Financial Modeling to Support Competitive Bidding in Renewable Energy Auctions

Masterarbeit

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vorgelegt von

Chris Stetter

[redacted]

Prüfer: Prof. Dr. Michael H. Breitner

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1. Introduction

Renewable energy resources are an increasingly important component in the production of electricity, and in particular play a key role in thwarting global temperature rise by lowering the magnitude of greenhouse gas emissions. Even though the coverage of power generating capacity from renewable energies is on the rise globally (IRENA, 2017), its further deployment, promotion and integration is still of high significance for reaching politically determined targets.

To limit negative ecological effects and pioneer a sustainable future, policy makers have introduced incentives to foster deployment of renewable energies in recent decades. Specifically, financial support mechanisms such as fixed feed-in tariffs were established for increasing the competitiveness of renewable energies compared to cheaper electricity production of conventional resources (Abolhosseini and Heshmati, 2014). However, mentioned support schemes feature high subsidy costs and, thus, lack of an economically- and cost-efficient expansion of renewable energies, due to its design being centered around governmental intervention and not instruments of market economies (Huntington et al., 2017).

Consequently, market-based support mechanisms are on the rise with policy makers shifting toward auction-based mechanism, introducing price discovery of feed-in tariff levels (Río and Linares, 2014). In recent years, there has been an increasing number of countries adopting renewable energy auctions, more precisely, an increase from 6 to 67 between the years 2005 and 2016 (Adib et al., 2016). The intentions of policy makers introducing auction-mechanism are a stronger market integration of renewable technologies and most importantly a cost-efficient energy transition. The latter in particular is achieved by reducing corresponding subsidy costs as in auction designs projects compete for the level of feed-in tariffs (Huntington et al., 2017). The introduced competition is a key and expanding instrument of current policy-making for advancing cost-efficient renewable energy deployment. The existing body of research on renewable energy auction designs arrives to the conclusion that auctions are almost always cost-efficient. Shrimali, Konda, and Farooquee (2016) for example, they have estimated economization of up to 58% compared to fixed feed-in tariffs.

In the realm of feed-in compensation for renewable electricity, competition among project developers for subsidized remuneration has become a central instrument in the deployment of renewable energies. Such competitive bidding, where project developers participate in auctions and rival for tendered electricity volumes, was introduced in Germany with the latest amendment of the Renewable Energy Sources Act (EEG) in 2017. Due to its recent entry into force and the ample and progressive intention of politics toward green energy, Germany is considered in this thesis. In addition, due the large share of these technologies (IRENA, 2017), the discussion will be narrowed to solar and onshore wind. The German auction-mechanism is designed as a tender, where project developers compete for a pre-defined volume by placing bids (in €/kWh) as well as a corresponding capacity (in kW) to be installed. The most cost-competitive projects will be granted funding until the tendered capacity volume is reached (EEG, 2017). The expectation is that the competition will drive feed-in prices down, which in turn will lower governmental subsidy costs and promote a step toward cost-efficient energy transition.

However, the newly evolving competitive environment causes new challenges to project developers for running renewable energy projects, mostly stemming from decreasing profit margins. As a result, adequate consideration of project risks and mitigation of error-prone project valuation methods is of key importance for quantifying bid prices. In existing literature little support focuses on deriving bid price quantification methods, in particular from a strategic perspective considering project exogenous factors such as the occurring competition.

What stands out in this regard is, that determining a bid price that is cost-competitive and sustainable in terms of a likely project realization is a major challenge that results from the shift toward auction-mechanisms. From this it follows, that the requirements of all project stakeholders comprising equity and debt capital investors should be considered in the valuation and bid price quantification process. Otherwise, bid prices may not be competitive or too low for a profitable and financially viable project construction resulting in low rates of project realization, which does not contribute to an economically and ecologically sustainable energy transition.

The main challenge faced by researchers and practitioners is to foster competitiveness of project developers while accounting for the requirements of all stakeholders, which is the key objective of this thesis. The motivation for research of this thesis stems from insufficient methodological support. As a first step, an approach for estimating the minimal level of remuneration for which a project realization is profitable and financially viable is presented. This is referred to as the non-strategic bid price.

In this regard, a holistic financial modeling approach is derived employing 1) state-of-the-art cash-flow analysis with the adjusted present value metric while considering 2) the risk-bearing capacity of all project stakeholders, 3) the complex financing and cost structure of renewable projects as well as 4) a broad range of risks and uncertainties modeled by Monte Carlo simulations. The main characteristic of the presented methodology is a risk-constrained optimization approach minimizing the required feed-in tariff while considering investment criteria of both equity investors and outside creditors. In a second step, an optimal bidding strategy is determined by utilizing 1) real option analysis, 2) game-theoretical solving algorithms and 3) statistical distribution fitting and parameter estimation techniques, which is referred to as the strategic bid prices.

Information systems (IS) research features capabilities for solution-oriented results, in particular for answering research questions related to environmental and renewable energy transition issues (Gholami et al., 2016; Malhotra, Melville, and Watson, 2013). Consequently, a prototypical implementation in Python is used for calculating and visualizing results for probability distributions of several key figures for a case study in Lower Saxony, Germany. This allows for a proof-of-concept and sound understanding of the holistic modeling approach to support competitive bidding in renewable energy auctions. Therefore, this thesis makes a major contribution to research on optimal and strategic bid price quantification.

The thesis is organized in the following way: It begins by presenting results from a systematic literature review on the current state of research in chapter 2, from which the research gap is identified. In addition, this chapter will cover the adopted design science research approach for addressing the research question in a transparent and rigorous process. It will then go on to defining a holistic modeling approach for quantifying bid prices from a non-strategic perspective in chapter 4. The aim is to satisfy the requirements of all project stakeholders for a cost-competitive and sustainable bid price. Chapter 5 is concerned with the methodology used for deriving an optimal bidding strategy by framing auctions as a game-theoretical problem being solved. An applicability check of a developed prototype comprising the presented modeling approach is performed in chapter 6, where a fictive wind farm in Lower Saxony, Germany is considered and obtained results are visualized. Theoretical and practical implications as well as limitations of the presented methodology and developed prototype for supporting competitive bidding in renewable energy auctions are discussed in chapter 7. Finally, along with recommendations for future research, conclusions are drawn in chapter 8.

2. Research Background

In the following, a systematic literature review on the current state of research is given. The focus is on articles published in high-ranked journals that make major contribution on assessing renewable energy investments based on financial and risk key figures, and define models that support competitive bidding in renewable energy auctions. For a sound definition of the research question, this approach yields a transparent identification process of a research gap. In addition, for addressing an informations system-driven research approach, the adopted design science research method of Peffers et al. (2007) is presented and described in the realm of the research topic.

8. Conclusion and Outlook

This thesis examined *how to optimize the strategic bidding behavior of project developers in renewable energy auctions*. The motivation for addressing this research question stems from a shift toward auction-based support mechanisms introducing competitive price discovery of feed-in tariff levels and the lack of appropriate and comprehensive methodological support. To answer this question, a holistic and integrated modeling approach was developed and thereby took an important step toward providing decision support for project developers in renewable energy auctions.

Specifically, the challenge for project developers is to quantify cost-competitive bid prices that fulfill the requirements of all project stakeholders and to behave strategically optimal under a specific auction design. Thus, deriving an appropriate modeling approach was divided into two submodels, one for quantifying a non-strategic bid price based on cash flow analysis and the other for deriving an optimal bidding strategy employing real option analysis. Its application and capabilities were demonstrated on a fictive onshore wind farm in Germany utilizing a DSS prototype. Alongside proposing improvements for each submodel and addressing challenges from project developers' perspective, the research of this thesis contributes to the integration of both individual models.

Nevertheless, suggestions for future work addressing identified limitations were given. On the one hand, further research in this area may include exploring agent-based modeling for simulating auction outcomes and thus may enrich the estimation procedure for the market clearing price distribution of the strategic bidding model. On the other hand, it should be examined how to consider the uncertain price development of the exchange price of electricity and its evolving risks and chances in the bid price in future investigations. In addition, further research is required to establish the viability of the modeling approach and the developed prototype by applying it to other renewable technologies and countries featuring different auction designs.