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Back to the future? Rethinking auctions for renewable electricity support

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ABSTRACT

The effectiveness and cost-effectiveness of two main types of instruments (feed-in tariffs and quotas with tradable green certificates) have usually been compared in the literature on renewable electricity promotion. Due to negative past experiences with a third instrument (auctions), this instrument has been broadly dismissed in academics and, until recently, also in policy practice. However, and based on an in-depth review of experiences with auction schemes for renewable electricity around the world, this paper argues that some of the problems with auctions in the past can be mitigated with the appropriate design elements and that, indeed, auctions can play an important role in the future implementation of renewable electricity support instruments around the world. The paper provides a proposal for the coherent integration of several design elements.

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1. Introduction

The effectiveness and cost-effectiveness of two main types of instruments, feed-in tariffs (FITs) and quotas with tradable green certificates (TGCs) have usually been compared in the literature on renewable electricity promotion. Effectiveness refers to increases in deployment of renewable electricity (RE) projects. Cost-effectiveness refers to minimisation of generation and support costs (€/MWh) (see [1]). Although usually treated separately, administrative and transaction costs are also part of the cost-effectiveness criterion. Other relevant (and interrelated) criteria include dynamic efficiency concerns (mostly related to the ability of instruments to encourage innovation, technology cost reductions and technological diversity) and social acceptability, which is mostly related to the not-in-my-backyard (NIMBY) phenomena, but also to the total costs of RE support.

The literature has traditionally focused on the comparison between FITs and TGC schemes and has shown that FITs have been more effective and cost-efficient than TGCs in Europe. Support levels minus generation costs (€/MWh) have been greater in countries with TGCs than in countries with FITs and, in the later countries, deployment levels (adjusted by the resource potentials) have also been larger [2–6]. This is (partly) attributed to the high risk and volatility and high TGC prices (e.g., [7]). In addition, mature technologies have been oversupported with TGC schemes, since, typically, all technologies receive the TGC price, which is set by the marginal technology needed to comply with the RE quota [8,9]. In contrast, FITs have provided greater revenue certainty and stability and, since they usually are technology-specific, support is generally better adjusted to generation costs, although this has sometimes not been the case with immature or expensive technologies with large (yet uncertain) potential for cost reductions, such as solar PV. In turn, auctions, although featuring low prices, have not delivered in terms of installed power (see Section 2). Some countries (e.g. Ireland, China, and the UK) have moved from auctions or TGC to FIT-based systems. Auctions have been broadly dismissed in academics and, until recently, also in policy practice.

However, a deeper review does not provide such a clear-cut picture. There are counter-examples of well-functioning TGC systems, such as the Texas Renewable Portfolio Standards (RPS) [10,11], and, although tendering schemes have proven ineffective in the past, this might be related to the design elements chosen (see Sections 2 and 3). In fact, a sensible conclusion of this review is that instrument choice is very context-dependent, but also that the critical element is not the type of instrument, but its design: as usual, the devil is in the details. FIT systems with low support levels resulted in very little installed power (e.g. Greece, see [12]). When the tariff was too high, or adjusted too slowly (PV in Spain) the scheme created a bubble that burst with significant collateral damage.

Auctions and FITs share some advantages. In contrast to TGCs, both ensure a reliable, long-term income for RE investors and they also allow regulators to know in advance the level of support provided. In fact, auctions allow them to know the quantity and the price, and therefore the total cost, whereas FIT only reveal the price, but not the quantity, unless complemented with a quantity cap. Under tendering schemes, the total amount of support provided can be more easily capped than under either FIT or TGCs, allowing investors to compete until the whole budget is gone.[1] FIT schemes for solar PV in the past (Spain, Czech Republic, Italy, among others) led to a dramatic increase in the total costs of support and reduced the social legitimacy for all renewables. Volume (capacity) control is easier under tendering. In addition, auctions deal better with the asymmetric information problem, i.e., they perform better than FITs when trying to know the true level of support required, especially for those technologies with large uncertainties about their cost trends, like offshore wind. Auctions reveal better the reduction in the costs of technologies over time and allow the support to be adapted accordingly. This ideally brings more efficiency into the system by preventing RE producers to be overcompensated. It also encourages competition between RE generators. Banded bidding schemes with pay-as-bid mechanisms allow support to be tied to generation costs, in contrast to TGC schemes (whether banded or not).

An additional argument for auctions is Weitzman's [13], which states that, under uncertainty, when cost curves are rather flat (the usual assumption for most RE technologies, see e.g., [14]), quantity instruments are better than price instruments, since potential mistakes in achieving a predetermined target are smaller.

Unfortunately, these theoretical advantages of auctions come at a cost. Due to the complexity of the bureaucratic procedures, and also to the planning required ahead, auctions have higher transaction costs [15] which, together with uncertainties on the final price and the tendering schedule, deter participation by smaller firms, resulting in a low degree of competition [16] and creating opportunities for market power. In turn, this may eliminate the higher theoretical efficiency of this instrument.

Moreover, if transaction costs are passed through to the final bid price, the cost of support increases. Dynamic efficiency (incentive for innovation) might also be lower than under FITs (see Section 2). Finally, particularly when the bid price is not the only criterion, the auction process is more opaque than the FIT. In turn, the lower cost of participation of FIT has also allowed for a more inclusive distribution of the benefits [17], particularly at the local level [18], thus promoting regional development and typically increasing the social acceptability of this instrument. In contrast, [19] argues that auctions encourage concentration of RES in certain locations and, thus reduces social acceptability. However, this can also happen with FIT, and in fact, auctions can do better here, by incorporating regional–national coordination mechanisms (see Section 4).

One usually cited disadvantage of auctions is that they do not give the right market signals to RE producers, which are therefore not encouraged to produce in peak times, to focus maintenance on lower demand seasons, or, generally, to increase operational efficiency. However, this is not a problem exclusive of auctions, it can also happen with FIT when the tariff is fixed.

Therefore, auctions present advantages and disadvantages compared to FITs and TGCs. However, many of these issues may be minimized by a careful design. In Section 2 the past experiences with auctions are reviewed and the major problems encountered. Accordingly, solutions are offered in Section 3. The aim is thus to identify key design elements of auctions which would likely result in an effective and cost-effective deployment of RE. This will become even more relevant in the future, due to the coming challenges for RE policy, particularly in Europe: the

[1] It can be argued that, since RE generation is capped under TGCs, the total amount of support would also be capped. However, this is not the case, since total support depends on the amount of RE generation times the level of support, which depends on the a priori unknown interactions between the demand and supply sides in the TGC market.

Table 1
Design elements of tendering in several countries.
Source: Own elaboration.

	Scope	Organisation	Penalty	Deadline	Band	Duration (years)	Other	References
Ireland (AER) (1995–2003)	Tender to set support level	Pay-as-bid	No	N.A.	Yes	15	On-shore wind, small-scale hydro, CHP, biomass-landfill gas, biomass-CHP, biomass-anaerobic digestion and offshore wind. Price cap set by the DCMNR. Offers ranked in ascending order of bid price for each type of RES, until there were no more bids of the target capacity or the AER round was met. Requirements for bidders: valid planning permission, Commission for Electricity Regulation authorisation/licence, evidence of site ownership/leasehold interest and a valid grid connection offer from the network operator	[26–29]
U.K. (NFFO) (1990–1998)	Support level	Uniform pricing until 3rd round. Pay-as-bid since	No	Grace period in NFFO 5	Yes	8 (NFFO1 and 2) Up to 21 (NFFO3, 4 and 5)	Under NFFO1 (1990), 2/3 of contracted capacity awarded to plants already generating and payments per kW h agreed between authorities and generators before they entered their contract bids. Since NFFO3 (1994): smaller and larger sized wind farm bands, to enable community projects	[30–33,16,27]
France (EOLE 1996)	Support level (tenders 1996–2004 for wind, 2000–2007 for biomass)	Pay-as-bid	N.A.	N.A.	Only wind initially, other RES > 12 MW since 2000	15 (EOLE) 15–20 (Law 2000–18)	A committee formed by Ministries, the French Environment Agency and EDF selected the winning projects based on the offer price, the industrial and economic interest and environmental impact of the project, the technology used, the opinion of regional committees and the geographic location of the project	[34–38,20]
France (PPI)(1996–2004 for wind, 2000–2007 for biomass)	Support level	Uniform price	Yes	Yes	Yes	10–20		
Denmark (2008-)	Procurement rights	Pay-as-bid	Yes	Yes	Only off-shore	15–20	Long-term plan for the targeted capacity increase. The Energy Agency (DEA) is a “One-stop-shop” for project developers. All Danish offshore wind projects must get permission either through a call for tenders or the open-door procedure. Pre-approved list of sites. Tenders may be cancelled if tender prices are “too” high	[39,20,40]
Italy (2013–)	Support level	N.A.	N.A.	N.A.	Yes	N.A.	Periodical tenders envisaged All RES (except biomass) > 5 MW. Starting price of the auction based on the incentive applying to the last bracket below the installation threshold. Minimum admission requirements for projects and participants	[40]
Latvia (2006–2009)	Procurement rights	FIT	N.A.	N.A.	Yes		Biomass, biogas, solar, wind. Annual tenders from 1 to 31 October	[40]
Lithuania (2009–)	Support level	Pay-as-bid	N.A.	N.A.	Yes	N.A.	Projects > 30 kW. Hydro, wind, biomass, solar PV	[40]

The Netherlands (SDE) (2009–)	Support level	Pay-as-bid.	YES (performance bond of 20M€)	YES (wind farm operational within 5 years)	Wind Offshore	N.A.	The best offers (cost per kW h) are granted subsidy until the budget is gone. Pre-approved list of sites Non-winners will not have a second chance to offer the project as their permits will be cancelled	[20,40]
Portugal (2005–2008)	Support level (wind and biomass) Procurement rights (solar PV and small hydro)	N.A.	N.A.	N.A.	N.A.	N.A.	Wind, small hydro, solar PV and biomass	[40,41]
China (2003–2009)	Support level	First-price sealed-bid	No	No	Wind on-shore > 50 MW	25[a]	70% of the components should be domestically made and the wind turbines should be assembled in China. In 2009 the requirement on local content was abolished. Initially, the lowest bid won the tender. Revision in 2005: bid price was given a 40% weight in deciding winning bids, reduced to 25% in 2006. In 2007, the wining criterion was set as the bid closest to the average bidding price, excluding the highest and lowest bids. In practice, the bidder offering the lowest price and highest local content won the bid ([42,43]). Auctions organised for pre-identified sites	[42–51,107]
India (NSM) (2009–)	Support level	Pay-as-bid	Yes (bid bond: 10,000–50,000 rupees/MW) and other bank guarantees	Yes. Project should be commissioned within 13 (PV) and 28 (solar thermal) months of PPA signing	Solar PV (5–10 MW 1st round, 5–50 MW, 2nd round), and solar thermal (5–100 MW)	25	Total capacity of solar PV projects allocated to a company is limited to 50 MW. Mandatory for all the projects to use crystalline PV cells and modules manufactured in India. Solar thermal: 30% local content in all plants/installations. Thin film PV is exempted. Project developer needs to submit proof of land possession. Target: 22 GW of solar in 2020, rolled out in three phases. Bidders should have a minimum net worth of $3 million	[52–56]
California (RAM1, 2011–)	Support level	Pay-as-bid	Yes ($20/kW of contract capacity for projects < 5 MW, 60$/kW for projects > 5 MW	Yes. The term start date must occur within 18 months of CPUC approval	Solar PV	20	Reverse auction. Projects > 1 MW but < 20 MW. Four rounds in two years. 761 MW will be procured. Demonstration of site control upon submitting bid; demonstration of developer experience; deployment of a commercialized technology; and filed interconnection application prior to bid submission. Existing capacity eligible for support. Seller concentration rule	[57–59]
Québec (2003–)	Support level	Pay-as-bid	Yes	YES (delivery between 2013 and 2015)	Wind on-shore (< 25 MW)	20 years (3rd call)	Minimum 30% to 60% regional content required for each wind farm. Winning bidders should obtain the administrative permits after the contracts have been signed. Criteria: 30% cost of electricity, 70% non-monetary criteria (feasibility of the project, experience and financial capacity of bidders and regional and regional content. Wind measurement requirements for bidders	[60–63]
Brazil (2007–)	Support level	Descending-clock auction + pay-as-bid sealed-bid	Yes (level depending on deviation from the	Yes (first delivery in July-2012)	Yes	20 (wind), 20 (biomass), 30 (hydro)	Wind, cogeneration of sugarcane bagasse, small hydro. Requirement of granted environmental licenses prior to participation in auctions. Grid access	[64,25,24,6,6-5,107]

Table 1 (*continued*)

	Scope	Organisation	Penalty	Deadline	Band	Duration (years)	Other	References
			electricity contracted)				studies showing a feasible and available connection point. New wind turbines must be used and wind measurement requirements for bidders. If the difference between the lowest bid and other bids is > than 5%, the submitter of the lowest bid wins the tender. If the difference is ≤ 5%, the auctioneer may set minimum amounts to be submitted between the bids. The lowest bid wins the tender. 60% local content required	
Argentina (2010)	Support level	Pay-as-bid	Yes (1000$ per MW of capacity contracted)	Yes (capacity should be built in two years)	Yes (1–50 MW)	15	Wind, geothermal, biomass, solar and small hydro. Equipment should mostly be manufactured or assembled in Argentina. Penalty for non-compliance with this local content requirement	[66–69,6,70]
Uruguay (2009)	Support level	Successful bidders will receive the average weighted bid price of successful tenders	N.A.	Yes (projects must come online within three years)	On-shore wind (30 MW – 50 MW)	15	Requirement for previous experience (in practice: incorporation of foreign operators). At least 20% of the total investment should correspond to national components. A two-round auction system: first participants bid without transmission costs and they have to rebid with such costs. A single bidder cannot contract more than 50 MW. Reserve price: 65$/MW h	[67,71–75]
Peru (2009)	Support level	Pay-as-bid sealed-bid	Yes (100,000/M guarantees required)	Yes (projects should start production before 1/1/2013)	Yes	20	Small hydro, wind, solar (PV and CSP), biogas and biomass. Bi-annual tenders. Reserve prices were not revealed in the first call ex-ante in order to avoid collusion. They were published ex-ante in the second call. Tenders will take place at least every two years. No local content was required. The bidder must submit proof of a range of technical requirements, provide resource assessments for a period not less than one year and submit a pre-feasibility study for each project Use of performance bonds deposited by the project developers in order to secure completion of projects Reserve prices were set by the regulator taking into account the type of technology, investment, operating and grid-connection costs and an annual internal rate of return of 12% over 20 years. The ceiling price is only revealed if it is exceeded by at least one bid received in the case where the total volume auctioned is not contracted in a complete auction round	[76–79,66,67,80,-107,110]
South Africa	Support level	Pay-as-bid sealed-bid auction	Not	Yes	Yes (> 1 MW for all projects and < 50 MW for CSP and	20	Wind, solar and hydro. Two phases: the pre-qualification phase and the evaluation phase. Bidders have to meet minimum criteria related to legal, financial, technical	[107,109]

					< 140 MW for wind)		and environmental requirements. Assessment criteria: Price (70%), contribution to economic development including local content (30%). Local content: currently 35%, increasing to 45% over time. The economic development requirements included 17 sets of minimum thresholds and targets. Guarantees had to be posted (US$12,500/ MW). Up to five discrete bidding rounds were envisaged, at six month intervals. Volume caps applied in the second round (not in the first one). In the first round, the ceiling prices for each technology were based on the FIT levels set under the preceding FIT scheme and they were disclosed to the public. They were undisclosed in the second round	
Morocco	Support level	First-price sealed-bid	Yes (for delays and underperformance)	Yes (2015 for CSP)	Yes	20 (wind), 25 (solar)	Technology-specific (wind on-shore, solar and hydro) and site-specific (designated locations) auctions. Two phases: the pre-qualification phase and the evaluation phase. The requirements for the prequalification include the project developers' financial capacity, access to finance and technical experience. Preference is given to regional or national companies. Local content requirement (30% of the plant capital cost for solar projects). Guarantee paid at signature of PPA. Public-private partnership model	[107]

[a] For the first 30,000 full-load hours (10 to 15 years, based on average Chinese wind resources), the project owner will receive their bid price as the FIT. After 30,000 full load hours, the project owner will receive the average local FIT on the power market at that time [42]).

significant increase expected for the share of RE in power systems [21], and the willingness to harmonise or at least coordinate support policies. The first one will amplify the two arguably major problems of FIT systems: overshooting the tariff, and therefore the RE target and the total cost of the system; and the lack of coordination between national governments (who set the tariff) and regional ones (who usually have the final say in permitting, and also collect some of the benefits of RE installation), which usually results in a loss of efficiency [22]. By introducing a price-discovery element and a physical cap, auctions help control the total cost of RE support; and they can also integrate coordination concerns into the auction design. The debate on the harmonization of RE policies in Europe will add another layer to this coordination problem.

Accordingly, the paper is structured as follows. Section 2 reviews past experiences with RE auctions, identifying their main problems. The causes behind these problems are analysed in Section 3 in order to understand the role of design elements as a determinant and mitigation factor of those problems. Based on this analysis, Section 4 presents a proposal for the design of RE auctions, which addresses all the critical elements. Section 5 concludes.

2. Past and present experiences with auctions: Advantages and drawbacks

Auctions have been used in recent times in an increasing number of countries, either as the main support scheme or for specific technologies. It is being used in some EU countries to set the support levels under FITs or FIPs (see [102]). According to [103], auctions are currently used in 45 countries, up from 21 countries in 2009 [104]. They have recently been considered as a very attractive instrument by the European Commission, which regards auctions as the most cost-efficient instrument, if well-designed [105].

Therefore, there are several experiences with RE auctions from which to learn.[2] Auctions have been used to promote RE development in several countries in Europe and Latin America, Quebec, California, India and China. Tables 1 and 2 summarize the main results and design elements of those experiences. There are other experiences with tendering schemes for RE, but they are too recent and, to our knowledge, there has not been any analysis on their functioning. South Africa switched from a FIT to tenders in 2011. Egypt relies on tenders for large scale onshore wind. Turkey, Indonesia (geothermal), Sri Lanka (large scale RE), Saudi Arabia, Algeria and Chile are other countries which have recently switched or are on the way to switch to tenders [6,24,25].

The design elements of tenders vary significantly across countries. They refer to several aspects:

- *Scope*. Whether the bidding procedure is used to set the support level or whether the support level is set by a different instrument (i.e., FITs) and auctions are used to grant procurement rights to deploy the project. This paper focuses on tendering schemes used to set the support levels.
- *Organisation of the tender*. Support levels in the tendering procedure may be set in different ways, i.e., either uniform pricing, pay-as-bid, Vickrey or median price auctions. Under uniform pricing, the strike price is set by the last bid needed to meet the quota, and all winners receive this price. Under pay-as-bid, the strike price sets the amount of generation eligible for support, but winners receive their bid. Under Vickrey auctions, the winner receives the second best price; the second receives a third best price etc. In median price bids, the median bid price sets the strike price.
- *Penalties for non-compliance and deadlines*. Penalties can be either be a fixed amount (i.e., the performance bond in the Netherlands) or be modulated by the delay (as in Denmark and India). They can be set per MW (as in Quebec, India, Peru and Argentina), per kW h (Denmark) or as a percentage of the investment made (Brazil).
- *Banding*. Tenders may be technology-neutral (i.e., all technologies are included in the same tender) or they may be technology-specific, with several bands.
- *Duration of the project.* The length of support affects investors' risks and profitability.
- Other relevant design elements include eligible technologies, requirements for administrative authorizations, minimum or maximum project sizes, maximum (reserve) prices, local content requirements and a tender schedule.

2.1. Positive aspects from existing experiences

2.1.1. Comparatively low support prices

Although there is a lack of data and international comparisons, auctions have generally delivered prices below other countries. This is the case of Brazil [25], France [34,36,37] and U.K. [20,30], Ireland [26,28] and China [44], although not in Argentina, which has had comparatively higher prices for wind auctions than in Brazil [6,66], despite similar wind resource potentials [67]. The price bids in South Africa were high [106].

2.1.2. Reductions of support levels over time

Support has been reduced over time with tenders [16]. This was certainly the case under the non fossil fuel obligation (NFFO) [81]. There is similar evidence in Portugal [41], Peru, Uruguay and Brazil [67], but not in China. Although a greater level of competition is often assumed for tenders, competition between the project developers has not been significant in the U.K. [17]. Butler and Neuhoff [16] observe that the long and non-predictable intervals between NFFO rounds inhibited the development of a competitive market.

2.2. Negative aspects from existing experiences

2.2.1. Low effectiveness

Ineffectiveness refers to the electricity commissioned being lower than the objective initially set, as in Ireland or to the contracted capacity not being built, as in the U.K., France or Nova Scotia (not reported in the table). There is also recent evidence of ineffectiveness (not in terms of contracted capacity but regarding projects actually being built) in Portugal, Peru and Brazil (see references in Table 2). However, it is too early to tell whether the contracted capacity has led to actual deployment of projects in the recent experiences with tendering.

Several factors may be the cause of ineffectiveness. In the U.K., the poor installation rate may be attributed to planning restrictions and to the low prices in the bidding procedure, or "underbidding" [17,18,82]. Those project developers offering the lowest prices were also those with a lower probability to finance the project [16]. Since project developers had a 5-year "grace

[2] Auctions are not exclusive of RE promotion and, therefore, the field for learning is much broader. Indeed, auctions have been used extensively to allocate public goods such as telecommunication licenses, and also for the procurement of energy. Latin America in particular is a region where auctions have been used recently to a large extent, and for which good assessments of their performance exist [23]. Indeed, auctions have been very effective for conventional energy. Why not for RE? These broader applications of auctions will also inform our analysis.

Table 2
Main results of tendering schemes for RE around the world.
Source: Own elaboration from the references in Table 1.

Country	Effectiveness	Cost-effectiveness	Other impacts: administrative costs, technology diversity, industrial and local impacts
Ireland (AER)	In all rounds, the electricity commissioned was lower than the objective initially set (built projects were 43% in relation to targets, 33% in relation to MW awarded)		Poor quality of equipment. No biomass-anaerobic digestion or offshore wind projects finally commissioned. High administrative costs reported (administration time around 1 year)
U.K. (NFFO)	Total amount of contracted capacity in all rounds: 3638.9 MW. Installed capacity initially contracted: 960 MW	The price paid under NFFOs 3, 4 and 5 decreased after each auction, the average being 3.3p/kW h (wholesale electricity price: 2.6 p/kW h)	Low technological diversity: Landfill-gas and wind on-shore projects dominated
France (EOLE)	Only 70 MW were built (20% of those winning the tenders)	Avg. price of 5.2 ECU cents in first round, higher than the NFFO4 round organized in parallel (but wind resources are better in the UK)	Diversity concerning the location of projects was emphasized. Local aspects and public acceptance were seen as important
France (PPI)	Construction expected to be completed by 2012. Delays in the calls for tenders for offshore wind	Avg. FIT obtained during the 2006 call for tender: 128 €/MW h. Avg. FIT in the 2009 call for tender: 45 €/MW h	
Portugal (2005–2008)	Positive impact on the contracting of biomass and wind capacity, but most of it has not been built	Price for wind and biomass was lower than the previous FIT	Project concentration regarding wind, leading to NIMBY initially and public opposition
China Wind Farm Concession Program (2003–2009)	As of 2008, a total of 8800 MW of wind energy contracted in five rounds, expected to come on-line by 2010. Significant delays in connecting to the grid	Contract prices (in $/MW h): 2003 (52.7, 61.9); 2004 (46.1–62.7); 2005 (56.3–73.1); 2006 (52.6–62.7); 2007 (59.1–69.5) No reductions in those prices over time can be observed due to changes in the design of the scheme in order to reduce underbidding and support the development of the local industry	A total of 59 participants, split as follows: 13 (1st round), 8 (2nd), 12 (3rd) and 26 (4th). Administrative costs and time have been low, since it is a negotiated process. Low prices and pressing deadlines have pushed the manufacturing sector to produce poor quality products, with capacity factors of wind farms using domestic technology 5% to 20% lower than those using foreign technology. Most turbines are imported
India	Contracted solar capacity: 650 MW (1st round, 2010), 350 MW (2nd round, 2011). 506.9 MW cumulative installed capacity as of April 2012. Of this capacity, 203.4 MW was commissioned under the NSM. However, by early 2012, the Indian government had fined 14 PV project developers for failing to meet their commissioning deadlines and warned another 14	Successful in driving down prices: Average prices in round one (2010): 12.25 rupees/kW h, Round two (2011): 8.77 rupees/kW h (17.36–12.43€cent/kW h), about half the fixed price at which the government was initially willing to buy power (15.4 rupees)	Only marginally effective in creating a vibrant domestic manufacturing base. Strong thin film bias. Great geographical concentration. · 3/4 of MWs are contracted in Rajasthan
Quebec (2005–2009)	First tender (2005): 990 MW of wind allocated, out of 1000 MW initially tendered. Second call (2008): 2004 MW of contracted capacity. Electricity production will start between 2011 and 2015	Relatively low prices, but increasing in the three successive tenders (8.3¢/kW h, 10.5¢/kW h and 11.5¢/kW h, respectively	Several component manufacturing and assembly plants for wind turbines have been built in eastern Québec
Brazil (2007–2011)	First auction (2007): unexpectedly low participation. 2009 auction (only wind): 1800 MW contracted. 2010 auction: wind (2050 MW), sugarcane cogeneration (713 MW), and small hydro plants (132 MW). 2011 auction: wind (976 MW, 81% of total capacity contracted). The construction of some of the first RE plants is already delayed	2009 auction: 77 US$/MW h (wind). 2010 auction: US $75/MW h (wind), US$82/MW h (biomass) and US$81/MW h (small hydro), 42% lower than the FITs under the earlier PROINFA scheme. 2011 auction: $56.83/MW h (wind). Bid prices for wind in the lower bound of other countries. Avg. winning prices below 5% to 26% of the reserve price	A diverse mix of investors won the contracts. Installation of three wind turbine factories (growth of the domestic wind industry). No solar PV being promoted
Argentina (2010–)	895 MW of contracted capacity, 754 MW (wind), 110 MW (biomass), 10 MW (small hydro) and 20 MW (solar)	Weighted average price of all bids fixed as auction cutting price: 136 US$/MW h (wind), 259–297$/MW h (biomass), 150–180 (small hydro) and 547–598 (solar PV)	All RE technologies except large hydro were represented. Minimum required capacity shares in the tender. Wind: 84% of this capacity
Uruguay (2010–)	2010 Tender: auction to acquire 150 MW of wind power expected to come online by 2014. 2011 tender: 192 MW contracted	2010 Tender: prices around 85 US$/MW h. 2011 tender: tender price: 63$/MW h, i.e., steep reduction	
Peru (2010–)	Success rate (volumes contracted over volumes auctioned): 2009/2010 call: Small hydro (37%), solar PV (96%), wind (178%), biomass and waste (17%); 2011 call: Small hydro (100%), solar PV (100%), wind (100%), biomass and waste (2%). Low ceiling prices account for not meeting the pre-determined volumes in the first round [107]	2010 tender: Average prices: 80 US$/MW h (wind), 60 US$/MW h (small hydro), 221 US$/MW h (solar PV), 63 US$/MW h (biomass). These prices were 47% (biomass), 27% (wind) and 18% (solar and small hydro) lower than the price cap. This could be due to the high level of competition among bidders, and the ceiling price being kept undisclosed. 2011 tender prices: 69 US$/MW h (wind), 47–56 US$/MW h (small hydro), 119 US$/MW h (solar PV) and 63 US$/MW h (biomass). No price caps in the 2011 call. Therefore, prices were reduced over time (except for biomass)	Winning investors: mostly foreign private companies
South Africa	Volumes auctioned in round 1 (all technologies): 3625 MW Volumes contracted in round 1 (all technologies): 1415 MW	The average prices of the bids were relatively high in the first round (US$0.143/kW h for wind, US$0.345/kW h for solar PV and US$0.38/kW h for CSP). The lack of competition owning to uncapped allocation, which failed to create pressure on the bidders to reduce their	No MW auctioned for biomass, biogas and landfill gas were contracted, probably due to low prices. The transaction costs for the auction program were high for both the government

Table 2 (*continued*)

Country	Effectiveness	Cost-effectiveness	Other impacts: administrative costs, technology diversity, industrial and local impacts
	Volumes auctioned in round 1 (all technologies): 1275 MW Volumes contracted in round 1 (all technologies): 1043 MW	offered price, the local content and economic development criteria are reasons mentioned in the literature for the relatively high prices (compared to other countries). Prices in the second round were much more competitive, falling on average by 20 percent for wind and 40 percent for solar PV. The price for CSP fell by 7 percent. The disclosure of price ceilings in the first round (and not in the second one), the slightly decreased price ceilings for each technology in the second round, the allocation of a capacity limit for each technology and high transaction costs in terms of advisers and financing (which fell in round two, along with equipment prices) are reasons behind the reduction of bid prices between the first and the second round. The low prices in the second round raised concerns for the Eskom Single Buyer Office that winning bidders may not be economically viable	and the bidders (and higher than for a REFIT program)
Morocco	Wind. Volumes auctioned in 2011: 150 MW. Volumes contracted: 150 MW Solar. Volumes auctioned in 2012: 160 MW. Volumes contracted: 160 MW	No information on bid prices for wind is available. Regarding solar CSP, the winner bid had an average price of USD 0.19/kW h, 22% lower than the next competing bidder	Only wind and solar are promoted

period" in order to initiate their projects, some of them based their bids on the expected cost reductions in the following 5 years. Since expectations on cost reductions were not met, and there was no penalty for failing to develop the project, many developers failed to build the project [81,18]. Ref. [18] argues that the lack of information on the schedule for the next rounds in the U.K. was also detrimental for RE deployment. There is also evidence that underbidding is causing some delays in Brazil [25] and India [55,56].

The uncertainty on the financial viability of the project at the moment of the tender under the French EOLE2005 programme, which promoted wind energy between 1996 and 2004, led to difficulties for project developers. When the projects were presented to the tender, their economic viability depended on several uncertain factors (especially, the availability of materials) which made it difficult to access financing [36]. This also happened in Ireland [26]. Furthermore, there was some uncertainty in France with respect to the profitability of projects, since developers incurred in high preparation costs [38]. Ref. [106] argues that the initial high risks for bidders led to high risks premiums for offshore wind in Denmark and biomass in France. However, while these risks were high before the bidding procedure, after winning the tender a project developer had certainty about his operating income and could use and negotiate favourable financing terms.

2.2.2. Low technological diversity

The instrument has shown a limited ability to promote technologies with different maturity levels. The more expensive technologies were not promoted in the U.K. [17]: Waste-to-energy and on-shore wind dominated [31]. No biomass-anaerobic digestion or offshore wind projects were commissioned in the Irish Alternative Energy Requirement (AER) programme [26]. This is also the case in Brazil [25] with solar PV and Argentina [6,66]. Technology neutrality leads to only a few technologies and a few locations. However, this problem may be circumvented with bands, i.e., with technology-specific auctions.

2.2.3. Modest impacts on the early stages of the innovation process

The evidence in this respect is quite thin, although no country that has used bidding exclusively has developed a vibrant and sustainable manufacturing sector. Butler and Neuhoff [16] suggest that the greater certainty on the return on investments in countries with FITs allows producers to invest more in R&D and consolidate their industrial base with respect to countries with tendering.

2.2.4. High transaction and administrative costs

Although empirical evidence (i.e., data) is scarce, there is some consensus that transaction costs were high in Ireland [26,28], U.K. [88,38] and France [36]. This is due to the complexity of bidding procedures, the lead times between proposing bids and the start of generation and the project planning before the bidding procedure [14]. Administrative costs have been reported to be high in EOLE [34], AER [26,84,85] and NFFO [32,33], although in China they were low [20,49]. They are likely to be high in the Danish tendering scheme for offshore wind, given the strong role played by the administration in controlling the location, time and amount of new capacity [20]. However, administrative costs may be minimized if similar mechanisms are in place. For example, in Colombia, where a tendering system for capacity payments exists, administrative costs have been estimated to be lower than $0.5/MW h [86].

2.2.5. Low social acceptability

It has been argued that the high degree of competition introduced by tendering led to pressure for developers to seek sites with high wind speeds, encouraging concentration of RE in certain locations, aggravating the NIMBY syndrome and increasing the hurdles encountered in obtaining planning permissions, as shown by [41] for Portugal and [31] and [87] for the U.K. The low level of acceptability is partly attributed to the disincentive for the participation of small actors [82,105], as shown in the case of Peru [107]. However, this problem has also occurred in countries using FITs (i.e., regions of Valencia and Catalonia in Spain) and, as with other problems, it can be mitigated with appropriate design elements, an issue addressed in the next section. On the other hand, the volume and budget control provided by auctions with

Table 3
Relating problems, factors behind those problems and design elements.
Source: Own elaboration.

Problem	Factors	Design elements
Effectiveness	– Sporadic, intermittent, stop-and-go bidding rounds – Too short support period – Support for existing plants – Underbidding (overestimation of capacity factors), strategic behaviour in bidding – Difficulties in the planning procedure and planning period required ahead (risks for investors) – Developers are able to back-off without consequences (no guarantees required and no deadlines for constructing the project) – Inherent incentive to concentrate wind farms in specific locations (affecting social acceptability) – Long period between the resolution of the bidding procedure and starting construction	– Irregular and unknown auction schedules – Short-term contracts – Existing plants allowed to participate – Information failure, particularly for small bidders (underbidding) – Need to obtain planning permits after winning the auction – No regional coordination – Lack of penalties and deadlines for constructing the project
Low social acceptability	– Inherent incentive to concentrate wind farms in specific locations (affecting social acceptability) – Total costs may not be capped	– No regional coordination – Need to obtain construction permits after winning the auction
Low level of competition, low participation of small actors, market power (cost-efficiency negatively affected)	– Information failure for small bidders – Difficult access to finance (especially for small actors) – Too many bands with respect to total tendering capacity may increase the risk of market power – High guarantees required would deter small bidders	– High uncertainty and administrative costs that deter participation from small bidders – Auction design not optimized to minimize market power – Inadequate design of banding – High risk for the government (non-compliance) and investors
Total costs	Total costs may not be capped	Auction design
Low level of technological diversity. Small influence on innovation in immature technologies	Cheapest technologies get most of the installed power	No banding
High administrative and transaction costs	Difficulties in the planning procedure and planning period required ahead (risks for investors)	Design of the auction and administrative process, provision of information

respect to the escalating costs experienced under FITs due to capacity booms (see, e.g., the case of solar PV in Spain, [108]) makes auctions more attractive for policy makers than FITs.

3. Factors behind these problems

Table 3 relates the main causes (factors) to the problems discussed in the previous section and suggests design elements that may be behind these factors. The link between problems and factors is discussed below, leaving the discussion on design elements for the next section.

A single factor is unlikely to trigger the negative effects shown in the table and some factors may affect more than one problem, suggesting that some criteria or problems are interrelated. Finally, some problems are not the sole influence of tendering schemes, but are common to other RE support schemes (for example, the small influence on innovation in immature technologies, which requires public R&D support).

Below, the main factors highlighted in the table are reviewed. A proposal for design elements that addresses these factors is presented in Section 4.

(1) *Sporadic, intermittent, stop-and-go bidding rounds*. The intermittent nature of the calls for tenders results in stop-and-go tender schemes not conducive to stable conditions [89], leading to greater risks for investors and possibly lower levels of participation, greater bid prices and negative impacts on the RE supply chain. For example, in the tranche-oriented system of the NFFO, a call for bids was made every 2 years and it was unknown when the next NFFO round would take place.

(2) *Too short support period.* Initially, tenders were granted based on short-term contracts. This led to high prices per kWh so that projects could recoup their capital within the short time-span (higher cost of finance). While the cost per kWh may have been high, the total amount of support may not, since support is received over a short period. If access to finance is more difficult for smaller actors, these will be more affected by the too short support periods.

(3) *Contracted capacity awarded to existing plants.* Obviously, if contracts are awarded to existing plants (as in NFFO1), there would be fewer resources left for new installations.

(4) *Underbidding (overestimation of capacity factors), strategic behaviour in bidding.* A tender scheme creates competition between bidders and, thus, inherently encourages them to bid as low as possible. However, the evidence in France, Portugal, Nova Scotia, U.K., India, China and Brazil shows that they may overestimate their capacity factors, underestimate their costs (because, for example material costs turn out to be higher than they were expected to be) and follow strategic behaviour in bidding (i.e., win the bid, then adjust).[3] The low bids in the

[3] According to ([84], p. 98), submitted projects under the French EOLE programme applied as low as 51€/MWh, whereas the EU Commission evaluates the French long-term minimal generation cost at 50€/MW h [89]. Ref. [34] notes that U.K. projects were bid at low prices to win contracts and, then, when it was

case of China were related to the especial characteristics of this central-planned economy. Successful bidders were state-owned enterprises (SOEs) which were prepared to sacrifice short-term profitability to win the projects. The principle for RES development investment from Chinese SOE was not for profits, but to comply with government targets [42]. Some bidders intentionally underestimated operating costs to get a lower grid-connection price compared to other bidders [47,90]. Underbidding results in delays and projects finally not being built. It is generally coupled with other factors such as lack of penalties or lenient ones, which allows investors to walk away, and long "grace periods" between winning the bid and being required to start construction, which increases the probability that "uncertain" factors such as increases in material costs play a role, discouraging investments.

(5) *Difficulties in the planning/permitting procedure.* Difficulties in obtaining planning and other permits increase investors' risks (especially the smaller ones) and transaction costs, acting as a deterrent to investors. Although they are common to other instruments, these problems are aggravated under tenders if the bidding procedure and the granting of administrative permits are not coordinated.

(6) *Developers are able to back-off without consequences.* If there are no deadlines for project construction and no penalties if the project is delayed or not built, then, together with the other factors, the support scheme would be ineffective. Successful projects not being built block projects which have not been successful in the tender.

(7) *The inherent incentive to concentrate power plants in specific locations* affects social acceptability by leading to NIMBY phenomena, feeding back negatively to the granting of authorisations.

(8) *Inappropriate banding.* A single band discourages technological diversity, since only the mature technologies are promoted. But too many bands may lead to a lack of qualified bidders in each band and too few actors, reducing the benefits of competition. It may also lead to market power.

(9) *Unfriendly for small projects and actors.* A major empirical lesson of tenders is that they are unsuitable for small installations and smaller actors. Competition may thus be affected. It has been argued that some of the aforementioned factors and, namely, information failure and difficult access to finance, have a disproportionately negative impact on small actors and, thus, that the instrument is not suitable for small actors, suggesting that smaller projects should be promoted with a different instrument [19,91]. It is difficult to tell a priori if encouraging large installation or actors instead of small ones is a negative aspect. Although it is explicitly assumed to be so in the specialised literature, size is a double-edged sword. Larger installations facilitate economies of scale in production but a model of distributed generation calls for smaller plants scattered around the territory. Furthermore, some RE projects are inherently large (offshore wind and concentrated solar power) and tenders may be particularly suitable for these technologies. In contrast, smaller projects may be more appropriately promoted with another instrument.

(*footnote continued*)
realized they were not sufficiently profitable, many bidders walked away. In Brazil, the low prices that resulted from the reserve energy auctions to deploy wind-based generation have raised the fear of non-implementation of projects because of financial insolvency. The 2009 auction did not result in a clear correlation between capacity factors and prices [25]. In China, the average resulting price of the tenders has been for some analysts too low (Table 2). In India, very aggressive bid prices have caused fears that many projects may not be commissioned [54,55,92]. In Portugal, support levels were too low for wind and biomass projects to be profitable and these were not built [41]. Underbidding has also occurred in Nova Scotia [83].

4. A revised design for RE auctions. Basic elements of a proposal

The aim of this section is to address the problems observed in the past implementations of auctions for RE support, and propose an integrated package of design elements that would tackle these problems.

4.1. Auction design

There is a large literature on how auctions should be designed to be efficient and effective.[4] There are two main alternatives to design the auction process. Under sealed-bid auctions, bidders do not have information on other bids. Under descending-clock ones, bidders react dynamically to other bids [106]. The RE auction should be a hybrid one: a descending-clock phase which will allow for price discovery and minimizes the winner's curse followed by a sealed-bid one which prevents collusion. This also induces a higher participation rate (and probability of success) for small participants [93] and addresses simultaneously the problem of social acceptability. This indeed has been the system chosen for RE auctions in Brazil. More sophisticated, strategy-proof mechanisms might be included (see e.g. [94]).

The auction will include potential renewable energy sites, as in the case of wind on-shore in China, where auctions were organised for pre-identified sites. Bidders will submit a price per MWh of electricity produced from every site. The bid must also include an amount of electricity to be produced annually, although the total production does not need to be binding, or can be expressed as a range. Although having site-specific bids may reduce the overall efficiency of the system, since it may decrease competition and lose some of the cost-cutting that would be facilitated by a greater flexibility, site-specificity is an important feature in order to reduce uncertainty and to achieve good regional coordination (see below).

Once bids are submitted, the auction moves from site-specificity to a global approach: The number of projects awarded is decided globally. And it is not based on the total energy procured or the sites auctioned, but on the total budget available in the overall tender, i.e., bidders do not compete for the energy, but for the money. This mitigates the concerns of policy makers regarding the uncertainty about the total costs of RE support, which is very convenient for budgetary purposes but also for allocating that cost to e.g. electricity consumers. This issue will become even more relevant with increasing RE penetration.

An alternative for controlling the cost (and also to deal with collusive behaviour) would be to set a reserve price. However, this usually biases the results of the auction if this price is disclosed as in South Africa [109] and Peru [107] since bidders tend to propose relatively high bids which are marginally close to that price. Therefore, if implemented, reserve prices should not be disclosed. In addition, reserve prices might be set either too high or too low. Setting the reserve price at an "appropriate" level is not a trivial exercise and bears the risk of falling under the asymmetric information problem which is a main feature of FITs.

Bids would be ordered from cheapest to most expensive, and would be awarded for all sites until the total budget available is gone. Every winning producer receives the amount he bids for a

[4] This literature will not be reviewed here. Interested readers are directed to [95,96] for an overview of general and natural resource auctions, respectively, and to [23] for a more energy-sector-specific analysis.

specific site, i.e., it is a pay-as-bid system. Unlike uniform pricing, pay-as-bid allows support to be adjusted to the costs of different bidders, reducing the overall policy costs.

4.2. Technology-specific tenders (bands)

The total budget is allocated to different technologies and, thus, technology-specific caps on the total amount of support are available. This mitigates the concerns that a single technology band may lead to a low deployment level for immature technologies. Bands also have disadvantages: they lead to a fragmentation of the tendering process and, thus, lower competition levels. Criteria for setting quotas for different technologies should be defined.

4.3. Pre-approved list of technology-specific RE sites

The list of technology-specific RE sites should have several characteristics:

– It should have been agreed by national and regional/local governments.[5] Regional governments could present their candidates, and then decide jointly how to allocate the total amount of sites to auction for each region, in order to keep a reasonable geographical balance. If the budget comes from the national government, this decision will clearly involve a regional distribution of funds, so regional governments will have an incentive to maximize the installed power allocated to them. Thus, it is important for the national government to participate, and eventually, have the final say, in order to control the location of sites and the total amount of capacity to be deployed. Indeed, the lack of coordination of the national and regional levels has proven to be a problem in a country with a quasi-federal structure such as Spain (see [22]).
– When the final list is decided, regions should grant a pre-approval for the installation license. This removes most of the uncertainty in the construction process, and also maximizes the likelihood that the projects will actually be built.
– The list should also be approved by the Transport System Operator which may introduce considerations regarding the cost of RE integration into the grid, and also take these sites into account for grid planning.

This pre-approved list, and the volume of information that accompanies it (including resource measurements possibly supported by the government, ideally conducted by independent, verified bodies), will minimize transaction and administrative costs since, then, the processes is much more streamlined before and after the auction. It will also remove part of the information failure affecting smaller bidders, and also the uncertainties in estimating the revenues of the RE plants. It addresses a main source of ineffectiveness in previous experiences, i.e., the granting of permits. This is different to requiring bidders to have their sites previously approved, which increases participation costs, because bidders must incur significant costs to get permits, which are sunk costs if they do not win the auction. In our proposal, the cost falls on the auctioning entity. Thus, risks are minimized and not transferred to bidders.

4.4. Auction schedule

In order to avoid stop-and-go problems, a schedule for regular auctions to be organised by the regulator should be published with sufficient anticipation (i.e., 3 years, depending on the technology). This provides more certainty to investors, avoids stop-and-go of the renewable industry and facilitates the budgeting and allocation of RE support costs. A long-term, regular and high-frequency schedule for auctions gives certainty to investors and technology developers about a future market for their technology, encouraging technological progress. To address the risk of underachievement, monitoring provisions should be included, allowing changes in the design to dynamically correct deviations from the expected goal.

4.5. Minimum number of bidders

This may be required to prevent that, if there is only a single bidder, he captures the whole budget with a very high bidding price (in the absence of a reserve price) and relatively small deployment (generation). Seller concentration rules might be implemented as done in California, India and Portugal. In California, one seller could not contract for more than 50% of capacity or revenue cap in each auction (across all bids) [98]. In Portugal successful bidder in one round cannot participate in the next round [41]. In India, the total capacity of solar PV projects to be allocated to a company is limited to 50 MW. The number or the size of bids per bidders may be limited. Another alternative would be to cancel the biding procedure if the bidding price is excessively high (as done in Denmark for offshore wind), but this would involve an arbitrary administrative decision, entailing substantial investors' risks. On the other hand, imposing qualification requirements and stringent non-compliance rules would deter potential non-compliers from participating in the auction, reducing the risk of underbidding [107].

4.6. Contracts awarded

Each project winner will sign a long-term contract (typically 10 to 20 years, depending on the technology) with the relevant entity (be it the market operator, the system operator, or the utility). Long-term contracts make it easier to raise finance and may lead to lower bid prices. For example, a longer duration period in NFFO3 (15 years) with respect to the NFFO2 was one of the factors leading to a reduction in the price, since the capital repayment costs per kWh decreased [20]. Contracts may differ depending on the technology: when it is interesting (and feasible) for the technology to receive the electricity market signal so that it can improve its operational efficiency, then it could be a contract-for-differences [97], cleared at an annual basis. This way the RE producer ensures receiving a guaranteed income, while simultaneously encouraging him/her to operate when the system needs it most (i.e., at peak times, when electricity prices are higher). An alternative is to use a fixed tariff with the obligation to pay balancing costs [99], or as a take-or-pay contract [100].

The contracts should include minimum and maximum levels of electricity generation (as in Brazil), again to ensure a correct performance and integration into the system.

4.7. Penalties for non-compliance

One of the usual problems of existing auction schemes is that, after winning the auction, many projects were not built because, among other factors, there was no penalty to ensure construction. Therefore, some penalty, which can be implemented as a requirement for a guarantee, should be implemented to deter winners from not building.

It may be pointed out that penalties may just increase the cost and that, by themselves, they will not ensure that projects are built; they may also deter participation, especially of small actors,

[5] Although this design element is of utmost relevance for countries with a federal structure, this framework can be extended to the supra-national level, something very relevant in the context of discussions on the harmonization of support mechanisms in the EU.

and, thus, reduce the number of bids and competition.[6] If there is a significant risk of not complying (i.e., paying the penalty), the bidder will include that into the bid price, and the project may still not be implemented.

However, the risks which cannot be controlled by bidders (RE resources, permitting process) would have already been mitigated by the list of pre-approved RE sites, so the penalty is just a last-resort instrument to deter speculative behaviour and unreasonably low bids. That is, credibly enforced penalties do not mitigate those risks, the other design elements do. So it is an issue of how penalties should be implemented and what their level should be rather than whether they should be there. Setting an "appropriate" penalty is certainly a challenge. There are mostly two alternatives: progressive penalties and performance bonds, or some combination of both. Progressive penalties for delays and non-compliance have been adopted in Denmark. Penalties (€/kWh) increase over time. A performance bond of 20M€ that the bidder has to place before participating in the tender and that the state can cash in case the developer fails to build the plant in time has been implemented in the Netherlands. Their level should neither be too low (rendering them meaningless) nor too high (discouraging participation by actors).

4.8. Deadlines for construction

Another relevant issue, related to the above, is whether to set a deadline for the winner projects to be built if they are to receive the contract, and how long this deadline should be. A short deadline increases investors' risks (of not deploying the project) and may put upward pressure on bids. A longer deadline will allow technology progress to take place, and therefore may result in lower expected prices for RE. However, it may also induce over-optimism, and introduce significant uncertainty into the process. Therefore, setting short technology-dependent deadlines is suggested so that uncertainty (and also overoptimism) is minimized. This may even be incorporated in the scoring of the auction [101].

5. Conclusions

The future brings many challenges for RE policy, including the need to adapt to a much greater penetration of RE into electricity systems, with its corresponding more salient costs, requirements for coordination between administrative levels and impacts on the rest of the electricity system. At the European Union level, an additional challenge is the aspiration towards greater harmonization of RE support.

Controlling the costs of RE support is absolutely critical for its political feasibility and social acceptability. Cost-containment involves an adaptation of support levels to technology costs and the absence of excessive total costs (generation times support levels). FITs do not necessarily do the job, since the regulator does not necessarily know the real costs of the different RE technologies and their evolution and, thus, support levels are likely to be set high above technology costs. While FITs have proven better than TGCs in adjusting support levels to the costs of low-cost gap technologies (i.e., on-shore wind), this has not been the case with high-cost gap ones (i.e., solar PV). While TGCs hardly support the most expensive technologies [8,9], support levels under FITs for these technologies have been excessive in some countries (e.g. Spain, the Czech Republic and Italy for solar PV).

Therefore, other instruments may be required which, by providing better information about the real cost of technologies, help adjust the total costs of RE support. Auctions have some advantages compared to FIT, whereas their disadvantages can be minimized (although probably not eliminated) through a careful design. Auctions place regulators in the right place: rather than have them guess industry costs, they will become providers of public information. In addition, by incorporating a coordination mechanism, this instrument ensures an efficient interaction between the different administrative levels involved in RE deployment. The lack of coordination between different entities has been one of the factors for the past problems with auctions, FITs or TGCs.

A proposal for the design of RE auctions has been presented in this paper. Besides addressing some of their major problems, it includes also elements to control the total cost of support and to facilitate the coordination between different administrative entities.

Of course, one size does not fit all, and this is not a perfect solution for all countries and technologies. The choice of instrument and its design elements should be context-dependent and technology-dependent. The design of auction schemes will reflect each country's priorities. Tendering may work for certain situations and aspects (promotion of large projects and actors) and not for others. Auctions will be more successful in mature, stable markets, with a sufficient number of players to achieve competition [25]. However, other less-mature, smaller markets may also benefit from this instrument, provided that there is enough regulatory and administrative capacity [23].

Political economy considerations should be very present when designing RE support systems, and may clearly affect the outcome. Indeed, stakeholders' interests may explain why some systems are chosen over others. Why, for example, have auctions been abandoned instead of trying to fix them? Was it because the major players pressed against them, and for a system where they could do better? It may be argued that auctions are difficult to sell politically because the only agent that is better off with them is the consumer (and its representative, the regulator). Developers, investors, or manufacturers all stand to lose, given the reduction induced in the producer surplus. Unfortunately, the consumer is usually underrepresented in the political process, and has less bargaining power in this field. For example, if investors/developers oppose this system and are well organized they could refuse to bid and therefore stall the system. But that does not mean that the merits of RE auctions should be disregarded. Some of the political feasibility issues are addressed in our proposal. Its implementation is deemed perfectly viable, at least in most European countries.

Our analysis suggests several avenues for further research. First, more research on how different context conditions affect the results of RE auctions should be undertaken. What preconditions make the success of auctions more likely? Second, empirical analysis on the change in the design elements of current RE auctions would be desirable. Whether these modifications are the result of political economy factors (i.e., the influence of interest groups) or learning from previous mistakes should be investigated.

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[6] Peru provides an example in this context. Initial quotas in Peru were not covered (500 MW for biomass, solar and wind and 500 MW for small hydro). One of the reasons for the relatively low participation in the first call was the high guarantees required (between 20,000 and 100,000€/kW) [79], which discouraged the participation of actors, especially small ones.

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