Department for
Business, Energy
& Industrial Strategy

# Rapid Evidence Assessment: The Role of Auctions and their Design in Renewable Energy Deployment

## A report by Technopolis Ltd on behalf of BEIS

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June 2019

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# Acronyms

| | |
|---|---|
| BEIS | UK Department for Business, Energy and Industrial Strategy |
| BNEF | Bloomberg New Energy Finance |
| CfD | Contract for Difference |
| DEA | Danish Energy Agency |
| EMR | Electricity Market Reform |
| FiTs | Feed in Tariffs |
| IRENA | International Renewable Energy Agency |
| LCCC | Low Carbon Contracts Company |
| LCF | Levy Control Framework |
| LCOE | Levelised Cost of Electricity |
| PFiTs | Premium Feed in Tariffs |
| RECAI | Renewable Country Attractiveness Index |
| RES | Renewable Energy Sources |
| RES-E | Renewable Energy Sources Electricity |
| RO | Renewable Obligation |
| ROC | Renewable Obligation Certificate |
| TSO | Transmission System Operator |
| VRES-E | Variable Renewable Energy Sources Electricity |
| WACC | Weighted Average Cost of Capital (WACC) |
| UKERC | UK Energy Research Centre |

# Executive Summary

This Rapid Evidence Assessment (REA) was carried out by Technopolis Ltd as part of the Scoping Phase of the evaluation of the Contracts for Difference (CfD) Scheme. The aim was to consolidate existing evidence on the impacts of CfD auctions in the UK, plus any emerging evidence that identifies ways in which scheme design or processes for delivery may be improved. This included a review of any transferable lessons that may be learned from the design of international renewable energy auctions. As part of the Scoping Phase of the evaluation, the REA was used to develop our understanding on the theory of change for renewable energy auctions and the extent to which they are delivering against their objectives, within different contexts. The review addresses two broad questions:

- *What does existing evidence tell us about how renewable energy auction design affects intended outcomes, around: encouraging investment and increasing supply of renewable electricity, while lowering technology and support costs?*

- *What implications do wider international trends in renewable energy investment and technology costs have on the continued use of auctions in the future?*

While auctions' theory literature is extensive and has been studied for decades, research on the field of renewable energy auctions has grown in more recent years. The REA search criteria identified 303 potentially relevant publications between 2008 and 2018, from which 67 quantitative and qualitative studies met our inclusion criteria and were used to draw out findings for this report (see Annex 1 for details).

## SUMMARY OF FINDINGS

### AUCTION DESIGN

- Auction mechanisms should be tailored according to the broader electricity market conditions of each country. Auction designs can be flexibly tailored according to different policy objectives and thus, can produce a wide array of outcomes. Assessing the 'success' of an auction will depend on country-specific goals.
- As with most policy renewable energy support instruments, auctions have advantages and disadvantages. Adverse consequences may include collusion among developers, market distortions, and low project realisation rates. The challenge of auction design is to put in place mechanisms that minimise these risks.

- A precondition for successful auctions is sufficient competition. Supply must exceed demand in a way that enough bidders are attracted to participate. Insufficient competition may result in high costs.
- In renewable energy auctions, some design elements have become more common, such as sealed-bids with pay-as-clear rules. However, penalties, prequalification requirements and the auction format, often diverge since countries have different goals or market characteristics.
- Auctions usually require some ex-ante calculation of energy costs to set floor or ceiling prices, in order to curtail strategic bidding. The most common strategy to set ceiling prices is to use the Levelized Cost of Electricity (LCOE), to identify the financial gap between renewable generation costs and energy market price.
- Running auctions at regular intervals and with a fixed schedule can give greater certainty and build trust among developers.
- Some auction design features have trade-offs that policymakers can choose between based on their objectives and market context. For instance, disclosing the auction volume in advance could incentivise more developers to participate in the auction process and increase competition (Haufe & Ehrhart, 2016). However, if the auction is already in a highly competitive market, there is a risk of strategic bidding, where developers may offer low prices as an attempt to capture a larger market share, resulting in projects that not financially viable (Del Rio, 2017c)
- Pricing rules provide another example. In general, bidders appear to be incentivised to propose lower costs in auctions with pay-as-clear rules. However, this price structure can also lead to underbidding because some participants hope that the marginal bidder will set a reasonable price for all projects awarded.
- The evidence suggests that penalties are necessary to avoid unnecessary delays to project implementation or low realisation rates. The types and severity of penalties used vary across countries.

## IMPACTS OF UK'S CFD SCHEME DESIGN ON AUCTION OUTCOMES

- Clearing prices achieved during CfD renewable energy auction rounds one, and two in the UK were considerably below the Administrative Strike Price (ASP). These results may imply that the Weighted Average Cost of Capital (WACC) or hurdle rate was overestimated, although some evidence suggests that the CfD clearing prices may have lowered hurdle rates by 3% (Newbery, 2016).
- Overall, UK based evidence suggests that auctions for long-term contracts appear to reduce investors' risk and hence cost of capital.

## DIFFERENCES IN FINAL PRICES

- Auction bid prices registered across countries and regions, and even within same countries, contain significant variation. The difference highlights the context-sensitive nature of renewable energy costs.
- The most commonly cited factors to influence bid prices include: the capacity resource factor, developers' capital costs and operating expenditures.
- The difference in installation and operation costs, determined by the cost of land, labour and energy, among others, can be significantly higher in European countries such as the UK or France than in emerging economies or developing countries.
- Operational costs and capital expenditures are also determined by fluctuations in foreign exchange rates, fiscal, labour and industry legislation which makes them very context-dependent.

## INVESTMENT TRENDS AND THE MATURITY OF SUPPORTED TECHNOLOGIES

- Global annual new investment in renewable power and fuels increased by more than US$ 200 billion over the last ten years. Overall, the level of investment in renewable energy increased six-fold 2005 to 2015 before dropping slightly in 2016 due to an economic slowdown in major markets such as China. However, globally, more capacity has been installed annually but at lower costs.
- The primary drivers of costs are: continuous technology innovation, increasing international competition for projects, and competitive procurement of renewable power generation. All forecasts reviewed, and all experts consulted for the REN-21 Futures study estimate that the costs of solar-PV and offshore & onshore wind will continue to fall in the next decades.
- The UK's parliament environmental audit committee report on 'Green finance: mobilising investment in clean energy and sustainable development', highlights recent changes in investor behaviour in the UK and the recent fall in renewable energy investments in the UK. For instance, reduced funding from the European Investment Bank, falling investments following the privatisation of the Green Investment Bank and the phase-out of several RES support policies in recent years.
- In general, cost forecasts indicate that it is likely that LCOEs will decrease and auction prices will have a decreasing trajectory. LCOEs have drastically decreased in the last seven years for solar PV, concentrating solar power, offshore wind and onshore wind technologies.

## THE FUTURE OF AUCTIONS AS A SUPPORT MECHANISM FOR RENEWABLE TECHNOLOGIES DEPLOYMENT

- As technology costs continue to decline, there is an emerging debate among market commentators across Europe over the extent to which renewables may become subsidy-free. There is not a commonly accepted definition of 'subsidy-free' as renewables policy and the types of Government support mechanisms available varies across countries. For this report, subsidy-free refers to deployment without a government regulated payment support scheme such as FiTs, the RO or CfDs.
- Vattenfall, a Swedish utility company, announced the construction of a 750 megawatt (MW) offshore wind farm, 'Hollandse Kust Zuid', to be built by 2022 in the Netherlands, which will become the world's first 'subsidy-free' offshore wind project. In this case, subsidy-free means no support regarding price stabilisation. However, it will still benefit from state support through grid connections paid by the Government.
- IRENA (2018) highlights that the trend towards reduced subsidies is making developers explore more innovative ways to reach previous revenue levels without subsidies. For instance, using corporate or utility backed Power Purchase Agreements (PPAs) to provide revenue certainty.
- Although RES costs continue falling and 'subsidy-free' projects are increasingly announced, there is no substantial evidence to suggest that most of new renewable installations will be entirely subsidy free in the near future. It seems that auctions, though perhaps in different formats and with different rules, will continue to be necessary for the deployment of RES technologies (mainly to support innovation in emerging technologies).

# Introduction

Globally, several Governments are supporting a low carbon transition in the power sector through policy and financial mechanisms to accelerate the deployment of renewable energy technologies. Investment in low carbon technologies is rising, and auctions have become one of the most common policy mechanisms used in this process. Remarkably, 84 countries had held auctions by the end of 2017 (REN-21, 2018). Auctions have facilitated the discovery of real technology costs, delivered low price outcomes year by year, and incentivised project developers to expand their presence in current markets or to enter new geographies. An advantage of auctions is that they can be designed to achieve different policy goals, such as accelerating innovation in particular technologies. However, they must also be tailored to country-specific conditions to be successful.

The United Kingdom has a long history of implementing climate change and low-carbon support policies. Several policy instruments designed to support growth in renewable energy have been used at least once, and often more than one in parallel (Newbery, 2016). The last policy change took place as a result of the 2013 Electricity Market Reform, which phased out the Renewable Obligation (RO), a quota-based subsidy mechanism, and introduced the Contracts for Difference (CfD) scheme, an auction-based approach. Under the 2017 Clean Growth Strategy, the UK aims to achieve decarbonisation targets by delivering a Clean, Smart, and Flexible supply of electricity while reducing power costs for consumers. The CfD Scheme aims to reduce developers' risks by providing more certainty in revenue and to support investment in a wide range of low-carbon technologies with different levels of maturity. So far, two auction rounds have been held, which have awarded contracts to 38 projects in total.

As part of a broader evaluation of the CfD Scheme, the Department for Business, Energy and Industrial Strategy (BEIS) commissioned a Rapid Evidence Assessment (REA) to take stock of existing evidence on the role of auctions in supporting the cost-effective deployment of renewable energy. This study reviews international examples of how the design of auctions has influenced the type of outcomes obtained. As part of the initial Scoping Phase of the CfD evaluation, this REA will be used to develop an understanding on the theory of change for the Scheme and the extent to which it is delivering against its objectives, within different contexts.

The REA addresses the following two high-level research questions:

- *What does existing evidence tell us about how renewable energy auction design affects intended outcomes, around; encouraging investment; increasing supply of renewable electricity, lowering technology and support costs?*
- *What implications do wider international trends in renewable energy investment and technology cost have on the continued use of auctions in the future?*

This study was conducted as a semi-systematic literature review. The evidence prioritised studies from 2008 to 2018 which focused on auctions for renewable energy technologies and the CfD Scheme implemented in the UK.

This report is structured as follows:

**Section 1** provides an overview of the methodology, including detail on the inclusion/exclusion criteria, keywords, data sources, quality assessment and quality assurance.

**Section 2** provides an overview of auction theory and its different elements and positions the CfD scheme within this body of literature. It also synthesises the evidence around how design elements impact on outcomes.

**Section 3** focuses on investment trends and the costs of technologies

**Section 4** provides three brief case studies on Germany, France and Denmark.

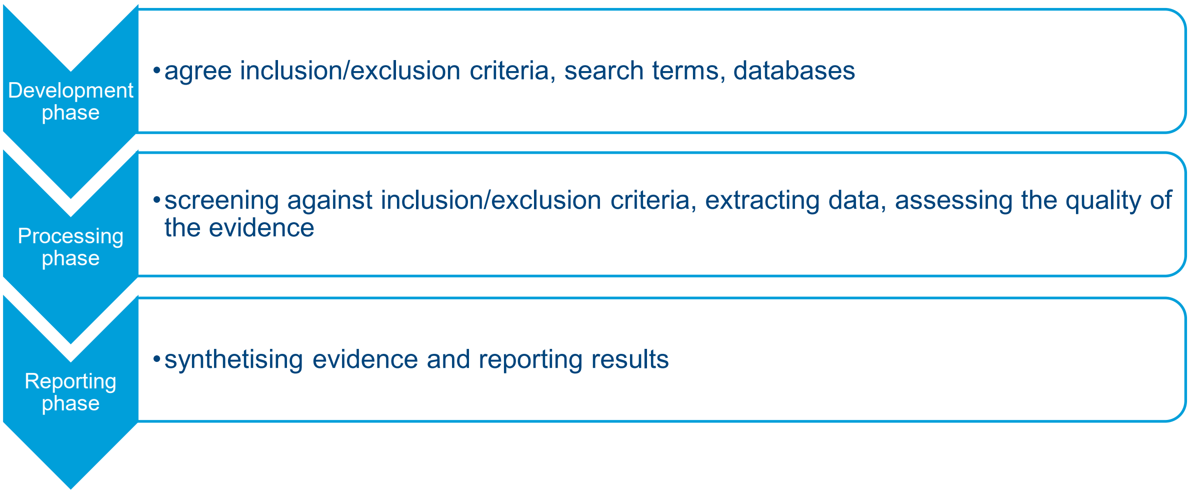
**Annex 1** provides more detail of the approach taken to assess the quality of evidence of sources reviewed.

**Annex 2** gives an overview of basic auction design features

# Methods

The REA followed a methodological approach that combined elements of a systematic evidence review with a more flexible form of 'quick scoping review'[1] and summarising evidence from known key sources. Hence, it focuses on renewable energy auction design outcomes: encouraging investment, increasing supply of renewable electricity, and international trends on technology, support costs and investment". This approach involved three main stages, as outlined in Figure 1 below.

**Figure 1: Steps for conducting a REA**




**Source**: Based on Collins et al., 2015; and Varker, et al., 2015

### Inclusion and exclusion criteria

In order to ensure the included studies were relevant to the research questions, the research team determined a list of inclusion criteria to filter search results as presented in Table 1.

The search protocol was designed to primarily focus on evidence from the UK, Denmark, France, Germany, the Netherlands and some emerging countries that were identified as being of interest to BEIS. However, evidence from a broader range of countries was included, where sources included international reviews that had drawn evidence from a broader pool of countries. The search covered literature published between 2008 and 2018 to provide evidence before and after the CfD was implemented in the UK. Finally, although the body of literature relating to auction theory

[1] Based on DEFRA's guide on 'The Production of Quick Scoping Reviews and Rapid Evidence Assessments', 2015

is vast, the team only considered studies focused on renewable/low carbon electricity auctions.

**Table 1: Inclusion criteria**

| Inclusion criteria | Description |
|---|---|
| Geographical references | **Europe/Emerging economies**<br>• UK, Germany, Denmark, France, and the Netherlands.<br>• Mexico, Chile, Brazil, and South Africa. |
| Language | English, German and Spanish. |
| Publication date | Publications between 2008-2018. |
| Publication format | Scholarly journals, grey literature. |
| Other restrictions | • Must discuss elements of RE auction design/differences in auction design elements such as eligibility criteria, disincentives for non-compliance, pot design; lessons learnt; strategic bidding; technology costs; hurdle rates; participation; operating costs and investment risks.<br>• Must be relevant to the research questions |

### Databases

The team used academic and open source databases relevant to the fields of economics, energy and policy to search for relevant studies. Table 2 presents the list of sources consulted during the database search.

**Table 2: Databases**

| Type of evidence | Database |
|---|---|
| **Peer-reviewed evidence:** | • Scopus, Web of Science, ScienceDirect |
| **Grey literature** (e.g. websites of key organisations): | • IRENA, AURES project, Oxford Energy Institute, IEA, REN21, Bloomberg |

**Keywords**

The project team tested the keywords and search strings across three academic search databases during the elaboration of the research protocol to ensure the search strategy returned relevant evidence. The team used the same keywords to find grey literature sources in relevant databases (see Table 2). During the search the following keywords were used:

“electricity auction design” AND renewable

"hurdle rate" AND renewable AND auction

auction AND Renewable AND design

Auction AND renewables

“Contracts for difference” or “electricity auctions” AND UK AND renewable

Auction AND price

“subsidy-free auctions”

“Renewable energy investment trends”

Additionally, in order to include any relevant piece of research that might have not been brought up during the database search, the team used citations of relevant studies within the sources identified for follow-up searching and inclusion, where they also met our quality assessment criteria.

### Quality Assessment Protocol

The evidence retrieved was coded according to the research type, method and journal. The quality of scholarly papers was assessed using three key dimensions of the recommendations in DFID’s ‘Assessing the Strength of Evidence’ Report: 1. conceptual framing, 2. transparency, 3. appropriateness (DFID, 2014). Any source with a score below five was excluded from the analysis (see Table 3).

For grey literature, the team used a different evaluation procedure based on its relevance to the research questions, leading organisation and source of funding. Key sources of grey literature used within the REA include the European Commission HORIZON 2020 funded AURES project which was conducted by a consortium of experts (universities, research institutes and think tanks) with a solid background and experience in auction theory and implementation (costing €1,552,601). Plus, the UN sponsored IRENA and REN21 initiatives[2], both of which involved comprehensive reviews of renewable energy auctions carried out by teams of international experts. These programmes have produced several publications summarising their findings, case studies and recommendations on best practice in renewable energy auction design. Not all publications include details of methodology, or other criteria used in our quality assessment protocol for academic literature. Nevertheless, given their direct relevance to addressing the REA questions, the transparency funding organisations (UN and EC) and descriptions given for the methods of their overall programme, these sources were included.

**Table 3 Dimensions of quality assessment**

Peer-reviewed sources

| Principle of quality | Associated questions | Scoring |
|---|---|---|
| Conceptual framing | • Does the study acknowledge existing research?<br>• Does the study construct a conceptual framework?<br>• Does the study pose a research question or outline a hypothesis? | 1 Low<br>2 Moderate<br>3 High |
| Transparency | • Does the study present or link to the raw data it analyses?<br>• What is the geography/context in which the study was conducted?<br>• Does the study declare sources of support/funding? | 1 Low<br>2 Moderate<br>3 High |
| Appropriateness | • Does the study identify a research design?<br>• Does the study identify a research method?<br>• Does the study demonstrate why the chosen design and method are well suited to the research question? | 1 Low<br>2 Moderate<br>3 High |

**Source:** ‘Assessing the Strength of Evidence’ Report by the Department for International Development (DFID, 2014).

[2] IRENA: Renewable Energy Auctions. 2017.

Grey literature

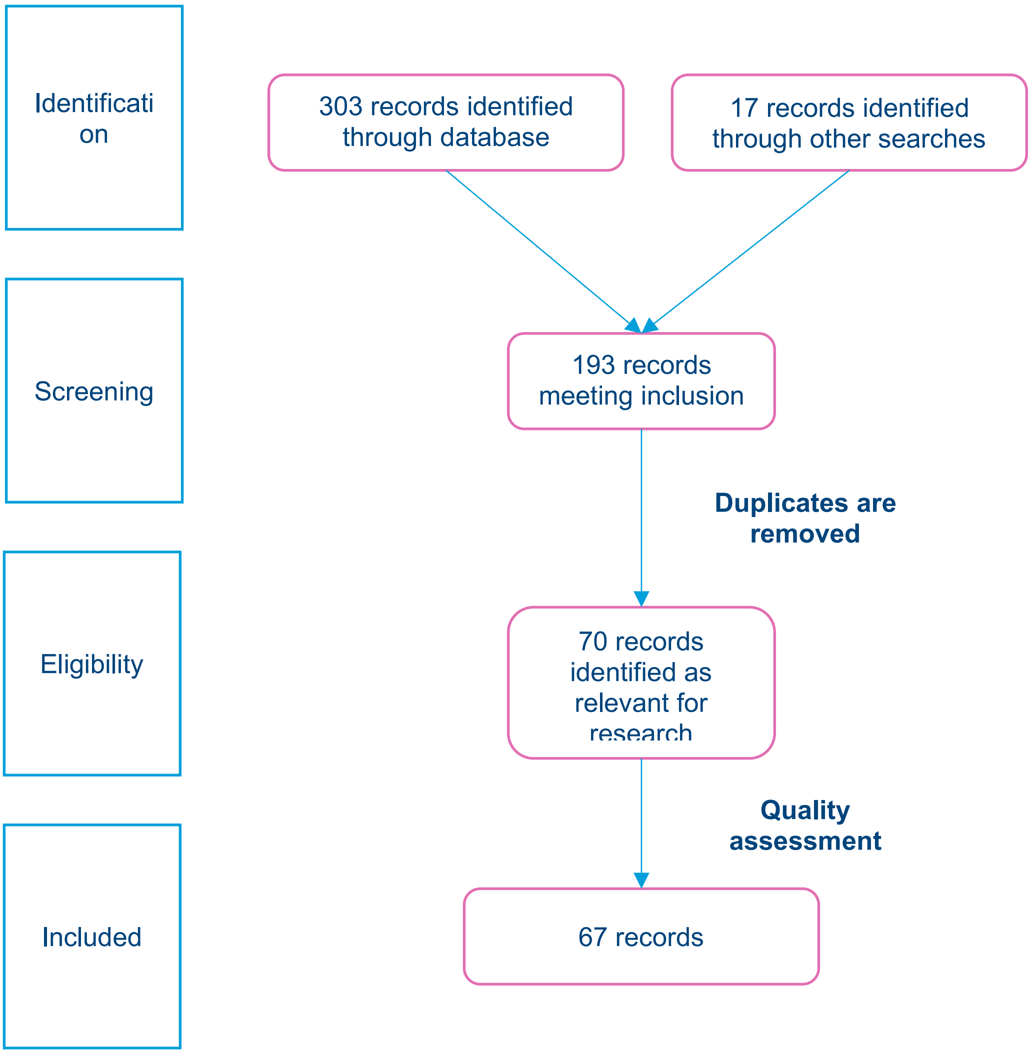
| Principle | Associated questions | Scoring |
|---|---|---|
| Appropriateness | • Does the study describe the methodology for selecting studies?<br>• Does the study assess the quality of the studies included?<br>• Are conclusions supported by the research? | 1 Low<br>2 Moderate<br>3 High |
| Transparency | • Does the study declare sources of support/funding?<br>• Has the study been developed by independent organisations?<br>• Is the study relevant for specific aspects of the research questions? | 1 Low<br>2 Moderate<br>3 High |

**Annex 1** provides the quality assessment score results and a brief explanation.

### Summary of sources reviewed

The evidence used consisted of 67 documents, including peer-reviewed and grey literature 'other sources'. The overall strength of the body of evidence can be assessed as a medium because most of the studies were of moderate quality but the key findings and conclusions are generally consistent. Figure 2 shows a flow diagram that documents the records of evidence found at each stage.

**Figure 2. Flow diagram to that documents the records of evidence found at each stage.**




## Data Management and Analysis

The records included were entered into bibliographic software (Mendeley Reference Management Software) to enable classification of findings to their sources and maintain citation lists. This process organised all studies and information included by year, journal, source and author's name. For each of the 67 pieces of evidence, the team extracted the following information in an excel file[3] to facilitate the analysis of data:

- Authors name
- Year

[3] The excel database has been provided to BEIS in order to ensure the transparency of the methodology.

- Title
- Abstract
- Journal name (peer-review only)
- Geographical focus
- Type of study (peer-review only)
- Design (peer-review only)
- Method (peer-review only)
- Source of Funding
- Lead organisation (grey literature only)
- Notes on what questions the reports address

The team followed DFID's (2014) categorisation of studies by type and design (Table 4).

**Table 4. Research Descriptors**

| Research Type | Research design |
|---|---|
| Primary | • Experimental<br>• Quasi-experimental<br>• Observational (non-experimental) |
| Secondary | • Systematic reviews<br>• Other reviews |
| Theoretical or Conceptual (TC) | • N/A |

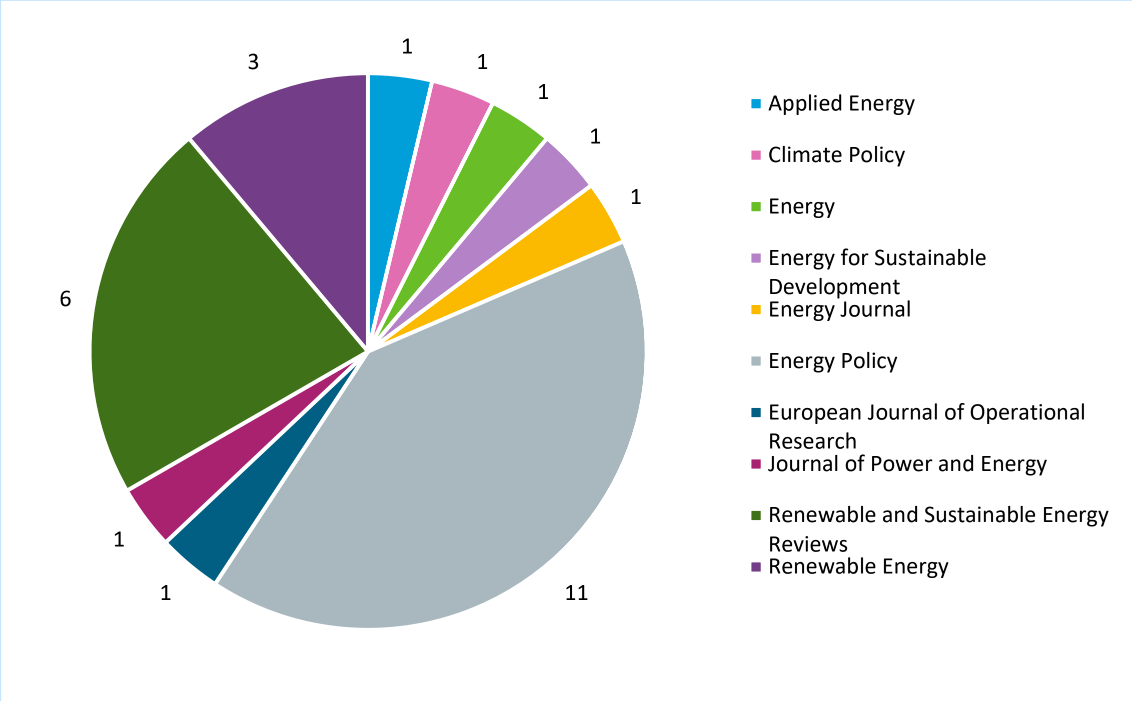
**Source:** 'Assessing the Strength of Evidence' Report by the Department for International Development (DFID, 2014).

## General findings

The peer-reviewed papers are primary (26) and secondary (1), following an observational approach (23), experimental (3) or quasi-experimental (1). The methods used are distributed unevenly between qualitative (19), quantitative (1) and mix methods (7). Most of the papers are published in the energy policy journal (11) and the energy journal (6). Figure 3 shows the distribution of papers by journal. Studies assessed as low quality is not considered in this analysis.

From the studies peer-reviewed studies included, most of them were assessed as moderate quality (19), and only a few were assessed as high quality (8). However, studies coded medium or low quality only reflect the fact that they did not meet the principles of research quality established for this study by DFID's guide 'How to Note: Assessing the strength of evidence' (2014).

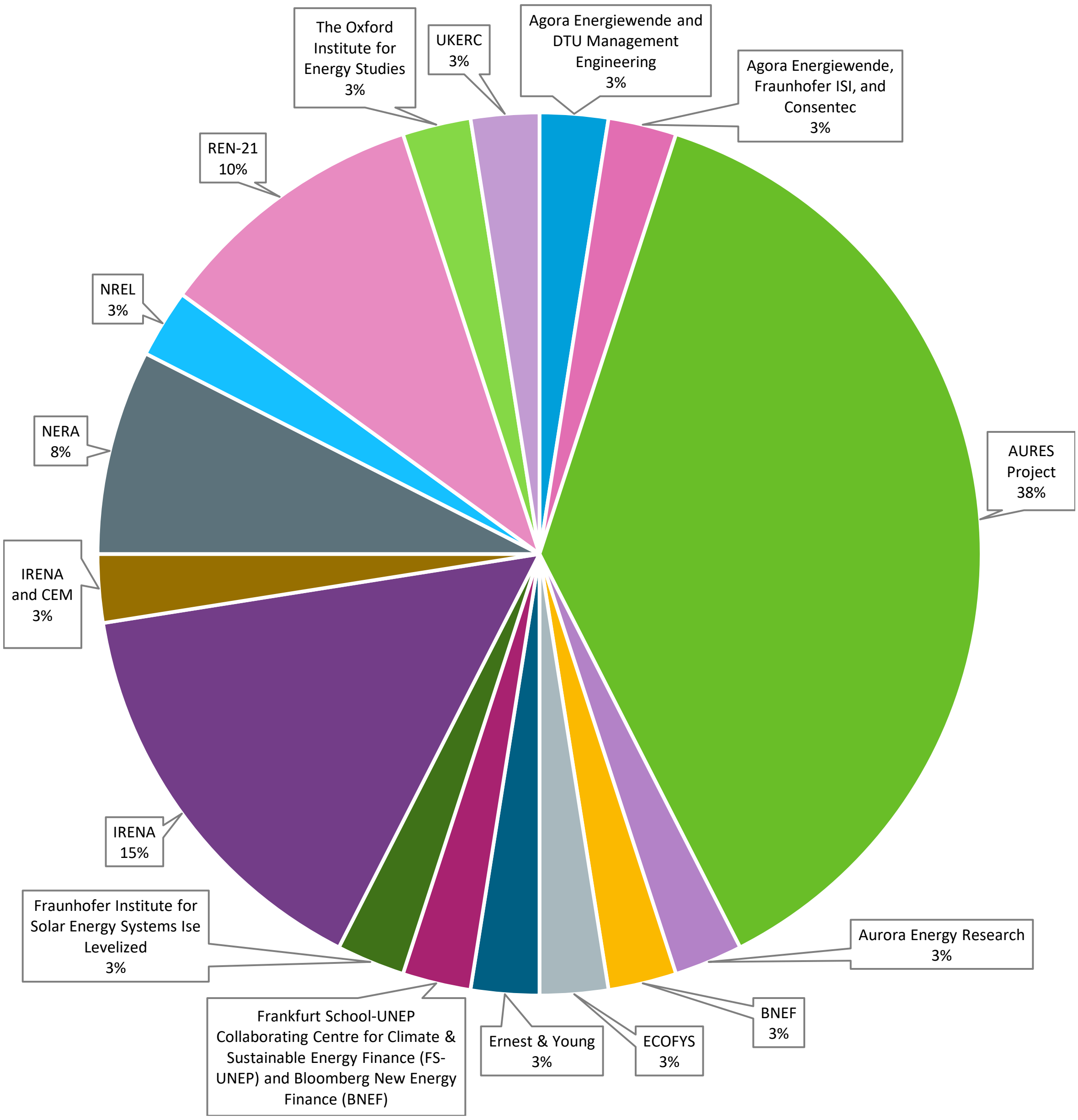
**Figure 3. Distribution of papers by scholarly journal**




Source: Technopolis, 2018

The secondary 'other sources' (40) primarily come from the large body of evidence generated by: the AURES project funded by the European Commission's Horizon 2020 programme, and the UN sponsored IRENA and REN21 initiatives. Figure 4 illustrates the distribution of studies and reports by lead organisation or project name.

**Figure 4. Other sources by lead organisation or project name**




Source: Technopolis, 2018

### Geographic coverage and transferability of findings

The geography of studies is focused mostly on European countries and emerging economies. Case study countries (Germany, France and Denmark) were identified by BEIS in advance as being of interest for inclusion in the review. The AURES and UN sponsored studies included case studies from wider international examples. The REA summarises key features of their auction design, with description of how country-specific auction design criteria are intended to meet context specific objectives within each country. The range of Government objectives for procurement of renewable electricity can vary across countries (for example, with a different balance of priorities across cost-effectiveness, security of supply, decarbonisation, supporting investment in technology innovation or local economic development). Therefore, auction designs of other countries are not necessarily transferable to the UK context, and the REA does not aim to provide policy recommendations on future design of the CfD Scheme. The report findings describe how and why outcomes from auctions have varied over time, even for the same technologies across countries, or within different regions of a country (see section 2).

### Limitations of methodology

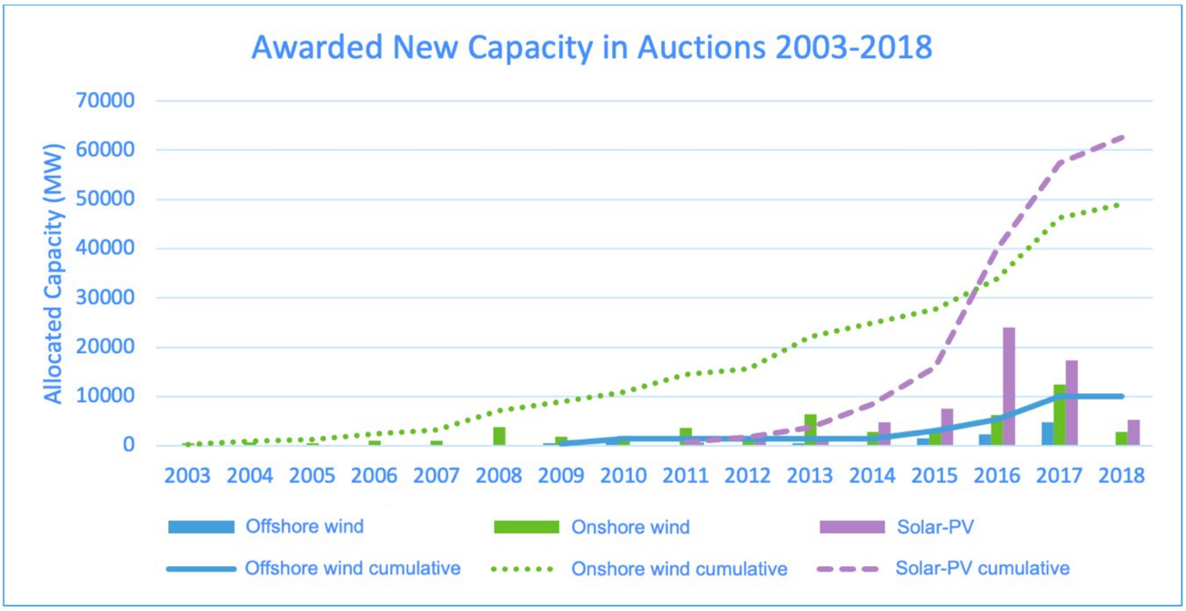
Some limitations to the methodology should be noted. Due to the limited time available to carry out this study, the search was delimited to a few databases, search strings and years. There is, therefore, some risk of missing relevant examples in the literature. However, the recent EU HORIZON 2020 sponsored AURES project and the UN IRENA and REN21 initiatives have included more systematic and comprehensive worldwide reviews of lessons learned from renewable energy auctions. As our search has included and built upon these leading research programmes, we consider the risk of missing key findings from other international studies to be reasonably low.

# Auction Design: theoretical background and common features

Renewable and low-carbon technology power auctions have allowed the discovery of real technology costs and thus, have facilitated lower cost support through long-term contracts. More and more countries have moved away from pure financial subsidy schemes to auctions or have chosen to implement auctions alongside other policy instruments. By 2017, at least 84 countries had implemented renewable electricity auctions, in contrast with only 6 countries in 2005 (IRENA, 2017; REN21, 2018).

A record 157 GW of new renewable electricity generation capacity was added globally in 2017, outpacing the 70GW of net fossil fuel generation capacity added (FS-UNEP, 2018). The proportion of world electricity generated by wind, solar, biomass and waste-to-energy, geothermal, marine and small hydro rose from 11% in 2016 to 12.1% in 2017 (FS-UNEP, 2018). Solar PV has been particularly successful as its rise in deployment has been steep since 2013. Figure 5 shows the growth in awarded new capacity via auctions for solar PV, onshore and offshore wind.

**Figure 5: Awarded New Capacity in Auctions 2003-2018**




Source: Technopolis 2018: Based on Bloomberg New Energy Finance data

Before synthesising results of how different design elements influence outcomes, this chapter aims to provide an overview of the standard design features of renewable energy auctions and their purpose. Additionally, it positions the UK CfD scheme within this general body of literature.

## Theoretical background

Auction theory has been used to efficiently allocate and price different natural resources through competition in a more transparent and cost-efficient way (Crampton, 2009). In the case of renewables, auctions have proven useful to deal with renewables' isolation from short-term markets. Electricity markets are 'inefficient in providing long-term investment signals. However, this problem is amplified in the case of renewables due to the intermittency of supply and the inverse relationship between renewable dispatch and wholesale power prices' (Hochberg & Poudineh, 2018).

Auction theory suggests that payments or revenues derived from different auction pricing methods, such as pay-as-bid and pay-as-clear[4], should be identical (Hochberg & Poudineh, 2018). The aforementioned is called the *revenue equivalence theorem*. It assumes that bidders are risk neutral, that there is an exogenous number of bidders, there is no collusion or corruption, information is symmetric, and bidders behave independently from private values (Crampton, 2009). In practice, however, these assumptions often do not hold true because bidders do care about risk; they estimate their bids at least partially on their estimates of competitors' bids, there are differences among bidders, collusion and corruption can occur and must be controlled, and furthermore, the configuration of these variables varies from context to context (Crampton, 2009).

Additionally, a crucial precondition in auction theory is competition (Crampton, 2009, IRENA, 2013;2016, Del Río, Haufe, Steinhilber, *et al.,* 2015). Supply must exceed demand in a way that enough bidders are attracted to participate, and players must have similar cost structures in order to compete against each other, which is not an exception for renewable energy auctions. Evidence found highlights that insufficient competition can result in high costs (Del Rio & Linares, 2014; Kitzing *et al.,* 2016, IRENA & CEM, 2016; IRENA 2015). For instance, solar PV auctions held in France in 2014 had a low level of participation because some prequalification requirements were not clear enough, which supposed higher risks for developers. Additionally, other bids were disqualified; in consequence, auction prices were on average 2 to 3 cent/KWh higher than under the previous FiTs scheme (Forster, 2016). Thus, in order to avoid an insufficient competition, elements such as auction volume, frequency of auctions, prequalification requirements and penalties must be carefully designed. A higher level

[4] Also known as 'uniform pricing' internationally.

of competition decreases the risk of collusion but also encourages more aggressive bidding (Del Rio, 2017c); however, Kitzing *et al.,* (2016) argue that other means rather than auctions may better support smaller markets.

## A review of Auction Design Features

Previous documented experiences with auctions have made clear that auction design must be tailored to the broader electricity market and country context, while being flexible enough to adapt to changes, avoid unwanted outcomes and incorporate lessons learnt from previous rounds (Held, Ragwitz, Fraunhofer *et al.,* 2014). Thus, successful auctions will be contingent upon auction design and the trade-offs between different elements (Del Rio, 2015a). Auction design can be tailored according to different policy objectives and produce a wide array of outcomes. Consequently, the challenge for policymakers is to create a balance between achieving auction success and avoiding unwanted outcomes such as collusion, market distortions, and low realisation rates.

Part of the complexity of choosing the 'right' auction elements relies on the inexistence of a 'model' auction design because what works in one context might not work in another. Moreover, defining the success of an auction process will depend on country-specific goals such as meeting renewable targets, reducing CO2 emissions, encouraging the deployment of specific technologies or in specific locations, developing local industries. **Annex 2** contains a table summarising the essential elements for auction design: targets and format; burden sharing of RES support; stage of project development supported; financial support levels; technology differentiation of support level; auction format and type; price limits, penalties, pre-qualification criteria; size, geographic specifications; and contract scheme. The table gathers element's definitions and examples of countries that have used the different design options from the AURES Project report "Overview of Design Elements for RES-E auctions" (2015) and the IRENA report "Renewable Energy Auctions: A guide to design" (2015).

## UK's CfD scheme

The UK Contracts for Difference auction scheme began in 2014 as part of a more extensive Electricity Market Reform, introduced by the Energy Act 2013. The CfD scheme substituted the Renewable Obligation (RO), a quota mechanism which placed an obligation on all licenced electricity suppliers to source a proportion of their electricity from renewable energy sources.

The CfD's objective is to give developers a higher level of confidence and certainty to invest in low carbon electricity generation by agreeing to a fixed price for the sale of electricity. Generators are awarded a 15-year contract for difference (CfD), with payments indexed to inflation, and a set of obligations to deliver the contracted capacity promptly (DECC, 2013). The basic premise is as follows: the contract guarantees additional revenue to developers when the wholesale market price, the "reference price", is below the "strike price", which is a measure of the cost of investing in low-carbon technology. When the reference price is higher than the strike price, developers are required to make payments back to the counterparty as illustrated in Figure 6.

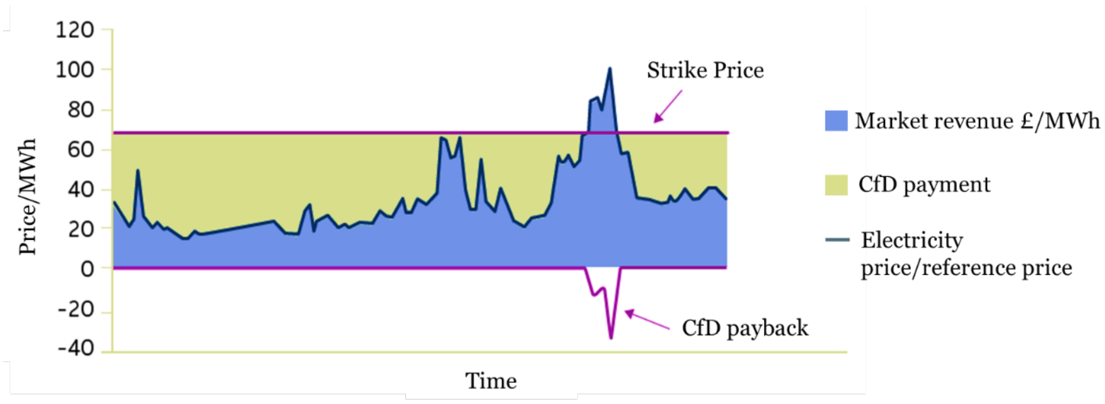



**Figure 6: CfD scheme**

Source: Technolopolis, 2018 based on LCCC data; DECC, 2014a

BEIS is the main body in charge of the auction design and ultimately responsible for the auctions and budget. The National Grid, the UK's Transmission System Operator, serves as delivery Body and it oversees administering the auction process. Also, the Government established the Low-Carbon Contracts Company (LCCC), as a private limited company, owned by the Secretary of State for Business, Energy and Industrial Strategy (BEIS) to act as the contract counterparty. Table 5 describes the main characteristics of the scheme.

**Table 5: CfD Scheme Characteristics**

| General design feature | Description |
|---|---|
| Targets and format (single unit or multi-unit) | • Multi-unit<br>– Generation (MWh)<br>– Capacity (MW) |
| Burden sharing of RES-support | • Funding comes from a levy linked to the consumption level and included into the final energy price (electricity consumers)<br>• The Treasury controls the budget through the Levy Control Framework (LCF) |
| Stage of project development | • New generation plants |
| Support levels | • The Administrative Strike Price sets out the maximum support, presented on a price per MWh basis, that the Government is willing to offer developers for each technology in each delivery year, otherwise known as the reserve price<br>• Generators will earn money from selling their electricity into the market as usual, but when the average wholesale price of electricity is below the strike price, generators will receive a **top-up payment** from suppliers, through LCCC, for the difference |
| Technology differentiation of support level | Technologies are divided into two pots:<br>• **'Established' technologies**: Onshore Wind (>5 MW), Solar Photovoltaic (PV) (>5 MW), Energy from Waste with CHP, Hydro (>5 MW and <50 MW), and Landfill Gas and Sewage Gas<br>• **'Less established' technologies**: Offshore Wind, Wave, Tidal Stream, Advanced Conversion Technologies, Anaerobic Digestion, Dedicated biomass with combined heat and Power and geothermal |
| Auction format (Price-only auctions vs multi-criteria auctions) | • Price-only auctions |

| General design feature | Description |
|---|---|
| Auction type (Sealed bid / descending clock/hybrid) and Price rule (pay-as-bid, Vickrey, Uniform price | • Sealed-bid, pay-as-clear basis<br>• Final support takes the form of a top-up payment calculated as the difference between an administratively prefixed price (the strike price) and a measure of the market price for electricity (the reference price). The auction clearing price is set by the bid made by the last project allocated a contract in the auction before the budget is used up.<br>• The strike price offered to each successful applicant will be equal to the clearing price for the relevant delivery year, but if this is higher than the administrative strike price for a particular technology, then developers will be offered a contract with the administrative strike price |
| Price limits | • Budgetary constraints determine auction volume. The mechanism establishes different budgetary constraints for different technology pots, and budgets are capped year by year<br>• The scheme sets technology-specific ceiling prices, also known as "administrative strike prices"<br>• The strike price is indexed to the consumer price index (CPI) and adjusted accordingly on an annual basis<br>• Also, the mechanism can make use of maxima (caps) and minima (floors) for particular technologies or groups of technologies within the budget available. In the first allocation round, there was a 100MW minimum threshold for wave and tidal stream technologies (i.e. not including tidal lagoon or tidal barrage) |
| Penalties | • There are two reasons why a developer can be penalised:<br>– Being offered a CfD contract but refusing to sign it: a 'non-signature case[5]' |

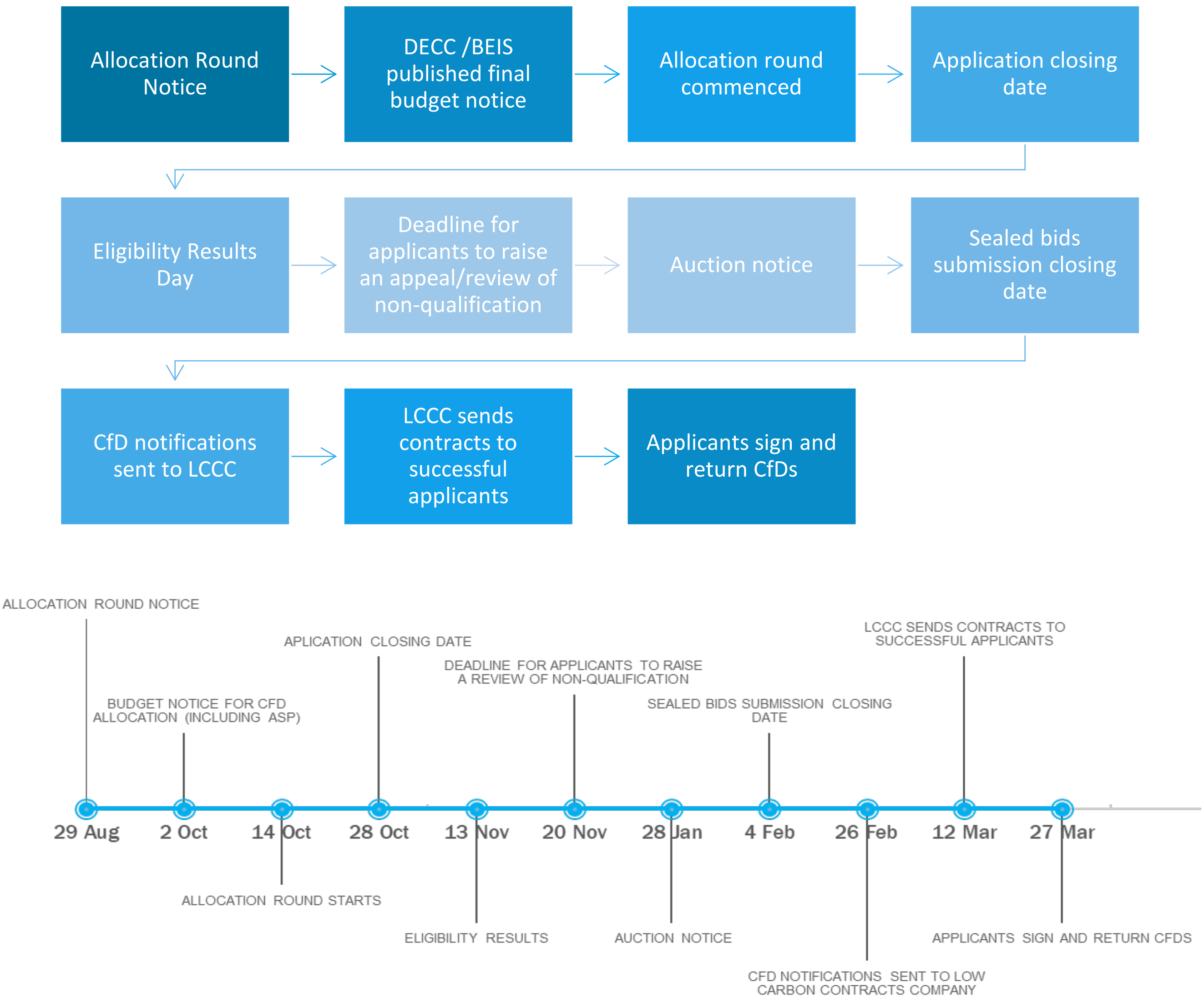
[5] For more details of penalties for non-signature cases see BEIS Report, "Non-Delivery Disincentive for Contracts for Difference. 2015

| General design feature | Description |
|---|---|
| | – Signing a CfD and failing to deliver the project, or failing to meet various milestones during the construction phase of the project 'a non-delivery case'<br><br>• The primary penalty is a period of exclusion of any project on the same physical location from future auctions (DECC, 2015b). |
| Pre-qualification criteria | • There are no local content requirements<br>• Prequalification requirements are:<br>–All spatial planning requirements are met, and permits issued to allow the project to go ahead;<br>–A connection agreement must be held;<br>–The project must be shown to not receive funds from other RES policies (the Renewable Heat Incentive, the Renewables Obligation and the Capacity market scheme) (DECC, 2014b)<br>–If the installed capacity is to be more than 300MW a 'supply chain plan' which details how the project will promote competition, innovation and skills in the supply chain must be submitted and approved |

Sources: Technopolis, 2018 based on DECC, 2014, Contract for Difference: Final Allocation Framework for the October 2014 Allocation Round; The Contracts for Difference (Allocation) Regulations 2014; DECC (2015b) 'Non-Delivery Disincentive for Contracts for Difference.'

The Levy Control Framework sets annual limits for projected costs of CfD, and the actual allocation process starts when the Secretary of State publishes a Budget Notice at least ten working days before an allocation round opens. However, the prequalification process occurs months before the allocation starts (DECC, 2014b). The prequalification process occurs months before the allocation starts (DECC, 2014b). Figure 7 Illustrates this process:

**Figure 7: Allocation Framework CfD and timeframe for the allocation round 1**




Sources: DECC, 2014b “Final Allocation Framework for the October 2014 Allocation Round”; DECC 2014d “Budget Notice for CFD Allocation Round 1”; DECC, 2015 “Contracts for Difference (CFD) Allocation Round One Outcome.”

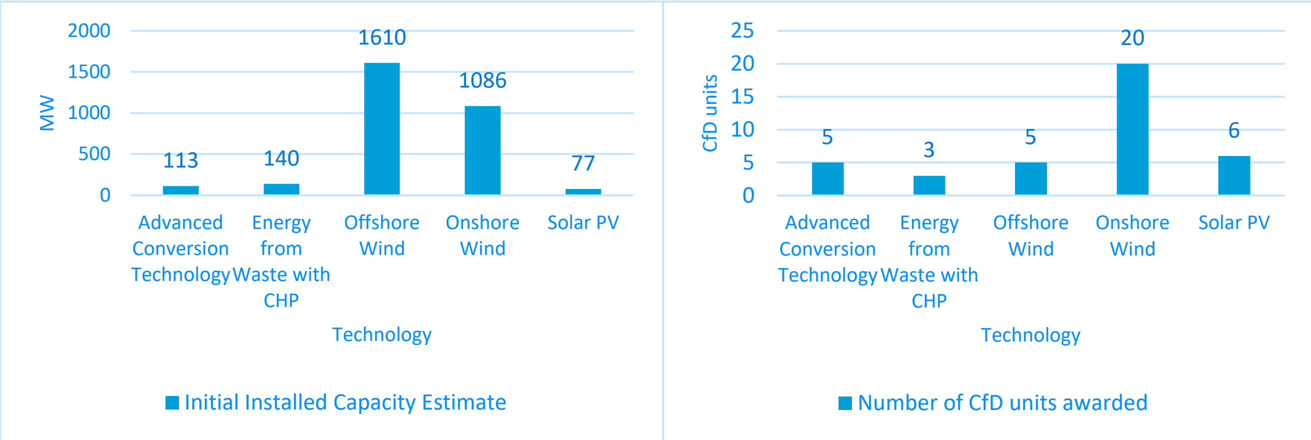
The Auction process is summarised below (DECC, 2014a):

1. Confirm eligibility
2. If the sum of the budget required to allocate a CfD to all applicants is less than or equal to each of the pot budgets, all applicants will be offered a CFD at the applicable Administrative Strike Price (Auction is not required).
3. If applications exceed the budget, the National Grid will invite applicants to submit a sealed bid containing the strike price which each applicant is willing to accept for their project. Bidders also need to indicate the delivery year, i.e. the project's Target Commissioning Date.
4. Applicants can send 'flexible bids' meaning they are flexible about when or how much they deliver. Applicants can submit up to 10 flexible bids.
5. Projects will compete across all delivery years and all technology types (within the pot of the respective technology).
6. The delivery body will rank all bids by strike price bid from lowest to highest (regardless of delivery year or technology type)
7. Each delivery year will have its clearing price, and the clearing price will be that of the highest successful strike price bid in that year.
8. Any successful project will be paid the clearing price for its delivery year, capped at the relevant administrative strike price. This means that if clearing price for a particular delivery year is higher than the strike price in that year for technology, the strike price is awarded as the contract price.

So far, two auction rounds have taken place. The first was carried out in 2014, and the second in 2016. There were 38 successful projects in the first two allocation rounds, being delivered by 34 developers. During the first round, BEIS awarded 27 CfDs with a total initial installed capacity[6] of 3026 MW. Most of the installed capacity came from offshore and onshore wind. The second round took place in 2016, and it was open only for less established technologies. It contracted a total of 11 projects with a total initial installed capacity of 3337.95 MW. BEIS expects that support costs will fall over time, as technology costs decrease, and technologies become more established. For instance, the second auction saw the cost of new offshore wind fall by 50% compared to the first round held in 2014.

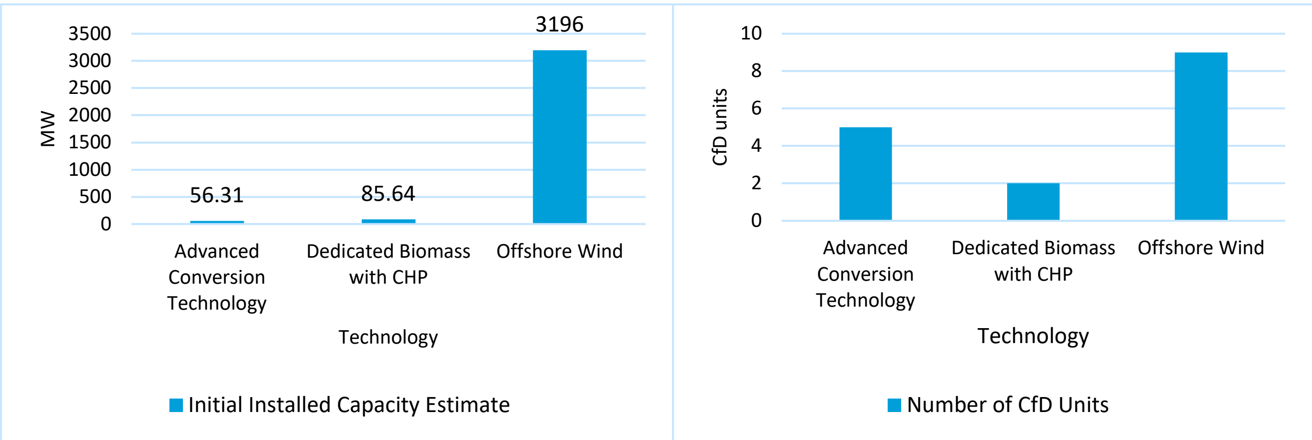
[6] In both rounds there were minor reductions to the final capacity installed of some CfD units.

**Figure 8: 1st Auction Round (2014) results: Initial capacity installed (MW) and CfD units awarded**




Technopolis, 2018 based on LCCC data (2018).

**Figure 9: 2nd Auction Round (2016) Results - Initial capacity installed by CfD unit (MW)**




Source: Technopolis, 2018 based on LCCC data (2018).

# What the evidence tells us about how different auction design features influence outcomes

A range of different forms of evidence point out that auctions may have different outcomes based on country-specific policy priorities in terms of technology, volume and location; framework conditions and auctions design (IRENA, 2013; 2014; AURES, 2016; 2017; Winkler, Magosh & Ragwitz, 2017; Held, *et al.,* 2014). Auctions must be tailored to specific market environments, objectives and broader country conditions, including politics and culture (Aquila et., al., 2017). Therefore, it can be said that the success of an auction will be based on country-specific goals and environments. Achieving auction goals will also depend on the existence of several conditions such as sufficient competition, low-cost financing, institutional capacity, grid access and bidding procedures, a clear communication strategy and a participatory approach, and contracting schemes (Del Rio, Haufe, Wigan *et al.,* 2015b). Therefore, policymakers must define their goals, choose its success criteria, design elements, and closely monitor changes in their parameters (Winkler, Magosh & Ragwitz, 2017; Del Rio *et al.*, 2015b).

The literature uses several criteria to assess the success of auctions. Effectiveness and efficiency are the most common criteria used to assess auction schemes (Del Rio *et al.*, 2015b). For instance, at the European level, the EU State Aid Guidelines (European Commission, 2014a), puts a strong emphasis on these two criteria. According to Del Rio, *et al.*, (2015b, the term effectiveness may be interpreted in the literature of renewable auctions as:

- Increased generation (MWh) or capacity (MW)
- Percentage of total electricity or energy consumption
- The ratio of the change in the normalised electricity generation over a given period and the additional generation potential of RES technology until 2020
- Target attainment, the extent to which targets for the penetration of renewable energy are fulfilled
- Project realisation rate

Efficiency can be understood as cost-effectiveness or as long-term technology effects, including the impact on innovation, technology diversity, and cost reductions over time (Del Rio, Steinhilber & Wigan, 2015b). Cost-effectiveness generally refers to the achievement of a given renewable generation target at the lowest possible cost to consumers. Therefore, policy instruments usually focus on encouraging low carbon technologies deployment by those technologies with lower deployment costs.

Another essential criterion considered when evaluating auctions is the level of support costs (Del Rio, Steinhilber & Wigan, 2015b). In general, policy instruments that support low carbon technologies imply a cost for taxpayers or consumers (Huber et al., 2004; Ragwitz et al., 2007; Steinhilber et al., 2011; EC, 2008; IEA 2008a; IEA, 2011). In the case of auctions supporting the power transition, the intention is that low carbon technologies achieve a maturity level high enough to bring down costs and reduce policy support levels. These support levels are related to efficiency, but also to distributional effects between taxpayers, consumers and generators (Del Rio, Steinhilber & Wigan, 2015b).

In renewable energy auctions, some elements have become more common, such as sealed-bids with uniform/pay as clear pricing rules. However, penalties, prequalification requirements and the auction format, often diverge since countries have different goals or market characteristics. Kreiss et al. (2016) noted that encouraging competition while ensuring high realisation rates by setting the correct parameters of the different measures is one of the most difficult challenges for policymakers. The following sections will analyse some auction elements and their trade-offs relating to effectiveness, efficiency and support costs, and how these impact investor’s risks bid prices, policy costs and realisation rates.

### Determination of price levels

Auctions may require some ex-ante calculation of energy costs to set floor or ceiling prices, in order to help avoid strategic bidding (Held, Ragwitz, Fraunhofer *et al.,* 2014). Studies suggest that administrative prices are necessary to reduce the risk of high costs to consumers, especially in the situation of low competition or collusion (Del Rio, 2015c; Del Río *et al.,* 2015a). To determine the level of support, the EU Commission (2013) highlights that most EU member countries use a cost-based approach to set the required level for renewables rather than setting it based on avoided costs to health, environment of society, because they can be misleading since they do not reflect the real cost of technologies. In the same line, the EU Commission (2013) recommends member states to use a cost-efficiency approach based on the Levelised Cost of Electricity (LCOE), and if members employ the same methodology that would allow having more comparable auction results (EU Commission, 2013).

Understanding the LCOE for each technology helps to identify the financial gap between renewable generation costs and energy market price (Held, Ragwitz, Fraunhofer *et al.,* 2014). However, the authors also suggest that once the LCOE has been set, the political and administrative procedure to set the actual level of support can be challenging and varies considerably among countries, because it is subject to potential lobbying from energy sector stakeholders and asymmetric information about technology costs held between developers and policymakers (Held, Ragwitz, Fraunhofer *et al.,* 2014). In the EU, price ceilings have been used in the Netherlands, Poland, Italy and Germany, contrary to Denmark (offshore) and France (Del Río, Haufe, Steinhilber, *et al.,* 2015).

**Administrative Strike Prices in the UK CfD scheme**[7]

In the UK, for the first CfD round, the Government set Administrative Strike Prices (ASP) at broadly comparable levels to the RO. For the second round, the ASP for a particular technology was not equivalent to the LCOE. The Government considered Technology specific factors, market conditions, and policy considerations, as summarised below.

1. CFD top-up payments were paid based on generation after taking account of the Generator's share of transmission losses.
2. Where the Generator is assumed not to be able to achieve the reference price because it sells its power through a PPA at a discount to the market price (or faces similar transaction costs within a vertically integrated utility), the ASP must be increased to compensate for this.
3. The levelised cost is defined over the operating life of a project. If the CFD contract length is shorter than the operating life and wholesale prices and capacity market revenue post-contract are lower than the levelised cost then, all other things being equal, the ASP must be increased above the levelised cost to compensate for this.

Once policymakers have decided whether to use ceiling prices or not, there is a different discussion when deciding if ceiling prices should be disclosed or not to developers in advance of the auction rounds. Disclosing ceiling prices could decrease developer's risks since some projects can be disqualified just because they did not know the ceiling price. Also, ceiling prices create a more transparent environment, and developers can feel more confident with the overall process (Del Río, Haufe, Steinhilber, *et al.,* 2015).

However, there is also evidence suggesting that disclosing ceiling prices could also work as a negative incentive for bidders, and they could orient their prices towards the ceiling price and not to their real costs, resulting in high support costs (Casseta,

[7] Source: BEIS, 2016 An explanation of the methodology used to set administrative CFD strike prices for the next CFD allocation round.

Monarca, Nava et.al. 2017; Eberhard, 2015; Del Rio, 2014a; IRENA, 2013; IRENA & CEM, 2015). This situation seems to be more common in sealed bid auctions (Del Rio *et al.,* 2017c).

**Ceiling Prices in South Africa**

'In South Africa, during the first renewable auction round under the Renewable Energy Independent Power Producer Procurement (REIPPP) in 2011, the ceiling prices were based on the FIT levels set under the other REFIT scheme, and they were disclosed to the public. From the 53 bids submitted only 28 qualified for submitting bids. However, the offered prices were close to the ceiling price because the only capacity limit that was set was the overall 3,725 MW target, which was to be met across five separate rounds of auctions and broken down into total individual targets for each technology. The total volume contracted was 1,416 MW; wind and solar PV were the main contracted technologies. However, the average prices of the bids were relatively high because of the lack of competition, and a strict volume cap failed to create pressure on the bidders to reduce their offered price. For instance, the disclosed ceiling price for onshore wind was 0.1416USD/KWh, and the average contracted price was 0.143 USD/KWh. The subsequent rounds, with undisclosed ceiling prices and well-defined volume caps, led to significantly lower prices'. Source: IRENA, 2013

### Auction volume

Determining the volume of an auction should be related to the capacity of the market to deliver, especially when there are limited developers and suppliers (IRENA, 2013). Thus, volume targets should consider the technology supply market but also, the RES targets (Del Rio *et al.*, 2015c). This is crucial for the effectiveness of the mechanism. If a high volume is auctioned, concerning the market, then little scarcity is created resulting in little price competition.

**Reduction of auction volume in Germany's auctions**

'For Germany's Solar PV auctions, which started in 2015, the amounts of MW being auctioned were reduced each year during the next three years and any amount not built passed on to future auctions (Morris, 2015 cited by Del Rio, Haufe, Wigan *et al.,* 2015). Additionally, if the annual target capacity is not reached, the following year's tender will be adjusted accordingly'.

Source: (Del Rio *et al.,* 2015a)

Disclosing the auction volume in advance could incentivise more developers to participate in the auction (Haufe & Ehrhart, 2016). However, Del Rio (2017c) argues that if the auction volume is attractive and it is a highly competitive environment, there is a risk of strategic behaviour. Developers may report low prices as an attempt to capture a larger market share, resulting in underbidding. This, in turn, could lead to low project realisation rates, bankruptcy, or a suboptimal allocation of resources (Hochberg & Poudineh, 2018).

### Frequency and time for auctions

More significant risks for investors arise from intermittent calls for auctions because they do not generate stable conditions to invest. Intermittent calls do not provide developers with a long-term sign to invest since support is only granted at a certain point in time (Del Río, Haufe, Steinhilber, *et al.,* 2015). This could discourage developers from participating, increase their costs or lead to underbidding. The literature shows that it is crucial to run auctions at regular intervals and with a fixed schedule, which can give greater certainty and build trust among developers (Huntington, Rodilla, Herrera, *et al.,* 2017; Del Río, Haufe, Steinhilber, *et al.,* 2015). For Poland, Kitzing & Wendring (2016) argue that the low frequency probably caused underbidding because developers did not want to miss the opportunity to participate since it was uncertain how long they would need to wait until the next round. Similar cases occurred in Ireland (Kitzing & Wendring, 2016) and Denmark (Steinhilber, 2016).

Nevertheless, standalone auctions have also often been used, and may be particularly appropriate when dealing with less-mature technologies or when the total quantity to be auctioned is small (IRENA, 2016).

**Auctions' schedule in Germany**

'In Germany, one of the main features of the newly designed auction in Germany is the longer-term planning and a pre-commitment to a schedule. Nine auctions are planned from 2015 to 2017, and all of them will take place every year in April, August and December and will be announced by the German regulatory agency, Bundesnetzagentur, six to nine weeks before the auction'.

Source: IRENA, 2016

Hochberg & Poudineh (2018) also draw attention to reasons for not holding auctions if it becomes apparent that the market is unprepared, for instance, when there is oversupply, transmission constraints or other foreseeable issues. For instance, in Brazil, only 14% of wind projects awarded between 2009 and 2012 were completed on schedule. This was due to 'delayed grid connection, delays resulting from the environmental feasibility studies, supply bottlenecks for wind power systems, the bankruptcy of the wind turbine manufacturer IMPSA, late financing approval through the development bank BNDES and poor project management' (Bayer, 2018).

## Auction format

The format can have a significant impact on the cost-effectiveness of the mechanism. In multi-criterial auctions, the lowest price bid may not be selected if there are other criteria involved besides price (Del Rio *et al.,* 2016b). This is the case of South African auctions which take into consideration local content requirements besides prices (See text box 5). Another example is France. The French auction system for solar PV has a point-based criteria system, whereby auctions are prioritised based not only on price but also on environmental impact and R&D contribution (Forster, 2016).

**Local requirements in South Africa**

'The South African Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) assesses bidders based on the price offered, but 30% is also allocated to the project's level of contribution to economic development (i.e. job creation, preferential procurement, enterprise development, SME participation and socioeconomic development). Policymakers clearly emphasised local industry development over minimising costs. This was consequently reflected during the first solar PV round results held in 2012, which led to high bid prices'.

Source: IRENA, 2016

## Auction type and price rules

Del Rio *et al.,* (2015c) mentions how different auction types impact participants' costs and bid prices. Sealed bids can lead to lower participation costs than other types because they are easy to understand and encourage competitively low bids. Casseta, Monarca & Nava et al. (2017) illustrate this point with the case of onshore wind auctions in Italy, in which simplicity of the sealed bid auction design certainly stimulated competition by encouraging many project developers to make bids, especially after the second round. However, the lack of information in sealed-bid formats could also lead to the 'winner's curse' because it is difficult to estimate other player's bids (IRENA & CEM, 2015) by leading to bids that are so low that developers are unable to deliver their project.

Information is particularly important for less mature technologies such as offshore wind and solar CSP because it can be challenging to calculate real costs without a price signal, and the asymmetry could increase developers' risks (IRENA & CEM, 2015). In descending clock auctions, the 'winner's curse' can be avoided since participants adjust their prices in each round. However, the risk to disclose prices when participation is not high enough is that participants could collude to achieve a higher final price (IRENA, 2015).

In the case of price rules, in pay-as-bid auctions, bidders aim to win by submitting the highest possible bid, which can cause an exaggeration of costs (Krishna, 2009), "the higher the bid the higher the profit in case of winning, but also the lower the probability to be successful at all" (Haufe & Ehrhart, 2015). However, information between participants is asymmetric and may also lead to underbidding and low realisation rates (IRENA & CEM, 2015). Another disadvantage is that granted prices may be very different among participants (Haufe & Ehrhart, 2015). Anatolitis & Welisch (2017) modelled onshore wind power auctions in Germany, and their results show that pay-as-bid resulted in slightly lower prices. However, the difference was not significant regarding total support costs.

Some evidence suggests that bidders seem to be better encouraged to disclose their real costs through marginal uniform prices (pay-as-clear), since the final price will be independent of their bid, resulting in lower costs of support (IRENA, 2015, Del Rio, *et al.*, 2017c, Del Rio *et al.*, 2015c). However, experiences in some countries such as Spain, highlight that even this price structure could also lead to underbidding (Del Rio, 2016). Participants bid low and hope that the marginal bidder will set a reasonable price for all projects awarded (Steinhilber, 2016 cited by Del Rio, 2017c).

### Prequalification requirements and Penalties

The objective of setting prequalification requirements is to reduce the risk of low realisation rates; however, they imply necessary trade-offs. On the one hand, requirements such as developers' experience are likely to increase the project realisation rate and decrease delays. On the other, strict requirements could hinder competency because fewer players are likely to fulfil requirements or are less encouraged to participate (Haufe, Ehrhart, 2016; Hochberg & Poudineh, 2018; Del Rio, 2015c). Prequalification requirements are sunk costs, and there is a high probability they cannot be recovered if developers are not awarded (Fraunhofer ISI et al. 2014). Thus, only bidders with a positive expected profit choose to participate in the auction (Kreiss, J., Ehrhart, K., Haufe, M. 2017). Thus, it is common that small players are discouraged from participating if requirements are too strict.

A common type of prequalification requirement is financial guarantees, which are pre-payments from participants to prove their commitment. These pre-payments can only be regained it if developers realise the project. Kreiss, Ehrhart & Haufe (2017) state that if the cost of realisation is higher than the cost of non-realisation, developers will not develop the project. Thus, this type of requirement decreases the likelihood of failing to deliver the project support and “makes non-realization less attractive” (Kreiss, Ehrhart & Haufe, 2017). Kreiss, Ehrhart & Haufe, (2017) suggests that auction designs should set high financial prequalifications but not too high in relation to the securities while aiming to reduce the sunk cost effect.

**Financial pre-qualification requirements in Germany**

‘In Germany, bidders are required to provide a security payment of EUR 4 per kW of the bid volume to the Federal Network Agency in order for the bid to be allowed. This payment may be reduced by 50% if the bidder submits the copy of a zoning plan allowing the construction of the installation as planned or the local government’s decision to carry out a public consultation of the draft zoning plan with the bid (Baker and McKenzie 2015). Moreover, bidders must provide information on the land on which the installation is planned to be constructed, in order to foresee and adequately take into account potentially conflicting land uses. In this context, they are also required to submit (at least) the copy of a competent local government’s decision to enact or alter a local zoning plan which would allow the construction of the planned solar PV installation. However, submitting decisions of a more advanced planning stage (i.e. an enacted zoning plan or a decision to carry out a public consultation of the draft plan, cf. Section 3(2) Federal Building Code) will entail a relaxation of the security payments (Baker and McKenzie 2015). The payment above of four Euros is cut in half to two Euros per kilowatt if the bidder can submit one of two types of building permits indicating that the land where the project is planned has already been set aside for ground-mounted solar PV (Morris 2015)’

Source: IRENA & CEM, 2015

In the case of penalties, the evidence analysed suggests that penalties are necessary to avoid realisations delays or low realisation rates (Hochberg & Poudineh, 2018; Held et al. 2014; Kreiss, Ehrhart & Haufe, 2017, IRENA, 2013; 2015). Hochberg & Poudineh (2018) accurately point out that penalties should be strict enough to discourage developers to take a position of "wait and see" after auctions are held. In the absence of penalties, ineffectiveness is likely to result, which Khana and Barroso, (2014) illustrate with the case of India's solar PV state auctions. However, penalties should be set with care, because they add a risk premium to the cost of capital and thus, increasing bid prices and potentially limiting actors' diversity.

Hochberg & Poudineh (2018) also suggest that auction designs should look for a balance between pre-qualification requirements and penalties. For instance, earlier auctions may be better designed with lower prequalification requirements balanced by penalties, while in late auctions, it may be better to set lower penalties balanced by pre-qualification requirements. Kreiss, Ehrhart & Haufe, (2017) provide a table of the trade-offs between pre-qualification requirements and penalties (figure 10).

**Figure 10: Penalties and Prequalification requirements trade-offs.**

| Auction design option | Desired effects | Undesired effects |
|---|---|---|
| **Financial prequalifications** | • higher expected realization probability | • higher expected support level |
| **Physical prequalifications** additive to financial prequalifications | • reduced cost uncertainty<br>• higher expected realization probability | • sunk costs<br>• reduced competition level<br>• higher expected support level |
| **Penalties** additive to financial prequalifications | • higher expected realization probability | • higher expected support level<br>• potentially inefficient |
| **Penalties** substitutive to monetary equivalent financial prequalifications | • lower expected support level | • lower expected realization probability<br>• potentially inefficient |
| **Second-price auction** in comparison to first-price auction | • lower expected support level | • lower expected realization probability |

Source: Kreiss, Ehrhart & Haufe, (2017)

**Different types of penalties: The Netherlands, Denmark, France and Germany**

"In the Netherlands, penalties are in place for non-realisation of projects within the required period. Project developers that do not realise their project within the predefined 4-year realisation period are excluded from SDE+ for five years for the same project. Penalties only apply to projects that claim over 400M EUR. For projects with a budget claim >400M EUR, a bank statement and a realisation contract are required. The contract states that the project has to be realised within the given timeframe".

Source: Held *et al.,* 2014

"In Denmark, penalties in the Anholt off-shore wind project depended on whether there is non-compliance with the contractor a delay and they are progressive in both cases. Penalties of 100M DKK (around 13M €) for delays up to 5 months, 200M DKK for delays between 6 months and one year and 400M DKK for delays beyond one year were implemented. Generation-based penalties apply to delays: reduction of support levels of 1 /kWh for delays between 1 and three months, 2 /kWh between four and eight months and 3 /kWh between nine and twelve months (Kitzing 2013). Also, there was a stand-by requirement: If the first winner of the bid opts out within the first six months, the second winner has to take over the contract and undertake the project within the same timeframe".

"In France, there are financial securities necessary for small-scale solar PV (Fraunhofer ISI et al. 2014). However, in case of construction delays: duration of support can be reduced by the delay, multiplied by two. The installation has to be up and connected eighteen months after publication of the auction results (extendable by two months if the delay is caused by the DSO). In case of delays, the duration of support can be reduced by the delay, multiplied by two (Held et al. 2014)."

"In Germany, successful bidders who do not apply for a certificate of support (*Förderberechtigung*) within 24 months after the commission of the plant have to pay a penalty of up to EUR 50 per kW based on the bid volume (Baker and McKenzie 2015). Projects are to be completed within 18 months, with delays leading to at least a contractual penalty: If the project has not been completed after 24 months, the grant funding will be revoked and the security deposit forfeited in full." During commissioning it must be shown that the project was built on the site specified in the bidding. If the project was completed elsewhere, the funding level will be reduced by €0.03 per kilowatt hour (transference penalty) (Hannen 2014)"

Source: Del Rio *et al.,* 2015c

## Impacts of UK's CfD scheme design on auction outcomes

Existing literature relating to the impact of the UK's CfD scheme is relatively limited. A possible explanation relates to the very recent implementation of the scheme, i.e. the first auction round was held at the end of 2014, and results were presented during the first quarter of 2015. Also, there are not many comparable case studies identified in other countries. Among the studies and reports found, they revealed insights about the relation between the Levy Control Framework and the CfD outcomes, a comparison of outcomes between the RO mechanism and the CfD, an analysis of offshore wind expansion based on CfD policy support, a comparative analysis of onshore wind energy, and an analysis of effectiveness and efficiency of the instrument. The next paragraphs present a review of the evidence found.

Newbery (2016) highlights that clearing prices achieved during both auction rounds in the UK were considerable below ASP, which implies that the Weighted Average Cost of Capital (WACC) or hurdle rate was overestimated. Then, the author calculates different internal returns for onshore wind based on different values of capacity factor, capital cost and operation expenses. The results show that clearing prices under the CfD scheme lowered hurdle rates (WACC) by 3% real (Newbery, 2016). This implies that if auctions could deliver for the estimated generation investment of £75 billion up to 2020 based on the LFM, the scheme would save £2.25 billion per year by 2020, continuing for 15 years (Newbery, 2016).

According to Newbery (2016), the CfD scheme can offer better results than Premium Feed-in Tariffs (PFiT). As the volume of a specific type of RES-E increases in a local market area so the output in favourable conditions will increase, depressing wholesale prices in those hours. This fall in prices should lead developers to choose better locations (higher local prices offsetting less sun or wind). A contract price independent of the spot price suppresses active signals, raising deployment costs. Also, Newbery (2016) argues that generation capacity auctions are required, but a high RES-E penetration also requires ancillary services such as ramping, frequency response, inertia, and need to be reflected in support costs, by demanding operators to purchase them.

In contrast, Bunn & Yusupov (2015) ran a model to estimate the negative correlation between prices and wind outputs in the UK. They argued that RO might be better able to reduce investment risk. The study shows that if wind investment continues as forecasted, the correlation factor increases enough to balance both instruments. Newbery (2016) debates this premise by arguing that Bunn & Yusupov (2015) assumptions may hold true for portfolio utilities. However, the CfD aimed also to encourage new sources of finance and thus it is a better instrument.

Overall, UK based evidence suggests that auctions for long-term contracts appear to reduce investors' risk and hence cost of capital. Batlle, Pérez-Arriaga, & Zambrano-Barragán, (2012); Del Rio & Linares, (2014) and Newbery (2017) consider that long-term contracts are decisive for low bid prices. However, it is important to consider that long-term contracts lock in short-run price signals for location and technology and it is therefore critical that all these price signals, including those for access and use of the transmission and distribution systems, give efficient signals (Newbery, 2017).

Lockwood (2016) states that uncertainty over the Levy Control Framework (LCF) after 2020 is affecting the long-term investment climate in the UK (Deben, 2015; Hamilton 2015, HoC ECCC, 2016a, 2016b; Johnston, 2016 cited by Lockwood, 2016). Lockwood argues that academic research attracted attention when suggesting the LCF underestimated future costs and that it could hinder further expansion of renewables due to budgetary constraints. Although government projections seemed to indicate that it is likely electricity targets will be achieved, it is still possible that budgetary targets may hinder the realisation of renewable energy targets. The implication of breaching the LCF is that the amount of funding for future CfD auctions would be limited and with it the amount of RES-E that can be supported (Lockhood, 2016).

Auctions help to remove the risk that future support payments would breach the LCF (although capping support risks breaching the RES target). Newbery (2016) suggests that this might seem to recreate the risk of the PFiT, although the contractual guarantee of capacity payments should allow a higher fraction of debt finance than the less likely ROC value.

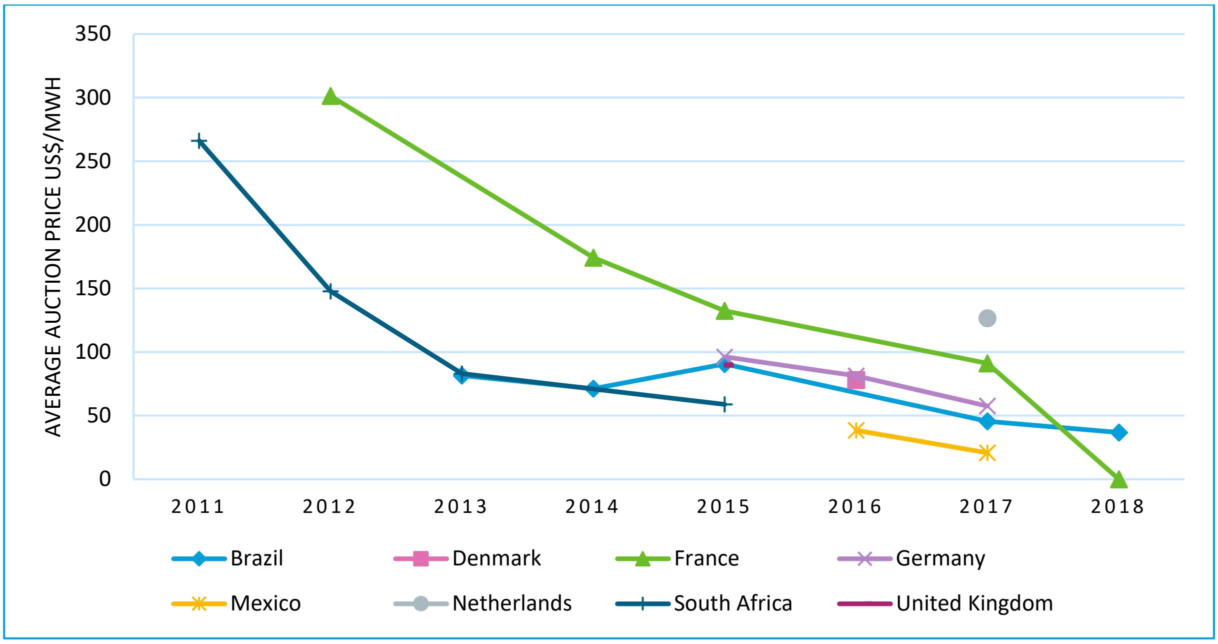
Fitch-Roy & Woodman (2016) analysed auction results based on Del Rio *et al.*, (2015b) criteria to assess RES-E auctions. The authors argue that the first round held in 2015 had limited effectiveness because it failed to allocate CfD in the first four years for which it was set a budget (2015-2018). However, this failure may be attributed to external factors. It also compares average strike prices; average final investment decision prices and auction clearing prices and concludes that the mechanism has proven cost-effective.

## Differences in final prices

The evidence on renewable electricity auctions strongly suggests that auctions have led to a reduction in technology costs and of the support level (Del Rio et al. 2017c, IRENA & CEM, 2016, IRENA, 2017). Auction design influences final prices. Lower prices are registered in auctions with long-lead times because investors can speculate on a decrease in investment costs between the time they submit their bids and the effective time when they execute the project.

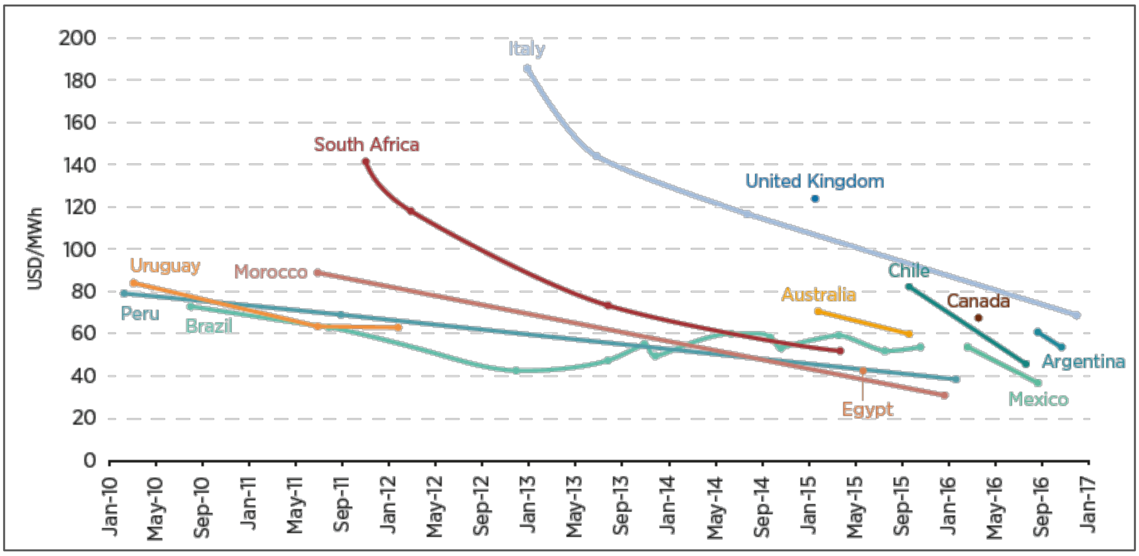
However, when looking at bid prices registered across countries and regions, and even within the same countries, there are significant differences. While lower prices can reflect a decrease in technology costs and an increase in market maturity, it is also true that lower prices can result from underestimations in bids, which eventually would lead to low realisation rates and project cancellations. Figure 11 illustrates the fall in Solar PV average prices in different countries from 2011 to 2018 and Figure 12 the evolution of average auction prices for onshore wind energy, 2010-2017. The UK 2015 strike price for Solar-PV was similar to those of Brazil and Denmark. Nevertheless, considering the differences in capacity factors and auction design, it is difficult to compare these.

**Figure 11: Evolution of average auction prices for solar PV, 2011-2018**




Source: Based on Bloomberg New Energy Finance data 2017

**Figure 12: Evolution of average auction prices for onshore wind energy, 2010-2017**



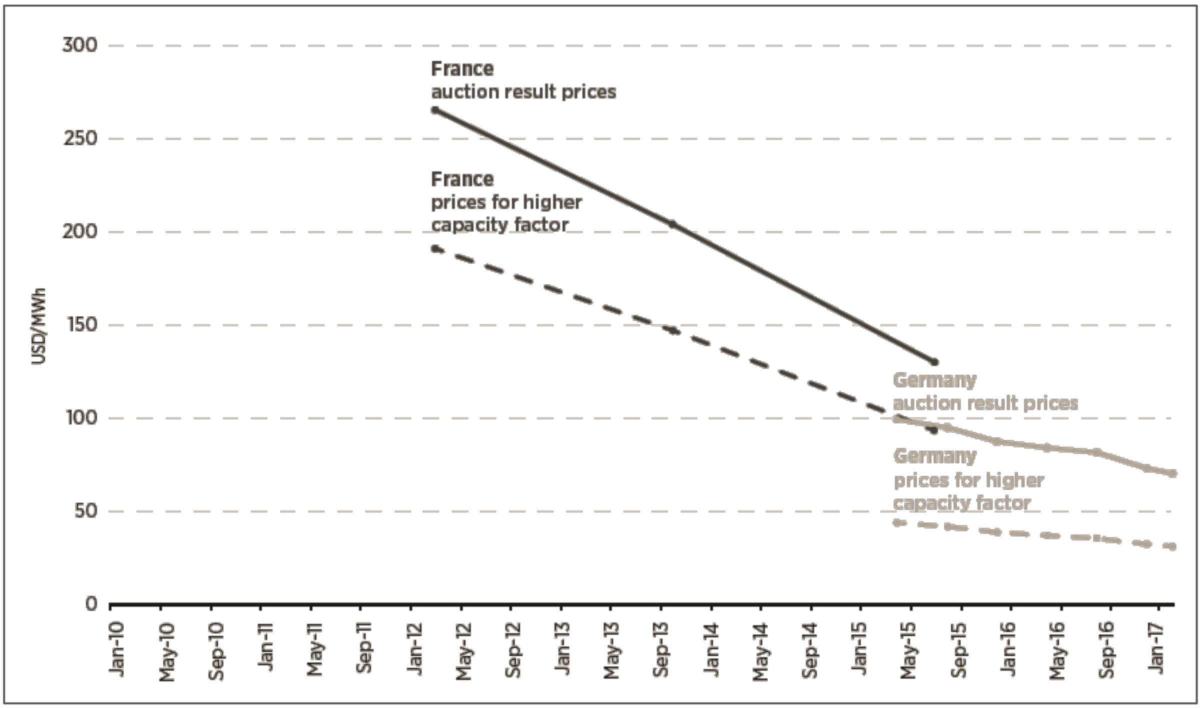

Source: IRENA (2017)

Prices are very context-sensitive; and the literature indicates that several factors contribute to the success in RES-E deployment besides auction mechanisms per se, such as the existence of abundant natural resources, a good investment climate, economic prosperity/crisis, easy access to credit, institutional conditions, including the features of the electricity system/market and market conditions in other countries that influence the level of competition worldwide (IRENA, 2017).

Among the most cited factors to have a decisive weight on final prices on technologies such as Solar PV and onshore wind, in different countries and regions, are the capacity resource factor[8], and developers' capital costs and operating expenditures (IRENA, 2017). IRENA (2017) illustrates the capacity factor feature in the cases of Germany and France. The capacity factor for solar energy in Germany averages 11%, while in Chile, for example, capacity factor averages 29%. By adjusting Germany and France's capacity factor to 25%, prices could be close to half of the actual results.

**Figure 13: Solar prices in France and Germany: actual and adjusted results assuming a capacity factor of 25%, 2010-2017**

[8] The ratio of the actual output of a power plant divided by the theoretical output of the same plant running at full capacity.




Source: IRENA, 2017

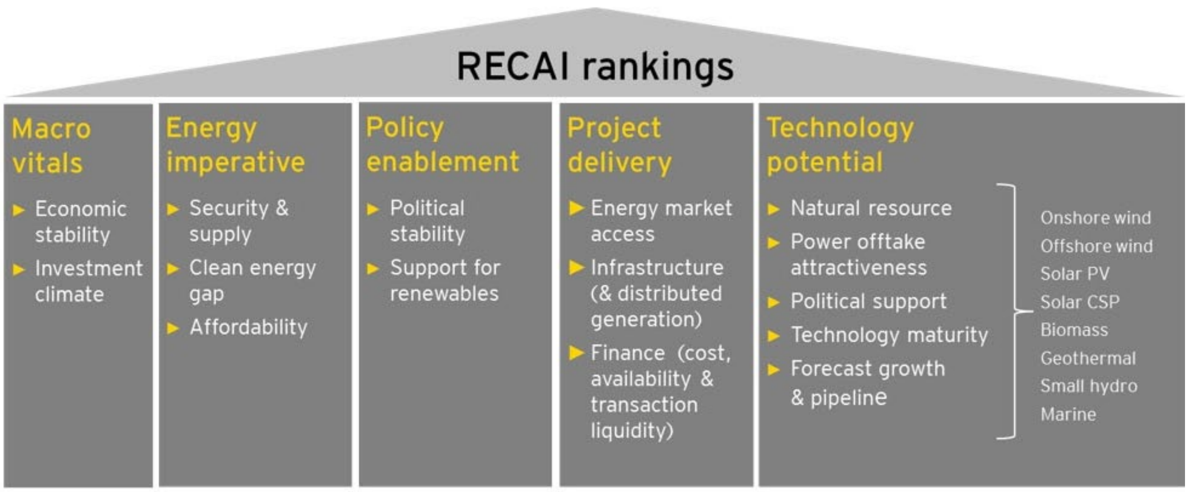
Another reason why cost varies among countries is the difference in installation and operation costs (IRENA, 2017). These variations are determined by the cost of land, labour and energy, among others. Labour and land costs can be significantly higher in European countries such as the UK or France than in emerging economies or developing countries such as India and Mexico. Such competitive advantage enables the development of economies of scale in production, and additionally, latecomer countries can be benefited by economies of scale in R&D which encourage large firms to invest and participate

Operational costs and capital expenditures are also determined by fluctuations in foreign exchange rates, fiscal, labour and industry legislation which makes them very context-dependent. For instance, the United States offers an investment tax credit, known as the federal solar tax credit, that can reduce the cost of installation by around 30%. Even in developing countries, operational costs and capital expenditures can be high under poor conditions. For instance, Aquila et al. (2017) analysed the Brazilian experience and found that even though auctions require that 60% of technology used in its financed projects must be manufactured in the country, investors face variations in technology costs and exchange rates because the manufacturing process also relies on equipment produced by multinationals. Therefore, the author's highlight that the government should also enhance fiscal and financial policies such as such as tax exemption or reduction for import-related taxes (Aquila et al., 2017)

Finance costs also influence the final price. These costs are dependent on the country's specific economic situation, its regulatory framework and political situation and thus, the risk perception by investors. Hu, Harmsen, Graus *et al.,* (2018) argue that energy policies are not enough to increase investment in RES technologies. It is essential to look at a broader context that incorporates fiscal and momentary policies, in a way that does not overlook negative interactions with other policy instruments. For example, austerity measures can reduce the support level for renewable investments, as well as adverse macroeconomic conditions could increase lending rates or decrease the availability of loans for RES investments.

For instance, the Ernst and Young Renewable Country Attractiveness Index ranks countries based on different pillars such as technology potential, project delivery, policy enablement, energy imperative and macroeconomic variables as illustrated in Figure 14.

**Figure 14: EY RECAI ranking factors**




Source: EY 2018

# Investment trends and the maturity of the supported technologies

This chapter briefly gives an overview of global trends and the recent UK investment landscape. It then summarises trends and forecasts regarding maturity, costs and prices, for supported technologies in pot 1 & pot 2. Finally, it explores evidence of any links between the implementation of renewable energy auctions schemes, the maturity of technologies, and the extent to which continued subsidies are likely to be required in the future. The purpose of this section is to answer the question: *What implications do wider international trends in renewable energy investment and technology cost have on the continued use of auctions in the future?*

## Global renewable energy investment landscape

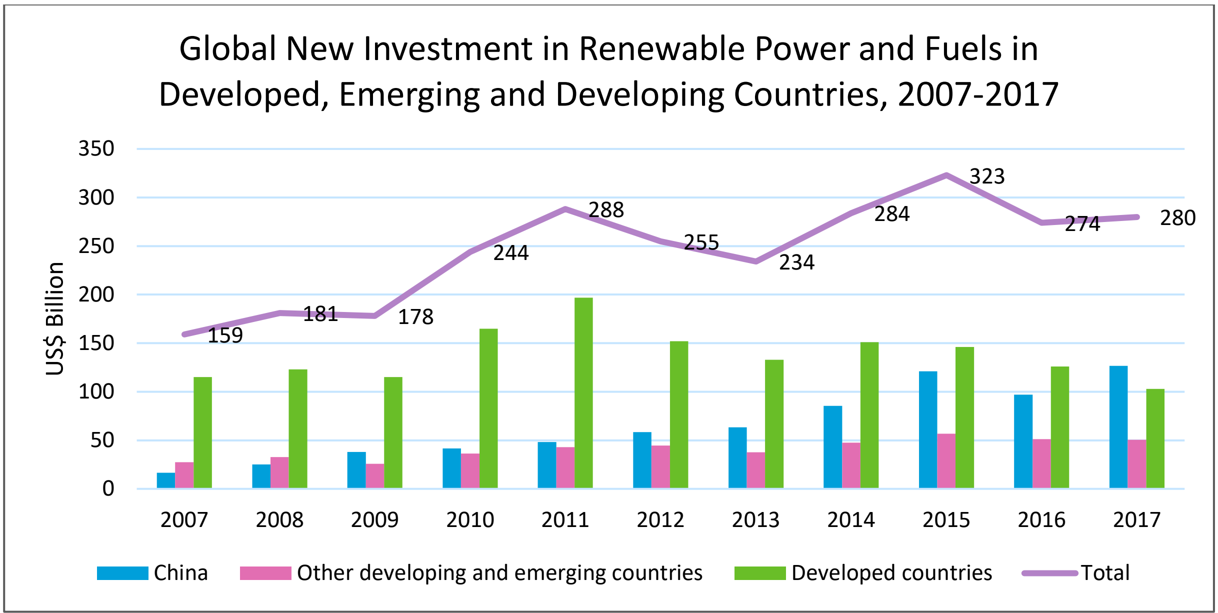
**Current investment level:**
The principal sources of information on global renewable energy investment flows include the annual 'Global Trends in Renewable Energy Investment Report' by the United Nations Environment Programme (UNEP), Bloomberg New Energy Finance, and the Frankfurt School of Finance - UNEP Collaborating Centre for Climate & Sustainable Energy Finance (FS-UNEP 2018).

The UNEP report provides data on an annual basis on global investments into renewable energy. As Figure 15 shows, global new investment in renewable power and fuels increased by more than US$200 billion over the period of the last ten years. Overall, the level of investment in renewable energy increased six-fold 2005 to 2015, before dropping slightly in 2016, due to an economic slowdown in major markets such as China.

However, any drops in rates of investments do not necessarily equate to the reduced installed capacity of renewable energy. The amount of investment required decreases in areas where costs are getting lower. Globally, more capacity has been installed annually but at lower costs. A significant trend in recent years has been developing countries increasing their share of global renewable energy investments, overtaking developed countries for the first time in 2015. Furthermore, China is now receiving higher investments than all developed countries combined. Fewer big offshore wind financings mainly caused the recent fall in investments in 2017 in developed economies in 2017, lower capital costs for energy, and policy changes. For Europe, the Global Trends in Renewable Energy Investment report highlights that the decline in investments by $40.9 billion was primarily caused by a fall of 65% in UK investment and 35% lower investments in Germany, caused by changing the support system for onshore wind to auctions. In the UK, this refers to the lack of further auctions for onshore wind after CfD Allocation Round 1. The previous decline between 2011 and 2013 can be explained by the delayed effects of the financial crisis' uncertainty over support policies in Europe and the United States (REN-21, 2017)

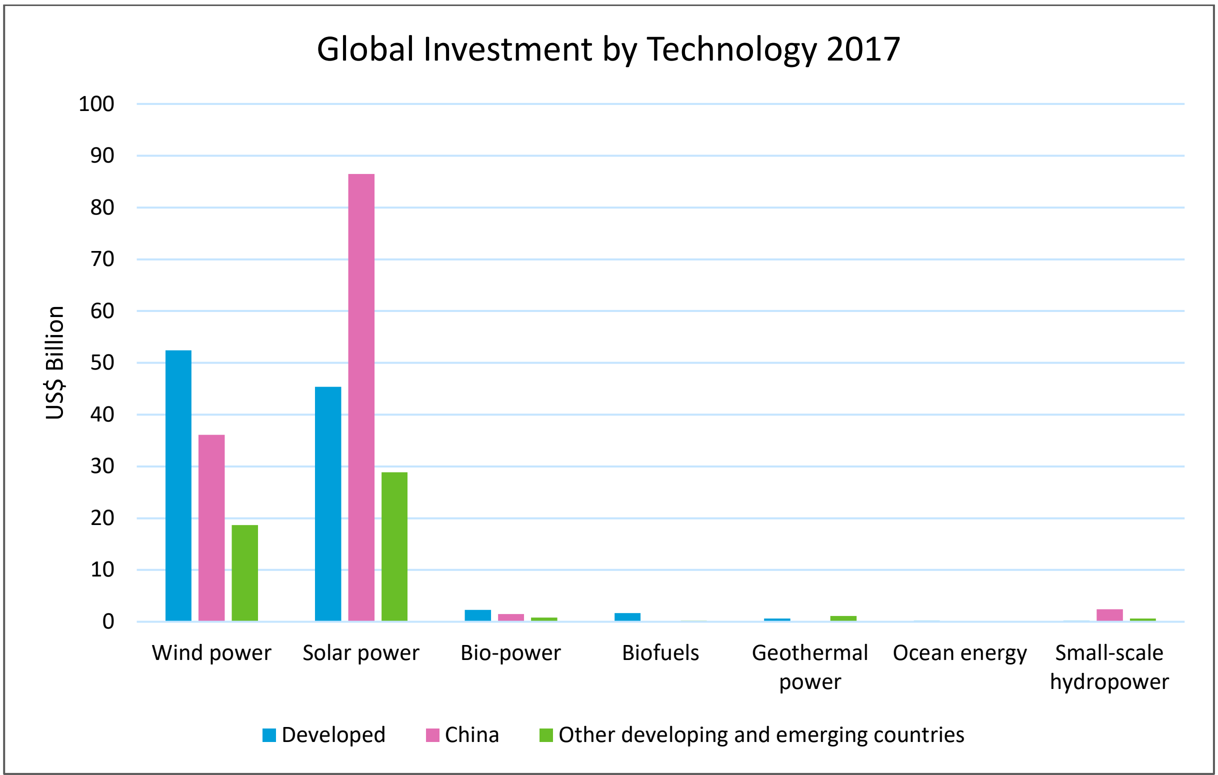
As Figure 16 shows, in 2017 the majority of global investment went into wind and solar technology. For instance, solar accounted for 38% of the net new power capacity in 2017. While wind energy is the preferred sector for developed countries, in developing countries and China, it is solar energy. Based on current investment levels there are no breakthroughs in other emerging technologies visible, and the market is dominated by wind and solar.

**Figure 15 - Global new renewable investment 2007-2017**




Source: FS-UNEP, 2018

**Figure 16: Global investment by technology 2017**




Source: FS-UNEP, 2018

### Investment forecast:

According to the latest Bloomberg New Energy Finance Outlook, between 2018 to 2050, an estimated $11.5 trillion will go into new power generation capacity. Bloomberg New Energy Finance forecasts that a majority of $8.4 trillion will be invested into wind and solar projects, $584 billion invested into battery capacity and a further $1.5 trillion into other zero-carbon technologies including nuclear energy.

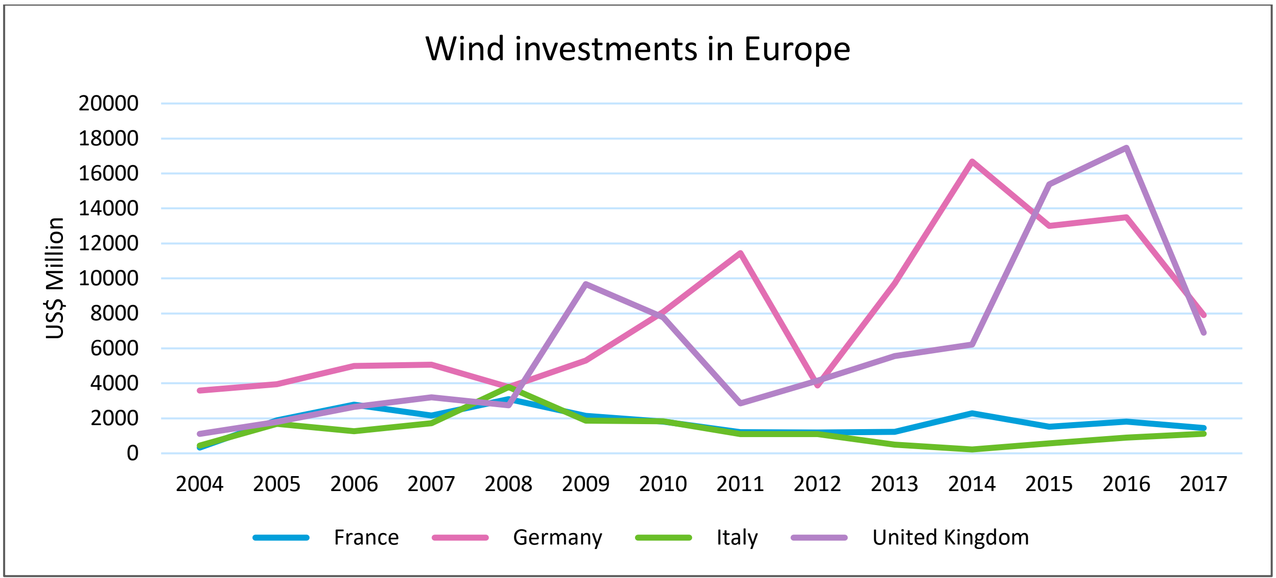
However, higher investment levels are needed to reach the sustainable development goals. The UN sustainable energy for all initiative has the goal to double the share of renewable energy in the global energy mix by 2030. Hereby, estimates from IRENA (2016) suggest that doubling the share of renewables by 2030 will require an annual investment in renewables of US$ 770 billion per year. This amounts to US$ 11.5 trillion in total, which is the number Bloomberg New Energy Finance estimates to be invested until 2050 in zero-carbon technology including nuclear. Therefore, if the UN 2030 target is to be achieved, the forecasted renewable investment up to 2050 must be accelerated by 20 years, i.e. the Bloomberg 2050 forecast investment level needs to be reached 20 years earlier.

An expert survey conducted for the REN Futures report (REN 21, 2017) finds that over 60% interviewees expect investments to double by 2050 and on the other hand only 12% believed that the investment volumes into renewables remain at the current level.

**UK investment trends:**

In the wind energy sector, the UK is ahead of similar countries such as France, Germany, and Italy. Figure 17 shows how investments changed for these countries based on Bloomberg New Energy Finance data. The FS-UNEP report suggests that the drop in investment between 2016 and 2017 in the UK for onshore wind and utility-scale solar may be due to changes in Government support mechanisms, such as the closure of Renewables Obligation and the lack of further auctions for these technologies since Allocation Round 1. It further highlights the substantial time intervals between offshore wind auctions as a reason for decreased investments (FS-UNEP 2018). For 2018 the UK currently has an investment landscape which is ranked by the Ernest and Young renewable energy country attractiveness index (RECAI) 7th out of 40 countries behind China, the US, Germany, India, Australia, and France. This is an improvement by three ranks since 2017. The RECAI ranks countries based on their macro vitals, energy imperative, policy enablement, project delivery, and technology potential (Ernest & Young 2018).

**Figure 17: Wind investments in Europe**




Source: Bloomberg terminal data

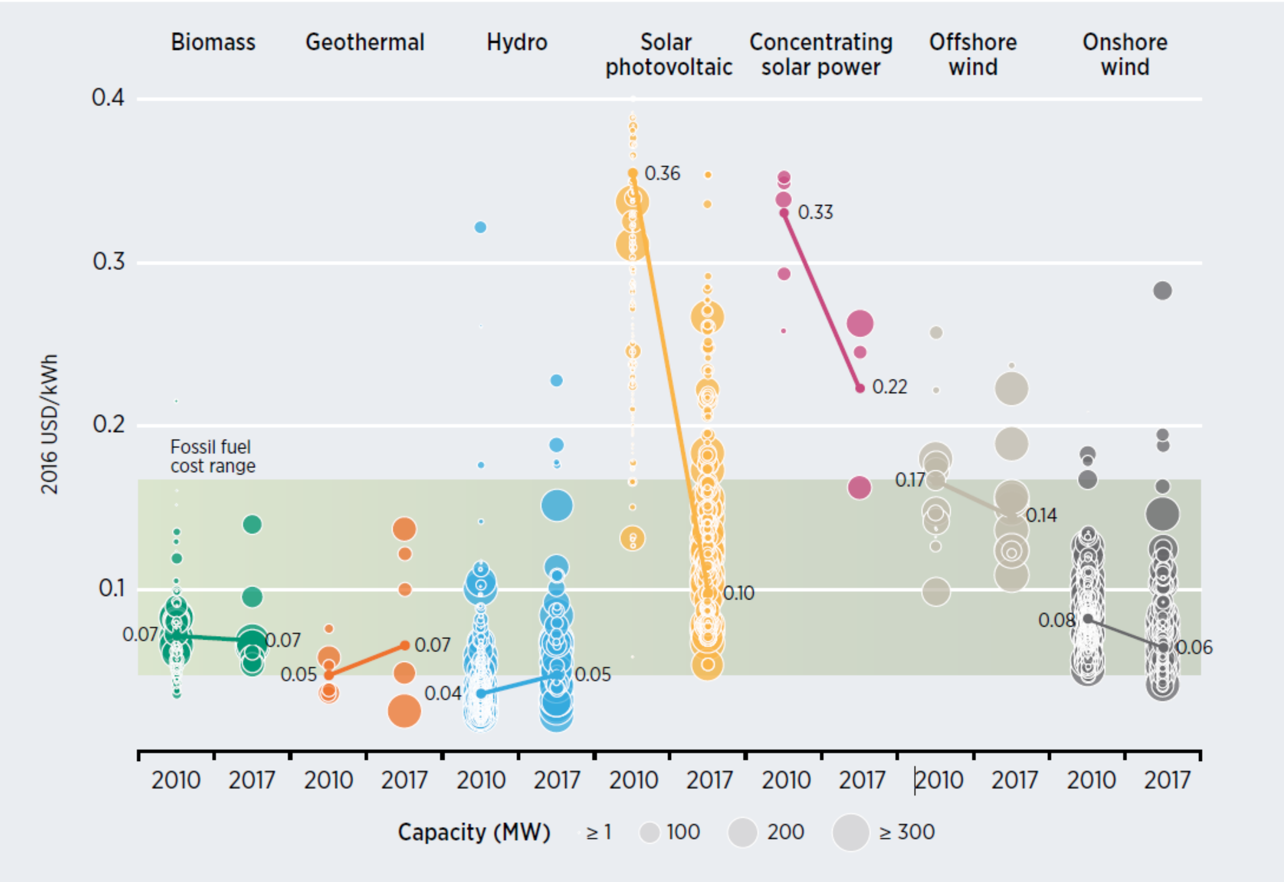
One piece of evidence on current UK investment trends is the recently published report on the state of UK green finance by the UK parliament environmental audit committee. This report *Green finance: mobilising investment in clean energy and sustainable development,* describes recent changes in investor behaviour in the UK and future implications. It includes witness statements on the recent fall in renewable energy investments in the UK. The report suggests some explanations. For instance, that the falling costs cannot be seen in lower installed capacity. However, the fall in investment might be only visible in some years since projects need several years to be developed. Other reasons suggested by the report include reduced funding from the European Investment Bank and falling investments following the privatisation of the Green Investment Bank. Moreover, recently several support policies were cancelled such as the close of the Renewable Obligation for onshore wind one year early, the removal of the Climate Change Levy exemption for renewables, reduced Feed-In-Tariffs for a small-scale renewable generation, and the Carbon Capture & Storage competition *(*House of Commons Environmental Audit Committee 2018).

## Recent development of costs

### Costs of energy

The economics of renewable energy are changing rapidly. Many mechanisms to encourage renewable energy investment have been designed – in various ways – to compensate for the fact that they are more expensive than fossil fuels. While on average, many renewable technologies remain more expensive than fossil fuels. As it was shown previously, global investments are concentrated on wind and solar power and driven by the falling costs. Figure 18 from IRENA (2018) shows how the Levelised costs of energy changed over the last seven years for different technologies.

**Figure 18: Levelised costs of energy by technology, 2010-2017**




Source: IRENA, 2018

## Drivers of falling costs - Why are the costs coming down?

A key report about the costs of energy is the IRENA report Renewable Power Generation Costs in 2017 (IRENA, 2018). The report identifies three main drivers for the current cost reductions:

1. Continuous technology innovation
2. Increasing international competition for projects
3. Competitive procurement of renewable power generation

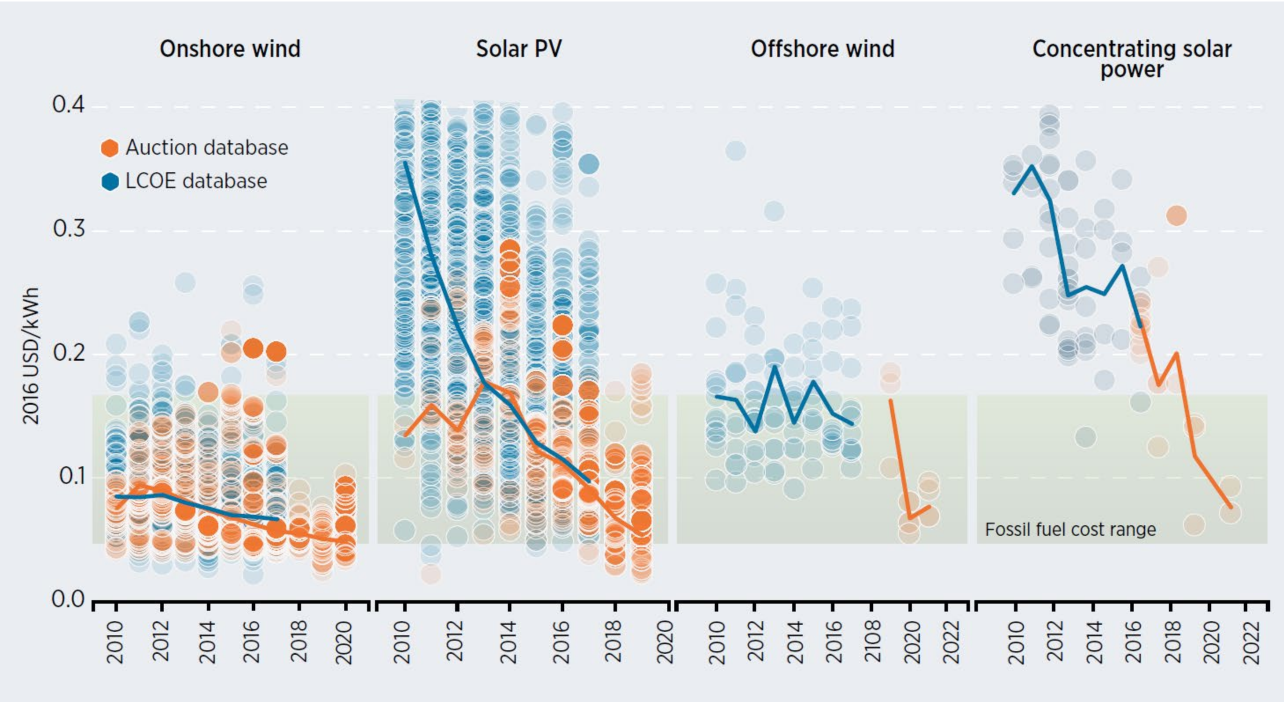
Technology innovation plays an active role in reducing the costs of energy. For example, wind energy, larger turbines can generate electricity more efficiently. For solar energy, improvements in the commercialisation of cell architectures reduced costs. Module prices have rapidly declined in the last years which led to solar projects ranging into the cost range of fossil fuels. Regarding international competition, recently many experienced developers moved into other markets outside of their home country to seize their opportunities. The experience from the falling costs of Solar-PV from increased Chinese competition is a good example.

As it was previously explained how auction design influences final prices, and that lower prices are registered in auctions with long-lead times because investors can speculate on a decrease in investment costs between the time they submit their bids and the effective time when they execute the project. The REN-21 futures report highlights that over the past 30 years for Solar PV, every doubling of market volume resulted in a cost reduction of 20%. This implies that in general, a higher market volume is always favourable (REN-21, 2017).

## Cost forecasts

Figures 11 & 12 already provided an indicative overview about how strike prices in consecutive auctions changed for Solar-PV & Onshore Wind. The IRENA Costs of Renewable Energy 2017 report (IRENA 2018) looked in-depth into the combination of falling LCOEs comparison with auction results. As Figure 19 shows strike prices and LCOE have similar trajectories and given that auction prices continue to decrease it is likely that LCOEs will decrease as well in the next years. Nevertheless, the IRENA report emphasises some problems with this comparison. For instance, auction design elements and regulations can highly distort prices.

**Figure 19: Development of LCOE and auction prices**




Source: IRENA, 2018

For the UK it is particularly relevant to distinguish between LCOE and auctions, in the BEIS Electricity Generation Cost Report (2016) this difference is defined as:

*"While levelised cost assumptions, such as those summarised in this report, form an input to the calculation of administrative strike prices, levelised costs are not the same as strike prices. Administrative strike prices are set using levelised cost evidence, but also take into account other factors such as market conditions and policy considerations."*

The report forecasts further falling costs for Solar, Offshore, and Onshore Wind until 2030 in the UK. Both Large-scale Solar PV and Onshore Wind are expected to fall to £60/MWh in 2030.

Globally the IRENA report *The Power to Change: Solar and Wind Cost Reduction Potential to 2025* (IRENA, 2016) forecasts that renewable energy technology costs will continue to decrease for all technologies, as well as investments costs. Furthermore, it is estimated that capacity factors will increase. While the decreases are higher for Solar, the overall LCOE decrease is still estimated to be 26% for onshore wind and 35% for offshore wind.

**Figure 20: Cost forecasts Solar, CSP, and Wind**

| | Global weighted average data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Investment costs (2015 USD/kW) | | Percent change | Capacity factor | | Percent change[2] | LCOE (2015 USD/kWh) | | Percent change |
| | 2015 | 2025 | | 2015 | 2025 | | 2015 | 2025 | |
| **Solar PV** | 1 810 | 790 | -57% | 18% | 19% | 8% | 0.13 | 0.06 | -59% |
| **CSP (PTC: parabolic trough collector)** | 5 550 | 3 700 | -33% | 41% | 45% | 8.4% | 0.15 -0.19 | 0.09 -0.12 | -37% |
| **CSP (ST: solar tower)** | 5 700 | 3 600 | -37% | 46% | 49% | 7.6% | 0.15 -0.19 | 0.08 -0.11 | -43% |
| **Onshore wind** | 1 560 | 1 370 | -12% | 27% | 30% | 11% | 0.07 | 0.05 | -26% |
| **Offshore wind** | 4 650 | 3 950 | -15% | 43% | 45% | 4% | 0.18 | 0.12 | -35% |

Source: IRENA 2016

The REN-21 Global Futures Report (REN-21, 2017) suggests that hydropower and biomass power generation, as mature technologies, have little chance for further cost reductions and will be mainly dependent on resource prices. Moreover, it mentions that cost reductions for new emerging technologies are not expected to be as high as for Solar-PV. Findings from the REN-21 expert survey showed that there is no consensus on the future of oil prices. However, renewable energy equipment costs, 67% of experts believed that these costs would fall faster than fossil fuel prices in the next ten years (REN-21, 2017).

Another critical factor is the uptake of battery storage, in the Delphi energy future 2040 study (PwC, 2016) 78% of experts believed that by 2040 renewable energy sources operating in conjunction with storage units will be the generation technology with the lowest electricity production costs. The IRENA report Electricity Storage and Renewables: Costs and Markets To 2030 (IRENA 2017) forecasts cost reductions by 42% to 68%, compared to 2017, until 2030. Furthermore, in a scenario where renewable energy capacity would double until 2030, the electricity storage capacity could increase by 155% to 227%. Based on the expectation that uptake in electric vehicles will increase the production of Li-ion battery manufacturing the cost for stationary use of batteries could decrease by 54 % to 61 % by 2030. Also, other types of batteries such as High-temperature sodium sulphur, sodium nickel chloride, and flow batteries have a cost reduction potential similar to Li-ion until 2030.

## The future of auctions as a support mechanism for renewable technologies deployment

This section will briefly explore evidence of any links between the implementation of renewable energy auctions schemes, the maturity of technologies, and the extent to which continued subsidies are likely to be required in future.

The evidence analysed shows mixed results about increased effectiveness and efficiency caused by auctions when compared with other policy instruments. On one side, Del Rio & Linares, 2014 point out that previous experiences in Europe with different policy support mechanisms, demonstrated that FiTs have been more effective and cost-efficient than auctions. 'Although [auctions] have delivered low prices, have not delivered in terms of installed power' (Del Rio & Linares, 2014). Nevertheless, this might have been related to inexperience in auction design. Thus, the disadvantages of auctions can be minimised through careful design. However, the authors stress that under auction schemes, it is easier to cap support levels, which is crucial for budget control. This feature reduces the uncertainty about the total costs of RE support and the burden sharing of RES support, which is becoming even more relevant with increasing RE penetration (Del Rio & Linares, 2014).

On the other side, the argument of auctions as effective mechanisms for price discovery have been broadly accepted (IRENA, 2013;2016,2017 Del Río, Haufe, Steinhilber, *et al.*, 2015). Additionally, according to De Mello, (2016) auctions are more cost-effective than FiTs in the short term if cost-effectiveness is defined as minimising consumer costs. Shrimali, Konda & Farooquee (2016), in their analysis of 20 different auctions around the world, found that auctions were 'almost always cost-effective, with savings of up to 58% from baseline feed-in tariffs'. However, 'auctions were not always deployment-effective, with only 17% of the auctions with greater than 75% deployment'. Based on this study for every 1% rise in total risk, deployment effectiveness decreased by 2% points. Second, the authors argue that deployment effectiveness is mainly hindered by auction design, realisation rates, and financial risks. Additionally, the authors pointed out that auction prices were almost always lower than the baseline feed-in tariffs for the auctions analysed.

Batlle, Pérez-Arriaga, & Zambrano-Barragán, (2012) argue that the Adequate RES-E support mechanism for a given power system depends on the sectoral maturity of the RES-E industry. Some mechanism options are best suited for less mature technologies such as price-based mechanism, and others are better for more mature ones, such as auctions. The study carried out by Becker & Fischer, 2013 in three Latin American countries, concludes that although 'there is no one size fits all policy', a strong industry policy focus has proved to be crucial for promoting RES-E deployment (Becker & Fischer, 2013).

As technology costs continue declining, following the original idea that once technologies were mature enough, subsidies would no longer be necessary, a new conversation is emerging across Europe around whether renewables could become subsidy-free. Since 2017, there have been statements of ‘subsidy free’ projects. For instance, the auction won by the Swedish state-backed utility Vattenfall announced the world’s first ‘subsidy-free’ offshore wind farm, the 750 megawatts (MW) Hollandse Kust Zuid, to be built by 2022 off the coast of the Netherlands.

Another example is the German offshore wind farms which were won with subsidy free bids to be commissioned in 2024 and 2025. However, there are some significant innovations and developments to be achieved, as well as estimations of the impact of critical factors to arrive at a required LCOE for German projects in order to allow these sites to be built subsidy-free (Smart, 2017). A final example comes from the UK, where the first ‘subsidy-free’ solar park of 10MW will be built by Anesco at Clayhill in Bedfordshire, as an addition to an existing site. However, the site is co-located with battery storage which will enable the owners to be eligible to bid for ancillary services from National Grid as an additional stream of revenue for the same grid connection.

In broader terms, subsidy-free means deployment without government support mechanisms such as FiT or auctions. In the case of the Vattenfall’s offshore wind farm, subsidy-free means no support regarding price stabilisation, but it will have benefitted from state support because the Government paid for the regarding grid connection. Thus, subsidy-free can have different meanings based on context-specific markets characteristics. A similar case occurs for the German projects, which will have grid connection benefits ‘as well as having the right to build ready-defined sites without having to manage the risk of site scoping, environmental assessment or planning permission’ (Carbon brief, 2018). Thus, it can be said those projects are partially subsidy-free. Moreover, cross-subsidisation is another alternative for projects, such as co-locating with projects that already have a connection to the grid or battery storage (Carbon brief, 2018). Moreover, all these projects are based on numerous assumptions such as future power prices.

In the evidence analysed for this study, there was no substantial evidence indicating renewable electricity generation will be utterly subsidy-free in the foreseeable future. Neuhoff; Wolter & Schwenen, (2016) argues that the economics of wind and solar PV projects are dominated by up-front investment costs. Thus, ‘sufficiently stable revenue streams are required for a longer-term horizon in order to allow for investments by risk-averse actors’ (Neuhoff; Wolter & Schwenen, 2016). This suggests renewable support will continue to play a role by facilitating an accelerated transition to a low carbon economy. The prospect of subsidy-free renewables is even more remote in developing countries. For instance, the Mastropietro, et al. (2014) study on the convergence of system adequacy and RES-E support in Brazil, Colombia and Peru conclude that conventional and renewable technologies are still far from competing under parity with fossil fuels.

One source of evidence that forecasts what proportion of renewable energy generation will be subsidy-free renewables is the Aurora Energy Research report 2018 'Renewables 2.0: Subsidy-free revolution'. According to this report, there is a potential to build new projects of up to 18GW by 2030 in GB alone, and over 60GW across North-West Europe. However, based on this one source, these estimates should be treated with caution.

The trend towards reduced subsidies which coincided with an increase in auctions is making developers explore more innovative ways to reach previous revenue levels without subsidies. For instance, by "*utilising corporate or utility PPAs to provide revenue certainty, or merchant solar PV plants being built in certain locations where wholesale market forecasts support their economics, storage to better access peak prices and potentially achieve new revenue streams by providing ancillary services to the grid*" (IRENA, 2018). One of the risks is that lenders stop investing if they see that the potential earning is not guaranteed through a government mechanism.

Therefore, although RES costs continue falling, supported by different mechanisms, no strong evidence supports a future where renewables are entirely subsidy-free. It seems auctions, though perhaps in different formats and with different rules, and other government support mechanisms will continue to be important for the deployment of RES technologies. Also, new challenges such as the intermittency of RES and flexibility in electricity systems, are becoming crucial to accelerating a low carbon transition and might need continuing dedicated government support.

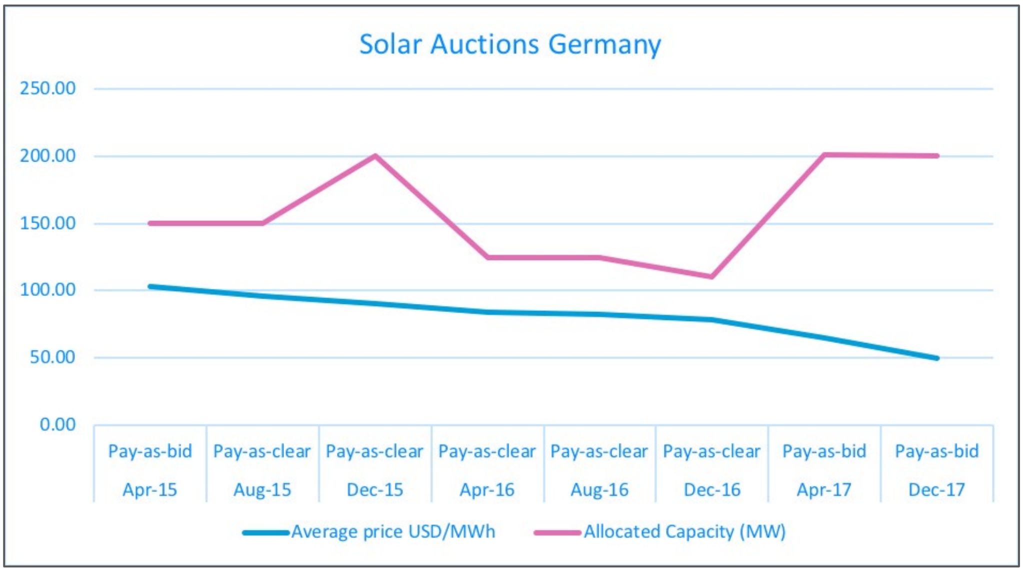
# Case Studies

## Germany

The central policy concept in current and future energy production in Germany is the Energiewende, or energy turnaround, which outlines the transition away from nuclear energy and fossil fuels and towards renewable energy sources. A feature of German energy policy is the commitment to phase out nuclear energy entirely by 2022. The renewables era in Germany started in 2000 with the passage of the Renewable Energy Act (EEG). Since then, there has been a significant uptake in solar, wind, hydro and bio-based energy. With the change of the EEG in 2017 providers of wind and solar plants higher than 750kW cannot receive a fixed feed-in premium anymore but have to participate in auctions[9].

Germany started with pilot auctions for Solar-PV in 2015 which are the basis of its current auction design. Figure 22, based on BNEF data, gives an overview of price development and awarded capacity. The average price of awarded capacity in the December 2017 auction was less than half the price per MWh in the first auction.

**Figure 21 Solar auctions in Germany**




Source: Bloomberg New Energy Finance data

[9] : https://www.bmwi.de/Redaktion/DE/FAQ/EEG-2017/fragen-und-antworten-zum-eeg-2017.html

**2015-16 Pilot auctions Solar PV**

During the 2015-2016 pilot, six auctions happened. 860 MW capacity was awarded, and the average price per MWh dropped from EUR 91.70 in the first auction to EUR 69.00 in the last auction of the pilot. For all auctions, the outcomes were below the price-cap. The pilot tested pay-as-bid in the first round and uniform-pricing in the second and third rounds. The official government report for the first three auctions describes the auction design in detail (Federal Ministry for Economic Affairs and Energy, 2016). The report gives information on the outcomes of the auctions. The first two pilot auctions received a high competition level with a total of 715MW in bids in the first round and 558MW in the second for 150MW total auction volume. In the third round, there was 561MW bid for a 200MW target.

The report describes that the design of the auction took into consideration that experience from international auctions shows that there is no ‘one size fits all’ auction design for auctions. Therefore, the German auctions were designed not by copying existing designs but focussing on carefully tailoring the auctions to the national market for creating maximum competition.

As mentioned earlier in this report any amount not built is passed on to future auctions to ensure that the desired volume is reached (Morris, 2015 cited by Del Rio, Haufe, Wigan *et al.,* 2015).

The pilot auctions were designed in a way to maintain Germany's high diversity of actors in renewable energy. Moreover, they also emphasised the engagement of SMEs since these are often very innovative. Small producers can propose projects in advanced stages. The pilot auctions had penalties of up to 5% of total investment. The reason for introducing penalties was that international experience showed that penalties increase project realisation. The report further suggested using a pay-as-bid mechanism for future auctions while still reviewing uniform-pricing options for the future.

Besides this report, other reports include: a scientific report commissioned by the German Federal Ministry for Economic Affairs and Energy, an outcome report was conducted by the German Federal Network Agency, and Germany's pilot featured as a case study in the AURES project.

The scientific report (Klessmann et al., 2015) assessed the auction and put the outcomes into context. Main findings are that the high number of participants could be attributed to the broad public consultation process in advance to the auctions which led to the early engagement of investors and developers with the scheme. The report highlights that it is important to identify whether the original developers and investors continue to own the project or whether the projects were resold. The German Federal Network Agency further evaluated the first round of auctions (Bundesnetzagentur, 2015). The results show that while investors and developers were unhappy that the system changed to auctions, this does not prevent them from participating and developing projects. The AURES case study from Germany's Solar PV pilot emphasised that the project design work by creating sufficient competition in technology-specific auctions in Germany. However, this also depends on sector-specific characteristics. It is also emphasised that a long project realisation rate allows developers to delay the realisation of the projects which leads to uncertainty regarding the level of support a project will have to receive from the government. (AURES 20x

The German Federal Ministry for Economic Affairs and Energy reports that 94% on average of Solar-PV projects which were awarded funding in 2015 were implemented within the two-year deadline and had since started to operate[10].

**New auctions**

After the pilot, Germany started public auctions based on the pilot design for Solar-PV, Onshore- an Offshore-Wind, and Biomass. Table 6 shows the volume. Furthermore, feed-in-tariffs are being phased out in preference of auctions. The REN-21 Future report highlights in this context that replacing feed-in-tariffs with auctions caused uncertainty and can be attributed to the recent decline in renewable energy investments in Germany (REN21, 2018).

**Table 6: Planned auctions in Germany 2018**

| Date | Technology | Auction Volume |
|---|---|---|
| 01/02/2018 | Solar | 200 MW |
| 01/02/2018 | Onshore Wind | 700 MW |
| 01/04/2018 | Offshore Wind | 1610 MW |
| 01/04/2018 | Joint Auction Onshore Wind and Solar | 200 MW |
| 01/05/2018 | Onshore Wind | 700 MW |
| 01/06/2018 | Solar | 200 MW |
| 01/08/2018 | Onshore Wind | 700 MW |
| 01/09/2018 | Biomass | 150 MW |

[10] https://www.bmwi.de/Redaktion/EN/Artikel/Energy/nationale-ausschreibung.html

| | | |
|---|---|---|
| 01/10/2018 | Solar | 200 MW |
| 01/10/2018 | Onshore Wind | 700 MW |
| 01/11/2018 | Joint Auction Onshore Wind and Solar | 200 MW |

Source: Based on Federal Ministry for Economic Affairs and Energy, 2018

As Figure 18 shows, solar prices continued to fall in the consecutive auctions. However, Germany had some unintended consequences in recent auctions. It had its first Biomass auction in 2017. However, only 27.5 MW of capacity were awarded of a target of 120MW in the pay-as-bid auction, and only 33 bidders participated of which 24 won with their bids[11]. Also, the German joint auction model which included both Solar and Onshore wind in one pot failed in Germany. In the first joint auction in April 2018 only solar projects were awarded, and not a single wind project could win in a bid. This was because the weighted average for Solar was with 4.82ct/kWh more than 2ct/kWh cheaper than Onshore wind which had a weighted average price of 7.23 ct/kWh[12]. Since the aim of these joint auctions was to provide an energy mix for the future of renewables in Germany, the results of the joint auctions show that the approach to use a single pot for Solar and Wind does not work in Germany. One interesting feature in Germany was that bids from regions with a less developed grid connection for renewable energy got a discount in the auction to stimulate grid development in these regions[13].

[11] Results available at: https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Ausschreibungen/Biomasse/BeendeteAusschreibungen/BeendeteAusschreibungen_node.html

[12] Results available at: https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2018/20180412_GEMA18_1.html

[13] Results available at: https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2018/20180412_GEMA18_1.html

## Denmark

The Danish electricity market is highly liberalised, and Denmark is a leading country in the deployment of renewable technologies. In 2015, the share of renewable energy systems (RES) reached 50.8% (European Environmental Agency, 2017), and in 2016, the share of total RES was 32.2%(Eurostat, 2016), surpassing its 2020 target of 30% RES total generation. Nevertheless, Denmark still has ambitious targets: 100% of power and heat supply covered by RES by 2035 and 100% energy consumption by RES by 2050.

Several instruments have been used for the promotion of renewable energy, including, fixed premium tariffs, PFiTs, net metering, loan guarantees for local initiatives for the construction of wind plants and auctions (Poblocka-Dirakis, 2017). Premium tariffs are one of the major schemes to support RES (wind, solar, biomass, hydro, biogas). Fixed FiTs through auctions are the other primary instrument and aim to support offshore and nearshore wind. The general objectives of the auctions are to achieve the ambitious RES targets efficiently and more recently, to establish a right balance between the interests of the investors and the public represented by the Danish Energy Agency (Kitzing & Wendring, 2015).

The first Danish offshore wind project (Vindeby) dates back to 1991, and the Danish auction scheme first started in 2004. Therefore, as an early mover, Denmark has already gained substantial experience in the application of auction schemes for offshore wind energy (Agora Energiewende & DTU Management Engineering, 2015). Due to geographical conditions, the auction mechanism distinguishes between offshore and nearshore projects. Auctions are sealed-bid, pay-as-bid and technology-specific. There are two schemes: 1. Open door and 2. Government tendering. In the first scheme, developers select an offshore or nearshore area and submit an unsolicited request for an authorisation to conduct the necessary site evaluation. By contrast, in the Governing tendering procedure, the Danish Energy Agency (DEA) selects a site for which interested developers can participate in the auction (Agora Energiewende & DTU Management Engineering, 2015).

The payment takes the form of a fixed FiT under a CfD scheme, and the maximum tariff depends on the location of the farm. For the most recent farm, Kriegers Flak, the support will be granted as a premium on top of the electricity price in the Nord-Pool market. The CfD scheme is similar to the structure in the UK. However, there are some differences. The winning bid determines the level of support.

Additionally, while in the UK the support is for 15 years, in the Danish scheme the support volumes are capped at 50,000 full load hours, equivalent to around 12 years by assuming a load factor of 47%. In other words, if the load factor is higher, then support required will be less (Radov, Carmel & Koenig, 2016). The price awarded is not inflation-indexed, and the burden sharing of RES support is allocated to consumers (Radov, Carmel & Koenig, 2016). Table 7 shows the results of off-shore auctions held in Denmark.

**Table 7: Support level and conditions for offshore capacity auctions**

| Project | Size MW | Auction year | Strike price (feed-in support tariff €/MWh) | Inflation-indexed | Commissioning year | Duration of support | Cost faced by the project |
|---|---|---|---|---|---|---|---|
| Horns Rev 2 | 209 | 2004-2005 | 70 | No | 2009 | Max of 10 TWh and max 20 years | Construction and operation of site only (not site development not gird) |
| Radsand 2 | 207 | 2008 | 84 | No | 2010 | Max of 10 TWh and max 20 years | |
| Anholt | 400 | 2009-2010 | 141 | No | 2013 | Max of 20 TWh and max 20 years | |
| Horns Rev 3 | 400 | 2013-2015 | 103 | No | 2020 | Max of 20 TWh and max 20 years. The bonus will not be paid during hours in which the market price is not positive | |
| Kriegers Flak | 600 | 2016 | 49.9 | No | 2022 | The bonus will not be paid during hours in which the market price is not positive | |
| 6 Nearshore | 400 | 2016 | | | 2018-2020 | | |

| Project | Size<br>MW | Auction year | Strike price (feed-in support tariff €/MWh) | Inflation-indexed | Commissioning year | Duration of support | Cost faced by the project |
|---|---|---|---|---|---|---|---|
| wind farms (expected) | | | | | | | |

Source: Based on Radov *et al.,* 2016, European Commission, 2017; Agora Energiewende & DTU Management Engineering, 2015 with data from ENS, 2015.

The Danish government has a predominant role in the administration of the auctions, simplifying the work of developers and lowering their costs, limiting developer's risks related to project implementation such as delays, and technology price changes (IRENA, 2015). For instance, developers do not need to pay for grid connection, transmission, or project and site development costs. Additionally, the documentation requirements in the qualification phase are relatively light touch since the government is responsible for pre-evaluating and selecting candidate sites. For instance, the DEA is responsible for undertaking Environmental Impact Assessments (EIA). In the qualification phase, participants need to prove their financial and technical capability to finance the wind farm's construction and operation (IRENA, 2015). Nevertheless, Kitzing & Wendring, (2015) also state that mainly large, experienced energy companies participated in the auctions because projects are large scale and pre-qualification criteria required significant experience in the construction and operation of offshore wind farms. So far, all auctioned projects have been realised at the contracted sizes.

The influential role of the Government did help to decrease both the risk premium and the costs of capital. The costs of capital which were significantly reduced in the latest auction held in early 2015 resulting in the Horns Rev 3 project. Also, the time between the auction and the actual contracting was also reduced, resulting in more accurate price estimations on main components and services. These benefits have contributed to the winning price level for the 400 MW Horns Reef 3, the lowest price level in Europe for offshore wind registered in 2015 (IRENA, 2015).

The auction system is designed in a way that ensures that the best locations are utilised first. The Anholt wind farm auction in 2010 was price-based, but strict penalties and non-compliance rules were applied to guarantee compliance with the schedule. For instance, a delay of up to five months resulted in a penalty of DKK 10 (GBP 1.19) per MWh (around 1% reduction of the remuneration) and a delay of more than a year was penalised with DKK 400 million (around GBP 47 million) (IRENA, 2015). A key lesson from this experience is that, while penalties can help to ensure project implementation, overly harsh limitations can reduce competition (IRENA, 2015). Kitzing & Wendring (2015) argue that in the case of Denmark, high penalties and inflexible auction design can lead to low participation and high bidding prices. The authors also highlight that a penalty scheme that reduces the length of support and not the support level is a relief for investors Kitzing & Wendring (2015).

In recent years, Denmark raised the need for greater technology-neutrality (Radov, Carmel, Koenig, 2016) because so far, only technology-specific auctions for offshore wind farms of a given installed capacity were eligible. Consequently, Denmark announced a remarkable accomplishment in 2017, and it has allowed solar PV and onshore wind to compete on equal subsidies during the 2018 and 2019 auctions (IEA, 2017).

## France

The renewable targets of France are to achieve a 40% share of RES by 2030 and 27% by 2020. In 2015, its share of RES in total energy production was 14%, while the share of RES-E was 18.5% (European Environmental Commission, 2017). Renewables have been supported through FiTs, PFiT, tax benefits, and auctions.

The Act on Energy Transition for Green Growth (2015) mandated to phase out FiTs and progressively replaced it with a premium tariff, called the “compensation mechanism” (mécanisme de compensation). The premium tariff can be allocated through two bidding procedures: a competitive dialogue procedure or through a call for tenders. The choice depends on the technology and size of the installation (Najdawi, 2017):

- **Competitive dialogue procedure:** Upon prior selection of candidates according to pre-qualification criteria, the Ministry of Energy shall enter into a dialogue with the candidates admitted participating in the procedure, in order to define the conditions on the basis of which the candidates are invited to submit an offer.
- **Call for tenders:** The Ministry of Energy chooses the most economically advantageous tender without negotiation, based on objective criteria previously communicated to the candidates in the specification document.

The multi-annual programming for energy establishes an indicative timing for national bidding procedures until 2019 for wind, solar, biogas, hydro and biomass. The number of rounds is likely to depend on the technology and situation of the market, with fewer rounds for technologies with potentially fewer actors (Offshore wind) and more frequent rounds in the case of technologies and bands with more potential participants (roof-top solar PV). For example, auctions in France (solar-PV) are quite frequent (5 rounds in 2012). Some characteristics of the scheme are as follows:

- The total capacity to be tendered for each bidding round is limited.
- The volume caps are technology-specific.
- Developers are obliged to conclude purchase agreements with the successful tenderers.
- The end consumers bear the costs arising from the suppliers' (EDF's and private suppliers') obligation to pay for all electricity from renewable sources exported to the grid.

Many solar and wind auctions have been multicriteria auctions. Besides price, bids are evaluated based on other factors such as the cost-efficiency of production, R&D support, local and environmental benefits and technical and financial reliability. Multicriteria formats may impact the cost-efficiency of results since bids with the lower prices might not be selected. Some evidence of this can be found by comparing the prices resulting from wind auctions held around the same time in France and the UK. The French auction resulted in an average price of 0.052 EUR/kWh compared to 0.047 EUR/kWh in the UK where the electricity price was the only criteria for bid selection (IRENA, 2015)

Forster (2016) argues that if the qualification criteria are unclear and prohibitively high, a high number of bids will be excluded. Therefore, the level of competition and therefore the efficiency of the scheme reduces. The qualification criteria must be designed adequately to ensure a high share of qualified bids. The documentation (requirements) should be kept clear, simple and straightforward.

However, a lack of strict requirements and penalties can lead to lower realisation rates, for instance during the EOLE 2005 French auctions programme, only 10% of the generation contracted was produced after five years (IRENA, 2015). Later auctions introduced specific and strict requirements for participation as well as sanctions for delays in constructing the plant. The penalties took the form of either a shortening in the length of the contractual period, a suspension of the licence to operate for a period or a financial fee (IRENA, 2015).

Pay-as-bid online-auctions for small-scale solar PV have been held since 2011. In this scheme construction delays are penalised with the duration of support, which can be reduced by the delay multiplied by two (Held et al. 2014). The installation must be up and connected 18 months after publication of the auction results (extendable by two months, if the DSO causes the delay) (Foster, 2016).

The French government, which has so far held separate auctions for the two leading renewable energy technologies, said joint tenders would help further reduce costs. The first auction will be open to projects not larger than 18 MW (IEA, 2018). Also, France and Germany have agreed to hold joint auctions for renewable energies. The two countries also agreed to set up a cross-border experiment dubbed “Smart Border Initiative” aimed at testing the integration of renewables into decentralised grids[14].

[14] https://www.bmwi.de/Redaktion/EN/Textsammlungen/Energy/foerderung-fuer-den-ausbau-der-erneuerbaren.html

# Conclusions

This review has assessed the available evidence on the *Role of Auctions and their Design in Renewable Energy Deployment.* The evidence review is structured around addressing the following research questions:

- *What does existing evidence tell us about how renewable energy auction design affects intended outcomes, around: encouraging investment in and increasing supply of renewable electricity, lowering technology and support costs?*

- *What implications do wider international trends in renewable energy investment and technology cost have on the continued use of auctions in the future?*

Evidence from the literature and the case studies has shown that there is no single approach to auction design and auctions need to be tailored to the conditions of the market of a country and Government policy objectives. The criteria for inclusion, award and non-delivery disincentives may vary according to a balance of priorities for renewable electricity procurement, including: cost-effectiveness, security of supply, decarbonisation, investment in technological innovation and local socio-economic development goals.

Additionally, designs must be flexible enough to adapt to changes, avoid unwanted outcomes and incorporate lessons learnt from previous rounds or changes in technology costs. Although auction theory, under certain assumptions, suggests that payments should be the same, independently from the pricing method, in practice auctions can have very varied outcomes. Policymakers need to address risks of strategic bidding, collusion, corruption, market distortions and low realisation rates. Competition is fundamental for any auction process. The evidence clearly shows that low competition levels may result in high prices and thus support costs. Evidence also strongly suggests that prequalification requirements and penalties play a crucial role to avoid low realisation rates.

Setting ceiling prices has been widely supported since it helps to reduce costs for taxpayers or consumers. In the UK, some evidence suggests that the CfD clearing prices have lowered hurdle rates by 3%. Prices differ among countries and regions. Lower prices can reflect a decrease in technology costs and an increase in market maturity, but they can also mean underbidding which eventually would lead to low realisation rates and project cancellations. Capacity factor, operation costs and capital expenses are among the most decisive elements affecting prices.

Regarding global investment trends, China, in particular, is driving global renewable energy investments while developed countries have indicated decreasing investment levels since 2014. The vast majority of investments are in wind and solar power. In the UK, the investment landscape has been volatile in recent years. The full implications of this period of decline in investment may only be visible in a few years' time once the installation rates of new projects are known.

On the cost side, the main drivers are continuous technology innovation, increasing international competition for projects, and competitive procurement of renewable power generation. The REN-21 Futures study estimated that the costs of solar-PV and offshore & onshore wind would continue to fall in the next decades. On the other hand, mature technologies such as hydropower and biomass are unlikely to experience strong falling costs in the future. For these, cost developments will be mainly linked to the prices of raw materials. It can, therefore, be expected there will be an increase in subsidy-free wind and solar-PV in the future since their costs are in some cases already in the range of fossil fuels. Nevertheless, other emerging technologies may not necessarily experience the same level of falling costs as solar-PV.

In broad terms, for the purpose of this report, 'subsidy free' renewable electricity means deployment without government support mechanisms such as FiT, RO or CfD auctions. However, this will have different meanings based on context-specific markets characteristics. For example, some projects have been subsidy-free in terms of not requiring price stabilisation support but still require other forms of state support for infrastructure and grid connection.

The trend towards reduced subsidies is making developers explore more innovative ways to reach previous revenue levels without subsidies such as private PPAs. Finally, as the deployment of RES-E generation increases, other factors become crucial for successful integration of renewables into the system. For instance, building flexibility into the system becomes much more critical.

# Annex 1 Quality Assessment

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| Anatolitis, V., Welisch, M. | 2017 | Putting renewable energy auctions into action - An agent-based model of onshore wind power auctions in Germany | Energy Policy | Germany | Primary | Experimental | 9 | European Commission, Horizon2020 Project AURES [grant number 646172]. |
| Aquila, Giancarlo; Pamplona, Edson de Oliveira; de Queiroz, Anderson Rodrigo; et al. | 2017 | An overview of incentive policies for the expansion of renewable energy generation in electricity power systems and the Brazilian experience | Renewable and Sustainable Energy Reviews | Brazil | Primary | Observational | 6 | Brazilian Government agencies CNPq, CAPES, and FAPEMIG |
| Batlle, C., Pérez-Arriaga, I. J. and | 2012 | Regulatory design for RES-E support mechanisms: Learning curves, market structure, and burden-sharing | Energy Policy | Europe | Primary | Observational | 6 | Undisclosed |

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| Zambrano-Barragán, P. | | | | | | | | |
| Bayer | 2018 | Experience with auctions for wind power in Brazil | Renewable and Sustainable Energy Reviews | Brazil | Primary | Observational | 6 | German Federal Ministry of Education and Research (BMBF) and the Brandenburg Ministry of Science |
| Becker, B.; Fischer, D. | 2013 | Promoting renewable electricity generation in emerging economies | Renewable Energy | China, India, South Africa | Primary | Observational | 7 | Undisclosed |
| Butler, L.; Neuhoff, K. | 2008 | Comparison of feed-in tariff, quota and auction mechanisms to support wind power development | Renewable Energy | UK and Germany | Primary | Observational | 8 | UK Research Council funded project SuperGen, grant RG37889. |
| Cassetta, E., Monarca, U., | 2017 | Is the answer blowin' in the wind (auctions)? An assessment of the Italian support scheme | Energy Policy | Italy | Primary | Observational | 7 | Undisclosed |

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| Nava, C.R., Meleo, L. | | | | | | | | |
| De Mello Santana, P. | 2016 | Cost-effectiveness as energy policy mechanisms: The paradox of technology-neutral and technology-specific policies in the short and long term | Renewable and Sustainable Energy Reviews | unspecified | Primary | Observational | 5 | Undisclosed |
| Del Río, P. and Linares, P. | 2014a | Back to the future? Rethinking auctions for renewable electricity support | Renewable and Sustainable Energy Reviews | worldwide | Primary | Observational | 7 | Partial support from the Spanish Ministry of Economy and Competitive-ness (ECO2009-14586-C02-01). |
| Del Rio, P. | 2017 | Designing auctions for renewable electricity support. Best practices from around the world | Energy for Sustainable Development | worldwide | Primary | Observational | 9 | EU-funded AURES project (grant number 646172) |

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| Del Rio, P., Mir-Artigues, P. | 2014b | Combinations of support instruments for renewable electricity in Europe: A review | Renewable and Sustainable Energy Reviews | worldwide | Primary | Observational | 6 | Undisclosed |
| Frisari, Gianleo; Stadelmann, Martin | 2015 | De-risking concentrated solar power in emerging markets: The role of policies and international finance institutions | Energy Policy | Moroco and India | Primary | Observational | 8 | Climate Investment Funds for funding on the case study of India |
| Huntington, S.C., Rodilla, P., Herrero, I., Batlle, C. | 2017 | Revisiting support policies for RES-E adulthood: Towards market compatible schemes | Energy Policy | worldwide | Primary | Observational | 5 | Undisclosed |
| Kreiss, J., Ehrhart, K., Haufe, M. | 2017 | Appropriate design of auctions for renewable energy support – Prequalifications and penalties | Energy Policy | Europe | Primary | Observational | 9 | EU Horizon 2020 program, grant number 646172 (AURES). |

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| Lockwood | 2016 | The UK's Levy Control Framework for renewable electricity support: Effects and significance | Energy Policy | UK | Primary | Observational | 8 | TheEngineeringandPhysical Sciences ResearchCouncil(EPSRC)[EP/K001582/1]. |
| Lorentziadis, P. | 2016 | Optimal bidding in auctions from a game theory perspective | European Journal of Operational Research | unspecified | Primary | Experimental | 6 | Undisclosed |
| Reus, L., Munoz, F. D. and Moreno, R. | 2018 | Retail consumers and risk in centralized energy auctions for indexed longterm contracts in Chile | energy policy | Chile | Primary | Experimental | 9 | FONDECYT #11150029, CONICYT/FONDAP/15110019 (SERC-CHILE), CONICYTBasal Project FB0008, the Complex Engineering Systems Institute (CONICYTCONICYT - PIA - FB0816; ICM P-05-004-F), Fondef/ ID15I10592, FONDECYT #11170012, The Energy Center of the University of Chile and Newton-Picarte/MR/N026721/1. |

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| Mastropietro, Paolo; Batlle, Carlos; Barroso, Luiz A.; et al. | 2014 | Electricity auctions in South America: Towards convergence of system adequacy and RES-E support | Renewable and Sustainable Energy Reviews | South America | Primary | Observational | 6 | Undisclosed |
| Moreno, R., Barroso, L.A., Rudnick, H., Mocarquer, S., Bezerra, B. | 2010 | Auction approaches of long-term contracts to ensure generation investment in electricity markets: lessons from the Brazilian and Chilian experiences | Energy Policy | Brazil and Chile | Primary | Observational | 8 | Undisclosed |
| Neuhoff, Karsten; Wolter, Sophia; Schwenen, Sebastian | 2016 | Power Markets with Renewables: New Perspectives for the European Target Model | Energy Journal | Europe | Primary | Observational | 8 | research grant EUREEM(funding number 03MAP274) from the Federal Ministry for Economic Affairs and Energy. |
| Newbery, D. | 2017 | Tales of two islands – Lessons for EU energy policy from electricity | Energy Policy | Europe, UK | Primary | Observational | 9 | ENEL<br>Foundation under the project The role of |

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| | | market reforms in Britain and Ireland | | | | | | energy subsidies in the European electricity sector. |
| Newbery, David M. | 2016 | Towards a green energy economy? The EU Energy Union's transition to a low-carbon zero subsidy electricity system - Lessons from the UK's Electricity Market Reform | Applied Energy | Europe, UK, Ireland | Primary | Observational | 7 | Undisclosed |
| Nielsen, Steffen; Sorknaes, Peter; Ostergaard, Poul Alberg | 2011 | Electricity market auction settings in a future Danish electricity system with a high penetration of renewable energy sources - A comparison of marginal pricing and pay-as-bid | Energy | Denmark | Primary | Quasi-experimental | 8 | Undisclosed |
| Shrimali, G., Konda, C., Farooquee, A.A. | 2016 | Designing renewable energy auctions for India: Managing risks to maximize deployment and cost-effectiveness | Renewable Energy | India, UK, Brazil, Moroco, South Africa, Peru | Primary/Secondary | Observational | 8 | Undisclosed |

| Authors | Year | Title | Journal | Geographical focus | Type | Design | Quality | Source of funding |
|---|---|---|---|---|---|---|---|---|
| Chilvers, J.; Foxon, T.; Galloway S., et al | 2017 | Realising transition pathways for a more electric, low-carbon energy system in the United Kingdom: Challenges, insights and opportunities | Journal of Power and Energy | UK | Primary | Observational | 9 | part of a major research grant awarded by the UK Engineering and Physical Sciences Research Council (EPSRC) entitled 'Realising Transition Pathways - Whole Systems Analysis for a UK More Electric Low Carbon Energy Future' [under Grant EP/K005316/1] |
| Hall, S.; Foxon, T., and Bolton R. | 2017 | Investing in low-carbon transitions: energy finance as an adaptive market | Climate Policy | UK | Primary | Observational | 9 | Project funded by the UK Engineering and Physical Sciences Research Council (EPSRC) (grant no. EP/K005316/1). |
| Batalla-Bejerano, Trujillo-Baute | 2015 | Impacts of intermittent renewable generation on electricity system costs | Energy Policy | Spain | Primary | Observational | 9 | support of the Generalitat de Catalunya SGR Project 2014-SGR-531 and from the Chair of Energy Sustainability (University of Barcelona and FUNSEAM). |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| Agora Energiewende and DTU Management Engineering | 2015 | A Snapshot of the Danish Energy Transition. Objectives, Markets, Grid, Support Schemes and Acceptance | Denmark | 4 | Agora Energiewende is a joint initiative of the Mercator Foundation and the European Climate Foundation. |
| Agora Energiewende, Fraunhofer ISI, and Consentec | 2014 | Auctions for Renewable Energy in the European Union: Questions Requiring | | 4 | Agora Energiewende |
| AURES Project | 2015c | Overview of Design Elements for RES-E Auctions | worldwide | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2015b | Assessment Criteria for RES-E auctions | worldwide | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| AURES Project | 2015a | A methodology note on the links between components for the assessment of design elements in auctions for RES | worldwide | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2016 | Assessment of Auction types suitable for RES-E | worldwide | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2017 | Auctions for renewable energy support - Taming the beast of competitive bidding | worldwide | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2017 | The winner's curse in discriminatory and uniform price auctions under varying competition levels | worldwide | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| AURES Project | 2015a | Auctions for Renewable Energy Support in Germany | Germany | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2015b | Auctions for Renewable Energy Systems in Germany: Pilot scheme for ground-mounted PV' | Germany | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2015 | Auctions for Renewable Energy Support in Denmark | Denmark | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2016 | Small-scale PV Auctions in France: Instruments and lessons learnt | France | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2016 | Auctions for Renewable Energy Support in the United Kingdom | United Kingdom | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| AURES Project | 2016 | Auctions for Renewable Energy Support in the Netherlands | The Netherlands | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2017b | Auctions for Renewable Energy Support in Mexico: Instruments and lessons learnt | Mexico | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2016 | Auctions for Renewable Energy Support in China | China | 4 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| AURES Project | 2016 | Comparison of auctions and alternative policy options for RES-E support | worldwide | 5 | The European Union's Horizon 2020 research and innovation programme under grant agreement No 646172 |
| Aurora Energy Research | 2018 | Renewables 2.0: Subsidy-free revolution | unspecified | 4 | not available |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| BNEF | 2018 | Summary of the New Energy Outlook 2018 | worldwide | 4 | BNEF |
| ECOFYS | 2014 | Design features of support schemes for renewable electricity | | 5 | European Commission, DG ENER |
| Ernest & Young | 2018 | Renewable Energy Country Attractiveness Index: Issue 51 | worldwide | 4 | Ernest & Young |
| Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance (FS-UNEP) and Bloomberg New Energy Finance (BNEF) | 2018 | Global Trends in Renewable Energy Investment 2018 | worldwide | 4 | Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance (FS-UNEP) and Bloomberg New Energy Finance (BNEF) |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| Fraunhofer Institute for Solar Energy Systems Ise Levelized | 2013 | Levelized Cost of Electricity Renewable Energy Technologies | | 4 | FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE |
| IRENA | 2013 | Renewable Energy Auctions in Developing Countries | Developing countries | 4 | IRENA member States |
| IRENA | 2017 | Renewable Energy Auctions Update | worldwide | 4 | IRENA member States |
| IRENA | 2016 | The Power to Change: Solar and Wind Cost Reduction Potential to 2025 | worldwide | 4 | IRENA member States |
| IRENA | 2016a | Roadmap for a Renewable Energy Future | worldwide | 4 | IRENA member States |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| IRENA | 2017 | Renewable Energy Auctions: Analysing 2016 | worldwide | 4 | IRENA member States |
| IRENA | 2018 | Renewable Power Generation Costs in 2017 | worldwide | 4 | IRENA member States |
| IRENA and CEM | 2015 | Renewable Energy Auctions: A Guide To Design | worldwide | 4 | it is a project of IRENA and the Multilateral Solar and Wind Working Group, an initiative of the CEM led by Denmark, Germany and Spain. |
| NERA | 2013 | Changes in Hurdle rates for low carbon generation technologies due to the shift from the UK renewables obligation to a contract for difference regime | United Kingdom | 5 | UK Government |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| NERA | 2015 | Electricity Generation Costs and Hurdle Rates Lot 1: Hurdle Rates update for Generation Technologies' | United Kingdom | 5 | UK Government |
| NERA | 2017 | Gale Force Competition ? Auctions and Bidding Strategy for Offshore Wind | United Kingdom | 5 | NERA Economic Consulting |
| NREL | 2010 | A Policymaker's Guide to Feed-in Tariff Policy Design | | 4 | the U.S. Department of Energy's (DOE) Solar Energy Technologies Program |
| REN-21 | 2016 | Renewables 2016: Global Status Report | worldwide | 4 | Financing was provided by the German Federal Ministry for Economic Cooperation and Development (BMZ), the German Federal Ministry for Economic Aairs and Energy (BMWi), the Government of South Africa, the Inter-American Development Bank (IDB), the United Nations Environment Programme (UNEP) and the World |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| | | | | | Bank Group. A large share of the research for this report was conducted on a voluntary basis. |
| REN-21 | 2017 | Renewables 2017: Global Status Report | worldwide | 4 | Financing was provided by the German Federal Ministry for Economic Cooperation and Development (BMZ), the German Federal Ministry for Economic Affairs and Energy (BMWi) and UN Environment. A large share of the research for this report was conducted on a voluntary basis. |
| REN-21 | 2017 | Renewables Global Futures Report: Great debates towards 100% renewable energy' | worldwide | 4 | Financial support of the German government and the World Future Council. |
| REN-21 | 2018 | Renewables 2018: Global Status Report | | 4 | Financing was provided by the German Federal Ministry for Economic Cooperation and Development (BMZ), the German Federal Ministry for Economic Affairs and Energy |

| Project/Organisation | Year | Title | Geographical focus | Quality score | Source of funding |
|---|---|---|---|---|---|
| | | | | | (BMWi) and UN Environment. A large share of the research for this report was conducted on a voluntary basis. |
| The Oxford Institute for Energy Studies | 2018 | Renewable Auction Design in Theory and Practice: Lessons from the Experiences of Brazil and Mexico | Brazil and Mexico | 4 | not available |
| UKERC | 2017 | The costs and impacts of intermittency – 2016 update A systematic review of the evidence on the costs and impacts of intermittent electricity generation technologies | United Kingdom | 4 | funded by The Research Councils Energy Programme |

# Annex 2 Auction Design Features

| General design feature | Description | Examples |
|---|---|---|
| Targets and format (single unit or multi-unit) | • Targets can be defined in terms of:<br>– Capacity (MW)<br>– Generation (MWh)<br>– Budget (M£) | • The Dutch Stimulation of Sustainable Energy Production scheme (SDE+) follows a multiple-item auction where bids/projects are selected up to the auctioned volume/annual budget is achieved (Noothout & Winkel, 2016)<br>• Mexico's auctions are held to contract energy, capacity and clean energy certificates (Hochberg & Poudineh, 2018) |
| Burden sharing of RES-support | • Funding may either come from the **public budget** (taxpayers) or a **levy** linked to the consumption level and included into the final energy price (electricity consumers). | • In Brazil, the allocation of costs differs between the types of auctions and their scope. In the regular auctions, which are addressed to cover the distribution companies' demand, the costs are allocated to them, while in the reserve auctions, meant to ensure the security of supply margin, the |

| General design feature | Description | Examples |
| --- | --- | --- |
| | | costs are allocated to all consumers (IRENA & CEM, 2015) |
| Stage of project development | • Auctions can support different stages of the project development process thus, either existing or new plants may be eligible to participate. | |
| Financial Support levels | • Renewable Electricity Financial support is usually provided per unit of output (MWh) or per unit of capacities installed (MW).<br>• Schemes require either the determination of the prices in terms of support levels or the quantity target, in case of volume-based schemes. | • Auctions in the Netherlands are based on a well-defined annual budget since 2011. the Government sets support levels that decrease from one round to the next (IRENA, 2016) |

| General design feature | Description | Examples |
|---|---|---|
| Technology differentiation of support level | • Auctions can be designed to be **technology-specific** or **technology-neutral**. The choice has implications in terms of price or volume differentiation.<br><br>• Policymakers may be interested in supporting specific technologies or permitting competition across all available technologies. The level of differentiation mainly depends on the country's technology targets and the cost of different technologies.<br><br>• Project-specific auctions involve competitive bidding for a particular project selected by the government. | • China, for example, wind-specific and solar-specific auctions have been used to promote these two technologies before the government setting FITs (IRENA & CEM, 2015)<br><br>• In Brazil, the renewable energy auctions in 2008 and 2009 were biomass-specific and wind-specific, respectively, followed by technology-neutral auctions (Hochberg & Poudineh, 2018)<br><br>• China, Denmark, Dubai and Morocco have held project specific auctions (IRENA & CEM, 2015) |
| Auction format<br><br>(Price-only auctions vs multi-criteria auctions) | • **Price-only auctions** award bidders using the price as the only criterion.<br><br>• In contrast, **multi-criteria auctions** take into consideration other criteria such local content rules, | • The French government emphasised a mix of factors such as the cost efficiency of production, research and development support, local benefits and the emergence of new technology (IRENA, 2016) |

| General design feature | Description | Examples |
|---|---|---|
| | impact on local R&D and industry, environmental impacts (Held et al. 2014). | |
| Auction type<br><br>(Sealed bid / descending clock/hybrid) and Price rule (pay-as-bid, Vickrey, Uniform price | • **Sealed bid**. - Bidders simultaneously submit their bids. The price and quantity are undisclosed. The bid is awarded according to ascending bid prices until the energy demanded is covered.<br><br>• Winners can receive a **pay-as-bid** payment which is their own offered price or a **uniform price** which can be set by the last successful (**second-price sealed-bid**) or by the highest losing bid. The last one is called a **Vickrey** auction.<br><br>• **Descending clock**. - Involves an iterative bidding process in which the auctioneer establishes a price ceiling and bidders offer the volume they are willing to provide at the stated price. This process repeats until the targeted volume is achieved. Prices can be | • The Stimulation of Sustainable Energy Production scheme in the Netherlands follows a sealed bid auction type (Noothout & Winkel, 2016)<br><br>• Brazil has combined a descending-clock auction followed by a pay as- bid round (Hochberg & Poudineh, 2018) to set the ceiling price first<br><br>• Mexico, Chile and Brazil have recently used a pay as bid formats. (IRENA, 2013) However, Mexico applies three types of adjustments to prices: Regional, hourly and inflation/exchange rate (Hochberg & Poudineh, 2018) |

| General design feature | Description | Examples |
|---|---|---|
| | undisclosed or not. Successful bidders get paid a **uniform price.**<br><br>• **Hybrid**. Some designs combine both types. Generally, a descending clock followed by a sealed bid auction. | |
| Price limits | • The auction design can establish a **ceiling price** to set the maximum level of support each technology can get. | • Denmark introduced a ceiling price for nearshore wind farms (Kitzing & Wendring, 2015)<br><br>• Germany set ceiling prices for its Ground-mounted PV Auction Ordinance (Tiedemann, 2015) |
| Penalties | • Establishing penalties are generally established as a mechanism to increase the realisation rate and decrease projects delays. For instance, termination of contracts, decreasing the level of support or support | • In the Netherlands, the auction scheme applies a payment penalty that consists of a fixed amount (Del Rio et., al. 2015c) |

| General design feature | Description | Examples |
|---|---|---|
| | period, confiscation of bid bonds or prohibiting bidders from participating in further rounds. | • Peru, India and Argentina set payment penalties in terms of MW while Denmark set them in kWh (Del Rio et., al. 2015c)<br><br>• In Brazil, penalties are set as a % of the investment made (Del Río & Linares 2014; Held *et al.*, 2014) |
| Pre-qualification criteria | • Before being able to participate in a bidding procedure, buyers can be requested to fulfil a list of specification criteria, such as project technical requirements or specifications, documentation requirements, preliminary licences, certifications, demonstrating financial capability, etc. | • Local content rules are used as a pre-qualification criterion in South Africa (IRENA &CEM, 2015)<br><br>• Other countries that have required local content are Canada, India, China, Brazil (IRENA & CEM, 2015)<br><br>• In Germany's 2015-2017 solar auctions, each bidder must provide a bid bond worth EUR 4 (USD 4.47 at 2015 average exchange rate) per kW to be |

| General design feature | Description | Examples |
|---|---|---|
| | | installed in order to be considered in the auction (IRENA &CEM, 2015)<br><br>• In Peru, in the 2013 auction, bidders were required to deposit a bid bond for 50 000 USD/MW of capacity installed which is lost if the bid is won and the bidder fails to sign the contract (IRENA &CEM, 2015) |
| Size, geographic requirements | • Policymakers may introduce design elements which increase diversity concerning technologies, the size of the installations, actors and locations for a number of reasons | • In the German solar PV auctions in April 2015, location requirements were introduced in order to avoid competition in the land usage between energy and food production (IRENA &CEM, 2015)<br><br>• In the 2014 project-specific solar auction in Dubai, the project was awarded at a very competitive. By increasing the project size from 100 MW to 200 MW during ex-post negotiations, a further price |

| General design feature | Description | Examples |
| --- | --- | --- |
| | | reduction of the winning bid was possible. (IRENA &CEM, 2015)<br><br>• In France, the support mechanism for promoting solar PV involves an auctioning scheme for projects greater than 100 kW (Forster, 2016) |
| Contracting Scheme | • The two main options are PPA arrangements or asset ownership retainment by the government. | • in the Dubai solar power auction in 2014, where the Dubai Electricity and Water Authority (DEWA) has a mandated 51% equity share in the project. (IRENA &CEM, 2015) |

Source: Technopolis, 2018 (based on Del Rio, *et al.,* 2015c; (IRENA &CEM, 2015)

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