Design and results of recent renewable energy auctions in Europe*

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Abstract

The Horizon2020 project AURES II aims at contributing to the effective implementation of auctions for Renewable Energy Resources with research-based insights and policy recommendations. The paper focuses on the main design elements applied in the recent renewable auctions and their impact on the effectiveness and efficiency of renewable support allocation. Drawing on 10 European case studies, the analysis investigates whether there is a convergence in the auction design across countries, whether a general cost reduction trend can be observed, and looks at how successful previous auctions were in delivering contracted capacities. It also assesses the new trends and developments, and presents some emerging, innovative forms of auctions targeting carbon emission mitigation.

Key words: renewable energy, renewable energy auctions, auction design, policy assessment.

1. INTRODUCTION

The Horizon2020 project AURES II aims at ensuring the effective implementation of auctions. Its second Work Package (WP2) collects and analyses information on the recently realised and planned auctions in Europe and globally. The Work Package assessed 10 recently finalised RES auctions (six EU countries and four outside) and also assessed four planned auctions (three in the EU and one outside). WP2 also assessed technology focused case studies on off-shore wind development in Denmark and the concentrated solar plant (CSP) technology auctions in various countries. This paper summarises the findings of the AURES II case studies and the Synthesis report which gave a detailed overview

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of the results and conclusions drawn (Szabó *et al.*, 2021). We focus on the main design elements applied in the recent renewable auctions and the impacts on the effectiveness and efficiency of these auctions. Due to size limitations this paper covers the European auctions, although the AURES II project itself covered non-European auctions as well.

The paper is structured as follows. Section 1 characterises the European auctions and the most important design elements. In Section 2 we take a closer look at the main design elements facilitating project realisation of winning bids, as an important element of the auctions. Section 3 provides an economic assessment of the European renewable auctions from a static and a dynamic efficiency point of view. It also assesses the policy effectiveness of the renewable auctions and explores how auctions try to increase actor diversity. Section 4 concludes.

2. CHARACTERIZATION OF THE AUCTIONS AND THE MOST IMPORTANT DESIGN ELEMENTS

Even though until 2020 many European countries introduced auction-based support schemes, these tenders differ in many aspects of their design. There are limited number of consensual best solutions in the auctions, most of the countries are still in experimenting phase and change their auction setup regularly to improve effectiveness and efficiency. In this section several important features of renewable auctions will be defined and assessed. The main aim of this section is to highlight the main characteristics and make a comparison of the existing auction designs in Europe.

One of the most important features of the renewable auctions is their coverage, *e.g.* which technologies are allowed to participate. There are two main types of auctions: technology specific and multi-technology ones, the latter are also called technology neutral. In technology specific auctions only the same type of technologies compete, while in a multi-technology setup different technologies enter in the auction, such as a PV power plant versus a wind farm. Multi-technology auctions have different forms, with and without restrictions on the participation of technologies.

Another important aspect is the subject of the auction. The auctioned product can be power plant capacity (in MW) or produced electrical energy (MWh). Independently from the fact whether capacity or energy is auctioned, auctions can efficiently reduce support needs only if there is scarcity with respect to the winners (winning capacity or production) of the tender. Therefore, in all auctions a cap is included which creates scarcity and competition. There are two main types of auctions: the ones with volume and the others with budget cap. For auctions with volume cap either the total available generation capacity (MW) or the total required electrical energy (MWh) is limited. If a budget cap is applied, then in general the total support payment expected to be paid by the auctioneer (in monetary terms) is capped. It is also possible to use the two types of constraints in the same auction simultaneously.

The form of support can also greatly differ in auctions. There are three main types of support payments: the one-sided sliding feed-in premium, two-sided sliding feed-in premium (often called Contract for Difference, CfD) and fixed premium. In a sliding premium scheme, producers sell their product on the market and receive a support equivalent to the difference of the market price and the strike price of the auction. In the one-sided case if the market price is higher than the strike price of the auction, then the producer can keep the extra revenue, while in the two-sided case there is a pay-back obligation toward the auctioneer. In the fixed premium schemes, the producers also sell their electricity on the market and receive a fixed bonus on top of the market price for each sold MWh of energy independently of the price level. The pricing method may differ as well, where the two main types are pay-as-bid and uniform pricing auctions. In the pay-as-bid schemes all winning projects receive support based on their own individual bids, while if uniform pricing is applied, all winning projects receive the same strike price, usually the highest winning bid. The bid of the individual power plant can be determined in one round (static auctions) or in several subsequent rounds (dynamic tender).

An additional very important aspect of renewable auctions is whether producers compete for one (or more) specific predefined connections points, as the tender setup only allows connections to these predefined locations, or if it is possible to freely connect to the power system at any available connection point within the county. The former design is often referred as single unit or single item auction while the latter refers to multi-unit or multi-item auctions.

As a final point of comparison, auctions can differ greatly with respect to the time period, during which the wining projects receive support. The support period is often differentiated between technologies as well. Some setups aim to provide support until the end of the lifetime of the power plants, while others aim for significantly shorter periods.

Table 1 compares several European auction designs with respect to the above listed general criteria. The comparison is based on the results of the Synthesis Report of European renewable case studies of the AURES II project (Szabó *et al.* 2021). The investigated countries are Denmark, Germany, Greece, Hungary, the Netherlands, Poland, Portugal and the United Kingdom.

Table 1

Comparison of several European auction designs

	Denmark	Germany	Greece	Hungary	Netherlands	Poland	Portugal	United Kingdom
Technology focus	Offshore wind, nearshore wind, solar PV	Onshore wind, offshore wind, solar PV, biomass, technology-neutral innovation auction	Onshore wind and PV	All RES-E (wind ruled out by regulation)	ALL RES-E and RES-H, biogas Offshore wind has its own auction scheme	All RES-E	Solar PV	All RES Various technology baskets
Technology differentia-tion	Technology specific (offshore wind, solar) Multi-technology	Technology specific and multi-technology tenders in parallel	Technology specific, which was changed to multi-technology	Multi-technology (wind ruled out by regulation)	Multi-technology	Multi-technology with technology baskets	Technology specific	Multi technology, with baskets (mature technology, less mature technology, biomass)
Auction product	Capacity (MW): offshore wind Energy (MWh): PV and multi technology	Capacity (MW)	Capacity (MW)	Energy (MWh)	Energy (MWh)	Energy (MWh)	Capacity (MW)	Energy (GWh)

Table 1 (continued)

Comparison of several European auction designs

	Denmark	Germany	Greece	Hungary	Netherlands	Poland	Portugal	United Kingdom
Volume or budget cap	Volume cap: offshore wind Budget cap: PV and tech-neutral	Volume	Volume	Volume and budget cap	Budget cap	Volume and budget cap	Volume cap	Yearly budget cap (with separate capacity limit on biomass)
Form of support auctioned	For offshore wind two-sided sliding FIP, otherwise fixed FIP	Sliding FIP	Two-sided sliding FIP	Two-sided sliding FIP	Sliding FIP	Two-sided sliding FIP	Special support scheme, possible to choose between FIT or fixed contribution to the system	Two-sided sliding FIP
Pricing rule	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Uniform
Static vs dynamic	Static	Static	Dynamic	Static	Static	Static	Dynamic	Static
Single vs multi-unit	Single unit (offshore wind) multi-unit (all other)	Multi-unit	Multi-unit	Multi-unit	Single unit (offshore wind) multi-unit (all other)	Multi-unit	Single unit	Multi-unit
Support duration	For offshore wind it is based on supported energy (approximately 12-15 years), otherwise 20 years	20 years	20 years	15 years	Depends on technology, 8 (boilers), 12 (biogas) or 15 (solar, onshore wind) years	15 years but not beyond 2035	15 years	15 years

Source: Based on the findings of Szabó *et al.* (2021).

Several different types of auction were organized in Denmark until 2018, including offshore and nearshore tenders as well. On top of that in 2018 a technology specific PV tender, and a pilot multi-technology auction featuring onshore wind and PV were also organized. Similarly to Denmark, several parallel auction schemes operate in Germany. There were technology-specific tenders held for solar PV, onshore wind and biomass, but also multi-technology tenders for PV and onshore wind were organized. Since 2020, Germany organizes innovation auctions, which are multi-technology tenders in which projects with installed storage capacity can also participate. Until 2019 technology specific tenders were held in Greece, but in 2019 a pilot multi-technology setup for solar and onshore wind were introduced (Anatolitis, 2020). Hungary organized its first renewable auction in 2019 (Bartek-Lesi *et al.,* 2020). The tender is in theory a multi-technology auction, where all technologies can participate, however, because of the strict location regulations for onshore wind power plants in the country, wind farms are not able to enter. As a result, almost all participant of the tender were solar PV power plants.

The Netherlands operates a special multi-technology auction scheme since 2011 (Jacob *et al.,* 2019). The specialty lies in the fact that in the Dutch scheme not only electricity, but heat producers can participate, which is uncommon in the EU but presents a possible future evolution path for renewable tenders. In Poland, yearly auctions are held since 2016. In these tenders all renewable technologies can enter, however, based on technology, several different auction baskets were made, and power plants participating within the same basket can compete against each other. In Poland, onshore wind and PV participated in a common basket, and there were separate baskets for agricultural biogas, biomass power plants and for other renewable technologies. Portugal held its first PV auction in 2019, which was a technology specific tender aiming at large scale power plant (del Río *et al*., 2019b) The final country of the comparison is the United Kingdom, where multi technology auctions were organized in a similar manner as in Poland, with different technology baskets defined.

It is visible that most of the countries are shifting toward a multi-technology design. The reason behind this trend lies in the European regulation, as it requires technology neutrality from the Member States when designing new renewable support schemes. Therefore, countries with technology specific designs face a regulatory pressure to change their setups.

By comparing the auctioned products of the different countries, it is evident that there is no clear trend in Europe, since both capacity or energy are auctioned. In

Denmark for example, differences are present within the country, as for offshore wind the auctioned product was power plant capacity, while it was produced electricity in the solar and the pilot multi-technology tender. Approximately half of the investigated countries operate auctions where the product of the tender is capacity such as Denmark (offshore wind), Germany, Greece and Portugal, while in the other Member States, energy-based auctions are present.

Similarly, a diverse picture emerges by investigating capacity or budget constrains in the assessed countries. A single volume cap was used in the Danish offshore wind auctions, in the German, Greece and Portuguese tenders and in the biomass auction of the United Kingdom. Two countries, however, opted for single financial cap. In the Danish (non-offshore) auctions the maximum amount of support was set, while a slightly different version was used in the United Kingdom, where a yearly total budget cap was determined. Interestingly in two countries (Poland, and Hungary) a simultaneous volume and capacity cap were introduced. The advantage of this tender design is that neither the per unit support cost, nor the supported amount of capacity/energy can surpass the expectations of the auctioneer.

In contrast to the previously investigated design elements, there is a larger consensus in the form of support between the analyzed European countries. In most schemes, support was paid in a form of sliding premium, predominantly in the two-sided form. One important tendency, however, is that fixed premium systems become more and more popular in European auctions. The fixed premium scheme is more market oriented than the sliding premium as it follows the evolution of wholesale market price and does not provide fixed revenues for the power plants. Therefore, a fixed premium scheme was introduced for the non-offshore Danish tenders and in the innovation auction in Germany. Portugal introduced a very special support scheme where producers were able to choose between a two-sided sliding premium scheme or a fixed contribution payment to the system. In Portugal prices were significantly below wholesale prices, therefore unlike in many European auctions, producers did not compete for support, but for the possibility to complete their project, even though they are required to pay to the system, based on their production level.

The similarity of the auction designs is even stronger when considering the pricing rule, the dynamic and static nature of the bidding, or location specific issues of the investigated setups. Almost all countries organized pay-as-bid and static, multi-item auctions, which seem to be also the most common setup in Europe. Exceptions are the United Kingdom, which operates a pay-as-clear (uniform pricing) mechanism. A similar design was tested in Germany, but the country has changed to a pay-as-bid setup. Dynamic auctions were used in Portugal and Greece, where producers had the opportunity to submit multiple bids in different rounds. The dynamic nature of the auctions is difficult to evaluate, as usually there is not enough available information on the separate rounds, given that the auctioneer generally publishes only the final results. With respect to location, single item auctions were used by the Danish offshore and nearshore tenders, because connection to the grid is generally more expensive. On top of the offshore auctions, only the Portuguese tender was designed with fixed connection points, as producers were only allowed to compete for 24 predefined grid connection points.

The final assessed design element is the length of the support period. Different technologies usually have varying support length, and large differences are observable with respect to the same technologies between countries. The shortest support period was 8 years for boilers in the Netherlands, while the longest were the 20 years long support periods of the Greek, German and Danish tenders.

We can conclude that, with respect to design elements, the investigated European auctions are homogenous in several aspects, but heterogenous with respect to many other design elements. Most of the organized auctions were pay-as-bid, multi-item, and static tenders. However, no clear design convergence is observable in other dimensions. It seems that, as the result of the European regulation concerning the competition rules of renewable support, auctions tend to move from technology-specific setups to multi-technology designs. Additionally, as fixed premium seems to be more market oriented, mature auctions also tend to shift toward this support type. There are several other aspects, however, which remain completely heterogeneous, such as the auctioned product, the type of cap used in tenders, or the length of support period.

3. DESIGN ELEMENTS FACILITATING PROJECT REALISATION

In order to increase the probability of project realization and timely project implementation among the winning projects of renewable energy auctions, prequalification requirements and penalties are applied. As auction rounds are limited by their volume or budget, selection of bidders by material and financial prequalification criteria together with the applied penalties can help to reduce the risks of underbidding, delay and non-realisation.

Material prequalification requirements relate to the characteristics and status of the project and to the technical and financial capabilities of the project developer. As the table below shows, seven countries require titles for land use, while six countries claim secured grid connection. These conditions aim to ensure the appropriate conditions of grid connection, all necessary permits and licenses and the consent of all stakeholders. Selection of bidders by financial criteria is applied in Denmark and the Netherlands. The Netherlands is the first country in Europe asking for a feasibility study to improve the inadequate realisation rate of awarded projects.

Financial prequalification of the projects can be based on two kind of guarantees: bid bonds and realisation bonds (also called second bid bond, completion bond or performance bond). Bid bonds are placed before the whole auction procedure starts in order to ensure that the developer is committed to realize the project. Those bidders who do not win support get back their guarantees as the official results are published. If a winner refuses to enter into a support contract, the auctioneer retains the bid bond. Realization bonds are required in case of two-stage guarantee systems, where the winners pay this second bond, serving as a guarantee for a potential penalty in case of non-realization. All countries covered apply two-stage financial guarantees (sometimes a one-stage bid bond serves the role of both guarantees, such as the Danish and German onshore wind and biomass auctions and Dutch off-shore wind auctions, and in Poland) with the exception of the UK and the SDE+ scheme of the Netherlands. A softer incentive to pre-select committed bidders is a non-refundable participation fee, which is required in most countries.

The likelihood of implementation is also higher if a project is in a more advanced phase, therefore many countries require an environmental permit, building permit or production license. Some countries, like Germany and Greece demand relatively strict material and financial criteria at the same time. In other cases, material requirements can supplement to some extent financial guarantees, like in Poland, where bidders must hold building and environmental permits as well as grid connection agreements, but bonds are relatively lower than in other countries. Setting strict requirements and high penalties might lead to higher realisation rates, but at the same time results in higher risks for project developers. The prospect of high sunk costs, losing deposited securities or realising a lower than expected remuneration deter developers from entering the auction, which can lead to too strong preselection and, consequently, insufficient competition. However, there are examples when high rates of project realization are reached with less stringent prequalification criteria. This was the case in the German technology-specific PV auctions between 2015 and 2017, where above 90 % realisation rates were achieved. At the same time, onshore wind auctions were undersubscribed, as obtaining environmental permits had become difficult due to the resistance of the local population. For onshore wind project, less stringent material prequalification might increase the number of bidders, but the realisation rate could remain low. In this case, other policy instruments can provide a solution, as recommended by Sach, Lotz and Blücher (2019).

77 % of awarded capacities were built within the prescribed realization period in the 2016 smaller sized Polish PV/onshore wind auctions (up to 1 MW), where delayed projects were likely underbid due to the fierce competition (Diallo *et al.,* 2019). UK and the Netherlands do not apply financial guarantees but use stringent material prequalification requirements and high penalties. When requirements are easier to meet and the competition is weak, this setup is more likely to lead to low rates of implementation. In the UK, 15 out of 29 projects awarded in the AR1 auction missed their deadlines and 5 of them were not implemented. It shows that delays of project realisation cannot be perfectly influenced by prequalification requirements. In the case of several wind farms, the delay was caused by the opposition to the environmental impacts of the facilities, in some cases the contracts were terminated due to underbidding or for other unknown reasons (Woodman and Fitch-Roy, 2019).

Table 2

Material and financial pre-qualification requirements and prescribed realization period

	Pre- qualification requirements: material	Pre-qualification requirements: financial	Realization period
Denmark	No debt exceeding 100 000 DKK (EUR 13.4 million) In case of off-shore wind: former experience, minimum annual turnover, equity ratio of min. 20 % or investment grade credit rating are also required	Tech. neutral and PV auctions: retention penalty (completion bond) EUR 22.8/MWh (onshore wind: 75.1 EUR/kW; PV: 25.5 EUR/kW; off-shore wind: 98.3EUR/kW) Off-shore wind auctions: EUR 13.4 million; Nearshore: 79EUR/kW; 22.4 EUR/kW in case of Kriegers Flak	Off-shore: 48 months, onshore wind and PV: 24 months
Germany	Onshore wind and biomass: installations are eligible if they have obtained environmental permits PV: Proof of access to the site, adopted land use plan and eligibility of site for ground-mounted plants	Onshore wind: Bid bond (also completion bond) of EUR 30/kW PV: Bid bond- EUR 5/kW, completion bond - EUR 40/kW (EUR 20 in case of adopted land-use plan) Off-shore wind: Bid bond/completion bond – EUR 100/kW. Biomass: Bid bond/ completion bond of EUR 60/kW	Onshore wind: 24 months, PV, biomass: 18 months, Off-shore wind: 18 months after grid connection
Greece	Generation licence Grid connection agreement/offer	Bid bond - 1% of investment costs ~ EUR 10/kW in case of PV and 12.5 EUR/kW for onshore wind Completion bond - 4% of investment costs: ~ 30 EUR/kW for PV and 37.5 EUR/kW for onshore wind	PV: 12-18 months, Onshore wind: 24-36 months (depending on size)
Hungary	Basic information on the company and the plant Grid connection agreement	Bid bond: 1.5% of investment cost. (~11 EUR/kW) Completion bond: 5% (~36 EUR/kW - for PV)	36 months
Netherlands	Environmental and mining permit, feasibility study, geological survey, energy yield calculations, permission of the owner of land Financing plan and technical details are also required for off-shore wind	Bid bond only required for projects claiming more than EUR 400 million (not yet applied) Off-shore wind auction: bank guarantee required if bid is successful (~50 EUR/kW)	1.5 - 4 years depending on technology, 5 years for off-shore wind

Table 2 (continued)

Material and financial pre-qualification requirements and prescribed realization period

	Pre- qualification requirements: material	Pre-qualification requirements: financial	Realization period
Poland	Building permit, environmental permit, grid connection agreement, land use plan, schedule of works and expenditures, schematic drawing of the installation	One stage bid bond: 30 PLN (~EUR 7) /kW for existing and 60 PLN (~EUR 14) /kW for new plants returned for non-winners after bidding, and to winners after entering into operation	18 months for PV, 30 months for onshore wind, 72 months for offshore wind
Portugal	Information on the company and owners. For awarded bidders: land rights, production licence	Bid bond: EUR 10/kW, performance bond: EUR 60/kW	30-36 months
United Kingdom	Grid connection agreement, Planning permission, Supply chain approval (>300 MW)	No bid bond /realisation bond	~4-5 years, contracts are awarded for delivery time

Project realization is also affected by the prescribed maximum length of the realisation period. If it is too short, it makes more difficult for investors to realize their projects in time, as there is a higher risk of losing their financial guarantees and right to support. Long realisation periods can lead to many uncertainties influencing the investors, like the relative change on returns compared to other investment opportunities and market conditions can also change significantly. If investors expect significant cost reductions, this incentivises underbidding and can lead to non-realisation.

Deadlines can be general or vary by technology (*e.g.* in Germany, Greece, Poland, Netherlands). When deadlines reflect the specificities of a certain technology, they provide a level playing field, especially in case of multi-technology auctions. The shortest completion time-period among the analysed countries was 12 months for smaller sized plants in Greece and 18 months for larger capacities in Greece, Germany and Poland. Shorter realization periods are often associated with other criteria to incentivize more advanced projects to enter the auction.

Delayed completion can be penalised by the reduction of awarded support or by a shortened support period, which can be accompanied by the gradual loss of the completion bond. After a predetermined grace period, the award right is lost and completion bonds are confiscated, either in a staggered way (e.g. Denmark, Germany, Portugal) or in one sum (*e.g.* in Greece, Hungary, Poland). Each country sets different penalty levels, and in some cases developers do not lose the opportunity to finish the project even after a significant delay. In case of the highly competitive German onshore auctions of 2017, some project developers being awarded lower support levels have abandoned their projects despite the penalties to re-enter more recent auctions with lower competition and likely higher support (Sach, Lotz and Blücher, 2019).

Table 3

Penalties applied in the analysed European cases

Denmark	Technology neutral and PV auction: Retention penalty has to be paid related to non-connected capacity Off-shore: if less than 95% of capacity is connected to the grid, eligible production decreases by 0.1 TWh (near shore)/0.3 TWh (Kriegers Flak) for each subsequent 6-month period.
Germany	Onshore wind: From month 24: gradual loss of completion bond, award withdrawn after 30 months PV: From month 18 award decreases by EUR 3/MWh, after 24 months the penalty is EUR 50/kW Biomass: from month 18 gradual confiscation of completion bond, after 24 months award withdrawn Off-shore wind: Non-delivery at the milestones leads to withdrawal of award and losing the financial guarantee
Greece	In case of late or non-realisation: 1) cancelled support agreement, 2) withholding of bid and completion bonds, 3) possible cancellation of generation license and/or grid access agreement/offer
Hungary	Performance bond is lost in case of delay. If the project is not completed within 1 year after deadline, right for support is lost and investors cannot participate in renewable auctions for 3 years
Netherlands	Loss of bank guarantee (if it was required). Otherwise, project loses support right and is excluded from the scheme for 3 years
Poland	Cancellation of support if the deadline is missed, 3 years ban for participating in another auction, loss of bid bond is a possible fine for the manager of the energy company
Portugal	Missing realization milestones results in losing different portions of the bid bond
United Kingdom	Contract terminated if project fails to spend 10% of costs in 12 months, or operation delays 12-24 months after deadline. Exclusion from future auctions for 24 months

4. ECONOMIC ASSESSMENT OF THE EUROPEAN RENEWABLE AUCTIONS

Renewable auctions were assessed in various dimensions in the AURES II project, including the economic dimensions of effectiveness and efficiency of the auctions. In this section four dimensions, the policy effectiveness, static efficiency, actor diversity and dynamic efficiency are analysed.

4.1. Policy effectiveness

Under policy effectiveness we mean if the targeted RES capacity is actually contracted and realised in the auctions. The AURES II project measured the effectiveness in two dimensions. First, we analysed if the specific auction managed to cover the full targeted volume, or if it failed to achieve so. There could be various reasons for target under-achievement. The specific design of the auction could have reduced the attractiveness of the auction if developers judged it too complex or with high transaction costs, or the expected income from the future power generation was not sufficient to cover the risk adjusted costs of the investments. Other power market related factors could also contribute to this failure, *e.g.* the expected wholesale price trend or the present market distortions or uncertainty in the intraday or balancing markets would prevent investors to participate. As a second dimension of the policy effectiveness, we have assessed if the winning projects of the auctions are realised within the planned period.

Looking at the period of 2015-2020, the European renewable auctions present a mixed picture in the first dimension, as the table 4 illustrates.

Denmark and Germany are on the top of this list, as many of their auctions managed to reach 100 % coverage, meaning that the targeted volumes were contracted in the auctions. In Denmark, both analysed auctions were realised with success, based on the data on the offshore wind auctions. The exception is the Rødsand2 tender, where the original winner withdrew from the project and the site was retendered. There was also an issue with the Nearshore Areas wind tender, where Vattenfall asked for a three-year extension for the project realisation because of a setback with the Environmental Impact Assessment in the project. Although we can observe high coverage rates in most of the German auctions, we see a more mixed picture there. The PV auctions managed to cover the targeted volumes, even over-achieved it, due to the fact that the last accepted bids had a higher capacity than targeted. The four assessed multi technology auctions had similar success, achieving 100 % coverage of targets. But, in the case on the onshore wind tenders, a much smaller 71 % result was attained in the auctions of 2017-2020, and there were auctions with a result as low as 30 % in this respect. As a result of low interest from developers, onshore wind prices

Table 4

Minimum, avarage and maximum ratios of the offered and submitted volume/budget (whichever is relevant) in the analysed European case study countries by auctioned technologies

Country	Technology	Covered years	Min	Average (unweighted)	Max
Denmark	Offshore wind	2015-2016	0.97	0.99	1
Denmark	PV	2015	1.08	1.08	1.08
Germany	PV	2015-2020	0.84	1.02	1.36
Germany	Wind	2017-2020	0.3	0.71	1.02
Germany	Bioenergy	2017-2020	0.19	0.34	0.54
Germany	Multi-technology	2018-2020	1	1.03	1.05
Greece	PV	2016-2019	0.23	0.67	1.1
Greece	Wind	2018-2019	0.37	0.64	0.99
Greece	Multi-technology	2019-2020	0.73	0.73	0.73
Hungary	Multi-technology	2019	0.95	0.97	0.99
Netherlands	Multi-technology	2012-2020	0.59	0.92	1.01
Poland	Multi-technology (PV & wind)	2016-2018	0.51	0.86	1
Poland	Multi-technology (other new)	2018	0	0.11	0.3
Portugal	PV	2019	0.82	0.82	0.82
UK	Multi-technology (established tech)	2015	0.87	0.87	0.87
UK	Multi-technology (new tech)	2015-2017	0.58	0.72	0.86

Source: Szabó *et al.* (2021).

have been at the ceiling price levels since 2018. Similarly, for the four biomass auctions only 34 % of the planned capacities have been awarded in the period. Reduced interest in onshore wind auctions is partially attributable to significant capacity additions in the 2017 auctions, reducing the number of available mature projects, and also due to the lawsuits against onshore wind projects realised in the preceding period.

Slightly above 96 % of the auctioned volume was awarded across the six rounds in Greece between 2016 and 2019 if volume reduction is considered, covering 13 technology baskets. However, it is important to note the impact of volume adjustment mechanisms on the tenders. A volume adjustment mechanism is applied in Greece's two-phase procedure, where bidders communicate their intention to participate in the first phase, with volumes indicated and pre-qualifications fulfilled. The target is not reduced If the intended volume is above the targeted volume by more than 40 %. Otherwise, the targeted volume is cut in order to reach the 40 % oversubscription rate. 18 % to 25 % of 'lost volume' could be attributed to the mechanism in the various rounds, compared to the case if the adjustment was not applied.

Hungary had realised one auction round in 2019, where the full capacity of the tendered two size groups were awarded. A next auction realised in 2020 showed an oversubscription ratio above 5, and the target was fully covered as well. Similarly, in Portugal, we can see high coverage ratios, out of the 22 offered slots in 2019, only two did not have winning bids and 82 % of the offered capacities at the available sites were covered at very competitive prices.

In Poland, there were auctions with various baskets of technologies in the period 2016-2018, with varying degrees of success. In 2018, the larger sized PV and wind categories, the full targeted volume was contracted at a very competitive price, where only half of the dedicated budget was used. The smaller size category also reached its volume cap in the first two rounds (2016, 2017) but only 50 % in the 2018 round. The rest of the auction baskets (in biomass, hydro, geothermal and offshore wind technologies) were realised with moderate and low participation, with many baskets without any bids. In the case of the UK, it is quite difficult to evaluate the target achievement in the auction rounds, as separated yearly budgetary caps were used, and in many cases they were far from reaching the budgetary cap.

Concerning the second dimension in policy effectiveness (the realisation rates), these show a mixed picture. Even in those countries where auction started early, we can see limited available information on the realisation rates, with few countries reporting these numbers regularly. Reliable numbers are only available for an assessment of Germany, Denmark, the Netherlands and Greece, while Hungary, Poland and Portugal have not reached yet the end of their realisation periods in most of their auctions. In the UK, PV and wind projects have been delayed for several reasons, but most of them are still in the development stage. It is too early to assess UK biomass projects realisation rates but already a significant number of projects are no longer part of the CfD scheme because of bidding too low or not achieving the Milestone Delivery Date.

As a result of the low availability of reliable figures, we are still not able to draw any solid conclusions regarding the realisation rate criterion. There is only data for Germany, Greece, Denmark, the Netherlands and UK, and even within this group significant project delays are noticeable, *e.g.* in the UK and the Netherlands. In Germany, realisation rates are high for PVs and lower for onshore wind technology. With the limited information available, it is impossible to accurately assess the policy effectiveness of the auctions at this moment. Therefore, governments should place higher priority and effort on tracking and reporting realisation rates in the future.

4.2. Static efficiency

According to the widely accepted definitions on auction results, static efficiency is achieved if a predetermined target is fulfilled at the lowest possible overall cost. However, it is extremely difficult to estimate the lowest possible costs, with factors beyond the auction design like market prices, balancing and system integration costs, forecast obligations influencing auction bid prices. As a second best solution, it was examined whether auctions lead to lower prices over time compared to previous support levels, treating this as “efficiency gains”, mainly triggered by the reductions in technology costs. Several EU case studies of the AURES II project reported efficiency gains in terms of the contracted price or discounts achieved in the period of 2016-2020 compared to earlier periods.

However, in some instances, especially for Germany in the case of onshore wind auctions and the Netherlands in the 2018/2019 auction, prices were flat or even increasing. A common trend was that many countries with RES-E auctioning starting after 2016 experienced significant price drops in their initial auctions compared to the previous, administratively set support levels. This was the case in Greece, Hungary and UK, where this price drop is at least partially attributed to the introduction of the auctions. This showed that suitable auction design helped to correct many of the mistakes in the previous renewable support schemes (mainly feed-in tariff schemes), and the generated competitive setting of the auction and their design contributed to these static efficiency gains.

In the case of Poland, Greece and the Netherlands it is slightly more difficult to draw any solid conclusion on the static efficiency gains. Poland moved from a green certificate system to auctions, therefore support levels are more difficult to assess. The three auctions with smaller sized PV and wind had a rather stable average price of around 85 EUR/MWh between 2016 and 2018, which has only fallen more recently. In the Netherlands, support levels were mostly determined by one price-setting technology in the various years, which then heavily influenced the price of the other technologies, either driving down prices for more expensive technologies or allowing cheaper technologies to bid up to their ceiling price. In Greece, it is quite difficult to identify clear trends for the various technologies as many design elements changed between the auction rounds for small and large PV.

4.3. Actor diversity

Several countries apply design elements promoting the participation of smaller actors or the involvement of local communities in the ownership of projects, with the aim of increasing the level of competition and fostering the social acceptability of renewable investments. The social acceptability issue is more and more emphasized. The example of Germany shows that this dimension needs special attention, as many onshore wind projects were legally challenged in the country by citizens living in the neighbouring locations. With the foreseen dynamic increase of deployment of wind and PV technologies in most EU countries, this issue will become even more important in the future.

Providing preferential conditions to these actors is possible by setting reduced prequalification requirements, different pricing rules, a dedicated proportion of offered volume or budget, or offering special bonus on top of the price (Steinhilber and Soysal, 2016).

One solution to give higher opportunities to local actors is to have separate auctions for smaller sized capacities, which would enable these local actors to participate more easily in these tenders. Hungary, Greece, and Poland designed this type of auctions, where smaller plants can compete for a separate budget/supported volume. In the case of the Polish and the Hungarian schemes, there are separate categories for plants below and over 1 MW capacity. In Greece, there are two size categories for off-shore wind (below 60 kW and 3 MW – 50 MW), while PV projects could compete separately in the size categories of 0.5 – 1 and 1 - 20 MW (this separation was abolished in 2019). In multi-technology auctions, Greece allows groups of several small projects to compete as one project in case they have a common grid connection point to facilitate the participation of smaller installations. As regards material prequalification criteria, no generation licence is required from PV projects up to 1MW and wind projects up to 60 kW in Greece.

Denmark and Germany followed a separate pathway in promoting local communities. They are encouraged to participate through preferential treatment in the RES-E auctions. In Denmark, a compensation scheme is ensured for citizens if the value of their properties decreases due to nearby RES-E plants. Communities can benefit from funding to help restore the natural environment or install renewable systems in public buildings. There is also a possibility for local citizens to become co-owners in wind energy projects, as it is required by regulation to offer at least 20 % of the ownership shares of wind projects to local residents (González and Kitzing, 2019). The German auction system also provided preferential treatment for citizen cooperatives, although with a rather questionable impact. Wind cooperatives with at least ten private individuals having projects under 18 MW (6 turbines) received preferential treatment in the 2017 auction. They had lower material pre-qualification requirements (being able to participate at an earlier stage of planning), reduced bid bonds, and a longer realisation period (additional 24 months). Additionally, a uniform pricing rule was applied to them instead of pay-as-bid. Unfortunately, the special rules induced a misuse of the preferential rules, as many well-established developers set up local companies to enjoy the benefits, while the loose prequalification requirements led to more delays and risk of non-realisation. Therefore, the rules have been changed so that only the special pricing rules remained applicable to community projects (Sach *et al.,* 2019)

4.4. Dynamic efficiency

Auctions can ensure dynamic efficiency if they contribute to the improvement and cost reduction of immature technologies that strengthens their deployment over time. Due to the fact that many technologies have already reached a high deployment level, only moderate price decreases could be observed in the case of PV and onshore wind in mature markets already concluding several auctions. These are the most often auctioned RES-E types, and the costs of the latter have even increased in some countries due to the lack of suitable project sites (*e.g.* in Germany).

In order to be competitive, higher cost technologies are allowed to compete in separate baskets in many countries, *e.g.* biomass, biogas or geothermal plants in UK or Poland. Although these technologies cannot be considered immature either, according to the present technology knowledge they have probably less cost reduction potential. On the other hand, offshore wind projects, which also compete in technology specific and usually site-specific auctions, have shown more considerable cost improvements lately in the UK, Denmark and Germany, while in the Netherlands the latest projects even required zero support (see Szabó *et al.,* 2021 for further details).

As regards less established technologies, a new development is observable. Some auction schemes started to offer support to storage combined with weather-dependent renewable technologies, *e.g.* in the latest Portugal auction and in the innovation auctions of Germany. If these auctions become more common, they might accelerate the deployment and cost decline of storage facilities. The observed wide cost range for CSP technology in the auctions indicates significant cost saving potential for this technology, and with the right support mechanism and learning rates, well designed auctions could promote cost reductions in the future (del Rio *et al.,* 2019a).

5. CONCLUSIONS

5.1. Converging design?

Countries adopt those design elements in their newly established auction systems that proved to work well in RES-E auctions previously implemented in other countries. These include the requirement of financial prequalification criteria, mostly in the form of two-stage bonds (bid and realisation bonds) to increase realisation rates, the selection of winners via a static, sealed bid auction procedure mainly based on a pay-as-bid, price only selection criteria, pre-determined ceiling prices (often differentiated by technologies) and support periods ranging between 15 – 20 years.

For example, the auction schemes of UK, Poland and Hungary share the application of both budget and volume caps to keep support spending under control. Some countries create separate groups (baskets) for technologies having similar cost levels that can compete for a given amount of support, to provide opportunity for more diverse technologies. Others differentiate categories according to plant size (*e. g.* Hungary, Poland and Greece) to involve them also in auctions and giving them chances to win.

Countries differ in whether they apply volume limits in the form of energy (MWh) or capacity (MW). The form of support is mostly floating premiums, but some countries provide one-sided premiums (*e.g.* DE, NL), while others offer two-sided premiums (*e.g.* DK, ES, HU, PL, PT, etc.) thereby ensuring a fixed income level for the auction winners. Countries follow various approaches in setting non-financial pre-qualification criteria, mainly shaped by their national legal and regulatory frameworks related to new power generation capacities.

As regards the technology focus of renewable energy auctions, member states do not follow a general approach to ensure technology neutrality in line with the relevant EU state aid guidelines. The first auctions were designed to be technology specific *(e.g.* in Denmark and Germany) and even though more technologies were involved later, mainly due to convergence in levelised costs, separate auction rounds were held for different technology groups. Poland and Hungary announced their auctions as technology-neutral, but this neutrality was not fully ensured in any of these cases. In Poland, RES-E plants compete in various multi-technology baskets, while in Hungary, wind energy is practically banned by national regulation requiring unachievable conditions for the construction of new plants. The Dutch auction system was the closest to neutrality, as even renewable heat was included in the technology mix.

In practice it seems rather difficult to organise technology neutral auctions which truly provide a level-playing field for the different technologies. Even if two technologies have a similar LCOE range, varying construction lead times, differing production patterns and, consequently, different reference prices will lead to distortions in auctions and, thus, one or the other technology will be disadvantaged. This is also supported by the auction results, as in many cases (Hungary, Poland, Germany) a dominant technology took the majority of the auctioned volume.

5.2. Price trends

Due to the different design and technology focus, prices are hardly comparable across countries. Even if we look at auctions organised within the same country for the same technologies, no clear trend is observable. For example, German PV auction prices fell from 2016 to early 2018, but since then stagnated and even increased. The German case study showed a close correlation between the level of competition (measured as bid/auction volume) and the resulting prices. The upward price trend in the German onshore wind auctions started at the end of 2017 as competition dissipated, with prices approaching the ceiling price from the middle of 2018.

The substantial price drops in the first auctions following the switch from the previous, administratively set feed-in tariff levels have demonstrated the efficiency gains associated with competitive support allocation. However, in Central and Eastern Europe, despite significant price reductions compared to the previous FIT levels, margins remain high compared to the more mature RES-E auctions in Western European countries.

In some cases, the fall in auction prices can be partially explained by the accumulation of numerous projects 'in the pipeline'. This can either be the result of long periods without opportunity for developers to access support, or the upcoming introduction of restrictive measures limiting the chances of specific technologies ('last chance to go'). In Portugal, despite the opportunities to develop subsidy-free PV systems under private PPAs from 2018 due to the reduction of technology costs and the advantageous solar irradiance in the country, challenges to integrate new RES-E plants into the electricity system slowed down PV deployment. Therefore, the new zone-specific auctions introduced for PV technology in 2019, offering connection capacity and remuneration for 1400 MW, provided a new opportunity for developers, resulting in highly oversubscribed auctions in most bidding zones and low bid prices. In Hungary, after the abolishment of the administrative FIT system, there were no opportunities to apply for support from early 2017 to late 2019. The pilot auction organised after the long pause resulted in an oversubscription rate above 2 and low prices in the size category over 1 MW. The wind auction for projects above 1 MW in Poland was affected by a regulation severely restricting the development of onshore wind plants (so called Distance Act) and the draft Energy Strategy projected a minor role for onshore wind technology in the future power mix. Some wind projects which have already accessed their building permits considered this auction as a last chance to apply for support, leading to strong competition and a very low price of 46 EUR/MWh for the Central and Eastern Europe region (Diallo *et al.,* 2019).

Although difficulties in securing proper sites and grid connection for RES-E plants have long been a challenge for renewable developers, falling technology prices and advanced development stage in some countries can create bottlenecks to further RES-E deployment. Scarce electricity injection points in Portugal are allocated through RES-E auctions. The undersubscription and increasing price in the latest German onshore wind auctions is partially attributable to local opposition limiting available project sites. In Germany's technology neutral auctions, a 'distribution network component' is used to adjust the level of bid prices upwards or downwards depending on whether the project is planned on an area with more or less densely occupied network.

5.3. New directions in auctioning

The Dutch SDE + support scheme ended in the spring of 2020, to be replaced by a new scheme in 2020 called SDE++. This scheme aims at supporting greenhouse gas (GHG) emission mitigation instead of renewable generation, providing premiums (contracts for differences) for projects that can mitigate GHG emission at the lowest cost. Although renewable heat has been already included in the Dutch support system, renewable gas production and other carbon-reducing technologies are also eligible under the new scheme, such as the production of hydrogen through electrolysis and carbon capture and storage (CCS) decreasing industrial emissions. With the different technologies competing for the same budget, the strike prices of renewable projects will have to be expressed in EUR/ton CO_2eq avoided, requiring the development of specific price calculating methodologies for each technology.

Another novelty is the introduction of the so called 'Innovation auction' in Germany, targeting projects that combine weather-dependent renewable sources with facilities providing flexibility services (*e.g.* biomass plant or storage). The auction that offers a fixed premium attracted applications for 1095 MW against the targeted 650 MW. The winning prices ranged between 19.4 EUR/MWh and 55.9 EUR/MWh, allocated mostly to PV plus storage projects. The fixed premium aims to ensure that the combined facilities optimise their electricity supply, taking into account actual electricity prices.

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