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Abstract

The Horizon2020 project AURES II aims at ensuring the effective implementation of auctions for renewable energies in the EU Member States (MS). In recent years, auction schemes for the allocation of support for renewable electricity sources (RES) have been advancing rapidly across Europe. Auctions are considered to have brought down support levels and increased planning capability for RES deployment and state budgets. In some unfortunate cases, they have, however, also resulted in delayed or unrealised projects and increased uncertainty for project developers. A variety of auction designs are still being tested and introduced in EU MS, as well as foreseen by European legislation. Therefore, there is still a need for further assessment and improvement of national auction design and implementation to ensure the future success of RES auctions in Europe. Applying different qualitative and quantitative methods in the various work packages (WPs), the AURES II project partners have already drafted and published a large number of reports and studies. This article aims at comprehensively presenting these results and provide a first overview.

Key words: renewable energy, electricity, auctions.

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Applying different qualitative and quantitative methods in the various work packages (WPs), the AURES II project partners have already drafted and published a large number of reports and studies. This article aims at comprehensively presenting these results and provide a first overview.

1. WP2 MONITORING OF AUCTION IMPLEMENTATION

Work Package 2 (WP2) deals with empirical aspects and deriving insights from RES auctions in Europe and worldwide. More specifically, currently conducted as well as planned auction schemes have been evaluated in several case studies with lessons learnt and best practices identified.

So far, concluded auctions in the following countries have been analysed: Argentina, Canada, Chile, Denmark, Germany, Greece, Hungary, Mexico, Netherlands, Poland, Portugal, and the UK. In addition, one multi-national, technology-specific case study on CSP has been conducted. Furthermore, three planned auction schemes have been analysed: the Thor offshore wind auction in Denmark, Slovakia, and Ukraine.

The AURES II consortium will shortly publish a synthesis report on the case studies, highlighting the lessons learnt and best practice examples. Nevertheless, a first version of this synthesis report will be part of this Special Issue.

Case cooperations, in which the AURES II consortium provides recommendations on auction designs, have been successfully ongoing with policymakers in four MS that have ongoing auction implementation processes. These are Austria, Denmark, Germany, and Hungary.

2. WP3 AUCTION DATABASE AND EMPIRICAL INSIGHTS

The work carried out in WP3 contains the development of a comprehensive database on past and ongoing auction rounds in the EU, including their design, timing, and results. Based on these data, two empirical papers are currently being drafted. In addition, WP3 comprises several policy briefs that analyse current and emerging topics in the realm of renewable energy auctions.

Although a rising number of countries in and outside the EU have implemented auctions to support RES, no single, publicly available database exists which comprises information on the concluded auctions. Therefore, the AURES II consortium closed this gap by collecting and updating the available data on RES auctions in the EU (http://aures2project.eu/auction-database/)[1]. The result is a database that covers more than 400 distinct RES auction in 20 EU Member States from the years 2011-2021 and which is being updated every six months. The database includes information regarding implemented design elements, such as prequalification criteria, pricing rules, auctioned volume, the auction outcomes (*e.g.* awarded prices and volumes, level of competition, etc.), as well as the realisation rates of the awarded projects, among other elements.

Based on the data gathered in the AURES II auction database, two empirical studies are being drafted and soon to be published: the first one evaluates the EU Member States' RES policy objectives and the implemented RES auction designs and the second one examines the efficiency and effectivities of European RES auctions quantitatively.

In the first forthcoming paper, Hanke and Anatolitis (forthcoming) collected the stated RES policy objectives of EU member states that have an auction scheme

1 Currently, the database can be downloaded as an Excel- file from the AURES II website: http://aures2project.eu/auction-database/. An interactive version of the database is currently being developed.

in place. In a first step, they summarised the objectives (*i.e.* effectiveness, cost efficiency, support cost efficiency, green growth, security of supply, and actor diversity) and identified the relationship between these objectives theoretically. Based on these relations, they were able to assess whether countries followed a consistent strategy when drafting their RES policy objectives. The results indicate that 7 out of the 13 analysed countries had well-aligned objectives, three followed an ambiguous strategy, and only two showed non-aligned policy objectives. One country followed a "neutral" strategy, stating only one objective. In the next step, the authors examined whether the countries in focus designed their RES auctions according to their objectives. Based on insights from auction theory and on each country's chosen auction design elements retrieved from the AURES II auction database, the authors concluded that 10 out of the 13 countries actually showed a suitable auction design. In contrast, three countries could improve their schemes by adapting their auction designs to their stated objectives.

In the second forthcoming paper, Anatolitis, Azanbayev and Hanke (forthcoming) use the data of the auction database to conduct an econometric analysis to quantitatively identify the impact of various RES design elements on awarded prices in RES auctions. Using a panel data regression model, they were able to show that prices dropped significantly over the years. Furthermore, besides observing the significant impact of financing conditions and RES share in a country, they identified a list of auction design elements with a significant effect on the awarded prices: project size, financial prequalifications, realisation periods, auctioned technology, competition, penalties, flexibility, multi-criteria auctions, quotas, and the remuneration scheme. These findings can support policymakers in designing efficient auction schemes. Nevertheless, some of the results contradict the predictions of auction theory, such as financial prequalifications or penalties decreasing the awarded prices, and should be further researched.

To date, three policy briefs have been published by the AURES II consortium, which provide timely analyses on selected auctions to keep stakeholders up to date on new developments:

Impact of COVID-19 on Renewable Energy Auctions: In May 2020, in the first AURES II policy brief, Wigand *et al.* (2020) analysed the impact of the (starting)

COVID-19 pandemic on RES auctions and derived recommendations for policymakers on how to deal with these challenges. Four major impact areas have been identified: 1) the Covid-19 pandemic leads to decreased energy demand, which results in potentially lower short-term demand for RES and potentially more EU Member States meeting their 2020 RES targets without additional policy action. 2) Disruptions in global supply chains and national permitting procedures might endanger project realization and increase accrued penalties. Several EU Member States had already prolonged realization deadlines while others have postponed or cancelled auctions. 3) Higher RES financing risks were observed due to an increased country and policy risk. 4) Falling wholesale market prices posed significant challenges for projects without market premiums with sufficient floor prices (*e.g.* merchant plants and plants with a low fixed premium).

Besides advocating that climate-friendly economic stimuli packages should increase public clean energy spending and access to finance, the authors recommended that policymakers should extend the realisation deadlines of awarded projects and in upcoming auctions. Furthermore, policymakers should allow for longer award periods and should increase the digitalisation of auction procedures. Lastly, the adjustment of auction schedules could be considered, but policymakers should avoid downward auction volume revisions.

How (not) to respond to low competition in renewable energy auctions: In this second policy brief, Hanke and Tiedemann (2020) analysed possible ways on how to deal with a lack of competition in RES auctions that leads to higher awarded prices and argued against the use of endogenous rationing. They argue that if the reason for the supply shortage is based on the auction design itself (strong disadvantages for one bidder group), then it is a good idea to change the auction design, including possible interventions for the disadvantaged bidders, to achieve a more favourable outcome. If the technology itself cannot generate enough supply, multi-technology or cross-border auctions can be helpful to fill the volume with supply from other technologies or countries without supply shortages. Another option is to reduce the auction volume temporarily and to add the missing volumes to future auctions when the supply side has recovered. Nevertheless, the authors argue that in no case the reduced auction volume or the ceiling price should be determined endogenously within the auction, but only

administratively prior to the auction. While short-term improvements may be possible with endogenous rationing, long-term effects such as missing renewable energy targets prevail. Endogenous rationing not only decreases social welfare and increases costs but also damages the market in the long term by further weakening the supply side and generating unwanted market distortions. This has been proven theoretically, experimentally, and with real-world examples.

The 2020 Nobel Prize for Economics and its connection to AURES II: In this third policy brief, Ehrhart, Ott and Hanke (2020) presented the work of Robert Wilson and Paul Milgrom, the 2020 laureates of the Nobel Prize for Economics. Robert Wilson extended the assumption of private values in auctions, *i.e.* that each bidder only knows the good's value to them and that different bidders have different values, by introducing common values. In a situation with a common value, the good has the same value for every bidder, but no bidder knows this value exactly. The value may depend on future developments, *e.g.* market prices, which are the same for all bidders but unknown at the time of the auction. An auction of this good may lead to the so-called "winner's curse": even if the bidders estimate the common value correctly on average, the bidder who misjudged the value the most will win and will most likely realise a loss. Paul Milgrom, Wilson's former PhD student, analysed a more general model that incorporates the two extreme cases of common and private values and provided insights into how more information in the auction process help reduce the winner's curse. In both AURES and AURES II, the consortium further investigated the findings of the two laureates both theoretically and experimentally to help reduce the risk of the winner's curse and to improve the design of auctions for RES.

3. WP4 EFFECTS OF AUCTIONS ON THE RES SECTOR

WP4 focuses on three aspects of the effects of auctions and auction design on the RES sector, *i.e.* including impacts on supply chains (focusing on market concentration in this sector), actor diversity (the impact on energy communities) and technological innovation.

It is often argued that a key feature of auctions is the competitive pressure created on the overall value chain, and indeed on all actors of the RES sector. Moreover,

it is often argued that auctions can induce a reduction in the level of actor diversity (AD) in some segments of the value chain, and especially in the project development sector. Auctions may favour certain types of actors over others, and this may lead to increased levels of market concentration (MC)[2].

Del Río *et al.* (2020) empirically analysed: 1) the impacts of different auction design elements (DE) on MC in the project development and component manufacturing segments of the RES value chain; 2) The relative impact of auctions (as compared to other (contextual) factors influencing the value chain) on MC in those two segments. Country and technology case studies were undertaken based on an expert-elicitation protocol (structured interviews with key experts) in four countries (Spain, U.K., Peru and South Africa).

Certain design elements stand out as having a consistently strong positive (increasing) or negative (decreasing) impact on the number and diversity of project developers and component manufacturers; impacts that are observed in all four countries of analysis. The use of transparent publicly-disclosed auction schedules, as well as conducting auctions with high frequency, are clearly considered to be elements that increase both the number and diversity of actors in project developer and component manufacturer value chain segments. The opposite is true for all kinds of prequalification requirements. Specifically, when prequalification requirements –whether financial, technical or related to bidder experience– are stringent (as opposed to lax), they tend to reduce both the number and diversity of actors in project developer and component manufacturer value chain segments.

In general terms, interviewed experts held a range of diverging views as to whether auctions, auction design elements, or context conditions, are most important in terms of shaping the number and diversity of actors in the two value chain segments of interest. Context conditions and related factors were found to affect the number and diversity of project developers and component manufacturers in an overall neutral or positive way. However, in some countries auctions themselves

2 MC is defined as the distribution of a given market among the participating companies. MC reflects both the number of firms within the market/sector (and/or participating in the auction) and the diversity of those firms (*i.e.* the degree of heterogeneity with respect to the size of those firms).

were not regarded as the major determinant of MC in the two considered stages of the value chain.

Amazo *et al.* (2020) aim to provide an overview of the impact of auctions on renewable energy communities (RECs) and assess measures to support these market actors in or outside auctions. According to article 12 (16) of the Renewable Energy Directive (REDII), a RECs is "a legal entity: (a) which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity; (b) the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities; (c) the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits". The REDII acknowledges the importance of RECs and requires Member States to consider the specificities of these market actors when designing support schemes.

RECs can foster the local acceptance and ownership of renewable energy development. As indicated by Amazo *et al.* (2020, p. 26), "RECs can support renewable energy development in various ways, for example by increasing local participation in planning and decision-making processes, as well as local benefits through project ownership. Furthermore, local engagement processes of RECs can facilitate the land acquisition process and thus ease the often-challenging pre-development of sites, particularly for new wind projects". Despite their importance, RECs face special challenges in auctions compared to administratively-set remuneration schemes, which is related to their limited project portfolio and size. "Participating and winning in an auction requires significant expertise and access to capital, which smaller actors do not have to the same degree as large, experienced renewable energy developers" (Amazo *et al.*, 2020, p. 26).

From their analysis, Amazo *et al.* (2020) broadly conclude that there is no easy solution to promote RECs in the context of auctions. Most importantly, the

authors find out that measures to address the impact of auctions on RECs can be taken either inside the auction (as in Germany or France) or outside the auction (as in Denmark). Measures within the auction include lower pre-qualification requirements, longer realization periods, citizen participation bonus and a different pricing rule (*e.g.* uniform pricing instead of pay-as-bid, PAB). However, while promoting RECs, these measures inside the auction rules may lead to distortions in the auction (Amazo *et al.*, 2020, p. 27).

In contrast, measures outside the auction, such as exempting RECs from the auction and a guarantee fund, can help address financing risk and the allocation risk and "interfere considerably less with the auction compared to preferential treatment or the exemption from auctions. Denmark's experience shows the uptake of this measure depends on the sufficiency of the guaranteed volume, and the limits of a measure's effectiveness in reversing a trend towards actor consolidation" (Amazo *et al.*, 2020, p. 27).

Another topic addressed in WP4 is the impact of auctions on technological innovation. Innovation in general and, more specifically, innovation in renewable energy technologies (RETs) will be a critical component of the energy transition (IEA, 2020). Del Río and Kiefer (2021) analyse the impact of auctions on technological innovation in RETs. Deployment policies, such as auctions, will not only have impacts on deployment itself (*e.g.*, on diffusion) but on previous stages of the innovation process as well (*e.g.*, invention and innovation). However, attention has not been paid so far in the auction literature to how auctions and auction design elements influence innovation in RETs. Del Río and Kiefer (2021) cover this gap by providing a first contribution on this issue and exploring the impacts of auctions and auction design elements on technological innovation. An analytical framework on the mechanisms linking diffusion-driven technological innovation and auctions and their design elements, which merges the insights from different approaches, is provided and a preliminary empirical analysis to identify the perception of key stakeholders on the topic is carried out. Based on theory and on those perceptions, the authors put forward some research proposals to be investigated in future research.

The authors follow an exploratory analysis based on a literature review and an exchange of views on the main aspects (actors, variables, relationships between

variables and causal links) with different relevant stakeholders knowledgeable of both innovation processes in RETs and auctions (and their design elements). The authors put forward the following research proposals, to be further investigated in the future:

- The design of the auction (different design elements) may affect innovation through several key channels: impact on private R&D through a greater profit margin and the expectation that there will be a market for the technology (*i.e.*, where manufacturers and technology developers can sell their technology), impact on technology diffusion (learning effects) and impact on the competitive pressures faced by manufacturers and technology developers to reduce costs or increase revenues.

- The negative effects on innovation from lower profit margins in auctions and lower levels of market creation for RETs compared to administratively-set FITs may offset the positive effects on innovation from greater competition in auctions. Whether this is so for all RETs and auctions depends on the technologies, the design of the auction and the details of the administratively-set remuneration to which the comparison is made.

- Auctions will be one of the factors influencing innovation in RETs, but probably not the main one. Many other policy (e.g., technology-push policies) and non-policy factors (*e.g.*, the pressure to reduce costs as a result of international competition in a globalised sector) influence innovation, and probably to a larger extent.

4. WP5 IMPACTS OF AUCTIONS ON COST OF CAPITAL

The aim of WP5 is to evaluate the effects of auctions and auction design on RES project financing, *i.e.*, the cost of capital of RES projects and to suggest auction designs that are compatible with the usual financing practices of RES projects. The final goal is to provide policy recommendations in terms of design element choices that reduce the risks and improve the financing conditions.

This is a crucial issue, since the costs of capital are one of the most significant cost factors of RES projects, due to their typically very high capital intensity. However,

this issue remains to date under-researched. Indeed, the reduction in different auction design elements (DE) of wind and solar PV in the last decades can partly be attributed to reductions in financing costs (Egli, Steffen and Schmidt, 2018).

Đukan *et al.* (2019) map out the potential effects that auctions might have on financing conditions of RES projects, focusing on the market effects of introducing auction schemes and the effects on financing of individual design elements. Therefore, its main purpose is to identify possible causal relationships between auctions and their impact on financing conditions for renewable energy projects.

The authors systematically explore possible impacts of different drivers (exogenous and endogenous) on financing conditions for investments in new RE assets. The drivers are endogenous (renewable energy policy and auction design) and exogenous (such as economy-wide effects, monetary policy and the structure of the capital market, among others). Three main dimensions of (direct and indirect) impact are considered: financing type (project financing vs. balance sheet financing), project phase (the project development lifecycle) and actor type. Financing conditions are defined as "both the ability to source financing for an investment and the cost of sourcing it" (Đukan *et al.,* 2019, p. 10). The authors analyse "effects via indicators related to 'cost of capital' on the one hand, and indicators related to 'loan conditions' on the other. We thus differentiate seven different impact indicators: weighted average cost of capital (WACC), cost of equity, cost of debt, debt-to-equity ratio, hurdle rate, debt service coverage ratio (DSCR) requirements and loan maturity" (Đukan *et al.*, 2019, p. 10).

The work relies mainly on qualitative research methods and the methodology is based on three steps: 1) a literature review of auction design and financial theory literature; 2) semi-structured interviews with seven industry professionals, with a background in financing renewable energy investments and/or project development; and 3) a validation workshop with industry stakeholders at the Wind Europe conference in Bilbao in April 2019 (Đukan *et al.,* 2019). The authors warn that their findings should be considered as hypotheses that need further research and validation rather than conclusions.

The results from this report can be summarized in five main categories:

1) *Cost of equity and hurdle rates experience both downward and upward pressure from auctions*. Growth limitations and competitive pressure induced by auctions may force project owners to accept lower profit margins, *i.e*. lead to a reduction in hurdle rates. On the other hand, the new risks faced by these owners in the auction may lead to higher risk premiums. In addition, "auctions may also lead to a decrease in support payments to individual projects, making them more dependent on volatile market revenues, potentially causing an increase in cost of equity" (Đukan *et al.,* 2019, p. 6). The impact on different types of actors can be expected to be different. In particular, small actors would probably be more negatively affected, leading to a reduction of actor diversity. The impact of some design elements is discussed. Some could be expected to affect the risks, the cost of financing a project and the willingness or capability to finance it.

2) *Debt financing is most likely impacted more by the remuneration scheme than by other auction designs*. The authors expect the support design in auctions to lead (under certain circumstances) to more difficult and expensive project financing[3]. They find that "two-sided Contract for Difference (CfD) schemes (which provide a fixed remuneration independent of the market price) have the most positive impact on loan financing conditions since they provide the most predictable revenues" (Đukan *et al.* 2019, p. 6).

3) *Auctions may change the investor landscape, through their diverging effects on actors, influencing actor diversity.* One of the main findings of this report is that auction schemes affect the investor landscape by creating new market conditions. Interestingly, the new market conditions have an impact on actor diversity, because "Unlike larger actors (such as utilities) that have diverse cash flows and easier access to capital, smaller project developers do not necessarily have the resources to diversify, and the risks they are exposed to could lead to greater financial distress" (op. cit., p. 49).

3 In addition, "the higher competitive pressure of auctions might also be reflected in the banking business, and potentially lead to a small decrease in debt margins" (Đukan *et al.*, 2019, p. 48).

4) *Auctions are a policy tool that, depending on its specific implementation, can be a barrier to RE financing, but also provide market stability.* On the one hand, auctions can improve the stability of support schemes which could be positive for financing, both on the equity and debt side. Some design elements would be highly positive in this regard, including fixed auction volumes, long-term schedules (with well-defined rounds in terms of frequency) and contractual commitments between auction winners and a governmental institution.

5) *The impact on financing depends on individual designs and market circumstances.* The authors stress that the impact on financing depends on individual designs and market circumstances. Regarding the former, CfD would have a positive effect on the cost of capital, but stringent bid bonds, unrealistic project realisation deadlines, unclear auction volumes, low auction round frequency, among others, could have a negative effect. Regarding the latter, other factors beyond auction design may have a greater influence on the costs of capital and financing, including country risks, monetary policy or regulatory barriers.

Đukan and Kitzing (2021) investigate the effects of the shift to auctioning on the costs of capital and financing conditions for onshore and offshore wind. They use the results from Đukan *et al.* (2019) as a first step and then proceed with the analysis by including more interviewees and focus groups with experts involved in financing wind energy projects in Europe to verify the analysed potential effects. The authors find that auctions create a competitive environment that pressures the industry into accepting higher risks and lower returns. Banks have reduced debt margins, while large investors decreased hurdle rates and equity returns, despite additional risks from auctions, such as uncertainty about future award prices, allocation and qualification risks. The risk of being awarded support and incurring sunk costs makes smaller bidders averse to participating in auctions. Despite increased price risk, project financing conditions have improved: the competitive pressure driven by project sponsors seems to lower financing costs and hurdle rates and reduce the cost of capital for offshore projects.

Roth *et al.* (2021) provide qualitative and quantitative insights intended to contribute to a better understanding of renewable energy financing in the European Union both in auction and non-auction environments. The results

of the interviews conducted by the authors between December 2019 and April 2020 show that there is still a considerable gap between EU Member States regarding their WACC values for wind and PV projects[4]. However, most EU countries reduced their WACC dramatically since 2014, as well as their Costs of Debt and Costs of Equity. The analyses show that multiple reasons are behind the observed reduction in the WACC apart from lower interest rates, technology improvements, and lower country risks: "1) capital is not only raised from EU sources, but it is also flowing from international sources, which could generate spillover effects in EU countries where the costs of capital are higher than the costs of international investments; 2) the non-standard monetary policy of the European Central Bank after the 2008 crisis has resulted in abundant capital which triggered lower loan fees and increased competition for business cases; 3) new market players, such as energy-intensive companies, are under political and regulatory pressure to green their portfolios and are consequently shifting to different auction design elements (DE) through, for example, corporate PPAs, which could add more competitive pressure on the market" (Roth *et al.,* 2021, p. 5). The results of an econometric analysis performed by the authors confirm the findings of the interviews: the main driver of the WACC is the country risk, but experiences with renewables are also significant. The introduction of auctions did not increase the WACC, rather the opposite was true: increasing experiences in auctions different auction design elements (DE) to have a dampening effect on the WACC. An interesting finding is that remuneration schemes that reduce the exposure to market risks tend to have a decreasing effect on the WACC.

To estimate the effects of different financing conditions on support costs, the authors develop a cash flow model that calculates minimum bid levels and debt shares, given several optimisation constraints. Based on this, they find that Member States should mainly focus on de-risking debt financing, as this would deliver the largest support costs savings and WACC reduction. The authors argue that, instead of additionally/marginally decreasing cost of debt, de-risking policies should also aim at increasing loan maturities and debt size. Such debt de-risking could be best achieved by adopting remuneration schemes that decrease the

4 A data note describing the accumulated data on the cost of capital is currently being drafted and will be published soon.

volatility of the projects cash flows, such as CfD. Furthermore, they also find that de-risking the cost of equity –through relaxing pre-qualification requirements, reducing bid bonds, prolonging realisation rates etc.– would not yield very large additional benefits in terms of support cost reduction. Therefore, policymakers should de-risk auction designs in the pre-bidding stage –decrease bid bond levels, relax pre-qualification requirements etc.– only if they have policy goals other than cost-efficiency, such as increasing actor diversity (Roth *et al.*, 2021, p. 5).

5. WP6 INTERNATIONAL AUCTIONS

In contrast to national auctions, international auctions are auctions in which projects from more than one country can participate, *i.e.,* projects located outside of the auction-conducting country can participate and compete for support (Ehrhart *et al.,* 2019). There are several good economic reasons for the implementation of cross-border auctions, including better use of natural resource potentials in Europe, higher market values[5], lower cost of capital and higher competition (von Blücher *et al.,* 2019).

These auctions have not been used by Member States, except for the PV auctions between Germany and Denmark in 2016, although the picture might change in the future, given several EU energy policy developments: the new 2030 RES governance, voluntary opening of national support schemes under the REDII, the new "Financing Mechanism" and renewables Projects of Common Interest (von Blücher *et al.,* 2019, p. 5).

Cross-border auctions are still perceived to be complex to design and burdensome to implement. The aim of WP6 is to define and analyse design questions specific to cross-border auctions from a theoretical and an empirical perspective and to provide concrete design recommendations to policymakers.

Von Blücher *et al.* (2019) assess various design options for cross-border auctions and provide practical guidance for Member States seeking to implement them.

5 Higher market values compared to the values of domestic RES power plants can lead to a significant decrease in support payments.

This report identifies three basic models of cross-border auctions which go from a low to a higher intensity of cooperation: Countries may choose to conduct unilateral, mutual cross-border auctions or joint auctions (see Table 1). The authors observe a trade-off between the transaction costs of preparing the cross-border auction (lowest under unilateral cross-border auctions, which are the simplest) and economies of scale (highest under multilateral auctions).

Von Blücher *et al.* (2019) also find that the support scheme design must be the same for all participants of a cross-border RES auction to allow for comparison of bids and thus effective bid selection. However, the conditions under which project developers can realise RES projects differ between countries due to the national specific regulatory and market conditions. These aspects cannot easily be aligned in the context of a cross-border auction, as they reflect a broader regulatory and political context. The authors propose three key options to level regulatory differences: 1) Adjusting bids by the cost impact of the regulatory framework; 2) Implementing quotas to limit the distributional effects of these differences, and; 3) Aligning the regulatory framework. They recommend refraining from levelling differences artificially in order to tap into the full efficiency potential of the auction. However, if differences need to be addressed, they recommend to consider quotas as they are the most straightforward solution to the challenge (*i.e.*, option number 2 above).

Table 1

Basic models of cross-border auctions

Models	Explanation
Unilateral auction	Both countries conduct auctions but only one country opens its support scheme to foreign projects
Mutual opening	Both countries open their auction schemes, either sequentially or in parallel
Joint auction	Two countries implement a common auction scheme, open to projects from both countries

Sources: von Blücher *et al.* (2019), Ehrhart *et al.* (2019).

The authors propose 8 good practices of cross-border auction design[6] and highlight and discuss other challenges in cross-border auctions[7].

A more formal (theoretical) analysis of the (support costs and allocative) efficiency of different types of cross-border auctions is performed in Ehrhart *et al.* (2019), which refer to different intensities of cooperation as in von Blücher *et al.* (2019). In addition to Separate auctions, the aforementioned three types of cross-border auctions are considered: Unilateral Auctions, Mutual Auctions and Joint Auctions. The authors perform auction-theoretic modelling. They conclude that Joint Auctions can achieve both allocative efficiency and moderate award prices (support cost efficiency). However, a complex implementation process and necessary bi-lateral coordination might make this option difficult to realise. Implementing this type of auction is quite complicated due to a high degree of cross border integration and regulatory coordination (Ehrhart *et al.,* 2019, p. 30). Sequential Mutual Auctions, *i.e.*, when the open auctions are conducted one after another and with enough time in between the auctions and not within a very short time frame, lead to similar outcomes, but with less administrative effort, since both participating countries can choose their own auction design. The remaining design choices all show a low probability of allocative efficiency and might lead to higher awarded prices. More generally, the analysis shows that parallel auctions (where project developers must choose in which auction they want to participate and cannot participate in both) tend to decrease the efficiency of a support scheme. Based on their theoretical analysis, the authors recommend Sequential Mutual Auctions when designing cross-border auctions since they combine "the benefits of relatively straightforward implementation with the allocative efficiency of a Joint Auction" (Ehrhart *et al.*, 2019, p. 35).

6 These good practices include: 1. Bids need to be comparable. 2. Adapt design to cross-border context. 3. Check cross-border applicability of all design elements. 4. Keep it simple. 5. Take care to not exacerbate differing conditions of participation for bidders. 6. Ensure RES deployment while limiting transaction costs. 7. Give sufficient consultation and bid preparation time. 8. Reduce the administrative complexity.

7 These other challenges include: the interactions of cross-border with national auctions (recommending that the auction schedules should be synchronised with a view to provide a continuous pipeline and avoid boom and bust cycles in the RES industry), the design of a suitable premium, the allocation of the costs and benefits, the practical implementation of cross-border auctions and the disbursement of funding and data transfer.

In turn, von Blücher *et al.* (2020) show the basic functioning of one pooled cooperation mechanism which is effectively a cross-border auction, the EU RES financing mechanism (ERFM). This is an instrument to support and ensure the cost-effective target achievement at the EU level, as provided in Article 33 of the Governance Regulation. Under the ERFM, Member States may choose to make voluntary financial contributions to the mechanism (contributing Member States). The mechanism subsequently implements a RES auction which determines support levels and allocates grants to RES projects in hosting Member States, which also choose to participate voluntarily. The hosting Member States transfer the RES target statistics from these RES installations back to the mechanism, which then redistributes the RES statistics to the contributing Member States according to their share of financial contributions.

The report shows that the ERFM provides an effective tool to aggregate RES cooperation among Member States, thereby increasing the cost-effectiveness of RES support. The ERFM can be tailored to Member State preferences, as they define whether they want to participate and under which conditions. Some recommendations are provided: retaining parts of the RES statistics for hosting Member States (*e.g.* 80/20) in order to increase their acceptance, providing support in the form of upfront investment aid and adopting multi-item, static, pay-as-bid auctions in which the auctioned good is capacity, with required financial pre-qualification / bid bonds and sufficient realization periods to cover country differences in project development lead times.

Bartek-Lesi *et al.* (2020) give an overview of the most important factors influencing the set-up of a cross-border auction between Hungary and possible partner countries using the Green-X model to assess the likely impacts. The results show that Hungary would be the host country in cooperation with Austria and the contributing country with Romania, while cooperation with Slovakia would lead to only small changes in RES-E deployment. Slovakia was chosen as the hypothetical partner country for this case study. The case study compared the tender design of the two countries to provide recommendations on how to harmonize to a cross-border relationship regarding the size of plants eligible for support, the prequalification requirements used in the opened auction, the dilemma on the type of feed-in premium (FIP) to be used and on setting the market reference

price for the winners in the host country, the setting of the length of the project realization periods and the setting of penalties. The Green-X modelling results suggested that the cooperation with Romania could bring the highest benefits for Hungary which can be evenly distributed to make the relationship mutually beneficial. However, it is not yet clear when and how Romania will shift to an auction scheme. Another option for Hungary is to consider participation in the EU's renewable energy financing mechanism.

Kerres *et al.* (2020) examine how the Contracting Parties (CPs) of the Energy Community can participate and benefit from cross-border renewable energy cooperation. It focuses on cross-border auctions and joint projects as the key instruments for the CPs to cooperate with each other and with EU Member States. The policy brief reviews the benefits, rationales and necessary considerations for cross-border cooperation, i.e. both from the perspective of the hosting and the contributing party. The report introduced each instrument and pointed out the associated benefits and risks. The policy brief concludes that cross-border cooperation with and amongst the CPs is possible. The regulatory framework includes various instruments, each characterized by certain benefits and risks. The authors argue that, subject to the design of the legal framework, a variety of instruments for cooperation between EU Member States and the CPs could be available, assigned to two tracks of cooperation: Cooperation via joint projects (possibly supported by funding from the Connecting Europe Facility) and national cross-border auctions and cross-border auctions via the EU financing mechanism. Cross-border auctions were examined in detail. In this context, a key issue meriting further attention is the CPs' varying stages of liquid day-ahead wholesale market development and implementation of market-based support schemes. This report suggests two main (transitional) solutions until all CPs have implemented liquid day-ahead wholesale markets on which to base premium calculation: the use of fixed premiums or the use of sliding premiums with proxy reference market prices. Different regulatory frameworks require adaptation of support scheme design: 1) if the hosting party has a wholesale market, then any support scheme design is feasible; 2) if the hosting party does not have a wholesale market yet, intermediary solutions are necessary until all Contracting Parties have wholesale markets.

6. WP7 THE FUTURE OF AUCTIONS

The framework conditions for renewables support continue to evolve. Thus, WP7 covers the implications of combining several RES technologies in one auction applying theoretical and empirical approaches, and more specifically, contributing to the discussion on technology-specific versus technology-neutral support. In addition, both the generation costs of renewables as well as the market environment in which they operate are likely to change until 2030. Thus, the WP furthermore explores the future role and design of auctions under changing electricity systems.

In a forthcoming paper, Hanke (forthcoming) conducted several rounds of experiments to examine whether it is advisable to conduct auctions with more than one technology. She shows that it is indeed favourable for an auctioneer (concerning prices as well as efficiency considerations) to include different technologies in one joint auction instead of conducting different auctions for different technologies. Nevertheless, it should be kept in mind that technologies should be able to compete at least on a basic level and that possible side effects, such as the elimination of one technology from the market, might occur. Further, the recommendation is to conduct pay-as-bid auctions, as these tend to generate lower prices combined with a lower risk of bankruptcy for bidders estimating their costs too low while still generating a comparable level of efficiency as uniform pricing.

In their report, Woodman and Fitch-Roy (2020) have developed four qualitative scenarios on the future energy systems and have examined the role auctions will play in those. The scenarios, which are characterised by the level of flexibility and decentralisation of the energy system, show that the status quo model of RES auctions is unlikely to be the dominant route to market by 2030. The only scenario where we would observe this, if all progress in transforming and pluralising the energy systems stalled (similar to the proposed "Leviathan" scenario[8]). Nevertheless, the authors do not argue that RES auctions will disappear entirely. Private, municipal, or community tenders for PPAs, are likely to grow

8 The Leviathan scenario is characterised by low flexibility and low decentralisation of the energy system.

in importance, requiring new and innovative auction designs that minimise transactions costs. The lessons learnt through Europe's roll-out of national scale support auctions may be valuable here. Finally, given both the urgency of the challenge of tackling climate change and the challenges of coordinating RES build-out with supply chain development and grid expansion, a regulatory role of some kind exists in all scenarios. Whether it is standardising auctions models and contracts or directing geographical density, public policy will continue to play a role in the buying and selling of renewable electricity for the near future.

Furthermore, two more reports are currently being drafted in this WP. The first one will provide an overview of the use of multi-technology auctions in the EU. It will cover descriptive statistics of their outcomes and compare the results to their technology-specific counterparts. Furthermore, the report will include several short case studies on multi-technology auctions.

The second report will give guidance to policymakers on how to design auctions in the changing energy systems of the future. Based on the identified scenarios in Woodman and Fitch-Roy (2020), the authors will derive explicit policy recommendation on possible auction design considerations.

7. WP8 MODELLING

WP8 aims to facilitate the topical analyses undertaken in other WPs with in-depth model-based quantitative assessments. These modelling activities provide further insights into interactions between the various WPs. Additionally, modelling plays an important role in the case cooperations with the member states in WP2.

In their policy brief, Resch, Geipel and Liebmann (forthcoming) analyse and model the need for and impact of RES cooperation across the EU in the 2030 context, practically done by establishing European and/or Cross-Border RES auctions. The findings are based on insights gained from the forward-looking model-based analyses where different scenarios for meeting (and exceeding) the EU's overall 2030 RES target have been derived. The 2030 RES ambition has been modelled both in accordance with past agreements taken (*i.e.* National Energy and Climate Plan (NECP) ambition to achieve an EU RES share of at least

32 %) and under consideration of the needs arising from the European Green Deal. The first finding is that, in order to achieve the NECP ambition of at least 32 % by 2030, only a limited number of MSs requires RES cooperation to meet their 2030 planned RES deployment. Summing up, the nationally planned RES shares for 2030 lead to an EU RES share of approx. 33.6 %, although strong differences in the RES ambition of individual MS can be observed. Modelling shows that, without RES cooperation, only an EU RES share of 33.0 % appears feasible, since some MSs would fail to achieve their planned RES share using only domestic resources. Allowing for RES cooperation would, in turn, assure that the planned deployment (33.6 %) can be reached across the whole EU. On the other hand, a strong increase of the RES ambition at short notice (by 2030), *e.g.* through the Green Deal, causes a strong demand for RES cooperation across the whole EU. Assuming an increase of the 2030 EU RES target to (at least) 40 %, the modelling activities revealed that without RES cooperation only an EU RES share of 37.8 % appears feasible – whereas with RES cooperation the planned deployment (40 %) can be reached. Thus, the conclusion can be drawn that, under these new framework conditions, EU-wide RES cooperation appears essential for achieving a stronger RES uptake at short notice (*i.e.* by 2030).

Apart from the above-identified needs for RES cooperation, there are several benefits of RES cooperation: Firstly, RES cooperation facilitates a levelling of country-specific risk for RES investors. Secondly, a (more) fair effort sharing can then be triggered by RES cooperation and, thirdly, it can be expected that this decreases the overall cost for reaching ambitious future RES targets, which was confirmed by the modelling. More specifically, cross-border RES action can reduce support expenditures for new RES installations (*i.e.* installed post-2020) by 23 % to 38 % percentage points compared to the default case where no such cooperation was presumed. Furthermore, the authors found out that targeted policies offering technology-specific incentives tailored to individual needs, done *e.g.* by use of dedicated RES auctions for feed-in premiums, appear highly beneficial for triggering a cost-effective uptake of RES in the electricity sector. Cost savings in the range of 28 % to 42 % have been identified when comparing average support under targeted RES policy approaches (*e.g.* RES auctions) with umbrella policy approaches (*e.g.* technology-neutral RES quotas with certificate trading).

Diallo and Kitzing (2020) examined technology bias between renewable power plants in technology-neutral auctions, caused by applying the same auction rules for the technologies that have very different characteristics. Four RES technologies (PV, onshore wind, offshore wind, and biomass) were evaluated using a quantitative model, which was used to determine LCOEs, bid prices, and social values of the technologies. Concerning the different design elements, the authors were able to formulate rather general and rule of thumb type of policy recommendations. The main reason behind this is that the bias is sensitive to the initial setup in terms of design elements[9]. Therefore, a case-by-case analysis is required to determine the effect of a design element change on the bias. The outcomes show that, while a change of the support period or the introduction of grid integration costs and environmental harm compensation may heavily influence average bias between technologies, the effects are more moderate when changes in granted realisation period or in balancing payment responsibility are applied, and almost negligible if changes in the timing of the auction within a year occur. Remuneration scheme design is a very important determinant as well, but there is no clear hierarchy identifiable which compares two-sided sliding premiums and fixed premiums. Both schemes are though clearly leading to a lower risk of technology bias than one-sided sliding premiums, as in several setups where a technology is mature enough to survive without support, one-sided premiums may result in very high biases. An additional very important conclusion of the report is that allocative and general efficiency do not necessarily occur simultaneously. This is due to the fact that by comparing two designs, it is often the case that a given setup results in allocative efficiency, but in terms of general efficiency it fares worse than another allocative inefficient auction setup.

Furthermore, three more reports are forthcoming in this WP. The first one examines by when a possible phase-out of RES support appears feasible for RES electricity in general and at technology level. The second one will conduct a model-based assessment of economic aspects of RES auctions illustrating the impact of improved financing conditions on the support needed to finance

9 This can result in the fact that the same change in the design (for example increasing support period from 15 years to 20), may increase the average bias in one setup and decrease it in another.

the required RES uptake. Finally, the last forthcoming report will provide all technical details of the modelling activities carried out in the AURES II project.

8. CONCLUSION

The first AURES project laid the groundwork for auctions in the renewable electricity sector (see Mora *et al.,* 2017). AURES II expands this knowledge by analysing the effects of auctions on the RES sector, technological innovation and project financing, and by examining the topics of multi-technology and cross-border auctions, changing electricity systems, as well as community projects in detail. It also builds a detailed database of auctions in the EU.

Although the work in WP7 has already shed some light, we believe the next step will be to analyse how renewable energy auctions will evolve in the future: will we see greater collaboration between member states? Or even EU-wide RES auctions? Will auctions expand to other energy-related fields besides the electricity sector: allocating support for hydrogen production, (district) heating networks, or in the transport sector? Will they be increasingly used by the private sector: big multi-national companies using auctions to procure corporate (green) PPAs in an efficient and effective manner? Or even smaller energy communities that aim to procure green electricity?

Whichever form auctions will take, we believe they will still play a crucial role in a future, sustainable energy system.

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