbH	2000	
		O-2.2	Baltic Sea OFW O2-2 GmbH & Co. KG	1000	
2023	5	N-3.6 (Delta Nordsee 1&2)	RWE - Nordseecluster B	480	1800
		N-3.5 (Delta Nordsee 3)	RWE - Nordseecluster B	420	
		N-6.6	Vattenfall by subrogation right, former RWE	630	
		N-6.7	Waterkant Energy GmbH	270	

Table 3 - Germany Allocated Projects Auction Round 1-5

There is a higher concentration among larger developers and joint ventures in the UK market. Furthermore, the projects are divided into different phases, each with separate volumes. The German market has auctioned fewer sites and an overall lower volume, but all auctions have been filled. The similar pattern of large consortia dominating the market is observed here as well. Lastly, the most recent round in the UK did not attract a single bidder, despite 4,000 MW being available to developers. In short, there is little diversity in terms of size, but there is some geographical diversity through consortia and joint ventures consisting of international companies. Despite less diversity, the consistent participation indicates that it does not necessarily affect auction success.

5.4.5 Auction Volume

Both countries define auction volume by a target budget, capping the maximum auctioned capacity. In the UK these budgets are predefined, and as of 2023 there have been four auctions with fixed budgets in 2015, 2017, 2019 and 2022. However, for pot 3 and offshore wind in AR 4, there was no such maximum or minimum. The number of pots was reduced to two pots in AR 5 in 2023, categorizing offshore wind as a mature technology in pot 1. This change serves as a source of uncertainty for developers, as it is hard to determine the amount of operational capacity at what time, compared to tendering on a fixed schedule for a specified generated capacity.

In Germany, the amendment of the WindSeeG in 2022 increased the capacity targets. The new capacity targets are 30 GW by 2030, 40 GW by 2035 and at least 70 GW by 2045. As of January 2023, Germany has 8.1 GW of operational offshore wind. The combination of tender process changes, opening for dynamic rounds with negative bidding and increased volume from non-investigated sites, has given clear signals that German offshore wind is expanding (European Commission, 2022).

The two 2023 auctions substantiate this, as their combined size is around six times the auctioned volume from previous years. The outlook for 2024 is to award 8 GW, up to 5 GW for 2025 and 2026, and followed by 4 GW being added each year for the coming decade (Ascherfeld et al., 2022). More details are currently not publicly available, as new auctions are being announced on a running basis. Like the UK, this too serves as a source of uncertainty for developers, as they are unable to plan and prepare for upcoming auctions.

In general, high auction volumes involves a longer realization period and is considered as beneficial to developers, allowing for greater output and revenue streams from applying economies of scale and spreading investment cost over a longer time horizon.

5.4.6 Prequalification Requirements

Both countries enforce requirements of prequalification for participants. In the UK, such requirements consider physical qualifications such as spatial planning and permits. Additionally, there are LCR which includes an approved Supply Chain Plan (SCP) for projects above a volume threshold of 300 MW. In AR5, these requirements are a compliance of 60 % for +300 MW projects, and 50 % for <300 MW projects. Should the offshore wind farms be phased out over multiple years, supplementary requirements follow, such as eligibility in terms of the size of each phase. In addition, a grid connection agreement with the NGESO is required for UK developers (Fitch-Roy & Woodman, 2016).

Financial pre-qualification such as security deposits or bid bonds were first implemented in AR 4. Here, an option fee for seabed leases is issued by the Crown Estate, to be paid prior to bidding to secure the right. This is paid on an annual basis until the necessary planning permits are obtained by the developer (Wind Europe, 2021). This, however, has been removed in AR 5, and is not set to be re-implemented (Gov.uk, 2023).

In Germany, bidders are also required to provide a similar financial security deposit, a bid bond, determined by the site volume multiplied by EUR 200/kW for pre-investigated sites. 25 % of the security deposit is due by the bid deadline, which is within three months of being awarded the contract. There is no financial payment needed to qualify for the auction (Radowitz, 2022).

The amendment of the WindSeeG in 2022 introduced multiple criteria for static auctions for the centrally pre-investigated sites in Germany (Stenzel et al., 2022). The quantitative, financial component represents 60 %, while the qualitative 40 % is distributed as:

1. (10 %) Developer plans to contribute to decarbonising the offshore wind industry
2. (10 %) Intended PPAs
3. (10 %) on noise impact reduction
4. (10 %) on contribution to the securing of skilled workers

To qualify for participation in the second phase, bidders must accept the pre-defined thresholds for the auction. These thresholds are the size of bids, normally done in increments of EUR 30,000/MW for the first session of negative bids. Consecutive sessions are then held until the first bidder forfeits the auction. Afterwards, the auctions continue in EUR 15,000/MW sessions until one bidder remains. The dynamic auctions in 2023 had between 55 and 72 sessions to close the market (Crampes & Ambec, 2023).

5.4.7 Penalties

For a penalty to apply in the UK, certain situations must arise; either refusing to sign after being awarded the contract or failing to meet the progress milestones of the project. Failing to do so, will result in exclusion from future projects in the project area for 13 months (Fitch-Roy & Woodman, 2016). This was increased in AR 5 and onwards, where the penalty is extended to consider the following two allocation rounds (Gov.uk, 2023). In AR 3, any shortcomings with the SCP were simply highlighted in a post-build report, which merely resulted in prejudice for developers in future projects, but no financial implications. From AR 4, failure of compliance by a shortstop date is extended to non-payment and termination of contract (France, 2022). Until AR 4, the auction rounds were every 24 months, and the UK penalties of non-compliance for 12 months could be considered as non-stringent. This because despite breaching a contract, the bidder would be able to participate in the next round of auctions. These previously non-substantial penalties could potentially have, and might still allow for real-option strategies for developers.

In Germany, the penalty for non-compliance of an awarded contract varies from 30 %, 70 % and 100 % of the pre-qualification bid-bond. Thus, the maximum expected loss is the full bid-bond value, and between 2.5 % and 3.8 % of the total development costs (F. Müsgens & I. Riepin, 2018). This results in an asymmetric payoff, where the loss is capped at the CfD price plus the penalty, while the potential upside is uncapped to the sale at wholesale market prices. In other words, given sufficiently low initial investment costs, deriving from state covered grid costs, the financial penalty can be considered non-substantial. Again, this allows for real-option strategies.

5.4.8 Support Conditions

The duration of the UK CfDs is currently for a period of 15 years, while in Germany contracts are for 25 years, with the option of extension of the operational lifetime up to 30 years. As such, German developers can spread the investment cost over a longer horizon, likely resulting in a lower LCOE and lower risk (F. Müsgens & I. Riepin, 2018b). Despite previously being covered by the developer in the UK, charges concerning “Balancing Services uses of System”, i.e. the charges for grid use, are from AR 4 no longer to be charged and compensation for this is set to be removed (Gov.uk, 2023). The budgets and strike prices for each AR are published in 2012 prices, allowing direct comparison between each auction round. The actual budgets are calculated using the Consumer Price Index Inflator, which is announced in each budget notice (Fitch-Roy & Woodman, 2016).

While UK developers must pay for all expenses concerning grid connection and site location scoping, historically these parts of the project are guaranteed by the state in Germany, serving as a form of hidden subsidy, effectively de-risking parts of the project and reducing capital expenditure. In addition, the German grid operation cost, is passed on to the end consumer. This further reduces the operation costs of German projects. However, for the 12.6 Bn record auction in Germany, pre-investigation had not taken place. Thus, the new auction format in Germany can have a higher real option value (Welisch & Poudineh, 2020).

5.4.9 Realization Period

A short realization period can be negative for investors, due to a short period to secure sufficient revenue streams to cover investment costs, increasing the risk-profile of the project. The UK seeks to alleviate this by allowing a "Merchant Nose" agreement, where the developer may postpone the start date for the CfD, and instead sells power in the spot-market for a year. Developers use this to acquire longer-dating debt and bid a lower strike price. However, the UK has implemented a temporary 45 % tax on extraordinary profits, the Electricity Generator Levy, from January 2023 to March 2028. This extraordinary profit is any profit exceeding a benchmark price of GBP 75/MWh, but only applies to profits generated above a certain volume threshold of 50 GWh annually, and not produced within a CfD (Norton Rose Fullbright, 2023b). This reduces the "merchant nose" incentive and makes CfDs more appealing to debtholders as a fixed revenue stream.

The UK has realization periods of five years. From the UK's AR 5, delivery flexibility is limited to developers facing a genuine delay in commercial operations. Also, the concept of structuring project development into several phases, so-called "phasing", is set to be removed. This is because it is considered to have achieved its purpose of early stage risk removal for the offshore wind industry. (Gov.uk, 2023). The option of phasing the project has potentially allowed for strategic, real option decision-making in each phase for the developer, as it may choose to exercise the option of abandoning the project in each phase, depending on the current market situation.

In Germany, the realization of the projects can be up to six years. This leads to increased time for technology cost reduction, and higher wholesale electricity prices. Both these factors can be considered as a positive value of waiting and learning, increasing the projects' real option value given the possibility of abandoning the project (F. Müsgens & I. Riepin, 2018).

5.5 Real Option Impact on Bidding Strategies

The concept of real options introduces aggressive bidding strategies. In the UK, the modest penalties for non-delivery, combined with the continued expectations of further technology cost reduction makes the real option value considerable. However, the likelihood of a zero-subsidy bid in the same fashion as Germany remains low, due to the following factors.

The realization period in both countries is four to five years, which leaves little time for cost reductions to materialize. In addition, the auction schedules have previously been irregular compared to the predefined schedule in Germany. What is more, the factoring of grid connection increases the pre-development cost for a developer relative to the German market – increasing financial risk for developers in the initial phase of the investment. Further, the distinct difference between Germany and the UK lies in the two-way design of the CfD scheme, as it does not simply provide a floor for the developer. The bid value represents the fixed revenue for the project lifetime. Therefore, it is irrational for a developer, no matter how aggressive, to pursue a project with a revenue of GBP 0/MWh. They base the minimum bid on the long-term expected wholesale market price of electricity, i.e. the reference price and their LCOE instead (NERA, 2017).

6. Comparative Analysis & Discussion

This chapter applies the defined assessment criteria on the reviewed data and auction systems in the UK and Germany, in the form of a comparative analysis. Specifically, it investigates whether performed auctions were successful in reducing subsidies and their allocation of planned capacity, taking into consideration its design elements, characteristics, and policy goals. This will subsequently serve as the background for the recommendations to policymakers on auction design in Norway.

6.1 Effectiveness

This thesis measures effectiveness by total installed capacity and evaluating it against the nation's policy target. In addition, it measures the project realization rate, and combined these serve to indicate the country's performance on auction effectiveness. All metrics are subject to the assumption that the auctioned capacity is commercialized and installed on time, in case no other public information states otherwise.

Metric	Germany	UK
Installed Operational Capacity	8.1 GW	13.9 GW
Auctioned Capacity per 2023	12.9 GW	16.8 GW
Planned Operational Capacity per 2030	29.8 GW	29.4 GW
OW Percentage of Power Production Mix	5.0 %	14 %
Realization Rate	99.5 %	96.2 %
Policy Targets	30 GW by 2030	50 GW by 2030

Table 4 - Comparison of Effectiveness Metrics

The table displays that the nations' progress in terms of planned and current installed capacity of projects are quite equal. However, the project realization rate in the UK is at 96.2 %, relative to 99.5 % in Germany. A major reason for the lower rate in the UK is Vattenfall's decision to postpone the delivery of the three-phased Norfolk Boreas project. It has a potential production volume of 1.4 GW and was allocated in AR 3, with expected completion in 2028. Vattenfall has, along with other developers, reported considerable cost increases driven by inflation, supply chain constraints and rising interest rates. This amounts to a total cost increase of 40 % (Reuters, 2023). This, alongside the zero-bid auction round in 2023, has reduced optimism around achieving the nation's net zero policy targets. The budgeted amount in AR 5 was a total of 4 GW, reducing the UK realization rate from 100 % to 96.2 % (FTI Consulting, 2023).

This result indicates how the UK penalty for non-compliance was considered less costly than pursuing the investment further, and that the price was too high compared to the potential payoff. Moreover, it highlights the need for revision of CfD terms to meet current market conditions, both for ASP calculation as well as penalties. This has been publicly stated by multiple developers, who point to low profitability and incentives for developers at current ASPs (FTI Consulting, 2023). Moreover, the attractiveness of the merchant nose has been reduced in favour of CfDs, due to the Electricity Generation Levy of 45 % (Norton Rose Fullbright, 2023b). Consequently, should the CfD-specified ASP not be considered profitable either, it will lead to a reduction in bids and lower installed capacity.

A measure to reduce the risk of non-realization and increase installed capacity could be allowing developers PPAs with commercial actors. Given high credit rating of the chosen commercial counterparties, the risk of these revenue streams could be considered equal to those from the state backed LCCC, and thus not increasing cost of capital for developers. In turn, developers may be able to reach agreement on contract prices higher than the government CfDs. Thus, recovering their investment cost quicker and become profitable. Likewise, commercial actors can lock in electricity prices and reduce risk on their end, which is attractive in the current macroeconomic climate. The risk of abandonment of the project could be lower in these agreements and higher contract prices may mitigate aggressive bidding behaviour and the "winner's curse". This is discussed and potentially implemented in the UK in AR 6, which would increase the potential upside, incentivizing participation and realization rate (Gov.uk, 2022).

6.2 Efficiency

The efficiency of the two markets is measured by their static and dynamic efficiency. These metrics highlights the auction designs impact on efficiency.

6.2.1 Static Efficiency

In terms of static efficiency, a sharp reduction in strike prices for offshore wind project auctions over time in both countries is observed. As such, static efficiency is considered to have increased, with the development illustrated in the tables in Table 5 and 6.

Year	Round	Project Name	Developer	ASP (£/MWh)	Strike Price (£/MWh)
2015	1	East Angolia - Phase 1 Wind Farm	Scottish Power Renewables	140	119,89
		Neart Na Gaoithe OFW Farm	EDF/ESB	140	114,39
2017	2	Triton Knoll OFW Farm	RWE/J-Power/Kansai Electric Power	105	74,75
		Hornsea Project 2	Ørsted	100	57,50
		Moray OFW Farm (East)	CTG/DGE /KEP/Mitsubishi/OW	100	57,50
2019	3	Doggerbank Creyke A P1	SSE Renewables/Equinor/Eni Pletitude	56	39,65
		Doggerbank Creyke A P2	SSE Renewables/Equinor/Eni Pletitude	53	41,61
		Doggerbank Creyke A P3	SSE Renewables/Equinor/Eni Pletitude	53	41,61
		Forthwind	Forthwind Limited	56	39,65
		Seagreen Phase 1	SSE Renewables/Total Energies	53	41,61
		Sofia Offshore Wind Farm Phase 1	RWE Renewables	56	39,65
2021	4	EA3, Phase 1	East Anglia Three Limited	46	37,35
		EA3, Phase 2	East Anglia Three Limited	46	37,35
		EA3, Phase 3	East Anglia Three Limited	46	37,35
		Hornsea Project Three Offshore Wind Farm	Orsted Hornsea Project Three (UK) Limited	46	37,35
		Inch Cape Phase 1	Inch Cape Offshore Limited	46	37,35
		Inch Cape Phase 2	Inch Cape Offshore Limited	46	37,35
		Inch Cape Phase 3	Inch Cape Offshore Limited	46	37,35
		Moray West Offshore Wind Farm	Moray Offshore Windfarm (West) Limited	46	37,35
		Norfolk Boreas (Phase 1)	Norfolk Boreas Limited	46	37,35
		Norfolk Boreas (Phase 2)	Norfolk Boreas Limited	46	37,35
		Norfolk Boreas (Phase 3)	Norfolk Boreas Limited	46	37,35
2023	5	East Anglia One North	N/A	44	N/A
		Seagreen 1A	N/A	44	N/A
		Norfolk Vanguard	N/A	44	N/A
		East Anglia Two	N/A	44	N/A

Table 5 - UK Awarded Projects and Strike Prices

Year	Round	Project Name	Developer	ASP (€/MWh)	Strike Price (€/MWh)
2017	1	He Dreiht	EnBW	120	0
		OWP West	DONG (Orsted)	120	0
		Borkum Riffgrund West 2	DONG (Orsted)	120	0
		Gode Wind 3	DONG (Orsted)	120	60
2018	2	Baltic Eagle	Iberdola	120	64
		Gode Wind 4	Orsted	120	98,3
		Wikinger Süd	Iberdola	120	0
		Kaskasi	Innogy	120	0
		Arcadis Ost 1	KNK Wind	120	0
		Borkum Riffgrund West 1	Orsted	120	0
2021	3	N-3.7	RWE Renewables Offshore Development GmbH	0	0
		N-3.8	EDF Offshore Nordsee 3.8 GmbH	0	0
		O-1.3	RWE Renewables Offshore Development One GmbH	0	0
2023	4	N-11.1	bp OFW Management 1 GmbH	0	-20,9
		N-12.1	North Sea OFW N12-1 GmbH & Co. KG	0	-21,4
		N-12.2	bp OFW Management 3 GmbH	0	-17,8
		O-2.2	Baltic Sea OFW O2-2 GmbH & Co. KG	0	-23,6
2023	5	N-3.6 (Delta Nordsee 1&2)	RWE - Nordseecluster B	0	0
		N-3.5 (Delta Nordsee 3)	RWE - Nordseecluster B	0	0
		N-6.6	Vattenfall by subrogation right, former RWE	0	-14,2
		N-6.7	Waterkant Energy GmbH	0	

Table 6 - Germany Awarded Projects and Strike Prices

Despite different factors affecting LCOE for any offshore wind project, such as grid connection costs, distance to shore and offshore infrastructure, certain auction design elements impacts the developer’s costs (Rubio-Domingo & Linares, 2021). These design elements should align with a nation’s policy goals. In particular, the support conditions are highly relevant for this efficiency.

For example, in the UK, the main driver of the lower strike prices is technological progress, economies of scale and cost-reduction through tighter margins for suppliers, rather than increased revenue expectations. This is because the UK developers do not benefit from a higher market price in the two-sided CfD scheme. Increased revenue is more likely expected for German projects, as the developer's willingness to pay increases with the upside potential in a one-sided CfD scheme, allowing higher wholesale market prices.

According to Côté et al., (2022) developer uncertainty is lower for scheduled compared to irregular auctions. In the UK, AR 1 - 3 was held between 2015 and 2019, each with a two-year interval. However, neither the schedule of auctions nor volumes auctioned were disclosed, likely impacting the outcome. In 2021, AR 4 was the first auction to include scheduled start and volume (Petrova, 2021). AR 5 in 2023 displayed the auction volume based on a target budget.

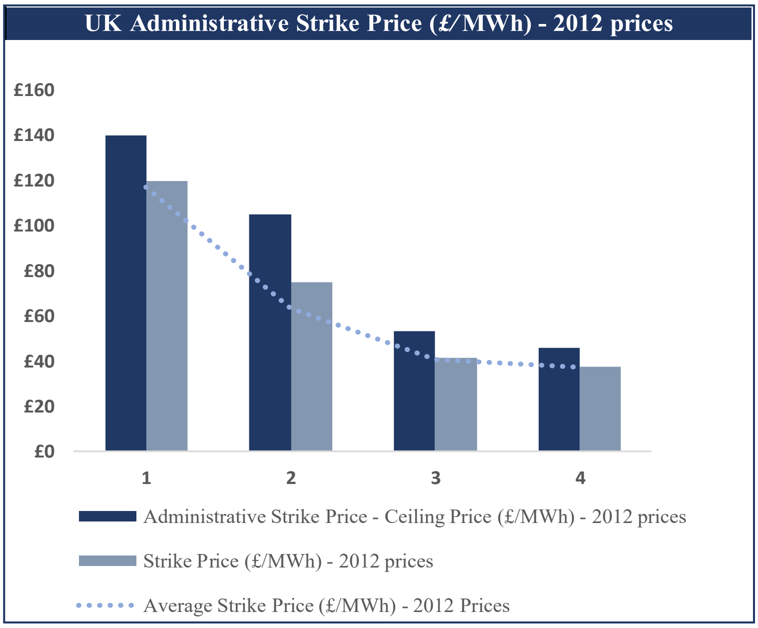

Figure 11 - Development of UK ASP vs Strike Price AR 1-4 (GOV.UK, 2023)

Figure 11 describes a falling ASP in all performed UK auctions up to AR 5, all higher than the winning bids. This indicates cost savings for the UK government, as the subsidy requirements are lower compared to the maximum limit. The risk in a CfD scheme is alleviated by the contract agreement with the government LCCC. Consequently, some projects have considerable leverage. This risk-reduction and revenue support is expected to be met by a lower ASP. However, it is likely that the continuous pursuit of setting a more competitive ASP has failed to consider the market conditions and rising technology costs. This resulted in a too low ASP and zero bids in AR 5 (LinkLaters, 2023).

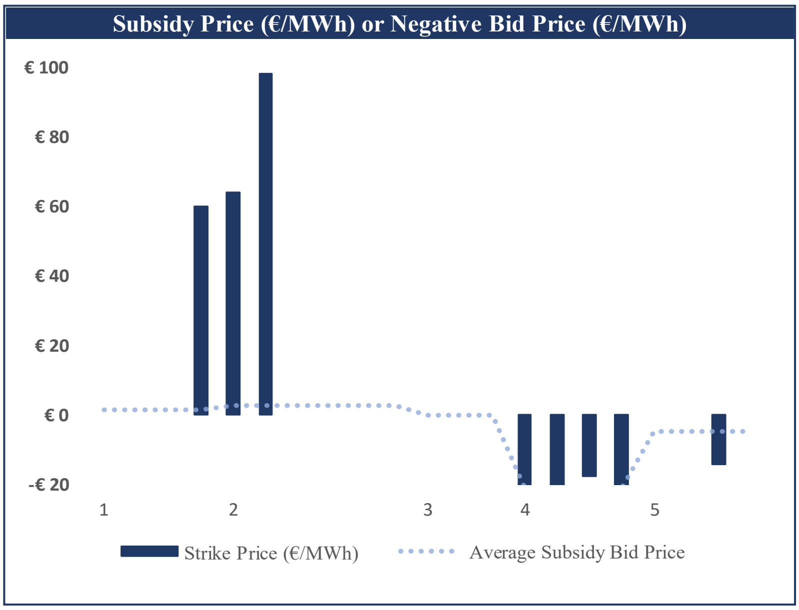

Figure 12 - Development of Germany Subsidy Price vs. Negative Bid

In the German market, Figure 12 shows a similar trend of descending subsidy prices from the first to the most recent auction rounds, including multiple zero-bid auctions. Considering the definition of static efficiency, the development illustrates a market with successful and highly efficient RES deployment.

Quantitative Analysis of Static Efficiency

Two key drivers of profitability in offshore wind are capital expenditure and cost of capital, which both have risen sharply over the last 12 months as a result of inflation and interest rates (FTI Consulting, 2023). This is highlighted by cost increases throughout the supply chain, where i.e. the price increase for raw materials at a leading installer and servicer of wind turbines, Vestas, has resulted in gross margins falling from 10 % to 0.8 % between 2021 and 2022 (Vestas, 2023).

Internal Rate of Return, Weighted Average Cost of Capital and Net Present Value

An important financial metric to consider when analysing returns of a renewable power project is the Internal Rate of Return (IRR). IRR is defined as the required return for any project to break-even, i.e. cover the required investment costs. The general decision rule considers only projects with an IRR above a given hurdle rate, normally equal to the Weighted Average Cost of Capital (WACC), as a viable investment. The WACC represents the rate of return which all investors, equity and debtholders expect to earn for investing in the project, as opposed to others with a comparable risk (FTI Consulting, 2023).

The Net Present Value (NPV) method discounts the expected revenue streams throughout the lifetime of the project with the hurdle rate. The general rule is to accept a project if the NPV is positive. It is the most common profitability metric, and often used when deciding between multiple projects, through an absolute measurement of the increase in market value from accepting a project. Combined, the two provide a reasonable indication of the profitability of a project.

When entering an auction, there are additional strategic motives to consider. Developers seeking a strategic advantage or other alternative motives can pursue aggressive bidding, i.e. requesting a lower strike price than their actual hurdle rate. These strategies can lead to the "winner's curse". The winner of the auction "overpays" for the contract due to overambitious estimates. This brings significant risk of non-realization, depending on the penalty cost for non-compliance relative to project development (Kell et al., 2023). Risk-averse bidders would rather bid marginally above their hurdle rate to mitigate this risk.

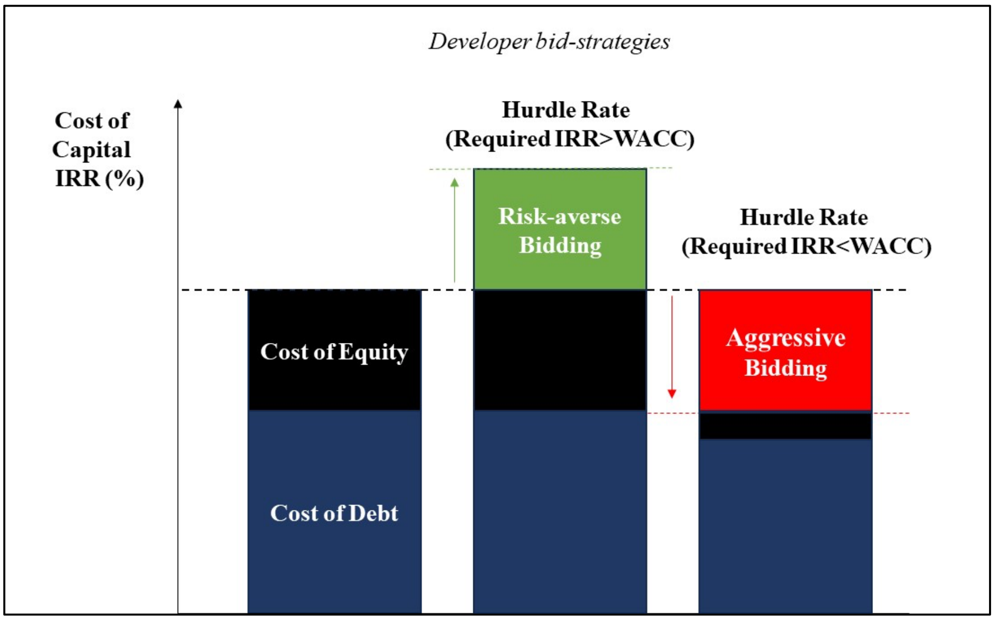

Figure 13 - Bidding Strategy relative to IRR and Weighted Average Cost of Capital (WACC)

Figure 13 illustrates the composition of the IRR in relation to risk-averse and aggressive bidding strategies which may be pursued by developers.

The situation is illustrated through different scenarios in a simplified IRR and NPV analysis of an offshore wind project in the UK, given the reported and expected ASPs, capital costs and leverage ratio, capital expenditure and capacity factors for developers in 2023 (IRENA, 2023).

The UK

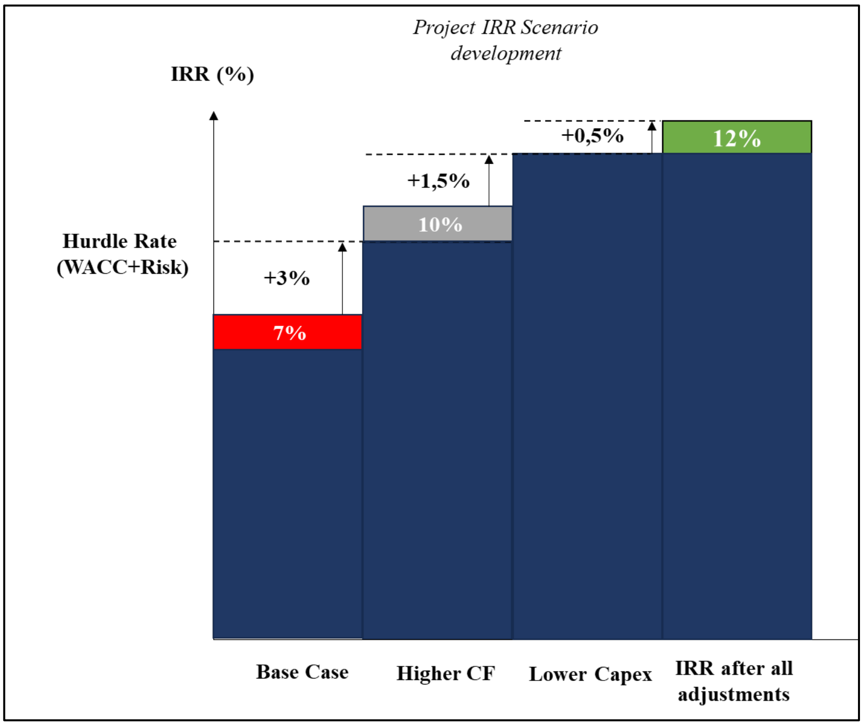

Figure 14 - IRR impact from cost and revenue scenarios (FTI Consulting, 2023)

The scenarios indicate an increase in capacity factor of at least 50 % may add 3 % expected IRR. To add another 1.5 %, the project must increase Debt-to-Equity leverage to 80 %, while an additional 0.5 % may be achieved by a reduction in Capital Expenditure of 10 % (FTI Consulting, 2023). As observed in Figure 14, there are very few auctioned projects which will pass the hurdle rate under the current macroeconomic climate – even with all adjustments available.

Scenario	2
Strike Price	50,00
Capacity factor	0,50
Opex (LCOE)	0,74
Capex	-1,33
Cash Flow	0,22
IRR	**4,29 %**
NPV	-£ 1,12
WACC	**6,20 %**
Market Price	62,00
Cash flow after	0,12

Table 7 - IRR and NPV, Average Offshore Wind Project UK

Price & Quantity Sensitivity						
Strike Price ($/MWh)						
IRR	**4,29 %**	25,00	40,00	50,00	65,00	75,00
Capacity factor	0,60	3,63 %	4,78 %	5,60 %	6,90 %	7,82 %
	0,50	2,63 %	3,60 %	4,29 %	5,39 %	6,16 %
	0,49	2,52 %	3,48 %	**4,15 %**	5,23 %	5,98 %
	0,40	1,47 %	2,27 %	2,83 %	3,72 %	4,34 %
	0,35	0,80 %	1,51 %	2,01 %	2,80 %	3,34 %

Table 8 - Scenario Analysis - Average Offshore Wind Project UK

Consequently, Table 7 and 8 observes that given the ASP in AR 5, the project has a IRR of 4.29%, based on IRENA figures (IRENA, 2023). This indicates that pursuing a project is below the industry hurdle rate at 10 – 12 %. This hurdle rate includes a developer's WACC + additional risk premiums (FTI Consulting, 2023).

Given a global industry average WACC of 6.2 %, the NPV is close to zero (Bloomberg, 2023), with a strike price equal to the announced ASP, despite a higher expected market price of electricity after CfD expiry. Despite the indicative calculated returns being subject to error and varies based on assumptions used, the scenario analysis in Table 8 underlines the industry impression that at current ASPs, a very optimistic expectation of the CfD strike price and the offshore wind farm's capacity factor is necessary to achieve profitability.

Germany

A zero-subsidy bid indicates a payment for the real option of developing the plant. The developer must in this case be convinced that the financial components, the market price of electricity, reduction in technology cost and socialization of grid costs will be advantageous. Combined with strategic considerations such as grid access and potential clustering, the payoff will be higher than the development cost of the plant, in addition to the lease option cost and potential penalties of non-compliance. I.e., the total project payoff is higher than the real option of the contract (F. Müsgens & I. Riepin, 2018). Therefore, the bid will display the valuation of the auctioned project by the bidder.

Scenario	2
Market Price	85,00
Capacity factor	0,46
Opex (LCOE)	0,74
Capex	-0,77
Cash Flow	0,34
IRR	**7,09 %**
NPV	**€ 0,39**
WACC	**6,20 %**
Market Price	85,00
Cash flow after	0,34

Table 9 - IRR and NPV - Average Offshore Wind Project Germany

Price & Quantity Sensitivity						
		Market Price ($/MWh)				
IRR	**7,09 %**	65,00	80,00	95,00	110,00	128,00
Capacity Factor	0,56	6,45 %	8,31 %	10,03 %	11,64 %	13,47 %
	0,51	5,69 %	7,46 %	9,08 %	10,60 %	12,33 %
	0,46	4,89 %	6,56 %	**8,10 %**	9,52 %	11,14 %
	0,41	4,04 %	5,62 %	7,06 %	8,40 %	9,91 %
	0,36	3,14 %	4,63 %	5,97 %	7,22 %	8,61 %

Table 10 - Scenario Analysis - Average Offshore Wind Project Germany

Table 9 illustrates that by using the forecasted market price of electricity in Germany (IRENA, 2023), and the current cost estimates for the German market, the IRR is higher for an average developer at 7.09 % and a positive NPV. Table 10 shows how the profitability of the project varies with the expected market price of electricity as well as the capacity factor of the project. Naturally, given the one-sided CfD in Germany, it demonstrates that the market price is an important factor for the profitability of the wind farm.

Profitability Comparison of the UK and Germany

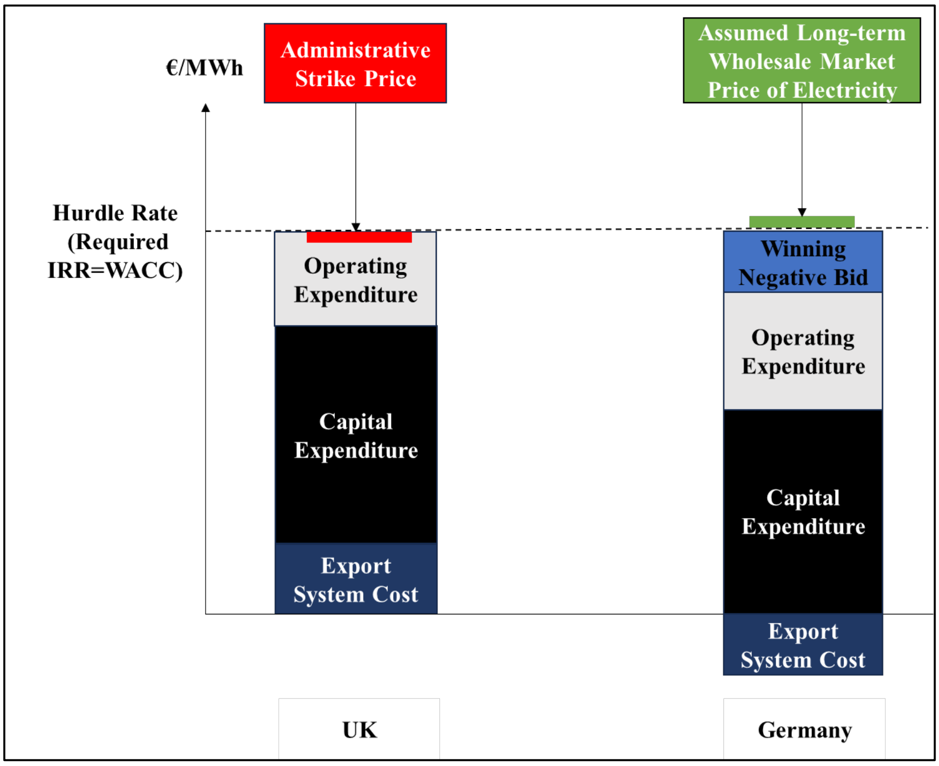

Figure 15 - Distribution of Offshore Wind Project Investment Cost - UK vs Germany (Horn Hansen, 2023)

Consequently, Figure 15 displays the different project cost components and their roles, contributing to the difference between the attractiveness in the two markets. In short, by internalizing the export system cost such as grid integration, the level of capital expenditure is lower in Germany compared to the UK. The developers face less up-front investments and risk, and combined with the one-sided CfD scheme, they can profit from the expected long-term wholesale market price of electricity. Conversely, the need for internalization of export system cost in the UK, combined with a lower ceiling on potential revenue fails to incentivize developers as it makes investment cost too high. The inability to adjust the ASP in a market subject to inflation, supply chain tightness and increased cost of capital has resulted a failed UK auction, in turn heavily impacting their policy goals.

The price of the real option to develop an offshore-wind project in the UK is observed to be too high for developers to even consider making the required initial pre-qualification investments. Thus, abstaining from participating in the auction in its current format. In Germany however, the potential revenues from the expected market price of electricity are believed to exceed the price of the real option across the board. Consequently, the zero-bids indicate no need for subsidies or guaranteed premiums for the investment to be profitable, resulting in higher volumes of allocated capacity and auction participants.

6.2.2 Dynamic Efficiency

The dynamic efficiency of the different formats is measured by investigating whether the countries have incentivized industry innovation and technological development. Floating wind turbine technology is assumed to be the future technology for offshore wind farms, due to higher energy yields by extracting larger wind resources further from shore. This technology, however, is currently subject to much higher capital costs compared to fixed-bottom technology. This is because of less standardization of equipment and supplies, limiting opportunities of economies of scale. Nonetheless, these costs are expected to drop as the technology matures. Consequently, the scale of floating technology deployment is used as one proxy for technological development.

As of 2023, there has been one floating offshore wind farm auctioned in the UK, the TwinHub Floating Offshore Wind Project, from AR 4. With a CfD strike price of GBP 87.3/MWh, significantly lower than the ASP at GBP 122/kWh and volume of 32 MW, the project is due to be delivered in 2026/27. However, there are no floating offshore wind projects in the performed auctions in Germany, making a comparative analysis on this technological development difficult. Another example of how the UK shows a higher degree of dynamic efficiency than Germany is the ScotWind leasing round. This included ten signed option agreements with an expected volume of 14.5 GW in the UK, signalling intent to expand capacity further. Technological development and cost reduction is also illustrated by lower strike prices. Lower strike prices indicate improved economies of scale, and less costly technology. Both markets display a steady decrease in ceiling prices each auction round as per Figure 11 and 12, indicating that projects have become increasingly profitable.

6.3 Minimizing Support Costs

The support costs in the CfD scheme are linked to the strike price, indicating that a lower strike price will imply lower support costs. A CfD protects developers from volatility in the electricity spot market. However, the strike price itself will vary based on other factors such as the calculated operation costs and CAPEX for developers. If the government covers grid infrastructure, this lowers the CAPEX of developers, which in turn should reduce the auction strike prices. This is the current practice in the German market, which has grid connection included in the site lease (F. Müsgens & I. Riepin, 2018b).

In the UK, such a CAPEX-alleviation was to be offered in AR 5. However, the CfD terms were considered unprofitable by bidders, leaving over 4 GW on the table (Energylive News, 2023). In turn, insufficient energy production would induce higher support costs, as a lower supply will, all things equal, lead to a higher market price of electricity paid by consumers, given an equal or rising demand. The total impact on support costs must consider both the cost for the government of pre- assessment of project areas, as well as the expansion and integration to the grid relative to the lower subsidy payment (F. Müsgens & I. Riepin, 2018b).

The UK is looking at the possibility of allowing for developers to enter PPAs with commercial actors, which incentivizes developers due to higher potential revenues (HM Government, 2023). This has been discussed in Germany as well as a possible further upside for future auctions (Stuchfield, 2023). In addition, this aids the green energy transition for industrial production. In summary, due to the descending trend of strike prices in the performed auctions in both countries, the auction designs are considered to have contributed largely to low support costs.

6.4 Local Impacts

Both countries have experienced positive local impacts from offshore wind projects. By pioneering local industrial development and attracting foreign investments, the UK has had successful socioeconomic impacts. This has led to local employment, reduced fossil fuel dependence and increased energy security for the UK. Moreover, they conducted Environmental Impact Assessments (EIAs) to reduce the environmental impact of the industry and infrastructure. In the UK, there are plans to support 90,000 jobs, as part of the UK's 50 GW ambition. This includes retraining the existing oil and gas workforce with transferable skillsets, which ensures employment while developing the offshore wind industry's competence (HM Government, 2023). The first, major auction design element in the UK's prequalification process is the SCP requirement to ensure necessary support infrastructure for delivery of a project, while promoting local development. As a result, 87 % of the blades for this project were manufactured in the UK and delivered locally (Hart, Campbell, 2022).

The qualitative criteria for the German pre-investigated static auctions, which represent 40 % of the bid weight, have local impact. First, the bidder must ensure their contribution to decarbonising the German offshore wind industry. Second, a share of the planned energy produced must be sold via PPAs. This can in turn lead to renewable energy being used for manufacturing, making that industrial production greener as well. Third, the turbines must have as little noise impact as possible. Last, a share of the bidders and their subcontractors' workforce must be apprentices. This helps build a competent workforce, increasing both local and German labour resilience (Stenzel et al., 2022). Figures from the industry association Network for Wind Energy in early 2022 report that 21,400 people are directly employed in the German Offshore wind industry. There is however a reported shortage of skilled workers to install, operate and maintain renewable power infrastructure in the coming years (Wehrmann, 2023). Because of this, a retraining program for German oil and gas workers has been started (BMAS, 2022).

6.5 Socio-Political Feasibility

While auction efficiency has increased, alongside support costs reductions over the last 10 years, local content in the respective markets have historically been low. Most projects are won by international companies or joint ventures in both countries (Norton Rose Fullbright, 2023). However, certain regional developers have been included in the UK auctions, such as Scottish Power Renewables and SSE Renewables. The ScotWind leasing round provided higher accessibility by granting seabed leases to other regional developers. This is considered to incentivize regional production and local content, which in turn may increase levels of social acceptance from the local population. This ambition is further substantiated by contractual demands for SCPs and local content in future allocation rounds (France, 2022).

According to the Sonnberger & Ruddat (2017) study on the German market, the socio-political acceptance of wind farms highly depends on the vicinity of the affected stakeholder group. Offshore wind farms are publicly perceived to have lower risks, higher fairness, and greater relevance in the energy transition. Thus, offshore wind farms hold the highest acceptance, compared to different types of onshore wind farms – increasing the socio-political feasibility of further offshore wind deployment.

6.6 Actor Diversity

The performed auctions in both countries have, in alignment with low participation rate from regional developers, lacked diversity in terms of actor size. The UK market is dominated by four international players owning in total over 40 % of the awarded projects (The Crown Estate, 2023a). A similar lack of actor diversity exists in Germany. The German market is however slightly more fragmented, due to increased attractiveness following its' new auction format.

The process of designing auctions to promote diversity in terms of size, however, is complex, given the large size of each single project. The economies of scale required to deliver competitive bids while remaining profitable is difficult for smaller developers, due to lack of financial capacity, competence, and ability to diversify project risk. At the same time, the many international companies and joint ventures does increase foreign investment in the UK and Germany (Norton Rose Fullbright, 2023).

Actor diversity can be part of the pre-qualification criteria. Examples might be requiring a percentage of project tasks to use local subcontractors. Signing contracts with local Small & Medium size Enterprises (SME) is another way to incentivize local traction, thus increasing political acceptance. However, this is a trade-off, balancing project costs and auction effectiveness and efficiency.

6.7 Summary of Findings

This comparative analysis extracts certain best practices from both countries, which serve as lessons on optimal RES-auction design for policymakers. Both countries have effectively deployed offshore wind as per national policy targets, up to 2023. The two exhibit different variations in policy implementation. The UK, with its two-sided CfD format, faces challenges of project delays from cost overruns. This is exemplified through Vattenfall's decision to postpone the Norfolk Boreas wind farm. Both countries have until 2023 also had high degrees of static and dynamic efficiency. This is displayed through falling subsidy prices between each auction round and reduced support costs. Germany has excelled in this matter with multiple zero-subsidy rounds.

The UK pursues static, sealed bid, auctions, due to its simplicity and speed for mature technologies such as offshore wind. Germany on the other hand, has utilized dynamic, ascending auctions, which enables price discovery. For less mature, emerging markets, it may be more suitable to use dynamic or hybrid auctions, due to its advantage of allowing price discovery. Both countries schedule auctions with volume set and disclosed, allowing developers to offer competitive pricing based on expected technological costs. The auction frequency is set to increase from 2023 and beyond, where both markets will hold annual auctions. Setting auction volumes based on an annual budget separate for offshore wind is a good strategy based on the level of maturity of offshore wind. The UK has performed technologically neutral auctions for all RES, dividing the technologies into different pots. Germany has held technology-specific auctions for offshore wind.

While both markets witness improvements concerning static efficiency through reduced strike prices, the driving factors behind differ. The UK attributes lower subsidy prices to technological progress and economies of scale. German developers benefit from revenue expectations in the market-driven approach. Ceiling prices are used in both countries to restrict the maximum bid value and support. Caution is needed when setting the value, i.e. it should be based on technological advancements and market conditions. Too high ceiling prices may result in weaker competition through low participation, and too low ceiling prices could lead to underbidding to secure contracts.

Support mechanisms have critical impacts on auction success. The two-sided sliding FiP (CfD) protects the developers from low market prices and the consumers from high market prices. The one-sided sliding FiP scheme, however, is riskier for the developer, but provides a higher upside. In the UK, a bid represents fixed revenue stream for the period, while a bid in Germany considers the minimum support required to develop the project. The UK pursues the two-sided, sliding CfD, seeking to de-risk investment for developers and the state, while incentivizing industry maturity through fixed remuneration.

Germany pursues a one-sided CfD and facilitates the integration to the grid, reducing up-front costs for developers. The revenues of German developers are more reliant on future wholesale electricity prices via the sliding FiP. On the other hand, it introduces a higher risk of non-realization through real-option strategy from developers. Given the UK’s policy goal of building a strong industry, a de-risking strategy has until recently been successful. Germany, with the policy goal of increasing its energy security has pursued a more aggressive strategy. This has resulted in many auction participants and large auction volumes.

Overall, RES auctions should include prequalification criteria to ensure that bidders are financially and physically capable to develop an offshore wind park, as they are considerably large projects. The UK has a current strategy of commitment to enhancing local content. Germany has criteria considering decarbonization, noise reduction and development of a skilled local workforce. What is more, a well-defined realisation period should ensure timely achievement of national policy targets, and penalties reduce chances for non-delivery of projects. This in turn reduces the risk of developers treating the auction as part one of a two-stage investment, i.e. a real option to build. The balance is important, as a too strict time-schedule and penalties can reduce investor interest, which in turn leads to moderate auction participation and potentially higher prices.

Both nations demonstrate commitment to dynamic efficiency by encouraging innovation and technological development. The UK's floating TwinHub project in Scotland showcases a proactive stance, whereas Germany is looking to auction floating offshore wind projects in the future. The challenges following rising inflation, increased capital and operating costs are affecting IRR and project profitability. The UK's aim of continued lower contract prices in AR 5, faces criticism for misalignment of extraordinary market conditions. The scenario analysis for UK projects illustrates the need for an optimistic business case to attract bids. Linking support schemes and strike prices are central goals for both markets. In particular, the incorporation of grid connection costs to site lease has been successful in Germany.

While both markets witness dominant international players and increasing foreign investment, the UK's more concentrated offshore wind market contrasts with Germany's fragmented diversity. This highlights adaptability in auction design elements to accommodate diverse market participants. For example, actor diversity may be promoted by involving smaller players in shared project ownership schemes, promoting social acceptance of offshore wind projects.

This analysis considers the different auction design elements in the two markets based on a comparative approach. The fact that certain design elements outperform others does not guarantee its applicability in all countries. Ultimately, it must be customized and applied based on market maturity, macroeconomic climate, and government policy.

7. Application of Lessons to Norway

Norway, with its long coastal line sits on vast expertise and infrastructure concerning offshore vessels and structures through its large petroleum industry, has a comparative advantage in this field. A long-lasting energy surplus from the hydropower industry however, reduces the need for energy security as political motivation compared to its European neighbours (Ryenbakken & Nieuwenhout, 2023).

This chapter discusses the current state of the offshore wind industry in Norway and applies the findings in the previous comparative analysis to provide recommendations on government policy and auction design. This can facilitate offshore wind as Norway's next green industrial adventure.

7.1 Norwegian Energy Mix and Offshore Wind Policy Goals

3.1 % of Norway's climate emissions came from energy generation in 2022 (SSB, 2023). 95 % of consumed electricity delivered through the grid in Norway derived from renewable energy sources in 2022, with hydropower and onshore wind being the most contributing power sources, accounting for 81 % and 12 % of consumed electricity on the Norwegian grid, respectively (NVE, 2023).

The ambition of the Norwegian government is to have allocated offshore wind sites for production of 30 GW within 2040, while the Norwegian TSO Statnett only receives funding to develop infrastructure to accommodate 15 GW of offshore wind production by 2040. Because the current production capacity plan exceeds the current infrastructure plan, the idea is to connect Norwegian offshore wind farms to the continental grid. A later goal is to have offshore wind power production from the Norwegian continental shelf feeding into the grid by the end of 2030 (Olje- og Energidepartementet, 2023).

7.2 Market Situation

Norway is no exception to the current realities of inflation and rising interest rates. The macroeconomic climate has cooled down in the last years, and cost reduction is high on the agenda. Therefore, fiscal expenditures into the renewable energy industries in the form of subsidies might seem counter intuitive, yet the industry needs signals of confidence. The UK did not respond to market needs, which resulted in a failed auction. Conversely, Germany tried a new auction format and achieved record-breaking results. Recent German auction results prove a way for offshore wind forward.

Norway is yet to build an offshore wind industry of similar scale as the UK and Germany. However, the Sørlige Nordsjø II auction signals that this has changed, and that a future offshore wind industry in Norway is becoming a realistic expectation (Tande, 2022). It is important to note that the Norwegian energy policy is primarily based on the principle of short-term cost efficiency, requiring that any new renewable energy production scheme must be profitable in the short term. Hence, the primary objective of the offshore wind auctions will be to ensure deployment with minimized support costs.

7.2.1 Market Regulation

The regulatory framework for offshore wind development in Norway is laid out in the Ocean Energy Law and the Ocean Energy Act. There is currently uncertainty around the licensing process and export cables for the two current projects Sørlige Nordsjø II and Utsira Nord. As part of the EEA and EU ETS/CBAM, Norway faces both challenges and opportunities from increased integration into EU Climate Politics and ESA involvement (Rustad, 2023).

7.2.2 Market Opportunities

A changing energy environment with lower dependency on fossil fuels and trend of global decarbonization may be an opportunity to transform Norway’s offshore competence into a powerhouse within the offshore wind industry. The IEA considers 40 % of the oil and gas supply value chain to coincide with the offshore wind value chain (IEA, 2019), and by adapting an early domestic market for deep-water offshore wind, developers in Norway have the potential to gain an advantage on technology innovation when competing for global deep-water projects.

Overall, offshore wind plays a role in many decarbonization scenarios. To unlock investment and industry development potential, policy must correspond with offshore wind deployment goals and incentive schemes. The Norwegian supply and service industry might benefit from introducing local content requirements as part of the policy. However, the additional cost of using domestic relative to international suppliers must be investigated in detail to keep subsidy requirements low, in alignment with short-term profitability requirements.

7.3 Current Norwegian Projects

7.3.1 Quantitative Analysis of Sørlige Nordsjø II and Utsira Nord

Sørlige Nordsjø 2 has a total capacity of 3,000 MW and will be developed in two separate phases of 1,500 MW each. Both phases are allocated in separate auctions. The power from the first phase will be transferred to the Norwegian mainland through a radial connection, while the power from the second phase is not yet determined. There is a potential for a hybrid cable which enables transfer to other countries. This allows for additional revenue streams, but this option has been scrutinized due to its impact on Norwegian power prices. There is a worry of cannibalization of the power produced from these projects by other EU projects in the North Sea. This increased supply may lead to lower market prices for the exported electricity, which in turn is less profitable for the developers and Norway as a country (Ånestad & Holter, 2023).

In 2040, the expected power price by the Norwegian Water Resources and Energy Directorate (NVE) is EUR 59/MWh (Birkeland, 2023). Furthermore, the inflation adjusted LCOE for Sørlige Nordsjø 2 is currently estimated at EUR 110/MWh, and Utsira Nord at EUR 130/MWh. The assumption is that bidders in both auctions ask for a strike price close to their LCOE. Moreover, the long-term power prices in the NO2-area, the area of the offshore wind projects, is predicted at EUR 59/MWh. Currently, the maximum subsidy cap is set at EUR 76/MWh. This is below the expected LCOE which sits at EUR 110/MWh as illustrated in scenario 2 (see Table 11, LCOE = 1.10). Thus, the ceiling price will likely be equal to the contract price asked by any developer considering auction participation (Jannicke, 2023).

Scenario	2
Strike Price	76,00
Capacity factor	0,50
Opex (LCOE)	1,10
Capex	-1,40
Cash Flow	0,33
IRR	**4,93 %**
NPV	-€ 0,52
WACC	**6,20 %**
Market Price	59,00
Cash flow after CfD	0,25

Table 11 - IRR and NPV - Sørlige Nordsjø II

Price & Quantity Sensitivity						
		Strike Price ($/MWh)				
IRR	**4,93 %**	25,00	40,00	50,00	65,00	75,00
Capacity factor	0,60	3,12 %	4,23 %	5,02 %	6,28 %	7,17 %
	0,50	2,13 %	3,08 %	3,74 %	4,81 %	5,55 %
	0,49	2,03 %	2,95 %	**3,61 %**	4,65 %	5,38 %
	0,40	0,99 %	1,76 %	2,31 %	3,17 %	3,77 %
	0,35	0,33 %	1,03 %	1,51 %	2,27 %	2,80 %

Table 12 - Scenario Analysis - Sørlige Nordsjø II

Despite the lower LCOE, resulting from using a proven, less costly bottom-fixed technology, Sørlige Nordsjø II will require higher subsidies to be profitable. This is due to high capital expenditure from a costly, long transmission cable to the Norwegian mainland, as well as difficult seabed conditions for the build of the bottom-fixed infrastructure. Consequently, the project is not profitable in the current conditions, displayed by a low IRR and negative NPV.

For Utsira Nord, the total costs are expected to be significantly higher due to the floating technology's maturity, despite a lower grid integration cost compared to Sørlige Nordsjø II. As such, it will require large subsidies to become profitable. Given the announced ceiling price of EUR 76/MWh and expected LCOE of EUR 130/MWh (Table 13, LCOE = 1.30), the subsidy cap is estimated to be reached within the first 8 years. In total, the cost of the farm may even exceed EUR 21.03Bn (NOK 250Bn), with EUR 6.73Bn (NOK 80Bn) in subsidies (Jannicke, 2023).

Scenario	2
Strike Price	76,00
Capacity factor	0,50
Opex (LCOE)	1,30
Capex	-1,70
Cash Flow	0,33
IRR	**2,69 %**
NPV	-€ 1,64
WACC	**6,20 %**
Market Price	59,00
Cash flow after	0,25

Table 13 - IRR and Net Present Value - Utsira Nord

Price & Quantity Sensitivity						
		Strike Price ($/MWh)				
IRR	**2,69 %**	30,00	45,00	50,00	65,00	80,00
Capacity factor	0,60	0,61 %	1,70 %	2,09 %	3,30 %	4,58 %
	0,50	-0,37 %	0,56 %	0,89 %	1,91 %	2,99 %
	0,49	-0,47 %	0,44 %	**0,76 %**	1,76 %	2,82 %
	0,40	-1,49 %	-0,73 %	-0,46 %	0,37 %	1,24 %
	0,35	-2,14 %	-1,45 %	-1,22 %	-0,48 %	0,29 %

Table 14 - Scenario Analysis - Utsira Nord

It is here used a WACC of 6.2 %, based on previous forecasted profitability analysis of the UK and German markets. The assumption is a project lifetime of 25 years, with 4,380 hours of production (Jannicke, 2023). The profitability case is illustrated by an even lower IRR and negative NPV. It is noteworthy that project valuation involves strategic valuations which must be taken into consideration. Specifically, the real option value of postponing project start, which increases in value with risk and uncertainty, is not explicitly valued in this model.

7.3.2 Market Reactions to Norwegian Auction Design

The current projects' affiliated risks may serve as a barrier for bidders. Strict and unclear prequalification criteria and penalties, combined with a complex concession process and a limited upside due to the macroeconomic climate, can reduce the attractiveness of the Norwegian auctions. This concern has been voiced publicly by industry organizations such as Fornybar Norge. Additionally, several consortia have dropped out of the prequalification process. This is illustrated by Ørsted and Aker withdrawing from the Sørlige Nordsjø II auction two days before application deadline, due to lack of project profitability in the current format (Holter, 2023a). Spanish Iberdrola, French Totalenergies and Swedish Vattenfall, as well as Norwegian Hafslund and Fred Olsen Seawind all dropped out of the auction.

Project Name	Confirmed Prequalifaction Applicants
Sørlige Nordsjø II	Hydroelectric Corporation Equinor/RWE Mingyang Smart Energy Norseman Wind/EnBW/Norgesgruppen Aker Offshore Wind/Statkraft/BP Shell/Lyse Energi/Eviny Parkwind/Ingka

Table 15 - Confirmed Prequalification Applicants - Sørlige Nordsjø II

The low number of applicants in Table 15 underlines the limited interest. Some developers highlight issues with calculating a profitable scenario of fully developing the wind farm. Two new, previously unknown applicants are Chinese turbine manufacturer Minyang Smart Energy and Hydroelectric Corporation. The latter is rumoured to be interested in the possibility of building an offshore pump storage, based on two applications to Norwegian government in 2022. Consequently, both new applicants are unlikely to satisfy the prequalification criteria. Considering the number of applicants, the government has announced that the auction may be cancelled, should the number of qualified applicants be lower than six, which is likely. (Holter, 2023b).

Important to note is that even though these consortia have applied for prequalification, there is no certainty that the project will be realized. Winning the auction provides the option for the winner to apply for a concession to build. A realization period of potentially 8 years leaves a lot of risk of non-realization present, should some of the uncertainty remain unresolved and the macroeconomic climate improve. On the other hand, the long realization period can be seen as a window for trends and uncertainty to be resolved. This again allows for more favourable terms which increases the option value to build.

Public reactions to the current format were met by the government by changing the prequalification criteria for both Sørlige Nordsjø II and Utsira Nord. Sustainability and positive local impact were changed to minimum requirements for participants in the competition included in the CfD, instead of being prequalification criteria. Furthermore, the wording of “positive local impact” were changed to “positive impact”, clarifying that they are not limited to Norway. These changes were made to speed up processing time and reduce the realization period, as the industry reacted to it as overly complicated. The consequence for Utsira Nord is likely a postponement of 12-18 months, and for Sørlige Nordsjø II 6 months (Lie, 2023).

7.4 Auction Design Assessment and Recommendations

Combining the framework analysis, quantitative analysis and policy discussion, this chapter makes recommendations for some auction design aspects to consider for future deployment of Norwegian offshore wind. The Norwegian Ministry of Petroleum and Energy (OED) states that the auction should ensure minimized support cost and align with the policy of short-term profitability. Thus, its’ design should incentivize low subsidy requirements, resulting in both high efficiency and effectiveness. Therefore, this chapter describes and assesses the current auction design in light of Norwegian policy and recommends changes to further improve auction design.

7.4.1 Auction Format and Selection Criteria

Sørlige Nordsjø II

For Sørlige Nordsjø II, the selection criteria involve a prequalification round, followed by a price-only, ascending auction. The prequalification round ensures the capability of the bidder to fulfil the contract. The ascending auction determines the award price through multiple rounds of bids. The winning bidder is decided based on the lowest bid-price. It awards a time-limited exclusivity of the project area and permission to initiate the licensing process for developing the windfarm. It is a straightforward, familiar winner selection method, which reduces uncertainty for bidders and incentivizes participation. Moreover, it should in theory lead to maximized socio-economic welfare, in alignment with the goal of the OED.

The main benefit of this auction format is its price discovery ability because bidders adjust their bids based on information uncovered from previous rounds of bidding. This is suitable given that offshore wind auctions have not been completed in Norway. Thus, information on marginal costs of bidders and their valuations prior to the auction is limited. Consequently, the auction format will reveal the valuation of each individual bidder. The bidder with the highest valuation, accepting the lowest support price, wins the auction. The chosen ascending auction is a good fit when there is risk of the winner’s curse, due to its’ sequential bidding process. In the Sørlige Nordsjø II auction there are as mentioned both elements of private and common factors which affects the valuation of the auctioned item. However, the format does leave the risk of collusion amongst bidders should the auction include few participants. Less auction demand opens for strategies such as signalling, where bidders do not disclose their actual ceiling price, i.e. the lowest price they are be willing to accept, due to the descending nature of the auction.

Given that such an ascending auction format is chosen, it should be designed to make it difficult to signal through bids. This can be done, for example, by using fixed-increment bids such as in Germany. This could mitigate strategic bidding and signalling, lowering the risk of collusion. Thus, the chosen format may be suitable for the auction, with weight on reducing the risk of the winner’s curse, maximizing probability of project realization. This could minimize subsidy price, given the lack of maturity and public information in the Norwegian market.

Utsira Nord

The 1,500 MW floating Utsira Nord project is divided into three areas and has applied multi-criteria decision-making. Further information on the project is currently limited.

Specifically, five qualitative criteria are assessed:

1. (30 %) Cost efficiency, the lowest possible cost estimate of developing the project
2. (20 %) Innovation and Technological Development, considering strategic initiatives and plans for future cost reduction and technological development in the industry
3. (30 %) Financial strength, experience, and capacity to ensure project completion
4. (10 %) Sustainability plans to ensure lowest amount of environmental impact
5. (10 %) Local community impact and job creation, development of supply chain and industry

It is recommended that qualitative criteria in the selection process are removed or given a reduced emphasis in the auction design. This is based on trend of RES auctions in general and offshore wind in particular. The German record-breaking auction removed qualitative criteria altogether, and a similar approach has now been decided for the Sørlige Nordsjø II auction. Continued emphasis on the quantitative aspects of the auction is recommended, given its simplicity both for developers and auctioneers, aligned with the goal of cost-efficiency.

7.4.2 Auction Volume

Sufficient auction volume is essential to incentivize auction participation. Annual, scheduled auctions, with large volumes aligned with development targets ensure attractiveness and a transparent pipeline for bidders. This is done in Germany and the UK. It enables planning of contracts with suppliers and permit applications, while unlocking economies of scale. Uncertainty around these volumes, or lack of size, likely lead to low auction participation and high prices, or even failed auctions.

In terms of policy development, Norway should look to the markets of UK and Germany for best practices on systemic cooperation between authorities, developers, and the supply industry. The UK has invested in infrastructure in partnership with supplier companies to enable a strong, domestic value chain. Germany on the other hand has a predictable plan for new capacity with regular announcements, infrastructure development and new job creation.

Year	Round	Project Name	Technology	Developer	Capacity (MW)	Round Total
2023/24	**1**	**Sørlige Nordsjø II (Phase 1)**	Bottom-fixed	TBA	1500	4500
		Sørlige Nordsjø II (Phase 2)	Bottom-fixed	TBA	1500	
		Utsira Nord (Area 1)	Floating	TBA	500	
		Utsira Nord (Area 2)	Floating	TBA	500	
		Utsira Nord (Area 3)	Floating	TBA	500	
N/A	**2**	Nordavind A	Floating	TBA	N/A	N/A
		Nordavind B	Floating	TBA	N/A	
		Nordavind C	Floating	TBA	N/A	
		Nordavind D	Floating	TBA	N/A	
		Nordvest A	Floating	TBA	N/A	N/A
		Nordvest B	Floating	TBA	N/A	
		Nordvest C	Floating	TBA	N/A	
		Vestavind A	Floating	TBA	N/A	N/A
		Vestavind B	Floating	TBA	N/A	
		Vestavind C	Floating	TBA	N/A	
		Vestavind D	Floating	TBA	N/A	
		Vestavind E	Floating	TBA	N/A	
		Vestavind F (incl. Utsira Nord)	Floating	TBA	N/A	
		Sørvest A	Bottom-fixed and Floating	TBA	N/A	N/A
		Sørvest B	Bottom-fixed	TBA	N/A	
		Sørvest C	Bottom-fixed	TBA	N/A	
		Sørvest D	Bottom-fixed and Floating	TBA	N/A	
		Sørvest E	Bottom-fixed and Floating	TBA	N/A	
		Sørvest F (Incl. Sørlige Nordsjø II)	Bottom-fixed	TBA	N/A	
		Sønnavind A	Bottom-fixed and Floating	TBA	N/A	

Table 16 - Auction Volume - Norwegian OW Projects

The OED has announced additional sites being assessed as potentially new offshore wind farm areas by the NVE. For Norway to achieve an offshore-wind capacity of 30 GW within 2030, the mentioned practices should be considered. However, processing and legal requirements for the EIA is delaying expansion, and the earliest allocation of additional capacity will be in 2025. This expansion will consider Utsira Nord and Sørlige Nordsjø II, part of the areas Vestavind F and Sørvest F highlighted above. Timelines and auction schedules for additional capacity is currently uncertain and undisclosed.

Norway should emulate the practices of the UK and Germany, where auctions are of large size, scheduled annually, with clear and distinct budgets, requirements, and application processes. This reduces developer uncertainty and lowers subsidy requirements. In other words, this aligns auction design with climate goals while minimizing support costs, in contrast to the current situation. Moreover, the total volumes of the current announced Norwegian projects are around the minimum recommended volume by industry stakeholders to ensure sufficient production to meet the required investments. This ideal minimum volume is 1 GW, and has been given as a proxy by industry stakeholders (Wind Europe, 2023).

7.4.3 Diversity

Project Name	Potential Bidding Consortia
Sørlige Nordsjø II	Norseman Wind/EnBW/Norgesgruppen Equinor/RWE Shell/Lyse Energi/Eviny Skjoldblad (Norsk Havvind/Total Energies/Iberdrola) Aker Offshore Wind/Statkraft/BP ***Brigg Vind (Vårgrønn/Å Energi/Corio Generation)*** ***Ventyr (Norsea Group/Parkwind)*** ***Blåvinge (Fred Olsen Seawind/Ørsted/Hafslund Eco)*** ***Deep Wind Offshore/Edf*** ***Seagust/Vattenfall***
Utsira Nord	RWE/Havfram/NTE Nordvegen Vind (Å Energi/Corio Generation) Equinor/Vårgrønn Energi/Varanger Kraft) UtsiraVIND (Source Galileo Norge/Odfjell Oceanwind/Ingka/Kansai Electric Power Company) Aker Offshore Wind/Statkraft/Ocean Winds Skjoldblad (Norsk Havvind/Total Energies/Iberdrola) Deep Wind Offshore/Edf Zephyr/RES Fornybar Norge Seagust/Vattenfall

Table 17 - Expected Prequalification Bidders - Sørlie Nordsjø II and Utsira Nord

As illustrated in Table 15, five actors have abandoned the auction, despite initial interest per 21. November 2023. Withdrawal was linked to limited profitability and uncertainty on key parameters.

The confirmed prequalification applicants are consortiums, made up of various international and domestic players in the wind and offshore industry, in addition to one Asian and one American supply company. The number has passed the current threshold of minimum participants (6-8) to hold the auction. However, the low total number leads to risk of low competition and high subsidy prices. Despite it not being a criterion for the auction, actor diversity is considered a positive factor in achieving lowest possible support cost. As such, the current auction design can be an obstacle in minimizing support cost. The auction is technology neutral. In theory this indicates a focus on short-term cost efficiency, which aligns with the Norwegian policy on short-term profitability of RES deployment. Last, there are no requirements for local content, which reduces barriers of participation for international bidders. Again, this increases competition and contributes to lower auction prices.

7.4.4 Ceiling Price

The initial subsidy cap set by the OED was NOK 15Bn (EUR 1.25Bn), later increased to NOK 23Bn (EUR 1.92Bn) (Birkeland, 2023) for Sørlige Nordsjø II. This is equivalent to NOK 0.66/kWh. In MWh, which translates to a ceiling price of EUR 56/MWh. Findings indicate the use of an estimated LCOE as a proxy. Setting a ceiling price this way seeks to limit support costs for governments in case of high degree of uncertainty or limited competition, which is the case in Norway – with only seven prequalification applicants. It is also set a minimum price of support of NOK 0.05/kWh. In the cases where the state needs production, but the developer faces a loss due to low spot price and payments to the state, there is a relief in repayments to the state to ensure that production is upheld. Also, it incentivizes stop of production in the rare cases of negative electricity prices. This is in alignment with EU legislation (Sveen & Grønlie, 2023).

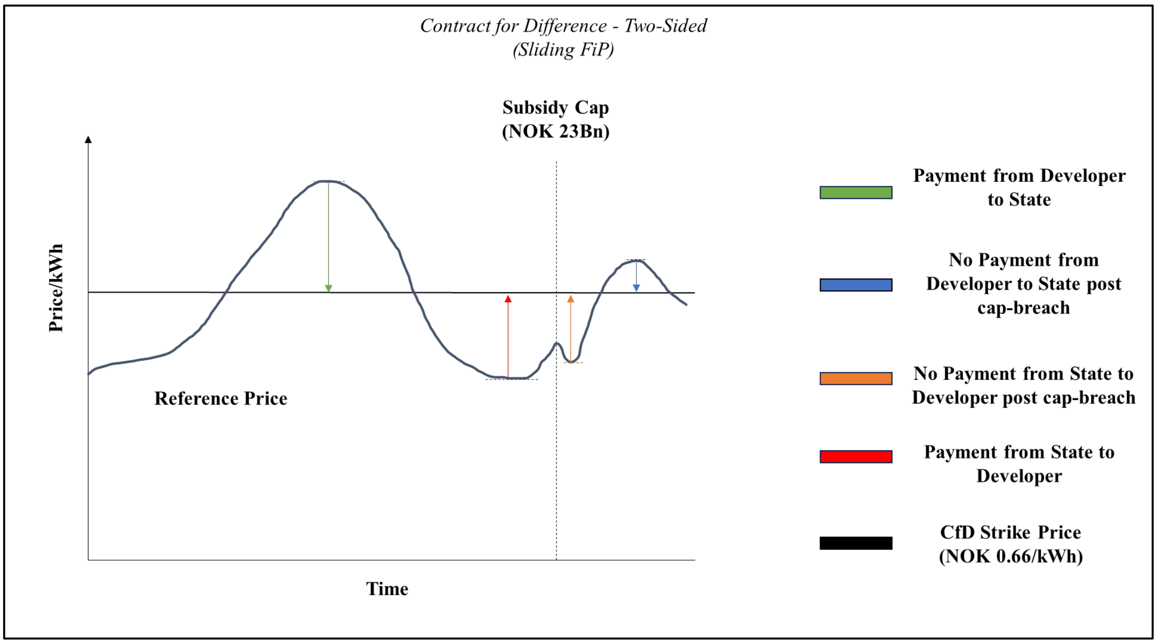

Figure 16 - Illustration of Contract for Difference, two-sided - Subsidy Cap of NOK 23Bn, Ceiling Price = Strike Price = NOK 0.66/kWh

Figure 16 illustrates that after the subsidy cap is reached, there are no more subsidy payments from the state to the developer in case of lower reference price than CfD price. However, given that subsidy cap considers net payments, this cap is topped up by repayments from the developer. Should the reference price be above the market price after reaching the cap, repayments will be made to the state, again topping up the subsidy cap. These payments are available as new subsidies should the reference price fall below the CfD price, until the CfD expires.

Inflation and Interest Impact on LCOE

The ceiling price of an auction must consider the discount rate applied by developers. Inflation and cost of capital, heavily influenced by interest rates, have large implications on discount rates for developers, in turn impacting the LCOE. Lack of inflation indexing of the contract means that bidders must discount the future subsidy payments with a nominal discount rate. NVE's previous LCOE estimate does not consider inflation, only the real price through the lifetime of the wind park. To break even considering inflation, the ceiling price must be higher, in nominal terms. This is because a higher discount rate reduces present value of future revenue streams.

Inflation alone removes much of the 15 % margin between the initial ceiling price of NOK 0.66/kWh, based on a preliminary forecast of LCOE of NOK 0.57/kWh. Adjusted for inflation, the LCOE is NOK 0.63/kWh. Using only inflation adjustment as a baseline, plus a 15 % safety margin leaves a ceiling price at NOK 0.75/kWh. Figure 17 shows the effect of inflation on the real value of a non-inflation indexed ceiling price. With 0 % inflation, the real value is fixed. With inflation at inflation target of 2 %, the value gradually drops and in 2046 at the end of the 15-year period. With 5 % and 10 %, respectively, the value rapidly decreases.

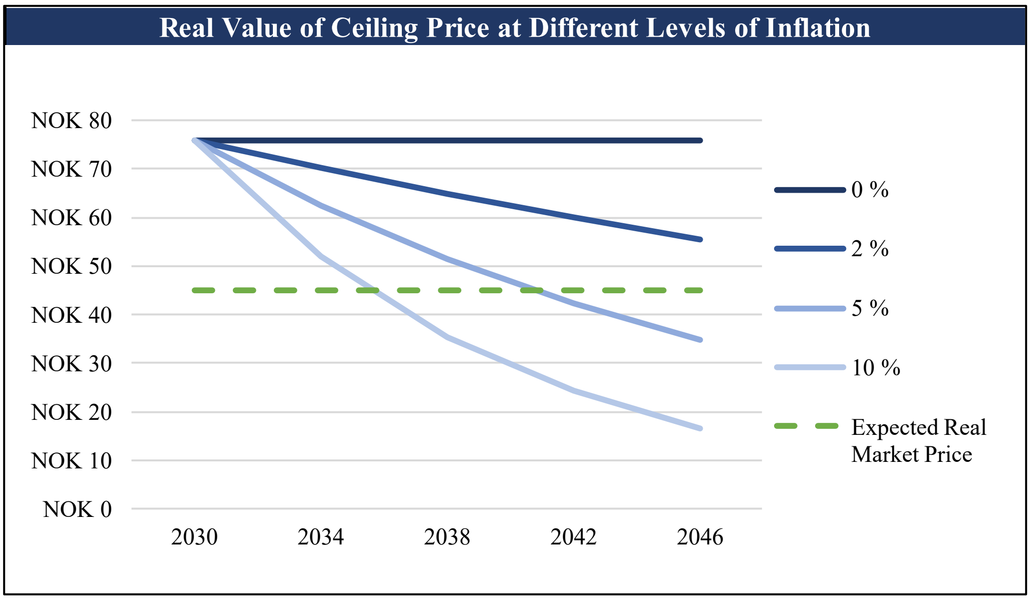

Figure 17 - Illustration of Inflation Effect on Real Value of Ceiling Price, Sørlie Nordsjø II

The dotted line shows NVE's estimate of market price in the NO2 area, as "Expected Real Market Price". With 5 % and 10 % inflation, the ceiling price is below expected market price by 2036 or 2041. This indicates that bids equal to the ceiling price result in the developer having to pay the state, despite operating at a net loss. It is further complicated by the possibility of payments from state to developer, as the real value of contract price falls below market price due to inflation.

Nevertheless, in isolation it does not mean that the project itself will be unprofitable, as net revenue is market value of production plus support payments. However, it indicates that the developer in a high inflation scenario submits a high bid to ensure sufficient income in the first years of operation for the wind farm to be profitable (Vista Analyse, 2023).

The government LCOE is calculated with a discount rate of 4 %, under the assumption that state payments are risk-free and discounted with the risk-free rate. This discount rate does not account for inflation either. Adding a small risk premium gives a discount rate of 6 %. With the base of 6 % plus the 2 % Bank of Norway inflation target leaves a price of NOK 0.80/kWh, but adjusting again for actual inflation between 2021 and 2023 plus a 15 % margin, the ceiling price may be as high as NOK 1.06/kWh (Vista Analyse, 2023).

Consequently, it would be wise to raise the LCOE which the ceiling price is based on to NOK 1.05/kWh. An alternative method to internalize inflation, is to offer continuous inflation-indexing of the CfD. However, as described, this is likely to increase the contract strike price in real terms, which may be against the policy of cost efficiency as it increases the subsidy amount, much like a higher ceiling price. A raise would nonetheless be aligned with the actions from the UK, and market reactions have been positive to an announced increase of 66 % of ASPs. Given the UK's experience and market status, it may be wise to follow.

Despite an increase in ceiling price raising subsidy prices, the socioeconomic impact of the auction ultimately depends on project realization. Too low ceiling prices increases the potential drawbacks from the ascending auction format, favouring larger developers and reducing diversity. Low competition further enhances the risk of higher subsidy price, as the risk of not winning with a high-subsidy bid is lower, and less information on bidder valuation is revealed throughout the auction rounds. As such, the elements of a subsidy cap and ceiling price is in alignment with best practices. However, they need to be adjusted upwards to internalize current market characteristics to minimize support costs. This increases the chances of auction success.

7.4.5 Prequalification Criteria

The prequalification criteria for Sørlige Nordsjø II include:

1. (60 %) Developer's potential and capacity to complete the project
2. (20 %) Sustainability impact
3. (20 %) Positive effects on environment and workforce

There are also financial requirements in the form of a bid-bond and a concession application fee. These are respectively NOK 400Mn and NOK 100,000.

These requirements resemble the UK and Germany, seeking to ensure project realization and minimizing support costs, while contributing to positive local and environmental impact However, the LCR requirements have been revised, not limiting the positive effects to the Norwegian borders. This is not necessarily working against the policy goal of minimized support costs, as it sets less costly requirements for developers which is likely to increase participation and lower contract prices.

7.4.6 Realization Period

The licensing process in Norway is presented below, with strict deadlines and penalties to reduce incentives for developers to postpone delivery and project realization.

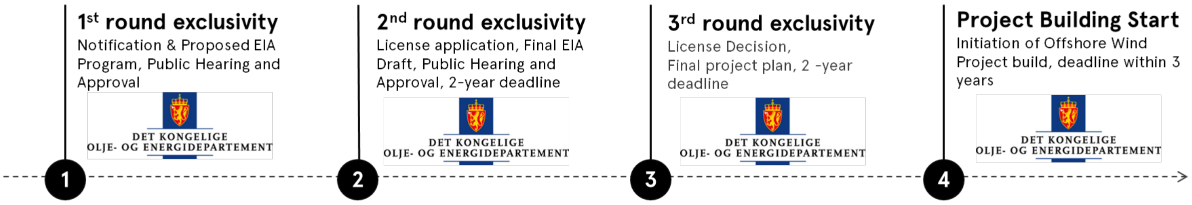

Figure 18 - Project Licensing Process - Norway

First, the regulation to the Offshore Wind Energy Law (Havenergiliovforskriften), states that the auction winner shall submit a proposal for a project specific EIA plan to OED through a Norwegian entity. This includes project description, costs, technology, development method, environmental effects, and business activities. A processing fee of NOK 100,000 is required. The proposed EIA plan is sent to a public hearing with relevant authorities and stakeholders such as the military, fishery department and shipping industry. Their inputs are reviewed, and subsequently the OED approves, disapproves, or amend the final EIA project plan. This process has no strict deadline on the OED, and they are free to change the area of the project.

Third, the approved EIA plan and license application grants the developer exclusivity to the project area. Within two years from the final EIA draft, a license application alongside a final EIA draft must be sent to the OED. Failure to meet deadlines without approved extension results in loss of exclusivity. The final EIA plan and license application include comprehensive documents about the project, environmental impact, societal effects, estimated annual energy production, grid connection, construction methods and costs. Step 5 involves a new hearing of the final EIA draft, and following this, the OED makes a license decision based on assessment of public hearing input, application, and previous experience of the developer. If approved, the license for the proposed OW project is valid up to 30 years from operation start, starting a second round of exclusivity. The OED may also set certain environmental terms and conditions to the awarded license.

A granted license triggers a new, two-year deadline to submit a final detailed project plan to the NVE, with a possible two-year extension. NVE approval is required on construction and operation prior to project start. This final, approved project plan gives third-round exclusivity to building in the zone. The final step, building the offshore wind farm, has a deadline for operation to start within three years of NVE approval. Regular supervision follows to ensure plan compliance and is overseen by members of the Petroleum Safety Authority and NVE (Birkeland, 2023).

The current process considers a potential 8-year realization period from auction close to production start. However, the process may be shortened if the concession application and EIA plan are processed simultaneously. Compared to international best practices, the current process is considered long and more uncertain. Practices vary from 18 months from grid completion in Germany, to specific delivery years being defined in the UK of normally three to four years.

Strict deadlines pose logistical and planning concerns for developers in already demanding circumstances. OED’s potential revision of selection criteria may further complicate the process. This, combined with potential changes to the Offshore Wind Energy Law as well as potential future implementation of resource rent taxation, add further uncertainty to the project. Thus, likelihood of real option strategies being pursued by developers can increase. In turn, this may lead to higher subsidy requirements, working against the goal of minimized support costs.

7.4.7 Penalties

To maximize socioeconomic impact, optimal penalties must balance maximizing realization rate and avoid excessive risk to project developers. Too strict penalties and financial guarantees could limit participation. This can lead to increased subsidy requirements to compensate for the internalization of these costs, increasing total support costs. Too low penalties may lead to longer realization periods and increase risk of non-realization. Specifically, it increases the risk of the project being considered as a real option with the auction as the first part of a two-stage investment decision, carrying the possibility of the winner’s curse.

The latter is of particular interest as the quantitative analysis indicates a lack of profitability under the current support conditions. It implies that the developer requires an ambitious estimate of future market prices to make up for the repayments made to the state during the support period to become profitable. However, the eight-year period of realization leaves room for positive development concerning uncertain factors such as electricity prices, technology cost, inflation, and interest rates.

Offshore wind auction is new in Norway. Thus, a risk of delay can be relatively high compared to more mature, certain markets such as UK and Germany. This is underlined by the long administrative process. Hence, a realistic, penalty-free period to perform required cost assessments and planning should be allowed to reduce developer risk. As the project is subject to delays from tight supply chains and applications for necessary infrastructure building permits, a developer should not be penalized for delays outside of their control.

The current penalties from failing CfD obligations are loss of the financial prequalification requirement, the bid-bond of NOK 400 Mn for Sørlige Nordsjø II. In addition comes a non-realization penalty of NOK 2 Bn and loss of exclusivity should the developer fail to meet deadlines. Furthermore, any failure of compliance with deadlines during the application process results in exclusivity loss. However, there are no additional penalties should the developer be delayed due to state delays in the concession process or other unforeseen circumstances. This lack of substantial penalties could warrant real-option strategies from developers. Specifically, in the event of cost overruns, the lack of financial penalties in the event of failure of compliance with EIA requirements, could be a low-cost option to abandon the project. Thus, it brings a risk of non-realization. To mitigate this, the state may implement financial penalties for such compliance failures and reduce the risk of the winner’s curse.

Compared to international best practices, these penalties do not differ significantly in either direction. However, there is a risk on non-stringent penalties for non-compliance, which opens for strategic bidding behaviour. If changes are made, it could create confidence in the Norwegian system, mitigating the probability of the winner’s curse. Moreover, it is aligned with the goals of project realization and minimizing support costs.

7.4.8 Support Conditions

Sørlige Nordsjø II follows a fixed FiP scheme. The winner of the auction will sign a two-sided CfD, with a duration of 15 years. The reference price is calculated monthly based on the spot-price of electricity. This scheme will contribute to transferring investment risk from developer to state and incentivize diversity due to lower financial risk in the initial phase. This is particularly important, given the immaturity and information asymmetry on technology cost.

For Utsira Nord, the support conditions are the same, but only two of three project areas will receive government funding. The remaining area will however be given a prolonged exclusivity to mature the project, and may participate in any future competition for government support or seek alternative funding (Birkeland, 2023).

Subsidy Cap

The subsidy cap considers net payments from the state to the developer. In the event of a breach of the subsidy cap, no more payments will occur from the state to the developer until there is a period where there are repayments from the developer to the state which fills the subsidy pool. The new subsidy payments available will be equal to the sum repaid by the developer to the state.

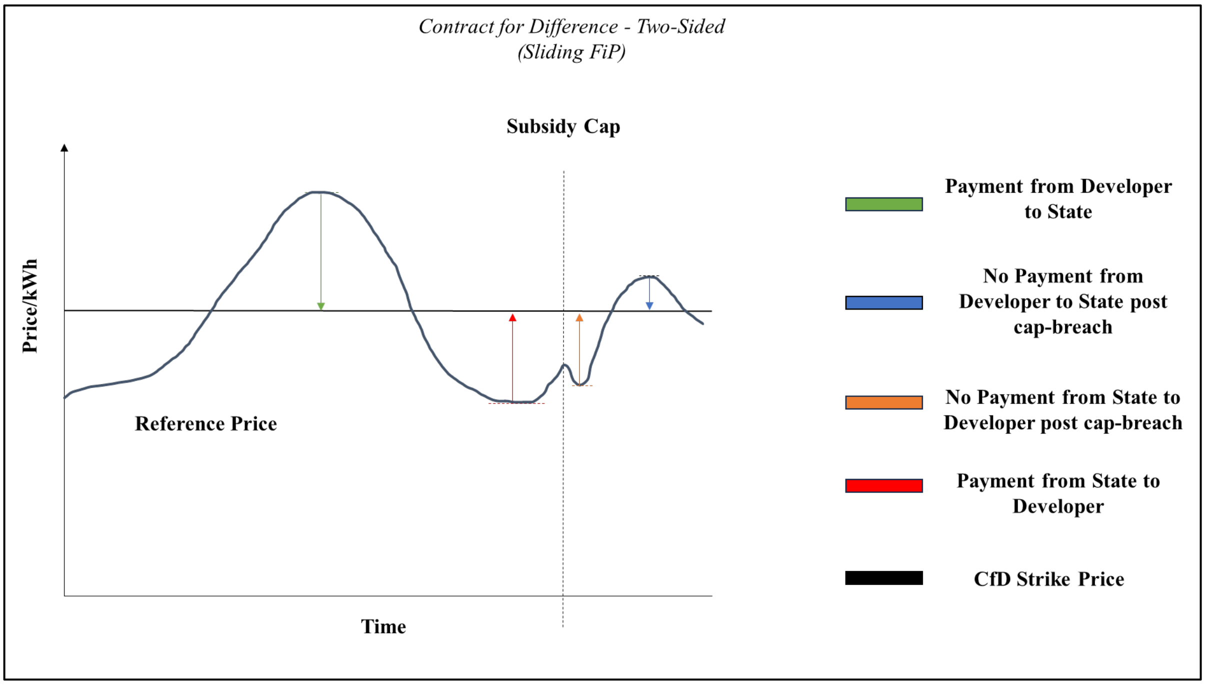

Figure 19 - Contract for Difference - Two-sided (Sliding FiP)

As the subsidy cap considers net payments, it reduces the revenue potential for the state, but limits total support amount. This net payment mechanism is likely to reduce some revenue risk for developers while mitigating some negative effects of the subsidy cap for the developer.

If market prices are higher than CfD prices after the subsidy cap is breached (when the subsidy pool is emptied before the contract date) or CfD expiry, the developer could be better off with sales at wholesale market prices rather than an extended subsidy cap or CfD period. Thus, the developer could be interested in termination of the CfD given a subsidy cap breach, should market prices be higher than the CfD price. Should market prices be lower, an extension is likely to be preferred. This in the form of increased length of the CfD, further reducing revenue uncertainty for the developer. An alternative is to increase the CfD price. The optimal choice would depend on the risk-profile of the developer, and the forecasts of electricity prices.

In case of market price volatility, the arrangement is more lucrative to the developer compared to the state. Thus, the net payment practice might be counter-productive towards achieving project realization at the lowest possible cost, compared to using gross payments or terminating the CfD, which stops state payments after subsidy cap breach. In general, developers prefer no subsidy cap, as this provides nearly full revenue-risk cover. This could become expensive for the state and the electricity consumers, despite potentially lowering the initial bid.

Alternative Remuneration

The government could allow a merchant nose solution as in the UK. By delaying the CfD start up to one year, the developer might benefit from market prices higher than the CfD price, which might de-risk the investment through a higher upside in a critical phase of the project. However, this depends on the effect of other, simultaneous projects in the North Sea on the market price which the developer would receive. Additionally, supplying electricity through PPAs with commercial actors allows for better prices. The combination of alternative revenue streams can attract developers to participate in the auction. This in turn could lead to reduced government subsidies aligned with policy goals, but its success depends on future market prices.

Grid Connection and Technology

Another important factor for auction success and efficiency is the grid delivery model. This interface is between the developer, governing transmission asset owner, and the entity responsible for financing the grid connection. The model must balance cost to consumers and governmental control on planning and realization timelines, seeking lower risk for developers and timely realization.

Several cable types are used to connect offshore power production. For offshore wind in Norway, the relevant options are Alternating Current (AC) or Direct Current (DC) and a corresponding High-voltage AC (HVAC) or High-voltage DC (HVDC) (Tennbakk, 2021). AC is a simpler structure for shorter distances, while DC is more complex, suited for longer distances. AC cables have significant power losses over longer distances, while DC is best suited for large amounts of power being transmitted over longer distances (Hestad, 2022).

For Sørlige Nordsjø II there is still uncertainty on whether Statnett or the awarded developer is the responsible party for the grid connection. The cable technology is however decided to be HVDC. Yet, with its close shore-proximity compared to Utsira Nord, an AC solution may be cheaper to install but result in more power loss. DC is likely more expensive to install but provide less power loss. It is not decided which party that will cover the cost. Flexibility on technology would provide more strategic agility. This may make covering the grid cost more appealing for a developer. Either way, requirements should be resolved prior to auction start, as the investment will be internalized in the developer's bid. Grid cost represent a large portion of up-front investments. In the UK the developer is fully responsible for all aspects of grid integration, while Germany has the government covering these costs. This difference is linked to the one- versus two-sided CfD scheme and a trade-off between high up-front support relative to the reduction in MWh subsidies and costs to consumers (Hoel-Holt, 2022).

7.4.9 Real Option Application to Norwegian Projects

Implications of CfD Conditions on Bidding Behaviour

A two-sided CfD format will not lead to zero-subsidy bids as in Germany. However, state coverage of grid cost will make it more attractive for developers to participate in the auction. This has been illustrated quantitatively earlier in this thesis, and supported by comments from an Equinor representative (Horn Hansen, 2023).

Nevertheless, assessing the cost of grid infrastructure relative to the potential reduction in strike price is noteworthy. It is reasonable to assume that the state, with large financial capability and access to cheaper capital, holds more negotiating power than a developer in the factor market. This would lower the cost of grid infrastructure. If so, the lower subsidy price could in sum be greater than grid investment cost, effectively minimizing support costs.

Uncertainty on Private and Common Factors in Norwegian Auctions

As the auctions will be the first of their kind in Norway, developers' bidding strategies will include strategic, private factors such as potential first-mover advantages and learning effects through information. This includes private learning effects on revenue from operational capacity, as well as costs, firm-specific technology, and potential bargaining power with suppliers. However, some of this uncertainty and information asymmetry on these factors also makes it less attractive to participate.

First, regulatory uncertainty around auction frequency, volume and grid connection costs increases developer risk. The postponement of Sørlige Nordsjø II application deadline to 15. November, and the indefinite postponement of Utsira Nord makes it less attractive for developers to invest in the necessary prequalification requirements to make a formal application.

This uncertainty creates difficulties for the supply chain to produce market forecasts and reduces incentives for long-term contracts, pressing margins for already congested bottlenecks in the supply industry. With rising inflation and interest rates, the risk-appetite of investors and developers is lower, and it will require increased premiums to pursue these projects or provide capital. The higher risk sets higher financial capacity requirements, favouring larger consortia.

Another common uncertainty factor considers the future market price of electricity. At the end of a potential contract, developers are allowed to sell to the wholesale market. The profitability of the offshore wind farm after CfD expiry relies on the expected wholesale market price for the remainder of the windfarm's lifetime. Moreover, the revenue from Sørlige Nordsjø II and Utsira Nord are likely to be cannibalized by other, simultaneous projects from more mature markets in the North Sea such as the UK, Denmark, the Netherlands and Germany. This drives the market price downwards as a result of higher supply (Ånestad & Holter, 2023). This in turn reduces the attractiveness of the projects.

In short, multiple aspects of the projects ae uncertain. This includes project costs, the future macroeconomic climate, technology development and support conditions. These uncertainties have a positive effect on real option value of the projects. They are combined with auction-specific factors such as the realization period and potential penalties of non-realization. Together, they provide an opportunity of postponing the project start while waiting for accurate information. This uncertainty can give the projects higher values relative to other, more certain projects and markets.

7.5 Summary of Recommendations

To achieve the goal of project allocation with minimized support costs, there are multiple aspects to consider. The current auction format is considered an adequate fit in terms of real price discovery. However, it is recommended to only allow fixed-increment bids to mitigate the risk of collusion between bidders. Design should ensure a sufficient ceiling price and capacity for developers to be willing to participate in the auction. Recalculation of the ceiling price to accommodate inflation, interest rate and cost increases should guarantee this. To attract necessary interest and auction participation, a site volume of minimum 1,000MW is recommended. Further, to increase transparency and predictability for bidders, it is recommended to provide a detailed auction schedule, including volume, concession process and requirements in good time before the auction. This decreases uncertainty and mitigates aggressive real option bidding strategies. Ultimately, this reduces risk of the winner's curse and incentivizes project realization.

What is more, the penalties and prequalification criteria must facilitate project realization, balancing the risk of strategic real option bidding and lack of auction participation. This is enabled by a balanced realization period and strict penalties. Support conditions should be designed to reduce revenue uncertainty for developers, and the ceiling price should be enough to cover expected costs while effectively capping state subsidies. This can be achieved with the state offering to take responsibility for grid integration costs, allowing for complimentary PPAs, inflation indexation, as well as flexible merchant nose and market adjusted CfD conditions. Combined, these recommendations can help Norway’s offshore wind industry develop, with an auction design and policy rigged for success.

8. Conclusion

This thesis concludes by answering the research questions from chapter 1.2. Then, the validity, reliability and limitations of the research is addressed, followed by further research suggestions.

First, this thesis describes the auction design elements and assessment criteria for auction systems set out in literature. It performs a comparative analysis of the market leaders in the offshore wind industry, the UK and Germany. Second, these parameters are applied to the Norwegian auction design. Third, based on the findings from the comparative analysis and identified best practices, recommendations to policymakers on optimal auction design for Norway is made.

Existing literature has not carefully researched the effect of recent macroeconomic changes on RES auctions. This thesis researches these changes' potential implications for Norwegian offshore wind auctions. With an ambitious target of 30 GW offshore wind capacity auctioned by 2030, understanding practice and experiences from similar countries are valuable. To provide a foundation for the recommendations, the first of the two research questions is the following:

"What are best practices in terms of design elements of auctions
to promote development of offshore wind today?"

Auction systems are the preferred allocation method for RES deployment internationally. The main advantage of the auction scheme is its ability for customization to fit government policy and market dynamics, contributing to minimization of support cost. Designing auctions based on each country's specific characteristics such as technology maturity, infrastructure, macroeconomic situation, and market maturity are elements for auction success.

In summary, the comparative analysis of offshore wind auction design in the UK and Germany finds variances and similarities in support cost management, local impacts, socio-political feasibility and actor diversity. The interplay of these elements has implications for the auction outcome, in turn affecting dynamic and static efficiency, as well as effectiveness. The main difference between the auction design is support mechanisms. In particular, the distinction between a two-sided and one-sided CfD. A bid in the second format displays the requested support to pursue the project, a mechanism which allowed zero-subsidy bids in Germany. A bid in a two-sided CfD represents the fixed subsidy payment over the project duration, like in the UK. Moreover, the government's responsibility for grid costs lead to higher potential upside in the German market, while the UK seek to de-risk the investment for developers through revenue security. Consequently, the German market's success is likely a result of high electricity prices in a market-oriented approach, while profitability in the UK relies on de-risking through cost reduction and technology development. In short, the German model has internalized the market situation, and is better suited for the current macroeconomic climate. Drawing from the comparative analysis, the thesis answers the second research question:

> *"Which recommendations can be made to Norwegian policymakers*
> *based on recent experiences in the UK and Germany?"*

The quantitative analysis of the current auction design for the Norwegian offshore wind farms Sørlige Nordsjø II and Utsira Nord shows, aligned with other public reports, that these are unprofitable. This is due to low internalization of market factors in CfD conditions like AR 5 in the UK. The ceiling price and subsidy cap is too low, without any complimentary revenues to compensate the increased developer risk. Uncertainty on grid cost and a long licensing process enhances this risk. Consequently, the price of the real option of the projects is too high compared to its potential payoff, resulting in low participation and higher risk of non-realization.

To increase auction and offshore wind deployment success, there are alterations to auction design applicable for the two planned auctions and future auctions. To minimize support costs, the dynamic auction format should allow only fixed-increment bids to mitigate the risk of collusion and enable real price discovery. Further, the government should provide information on upcoming auctioned sites, including date, EIA permits, and capacity- and grid-technology requirements. This transparency should reduce uncertainty, mitigate aggressive real option bidding strategies, and allow for planning and project de-risking for developers. This reduces risk of the winner's curse and facilitates project realization. It is further essential to internalize current market conditions. Recalculation of the ceiling price accommodates inflation, interest rate and cost increases. The impact of these on future revenue streams and current cost of capital, confirms that the government should consider carrying the grid connection cost. It serves as a large barrier for developers in form of a costly up-front investment.

The penalties and prequalification criteria should prioritize project realization, balancing the risk of strategic real option bidding and risk of reduced auction participation. Support conditions should be designed to reduce revenue uncertainty for developers, while limiting state subsidies. To further de-risk projects, the government can improve support conditions by allowing for complimentary revenue streams such as commercial PPAs and merchant nose agreements. Combined, these auction design alterations could moderate the current barriers for auction participation and facilitate successful offshore wind development in Norway.

8.1 Validity & Reliability of Research

Reliability considers whether the researchers act in a reliable manner when conducting research (Thagaard, 2013). This is supplemented by Sverdrup (2022) asking what the consistency and dependability of the method used to answer the question (Saunders et al., 2019). This thesis has a structured method when breaking down the topic into relevant subtopics. Due to a combination of established auction theories, historical data collection from credible sources and expert analyses, the research conducted is considered reliable. Further, Thagaard points to validity being whether interpretations from the research are grounded in a valid manner. Sverdrup asks what the relevance and credibility is, of what is measured in the thesis. The thesis advocates the relevance of the topic of auctions, confirmed by the political discussions on the topic of offshore wind development.

Saunders et al. addresses reliability when using a case study for research (Saunders et al., 2019). Through the case study approach used in this thesis' research and comparative analysis, some aspects that covers reliability are the following. It provides an in-depth understanding. By comparing several cases, the thesis aims to point at key differences and similarities, and how they correspond with policy and auction results. Further, transferability of findings is discussed, and serves as the basis for the research. Moreover, using several sources of information has been key to understanding the topics on the depth necessary to make recommendations.

A further consideration to address is the work of Yin (2014), which underlines the need for researchers to avoid biased views and opinions to influence the interpretation, discussion, and analysis (Yin, 2014). This includes the conclusion and findings, and in the case of this thesis, the recommendations that are being made to Norwegian policymakers. The analysis in this thesis relies on available data combined with proved quantitative and qualitative method. Thus, this issue is addressed. What is more, it aligns with Saunders et al.'s definition that reliable research is reproductible, meaning that the data collection techniques and analytic procedures would produce the same results or findings if repeated by someone else at some other time (Saunders et al., 2019).

Last is construct validity, which looks at how well the research measures what it aims to measure? Does this thesis provide a valid measure of auction design for offshore wind? The background for this master thesis' choice of topic is to deliver just that. By creating an overview of the practices in Germany, the UK and Norway, comparing the auction outcomes and alignment to the countries' policy goals, this thesis should achieve sufficient construct validity.

8.2 Limitations of Research

This section discusses limitations of the conducted research, by acknowledging factors which may implicate the accuracy of the thesis. Despite the best practices being derived from two market leaders within the offshore wind industry, auction success is dependent on individual market characteristics. An auction design that works well in one market might not work well in another with different policy goals, economy and regulatory framework.

The recommendations must be seen in context with the time of writing. Offshore wind development is a debated topic in Norway, and changes to auction design or government policy may occur before the publication of this thesis. This is illustrated through the changes to the Sørlige Nordsjø II requirements and publication of CfD terms during this work. Hence, the recommendations are based on the current auction design and political framework with the latest information available at the time of this thesis' publication.

An additional limitation to the thesis considers the quantitative analysis. A major risk to any profitability analysis considers the uncertainty in estimates. These are based on current available data and assumptions on interest rates, inflation, capital, operational expenditure as well as forecasted market prices of electricity. Actual cost data is difficult to obtain, and governmental policy such as transmission asset responsibility varies between markets, making direct comparative analysis subject to error. As a result, the calculations and estimates are illustrative, highlighting the impact of certain factors on offshore wind project profitability, supporting the qualitative analysis of this thesis.

8.3 Further Research Topics

This thesis has researched the highest performing markets to identify best practices. To provide more conclusive evidence, less successful markets could be analysed. Furthermore, researching the value of exported electricity to other offshore applications would provide valuable insight. Specifically, into the financial viability of both Sørlige Nordsjø II and Utsira Nord and the coming offshore wind areas. With the potential cannibalization of projects being built in the North Sea in the coming years, the effects of project development in the northern parts of the Norwegian coast, where the wind is uncorrelated with North Sea projects, should be further investigated as an alternative (Tande, 2022). Research should also be made on the requirements and feasibility of grid connectivity both on- and offshore to ensure a comprehensive understanding of viability and sustainability of integration of offshore wind into the Norwegian energy mix.

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