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Auctions for the support of renewable energy: Lessons learnt from international experiences

Synthesis report of the AURES II case studies

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Contents

Executive summary

This paper is a comprehensive summary of world-wide renewable auctions, based on the in-depth case studies of several EU and non-EU countries in the AURES II project.

As a result of the European competition and renewable energy regulation, progress is being made towards competitive auction-based support schemes from the feed-in tariff or green certificate subsidy systems. This is also happening in the non-European countries but at a slower pace. The main aim of this report is to evaluate the core design elements, the efficiency and effectiveness of the analysed auctions, and, through comparative analysis, highlight some general trends.

Among European auction schemes there are several common design elements as well as a mixture of variations, however, similar to the conclusions of the first AURES project, no single 'best' design solution can be concluded. The differences are more accentuated in non-European countries where the deviations of the auction designs are even greater. Based on the findings of the AURES II case studies, this report finds mostly pay-as-bid, static, multi-unit auctions providing support for 15-20 years on average, with price being the main determining factor of winner selection. Another common feature worth highlighting here is the application of a one or two stage bid bond to achieve higher realisation rates.

On the other hand, there is a clear divergence in several important elements of renewable tender design. First, the technology focus of the auctions varies greatly. Some older tender schemes, for example in Germany, still operate technology-specific auctions, but this setup also applies in other countries like Portugal. New auctions tend to be multi-technology auctions, where different technologies compete against each other. It is important to note that multi-technology auctions can be organised in several different ways, without any technology restrictions or by creating several technology baskets. In some non-EU countries, conventional technologies participated in the auctions along with renewable technologies, e.g. Mexico, Chile. In terms of support payments there are also differences both in EU and non-EU countries. In general, the two-sided sliding feed- in premium schemes (CfD) are most common. Some countries, like Germany, apply one-sided sliding premium systems, while others, like Denmark, introduce a fixed premium. Material and financial guarantees are widely used to varying degrees. Lower levels of financial guarantees are usually associated with more demanding material prequalification criteria and vice versa, albeit some countries (like Germany, Greece and Argentina) set relatively strict material and financial prequalification requirements.

Beyond the most important design elements this report also analyses the effectiveness and efficiency of the applied schemes. In most countries the desired decline in prices is observable, however due to the many exceptions and very different auction designs, it is difficult to draw precise conclusions without more sophisticated in-depth analysis. However, in most of the countries the introduction of auctions resulted in lower support requirements than the previous feed-in-tariff system, verifying that renewable tenders indeed serve as a more efficient tool for allocating support. In terms of effectiveness, most auctions are oversubscribed, except for some cases such as onshore wind tenders in Germany, or biofuels/biomass auctions in Poland. It is more difficult to draw conclusions about the realisation rates because data from past auctions is limited. This is a clear caveat that has to be reconciled to draw proper conclusions as to the effectiveness of future renewable auctions.

The case studies also provided some new insights. In some countries low auction prices can partially be explained by the accumulation of numerous projects 'in the pipeline'. This can either be the result of long waiting periods without opportunity for developers to access support, like in Portugal, or the upcoming introduction of restrictive measures limiting the chances for specific technologies to participate in the auctions, like in Poland. In some recent auctions, the scope of auctions has become broader, for example in case of the Dutch SDE++ system, where support is provided for projects that can mitigate GHG emission at the lowest cost, or Germany's innovation auction where mainly joint storage and PV projects won. These new directions may gain momentum in future tender development. Portugal is also unique because with PV technology costs already below wholesale prices, producers compete for grid connection capacities instead of RES-E support. With the expectation that securing proper sites and network connection points might prove to be increasingly challenging in many regions, countries may follow suit and use similar styled auctions to allocate scarce network connection opportunities.

1 Introduction

Many more EU Member States (MS) have introduced auctions since the last AURES assessment in 2016. (See the project website for more details: https://www.auresproject.eu/publications) Amongst other factors this process is driven by the EU State Aid Guidelines (2017) obliging Member States (MSs) to switch to RES auctions to grant support for new installations generating electricity from renewable energy sources (RES). Similarly, the Energy Community Contracting Parties have also started to introduce auctions to align their support schemes. Their experience showed that auctions are efficient instruments to follow the cost reductions of RES-E technologies compared to administrative procedures (e.g. Feed-in Tariff schemes). The examples of many countries (e.g. Denmark, Hungary, UK) show significant cost reductions after switching from the former, more administrative support schemes, The flexible nature of the design process also allows policy makers to adapt auctions to adapt to country specific circumstances.

We can observe convergence of many design elements in European countries already applying RES-E auctions. Only seven MSs have not yet introduced RES-E auctions up till 2020, out of which two are in a more advanced planning phase. Slovakia cancelled its planned auction due to the COVID pandemic. In the growing number of RES-E auctions we can observe heterogeneity in some auction design elements, but at the same time we can also detect some harmonisation of other elements due to the observable learning effects taking place in the last years. These differences will be analysed in this synthesis report.

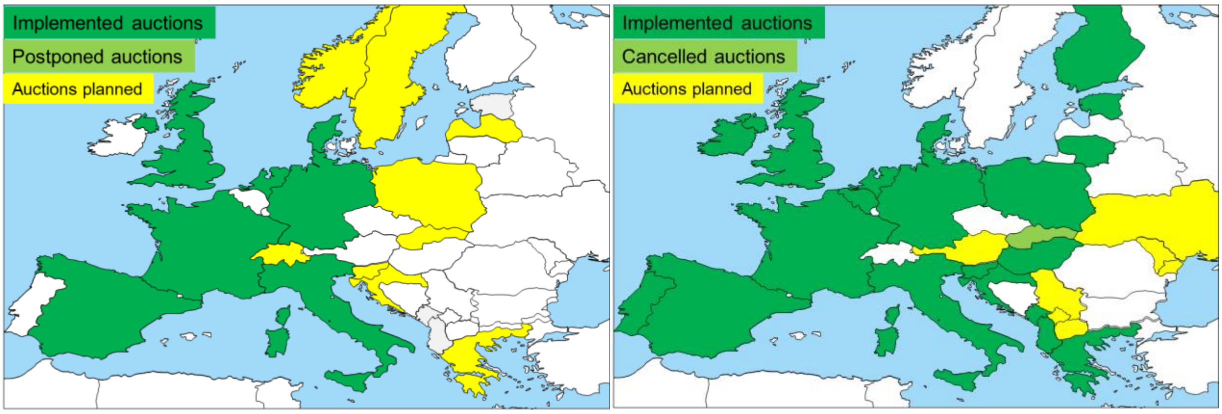

Figure 1: Auctions implemented till 2016 (Aures I synthesis report) and till first quarter of 2020

The report synthesises the findings of Work Package 2 (WP2) of the AURES II project. WP2 assessed 10 ongoing RES auctions (six EU countries and four outside) and also assessed 4 planned auctions (three in the EU and one outside), of which one (Hungary) already started the auction in 2019. WP2 of AURES II also assessed technology focused case studies on off-shore wind development in Denmark and the concentrated solar plant (CSP) technology auctions in various countries. The case studies together with the database constructed in WP3 serve as inputs to other WPs, research communities and policymakers. WP2 applied the methodology used in the previous AURES project: open source literature research was complemented by expert interviews from industry, responsible Ministries and regulatory authorities. The case studies can be consulted on the AURES II website: http://aures2project.eu/case-studies/.

We have structured this report into 5 chapters. This introduction is followed by a short overview of each on-going and planned case study. The third chapter analyses the trends in auction design across the selected case studies. It characterises the auction types and assesses the main design elements for awarding bids facilitating project realisation. The next chapter looks at the policy effectiveness and static efficiency of the various RES-E auctions realised in the EU and non-EU countries and examines the elements that help to increase actor diversity. The last chapter summarises the main lessons from the case studies while reflecting on upcoming innovations, e.g. the innovation auctions in Germany and the planned GHG auctions of the Netherlands.

2 Summary of case studies

This chapter includes short summaries of the 16 auction case studies of the AURES II project. The planned Ukraine auction could not be included as a case study as it was finalised later, but it is available on the AURES II website. The following summaries highlight the main characteristics of the case studies, the most important elements are described in more detail in later chapters.

It is important to note, that in some cases, different terminology refer to the same characteristics of auctions, due to different practices in the covered countries. For example, the study uses the expression 'basket' when competing projects are divided according to their size or technology to compete separately, but 'pot', 'brackets' or 'category' share the same meaning in the original case studies. Similarly, two-sided sliding feed-in-premium and contract for differences (CfD) are the same rewarding method (see details later). Technology differentiation of eligible renewable technologies is described as technology neutral in some cases, although in practice full technology neutrality was not achieved in these auctions as level of playing field cannot be guaranteed. According to our evaluation every auction design favours some technologies against others, so we found 'multi-technology' a more appropriate term in these cases.

2.1 Denmark

Denmark is one of the leading countries in the world in terms of deployment of new (non-hydro) RES; 8 GW of the 15 GW total installed electricity, including 6 GW wind energy and 1 GW solar PV. Wind energy covered 47% of the electricity consumed in 2019.

Until now, 11 RES-E auctions have been held, including the multi-technology tenders for wind and solar in 2018 and 2019 and PV solar tender for projects with a capacity less than 1 MW in 2018.

There has been significant reduction of support levels considerably undercutting the ceiling prices set in the tenders. There are only few players that have won in the auctions with a citizen-based consortium failing to pre-qualify for the Nearshore Tender.

All renewable energy auctions are static sealed bid auctions with pay-as-bid pricing. All past offshore wind auctions have been single-item, technology specific auctions for projects with predefined size and location, providing sliding premium tariffs for a fixed amount of produced electricity over 12-15 years. For the nearshore areas, a multi-site tender was introduced, with a maximum capacity of 350 MW distributed over 5 predefined areas.

With the introduction of the multi-technology tender in 2018, the Danish government has for the first time taken a technology-agnostic approach with a fixed premium per generated kWh added on top of the electricity price for 20 years. The first round of the multi-technology auctions had shown strong competition, with winning and losing bids from both wind onshore and solar PV, resulting in the procurement of 165 MW onshore wind and 101 MW solar PV. In the second multi-technology auction the following year, bids combining onshore wind and solar capacity in hybrid projects successfully applied for. It resulted in procurement of 135 MW onshore wind and 117 MW solar PV. The 2019 auction was the first auction in Denmark that was undersubscribed, leaving 39% of the support budget unallocated, while also resulting in the lowest prices to date.

Most auction volumes were based on a capacity limit except for multi-technology and small-scale solar PV tenders. The multi-technology tenders have a total financial support budget.

So far, all energy auctions except for the first offshore wind farm tender Rødsand 2 were realised in time. Also, Power Purchase Agreements (PPAs) are increasingly being concluded in parallel to the obtained support.

A right given to local citizens to purchase shares of installed onshore wind projects was only partially successful in terms of shares sold. Project owners have ambiguous incentives towards the offering, and results are very much divergent between projects.

2.2 Design of the upcoming offshore wind tender Thor in Denmark

As part of the Energy Agreement of 2018, Denmark decided to establish three offshore wind farms before 2030. The first of these wind farms is the Thor Offshore Wind Farm. With a capacity between 800 and 1000 MW, it will be the largest offshore wind farm in Denmark. The upcoming tender design for the Thor offshore wind farm carries two important distinctions, a wider scope that includes the full offshore grid infrastructure and a new design for the remuneration scheme.

During 2019 the Danish Energy Agency (serving as auctioneer) held a conference and bilateral meetings with interested market players as part of a stakeholder dialogue. The market dialogue was conducted to collect input and reactions to the proposed elements of the tender; to clarify a range of issues, and to make valuable adjustments to the tender.

The Danish tender procedure is a competitive procedure with a pre-qualification and a negotiation phase. To be pre-qualified, candidates must prove economic and financial capacity, as well as technical and professional ability. The pre-qualification phase closes in January 2021. The final tender material is expected to be published in Q3 2021 with final bids expected in Q4 2021. The auction will be conducted as a static sealed bid auction whereby the concession is awarded to the tenderer quoting the lowest price if the expected subsidy cost over the 20-year period is below 3.7 billion DKK. However, in the event that no bids fall within the budget evaluation threshold, there is a chance that a bid can still be accepted by the political parties to the Energy Agreement of 2018. If there are two or more bids with the exact same bidding price, the highest capacity (MW) bid will be chosen. The grid connection window for the winning bidder for the Thor wind farm is 2024 to 2027.

The remuneration scheme is a Contract-for-Difference mechanism over 20 years based on a reference price calculated as the average spot price from the previous year. Compared to the 'traditional' hourly based system, this increases the short-term risk of price fluctuations for the concession owner. The purpose behind this change is to incentivize the concession owner to maximise the market value of production rather than simply maximise output. The total net value of the remuneration payments has been capped for both the state and the concession owner.

2.3 Germany

Renewable energy auctions have become the new standard for determining subsidy levels for renewable energy sources (RES) in Germany. From 2015 to 2019, a total of 17.25 GW of renewable energy capacity has been added in 40 auction rounds. However, significant undersubscription in the recent onshore wind auctions threatens their expansion trajectory.

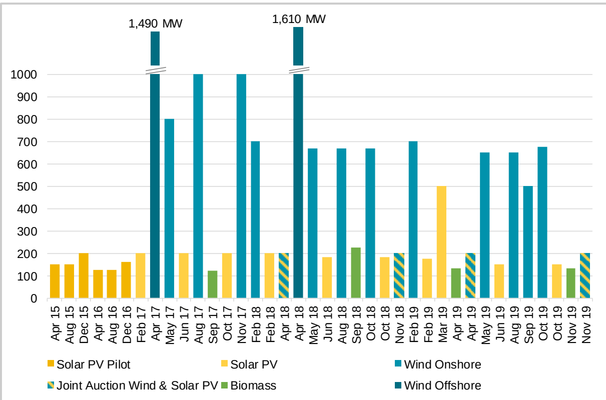

Figure 2: German RES-E auction rounds and volumes

The German auction schemes include wide ranging auction formats, rounds and volumes. Now the focus is on auctions for onshore and offshore wind and solar PV, which are at the core of the German renewable support scheme. Specific design elements reflect the characteristics of the German power system. One example is the maximum quota for the yearly capacity addition of onshore wind in the so-called grid expansion area (Netzausbaugebiet) that is applied in the auction to account for regional capacity limitations of the transmission grid.

The results of German RES-E auctions demonstrate that competition is a key success factor for renewable auctions. While the auctions for solar PV and offshore wind had sufficient competition and provided satisfying auction results, the auctions for onshore wind and biomass suffer, for different reasons, from a lack of bid volume.

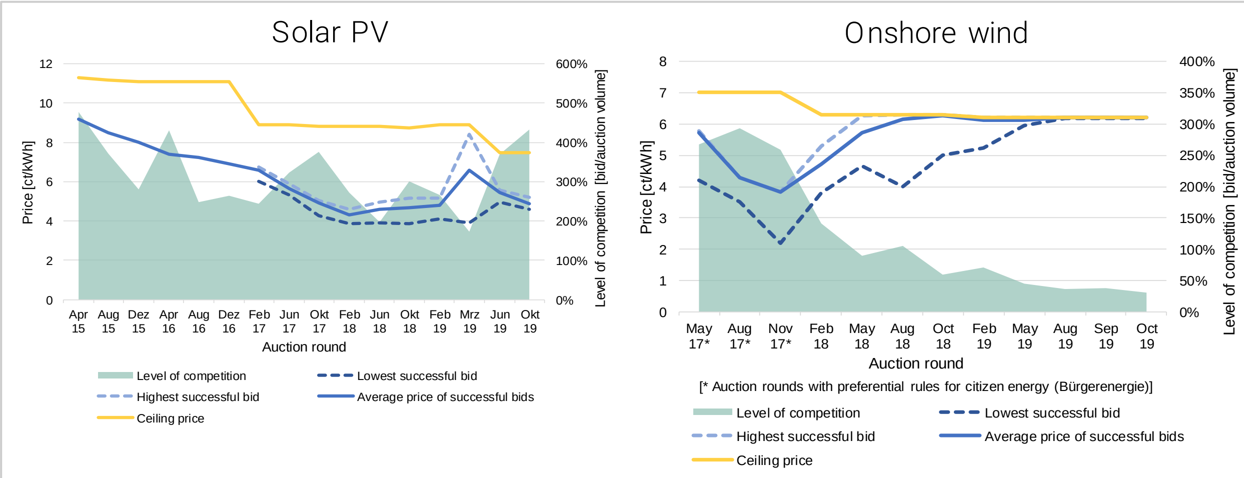

Figure 3: Price levels of the German solar PV and onshore wind auctions

Since the introduction of the auction scheme for solar PV, the weighted average price of successful bids went down substantially. Starting from 91.7 EUR/MWh in the first auction in April 2015, this fell 47% to 49 EUR/MWh in the latest auction in October 2019.

The first onshore wind rounds were highly competitive with declining prices. The weighted average price of a successful bid, 57.1 EUR/MWh in May 2017, fell to 42.8 EUR/MWh in August 2017 and 38.2 EUR/MWh in November 2017. However, since the preferential rules for community energy projects had been put on hold for 2018 and onwards, the bid volume in the onshore wind auction volume decreased and prices increased steadily, getting close to the ceiling price from August 2018 onwards and reaching it in August 2019.

The experiences made with renewable auctions in Germany are mixed. The case of solar PV has proven that auctions can be an effective tool to award support in a competitive manner, drive down support costs and at the same time ensure steady RES-E development with high realisation rates. On the other hand, the case of the onshore wind auctions shows that designs aiming to support particular types of bidders, as a preferential rule for energy community projects in 2017 that did not need to show an advanced project predevelopment status to submit a bid, can have adverse effects on the project realisation timeframe. A lack of available sites and project pipeline also reduced competition in wind onshore auctions, resulting in high prices.

2.4 Greece

In 2010, Greece committed itself to achieve 20% RES in its gross final energy consumption and at least 40% in its gross final electricity consumption by 2020. After retroactive feed-in tariff cuts and the subsequent turmoil in the Greek RES sector, Greece introduced an auction-based support scheme in June 2016 for onshore wind and PV – with both technology-specific and multi-technology auctions.

According to the Greek auction design, the government defines the maximum volume to be auctioned in each year. Afterwards, RAE, the auctioneer, announces the specific auction volume for each round and interested bidders can apply with their projects to participate in the actual auction. Qualified bidders are then invited to submit their bid prices in a dynamic auction procedure – after the auction volume is adjusted based on the total capacity of submitted bids.

There are two distinctive features of the Greek auction scheme: the volume adjustment mechanism and the segmentation of PV auctions.

The volume adjustment is meant to ensure sufficient competition in the auctions. If the total bid capacity (by qualified bidder) does not surpass the initial auction volume by a certain threshold (e.g. 40%), the auction volume for the dynamic auction is adjusted downwards, until the threshold is reached. Indeed, the mechanism might have led to relatively low awarded prices – at least in the short-term. Nevertheless, in at least one auction round bidders participated with "fake projects" in order to circumvent the volume adjustment. Furthermore, almost 500 MW of onshore wind and PV projects could have been additionally awarded based on the initial auction volumes without the adjustment.

In the first PV auctions two different segments existed, small-scale projects below or equal 1 MW and projects above 1 MW up to 10 MW/20 MW. After the auction of the smaller segment resulted in similar prices to larger projects, RAE decided to pool both into one category. This significantly curtailed small-scale winning projects, indicating that small-scale projects were not as competitive and project developers might have split up their large-scale projects in the first auction rounds to secure an award with a higher bid price in the small-scale segment.

Greece has completed 13 auctions successively pushing down the strike prices well below the administratively set feed-in tariffs in place before. By the end of 2019 prices fell to 60 EUR/MWh for PV and 58 EUR/MWh for onshore wind. Furthermore, Greece has been able to attract a rising number of international investors and project developers, which shows that the auction scheme is perceived as a stable and financially sustainable mechanism.

2.5 Hungary

Hungary reached its overall 2020 renewable target (13%) in 2011 owing to a revision of biomass accounting. Indeed, renewable energy in Hungary is predominately biomass utilised for in heating, and yet RES share fell below 13% in 2018 because of weather conditions and other economic factors.

After joining the EU in 2004, Hungary set its 2010 renewable electricity (RES-E) target to 3.6%. It exceeded this with a feed-in tariff subsidy system launched in 2002 that was in operation until 2017. The scheme mainly incentivised coal and biomass co-firing in existing power plants, and with wind capacities capped at 330 MW in 2006 by the Hungarian Energy Regulator further expansion of RES-E is mainly expected for solar PVs.

The Renewable Energy Support Scheme (METÁR) launched in 2017 was developed according to EU guidelines. The new system kept the mandatory FIT system exclusively for units below 0.5 MW and for demonstration projects of any size (METÁR-KÁT). Installations from 0.5 to 1 MW were able to apply for a feed-in-premium over the market price and those above 1 MW had the obligation to enter competitive auctions. In November 2019, Hungary executed its first pilot auction for renewable energy support and announced the results in March 2020. The auction was successful in providing information on current technology prices and driving down support costs, born exclusively by non-household consumers in Hungary. This was technology-neutral by name but in practice all awarded projects were PV except for one small-scale landfill gas power plant.

The auction volume was set at 200 GWh/year with a budget of EUR 2.9 million divided into two baskets: small installations with a capacity between 0.3 MW and 1 MW and large installations between 1 MW and 20 MW. The ceiling price was the same for all technologies in both baskets, 26.08 HUF/kWh (78 EUR/MWh). Altogether, 168 bids totalling 349 MW capacity were submitted, 269.4 MW of which qualified. The pilot auction revealed that the actual costs of PV generation are well below the previous feed-in tariff level, creating substantial savings in support costs.

Although volatility in the electricity and foreign exchange markets caused by the COVID-19 pandemic might affect the implementation of the winning projects, the national regulatory authority expects to meet its objective by connecting 131.84 MW renewable capacity to the grid.

2.6 Netherlands

The SDE+ was the main renewable energy support scheme in the Netherlands during the 2010s and is soon to be replaced by SDE++ in 2020. It was one of the first large technology neutral support schemes in Europe, which allowed for large fluctuation in the type of capacity contracted, as well as the auctioning of budget instead of capacity.

The SDE+ combines all technologies except offshore wind energy under a single budget. Technologies compete against each other but are restricted by technology specific ceiling prices. Until the auction round in spring 2019, the SDE+ succeeded in auctioning support for over 25,6 GW of renewable energy capacity, 18

GW of which are still under construction. However, it failed to achieve significant reductions in overall support levels. Offshore-wind tenders, which have been implemented under a separate budget, are an exception to this as resulted in subsidy free bids in 2017. Especially in the earlier years of the SDE+ it occurred that projects bid at considerably lower costs to be able to receive support at all. More often cheaper technologies bid at higher prices because another, more expensive, technology was setting the price. Overall, it can be said that the technology-specific ceiling prices were important and relevant for the small price decline in recent years. Figure 1 below provides an overview of contracted volumes per round and volume weighted strike prices.

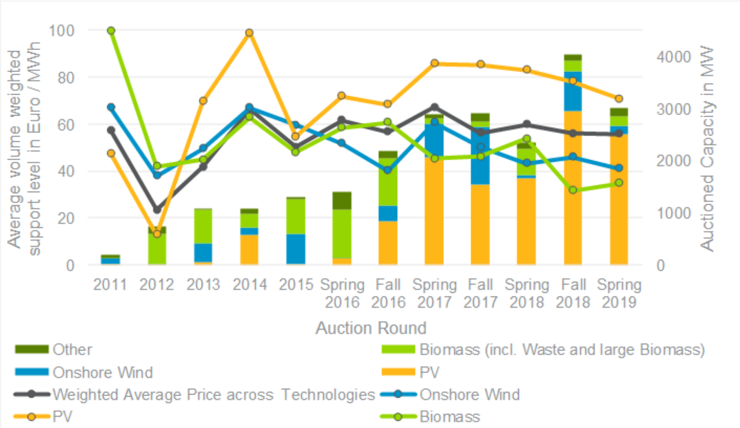

Figure 4: Maximum SDE+ support level (average per technology) and contracted capacity

The overhaul and development of the SDE+ towards the SDE++ changed it from a renewables support scheme to a CO2 emission reduction support scheme, aiming mainly to reach national GHG targets rather than renewables targets. The introduction of new industrial technologies and a methodology based on Euros per ton of CO2 avoided poses several challenges such as setting correct base levels (ceiling prices).

The experience from SDE+ are mixed. While it succeeded in contracting large amounts of renewable capacity, non-realisation rates in the early rounds showed how important proper pre-qualification requirements are. Furthermore, the price and capacity fluctuations characterising the early auctions highlights how difficult it is to design and implement a truly technology neutral auction.

2.7 Poland

With its share of renewable energy of only 11% in 2016, Poland had to make a strong late push to reach its 2020 target of 15%. In fact, the country voluntarily increased its renewable electricity target to 19.3% for 2020 (Ministry of Economy, 2009). Furthermore, RES-E support should be shaped with a long-term vision since the country's electricity system today relies heavily on coal and lignite inputs.

In 2017, Poland generated more than 170 TWh (NECP, 2019) of electricity, 86% from fossil fuels (hard coal, lignite, natural gas) compared to only 24 TWh from renewable sources. Onshore wind is the dominant renewable technology accounting for 9% of total generation, compared to 3% biomass and small amounts of hydro, biogas and PV.

Poland has been operating a hybrid support scheme since 2016. New renewable power plants can receive support in an auction-based feed-in premium (FIP) system, while old power plants are part of a green certificate system. It is possible, however, to migrate from the green certificate system to FIP through auctions. The auction system in Poland is highly fragmented compared to other European countries with baskets separated according to three main features: technology, size (separate auctions for power plants with less and with more than 1 MW capacity), and whether the power plant is new or existing with the aim of shifting from the green certificate system to the FIP system.

In three rounds (2016, 2017 and 2018) Poland organised 18 auctions with varying baskets of technologies. Some included only single technologies and others multiple technology baskets. A second dimension divided the auction by size, below and above 1MW. The Polish government is attempting to achieve several objectives simultaneously under the new scheme. On the one hand it wants to move RES production away from the green certificate scheme to reduce the support needed for the expansion of renewable generation. On the other hand, it wants to help advance RES capacities that would not be able to compete with large-sized wind or PV installations (e.g. small-sized biogas and biomass-based generation) to expand market participation and increase actor diversity. However, support for small-scale producers is inherently more costly and their participation erodes cost efficiency. Data shows that for a technology basket containing onshore wind and PV, support for smaller installation can be twice as high as larger plants, resulting in about 40 EUR/MWh price difference. Therefore, a trade-off between these two objectives should be discussed. It is also evident that the ceiling prices of the small-scale mixed PV and onshore wind auction rounds favour PV technologies.

The auctions were more successful in the case of hydro technology, where auctions had high participation rates and resulted in relatively moderate prices. Nevertheless, biomass and biogas producers performed poorly, and in many auction baskets there were no participants (6 out of 9 auctions), while in others only very few. In these categories, only hydro installation investors were targeted (above 40 participants), albeit only around 30% of the total budget was allocated. Biogas and biomass producers likely refrained from participation probably due to the rising certificate prices and the changing regulation defining the RES markets. It is not clear either how the transferred amount of RES production from the certificate market is managed in the system, or how it impacts the supply/demand relation of Poland's remaining certificate market.

The tender for mixed wind-photovoltaic above 1 MW resulted in the most competitive prices (45.93 EUR/MWh average price), even below the 2018 German price levels. However, the competitive pressure was not a result of the auction design itself. Onshore wind connection license owners in Poland must realise their projects before July 2021, which encourages participation in competitive bidding. At the same time the Polish energy policy precludes onshore wind from further expansion in the future. This poses a serious question to the auction design: which technology should be promoted if the low-cost onshore wind is excluded from the technology mix? This creates an advantage for PV technology in the short term and offshore wind in the longer term.

2.8 Portugal

The deployment of RES-E capacities has experienced considerable momentum over the last two decades, positioning Portugal as one of the leaders in the EU. Both RES-E installed capacity and generation have doubled between 2005 and 2016, following a 6-7% average annual growth rate. With additional capacity of 5124 MW, wind energy has experienced the largest gain over the period (five-fold), before starting to plateau in the last few years. Solar has also been stagnant at much lower deployment levels.

The Portuguese government outlined a path of diversification through sustainable endogenous RES aiming for 47% of gross final energy consumption in 2030, up from 28.5% in 2016 and 31% in 2020 (the target for that year) in the National Energy and Climate Plan. The government aims to increase the RES share in electricity generation from 68% in 2020 to 80% in 2030 and to 100% by 2050.

The evolution of the Portuguese RES-E regulation and support schemes have a long history with several different regimes Between 2006-2008 Portugal's renewable auction support scheme was one of the first in Europe. According to the government, with scarce grid capacities auctions are the best way to satisfy demand for production licenses.

Portuguese auctions can be labelled as "2nd generation auction", completely different from renewable auctions across Europe usually organised to assign price support for renewable power plants. In Portugal, however, producers compete for the opportunity to connect to the grid.

The Portugal PV auction is a dynamic auction which incorporates several rounds of bids. The process is an "ascending clock" type of auction (increasing NPV) and the number of rounds is not fixed but dependent on the bidding behaviour of the participants. The tender offers bidders the choice between a "guaranteed remuneration" or a "general remuneration". Under the guaranteed remuneration, participants bid for a discount (%) from a given tariff level (at around 45 EUR/MWh) to receive a two-sided sliding premium (CfD) for 15 years. Under the general remuneration, bidders receive the market remuneration for 15 years but they offer payments to the electricity system operator.

For the offered 1.4 GW capacity, more than 10 GW of offers were made, however only 1.15 GW were awarded because of the location specific nature of the auction. The winning investors have three years to commission their power plants and will pay the network contribution fee or receive the feed-in premium depending on the selected scheme for a period of 15 years. Out of the 1.15 GW, 862 MW were assigned under the guaranteed and 288 MW in the general remuneration scheme. A single company won 32% of the awarded capacity but the remaining capacity was distributed more evenly between 12 other firms. Incumbents of the Portuguese electricity market did not make any winning bids in the auction.

Competition achieved low auction prices, with the average winning price of the guaranteed remuneration scheme a premium of 20 EUR/MWh and the lowest bid of 14.46 EUR/MWh, the lowest feed-in premium for PV ever in Europe. In the general remuneration scheme winners paid an average of 21 EUR/MWh for every MWh sold to the system operator. We can conclude that these prices are drastically lower than the wholesale market price.

As renewable technologies become more and more competitive, auction results may fall below the wholesale price across Europe, similarly to Portugal. This should shift the objective of auctions from providing financial operational support to the allocation of scarce network connection capacities.

2.9 Slovakia

More than half of electricity generated in Slovakia comes from nuclear power and fossil fuels are falling with the phase out of coal and the declining role of natural gas and oil. RES-E was composed entirely from hydroelectricity until 2005, when gaseous and liquid biofuels and renewable municipal waste were first introduced. Solar and solid biofuels entered the Slovakian power system in 2010 and has since generated significant volumes of electricity.

Growth in RES-E production in Slovakia has plateaued since 2014 when it reached 22.9%, falling to 21.5% in 2018 (Eurostat, 2020). The overall renewable energy share peaked at 12.8% in 2015 and fell back to 11.9% in 2018, well below Slovakia's 2020 target of 14%. The main reason for this drop was that new RES-E installations since 2015 have not kept pace with growing energy consumption in transport and heating and cooling of buildings. In an effort to address this gap, the Slovakian government introduced legislative changes in 2018-2019 to support larger sized RES-E capacities by making them eligible for auctioned feed-in premium.

However, the first auction planned for spring 2020 was cancelled 10 days after the new government took office due to the COVID-19 pandemic. The fact that it was cancelled rather than postponed suggests that it might be redesigned before relaunching. It was planned as a multi-technology auction with some technology specific conditions where relatively small solar PV power plants would have been eligible (0.1 - 2 MW) while other technologies could be larger (0.5 - 10 MW).

The auction design presented relatively high cost and risk to potential to investors compared to other European auctions, from the high bid bond to short realisation times and high fees for delays. These design elements can potentially decrease participation rate, in the Slovakian auction, although they can improve the realisation rate of the winning projects. The grid connection process puts project promoters at a further disadvantage by making them wait until the announcement of the winning bids to present detailed connection planning rather than acquiring a concrete pre-agreement with the relevant DSO in advance.

2.10 United Kingdom

The UK conducted its third Allocation Round (AR3) for Contracts for Difference (CFDs) between May and September 2019. There was £65 million pounds of support available for projects coming online in 2023/24 and 2024/25, and the auction was open only to Pot 2 (less mature) technologies. The definition of Pot 2 technologies differed slightly from previous ARs, with the most significant change being the inclusion of remote island onshore wind projects >5MW in AR3.

The contracts awarded in each Allocation Round auction are limited by a budgetary cap which limits the total overall spending on successful projects in each year (i.e. £65 million for AR3 projects, DBIES (2019a)). In addition, AR3 introduced an overall capacity cap of 6GW for projects which could be awarded a contract.

The contracts awarded in AR3 demonstrate the strong downward pressure on price created by competition between bidders. The contract prices offered after AR3 were in many cases below the projected electricity market references prices which are used to calculate the budgetary impact. CFDs require generators to pay back any difference between their contracted price and the market price if the market price is the lower of the two. This has resulted in a strongly negative projection of the costs of AR3 – in other words, net revenue for generators is lower than the projected wholesale price of electricity (DBIES 2019b). This appears to demonstrate that the developers value the certainty given by a CFD as well as the price paid for contracted generation. In addition, given that the £65 million budgetary cap for AR3 was not exceeded, the 6GW capacity cap limited the contracts awarded, rather than the cost of the support scheme.

As with ARs 1 and 2, AR3 was dominated by offshore wind, with 5.466 MW contracted. In total, offshore wind has received 87% of the CFDs awarded in the three ARs. This reflects the strategic priority that the UK Government has given to developing an offshore wind industry as well as the rapidly declining cost of the technology. However, it does raise concerns about the lack of diversity emerging in the UK's renewable generating sector. This issue may be addressed through the potential inclusion of onshore wind and solar in the fourth AR which is due to take place in 2021 (DBIES 2020).

It is too early to speculate on the success rate of AR4 contracts. Given the low prices awarded in the contracts, for offshore wind in particular, the deployment rate depends on the costs of the technology declining rapidly before the delivery years (i.e. 2023/24 and 2024/25).

2.11 Argentina

Argentina is aiming to meet 20% of national electricity demand from renewable sources by 2025, with interim targets of 8% for 2018 and 16% for 2021. In order to raise the share of renewables in the electricity mix, the country launched the RenovAr programme in 2016. RenovAr features an open call for tenders in several rounds, with eligible projects comprising those based on wind power, solar PV, mini hydro, biomass and biogas power generation. A decisive feature of Argentina's RenovAr support programme is a multi-level safety net of payment and solvency guarantees designed to support competitive bid prices. On the first level, in addition to entering into a PPA with the country's Electricity Wholesale Market Administrator (CAMESA), the successful bidder joins a Trust Adhesion Agreement ("FODER"). A second level guarantee is provided in the form of a put option mechanism, which allows developers to transfer project assets to FODER in case CAMMESA fails to pay for the supplied energy. Furthermore, the World Bank acts as a backstop guarantor (through the International Bank for Reconstruction and Development) to FODER. The World Bank guarantee comprises an optional third level that seeks to further secure against the risk that the Government of Argentina cannot back up the repayment guarantees established through FODER.

The RenovAr programme has held four renewable technology-specific auction rounds to date. These have resulted in PPAs for combined generation capacities of more than 2.2 GW of wind, 1.5 GW of solar, 30 MW of small-scale hydro, as well as almost 190 MW of biogas and biomass power generation capacity. Three of the four RenovAr rounds have attracted considerable interest from the private sector and have been significantly oversubscribed, at least for solar PV and wind power. Moreover, they have yielded competitive prices in comparison to other countries in the region. Wind power is the most cost-competitive technology in Argentina according to the RenovAr programme, with prices as low as USD 37.3 per MWh. Overall, given the limited experience (and levels of installed RE generation capacity) in Argentina prior to the introduction of renewable auctions in that country, the RenovAr programme has so far proven to be an effective way to quickly scale up installed generation capacity and continue progressing towards meeting the national 2025 RE target.

2.12 Alberta (Canada)

Alberta's Renewable Electricity Programme (REP) was launched in 2016, reaching three auction rounds to date, with the aim of incentivising the deployment of renewable energy capacity in Alberta to 2030.

The REP auction rounds were designed to feature three stages. The initial Request for Expression of Interest (REOI) stage is intended to attract and assess the level of interest in the support mechanism, including information sessions for potential bidders to address the Alberta Electric System Operator (AESO) with questions and concerns. During the subsequent Request for Qualifications stage, bidders submit project proposals and required documentation, but only as evidence of eligibility for qualification. In the final Request for Proposals stage, bidders are asked to confirm their project proposals and submit a final bid for support.

A key feature of the REP is the Indexed Renewable Energy Credit (Indexed REC) payment mechanism. With the Indexed REC payment mechanism, which is essentially a two-sided sliding FIP (Contract for Differences) scheme, the AESO pays the successful bidder the difference between the strike price and the pool price if the former is above the latter, or vice versa (i.e. the generators pay the difference to AESO). The three technology-neutral capacity auction rounds have awarded a total volume of approximately 1360 MW of wind power capacity.

Alberta's REP has been successful in the three years since its initiation. All three REP auction rounds were oversubscribed, yielding record low strike prices for Canada. The overall success of the auctions, in terms of the high participation and competitive awarded prices, is understood to have stemmed from the considerable preparation that was undertaken before the auctions were held, as well as from the choice of payment mechanism. It is, however, too early to make definite claims about the overall effectiveness of the scheme as only successful projects from REP Round 1 have very recently reached the stage of commercial operation. Nevertheless, it is encouraging that three of the four projects began operating without delays.

2.13 Mexico

In Mexico, 98.7% of the growing population has access to electricity and the challenge is to connect the remaining remote areas (IEA 2019). Retail electricity prices are relatively high (25% higher than in the United States) for both residential and commercial buyers. Currently, the fuel-mix is dominated by thermal sources, with fossil fuels accounting for 75.8% of the electricity generation. On the other hand, Mexico has ambitious renewable energy targets: 30% RES by 2021 and 35% by 2024 as obliged under the Energy Transition Law issued in 2015. Furthermore, the Transition Strategy to Promote the Use of Cleaner Technologies and Fuels (2016) envisions 37.7% RES by 2030 and 50% by 2050. Mexico has abundant and high-quality RES-E, especially onshore wind and PV though shares are low (3.6% and 0.7% in 2018, respectively). The main renewable generation comes from large hydro with 10.3%.

Since 2013 Mexico has worked to reform its electricity sector, beginning with unbundling and restructuring the public Comisión Federal de Electricidad (CFE) to facilitate private sector participation and increase the competitiveness of the electricity and energy markets. In 2014 the Electricity Industry Law provided a new regulatory framework including auctions, renewable energy quota obligations and Clean Energy Certificates. The new Centro Nacional de Control de Energía (CENACE) is responsible for system operations and IPPs can build and operate power plants and sell the electricity under long-term power purchase agreements to CFE.

In 2015, 2016 and 2017, three long-term power auctions (LTPAs) were organised, resulting in PPAs between renewable energy generators and retailers (CFE being the main retailer). The LTPAs are designed to help generators avoid the risks of volatile short-term prices and to benefit from stable revenues in order to finance their investments. To briefly summarise, the auctions work as follows: retailers announce their demand for energy (MWh); capacity (MW) and Clean Energy Certificates (CELs) are auctioned by CENACE; generators bid for them separately or in packages.

The last auction (2017) introduced some novelties compared to earlier ones (2015 and 2016). Private off-takers/buyers were allowed to participate alongside CFE. An independent clearinghouse executes separate contracts between developers and off-takers, assessing financial credibility and socialising risk of default. The nodal price signal was reduced. Bidders cannot bid separately for different products using the same plant. The role of CELs is also relevant for additional financial support. CELs are expected to be slightly adjusted and increased in importance for the next auction round in Mexico.

The auction was successful in achieving lower prices that were much lower than in previous auctions in Mexico as well as comparable auctions elsewhere. One of several reasons behind the success was the high competition rate. Others were experienced bidders, favourable finance and macroeconomic conditions, project economies of scale, guarantees and contract condition, etc. The average bid price for the whole package was 20 USD/MWh compared to 47USD/MWh in the first and 33USD/MWh in the second auctions.

2.14 Chile

Chile experienced a very significant growth (42%) in electricity demand from 2006 to 2016. The country consists of four (now somewhat interconnected) separate electricity systems and very few cross-border interconnections. The mining industry is the single most important consumer (37%) of electricity, with a profile of considerable night consumption. Currently, the mix consists of coal (33.6%), gas (13.4%), large hydro (24.7%), PV (10.5%), onshore wind (8.3%) and small hydro (2.1%). In addition, Chile has excellent RE sources available.

Chile's main objectives were to lower electricity retail prices, increase competition in the market, reduce outages, increase intra-Chilean connectivity, and reduce CO_2 emissions. The RES quota for electricity generation is 60% by 2035 and 70% by 2050. The auctions in Chile are technology-neutral and include fossil-fuels with some special features: hourly supply blocks and a price revision mechanism are included so the price may be modified in the event of significant and unexpected legal, regulatory, or fiscal changes. Also, indexation factors are considered when assessing the bids (levelised price).

The latest auction (2017) innovates with some criteria: seasonal (quarterly) blocks (in addition to hourly blocks) were introduced. The goal of the hourly blocks is to arrive at the lowest price possible for every 24-hour period. The goal of the quarterly block is to lower annual prices. In this case, seasonal renewables may have an advantage. Bid restrictions could be stated by auction participants (realisation contingent on multiple awards). Auctions were awarded through first hourly then quarterly blocks. Also, the financial prequalification requirements were stricter than in earlier auctions.

In achieving the very low weighed average price of 32.5 USD/MWh, the competition and efficiency of the auctions appears strong, both with respect to international experiences and previous auctions in Chile (47.6 USD/MWh). The hourly blocks were more competitive than the quarterly blocks.

Some experts are concerned that the time allotment for project completion is too generous. Projects must start producing electricity only until 2024, 6 years after being priced, in October 2017.

The case of Chile shows that renewables can successfully compete with fossil-fuel technologies in technology-neutral auctions, especially if designed in a way which takes into account their dispatch profiles. Consequently, RES projects can be built without subsidies in Chile.

2.15 Austria[1]

In the final version of the Austrian National Energy and Climate Plan (BMNT, 2019), the Austrian Federal Government set an ambitious target for the domestic expansion of RES-E to fully cover the total electricity consumption (at a yearly balance)[2]. Furthermore, full climate neutrality of the whole economy shall be reached by 2040.

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[1] Although it was planned as a case study, due to delayed planning a finalised case study on Austria could not be included in the AURES II project. This summary is given to summarize latest developments concerning its auction design.

[2] Considering exceptions from the definition of demand this translates into a RES share of approx. 92% in gross electricity demand (following commonly applied statistical definitions of that). More precisely, as postulated in BMNT (2019), the calculation of the 100% renewable electricity supply should not include balancing needs as well as industrial auto-production for reasons of resource efficiency. Both together are estimated to be in the range of 5.5 to 6.5 TWh, corresponding to a demand share of ca. 8%.

The forthcoming Renewable Expansion Act (in German Erneuerbaren-Ausbau-Gesetz (EAG)) shall make a significant contribution to this long-term goal by creating a stable legal framework for the significantly accelerated expansion of electricity generation from renewable sources. On 16 September 2020 the Federal Ministry for Climate Protection launched a public consultation for the legal draft (cf. BMK, 2020a). As postulated in BMK (2020b), in addition to the redesign of the subsidy system, which was previously defined in the Green Electricity Act 2012 (BMWi, 2012), and the adjustments to the applicable state aid requirements of the European Union, measures are being taken to expand and reorganise the market to integrate RES. At the same time – particularly in view of the current COVID-19 crisis – a positive investment climate should be ensured and administrative barriers removed.

To achieve the 2030 RES target for electricity, based on the 2020 production level, the annual electricity generation from renewable sources must be increased by 27 TWh in terms of volume in the next decade. 11 TWh of this should be photovoltaics, 10 TWh wind, 5 TWh hydropower and 1 TWh biomass.

The default financial support mechanism is a market premium model, implying for RES-E producer to market their green electricity and to receive a market premium per kilowatt hour as support. More specifically, sliding market premiums are planned. These are defined as the difference between a value to be applied (which is administratively prescribed or determined by an auction) and – in the case of wind power, photovoltaics and hydropower – the actual reference market value of the respective technology, determined on a quarterly basis. For small installations and for certain technologies investment incentives shall serve as an alternative. This marks a major change compared to current practices whereby RES support is offered via fixed feed-in tariffs. Finally, the guaranteed duration of support is extended from 13-15 to 20 years.

RES-E auctions will determine the maximum support for photovoltaics and large-scale biomass systems and, from 2024 onwards, for wind power. Moreover, in the case of wind power the law enables the responsible minister to issue ordinances for differentiating funding according to location (by means of surcharges or discounts of up to 20% compared to default).

The annual support expenditures under the EAG and the Green Electricity Act 2012 together should not exceed one billion euros on a three-year average. If this limit is exceeded, a proportional reduction of the upcoming funding quotas may be applied. For refinancing support, an adaptation of the current refinancing mechanism is planned, but in general a continuation of current practices shall be followed.

Further provisions of the planned EAG also include:

- Renewable Energy Communities: Enabling shared RES where the proximity criterion should be respected (i.e. the requirement to connect consumption and generating systems via a medium or low-voltage distribution network).
- An integrated Austrian network infrastructure plan must be drawn up.
- Ecological criteria for the promotion of hydropower plants shall be established.

2.16 CSP

CSP (concentrated solar power) is a dispatchable renewable electricity technology (RET) that can be instrumental to the sustainable energy transition especially in countries with high solar irradiation (DNI), in tandem with an increasing penetration of variable RETs. Compared to intermittent RETs, its dispatchability feature allows CSP to balance intermittent renewable electricity sources if these achieve a high penetration in the future. CSP plants contribute to grid balancing, spinning reserve, and ancillary services. They can shift generation from sunny hours to maximise generation at peak demand times

CSP has been promoted through technology-specific auctions in several countries from around the world (South Africa, Dubai and Abu Dhabi in the United Arab Emirates, South Australia in Australia and India). In addition, CSP participated but did not win any bids in the technology-neutral auction in Chile. Apart from auctions, CSP has been supported by other mechanisms in Spain and China. The strike prices range from 73 USD/MWh in Abu Dhabi to 610 USD/MWh in South Australia showing a very wide price range.

Some design elements are common or predominant in all the CSP auctions being analysed: they are often technology-specific, site and size-specific auctions. The volume is set in capacity terms and remuneration is generation-based. Static auctions have been adopted everywhere, using the pay-as-bid pricing rule. However, the design elements in the countries differ in other respects and, most importantly, regarding the stringency of prequalification requirements. Although price-only auctions dominate, some countries have local content rules.

An empirical assessment found that CSP auctions have led to relatively low and/or decreasing prices over time. Results are somewhat mixed with respect to effectiveness are observed, with some delays in South Africa and even failure to build projects in India, but strong performance in Morocco.

Although designing CSP auctions is strongly influenced by the respective policy goals, some design elements have been particularly suitable. These include technology-specific auctions (which create a niche for CSP), site-specific auctions (which facilitate coordination of the auction and grid connection procedures and secure land and water), long lead times and long deadlines for construction of projects, stringent prequalification requirements (developer experience), provision of DNI[3] measurements and valuation of dispatchability. Given the importance of large size and economies of scale in CSP cost reductions, a maximum size of projects should not be required. Valuation of dispatchability will be a common design element in future CSP auctions. Dispatchability requirements may lead to success in technology neutral auctions in the future (especially in places with a high DNI), while simultaneously contributing to the minimisation of system costs. The dispatchability feature is often not taken into consideration in past and present RES-E auctions.

[3] Direct Normal Irradiance, a measure used in solar resource assessment

3 Trends in auction design across the selected case studies

This chapter presents the main trends in auction design across the EU and non-EU case studies prepared under the AURES II project. These are based on the sample of 12 cases and therefore should not be taken as descriptive of all auction schemes in the whole EU.

3.1 Characterisation of auctions in the analysed countries

3.1.1 EU countries

The analysed auction rounds were introduced and organised in the second half of the 2010's except in the Netherlands where the covered rounds started in 2011. Also, the Danish offshore auctions have more than a decade long history before the analysed rounds. Based on the auction schemes covered in the project it seems that auctioning capacity (MW) or energy (MWh) is equally as popular as the auction product. The auction product and the cap or limit of a specific round are closely correlated among the covered countries, whereby a budget or energy volume cap is applied to energy auctions. Hungary and Poland are the exceptions, applying both volume and budget gaps. The UK used a mixture of the two approaches.

Hungary, the Netherlands and Poland organised auction rounds which are inclusive of all renewable based technologies (except offshore wind in the Netherlands which has its own separate auction scheme and Hungary, where the installation of new wind capacities is legally banned). The UK is somewhat unique in its approach by dividing technologies into three groups: mature (e.g. solar, onshore wind), less mature (e.g. offshore wind) and biomass. Portugal is the only country where technology specific auction is limited to exclusively solar power. Denmark, Germany and Greece organise both technology specific and multi-technology rounds.

The timing of the auctions is pre-set by defining the yearly frequency of rounds in most of the cases, with some exceptions, e.g. Hungary, and Poland do not apply any strict calendar. The Danish multi technology rounds are held annually.

Both minimum or maximum size limits can be set as a project eligibility criterion in RES-E auctions. Netherlands and Portugal only apply minimum size requirements. Germany and Hungary set lower and upper boundaries though they are at different stages of development in organising RES-E auctions. In Hungary, the higher upper boundary is aimed to attract higher number of bidders in the scheme. Both countries apply a minimum limit as well. Denmark also applies a cap for solar projects and location based cumulated capacity for offshore wind. In Greece size baskets are defined in the eligibility criteria, which excludes only very specific project sizes (PV under 0.5 MW and onshore wind between 60 kW and 3 MW). Poland does not limit sizes but has baskets for smaller and bigger installations. The UK organises separate rounds for large installations with 5 MW minimum project size.

The support types are also quite diverse across Europe. The sliding feed-in-premium (FIP) is applied in Germany and Netherlands, the two-sided sliding FIP in Hungary, Poland, Denmark (off-shore wind), the United Kingdom and Greece. In these later countries, Contract for Differences (CfD) terminology is used for this form of support. Denmark applies a fixed FIP for the other technologies. Portugal designed an exceptional scheme with two options, the so called 'guaranteed' (fixed tariff) and 'general remuneration' (CfD) schemes, coexist and bidders compete for grid access at specific injection points.

Only Denmark and Netherlands differentiate the duration of support for different technologies, otherwise general support period applies, 20 years for Germany and Greece and 15 years in the other four country cases.

Table 1: Trends in auction design in EU countries

	Denmark	Germany	Greece	Hungary	Netherlands	Poland	Portugal	United Kingdom
Year of first RES-E auction organised	2005 - offshore wind 2016 - PV 2018- tech neutral	2015	2016	2019	2011	2016	2006	2014
Year of first RES-E auction organised under the scheme described in the case-study	2016 - offshore wind 2018- PV, tech neutral	2017	2016	2019	2011	2016	2019	2019 (2015)
Auction product	Capacity (MW): offshore wind Energy (MWh): PV and multi tech.	Capacity (MW)	Capacity (MW)	Energy (MWh)	Energy (MWh)	Energy (MWh)	Capacity/grid access (MW)	Energy (GWh) with budget cap. AR3 had capacity limit as well
Technology focus	Offshore wind, nearshore wind, solar PV	Onshore wind, offshore wind, solar PV, biomass, technology-neural innovations	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	Various technology baskets
Technology differentiation	Technology specific for offshore wind and solar PV, Multi technology for onshore and nearshore wind, and PV	-Technology-specific for onshore wind, offshore wind, solar PV, biomass -Multi-technology and cross border auctions for solar PV and onshore wind	Technology specific by default, one pilot multi-technology round was concluded in 2019	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)
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)

Frequency of auctions (Is there a pre-set auction schedule?)	Multi-technology rounds: yearly Otherwise non specified	Onshore wind and solar PV: 3 rounds per year from 2022 and onwards are planned for each technology. Biomass: two rounds are planned from 2019 Wind offshore: further rounds with smaller capacities are planned from 2021	At least once a year until 2020, overall 13 rounds were held until 2019	2 rounds are planned annually	2 rounds annually with 3 phases (the new scheme is yet uncertain, but planned schedule exists for offshore wind until 2025).	Yearly (without a longer-term schedule)	Not specified	Two-year frequency is intended
Min. / max. size of project	Offshore wind: only cumulated capacity limit 300-1000 MW based on location Solar: Maximum project size of 1 MW Multi tech rounds: no limitation	Wind and PV: over 750 kW. Ground-mounted PV installations up to 10 MW Biomass: min. 150 kW for new installations, max. 20 MW for existing and new Multi tech. auctions: same as above, in certain districts maximum bid size is 20 MW	Eligible project sizes: Onshore wind -up to 60 kW -from 3 MW up to 50 MW - over 50 MW PV -from 0.5 MW to ≤ 20 MW - over 20 MW	Small size category: 0.3 - 0.999 MW, large size category: 1-20 MW (increased to 50 MW in new round)	Minimum project size prescribed by technology, except for onshore wind	Auction was separated into two categories for all technology baskets, in the first projects maximum of 1 MW capacity were able to participate while in the second projects larger than 1MW.	Only minimum requirement, 10 MW for installations connecting for distribution system, and 50 MW for those connecting to the transmission system	Defined separately in every round Minimum project size is 5MW for onshore wind, solar, hydro, etc. in specific baskets
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
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

*Volume cap refers to cap either in capacity or in energy.

3.1.2 Non-EU countries analysed

The analysed auctions in the non-EU countries took place between 2015 and 2017, just like in most of the EU countries. The auctioned product applies capacity limits in Canada and Argentina, energy in Chile, and all countries apply a volume cap for certain rounds. Mexico applies a package of capacity, generation and clean energy certificates as auctioned products capped in each round.

The technology focus is very inclusive in the illustrated countries. Argentina covers 5 renewable based technologies and organises technology specific auctions. In all other countries several or all RES-E technologies are eligible and compete in multi-technology auctions. In Chile fossil fuel technologies are eligible too. In Mexico fossil fuel technology is eligible for capacity auction, while nuclear is eligible for capacity, generation and CELs.

None of these case studies had a precisely defined auction schedule. Mexico prescribes at least one round per year, but in practice this target has not been met. Canada sets overall and interim capacity targets which are indicative of the yearly volumes.

The project size is not limited in Mexico and Chile and Canada defines a 5 MW minimum. Only Argentina prescribes separate size ranges for each eligible technology, which were lowered for biomass and biogas after the first round and for all categories in the third round.

Mexico, Chile and Argentina use PPA contracts as support the winning projects. Mexico supplements PPAs by using hourly and regional adjustment for the energy delivered. In Argentina, a second contract is auctioned, and the Trust Adhesion Agreement provides energy payment and early termination guarantees. Canada defined CfD as form of support.

All countries provide support for 20 years except Mexico where support duration is 15 years for energy and 20 for clean energy certificates.

Table 2: Trends in auction design for non-EU countries

	Mexico	Chile	Alberta (Canada)	Argentina
Year of first RES-E auction organised		2015	2017	2016
Year of first RES-E auction organised under the scheme described in the case-study	2017 (2015 ?)	2015 - changes were introduced for the 2017 auction	2017	2016
Auction product	Packages of capacity, generation and clean energy certificates (CELs)	Energy (MWh)	Capacity (MW)	Capacity (MW)
Technology focus	Multi-technology, Fossil-fuel technologies are also eligible for capacity	All RES-E and also fossil-fuel sources	All RES-E	Wind, PV, Biomass, Biogas, Mini hydro
Technology differentiation	Multi-technology	Multi-technology	Multi-technology	Technology specific
Volume or budget cap	Capacity (1414 MW), generation 6089 GWh/year) and CELs, no budget cap	Volume	Volume	Volume
Frequency	At least yearly	Not specified	Not specified	Not specified

Min. / max. size of project (MW)	no	no	Project size must be at least 5MW	- Wind+PV: 1 -100 - Biomass: 1 – 65; 0.5 – 50 in Round 2 - Biogas: 1 – 15; 0.5 – 10 in Round 2 - Mini Hydro: 0.5 – 20 Round 3: general 500kW-10MW
Form of support auctioned	A total PPA price, with energy price and CEL price, with hourly and regional adjustment	PPA	two-sided CfD	- PPA -Trust Adhesion Agreement
Support duration	15 years for energy and 20 years for CELs	20 years	20 years	20 years

3.2 Design elements defining how bids are awarded

3.2.1 EU case studies

Multi-unit auctions are the most common in the EU, but offshore developments in Denmark and the Netherlands use single unit auctions. There pre-defined size and locations reflect capacities available at existing network connections. Portugal is also an exception, using a very specific auction form with several single item auctions (meaning auctioning injection points) in its 2019 PV auction. Pre-defined locations with given capacities at 24 spots were selected in Portugal, out of which 22 locations had a winning bid.

The static, sealed bid auction procedure was the most common among the case studies, meaning single price and volume (either capacity or energy) based bids were submitted without knowledge of the other bidders' price or iteration between competitors. The UK used a special auction format (reverse) that only started if bids exceeded planned volumes at the pre-stated auction price. If the volume of bids does not exceed the targeted support budget, bidders will receive the administratively determined ceiling price. Greece, the Netherlands and Portugal used dynamic auctions and all, but Greece applied the ascending clock procedure. In the Netherlands phase-specific and technology-specific ceiling prices were used.

Price-only auctions are the most common evaluation method. Poland uses a price based evaluation system which is supplemented by a minimum number of bids per basket requirement is also applied (a maximum of 80% of the submitted bids could win). In the case of Portugal, a special decision criteria is used to calculate the Auctioneer's net present value (NPV) based on the bid prices and assumed reference prices, serving as a common denominator between the two types of bidding procedures. Based on the bid prices and assumed reference prices the NPV of the Auctioneer was calculated and maximised. Although very special in design, the price of the bid serves as the only selection criteria.

Most EU auctions use ceiling prices. The only exception is the Danish offshore wind tender in 2016, where in some locations no ceiling price was applied at all. For the Netherlands and Poland, the ceiling price was differentiated by technology, and Polish ceiling prices were even differentiated within the various auction baskets. In the UK auctions the pre-set strike price functions as the ceiling price. If volume limits are not achieved, this is the strike price for the bidders, and if the volume limit is reached, reverse auction started from the strike price.

Table 3: Design Elements that define how bids are awarded in EU countries

	Denmark – PV and Technology neutral (offshore wind in brackets)	Germany	Greece	Hungary	Netherlands	Poland	Portugal	United Kingdom
Multiple- or single-item	Multi-unit (offshore: several single item auctions)	Multi-unit	Multi-unit	Multi-unit	Multi-unit (wind offshore: single unit)	Multi-unit	Several single item auctions at the same time	Multi-unit
Auction procedure	Static, sealed bid	Static sealed bid	Dynamic	Static (sealed bid)	Dynamic, ascending clock	Static, sealed bid	Dynamic, ascending clock	Static (reverse)
Evaluation criteria	Price only	Price-only	Price-only	Price-only	Price-only	Price based	Special criteria - Auctioneer's NPV	Price based
Pricing rule	Pay-as-bid	Pay-as-bid Exemptions: uniform pricing rule applied in two PV rounds in 2015	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Uniform
Ceiling price	Yes (offshore: not for all tenders)	Yes	Yes	Yes	Yes	Yes, different for different technologies even within the same auction baskets	Yes	Yes

3.2.2 Non-EU case studies

Similar design elements determine how winning bids are awarded in the assessed non-EU countries. Multi-item auctions were applied in all non-EU countries in a static procedure. Mexico, Chile and Alberta (Canada) use the price as the single evaluation criteria, while Argentina follows a multi-criteria evaluation procedure. In Argentina transmission loss was priced in the bid, and for equal bids the integration of local content and other factors were included in the evaluation.

The applied pricing rule was pay-as-bid in all four countries and all of them used ceiling prices. The Mexican auction applied separate ceiling prices for capacity, energy and CELs (the clean energy certificates). Chile applied a unique approach to the ceiling prices: they were not disclosed before the announcement of the winners.

Table 4: Design Elements that define how bids are awarded in non-EU countries

	Mexico	Chile	Alberta (Canada)	Argentina
Multiple- or single-item	multi-product	multi-item	multi-item	multi-item
Auction procedure	static	static	static	static
Evaluation criteria	price only	price only	price only	Multi-criteria evaluation: Main criteria: bid price adjusted for transmission losses. Potential non-price criteria in case of bid price ties: - local content integration, - delivery time, - amount of requested FODER financing, - compliance with documentation requirements.
Pricing rule	pay-as-bid	pay-as-bid	pay-as-bid	pay-as-bid
Ceiling price	yes, separately for capacity, energy and CELs	yes, but they are not disclosed before the announcement of winners	yes	yes

3.3 Design elements facilitating project realisation

Prequalification requirements and penalties are applied in renewable energy auctions to increase the probability of timely project implementation. The next two tables summarise the related auction design elements in the European and non-European countries covered by the AURES II case studies.

Setting material and financial prequalification criteria can result in a pre-selected group of bidders participating in the auction, which, together with the anticipated penalties, can reduce the risks of underbidding, delay, and non-realisation of the awarded projects.

Material prequalification requirements are usually related to the characteristics and status of the project and to the technical and financial capabilities of the project developer. As Table 5 andTable 6 show, titles for land use are required in seven countries, while secured grid connection are claimed in six countries. The aim of setting these conditions is to ensure that the plants will be likely to secure grid connection, receive (or have already received) all necessary permits and licenses, and have the consent of all stakeholders. Financial capabilities are demanded in all non-EU cases, and in Denmark and the Netherlands. The feasibility study was introduced as a qualification requirement in 2014 in the Dutch auction system to improve the inadequate realisation rate of awarded projects.

Financial prequalification criteria can cover two kinds of financial guarantees: bid bonds and realisation bonds (also called second bid bond, completion bond or performance bond). Bid bonds have to be placed before the bidding procedure to ensure that only committed developers enter the auction. Bidders failing to win support usually get back their guarantees after the announcement of the auction results. If a winner refuses to enter into a support contract, the auctioneer retains the bid bond. In case of two-stage guarantee systems, awarded project developers are required to deposit the realisation bond to demonstrate their willingness to build their facilities and to serve as a guarantee for a potential penalty.

Financial guarantees are required in all countries except the UK and SDE+ scheme of the Netherlands. The other countries claim both bid bonds and realisation bonds, although 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 and Mexico. A non-refundable participation fee is required in most countries which also serves as a tool to increase the chances of serious bidding.

The purpose of requiring an environmental permit, building permit or even production license is to ensure that the participating projects are already in a more advanced stage of project implementation, increasing the likelihood of implementation. Therefore, we could expect lower level of financial guarantees in countries setting such conditions, 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. Some countries like Germany, Greece and Argentina demand relatively strict material and high financial prequalification. Setting strict requirements and high penalties might help increasing the realisation rate, but also results in higher risks for project developers. The prospect of sunk costs, losing deposited securities or realising lower than expected remuneration deters developers from entering the auction. In Germany, over 90% of PV projects were realised with less stringent prequalification criteria in technology-specific auctions organised between 2015 and 2017. On the other hand, onshore wind auctions were undersubscribed, as obtaining environmental permits has become difficult due to the resistance of local population. For onshore wind, less stringent material prequalification might increase the number of bidders, but the realisation rate would remain low. The solution has to be provided by other policy instruments of the government as recommended by Sach et al. (2019).

In Poland, 77% of awarded capacity in the 2016 PV/onshore wind auctions for installations below 1 MW were built within the 24 month period available, with delays in projects that likely underbid due to the fierce competition (Diallo et al. 2019). Ensuring timely implementation and compliance with the supply of energy contracted was essential for Argentina to react quickly to the increased electricity demand, justifying the high level of financial guarantees and strict requirement for participation (Menzies et al., 2019)

Countries with relatively lax prequalification criteria (no financial guarantees) include the UK, the Netherlands and Chile. In this later country the financial guarantee is quite small relative to other countries, material prequalification criteria are minimal, and the time for implementation very long, raises concerns about timely implementation (Del Río, Kiefer, 2019). Although stringent prequalification requirements and high penalties can reduce competition and result in undersubscription in a specific auction, the effects of prequalification criteria can only be fully evaluated after the realisation periods (and grace periods), when the relevant national authorities publish information. In case the requirements are easier to meet and the competition is weak, it is more likely that the lack of safeguards results in a low rate of implementation. In the UK, 15 out of 29 projects awarded in the AR1 auction with realisation dates between 2015 and 2019 missed their deadlines and 5 of them were not implemented. Although in 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 5: Design elements related to project realisation, European cases

	Denmark	Germany	Greece	Hungary	Netherlands	Poland	Portugal	United Kingdom
Pre-qualification requirements: material	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	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.	Generation licence Grid connection agreement/offer	Basic information on the company and the plant Grid connection agreement	Environmental and mining permit, feasibility study, geological survey, energy yield calculations, permission of the owner of land. In case of off-shore wind, financing plan and technical details are also required.	Building permit, environmental permit, grid connection agreement, land use plan, schedule of works and expenditures, schematic drawing of the installation	Information on the company and owners. For awarded bidders: land rights, production licence	Grid connection agreement, Planning permission, Supply chain approval (>300 MW)
Pre-qualification requirements: financial	Tech. neutral and PV auctions: retention penalty (completion bond) DKK 170/MWh ~ 75.1 EUR/kW for onshore wind ~ 25.5 EUR/kW for PV ~ 98.3 EUR/kW for off-shore wind Off-shore wind auctions: DKK 100 million (EUR 13.4 million) ~ 79 EUR/kW for nearshore, ~ 22.4 EUR/kW in case of Kriegers Flak	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	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	Bid bond: 1.5% of investment cost. (~11 EUR/kW) Completion bond: 5% (~36 EUR/kW - for PV almost exclusively winning)	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)	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	Bid bond: EUR 10/kW, performance bond: EUR 60/kW	No bid bond /realisation bond

Penalties	Tech neutral and PV: 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.	Onshore wind: From month 24: gradual loss of completion bond, after 30 months award withdrawn 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	If case of late or non-realisation: Cancelled support agreement Withholding of bid and completion bonds Possible cancellation of generation license and/or grid access agreement/offer	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.	Loss of bank guarantee (if it was required). Otherwise, project loses support right and is excluded from the scheme for 3 years.	Cancellation of support if missing the deadline, 3 years ban for participating in another auction, loss of bid bond possible fine for the manager of the energy company	Missing the implementation milestones results in losing different portions of the bid bond.	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.
Realisation period	Off-shore: 48 months, onshore wind and PV: 24 months	Onshore wind: 24 months, PV, biomass: 18 months, Off-shore wind: 18 months after grid connection	PV: 12-18 months, Onshore wind: 24-36 months (depending on size)	36 months	1.5 - 4 years depending on technology, 5 years for off-shore wind	18 months for PV, 30 months for onshore wind, 72 months for offshore wind	30-36 months	~4-5 years, contracts are awarded for delivery time

Note: The Euro values of financial guarantees per kW are taken from the related case studies and are approximate values used only for the purpose of comparison.

Table 6: Design elements related to project realisation, non-European cases

	Mexico	Chile	Canada	Argentina
Pre-qualification requirements: material	Experience, evidence of being a service provider, obtaining financing for similar projects. Identifying potential sites, and relevant documentation (resource assessment, grid connection).	Minimum credit rating requirements, specific-purpose company formed, basic information on the projects.	Proof of financial viability, technical capability, experience, land rights, Equity of at least 25 % by indigenous people for min. three years.	Proof of a minimum of USD 250,000 equity/MW authorisation for wholesale market operations, availability of resource, legal titles for resource and land use.
Pre-qualification requirements: financial	Bid bond: Deposit of ~USD 93,000 plus ~USD 20.15/kW of capacity offered, ~USD 9,3/MWh of electricity offered, and ~USD 4.6/CEL if offering certificates. Performance bond: same amount except the fixed part, it can be halved in case of early grid connection	Bid bond: ~USD 87.4/MWh, plus ~ USD 3.7/MWh if the generator is not registered in Chile. Performance bond: ~ USD 26.4/MWh. Additionally, to cover possible third-party damages insurance of up to USD 3 million.	Participation fee, Completion guarantee: CAD 50,000/MW (USD 37.675/kW)	Participation fee, Bid bond USD 35/kW Performance bond USD 250/kW
Penalties	Withholding bid bond or increasing performance guarantee, and reduced payments for energy or CELs	The performance bond is lost if supply commitments are not met. In case of non-delivery, projects have to settle the difference to spot market prices. In case the production milestones are not achieved, a fine is charged (~USD 1.1/MWh)	Support period shortened for each day of delay. 18 months after the targeted deadline, support is terminated, and the financial guarantee is lost.	Economic penalty for a delayed start. A production deficit (<10%) may be carried over to the next period. Greater deficits lead to a fine (USD 160/ MWh).
Realisation period	3 to 5 years	6 years	24 months (round1) 30 months (rounds 2 and 3)	max. 730 days, part of bidding process

Note: The USD values of financial guarantees are taken from the related case studies and are approximate values used only for the purpose of comparison.

Delayed implementation or non-completion is usually penalised by a reduction of awarded support after passing the deadline (off-shore in Denmark, PV in Germany, Mexico) or reducing the support period, which can be accompanied by a gradual loss of the completion bond. After a predetermined grace period the award right is lost. Completion bonds are confiscated, either staggered (e.g. Denmark, Germany, Portugal) or one sum (e.g. in Greece, Hungary, Poland, Chile). The level of penalty also varies, in some countries there is opportunity to finish the projects even after a significant delay, while in other countries the high penalty level provides a strong incentive to complete projects and supply the contracted electricity in a timely manner.

In Germany, some project developers gaining lower support in the highly competitive onshore 2017 auctions have reconsidered their project implementation and abandoned their projects despite the penalties to re-enter more recent auctions where the participation rate is substantially lower and prices are much higher (Sach et al., 2019).

The length of the realisation period also affects the chances of project realisation. If it is too short, investors might be afraid to lose their financial guarantees and right to support, while long realisation periods can incentivise underbidding if investors count on technology cost reductions, which might ultimately lead to non-realisation. It is also possible that market conditions change during the long time period, (e.g. construction costs increase or market prices rise above bidding price in case of two-sided premium) changing the economics of the project and leading to its abandonment if other, more profitable, investment opportunities are available.

Deadlines can be the same for all kinds of plants or vary by technology (e.g. in Germany, Greece, Poland, Netherlands). Adjusting the deadlines to reflect the time required for bringing different kinds of renewable plants to come on-line provides a more level playing field, especially in case of multi-technology auctions. In the analysed countries, the shortest completion time-period was 12 months for smaller plants in Greece 18 months for larger plants in Greece, Germany and Poland. The shorter time periods were reached because projects were required to enter the auction in an advanced phase (i.e. having building permits or generation license). In the UK and Argentina, the realisation period was part of the bidding process, resulting in shorter than the maximum two years available in Argentina for some projects, but quite long realisation periods in the UK. Project developers have also quite a long time, 3-5 years in Mexico, and six years in Chile to commission their plants.

4 Assessment of the European auctions

4.1 Policy effectiveness

Policy effectiveness is measured in two dimensions. The first looks at the proportion of contracted volume compared to the volume of energy or capacity offered in the auction. Support for the targeted volume contracted in a specific auction is considered effective. If the auction did not manage to cover the full targeted volume, it can indicate shortcomings either related to the auction design or other elements determining the auction performance, e.g. the wholesale electricity price trend, the ceiling price, the availability of suitable sites, or free network connections. The second assessed dimension is the realisation rate of the winning projects, looking at the share of awarded projects completed on time. One would expect more information to be available on project realisation in 2020 than 2016, but in fact information is still limited and only few countries report reliable numbers in a timely manner on project realisation.

Concerning the volume of contracting the desired capacity (measured as awarded volume/auctioned volume), we can observe a mixed picture of the covered European auctions. The main results are summarised in
Table 7.

Table 7: Minimum, avarege and maximum ratios of the offered and submitted volume/budget (whichever is relevant) in the analyised case 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: AURES II auction database[4] and relevant AURES II case studies

In Denmark, most auctions were realised with success, based on available data about the offshore wind auctions, and the small sized PV tender. The exception is the Rødsand2 tender, where the original winner

[4] http://aures2project.eu/auction-database/

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.

Germany also presents a mixed picture. In most of the PV auctions rounds the intended volume to be awarded were achieved (even over-achieved a bit, due to the fact that the last accepted bids had a bit higher capacity than targeted). Similarly, the four multi-technology auctions had more than 100% coverage rate by the winning bids. But for the onshore wind except for the first couple of auctions undersubscription is common on average 71% of the offered amount were auctioned between 2017-2020 but there was an auction where this ratio was only 30%. With low interest from developers, onshore wind prices have been at the ceiling since 2018. Similarly, for the four biomass auctions only 34% of the planned capacities have been awarded. 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 the lawsuits against onshore wind projects realised in the preceding period also reduced the interest of developers.

More than 96% of the auctioned volume was awarded across the six rounds (13 technology basket rounds) in Greece between 2016 and 2019 if volume reduction is considered. The July 2018 offshore wind and August 2019 multi-technology tenders had 96% coverage rates, compared to 98-99% volume in others (calculated as awarded volume/auctioned volume). 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 intention to participate in the first phase (with volumes indicated and pre-qualifications fulfilled). If the intended volume is above the targeted volume by more than 40% the target is not reduced, otherwise it will be 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 one auction round in 2019, where almost the full capacity of the two size groups was awarded. Although not finalised yet, in its second auction the oversubscription ratio is above 5, so probably the recent auction will be fully covered as well.

In the Dutch SDE+ auctions the full available budgets were auctioned up till 2017. However, in 2018 and 2019, the auctioned support fell short of the available budget. Even with the significant increase in the yearly auction budget from EUR 1.7 billion to EUR 6 billion between 2011 and 2018, the scheme failed to bring sufficient RES-E producers to the Dutch market to achieve the country's 2020 target, therefore many experts evaluate the available budget as insufficient.

In Poland, there were various baskets of technologies in the three auction rounds in the period 2016-2018. In 2018, the larger sized PV and wind categories, the full targeted volume was contracted at a very competitive price (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. In the new projects baskets (6 baskets with mixed biomass, hydro, geothermal and offshore wind technologies) moderate or low level of targeted volumes were contracted, with biomass and non-agricultural biogas achieving higher participation. In the so-called migrating auctions, where projects were allowed to move from the former green certificate system to the premium system, participation rates were low. Only two out of the nine technology baskets had awarded volumes (hydro and biogas categories) and the rest awarded zero bids due to insufficient interest.

In Portugal, the 2019 auction round was very successful: out of the 22 slots, only two did not have winning bids and 82% of the offered capacities at the available sites were covered at very competitive prices.

In 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. In the later auctions capacity limits were introduced, and the third round (2019) awarded 5.7 GW out of the 6 GW target.

It seems most **post-2016 EU auction case studies were successful at covering significant part of the targeted volumes, though varying by technology**. In case when the auction targets technologies other than PV or wind, e.g. **biomass, biogas or geothermal, there were shortcomings that could require special auction design**.

Concerning the other dimension – the realisation rates – it shows a mixed picture. Even in those countries where auction started early, **we can see limited availability of numbers on the realisation rates, with few**

countries reporting these numbers regularly.

In Denmark, the Kriegers Flak offshore development is on time with construction but there is no information available on the status of realisation for the other tenders.

Germany regularly publishes its realisation rates. PV realisation rates are high for the pre-2018 tenders, with the lowest rate being 90%, and most above 97%. In opposite, realisation rates for onshore wind is difficult to assess as the realisation periods for projects have not yet passed.

In Greece the first 2016 pilot tenders and first round of the 2018 tender show realisation rates between 90% and 100%.

Hungary, Poland and Portugal have not reached yet the end of their realisation periods.

In the Netherlands, there were high non-realisation rates in the early auctions, while the introduction of a mandatory feasibility study led to higher realisation rates from 2014. However, of the early tenders from 2014-2015, 25-35% of the projects are still in the development phase and 5-10% have been withdrawn.

In the UK, PV and wind projects have been delayed for several reasons, but most of them are in the development phase of the first two rounds of auctions. It is too early to assess 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.

In summary, **we are still not able to draw any solid conclusions regarding in 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**. It would be particularly useful to see whether delays are caused by external factors, outside the auction design, or if some of the design elements need to be reconsidered. Thus, **governments should place higher priority and effort on tracking and reporting realisation rates** (reliable realisation rate information is available for five EU countries in the AURES database.)

4.2 Static efficiency

Static efficiency is achieved if a predetermined target can be fulfilled at the lowest possible overall cost. It difficult to estimate the lowest possible cost, with factors beyond the auction design like market prices, balancing and system integration costs, forecast obligations can influence auction bid prices. This section examines whether auctions lead to lower prices over time compared to previous support levels, treating this as “efficiency gains”, mainly triggered by the reducing technology costs. **Several EU case studies 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 Germany in the case of onshore wind and the Netherlands in 2018/2019 price were flat or even increasing. Another common trend was in many countries starting RES-E auctioning after 2016 to experience significant price drops in their initial auctions (e.g. Greece, Hungary, UK) compared to the previous, administratively set support levels.

In Denmark auction prices fell in offshore wind auctions between 2015 and 2016 more than 40%. The country introduced a new multi-technology auction format in 2018 and 2019 from technology specific sliding premium to fixed premium, where the fixed premium levels in the 2019 multi-technology auctions were well below the 2018 levels in all categories including onshore wind and PV technology.

Since German PV prices bottomed out in February 2018 at an average of 43.3 EUR/MWh, prices have risen slightly with more frequent and higher volume auction rounds, as the higher demanded quantity reduced the competition levels and consequently included more costly projects. In the technology specific wind auctions prices have been rising from 2017 and plateauing from August 2018 just above 60EUR/MWh (i.e. the ceiling price). With less competition (bid quantity below the targeted volume) prices converged at the ceiling. There is not a clear trend in the biomass auctions with only four rounds organised. Similarly, there were only four rounds of the multi-technology auctions, where prices followed the moderate growth trend of the single technology PV auctions in 2018 and 2019.

Since its 2016 pilot auction, Greece organised several wind and PV auctions with various size categories including multi-technology one. The 2018 - 2019 auctions achieved much lower prices than the pilot or the first rounds of auctions in July 2018. The July 2018 auction price levels were between 63.8 - 78.4 EUR/MWh compared to later auctions at 57 – 67 EUR/MWh. However, it is difficult to identify clear trends for the various technologies as many design elements changed between the auction rounds for small and large PV.

In Hungary the first auction round results show significant savings (23 - 32 EUR/MWh) from the previous FIT tariff scheme, which was above 100 EUR/MWh. Even for the delayed FIT based projects where project realisation time was extended till end of 2021, project developers are still eligible for the high prices FIT level. The ongoing second auction will achieve additional savings as the bid prices indicate.

In the Netherlands, PV has been the price setting technology with support levels dropping since 2016. This is true for most technologies from 2017 onwards. Support levels were mostly determined by one price-setting technology, 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 Poland cost efficiency is difficult to analyse since it moved from a green certificate system to auctions. The three auctions with smaller sized PV and wind had a rather stable average price around 85 EUR/MWh between 2016-2018 that has fallen more recently.

The 2019 Portugal PV auction achieved very competitive price levels, at that time the lowest in the world. It has to be noted however, that PV developers had limited chance to get license to the Portuguese power system since 2016, which resulted in a very aggressive bidding strategy in the auction.

In the UK the first two auction rounds achieved lower prices compared to the previous support system of bilateral contract prices (FIDeR). It is difficult to make any assessment of the resulting prices since many rules have changed between the rounds.

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. 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).

Smaller plants can compete for a separate budget/supported volume in Hungary, Greece, and Poland. In 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 3MW – 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 Denmark, small plants are not treated preferentially in the auctions, although in 2018 a special auction round was organised for PV plants below 1 MW. In the Netherlands, no explicit size differentiation is in place, but different ceiling prices are set in the SDE+ auctions according to technology and size, providing opportunity to smaller installations to gain support.

Local communities are encouraged to participate through preferential treatment in the RES-E auctions of Canada, Denmark and Germany. In Canada, one of the prequalification requirements in the second round was ensuring 25% of equity ownership by indigenous people, which had to be maintained at least for 3 years (Menzies, Marquardt, 2019). In Denmark, a compensation scheme is ensured for citizens if the value of their properties decrease due 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 a at least 20% of the ownership shares of wind projects to local residents (González, 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 bond, 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. 2018)

Argentina, Mexico, Chile, UK and Portugal do not have special design elements for encouraging actor diversity.

4.4 Dynamic efficiency

Auctions ensure dynamic efficiency if they contribute to the improvement and cost reduction of immature technologies that strengthens their deployment over time. As most countries aim to reach their renewable energy targets at the lowest possible cost, and **many technologies have already reached a high deployment level, only moderate price decrease could be observed in case of PV and onshore wind in mature markets already concluding several auctions**, 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). Higher cost technologies are allowed to compete in separate baskets in some countries, e.g. biomass, biogas or geothermal plants in UK or Poland, although they cannot be considered immature either, and do not have substantial cost decreasing 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.**

As regards less established technologies, **some auction schemes started to offer support to storage combined with weather-dependent renewable technologies** (in Portugal 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 wide cost range for CSP technology in the auctions indicate significant potential with the right support mechanism and learning to push cost reductions in the future.

5 Lessons learned from international experiences

A wider range of EU countries apply the auction tool since the last AURES case study assessment of 2016. By 2020 Central Eastern Europe (CEE), Baltic countries, Ireland, Portugal and Greece began using auctions to select new renewable producers to enter their electricity systems. Of those that did not, Austria is already in the planning phase and Slovakia cancelled its first RES auction due to the COVID19 pandemic.

As a general pattern, we can observe a clear learning effect amongst the European countries. Newcomers to the RES-E auctions apply similar design elements in their RES-E auctions that were used successfully in other countries. Core design elements are:

- Application of two stage bonds (bid and realisation bonds) to increase realisation rates of winning projects
- Multi-unit auction;
- Static auction procedure, meaning a single sealed bid is used without interaction between bidders;
- Pay-as-bid selection criteria, uniform pricing is applied only in the UK and was tested in two German PV auction rounds
- Bid price as the single decision criteria and a pre-determined ceiling price;
- 15 to 20 year support period

The UK, Poland and Hungary are good examples of the design learning effect, applying both budget and volume cap to limit the maximum support spending on renewables. Similarly, the UK and Poland group various technologies in the same basket. Hungary, Poland and Greece apply distinct baskets by size, allowing smaller sized installations to compete in separate budget or volume thresholds.

Countries, however, are split between applying volume or capacity limits. The form of support is generally floating premium, but there is also divergence on one-sided or two-sided premiums. Similarly, countries follow various approaches in applying pre-qualification criteria, mainly shaped by the legal and regulatory framework governing new power generation capacities. There is some trade-off between financial and material pre-qualifications and varying level of bid-bond and performance bond levels.

CEE is catching up. Slovenia, Poland and Hungary had more rounds of auctions by 2020, Croatia started its auction and Slovakia will reschedule. Austria is already well advanced in its auction design after a public consultation procedure started in September 2020.

Technology focus

We can observe a changing pattern in the technology focus of renewable auctions, although we probably cannot judge it as a clear, straightforward trend. Many first auctions in the leading countries were technology specific auctions, e.g. in Denmark and Germany. Even if more technologies were involved, they competed in separate auction rounds. This was due to the diverging conditions and characteristics of the various technologies (e.g. required lead time, varying investment costs or production pattern) it was easier to design an auction for a single technology. Due to the fact that the levelised cost of PV and wind technologies converged to a similar range (IRENA 2019), multiple-technology auctions could be tested with PV and wind developers competing for the same volume or budgetary cap. These auctions took place in many countries in the course of 2018-2020, e.g. in Germany, Denmark and Greece. While Poland and Hungary organised technology-neutral auctions, this neutrality was not fully ensured. Poland uses a series of multi-technology baskets, where mainly two technologies compete within a basket, while Hungary banned wind by other national regulations. Therefore, in practice, full technology neutrality was not achieved in these auctions. They might have been introduced to meet the requirements of the state-aid decisions related to the support schemes. It is difficult to organise a fair, fully technology neutral auction. Even if two technologies have a similar LCOE cost range varying construction lead times and differing production patterns (and consequently different reference price) can lead to distortion in auctions, where one or the other technology will be disadvantaged. This is also shown in the auction results, where in many cases (Hungary, Poland, Germany) a dominant technology took the majority of the auction volume. The Dutch auction system was the closest to neutrality, as even renewable heat was included in the technology mix. A separate AURES II study will seek to determine if it is the EC State Aid decision or the national initiatives that drives the multi-technology process.

General price trends:

It is **difficult to observe any clear price trends in the renewable auctions since given the design and technology focus of the auctions prices are hardly comparable**. Even if we look at auctions organised within the same countries and for the same technologies, the trend is still ambiguous. German PV auction prices fell from 2016 - early 2018, but since then prices stagnated or even increased. The Germany case study showed a close correlation between the level of competition (oversubscription rate: 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 reaching the ceiling from the middle of 2018.

A good indicator for whether auctions follow LCOE reductions better than other support schemes (e.g. FITs) is the price difference following the change of the schemes. **Prices dropped significantly in many countries (Germany, Greece, Poland, Hungary) which indicates the effectiveness of more competitive RES-E auctions over the previous support schemes.** In three out of four case studies where this information was available (UK, Greece, Hungary) the RES premium required decreased compared to the previous support scheme. In CEE, RES-E auctions already brought significant price reductions compared to the previous administrative FIT levels, but margins between the Polish, Hungarian and German auction prices remain significant. It remains to be seen if CEE will follow the trend of falling prices over time, as observed in countries with more mature RES-E auctions with several rounds. The ongoing Hungarian second round indicates this reducing trend, although some elements in design might have also contributed (e.g. increasing the max allowable size).

5.1 New developments

Accumulation of projects in the pipeline

In some of the case studies 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 to participate in the auctions** (‚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 fixed/sliding renumeration for 1400 MW provided a new opportunity for developers, resulting in a 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 of 1.5 and 2 and lower prices in the size category over 1 MW. The wind auction for projects above 1 MW in Poland was affected by regulation severely restricting the development of onshore wind plants (so called Distance Act) and the release of the draft Energy Strategy projecting a minor role for onshore wind technology in the future power mix of the country. 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 a very low price of 46 EUR/MWh for the CEE region (Diallo et al. 2019).

Replacing small-size FIT, FIP scheme with auctions

Size differentiation is one tool for auctions to increase the chances of participation for smaller RES-E plants and thus increase actor diversity. In some cases, small-size auction categories also serve as the support allocation mechanism instead of administrative FIT and FIP schemes for small installations (below 0.5 and 1 MW, respectively). It has to be mentioned here, that the State Aid guidelines does not require the auction process for projects below 1 MW size. Poland has two size categories above and below 1 MW. The Polish system transited from a green certificate system to auctioning RES-E support, and does not have a new administrative support scheme for small projects. In Hungary, the support scheme introduced in 2017 provided the possibility to apply for administrative FIT and FIP, but budgets were absorbed in a very short period of time owing to high demand. To provide an opportunity for small installations, plants with a capacity between 0.3 and 1 MW can compete in a small size category in the national auction. The Greek support scheme provides FIT/FIP to PV projects smaller than 0.5 MW and onshore wind under 3 MW, although the former is also allowed to participate in the auctions. PV plants between 0.5 and 1 MW are obliged to compete for support. In the Netherlands, small installations (0.15 - 1 MW) have a special ceiling price that increases their chances to gain support in the auction. In Germany, RES-E plants are obliged to participate in auctions over 0.75 MW capacity.

Scarcity of site and grid injection points

Although difficulties in securing proper sites and grid connection points for RES-E plants has 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 densely occupied network or outside, in the so called 'Distribution Network Expansion Areas'. In Argentina, limited electricity transmission capacities have caused delays in the next auction expected to be linked to private sector financed transmission network expansions (although no specific details are available yet) (Menzies et al. 2019).

5.2 New directions

Auctioning carbon mitigation in the Netherlands

The Dutch SDE + support scheme ended in the spring of 2020, to be replaced by a new scheme in 2020 called SDE++supporting greenhouse gas (GHG) emission mitigation instead of renewable generation. The **new scheme will provide contracts for differences for projects that can mitigate GHG emission at the lowest cost. SDE++ will extend the support scheme to technologies beyond renewable energy generation**. Although renewable heat is already included in the system, **renewable gas production and other carbon-reducing technologies will also be eligible for support, such as the production of hydrogen through electrolysis and carbon capture and storage (CCS)** decreasing industrial emissions. The goal of the scheme is to achieve the 49% GHG emission target of the Netherlands by 2030 (compared to 1990). With the different technologies competing for the same budget, the strike prices of renewable projects will have to be expressed in EUR/ton CO2eq avoided, requiring the development of specific price calculating methodologies for each technology.

Innovation auctions in Germany

Germany has recently started to organise so called **'Innovation auctions' asking for projects bids combining weather-dependent renewable sources with facilities providing flexibility services** (e.g. biomass plant or storage). The fixed premium auction attracted 1095 MW capacity bids for 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 provides incentive for the combined facilities to optimise their electricity supply taking into account real electricity prices.**

6 Summary

The report provides a synthesis of the findings of the country case studies presenting the renewable auction schemes of ten EU and four non-EU countries prepared under the AURES II project. The most important findings of the report are the following:

- A wider range of EU countries launched and apply auction schemes since the last AURES case study assessment of 2016. By 2020 Central Eastern Europe (CEE), Baltic countries, Ireland, Portugal and Greece began using auctions.
- A clear learning effect can be observed amongst the European countries regarding the employment of design elements that were successfully applied previously. The most often shared features include the application of two stage bid bonds, the use of static, single sealed bid auction procedure with pay-as-bid selection criteria, setting pre-determined ceiling prices and support periods of 15 to 20 years.
- On the other hand, countries are split between applying volume or capacity limits. The form of support is generally floating premium, but there is divergence on one-sided or two-sided premiums. Similarly, countries follow various approaches in applying pre-qualification criteria, mainly shaped by the legal and regulatory framework governing new power generation capacities and the required level of stringency.
- Renewable auctions are gradually shifting from technology specific auctions to multiple-technology auctions. Although required by the relevant EU state aid regulation, ensuring technology neutrality is hard to accomplish even if two technologies have a similar LCOE cost range, as varying construction lead times and differing production patterns (and consequently different reference price) can lead to distortion in auctions, where one or the other technology will be disadvantaged.
- The effectiveness of competitive support allocation is reflected in the significant price drops relative to the FIT levels of previous support schemes. However, it is difficult to observe any clear price trends in the auctions since the varying technology focus and other design features make them hardly comparable. After initially falling prices, support levels might stagnate or even increase in countries with higher penetration rates (e.g., in Germany).
- In some cases, the fall in auction prices can be partially explained by the accumulation of numerous projects ‘in the pipeline’, which can be a result of long periods without opportunity for developers to access support, or the upcoming introduction of restrictive measures affecting some technologies (‚last chance to go’, e.g., in Portugal, Poland and Hungary).
- Creating small-size auction categories in auctions can serve as an alternative to administrative FIT and FIP schemes for small installations (below 0.5 and 1 MW, respectively), extending the scope of competitive bidding and increasing actor variety, as implemented in some EU countries (Poland, Hungary, Greece, Germany, Netherlands).
- 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.
- Recently, some new, innovative directions in auction design emerged in the EU. In addition to renewable electricity development, the auctioning of carbon mitigation solutions in the Netherlands (SDE++) provides opportunity to renewable heat, renewable gas, as well as carbon capture and storage (CCS) projects. Innovation auctions in Germany invite projects combining weather-dependent renewable sources with facilities providing flexibility services (e.g., biomass plant or storage).

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

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