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Multi-unit renewables auctions for small markets - Designing the Danish multi-technology auction scheme

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ABSTRACT

This paper investigates different criteria for the design of multi-unit renewable energy (RES) auctions in small markets. The multi-technology RES auctions which are to be implemented in Denmark in 2018 serve as an exemplary case for the assessment. Focus of the analysis is how setting the auction schedule and the auctioned volume per round impacts the auction outcomes, accounting for the particular challenges of small markets. Agent-based modelling of the Danish auctions scheme demonstrates that the Danish RES market provides sufficient competition to auction higher volumes and follow more ambitious expansion goals. Furthermore, with a fixed budget, it is more effective in terms of deployment achieved, to hold fewer auctions with a larger volume. A flexibility mechanism that allows up to 50% of the auction volume to be shifted between auction rounds to accommodate potential large-scale marginal bidders, proves to be a useful tool to increase deployment rates, without negatively affecting bid prices. Furthermore it was shown that at current cost levels, only onshore bidders would be awarded in the envisaged multi-technology scheme. Also, large-scale and multi-project bidders are likely to be most cost competitive - indicating that further measures to maintain diversity could be useful.

1. Introduction

This paper investigates different criteria for the design of multi-unit renewable energy (RES) auctions in small markets. Auctions to support renewable energy have been made mandatory by the European Commission by 2017 [1] and in consequence have been carried out in a variety of European Member States. Small markets with a limited number of potential auction participants are quite frequent in the European Union. Implementing renewables auctions there can be challenging - due to potential lack of competition, relatively small auctioned capacities and other factors. The multi-technology RES auctions which are to be implemented in Denmark in 2018 serve as an exemplary case to look into these challenges. After calculating bidder's pre-auctioning cost assessments, the main research question is answered: how setting the auction schedule and the auctioned volume per round impacts the outcomes of the auction. Furthermore, a flexibility mechanism is tested, that allows budget shifts between rounds and can potentially increase deployment rates. Close cooperation with the Danish Energy Agency (ENS) provided crucial insights into this highly relevant topic.

The paper is structured as follows: a brief overview of the Danish electricity market and auction scheme as well as the related literature is given in this section. Section 2 then provides insights into the agent-based model simulating bidding behaviour in renewables auctions, which is applied to answer the research questions that concern auctioning. Next, chapter 3 shows the calculation procedure and theoretical implications for the expected bid price (pre-auctioning) as well as the auctioning procedure itself, by explaining the background to the model and its input parameters. Next, the results are presented and discussed in chapter 4. Conclusions and policy implications can be found in section 5.

To provide context to the following analysis, it is important to know that the Denmark ranks among the leading countries worldwide in terms of renewables deployment (non-hydro) as well as in wind-power technology. The RES share of annual gross electricity supply in Denmark has been on average 45% in 2016 [2]. Among Denmark's ambitious targets are 100% renewable energy consumption in 2050, (35% by 2020, including wind power as a provider of 50% of Denmark's electricity demand). Furthermore, the Danish electricity market is highly liberalised and split into two price zones (DK1 and DK2), which are part of the Nordpool area.

The Danish government plans to roll out a large-scale multi-unit

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multi-technology RES auction scheme beginning in September 2018. While Denmark has significant experiences with single-unit offshore auctions, the only multi-unit RES auction that took place in Denmark until now was a cross-border pilot scheme for 20 MW of solar photovoltaics (PV) together with Germany in 2016 [3]. This pilot auction provides some empirical evidence to draw upon, which is however limited (technology and volume-wise). Key facts on the auction scheme planned to start in September 2018 are the following: a fixed premium on top of the market price (20 years support period), capped by a certain budget per round will be auctioned. The auction will be pay-as-bid and will apply to multiple technologies (including onshore wind and solar PV). Some of the design elements in this scheme could be subject to change in the long term. The following analysis will shed some light on the impacts of their respective implementation.

The Danish energy system has been extensively covered from different scientific perspectives and has, not least due to its high shares of renewable electricity generation, received a substantial amount of recognition in the renewable energy literature. From an energy system perspective, for instance, Lund and Mathiesen [4] have assessed how Denmark could reach a 100% renewable energy system by 2050 using a large-scale energy system model and showing two different ideas, a biomass- and a windpower based approach as potential solutions. Mathiesen et al. [5] look into the same scenarios and calculate economic effects of these system developments. Parajuli [6] provides a review paper which shows how different Danish energy policies have complemented each other in achieving large renewable energy shares without generating substantial problems for the overall energy system. As the multi-unit renewables auctions that are discussed in this paper have not yet been applied, there is no scientific coverage of this support system to date. A very insightful overview of other recent experiences with renewable energy auctions has been however provided by Winkler et al. [7]. The authors show that experiences with auctions for renewable energy were mixed and that the decision on implementing auctions as well as on their design has to be made carefully. For this reason, this paper focuses particularly on certain design elements of renewable energy auctions, analysing how these could fit to achieve the policy goals envisaged by the auctioning entity in Denmark and which overall conclusions for other small markets can be drawn.

2. Material and methods

The methodology most suitable to address the given research question is modelling bidding behaviour in the Danish RES auctions by applying an agent-based model (ABM). Whereas a large-scale energy system model is ideal to simulate highly frequent auctions in a day-ahead market, see e.g. Nielsen et al. [8]; ABM proves useful to model RES auctions which are less frequent and require more strategic and long-term investment planning than an hourly trading situation. The model used has been developed and previously described in Anatolitis and Welisch [9]. The interested reader is therefore referred to this paper for more details. The following model features allow to assess the underlying research questions: the ABM 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 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 different technologies and cost distributions of bidders and gain specific insights concerning the auction outcome in a particular setting. In this research, aside of adapting the setting to accommodate the features of the Danish electricity market and auction scheme, the model has been expanded to allow for volume flexibility. A second model extension allowed for participation of multi-project bidders. This is an important feature for testing the feasibility of a non-flexible volume as well as the impacts of varying the schedule of the auction. The model including its new features and the calibration to the Danish market has been tested and validated using two real-world examples (see the appendix of this paper).

A high amount of detail was achieved in the representation of the Danish auction scheme, as the Danish Energy Agency (ENS) provided insights into all planned design features as well as into technology data and detailed outcomes of the joint Danish-German PV pilot auction. Based on insights of the cooperation with ENS (see also the temporary document by the Danish Energy Agency ENS [10], the following features were modelled:

- Two auction rounds of 200 MW each in 2018–2019
- A pay-as-bid pricing mechanism
- An “open-door” common tender scheme for onshore wind, solar PV and offshore wind.[1]
- A ceiling price of 15 DKK øre/kWh or 2.02 €ct/kWh
- Auctioning at late stage project development[2]
- A retention penalty of 30 €/kW
- A limit of three submitted projects/bidder

The agents have been designed with the following parameters using data from different sources: 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 (see ENS [3]).[3] The number of onshore wind bidders stems from the most recent analysis on the Danish market [11]. The range of capacity bid per year is an estimate based on the solar PV auction results (for the solar PV participants). For wind power, the numbers are based on the projects currently in the pipeline. Table 1 summarises all input data for the agent simulation. The average cumulative capacity bid per year is based on the expected yearly deployment in Denmark.[4] The time span takes into account the two upcoming years, although a longer period of time (up to 2025) is also modelled in addition, to show long-term developments of different variations of the

Table 1
Agent distribution.

Bidder type	Onshore wind			Solar PV
	small	medium	large	
Single project bidders	3	6	1	1
Cost distribution [ct/kWh]	1–1.5	1–1.5	1–1.3	1.5–2
Multi-project bidders	1	2	0	1
Cost distribution [ct/kWh]	1–1.3		1.5–1.8	
Capacity per project [MW]	6–20	20–60	60–135	2–50
Cost degression/round	0.5%			1.25%
Time span	t = 0,1 … 3/t = 0 … 1 (equals 4 or 2 rounds)			

[1] Although participation of offshore wind, at least in the initial years is not likely to be expected, not least because alternative single-unit auction schemes are existing for this technology (see ENS [27], offering a negotiated procedure with prequalification and a preliminary technical dialogue with the potential tenderers and investors, see Danish Wind Industry Association [28].

[2] Projects already need approval, environmental impact assessment and a variety of pre-approvals to participate in the auction.

[3] The Danish Energy Agency provided further detailed insights into the bid distribution, which are however not to be made public.

[4] Again, these detailed shares have been made possible by the Danish Energy Agency providing insights into project databases and capacity expansion plans.