RENEWABLE ENERGY AUCTIONS : A Global Overview

Wikus Kruger, Anton Eberhard & Kyle Swartz
Management Programme in Infrastructure Reform and Regulation (MIR)

Report 1: Energy and Economic Growth Research Programme (W01 and W05)
PO Number: PO00022908

May 2018
Version 1.1

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Acronyms

AFDB	African Development Bank
BRICS	Brazil, Russia, India, China and South Africa
CA	Connection Agreement
CCGT	Close Cycle Gas Turbine
CELs	Clean Energy Certificate
CSP	Concentrated Solar Power
DA	Direct Agreement
DN	Direct Negotiation
EU	European Union
FODER	Fund for the Development of Renewable Energy
GDP	Gross Domestic Product
GW	Gigawatt
IA	Implementation Agreement
ICB	Internationally Competitive Bidding
IRENA	International Renewable Energy Agency
kWh	Kilowatt hour
MENA	Middle East and North Africa
MW	Megwatt
MWh	Megawatt (hours)
OCGT	Open Cycle Gas Turbine
PPA	Power Purchase Agreement
PPP	Public-Private Partnerships
PV	Photovoltaic
RAB	Regulated Asset-Based system
RE	Renewable Energy
REFiT	Renewable Energy Feed-In Tariff
RRR	Reasonable Rate of Return
SSA	Sub-Saharan Africa
USDc	United States Dollar Cent
VAT	Value Added Tax

Introduction

The Sub-Sahara African electricity sector stands out for all the wrong reasons. It is the world region with the lowest per capita electricity consumption – 181 kWh per person each year, or 3% of the European average. Half of the region's installed generating capacity (45 GW) is found in one country – South Africa – with the remaining 45 GW spread among the other 45+ countries in the region. To put this into perspective: a single European country – Spain (110 GW) – has more installed power than Sub-Saharan Africa. This lack of generation capacity constrains economic growth and social development in the region, with 2 out of every 3 people lacking access to electricity (Findt, Scott & Lindfeld, 2014; IEA, 2014; African Development Bank Group, 2017; The World Bank, 2017). While there has been some growth in the installed capacity in the region, much of this has only taken place in the last 10 years (Figure 1) at a rate far below what is required (Castellano et al., 2015).

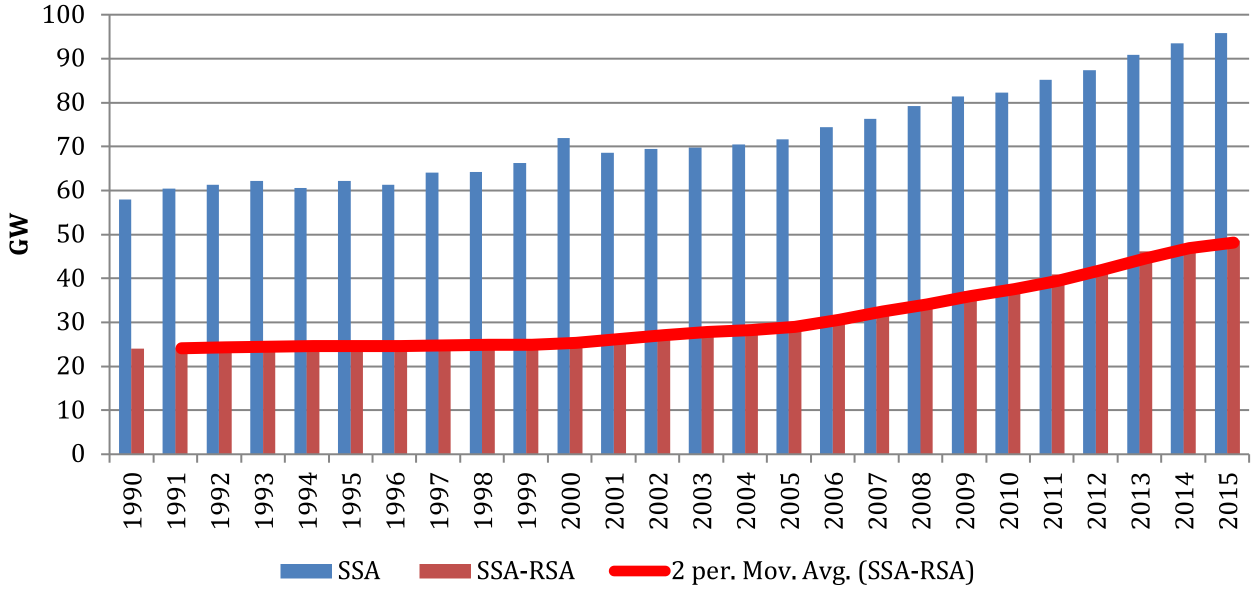

Figure 1: Installed Generation Capacity in sub-Saharan Africa, 1990-2015. Source: Authors' calculation, based on EIA data, 2017.

Independent power projects (IPPs) – built, financed, owned and operated by the private sector – have become one of the fastest growing sources of investment in the region's power sector (along with Chinese investments) (Figure 2). The majority of these IPPs have been directly negotiated and are thermal-based, with over 65% of installed IPP capacity coming from gas turbines (OCGT and CCGT), diesel/HFO and coal. Most IPP capacity is concentrated in about a handful of countries, with only a few having more than 500MW installed: Nigeria (1980 MW), Ghana (1643 MW), Kenya (1079 MW), Cote D'Ivoire (866 MW), Uganda (577 MW), Senegal (549 MW) and Zambia (517 MW). In terms of the number of projects, the picture looks more or less the same, with only a few countries hosting five projects or more: Uganda (27), Kenya (17), Namibia (16), Senegal (9), Mauritius (9), Ghana (8), Cote D'Ivoire (6) and Nigeria (5). Adding South Africa's recent (2011 - 2018) IPP additions might distort this picture (92 projects contributing 6300+ MW), but also emphasises the importance of this investment trend for the region's power sector.

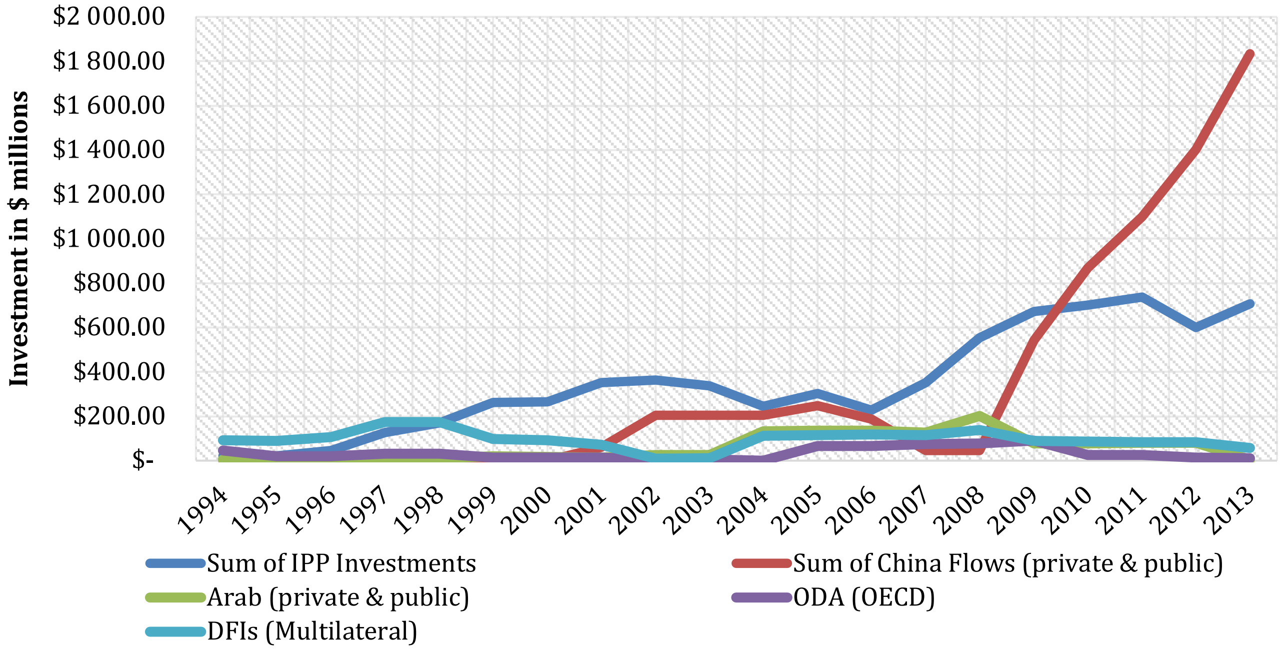

Figure 2: Investments in sub-Saharan African power generation sector, 1994 - 2013 (Five year moving average). Source: Eberhard et al., 2016[1].

Recent data shows that a rapidly growing portion of these IPPs is renewable energy-based (Figure 3 and Figure 4), many of which have been competitively procured (Figure 5) (Eberhard, Gratwick, Morella, et al., 2017). Whilst several African countries have started down the path of setting up competitive procurement programs for large-scale renewable energy projects, less than a handful have successfully realised investments. Those that have succeeded – mainly South Africa and Uganda - are now reaping considerable benefits, primarily in the form of clean, low-cost energy wholly financed, built and operated by the private sector (Kruger & Eberhard, 2016). This coincides with a global surge of low-cost utility-scale renewable energy projects, competitively procured through long-term contracts with the private sector (IRENA, 2017a). These three trends – the surge in private power investment, the growth in competitively priced renewable energy projects, and the use of competitive procurement (auctions) for IPPs – represent important departures from the status quo in the Sub-Saharan region.

[1] DFI = Development Finance Institutions; ODA = Official Development Aid.

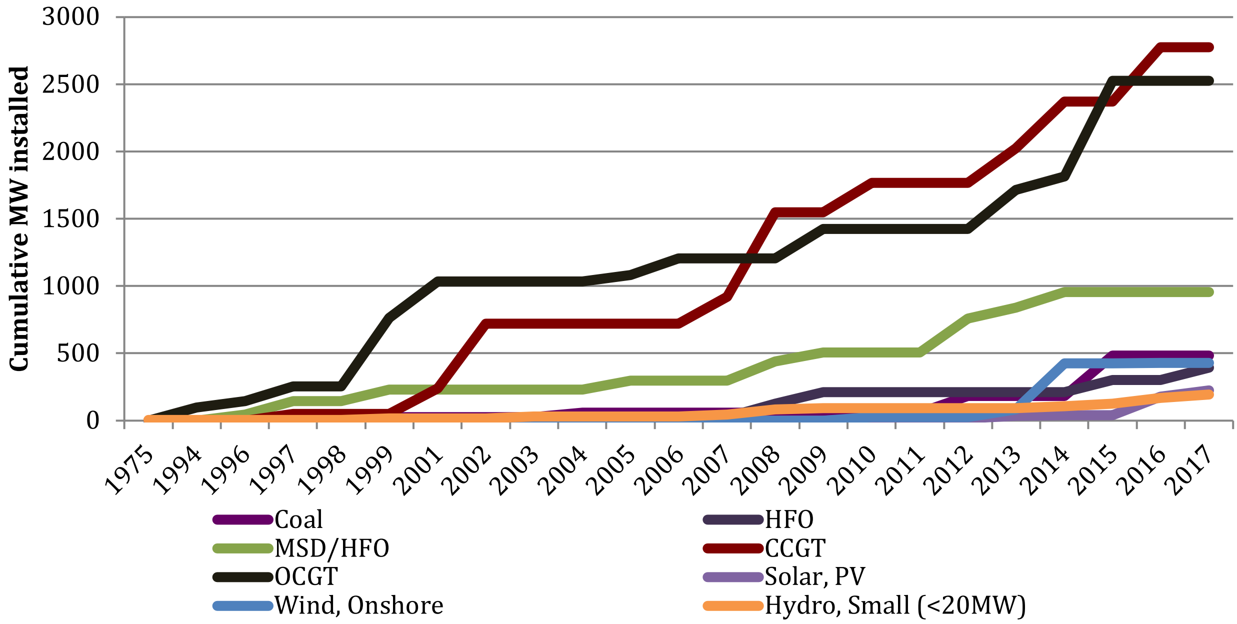

Figure 3: Cumulative private (IPP) MW installed per technology in sub-Saharan Africa, 1975 - 2017. Source: Authors' calculations[2].

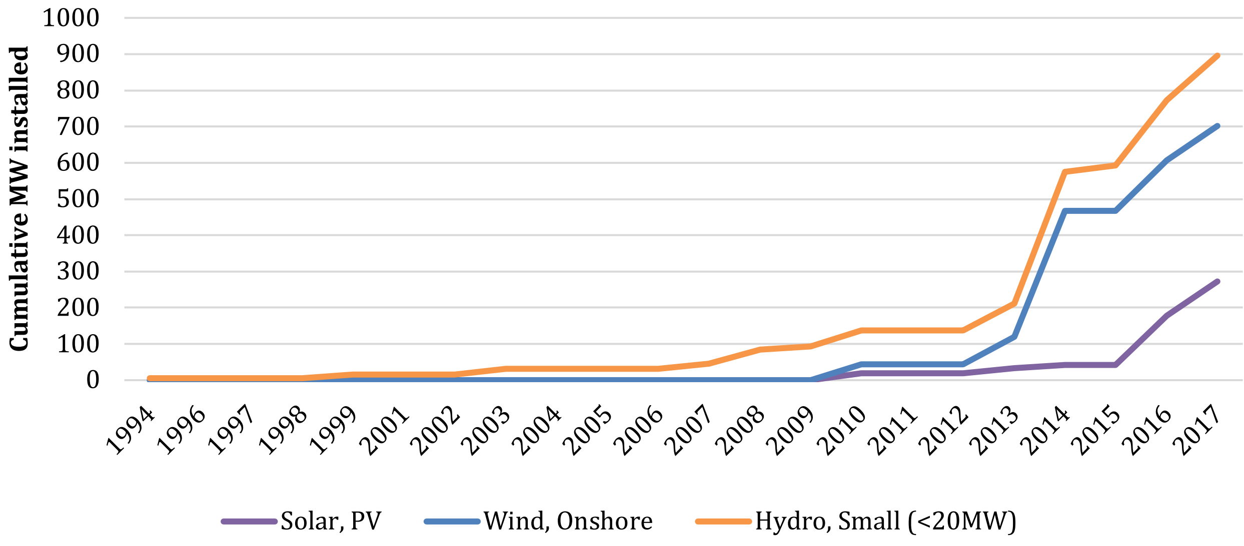

Figure 4: Cumulative private (IPP) MW installed for Solar PV, Onshore Wind and Small Hydro, 1994 - 2017 in sub-Saharan Africa. Source: Authors' calculations

[2] MSD = Medium Speed Diesel; HFO = Heavy Fuel Oil. OCGT = Open Cycle Gas Turbine. CCGT = Closed Cycle Gas Turbine.

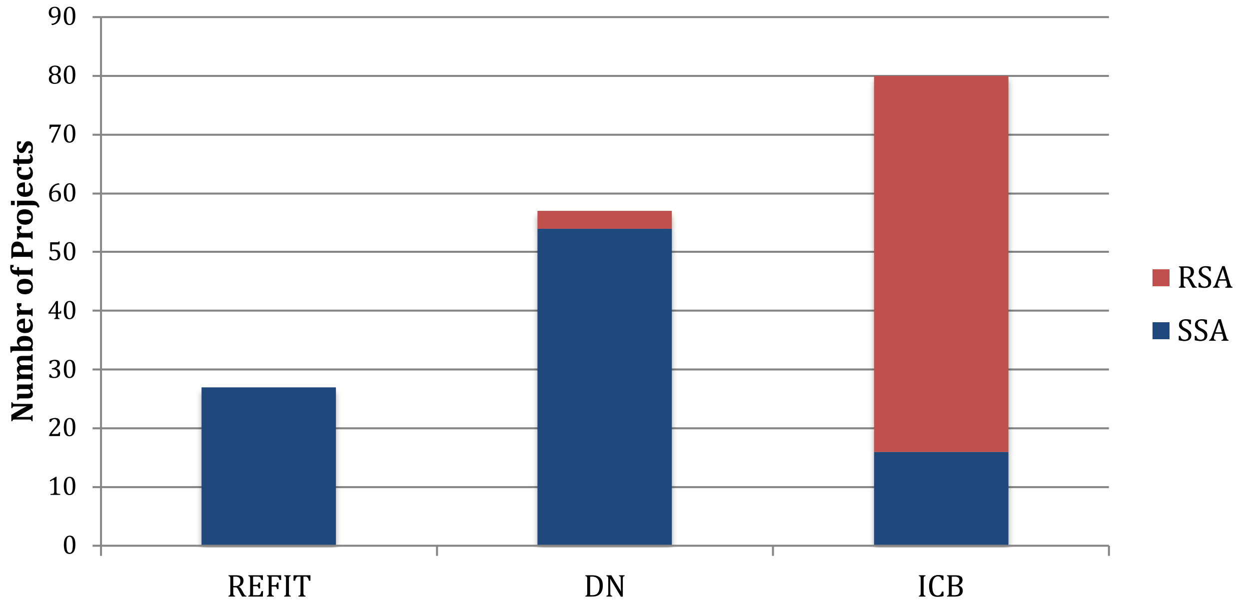

Figure 5: Procurement method of IPPs in Sub-Saharan Africa. Source: Authors' calculations[3].

Auctions, although quite recent, have already delivered more investment in RE at lower prices than any other procurement or contracting method for the region. Previously, feed-in tariffs were the most widespread RE support mechanism, but delivered little investment in Sub-Saharan Africa[4] (SSA). Running effective auctions requires dynamic least-cost power sector planning[5], considerable procurement and contracting capacity, and can involve significant transaction costs. These costs are however easily offset by the benefits of lower tariffs; recent research has shown that competitively procured power projects in sub-Saharan Africa – whether thermal or renewable based – are contracted at much lower prices than directly negotiated, or feed-in tariff-based projects (Eberhard et al, 2016). Auctions still risk attracting too little bidding interest, leading to higher prices; as well as delays in reaching financial close and construction, especially if there has been "low balling" in bid prices (del Río, 2017a; Lucas, Del Rio & Sokona, 2017; Mora et al., 2017). While these are important risks to consider, experience has shown that a well-designed and -implemented program can effectively mitigate these risks (Naude & Eberhard, 2016).

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[3] REFIT = Renewable Energy Feed-In Tariff; DN = Direct Negotiation; ICB = Internationally Competitive Bidding; SSA = Sub-Saharan Africa; RSA = Republic of South Africa.

[4] Namibia is a recent exception to this rule, having procured 14 IPPs (5 MW each) through its feed-in tariff program. However, the Namibian regulator has indicated that the country will be moving towards auctions on the back of recent results from its first solar PV auction, which delivered renewable capacity at a much cheaper price.

[5] The planning needs to be dynamic in the sense that it requires regular (perhaps annual) updating to keep track of developments in the sector. Planning needs to be least-cost in that it seeks to match future power demand requirements using the least-expensive new power generation sources available (given policy limitations). Ideally this plan is legally binding and all power sector investments are required to conform to this plan. The South African Integrated Resource Planning approach is a useful example of such a planning approach.

Private power investment and procurement in sub-Saharan Africa

Studies on private power investment in Sub-Saharan Africa have mainly concentrated on the identification of success factors for IPP development and implementation. Research by Woodhouse, (2005) and Eberhard & Gratwick (2013a, 2011, 2013b) has identified more than 40 such success factors in an emergent, bottom-up manner through the use of comparative case studies. While these IPP success factors have been empirically-derived, they correspond with the risks, barriers and bankability requirements identified in the project finance, PPP and infrastructure finance literature (Babbar & Schuster, 1998; Pollio, 1998; Thobani, 1999; Grimsey & Lewis, 2002; Farrell, 2003; Jamali, 2004; Bonetti, Caselli & Gatti, 2010; Siemiatycki & Farooqi, 2012; Annamalai & Jain, 2013; Collier, 2014; Collier & Cust, 2015; Estache, Serebrisky & Wren-Lewis, 2015). These factors are grouped into five sub-categories at the country level (stable country context; clear policy framework; transparent, consistent and fair regulation; coherent power system planning; and competitive bidding practices); and seven sub-categories at the project level (favourable equity partners; favourable debt arrangements; creditworthy off-taker; secure and adequate revenue stream; credit enhancement and other risk management and mitigation measures; positive technical performance; and strategic management and relationship building).

Further recent analyses of IPP investments in Africa by Eberhard et al., (2017a, 2017b, 2016) has in particular emphasized the importance of two country-level factors as critical for accelerating investment: *least-cost power planning*, linked to the timely initiation of *competitive procurement* for power generation. This emphasis is supported by theoretical assertions and empirical evidence from literature on procurement theory and infrastructure investment (Estache & Iimi, 2008; Bajari, McMillan & Tadelis, 2009; Chong, Staropoli & Yvrande-billon, 2014; Estache, 2016) and points to the need to further develop procurement design and implementation as part of the literature on IPP investment in sub-Saharan Africa. This contribution should be focused at the "programme" level, complementing the "country" and "project" levels of analyses thus far employed.

A body of literature that is both useful and timely for informing IPP success factor analysis at the programme level is the growing field of renewable energy auction design. Auctions have been used to sell a variety of goods and services for centuries. One of the earliest written accounts of an auction mechanism being used was when the Praetorian Guard sold the Roman Empire in A.D. 193. Auctions have also made an important contribution in theoretical terms – informing our understanding of pricing theory, competitive markets and game theory. As a public sector procurement mechanism, (reverse) auctions are particularly popular (Klemperer, 2004).

Electricity auctions – technology neutral and technology specific (e.g. renewable energy) – have now become standard practice for procuring new power for many countries across the world – including several African countries. In the electricity sector, (reverse) auctions have been used to procure power for more than two decades. The first auctions took place in Brazil, Canada, Chile, China, Ireland, Portugal and the UK (Lucas, Ferroukhi & Hawila, 2013). The second wave of power sector reforms (2004) were introduced (mostly in Latin America) in a context where many low- to middle-income countries were struggling to increase new electricity supply – and needed a new way of attracting generation capacity. Investors were more interested in bidding for long-term contracts than constructing merchant plants that had to compete to sell power. Auctioning off these long-term agreements to the lowest bidder proved to be effective at increasing power generation capacity at low cost (Hochberg, 2018). In the renewable energy field, auctions are fast becoming the dominant policy mechanism for procuring new capacity (REN21, 2016; IRENA, 2017b).

Renewable energy auction design is an area of growing scholarly interest. Historically, the majority of publications on renewable energy auctions tried to answer whether auctions or feed-in tariffs are the more appropriate support policy for renewable energy technologies (Del Río & Mir-Artigues, 2014; Toke, 2015; Ngadiron & Radzi, 2016a; Aquila et al., 2017), and as such was primarily coming from the global North. While evidence of the global rise and drastic impacts of RE auctions (IRENA, 2017b; REN 21, 2017) seem to have accelerated scholarly interest in this question, we have seen a concurrent increase in publications looking specifically at RE auctions design elements, an area that until recently was the primary domain of so-called "grey literature" (GIZ & Ecofys, 2013; Azuela & Barroso, 2014; IRENA & CEM, 2015; Meyer, Tenenbaum & Hosier, 2015; Tietjen, Blanco & Pfefferle, 2015; IRENA, 2017b; Tongsopit et al., 2017).

Recent scholarly publications on RE auction design have mainly focused on developing a more theoretically-informed understanding of how specific auction design elements (e.g. auction volume, auction frequency, auction type and price rule, ceiling price, pre-qualification requirements, penalties) affect price and investment outcomes (Shrimali, Konda & Farooquee, 2016; del Río, 2017a; Gephart, Klessmann & Wigand, 2017; Kreiss, Ehrhart & Haufe, 2017; Dobrotkova, Surana & Audinet, 2018). These articles have therefore been principally drawing from economic theories in their analyses and conclusions. Where authors have made use of empirical evidence, this has mostly been based on high-level, large-N comparative case studies (e.g. del Río, 2017).

Country-specific RE auction case studies and recommendation documents have been making important contributions to auction design literature, including on Brazil (Rego & Parente, 2013; Hochberg, 2018) South Africa (Eberhard, Kolker & Leigland, 2014; Montmasson-Clair & Ryan, 2014; WWF international, 2014) and India (Shrimali, Konda & Farooquee, 2016). While these BRICS member states were considered trailblazing renewable energy market pioneers two or three years ago, the most exciting frontier markets have since moved on to places like Zambia, Senegal, Dubai and Mexico. There is thus a natural lag built into the literature as best practice seems to constantly move into deeper frontier territory. The implication is that our ability to explain auction outcomes in these new best practice cases is limited to what has gone before. We therefore need to draw on the RE auction design literature, but also allow these new cases to contribute important new information on what makes for an effective RE auction program.

The expansion of RE auction literature furthermore needs to not only consider design elements, but also auction *implementation* success factors. This includes considerations such as the institutional setting and capacity of the procurer; the political support for and coordination of the program; and the implementation process (consultation & responsiveness; transparency of evaluation etc.). These implementation factors have been identified in some of the empirical literature on RE auctions in the sub-Saharan region (Fergusson, Croft & Charafi, 2015; Meyer, Tenenbaum & Hosier, 2015; Eberhard & Kåberger, 2016; Kruger & Eberhard, 2016; Lucas, Del Rio & Sokona, 2017). Many of these elements have also been identified as contributing to the success of Public-Private Partnerships (PPPs) and general infrastructure investment and procurement processes in developing countries, yet has largely failed to show up in RE auction design literature (Estache & Iimi, 2012; Nel, 2013, 2014; Collier & Cust, 2015; Liu, Wang & Wilkinson, 2016; Hilmarsson, 2017). There is thus a need to identify and develop a more complete and sophisticated understanding of these auction implementation elements, based primarily on empirical evidence from RE auctions in the sub-Saharan region.

This report provides a global overview of renewable energy auction design and implementation trends, with the aim of informing the design of the analytical framework and the consequent analysis African case studies. It also offers an important introduction to the world of renewable energy auctions.

Renewable Energy Auctions: Analytical Framework

Different frameworks have been proposed to analyse the design, implementation and success of renewable energy auctions (Appendix A: Auction Design Analysis Frameworks). While there is no prioritised measure of auction success in the literature (Hochberg, 2018), most analyses are primarily interested in the resulting auction prices and project realisation rates[6] (IRENA & CEM, 2015; Tongsopit et al., 2017; Winkler, Magosch & Ragwitz, 2018). Other proposed measures of success include the diversity of bidders/winners, technologies and locations; the impact on the local value chain; and social acceptance/impact (GIZ, 2015; Lucas, Del Rio & Sokona, 2017; Mora et al., 2017; Hochberg, 2018). For the purposes of this report, we will focus primarily on price and, where available, project realisation outcomes. The in-depth country case studies (future reports) will in addition focus more explicitly on the additional measures of success identified in the literature (Appendix B: Integrated Analysis Framework).

Auction design

Renewable energy auctions have been analysed by a wide variety of researchers and organisations (Azuela, Barroso & Cunha, 2014; Del Rio & Linares, 2014; Kylili & Fokaides, 2015; GIZ, 2015; IRENA & CEM, 2015; Ngadiron & Radzi, 2016b; Shrimali, Konda & Farooquee, 2016; Eberhard & Kåberger, 2016; Cassetta et al., 2017; Lucas, Del Rio & Sokona, 2017; Mora et al., 2017; Tongsopit et al., 2017; del Río, 2017a; Kreiss, Ehrhart & Haufe, 2017; Winkler, Magosch & Ragwitz, 2018; Hochberg, 2018; Kruger & Eberhard, 2018). While there are differences between the analytical frameworks used, these differences mainly relate to how different elements are classified and/or the a priori prioritisation of certain elements (see Appendix A: Auction Design Analysis Frameworks). We have distilled these frameworks based on analyses of the literature and empirical evidence from the region, resulting in the following auction design analytical framework:

One of the first auction design decisions is on project **site selection:** whether the project site is to be chosen by the government (often through the procuring agency), or by the project developers. For renewable energy plants, the proposed project site is of fundamental importance given the geographic specificity of most renewable energy resources. Government-led project site selection is usually the result of concerns regarding grid stability and transmission costs in weak and/or small grids, as well as uncertain or risky land tenure arrangements. Governments might also want to pre-select a project site with the intention of lowering risks (and thereby the tariff) for the project, as well as shortening the project realisation period (Fergusson, Croft & Charafi, 2015; del Río, 2017a; Lucas, Del Rio & Sokona, 2017). Government site selection most often also overlaps with some site preparation by the procurer, including the provision of transmission infrastructure and key permits (incl. environmental impact assessment). While in theory a government-led site selection approach might lead to reduced risk profile for projects, research has shown that a poorly executed site selection and preparation strategy increases developer risks, resulting in poor project realisation (Kruger, Strizke & Trotter, n.d.).

Auction demand is mainly concerned with how much is being procured (volume), and how that is divided between technologies, bidders, regions, projects and time periods. Auction volume is a key

[6] Realization rate refers to the degree to which procured projects are built on time. A simple metric for determining the realization rate is: Volume procured/Volume commissioned.

determinant of the level of competition (and therefore pricing) in an auction, and should be clearly informed by an integrated planning framework. The auction volume can also be bid out in a technology neutral manner (where all technologies compete against each other – incl. fossil fuels; or where only renewable energy technologies compete against each other), or through using technology specific demand bands. The latter option is often preferred where there are concerns regarding supply security in the power system and therefore a need for a diversification of sources. Auction demand can also be set in terms of capacity (MW) or energy (MWh). Project size limits also ensure increased competition, but might still result in higher prices due to reduced economies of scale. The auction volume can also be divided across regions – perhaps based on grid capacity studies or other policy objectives. Different types of bidders (e.g. small, local vs. large, international) might also be provided with specific demand bands to achieve certain policy goals. Finally, auction demand can be spread over several rounds of auctions; evidence from various analyses clearly shows the positive impacts, especially in terms of price and localisation, resulting from regular, scheduled auction rounds (Eberhard & Naude, 2016a; International Renewable Energy Agency, 2017; Lucas, Del Rio & Sokona, 2017; Kruger & Eberhard, 2018).

Qualification and compliance requirements are meant to increase project realisation rates and ensure that other policy objectives are achieved. This can be structured as a one-stage or a two-stage (pre-qualification round) process: a two-stage process reduces the administrative burden and transaction costs for bidders and policy-makers, but might also result in longer procurement timelines. Reputation requirements are usually concerned with establishing the financial health and technical expertise of the bidding entity; setting these requirements too high might result in lower competition, while setting these too low might result in low project realisation rates. Qualification requirements are further interested in ensuring that the projects being procured conform to international technology standards; that the site is secured, permitted and that grid access is ensured (where this is not being provided by the government/procurer); that the project conforms to local and/or international environmental and social performance standards; and that the project meets any local economic development requirements (e.g. local content; shareholding thresholds; job creation etc.)

The **winner selection process** is primarily concerned with establishing the process of and criteria for selecting auction winners. It therefore concerns the bidding procedure: whether the auction is based on a sealed bid process (the most popular and simpler choice) (del Río, 2016), a dynamic process (e.g. a descending clock auction[7]), or a combination of the two. Auctioneers also need to decide whether (and at what level) to set ceiling prices for the auction (and whether to disclose these); whether winners will be selected based only on price, or other criteria as well (e.g. economic development commitments, location); and whether winners will be paid at the price that they bid, or at a uniform or clearing price[8].

Seller and buyer liabilities cover a range of issues that aim to reduce the risks for bidders and the auctioneer. These include the use of bid bonds (to ensure that bidders are committed to signing the contracts); a clear and realistic auction and contract schedule (incl. lead times between contract award

[7] In a descending clock auction, the auctioneer starts by setting a ceiling price, and asking bidders how much volume they are willing to sell at this price. The price is then lowered until the quantity offered is equal to the quantity to be procured (Maurer & Barroso, 2011).

[8] While in practice most renewable energy auctions are pay-as-bid, the uniform pricing option is theoretically better suited to the auction since bidders are incentivized to reveal their true costs (Hochberg, 2018).

and project commissioning); the remuneration profile of the contracts (e.g. whether prices are fixed, indexed to inflation or another metric, or varying with market prices); how projects are penalised for underperformance and delays (incl. the use of completion bonds); and how liabilities for transmission delays are to be distributed (incl. deemed energy payments).

Bankability and risk mitigation refers to elements that enhance the profile of the program from the perspective of potential lenders into the renewable energy projects. A key element is the provision of high quality, standardised, non-negotiable contracts that have been tested with lenders for bankability. These contracts include the Power Purchase Agreement (PPA), Implementation Agreement (IA), Direct Agreements (DA) and Connection Agreements (CA). Auctions in challenging jurisdictions or where off-takers face financial difficulties often also come with credit enhancement and loan/payment security measures, such as sovereign guarantees, letters of credit, and guarantee mechanisms offered by international financial institutions (e.g. MIGA and PRG cover from the World Bank). A key requirement in attracting international financing to auctions (especially where local capital markets are limited in size or unfamiliar with the technology) is to offer payment contracts in hard currency (e.g. US dollar). While hard currency payments open up programs to international lenders, it also exposes off-takers (and, in turn, governments) to substantial fiscal risks due to currency depreciation (Duve & Witte, 2016).

Renewable Energy Auction Implementation: Key elements

The ability of a well-designed auction to deliver successful outcomes depends on how well it is implemented. Renewable energy auction implementation is an area that has received less attention as compared with auction design, yet appears to be of at least equal importance in determining renewable energy auction outcomes (Eberhard & Naude, 2016a; del Río, 2017a; Lucas, Del Rio & Sokona, 2017; Tongsopit et al., 2017; Kruger & Eberhard, 2018).

Successful auction implementation is firstly a function of the overall **enabling environment**, manifest primarily through high-level political support not only for the program, but also for a capable, mandated, authorised auctioneer that is able to coordinate across government departments. An enabling environment is furthermore created through the establishment of clear, supportive policy and planning framework. It is moreover important that the procurement programme is well-resourced: designing and implementing a renewable energy auction is a complex and resource-intensive process requiring extensive financial, legal and technical expertise. The costs involved in setting up and running the program is however offset by the low prices achieved. A further requirement concerns the need for grid planning coordination, with the grid operator's continuous inputs being essential to ensuring that the overall system costs of the auction are minimal.

The **implementation process** primarily concerns a commitment to fairness, transparency and trust. This is achieved through the establishment of the aforementioned respected auctioneer; through continuous open dialogue with bidders; and through ensuring that the bidding process (incl. evaluation) is done in a secure and transparent manner.

Renewable Energy Auctions in sub-Saharan Africa

In sub-Saharan Africa, at least 18 countries are currently in the process of developing and implementing a renewable energy auction programme; more than half of these programmes were launched in 2017 alone.

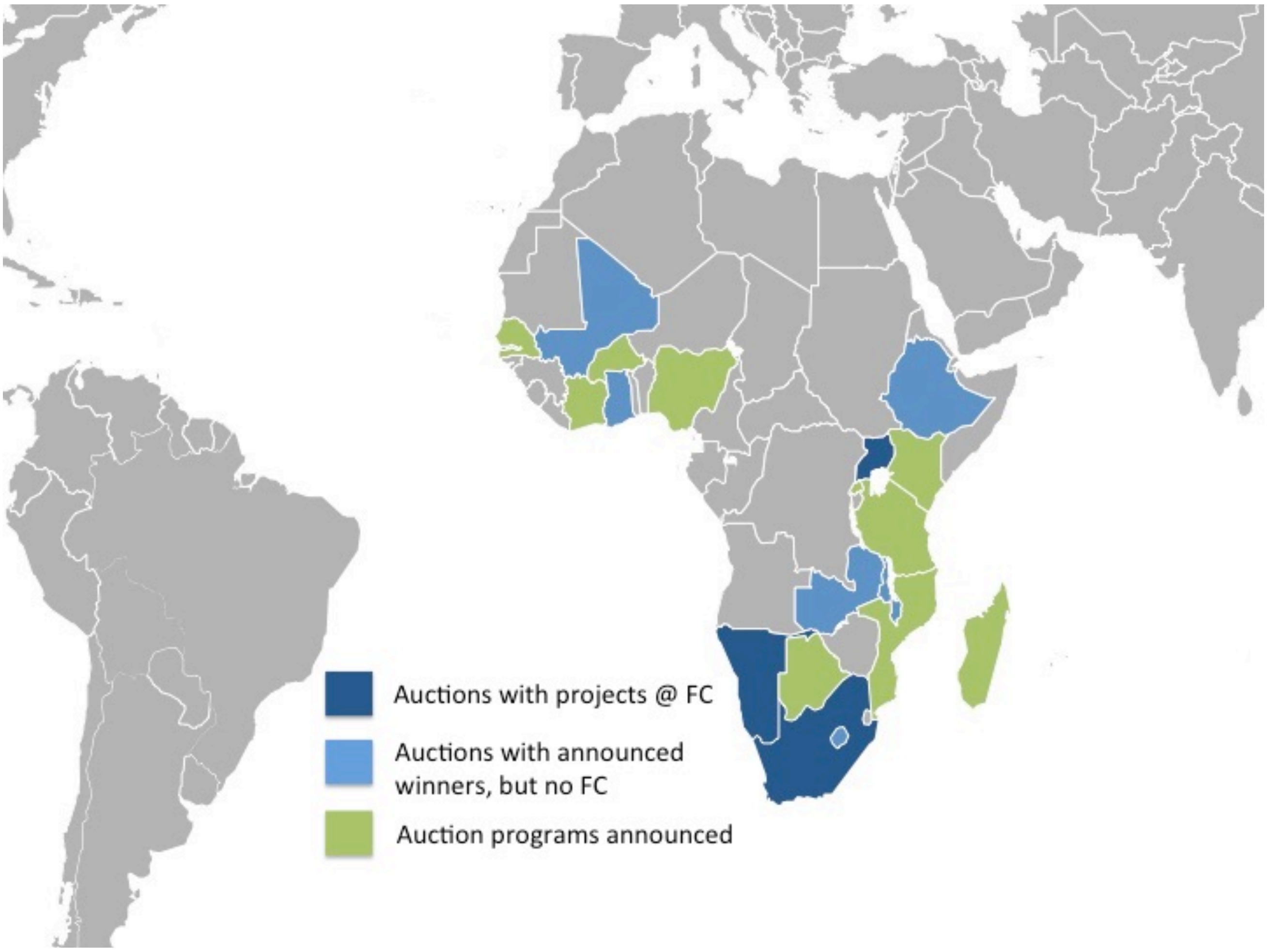

Figure 6: Countries in sub-Saharan Africa using renewable energy auctions. Source: Authors' data[9].

Many African countries have struggled to successfully address the risks and costs involved in renewable energy auctions, resulting in potentially poor outcomes. Additionally, many countries are desperate for affordable power generation investment, yet cannot afford the "school fees" involved in a poorly designed and implemented auction programme. There is thus an important need to learn from and distil current experiences with renewable energy auction programmes in and for the African context.

[9] Note: FC = Financial Close.

Table 1: Main features and outcomes of renewable energy auctions in Sub-Saharan Africa

	South Africa*	Uganda*	Zambia*	Ghana	Namibia*	Malawi	Ethiopia	Senegal
Year	2011 - 2018	2014	2016	2016	2017	2017	2017	2018
Auction Demand	6,300 MW (4 rounds) Multiple RE	4 x 5 MW Solar PV	2 x 50MW Solar PV	1 x 20MW Solar PV	1 x 37 MW Solar PV	Max 80 MW Solar PV (4x sites)	1 x 100 MW Solar PV	2 x 30 MW Solar PV
Site Selection	Developer	Developer (3km - grid)	Selected by govt.	Developer (input from offtaker)	Selected by govt./ utility	Substations identified by govt.	Selected by govt.	Selected by govt.
Local Content	40% min	None	None	20%	None (but 30% local share-holding)	5% develop ment & construction 20% O&M	15%	None
Evaluation	70:30 Price: Economic Develop-ment	70:30 Price: Technical	Price	Not clear	70: 30 Price: Technical	Price	70:30 Price: Technical	Price
PPA	20 Years	20 Years	25 Years	20 Years	20 Years	25 Years	20 Years	20 Years
Guarantees	Sovereign	Sovereign & Liquidity	Sovereign & Liquidity	Sovereign & Liquidity	None	Sovereign & Liquidity	Sovereign	Sovereign & Liquidity
Winning Price (USDc/ kWh)	4,7*	16,37	6,02	11,47	6,02	7,35 – 10,35 (TBC)	Below US$c6 (TBC)	4,7
Currency	ZAR	US$/EUR	US$	US$	NA$	US$	US$	US$
Financial Close	Yes	Yes	Yes/No	No	Yes	No	No	No

Table 1 provides an overview of some of the main features and outcomes in renewable energy auctions in sub-Saharan Africa. A few important points are worth highlighting:

- The majority of auctions focus on a single technology: solar PV. According to Lucas, Del Rio & Sokona, (2017), this is mainly due to the fact that the technology is modular (meaning that relatively small plants are still feasible), relatively simple and quick to build, and – recently – relatively cheap. These features make solar PV an ideal option for many African jurisdictions, especially when considering the excellent solar resources in most African countries. However, solar PV also faces challenges when it comes to the integration of this variable resource in small, weak grids – as is the case in many African countries (Lucas, Del Rio & Sokona, 2017; Trotter, McManus & Maconachie, 2017).

- Apart from South Africa, auction demand is relatively small, usually concentrated in one or two projects that are bid out. This is in contrast with international trends, where larger volumes, often spread across multiple projects, is the norm (del Río, 2017a). Considering the small sizes of most African power systems, this is not a surprising outcome.

- Linked to the point above is the issue of site selection: with the exception of South Africa, project sites are in the main selected and prepared by the government or its off-taker. Given the abovementioned small and weak grids, as well as the uncertainties around land tenure and permitting in many African jurisdictions, this is a practical design choice meant to lower risks (and therefore costs) as well as speed up implementation (although whether this is the outcome in practice needs to be further investigated) (Lucas, Del Rio & Sokona, 2017).

- Apart from South Africa, local content requirements are minimal. This might reflect the prioritisation of cost-effective pricing as the main objective of most auction programs in the region, as well as the realisation that local supply chains are as yet unable to provide many of the services and products needed to support stringent local content requirements.

- Similarly, price is the main evaluation criterion used in the winner selection process for most auctions (again, with the exception of South Africa and also Uganda) – again reflecting the prioritisation of a low tariff.

- A key feature of most African auctions – which is somewhat of an exception when looking at global practice – is the presence of credit enhancement and de-risking mechanisms such as loan and payment guarantees, escrow accounts and put-call options. These mechanisms are often provided by or in partnership with multilateral development organisations and are crucial in ensuring the bankability of these auctions – oftentimes due to the poor financial health of off-takers and the low credit ratings of sovereigns. This is also one of the design features of auctions that is most valued by the private sector in the region (Lucas, Del Rio & Sokona, 2017). An important exception to this rule is Namibia, which has offered no sovereign guarantee.

- Namibia and South Africa are also the two countries that are remunerating their projects in local currency. All other auctions offer remuneration in hard currency – usually US dollar. This is a further requirement for improving the bankability of the long-term contracts in countries that often face rapid currency depreciation, and which do not have local capital markets deep and/or experienced enough to finance these projects (Eberhard & Naude, 2016b). Host countries of these projects are in turn exposed to significant foreign currency risk, which has been identified by some as one of the key long-term risks facing renewable energy projects in developing countries (Duve & Witte, 2016).

- Prices across the region vary considerably – from more than USDc 16/kWh in Uganda to less than USDc 5/kWh in South Africa and Senegal. Some of these outcomes can be explained by the sizes of the projects, the timing of the auction (and, critically, the commissioning date of the projects), the amount of de-risking in the program, and the presence of concessional finance (Meyer, Tenenbaum & Hosier, 2015; Kruger & Eberhard, 2016; Lucas, Del Rio & Sokona, 2017; Dobrotkova, Surana & Audinet, 2018). Still, this is a key measure of an auction's effectiveness and further case-specific analysis is needed to improve our understanding of drivers of these prices and how they interact with auction design and implementation elements.

- A further measure of auction success is the realisation rate of projects: whether projects get built, and do so on time. Due to the relatively recent nature of many of the auctions in the region, there is unfortunately not that much data available as yet on this outcome since many of the projects procured have not yet reached their expected commissioning dates. A useful proxy is however the date that a project reaches financial close, since this usually marks the point at which construction starts and where most risks have been sufficiently addressed from the financiers' perspective. While it is again quite early for some of the projects in this regard, it is noteworthy that only South Africa, Uganda, (one project in) Zambia and Namibia have reached financial close. While there have been delays in some jurisdictions, it needs to be pointed out that on average IPPs take around seven years to reach financial close in sub-Saharan Africa. The timelines represented by these auctioned renewable energy projects are much shorter – even when delays occur.

Renewable Energy Auctions: A Global Tour

Auctions are now officially the preferred procurement method for contracting renewable energy capacity globally, and set to grow in prominence (Figure 7). Despite the costs and risks involved, more than 67 countries worldwide have embarked on, or are busy developing, renewable energy auctions – up from 5 countries in 2005. At the same time, we are also seeing the rapid development of sub-national auction programs at state/provincial and municipal/local government level (REN 21, 2017). The volume of auctioned renewable energy capacity, completed and announced in 2017, reached a record 50,6 GW globally – up from 33,6 GW in 2016. This brings the cumulative capacity of renewable energy auctioned since 2003 to 137,3 GW[10]. The majority of renewables-based investment (incl. through auctions) has been taking place in the developing world, marking a significant shift in the global renewable energy market (McCrone et al., 2018).

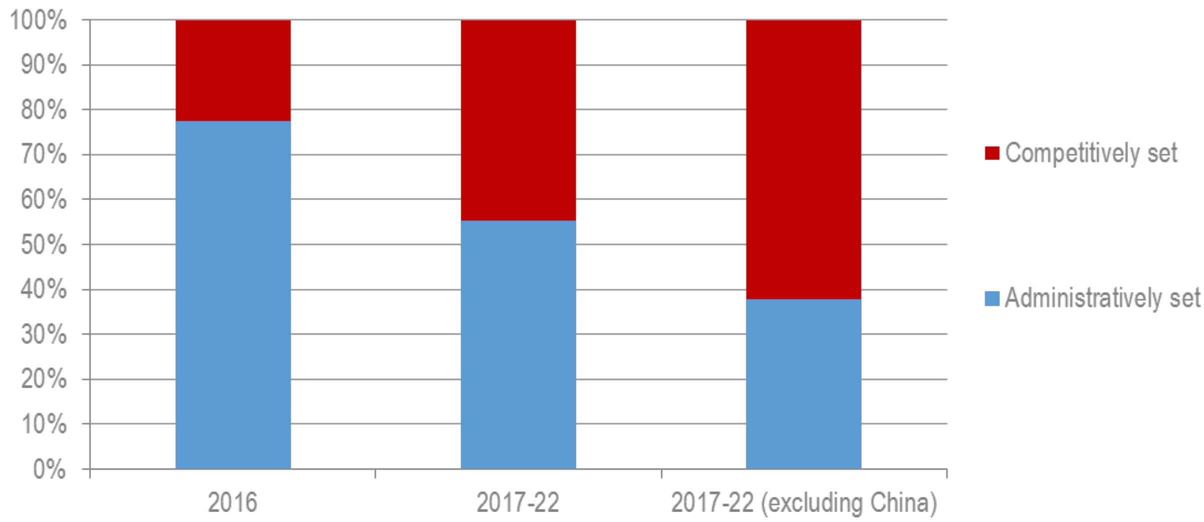

Figure 7: Renewable energy capacity growth by type of policy defining remuneration levels. Source: IEA, 2018.

Auctions have introduced a significant shift in global electricity markets. The rising prominence of auctions is primarily due to the introduction of competition in the procurement process, causing significant downward pressure on renewable energy project prices (Solar PV - Figure 8; Onshore Wind - Figure 9). The lowest renewable energy prices globally are currently being announced in auctions in developing countries (Dobrotkova, Surana & Audinet, 2018). The result is that the least-cost new build electricity generation capacity options in many developing countries are now renewable energy based (CSIR, 2016; Dezem, 2016; McCrone et al., 2017).

[10] This excludes 60.8 GW of renewable electricity auctioned in Chile between 2006 and 2017, because it was not allocated on a GW basis.

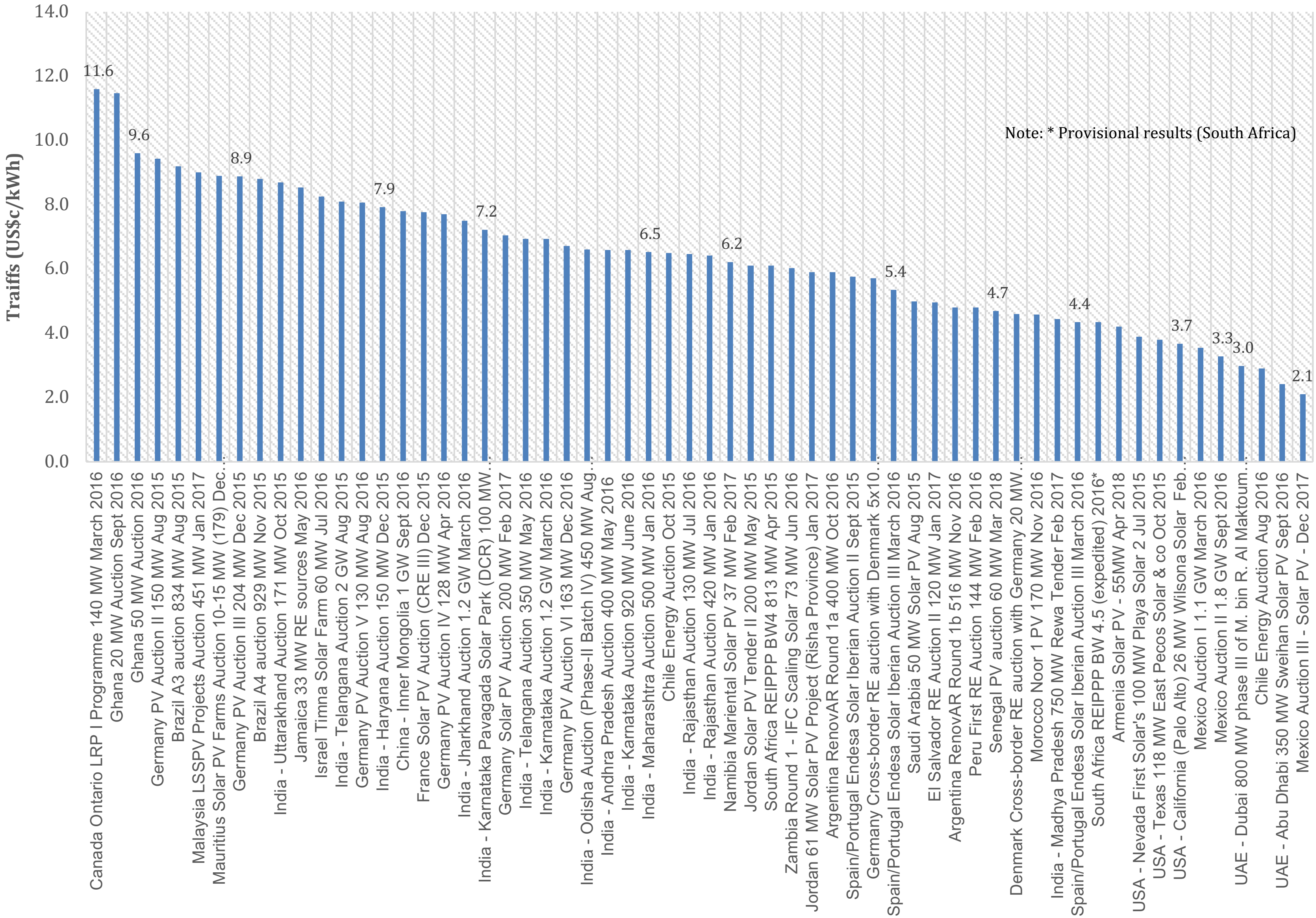

Figure 8: Announced minimum or average auction prices for utility-scale (> 10MW) solar PV projects, 2015 – 2018. Source: Authors' calculations

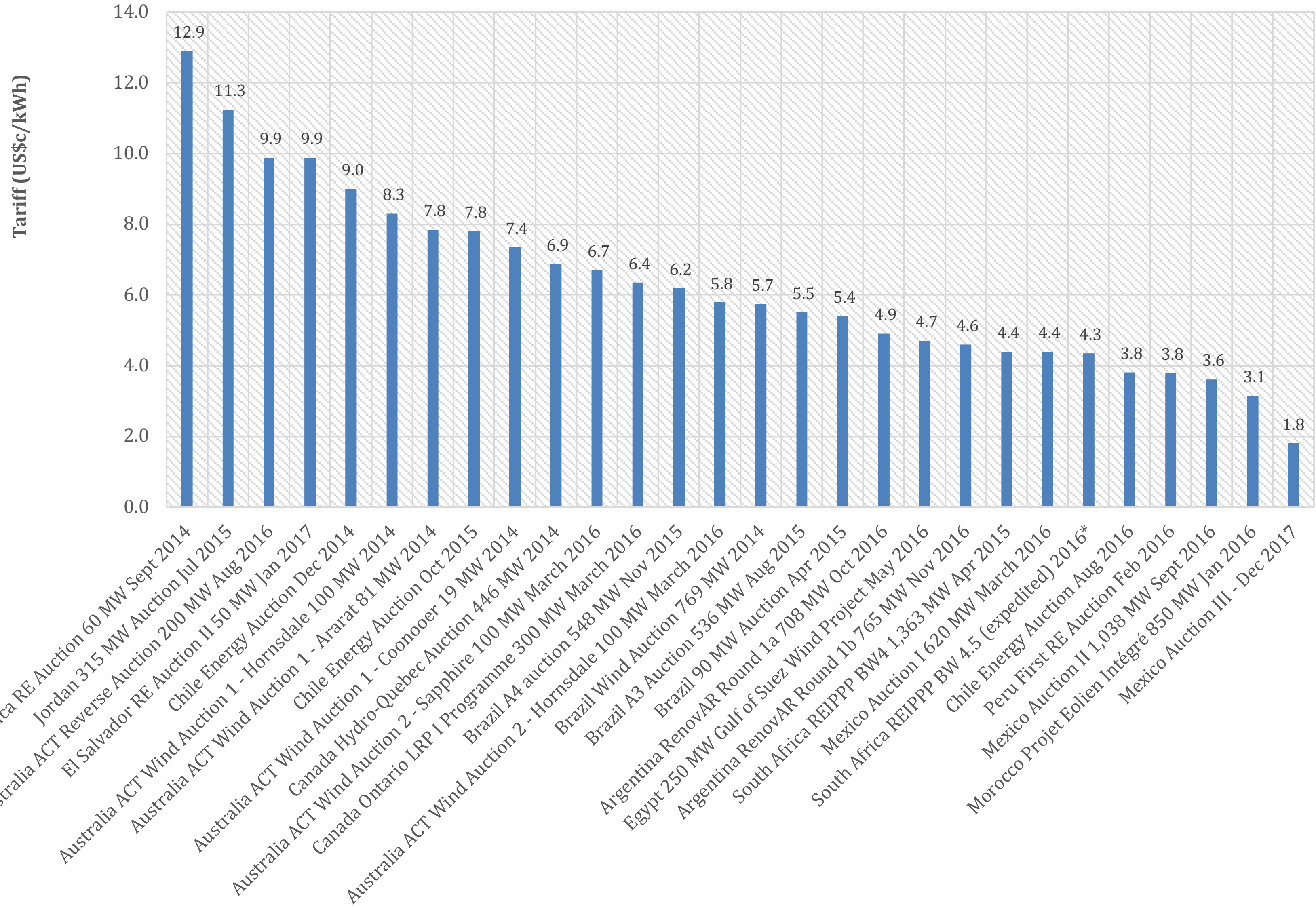

Figure 9: Announced minimum or average auction prices for utility-scale (> 10 MW) onshore wind, 2015 – 2018. Source: Authors' calculations

Regions, countries and key design elements analysed

The main purpose of this global overview is to provide a broader comparative context for the more in-depth analyses of the selected African cases to follow. As such, the global analysis provides a high-level overview of each case study country, focusing on specific auction design, implementation and outcome elements. Our analysis concentrates on selected prominent and noteworthy countries. Cases have been selected based on their prominence in the literature, noteworthy auction results and design choices, as well as accessibility of data.

Our country case studies focus on a handful of prominent renewable energy auction design, implementation and outcome elements. We first seek to establish a country's familiarity with auctions as a procurement mechanism in the (renewable) energy sector. As such, we are interested in establishing the date of the country's first auction, as well as the number of auction rounds that have taken place already. We also analyse the overall volume of renewable energy auctioned; the types of renewable energy technologies supported; the length and currency of the PPA; as well as specific auction design choices such as the pricing regime, bidding system and qualification requirements. These metrics provide a cursory overview of the auction-based market size and development, as well as some of the key project finance inputs that influence outcomes such as price. For auction implementation, we specifically focus on identifying the key institutions that play a role in the auction programme, including policy-makers, the sector regulator, procurer and off-taker. Auction outcomes are primarily measured in terms of MW procured, how this is divided between technologies, and the resulting prices.

Latin America

The Latin American region is home to considerable experience with and innovation in renewable energy auction design and implementation, and as such it features prominently in our analysis. Since the 1990's, the Latin American region has experienced widespread liberalisation of the energy sector to allow private sector participation in the generation and distribution of electricity. The adoption of utility-scale renewable energy technologies has largely been driven by government-led renewable energy auction programmes aimed at procuring new generation capacity through private sector investments. Argentina, Belize, Brazil, Chile, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Panama, Peru and Uruguay are all currently using auctions to procure renewable energy. The result is that Latin American countries have high shares of electricity generation from renewable energy sources, with rapid growth in installed capacity from especially onshore wind and solar PV technologies (Bradshaw, 2016; IRENA, 2016; REN21, 2017; Hochberg, 2018).

Despite this long history with electricity auctions, there is considerable variation across countries in terms of their auction designs and outcomes. In the region, Brazil has the longest history of using electricity auctions. The frequency of auctions in Brazil is one of the highest across the developing world, with frequent and specific auctions held to meet demand growth and ensure security of supply. Most other countries in the region have only recently adopted auction schemes. Brazil and Chile have allocated a large portion of auction capacity towards small- and large-scale hydropower for both existing and new generators. In addition, the region allocates and procures relatively large volumes of biomass energy in comparison with other regions. The region is also currently setting the pace in terms of RE auction pricing: auctions in 2017 in Mexico resulted in global price records for solar PV (USDc 2,0) and wind energy (USDc 1,8/kWh) (Weaver, 2017). We analyse auction programmes in Argentina, Brazil, Chile, Mexico and Peru.

Argentina

Argentina's economy is in large part built on cheap, fossil fuel-based electricity[11]. It is one of Latin America's biggest economies, with a GDP of USD 545 billion and a population of 43,6 million people (USD 12 507 GDP per capita) (Focus Economics, 2018a). Only 2% of Argentina's 32 GW of installed electricity generating capacity is renewable energy based[12]. Historically, Argentina has also been charging its electricity consumers some of the lowest tariffs in the world, covering only a small portion of the overall cost (Hochberg, 2016a). This has however changed since 2017, with tariffs increasing substantially to such a degree that tariffs for large industrial consumers are now among the most expensive in the region.

Argentina's renewable energy programme, RenovAr, is aimed at increasing the country's share of renewables to 20% by 2025 through renewable energy auctions supported by a combination of risk mitigation and credit enhancement measures. The Argentinian government passed a legal framework in 2015 that created FODER (the government Renewable Energy Fund), establishing fiscal incentives[13] and setting competitive and transparent market rules to attract international investors[14] (World Bank, 2018). The first round of RenovAr was held in October 2016 – procuring more than 1 GW of renewable energy capacity. A second round (Round 1.5) was held in October 2016, awarding an additional 1,282 MW. In 2017 a third round was held (Round 2), with more than 1,400 MW being awarded.

Table 2: Overview of the RenovAr renewable energy auction programme in Argentina

Design	Year of introduction	2016
	Frequency of auctions / rounds	3 rounds since 2016. Round 1, 1.5. and 2. Round 1.5 for unsuccessful round 1 bidders, with stronger conditions and stipulations
	Volume requested per auction	Round 1: 1 GW Round 1.5: 600 MW Round 2: 1,200 MW
	Technology requested (Supply specification)	Round 1: 600 MW wind 300 MW solar 80 MW biomass and biogas

11 Large-scale hydro contributes about 30% of generation as well.

12 Excluding large-scale hydro (around 10 GW)

13 Each bidder could ask for different types of tax support, and requests ended up being quite different. For Round 1, the range in support was from USD 800 000/MW to USD 0/MW. The price comparison of the award did not take into account the requested tax support.

14 The law also established obligations of renewable energy purchases for large users.

		20 MW small hydro Round 2: 550 MW wind 450 MW solar PV 100 MW biomass 50 MW hydroelectric 35 MW biogas 15 MW landfill gas
	PPA length	20 years
	Currency	USD (indexed)
Implementation	Policy and regulation guidelines	Ministry of Energy and Mining
	Regulator	Ente Nacional Regulador de la Electricidad, (ENRE)
	Procurer	CAMMESSA (wholesale electricity market administrator)
	Off taker	CAMMESSA (wholesale electricity market administrator)
Outcomes	MW procured	3,832 MW
	Technology procured	Wind, solar, biomass, biogas and small hydro
	Prices (2017, USDc /kWh)	<u>Round 2 (2017):</u> Solar PV and wind: 4.0 Biomass: 10.0 Biogas: 15.0 Small Hydro: 9.0 Landfill biogas: 13.0

Design

RenovAr was designed as a sealed bid, pay-as-bid, technology-specific auction, with demand bands dedicated to onshore wind, solar PV, biomass, biogas, small hydro and landfill gas. Project sizes were limited to between 1MW-100 MW for solar PV and wind; 65 MW for biomass; 15 MW for biogas; and 20 MW for hydro. Project location was also restricted to specific regions in the country by technology, mainly due to transmission constraints; for example, in Round 2, solar PV projects could only be located in the North-Western part of the country, while onshore wind projects were again restricted to the Southern half of the country.

Qualification was based on compliance with stringent technical (e.g. experience with similar project of at least a third the size of the proposed project) and financial (e.g. min. USD 500,000 net worth per MW offered) requirements, as well as bidders having secured land rights and environmental permits for their proposed projects. Each bidder had to provide a bid bond of USD 50,000 per MW offered and must prove shareholders equity of USD 250,000 per MW offered. Once awarded, a performance bond of USD 250,000 per MW had to be posted. 20 year PPAs were offered, denominated in US dollar and indexed to a pre-determined index (Table 21). Prices were also adjusted by an incentive factor, starting at 1.25 in

Year 1 and reducing to 0.8 from Year 15 onwards (Table 22)[15]. Projects were also offered a decrease in VAT, exemption from national income tax, returns distribution tax, import duties, provincial and municipal taxes. A tax credit equal to 20%-30% of local content was also provided (as well as priority access to FODER finance), with the provision that projects include at least 60% local content (or can prove that it could not meet this threshold) (Navia, Sewell & Avila, 2016; Jimeno et al., 2017; PwC, 2017).

Winner selection was based on a weighted basket of elements, including the project price, location (incl. interconnection node), the time to reach commercial operation, compliance with bid document requirements and compliance with requirements to obtain a certificate of inclusion[16]. Undisclosed ceiling prices were set for round 1, resulting in no contracted capacity for biomass, biogas and small hydro in that round. Projects are in general expected to reach commercial operation within 2 years of the PPA being signed (Navia, Sewell & Avila, 2016; IRENA, 2017b).

A main innovation of the Argentinian programme has been the guarantee and loan structure developed under FODER – a national trust fund for renewable energy. Due to the Argentinian government's 2001 default on sovereign bonds, no government agency has an investment grade rating, resulting in limited appetite from financiers to invest in projects. FODER provides payment guarantees (through an escrow account for 12 months' worth of payments backstopped by the ministry of finance), termination guarantees (put-call option, backstopped by the World Bank) as well as long-term loans, interest rate subsidies and equity contributions to projects (Jimeno et al., 2017; King & Spalding, 2017; REN21, 2017).

Implementation

The auction is implemented by a combination of government entities that mainly support the system operator in its auctioneer duties. CAMMESA (Compañía Administradora del Mercado Mayorista Eléctrico) is the administrator of the wholesale market, and operates and dispatches electricity as well as administers commercial transactions. Under RenovAr, CAMMESA administers the long-term agreements, acting as both procuring agency as well as off-taker of the power on behalf of distribution utilities as well as large customers[17]. The ministry of energy (ME&M) sets national energy policy and regulatory objectives. The independent regulator (ENRE) ensures compliance across the entire electricity sector. FODER is administered by a trustee, the state bank for Investments and Foreign Trade (BICE) (IRENA, 2017b; Jimeno et al., 2017).

[15] The incentive factor improves the financial profile of the project (through increasing cash flow in the initial years), as well as incentivizes projects to come online as soon as possible.

[16] This certificate is obtained after the bidder registers as an agent to participate in the wholesale market, submits fiscal and tax information as well as project details. The application also includes a bond of 10% of all tax benefits requested.

[17] Large customers can opt out of the CAMMESA managed purchases and purchase directly from RE generators, or self-generate. If they choose to fulfill their purchase obligations through the CAMMESA mechanism, they pay a fee to CAMMESA.

Outcomes

Each of the Argentinian auction rounds has been oversubscribed, resulting in more capacity being awarded than initially requested and significant price reductions. 123 bids were submitted with an accumulative total of 6,346 MW for RenovAr round 1. Wind was oversubscribed by nearly 6 times, while solar PV was oversubscribed by 9 times. Despite 1 GW (1,000 MW) being requested, 1,108 MW was awarded. Owing to the overwhelming interested in round 1, the Argentinian government subsequently initiated the impromptu round 1.5 for unsuccessful round 1 bidders. This additional tender requested a further 600 MW, with the total awarded volume at 1,281.5 MW, at a lower average price for wind compared to round 1. RenovAr round 2 requested 1,200 MW of renewable energy capacity – although this round was pushed out slightly since developers took longer than anticipated to secure financing for Round 1 and 1.5 projects. This round (2) received 228 offers totalling 9,403 MW of capacity. A total of 66 projects were selected, for 1,408 MW of capacity. Average prices for wind and solar PV in this round was at USDc 4/kWh (Morais, 2017).

Despite the apparent success, key concerns remain in the Argentinian market: more than 5,000 km of new transmission lines will need to be built for new projects, which represents an important deemed energy payment risk for the off-taker as projects are expected to come online within 2 years of being awarded. Part of the government's response has been the promulgation of a transmission line auction in 2017[18], as well as limiting new projects to specific geographic regions. Inflation also remains in the double digits (40% in 2016; 20% in 2017), posing financial challenges to projects since their tariffs are not indexed to inflation, but to a different index. Some projects have also experienced significant delays in securing financing, with potential implications in terms of the overall realisation rates. Nevertheless, the Argentinian case offers important lessons on how to kick-start a national renewable energy programme in a fiscally challenging environment (Djordjevic, 2017; Gray & Agra, 2017; Rosenfeld, 2017).

Brazil

Brazil is home to the region's largest population (200 million people) and largest (unbundled) electricity system, with considerable experience in auction design and implementation. The country experienced considerable economic growth from 2003, but a deep recession starting in 2010 has cut annual GDP growth rates to 2.1% (2011 – 2014) (World Bank, n.d.). The Brazilian power system is the region's largest, with more than 160 GW installed generating capacity (mostly large hydro). Before 1995, Brazil's power sector was predominantly government controlled, with vertically integrated companies. Sector reforms were introduced to increase security of supply and help the government clear its debts (Hochberg, 2018). As a result, the Brazilian power sector moved away from a central state controlled model to a coexistence model of both government and private sector, with substantial emphasis on privatisation. Auction schemes were introduced in 2004 in reaction to limited new investment in the sector and concerns about supply security. Renewables specific auction schemes were introduced in 2007 (small hydro, biomass), 2009 (onshore wind) and 2014 (solar PV) (Förster & Amazo, 2016).

[18] The auctions are set to be held in the last quarter of 2018, through a PPP mechanism

Table 3: Overview of the renewable energy auction programme in Brazil

Design		**Regular New Energy Auction**	**Reserve Auction**
	Year of introduction	Biomass and small hydro: 2007 Wind: 2009	Wind (and other RE): 2008/9 Solar PV: 2014
	Frequency of auctions/ rounds	Twice per year. At least 29 RE-eligible rounds since 2007.	No fixed schedule. Yearly since 2008. At least 9 rounds to date.
	Volume requested per auction	Varies per auction (based on 5-year demand estimates from distribution companies)	Varies per auction (based on reserve margin estimates from MME/EPE).
	Technology requested (Supply specification)	Wind, solar PV, small and large hydro and biomass	Wind, biomass, hydro & solar PV
	PPA length	Hydro: 30 years Small hydro, Wind, Solar PV and biomass: 20 years	20 years
	Currency	Brazilian Real (BRL) and indexed	Brazilian Real (BRL) and indexed
Implementation	Policy and regulation guidelines	Ministry of Mines and Energy (MME)	Ministry of Mines and Energy (MME)
	Regulatory authority	Agência Nacional de Energia Elétrica, (ANEEL)	Agência Nacional de Energia Elétrica, (ANEEL)
	Procurer	CCEE (market operator), by delegation from ANEEL	CCEE (market operator), by delegation from ANEEL
	Off taker	Distribution companies	CCEE
Outcomes	MW procured	60 GW (incl. large hydro)	Not available
	Technology procured / installed	Wind, solar, biomass, small and large-scale hydro	Wind, biomass, hydro & solar PV
	Prices (USDc/kWh)	<u>April 2018</u> Solar PV: 3.5 Onshore Wind: 2.0 Hydro, Biomass: 5.6	<u>2015</u> Solar PV: 8.0 Wind: 5.0

Design

Brazil's has two main types of energy auctions - New Energy Auctions and Power Reserve Auctions – with important differences and similarities in terms of their design. New Energy Auctions aim at procuring new electricity generation capacity to meet the market needs of distributors. The distribution companies therefore set auction volume and projects are exposed to spot market prices[19]. Power Reserve Auctions are aimed at increasing security of supply to the National Interconnected System by procuring reserve margin capacity from new and existing suppliers as needed. Reserve auction volume is determined

[19] There are two kinds of contracts used: Availability contract: The difference between the contracted amount and the amount produced or consumed is settled on the spot market by the consumer. Quantity contract: The difference between the contracted amount and the amount produced or consumed is settled on the spot market by the investor.

by the government, and projects are less exposed to spot market prices[20] (Bayer, 2017; IRENA, 2017b). Both types of auctions are run as hybrid auctions, with bidders first taking part in an online descending clock auction, followed by a pay-as-bid sealed bid round[21]. Qualification requirements for both types of auctions are also stringent, especially since developers select their own sites and therefore need to submit a range of site-specific documents (incl. environmental authorisation[22], grid access authorisation and resource studies) (IRENA, 2017b).

New Energy Auctions are further subdivided into A-numerical type categories (i.e. A1, A3, A4, A5, A6). The numerical value of the auction type determines the number of years within which a project is expected to come online. For example, A3 auctions expect projects to be providing electricity within 3 years from the date the project was awarded. A3 auctions are typically used for onshore wind, solar PV and small hydro projects, while A5 auctions are aimed at large scale hydro and conventional power sources (Förster & Amazo, 2016). A1 auctions are used for existing capacity, as supply is expected to begin one year following the tender. In 2017, Brazil introduced A4 (exclusively for renewables) and A6 (renewables and natural gas) new energy auctions to provide further flexibility[23] (Hochberg, 2018).

There are no local content requirements in the prequalification or bid evaluation criteria of auctions. However, to obtain favourable energy financing packages from the Brazilian National Development Bank (BNDES), an interested party will have to meet the substantial local content requirements set out by the development bank[24] (Eberhard et al., 2016b).

Implementation

Brazilian electricity auctions require considerable coordination of and support from various institutions, and are either implemented by the sector regulator or the market operator – depending on the type of auction. The Ministry of Mines and Energy is the government entity that sets policy and regulatory guidelines, and provides the technical requirements needed for an auction. The auction process for New Energy Auctions is led by the Brazilian Electricity Regulatory Agency, Agência Nacional de Energia Elétrica (ANEEL), that coordinates all administrative process of the auctions: determining the rules of the auction, contracts, financial and technical obligations. A committee made up of the Ministry of Energy and Mines (MME), the Energy Research Company (EPE) and the Chamber of Commerce for Electric Energy (CCEE) – Brazil's power market operator - assists ANEEL. All winning bidders for New Energy Auctions sign contracts with all distribution companies – effectively reducing risks for both generators and off-takers. For Power Reserve Auctions, the auctioneer and off-taker is CCEE – which recovers an energy reserve charge from all customers (Hochberg, 2018; Viana & Ramos, 2018).

[20] The reserve energy is settled in the spot market. All the consumers pay a reserve energy charge. The reserve energy charge plus the revenue from the energy settled in the spot market should cover investors' income, the operation cost of CCEE and a warranty fund.

[21] MMEE changed the auction methodology in 2017.

[22] The environmental licensing process takes particularly long, and is a significant barrier to participation in the auctions.

[23] While A3 and A5 auctions continue to exist in legislation, in reality the A4 and A6 auctions have replaced them.

[24] The local content requirements by BNDES are usually 80%+. With BNDES providing the cheapest debt in the market, most projects make use of this funding. As a result, Brazil now has a growing wind energy industry, with blades, towers and generators all being produced nationally.

Outcomes
Auctions have played a key role in increasing Brazil's renewable energy capacity and ensuring security of supply. The total renewable energy capacity installed in Brazil by 2016 was 123 GW. 98 GW of this total is made up by hydropower (large, medium and small); installed bioenergy capacity is 14 GW; onshore wind is 10,7 GW and solar PV is 23 MW (IRENA, 2017c). Around 60 GW of this installed RE capacity has been achieved through auctions (incl. for large hydro).

By April 2018, 29 New Energy Auctions have been concluded, with the most recent auction (A-4) held in April 2018. The 29th New Energy Auction received more than 20 GW of bids, and allocated approximately 1 GW of renewable energy capacity: 806,6 MW of solar PV, 114 MW of wind, 61,8 MW of thermal capacity from biomass and 41.6 MW of small scale hydroelectric power. The auction resulted in an average price of USDc 3,5/kWh[25] (ANEEL, 2018; Bellini & Sanchez, 2018). This is a noteworthy financial outcome given the fluctuating prices of Brazilian renewable energy projects (IRENA, 2017b).

Reserve Power Auctions have not been necessary in recent years, mainly due to economic stagnation and slow electricity demand growth – reducing the need for reserve capacity. In 2017, Brazil therefore held a de-contracting auction to cancel projects that had been awarded in the 2014 and 2015 reserve auctions (mainly solar PV and wind). These projects had been significantly delayed – not only due to the economic downturn, but also due to administrative and permitting issues. Bidders were therefore able to avoid non-completion fines and the forfeiture of their bid bonds by taking part in this first de-contracting auction (Hochberg, 2018).

Chile
Chile is a regional and global leader when it comes to the use of innovative market mechanisms in the electricity system. It is considered a high-income country by the World Bank, and is ranked 33rd by the World Economic Forum in the World Competitiveness Index 2017-2018, the highest rank for a South American country. The country has a population of 18.2 million people, with a GDP of USD 247 billion (GDP per capita of USD 13,576) and an investment grade sovereign credit rating (Schwab, 2017). Chile has 20 GW of installed generation capacity, about 42% of which comes from non-fossil fuel sources (incl. hydro). 1.3 GW of this capacity comes from onshore wind, with 1.6 GW in installed solar PV capacity. Chile was the first country globally to liberalise its electricity sector (1982), and introduced centralised auctions in 2006 to meet the demand of distribution companies in response to concerns around supply security (Global Data, 2017; IRENA, 2017b; Reus, Munoz & Moreno, 2018).

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[25] In Brazil's 28th New Energy Auction (A-4) held in December 2017, 574 MW of solar PV was allocated at an average price of USDc 4,4/kWh.

Table 4: Overview of the renewable energy auction programme in Chile

Design	Year of introduction	2006
	Frequency of auctions / rounds	10 rounds to date
	Volume requested per auction	2015: 1,200 GWh/year 2016: 12,430 GWh/year 2017: 2,200 GWh/year Demand is divided into time-blocks or quarterly (firm supply) blocks. Volume is based on demand estimations from distribution companies.
	Technology requested (Supply specification)	Technology neutral (includes fossil fuels)
	PPA length	20 years (before 2014: 15 years)
	Currency	USD and indexed
Implementation	Policy and regulation guidelines	Ministerio de Energia
	Regulatory authority	National Energy Commission (NCE)
	Procurer	National Energy Commission (NCE)
	Off taker	Distribution companies
Outcomes	MW procured	Geothermal: 48 MW Wind: 1,424 MW Solar thermal: 39 MW Bioenergy: 481 MW PV: 1,840 MW Small hydro: 615 MW Total: 4,447 MW
	Technology procured / installed	Geothermal, wind, solar, biomass
	Prices (2017, USDc/kWh)	Average: 3,25 Lowest bid: 2,15 (Solar PV)

Design

Chile organises technology neutral auctions (including conventional sources) and bidders compete either for hourly supply blocks of energy or quarterly (3 month) blocks. In the 2017 auction, for example, 2,200 GWh/year was bid out: 1,700 GWh in hourly blocks – three blocks (11pm – 8am; 8am – 6 pm; 6m – 11 pm) covering a 24 hour period; and 500 GWh in seasonal blocks (3 months per block). Failure to deliver energy in the contracted supply blocks (whether hourly or quarterly) requires projects to settle the difference at spot market prices. Renewable energy technologies such as solar PV are free to bid only for the 8am to 6pm blocks – which matches their generation profile – effectively limiting these projects' exposure to spot market prices. Renewable energy sources such as wind and hydro that are more seasonally affected also benefit from bidding for the quarterly blocks (which requires continuous supply). Projects normally have a long period before they need to deliver power: the energy bid out in 2017 for example only needs to be delivered in 2024 (del Río, 2017b; IRENA, 2017b; Munoz, Pumarino & Salas, 2017).

Chile's auctions prioritise financial criteria, both in terms of qualification requirements as well as winner selection. IPPs must submit financial risk rating reports from an authorized financial consultant confirming their company's risk rating is not lower than a BB+. In addition, three years' worth of company accounts proving financial solvency are also required for participation in the auction for developers (IRENA, 2017b). Nevertheless, the Chilean auctions have some of the lowest qualification requirements, making no distinction between existing and new plants and requiring no bid bonds (although it is assumed that spot market price exposure provides enough incentive to bidders to complete projects). Winners are selected solely based on price in a sealed bid pay-as-bid manner.

Implementation
The implementation of Chile's auction program requires coordination between the ministry, the regulator and the distribution companies. The Ministerio de Energia (Ministry of Energy) sets out the country's energy policy and auction rules. Auctions are implemented by the regulator (CNE), which also sets out the volume to be procured as well as the corresponding partitioning of that volume into time and quarterly supply blocks. Auctions were first introduced by a bill of law approved in 2004 (and a later legal reform in 2015[26]) that transferred the responsibility for organising auctions to the regulator (CNE). Winning generators sign contracts with the distribution companies as off-takers.

Outcomes
The results of the Chilean auctions are remarkable for two reasons: firstly, it has shown that renewable energy technologies are able to compete with conventional technologies. In 2016's 12,483 GWh/year auction, for example, 47% of the awarded capacity went to onshore wind projects, with solar PV securing 6%. The second reason relates to prices: the lowest price in the 2016 auction came from a 120 MW solar PV plant that had bid for one of the hourly supply blocks: USDc 2,9/kWh (compared to the auction average price of USDc 4,8/kWh) (IRENA, 2017b; Munoz, Pumarino & Salas, 2017). In 2017's 2,200 GWh/year (equivalent to 600 MW of installed capacity) auction the lowest bid price was USDc 2.2 – again for a solar PV plant bidding for an hourly supply block (average price for auction: USDc 3,3/kWh) (Bellini, 2017a). Chile has therefore seen remarkable cost reductions in each round of the auction and is now a leader in electricity market innovation and auction design.

Mexico
Mexico's newly liberalised electricity sector has introduced auctions for various electricity products to meet the country's growing energy demand and meet its clean energy obligations. The country's large population (127 million people) and large economy (GDP of USD 1 trillion; USD 8,551 per capita) has caused considerable growth in natural gas and coal imports for power generation (Focus Economics, 2018b). Mexico enacted a number of energy sector reforms in 2014 to open up the sector to the market,

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[26] The bill also introduced some regulatory improvements, e.g. to prevent the possibility that consumers would be left without electricity supply if projects were not completed.

in part to address its dependence on fossil fuels: in 2013, 72% (46 GW) of the nation's electricity came from fossil fuels. Renewable energy contributed 22% (14 GW) to the installed electricity generation capacity in 2013, characterized by a dominance of large hydro (11.6 GW), wind (1.6 GW), geothermal (823 MW), biogas (44 MW) and solar PV (40 MW) (IRENA & SENER, 2015; Hochberg, 2018). Previously, generation, transmission, distribution and supply were controlled by the state owned Comisión Federal de Electricidad (CFE). The new regulatory framework was promulgated on 11 August 2014 to open up the power sector generation and the wholesale market to competition (del Río, 2017d). This resulted in the creation of a wholesale power market and the introduction of medium and long term power auctions for firm capacity (MW), clean energy (MWh) and clean energy certificates (CELs)[27] (Tisheva, 2017). The electricity law required the vertical and horizontal unbundling of CFE, including the separate establishment of power system operator CENACE. Furthermore, with the sector reform and implementation moving forward, the third long term energy auction included a further opening toward establishing a market clearinghouse to respond to a further decentralized market.

Table 5: Overview of renewable energy auction programme in Mexico

Design	Year of introduction	2015
	Frequency of auctions / rounds	1st and 2nd rounds in 2016. 3rd round September 2017
	Volume requested per auction	1st round (March 2016): 500 MW (firm capacity); 6,361 GWh (clean energy) 2nd round (September 2016): 1,483 MW (firm capacity); 10,630 GWh (clean energy) 3rd round (November 2017): 1,414 MW (firm capacity); 6,089 GWh (clean energy) Volume for each round set through offtaker bids.
	Technology requested (Supply specification)	Wind, solar, geothermal, hydropower, combined cycle gas technology
	PPA length	15 years (for energy and firm capacity); 20 years (CEL)
	Currency	Mexican Pesos or USD (indexed)[28]
Implementation	Policy and regulation guidelines	Ministry of Energy (SENER)
	Regulatory authority	Energy Regulatory Commission (CRE)
	Procurer	Centro Nacional de Control de Energía (CENACE) – system operator
	Off taker	Federal Energy Commission (CFE) – Round 1 & 2 Market Clearinghouse/Compensation Chamber (CC) – Round 3
Outcomes	Capacity (MW)/ Energy (MWh) procured[29]	Round 1: 5,408 MWh (Energy) Round 2: 1,158 MW (capacity); 8,909 GWh (Energy) Round 3: 593 MW (capacity); 5,493 GWh (Energy)

[27] CELs provide a market mechanism for Mexico to meet is clean energy policy goals (e.g. 25% by 2018). Generators receive one CEL for each MWh of clean energy produced.

[28] Generators are paid in Mexican Pesos, but can opt to have their tariffs indexed to the US Dollar exchange rate and inflation

[29] Firm capacity procured has mostly been gas (85%), with the rest split between solar and wind in the 3rd auction.

	Technology procured / installed	Wind, solar, geothermal, hydropower, combined cycle
	Prices (2017, USDc/kWh)	3rd Auction (2017. Excl. CEL): Average: 2.1 Lowest price for wind: 1,8 Lowest price for solar PV: 2,1

Design

Mexico's first sealed bid, pay-as-bid RE auction was held in March 2016, the second in September 2016 and third in November 2017. Long-term auctions are held for three products: firm capacity, clean energy and clean energy certificates (CELs). Firm capacity tenders are technology neutral, but energy and CEL auctions are limited to what is defined by the ministry as clean energy technologies (mainly renewables and efficient co-generation). Existing and new plants are able to participate in the auctions. PPAs for energy and firm capacity are offered for 15 years, while CELs are valid for 20 years. Bidders provide a package of bids, including capacity (MW), clean energy (MWh), and clean energy certificates (CELs). Projects are expected to come online in three years (IRENA, 2017b; REN21, 2017; Hochberg, 2018).

Qualification requirements are strict, requiring substantial evidence of technical and financial capacity and experience, as well as site-specific documentation (incl. resource assessment, grid access). Bidders also have to post bid bonds for capacity (USD 20,000/MW), energy (USD 9/MWh) and CELs (USD 4,5/CEL); as well as a bid bond of USD 93,000, irrespective of the size of the plant. For winning bids, the bonds are used to cover fees for interconnection, with the balance returned to the bidder. Generators are also required to post performance bonds for construction and operations, set to cover penalties if milestones or performance targets are not met. If generators fail to achieve commercial operation in time, they have to increase the performance bond[30], pay liquidated damages and cover their contracted supply obligations through spot market purchases – quite a severe penalty regime (REN21, 2017; Clifford Chance, 2018; Hochberg, 2018).

The Mexican auction makes use of a very sophisticated winner selection process, in which the auctioneer seeks to maximise the economic surplus of the bids for the off-taker (and, in turn, consumers). Bids are therefore evaluated not only on price, but also based on location price signals as well as hourly adjustment factors (both of which are "provisionally" published beforehand). CENACE's algorithm for determining winning bids also take into account additional factors, such as the exchange rate and volume of energy, capacity and CELs. This optimisation model prioritises cost, meaning that not all demand might end up being contracted (del Río, 2017c; IRENA, 2017b; Hochberg, 2018).

Implementation

The auction is implemented by the system operator - Centro Nacional de Control de Energía (CENACE) - with support from the ministry and regulator. The ministry of energy (SENER) publishes the rules for the long-term auction. Auction volume is determined by bids submitted by the offtakers: in the case of the 1st and 2nd auctions, this was CFE (the investment-grade utility); in the 3rd auction, larger customers

[30] The amount by which this increases depends on who is responsible for the delay – capped at 2x the original performance guarantee.

were also allowed to participate through a new clearinghouse – the Compensation Chamber (CC). The regulator – CRE – has the right to set ceiling prices, but in practice this has been set by the bids from the offtakers (del Río, 2017c; Hochberg, 2018).

Outcomes
Results from the three auction rounds have been record-breaking. In 2016, 3,483 GWh of solar PV and 1923 GWh of wind were contracted through energy and CEL auctions. Prices (incl. CEL pricing) ranged between USDc 3,5 – 6,8 for solar PV, and USDc 4,3 – 6,8 for onshore wind. No capacity projects were awarded since the set ceiling price was too low. In the second energy (and CEL) auction round, 4,836 GWh of solar PV, 3,874 GWh of onshore wind and 198 GWh of geothermal energy were awarded. The average price for this auction was USDc 3,4/kWh (incl. CEL). The capacity auction also saw the participation of solar PV (184 MW), onshore wind (128 MW) and geothermal power (25 MW), although the majority of capacity was awarded to closed cycle gas turbine (CCGT) plants (850 MW). Results from the third energy auction held in November 2017 produced further record breaking prices: onshore wind at USDc 1,8/kWh (excl. CEL) and solar PV at USDc 2,2/kWh (excl. CEL). 3,040 GWh of solar PV and 2,452 GWh of wind energy was contracted. The average price (excl. CEL) for the auction was USDc 2,1/kWh. Most of the volume auctioned in the firm capacity auction (3rd round) went to CCGT (84%), but solar PV (2%) and onshore wind (14%) also managed to secure contracts. Over the three auction rounds conducted, a total of US$ 9 billion has reportedly been invested (IRENA, 2017b; Mora, 2017; REN21, 2017; Hochberg, 2018).

Peru

Peru (population: 31 million) has slowly been adding renewable energy capacity through auctions to help power one of the fastest growing economies in the Latin American region (5,7% annual GDP growth) International Monetary Fund (2017). In 2014, half of the 45.7 TWh worth of electricity generated in Peru was derived from non-renewable energy sources, with the remaining half dominated by hydropower (del Río, 2017d). In recent years, there has been a slow increase in the share of wind and solar capacity added to the country's renewable energy mix, largely due to the introduction of Peru's renewable energy auction programme, Subastas de Recursos Energéticos Renovables, in 2009.

Table 6: Overview of the renewable energy auction programme in Peru

Design	Year of introduction	2009
	Frequency of auctions / rounds	Biannual; 4 auctions to date
	Volume requested per auction	5% of annual national electricity consumption
	Technology requested	Technology neutral
	PPA length	20 - 30 years
	Currency	USD and indexed
Implementation	Policy and regulation guidelines	Ministry of Energy and Mines (MINEM)

	Regulatory authority	Organismo Supervisor de la Inversion en Energia y Minera (OSINERGMIN)
	Procurer	Committee for the Economic Operation of the Electric System
	Offtaker	None. Power is sold on spot market and supplemented by premium
Outcomes	MW installed	5,228 MW
	Technology procured	Solar, wind, biomass and hydro
	Prices (2016, USDc/kWh)	Solar PV: 4,8 Wind: 3,7 Hydro: 5,0

Design

The Peruvian renewable energy auction program is held biannually and heavily focused on lowering prices. Characteristics of the auction include technology-specific demand bands, evaluation based solely on price, geographically neutral project locations and no local content requirements. The volume offered in each auction is proportional to 5% of the country's overall electricity consumption in the previous year. There is no limit set on the amount of MW or percentage of auction volume that can be awarded to a single bidder. Price ceilings were set, but not disclosed in the first three auctions; in the fourth auction, the ceiling price was made public. The guaranteed price is met through the market spot price plus a premium (covering the difference), financed through a surcharge on users' connection fee (del Río, 2017d; IRENA, 2017b; REN21, 2017).

The auction programme relies heavily on bid and performance bonds (as opposed to stringent financial and technical qualification criteria) to ensure project realisation. Bidders still have to meet several financial conditions for the qualification of bids and pay penalties linked to the delayed construction and completion of projects. If a producer generates less electricity than it was contracted for, the guaranteed price is reduced by the same percentage. Over-production of electricity is sold at the electricity spot market price, which is typically lower than the agreed-to PPA price (del Río, 2017d). Still, qualification requirements are considered relatively "loose" and there is no dedicated qualification round in the auction. In the latest round of auctions, a bid bond of USD 50,000/MW needed to be taken out for each project - an increase from USD 20 000/MW stipulated in the first round in 2009. In addition, a performance (construction completion) bond of USD 250,000/MW is required (del Río, 2017d; IRENA, 2017b; REN21, 2017).

Implementation

Peru's auction programme is dependent upon three key entities: The Ministry of Energy and Mines of Peru (MINEM), Organismo Supervisor de la Inversion en Energia y Minera (OSINERGMIN) (regulator) and the Committee for the Economic Operation of the Electric System (COES). MINEM is the government representative, with the responsibility of developing regulations and standards for the procurement of energy in the country and licensing. OSINERGMIN is responsible for conducting the auction, determining the price cap for each renewable energy technology, and determining the premium. COES is the grid operator who provides approval of pre-operating conditions and essentially coordinates the operation of the national grid at minimum cost (del Río, 2017d).

Outcomes

Through its regular auction rounds, Peru has been able to contract large volumes of renewable energy (5,228 MW) at lower and lower prices, although there are concerns about whether all of this capacity will get built. The average price bid in the latest auction (2016) was below USDc 5/kWh (Solar PV: USDc 4,8/kWh, Wind: USDc 3,7/kWh) (IRENA, 2017b). For solar PV pricing, this is an 80% reduction compared to prices bid in 2010. Project realisation rates are at 55%, which apparently prompted the Minister of Energy to cancel the auction scheduled for 2017 (Bellini, 2017b, 2018; del Río, 2017d).

Middle East and North Africa (MENA)

Renewable energy auctions are relatively recent phenomena in the MENA region, yet countries have managed to secure some of the lowest renewable energy project prices in the world. This includes projects for CSP (USDc 7,9/kWh), solar PV (USDc 2,4/kWh) and onshore wind (USDc 3/kWh). Apart from the aforementioned resources, this remarkable price trend is the result of a number of key auction design and implementation choices, in particular:

- The provision and preparation of large-scale renewable energy parks to project developers
- The procurement of ever-larger projects (up to 800 MW solar PV)
- The provision of concessionary finance, often facilitated through shareholding by a government entity (e.g. the off-taker)

We investigate how renewable energy auction programmes in Morocco, Saudi Arabia and the United Arab Emirates (UAE) have used these and other auction design and implementation elements to achieve these noteworthy results.

Morocco

Morocco's high dependency on energy imports, combined with a steep electricity demand growth rate, has prompted the government to launch a series of renewable energy auctions aimed at achieving ambitious renewable energy targets. Energy import costs take up a significant portion of Morocco's GDP and adds significantly to government debt. The North African country aims to achieve a 42% share of renewables (wind, solar, and hydro) in the electricity sector by 2020 and 52% by 2030. In addition, Morocco aims to generate 2 GW of solar power by 2020 using a combination of solar thermal and PV technologies (Carafa, Frisari & Vidican, 2016; Yaneva, 2016; Choukri, Naddami & Hayani, 2017).

Table 7: Overview of renewable energy auction programme in Morocco

Design	Year of introduction	2010
	Frequency of rounds/ number of rounds	4
	Volume requested per auction	Varies by auction round
	Technology requested (Supply specification)	CSP: 530 MW PV: 177 MW Wind: 1,650 MW
	PPA length	CSP: 25 years PV & Wind: 20 years
	Currency	Moroccan dirham (indexed to Euro and/or USD as per the bidders' financial proposal)
Implementation	Policy and regulation guidelines	Agency for the Development of Renewable Energies and Energy Efficiency (ADEREE)
	Regulatory authority	Agence Nationale de Régulation de l'Energie (ANRE)
	Procurer	Solar: Moroccan Agency for Solar Energy (MASEN) Wind: Office National d'Electricité (ONEE)

	Off taker	MASEN (solar) ONEE (wind) (recently changed to MASE)
Outcomes	MW procured	2,357 MW
	Technology procured	CSP, solar PV and wind
	Price (2016, USDc / kWh)	Wind: 3.0 Solar PV: 4.55 CSP: 13,5

Design

Morocco has two separate auction programmes for solar (PV & CSP) and onshore wind: The Moroccan Integrated Solar Energy Project, and the Wind Energy Programme. Both auction programmes operate on a pay-as-bid sealed-bid tendering system. The auction programme also uses a pre-qualification round with stringent technical, financial and legal criteria, as well as a local content threshold of 30%. Projects also have to post completion and performance bonds. Bids are evaluated on price alone (Davies, Ahmed & Wang, 2016). Auctions are site-specific, with sites being pre-selected and prepared (incl. permitting, studies, infrastructure and grid access) by a government agency (MASEN in the case of solar). The government also provides a letter of support, covering payment default on the PPA's (GIZ & Ecofys, 2013; Choukri, Naddami & Hayani, 2017).

Implementation

Morocco has tried different institutional arrangements for implementing its renewable energy auctions, but seems to have settled on a model that relies on a relatively independent institution that is able to centralise a number of core auction functions. Moroccan auctions are implemented in the context of a vertically integrated electricity market, structured around the national utility, the National Agency for Electricity and Water (ONEE), which is under administrative and technical control of the Ministry of Energy, Mines, Water and the Environment (Choukri, Naddami & Hayani, 2017). For solar auctions, this context prompted the creation of the Moroccan Agency for Solar Energy (MASEN), which acts as the procurer and off-taker for the auctions[31]. MASEN signs a second PPA with ONEE for revenue from electricity sales; any difference between the PPA costs with the project and the electricity sales revenue is covered by the government of Morocco (Hochberg, 2016b). For onshore wind auctions, ONEE was both the procurer and offtaker of power. In 2016, MASEN's scope was extended to include procuring all renewable energy (including wind and hydro power) and subsequently changed the name of organisation to the Moroccan Agency for Sustainable Energy (MASE) to reflect the organisation's extended mandate (Choukri, Naddami & Hayani, 2017). In future auctions, MASE will also be the offtaker for all procured renewable energy projects. MASE also becomes the minority equity partner (25%) in solar projects and provides debt financing for IPPs through multilateral agency funds borrowed by the Moroccan government (Hochberg, 2016b).

[31] Prior to 2016, MASEN's role was limited to solar power procurement and off-take. ONEE was responsible for the procurement and off-take of wind energy projects. This has recently been changed, with MASEN now being responsible for all RE auctions.

Outcomes

Moroccan auctions have been dominated by onshore wind power, both in terms of procured volumes and prices. Over the 4 rounds conducted from 2010 to 2016, 2,357 MW of electricity capacity has been procured from wind (1,650 MW), CSP (530 MW) and Solar PV (177 MW). Prices in the latest (2016) auction were USDc 3/kWh for wind, USDc 4.55/kWh for solar PV and USDc 13,5/kWh for CSP. These outcomes, along with the creation of MASE, will likely increase the prominence of solar PV in future rounds along with wind.

Saudi Arabia

Despite (or perhaps because of) being home to the world's largest oil reserves and the fourth largest concentration of natural gas globally (accounting for 42% of GDP and 80% of export earnings), Saudi Arabia has recently implemented an ambitious renewable energy auction program (Davies, Ahmed & Wang, 2016). Saudi Arabia has a domestic target of installing 9.5 GW of renewable energy by 2030 (Poudineh, Sen & Fattouh, 2016), of which energy auctions will target the procurement of 3.45 GW of renewables by 2020 over three auction rounds (Kingdom of Saudi Arabia, 2016).

Table 8: Overview of renewable energy auction programme in Saudi Arabia

Design	Year of introduction	2017
	Frequency of auctions / rounds	1
	Volume requested per auction	700 MW
	Technology requested (Supply specification)	PV: 300 MW Wind: 400 MW
	PPA length	PV: 25 years
	Currency	Saudi Riyal
Implementation	Policy and regulation guidelines	Ministry of Energy, Industry and Mineral Resources
	Regulatory authority	Electricity & Cogenerations Regulatory Authority
	Procurer	Renewable Energy Project Development Office (REPDO)
	Off taker	Saudi Electric Company
Outcomes	MW procured	300 MW
	Technology tendered	Solar PV, onshore wind, CSP and waste to energy
	Prices (2017, USDc/kWh)	Solar PV: 2.34

Design

Design details of the Saudi auction have been limited – prompting concerns about transparency in the implementation of the country's renewable energy auction program. The auctioneer has made use of a pre-qualification round and provided project sites. Pricing appears to follow a pay-as-bid model. The first round of auctions held in 2017 required 30% local content for projects, increasing to 40% - 60% in 2018, and 60%+ in 2019 and beyond. The auctions therefore have an aggressive industrial development component as part of its design. Solar PV projects are also provided with a 25-year PPA, while wind projects are offered a 20-year PPA (Scott, 2018).

Implementation
The Renewable Energy Project Development office (REPDO), an office within MEIM, is the organisation responsible for the implementation of the NREP, which mandates and promotes the use of competitive auctions to procure renewable energy capacity. MEIM is responsible for the policy and regulation guidelines for the auction. The Saudi Electric Company is the designated offtaker of the procured projects.

Outcomes
The first round of auctions began in early 2017, in which REPDO issued a tender for 400 MW of onshore wind and 300 MW of solar PV. Shortlisted bids for the solar power tender released in April 2017 were made public by October 2017. The list included the lowest ever quoted tariff for solar energy at USDc 1.78/kWh – a bid by UAE's Masdar and French company EDF. However, this bid was not ultimately selected, prompting concerns about transparency in the evaluation process (Mahapatra, 2018; Reed, 2018). The awarded Sakaka project is set to cost US$ 302 million and is backed by a 25 year PPA at USDc 2.4 /kWh (Gnana, 2018).

REPDO plans to auction 3.25 GW of solar and 800 MW of wind energy capacity in 2018. The auction will be spread over two rounds, with the first auction featuring 250 MW of solar PV, and the second round requesting 3 GW of solar PV and 800 MW of wind capacity[32]. Saudi Arabia is also considering waste-to-energy and CSP as future power sources (Gnana, 2018).

United Arab Emirates (UAE)
The UAE (population 9.4 million people) is also attempting to diversify its fossil-fuel based energy mix and economy (GDP USD 350 billion) using solar auctions (CIA, 2018). The UAE receives on average 10 hours of daily sunlight and 350 sunny days per year, with solar radiation potential of 6.5 kWh/m2/day (Alnaser and Alnaser, 2011 as noted in Poudineh, Sen & Fattouh, 2016). The government has set domestic targets for the deployment of renewable energy generation capacity for the country. These targets include a national target of 24% clean energy into the energy mix by 2021 (including nuclear energy) and local targets of 7% by 2020 for Abu Dhabi and 7% for Dubai by 2020, increased to 15% by 2030 (Poudineh, Sen & Fattouh, 2016).

[32] The Crown Prince of Saudi Arabia recently signed a MoU with Softbank for a USD 200 billion solar plant, which had the effect of stalling the entire procurement plan (incl. the 400 MW wind project). The only project that is currently going ahead is therefore the 300 MW solar PV project.

Table 9: Overview of renewable energy auction programme in the United Arab Emirates

Design	Year of introduction	2012
	Frequency of auctions / rounds	4
	Volume requested per auction	Solar PV: 1,013 MW total (Dubai); Pilot (13 MW); DEWA II (200 MW); DEWA III (800 MW) 1,170 MW (Abu Dhabi) CSP: 700 MW (Dubai)
	Technology requested (Supply specification)	PV and CSP
	PPA length	CSP: 35 years PV: 25 years
	Currency	AED/USD (indexed)
Implementation	Policy and regulation guidelines	Dubai: Dubai Electricity and Water (DEWA) Abu Dhabi: Abu Dhabi Electricity and Water Authority (ADWEA)
	Regulatory authority	Regulatory & Supervisory Bureau (Dubai) Abu Dhabi Energy Authority (Abu Dhabi)
	Procurer	DEWA (Dubai) ADWEA (Abu Dhabi)
	Off taker	DEWA (Dubai) ADWEA (Abu Dhabi)
Outcomes	Total MW procured	2,883 MW
	Technology procured / installed	Solar PV and CSP
	Prices (2016/17, USDc/kWh)	CSP: 7,3 PV: 2,9 (Dubai) PV: 2,42 (Abu Dhabi, includes 60% summer bonus over 4 months)

Design

Renewable energy auctions in the UAE are built around a unique financing structure that has resulted in record low prices. All projects are to be jointly held by the developer, with the utility (DEWA or ADWED) holding the majority (51% - 60%) of shares in the project. This auction design resembles a public-private partnership more than a classical IPP model and is regarded as a strategic financial advantage to projects. Government-owned utilities' creditworthiness allows them to secure favourable loan terms (low interest rates and long tenors). In Abu Dhabi, solar PV projects are also remunerated at 1.6 times their bid prices using a Summer bonus (June – September) (IRENA & CEM, 2015; IRENA, 2017b).

All projects are site specific, whereby the government predetermines and prepares sites for the construction and connection to the grid, which further reduce risks and costs to developers. In addition, there are no size limits to projects – meaning that considerable economies of scale come into play. In

Dubai, for example, 800 MW (the total auction volume for that round) was awarded to a single consortium in 2016. Qualification criteria include stringent technical and financial requirements for project bids. Winner selection is based solely on price following a sealed bid, pay-as-bid-mechanism[33]. (IRENA & CEM, 2015; Mahapatra, 2017)

Implementation

Dubai and Abu Dhabi's respective utilities (DEWA and ADWEA) are the sole government-owned entity/utility responsible for the implementation processes of the auctions, also acting as off-takers of the projects as well as majority share equity investors.

Outcomes

The UAE auctions produced global record low prices for solar technologies at the time projects were awarded (2016/17). A total of 2,883 MW has been procured from solar PV and CSP plants, with prices reaching USDc 7,3/kWh for CSP, USDc 2,9/kWh for solar PV in Dubai and USDc 2,42/kWh for solar PV in Abu Dhabi[34].

[33] The 1170 MW Sweihan project in Abu Dhabi started as a 350 MW project open to alternative bids, and DEWA IV was a 200 MW twin tower which resulted in a 700 MW tower-trough combination being awarded.

[34] As previously noted, the price in Abu Dhabi includes a 1.6x bonus payment in Summer to meet the critical air-conditioning loads during these months. A levelised price for this auction therefore comes closer to USDc 2,9/kWh.

Europe

While the European region has been relatively slow to adopt auction mechanisms, and experience with auction outcomes have been mixed, recent years have seen acceleration in specific markets (e.g. Germany, Spain) and technologies (e.g. offshore wind). Historically, Europe has been the leading world region for developing renewable energy markets, driven in large part by generous feed-in tariff policies. Recent regulatory and legislative changes at the EU level have resulted in auctions becoming a mandated mechanism for procuring utility-scale renewable energy projects. A big part of the European auction story is therefore concerned with how countries have attempted to deal with some of the legacy issues connected with a transition from a feed-in tariff based regime, to one with more competition. In Germany, for example, the continued support of community-based projects is a key political concern; while in Spain there is continued regulatory uncertainty due to the country's retroactive FiT policy changes. Some countries that have adopted auctions have also started out quite cautiously, with smaller pilot projects being tendered before larger volumes are put to market. The results have however been remarkable, with large volumes of renewable energy being secured at ever-lower prices (often without subsidies) – prompting an important reconsideration of the structure of these advanced energy markets. We investigate auctions in Germany – Europe's leading renewable energy investment destination; Spain – a recent large-scale market for various technologies; and Denmark – a leading offshore wind investment destination.

Germany

Germany (population 82 million; GDP USD 3,4 trillion) replaced its successful fixed support level funding system for utility-scale renewable energy in favour of auctions in 2014/15[35] (Fowlie, 2017). A pilot auction was held in 2015 for ground mounted solar PV installations, and auction schemes for other technologies (onshore wind, offshore wind and biomass) have been introduced in early 2017. The German Ministry for Economic Affairs and Energy established that hydropower, geothermal and gas technologies are excluded from auctions as there is not enough competition in these technologies to make auctions meaningful (Appunn, 2016). Small wind and solar projects (<750 kW) will continue to benefit from the fixed support level.

Table 10: Overview of the renewable energy auction programme in Germany

Design	Year of introduction	Solar (pilot): April 2015 Wind (Onshore and Offshore): 2017 Biomass: December 2017
	Frequency of auctions / rounds	Solar: 3 times per year Onshore wind: 3 in 2017, 4 in 2018
	Volume requested per auction	Solar: 200 MW per round Onshore wind: 2.8 GW in blocks of 800MW – 1000 MW per round (2017- 2019), 2.9 GW (after 2020)

[35] Germany's feed-in tariff system was replaced by a direct marketing system with a sliding market premium but a fixed level of support in 2012. The auctions changed the fact that the level of support and the entitlement of support is now issued by a competitive tender, but other features of the support scheme remain unchanged.

		Offshore wind: 500 MW annually (2021 – 2022), 70 0MW annually (2023 – 2025) and 840 MW annually (2026 onwards). Biomass: 150 MW annually (2017 – 2019), 200 MW (2020 – 2023).
	Technology requested (Supply specification)	Solar PV (700 kW – 10 MW) Wind (onshore and offshore) Combined heat and power (CHP)
	Support length	20 years
	Currency	Euro (Contract for Difference/Sliding Feed-in Premium)
Implementation	Policy and regulation guidelines	The Ministry of Economic Affairs and Energy
	Regulatory authority	Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur)
	Procurer	Bundesnetzagentur
	Off taker	Bundesnetzagentur
Outcomes	MW procured	Solar PV: 600 MW Onshore Wind: 2,800 MW (2017); 1,300 MW (2018) Offshore Wind: 1,500 MW (2017); 1,600 MW (2018) Biomass: 28 MW
	Technology procured	Solar PV Wind (onshore and offshore) Biomass
	Prices (2017/18, USDc/kWh)	Solar PV: 5.7 (2017: Euro c 4.9; 2018: Euro c 4,5) Onshore wind: 5.6 (2017: Euro c 4.5; 2018: Euro c 5,2) Offshore wind: 5.7 (2017: Euro c 0,4; 2018: Euro c 4,7) Biomass: 17.5 (Euro c 14.3)

Design

German auction design has in general been relatively straightforward, although project size limits have been at the lower end of the scale. Auctions are technology-specific, although a joint solar PV-onshore wind auction was held for the first time in April 2018. Ceiling prices are made public prior to the auctions. Bidders have to post bid bonds of between Euro 25 – 50/kW (Euro 100/kW for offshore wind) and need to prove that they have municipal clearance for projects (i.e. developer-selected sites). Bidders in the solar auctions can change their projects for a reduction in support level[36], while the support entitlement for wind and biomass projects cannot be moved to another project. For offshore wind projects, the system operator provides sites and grid connections. Project size limits apply, with solar PV projects e.g. being limited to 10 MW. Projects generally bid on a sealed-bid, pay-as bid basis and have a realisation period of between 18 – 30 months (depending on technology and size; for offshore wind the realisation period is 6 to 7 years). In general the auctions are for a "sliding feed-in premium": if the electricity spot market price is below the auction price, the difference is covered; however, if the market price is above the auction price, the project gets to keep the difference. The auction price therefore functions as a minimum price for the project (Klessman & Wigand, 2017; Walendzik, 2017).

[36] This is a key auction design feature meant to mitigate project realization failure risk.

Germany also limited the amount of renewable capacity that can be auctioned in specific geographic areas where the transmission grid is congested. In the onshore wind auctions, a reference wind yield condition is provided according to which projects bid; if the project's wind yield is in fact lower than the reference yield, its tariff is adjusted upwards – and vice versa if the yield is better than the reference value. The aim of this design feature is to ensure a more even distribution of wind projects within the country – instead of a clustering of projects in high-yield zones only[37]. Another design feature of German auctions is that biomass plants will only be granted half of the hours of a year. This is to encourage a time of day tariff when the wholesale price is high during periods of low solar and wind yield, and during peak demand periods (Tiedemann, 2015a; Walendzik, 2017).

German auctions try to incentivise "citizen projects" by energy cooperatives through lowering qualification requirements and penalties (e.g. not needing a Federal Emission Control Act permit and lower bid bonds: Euro 15/kW), offering longer realisation periods (54 months) and a preferential price rule (projects are paid a clearing/uniform price). Citizen onshore wind projects are limited to 18 MW in size (Klessmann & Tiedemann, 2017; Wehrmann, 2017).

Implementation

While auction rules and procedures are determined by Germany's ministry of Economic Affairs and Energy, the tendering procedures are carried out by the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur). Bundesnetzagentur publishes submission dates and required information on its website and will choose the lowest bids in the auction according to the award procedure set out in detail in the renewable energy law by the ministry for each stipulated technology (Norton Rose Fulbright, 2017).

Outcomes

Germany has seen rapid advances, both in terms of volumes and prices, across solar PV and wind technologies. 1,500 MW of offshore wind was procured in 2017, at 4,4 Euro cents/kWh (USDc 5,4)[38] – a remarkable achievement for a relatively new technology. A further 1,500 MW of offshore wind was auctioned in April 2018 at 4,7 Euro c/kWh (Walendzik, 2017). Onshore wind tenders have been dominated by so-called "citizen projects", securing between 71% and 84% of auctioned capacity in the 2017 auctions. This has led to a considerable amount of controversy, as it appears that most of these citizen projects are actually larger project development companies that have used a legal loophole to secure projects on better terms. While Germany's first solar PV auction have seen a realisation rate of close to 100%, the special provisions afforded to winning bidders in the citizen projects for onshore wind have raised concerns about possible low realisation rates of these projects since realisation deadlines are very long and penalties quite low. As a result, special provisions for citizen projects have been suspended for 2018 and might be abolished altogether. Nevertheless, 1,800 MW of onshore wind was procured in 2017, with a further 1,300 MW procured in 2018. While the average price for onshore wind in the third auction of 2017 (Nov) was 3,8 Euro cents/kWh (as opposed to 5,7 Euro cents/kWh in May's auction and

[37] It is also meant to reduce windfall profits for producers with high yields, reducing total support funding.

[38] It should be noted that this price does not include the cost of the grid infrastructure (paid by the TSO), which is estimated to add another 3-6 Euro cents/kWh (Walendzik, 2017).

4,3 Euro cents/kWh in August), the 2018 auction prices have been slightly higher: 4.7 and 5,7[39] Euro cents/kWh. The increase in the average price has been largely ascribed to the change in rules regarding citizen energy projects (Tiedemann, 2015a; Klessmann & Tiedemann, 2017; Walendzik, 2017; Wehrmann, 2017).

In contrast to onshore wind, solar PV projects have seen no citizen projects being awarded, despite more than 600 MW being procured in 2017. In 2018, so far 410 MW have been procured, with 200 MW procured in the regular auction in February and 210 MW (the full auction volume) being awarded to solar PV in a "joint, technology-neutral" auction in April. Solar PV prices have also decreased substantially - from 9.2 Euro cents/kWh in 2015 to 4.3 Euro cents/kWh in 2017; but 2018 prices have been slightly higher (4,7 Euro cents/kWh). In general, all of the auction rounds have been majorly oversubscribed – with the important exception of biomass energy. While 122 MW of biomass energy capacity was bid out in 2017, only 28 MW was awarded, at an average price of 14.3 Euro cents/kWh (Tiedemann, 2015b; Klessman & Wigand, 2017; Walendzik, 2017; Clean Energy Wire, 2018; Enkhardt, 2018).

Spain

Spain (population: 46.3 million; GDP €1.1 trillion GDP) is aiming to rapidly meet its renewable energy obligations through auctions after several years' hiatus in the sector. Spain is notorious for its decision to place a moratorium on new renewable energy installations and retroactively change its feed-in tariff levels in 2012, prompted by a decrease in electricity demand, economic stagnation and a growing electricity tariff deficit[40]. As such, regulatory risk remains a key concern for investors in the country's renewable sector. The first renewable energy auction was held in January 2016, after being delayed from November 2015. The country also held two additional auctions in 2017 (del Río, 2016; S&P Global Ratings, 2018).

Table 11: Overview of renewable energy auction programme in Spain

Design	Year of introduction	2015
	Frequency of rounds	3 rounds since introduction
	Volume requested per auction	Round 1: 700 MW (wind, biomass) Round 2: 3,000 MW (technology neutral) Round 3: 3,000 MW requested; 5,037 MW awarded (wind, solar PV)
	Technology requested (Supply specification)	Onshore wind, solar PV, biomass
	Length of investment-based support	Wind and solar PV: 20 years Biomass: 25 years
	Currency	Euro
Implementation	Policy and regulation guidelines	Ministry of Energy, Tourism and the Digital Agenda, through the State Secretariat for Energy
	Regulatory authority	State Secretarariat for Energy, CNMC

[39] This is the latest result from the May 2018 onshore wind auction, which was undersubscribed

[40] This was caused in part by Spain's electricity system, characterized by low interconnections and overcapacity.

	Procurer	OMI-Polo Español, S.A. (OMIE), through its subsidiary OMEL Diversificación
	Off taker	OMI-Polo Español, S.A. (OMIE), through its subsidiary OMEL Diversificación
Outcomes	MW procured	8,373 MW
	Technology procured / installed	Onshore wind, solar PV and biomass
	Prices (2017, USDc/kWh)	Round 3: USDc 3,4 – 3,9 (Euro cents 2.8-3.2/kWh (price floor))

Design

Spanish auctions have rapidly ramped up demand and are primarily focused on quick procurement. The inaugural auction round in 2015/16 requested 700 MW of capacity, with a 500 MW allocation towards wind and 200 MW towards biomass. Round two (May 2017) was technology neutral (but limited to renewables), and offered 3,000 MW. Round three (July 2017) initially requested 3,000 MW but eventually awarded more than 5,000 MW. The auctions are geographically neutral, without any limits in terms of project size or MW awarded. Qualification requirements for the first round were relatively "loose", with no previous experience required, no administrative permits (incl. land) required, and only a bid bond of around Euro 20/kW. For the second and third rounds, the bid bond was increased to Euro 60/kW and projects needed to have a building permit secured. There are furthermore no local content requirements, and projects need to be commissioned by January 2020 (del Río, 2016, 2017e; Hill, 2017).

The remuneration and consequent evaluation scheme of the Spanish auction is both unique and relatively confusing to the market. When Spain abandoned its FiT scheme, it was replaced by a standardised regulated asset-based system (RAB): the government remunerates each plant to ensure a "reasonable rate of return" (RRR) based on a recognised asset value. The reasonable rate is the government bond yield plus a spread (reviewed every six years) – currently at 300 basis points. This implies a 7.5 % financial remuneration. A "standard asset" is used by the government to define operating assumptions (del Río, 2016; S&P Global Ratings, 2018).

In the auctions, evaluation is based solely on price. However, they do not bid in a specific tariff for the support period; instead, bidders bid at a discount over the Regulated Asset Base (RAB) – effectively ensuring that the government provides subsidies only if the market power prices are insufficient for the project to reach the RRR. Pricing is uniform – meaning that all winning projects get the same discount rate (del Río, 2017e; Losana, 2017; S&P Global Ratings, 2018).

Implementation

There are several institutions involved in Spain's auction programme. The State Secretariat for Energy (a body belonging to the Ministry of Energy, Tourism and the Digital Agenda) is the regulator setting the rules of the auctions and passes the relevant legislation (through royal decrees, Ministerial Orders and Resolutions). The state secretariat further issues legislation on tariff structure and measures to ensure energy supply. However, the Ministry of Industry, Energy and Tourism has the lead responsibility for formulating and implementing energy policy. The Comisión Nacional de los Mercados y la Competencia

(CNMC) is an independent organisation that supervises and manages the auction procedure and outcome, while the OMI-Polo Español S.A. through its subsidiary OMEL Diversificación, is in charge of the management of the auction (del Río, 2016).

Outcomes

Auctions results are ushering in a new era in the Spanish renewables market, and are raising concerns about the ability to secure long-term finance for these projects. In the first auction, no maximum discount rate was set, resulting in all projects bidding at a 100% discount rate. This means that the projects are fully exposed to the spot market, with no subsidies from the government. In the second auction, the government defined a maximum discount rate (63.4 %), which all developers again bid at. More than 2,900 MW of the auctioned 3,000 MW was awarded to onshore wind projects. The third auction saw discount rates set at 69.9% for onshore wind and 87,1% for solar PV. Again, projects bid at the maximum discount rates, with 4 GW awarded to solar PV and 1 GW awarded to onshore wind projects. Estimations are that the price floors effectively set by the discount rates in auctions 2 (Euro 40/MWh) and 3 (Euro 28-32/MWh) are so low that projects effectively remain fully exposed to market prices. There are also further concerns regarding realisation deadlines given the low bid bonds, and low qualification requirements[41] (del Río, 2017e; GlobalData, 2017; Hill, 2017; S&P Global Ratings, 2018).

Denmark

Denmark (5.7 million people, USD 306 billion GDP) has several instruments for the development of renewable energy, including feed-in-tariffs, premiums, tax incentives and auctions. Auctions are currently limited to the procurement of offshore and near-shore wind projects[42]. The introduction of wind energy auctions began in 2004 with two types of auction schemes used thus far, each with differing auction design types (Kitzing & Wendring, 2015; OECD, 2017).

Table 12: Overview of renewable energy auction programme in Denmark

Design	Year of introduction	2004
	Frequency of auctions / rounds	Irregular. 7 between 2004 – 2016
	Volume requested per auction	Offshore: Site specific (determined by government) Near-shore: 350MW
	Technology requested (Supply specification)	Offshore and near-shore wind
	PPA length	12-15 years (depending on full load-hours)
	Currency	DKK

[41] The delays in Round 1 projects is in large part due to the fact that the projects are not "bankable" from a project finance perspective, since they are fully exposed to the spot market. Projects required a direct PPA and equity from the equipment supplier to convince financial institutions to lend to these projects.

[42] Denmark is looking into introducing "technology neutral" auctions in 2018, that would cover solar PV as well as onshore and offshore wind.

Implementation	Policy and regulation guidelines	Ministry of Energy, Utilities and Climate
	Regulatory authority	Danish Energy Agency (Energistyrelsen)
	Procurer	Danish Energy Agency (Energistyrelsen)
	Off taker	Energinet (Danish TSO)
Outcomes	Total MW procured	2,350 MW
	Technology procured / installed	Offshore wind and near-shore wind
	Prices (2016, USDc/ kWh)	Nov 2016 auction: 5.7 (5 Euro cents/kWh)

Design

Denmark uses two types of auctions to procure offshore wind projects. Udbud efter forhandling is characterised as a public auction with a prequalification round used to procure several offshore wind projects and near-shore areas. Investors were pre-selected in a first round and discussions and negotiations took place between this first round and the final bidding round (Kitzing & Wendering, 2015). Offentigt udbud (a pure public auction) was used for the second round of bidding for two offshore wind projects: Rødsand 2 and Anholt. The auction had one bidding round and no negotiations between investors and authorities (Kitzing & Wendering, 2015).

Offshore wind auctions are run as sealed bid, pay-as-bid auctions with no price cap (except for near-shore, where a price cap of around 9 Euro cents/kWh applies). The general design (for both auction types) is a single item, technology specific auction with predetermined project sizes (200 – 600 MW) and locations. For near-shore areas, a multi-site tender was introduced with a maximum capacity of 350 MW distributed over 6 predefined areas (Kitzing & Wendering, 2015). Project remuneration is based on sliding feed-in-premiums that are limited to certain full load hours (50 000 hours/acre – equivalent to about 12 – 15 years of operation) (Ragwitz et al., 2014). Evaluation was based on a multi-criteria framework for the initial rounds of offshore auctions, but it has subsequently been replaced by price as the only evaluation criterion.

Prequalification criteria have been project specific, but in general require proof of the financial health of the developer and guarantees by a financial institution; site specific technical requirements of the project including previous technical experience in the construction and maintenance of offshore wind farms; and use of environmental, quality and risk management systems (Kitzing & Wendering, 2015). The Horns Rev 3 project required a social clause on apprenticeships that ensures a certain number of trainees are used in the construction of the wind farm. Furthermore, developers are required to include local actors as part project owners (minimum 20% ownership) (Ragwitz et al., 2014).

Implementation

The Danish Energy Agency (ENS) acts as the procurer of the offshore wind auctions, setting auction volumes, determining auction sites and providing the necessary infrastructure and permitting. Energinet, the Transmission System Operator (TSO), is the offtaker. All final tariffs also have to be ratified by the Danish parliament before being included in the country's renewable energy support law, and in some cases the ministry of energy might wish to use a third party to investigate the reasonableness of winning prices (Kitzing & Wendering, 2015).

Outcomes
Denmark has contracted more than 2,350 MW of offshore and near-shore wind power at highly competitive rates, with the latest tariff of USDc 5,6/kWh being bid in 2016 for the 600 MW Kriegers Flak offshore wind project. Project sites are provided by the government (incl. grid infrastructure, a key cost item for offshore infrastructure) and investors appear to be increasingly comfortable with the technology. Realisation rates for offshore wind projects to date has been 100% (for projects with currently expired realisation deadlines) (Kitzing & Wendering, 2015; Klessman & Wigand, 2017).

Asia

With the notable exception of India and China, the Asian region has been relatively slow to adopt renewable energy auctions. Some of this hesitancy can be explained by experiences in countries like Indonesia, which auctioned around 140 MW of solar PV in 2013, yet secured only 20 MW of capacity. The country's recent (2016) attempt at auctioning geothermal capacity further resulted in no projects being awarded. While countries like Malaysia (450 MW solar PV) and Thailand (36 MW biomass and 5 MW biogas) have had slightly more success in recent auctions, these countries have struggled to achieve some of the price and timely investment outcomes that have marked auctions in other regions. Much of these outcomes can be explained by poor auction design (e.g. unrealistic local content and ownership requirements; small project sizes; short bidding and implementation timelines) and implementation choices (e.g. political and regulatory uncertainty; poor quality auction documentation and data; poor inter-government coordination). Despite this fact, many countries in the region (incl. Pakistan and Vietnam) are considering their own renewable energy auction programmes – oftentimes in partnership with multilateral development institutions such as the World Bank Group. India is a notable exception, being a leader in the region in terms of its long-standing commitment to renewable energy, as well as its impressive recent renewable energy auction outcomes (Tongsopit et al., 2017).

India

Prompted by rapid economic growth (7% annual GDP growth), increasing electricity demand and electrification challenges (79% access rate, population 1,2 billion), India has set itself the target of becoming a global leader in solar energy. The Ministry of New and Renewable Energy (MNRE) introduced the National Solar Mission (NSM) in January 2010 – under the direction of Prime Minister Modi. The NSM aims to reduce the cost of solar power generation in the country by integrating (i) long term policy; (ii) large scale deployment goals; (iii) aggressive R&D; and (iv) domestic production of raw materials, components and products (Ministry of New and Renewable Energy, 2017; Solar Energy Corporation of India, 2017). The initial target of the NSM was 20 GW of grid connected solar by 2022. In 2014 this was revised to 100 GW within the same timeframe. In addition, over the same time period, MNRE has a target of achieving 60 GW of wind power capacity (IRENA, 2017b). The rollout of solar technologies under the NSM is deployed in phases and batches. Phase 1 took place from 2010 to 2013, phase 2 from 2013 to 2017 and phase 3 from 2017 to 2022.

India has implemented an auction-based approach to achieve the country's renewable energy targets. Auctions are held for large scale solar (PV and CSP[43]) and wind projects, as well as rooftop solar PV projects. Different auction schemes are implemented at national and state level, driven by the NSM targets (IRENA, 2017b).

Table 13: Overview of the renewable energy auction programme in India

		Federal	State
Design	Year of introduction	Solar: 2010 Wind: 2017	
	Frequency of auctions / rounds	25+	15+
	Volume requested per auction	Solar PV: 13 GW (total); Wind: 6 GW (total); 1-2 GW per auction round	14,800 MW (total)
	Technology requested (Supply specification)	PV: 10,500 MW Wind: 3,000 MW	PV: 13,800 MW Wind: 1,000 MW
	PPA length	25 years	25 years
	Currency	INR (non-indexed)	INR (non-indexed)
Implementation	Policy and regulation guidelines	Ministry of New and Renewable Energy	State-level executive branch
	Regulatory authority	The Central Electricity Regulatory Commission (CERC)	The State Electricity Regulatory Commission (SERC)
	Procurer	Solar Energy Corporation of India (SECI)	State distribution company
	Off taker	Wind: PTC India Ltd Solar: SECI; National Thermal Power Corporation (NTPC)	State distribution company; DMRC (private)
Outcomes	MW procured / installed	Solar: installed capacity 16GW and 10GW procured (2017) Wind: 6 GW procured (2017)	Wind: 1,5 GW
	Technology procured / installed	Solar and wind	Solar and wind
	Prices (2017/18, USDc / kWh)	Wind: 3.6 (2,4 INR) Solar PV: 3.6 (2.4 INR)	Wind: 3.6 (INR 2,4) Solar PV: 3.8 (INR 2.6)

Design

The sheer number and diversity of renewable energy auction schemes in India is staggering, with more than 30 GW of renewables (mostly solar PV) having been procured to date (more than half of this capacity in the last 18 months alone). About half of this capacity has been procured at the federal (national) level,

[43] CSP has not been included in any recent auctions

with the remaining half split between various Indian states (provinces). Auctions are in general organised as sealed-bid, pay as bid schemes[44], with non-indexed[45] tariffs denominated in Indian Rupees for 25 years[46] and ceiling prices disclosed beforehand. The use of solar parks has increased substantially in the last two to three years, both at a federal and state level. While Indian auctions use penalties in their design, the use in practice for project delays has been limited, increasing the risk of bidder speculation (Bridge to India, 2017; IRENA, 2017b).

India introduced a Viability Gap Funding (VGF) mechanism (also used in other PPP infrastructure projects), by which developers bid for a capital subsidy grant (max. 20% of capital cost) on top of their tariff. The VGF grant is paid 50% on commissioning, with the remaining 50% spread over the first 5 years of operation. The aim of the VGF is to lower price exposure for distribution companies (Khana & Barroso, 2014; IRENA, 2017b).

A controversial element in the Indian auction programme is the issue of local content requirements: phase 1 of the NSM required a 50% share of any crystalline silicon solar PV modules to be manufactured in India. This led to the United States launching a formal complaint with the World Trade Organisation, which ruled against India. Subsequently, after 2 rounds conducted in phase 2 of the NSM, local content requirements were lowered substantially and dedicated auction volumes set out for local content and "open" (no local content). This continues to be an area of great uncertainty in the Indian solar market, with the government currently looking at introducing substantial import duties on solar components (Khana & Barroso, 2014; Shrimali, Konda & Farooquee, 2016; Bridge to India, 2017; IRENA, 2017b; Mathur, Pandey & Roy, 2017).

Implementation

The Indian constitution allows for federal and state-level government to have a share of administrative power. Both federal and state levels of government have their own regulators for the oversight of the Indian power sector, including policies and regulations for promoting renewable energy. Guidelines for federal/national auctions are announced beforehand by MNRE, and the Solar Energy Corporation of India (SECI) manages procurement. SECI or the National Thermal Power Corporation (NTPC) act as intermediary off-takers (signing back-to-back PPAs with state distribution companies or institutional off-takers), with both entities having investment grade credit ratings.

State level auctions are used to meet individual state-level renewable energy targets with state distribution companies as off-takers. State auctions are usually conducted by a state entity (mostly the distribution company) that also acts as the designated off-taker. Oftentimes these distribution companies are not investment-grade rated – an issue that has been addressed in some auctions by implementing a payment security agreement between the Reserve Bank of India, the national government and state governments. A recent solar park auction for the first time also introduced a private off-taker (the national railway

[44] Several auctions, such as the recent REWA solar park auction, have introduced a hybrid scheme, in which projects first submit sealed bids, after which an "e-auction" (descending clock) takes place. For REWA, this reduced bids from INR 3.9 to INR 3.3/kWh (Goyal, Mhorotra & Purohit, 2018).

[45] Some state-level auctions have introduced a fixed escalation rate for projects – usually limited to around 1%.

[46] Uttar Pradesh tried to introduce a 10-year PPA to offset some of the inflation risk

company) as part off-taker to offset some of the state distribution company credit risk (Khana & Barroso, 2014; IRENA, 2017b; Goyal, Mhorotra & Purohit, 2018). A hybrid auction model also exists that involves the development of solar parks, where central and state institutions jointly create implementing bodies that undertake land procurement and infrastructure development, and invite the private sector to develop projects within these solar parks (Khana & Barroso, 2014; IRENA, 2017b; Goyal, Mhorotra & Purohit, 2018).

Outcomes

A key feature of the Indian auction programme has been the sheer scale of procurement: in two years, the country has procured more than 16 GW of solar PV and 7 GW of onshore wind capacity – both at national and state level. This has been coupled with impressive price outcomes (USDc 3.6 – 3.8/kWh) across both technologies in federal and state-level auctions. The level of VGF has been substantially reduced, with many projects bidding without any VGF contribution.

Despite these achievements, there remain a number of important challenges in the sector: some state-level off-takers refuse to sign PPA's for projects that they deem to be expensive, even after running an effective procurement programme; there are also concerns about the impact of inflation and grid curtailment (given the increasing share of renewables) on projects, especially with very aggressive bidding assumptions in recent rounds and some recent project realisation delays; and projects subject to local content requirements have consistently been awarded at prices 10% to 15% higher than those not requiring local content (Khana & Barroso, 2014; Shrimali, Konda & Farooquee, 2016; Bridge to India, 2017; IRENA, 2017b).

Analysis: Price Outcomes

Renewable energy auction success is most often measured in terms of (announced) prices[47], with a new record-breaking tariff being announced every few months. Analysts are quick to point out that while these prices are both impressive and indicative of larger price movements in the market, they often obscure important differences in market conditions and auction design (IRENA, 2017b; Mahapatra, 2017). While the aim of this report is not to provide a comprehensive answer to the question as to whether these prices are "realistic" or sustainable, it is worth investigating whether there are specific auction design or market conditions that correlate to specific price outcomes. We therefore provide a summary description of several conditions highlighted in the literature (Eberhard, Kolker & Leigland, 2014; Ondraczek, Komendantova & Patt, 2015; Dobrotkova, Surana & Audinet, 2018) as helping to explain price outcomes in the auctions analysed (Table 14)[48].

[47] Realisation rates is another important measure of auction success, although the relatively recent nature of most of the auction programmes analysed makes it difficult to provide a comprehensive analysis at this stage since the scheduled CODs for most of the awarded projects have not yet elapsed.

[48] Please note that this is not a rigorous statistical analysis

Table 14: Summary of global solar PV auctions – ranked by USD price (low to high)

	Latest Average Price (USDc/ kWh)	Site selection	Concessional financing	Guarantee instruments	Economic Development/ Local Content	Expected COD	PPA Currency	Credit Rating (Fitch)
Mexico	2,1	Developer (but incl. in evaluation)	No (but projects get CEL payments)	No[49]	No	2020	Peso's or USD (indexed)	A3
Saudi Arabia	2,34	Government	No	No	30% (2017); 60% (2018)	2019	Riyal	A1
UAE	2,4 – 2,9	Government	Secured through utility shareholding	No	No	2018	AED/USD (indexed)	Aa2
Chile	3,25 (all tech)	Developer	No	No	No	2024	USD (indexed)	Aa3
Spain	3,4	Developer	No	No	No	2020	Euro	Baa1
Brazil	3,5	Developer	Through BNDES (development bank)	No	Local content requirements for accessing BNDES financing	2022	BRL (indexed)	Baa2
India	3,6	Developer or Government	Viability Gap Funding mechanism	Payment security for some state auctions	Local content (50%+) and "open" (no local content) auctions	2019	INR (non-indexed)	Baa2
Argentina	4,0	Developer (but limited to pre-determined regions)	Concessional loans (FODER)	Payment & termination guarantees (with WB support)	60% local content required for accessing tax credits and concessional finance	2019	USD (indexed)	B3
Morocco	4,5	Government	Concessional financing from MASE, through multulateral borrowing from GoM	Termination guarantee	30% local content	2018	Dirham (indexed – also to USD/Euro)	Ba1
Peru	4,8	Developer	No	No	No	2018	USD (indexed)	A3
Germany	5,7	Developer (but limited to pre-determined regions)	No	No	Evaluation incentives for "citizen projects"	2022	Euro	AAA

It appears that the factors exerting the strongest influence on price outcomes are: the cost of capital (sovereign credit rating); solar resources (global horizontal irradiation levels - Figure 10); and (to a lesser extent) the expected date of commercial operation (COD) (Figure 11). None of these factors on their own

[49] From the third round of auctions other offtakers (5MW+) are able to participate in the auction. These offtakers (other than CFE) are required to provide a payment guarantee and reserve account. In addition, a defaulting offtaker (other than CFE) can be replaced by another through the clearinghouse (Clifford Chance, 2017). If CFE defaults on its payments (as offtaker), it has to cover the remaining PPA payments through a trust .

is sufficient to explain price outcomes, but together they are able to provide a useful framework to understand pricing. There is for example a clustering of prices at or below USDc 3/kWh for countries that have investment grade credit ratings – with the important exceptions of Germany and Peru, whose pricing is influenced by the solar resource (Germany) and – possibly - the expected commissioning date (Peru)[50]. Countries with B-level credit ratings all present pricing that cluster between USDc 3,5 – 4,5/kWh. The clustering of the lowest prices in Mexico, Saudi Arabia and the UAE also corresponds with the highest average solar resources (Figure 10). It is also clear that the timing of projects' commercial operations date (COD) is another influential factor, with a downward trend visible up until at least 2020 – after which more uncertainty in future pricing seems to make way for some of the previously discussed factors (Figure 11). These trends generally support and correspond to some of the main findings in the literature on solar PV pricing (Ondraczek, Komendantova & Patt, 2015; Dobrotkova, Surana & Audinet, 2018).

[50] The expected 2018 commissioning date in Peru is in line with that of the projects in UAE, and therefore the explanatory power of this variable is somewhat limited. That being said, the Dubai price result is an outlier in terms of commissioning date, and can also be further explained through: the majority shareholding of the off-taker in the project company (and consequent access to low-cost financing); the provision and preparation of the site; and the sheer scale (1 GW+) of the project. If one were to take these additional factors into account, it should be clear that there will be a price difference between Peru and UAE, despite similar credit and solar resource positions.

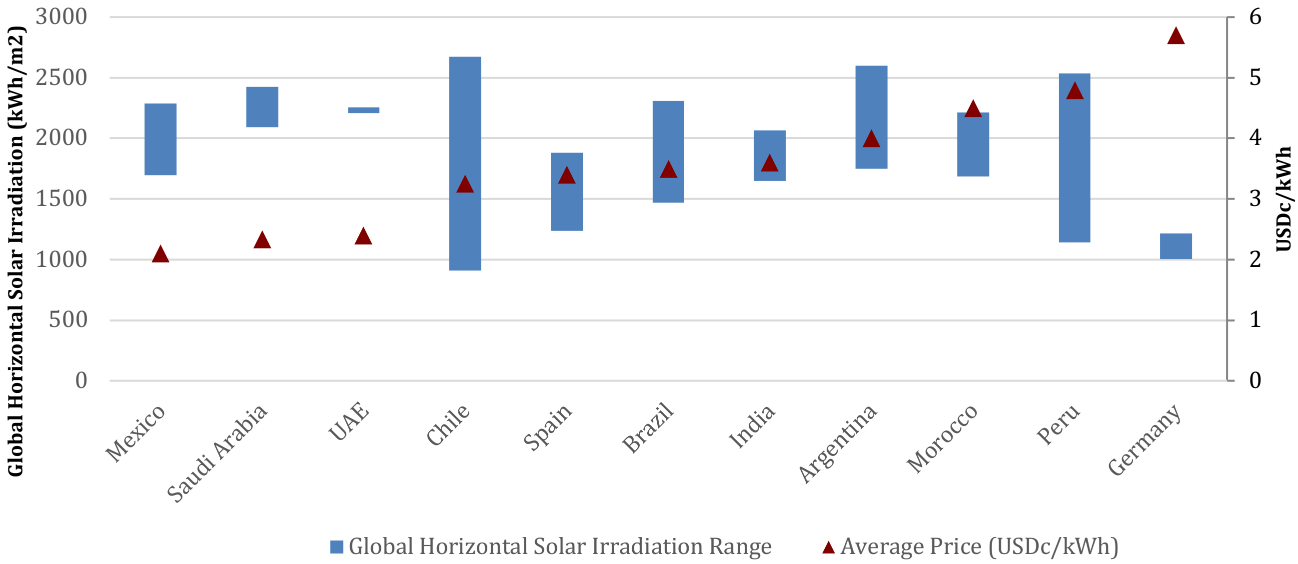

Figure 10: Solar Irradiation Levels vs. Auction Prices for Case Study Countries. Source: GlobalSolarAtlas, 2018.

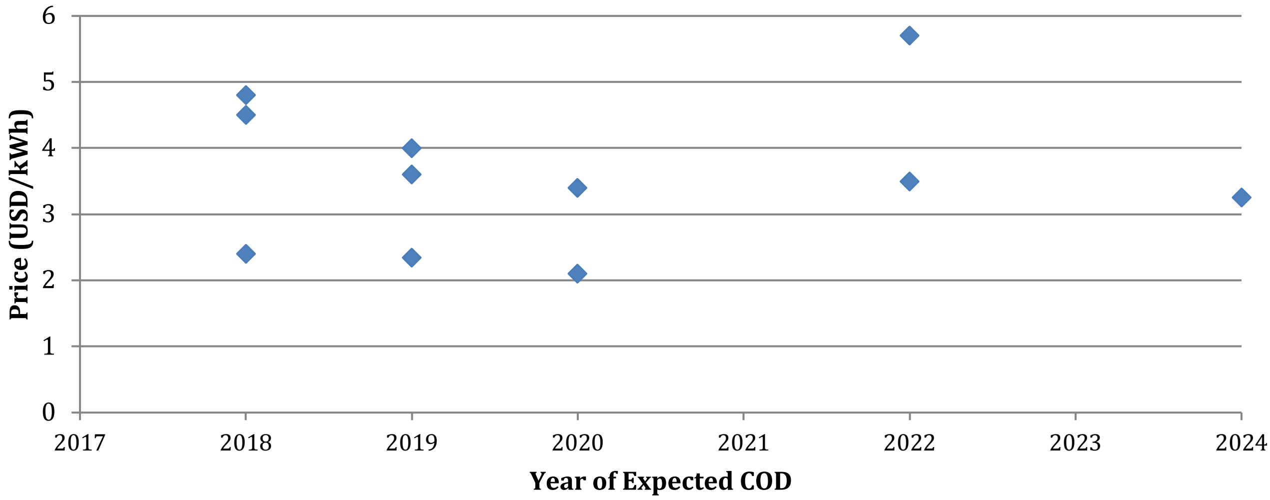

Figure 11: Auction prices vs. Year of expected COD.

While the other factors analysed (site selection, guarantees, concessional financing, local content requirements) are very likely to exert some influence on price, our analysis does not appear to show a clear correlation between these factors and pricing. PPA currency denomination appears to exert relatively little price influence, as do local content requirements. There is also no clear pattern visible in terms of site selection and preparation, with both government- and developer-selected sites featuring in more or less equal measure throughout. Still, countries with lower credit ratings (e.g. Argentina, Brazil, India, Morocco) all provide some form of concessional financing and/or guarantee mechanism (payment and/or termination) to make up for the possible higher cost of capital in these markets. This is not to say that these other factors (concessional financing, local content, site selection, PPA currency etc.) do not play a role in pricing; there is enough literature on the subject to prove otherwise. Rather, within the limits of this dataset and report, it appears that these factors – while still important - are perhaps secondary to some of the more fundamental price determinants (cost of capital, solar resource, expected COD). This is potentially good news for many sub-Saharan African countries with excellent renewable energy resources, but also potentially troubling given the high cost of capital in these markets. The good news borne out by this analysis is that while the former factor (solar irradiance) is not something anyone can influence, the latter (cost of capital) is open to adjustment based on clever project de-risking and financing strategies. It is therefore important for auctioneers in sub-Saharan Africa to appreciate the level of de-risking and financing support needed to achieve good pricing outcomes.

While this analysis has focused primarily on price outcomes, the concluding sections of the report will provide a more comprehensive analysis of major trends and best practice identified from prominent global renewable energy auctions.

Conclusion: Global Renewable Energy Trends & Best Practice

This report is the first phase of a research programme dedicated to understanding and improving renewable energy auction design and implementation in sub-Saharan Africa. As such, it set out to establish a global baseline in terms of renewable energy auction trends and best practice. A framework that focuses on both auction design and implementation factors[51] has guided this high-level analysis of specific national renewable energy auction programmes. This concluding section therefore summarises the key findings from our analysis based on our analytical framework under the headings of "Auction Design" and "Auction Implementation", after which we identify seven key trends and lessons of particular importance to sub-Saharan Africa.

Auction Design

Site Selection

Government played some role in the selection (and preparation) of project sites in most auctions – with the exception of Spain, Peru, Brazil and Chile[52] (Table 14). In all other cases analysed, government involvement ranged from guidance or restrictions on project location (e.g. Mexico, Argentina, Germany) to the provision of fully prepared and serviced sites (e.g. Morocco, UAE, India). Government's role in the site selection process has been justified based on the need to protect grid stability, limit transmission costs and losses, shorten project development timelines and reduce investor risks and costs. The ability of government to direct project location – whether through price signals or solar parks – is one of the chief advantages of auction programmes compared to traditional feed-in tariff schemes. In addition, the provision of a suitably selected and prepared site is useful not only when dealing with land scarcity and tenure issues (as is the case e.g. in India), but also enables government to rapidly develop renewable energy capacity in a new market (e.g. Morocco, UAE).

Auction Demand

The auctions analysed (Table 15) have generally bid out large volumes (100+ MW) of renewables (in relatively large project chunks), usually set in terms of capacity (MW) as opposed to energy (MWh). Chile's time-block based energy auctions are an important exception (as is Peru's energy-based auction), and are seen as being in large part responsible for the success of renewable energy projects vis-à-vis conventional technologies in the country's technology neutral auctions. While Chile provides some innovative direction in terms of the future of technology-neutral auction design, most programmes analysed prefer to procure specific technologies through limiting participation to renewables (e.g. Mexico, Germany), establishing dedicated technology demand bands (e.g. Peru, Argentina) or just procuring a single technology (e.g. Saudi Arabia, Morocco).

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[51] While our analytical framework makes it clear that auction implementation factors are as important as those dedicated to design, our analysis has emphasized only a limited number of auction implementation factors. This is mainly due to the fact that these factors are rarely investigated and reported on (as opposed to auction design factors). Nevertheless, our in-depth case study analyses of auction programmes in sub-Saharan Africa will dedicate more time and analysis to auction implementation factors.

[52] As well as some state- and federal auctions in India.

Auction volume is most often determined through reference to a national renewable energy target or electricity-planning framework (e.g. Spain, Argentina, India, Morocco) and/or through market signals from potential off-takers (e.g. distribution companies in Brazil, Mexico); the latter is most often the case in fully unbundled, liberalised electricity markets. A universal design feature has been the use of multiple auction rounds, through which procurers have been able to secure successively better priced renewable energy. While some programmes have a limit in place in terms of project size, the majority have opted not to restrict project size. The result is a wide range in project sizes: from 10 MW in Germany to more than 1 GW in Abu Dhabi. The lowest priced projects (Table 14) are currently coming from programmes without project size limits[53]. That being said, many countries (e.g. Germany, UAE) started their auction programmes with relatively small pilot programmes that aimed to test the market and the mechanism, before proceeding to large-scale volumes.

Table 15: Summary of Case Studies' Auction Demand Features

	Capacity/ Energy	Technology Neutral/ Specific	Auction volume (latest round)	Project size limits	Multiple rounds	Location neutral/ specific
Argentina	Capacity	Technology Specific	550 MW (onshore wind) 450 MW (Solar PV) 100 MW (Biomass) 50 MW (Hydro) 35 MW (Biogas) 15 MW (Landfill gas)	100 MW (Solar PV & Wind) 65 MW (Biomass) 20 MW (Hydro)	Multiple rounds	Location specific (technology capacity allocated to specific regions)
Brazil	Capacity	Technology Neutral or Specific (auction round specific rules)	806 MW (Solar PV) 114 MW (Onshore wind) 61 MW (Biomass) 41 MW (Small hydro)	No	Multiple rounds	Location neutral
Chile	Energy	Technology Neutral	2,200 GWh/year	No	Multiple rounds	Location neutral
Mexico	Capacity	Technology Neutral (Limited to "Clean Energy Technologies" in Energy Auctions)	3.040 GWh (solar PV) 2,453 GWh (onshore wind) 10 MW (Solar PV) 83 MW (Onshore wind)	No	Multiple rounds	Location neutral* - auctioneer provides locational price signals
Peru	Energy	Technology Specific	165 GWh/year (Onshore Wind) 108 GWh/year (Solar PV)	No	Multiple rounds	Location neutral
Morocco	Capacity	Technology Specific	850 MW (Wind) 200 MW (CSP) 170 MW (Solar PV)	No	Multiple rounds	Location specific (e.g. solar park)

[53] In auctions in the UAE and Saudi Arabia, for example, the entire auction volume has been awarded to a single bidder. Inversely, the relatively expensive prices for solar PV in Germany can in part be explained by the relatively small project sizes (as well as the poor solar resource).

Saudi Arabia	Capacity	Technology Specific	400 MW (Onshore wind) 300 MW (Solar PV)	No	Multiple rounds	Location specific (e.g. solar park)
UAE	Capacity	Technology Specific	1,000+ MW (Solar PV) 700 MW (CSP)	No	Multiple rounds	Location specific (e.g. solar park)
Germany	Capacity	Technology Specific (but also recent wind/PV neutral auction)	100 – 200 MW (Solar PV) 500 MW (Offshore wind) 800 MW (Onshore wind)	10 MW (Solar PV)	Multiple rounds	Location specific* - limits on project geographic concentration
Spain	Capacity	Technology Specific	5,037 MW	No	Multiple rounds	Location neutral
Denmark	Capacity	Technology Specific	600 MW (single site)	Yes (specific projects)	Multiple rounds	Location specific (offshore wind projects)
India	Capacity	Technology Specific	1,000 – 2,000 MW	Auction specific rules	Multiple rounds	Location neutral and specific (solar parks)

Qualification & Compliance Criteria

All auction programmes required bidders to provide proof of adequate financial and technical capacity (and experience) to qualify for bidding, although the minimum compliance levels varied between programmes. In general though, the main emphasis has been on establishing the ability of project developers/sponsors to realise projects. In some cases, additional policy objectives have been incorporated through e.g. local content requirements [54] (e.g. Morocco, India, Saudi Arabia). Most programmes that relied on developers to select and develop their project site usually also required a comprehensive set of site-related documents, permits and project details to ensure compliance – although in some cases projects could opt to obtain some of these only after their bid being awarded. None of the programmes analysed seemed to require some indication of financing (lending) commitments at the time of bidding.

Winner Selection

Winner selection in the case study countries has most often been based on a project's price (Table 16), although we are also seeing increasing sophistication from programmes in e.g. Mexico with regards to how the evaluation process is being adapted to maximise the value of the programme. Nevertheless, the majority of countries opted to filter out projects that failed to deliver on specific policy or other objectives through their qualification criteria, enabling them to focus on price alone as the only determinant of winning bids. Where countries have opted to use additional evaluation measures not supported by transparent evaluation processes (e.g. Saudi Arabia), results have been mired in controversy.

[54] Several countries (e.g. Argentina, Brazil) opted to use local content requirements as a condition for accessing concessional financing and other fiscal incentives, instead of as a specific auction qualification requirement.

Table 16: Summary of Case Studies' Winner Selection Criteria

	Winner Selection Criteria
Argentina	Price, Location, Time to COD, Legal Compliance
Brazil	Price
Chile	Price
Mexico	Price, Location, Hourly Adjustment Factors, Exchange Rate, Volume of Energy, Capacity & CELs
Peru	Price
Morocco	Price
Saudi Arabia	Price & Technical/Local Content
UAE	Price
Germany	Price, Location, Wind Resource, Citizen Project Status
Spain	Price (discount over Regulated Asset Base)
Denmark	Price
India	Price & Technical

Seller & Buyer Liabilities

Most programs opted for relatively expensive bid (and performance) bonds to ensure bidder compliance and project realisation – again, with the notable exception of Chile (Table 17). In some cases (e.g. Brazil, Peru), bid (and performance) bonds seem to serve as "stand-in" for stringent qualification criteria, with procurers being comfortable that these financial "incentives" are sufficient to "weed out" non-serious bidders. These guarantee instruments are proving to be very popular for ensuring project realisation (through e.g. limiting speculative bidding or "low-balling"), although their actual impact is still to be established. In general though, the trend has been to increase bid and performance bond requirements, especially in markets that have historically struggled with project realisation. Combined with effective penalty mechanisms (e.g. reduction in support levels/periods, performance bonds), the bid guarantee (bond) requirements are one of the most powerful tools for procurers to ensure an effective auction outcome. This of course also requires that procurers actually use these instruments when needed; when they don't (as is the case in some auctions in India), these instruments lose their value and the market becomes more risky for all players.

Contract schedules for reaching commercial operation also vary somewhat, although most auction programmes require projects to come online within 2 to 3 years. Notable exceptions are (again) Chile (5-6 years), but also Brazil (4/6 years) and Germany (5 years). Given the relatively short construction periods needed for the projects (mostly solar PV, onshore wind) procured in these markets, the long project realisation periods introduce additional construction and pricing uncertainty. In the case of Denmark, which has contracted offshore wind projects, the relatively new nature of the technology and the challenges posed by the sites warrant longer development timelines.

There seems to be a relatively even split between "hard" currency (USD/Euro) and local currency denominated tariffs[55], with some auctions giving sponsors the option of choosing either (e.g. Mexico, UAE). This shows a growing willingness of domestic financial institutions to invest in these renewable energy markets, and also reflects on the relative availability of capital in these markets. Most programmes

[55] Although in Europe, the Euro is the local currency

also deal with inflation risk through indexing prices[56], although India famously does not provide for this in their contracts[57].

Table 17: Summary of Case Studies' Sellers' and Buyers' Liabilities

	Bid & Completion Bonds	Expected COD	PPA Currency & Indexation
Argentina	USD 50 000/MW (Bid) USD 250 000/MW (Completion)	2-3 years	USD (indexed[56])
Brazil	1% of investment cost (Bid) 5% of investment cost (Completion)	4 Years (A4) 6 Years (A6)	BRL (indexed)
Chile	None	5 - 6 Years	USD (indexed)
Mexico	USD 9/MWh USD 4,5/CEL +Bid bond: USD 93,000	2 – 3 Years	Peso's or USD (indexed)
Peru	USD 50 000/MW (Bid) USD 250 000/MW (Completion)	2 Years	USD (indexed)
Morocco	Bid & Completion Bonds, but amounts not made public	2 Years	Dirham (indexed, also to USD/Euro)
Saudi Arabia	USD 5.3 Million (Bid) USD 12 Million (Performance)	1 – 2 Years	Riyal (indexed)
UAE	10% of project value (Bid)	1 – 2 Years	AED/USD (indexed)
Germany	Euro 25,000 – 50,000/MW (Bid)	5 Years	Euro (indexed)
Spain	Euro 20,000/MW (Bid)	2 - 3 Years	Euro (indexed)
Denmark	DKK 100 million (Bid)	3 – 5 Years	DKK (indexed)
India	Auction specific e.g. REWA 750 MW solar PV park: USD 16,000/MW (Bid) USD 28,000/MW (Performance 1) USD 18,000/MW (Performance 2)	2 – 3 Years	INR (non-indexed)

Bankability & Risk Mitigation

Concessional financing and guarantees have helped to kick-start several renewable energy markets, especially in countries with lower credit ratings (also for off-takers, e.g. India) and less established programmes (Table 18). Concessional financing has been provided in a number of ways: from purely concessional loans in Argentina and Brazil, low-cost financing secured through utility-shareholding in the UAE, to what are effectively "subsidies" through CELs or VFG mechanisms in Mexico and India. All of these financing mechanisms have helped establish the market and ensure low prices, but also give the government further leverage to ensure that the projects achieve specific policy objectives (e.g. local content requirements for BNDES funding in Brazil).

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[56] Certain jurisdictions with particularly high inflation, e.g. Argentina, index projects to a pre-determined index that is not linked to inflation.

[57] Many would of course argue that India's non-indexed tariffs are "higher" than they need to be since bidders merely price in inflation assumptions.

Markets with sub-A level credit ratings have generally also required some form of guarantee (termination and/or payment) to ensure bankability; in the case of Argentina these have had to be backstopped by the World Bank to ensure investor comfort. Other markets have also sought to mitigate risks by e.g. off-taker/government shareholding in the awarded projects. Generally speaking though, these are the exception rather than the rule in the cases studied, although it has to be noted that most of these markets are investment grade. Still, for markets with risky investment environments (e.g. sub-Saharan Africa), the effectiveness of risk mitigation instruments like guarantees in securing renewable energy projects at reasonable prices is encouraging.

Table 18: Summary of Case Studies' Bankability and Risk Mitigation Measures

	Concessional Financing	Guarantee Instruments	Off-taker/Government Shareholding
Argentina	Concessional loans (FODER) & fiscal incentives. Incentive index.	Payment & termination guarantees (with WB support)	No
Brazil	Through BNDES (development bank)	No	No
Chile	No	No	No
Mexico	No (but projects get CEL payments)	No	No
Peru	No	No	No
Morocco	MASE loans	Termination guarantee	Yes
Saudi Arabia	No	No	Yes
UAE	Secured through utility shareholding	No	Yes
Germany	No	No	No
Spain	No	No	No
Denmark	No	No	No
India	Viability Gap Funding mechanism	Payment security for some state auctions	No

Auction Implementation

Enabling Environment

Most of the auctions studied have been implemented in an environment characterised by strong market rules (and adherence to these rules) within an overall supportive political milieu. Auctions work well in various types of electricity markets, but seem especially prevalent and advanced in liberalised electricity markets (e.g. Chile, Mexico, Brazil). The importance of global climate change mitigation commitments (linked to renewable energy targets) has been a key political driving force (e.g. Spain) – especially in relatively new renewable energy markets (e.g. Saudi Arabia, UAE) - along with concerns around energy security and pricing (e.g. in Morocco). The European market in particular has seen the ascendance of auctions based on explicit changes in EU-level energy policy, which has been essential in establishing some level of political support. Achieving low prices for renewable energy – and having more control over the expansion of these technologies within current electricity systems – have further secured political support for the mechanism in most studied jurisdictions.

A further key feature has been the importance of strong institutions running the programme, often with significant government backing (political and resources). The exact type and “location” of these institutions vary across countries, with some opting for the procurement function to form part of the regulatory authority (e.g. Denmark, Germany, Chile, Brazil), others preferring this to be the system operator (e.g. Argentina, Mexico, Peru) or the off-taker (e.g. UAE), and other still housing this function in a dedicated, independent institution (e.g. India, Saudi Arabia, Morocco) (Table 19). Despite this variety of locations, the overarching principle is that the procuring institution needs to be credible, capable and politically supported.

Implementation Process

The importance of transparent and clear evaluation processes cannot easily be overstated. In general, countries with a history of using auctions for procuring new power and strong electricity markets (e.g. Brazil, Chile, Peru) appear to have faced relatively few challenges in establishing trusted renewable energy auction processes. As the only country using a descending-clock type auction (which potentially increases the likelihood of bidder collusion), Brazil introduced a hybrid bidding system in which the first round of bidding is followed by a final, sealed-bid round. This has had the effect of further reducing project prices, but has also added a level of transparency to the bidding process.

In most of the cases studied, procuring authorities have made use of web-based platforms (and pre-bid briefings) to communicate with the market during the (pre-)qualification and bidding processes. In selected cases (e.g. Denmark), dedicated dialogue processes with bidders have been incorporated into the bidding process – although this is in large part due to the complex and novel nature of the offshore wind projects. In general though, there has been emphasis on qualification and evaluation results being communicated clearly to the market (and the public), based on clear, established evaluation criteria. Where this has not been the case (e.g. Saudi Arabia), it has led to speculation and controversy – damaging the overall long-term reputation of the auction programme in that market. Given the importance of competition for achieving effective and efficient auction outcomes, it is important that programmes maintain a high level of trust with participants (incl. developers, investors and lenders).

Table 19: Summary of Case Studies' Auction Implementation Agencies

	Policy & Regulation	Procurer	Off-taker
Argentina	Ministry of Energy & Mining; Ente Nacional Regulador de la Electricidad (ENRE)	CAMMESSA (Wholesale electricity market administrator)	CAMMESSA (Wholesale electricity market administrator)
Brazil	Ministry of Mines and Energy (MME); Agência Nacional de Energia Elétrica, (ANEEL)	New energy auction: ANEEL, with auction committee: CCEE (market operator); MME; Energy Research Company (EPE) Reserve auction: CCEE	New energy auction: distribution companies Reserve auction: CCEE

Chile	Ministry of Energy National Energy Commission (NCE)	National Energy Commission (NCE)	Distribution companies
Mexico	Ministry of Energy (SENER) Energy Regulatory Commission (CRE)	Centro Nacional de Control de Energía (CENACE) – system operator	Federal Energy Commission (CFE) – Round 1 & 2 Compensation Chamber (CC) – Round 3
Peru	Ministry of Energy and Mines (MINEM) Organismo Supervisor de la Inversion en Energia y Minera (OSINERGMIN)	Committee for the Economic Operation of the Electric System	MINEM pays premium; Power sold on spot market.
Morocco	Agency for the Development of Renewable Energies and Energy Efficiency (ADEREE) Agence Nationale de Régulation de l'Energie (ANRE)	Solar: Moroccan Agency for Solar Energy (MASEN) Wind: Office National d'Electricité (ONEE)	MASEN (solar) ONEE (wind) (recently changed to MASE)
Saudi Arabia	Ministry of Energy, Industry and Mineral Resources Electricity & Cogenerations Regulatory Authority	Renewable Energy Project Development Office (REPDO)	Saudi Electric Company
UAE	Dubai: Dubai Electricity and Water (DEWA); Regulatory & Supervisory Bureau Abu Dhabi: Abu Dhabi Electricity and Water Authority (ADWEA) Abu Dhabi Energy Authority	DEWA (Dubai) ADWEA (Abu Dhabi)	DEWA (Dubai) ADWEA (Abu Dhabi)
Germany	Ministry of Economic Affairs and Energy; Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur)	Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur)	Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur)
Spain	Ministry of Energy, Tourism and the Digital Agenda, through the State Secretariat for Energy	OMI-Polo Español, S.A. (OMIE), through its subsidiary OMEL Diversificación	OMI-Polo Español, S.A. (OMIE), through its subsidiary OMEL Diversificación
Denmark	Ministry of Energy, Utilities and Climate; Danish Energy Agency (Energistyrelsen)	Danish Energy Agency (Energistyrelsen)	Danish Energy Agency (Energistyrelsen)
India	Federal: Ministry of New and Renewable Energy; The Central Electricity Regulatory Commission (CERC) State: State-level executive branch; The State Electricity Regulatory Commission (SERC)	Federal: Solar Energy Corporation of India (SECI) State: State distribution company	Federal: Wind: PTC India Ltd Solar: SECI; National Thermal Power Corporation (NTPC) State: State distribution company; DMRC (private)

Trends, Lessons & Implications for Sub-Saharan Africa

Our analysis of global renewable energy auctions has revealed seven major trends with important implications for similar programmes in sub-Saharan Africa.

1. **Renewable energy auctions work in many different market contexts with various renewable energy technologies.** Auctions have been able to secure large volumes of privately financed, built, owned and operated renewable energy capacity while at the same time reducing prices – oftentimes to levels below a system's average cost of supply or below the cost of new-build conventional power sources. Auctions have been shown to work in numerous types of electricity markets, from fully unbundled, liberalised power systems such as Brazil, Chile and the EU; to hybrid systems dominated by vertically integrated, state-owned utilities such as the UAE and Morocco. While solar PV and onshore wind dominate renewable energy auction programmes, recent experience has shown that auctions are also able to successfully procure technologies such as CSP and offshore wind (and to a lesser degree biomass and hydro).

   Renewable energy auctions are well suited to most sub-Saharan African power sectors, where competition for long-term power purchase agreements can easily be integrated with existing regulations and structures. Sub-Saharan African countries are also advised to focus on proven technologies such as solar PV and onshore wind, at least in initial auction rounds. These technologies have seen rapid decreases in costs, can be deployed quickly, and are not as beholden to economies of scale as various other conventional power sources. An important caveat is the use of storage technology: given the small size and fragility of many sub-Saharan African grids, it might be essential to integrate storage as part of the auctioned product to achieve sufficient scale that does not threaten grid stability.

2. **A coherent, clear integration of energy policy, electricity sector master planning, and procurement is essential for achieving successful auction outcomes**. Auction volume and rounds need to be clearly linked to renewable energy targets as well as sector planning frameworks (incl. transmission planning). This provides predictability to investors and enables the procurer to implement auction rounds with some regularity, which has proven to consistently drive down prices and develop a pipeline of strong projects. It might be wise to start relatively small to test the auction framework.

   Sub-Saharan African governments and regulators are advised to develop renewable energy auction programmes based on least-cost, dynamic integrated resource plans. Overall auction volumes, technology-specific tranches and frequency of rounds should be established by these plans. Given the relatively small and weak grids in most sub-Saharan African countries, it is also imperative that auction design takes into account transmission capacity and planning.

3. **Auction participants need to not only have the capacity (financial, technical) to stand behind their bids, but more importantly, should be committed to realising auction outcomes.** The use of stringent qualification criteria, right-sized financial guarantees (e.g. bid & performance bonds), and

effective penalty mechanisms has ensured high project realisation rates. In the absence of these mechanisms, auction programs have been subject to speculative bidding and underperformance (e.g. India, Peru).

Sub-Saharan African auctioneers would be well advised to use an effective combination of qualification criteria, bidder guarantees and penalty mechanisms to ensure adequate bidder capacity and commitment to project realisation.

4. **Most renewable energy auctions tend to favour simpler, more intuitive design options** such as e.g. capacity-based volumes, energy-based payment, and sealed bid processes with pay-as-bid pricing rules. While there have been various innovative design options used (e.g. bidding for time blocks in Chile; bidding for various energy products in Mexico; hybrid bidding procedure in Brazil), these have tended to be concentrated in quite advanced electricity markets and depends on the sophistication of procurers and bidders. Nevertheless, these design innovations point the way for electricity markets of the future, and show us how electricity auctions might have to adapt to these new realities.

   A simple, straightforward auction is likely to not only be easier to implement, but will probably also attract greater bidder interest. Given the relatively high transaction costs of auctions for bidders and auctioneers, it is suggested that at least the first few rounds of auctions be implemented using tried-and-tested auction design options. That being said, the need for auction innovation around potential additional products such as energy storage might prompt some sub-Saharan African auctions to introduce auction design elements that have not been used in other contexts.

5. **Deciding beforehand on clear auction objectives is important, since there tends to be a trade-off between different objectives.** Price reduction is of course one of the main objectives of an auction programme, but policy makers need to be aware that adding additional objectives such as local industrialisation and community ownership requirements will affect auction pricing. Local content requirements in particular need to be realistic.

   While the overwhelming need in most sub-Saharan African countries is for additional, competitively priced electricity capacity, there are also various other socio-economic needs that need to be met. Where sub-Saharan African countries choose to use e.g. local content requirements in their renewable energy auctions, they need to ensure that these requirements are realistic and will add value through being integrated in a broader national industrialisation strategy.

6. **Project derisking and credit enhancement have proven to be important for achieving lower prices, and ensuring project realisation**. Various auction programmes have used payment and loan guarantees, offered concessional financing, and provided other fiscal incentives to drive down the cost of debt for projects. Some offtakers have even provided substantial amounts of equity. One of the most frequently used risk mitigation measures has been the provision and preparation of the project site, along with the relevant infrastructure, permits and data.

For many sub-Saharan African countries, the only way to ensure that private power projects are bankable is by providing guarantees (usually sovereign, but also payment guarantees) and other credit enhancement mechanisms. An auction makes it possible to provide these benefits at a programmatic level (as opposed to a case by case basis), and to ensure that only the best (winning) projects benefit from scarce government resources.

7. **Effective renewable energy auction implementation requires substantial institutional capacity and commitment at various levels of government**. It is important to have a credible, capable procurer (often the sector regulator or system operator) that is able to coordinate multiple institutions; a credible (if not credit-worthy) and committed off-taker (government utility, intermediary off-taker or distribution companies); and high-level political support. Auction rules and procedures should be clear and evaluation needs to be done transparently. A well-designed auction program that is poorly implemented will struggle to realise effective outcomes.

   Renewable energy auctions in sub-Saharan Africa need to be well resourced to ensure that the procuring entity is able to effectively implement and coordinate the auction programme. Off-taker commitment can be ensured through dedicated equity participation in the project company. Ensuring that projects are procured and built within an electoral cycle can strengthen political commitment.

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Appendix A: Auction Design Analysis Frameworks

IRENA & CEM, (2015) have developed a relatively comprehensive, primarily descriptive framework for analysing renewable energy auctions, analysed within the following four categories:

- *Auction demand*: choice of the auctioned volume, and how it is shared between different technologies and projects.
- *Qualification requirements*: minimum requirements for participation in the auction.
- *Winner selection process*: defines how the supply curve information is collected and based on what criteria the winner is selected.
- *Sellers' liabilities:* rules to ensure high implementation rate of awarded projects in a timely manner.

GIZ, (2015) analyse auction design in terms of trade-offs between specific design choices:

- Prequalification requirements vs. penalty levels
- Technology vs. regional specific requirements
- Auction decision (winner selection criteria): price vs. other criteria
- Information level before and within auctions (pricing rule): sealed bid vs descending clock mechanisms
- Auction award: pay-as-bid vs uniform pricing.
- Price ceiling: defined vs. undefined (or undisclosed)
- Maximum bid volume (project size limits)
- Electricity price risk: the degree to which the project is exposed to electricity market prices.

Shrimali, Konda & Farooquee, (2016) use a risk analysis framework to analyse auctions and their outcomes. Design is analysed in terms of how the following risks are addressed:

- Auction design risk, defined as risks possibly resultling in lack of competition, flawed tariff determination etc.
- Underbidding: the risk of bids being overly aggressive in their pricing.
- Collusion: the risk of bidders strategically working together to achieve higher prices.
- Completion risk: includes all factors that could delay the commissioning of the projects.
- Financial risk: related to the bid placed, off-taker risk, developer credit-worthiness, payment security etc. usually
- Off-taker risk refers to the financial health of the utility taking the power.
- Technology risk refers primarily to the quality of resource assessment studies.

del Río (2017a) provides one of the most comprehensive analytical frameworks, specifically relating auction design elements to various auction "success criteria" (outcomes e.g. effectiveness, support costs, local impacts etc.) (Figure 12 and Table 20). The auction design elements analysed include:

- Auction Volume
- Timing (to bid)
- Diversity (technology, locations, actors, sizes)

- Participating conditions: prequalification requirements, local content
- Types and forms of remuneration: MW/MWh. FIT/FIP
- Selection criteria: price vs. other
- Auction format: single vs. multiple
- Auction type: static (sealed bid) vs. dynamic (descending clock)
- Pricing rules: pay as bid, uniform
- Price ceilings
- Realisation periods
- Penalties

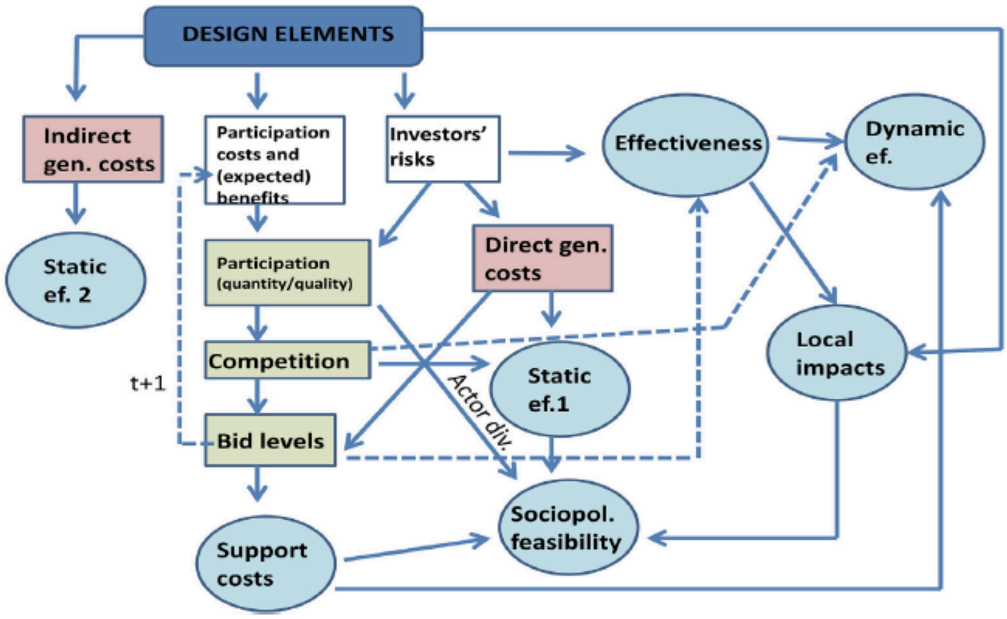

Figure 12: Relating RE auction design elements to outcomes (Source: del Rio, 2017b)

Table 20: Summary of the impact of design elements on the auction success criteria. Source: del Rio, 2017

Design elements		Effect	Support costs	Alloc. EF	Indirect costs	Local impacts	Dyn EF	Actor DIV	Social accept.
1. Volume	Generation-based	+	=	=	+	=	=	=	?
	Budget-based	−	+	=	−	−	−	=	?
	Capacity-based	=	−	=	−	=	+	=	?
	Level too high	+	−	−	=	+	+	+	?
	Level too low	−	+	+	=	−	−	−	?
	Disclosure (vs. non-disclosure)	=	+	=	=	=	+	=	=
2 Periodicity	Long lead times	=	+	+	=	=	=	=	=
	Short lead times	=	−	−	=	=	=	=	=
	Schedule (vs. no schedule)	+	+	+	=	=	+	=	=
3 Diversity (vs. its absence)	Technology-neutral	=	+	+	−	−	−	−	?
	Geographically-neutral	=	+	+	−	?	=	−	?
4 Participation conditions	Improving administrative procedures*	+	+	+	+	+	+	+	+
	Supporting dialog with stakeholders*	+	?	?	=	=	=	=	+
	Prequalification requirements*	+	−	−	=	=	=	−	?
	Prequalification too strong	+	−	−	=	=	=	=	=
	Prequalification too weak	−	+	+	=	=	=	=	=
	LCRs*	=/−	−	−	=	+/=	+	=	?
	Information provision*	=	?	+	=	=	=	+	=/+
5 Support cost conditions	Generation-based (vs. investment-based)	=	−	+	+	=	=	=	=
	FIT	+	+	+	−	=	+	+	+
	FIP fixed	−	−	−	+	=	−	−	−
	FIP sliding	=	=	=	=	=	=	=	=
6 selection criteria	Multicriteria (vs. price-only)	=	−	−	=	+	+/=	=	?
7 auction format	Single-item (vs. multi-item)	−	=	+	=	−	=	−	?
8 auction type	Static (vs. dyn.)	−	+	?	=	=	=	+	+
9 pricing rules	PAB (vs. uniform)	+	−	−	=	=	=	=	?
10 pricing rules	Ceiling prices (vs. their absence).	=	+	+	=	=	=	=	+
	High ceiling prices	+	−	=	=	=	=	=	?
	Low ceiling prices	−	+	=	=	=	=	=	?
	Disclosed (vs. non-disclosed)	=	?	?	=	=	=	=	+
11 Realization period	Too short	+	−	−	=	=	=	=	?
	Too long	−	+	+	=	=	=	=	?
12 penalties	Too high	+	−	−	=	+	=	−	?
	Too low	−	+	+	=	=	=	+	?

Note: The design element scores (+) better than the alternative in the considered criterion; (=) similarly to the alternative (or no change can a priori be expected); (−) worse than the alternative; (?) refers to opposing effects, with an unclear net effect.
* vs. their absence.

Tongsopit et al., (2017) focus on four key areas of auction design in their analysis:

- General design:
  - Whether the auction volume is defined in terms of capacity (MW) or energy (MWh)
  - Whether the auction is technology-specific or technology neutral
  - Frequency of auction rounds
  - Diversity of projects, bidders and locations.
- Auction procedure:
  - Sealed-bid vs. descending clock
  - Pricing rule (uniform vs. pay-as-bid)
  - Evaluation criteria: price vs. multi-criteria
- Conditions for participation
  - Material prequalifications
  - Financial guarantees
  - Price ceilings

- Deadlines and penalties

Winkler, Magosch & Ragwitz, (2018) analyse auction design in terms of:

- *Technology*: whether the auction is technology neutral or provides specific demand bands for specific renewable energy technologies
- *Project size restrictions*
- *Pricing rule*: whether the auction makes use of a sealed bid mechanism, a dynamic descending clock mechanism, or a combination of both.
- *Selection criteria*: whether bids are evaluated on price alone, or other factors as well.
- *Trading of auction awards permitted*: whether bidders are allowed to trade their allocated winning bid awards to other participants
- *Deadline for deployment*: the amount of time between the auction award and the deadline for project commissioning.

They also analyse how prequalification criteria, penalties and guarantees are structured in different auction schemes, in particular paying attention to:

- *Financial viability*: whether and how bidders' and projects' financial strength is assessed.
- *Location access*: whether and how bidders' access to the project site is assessed.
- *Grid access*: whether and how projects' secured access to the grid is assessed.
- *National/regional development*: whether and how projects' national/regional development impacts (e.g. local content) is assessed.
- *Environmental aspects*: whether and how projects' environmental impacts and clearance is assessed.
- *Guarantees*: how projects need to guarantee their performance through e.g. the posting of bid and performance bonds.
- *Penalties*: how projects might be penalised for delays, underbuilding, poor performance.

Hochberg (2018) focuses on the following auction design elements in his analysis of auctions in Brazil and Mexico:

- Auction classification: single vs. multiple unit
- Auction and bid design options: sealed bid vs descending clock; pay-as-bid vs. uniform/clearing price
- Technology specific vs. technology neutral auctions
- Auction products: energy, capacity, reserve, clean energy certificates
- Auction volume: energy (MWh), capacity (MW), budget
- Auction frequency
- Lead times to commercial operation
- Prequalification and penalties
- Grid connections: generator vs. transmission network operator vs. third party
- Balancing responsibilities
- Curtailment risk

Appendix B: Integrated Analysis Framework

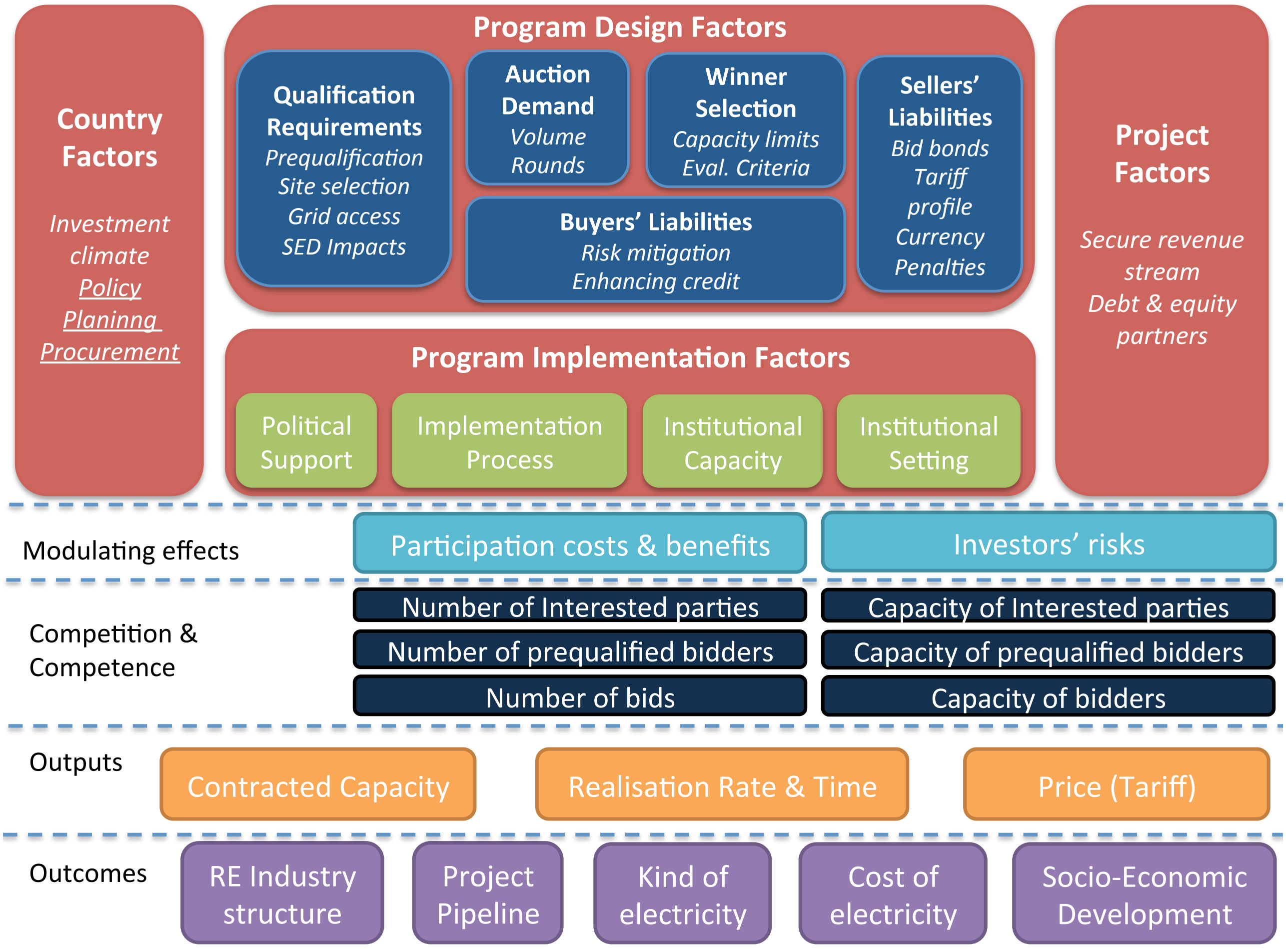

Figure 13: Integrated Analysis Framework

Appendix C: Indexation and Incentive Factors for Argentinian Projects

Table 21: Indexation factors for RE projects in Argentinian auction

ANEXO B
PRECIO ANUAL

Año de Producción	Precio Anual
1	Precio Adjudicado * 1,0171
2	Precio Adjudicado * 1,0344
3	Precio Adjudicado * 1,0521
4	Precio Adjudicado * 1,0701
5	Precio Adjudicado * 1,0883
6	Precio Adjudicado * 1,1069
7	Precio Adjudicado * 1,1258
8	Precio Adjudicado * 1,1450
9	Precio Adjudicado * 1,1646
10	Precio Adjudicado * 1,1845
11	Precio Adjudicado * 1,2047
12	Precio Adjudicado * 1,2253
13	Precio Adjudicado * 1,2462
14	Precio Adjudicado * 1,2675
15	Precio Adjudicado * 1,2891
16	Precio Adjudicado * 1,3111
17	Precio Adjudicado * 1,3335
18	Precio Adjudicado * 1,3563
19	Precio Adjudicado * 1,3794
20	Precio Adjudicado * 1,4030

Table 22: Annual incentive factors for RE projects in Argentinian auction

ANEXO C
FACTOR DE INCENTIVO

Año Calendario	Factor de Incentivo
2017	1,20
2018	1,15
2019	1,15
2020	1,15
2021	1,15
2022	1,10
2023	1,10
2024	1,10
2025	1,05
2026	1,05
2027	1,05
2028	1,00
2029	1,00
2030	1,00
2031	1,00
2032	1,00
2033	0,90
2034	0,90
2035	0,90
2036	0,80
2037	0,80
2038 y posteriores	0,80