



## Policy relevant lessons from research on renewable energy auctions

Vasilios Anatolitis <sup>a,1</sup>, Pablo del Río <sup>b,\*</sup>, Lena Kitzing <sup>c</sup>, Oscar Fitch-Roy <sup>d</sup>, László Szabó <sup>e</sup>

<sup>a</sup> Fraunhofer Institute for Systems and Innovation Research ISI, Breslauer Str. 48, 76139, Karlsruhe, Germany

<sup>b</sup> Institute for Public Policies and Goods (IPP), Consejo Superior de Investigaciones Científicas (CSIC), C/Albasanz 26, 28037, Madrid, Spain

<sup>c</sup> Technical University of Denmark, Department of Wind and Energy Systems, Roskilde, Denmark

<sup>d</sup> Faculty of Environment, Science and Economy, University of Exeter, Penryn Campus, Penryn, Cornwall, TR10 9FE, United Kingdom

<sup>e</sup> Regional Centre for Energy Policy Research, Corvinus University of Budapest, Budapest, Hungary

### ARTICLE INFO

#### Keywords:

Auction  
Tenders  
Renewable energy  
Efficiency  
Effectiveness

### ABSTRACT

Renewable energy auctions have emerged globally as a primary tool for promoting electricity from renewable energy sources (RES-E) by awarding operational support to projects that bid the lowest level of required support. While their widespread adoption reflects perceived efficiency advantages over other support mechanisms, such as administratively-set tariffs, the effectiveness of RES-E auctions in meeting policy objectives is highly sensitive to specific design elements. This paper synthesizes policy-relevant insights from extensive research in the EU-funded AURES II project, which has analysed renewable energy auctions in diverse contexts with a focus on European countries. Key findings from the AURES II project address how auction design influences outcomes across multiple criteria, such as cost-effectiveness and project realisation rates. The paper highlights both successes and challenges in auction implementation, emphasizing the common trade-offs between policy objectives. Results underscore that well-designed auctions can promote RES-E efficiently, but also caution that suboptimal design can lead to unintended outcomes. Based on these findings, the paper offers forward-looking recommendations to guide policymakers in optimizing auction design to balance policy goals and enhance renewable energy deployment.

### 1. Introduction

Renewable energy auctions are best understood as novel sub-category of procurement auctions, where bidders compete for a form of financial derivative rather than for the physical sale of their energy production. These auctions typically result in an agreement that modifies the effective sales price of renewable electricity and re-allocates certain risks, rather than transferring ownership of the energy.<sup>2</sup> Structurally, the process resembles a buyer-seller relationship between a public agency (buyer) and private project developers (sellers). A public agency offers a specific capacity or energy quantity (in MW or MWh) for bidding, with project developers proposing the minimum price at which

they can supply part or all of this capacity/energy quantity. Bids are then ranked in ascending order of price, and the lowest bids within a set budget or capacity are selected. Winners secure favourable offtake terms for their energy production—often, but not always, in the form of enhanced pricing—over a specified period (Mora et al., 2017).

Globally, auctions have become the dominant method for supporting investment in electricity from renewable energy sources (RES-E) projects. By 2021, 131 countries had adopted RES-E auctions, up from just six in 2005 (REN21, 2022). The main alternative remains administratively-set remuneration via feed-in tariffs (FIT) or feed-in premiums (FIP), implemented in 92 countries in 2021 (REN21, 2022).<sup>3</sup> Auctions' popularity is largely attributed to their perceived efficiency,

\* Corresponding author.

E-mail address: [pablo.delrio@csic.es](mailto:pablo.delrio@csic.es) (P. Río).

<sup>1</sup> Present address: International Energy Agency, 9 rue de la Fédération, 75739 Paris, Cedex 15, France. Contributions to this paper were completed before joining the IEA, and therefore this paper does not necessarily reflect the views of the IEA Secretariat nor of its individual member countries.

<sup>2</sup> Auctions tend to complement rather than replace the need to sell physical output through contracting or trading.

<sup>3</sup> Note that the remuneration in FITs and FIPs can be set either administratively or through auctions. Administratively-set remuneration refers to the level of support being set by an administrative authority. Thus, although the literature often opposes FIT/FIPs to auctions, this is not correct. In this article we distinguish between administratively-set FITs and FIPs (ASFIT/FIPs) and auctions. On the other hand, while in the global North the alternative to auctions are ASFIT/FIPs, for many other countries (especially in the global South), unsolicited bids resolved through direct negotiation, and not ASFITs, have been the alternative to auctions.

lower costs for RES-E support, and ability to manage the pace of renewable energy growth more effectively than options like ASFIT/FIPs (IRENA, 2019; del Río and Kiefer, 2023). This rapid adoption has spurred extensive academic and policy research, notably within the EU-funded AURES and AURES II projects.

This policy perspective aims to present key policy lessons derived from research on renewable energy auctions conducted during the AURES II project.<sup>4</sup> The project set out to address several critical policy questions concerning the operation and design of renewable energy auctions. Research spanned multiple thematic workstreams, each focused on analysing both past and current auction performance with a forward-looking, policy-oriented approach. The overarching goal was to offer recommendations that could inform future auction design. Findings indicate that the effectiveness of auctions in achieving policy objectives is highly dependent on specific design choices, with frequent trade-offs between different policy goals and auction elements.

This policy perspective is structured as follows. The next section briefly describes the methods used in the project. The main results on key lessons from research on RES-E auctions are discussed in Section 3. Section 4 concludes and provides policy recommendations.

## 2. Methods

Due to the character of the different research questions and data availability, different methods were used. Methods included case study research, other type of qualitative research, econometric analysis and use of energy models (Table 1 and Appendix 1).

A comprehensive overview of the studies (see Appendix 1) provides insights on their temporal, geographical and technological scope, as well as the data that they used. Most research focuses on the period 2018–2021, although some country case studies refer to RES-E auctions conducted before. In some papers, the temporal scope is undefined, or at least not explicit, because the analysis performed is a generic one (i.e., conceptual/analytical). In addition, some studies provide a forward-looking perspective, with scenarios for 2030 and 2050. An overwhelming majority of them focus on European countries. However, some case studies refer to non-European countries, whether in America

**Table 1**  
Themes, policy lessons and methods of research on renewable energy auctions.

Theme (policy lessons)	Methods
Efficiency and effectiveness of individual countries' auction schemes	Case study research
Impact of auction design elements on awarded prices in auctions (support cost efficiency)	Econometric analysis
Policy objectives and auction design	Qualitative research Qualitative comparative analysis (QCA)
Effects of auctions on supply chains and technological innovation	Qualitative research
Effects of auctions on RES communities	Case study research
Cost of capital	Econometric analysis
Design of cross-border auctions	Conceptual study (auction theory), modelling (Cash-flow) modelling
Design of multi-technology auctions	Qualitative research, modelling
Future of auctions	Qualitative research, modelling

Note: See Appendix 1 for further details.

<sup>4</sup> AURES II has sought to not only generate new, timely insights regarding auctions for renewable energy support, but also disseminate them amongst policymakers and other practitioners and build their capacity to implement effective, cost-efficient auctions. Reports from this project with the findings on which this paper is based are available at the project website <http://aures2project.eu/> and on <https://cordis.europa.eu/project/id/817619/results>.

(Chile, Alberta (Canada), Mexico, Peru and Argentina), Africa (South Africa and Morocco), Asia (concentrated solar power (CSP) auctions in Dubai, Abu Dhabi and India), or Australia (CSP auctions in South Australia). Some contributions are generic analysis whose implications transcend European boundaries. The studies most often pay attention to two renewable energy technologies (wind and solar PV), although some of them refer to all renewable energy technologies. The data used for the empirical studies come either from official sources, the AURES II database (AURES II, 2022) or surveys or interviews to relevant actors (investors, manufacturers and other stakeholders). In addition, some contributions are mostly theoretical (and draw on auction theory or other relevant approaches).

## 3. Results: key lessons from research in renewable energy auctions

### 3.1. Both convergence and divergence in auction design can be observed. There isn't a one-suits-all auction design

Auctions have a high degree of flexibility in their design, reflecting national goals and context conditions. This makes it difficult to recommend a single “best design”. Table 2 summarises the main design

**Table 2**  
Key auction design elements in the various EU Member States.

Auction design element	Type	Number of auctions	Countries
<b>Static/Dynamic</b>	Static	416	Majority
	Dynamic	18	EL, PT
<b>Single Unit/Multi Unit</b>	Single Unit	20	DK, FR, NL
	Multi Unit	414	Majority
<b>Location</b>	Pre-defined	23	DK, FR, ND, PT
	Free selection/na	411	Majority
<b>Technology</b>	Technology neutral	121	FR, DE, PT
	PV or Onshore wind	313	Majority
<b>Cross Border auctions</b>	Budget	2	DK, DE
	Auctioned product	44	DK, NL, SL, U.K.
	Electricity	32	EE, FI, HU, IE, LT, PL
	Capacity	358	HR, DK, FR, DE, EL, IT, LT, LU, MT, NL, PT, ES
	<b>Duration of Support</b>	Below 15 years	32
15 years		73	HU, IE, LU, ND, PL, SL, U.K.
	Above 15 years	296	DK, FR, DE, EL, IT, MT, ES
	<b>Financial prequalification applied</b>	Yes	377
no		57	DK, LT, NL, SL, U.K.
<b>Material prequalification applied</b>	yes	415	Majority
	no	19	DK, DE, PT, ES
<b>Award procedure</b>	Multi-criteria	156	FR, IT, NL
	Price only	278	Majority
<b>Remuneration scheme</b>	FIT	75	HR, FR, LT
	One sided FIP	123	DE, HR, IT, LU, MT, SL
	Fixed FIP	30	DK, FR, DE, PT
	CFD	173	DK, FR, EL, HU, IE, IT, PL, ES, U.K.
	other (investment grant, hybrid)	33	FI, LT, NL, PT, ES

Source: AURES II database. [aures2project.eu/auction-database/](http://aures2project.eu/auction-database/) and <https://data.mendeley.com/datasets/2h9jpy3wx/1>. AT = Austria, BE=Belgium, BG=Bulgaria, CY=Cyprus, CZ=Czechia, DE = Germany, DK = Denmark, EE = Estonia, EL = Greece, ES=Spain, FI=Finland, FR=France, HR=Croatia, HU=Hungary, IE=Ireland, IT=Italy, LT = Lithuania, LU=Luxembourg, LV=Latvia, MT = Malta, NL=Netherlands, PL=Poland, PT=Portugal, RO=Romania, SE=Sweden, SI=Slovenia, SK=Slovakia, U.K. = United Kingdom.

features of European RES-E auctions based on the AURES II project auction database. It includes data on 434 auctions concluded between 2011 and 2021, where auctions split into various sub-baskets are accounted for separately.

Table 2 shows that the majority of European Member States (MSs) (above 75 %) conducting auctions applied similar design elements with respect to the following choices: static/dynamic, single unit/multiple units, location, and financial and material prequalification requirements. In contrast, the choice of other design elements was more mixed across countries. In addition, Table 2 also indicates that some countries experimented with different designs between 2011 and 2021 (Denmark, Germany, the Netherlands, Portugal and Spain).

In the analysis carried out in Szabó et al. (2020), convergence of many design elements can be observed in European countries already applying RES-E auctions. The common elements include pay-as-bid, static and multi-unit auctions, with an average 15–20 years of support and price as the main award criterion. Another common feature 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, such as in Germany (Sach et al., 2019) and Portugal, still operate technology-specific auctions. New auctions tend to be multi-technology auctions, where different technologies compete against each other. In general, the two-sided sliding feed-in premium (FIP) schemes (or Contracts for Difference [CFD]) are the most common. Third, although material and financial prequalification requirements are widely used, their stringency varies from country to country (Szabó et al., 2020).

### 3.2. Assessment of auctions with different criteria shows ambiguous and sometimes unclear results. Design elements may favour one particular criterion over others

Auctions are often assessed according to different criteria, of which effectiveness and efficiency in RES deployment are the most common.

#### 3.2.1. Policy effectiveness: a mixed picture (ex-ante effectiveness) without solid conclusions (ex-post effectiveness)

Policy effectiveness is measured in two dimensions. The first (ex-ante effectiveness) takes into account the ratio of contracted volume to the volume of energy or capacity offered in the auction, while the second (ex-post effectiveness) assesses the realisation rate of the winning projects i.e. the share of awarded projects completed on time. Ex-ante effectiveness shows a mixed picture in the European auctions. Most post-2016 EU auctions were successful at covering a significant share of the targeted volumes, although to varying degrees across technologies. In case the auction targeted technologies other than PV or wind (e.g. biomass, biogas or geothermal), there were significant gaps in target achievement that could require special auction design. Regarding ex-post efficiency, limited information on the implementation of the projects did not allow firm conclusions to be drawn on the realisation rate. Nevertheless, in case of delays, it would be particularly useful to examine whether they are caused by external factors, or if some of the design elements need to be reconsidered. Governments should place higher priority and effort to monitor and report realisation rates (Szabó et al., 2020).

#### 3.2.2. Static efficiency: efficiency improvements triggered by lower technology costs over time

Static efficiency is achieved when a predetermined target is fulfilled at the lowest possible overall cost. However, estimating the lowest possible cost is a difficult task, as factors beyond the auction design such as market prices, balancing and system integration costs may influence auction bid prices. However, looking at whether auctions led to lower prices compared to previous support levels, it can be assumed if “efficiency gains” are achieved over time, driven primarily by lower

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 previous periods. However, in some instances, especially in Germany (onshore wind) (Sach et al., 2019) and in the Netherlands (2018/2019), prices stagnated or even increased. Many of the countries starting auctioning after 2016 (e.g. Greece, Hungary, UK) experienced significant price reductions in their initial auctions compared to the previous, administratively set support levels. However, this approach to measure efficiency can be criticised on the basis that observed price reductions are due to the auction itself, or to the general learning effects.

#### 3.2.3. Dynamic efficiency: moderate cost decreases but further potential cost reductions in the future for some of the less established technologies

Auctions ensure dynamic efficiency by contributing to the development and cost reduction of immature technologies. As most countries aim to reach their renewable energy targets at the lowest possible cost, and many technologies have already reached high deployment levels, auctions in mature markets have seen only modest price declines for PV and onshore wind in the last years. Higher cost technologies are allowed to compete in separate baskets in some countries, e.g. biomass, biogas or geothermal plants in the UK or Poland. However, they cannot be considered immature either, and do not have substantial cost reduction potentials. Offshore wind projects, which also compete in technology-specific and usually site-specific auctions, showed greater reductions in the UK, while projects in the Netherlands, Germany and Denmark required zero or even negative support (i.e. project developers willing to pay to access the renewable resource). Regarding less established technologies, some auction schemes started to offer support to storage combined with non-dispatchable renewable energy technologies (in Portugal and in the innovation auctions of Germany). If these auctions become more widespread, they could accelerate the deployment and cost reduction of storage facilities. The wide cost range of CSP technology in the auctions could be a sign for potential cost reductions in the future (del Río et al., 2019a).

#### 3.2.4. Actor diversity: design elements have been adopted to encourage the participation of small actors

Several countries include special rules to encourage the participation of smaller players or local communities in auctions. This enables the support of small-scale projects in an efficient and competitive manner and enhances the social acceptance of renewable investments. More favourable conditions for participation could include less stringent prequalification requirements, different pricing rules, the option to compete for a fixed proportion of the auctioned volume or budget, or the provision of a bonus on top of the price. In Hungary, Greece, and Poland, separate budgets/quantities have been allocated for small-scale power plants. Denmark held a dedicated auction in 2018 for PV plants below 1 MW. In the Netherlands, the SDE + auctions have different maximum prices per technology and size, allowing smaller plants to be awarded. Additionally, the participation of local communities is encouraged in Canada, Denmark, and Germany by offering preferential conditions (Szabó et al., 2020).

### 3.3. Auction outcomes depend on the context conditions

RES auctions do not function independently of the context in which they are conducted. Their functioning and outcome are affected by conditions beyond auction design (e.g., permitting procedures, tensions

in the value chain, technology costs, etc.). For example, in some countries, low auction prices can partially be explained by the accumulation of numerous projects “in the pipeline”.<sup>5</sup> Falling technology prices and projects in an advanced development stage in some countries can create bottlenecks to further RES-E deployment due to, e.g., scarcity of electricity injection points or social acceptability. The undersubscription in the German onshore wind auctions is partially attributable to local opposition limiting available project sites (Szabo et al., 2022).

### 3.4. Some innovative designs have recently been introduced to address grid-related problems and flexibility issues, showing possible future trends

Scarcity of grid connection capacities and other challenges related to integrating variable renewable resources into the electricity system (e.g., ensuring operation security, supply quality or avoiding network congestion) led to some innovative auction designs. Portugal has allocated scarce grid connection capacities in a competitive manner through auctions (del Río et al., 2019b). In the German multi-technology auctions, bid prices were adjusted upward or downward, depending on whether the installation would be located in an area where installed RES-E capacities exceeded peak load. Germany also organizes “innovative auctions” in which combinations of dispatchable and non-dispatchable renewable energy sources compete for support (Sach et al., 2019). In Argentina, limited electricity transmission capacities delayed the auctions related to privately financed transmission network expansions (Menzies et al., 2019). The Spanish auction system adjusts the award price level with a factor that takes into account the flexibility and dispatchability of renewable installations (del Río and Menzies, 2021). As ensuring grid connection points and integrating new RES-E power plants is becoming a bottleneck to further deployment in more and more regions, other countries may follow suit.

### 3.5. Conflicting objectives represent a key challenge for policymakers when designing auctions, requiring them to balance difficult trade-offs

Besides quantified RES targets (effectiveness), many countries have defined additional objectives of their renewable energy policy, e.g., support cost efficiency or actor diversity. In the AURES II project, it was qualitatively analysed whether countries designed their renewable energy auctions in accordance with their designated objectives (Fleck and Anatolitis, 2023). Thus, an analysis of the effects of different design elements on objectives was performed (Table 3).<sup>6</sup> Linking these effects to the countries according to their actual auction design (based on the AURES II Auction database<sup>7</sup>), we were able to identify whether the auction design was suitable for the designated objectives. Differentiating countries based on their alignment with objectives, 10 out of 23 auction scheme designs were found to have room for improvement (Fleck and Anatolitis, 2023).

Difficulties result from conflicting objectives since they are unlikely to be achieved simultaneously, as for instance actor diversity and support cost efficiency. Thus, policymakers should be clear about their objectives, set priorities regarding their fulfilment and design their auctions accordingly to prevent disappointments. The inevitable

<sup>5</sup> This can either be the result of long waiting periods without opportunity for developers to access support, as in Portugal or Greece, or the expected introduction of restrictive measures limiting the chances for specific technologies to participate in the auctions, as with onshore wind projects in Poland (Szabó et al., 2020).

<sup>6</sup> Table 3 has been built based on the findings of auction-theoretic considerations as well as existing literature (e.g., Haelg, 2020; Fleck and Anatolitis, 2023). A detailed discussion per impact is provided in Fleck and Anatolitis (2023).

<sup>7</sup> AURES II Auction database: <http://aures2project.eu/auction-database/> and <https://data.mendeley.com/datasets/2h9jpy3wx/1>.

prioritisation should be done before passing a law, not afterwards. Therefore, policymakers should consider the following recommendations: 1) Relations between the intended objectives should be carefully analysed; 2) Objectives in RES-E policies should be aligned to ensure the possibility of simultaneous achievement; 3) In case of incoherent objectives, a conscious prioritisation of objectives is necessary; 4) Implemented auction design elements should be chosen carefully to support the (prioritised) objectives.

### 3.6. Achieving support cost efficiency depends on the adoption of appropriate auction design elements

Support cost efficiency implies achieving low award prices in RES auctions. Thus, in the AURES II project, we empirically assessed the effects of several auction design elements on the awarded prices (Anatolitis et al., 2022). We conducted a fixed effects panel data regression using data collected in the AURES II database, consisting of 250 observations from 220 auctions in 16 European countries between 2012 and 2020. The results show that, if support cost efficiency is the only objective in auctions, policymakers should: 1) avoid restricting auctions to small-scale projects under 1 MW; 2) implement a ceiling price; 3) favour PV if auctions are restricted to small-scale projects<sup>8</sup>; 4) avoid quotas; 5) avoid multi-criteria auctions and; 6) carefully coordinate the realisation period with financial prequalification requirements. In this latter case, policymakers should either implement short realisation periods with financial prequalification or long realisation periods without financial prequalifications. However, flexibility for bidders does not have a significant impact on the prices and the effect on awarded prices is not significantly different between a (one-sided) sliding feed-in premium and a (two-sided) Contract-for-Difference (Anatolitis et al., 2022).

### 3.7. Auctions can positively influence financing conditions for RES-E projects, but other factors play an equally important role

Auctions can significantly impact the financing conditions of renewable energy projects. Impacts arise from the exposure to different risks in different phases of project development and can affect projects in different ways, including access to financing (project financing vs balance sheet financing), financing conditions (loan tenor, coverage ratios, etc.), and cost of financing. Risk is a major factor in this. Auctions do increase risks for investors in several ways, including the introduction of allocation risks (the risk of not winning and incurring sunk cost), qualification risks (not qualifying in the auction after pre-developing a project), penalty risks (risk of being subject to penalty payments due to delays) and, depending on the remuneration mechanism allocated in the auction, the allocation of revenue risks. These risks can impact the financing of projects in various directions.

The weighted average cost of capital (WACC) of wind and PV projects was reduced between 2014 and 2020 in the EU (Roth et al., 2022). The emergence of new investors with new business models and interests (such as greening their investment portfolios) was a factor behind the reduction in the cost of equity, suggesting that auctions and changing financing conditions are not the only factors having an impact on the cost of individual projects. Auctions also change the investor landscape of the market, since size and financial resources play an increasingly important role due to the competitive nature of bidding. The empirical analysis showed that the presence of auctions in a competitive market environment did not push the cost of capital upwards (Roth et al., 2021). On the contrary, increasing experience with auctions was associated with a lower WACC. The results of the econometric analysis confirmed the findings of the interviews: the main driver for cost of capital was

<sup>8</sup> In auctions open to large-scale projects, onshore wind seems to perform better than solar PV.

**Table 3**  
Analysis of the impact of selected auction design elements on the objectives.

Design element	Effectiveness	System cost efficiency	Support cost efficiency	Green growth	Security of supply	Actor diversity
Multi-technology	o	+	+	-	-	-
Financial prequalification	+	o	-	o	o	-
Ceiling price	o	o	+	o	o	-
Floor price	+	-	-	o	o	+
Multi-criteria	o	-	-	+	o	+
Geographical control	o	+	-	o	+	+
Bidder group control	o	-	-	+	+	+
Favourable treatment for specific actors	-	-	-	o	o	+
Penalties	+	o	-	o	o	-

Source: Fleck and Anatolitis (2023). Note: (+) positive impact, (o) no impact, (-) negative impact.

country risk, but the experience of a country with renewables reduced the WACC. Finally, even though the remuneration scheme variable was not statistically significant, the schemes indirectly reveal an effect through their impact on the significance of auctions, suggesting that remuneration schemes that reduce the exposure to market risks also lead to a lower WACC (Roth et al., 2021).

### 3.8. Some design elements influence the cost of capital of RES projects and need to be taken into account by policymakers

Work carried out in the AURES II project has shown that auction design influences financing conditions in many ways, both in a positive and a negative direction, depending on the individual designs and market framework (Đukan et al., 2019; Đukan and Kitzing, 2021, 2023). To create a low-risk environment for investment in renewable energy projects, policymakers can focus on choosing designs that specifically ease financing conditions and reduce the cost of capital, as well as on implementing a stable enabling framework that reduces risk. Key lessons for de-risking auction policy include:

1. *Support policy designs that reduce market risk exposure have a slightly reducing impact on the cost of capital.* A focus on de-risking of debt financing would deliver the largest WACC reductions and thus lead to support costs savings. De-risking policies should also increase loan maturities and debt size. Such debt de-risking is best achieved by remuneration schemes that decrease the volatility of the project's cash flows through revenue stabilisation (i.e. a CfD or a one-sided sliding FIP).
2. *De-risking of cost of equity (through relaxing prequalification requirements, reducing bid bonds or prolonging realisation rates) does not yield large additional benefits in terms of support cost reductions.* Instead, it may create unwanted effects (e.g., lowering project realisation rates). Material prequalification requirements should not discourage the participation in the auction. Bid bonds can effectively lock small and medium developers out of an auction. Penalties should be clearly defined but gradual to allow for a penalty proportional to the extent of the commissioning delay.<sup>9</sup>
3. *Auctions can de-risk by providing stability, but this needs active political commitment.* A lack of long-term market predictability (in terms of continuity and schedules) may reduce the willingness and ability to develop and finance new projects as well as to less favourable financing conditions. Sufficiently large volumes and multi-year auction schedules foster competition and visibility for investors.

<sup>9</sup> This would allow for controlling the impact on future cash flows in a more nuanced way than applying the full penalty would.

These allow for economies of scale and low allocation and qualification risk.<sup>10</sup>

4. *De-risking through transparent rules and communication can facilitate participation and help avoid undersubscription.* Auction procedures and rules must be determined and communicated to developers and finance providers ahead of the auction so that they will be better able to assess the potential consequences for their projects. For example, undisclosed ceiling prices and post-auction volume reductions can deter participation.
5. *Effective de-risking takes the local financing conditions of developers into account.* It should be tailored to minimise unnecessary risks arising from local specificities.

### 3.9. The number and diversity of project developers and component manufacturers is influenced by auctions and their design elements

A high market concentration (MC) due to a large share of few and large firms in a given sector is a main concern for governments all over the world since it is believed to affect competition. Actor diversity is deemed a key element of a just energy transition and for the well-functioning of auctions. A low actor diversity would be detrimental in the context of a fair and inclusive energy transition because small and local players are important components of such a transition. Furthermore, a high MC with a small number and a low diversity of firms and a dominance of only a few large firms may affect the price outcome of the auction itself, i.e. its efficiency decreases and its support costs increase. Analysis in AURES II suggests that some design elements lead to large impacts on the number and diversity of firms in both the project development and component manufacturing stages, including the frequency of auction rounds, the existence (or not) of a transparent schedule and stringent prequalification requirements (del Río et al., 2020). It also suggests that the role of auctions on MC has to be contextualised, since other factors apart from auctions are a main driver of the number and diversity of firms. Context factors define the socio-economic landscape in which RES-E auctions take place. The experts were asked to estimate the impact of specific contextual factors on the number and diversity of project developers and component manufacturers<sup>11</sup>. The experts interviewed held a range of diverging views as

<sup>10</sup> Such clarity and long-term visibility are key, not only for mitigating risks for project developers but also for banks and finance providers. As auctions become more established (i.e. more auction rounds implemented and large volumes auctioned), the cost of capital can decrease.

<sup>11</sup> The context conditions analysed comprised: 1). Policy framework conditions in the country of interest (ambitious targets, policy stability). 2). Broader policies (energy, industrial development and environmental) in the country of interest or in other countries. 3). Socioeconomic conditions in the country of interest (i.e. the existence of an industry, capabilities in the country, resources, etc.). 4). Context factors in the country of interest (investment climate in the country, size of the market, availability of transmission/distribution infrastructure, renewable energy (RE) resource potentials, financing costs, installation and building costs, ease of access to equipment).

to whether auctions, auction design elements, or context conditions, are most important in terms of shaping the number and diversity of actors in those two value chain segments (see del R o et al., 2020). Context conditions were found to affect the number and diversity of project developers and component manufacturers in an overall neutral or positive way.

### 3.10. Energy communities may be discouraged in auctions, but promoting them with auction design elements or with measures outside the auction can be challenging

The Renewable Energy Directive defines a renewable energy community (REC) as a legal entity which is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members located in the proximity of renewable energy projects owned and developed by that legal entity. Policymakers pay special attention to RECs to foster the acceptance and ownership of RES development, and RECs can also support the functioning of auctions (Amazo et al., 2020). The results of the analysis in AURES II suggested that auction-related risks pose a strong challenge to energy community project developers due to their limited project portfolio and size (Amazo et al., 2020). Measures can be taken inside and outside the auction to encourage RECs. The former can facilitate participation but may lead to market distortion. In contrast, measures outside the auction interfere less with the auction but have a limited impact against the actor consolidation trend. An intermediate alternative could be exempting energy RECs from the auction but linking support for them to the auction outcomes (Amazo et al., 2020).

### 3.11. The impact of auctions on technological innovation is unclear and probably limited

Auctions and auction design elements influence innovation through their indirect impact on manufacturers and technology developers. Del R o and Kiefer (2021) provided an analytical framework on the mechanisms linking diffusion-driven technological innovation and auctions and their design elements and carried out an empirical analysis to identify the perception of key stakeholders on the topic. A questionnaire to test the mechanisms linking auctions and auction design elements and technological innovation was sent and completed by 19 experts. It was found that auctions and their design elements affect technological innovation through four main channels: 1) impact on private R&D through greater profit margins; 2) the expectation that there will be a market for the technology (i.e. where firms can sell their technology); 3) impact on technology diffusion and 4) impact on the competitive pressures faced by manufacturers and technology developers to reduce costs or increase revenues. However, opposing effects are likely to occur (market creation/profit margins vs. competition effects). It was also found that some design elements in auctions tend to discourage innovation (multi-technology and price-only auctions), while others encourage it (having a schedule of auctions, a relatively high frequency of auction rounds and strict prequalification requirements). In addition, auctions are one of the factors influencing innovation in renewable energy technologies, but other policy and non-policy factors influence technological innovation, including technology-push policies or the international competition in a globalised sector.

### 3.12. Despite their potential benefits, cross-border auctions have rarely been used in the EU. Implementing cross-border auctions requires the adoption of different measures

Countries can cooperate on RES deployment through cross-border RES auctions, in which project developers from more than one country can submit their bids. These auctions increase auction efficiency by accessing better natural resource potentials, achieving higher market values, lowering the cost of capital and increasing competition

compared to purely national auctions (von Bl ucher et al., 2019; Ehrhart et al., 2019; Bartek-Lesi et al., 2023). In general, cross-border auctions can take the form of a unilateral opening, where one country contributes to supporting a project in a host country, or a multilateral opening, where partner countries allow bidders from both countries to participate in their own cross-border auctions. The third, most integrated auction type is the joint auction, where participating countries agree on all elements of the design of the commonly organised auction and the statistical attribution of the resulting renewable generation, and where the renewable project can be located in any of the participating countries. The AURES II project mainly dealt with the last two types of projects, i.e. the multilateral and joint auctions. These types of projects may benefit countries that host RES projects supported by another country by adding RES capacities beyond the capacities encouraged by national support schemes, triggering additional investments and reducing import dependency. However, cross-border auctions also pose challenges, which are behind their little use by European Member States. If Member States host projects, auctioned sites are no longer available for national auctions, which may increase the host country's support costs for future domestic RES deployment. Political acceptance may be low in countries supporting RES outside of their territory.

These barriers can be mitigated through an adequate and clear communication strategy of the net benefits for both the host and contributing Member States and the management of local concerns.<sup>12</sup> In addition, the design of cross-border auctions should follow several recommendations (von Bl ucher et al., 2019). First, the schedules of national and cross-border auctions should be synchronised to provide a continuous pipeline and facilitate planning in the RES industry. Second, while the potential impact of different national regulations on the outcome of cross-border auctions should be taken into account in the set-up of auctions, country differences cannot be fully harmonised, as this would involve areas beyond energy sector regulation.<sup>13</sup> Third, a combination of shorter realisation deadlines and higher financial prequalification requirements rather than material prequalification criteria is preferred in order not to discriminate against bidders from certain countries.<sup>14</sup> However, the level of financial prequalification should not be too high in order not to disadvantage bidders from markets with less favourable access to financing. Fourth, the difference in market values between Member States needs to be considered when adopting the right support premium, but no design (fixed premium vs. sliding premium) is clearly preferable.

### 3.13. Compared to technology-specific auctions, multi-technology auctions result in a higher static efficiency and lead to technology biases

Work performed in AURES II shows that multi-technology auctions can in certain cases have advantages over technology-specific auctions, in particular for technologies at a similar stage of development and similar costs. The results from the experiments indicate that they significantly increase static efficiency, although the awarded prices show large differences between countries. The model-based analysis of different renewable auction design elements in multi-technology auctions suggests that there is no such thing as a "technology neutral" tender, since the auction design will always implicitly favour one

<sup>12</sup> Checklists that cover important elements that Member States may want to consider in the implementation process are provided in Kerres et al. (2021).

<sup>13</sup> For example, the prevailing tax regime as well as the land use regulation can have a significant impact on the economic performance of a renewable project, but these are areas that cannot be fully harmonised, due to varying national interests.

<sup>14</sup> Due to differing national regulations, for example on permitting, it is not advisable to define extensive prequalification requirements on project predevelopment as this could favour bidders of one country over bidders from other countries.

technology over another (Diallo and Kitzing, 2024).<sup>15</sup> Different auction design elements influence technology bias differently. The change of support period, the introduction of grid integration costs and environmental harm compensation into the tender design or changes of the remuneration scheme may heavily influence the bias between technologies.

The empirical assessment of multi-technology auctions in the EU shows that, while there are often dominating technologies in these auctions, the technology mix can change over time. Multi-technology auctions can indeed cause problems due to stop-and-go for some technologies. However, it is unclear whether they cause more challenges than technology-specific auctions which, in many countries, do not guarantee a stable demand either. The argument that less mature technologies have lower chances in multi-technology auctions could also be partly confirmed.

### 3.14. How should multi-technology auctions be designed?

Multi-technology auctions can be a suitable means to reach renewable expansion targets. However, this is only the case when the auctions are adequately planned and meet the requirements of their specific market. The research conducted in AURES II suggests the following policy recommendations for designing multi-technology auctions (Diallo and Kitzing, 2024).

- *Avoid outside options for RES projects:* Do not conduct technology-specific and multi-technology auctions for the same project size and technology in a similar timeframe.
- *Be aware of implicit technology bias:* A simple design with the same elements for all technologies (i.e. ceiling prices, realisation periods etc.) often implies a technology bias. More complex designs differentiating between technologies might be needed to enable a level playing field.
- *Technologies with similar LCOEs should compete:* Multi-technology auctions are most useful for technologies at a similar stage of development and similar costs. Therefore, EU countries use these auctions mostly for PV and onshore wind. Other technologies have problems to compete with these cheaper technologies. If Member States aim for technological diversity, auction design needs to be adapted (e.g. using minimum quotas for other technologies) or technology-specific auctions should be conducted.
- Results from the experiments (Fleck, 2023) suggest that multi-technology auctions *should be conducted with a pay-as-bid pricing rule* in order to achieve lower prices and a higher degree of static efficiency, while lowering the risk of irrationality by unexperienced bidders.
- *Acknowledge supply chain uncertainties:* The main disadvantage of multi-technology auctions is a lower stability with regards to technology expansion when compared to correctly designed and regular technology-specific auctions. One needs to be aware of this challenge to avoid disruptions in the supply chain for specific technologies.

### 3.15. The possible role of zero-support auctions

Especially in countries endowed with favourable RES resources, we can increasingly see a trend for prices revealed through auctions to drop below wholesale electricity prices, raising questions about the applicability for auctions as something other than a revenue support instrument. The case studies carried out in the AURES II project (Szabó et al., 2020) provide some examples for this trend, raising interesting

<sup>15</sup> The analysis focused on a comparison of the impact of seven different auction design elements in relation to three different remuneration schemes i.e. a one-sided sliding feed in premium, two-sided sliding premium and fixed premium.

questions as to how the auction schemes will evolve in the future.<sup>16</sup> The experience of the auctions in Portugal, Denmark, and Spain highlight possible future directions (Table 4). It was concluded that it was still uncertain whether 'zero-subsidy' auctions and/or power purchase agreements (PPAs) that provide long-term offtake but without above-market revenues, are here to stay.

In the absence of a revenue premium, zero-subsidy auctions produce an offtake arrangement similar role to many conventional private-law PPA contracts, raising the question of whether auctions or PPAs offer the best outcomes. In Spain, PPAs were settled at 38–40 €/MWh, compared to 24–26 €/MWh pricing achieved through the 2021 auction, reflecting higher perceived risks in the purely private PPAs compared to the public auction. If auctions and PPAs face the same conditions (connection, access, balancing and timing), the ultimate difference is that the auctions would transfer the savings to the public counterparty – typically the state or grid operator. The savings could then be used to improve the grid or to reduce the support burden of previous RES support schemes. With PPAs, the risk of market price changes and volatility is shared between the contracting parties whereas, with auctions, the risk is socialised to different degrees depending on the type of remuneration.

**Table 4**  
Summarising the experience in related to zero-support auctions.

Country	Lessons
<b>Portugal</b>	A dynamic, location-specific PV auction was held in July 2019 in Portugal, with two parallel bidding schemes offering bidders the choice between competing 1) for a two-sided sliding premium/CfD below a ceiling price that is lower than the current market price, or 2) offering a certain level of payment per MWh produced to the electricity system operator. In this auction, producers basically competed for a limited opportunity to connect to the grid, with the ceiling price (around 45 €/MWh) set below expected future wholesale electricity prices (del Río et al., 2020). The competition led to average winning prices of 20 and 21 €/MWh in the two bidding schemes. In addition to the vast solar resources, the low bids can be explained by the economies of scale associated with the large minimum size set for participants, the large number of projects in the pipeline in the absence of available support since the mid-2010s, and the shortage of available grid connection points.
<b>Denmark</b>	The most recent offshore wind auction organized in Denmark at the end of 2021 (cf. Larsen and Kitzing, 2020) is another example where auctioneers mainly competed for the opportunity to complete their projects. The tender for the 1 GW Thor offshore wind farm in November 2021 was a single-unit auction, with several participants bidding at the minimum price of 0.0001 DKK/kWh (around 0.013 €/MWh). Since the remuneration scheme was a CfD, this would mean that participants would be willing to pay almost all of their electricity market revenues for the right to implement their project. However, the Danish tender set a cap of DKK 2.8 billion (around € 380 million) on the repayment obligation. Therefore, the minimum price bids represent a willingness on the part of developers to pay large sums to the Danish Government for the right to develop the site, without the need for revenue support. The Thor auction also created an unusual allocation problem; in the absence of differentiated price bids to determine the winner, the successful bidder was selected through a lottery.
<b>Spain</b>	The first 2021 Spanish auction resulted in average prices between 24 and 26 €/MWh for the auctioned CfDs, well below electricity market prices (del Río and Menzies, 2021). Auctions held in other EU countries in the same period led to prices between 45 and 68 €/MWh for wind and PV technologies. After the auction was completed, the annual savings for consumers were initially estimated at € 173 million at the expected wholesale prices, but these savings would be even higher due to the recent surge in spot market prices.

<sup>16</sup> Will renewable capacities be installed on a pure market basis? Can we expect the role of private/corporate power purchase agreements (PPA) to increase, serving as a risk mitigation tool for investors and users? Will national governments reconsider their remuneration schemes to take account of the costs of grid integration?.

neration scheme (fixed or floating, one-sided or two-sided premium).

The importance of PPAs in the future will largely depend on the regulation of the country concerned. In some Member States, they are subject to regulatory restrictions or an additional financial burden. In this framework, RES auctions can result in a significant part of the welfare of producers being passed on to consumers, either in the form of a reduction in the contribution to renewable support or a reduction in grid costs. The trend towards auctions that combine RES generation capacity with storage also points in this direction, and thus reduces balancing costs.

The long-term offtake certainty provided by zero-subsidy auctions or PPAs can increase projects' gearing by enabling a greater share of debt capital, thus potentially reducing the cost of capital and increasing the rate of return compared to a fully merchant counterfactual, partially explaining the willingness to accept below-market prices. From an economic point of view, the deployment of renewables through both PPAs and zero-subsidy auctions will only take place if the expected market returns to investors exceed their investment and operating costs, e.g. in a context of high spot market prices. This has certainly been the case for some European countries due to the demand-side catch-up effects of COVID, the impact of the war in Ukraine on energy and raw material prices, and the significant ramp-up of direct electrification in the transport sector. Expansion of renewables without additional revenue support would be the norm if relatively high spot prices are expected in the future.

### 3.16. *Given the limited ability of the electricity system to integrate variable renewables, dedicated RES support will be needed in the next years, making the current trend to zero-subsidy auctions uncertain*

A critical consideration in the trend towards zero-subsidy auctions and/or PPAs is the limited ability of the electricity system to integrate variable RES (vRES), leading to a reduction in market values through "price cannibalisation" and, thus, a reduction in incentives for market-based expansion. Qualitative scenario developments (Woodman and Fitch-Roy, 2020) and accompanying modelling activities (Resch et al., 2022b,c; Resch and Geipel, 2022) in AURES II aimed to shed light on this. The outcomes of the modelling have shown that a high degree of system flexibility and decentralisation can be an enabler and even a prerequisite for successful RES market integration. The key parameter to determine whether or not only low (or almost zero) subsidies will be required to accommodate the future RES uptake is the future price level in wholesale electricity markets. These prices are, in turn, determined by the future prices at which key zero-carbon flexibility options on the supply side like biogas or green hydrogen will be available. In general, due to the massive amounts of high vRES infeed, there are times during a day and year when prices are well below current wholesale price levels. During times of low solar radiation or low wind, hydrogen, green gas, batteries and other flexibility options must contribute to meet the given demand. If these flexibility options are available at low cost/prices, the need for dedicated support increases but consumer cost are then expected to decline and vice versa.

### 3.17. *Auctions in related (low-carbon) sectors can learn from RES auctions, but certain fundamental aspects need to be considered*

In the past, with few exceptions, auctions have mainly been used to allocate price support for electricity from renewable sources. In recent years, however, the use of auctions has been expanded to other sectors and low-carbon technologies (Winkler, 2022). In principle, there is a range of applications beyond electricity where auctions can play a useful role in allocating scarce support financing. We expect that this recent trend will become more important in the future. In the context of the AURES II project, we have looked into the use of auctions in different sectors (Winkler, 2022), including transport and industry as well as heating and cooling (Blömer et al., 2022) and hydrogen support (Kerrer

et al., 2022). And indeed, since our analysis, Germany has conducted a first support auction for the decarbonisation of the industry, allocating Carbon Contracts for Difference (Richstein et al., 2024), while several countries have held auctions for (green) hydrogen support (IRENA, 2024). In addition, broader integrated auctions for decarbonisation technologies in general (SDE++) as well as auctions for renewables and energy efficiency have been analysed. While some lessons learned and experiences from the electricity sector can be used as a basis for designing auctions for other sectors and technologies, it is obvious that the auction design always needs to be adapted to the framework conditions, markets and technologies in different sectors (Winkler, 2022).

A summary of the main findings and policy recommendations from the studies carried out in the AURES II project is provided in Table 5.

## 4. Conclusions and policy implications

This policy perspective aims to present key policy lessons derived from research on renewable energy auctions conducted in the AURES II project. Therefore, several policy implications can be derived from our findings. They can be grouped according to the main themes in RES-E auction design addressed in Section 3 (see Table 5).

An overall conclusion is that the effectiveness of auctions in achieving policy objectives is highly dependent on specific design choices, with frequent trade-offs between different policy goals and auction elements. Therefore, a one-suits-all auction design does not exist, but the choice depends on national goals and context conditions. The choice of a given design element would make more sense if the government prioritises a given goal (i.e., multi-technology auctions if static efficiency in renewable electricity generation is the goal, minimum quotas for given technologies in multi-technology auctions or technology-specific auctions if technological diversity is the goal, or less stringent prequalification requirements if governments aim to encourage smaller actors to participate in the auctions). However, in particular settings, goals may be in conflict (i.e., support cost efficiency and promoting actor diversity). Therefore, governments should have their objectives clear from the start, acknowledge the potential interdependencies and trade-offs between objectives, potentially prioritise them, and select the auction design elements accordingly. They may try to select the auction design elements so as to achieve a maximum overlap with the intended policy objectives. In addition, the socioeconomic, institutional and electricity system contexts should be considered when designing auctions, that prevents proposing a common list of best design practices to be adopted in all situations.

A main goal of governments is usually support cost efficiency. If this is so, then the results of our research indicate that certain design elements should be adopted. Policymakers should avoid restricting auctions to small-scale projects, implement a ceiling price, favour PV if auctions are restricted to small-scale projects, avoid quotas, avoid multi-criteria auctions, and carefully coordinate the realisation period with financial prequalification requirements. In this latter case, policymakers should either implement short realisation periods with financial prequalification or long realisation periods without financial prequalifications.

If static efficiency, rather than support cost efficiency, is the goal, then multi-technology auctions are an appropriate choice. However, the design of these auctions should follow several recommendations. They should not be simultaneously organised with technology-specific auctions for the same project size and technology, and only technologies at a similar stage of development and similar costs should be included in the multi-technology auction. Multi-technology auctions have particular drawbacks but also advantages for some areas of application. Different auction design elements can cause significant biases between

<sup>17</sup> In auctions open to large-scale projects, onshore wind seems to perform better than PV.

**Table 5**

Summary of the main findings and policy recommendations from research in AURES II.

Section	Main findings	Policy recommendations
3.1	<b>Both convergence and divergence in auction design can be observed.</b>	A one-suits-all auction design does not exist, but the choice depends on national goals and context conditions.
3.2	<b>Assessment of auctions with different criteria shows ambiguous and sometimes unclear results. Design elements may favour one particular criterion over others.</b>	<p>When introducing auctions, beware that they may have impacts on four criteria:</p> <ul style="list-style-type: none"> <li>• Regarding <u>static efficiency</u>: it could be expected that introducing auctions leads to price reductions compared to the previous, administratively set support levels.</li> <li>• Regarding <u>policy effectiveness</u>, a clear picture does not emerge. It would be particularly useful to examine whether effectiveness is influenced by external factors, or if some of the design elements need to be reconsidered. Governments should place a high priority and effort to monitor and report realisation rates.</li> <li>• Auctions ensure <u>dynamic efficiency</u> by contributing to the development and cost reduction of immature technologies.</li> <li>• The participation of <u>small actors</u> is usually discouraged in auctions.</li> </ul> <p>Beware that design elements may favour one particular goal/criterion over others and that they may influence the outcome of auctions regarding a particular criterion. For example, the participation of small actors can be encouraged with less stringent pre-qualification requirements, different pricing rules, the option to compete for a fixed proportion of the auctioned volume or budget, or the provision of a bonus on top of the price.</p>
3.3	<b>Auction outcomes depend on the context conditions.</b>	Take into account the context conditions when implementing and designing auctions
3.4	<b>Some innovative designs have recently been introduced to address grid-related problems and flexibility issues.</b>	Consider addressing grid-related problems and flexibility issues with innovative designs (e.g., auctions with battery storage requirements
3.5	<b>Conflicting objectives represent a key challenge for policymakers when designing auctions, requiring them to balance difficult trade-offs.</b>	Introducing incentives for participating in flexibility provision) Policymakers should be clear about their objectives, set priorities regarding their fulfilment and design their auctions accordingly to prevent disappointments. The inevitable prioritisation should be done before passing a law, not afterwards. Thus, be clear about your goals, consider the relations and trade-off between them as well as the possibility of simultaneously achieving them. In case of incoherent objectives, prioritise them and design auctions to balance the trade-offs.
3.6	<b>Achieving support cost efficiency depends on the adoption of appropriate auction design elements.</b>	Use appropriate design elements if support cost efficiency is the main goal: 1) Avoid restricting auctions to small-scale projects under 1 MW; 2) implement a ceiling price; 3) favour PV if auctions are restricted to

**Table 5 (continued)**

Section	Main findings	Policy recommendations
		small-scale projects <sup>17</sup> ; 4) avoid quotas; 5) avoid multi-criteria auctions, and; 6) carefully coordinate the realisation period with financial prequalification requirements. Policymakers should either implement short realisation periods with financial prequalification or long realisation periods without financial prequalifications.
3.7	<b>Auctions can positively influence financing conditions for RES-E projects, but other factors play an equally important role.</b>	If the aim is to improve the financing conditions, use remuneration schemes that reduce exposure to market risk. Be aware that the presence of auctions in a competitive market environment does not necessarily push the cost of capital upwards and that the main driver for cost of capital is country risk.
3.8	<b>Some design elements influence the cost of capital of RES projects and need to be taken into account by policymakers.</b>	To create a low-risk environment for investment in renewable energy projects, policymakers can choose designs that specifically ease financing conditions and reduce the cost of capital: 1) Support policy designs that reduce market risk exposure have a slightly cost reducing impact on the cost of capital; 2) the cost of equity can be de-risked through relaxing prequalification requirements, reducing bid bonds or prolonging realisation rates; 3) provide stability; 4) determine the auction procedures and rules before the auction and communicate them transparently to developers and finance providers. 5) Effective de-risking takes the local financing conditions of developers into account and is tailored to minimise unnecessary risks arising from local specificities.
3.9	<b>The number and diversity of project developers and manufacturers is influenced by auction design elements.</b>	If the aim is to increase the number and diversity of project developers and component manufacturers, then increase the frequency of auction rounds, adopt a transparent schedule and moderate the prequalification requirements.
3.10	<b>Energy communities may be discouraged in auctions, but promoting them with auction design elements or with measures outside the auction can be challenging.</b>	RECs can be supported with measures inside and outside the auction. The former can facilitate participation but may lead to market distortion. In contrast, measures outside the auction interfere less with the auction but have a limited impact against the actor consolidation trend. An intermediate alternative could be exempting energy RECs from the auction but linking support for them to the auction outcomes.
3.11	<b>The impact of auctions on technological innovation is unclear and probably limited.</b>	If the aim is to encourage technological innovation, then use a schedule of auctions, a relatively high frequency of auction rounds and strict prequalification requirements. But beware that auctions are one of the factors influencing innovation in renewable energy technologies.
3.12	<b>Despite their potential benefits, cross-border auctions</b>	If the aim is to implement cross-border auctions, the net benefits for

(continued on next page)

Table 5 (continued)

Section	Main findings	Policy recommendations
	<b>have rarely been used in the EU. Implementing cross-border auctions requires the adoption of different measures.</b>	both the hosting and contributing Member States and the management of local concerns should be clearly communicated. The design of cross-border auctions should follow several recommendations: 1) Synchronise the schedules of national and cross-border auctions; 2) Do not artificially level differences between national regulations; 3) Combine shorter realisation deadlines and higher financial prequalification requirements rather than stringent material prequalification criteria. However, the level of financial prequalification should not be too high in order not to disadvantage bidders from markets with less favourable access to financing; 4) Consider the difference in market values between Member States when adopting the right support premium, although no design (fixed premium vs. sliding premium) is clearly preferable.
3.13	<b>Compared to technology-specific auctions, multi-technology auctions result in a higher static efficiency and lead to technology biases.</b>	If the aim is to have a high static efficiency, use multi-technology auctions. Beware that different auction design elements influence technology bias differently.
3.14	<b>How should multi-technology auctions be designed?</b>	If you organise multi-technology auctions, design them according to the following recommendations: 1) Do not conduct technology-specific and multi-technology auctions for the same project size and technology in a similar timeframe; 2) be aware of implicit technology bias; 3) include technologies with similar LCOEs; 4) acknowledge supply chain uncertainties.
3.15	<b>The possible role of zero-support auctions</b>	Purely private arrangements (with no public intervention) result in a risk premium (and higher pricing) compared to the 'zero-subsidy' auction approach. Therefore, all things being equal, auctions may be able to reduce the overall level of risk in the market, thereby leading to lower costs and enhanced consumer welfare.
3.16	<b>Given the limited ability of the electricity system to integrate variable renewables, dedicated RES support will be needed in the next years, making the current trend to zero-subsidy auctions uncertain.</b>	During times of low solar radiation or low wind, hydrogen, green gas, batteries and other flexibility options must contribute to meet the given demand. Take into account that, if these flexibility options are available at low cost/prices, the need for dedicated support increases but consumer costs are then expected to decline and vice versa.
3.17	<b>Auctions in related (low-carbon) sectors can learn from RES auctions, but certain fundamental aspects need to be considered.</b>	In principle, there is a range of applications beyond electricity where auctions can play a useful role in allocating scarce support financing. Beware that the auction design always needs to be adapted to the framework conditions, markets and technologies in different sectors. As with RES-E auctions more generally, there is not one-size-fits-all approach for designing a competitive bidding process but every auction design needs to be customised to the specific context.

Source: Own elaboration (see Section 3 for further details).

technologies in these auctions and, thus, it is very difficult to design an auction in a way that does not favour one or several of the participating technologies. Multi-technology auctions can be a suitable means to reach renewable expansion targets, but have to be adequately planned and tailored to the specific market conditions.

The costs of capital are a main element of RES-E projects, and financing conditions may be a crucial barrier to their uptake. Auctions can considerably influence access to finance, financing conditions and the financing costs of RES-E projects. Policymakers can, however, mitigate some auction-specific risks by appropriately designing auctions, e.g. reducing market risk exposure. However, a main aspect that policy makers should consider is that other factors apart from auctions (e.g., country risk) are more influential on the cost of capital of RES-E projects than auctions themselves. Nevertheless, financing conditions can be improved with the choice of some de-risking design elements, i.e. adopting remuneration schemes that decrease the volatility of the project's cash flows through revenue stabilisation (i.e. a CfD or a one-sided sliding FIP) and providing long-term market stability/predictability (in terms of continuity and schedules, with sufficiently large volumes and multi-year auction schedules). In contrast, relaxing prequalification requirements, reducing bid bonds or prolonging realisation rates would not lead to large additional benefits in terms of support cost reduction and may lead to undesirable effects (e.g., lowering project realisation rates). Furthermore, measures should be adopted in the auction which go beyond the choice of specific design elements. Auction procedures and rules should be set before the auction and communicated transparently. Finally, the context conditions (e.g., the local financing conditions of developers) should be taken into account.

On the other hand, cross-border auctions are a strategic tool to increase the efficiency of RES auctions through use of better resource potentials, higher market values, lower costs of capital and increased competition compared to national auctions. However, there are several barriers to their implementation (e.g., higher support costs in host countries in the future and low social acceptability in off-taker countries), which need to be removed or mitigated. The adoption of several design elements can be recommended in this context: synchronisation of the schedules of national and cross-border auctions, a combination of shorter realisation deadlines and higher financial prequalification requirements rather than material prequalification criteria and considering the difference in market values between countries when adopting the right support premium. In contrast, policy makers should not adopt too high financial prequalifications, should not artificially level the differences between national regulations.

Apart from impacts on support cost efficiency, the broader effects of auctions and their design elements on RES-E sectors and value chains should be taken into account. Two of these are market concentration and technological innovation. Policy makers should take into account that auction design elements or even auctions themselves have a limited role to play in these contexts. However, if the aim is to increase the number or diversity of firms in both the project development and component manufacturing stages, then a higher frequency of auction rounds, a transparent schedule and relatively low prequalification requirements should be adopted. If the aim is to encourage technological innovation, then a schedule of auctions, a relatively high frequency of auction rounds and strict prequalification requirements should be adopted.

Our research suggests that there are two important topics for future research. One is the role of zero-support auctions. Our analysis suggests that it is still uncertain what will be the trend of these auctions in the future, i.e. whether these auctions and/or PPAs are here to stay. One critical factor opposing this trend is the limited ability of the electricity system to integrate variable RES leading to a reduction in market values and, thus, a reduction in incentives for market-based expansion.

Another relevant topic is the use and design of auctions in related low

carbon sectors. Whilst, in the past, auctions have mainly been used to allocate support for RES-E, recent years saw a growing interest in expanding their scope into new areas. Auctions can be applied in different sectors, i.e. in transport and industry, heating and cooling and hydrogen support. In addition, broader integrated auctions for decarbonisation technologies in general as well as auctions for energy efficiency are a possible area of application. It was found out that, while some lessons learned and experiences from the electricity sector can be conferred to other sectors and technologies, the auction design will need to be adapted to the framework conditions, markets and technologies in different sectors.

As any study, this one has limitations. Some of these refer to the data. Unfortunately, data on outcomes are only partial, and full disclosure of all bids is not available, which limits the depth and breath of the analysis. For example, it is especially difficult to determine deterrence or bidding behaviour. In addition, the quality of the data published by the EU Member States on the realisation indicators (e.g., time and rate) is generally poor. Finally, interviews have been used in this project to obtain relevant data. However, not all interviewees wanted to disclose specific information, probably due to this being a very competitive area. Another limitation refers to the geographical scope of our study. The focus of the work undertaken in AURES II has been on European countries, although a few case studies have been performed in non-European countries, and some theoretical analysis carried out in this project could have implications for both European and non-European countries. Therefore, the policy implications on the design of auctions are mostly related to a European context. Although the results of our investigations on EU countries may have implications for the design of auctions in non-EU countries, this should be the focus of further research. Finally, one of the findings of research carried out in AURES II is that there might be conflicts and trade-offs between objectives. However, a quantitative (marginal) analysis of those trade-offs has not been carried out in this project. It would be valuable information to know e.g., the extent to which including special provisions on actor diversity would affect the support cost efficiency of the auctions as well as other common trade-

offs that occur in renewable energy auctions. Therefore, this would be a relevant line of future research.

**CRedit authorship contribution statement**

**Vasilios Anatolitis:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Pablo del Río:** Writing – review & editing, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lena Kitzing:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Oscar Fitch-Roy:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **László Szabó:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

**Declaration of competing interest**

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: none.

**Acknowledgements**

This research was conducted as part of the project AURES II (Auctions for Renewable Energy Support II). This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 817619. We would like to thank our fellow AURES II project partners for their contributions and the excellent collaboration throughout the project.

**APPENDIX 1**

Details on the studies carried out in the AURES II project.

Theme	Study	Aim	Temporal scope (date)	Geographical scope (country)	Technological scope	Data	Method
<b>Trends and issues in auction design</b>	Szabó et al. (2020)	To evaluate the core design elements, the efficiency and effectiveness of auctions in EU and non-EU countries, and, through comparative analysis, highlight some general trends. It assessed 10 ongoing RES auctions (six EU countries and four outside) and also assessed 4 planned auctions (three in the EU and one outside),	10 ongoing RES auctions: Denmark (2016 - offshore wind 2018- PV, tech neutral) Germany (2017), Greece (2016), Hungary (2019), Netherlands (2011), Poland (2016), Portugal (2019), United Kingdom (2019/2015), Argentina (2016), Alberta (Canada) (2017),	Denmark, Germany, Greece, Hungary, Netherlands, Poland, Portugal, Slovakia, United Kingdom, Argentina, Alberta (Canada), Mexico, Chile, Austria, CSP, Offshore wind tender Thor in Denmark.	The technology case studies focused on off-shore wind development in Denmark and the concentrated solar power (CSP) technology auctions in various countries. The country case studies focused on a wide range of renewable energy technologies, but especially solar PV and wind (on-shore and off-shore). Auctions were multitechnology and technology-specific (see below for details).	Data from 16 case studies, based on official statistics and interviews (see below for details).	Comparative assessment of 16 auction case studies

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Theme	Study	Aim	Temporal scope (date)	Geographical scope (country)	Technological scope	Data	Method	
<b>Efficiency and effectiveness of individual countries' auction schemes</b>			Mexico (2017) and Chile (2015), Planned auctions: Austria, Croatia, Slovakia, offshore wind tender Thor in Denmark, (in parentheses, year of first RES-E auction organised under the scheme described in the case-study).					
		(see above)	(see above)	(see above)	(see above)	(see above)	(see above)	
		Szabó et al. (2020)	To describe the auction, procedure, its design elements, its incentive structure, and the stakeholder engagement process	2019–2021	Off-shore wind tender Thor in Denmark	Off-shore wind	Official documents and other sources	Case study
		Larsen and Kitzing (2020)	To describe the auction design elements and assess the outcome of the auction.	2020	Croatia	PV, biomass, biogas, hydropower	Official documents, official statistics and other sources	Case study
		Dézi et al. (2022)	To describe the auction design elements and assess the outcome of the auction.	2019–2021	Italy	All RES-E	Official documents, official statistics and other sources	Case study
		Diallo et al. (2021)	To describe the auction design elements and assess the outcome of the auction.	2017	Alberta (Canada)	All RES-E	Official documents, official statistics and other sources	Case study
		Menzies and Marquardt (2019)	To describe the auction design elements and assess the outcome of the auction.	2016 - offshore wind 2018- PV, tech neutral	Denmark	Offshore wind, nearshore wind, solar PV	Official documents, official statistics and other sources	Case study
		Garzón and Kitzing (2019)	To describe the auction design elements and assess the outcome of the auction.	2016	Greece	Onshore wind and PV	Official documents, official statistics and other sources	Case study
		Anatolitis (2019)	To describe the auction design elements and assess the outcome of the auction.	2019	Hungary	All RES-E (wind ruled out by regulation)	Official documents, official statistics and other sources	Case study
		Bartek-Lesi et al. (2020)	To describe the auction design elements and assess the outcome of the auction.	2017	Mexico	Multi-technology, Fossil-fuel technologies are also eligible for capacity	Official documents, official statistics and other sources	Case study
		Del Río (2019)	To describe the auction design elements	The first auction planned for spring 2020 was cancelled	Slovakia	All RES-E	Official documents, official statistics and other sources	Case study
		Jakob et al. (2019)	To describe the auction design elements and assess the outcome of the auction.	2011	Netherlands	ALL RES-E and RES-H, biogas Offshore wind has its own auction scheme.	Official documents, official statistics and other sources	Case study
		Diallo et al. (2019)	To describe the auction design elements and assess the outcome of the auction.	2016	Poland	All RES-E	Official documents, official statistics and other sources	Case study
	Woodman and Fitch-Roy (2019)	To describe the auction design elements and assess the outcome of the auction.	2019/2015	UK	Various technology baskets	Official documents, official statistics and other sources	Case study	
	Anatolitis and	To describe the auction design elements	The first auction was envisaged for	Ukraine	All RES-E	Official documents, official statistics, other sources and	Case study	

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Theme	Study	Aim	Temporal scope (date)	Geographical scope (country)	Technological scope	Data	Method
	Grundlach (2020)		2019 but it was not conducted			interviews with a Ukrainian energy market expert	
	Sach et al. (2019)	To describe the auction design elements and assess the outcome of the auction.	2017	Germany	Onshore wind, offshore wind, solar PV, biomass, technology-neural innovations.	Official documents, official statistics and other sources	Case study
	Menzies et al. (2019)	To describe the auction design elements and assess the outcome of the auction.	2016	Argentina	Wind, PV, Biomass, Biogas, Mini hydro	Official documents, official statistics and other sources	Case study
	Del Río and Menzies (2021)	To describe the auction design elements and assess the outcome of the auction.	2020(2021)	Spain		Official documents, official statistics and other sources	Case study
	Del Río et al. (2019a)	To describe the CSP auction design elements and assess the outcome of the auctions.	Different dates per country (from 2010 to 2017).	South Africa, Morocco, Dubai, Abu Dhabi, South Australia and India	CSP	Official documents, official statistics and other sources	Case study
	Del Río et al. (2019b)	To describe the auction design elements and assess the outcome of the auction.	2019	Portugal	Solar PV	Official documents, official statistics and other sources	Case study
	Del Río and Kiefer (2019)	To describe the auction design elements and assess the outcome of the auction.	2015	Chile	All RES-E and also fossil-fuel sources	Official documents, official statistics and other sources	Case study
<b>Impact of auction design elements on awarded prices in auctions (support cost efficiency)</b>	Anatolitis et al. (2022)	To assess the effects of several auction design elements on the awarded prices in European auctions	2012–2020	16 European countries (United Kingdom, Spain, Slovenia, Portugal, Netherlands, Malta, Luxembourg, Lithuania, Italy, Ireland, Hungary, Greece, Germany, France, Estonia and Croatia)	Wind and solar PV	AURES II Auction Database (AURES II, 2022)	Econometric analysis (a fixed effects panel data regression)
<b>Policy objectives and auction design</b>	Fleck and Anatolitis (2023)	To analyse the relationship between policy objectives and show if countries with renewable energy auctions in place have defined incoherent policy strategies in their renewable energy legislation and to analyse which objectives lead to the choice of which auction design elements	2011–2020,	20 European countries: Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, and the United Kingdom.	Wind and solar PV	AURES II auction database (AURES II, 2022)	Qualitative research. Qualitative comparative analysis (QCA)
<b>Effects of auctions on supply chains and technological innovation</b>	Del Río et al. (2020)	To analyse the impacts of different auction design elements on market concentration in the project development and component manufacturing segments of the RES value chain and the relative impact of auctions (as compared to other factors) on such concentration	2020	Peru, Spain, South Africa and United Kingdom	Solar PV, onshore wind, CSP, offshore wind	Structured interviews with key experts	Qualitative research: comparative case studies in four countries
	Del Río and Kiefer (2021)	To provide an analytical framework on the mechanisms linking diffusion-driven technological innovation and	2020	Spain	Solar PV, CSP, wind on-shore and biomass	A questionnaire to experts (19 experts)	Conceptual paper (provision of an analytical framework on the link between auctions and auction design elements and

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Theme	Study	Aim	Temporal scope (date)	Geographical scope (country)	Technological scope	Data	Method
		auctions and their design elements and to carry out a preliminary empirical analysis which allows the identification of the perception of key stakeholders on the topic and, based on theory and on those perceptions, to put forward some research proposals to be investigated in future research.					technological innovation)
Effects of auctions on RES communities	Szabo et al. (2022)	To explore how the introduction of auctions impacted the wind energy ecosystems of Germany and Spain.	2021/2022	Spain and Germany	Wind	Interviews with 15 stakeholders and official statistics	Comparative case studies.
	Amazo et al. (2020)	To describe the challenge of finding a definition for renewable energy communities (RECs), discuss the risks faced by RECs in RES auctions, explore measures to promote RECs and discuss experiences from three countries	Undefined	Germany, France and Denmark.	All RES-E	Theoretical analysis and experiences from Germany, France and Denmark	Theoretical analysis and experiences from Germany, France and Denmark
Cost of capital and financing	Roth et al. (2022)	To present a dataset with values for financing conditions for renewable energy projects in Europe	September 2019 and April 2020	Five EU Member States were selected as focus countries: Denmark, Germany, Greece, Portugal, and Spain. Costs of capital and financing conditions data for wind onshore (19 European countries), solar PV (10 European countries), and wind offshore (four European countries):	Solar PV, wind onshore, and wind offshore	An extensive survey (structured interviews) was conducted with different stakeholders involved in the renewable energy industry	Qualitative descriptions of survey inputs
	Dukan et al. (2019)	To map out the effects that auctions might have on financing conditions of renewable energy projects.	2019	EU Member States	Wind and solar PV	Seven semi-structured interviews with bankers, project developers and a financial advisor from Germany, Denmark and the UK. In addition, a validation workshop at the Wind Europe 2019 conference in Bilbao (Spain) was conducted	Qualitative research methods
	Dukan and Kitzing (2021)	To investigate the effects of the shift to auctioning on costs of capital (CoC) and financing conditions	2019–2020	Scope: European countries. Interviewees are from Germany, Denmark, Spain, Belgium, France, Luxembourg, Switzerland and U.K. The data sample	onshore and offshore wind	Semi-structured and focus group interviews with 40 experts in onshore and offshore wind project development and financing in Europe	Co-occurrence model

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Theme	Study	Aim	Temporal scope (date)	Geographical scope (country)	Technological scope	Data	Method
	Dukan and Kitzing (2023)	To investigate the potential for lowering support payments to RE projects by de-risking financing conditions through measures including revenue stabilisation and low-risk auction designs	September 2019 to March 2020	comprises one interview that mentions only North African experiences with auctions. 21 countries in Europe.	Solar PV and onshore wind	Several data sources: pre-existing survey of financing conditions (Roth et al., 2021) and a review of past auction rounds (AURES II, 2022) and primary investment data collected from publicly available sources	Cash-flow optimization model and sensitivity analysis
	Roth et al. (2021)	To contribute to a better understanding of renewable energy financing and energy and climate policy in the European Union	September 2019 to March 2020	All the EU Members States and the United Kingdom.	Wind and PV projects	Survey and in-depth interviews. The interviewees were mainly RE project developers, bankers, financial experts and other RE related stakeholders	Econometric data analysis and cash-flow modelling
	Resch and Geipel (2022)	To inform on the modelling works undertaken to illustrate the impacts of recent changes in RES financing conditions across Europe. To showcase the impacts of related changes in RES financing on RES support and on the future market uptake of renewables.	2030	All the EU Members States and the United Kingdom.	Wind projects	Based on Roth et al. (2021) above	Green-X model (a specialised energy system model).
	Amazo et al. (2021)	It provides auction design recommendations compatible with financing. To discuss the effect of certain auction designs on bidder's risk exposure and recommendations for auction design	2021	European countries	Wind and PV projects	Findings from tasks 5.1 and 5.2 of the AURES II project, a critical discussion with members of the Finance Working Group of Wind Europe gathered by Wind Europe during an online workshop in May 2021, and practical insights by the authors from designing and introducing auctions.	Qualitative policy analysis
<b>Design of cross-border auctions</b>	Bartek-Lesi et al. (2023)	To provide a model-based assessment of what a cross-border cooperation could mean for Hungary and its neighbouring countries.	2030	Hungary	All RES-E	Official statistics and data from Green-X model	Conceptual study (auction theory) and modelling
	Ehrhart et al. (2019)	This paper examines how opening auctions to projects in other countries influences both the allocative efficiency and the resulting award prices	Undefined	Generic	All RES-E	Theoretical analysis	Theoretical analysis (theoretical model)
	Kerres et al. (2020)	This policy brief seeks to provide an analysis on how the Energy Community Contracting Parties	Undefined	Contracting Parties of the Energy Community	All RES-E	Conceptual study	Conceptual study

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Theme	Study	Aim	Temporal scope (date)	Geographical scope (country)	Technological scope	Data	Method
		(CPs) may benefit from cross-border cooperation under the current legal framework applied in the Energy Community, and how the new possibilities given by the Clean Energy Package and associated financial instruments available at EU level can best contribute to the cross-border cooperation between the CPs and the EU Member States					
	Kerres et al. (2021)	To provide guidance on the implementation of cross-border auctions.	Undefined	EU and its Member States	All RES-E	Policy-based theoretical analysis	Policy-based theoretical analysis
	von Blücher et al. (2019)	To address the potential complexity of cross-border auctions and to show how they can be designed to be effective and efficient.	Undefined	All EU Member States (focus on insights from the German-Danish auction)	All RES-E	Theoretical analysis and experience from the German-Danish auction	Theoretical analysis and experience from the German-Danish auction
	von Blücher et al. (2020)	To show the basic functioning of the EU RES financing mechanism of the EU through a hypothetical case study	Undefined.	Luxembourg, Italy, Germany, Greece, Estonia and Lithuania.	All RES-E	Theoretical policy analysis. Assumptions checked and input provided by Member State representatives.	Theoretical policy analysis, case study (hypothetical)
<b>Design of multi-technology auctions</b>	Diallo et al. (2020)	To develop a concept to identify and quantitatively assess technology selection bias in multi-technology renewable energy auctions. The article develops an approach to identify implicit biases in renewable energy auctions and to assess the extent of the issue by quantification	Undefined	Generic (illustrative case is based on European average technology assumptions, see last column)	onshore wind power and PV	Development of a theoretical concept illustrated in a case that compares wind and solar energy and two remuneration types applied in Europe (contract for difference and fixed premium).	Development of a theoretical concept illustrated in a case that compares wind and solar energy and two remuneration types applied in Europe (contract for difference and fixed premium). The illustrative case is based on European average technology assumptions, as well as a country case study with specific assumptions for Italy and their current CfD implementation.
	Diallo and Kitzing (2020)	To identify technology bias between renewable power plants in technology neutral auctions, caused by different auction design elements	Undefined	Generic	Onshore wind, offshore wind power, PV and biomass	In the model, inputs from different sources are used for the technologies and other important parameters. Thus, the cases are not a representation of a given country or energy system, Data from AURES II database (AURES II, 2022)	An LCOE model was built, with which it is possible to calculate technology bias between renewables and evaluate different market design elements through scenario analysis. Descriptive analysis
	Winkler (2021)	To provide an overview of the current state of multi-technology auctions in the EU Member States.	2011–2020	EU Member States (focus on Denmark, France, Germany, Greece, Hungary, Italy, the Netherlands, Poland, Slovenia and U.K.).	All RES-E	Data from AURES II database (AURES II, 2022)	
<b>Future of auctions</b>	Woodman and Fitch-Roy (2020)	To initiate and structure a debate with stakeholders on RES auction design and implementation in	2030–2050	Europe	All RES-E	Project partners identified key system drivers at a workshop in Vienna (November 2019).	Qualitative research, modelling (qualitative scenario analysis)

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Theme	Study	Aim	Temporal scope (date)	Geographical scope (country)	Technological scope	Data	Method
		Europe about the future of the instrument through the creation and analysis of qualitative scenarios.				Using these insights, the University of Exeter produced a short briefing outlining four possible storylines for discussion and development at a stakeholder event in October 2020 (28 stakeholders). In addition, an online questionnaire was designed to allow participants to provide feedback on key assumptions in the study.	
	Resch et al. (2022c)	This model-based analysis complemented the narrative scenarios describing plausible visions of EU electricity markets and networks in the period up to 2050	2050	EU	All RES-E	Based on Woodman and Fitch-Roy (2020) above. Scenarios were derived using TU Wien's Green-X model,	Green-X model (a specialised energy system model).
Other sectors	Blömer et al. (2022)	To address the prerequisites, design options, and success factors for auctions in the heating sector and outline potential starting points for expanding the use of auctions in the heating sector.	2017–2021 (new heating system in Hamburg: 2007)	Europe: Descriptive analysis, policy analysis: description of auctions in the heating sector from a theoretical perspective and already established auctions: for CHP (Germany, Poland and Slovenia), for heat generation plants (Estonia, Lithuania and the Netherlands) and for district heating (DH) systems (Ireland and Germany).	Heating, combined heat and power (CHP)	Country examples	Descriptive analysis, policy analysis: description of auctions in the heating sector from a theoretical perspective and already established auctions: for CHP (Germany, Poland and Slovenia), for heat generation plants (Estonia, Lithuania and the Netherlands) and for DH systems (Ireland and Germany).
	Kerres et al. (2022)	To inform the debate on hydrogen support policies by providing practical, near-term considerations on auctions for renewable hydrogen support allocation and discussing four basic auction models.	2030 (2050)	Europe	Hydrogen	Four different auction models for the support of hydrogen were developed, and assumptions on those options were made.	Policy analysis
	Winkler (2022)	To analyse the role of auctions to decarbonise transport, heating and cooling and industry	2050	EU	Electrification, direct uses of renewable energy and hydrogen in transport, heating and cooling or industry	Official statistics and other sources.	Descriptive analysis, policy analysis

## Data availability

The data used in this research is publicly available

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