Report D7.6, November 2017

Model-based and qualitative analysis of the Danish auction scheme

AURES

HORIZON 2020

D7.6, November 2017

Model-based analysis of specific cases

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Executive Summary

The Danish multi-technology auction scheme

This report investigates how to design the parameters for a Danish multi-unit auction scheme yielding the most favourable outcomes and achieving the policy goals envisaged. The Danish Energy Agency has presented two different schemes: a first base case and in order to assess the importance of selected design parameters a variation of this scheme. The most crucial design features in which these schemes differ will be contrasted in an agent-based game theoretic model. These questions concern the implementation of volume flexibility, auction frequency and auction volume. Then, further questions will be addressed without the use of the agent-based model. These questions concern setting the optimal ceiling price and the implications of implementing a fixed market premium compared to a sliding one.

Results on the Danish auction design are the following:

- **Impact of increased budget flexibility:**

  A flexible budget option was compared to a fixed budget, meaning specifically that if the final (marginal) bidder in an auction round surpasses the foreseen budget, he can still be awarded. In the following round, the budget will then be adapted, i.e. decreased by the excess capacity of the previous round. This allows for more flexibility, especially in situations with little auctioned capacity and particularly large-scale bidders, likely to exceed the capacity with their bid.

  In the modelling, the flexible budget option was used in all modelled rounds, meaning that the original budget was surpassed in the first round, and in the following rounds, the adapted budget was (at least slightly) surpassed again, leading to a slightly reduced demand in each round. The average excess volume awarded per round is 20% of the total volume. The average awarded bid price is basically identical to the bid price in the case of a non-flexible mechanism. A flexible mechanism is thus the more effective option, as the capacity envisaged can actually be realised, without leading to a decrease in (cost-) efficiency.

- **Impact of varying frequency and volume:**
  One main take-away from simulating the auction rounds for 2018-2019, is that a joint technology auction with onshore wind and solar PV will yield only onshore wind bidders to be awarded. Furthermore, it can be seen that increasing the volume only leads to slightly higher average awarded bid prices in the short run – i.e. there seems to be sufficient competition to auction larger amounts of capacity.

  Looking into longer term outcomes up to 2025, one can see that in the Danish case, a 200 MW annual auction would be more efficient in terms of deployment, at the expense of slightly higher bid prices and thus support costs. Overall, the support costs per MW constructed would be around 92,000 € higher across the total support period of 20 years, assuming average full load hours, leading however to on average 88 MW more realised capacity between 2018 and 2025. Also in the longer term up to 2025, under the current technology cost assumptions, only wind onshore bidders would be awarded.

- **What impact does a fixed compared to a sliding feed-in premium have?**
  A fixed premium shifts market risks to the generator. This would lead to disadvantages for (especially) wind power generators, as they are more exposed to market risk and thus would have to put a mark-up on top of their bids to account for this additional risk exposure. Therefore, wind power would become less competitive in the auctions, possibly leading to an overrepresentation of solar PV bidders. Depending on the goals of the auctioning entity, this might be a desired development i.e. if more technology diversity through an increased solar capacity is envisaged. If, however, the expansion goal is supposed to be followed in a level-playing field way for both technologies, a more balanced way to support both technologies equally would be to implement a contract for difference (CfD) or sliding premium, which would shift the market risk to the government.

- **How does setting the ceiling price impact the auction outcome?**

  Setting an adequate ceiling price has an important signalling effect to bidders. A very ambitious low ceiling price could deter smaller bidders and thus lead to concentration in the long term, whereas a too high ceiling price could incentivize price mark-ups and lead to an inefficient outcome due to the so-called anchoring effect. A good rule of thumb to set the ceiling price is to have it set at or slightly above the current LCOE. It can be adapted dynamically with future auction results and/or technology cost and market developments.

Overall Policy Implications

From the modelling results, one can draw the following general policy implications: a higher deployment rate can be reached with less frequency and a higher volume, whereas lower prices can be achieved by increasing the frequency and lowering the volume. If the volume or budget is however too low, the default rate, due to the marginal bidder having to drop out will increase. Implementing a flexible budget can help avoid this. In general it can be said that the competition level seems to be sufficient to auction larger volumes, as overall bid prices to not increase substantially with a larger volume.

1 Introduction

This report investigates different policy relevant questions for the design of the multi-technology RES auctions to be implemented in Denmark in 2018. It belongs to AURES work package (WP) 7. The objective of the WP is to explore and facilitate future implementation possibilities for auctions in Europe based on specific cases with significant replication potential. Strong focus is thereby placed on the interaction with policy makers and market participants.

This approach was followed for deriving the most relevant questions to be analysed in this report: consultations with the Danish Energy Agency and the AURES consortium were held and a mutual decision was taken on the most relevant features of the auction design to be assessed. Four main questions have been selected, some of which contain further sub-questions. These questions will be described in detail in section 2. While the agent-based model, developed in AURES task 5.3 and described in AURES deliverable 5.2, could be applied to two of the four questions, the remaining open issues were answered by a qualitative analysis. This specific additional effort – which was not foreseen in the original work plan – as well as the fact that the government negotiations in Denmark are ongoing until the end of November 2017 – led this deliverable to be transformed into a stand-alone work (AURES D7.6.) instead of including it in the collection of country modelling cases published in July 2017 (AURES D7.4). Nevertheless, the two reports complement each other.

The structure of the report is as follows: first, in section 1 the game-theoretic model applied will be outlined very briefly. The interested reader may find more detailed insights in AURES D5.2. Next, the Danish auction design foreseen is presented, together with a short description of the Danish electricity market. For more details on Denmark and the first pilot auction held there in 2016, please refer to AURES D7.2-DK. Then, the model set-up, accounting for the specific characteristics of the Danish market and its market participants as well as the relevant design features for the envisaged auction are presented.

Section 2 contains the results: the questions investigated are described and then followed by a detailed account on the methodology, findings and conclusions on each part. The final part of the report contains a short concluding section.

1.1 Game-theoretic (agent-based) modelling overview

Figure 1 depicts the modelling framework applied to answer the first two auction design questions in this report (flexibility and volume/schedule). More details on this model can be found in AURES D5.2 “Modelling of Renewable Energy Auctions: Game theoretic & Energy system Modelling (Methodology Report)”. Additional modelling features that were developed for and applied in the Danish modelling case will be depicted in the following chapters.

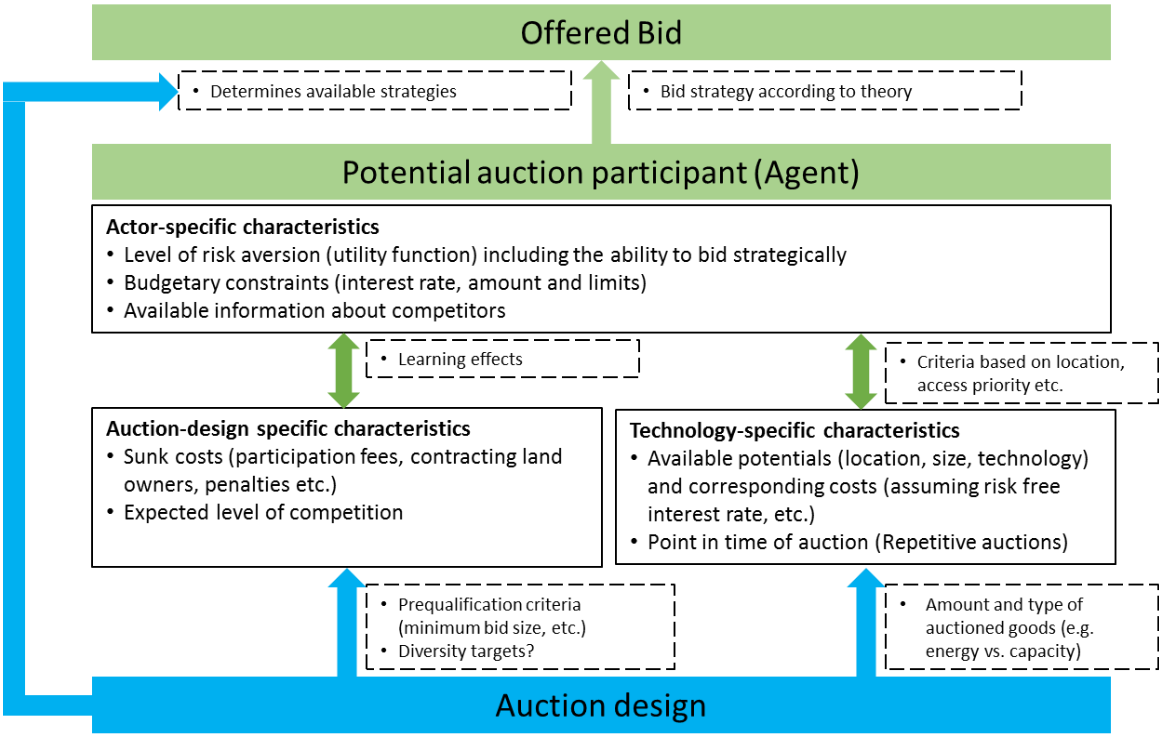

Figure 1: Game-theoretic agent-based modelling framework for assessing auction designs

A short summary account of the model’s features can be given as follows: the agent-based model can depict a variety of auction schemes and their respective design elements as well as regulatory features as e.g. restrictions to participation. Pay-as-bid and uniform pricing auctions can be shown, either as a one-shot auction or a multi-round auction that allows participants and the auctioning entity to learn. It is furthermore possible to model the agents in a very detailed manner, to depict the respective auction participants in a country or to investigate a certain question concerning the auction outcome. Several applications of the model in other European Member States have also been published in AURES D7.2 “Model-based analysis of specific cases”.

1.2 The Danish multi-technology auction scheme

Denmark (DK) has a population of 5.7 million and had an annual energy consumption of 775 PJ in 2016[1]. With peak load of around 6.6 GW and interconnectors totalling 5.5 GW, it is well integrated in the European electricity system (Gephardt and Kitzing, 2016). 223 PJ, so around 29% of the annual gross energy consumption in 2016 was supplied by renewable sources, mainly wind power. This makes DK one of the leading countries in the world in terms of deployment of new renewable energies (non-hydro) and ranks it among the world leaders in wind power technology. Among Denmarks ambitious energy targets are:

- Energy consumption covered 100% by renewable sources in 2050
- Power and heat supply covered 100% by renewable sources in 2035
- Coal totally phased out by 2030

For the year 2020 the following targets can be expected to be achieved:

- 35% renewable energy in final energy consumption
- 50% of electricity consumption covered by wind power

The Danish electricity market can be characterised as a highly liberalised market. DK is part of Nordpool, with two price zones (DK1 and DK2). Market concentration in DK2 is one of the highest in the Nordic region. Overall, the two largest players own 50% of total installed capacity (Dong Energy 39% and Vattenfall 11%, in 2013) (Gephardt and Kitzing, 2016). Several different instruments have been used for the promotion of renewable energy, including feed-in tariffs, premiums and tax incentives. Up to today, fixed premiums and sliding premium tariffs are the major schemes for supporting RES. Auctions for renewable support are currently used for offshore and nearshore wind.

The only multi-unit renewable energy auction that took place in Denmark until now was a cross-border auction scheme for 20 MW of solar PV together with Germany in 2016. However, the Danish government plans to roll out a large-scale multi-unit auction scheme beginning in 2018. The Danish case therefore differs from the previous modelling cases, as there is no existing scheme providing insights to assess the question of interest. Instead, different questions of relevance for the design are modelled as a consultation process to the implementing agency.

[1] https://ens.dk/sites/ens.dk/files/Statistik/foreloebig_energistatistik_2016_eng.pdf

Table 1: Factsheet on the scheme for Danish technology neutral auctions*

Contracting authority	Energistyrelsen (Danish Energy Agency)
Main features	A common tender scheme for onshore wind, solar PV and offshore wind under the “open-door” scheme. The tender scheme covers commercial plants exclusively.
Timing	Begins in 2018
Min. /max. size of project	No limitations
What is auctioned?	Fixed feed-in premium in 20 years
Frequency	There are two auction rounds, one in each year. The budget for 2018 corresponds to approximately 75 MW and the budget for 2019 to 125 MW.
Volume	The total budget for the period 2018-2019 corresponds to approximately 200 MW onshore wind (assuming a support level of 13 øre/kWh and 3.100 full load hours). The budget for each auction round has to be strictly respected, i.e. no budget flexibility between rounds. If the bid from the marginal bidder exceeds the remaining budget, the bidder is offered to build a RE plant with reduced size (and with the same support per kWh) in order to comply with the remaining budget. The offer is non-negotiable.
Pricing rules	Pay-as-bid
Ceiling price	Price ceiling on 15 DKK øre/kWh (2,02 EUR cent/kWh)
Qualification criteria	Late stage auction, i.e. auctioneer sets timing of the auction at a late stage of project development. Project developers must achieve the necessary permissions and authorizations before the bid is made. This concerns mainly municipal planning approval, including the environmental impact assessment.
Penalties	Retention penalty of 30 EUR per kW of expected production from onshore wind and solar panels is implemented. It could also be considered whether developers that do not realize winning projects should be excluded from one or more future tenders.
Exceptions from requirements for small plants/developers?	Household wind, small solar panels and other plants established in order to produce electricity for own use is not included.

*Source: Energistyrelsen (Danish Energy Agency)

1.3 Model set up

For technical details of the model, again please refer to AURES D5.2 “Modelling of Renewable Energy Auctions: Game theoretic & Energy system Modelling (Methodology Report)”. Here, only the model’s input parameters and the technical implementation of the respective auction design setscrews – extensions of the original model – will be described.

The agents have been implemented with the following parameters. A high amount of detail was achieved in the representation of the Danish auction scheme, as the Danish Energy Agency provided insights into all kinds of planned design features as well as into technology data and data on the joint Danish-German PV pilot auction.

Table 2: Agents’ distribution for the first rounds (2018-2019)*

Parameter	Solar PV		Onshore Wind	
	Single project	Multi-project	Single project	Multi-project
Number of each type	5	1	9	1
Bids submitted	5	3	9	3
Cost distribution range [ct/kWh]	1.75-2.25	1.5-2	1.5-2	1.25-1.75
Average cumulative capacity bid per year [MW]	20-70		200-350	
Range of project sizes bid [MW]	2-50 (uniformly distributed)		6-135**	
Discount factor	0.9			
New projects in each round	10% of previous bidders			
Time span	2018-2019 (2-4 rounds) or possible long-term auctions (up to 2025, 8-16 rounds)			

* This table shows all agents’ model input parameters. Most parameters stem from insights given by the Danish Energy Agency or from official sources on technology data (ENS, 2017a). The discount factor is chosen by the authors to reflect differences in agent’s long-term optimization. The results of the analysis also hold when these factors are varied (the interested reader can request sensitivity results directly from the authors).
**Distribution: 30% are 6-20 MW, 60% are 20-60 MW, 10% are 60-135 MW.

Data on the design of these agents stems from different sources. First of all, the Danish Energy Agency provided data on the number of project developers for the respective technologies. The number of solar PV bidders has been estimated by taking into account the outcome of the recent joint solar PV auction between Denmark and Germany. The number of onshore wind bidders stems from the most recent analysis on the Danish market (2014). The range of capacity bid per year is an estimate based on the solar PV auction results (for solar PV only): a uniform distribution (2-50 MW) is assumed. For wind power, the numbers are based on the projects currently in the pipeline. The distribution for those projects is not uniform, but estimated as 30% of smaller projects (6-20 MW), 60% of medium-sized projects (20-60 MW) and 10% large-scale projects (60-135 MW). The average cumulative capacity bid per year is based on the expected yearly deployment in Denmark. The time span takes into account the planned auction for 2018-2019, although a longer period of time is also modelled to show long-term developments of different variations of the scheme.

Bidders were furthermore subdivided into multi- and single project bidders. This is due to insights from the solar PV pilot that took place in the end of 2016.[2] In this pilot, the maximum allowed number of projects to be submitted per bidder was three. The nine winning bids of the auction came from three entities all owned by the same parent company (Danske Solparker/Better Energy). All bids had the same price i.e. 12.89 øre/kWh (1.73 € ct/kWh) for a 20 year fixed premium. This indicates that these three bidders made use of economies of scale, i.e. by offering several projects at once, they were able to lower their costs and thus submit a lower bid compared to single project bidders. For simplification purposes it was assumed in the modelling, that multi-project bidders submit 3 bids each, as was the maximum allowed amount in the PV pilot auction. As these bidders can make use of economies of scale, their cost distribution is assumed to be lower than that of the single project bidders.

Data on technology costs stems from the technology data catalogues published by the Danish Energy Agency (ENS, 2017a). This data was used to calculate the levelised cost of electricity (LCOE) for the participating technologies each. Furthermore, the LCOE was then multiplied with the market value factor of the corresponding technology to account for the differences in market value which are extremely significant between wind power and solar PV in Denmark, due to differences in the diffusion rate (installed capacity) in the respective countries as well as to the hours of (peak) generation. Then, to assess support needs for generators, electricity market price projections by Energinet were used (Energinet, 2017). An average of the estimate for the two price zones was taken, as it is not known in which area the respective plants will be built. Taking the difference between the expected market price and the LCOE yields the gap needed for the generators to break even. The calculations yield an LCOE for onshore wind at 37.99 € /MWh and for solar PV at 54.31 € /MWh. Taking into account ENS and other electricity price projections, this would lead to an average support need of 0.83 € ct/kWh for onshore wind and of 1.94 € ct/kWh for solar PV. Assuming differences in location, generator type and other factors, a cost range was assumed around this factor to introduce some bid price variation among the participants. Furthermore, it was assumed that the bid price range is in

[2] https://ens.dk/en/our-services/current-tenders/pilot-tender-price-premium-electricity-solar-pv

general lower for the multi-project bidders (irrespective of which technology), as they can make use of economies of scale.

The discount factor as well as new entry of agents in each round stem from a previous studies on Germany (Anatolitis and Welisch, 2017), as Denmark has no long-term experiences with multi-unit auctions. The parameters are chosen to be rather conservative, i.e. not assuming a very strong change over the two to four rounds. As explained beforehand, the period of time (2018-2019) is overseeable and rather short-term, such that strong differences in preference over time should not be expected. The expected probability of winning for participants that decreases over time is already accounted for in the bidder's respective optimization function (as seen in AURES D5.2).

2 Questions investigated

The following questions have been chosen to investigate the most relevant design parameters for a Danish multi-unit auction scheme. First of all, two different schemes have been proposed: a first draft/base case was developed and a variation of this scheme has been proposed by the Danish Energy Agency to assess the importance of design parameters. The most crucial design features in which these schemes differ will be contrasted in the agent-based game theoretic model (described in AURES D5.2). These questions concern the implementation of budget flexibility, auction frequency and auction volume.

Table 3: Auction scheme variations for the Danish multi-technology auctions*

Budget Flexibility Mechanism	Will the auctioned volume be flexible, i.e. in case the marginal bidder submits a bid above the planned budget, can the budget be increased in a round (up to 150%) and adapt the budget in the following round instead?
Frequency and Volume	Will there be annual or bi-annual auctions? Will 100 or 200 MW per year be auctioned?
What is auctioned?	Will a CfD or a fixed feed-in premium be auctioned (electricity market price risk with the auctioneer or the bidder)?
Ceiling price	What impact does setting the ceiling price have? Does a very low ceiling price deter participants? And on the contrary, does a high ceiling price lead to an anchoring effect, i.e. do bidders orient themselves closely to the ceiling price with their bids?

*Source: Energistyrelsen (Danish Energy Agency)

A chapter on how setting the ceiling price of an auction impacts its outcome and a chapter on the expected impacts of a fixed compared to a sliding premium is also included. These two sections are answered qualitatively, as the agent-based model is not suitable to provide any non-generic insights in this respect.

2.1 Modelling the impacts of increased budget flexibility on auction outcomes

2.1.1 Model set up

The focus for this particular question is on the **planned auction rounds for 2018-2019** and two different approaches concerning volume or budget[3] **flexibility** are compared. In the first case, the volume auctioned in each round is fixed. The marginal bidder, i.e. the one whose bid exceeds the planned budget (translated from the volume) in each round is offered to a) construct a smaller version of her project to be inside the bounds of the auctioned volume or to b) not receive an award, i.e. not build at all. Depending on the size of the marginal bidder's project and the point where the volume cap is reached, this could lead to a substantial decrease in project size, making the construction of the project unprofitable or unattractive for the project developer. This is depicted in Figure 2 below. In this figure, exemplarily, the section shown in purple on the right hand side, is the part of the marginal project that exceeds the budget. It makes up more than half of the project size. It is therefore quite probable, that in this case, the project developer would choose not to construct at all instead of constructing a smaller part, as the loss in terms of economies of scale would be too substantial otherwise.

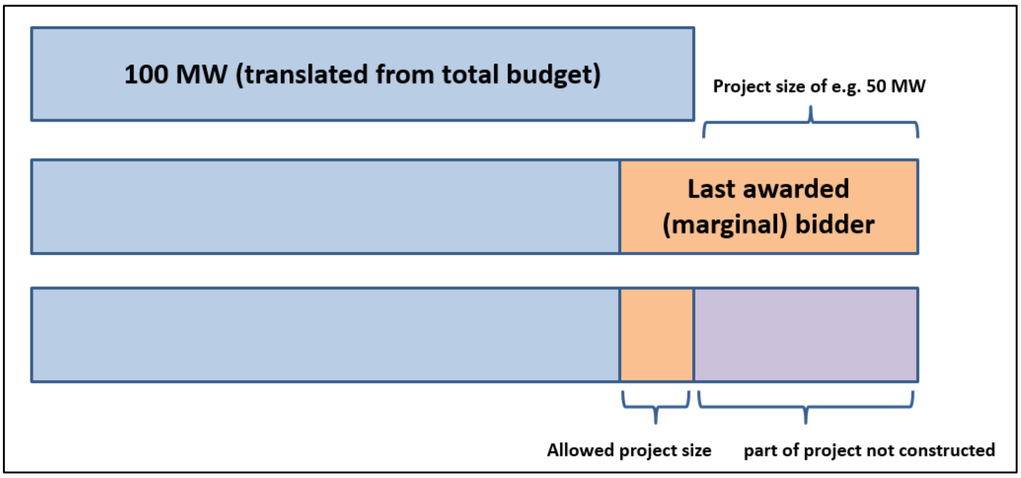

Figure 2: Visualisation of fixed budget auction scheme in the case of a large-scale marginal bidder

[3] In the following, it is always referred to budget, although the budget is translated into a corresponding volume in the modelling.

Figure 3 shows how this spotlight on a large-scale marginal bidder fits into the comparison of the two auction schemes. Specifically it is shown how the flexible auction (above, blue) is applied in comparison to the fixed-buget auction (below, green): excess budget (translated into volume), up to 50% of the actually tendered amount, can be awarded, leading to a budget reduction in the next round. If the budget in the next round is surpassed again, this budget deficit is again passed on. This way, the overall budget is balanced over time.

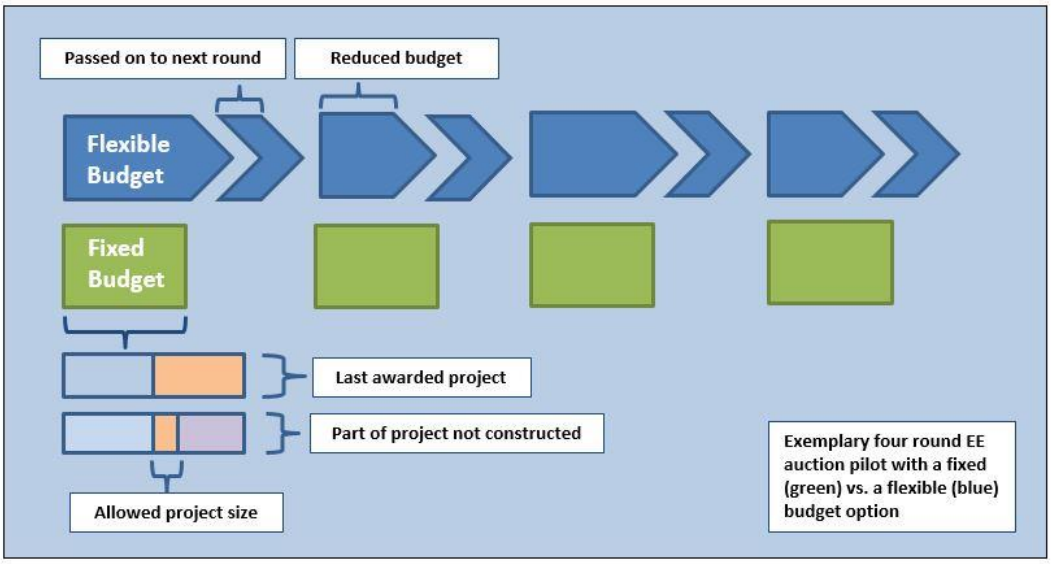

Figure 3: Comparison of the fixed and flexible budget auction design

The model to further investigate this is set up as follows. A fixed mechanism is modelled, where the marginal project is rejected as soon as it would require the marginal bidder to construct a more than one third smaller project size. This is due to simplification purposes and the aforementioned reasons, i.e. economies of scale, project planning etc. This also holds for multiple project bidders: for these bidders, all projects are counted as one and if more than one third of the total amount of the project volume is cut off due to the budget cap, it is assumed that the project is pulled out altogether. Then a second mechanism is simulated, where the marginal project is awarded in full, as long as it does not exceed 150% of the originally planned budget. If the budget is exceeded, this leads to the following round's budget being decreased by exactly that amount. Both cases are simulated for the first rounds (four auctions in 2018-2019). Outcomes in terms of constructed capacities and average awarded bid prices are then compared for both schemes.

2.1.2 Theoretical implications

Jeitschko (1999) argues that an uncertain supply can decrease prices in a classic multi-unit auction. This could implicate for this case, dealing with a procurement auction, that the uncertainty about the budget/volume to be auctioned could yield bidders to submit higher bids. However, the insecurity in this case could also go the other way, depending on bidders' expectations: a marginal large-scale bidder in the first auction round could lead to a budget decrease of up to 50% in the second round. This in turn, could increase competition and induce more aggressive bidding in the first round.

An argument in favour of the flexible volume can be found in Held et al., 2014: the authors argue that flexibility can increase cost control. A further argument in favour of implementing a certain amount of budget flexibility is inherent to the nature of the Danish market and auction design. Firstly, the market is relatively small and the to-be auctioned volume is also quite limited. Secondly, however, project sizes are the same as in other European countries (e.g. Germany), meaning that they can size-wise easily amount to half the auctioned volume (translated from the budget). This leads to problems when the marginal bidder exceeds the budget by a large share of his project. With an inflexible budget, this would lead to the bidder either having to realise a project with a downscaled size, which could lead to problems concerning the price (economies of scale). If the bidder does not construct the project, this means he will have to participate again in a future round or, depending on the timing, might even lose his permit, even though the project would have been economically competitive in the auction round he was awarded.

2.1.3 Results

In the flexible case, the budget for the auction – translated into an auction volume in the model for simplification purposes – can vary. If one bidder exceeds the budget, she is still awarded as long as her bid does not increase the total budget by more than 50%. In the next round, the volume is then decreased by the excess capacity awarded in the previous round.

In the non-flexible case, the marginal bidder (who surpasses the auctioned volume) is offered to either construct her project with a decreased size or to not construct at all. It is assumed that a multi-project bidder will reject this offer if the decrease makes up more than one third of its total size, as not being able to make use of economies of scale will make her project non-viable. A multi-project bidder is thus assumed to realise her project, as long as the quantity rejected affects only one out of her three projects. If the marginal bidder is a single-project bidder, she is assumed to still realise her project, even though the size has to be reduced, as long as only one third of the size is affected. This simplification allows for variation among the bidders. At the same time, it assumes bidders to be rational, i.e. to not construct a project that will result in an expected loss.

A **comparison of the flexible and the non-flexible budget** case has been modelled taking these assumptions into account. To investigate this, the planned rounds for 2018 and 2019 have been investigated. As several rounds are needed to see the impact of inter-round flexibility as described above, it is assumed that a bi-annual auction of 100 MW per round will take place – i.e. four rounds in two years. Their main outcomes are shown in Table 4. Summarizing, one main finding is that the budget is often surpassed by a substantial amount in both cases. This leads to different outcomes depending on the auction design in place:

Table 4: Comparison of flexible (upper table) and non-flexible auction mechanism (lower table) over four auction rounds of 100 MW each in 2018-2019

Auction round	Demand (MW)	Mean awarded Bid (€ct/kWh)	Ceiling Price (€ct/kWh)	Average Number of Bidders		Average Profit (€ct/kWh)
				Wind	PV	
1	100	1.12	2.02	2.76	0	0.095
2	82.36	1.12	2.02	2.72	0	0.128
3	83.96	1.06	2.02	2.88	0	0.059
4	81.48	1.03	2.02	3.56	0	0.03230

Auction round	Demand (MW)	Mean awarded Bid (€ct/kWh)	Ceiling Price (€ct/kWh)	Average Number of Bidders		Average Profit (€ct/kWh)
				Wind	PV	
1	100	1.15	2.02	2.88	0	0.091
2	100	1.14	2.02	3.16	0	0.135
3	100	1.07	2.02	2.72	0	0.0591
4	100	1.04	2.02	2.84	0	0.028

In a non-flexible case, less than 100 MW is actually awarded on average, because it is assumed that multi-project bidders do not build their project if more than one third of their multi-project offer is able to be constructed due to the budgetary limit and that single-project bidders take on similar considerations. This leads to overall slightly lower support costs, due to the fact that less projects are awarded in total. Specifically, the expected capacity falls short by roughly 13.45% (how this spreads out over the different rounds will be shown in more detail in section 2.2.3.2). Depending on the goals pursued by the auctioning entity, the strict budget serves to lower the costs, however at the expense of not reaching the capacity goals.

The flexible budget option was used in all modelled rounds, meaning that the original budget was surpassed in the first round, and in the following rounds, the adapted budget was (at least slightly) surpassed again, leading to a slightly reduced demand in each round. The average excess volume awarded per round is 18 MW (roughly 20% of the total volume), amounting to a decreased demand of roughly 80 MW in the upcoming rounds, as seen in the upper part of Table 4. Overall, average bid prices were marginally lower than in the non-flexible round. This difference is negligible, but shows the positive impact of the flexibility mechanism – allowing to reach the capacity goals without increasing the overall average bid price.

As the capacity envisaged was reached, overall support costs are slightly higher, as more projects will receive support. A flexible mechanism is thus the more effective option, as the capacity envisaged can actually be realised. As seen in the following, a non-flexible mechanism leads to a default rate of on average 13.45 % for a volume of 100 MW per round in the simulation. The two mechanisms thus have a substantial discrepancy in deployment while being very similar in terms of bid prices.

In light of growing electricity demand in Denmark[4] and less deployment of RES due to older plants being phased out and the discontinuation of current support policies (ENS, 2017b), the flexible budget option would thus be the more sensible choice to guarantee reaching Denmark's ambitious renewables deployment goals (Steinhilber, 2015) and guaranteeing security of supply in the future.

2.2 Modelling variations of auction volume and frequency

2.2.1 Model set up

In this modelling exercise, variations of the auction volume are shown. Specifically, the budget size is varied, as well as the way the budget is split, i.e. whether there are a few auctions with a large budget or several auctions of a smaller size. The scenarios are then compared – this gives insights into how to ideally design an auction for a relatively small market. The modelling is first performed for the two planned auction rounds in 2018-2019. In a second step, scenarios for a long-term development up to 2025 are shown.

2.2.2 Theoretical implications

From a theoretical perspective, there should be identical outcomes between an annual and a bi-annual auction scheme. Milgrom and Weber (1982) show that a bid is an increasing function of value. In each subsequent auction the bidder with the highest value among all active bidders wins. Nevertheless, the winner in the present auction has a lower value than the winner in the previous auction. This effect decreases the bids. Another effect at play is that in subsequent rounds bidders

[4] An increase in electricity demand after 2020 is expected, not least due to construction of new data centres, see e.g.: https://www.reuters.com/article/us-facebook-denmark/facebook-to-build-third-foreign-data-center-in-denmark-idUSKBN15310F.

bid more aggressively due to the fact that their probability of winning decreases, because there are fewer rounds left in which they could still be awarded. In equilibrium these two effects exactly offset each other. This means that the expected price in the current auction should be equal to the realized price in the previous auction (Trifunovic and Ristic, 2013). However, it has been shown in reality that sequential auctions are likely to differ in their outcome compared to one-shot auctions. According to Maurer and Barroso (2011) there are several benefits to sequential auctions – i.e. they help in price discovery in the case of uncertainty and are also more suitable for risk averse bidders. The authors also state, that on the other hand, if the transaction costs of holding several auctions are higher than the actual gains from price discovery, a single auction could be more suitable. Betz et al. (2010) also find that auctioning sequentially has positive impacts on revenues as fiercer competition can be induced.

As RES auctions in recent years have all shown a downward trend in terms of support costs, the theoretical perspective is adopted assuming that a higher frequency of auctions leads to a price decrease through learning. This learning is technological as well as intra-auction. Intra-auction means that agents adapt their bidding function taking into account previous auction outcomes.

Having stated that, two important factors still have to be considered - especially concerning the first two years: it might not make sense to split a very small volume into several rounds, especially taking into account that this could exclude larger projects from being awarded if the budget cap is being met too quickly. As larger projects are often cheaper, this would potentially deter large bidders from participating, due to their lower award probability. Also, large bidders offering cheap bids could participate but not be awarded, because their bid exceeds the volume by a certain extent. Instead, they would either have to offer a smaller project size (probably increasing their costs as they cannot use economies of scale as planned) or pull out altogether. This would lead to either a lower amount of capacity being built altogether or a bid to be offered to the next best bidder, increasing overall support levels. This depends on how the auction design deals with this kind of scenario.

Furthermore, as the Danish market is relatively small, competition levels could be too low to execute several rounds. For an auction with a limited amount of rounds (two to four) and in an overseeable time period of 2 years, one could also assume perfect foresight of the participants – i.e. it would not make a difference in their estimation of expected revenues if the budget is split over several rounds or auctioned all at once. In the long run, however, looking into future auctioning of RES support in 2020 and beyond, decisions on frequency and volume become more important.

2.2.3 Results

Firstly, **modelling runs for the planned auction (2018-2019)** are executed to give insights into the impact of setting a different **volume.** As this delivers only limited insights into the impacts of changing the auction's **frequency**, due to its short duration and limited budget, **future scenarios up to 2025** are also modelled, comparing annual to bi-annual auctions and their results. For the long-term scenario, 200 MW are assumed to be auctioned per year, which is the more ambitious expansion goal proposed by the Danish Energy Agency.

2.2.3.1 Volume

For this analysis, auctions of **a volume of 100 and 200 MW** per year are compared.[5] This gives insights into how the auction outcome behaves in terms of deployment, prices and agent distribution. In Table 5 below, the main auction simulation outcomes are shown for varying the budget and therefore the auction volume in the two upcoming years. One can see the following differences between a more and a less ambitious volume target. Auctioning 100 MW annually in 2018 and 2019, the bid price is on average 1.13 € ct/kWh in the first round and 1.1 € ct/kWh in the second. A slight decrease can thus be observed. In the two auction rounds, there is also a certain extent of non-realisation to be expected. This will be described in more detail in section 2.2.3.2. All of the awarded bidders are onshore-wind bidders, as they are more cost-competitive.

Table 5: Comparison of auction outcomes for the planned auction rounds in 2018-2019 with a different volume target (200 MW above, 100 MW below)

Auction year	Demand (MW)	Mean awarded Bid (€ct/kWh)	Ceiling Price(€ct/kWh)	Average Number of Bidders		Average Profit (€ct/kWh)
				Wind	PV	
2018	200	1.16	2.02	4.77	0	0.08
2019	200	1.15	2.02	4.72	0	0.12

Auction year	Demand (MW)	Mean awarded Bid (€ct/kWh)	Ceiling Price (€ct/kWh)	Average Number of Bidders		Average Profit (€ct/kWh)
				Wind	PV	
2018	100	1.13	2.02	2.67	0	0.08
2019	100	1.10	2.02	2.74	0	0.09

[5] A further increased frequency was not tested, as the volume is relatively small and a volume of less than 100 MW is very likely to be surpassed by one large project or one multi-project bidder, taking into account the current distribution of bidders in the Danish market. Executing four test rounds of 50 MW leads to a price decline yielding 1.05 € ct/kWh on average for the projects awarded. However, assuming the budget to remain fixed, having four rounds of such little quantity leads to a substantial non-realisation rate due to the marginal bidder oftentimes exceeding the allowed budget by a substantial amount.

Amongst the awarded bidders, multi-project bidders are the cheapest and thus most prominently awarded. At the same time, the multi-project bidders were also those affected most by rejection due to the fixed budget.

In the two rounds of 200 MW, the bid price stays roughly the same, i.e. drops from 1.16 € ct/kWh to 1.15 € ct/kWh. The higher average bid price is due to the fact that more projects are awarded on average and thus not only the very cheapest receive support for their projects. The bid price is however only marginally higher than the one in the case of auctioning only half the capacity. Assuming the budget to be fixed, again yields a certain amount of non-realisation, which is due to the fact that being the marginal bidder more likely falls onto a large-scale, cheaper bidder whose bid is ranked among the cheapest. A lower total award capacity is more likely to have a cut-off at a point of a larger bidder, who in turn has a larger likelihood to then drop out, not being able to realise the main share of his project. However, non-realisation is not as severe as in the previous case.

One main take-away from this simulation is thus that a joint technology auction with onshore wind and solar PV will yield only wind onshore bidders to be awarded. Furthermore, it can be seen that increasing the volume only leads to slightly higher average awarded bid prices in the short run – i.e. there seems to be sufficient competition to auction larger amounts of capacity. The impacts of auction frequency, i.e. auctioning the same volume in one round or spreading it over several rounds, will be assessed in the following.

2.2.3.2 Frequency

Starting point to assess the **impact of auction frequency** is the less ambitious target of auctioning a budget representing 100 MW annually for the period between 2018 and 2019. Splitting this budget into more than one round per year seems not very reasonable in view of the size of the participating projects. For reasons of completeness, a simulation with 2 auctions of 50 MW per year was however also performed – proving exactly the point that non-realisation due to cut-off would be too substantial. The first finding is therefore, that in a market as the Danish, with a substantial amount of large scale bidders, it does not make sense to split a budget of 100 MW into several rounds.

The **long-term comparison (2018-2025)** was then made for the more ambitious budget representing 200 MW per year to look into frequency developments. Annual and bi-annual auctions were simulated and the aggregate outcomes compared. As one can see in Figure 4, bi-annual auctions of 100 MW per round yield a substantial price decline in the first years, but then a relatively stable bid price of slightly below 1 € ct/kWh. Only at the end of the auctioning period, this price falls again, potentially due to more aggressive bid-shading due to the lower award probability towards the end. It can be seen that the non-realisation, which is in this case due to large marginal projects being awarded and then cut off due to the non-flexible budget, can fluctuate quite strongly. Overall it is at around 13.45 % yielding a shortfall of 215 MW capacity over the total period.

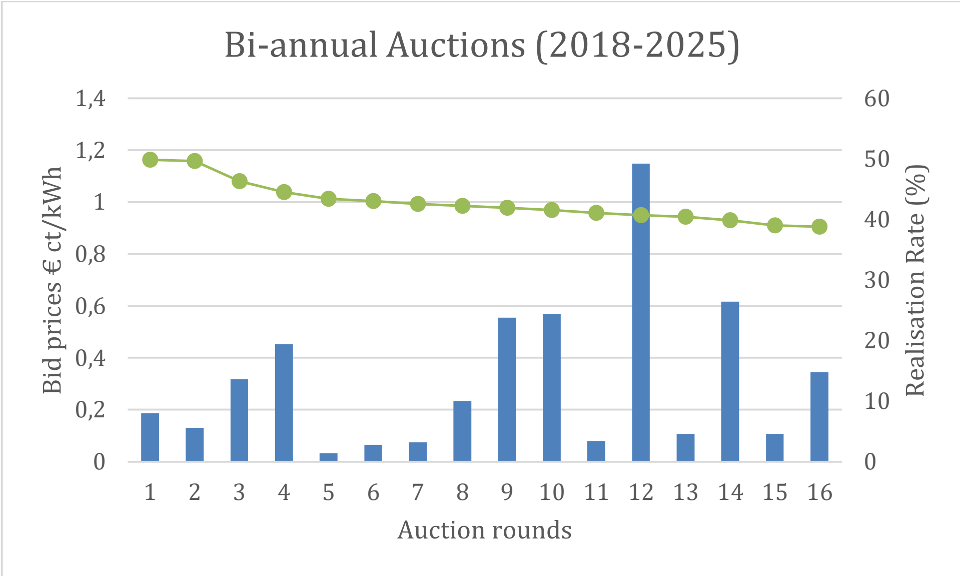

Figure 4: Bi-annual auction outcomes at a volume of 100 MW each (bid prices and realisation rate, depicted as the amount of projects cut off due to volume constraints and a non-flexible budget)

Figure 5 depicts an annual auction scheme. Basically, the same volume as before is auctioned over eight years, but at a different frequency and with higher volumes per round. Two differences can be observed, compared to the auction scheme with the higher frequency. Prices are higher on average and do not come down as strongly over time. This is due to the fact that in each round, more projects are awarded and thus not only the cheapest bidders make up the average bid price. The difference is however not very substantial: on average the bid price is 0.15 € ct/kWh higher than in the bi-annual auction case.

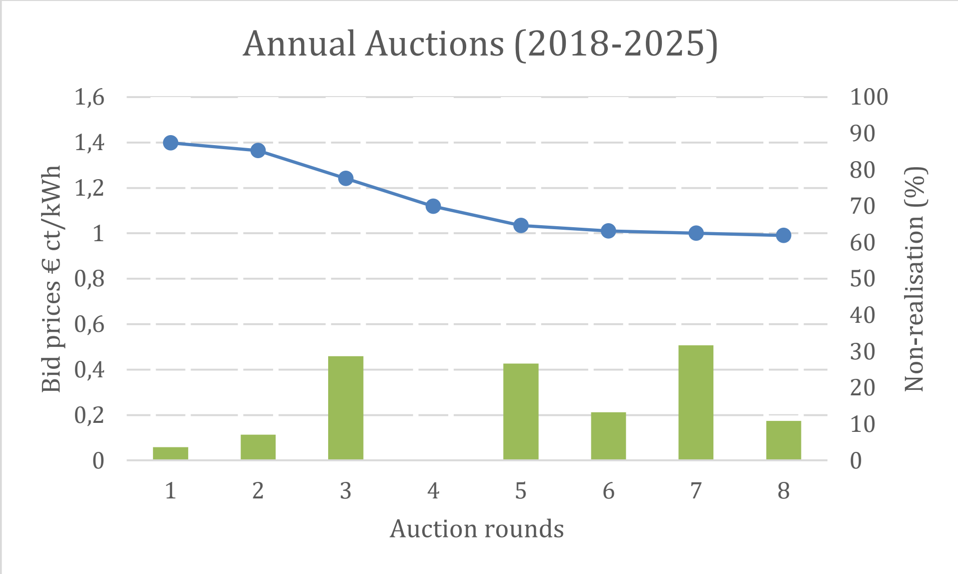

Figure 5: Annual auction outcomes at a volume of 200 MW each (bid prices and realisation rate, depicted as the amount of projects cut off due to volume constraints and a non-flexible budget)

The second difference to be seen is more substantial. The average default rate is almost double in the bi-annual auction case as compared to the annual one. This is not an inherent issue of having a higher auction frequency, but rather due to the fact that a) the budget is not flexible and cannot be adapted to a potentially large-scale marginal bidder and b) that the volume is relatively small and a split of a small volume does not necessarily make sense. As explained earlier there is a trade off in auctioning frequently to better accommodate market developments and technology cost decreases and in having sufficient volume and competition for each respective round. Having sufficient competition is not an issue in this case as the demand/supply ratio (total capacity auctioned compared to the capacity offered by the number of bidders) is relatively high in the 100 as well as the 200 MW case. Due the project sizes of bidders participating in the Danish RES auctions, however, a smaller auction volume can cause higher default rates, due to the reasons described above.

Summarizing one can thus see that in the Danish case, a 200 MW annual auction would be more efficient in terms of deployment, at the expense of slightly higher bid prices and thus support costs. Overall, the support costs per MW constructed would be around 92,000 € higher across the total support period of 20 years, assuming average full load hours, leading however to on average 88 MW more realised capacity. It thus depends on the policy goals which system is to be preferred. A higher deployment rate can be reached with less frequency and a higher volume, whereas (slightly) lower prices can be achieved by increasing the frequency and lowering the volume in each round.

2.3 Additional findings from modelling

Overall findings on the auction outcome are the following: under the assumption of multi-project bidders being the most cost competitive due to economies of scale, most awarded projects are provided by this type of bidder. This means that relatively few bidders with relatively large projects (or with a number of projects) are awarded. Furthermore, only wind onshore bidders are awarded, as their costs are still substantially lower than those of solar PV bidders.

These findings show that the multi-technology approach would, under current preconditions, lead to a further expansion of onshore wind but no technology diversity. Furthermore, market concentration is likely to increase, due to the fact that the relatively fierce competition allows only the least cost (likely large-scale) bidders to be awarded, especially in the case with higher frequency, lower volume auctions.

2.4 A fixed compared to a sliding feed-in premium

The discussion on whether to implement a fixed or sliding feed-in premium/tariff has started over a decade ago (see e.g. Ragwitz et al., 2007). While a fixed premium is simpler from its design, it has been more or less replaced in the majority of EU member states by a more flexible sliding premium. A fixed premium is a more market-oriented instrument as it induces generators to take fluctuations in the price into account. A sliding premium guarantees a certain price and covers the difference between this price and the actual market price. It can either be in the form of a contract for difference (CfD), where the generator always receives this price and all surplus goes to the regulator or it can cover everything below the agreed price and the generator can also retain a potential surplus.

The main difference between a sliding and a fixed premium is the distribution of the electricity market risks. In the case of a fixed premium, the renewable generators bear all the market risk. This can be reduced to a certain extent by implementing a corridor with cap and floor prices. In the case of a sliding premium or contract for difference (CfD), where the premium is a function of the average electricity price, the risk is put onto the regulator's side (Ragwitz et al., 2012).

According to Noothout et al. (2016), risk exposure is significantly higher under surplus capacities. Regarding a fixed feed-in-premium, the revenues fluctuate in line with the electricity price fluctuations as the premium paid on top of the market price is independent from the electricity market price. Therefore, revenues are less certain and stable, as extreme fluctuations of revenues might occur. Price risk exposure in the case of a sliding feed-in premium is low. However, the volume risk is large, since generators have to forecast and market their produced electricity (Noothout et al., 2016). A further determinant is how negative prices will be handled. If there is no sliding premium paid in hours of negative prices, this is an additional risk for generators.

Another important factor to take into consideration, when doing a technology-diverse auction as the Danish one is laid out for, is that different technologies exhibit different levels of exposure to market risk. That is to say, when looking and onshore wind and solar PV their generation patterns make them more (wind) and less (solar PV) vulnerable to market price fluctuations. The merit-order effect, as described beforehand has quite a substantial impact on prices – and especially as Denmark has a large share of wind power in its system, wind power plants would be likely to suffer large market losses in times of high generation. This does not affect solar PV as strongly, as its share in the system, up to now, is rather negligible.

Furthermore, wind is affected through (forced) curtailment in hours of excess supply (Giebel and Breitschopf, 2011). This can be absorbed by offering generators some kind of compensation, as the grid operator does in Germany.

Giebel and Breitschopf (2011) further show, that a variable premium is on average more beneficial for a project with higher full load hours. Even though these findings are based on an older study on only onshore wind, in theory this shows how price risks are perceived differently by generators with different predispositions. Furthermore, it has to be considered how the redistribution of the risk by implementing a fixed instead of a sliding market premium impacts financing conditions for renewable generators. This assessment is however beyond the scope of this analysis.

Summarizing, this would lead to the following effects: a fixed premium would lead to disadvantages for (especially) wind power generators, as they would have to carry more of the market risk and thus have to price it into their bids. Therefore, wind power would become less competitive in the auctions, possibly leading to an overrepresentation of solar PV bidders. Depending on the goals of the auctioning entity, this might be a desired development i.e. if more technology diversity through an increased solar capacity is envisaged. If, however, the expansion goal is supposed to be followed in a level-playing field way for both technologies, a more balanced way to support both technologies equally would be to implement a CfD or sliding premium, which would shift the market risk to the government.

2.5 Impacts of setting a correct ceiling price

Ceiling prices are necessary to cap the risk of high cost to consumers, especially if competition is weak (Del Rio et al., 2015). Setting the ceiling price at an “appropriate” level is not a trivial exercise and bears the risk of falling under the asymmetric information problem which is a main feature of administratively-set FITs (Del Río and Linares, 2014). Milgrom and Weber, (1982b) claim, in the context of a common value model, that if the auctioneer has private information, he can benefit by making it public. A ceiling price is, to a certain extent, a means to make private information public. It on the one hand reflects the auctioning entities' maximal willingness to pay and also should, to a certain extent, reflect assumptions on support cost needs.

How to set this price is however a crucial issue since it affects the level of competition and technological diversity – which is especially important for a multi-technology auction as is planned in Denmark. If this price is set too high, auction results might be inefficient, since bidders might collectively be tempted to bid well above their lowest possible profit margin, due to the so-called anchoring effect. If it is set too low, only few bidders will enter into the auction, which could lead to undersupply and a lack of competition (Del Rio et al., 2015). If only strong bidders enter, this could decrease the price in the short run, but could lead to market concentration in the long term, if only the largest bidders compete. Chakraborty (2002) describes, how in a common value auction, the ceiling price prevents the better informed bidder from outbidding the less informed bidders. Furthermore, he states that it increases the seller revenue (which in the case of RES auctions would translate into that it lowers the overall support costs) by generating participation from less informed bidders.

There are two main options for calculating ceiling prices: based on an assessment of generation costs (LCOE) or based on a calculation of opportunity costs. An LCOE-based technology specific approach is the best methodology to calculate ceiling prices. Compared to an opportunity cost approach, it provides a realistic production costs assessment. In the LCOE-based approach, the ceiling price is set at or slightly above LCOE level. LCOE should be calculated from the perspective of a typical investor (Steinhilber and Rosenlund, 2017).

Consequentially, the methodology should take the broader regulatory framework and transaction costs into account (taxes and tax exemption, market risk premiums, financing conditions etc.). As auctions increase risks for investors (as compared to administratively set support) the LCOE calculation should also account for this risk – otherwise the ceiling price may become too stringent and thereby impede competition. Adjustment of ceiling prices on a regular basis is likely to be required as LCOE of renewables develop: In an auction scheme, there are three possible procedures to adjust prices. First, an administrative authority could recalculate the LCOE and the ceiling price on a regular basis. Second, the ceiling prices could be indexed to economic indicators (such as steel prices etc.) and changed automatically or by discretion of the auctioning authority. Third, ceiling prices could be adjusted based on the auction outcomes of previous rounds. The first option involves regular transaction cost but is well established in many EU Member States with feed-in tariffs, the second option requires higher transaction cost to set up the methodology and the third option requires some attention to avoid strategic bidding (Steinhilber and Rosenlund, 2017).

Even though this case is not a classic example of a common value auction,[6] there are certain features (i.e. technology costs and the country's WACC) which are common value to all bidders. This is why the ceiling price has an important signalling effect for bidders. Concerning the participation from less informed bidders, this auction feature could be especially important for smaller bidders who do not have the resources to assess future market developments. The Danish ceiling price is very ambitious but does align with past empirical evidence of other renewable energy auctions which yielded exceptionally low levels of support. The difference between these auction outcomes and the Danish case is however that the low results were all for CfDs/sliding market premiums and not for a fixed market premium. A fixed market premium (as explained more thoroughly in the previous chapter) leaves the market price risk with the electricity generator. For this particular reason, it could be that the ambitious ceiling price set in Denmark could actually deter especially smaller participant (and especially wind power generators, as they are more exposed to market risk) from the auction, if they have to fear to not being able to cover their costs.

[6] A complete common value auction can for example be assumed in the case of drilling for oil rights – as the source has the same common value, albeit the uncertainty, for all participants (Cramton, 2007).

2.6 Summary and Conclusions

The game-theoretic (agent-based) modelling of variations of the Danish auction scheme and the complementary qualitative analysis, show that depending on the goals of the policy maker, different auction design elements can play a crucial role for achieving the desired outcome of an auction.

The Danish RES market provides sufficient competition to auction higher volumes and follow more ambitious expansion goals with renewables auctions (i.e. 200 as compared to 100 MW): increasing the volume yields only slightly higher bid prices. A flexibility mechanism that allows the auction budget to be increased by up to 50 %, to accommodate potential large-scale marginal bidders, proves to be a useful tool to increase deployment rates, without negatively affecting bid prices. With the help of this flexibility mechanism, an increased frequency of auctions with a lower volume each, could also be executed. It has to be taken into account, however, that more planning security in terms of capacity will be achieved with fewer auctions of a larger size. Furthermore, a larger variety of bidders can be awarded that way. The desired outcome thus depends on the envisaged policy goals of the auctioning entity.

In all modelling rounds, only onshore wind was awarded, due to its cost competitiveness. This was still the case, even after accounting for the lower market value of wind, due to its high penetration rate in the Danish electricity market. At the current state of technology development, a multi-technology auction would thus yield only a further increase in the share of onshore wind power.

Findings from the qualitative analysis show that a dynamically adapted and well-calculated ceiling price can aid bidder’s in estimating their costs, but that calculating the ideal ceiling price for a given market setting is not a trivial exercise. Furthermore, it can be said that a fixed premium leaves the market risk with the generators and that among the generators, (onshore) wind is especially prone to risks from the electricity market, due to its generation pattern and the high share already reached in the Danish electricity market. Pricing this risk into the bidding strategy however still leaves onshore wind as the most cost competitive technology.

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AURES is a European research project on auction designs for renewable energy support (RES) in the EU Member States.

The general objective of the project is to promote an effective use and efficient implementation of auctions for RES to improve the performance of electricity from renewable energy sources in Europe.

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