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The Limits of Auctions:

reflections on the role of central purchaser auctions for long-term commitments in electricity systems

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Contents

Figures

1. Introduction

This paper looks at the deployment of auctions in electricity systems, and in particular at the predominant form of auction currently in use: a 'one-sided' auction in which a central purchaser, usually acting as an agent of the government, acquires capacity for the purposes of meeting carbon targets or securing reliability. The use of this particular form of the instrument has been spreading rapidly in many countries across the world[1] to the extent that it may be regarded as normal practice in some contexts – such as the procurement of conventional generation capacity and renewable energy sources – and that further extensions into other areas – like network expansion – have been proposed. However, the widespread use of auctions of this sort is a relatively recent phenomenon and it raises a number of questions.

- How should we view the development?
- Are auctions of this kind a useful market-based tool to complement other methods of resource development?
- Are they a type of second best – a symptom of the fact that electricity markets themselves are broken and can no longer give appropriate signals?

This paper aims to discuss these general questions relating to the use of such auctions. It does not attempt to go into the details of central buyer auction design or to study particular uses of the auction tool in different countries. Nor does it explore or question the use of auctions by private buyers to acquire electricity. It concludes that, while auctions will certainly continue to have an important place in electricity, governments should be more cautious about their use and should be thinking about alternatives; these would include new energy market designs that reflect twenty-first century technologies and economics, especially those reflecting the high penetration of renewables and the more active participation of consumers. A key goal in developing markets for a sustainable future should be to empower consumers as far as possible – and 'one-sided' auctions, at least in their present form, are not necessarily the best tool for this purpose.

2. Background

It may first be helpful to consider the broad aims of liberalization and the rationale for the development of electricity markets. Liberalization, including privatization and the ending of industry monopoly, had many objectives. In the UK, for example, these included the reduction of both government involvement in the industry and pressure on public funds (a consequence of nationalized industries). But perhaps the main aim was to improve the incentives for efficiency at a time of increasing globalization; exposing the industry to the forces of competition was seen as the best means of achieving this. The route generally chosen was the development of competitive markets based on the short-run marginal costs of generation (namely kWh). It was thought that this would promote efficiency in three areas:

- **Operating efficiency** – kWh-based markets would ensure that the cheapest generator available at any particular time was despatched, thus giving strong incentives for operating efficiency.
- **Allocative efficiency** – as part of the process of liberalization, governments largely (though not in all cases) dropped price controls on electricity. Along with the introduction of market forces, this led to the unwinding of most subsidies and cross subsidies, as generators and

[1] This paper examines key issues related to the role of auctions and draws on examples from around the world, including European countries where auctions are now a central policy feature of the power sector. However, the paper is not intended as a review of the experience of any country or region in particular.

suppliers tried to avoid selling at a loss. This helped ensure that electricity prices more closely reflected the costs of production, and thus that electricity was not over, or under, consumed as compared with other products.

- **Dynamic efficiency (in other words, efficient investment)** – one of the key aims of the liberalization process was to transfer investment risk to those making the investments, so as to sharpen up the incentives to efficiency. In non-competitive markets, investment decisions were typically made centrally, while the costs and risks were passed on to consumers. In many cases, this led to very expensive and inefficient decisions for which consumers had to pick up the bill – US and UK experiences with nuclear power are examples of this (Henney, 1994; Taylor, 2016). One key objective was therefore to stop this sort of situation from arising again.

In general, liberalized markets have performed fairly well in relation to the first two types of efficiency. However, efficiency is ultimately about the best way of meeting objectives, and this may well go wider than mere cost reduction. In this paper we take government policy objectives (such as the promotion of renewable sources) for granted and focus on efficiency and effectiveness in meeting these objectives, rather than whether they are the right objectives in the first place.

In any event, there was always a question mark over the third type (Newbery, 1999). Power sector investment continued to be a contentious area as liberalization progressed. In 2003, for instance, a report by the International Energy Agency noted that:

> 'Governments have remained concerned about the adequacy and composition of power generation investment in a liberalised market.' (IEA, 2003)

A year later, a study by the Union of the European Electricity Industry – Eurelectric – concluded that:

> 'Since the liberalised market is still only a few years into the investment cycle, it can fairly be said that the "jury is still out" concerning whether liberalization has yet proved, or will prove, to be a sustained success'. (Eurelectric, 2004).

Some years later, in a paper entitled 'Lessons learned from Electricity Market Liberalization', Paul Joskow, one of the pioneers in this field, used the same expression, saying that:

> 'the jury is still out on whether competitive power markets can stimulate levels of investment in new generating capacity in the right places at the right times consistent with political preferences'. (Joskow, 2008, 26)

Efficient investment has many dimensions – quantity, type, location, aggregate mix, and so on. With the additional challenge of meeting policy objectives, it may well be unrealistic to expect markets alone to deliver all these goals. (Keay, 2006)

Many systems introduced capacity or reliability markets of one sort or another to ensure that sufficient capacity was built, or at least not decommissioned. This was because there was a fear that kWh markets might not incentivize the necessary construction because of the real or perceived problem of 'missing money' – that revenues from energy and system service markets would be insufficient to cover investment and operating costs. Since short-run marginal costs (srmc)-based prices would normally cover only short-term operating costs, prices would have to rise very sharply above the level of short-term costs when capacity was short to ensure that all generators could recover their capital costs. There was a risk that governments would not allow this to happen. The position was not clear-cut: many countries (including the main European markets) did not see the need for special arrangements to remunerate capacity, since investment was either unnecessary or already forthcoming. What was clear, however, was that in this situation, although investment could still take place, it consisted of the lowest-risk form of investment (namely that with the lowest capital cost in relation to output and expected revenues) in the form of combined cycle gas turbines (CCGTs). Even if there was sufficient capacity in one sense, it was not clear whether private investment would meet other government objectives (such as a diverse mix of plants), or would be able to protect consumers in the case, for instance, of a rapid increase in gas prices. So, even in the early stages of liberalization there was no consensus on whether srmc-based markets would deliver sufficient quantities of policy-compatible investment (Keay, 2006).

The question became more prominent after about 2000, when climate change considerations started to dominate and doubts about the ability of markets on their own to generate the huge quantities of low-carbon investment needed became acute. This was, after all, the 'greatest and most wide-ranging market failure the world has seen' (Stern, 2006). In principle, governments could have introduced carbon taxes or other market-friendly measures to address this failure, but for various reasons, these were never more than supporting measures. Carbon prices through the EU ETS were too low to incentivize investments in low-carbon generation capacity, and were often too low even to change the merit order from coal to gas.

It is beyond the scope of this paper to examine the arguments in detail, but there were clear reasons for avoiding the loading of too much policy weight on taxes, among them that:

- Taxes at a level which would have made renewables economic, at least in the early 2000s, would have needed to have been unacceptably high (OECD, 2013; Schuman, 2014). In practice, the acceptable level of a carbon tax, whether in the EU or even in the UK (which has unilaterally imposed a higher tax because of the low level of the ETS price) has proved to be well below the level of effective support for renewables (>€100 per tonne).
- Experience with the ETS price and the UK carbon floor price shows (Buchan and Keay, 2015) that it is almost impossible, politically, to make a strong enough commitment to a carbon tax – especially a carbon tax on a rising trajectory – to make it sufficiently credible well into the future, in order to underpin investment in long-term assets.
- A carbon price would be highly visible and therefore politically difficult. It would have potentially big distributional impacts, especially in the initial stages. In the early 2000s, at any rate, a tax applying to all fossil fuels would have had a major and transparent impact on electricity prices, especially in countries relying heavily on coal. The cost of renewables support, by contrast, was hidden in overall electricity prices and rose in a relatively gradual manner as supply from these sources grew (and even then there was strong political resistance in some countries).
- There is also the problem of broken markets (Keay, 2016). When markets are based on short-run marginal costs (srmc), an increasing penetration of renewables tends to lower wholesale electricity prices at times when they are generating (because they tend to be correlated), while carbon prices would normally come into play to a significant extent only at times when renewables were not generating. Even a high carbon price might thus do little to promote renewables unless accompanied by significant market reforms.

Clearly there are, at least in principle, ways round these problems and there is scope for different approaches to carbon pricing which might have more popular support – for example by recycling revenues to addressing fuel poverty or encouraging energy efficiency (Klenert et al., 2018). Nonetheless, the fact remains that no government has chosen to make carbon taxes the central element of its decarbonization policy.

So instead of going for technologically neutral market measures, most governments have opted for specific forms of support for renewables, mainly using two broad groups of policy instruments:

- Portfolio Obligations (Renewables Obligations in the UK)
- Feed-in Tariffs (FiTs), which offer guaranteed prices for renewable sources. In the past, these prices were usually set administratively by the government or the regulator, though increasingly the level of the FiTs is being set by auction.

There was some debate about the choice of instruments, with the conclusion generally being that FiTs were more effective, but not necessarily more efficient (Mitchell et al., 2006; IEA, 2008; Butler and Neuhoff 2008).[2] This problem was partly self-generated. Renewables costs have been falling sharply – to a significant extent because of these support measures – and this has created demand for renewables technology and enabled economies of scale and 'learning by doing', bringing strong downward pressure on costs. But when costs are falling, administratively fixed prices often turn out to be higher than needed – a process which in many European countries has resulted in the contracts being withdrawn or changed retrospectively. Furthermore, fixed price contracts are unresponsive to short-term market signals, so do little to ensure that power is produced when it is actually needed.

Many different forms of support are still in place across the world, and a number of these are discussed below. However, given the problems noted above, support systems across Europe have converged on a more sophisticated form of support based on Contracts for Differences (CfD) or Floating Feed-In Premia; these are generally awarded by auction (in the UK, France, Netherlands, and Ireland, for example).[3] The idea is that bidders frame their bids in terms of an energy market 'strike price'. Payments are then made during the lifetime of a project on the basis of the difference between that price and a reference market price:

- when the market price is less than the strike price a top-up payment (the 'Floating Premium') is made;
- when the market price is more than the strike price the generator pays back the difference to the system.

Usually the strike price is fixed rather than variable and does not depend, for instance, on the time of day. In general the auctions seem, at first glance, to have proved remarkably successful. The costs of solar and offshore wind have fallen very considerably. In many countries these are now at a level below those of conventional sources (at least when measured on a levelized cost of electricity basis) although, as discussed below, the full picture is rather more complicated.

But the impact of renewables has not only been to stimulate the development of new policy instruments; it has also changed the whole dynamic of power markets. Their cost structures (usually zero marginal costs) and operating characteristics (generally not dispatchable but dependent on the sun or wind to enable operation) have meant that they were not suited to the srmc-based markets to which they were being introduced. On the other hand, the fact that governments[4] (with support from the industry and the banks) were continuing to flood markets with sources which could not remunerate themselves from those markets undermined the price signals coming from those markets and hence the basis for investment (Keay, 2016). Not only was it not clear whether dynamic efficiency was being achieved in renewables investment,[5] but the 'missing money' problem referred to above had become acute; in very recent years, little or no investment in conventional plant has taken place, except where it had support via some form of capacity remuneration system. Furthermore, without that support, even the newest and most efficient CCGT plant was uneconomic.

So, despite the reservations of the European Commission, there has been an increasing trend across Europe to introduce capacity mechanisms of one sort or another. While no clear consensus on the need for, or form of, such mechanisms has yet emerged, one of the most significant, the UK capacity market,

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[2] The conclusion on comparisons is very context-specific. (del Rio and Linares 2014)

[3] In the EU, support for renewables must be approved by DGCOMP under the European Commission Guidelines on State aid for environmental protection and energy 2014–2020. (EC, 2014)

[4] In many countries, governments also supported the penetration of renewables as a way of developing a new industrial sector with global markets.

[5] This was because it came in quantities and types ultimately determined by government decisions, which in turn were based on the need to meet climate change targets rather than the need to optimize electricity systems, rather than on any attempt to co-optimize both dimensions.

has also taken the form of an auction. This has been successful in at least one respect – driving down prices well below original expectations – though again, the full picture is rather more complex.[6] Since then, DG COMP has approved other capacity mechanisms, including those in Belgium, France, Germany, Greece, Italy, and Poland.

The above examples refer to the purchase of electricity and capacity. However, auctions have also been held for more specialized system services (such as frequency response, demand response, and black start) and the overall success of the approach has led to calls for auctions to be extended into new areas and specifically into infrastructure development and network expansion (see Section 6).

3. Some general considerations relating to auction theory

The brief outline above indicates why governments are increasingly moving towards the use of auctions in electricity and – as further discussed below – the very extensive use they are now making of them. As the Introduction explains, this paper does not attempt to go into the details of auction design or the intricacies of auction theory. Nonetheless, it may be worth taking a brief look at some of the theoretical considerations which governments should perhaps be taking into account in their increasing reliance on auctions.

The normal dictionary definition of an auction is usually roughly on the following lines: 'a public sale in which goods or property are sold to the highest bidder'. In practice, most electricity auctions are so-called reverse auctions in which the auctioneer is buying rather than selling, and would normally choose the lowest price bid. As can be seen, this definition highlights two characteristics of auctions in their simplest form:

- auctions are a one-off event rather than a continuous market;
- they are essentially one-sided – that is, rather than bringing buyers and sellers together there is a single buyer selecting between various bids.

In practice, things are rather more complicated: auctions can be 'multi-round' rather than one-off, and it is possible to organize two-sided auctions in which both buyers and sellers participate. However, the main focus of this paper is on the one-off, one-sided auction, since this has been the main form of auction in use in electricity systems.

In a general sense, of course, auctions have always been a feature of electricity. There are two main forms of liberalized electricity market:

- bilateral markets where market participants trade electricity with each other;
- pools where some central body (the system or market operator) operates a central bidding system designed to select the lowest-cost electricity available at any particular time. In a sense, pools are a sort of continuing auction.

However, as discussed above, such arrangements are not the central concern of this paper (though some of the analysis will be relevant to pools). Pools, like other forms of kWh market, are based on the principles of promoting efficiency by basing prices on srmc, and operate over short time scales.

The new auctions which have come increasingly to the fore are rather different; they are designed, essentially, to underpin the 'policy compatible' investment which traditional markets may not generate and they are normally based on long-term contracts or regulatory commitments rather than short-term

[6] As explained later in the paper, the UK capacity market mechanism has been challenged successfully in court and is now being revised.

market prices. It is on this sort of auction that this paper focuses, especially on those organized by governments (or their agents) to ensure resource adequacy or investment in renewable power.

Auctions in the electricity sector also have special features and problems which differentiate them from traditional auctions, these include:

- **Product definition**: in many cases the 'product' being purchased is not concrete or pre-existent, but is more the expression of a policy objective (reliability or environmental acceptability). In trying to translate their policy objectives into defined products, governments have to tread a narrow line between over-specification (which amounts to picking winners, with all the risks that approach entails) and setting broad principles (which may allow gaming or produce a result which governments neither expected nor wanted).[7] Furthermore, the way in which a product is defined may, in effect, determine the result. For instance, it is arguable that reliability should not be a public but a private responsibility in the first place (see below) and that setting a government standard of reliability amounts *a priori* to a market distortion. When that standard is further translated into a specific product, further distortions may be introduced. An example of this can be seen in the UK capacity market, which is implicitly based around the option of generating capacity rather than demand response; this has had little success in delivering the latter sort of resource (indeed it recently led to a decision by the European Court of Justice, which rejected the UK approach – see below). This aspect of the issue has received comparatively little attention; even when it comes to what should be straightforward auctions for the purchase of electricity, the definition can make a huge difference to the outcome. For instance, an analysis of the 2006 Illinois Electricity Auction showed that:

  > 'a poorly formulated product definition can erode the performance of such markets'. (De Castro et al., 2008)

  Similarly, just as it is not clear whether a level playing field can be created between generating capacity and demand response, it is also not clear whether auctions can create a truly level playing field when comparing renewables with conventional sources. A recent study concluded that:

  > 'although the first impression might lead to the conclusion that conventional and RES-E technologies are in some cases close and even ostensibly competing in the same auctions, the fact is that full convergence is still far to happen, as the rules and products applied to the different technologies differ significantly'. (Mastropietro et al., 2014)

- **System issues:** Electricity is an interactive system in which every part affects every other part. Actions which deal with only part of the system will have impacts on the system as a whole – an example was noted above regarding the unintended consequences of higher renewables penetration. The consequence is that optimizing one part of the system may not optimize the system as a whole – for instance, acquiring large volumes of offshore wind at lowest cost may have significant consequences for the rest of the system in terms of transmission and balancing needs and will not necessarily amount to acquiring low-carbon power at the lowest possible cost, in terms of the system as a whole.

- **Principal/agent issues and risk transfer:** Auctions of the sort this paper is concerned with are run centrally, usually by a government or by a regulator or system operator acting as the government's agent. But the government itself is, in effect, acting as an agent for consumers, though it is not always clear whether such an agent is needed (for instance, as mentioned above, it might be better for consumers to choose their own level of reliability,

[7] Some examples of this sort of problem are discussed below

rather than relying on the government to provide them with the degree of reliability which the government thinks they want). Even if there is a clear case for government intervention (as with climate change or other externalities) it does not necessarily follow that the optimum form of intervention is for the government to define some sort of intermediate goal (in terms of technology or techniques) which can be the subject of an auction process (as with renewables auctions), rather than using a more flexible economic instrument to achieve the ultimate objective. Electricity auctions involve a rather extended chain of principal/agent relationships which complicate auction design and product definition – for instance, setting an appropriate level of reliability is a highly contentious process and governments may well choose to over-provide in the interests of a quiet life (Keay, 2016). In most existing cases, the costs of the product procured at auction are simply transferred to consumers via a mark-up on electricity prices, so neither the government nor the supplier is itself bearing the price risk, only the political risk, of an interruption to supply. In other words, decisions about risk have been taken without reference to consumers, while the price consequences have been passed on to them. Indeed, one of the key problems which led to the adoption of liberalization (that investors do not have to face the investment risk of particular sources, such as nuclear) has been ignored.

- **Complexity** As a result of the above factors, among others, electricity auctions present particular complexities and auction design is especially difficult. As one study in this area (Maurer and Barroso, 2011) points out, 'the devil is in the details', and other such studies make similar points (for instance, del Rio and Linares, 2014; IRENA, 2015).

Turning to the auction literature itself, one notable feature (at least to an outsider) is that it says relatively little about the circumstances in which auctions, as opposed to other forms of market (such as bilateral OTC or exchange-based trading) should be used. Most of the literature is devoted to the format and design of auctions and to what sort of auction should be used in particular circumstances, rather than to considering whether an auction should be held in the first place. Nonetheless, some broad criteria seem to emerge (Bulow and Klemperer, 2009; Einav et al., 2016; Roberts and Sweeting, 2012). Considerations to be taken into account include:

- The cost of bidding.
- The cost of acquiring information.
- The 'idiosyncrasy' of the object at auction and how far its value is known *ex ante*.
- The extent to which the seller is experienced.
- Whether the item is scarce relative to consumer demand.

It is by no means clear how far electricity auctions meet these criteria, in particular that of idiosyncrasy. For some sorts of product (such as works of art) auctions may be a suitable instrument because there is usually no way of assessing the value of the product by reference to similar ones – each is effectively a separate entity in its own right (as further discussed below). But electricity is not like that.

In a more general sense, it is also not clear whether one-off auctions promote overall efficiency, as opposed to maximizing the seller's revenues (or minimizing the buyer's costs). The Bulow and Klemperer paper makes the point that, rather than a single auction:

> 'a sequential process in which potential buyers decide in turn whether or not to enter the bidding … is always more efficient. But pre-emptive bids transfer surplus from the seller to buyers. Because the auction is more conducive to entry – precisely because of its inefficiency – it usually generates higher expected revenue.' (Bulow and Klemperer, 2009)

The efficiency of auctions can of course be improved by more sophisticated design, but it can be difficult to avoid adding to complexity and transaction costs and potentially discouraging entry (Noussair et al., 1998). In practice, most governments have not used sequential processes for any particular auction, though in a way the successive rounds of renewables auctions have had a rather similar effect in revealing costs over time. Nonetheless, the inherent inefficiency of the single auction process might give some governments pause for thought; in a situation of rapidly falling prices, as described above, it is worth devoting some time to systems which reveal costs in a dynamic manner rather than waiting for this trend to emerge over time. Governments should therefore consider multi-round auctions or other forms of market arrangement. In particular, they should always consider whether a continuous market solution (such as a well-designed tradable renewables obligation) is possible, since that is likely to give much more responsive information about underlying cost trends.

The so-called ‘winner’s curse’ (the tendency for the winning bid in an auction to exceed the intrinsic value or true worth of an item) is another well-known, and closely related, issue in relation to auctions. In addition, since electricity auctions are normally so-called ‘reverse auctions’ the parallel effect is that the winning bid may often be well below the true cost of providing the service in question. Some examples of this phenomenon are cited below – and there may be more to be revealed as bidders try to develop their projects at the very low costs with which they won the auctions (Andrews, 2018). This is not an insurmountable problem, but mitigating the risk does require special care when designing the auction (Harbord and Pagnozzi, 2014).

Another feature of the auction literature is that it says relatively little about the definition of the product at auction – although, as noted above, this can be a key issue with electricity. This gap is probably because the normal starting point of an auction is a predefined object (say, a painting) or something clearly within the ownership and control of the auction holder (say, spectrum auctions). But electricity auctions are rarely about such clearly pre-defined products. Even if the auction is for nothing more complex than electricity supply, product definition can make a huge difference to the outcome, while the task is orders of magnitude more complex when it comes to less tangible services such as reliability or network expansion. The auction holder has to define the product; the way in which they define it will determine the outcome; and neither the product nor the outcome may be what would have been preferred by consumers if they had had the choice (for instance a different level of reliability, or a non-nuclear source of low-carbon power).

There are also complex interactions between network and generation costs. For instance, a study commented that:

> ‘We find that the laws of physics that rule power transmission networks defeat ex post productive efficiency: the cheapest combination of generating plants is not always selected, not even in the optimal auction. Furthermore, neither the pay-your-bid nor the uniform-price auction coincides in general with the optimal auction, nor do they yield productive efficiency. Our analysis also sheds light on behavior observed in existing power markets, and leads to policy recommendations. First, producers protected by transmission constraints must see their bids capped in the short run to curb their ability to extract large rents. Second, producers apparently hurt by the unavailability of transmission capacity may benefit from it. Hence, contrary to common wisdom, policy makers cannot rely on them to finance or advocate transmission expansion.’ (de Castro et al., 2008)

Similarly, David Newbery has commented that:

> ‘Long-term capacity auctions by themselves are either not credible or not sufficient as a mechanism to secure adequate investment in network capacity, particularly where this capacity is critical for the efficient and secure operation of the system. Nevertheless, auctions can work well for allocating existing capacity.’ (Newbery, 2003)

Finally, it may be worth quoting the abstract of a paper by Professor Paul Klemperer, the acknowledged doyen of auction theory, entitled ‘Using and Abusing Economic Theory’. He says:

> ‘Economic theory is often abused in practical policy-making. There is frequently excessive focus on sophisticated theory at the expense of elementary theory; too much economic knowledge can sometimes be a dangerous thing. Too little attention is paid to the wider economic context, and to the dangers posed by political pressures. Superficially trivial distinctions between policy proposals may be economically significant, while economically irrelevant distinctions may be politically important. I illustrate with some disastrous government auctions, but also show the value of economic theory.’ (Klemperer, 2003)

In line with this prescription, the discussion below focuses on the wider economic context and on political factors. This is not to downplay the importance of auction theory but to emphasize the importance of getting the basics right – for instance, the existence of market power, which has long been a concern in electricity, is not necessarily solved, and may actually be exacerbated, by the use of auctions. Furthermore, as the discussion above indicates, electricity auctions present many special and problematic features and do not fit neatly into the standard auction types usually discussed. In addition, as Klemperer points out, auctions are not in any event guaranteed to produce optimum results. There have been many disasters in this area – principally because of a failure to consider basic economic principles or because of the distorting effect of political imperatives – which are inevitably going to have a very significant impact on electricity auctions. In the view of the authors of this paper, governments need to give more thought to these basics before deciding that auctions are the best way of harnessing the forces of competition in the delivery of policy-compatible investment.

4. Review of selected empirical evidence on the success of auctions

The sections above have looked at the general background to the current widespread use of auctions and at some theoretical considerations which need to be taken into account in their use. This section and the next look at selected empirical evidence – how far have auctions been a success or otherwise?

Resource adequacy – generation[8]

Resource adequacy procurement auctions are a competitive capacity remuneration mechanism (CRM). They are often considered – for theoretical and practical reasons – to be a necessary feature of liberalized electricity markets due to the ‘missing money’ problem explained earlier in the paper. This problem is especially acute in Europe, due to the deep penetration of intermittent renewable power which depresses wholesale energy prices and margins for conventional power stations, while at the same time requiring flexibility from those conventional generation stations and other sources. CRMs also exist in liberalized electricity markets elsewhere, especially in North and South America.

The main economic rationale for resource adequacy auctions is that they are a more efficient means of ensuring investment in conventional generation than administrative payment mechanisms. In many jurisdictions, for instance still today in Spain, governments determine payments for generation capacity on an administrative basis, which has some advantages from the perspective of the government, notably the ability to encourage a desired level of capacity, to influence the mix and avoid severe price spikes. However, these systems are now widely recognized as inefficient. There is no guarantee that investment will occur if payments are too low, while if payments are too high, excess investment will occur, which is equally inefficient. Furthermore, this approach often introduces distortions that are magnified; the process starts by supporting new plants, but this depresses energy market revenues and leads to payments being extended to existing plants to avoid their closure.[9] Administrative flexibility also introduces political risk for investors, raising costs and distorting investment choices.

[8] For an introduction to different approaches to ensuring resource adequacy, see Hesmondhalgh et al. (2010).

[9] Payments to existing plants that enable them to remain open may be more economic than investing in new plants, but the point is that the initial capacity payments depress energy market prices to levels that are unsustainable. A related point is that regulators set reliability standards plus a legal condition not to close down without regulatory approval. There are cases in

As a result, governments and regulators have increasingly adopted quantity-based CRM and are, in particular, using auctions to ensure resource adequacy and to determine the price for capacity. In many cases, these models respond to a requirement on retail suppliers to demonstrate that they have built (or contracted) enough capacity to meet the demand of their customers, in addition to a reserve margin. In Europe, it is more common for an agent of the government – such as the regulator or the system or market operator – to hold the auction, with the aim of meeting a reserve margin and providing flexible backup for intermittent renewables.

There are many different CRM auction designs. Some involve the acquisition of a strategic reserve, which is supposed to be kept out of the energy market and only used in situations of system stress. Others allow bidding by generators who also participate in the energy market. In the EU, there are both strategic reserves and capacity markets. An increasingly common model (used, for instance in Italy) involves bidding to receive an option fee in return for guaranteeing to provide electrical energy at an energy market strike price under conditions defined in the auction. Sometimes these auctions are open to existing and new capacity, while in other jurisdictions only new capacity bids both prices and quantities into the auction.

The main advantage of CRM auctions, when well designed, is that they almost guarantee that the desired level of reliability is achieved. Furthermore, competitive bidding reduces prices and can encourage innovation, especially when bidding is open to new and existing capacity, both from the demand and the supply sides.

One measure of the success of CRM auctions is their increasingly widespread use. For instance, they have been central to almost all North American liberalized markets (with the exception of Texas), many Latin American countries (notably Colombia, Brazil, Peru, Chile), and a growing number of European countries including the UK, Belgium, France, Germany, Italy, Ireland and Poland.

An example will illustrate why they can be considered valuable as a means of real price discovery and reducing costs, in comparison to either administrative procedures or government assumptions on cost. In the UK capacity mechanism, governments set a reference price for the CRM auction, which is based on the cost of a new CCGT. In all of the auctions held to date, the resulting price has been significantly below this reference price. This reflects the fact that many other existing generation resources are able to guarantee services at well below the cost of a new CCGT and that the auction was designed so that existing and new capacity could bid. Whether the outcome is what the government intended is another question. In some countries, the aim is to encourage investment in new plants, rather than to remunerate existing ones. For instance, in Colombia, existing generation capacity must bid its availability, but not prices, so that only new capacity sets prices and receives a long-term contract. There too, the auction acts as a means of revealing and reducing cost, but only as far as new capacity options are concerned. Existing plants selected in the auction receive the market clearing price but no long term contract.

Resource adequacy – demand response

In a growing number of countries, governments and regulators wish to involve the demand side in meeting resource adequacy targets and providing flexibility. In traditional electricity systems, characterized by large-scale fossil and nuclear generation, the flexibility to cope with variations in demand or supply was provided primarily by dispatchable generation. Regulators sometimes provided time of day (ToD) or seasonal tariffs to encourage consumers to consume less at times of system peak. However, with the penetration of intermittent renewable energy, the need for flexibility has grown. While the generation side of the system has become less controllable, smart metering and digitalization have

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Spain, Germany, and other countries where owners are prevented from shutting their plant. In these cases, governments and regulators may agree to an administrative CRM.

increased the potential for the demand side of the market to provide the flexibility needed to balance the system when it is under stress.

In these new circumstances, the provision of mechanisms to encourage flexible demand response has become more important. ToD and seasonal tariffs no longer provide the necessary signals, because intermittent renewables require flexibility at unpredictable times. There are different ways in which auctions can enable this sort of flexibility. On the one hand, efficient short-term energy and balancing markets are auctions that can provide price signals to guide consumption and investment decisions. For instance, the consumer (or an aggregator on the consumer's behalf) may postpone or bring forward consumption, depending on anticipated prices, and may choose to invest in storage if this would enable the consumer to purchase energy when prices are lowest, for use later. On the other hand, system operators or regulators may wish to purchase longer term guarantees of consumption flexibility in much the same way that they purchase guarantees from generators through CRM. Auctions may be helpful mechanisms to acquire this sort of demand-side flexibility.

There are many examples in the USA and Europe where reserve adequacy is guaranteed, in part, through auctions for demand response. For instance in Europe, the CRM in Italy, Poland, and Belgium includes operators with demand response, as well as supply-side alternatives. Furthermore, in France, Greece, and Spain, auctions are held specifically to purchase demand response (or 'interruptibility'). Recently, in France, interruptible load was called on to cope with a decrease in frequency.

In Spain, for instance, the government holds annual auctions to purchase interruptible demand commitments from large industrial consumers. The government argues that these auctions have substantially reduced the cost of purchasing demand response, compared to the (administratively determined) tariffs that were previously paid to customers who agreed to be interrupted. The total system cost of purchasing the interruptibility service for Peninsular Spain fell from about €500 million in 2015 for 3,020 Megawatts (MW) to about €300 million in 2018 (for 2,600 MW), a reduction of almost 30 percent in the cost/MW/year. The total cost and the cost per MW fell even further in the auction for the first half of 2019.[10]

Renewable power

Liberalized electricity markets were designed for technologies dating from the twentieth century, in particular for large-scale plants generating electricity from nuclear or fossil fuel energy. The policy decision to promote decarbonization through the penetration of renewable energy in a liberalized market posed a problem, because renewable power was not economic when compared to existing power station options. As discussed above, governments have developed mechanisms outside the wholesale electricity market to support the penetration of renewables, in particular regulated feed-in tariffs (FiTs) and renewables obligations (RO); but auctions have increasingly emerged as the main such mechanism.

Whereas in 2006, fewer than 10 countries were using renewables auctions, by 2016 the number had risen to almost 70 (IRENA, 2017). According to IRENA, this reflects the strengths of renewables energy auctions:

- the flexibility of their design;
- certainty regarding prices and quantities;
- the potential for *improved price discovery* and lower support prices;
- the *degree of commitment and transparency*.

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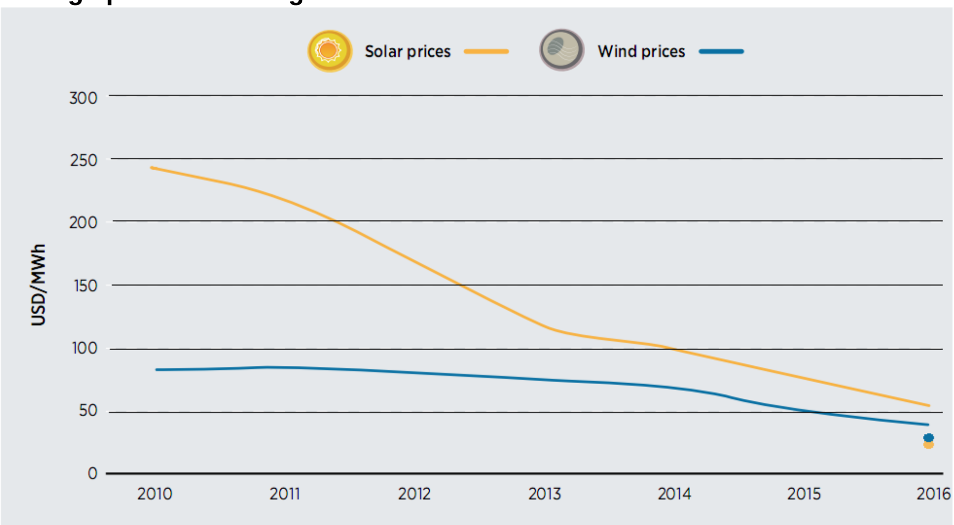
[10] *Spain's News*: https://spainsnews.com/the-closures-of-alcoa-coincide-with-a-reduction-of-40-of-the-electric-incentive-to-the-industry-companies/ See also REE, 2019.

All these features, no doubt, help to explain their popularity. Below, we focus on the last two issues, which are particularly relevant to the decline in auction prices.

IRENA and others argue that auctions have contributed to *improved price discovery*, as they have reduced the information asymmetry between project developers and those who are responsible for determining prices and quantities. This has been especially important, given the rapid decline in costs and the growing maturity of the market for certain renewables, and has led to lower support costs (del Rio and Linares, 2014). As illustrated in Figure 1, between 2010 and 2016, average solar PV auction prices fell from about €250 to about €50/MWh. Onshore wind prices fell less than solar, but from a much lower base, and were below €50/MWh by 2016. Since then, auction prices for both technologies have continued to fall, and indeed have reached levels that were unthinkable a few years earlier, with prices for each of these technologies below €20/MWh. In many jurisdictions, these two technologies are now recognized as the least-cost source of electricity, with both fixed and variable costs below the variable cost of existing conventional (coal, gas, nuclear, and oil) power stations.

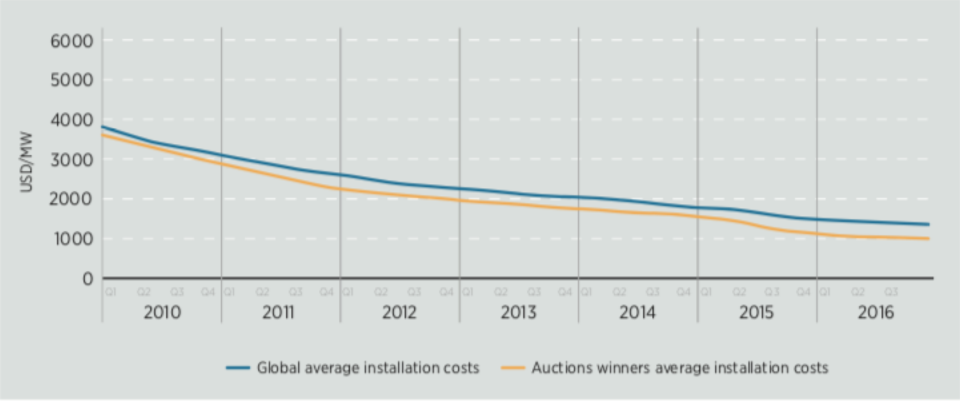
Figure 1: Average prices resulting from auctions 2010–16



Source: IRENA, 2017.

Figure 2 suggests that auctions are not only improving price discovery, but may also be contributing to a reduction in the cost of renewable power. The average price of auction winners has been systematically below the estimated costs of utility-scale PV since 2010. However, as discussed below in Section 5, there is a risk of overstating the cost-reducing impact of auctions.

Figure 2: Estimated installation costs of utility-scale PV projects: global versus auction winners, 2010–18



Source: IRENA 2017.

For further evidence that auctions contribute to price discovery and may help to reduce costs, other authors have compared the administratively set price (ASP) cap in UK auctions with the actual bids (Welisch and Poudineh, 2019). For example, in the first round of renewables CfD auctions in the UK (back in 2014) approximately 1,910 MW was allocated to wind farms, and for onshore wind farms the lowest strike price was £79.23/MWh; this figure was around 17 per cent lower than the ASP of £95/MWh for an onshore project to be delivered in 2016/17. Similarly, offshore wind projects had a minimum clearing price of £119.89/MWh, around 18 per cent lower than the ASP of £140/MWh for an offshore project to be delivered in 2017/18. This trend continued with the latest auction results for offshore wind projects.

The success of procurement auctions in reducing the price of renewables is sometimes attributed to *the degree of commitment and transparency* they offer; this can increase investor confidence, thereby lowering risk and the cost of capital. Of course, this is not always the case; auctions are not a panacea. In some cases, notably in Brazil, governments decide to undo the result of an auction. Furthermore, there are administrative procedures that could also provide the necessary confidence. Much depends on the details, and on the government and country in question. Nevertheless, by comparison to less transparent regulatory systems, or regulations that can easily be changed, auctions have proven increasingly attractive to investors.

For instance, in Spain, FiTs set in the period prior to 2012 attracted significant investment in wind, solar PV, and solar thermal. The FiTs were particularly generous for the latter two. As explained below (in Section 5), these subsidies and the reluctance of the government to pass the cost of these subsides through to final electricity prices (or to the public budget), contributed to a significant tariff deficit. In 2012, to stem the growth of the tariff deficit, a new government introduced reforms that significantly and retroactively reduced the return of investment on renewables plants that had already been built, and then withdrew support for new renewables over the subsequent five years. As a result, investors in renewable power sought opportunities elsewhere, notably in countries that continued to offer FiTs. However, in these other countries, governments also began to reduce FiTs (although usually not with retroactive effect, as in Spain) and to switch to procurement auctions. Most auctions were considered to be transparent and the results very difficult for governments to walk away from. In the words of a World Bank Study:

> ‘An electricity auction increases the competition and transparency of the electricity procurement process, making it less likely to be challenged in the future as the political and institutional scenarios change.’ (World Bank, 2011, p xi)

When the Spanish government decided, in 2017, that it wanted to encourage new investment in renewables in order to meet EU renewables targets for 2020, auctions were arguably a necessary condition for attracting investors.[11] Interestingly, the latest Spanish auctions for renewable power led to major investment commitments – almost 8 gigawatts (GW) – with very limited guarantees that come into effect only if wholesale prices fall to very low levels. Indeed, as we will argue later, the economic conditions in Spain now allow for the financing of merchant renewables plants, with no government guarantees. However, in 2017 and 2018, auctions were considered to be a necessary step in order to win back the confidence of investors, especially for new entrants. The latter (for instance Forestalia) were among the biggest winners in the latest Spanish auctions, in large part because they were able to finance their projects through debt financing that would almost certainly not have been available in the absence of some minimum revenue guarantee offered through the auction. Low-cost financing for these new entrants was an important reason for their success, and helps explain the failure of some of the larger companies in the auction (they were affected by the relatively high capital costs of self-financing).

5. Some problems with auctions

This section of the paper highlights some of the problems, and offers a perspective on the limits of auctions.

1. We qualify the view that auctions are largely responsible for the decline in costs, in particular for renewables.
2. We identify problems addressed through better auction design.
3. We identify problems we think are inherent in any approach (including auctions) that involves technology push by governments. Auctions may be superior to other more administrative approaches, but in the power sector they are almost inevitably going to run into problems of product definition, system issues, principal/agency, and complexity.
4. When thinking about whether there is a better alternative to auctions, we note that some investors in renewables seem to prefer markets over auctions, suggesting that we may be approaching ‘peak auction’, but that market and regulatory conditions will need to change before non-auction investment becomes the norm.

Qualifying the view that auctions are responsible for cost reductions

One should not exaggerate the importance of auctions as an explanation for the decline in prices at auctions, especially for renewable power. While auctions can reduce information asymmetry, improve price discovery, and contribute to cost reductions (for example, by lowering the cost of capital), cost reductions also reflect changing supply conditions. In particular, technological innovation, scale and learning economies, competition among solar panel and wind turbine manufacturers, government support in China and other countries promoting the development of low-carbon technologies, excess capacity of solar and wind manufacturing, and global monetary conditions (capital availability leading to lower interest costs) all help to explain falling costs. Auctions help to reveal the decline. The buy-side pressure is not irrelevant to falling costs and prices, but the supply-side factors are very powerful.

[11] There was a huge project pipeline and investors were waiting for auctions, possibly because of the guaranteed income floor implicit in the supported RES regulation. In the absence of auctions, and in the expectation that they would not be held, some investment would probably have come; as explained below, we are now witnessing merchant investment in Spain. However, the amounts and timing of merchant investment were very uncertain and would not have enabled Spain to meet its 2020 (EU) targets.

Auction design challenges

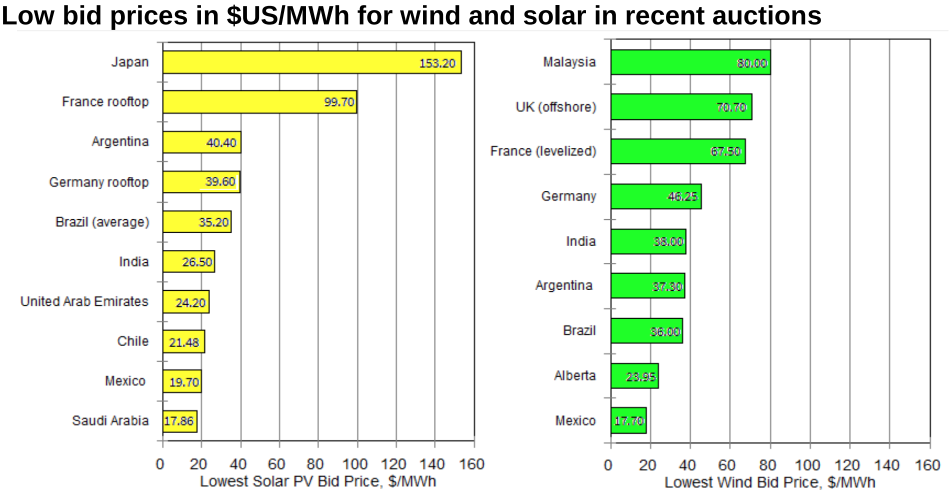
Poor auction design has been responsible for inefficient and unintended outcomes, and designs can of course be improved. For instance, del Rio and Linares (2014) have catalogued a variety of drawbacks in the early renewables power auctions, including: low effectiveness (less than the objective); low technological diversity; modest impacts on the early stages of innovation; high transactions costs; and low social acceptability (the NIMBY effect). They also explain the factors behind these problems and recommend revised designs for renewables auctions, including: technology-specific tenders; pre-approved technology-specific sites; an auction schedule; contracts awarded; penalties for non-compliance; and deadlines for construction. These recommendations now feature in a growing number of renewables power auctions, which no doubt helps to explain their popularity and greater success in terms of revealing costs. Even though these problems have not disappeared entirely, it is relatively easy to understand how to resolve them through improved auction design.

Another problem that might and probably should be fixed by improved design is the winner's curse. This is worth mentioning since it is widely regarded as a feature of auctions and there is recent evidence that it is a problem in the power sector with potentially serious implications. For example, the Colombian firm energy auctions illustrate how the winners' curse can be a curse for the entire system. There, the firm energy auction requires winners to supply electricity at the strike price defined in the auction whenever the energy market price rises above that strike. This happened during a recent el Niño (dry) period, which lasted many months. The owners of some of the fossil-fired plants that were obliged by the rules of the auction to meet their commitments refused to do so on the grounds that the (raw material) cost of doing so would lead to bankruptcy. The government had to introduce extraordinary measures to avoid major black-outs.

Recent renewables power auctions also show potential signs of the winners' curse, although it is possible that the prices bid reflect genuine, anticipated cost reductions. As reflected in Figure 3, Andrews compares recent bids for solar PV and wind with estimates of the levelized cost of electricity (LCOE) for these technologies. He ran the best-possible-case analysis on a solar system in the Atacama desert, and concluded that the LCOE would be at least $23/MWh, which is higher than the $17.86/MWh resulting from an auction in Saudi Arabia, where the solar conditions are less favourable. That LCOE is also higher than the lowest successful bid of $19.70 for Mexico, whose solar conditions are inferior. His conclusion is that it is

> 'hard to see how the bidders are going to make money at these prices, which raises the question of whether they bid low simply to secure rights to develop the MW or GW they bid for while hoping to negotiate a better deal in the future.' (Andrews, 2018)

Figure 3: Low bid prices in $US/MWh for wind and solar in recent auctions



Source: Andrews 2018.

While the winners' curse is still a common problem with auctions, there are ways to minimise the problem, for instance through stricter penalties for non-delivery and larger financial guarantees.

Problems with technology-push mechanisms in the power sector, including auctions

Auctions may be better than other, more administrative, mechanisms in meeting certain policy objectives, but we think they are unlikely to avoid problems related to product definition, system issues, principal/agency, and complexity. To a large extent this is due to the challenges of technology-push mechanisms and the specific characteristics of the power sector.

Product definition

As noted earlier in the paper, the 'product' being purchased may express a policy objective (such as reliability), which leads to a risk of over-specification (picking winners) or broad principles which lead to results the governments did not expect or want. We can illustrate this problem by referring to capacity auctions in the UK, firm energy auctions in Colombia, and interruptibility auctions in Spain.

The UK capacity auction adopted a very general definition of the product: capacity guarantees from existing gas, coal, and other plants not receiving subsidies, as well as new CCGT or other lower-carbon power stations. The result was that the government did not achieve one of its primary objectives, which was to develop new CCGT plants or alternative low-carbon options. The government could have restricted bidding to plants whose emissions were below a defined threshold (550 gCO_2/kWh is the proposed EU limit). Instead, the UK auction enables polluting power stations to remain open, rather than encouraging them to be shut and replaced by cleaner ones.

Furthermore, the product definition and auction design adopted in in the UK implicitly ruled out demand-side services. Although there was a parallel auction to enable demand-side options to offer a different capacity service, the products in the main capacity auction effectively meant that only generation assets could compete. The European Court recently annulled a 2014 European Commission decision not to raise objections to the UK's Capacity Market (the Commission's view at that time was that the UK had conformed with the guidelines on State Aids for Energy and Environment). The recent decision followed a challenge by Tempus Energy, which claimed that the UK Capacity Market privileged generation over demand-side response (DSR) in a discriminate and disproportionate manner. Consequently, UK capacity auctions and payments were suspended and new rules must be put in place to take DSR into consideration to comply with the European Court objections.[12]

In **Colombia**, product definition is important in "firm energy" auctions, which are a CRM. On the positive side, the auctions are designed to achieve a clear objective: the building of new plants. Market prices for firm energy are determined by the marginal offer selected through the auction. New plants bid prices and quantities for new firm energy contracts to meet expected demand growth, and are paid the reliability charge defined by the new auction for 20 years. Existing plants are price takers and passive bidders in the reliability auctions – which means that their quantities are taken into account in the auction and the price they receive changes with each new auction (Giraldo and Robinson, 2018). On the negative side, like the UK auctions, they are biased towards generation and indeed do not include demand response as an alternative. Had demand-side flexibility been chosen in the auction, the Colombian system would have needed to rely less than it did on conventional thermal and hydro plants during critical periods related to el Niño hydro shortages in 2015–16. When, in 2016, some of the conventional plant owners refused to meet their commitments due to the high cost of doing so, the government turned to consumers in an ultimately successful effort to reduce demand. There are other

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[12] 'European court annuls State Aid clearance for GB Capacity Market', *New Power*, 15 November 2018: https://www.newpower.info/2018/11/european-court-annuls-state-aid-clearance-for-gb-capacity-market.

problems of product definition in the Colombian auction (discussed below), notably a bias in favour of coal and gas plants and against renewable power (Giraldo and Robinson, 2018).

Product definition also allows governments to favour certain technologies or consumers. In **Spain**, through the definition of products to be purchased, auctions for interruptibility have enabled governments to favour particular large consumers, with the costs passed on to smaller consumers. In 2013, the government decided to use auctions to replace special discounted tariffs for very large electro-intensive consumers who agreed to be interrupted when the system was under stress. As mentioned earlier, the introduction of the auctions eventually led to a reduction in financial support for these consumers. However, for three years, the remuneration through auctions actually rose, before falling in 2018 (see Figure 4), largely as a result of a change in the rules. Until 2018, the government had a budget to spend on this service, in addition to an interruptible capacity target. If it met the capacity target but did not spend the full budget, it would hold an additional auction. In 2018, the government ended this practice. One of the reasons it did so was pressure from European Competition authorities.

Figure 4: Remuneration to Spanish industrial consumers for interruptibility (millions EUR)[13]

Source: *Spain's News*: https://spainsnews.com/the-closures-of-alcoa-coincide-with-a-reduction-of-40-of-the-electric-incentive-to-the-industry-companies/

For many years, European and Spanish competition authorities had expressed concern that the Spanish interruptibility auctions were hiding illegal State aid. First, Spanish reserve margins (>30 percent) were sufficiently high that the value of interruptibility must be very low indeed. Second, the administratively determined capacity payments to generators (per MW) have been significantly below interruptibility payments made to the large consumers through the auction[14]. Third, the government defines the conditions for participating in the auction such that only a relatively small number of very large companies are allowed to bid, thereby limiting competition. Such favouritism has been especially visible for the aluminium manufacturer Alcoa which, according to press reports, has received about 30 per cent of the interruptible service payments.[15] In 2014, the company withdrew its decision to fire staff, following a special auction organized by the government. Recently, arguing that electricity costs were too high and that the auctions were not providing sufficient revenue to remain open, Alcoa announced a decision to shut two of its plants and to fire 700 employees. At the time of writing, the Government was negotiating a special contract with the company to avoid that closure and had begun public consultations about legislation to support electro-intensive consumers.

[13] 'The closures of Alcoa coincide with a reduction of 40% of the electric incentive to the industry', *Spain's News*: https://spainsnews.com/the-closures-of-alcoa-coincide-with-a-reduction-of-40-of-the-electric-incentive-to-the-industry-companies/.

[14] The capacity payments to generators have recently been suspended.

[15] 'Spanish power not main driver for plant closures – Alcoa', *Montel*: https://www.montelnews.com/en/story/spanish-power-not-main-driver-for-plant-closures--alcoa/945084

In summary, the issue of product definition requires further attention. Although auction design could be improved to address the issue, the problem of intended or unintended bias can make a significant difference to the outcome, in terms of the costs, of who benefits and who pays.

System issues

The power sector is essentially an interconnected system: what happens in one part of the system affects all the other parts to a greater or lesser extent. We illustrated this earlier by referring to how renewables penetration had made existing wholesale electricity markets in Europe unsustainable. The problem is that system-wide consequences are often unintended and can be very costly for investors and consumers. Auctions face the same problem.

China offers an example. There, through auctions and other technology-push mechanisms, the government promoted a very rapid increase in renewables. However, this occurred without adequate incentives for the development of the grid, the connection of these renewables, and the use of the renewable electricity (which would have displaced coal-based generation that had been contracted). The result was very high levels of curtailment, reaching about 30 per cent. China is overcoming this problem, but that experience is a good example of the system effects of auctions and the costs of not addressing them adequately in advance.

Principal/agent issues

Any mechanism where government is acting as an agent for consumers in the power sector raises potential cause for concern. Governments have poor incentives to make efficient investment decisions, primarily because they do not themselves assume the economic costs related to their mistakes; these costs can usually be passed on to consumers. However, if there is a risk that does concern governments, it is the political risk of a shortage or a black-out. This gives them understandable reasons for erring on the side of excess capacity. Furthermore, governments frequently use their power to push certain technologies, at a cost that is borne by consumers. Auctions are a means of achieving these political objectives and are open to the same principal/agent concerns.

One example is the UK capacity market. It may have provided no additionality in terms of greater resource adequacy. Plants may have been paid (in total over £1 billion) for doing what they were going to do anyway – namely stay open and be available to provide energy during ‘stress events’ in four years’ time.[16]

A related example is the UK auctions to build new nuclear plants. The government decided that these would be required to achieve ambitious decarbonization targets set by the Climate Change Act 2008, especially since nuclear now generates about 20 per cent of UK electricity and about half of the country’s nuclear capacity is to be retired by 2025 (along with a lot of coal-fired capacity). The government organized an auction to select the sites for future nuclear plants. However, the only outcome to date has been the approval of one power plant, Hinkley Point C. Furthermore, that selection process essentially ended up as a series of bilateral negotiations between the investors (who could walk away) and the government (which could not). The result to date is a 40-year contract at prices that are widely regarded as extremely expensive.

For a third example, it may be worth referring to a case that does not involve auctions, but is indicative of the principal/agent problem we face when governments decide to push a certain technology. The EU decided to adopt renewable energy targets, with electricity contributing most of the renewables; governments decided to pass on the extra costs of these renewables mainly to small electricity consumers, rather than share the costs more evenly through the tax system (as recommended by Newbery, 2015; Robinson, 2017; and Robinson et al., 2019). The result was a significant increase in

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[16] ‘The UK capacity auction made power companies merry this Christmas’, *The Guardian*, 24 December 2014: https://www.theguardian.com/environment/2014/dec/24/the-uk-capacity-auction-made-utility-companies-merry-this-christmas.

the residential price of electricity over the period 2008–15. Governments of course have every right and reason to adopt these targets and to ensure they are met. However, the way they are met can have a significant impact on the total cost and who bears it. Spain, for instance, introduced very generous feed-in tariffs for solar PV and solar thermal, which led to a rapid increase in renewable capacity and cost. The government chose to pass some of the resulting costs on to existing electricity consumers, whose tariffs rose almost 50 per cent between 2008 and 2015. They also chose to pass another share of these costs on to future consumers, who will pay for a 'tariff deficit' of almost €30 billion related to the regulatory entitlements that governments chose not to pass on to customers at the time they were incurred. Furthermore, to stop the tariff deficit from growing further, in 2013 the government introduced (with retroactive effect) a significant reduction in payments to renewables operators and other companies in the sector. None of these costs had resulted from an auction and, indeed, auctions could have significantly reduced the costs and their impacts. However, they are illustrative of the effect of the principal/agent problem, where governments make decisions whose costs are then passed on to consumers and, in this case, investors who had been misled.

Complexity

The electricity sector is complex; this contributes to the problems mentioned above and to the importance of the details in auction design. The fact that the 'devil is in the details' means that auction design really matters, but the complexity of the details is a reminder of why auctions can be a problematic instrument to use.

Complexity is often ignored in resource adequacy auctions. The latter generally focus on meeting demand when the system is under stress due to peak demand or for other reasons. However, with the penetration of intermittent renewables, reliability requires not only sufficient energy resources to meet demand at times of peak, but also the flexibility to respond to changing output from renewables. In these new circumstances, flexibility from a wide range of sources – including flexible generation, demand response, storage, and interconnectors – needs to be integrated. Auctions that ignore this sort of complexity will not resolve key problems related to the reliability of the system.

On the other hand, trying to capture complexity is extremely difficult, as illustrated in this example from Colombia. The Colombian firm energy auction defines how much firm energy each generation technology can sell in the auction. In other words, what percentage of the capacity (the capacity factor) will be treated as providing firm energy in the auction. This seems relatively straightforward for conventional power stations (coal, oil, and gas) since they can stockpile coal and are assumed to be able to obtain the other fuels when needed. They are awarded capacity factors of 87–98 per cent. In practice, being able to produce depends both on the ability and the willingness to obtain the fuels when required, when fuel prices are very high. As mentioned earlier, companies were not always willing to meet their commitments.

The complexity of defining the capacity factor is greater for hydro, which accounts for 70 per cent of Colombia's total generation capacity, on average. Under normal weather conditions, hydro is responsible for 85 per cent of the country's total generation, but this falls to 65 per cent during el Niño weather events, typically for 5–12 months. The equivalent capacity factors for hydro depend on the nature of the resources, ranging from a factor of 55 per cent for hydro with storage to 30 per cent for hydro without storage.

The difficulty of deciding the capacity factors is even greater for non-conventional renewables, such as wind and solar, partly because there is very little history to use as a reference. The regulator assumes a capacity factor for wind plants of 14 per cent or less, but even that figure is only used for plants with more than 10 years of wind speed data. However, some studies have demonstrated firm energy availability of 25–40 per cent during critical hydro periods, suggesting that the regulator has been discouraging the development of renewable power, since low capacity factors translate into lower fixed energy revenues for auction winners. To make matters more complex, the argument in favour of a higher capacity factor for wind is based on evidence of the complementarity of different resources –

especially between hydro and wind. Recent studies have shown high correlations between low water inflows and high wind and solar availability. This complementarity is ignored by the regulator, which calculates the contribution of each plant on a stand-alone basis.

Have we reached peak auction for renewable power?

Finally, as the cost of renewables falls, the case for auctions becomes less obvious. For some regions and technologies, notably solar PV and onshore wind, we may have already reached, or will soon reach, 'peak auction'. The costs of participating in auctions and the obligations on bidders and winners (e.g. bid bonds, penalties for not delivering) are significant, whereas the premia being earned through auctions are sometimes zero or close to zero. For instance, this has been the case in Spain in recent auctions for almost 8 GW of wind and solar PV generation, where premia for contracts (above current energy market prices) were zero. The outcome of German offshore wind power contracts was similar. We need to be careful about reading too much into these results. In Spain, the auctions offered an insurance policy that provides a premium if the energy price falls below a floor. In Germany, the auction prices do not include the cost of the network built to connect the offshore plants. Nevertheless, as the costs of renewables fall, the case for merchant plants and power purchase agreements (PPAs) grows.

Indeed, we are beginning to see investment in large-scale renewable plants outside auctions[17]. For instance, we see growth in the sourcing of renewable energy by industrial and commercial consumers. IRENA (2018) reports the corporate sourcing of renewables in more than 75 countries, mostly in Europe and North America. Active corporate sourcing globally, reached 465 TWh of renewable electricity in 2017, representing about 18.5 per cent of total renewable electricity demand in the commercial and industrial sector. By volume, the majority of renewable energy sourced by corporations was by the materials sector, which includes mining, pulp and paper and chemicals. The highest shares of corporate-sourced renewable electricity are from Financial (24%) and Information Technology (12 percent) companies.

The most common sourcing model (35 percent) has been renewable power production for own-consumption. Energy Attribute Certificates (EACs) and corporate Purchase Power Agreements (PPAs) each account for about a quarter of the total. PPAs are increasingly common and involve a company entering into a contract with an independent power producer, a utility or a financier. The buyer commits to purchase a specific amount of renewable electricity, or the output from a specific asset, at an agreed price and for an agreed period of time. By early 2018, over 900 PPAs had been signed, amounting to over 20 GW. Corporations also buy EACS (like certificates of green origin) that are unbundled from the energy itself.

There is also evidence of vertically integrated companies using PPAs for their internal transactions. In Mexico, for instance, one company´s bids were not selected in a specific auction for renewables. However, the company built the renewables capacity anyway and has used the auction price as the basis for selling the electricity to its downstream affiliate.

In Spain, we see growing interest in non-auction investment in renewable power. Already, some of the generators' have locked in revenues through a combination of PPAs and forward contracts (up to six years) or supplementary generation to hedge price risks associated with meeting firm commitments when the renewables plants are not operating. Even more revealing is the government's energy and climate plan just submitted to the European Commission (Spain 2019). That plan calls for 6 GW of additional renewable power capacity each year between 2021 and 2030. At least 3 GW will be awarded through central auctions, but the plan anticipates significant additional investment in renewable generation outside of the auctions, especially for own-consumption.

[17] Of course, there is significant growth in rooftop solar and other small scale renewables. However, this is usually driven by regulatory incentives rather than energy market revenues.

These examples suggest less reliance on central auctions for large scale renewable plants. Non-auction investment is still a small proportion of the investment occurring in large-scale renewable power, but perhaps it is a sign that we are approaching peak auction in some countries and with mature technologies.However, we are not there yet. For this sort of non-auction investment to become commonplace, there are three related conditions.

- *Energy market prices that support efficient investment*. The first condition for peak auction is that investments can be financed from expected energy market revenue streams without an auction. Investors must expect to realize wholesale energy prices – or secure revenues – that are sufficiently high to recover investment and operating costs. At the OIES, we are carrying out research on this. Our initial hypothesis is that there is a three-stage process.

    1. At relatively low levels of penetration by renewables, and with high renewables costs, investment in renewables cannot be recovered through energy-only markets.
    2. With low or moderate penetration by renewables and much lower renewables costs than in Stage 1, investment costs may be recoverable because expected wholesale energy market prices that apply to those renewables are high enough to allow cost recovery.
    3. With deep penetration of renewables and very low costs, wholesale energy market prices that apply to the plant will be so low that investment in renewables cannot be recovered without an auction or other support.

    We think that some European countries, such as Spain, may now be entering into Stage 2, although very few PPA contracts have been signed. It is unclear how long Stage 2 will last, since rapid penetration of renewables between now and 2030 could mean that we move very quickly from Stage 1 to Stage 3, meaning that auctions or other support mechanisms continue to be required to achieve the penetration that governments are committing to. In order to avoid the need for future auctions over the longer term in electricity systems that rely on energy-only markets, we are convinced that market reform is required, as explained in previous reports (Keay, 2016; Keay and Robinson, 2017). Without the confidence that these markets will provide the required revenues, it will be very difficult to attract investment, especially by new entrants.[18]

- *Regulations for permitting and connections*. The second condition is the need for clear regulations for permitting and connections. Centrally organized auctions serve as a basis for controlling the speed of penetration by renewables, determining, or at least influencing, which projects will be awarded permits and connections. In the absence of auctions, it is possible that investors will overwhelm network operators with requests for early connections, especially if the perception is that energy market prices will begin to fall when penetration rises significantly. Even if the government continues to organize central auctions, it is important to develop efficient regulations to manage permitting and connections so as to allow non-auction projects to proceed.
- *Clear policy signal to end or limit auctions.* Governments should state clearly that they will no longer subsidize technologies that are viable without public support; most potential bidders are unlikely to turn away potential public funding even if they no longer need it. One less radical proposal is that the government initially limit the amount that will be auctioned, leaving the remaining capacity to be developed through bilateral or other transactions.

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[18] New entrants in Spain have been able to raise low-cost debt finance because of the security provided by auctions, allowing them to compete successfully with incumbents who continue to rely on internally generated funds. There is a risk that the end of auctions would reduce the potential for new entrants to compete, leaving incumbents as the only investors.

Once these three conditions are met, investment in mature technologies can proceed without relying on auctions, or at least relying less on them. Indeed, from discussions with some investors, the latter may well prefer to rely on markets, which are difficult to change, rather than on specific regulations that governments can easily change, or on auctions that governments control. Then, auctions and other forms of public support can focus on promoting innovation in alternative renewable technologies (e.g. generation from biomethane or hydrogen) and in other goods and services (such as storage) that can be considered "public goods".

6. Network expansion and other possible developments

But there have also been proposals for widening the scope for auctions, in particular to address one of the problems noted above, the systems nature of electricity; this relates to the fact that rather than trying to get a particular sort of resource at the lowest cost, the emphasis should be on securing the optimum mix of resources to meet the needs of the system as a whole. Some analysts have therefore put forward proposals for a form of franchising of network expansion. This should help deal with some of the issues because: such auctions could specify the problem to be addressed (rather than identify a particular solution), and because they invite applicants to deal with a system (or at least part of the system) they should be more effective in promoting system optimization and should in principle be less sensitive to the precise auction criteria. It may also be easier to involve consumers in decisions about the approach to be adopted and to limit the amount of risk to be passed on to consumers (for example by setting a fixed price for the expansion contract).

Two significant proposals have recently been made in this area and they bear many similarities:

- The **Helm Review** *The Cost of Energy Review* by Professor Dieter Helm, published in October 2017 (Helm 2017) made a number of wide-ranging recommendations for changes to electricity markets in the UK; these included the abandonment of network regulation as it has been traditionally practised, and its replacement by a system of auctions for network expansion. Helm argues that the existing system of periodic tariff reviews has had its day. Technologies are moving so fast that it is almost impossible to forecast future cost savings – companies are therefore able to outperform against regulatory expectations, in effect making extra profits which could have benefited consumers. Furthermore, the traditional approach to network regulation, based on unbundling the industry into monopoly and competitive elements, is probably outdated. The distinctions between transmission, distribution, generation, and supply are being undermined. Different parts of the system are increasingly in competition with each other; for instance, a proposal for reinforcement or extension of the distribution network might in the past have been met by spending on the wires business, but now there are also other options which include local generation, storage, and demand-side resources. Helm argues that this means considering all the options together and, among other things, doing away with the distinction between different sorts of licence for generation, supply, and distribution. He would also considerably downplay the role of Ofgem after the end of periodic reviews. Instead, he would establish new public system operators at national and regional level; these bodies would determine what operations, maintenance, and enhancement to the networks were required and then be responsible for ensuring that these were delivered, normally through competitive bidding.
- **Corneli** Steve Corneli, a US consultant and industry expert, has independently made a rather similar proposal, summarised in an article entitled 'Efficient markets for high levels of variable renewable energy'(Corneli, 2018). Corneli reviews the market issues outlined above to propose a new approach, which is designed to adapt innovative and emerging system planning tools to serve as a platform for operating a periodic (for example every three to five years) regional long-term investment market for the specific mix (in terms of

quantity, type, and location) of resources needed. Such a market, which Corneli calls a 'configuration market', would select only those resources and assets that are found, analytically, to be part of the least-cost portfolio that meets reliability, integration, carbon emission, and related standards. In his view, it would be superior to current planning approaches because it would replace planning cost assumptions with actual competitive bids to develop and operate new resources – supply side, demand side, storage, and transmission – as well as maintaining and operating existing resources. It could also, when used by regional and interregional market operators, avoid the artificial constraints on optimization and decarbonization that have been created by state and utility service territory boundaries. Further, these bids would not only identify real costs, but would also identify commercially feasible projects, rather than assuming them. This would allow the configuration market to identify least-cost and reliable combinations of feasible resources that would support each other, rather than cannibalize, curtail, or otherwise conflict with each other. The periodic, regular nature of the market would support the development of a 'ladder' or 'stair' of clean energy projects and PPAs over time, allowing the portfolio and the market as a whole to identify, support, and embrace changing technologies, innovation, and energy use patterns over time.

These are fairly fundamental proposals. However, they go with the flow of current regulatory thinking, at least in the UK. In its 'RIIO-2' proposals (Ofgem, 2018) Ofgem is seeking to drive innovation and efficiency by, amongst other proposals, extending the role of competition for the provision of infrastructure. The proposals are relatively cautious when compared with the wholesale system reorganizations described above. Ofgem intends to build on an existing set of criteria originally developed for electricity transmission – that competition is possible in cases where infrastructure is new, of high value, and separable – and to extend this approach to other sectors such as distribution networks. This is all part of Ofgem's generally evolutionary approach; it believes it has the tools to deliver 'whole system' outcomes – a term it intends to further clarify – without major structural changes to the regulatory approach and it is likely to involve the use of auctions of the sort described above.

As far as the empirical evidence is concerned, Ofgem's caution may be justified; there are, as yet, few examples within the electricity sector itself to draw on and examples from outside the sector (for example, UK rail franchising) suggest that there are many pitfalls. It is beyond the scope of this paper to discuss rail franchising, but it is worth noting that this approach has not been a total success in the UK and is currently under review.[19] For instance, it has led to high bidding and transaction costs, due to the extensive and complicated contractual relationships between different parts of the system; it has also blurred accountability, leading to accusations that 'no-one is in charge'. It has not been effective in engaging consumers. Customer satisfaction levels are falling and prices are rising at a time when service quality is, in most consumers' view, declining.[20] The system has also had limited success in transferring risk – a number of franchises have been curtailed or abandoned when the franchisees could no longer viably deliver their commitments, with the ultimate risk falling on consumers. Similar problems were encountered in relation to a reverse auction undertaken by the Nuclear Decommissioning Authority in the UK. A Parliamentary Report[21] concluded that

[19] 'Government announces "root and branch" review of rail', Department for Transport (UK), 20 September 2018: https://www.gov.uk/government/news/government-announces-root-and-branch-review-of-rail.

[20] 'Rail passenger satisfaction at lowest level for a decade as watchdog says timetables are "work of fiction" ', *The Telegraph*, 24 January 2017: https://www.telegraph.co.uk/news/2017/01/24/rail-passenger-satisfaction-lowest-level-decade/ https://www.theguardian.com/money/2019/jan/02/rail-passengers-protest-stations-fare-rises.

[21] 'The Nuclear Decommissioning Authority's Magnox contract', House of Commons Committee of Public Accounts, Twenty-First Report of Session 2017–19, HC 461, 28 February 2018: https://publications.parliament.uk/pa/cm201719/cmselect/cmpubacc/461/461.pdf.

> ‘The NDA ran an overly complex procurement process, resulting in it awarding the contract to the wrong bidder, and subsequently settling legal claims from a losing consortium to the tune of nearly £100 million.’

Complex auctions add to the risks, highlighted earlier, that things can go seriously wrong.

7. Concluding comments

This paper has looked at experience with auctions in electricity organized by central purchasers for the purpose of procuring reliable capacity or low-carbon resources. In general, these sorts of auctions have been regarded as a success in helping bring down the cost of such capacity. But the paper has also considered some wider issues occasioned by the use of auctions, and has identified a number of problem areas. The paper has not attempted to look at auction design in detail, to explore their use by private buyers or to set out the alternatives to the use of auctions by governments – which would greatly increase the length of the paper.

Nonetheless, the discussion above does suggest some general considerations in these areas. First, in relation to **auction design**, perhaps the primary message is that underlined in Section 3: complexity. Circumstances differ in every case and there can be no simple answer or one-size-fits-all solution. But the analysis above can provide some general pointers, in relation to the three special features of electricity highlighted in that section and illustrated in section 4.

Product definition: perhaps the easiest way to mitigate the problem of product definition is not to define a product in the first place, but to think in terms of a service which is needed and would not otherwise be provided. For instance, rather than necessarily defining a need in terms of capacity, it may be better to consider the level of reliability needed and how best to promote it. Similarly, with low-carbon sources, the aim should be, as far as possible, technological neutrality rather than an attempt to promote any specific resource. This does not necessarily mean trying to cover everything with a single auction – for instance, an auction whose aim is to help immature resources develop towards maturity may need a different structure from one whose aim is simply to maximize the amount of low-carbon resource developed at a given cost.

System issues: this is a particularly difficult problem. Short of franchising a whole system (which would raise many other issues) it is inevitable that any given auction will involve only part of the system. This means that governments and system operators will need to think through the issues very clearly **before** they start the auction design itself. For instance, building a given quantity of low-carbon capacity may have implications in terms of transmission costs. Even if governments do not necessarily want these costs to fall directly on the low-carbon resources themselves, they should take them into account in planning the auction, if their goal is to develop a sustainable low-carbon system at minimum cost. Similar considerations apply with balancing, backup, and other wider system issues.

Principal/agent issues and risk transfer: the first question to be asked in this area is: does the government (or system operator) have to act as agent in this respect? For instance, does it really have to impose its own definition of reliability or can it increase the extent to which consumers can determine their own liability preferences (see below)? In relation to risk transfer, two options may be worth considering:

1. leave some of the risk with developers, for instance via feed-in premia or other ways of exposing developers to market prices, or by limiting the term of contracts granted via auction so that consumers are not bound, without their involvement, into expensive long-term commitments.
2. limit the risk transferred to consumers as far as possible by better auction design. For instance, the use of multi-round auctions, or holding frequent auction rounds, is likely to be better at revealing true costs and in limiting the risk that consumers are tied into unnecessarily expensive contracts.

In summary, therefore, the evidence suggests that not only have auctions had a positive impact in revealing and reducing costs, but that there may also be further scope for improvements in this area. In this sense, auctions have been a success. However, this is essentially a relative judgement – auctions have in general been an advance on the administrative pricing of renewables or of reliable capacity. But in the view of the authors of this study, even with the various refinements discussed above, the use of auctions does not solve the underlying problems, in the three areas above, of using specific support mechanisms for favoured technologies or techniques; furthermore, they add additional issues in terms of inherent complexity. Governments should not therefore see the success of auctions to date as an indication that they represent the optimum long-term solution for the sustainable low-carbon market of the future.

As regards the alternatives to auctions, this is not the place to go into any detail, and the authors have discussed some ideas at greater length elsewhere. They believe that fundamental changes are required in two main areas.

The first is **market design** (Keay, 2016). Existing electricity markets are based around twentieth century technologies and on short-run marginal costs (srmc), which have little relevance to most renewables resources, with their zero marginal costs. Reforms are needed which enable these zero marginal cost sources to remunerate themselves from markets and, at the same time, provide meaningful signals to consumers about the cost of supply and reliability. Keay and Robinson (2017) proposes one such solution, but many other ideas are currently under discussion, including in Billimoria and Poudineh (2018).

The second is **low-carbon support**. Because combating climate change has the nature of an externality or public good, it is unlikely to be delivered by markets on their own. On the other hand, measures designed to promote specific forms of low-carbon generation are liable to introduce distortions by favouring particular government-preferred techniques or technologies. A wider use of economic instruments to support low-carbon power should deliver greater efficiencies. One option, of course, is a carbon tax or trading scheme. However, this raises some difficult political issues, as noted above, and – for the reasons given in Keay 2016 – such a measure would not, in any event, work on its own without effective market reform. Other market-friendly instruments are therefore worth consideration; one option is to adopt tradable carbon intensity targets (Buchan and Keay, 2015, Annex 2).

If action can be taken in these areas and markets can be redesigned around these principles, the need for auctions should fall away and low-carbon and reliability resources could be developed in response to market signals from consumers.

The overall conclusion of this paper is thus that while electricity auctions organized by, or on behalf of, governments have their place, and are in many ways an improvement on what went before, governments should still be cautious about using them and should consider the alternatives. They are unlikely, in general, to provide the basis for an efficient and sustainable low-carbon system in the longer term. For some purposes, for instance short-term balancing, continuous auctions are likely to be a permanent feature, but these should be adapted to reflect changing technologies and economics, in particular to enable consumer participation. For most other purposes, notably related to investment, auctions may be better than today’s alternatives, but they reflect temporary conditions (such as uneconomic technology) or the absence of well-designed markets (namely those that recognize the externalities). Electricity markets are ultimately designed (or their designs approved) by regulators and governments. There is always a temptation to design them around government objectives rather than consumer preferences and governments should be constantly alert to the need to consider whether the balance is right. When circumstances change, auctions may no longer be better than competitive market alternatives. With that in mind, it is important to keep thinking about the scope for redesigning markets and regulations for the future, allowing consumer preferences to drive decisions, and leaving investors to bear the risks associated with their investments.

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