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Achieving the objectives of renewable energy policy – Insights from renewable energy auction design in Europe

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ABSTRACT

Many countries choose policy objectives around their renewable energy expansion targets, such as efficiency and effectiveness. Due to the different nature and impact of those objectives, not all can be achieved simultaneously, so prioritising objectives is advisable. In this paper, we theoretically analyse the relationship between objectives and show that most European countries with renewable energy auctions in place have defined incoherent policy strategies in their respective renewable energy legislation. Based on these strategies, we analyse which objectives lead to the choice of which auction design elements conducting a qualitative comparative analysis. Considering 269 auction rounds from 20 European countries in the period 2011–2020, not all resulting choices of auction designs are in line with auction theory and existing literature's findings on the relationship between objectives and auction design. Nevertheless, we show that on a country-level basis, most considered countries choose congruent auction designs, which either support all their (coherent) stated objectives or prioritise one or several of their incoherent objectives. For those countries with an incongruent auction design, we give recommendations on how to adapt their auction design depending on their exact choice of policy objectives.

1. Introduction

To ensure a sustainable future and to mitigate global warming, as outlined in the "Paris Agreement" (United Nations, 2015), it is of vital importance to increase the share of renewable energy sources (RES) in the energy system (Plessmann and Blechinger, 2017). Nevertheless, RES (still) need dedicated financial support to achieve this expansion (Held et al., 2019). Thus, in 2021, 164 countries worldwide have had RES policies in place, while by 2021, 131 countries have used auctions to allocate and determine the levels of financial support to RES projects (REN21, 2022), making auctions an important instrument in establishing RES in the energy supply (Bersalli et al., 2020). In the European context, auctions are typically used to determine a premium that RES electricity generators receive on top of the regular electricity market price. The lowest bids are awarded until the announced auction volume is reached. In these auctions, a multitude of different design elements can be implemented (del Río et al., 2015a), which further specify the auction rules. A detailed list of these design elements can be found in del Río et al. (2015a).

Although auctions for RES support have been criticised for their obstacles for smaller project developers and energy communities (Grashof, 2019), in the European Union (EU), Member States are generally obligated to determine support levels through a competitive mechanism (European Commission, 2014; European Parliament and Council of the E.U., 2018; European Commission, 2022a). Further, according to the "Renewable Energy Directive" (European Parliament and Council of the E.U., 2009), Member States had to determine specific RES targets, which consisted of a specific share of their gross final energy consumption in 2020. In 2018, the "Recast of the Renewable Energy Directive" set an overall target of a RES share in the EU's gross final energy consumption of at least 32% by 2030 (European Parliament and Council of the E.U., 2018). In 2021, the proposal for an amendment to the RED II proposed an increased target of a 40% RES share by 2030 (European Parliament and Council of the E.U., 2021), which might be even further increased to 45%, as proposed by the "REPowerEU Plan" in 2022 (European Commission, 2022b).

In addition to the targeted RES shares, countries typically define other economic and social objectives they pursue with their RES policies. In this paper, we gather and analyse these different objectives stated in the national renewable energy legislation of the EU Member

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States, which set the regulatory framework for national RES auctions. In addition, we conduct a cross-check with the objectives stated in each country's national renewable energy action plan (NREAP) (European Commission, 2020), which are mainly aligned with the objectives in the respective national legislation.

In contrast to much of the existing literature outlined in Section 2, our research does not focus on the choice of RES support instruments, for instance auctions or administratively-set feed-in tariffs, which corresponds to the meso-level of policy means in the taxonomy of policy design proposed in Cashore and Howlett (2007) and Howlett (2009). We focus on the detailed auction design, which corresponds to the micro-level of policy means (Cashore and Howlett, 2007; Howlett, 2009; Matsuo and Schmidt, 2019), and its relationship with various (qualitative) RES policy objectives. We combine literature on policy design (Cashore and Howlett, 2007; Howlett, 2009; Howlett and Cashore, 2009) with literature on RES auctions and auction theory to understand the interrelations between policy objectives and auction design. According to Howlett (2009, p.73), "successful policy design requires (1) that policy aims, objectives, and targets be coherent; (2) that implementation preferences, policy tools and tool calibrations should also be congruent; and (3) that policy aims and implementation preferences; policy objectives, and policy tools; and policy targets and tool calibrations, should also be congruent and convergent." We, therefore, analyse how specific design elements of RES auctions, the main RES support instrument in the EU, assist in achieving these objectives. In this analysis, we focus exclusively on solar PV and onshore wind technologies, which are expected to be the main drivers for the low-carbon transition in Europe and which make up the largest share of conducted RES auctions (IRENA, 2019).

Therefore, the first question we want to answer is whether countries chose coherent objectives, or in other words, whether incoherent objectives are included in the legislation so that their (simultaneous) achievement is more difficult. Thus, we examine the interactions between objectives and discuss their effects on each other. Our second question is whether the actual RES auction designs are congruent, meaning whether they reflect the stated policy objectives. Firstly, based on existing (theoretical) literature, we derive the effects of the different RES auction design elements on the selected objectives. Secondly, we analyse which stated policy objectives led to the choice of certain auction design elements by conducting a qualitative comparative analysis (QCA), a set-theoretic method, across countries. Thereby, we use data from the AURES II auction database (AURES II, 2021). Thirdly, we compare the results of the QCA with our findings on the effects of the auction design elements from the literature. The QCA results are ambiguous with regard to theoretical predictions. Therefore, we evaluate the auction design based on the stated objectives for each country separately. Fourthly, when selecting certain design elements, countries consequently show a prioritisation of objectives, which can lead to numerous effects (Matsuo and Schmidt, 2019). Thereupon, we examine if the countries actually implemented the appropriate design elements to achieve their objectives. We find that three countries have incongruent auction designs, as these either do not fully support their coherent strategies or do not prioritise their incoherent objectives. Our findings are an important contribution, so that policymakers can decide on their objectives in an informed manner and design their auctions accordingly. We thus assist in achieving a successful policy design.

The remainder of the paper is structured as follows. In Section 2, we discuss existing literature related to our work. Section 3 presents the theoretical framework for our analysis of the relationship between objectives and design elements. In Section 4, we discuss the countries' objectives, their implemented auction design, and the applied QCA. In Section 5, we present the results of our analysis, i.e., which countries pursue coherent policy strategies, which design choices based on the objectives are indeed sensible across countries, and which countries implemented a congruent auction design. A conclusion and outlook are given in Section 6.

2. Literature review

So far, most literature with regard to policy objectives in the context of RES in the EU concentrates on the rather abstract level (Matsuo and Schmidt, 2019), corresponding to the macro- and meso-levels of the policy design framework proposed by Howlett (2009). The existing literature includes studies on technological development (e.g., Potočnik, 2007; Lund, 2007), consumers' behaviour (e.g., Bryngelsson et al., 2016), and a more general analysis of different support schemes (e.g., Den Elzen et al., 2003; Kriegler et al., 2015), comparing the different scenarios and highlighting the advantages and disadvantages of various support schemes. Other studies focus on single countries and develop guidelines for policymakers who design policy measures while pursuing conflicting objectives (Grace et al., 2011; Khosla et al., 2015). Other strands of literature focus on the efficiency of policy instruments in general, without highlighting auctions as the (in the EU) predominant mechanism to determine support and supported projects (Quintana-Rojo et al., 2020). Kilinc-Ata (2016) econometrically analyses different systems in the EU and the US and finds that both auctions and feed-in tariffs positively affect RES deployment. Bersalli et al. (2020) econometrically evaluate policy measures in the EU and Latin America and find that feed-in tariffs and auctions reduce RE investment risk. Grashof (2019), Grashof et al. (2020), and Jacobs et al. (2020) critically analyse auctions for RES support and find that, especially for energy communities, auctions have adverse effects, and not all price decreases in the past can be attributed to the introduction of auctions. Additionally, they find that auctions lead to lower realisation rates than feed-in tariffs. They conclude that a careful policy design is necessary to address all aspects of RES expansion.

The basis for our analysis of objectives' coherence is standard auction theory (e.g., Krishna, 2010; Vickrey, 1961) which helps us assess the effects of auction design elements on auction outcome. This approach is well known in the literature (compare Haufe and Ehrhart, 2018; Kreiss et al., 2017; del Río et al., 2015a). We do not assess the renewable energy share itself but rather the variety of policy objectives set in the national legislation. We collect the countries' policy objectives and provide an overview in Fleck and Anatolitis (2022). These policy aims, which are mostly stated on a macro- or meso-level (Matsuo and Schmidt, 2019), are then translated into micro-level policy objectives in this paper in order to compare the effects of auction design elements on those objectives. Pahle et al. (2016) examine a similar question but do not focus on auctions but on general governmental actions in four countries. An interesting approach can be found in Khosla et al. (2015), who analyse India's energy and climate policy in a multi-criteria decision analysis, while defining several general goals and "subgoals". We relate to the broader objectives on the micro-level and analyse the interconnections between different objectives of a country, following the approach of coherence and congruence in Howlett (2009). We contribute to this literature by operationalising the framework introduced in Howlett (2009).

With regard to the coherence of policy objectives, the work closest to ours can be found in del Río et al. (2015b). The authors provide an overview of the relation of various policy objectives of RES auctions. Nevertheless, their comparison is mainly based on a conceptual approach, with only limited use of literature. We, therefore, provide a new holistic overview of RES policy objectives of EU Member States and a general analysis of the trade-offs between these objectives.

An important strand of related literature assesses the effects of auction design elements on one or more policy objectives. For instance, IRENA (2013) was one of the first studies to present several auction schemes and their design elements. del Río et al. (2015a) offer a comprehensive list of auction design elements and discuss their advantages and drawbacks. Gephart et al. (2017) analyse auction design elements with regard to their impact on effectiveness and support cost efficiency. Kreiss et al. (2017) also focus on effectiveness and support cost efficiency, but examine only the effects of prequalifications and penalties. Anatolitis et al. (2022) explore the effects of various auction design elements on support cost efficiency by conducting an econometric analysis using data from several European auction schemes. Haelg (2020) analyses the effects of design elements on multiple objectives, yet without focusing on specific country settings or the relation between objectives. We thus extend her work to better grasp different aspects of interactions between policy objectives and improve resulting recommendations for policymakers. A work that is close to ours concept-wise, is Matsuo and Schmidt (2019), who examine trade-offs in green industrial policies but focus on two particular countries in a case study. While acknowledging that the choice of auctions as an allocation mechanism in itself makes a substantial difference (Grashof et al., 2020; Jacobs et al., 2020), we limit our analysis to auction design elements, as the EU obligates its Member States to introduce auctions or competitive bidding processes for RES support (European Commission, 2014; European Parliament and Council of the E.U., 2018; European Commission, 2022a).

3. Analytical framework

In Section 3.1, we present our choices on data selection. To analyse the coherence of countries' policy objectives and congruence of auction designs, we then analyse the interrelations between different objectives on the micro-level based on literature review and micro-economic reasoning (Section 3.3). Lastly, in Section 3.4, we deduce the theoretical effects of auction design elements on the micro-level objectives again based on existing literature and auction-theoretic considerations. We present our assumptions for the auction-theoretic considerations in Section 3.2.

3.1. Data selection

In this section, we outline our choices of countries and technologies (Section 3.1.1), policy objectives (Section 3.1.2), and auction design elements to be considered (Section 3.1.3).

3.1.1. Countries and technologies

Since our main analysis focuses on the relationship between policy objectives and policy instrument calibration (RES auction design), we only examine EU Member States (and the United Kingdom) that have had a specific RES auction framework in place by 2020, limiting the number to 20 countries.

Thus, we consider in our analyses the following countries: Croatia (HR), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), Ireland (IE), Italy (IT),[1] Lithuania (LT), Luxembourg (LU), Malta (MT), the Netherlands (NL), Poland (PL), Portugal (PT), Slovakia (SK), Slovenia (SI), Spain (ES),[2] and the United Kingdom (UK).

In our reduced dataset for this paper, we focus only on auctions in which PV and onshore wind are auctioned. Both technologies are regarded as technologically mature (Victoria et al., 2021; Serrano-González and Lacal-Arántegui, 2016) and are expected to be the primary driver of RES expansion in the following decades (in addition to offshore wind) (Victoria et al., 2021; IEA, 2022).

[1] We split the analysis for Italy into three parts. Italy had three distinct RES laws in place over the years. Thus, IT1 refers to the auctions from 2012–2014 conducted under D.M. 06/07/2012, IT2 to the auctions in 2016 under D.M. 23/06/2016, and IT3 to the auctions in 2019 and 2020 under D.M. 04/07/2019.

[2] We split the analysis for Spain into two parts. Spain had two distinct RES laws in place over the years. ES1 refers to the auctions in 2016 and 2017 under Law 24/2013 and Royal Decree 413/2014, and ES2 to the auctions in 2020 under Royal Decree-Law 23/2020 and Royal Decree 960/2020.

3.1.2. Policy objectives

All EU Member States are required to contribute to reaching the EU's renewable energy targets based on the Renewable Energy Directive (European Parliament and Council of the E.U., 2009) for the period until 2020 and the period between 2021 and 2030 (European Parliament and Council of the E.U., 2018). For this purpose, Member States are using different support schemes for renewable energies. In this paper, we focus on the electricity sector and those countries with auctions to support electricity from RES.

Apart from reaching the expansion targets, many EU countries have additional objectives when increasing the share of renewable electricity. We collect and review the national laws to distinguish the most prominent objectives. We present the results of this review, i.e., an overview of all objectives and the relevant parts of the respective primary RES laws of the countries, in our collection (Fleck and Anatolitis, 2022). If the law is non-existent or does not provide any information on the pursued objectives, we consider the secondary legislation usually specifying the RES auction design.[3] Based on our findings, we concentrate on the five most cited objectives in this paper, namely effectiveness, support cost efficiency, green growth, security of supply and actor diversity. Following the approach in Matsuo and Schmidt (2019), we collect the (abstract) policy objectives on the meso-level and translate them into their micro-level equivalent. We then analyse the instrument calibrations on the micro-level, i.e., the auction design elements, and their effects on the policy objectives.[4]

The first objective we analyse is *effectiveness*. All EU Member States are required to determine a specific target of RES shares. Nevertheless, setting a target does not ensure an increased willingness to actually deploy RES (or meet the targets at all) in the electricity generation. Therefore, we only consider countries to pursue effectiveness, if they explicitly mention the goal of increasing RES capacities or limiting fossil fuels in their legislation. An easy way to measure effectiveness on the micro-level is to determine whether projects are actually realised.[5]

As countries state the wish to reduce the support costs for RES on the meso-level, we consider *support cost efficiency*, i.e., (on the micro-level) lowest possible auction prices (Álvarez and del Río, 2022). Support payments are often calculated as the difference between bid prices and the average electricity market prices/market values (Anatolitis and Klobasa, 2019).

Countries also state the objective of industrial development through an increasing share of RES. Thus, we define the third objective, *green growth*, as the (short-term) economic growth and especially increased employment induced by investments in renewable energy technologies (Huberty et al., 2011; Eicke and Weko, 2022). On the micro-level, this is the local economic growth in RES sectors (Matsuo and Schmidt, 2019).

Many countries also state the wish for a guaranteed supply of electricity. Hence, we include *security of supply*, which is defined as ensuring a stable electricity system (sufficient electricity supply) and power grid in the short-term (r2b energy consulting GmbH, 2019; Paravantis and Kontoulis, 2020), e.g., to avoid outages. Considering the micro-level, this corresponds to a diverse field of actors and the geographical distribution of awarded projects.

Lastly, some countries state *actor diversity*, which should guarantee a diverse field of players (Fleck and Anatolitis, 2022). For auction design

[3] Furthermore, we conduct a cross-check with the individual countries' NREAPs, where each country was asked by the EU Commission to provide its objectives. As the objectives in the legislation and the NREAPs are mostly aligned and since we can assume a direct connection between RES legislation and the specific auction design, we focus exclusively on the objectives stated in the legislation.

[4] The meso-level of policy means is not considered here, since the choice of the policy instrument, i.e., the auction, is determined by the EU legislation.

[5] This objective is sometimes referred to as "ex-post" effectiveness (e.g., del Río, 2017, 2018; Jacobs et al., 2020).

(and outcomes) on the micro-level, this means awarding projects from small-scale players, e.g., energy communities.

Although important in the energy transition context, we do not consider system cost efficiency for several reasons. Firstly, system cost efficiency, i.e., low system integration costs, is not directly reflected in the auction design of a majority of auctions (AURES II, 2021). Therefore, auction design elements are not the main driver of those costs. Secondly, system integration costs depend mainly on external circumstances, e.g., grid development, and can thus be very different for similar projects, which are simply at different locations. The indirect influence of design elements on system integration costs can therefore not be measured in the scope of this paper.

3.1.3. Auction design elements

For our analysis, we intend to see if the countries have implemented a specific design element – or not. Based on our available data and existing literature (see Section 2), we agree on several design elements, which we consider the most important to analyse. Nevertheless, in some countries, the choice of design elements is not straightforward: Germany, e.g., conducted both technology-specific and multi-technology auctions. To derive a conclusion, we consider the auctioned volumes of each round. For instance, in the German case, merely 600 MW were auctioned in multi-technology auctions, while 12.3 GW were tendered in technology-specific ones. Thus, we assume Germany to have implemented technology-specific auctions, since this format is the predominant one. We apply the same procedure for the remaining design elements.

Due to unclear effects and missing data (e.g., for local content requirements), we cannot include all design elements presented in del Río et al. (2015a) in our analysis. Other design elements are not considered, since in auction theory (and under certain conditions) they do not have any influence, for instance, the auction format or the pricing rule. Thus, out of the detailed list of design elements in del Río et al. (2015a), we choose the following for our analysis, which we describe briefly in the following. An overview of the countries' actual auction designs is presented in Table 4 in Section 4.1.2.

1. Type of auction:
   This element deals with the number of competing technologies in one auction. If there is only one technology, the auction is referred to as technology-specific, if there are more, as multi-technology.
2. Financial prequalification:
   Financial prequalifications are financial securities, bidders need to deposit to participate in the auction. Financial prequalifications, e.g., bid bonds, should ensure the seriousness of bids.
3. Material prequalification:
   Material prequalifications are typically permits or other documents needed to participate in the auction. Generally speaking, bidders need to invest more money before the actual auction in late auctions.
4. Ceiling Price:
   The ceiling price sets the upper limit for bids and protects the auctioneers from spending more than they intend in the auction.
5. Floor price:
   The floor price sets the lower limit for bids and protects bidders from too low payments in the auction.
6. Multi-criteria:
   In multi-criteria auctions, other bid components such as local content requirements or quality characteristics are included in the award procedure. Thus, the price in these auctions is not the only award criterion.
7. Bidder group control:
   This element includes bonuses and maluses, favourable treatment of specific actors, or the case of limiting some auctions to small-scale projects. Bonuses or maluses are usually used to balance out the advantages of one (group of) bidder(s). The favourable treatment of specific actors is closely related to bonuses or maluses but is usually more limited in its application.
8. Penalties:
   When penalties are implemented, usually bidders not fulfilling their contractual responsibilities, e.g., if they are behind their schedule or do not realise their project, do not regain their financial prequalifications.

3.2. Theoretical assumptions

An auction is an allocation mechanism. If there is not enough competition in the first place, an auction is not the ideal instrument choice to allocate supply and demand (Hanke and Tiedemann, 2020). To compare the effects of design elements on auction outcomes, the benchmark case is a technology-specific auction without the design elements mentioned in Section 4.1.2, with a sufficient number of potential participants who can but need not participate. We consider different bidder groups, i.e., small-scale and large-scale bidders, and different project groups, i.e., different technologies. Within each group, the bidders are a-priori symmetric, i.e., their LCOE and their system integration costs, are drawn from the same interval. This assumption is standard in auction theory (Vickrey, 1961).

3.3. Simultaneous achievement of multiple objectives

In the first step, we examine the objectives' interrelations. Following the wording of Kern and Howlett (2009), we speak of *coherent* objectives when they "can be achieved simultaneously without any significant trade-offs" (Kern and Howlett, 2009, p.395). On the other hand, objectives can also be *incoherent*, which means that it is not possible to achieve those objectives at once. At least one goal in this case has to be prioritised, while the other can only, if at all, be realised with some cutbacks (Matsuo and Schmidt, 2019). Some objectives are *neutral*, so the achievement of one has neither positive nor negative effects on the achievement of the other. In this section, we use the five objectives introduced in Section 3.1.2 to analyse and compare their pairwise relationships. These objectives are *effectiveness*, *support cost efficiency*, *green growth*, *security of supply* as well as *actor diversity*.

In Table 1, we provide an overview of our assessment of the objectives mentioned above, where + represents a positive, *o* a neutral, and - a negative relation.

Support cost efficiency is defined as the achievement of the lowest possible awarded prices. *Effectiveness* goes hand in hand with a high number of awards. By the basics of micro-economic theory, the more awards there are, the higher the prices (Mankiw, 2017). Thus, those two are negatively correlated and rather incoherent.

Effectiveness with *security of supply* are coherent, since an increasing number of realised projects leads to more available energy from this source and also lowers the probability of grid failures and shortages in supply (Cox et al., 2019). Also, a mix of different RES tend to increase security of supply by not exclusively depending on one technology (Cox et al., 2019). Furthermore, *effectiveness* and *green growth* are coherent, as investment and thus more jobs in the renewable sector will only be created if the number of awarded projects is high and projects are realised (Hao et al., 2021). For the expansion of renewables per se, it does not matter to whom the awarded and realised projects belong. Effectiveness can thus be reached by only a small pool of bidders or a large one. Nevertheless, project developers with a large portfolio have less financial insecurities and more experience (Álvarez and del Río, 2022), leading to a higher chance of realised projects (Álvarez and del Río, 2022; Wierling et al., 2018). Therefore, *effectiveness* and *actor diversity* are incoherent.

Green growth can most easily be achieved by creating new local industries and jobs. When the minimisation of support costs is the only priority, other factors favouring *green growth* have to be subordinated,

Table 1
Analysis of relation between the aforementioned objectives.

Design element	Effectiveness	Support cost efficiency	Green growth	Security of supply	Actor diversity
Effectiveness					
Support cost efficiency	–				
Green growth	+	–			
Security of supply	+	–	o		
Actor diversity	–	–	+	+	

+ = Coherent, o = Neutral, – = Incoherent.

Table 2
Analysis of the impact of selected auction design elements on the objectives.

Design element	Effectiveness	Support cost efficiency	Green growth	Security of supply	Actor diversity
Multi-technology	o	+	–	–	–
Financial prequalification	+	+	o	o	–
Material prequalification	+	–	o	o	–
Ceiling Price	o	+	o	o	–
Floor Price	+	–	o	o	+
Multi-criteria	o	–	+	o	–
Bidder group control	–	–	+	+	+
Penalties	+	–	o	o	–

+ = Positive impact, o = No impact, – = Negative impact.

leading to a slight incoherence between *green growth* and *support cost efficiency* (Matsuo and Schmidt, 2019; Probst et al., 2020). If the minimisation of support costs is the priority, most probably, only one technology should primarily be awarded.[6] Having only one technology awarded might have negative consequences for the grid stability and thus on the *security of supply* (Aslanturk and Kıprızlı, 2020). Therefore, *security of supply* and *support cost efficiency* are incoherent. Also, *actor diversity* is incoherent with *support cost efficiency*, as small-scale projects, which are more likely to face financing risks, might increase support costs (Côté et al., 2022; Álvarez and del Río, 2022).

Green growth is rather neutral with *security of supply*. Either of the goals can be achieved without affecting the achievement of the other, as we do not expect possible advantages regarding the impact on employment of one bidder group to be correlated with the impact on the electricity grid. On the other hand, *green growth* is rather coherent with *actor diversity* as a diverse field of awarded bidders, especially small-scale actors, e.g., energy communities, ensures that at least some bidders with advantageous effects on local employment and economic growth are awarded. Further, actor diversity helps achieve social acceptance and, thus, advanced economic growth in these fields (Mey and Hicks, 2019; Eicke and Weko, 2022).

Since *actor diversity* may also lead to a broader geographic distribution of projects and thus to less impact on the grid (e.g., via grid congestion), we expect this objective to potentially have a positive effect on *security of supply* (McKenna et al., 2015).

3.4. Impact of selected auction design elements on objectives

Table 2 gives an overview of the impact of the chosen design elements on the six objectives, which is elaborated in detail in the next paragraphs. These findings are based on auction-theoretic considerations as well as existing literature (e.g., Haelg, 2020).

Effectiveness

Financial and material prequalifications and penalties, exclude bidders from the auction, whose projects have a lower realisation probability (Kreiss et al., 2017). Thus, they are favourable for effectiveness (Haelg, 2020). Floor prices also have a positive effect on realisation rates, as bidders who would have realised their projects with lower awarded prices will also realise with the higher floor price. Bidder group control may lead to less advanced technologies or inexperienced project developers being awarded, reducing the effectiveness (Álvarez and del Río, 2022). The ceiling price, if determined correctly, i.e., not too low, does not exclude those bidders who are awarded,[7] and can realise their projects, and thus is rather neutral with its effect on effectiveness. Multi-technology auctions do not have a direct influence on effectiveness as well (Haelg, 2020). Multi-criteria auctions aim at a different allocation of awards, and do not affect ex-post effectiveness (Haelg, 2020).

Support cost efficiency

If the only goal is to achieve support cost efficiency, i.e., low awarded prices, Anatolitis et al. (2022) find that the introduction of financial prequalifications and multi-technology auctions have a decreasing effect on prices, thus, a positive effect on support cost efficiency. Further, the ceiling price also has a positive influence, as it excludes bidders with high costs (e.g., Gephart et al., 2017). A floor price harms support cost efficiency, as it prevents potentially lower prices. Bidder group control also harms low prices (Anatolitis et al., 2022) since not the bidders with the lowest costs are awarded, but specific bidders are favoured either by additional payments or facilitations in the bidding process. In multi-criteria auctions, the price is not the sole award criterion, which negatively affects support cost efficiency (Anatolitis et al., 2022). Penalties can increase awarded prices (Haelg, 2020), negatively affecting support cost efficiency.

Green growth

Most design elements seem to not impact green growth, as they do not influence choosing those bidders with the highest impact on local economic growth. These design elements include prequalification requirements and penalties, as well as floor and ceiling prices. Multi-criteria award procedure impacts green growth positively, as industrial policy criteria can help to select bidders with a higher impact on economic growth. When favouring small actors, e.g., in energy communities, local industries can also be supported, leading to a positive influence. Between different bidder groups (e.g., technology), the number of jobs created differs (IRENA, 2013), so favouring this group via bidder control is positive for green growth. Similarly, multi-technology auctions are negative for green growth, as technology control is not as good as in technology-specific auctions.

[6] Here the assumption of different bidder groups in Section 3.2 is important.

[7] Assumption of a sufficient number of bidders (Section 3.2).

Security of supply

Supporting different technologies and geographically dispersed projects helps ensure security of supply (Cox et al., 2019). Thus, bidder control has a positive impact on security of supply. With more projects being located and operated non-centralised, and in direct proximity to consumers, security of supply is also increased (McKenna et al., 2015). Multi-technology auctions harm security of supply, as they cannot steer the distribution of awards (at least without implementing other design elements, like quotas). The other design elements affect the awards within each technology and are therefore neutral concerning security of supply.

Actor diversity

Design elements that favour strong project developers (in terms of LCOE or risk assessment) have a negative impact on actor diversity. These design elements include prequalification requirements, penalties, and the ceiling price (Haelg, 2020). Multi-technology auctions increase competition for weaker players (Haelg, 2020), negatively affecting actor diversity. Further, multi-criteria auctions "may disincentivise small bidders as their transaction cost are higher" (Haelg, 2020, p.12). Floor prices and bidder group control positively impact actor diversity since they favour weaker players either directly through quotas or bonuses or indirectly through measures hindering strong players like a floor price or maluses.

4. Methodology

Applying the analytical framework from Section 3, we first collect information on the countries' stated objectives and data on their implemented auction designs, and present those in Section 4.1. In Section 4.2 we then outline the analysis on the coherence and congruence of countries' decisions, as well as the QCA.

4.1. Data collection

To analyse the relationship between stated objectives and implemented auction design, we first must understand the countries' choices. Thus, Section 4.1.1, provides an overview of the countries' objectives, and Section 4.1.2 of the national auction designs.

4.1.1. Overview of countries' objectives

Table 3 provides an overview of countries' objectives stated in their national legislation from Section 3.

18 of the 20 countries explicitly state reaching their renewable energy targets as an objective of their renewable support scheme. Only Estonia and Poland did not explicitly state effectiveness as an objective. Many countries state support cost efficiency as one of their objectives, except Croatia, Finland, Lithuania, Malta, the Netherlands, Slovakia, and Slovenia. This shows that financial considerations concerning cost savings are of great importance. Only three countries (Croatia, France, and Greece) decided to introduce green growth as one objective, and only Germany, Ireland, and Spain (in its new scheme) decided to explicitly set actor diversity as an objective in their legislation. In contrast, 14 countries chose to include security of supply in their objectives.

4.1.2. Overview of countries' auction design elements

In the project AURES II, information on all RES auctions conducted in the EU – with the first auction stemming from 2011 in the Netherlands – was collected. Besides the specific auction outcome, which includes the average awarded price and awarded volume, information on the specific auction's design elements was gathered. All data is contained in AURES II (2021).

Our reduced dataset (see Section 3.1.3) contains 269 auction rounds from the aforementioned 20 countries, covering the years 2011–2020, of which 267 rounds were concluded, and 2 rounds were cancelled.

13 of the 23 schemes had multi-technology auctions in place, such as Denmark or the UK. Almost all assessed countries had financial prequalification requirements in place, except Lithuania, the Netherlands, Slovenia, and the UK. 21 of the 23 schemes had implemented material prequalifications, with Portugal and Spain being the exceptions. All countries used a ceiling price, while only three countries, namely France, Italy, and Spain, implemented a floor price. Only France had multi-criteria auctions in place. 13 out of 23 schemes in our study included bidder group control measures. Except the Netherlands and the UK, all countries in our study used penalties for non-realisation/delays of the awarded projects.

An overview of the implemented design elements in the different countries is given in Table 4.

4.2. Methods

In the following, we explain the methods used to assess the performance of countries choosing their RES strategies. In Section 4.2.1, we explain the qualitative assessment of these strategies, which uses the analytical framework in Section 3 and the data from Section 4.1. Section 4.2.2 explains the QCA performed to see which stated policy objectives led to the choice of specific auction designs.

4.2.1. Qualitative assessment

In order to answer the question whether countries chose coherent objectives, we compare the stated objectives and their relationship with each other to gain a general tendency of the countries' strategies. We refer to *coherent* strategies when the chosen objectives are all (bilaterally) coherent or neutral. If there is at least one conflict between two chosen objectives, i.e., they are incoherent, we conclude that the strategy is *incoherent* as well. The German and Croatian cases give an example of how these categorisations are derived. Actor diversity is incoherent with the objectives of effectiveness and support cost efficiency (see Table 1), the other two stated objectives of Germany. Thus, the objectives of Germany are incoherent and thus, Germany's strategy is incoherent. Croatia included effectiveness, green growth, and security of supply. These objectives are either coherent or neutral. Consequently, they can all be achieved simultaneously, and Croatia has a coherent strategy.

The next assessment deals with the auction design and whether design elements actually support the chosen objectives or not. The auction design is *congruent*, if the single design elements help achieve a policy objective (Kern and Howlett, 2009) and *incongruent*, if they are counterproductive.[8]

To determine the congruence of a country's auction design, we first map the implemented design elements of this country (Table 4) to its pursued objectives (Table 3). We then analyse whether design elements with positive impact are implemented for each designated objective. If so, this accounts positively for the assessment of the auction design. If not, this accounts negatively.[9] A negative impact is also measured when design elements with negative effects on the objective are implemented, while a positive impact is measured if they are not.

Based on the countries' coherence of strategies, we now assess whether the countries chose congruent designs.[10] With coherent strategies, it is possible to design an auction where all chosen auction design elements contribute to the strategy without the need to prioritise.

[8] Please note that an incongruent auction design does not necessarily mean the auction is misdesigned. The design simply does not reflect the designated objectives but might be fulfilling others instead. Thus, the same auction design can be assessed differently for countries with different objectives.

[9] This generalisation can be made since the missing of a supporting element is negative for reaching the objective, and not only neutral on its achievement.

[10] The exact approach of the assessment can be found in the Supplementary material.

Table 3
Overview of identified objectives of the analysed countries.

	Effectiveness	Support cost efficiency	Green growth	Security of supply	Actor diversity
HR	✓	✗	✓	✓	✗
DK	✓	✓	✗	✓	✗
EE	✗	✓	✗	✓	✗
FI	✓	✗	✗	✗	✗
FR	✓	✓	✓	✓	✗
DE	✓	✓	✗	✗	✓
EL	✓	✓	✓	✓	✗
HU	✓	✓	✗	✓	✗
IE	✓	✓	✗	✓	✓
IT1	✓	✓	✗	✗	✗
IT2	✓	✓	✗	✗	✗
IT3	✓	✓	✗	✗	✗
LT	✓	✗	✗	✓	✗
LU	✓	✓	✗	✓	✗
MT	✓	✗	✗	✗	✗
NL	✓	✗	✗	✗	✗
PL	✗	✓	✗	✓	✗
PT	✓	✓	✗	✓	✗
SK	✓	✗	✗	✗	✗
SI	✓	✗	✗	✓	✗
ES1	✓	✓	✗	✓	✗
ES2	✓	✓	✗	✓	✓
UK	✓	✓	✗	✓	✗

Table 4
Overview of chosen auction design elements of different EU countries.

	Multi-technology	Financial prequalification	Material prequalification	Ceiling price	Floor price	Multi-criteria	Bidder group control	Penalties
HR	✗	✓	✓	✓	✗	✗	✓	✓
DK	✓	✓	✓	✓	✗	✗	✗	✓
EE	✓	✓	✓	✓	✗	✗	✗	✓
FI	✓	✓	✓	✓	✗	✗	✗	✓
FR	✗	✓	✓	✓	✓	✓	✓	✓
DE	✗	✓	✓	✓	✗	✗	✓	✓
EL	✗	✓	✓	✓	✗	✗	✓	✓
HU	✓	✓	✓	✓	✗	✗	✓	✓
IE	✓	✓	✓	✓	✗	✗	✓	✓
IT1	✗	✓	✓	✓	✓	✗	✓	✓
IT2	✗	✓	✓	✓	✓	✗	✓	✓
IT3	✓	✓	✓	✓	✓	✗	✓	✓
LT	✗	✗	✓	✓	✗	✗	✗	✓
LU	✗	✓	✓	✓	✗	✗	✓	✓
MT	✗	✓	✓	✓	✗	✗	✓	✓
NL	✓	✗	✓	✓	✗	✗	✗	✗
PL	✓	✓	✓	✓	✗	✗	✓	✓
PT	✗	✓	✗	✓	✗	✗	✓	✓
SK	✓	✓	✓	✓	✗	✗	✓	✓
SI	✓	✗	✓	✓	✗	✗	✗	✓
ES1	✓	✓	✓	✓	✓	✗	✗	✓
ES2	✓	✓	✗	✓	✓	✗	✓	✓
UK	✓	✗	✓	✓	✗	✗	✗	✗

Thus, if even one objective is not supported, we deduce the design is improvable.

If countries chose an incoherent strategy, they should prioritise their conflicting objectives (Howlett, 2009). Here, since at least one objective cannot be fulfilled to the full extent, we need to use a different rating scheme.[11] Here we look at which objectives are conflicting: in the example of Denmark these are support cost efficiency and security of supply. If one of those is supported by the design elements, we assume a prioritisation of (incoherent) objectives. If all other coherent objectives are supported by the design, we conclude a well-designed auction based on their not ideally chosen objectives, i.e., a congruent choice. The overall design is marked as improvable, if one of these conditions is not fulfilled.

[11] Otherwise no country with an incoherent strategy could design an auction congruently.

4.2.2. Qualitative Comparative Analysis (QCA)

We use a set-theoretic method, the Qualitative Comparative Analysis (QCA), to complement our analysis. This method, typically applied in social and political sciences and developed by Ragin (1987), enables researchers to understand the relations between certain conditions and a specific outcome and is especially suitable for small and medium sample sizes like the one in this paper. The QCA distinguishes between necessary and sufficient conditions. Necessary conditions need to be present for the outcome to occur, while sufficient conditions are usually associated with a particular outcome but are only one of several other conditions (Schneider and Wagemann, 2010). In this paper, the QCA supports us in investigating which stated policy objectives lead to the choice of a certain design element. In other words, we aim to understand which stated policy objectives led to the choice of a specific auction design element across countries.

We conduct the QCA in four steps, drawing from Kahwati et al. (2016), Schneider and Wagemann (2010), and Invernizzi et al. (2020).

Table 5
Categorisation of the countries' strategies based on their chosen objectives.

Coherent	Incoherent
Croatia	Denmark
Finland	Estonia
Lithuania	France
Malta	Germany
Netherlands	Greece
Slovakia	Hungary
	Ireland
	Italy1
	Italy2
	Italy3
	Luxembourg
	Poland
	Portugal
	Slovenia
	Spain1
	Spain2
	UK

Firstly, we need to calibrate our data. We use the crisp-set approach of QCA, since both our conditions (i.e., policy objectives) and the outcome variables (i.e., design elements) are already dichotomous. Secondly, we derive the necessary conditions, i.e, the conditions that need to be present for the outcome to occur. Thereby, we investigate each variable (policy objective) on its own. We consider a variable to be necessary if it surpasses a certain threshold, thereby distinguishing between a rather strict threshold (consistency level of at least 0.9 and coverage level of at least 0.8 (Hojnik et al., 2021; Ragin, 1987; Schneider and Wagemann, 2010)) and a rather relaxed minimum threshold (consistency level of at least 0.75 (Loures and Ferreira, 2019; Ragin, 2000) and coverage level of at least 0.6). Thirdly, to derive the sufficient conditions, the truth tables need to be constructed. Truth tables aggregate the information provided in the sample and represent the various combinations of conditions (stated policy objectives) that are associated with a certain outcome (design element).

Fourthly, we derive the sufficient conditions using the Consistency Cubes algorithm for minimisation (Dusa, 2019), which returns the same exact solutions as the classical Quine–McCluskey algorithm (Dusa, 2018; Dusa and Thiem, 2015). We report the parsimonious, as well as the intermediate solution. The first one is a superset of the latter but uses more assumptions with regard to logical remainders, which are combinations of conditions without any information on their associated outcome. We derive the intermediate solution by excluding the cases used in the minimisation process of both the presence and absence of the outcome, i.e., choosing or not choosing the specific design element, respectively. This makes the intermediate more complex than the parsimonious solution, but relies on less strict assumptions.

The QCA is conducted in R (version 4.1.2) using the "QCA" package (Dusa, 2019).

5. Results

5.1. Did countries choose coherent objectives?

We first want to answer whether countries chose coherent objectives or if their indicated objectives cannot be combined easily and need prioritisation. Using the nomenclature and methods described in Section 4.2.1, we analyse the relationship between different objectives. The results of this analysis can be found in Table 5.

A striking implication of the analysis is that the coherence of objectives is not necessarily dependent on the number of objectives. While Croatia, with three different objectives, has a coherent strategy, Estonia chose only two yet conflicting objectives. Thus, more objectives do not necessarily lead to an incoherent policy strategy.

5.2. Did the countries design their auctions according to their objectives?

In a first step, we employ the QCA to understand which stated objectives lead to the choice of the auction design element presented in Section 4.1. This analysis is conducted across countries. Then, using our findings from Section 3.4, we assess the relation between stated objectives and actual auction design on a country level. This allows us to gain more profound insights into whether the instrument calibration has been conducted according to the stated policy objectives and whether individual countries have prioritised one objective over the other.

5.2.1. Results of the QCA

Using the QCA, we investigate which stated policy objectives lead to the choice of a certain auction design element across countries.

Necessity analysis

Table 6 presents the necessary conditions for each analysed design element. We indicate the absence of a condition/policy objective by using the symbol "~". Taking into account the more conservative threshold in terms of consistency and coverage (0.9 and 0.8, respectively) we can see that the presence of the policy objective of effectiveness is a necessary condition for the following design elements: financial prequalifications, material prequalifications, ceiling price, and penalties. In other words, if one of these design elements was chosen, countries need to have stated effectiveness as a policy objective. Furthermore, the absence of actor diversity is a necessary condition for choosing material prequalifications. Except for the ceiling price, to which we attribute no effect on the effectiveness (see Table 2), these findings are in line with our predictions/recommendations, i.e., countries chose these design elements according to their objectives.

With the more lenient threshold of 0.75 consistency and 0.6 coverage, we find a larger number of necessary conditions. Effectiveness is now a necessary condition for choosing bidder group control measures, which is not in line with our previous analysis. Support cost efficiency seems to be a necessary condition for financial prequalifications, bidder group control, and penalties. In contrast to financial prequalifications, choosing bidder group control and penalties is incongruent with the objective of support cost efficiency. The absence of green growth as a stated policy objective is for many design elements a necessary condition: multi-technology auctions, financial prequalifications, material prequalifications, ceiling price, bidder group control, and penalties. Nevertheless, only in the case of multi-technology auctions this is in line with our expectations, while for bidder group control, this goes against the predictions. The remaining design elements (financial prequalifications, material prequalifications, ceiling price, and penalties) are not expected to have any effect on green growth. Furthermore, the absence of actor diversity is a necessary condition for the choice of financial prequalifications, material prequalifications, ceiling price, bidder group control, and penalties. Except for bidder group control, the results are in line with the predictions, as the remaining design elements have a negative impact on actor diversity. Thus, choosing those design elements while pursuing actor diversity would be counterproductive. Having bidder group control measures in place while not pursuing actor diversity is rather counterintuitive and further discussed in Section 5.3.

Summarising the results of the necessity analysis, it appears that most necessary conditions are in line with the predictions. Only the necessary conditions for bidder group control, as well as support cost efficiency in the case of penalties, seem to contradict the theoretical expectations. Thus, we can state that when a design element has been implemented, the countries have in most cases stated the appropriate objective.

Table 6
Necessary conditions for the choice of a certain design element.

Condition	MULT		FIN		MAT		CP		FP		MC		BID		PEN	
	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Effectiveness	0.846	0.524	**<u>0.895</u>**	**<u>0.81</u>**	**<u>0.905</u>**	**<u>0.905</u>**	**<u>0.913</u>**	**<u>1</u>**	1	0.286	1	0.048	**0.933**	**0.667**	**<u>0.905</u>**	**<u>0.905</u>**
~Effectiveness	0.154	1	0.105	1	0.095	1	0.087	1	0	0	0	0	0.067	0.5	0.095	1
Support cost efficiency	0.769	0.588	**0.789**	**0.882**	0.714	0.882	0.739	1	1	0.353	1	0.059	**0.8**	**0.706**	**0.762**	**0.941**
~Support cost efficiency	0.231	0.5	0.211	0.667	0.286	1	0.261	1	0	0	0	0	0.2	0.5	0.238	0.833
Green growth	0	0	0.158	1	0.143	1	0.13	1	0.167	0.333	1	0.333	0.2	1	0.143	1
~Green growth	**1**	**0.65**	**0.842**	**0.8**	**0.857**	**0.9**	**0.87**	**1**	0.833	0.25	0	0	**0.8**	**0.6**	**0.857**	**0.9**
Security of supply	0.692	0.6	0.632	0.8	0.619	0.867	0.652	1	0.5	0.2	1	0.067	0.6	0.6	0.667	0.933
~Security of supply	0.308	0.5	0.368	0.875	0.381	1	0.348	1	0.5	0.375	0	0	0.4	0.75	0.333	0.875
Actor diversity	0.154	0.667	0.158	1	0.095	0.667	0.13	1	0.167	0.333	0	0	0.2	1	0.143	1
~Actor diversity	0.846	0.55	**0.842**	**0.8**	**<u>0.905</u>**	**<u>0.95</u>**	**0.87**	**1**	0.833	0.25	1	0.05	**0.8**	**0.6**	**0.857**	**0.9**

Abbreviations of design elements: MULT = multi-technology auctions, FIN = financial prequalifications, MAT = material prequalifications, CP = ceiling price, FP = floor price, MC = multi-criteria auctions, BID = bidder group control, PEN = penalties. Furthermore, "~" indicates the absence of a condition/policy objective. Con = Consistency, Cov = Coverage. For a variable to be necessary, the consistency and coverage levels need to surpass certain thresholds. Values surpassing the minimum consistency level of 0.75 and minimum coverage level of 0.6 are **in bold type**. Values surpassing the more stringent threshold of a consistency level of at least 0.90 and a coverage level of 0.80 are additionally **<u>underlined</u>**.

Table 7
Sufficient conditions for the choice of a certain design element.

	MULT			FIN				MAT		FP	BID			PEN	
	1a	1b	2	1	2	3	4	1	2	1	1	2	3	1	2
Effectiveness	⨂	⨂		⨂											
Support cost efficiency	•	•	•	•		•	●			●		•	●	●	
Green growth	⊗	⊗	⊗		●						●				
Security of supply	•		●				⨂	⨂		⨂			⨂		●
Actor diversity		⊗	●			●			⨂	⨂		●			
Consistency	1	1	1	1	1	1	1	1	0.95	1	1	1	1	0.941	0.933
Raw Coverage	0.154	0.154	0.154	0.105	0.158	0.158	0.211	0.381	0.905	0.5	0.2	0.2	0.267	0.762	0.667
Unique coverage	0.154	0.154	0.154	0.105	0.158	0.105	0.158	0.048	0.571		0.2	0.133	0.2	0.19	0.095
Solution consistency	1			1				0.952		1	1			0.947	
Solution coverage	0.308			0.579				0.952		0.5	0.6			0.857	

Fiss configuration chart explaining choice of design elements.
●/• Core/contributory condition present, ⨂/⊗ Core/contributory condition absent. The core conditions represent the parsimonious solution, while the contributory condition represent the additional conditions present in the intermediate solution.

Sufficiency analysis

We created the truth tables based on our sample (see Supplementary material), which are needed to derive the sufficient conditions for choosing the respective design elements. Two out of the eight design elements could not be investigated (ceiling price and multi-criteria auctions) since all observed combinations of conditions/policy objectives lead to the same outcome. Practically, all countries implemented a ceiling price and almost no country (besides France) had multi-criteria auctions. Therefore, we could only analyse multi-technology auctions, financial prequalifications, material prequalifications, floor price, bidder group control, and penalties. Table 7 presents the sufficiency conditions.

Regarding multi-technology auctions, three configurations can lead to the implementation of this design element. Configurations 1a and 1b are similar in the core condition (absence of effectiveness, which is in contrast to our expectations) but differ slightly in their contributory conditions. The presence of support cost efficiency and the absence of green growth are again important conditions and in line with our predictions. The presence of security of supply is important in 1a, but contradicting our predictions. The absence of actor diversity in 1b is again in line. Configuration 2 shows in its parsimonious form that if security of supply and actor diversity are stated, multi-technology auctions are implemented (which contradicts our prediction). Looking at the contributory conditions, we see that support cost efficiency and the absence of green growth are also needed for configuration 2 to be sufficient. This finding is actually in line with our predictions.

Four different configurations present sufficient conditions for the implementation of financial prequalifications. The first configuration consists of the absence of effectiveness as a core condition and support cost efficiency as a contributory condition. The absence of effectiveness is in contrast to our expectations and contradictory to the necessity analysis, which shows that effectiveness is indeed a necessary condition (see Section 5.3). Support cost efficiency as a sufficient condition is again in line with the predictions. Configuration 2 consists of green growth as a sufficient condition, which is not contradictory to our predictions but, again, in contrast to the necessity analysis. Configuration 3 is again contradictory to our predictions, as the presence of actor diversity seems sufficient to choose financial prequalifications. Configuration 4 is mostly in line with the expectations, as the presence of support cost efficiency and the absence of security of supply are sufficient conditions.

The absence of either security of supply or actor diversity is sufficient to implement material prequalifications. Thus, the absence of actor diversity is a necessary and sufficient condition and hints at the fact that only countries not pursuing actor diversity choose this design element. Furthermore, this finding is in line with our prediction, as we expect material prequalifications to harm actor diversity. In contrast, the absence of security of supply is only sufficient and not necessary, and additionally, we assume material prequalifications to not affect this objective.

The only combination of stated policy objectives that is sufficient to explain the choice of implementing a floor price is the presence of support cost efficiency and the absence of security of supply and actor diversity. This finding hints at an incongruent instrument calibration, as a floor price typically harms support cost efficiency and positively affects actor diversity (without affecting security of supply).

Three configurations can explain bidder group control. The first one is the presence of green growth, which is not a necessary condition, and is in line with our prediction. The second configuration consists of the presence of actor diversity in the parsimonious solution and of the combination of actor diversity and support cost efficiency in the

Table 8
Overview of performance of EU countries with coherent strategies.

	Effectiveness	Support cost efficiency	Green growth	Security of supply	Actor diversity	Overall design performance
HR	✓		✓	✓		+
FI	✓					+
LT	✓			✗		−
MT	✓					+
NL	✗					−
SK	✓					+

intermediate solution. As bidder group control supports actor diversity, the parsimonious solution is in line with the predictions, while the inclusion of support cost efficiency contradicts those. The third configuration includes the presence of support cost efficiency and the absence of security of supply. This contradicts our prediction, as bidder group control is expected to harm support cost efficiency and support the achievement of security of supply.

Stating support cost efficiency or security of supply are sufficient conditions to choose penalties. Since we assumed no effect of penalties on security of supply, this finding is somewhat surprising. On the other hand, support cost efficiency being sufficient to implement penalties is counterintuitive since penalties are assumed to harm support cost efficiency.

Summarising the results of the sufficiency analysis, we can observe that most sufficient conditions (except for material prequalifications and bidder group control to some extent) are not in line with our predictions. In other words, when countries state a certain combination of objectives, their choice of design elements is not congruent in most cases. A more substantiated discussion on this finding can be found in Section 5.3. Furthermore, as the QCA is not able to reveal prioritisation in terms of policy objectives, we perform in the following subsection a country-level analysis of the stated objectives and auction designs to gain further insights.

5.2.2. Country-level analysis

Based on the identified design elements and the impact on the objectives, we are able to analyse whether the countries designed their auctions according to their objectives, or if they decided to prioritise one of the incoherent objectives, which is not possible in the QCA in Section 5.2.1.

As described in Section 4.2.1, we assess the effects of the chosen design elements on each of the stated objectives and derive a conclusion on whether the auction design is fit to achieve the objectives, i.e., congruent. The outcome of this analysis is presented in Tables 8 and 9. If a country did not design the auction in favour of the considered objective, i.e., if too many design elements were implemented that hinder the fulfilment or too few design elements were implemented that support the objective, this objective is marked with ✗. If the design supports the objective, it is marked with ✓.

Following the categorisation in Section 5.1, we distinguish in the further analysis between countries with coherent and incoherent strategies, as explained in Section 4.2.1. The results overview of countries with coherent strategies can be found in Table 8. Countries with a coherent strategy and a design that is not optimal and could be improved to achieve more goals are marked with - in Table 8. If the design is congruent, i.e., supporting all stated objectives, this is marked with +. Croatia, Finland, Luxembourg, Malta, and Slovakia use congruent design elements. Lithuania and the Netherlands still could improve their auction design, as at least one objective is not supported by the implemented design elements, leading to an incongruent auction design.

In contrast, countries with incoherent strategies have difficulties achieving all of their objectives at once and need to prioritise them (Howlett, 2009). Table 9 shows the results of their assessment. The symbols used are similar to Table 8. Based on this assessment, only Germany needs to improve their design according to their objectives, as it neither prioritises support cost efficiency nor actor diversity. Again, this does not mean that Germany's auctions are misdesigned, just that the auction design does not reflect the designated objectives, and Germany needs to prioritise its objectives. All other countries with incoherent strategies at least conducted a prioritisation and chose the design elements accordingly.

5.3. Discussion

The comparison of different auction schemes in various countries with different market characteristics is challenging. Therefore, we choose a method not to compare countries on their auction outcome but on their designs based on their selected objectives. Therefore, the first step to analyse is the coherence of the selected objectives themselves. Since the exact effects of one objective on the other is strongly dependent on external circumstances and thus hard to quantify, we choose a qualitative approach where we differentiate between coherent, incoherent, and neutral relations, a method that has been applied before (Howlett and Cashore, 2009; Matsuo and Schmidt, 2019). For this assessment, we use standard assumptions in auction theory. While they have been used to model auctions for RES support and other real-world applications of procurement auctions multiple times (e.g., Kreiss et al., 2017; Parlane, 2003; Ehrhart and Ocker, 2021), still they may not always accurately reflect real-world situations. Applying our results, one should bear in mind this possibility. Further, we analyse the objectives on the micro-level (Matsuo and Schmidt, 2019), as this is the level mostly affected by the micro-level policy instrument choice of auction design elements.

We also use qualitative measuring to analyse the congruence of choosing objectives. Since our aim is not to rank the countries in their performance but to show where there is room for improvement, we do not compare country schemes with each other. Thus, the results in Table 5 can be understood as a review of countries' strategies. It shows that only a few countries choose coherent strategies, and thus many countries need to prioritise their objectives when drafting their legislation to avoid conflicting pursuing objectives. This does not necessarily mean that the auctions in these countries are misdesigned or that the design will not result in appropriate auction outcomes, but only that the objectives are hard to achieve simultaneously. While a large variety of objectives can also be a sign of a thorough analysis of RES expansion, those goals still need to be prioritised (Howlett, 2009) as they cannot be achieved all at once to the same extent. Also, not the number of objectives is relevant for the general coherence, but rather the selection of objectives.

The results of the sufficiency analysis in the QCA are valid since their consistency levels exceed the threshold of 0.75, used, for instance by Hojnik et al. (2021). The raw coverage, which measures how much of the outcome is explained by the causal condition, differs between 0.105 and 0.905. The unique coverage, which shows how much of the outcome is explained uniquely by a certain condition, is between 0.048 and 0.571. These values surpass the threshold of 0.03 used in Loures and Ferreira (2019) and are in approximately the same range as the results of similar studies (Loures and Ferreira, 2019; Hojnik et al., 2021). Nevertheless, the sufficiency analysis indicates many inconsistencies in the auction design. Therefore, it should be kept in mind that most of the sufficient solutions have relatively low coverage levels, such as

Table 9
Overview of performance of EU countries with incoherent strategies.

	Effectiveness	Support cost efficiency	Green growth	Security of supply	Actor diversity	Overall design performance
DK	✓	✓		✗		+
EE		✓		✗		+
FR	✓	✗	✓	✓		+
DE	✓	✗			✗	−
EL	✓	✗	✓	✓		+
HU	✓	✓		✗		+
IE	✓	✓		✗	✓	+
IT1	✓	✗				+
IT2	✓	✗				+
IT3	✓	✗				+
LU	✓	✗		✓		+
PL		✓		✗		+
PT	✗	✓		✓		+
SI	✓	✓		✗		+
ES1	✓	✓		✗		+
ES2	✓	✓		✗	✗	+
UK	✗	✓		✗		+

configuration 1 of financial prequalifications. This means, that only a small proportion of the outcome, in our case the choice of the respective design element, is “explained” by the solutions. This indicates that an incongruent auction design of a small number of countries has a decisive impact on the sufficiency solutions and hence the interpretation. Another limitation of the method is that the sufficient solutions contradict the necessary solutions in some cases. This stems from the fact that the threshold level for necessary solutions is not completely 1, i.e., the outcome can be observed for some cases where the necessary solution is not fulfilled. In the minimisation process, it can happen that this case has a decisive influence on identifying the sufficiency conditions. Therefore, to shed further light on the relation between policy objectives and auction design, we examine the auction designs at the country-level.

We conclude that most countries design their auctions according to their objectives or have prioritised at least one. Those countries that have room for improvement in their auction designs are Germany, Lithuania, and the Netherlands. Germany should prioritise either support cost efficiency (e.g., by abolishing bidder group control measures) or actor diversity (e.g., by introducing quotas for energy communities or abolishing material and financial prequalification requirements completely), as the current design does not favour any of the two (incoherent) objectives. On the other hand, Lithuania and the Netherlands have coherent strategies. Therefore, Lithuania could improve their auction design by focusing (more) on security of supply, e.g., by introducing bidder group control measures. The Netherlands could strive more for their stated objective of effectiveness, e.g., by introducing financial prequalifications.

The boundaries of our analysis are thus given by the manifold effects and market environments each country has to face, and that will manifest in auction outcomes. Further, system cost efficiency as a major objective is not included in this analysis due to contradicting effects of, e.g., grid integration costs on support costs, which can also differ between countries and regions. The effects of design elements on objectives are mostly concluded by literature review and auction-theoretic considerations. The next step is, therefore, the thorough analysis of auction outcomes, as well as socio-economic data in the form of indicators. Then the question of how the objectives of each country are achieved can be answered qualitatively and quantitatively. Our paper thus contributes to the difficult task of choosing RES policy objectives properly and how to design auctions for RES support.

6. Conclusion and policy implications

Instead of solely focusing on the achievement of a country’s targeted renewable energy share, we consider other objectives listed in the countries’ RES legislation. We collect the RES policy objectives from 19 EU countries and the UK for our analysis. These countries are chosen since they have existing RES auction frameworks and have defined objectives in their RES legislation. Based on these objectives, we analyse whether the countries follow coherent renewable energy policy strategies, as proposed in the policy design framework by Howlett (2009). Our analysis shows that six countries chose coherent strategies, while the others have at least one incoherent objective pair. While we do not judge or rank different strategies, we point to the difficulties resulting from incoherent objectives. They can only hardly be achieved to a full extent simultaneously and priorities regarding the fulfilment of objectives usually need to be set.

Further, we test whether countries designed their RES auctions following their designated objectives. For this purpose, we analyse the effects of different design elements on objectives on a theoretical basis. We first perform a crisp-set QCA to identify which stated objectives led to the choice of certain auction design elements across countries. While the necessary conditions seem to be largely in line with our predictions, the sufficiency analysis shows rather incongruent choices.

Considering the countries’ actual auction design, we state whether the auction design is suitable for the designated strategy or whether there is room for improvement. Differentiating countries based on the coherence of their objectives, we conclude that three out of 23 auction schemes could be improved. While the auction design itself may work for another country with different objectives, it is important for policymakers to check their objectives and design their auctions accordingly. Not only does this simplify further decisions regarding future developments, but it also prevents disappointments when not all objectives are achieved simultaneously. The inevitable prioritisation should be done before passing legislation, not after.

In general, we derive the following policy recommendations:

- Policymakers should carefully analyse the relations between the objectives they intend to pursue in their RES policies, e.g., based on our proposed methodology
- Objectives in RES policies should be coherent to ensure the possibility of simultaneous achievement
- In case of incoherent objectives, a conscious prioritisation of objectives is necessary
- Implemented auction design elements should be chosen carefully to support the achievement of the (prioritised) policy objectives

More specifically, for the countries considered in this paper, we recommend the following: the coherent Lithuanian strategy could be strengthened by the introduction of, e.g., bidder group control, while the Netherlands could introduce financial prequalifications to increase effectiveness. Germany has selected many objectives, which shows a thoughtful aim determination, but does not clearly prioritise their incoherent objectives. Here, we advise to focus more clearly on one objective, e.g., increasing actor diversity by implementing an auction design more favourable for energy communities.

For future research, one could also compare the countries quantitatively based on auction outcomes and other indicators to measure further whether all objectives, not only renewable energy shares, have been achieved. In addition, the analysis should be expanded to countries in other regions to assess the policy objectives and auction design elements and to derive a more general picture.

CRediT authorship contribution statement

Ann-Katrin Fleck: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft. **Vasilios Anatolitis:** Conceptualization, Methodology, Validation, Software, Formal analysis, Investigation, Resources, Data curation, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data is publicly available as specified in the paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.enpol.2022.113357.

R code of the QCA and Excel files of the QCA data set and the coherence and consistency analysis.

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