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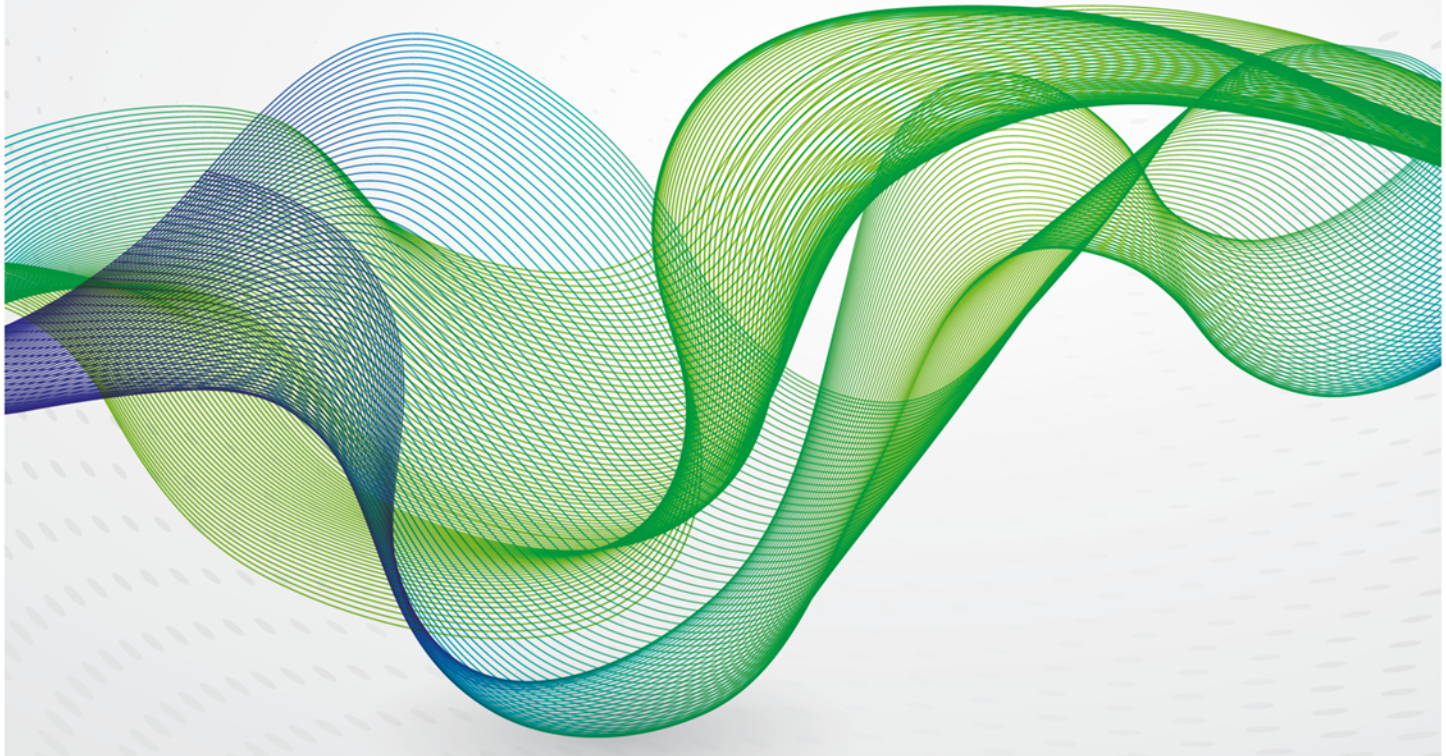
Glimpses of the future electricity system?
Demand flexibility and a proposal for a special auction



Oxford Energy Comment

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During the course of 2020, we have witnessed glimpses of what the future electricity system may bring. In particular, we have seen evidence of the need to deal with the significant increase in the penetration of intermittent solar PV and wind energy. The recent outages in California have illustrated the absence of preparation to cope with the reduction of solar PV when the sun sets. Likewise, periods of abundance of renewables both there and in other countries lead to questions about a system's ability to absorb renewables and the costs imposed to cope with the excess.

This comment[1] poses a question: if these glimpses are reasonably accurate, what implications do they have for policy makers? We are not saying that the glimpses are an exact representation of the future. However, they are consistent with many longer-term forecasts and have made more evident some changes that were already underway.

The aim here is to reflect on these glimpses and propose a two-market approach that would help to address the challenge of integrating intermittent renewables, in particular by encouraging flexible demand to match output from renewables. Since this approach would require fundamental change to existing markets, that might be too much to expect in the near term. However, we believe that experimenting with the introduction of individual elements of the proposal could still deliver considerable gains and might be easier to introduce without major disruption. One proposal is for governments that organize centralized auctions for renewables to use them to incentivize demand-side flexibility through supply contracts that mirror the generation contracts with renewable generators.

The first section looks at some of the ways in which COVID-19 could be giving us glimpses of a future decarbonized energy sector. It lists a number of features of the energy scene in the early lockdown period which seem consistent with forecasts for the longer term in many climate scenarios. The second section refers to the challenges posed by the penetration of intermittent renewable electricity. The third introduces the 'two-market' approach and the fourth recommends ways to introduce one key element (demand flexibility) from that approach to facilitate the penetration of renewable power. The fifth section proposes introducing demand-flexibility incentives into the planned renewables auctions in Spain.

Glimpses of the future electricity sector

During the early period of the COVID-19 epidemic (Q1–Q2 2020), the world witnessed changes which are consistent with developments that have been widely forecast for 2030 and beyond. For instance, with respect to electricity:

- **There was a shift towards electricity, especially in residential use**. Global electricity demand fell by much less than demand for other types of energy, due to increasing residential consumption – matching a shift seen in many decarbonization scenarios.
- **Renewables provided an increasing share of energy generation**, while baseload operations declined. Renewable energy generation increased by 1.5 per cent globally, while generation from other sources fell. This reflects policy-driven support for renewables investment and the fact that renewables run when they are available and displace baseload generation.
- **Absorbing renewables has presented major challenges**. Lower demand has caused problems for many systems, especially where renewables were an important part of the mix. In California, for instance, for the first quarter of 2020, curtailments of renewables were twice as high as in the first quarter of 2019. Furthermore, we recently witnessed rolling blackouts there, due to inadequate firm and flexible resources to replace solar energy after the sun goes down.

[1] This Comment draws on two articles by the authors, 'COVID-19: Glimpses of the energy future?', *Oxford Energy Forum 123*, July 2020; and *The Decarbonised Electricity of the Future: the 'Two Market' Approach*, Oxford Institute for Energy Studies, June 2017.

- **Falling and negative wholesale electricity prices have coincided with rising final tariffs**. Lower demand and rising renewable output are driving wholesale prices down, while negative prices have become more common as generators have to be paid to reduce output in the face of low and inflexible demand. In a small number of cases, consumers have been able to enjoy these negative prices; more commonly, final tariffs are rising or will rise. In Germany, for instance, network charges (per kWh) increased to recover fixed costs from lower throughput, subsidies for renewables rose with higher renewables output, and balancing charges increased.
- **Balancing the electricity system to cope with the penetration of renewables is becoming increasingly difficult**. In the UK, balancing costs as a percentage of quarterly energy costs rose to over 20 per cent in the first half of 2020, compared to about 5 per cent over the last decade and 10 per cent last year.
- **Confinement at home has significantly increased consumer use of the internet for working from home, online shopping, and communications**. The accelerated digitalization of society is consistent with an increase in the potential for more active consumer participation in the power sector, especially with the support of aggregators and energy communities, and, more widely, with the increase in telework and reduction in business and leisure travel.

Experience during COVID-19 has thus introduced and tested new patterns of energy demand and supply. As we mentioned at the outset, we are not arguing that we have witnessed an exact replica of the future. However, many of these new patterns are in line with those that have been widely predicted for a more distant future and some (such as negative prices) were already evident before COVID-19, but such patterns have become more obvious during the pandemic. We think it is therefore reasonable to ask what the implications of these changes are for policymakers in the energy sector.

Electricity – coping with the penetration of intermittent renewables

In recent years, the Oxford Institute for Energy Studies (OIES) has researched and analysed the changes under way in the electricity industry. These have been driven by two main forces: the increasing penetration of intermittent renewable sources, in response to climate change measures and declining cost; and developments in information technology, which have transformed the industry's capacity to control, monitor, and coordinate different sources and activities, thereby facilitating the growth and scale of decentralized energy resources. Together, these developments have fundamentally changed the nature and operations of the sector, turning it 'upside down'. The table below summarizes the ways in which the industry of the future is likely to differ from the existing position.

Projected changes to the electricity industry

	2020	**Future**
Cost structure	Mainly marginal	Mainly capital
Generation structure	Mainly centralized	Decentralized
Pricing	Per kWh	?
Planning and operation	Flexible supply to match demand	Flexible demand to match supply
Control and dispatch	From centre	Throughout system (internet)
Role of demand side	Passive	Interactive
Role of grids	Neutral conduit	Smart player

To a significant extent, the glimpses discussed above have provided a preview of this future system and the challenges it poses. We draw on two examples to illustrate especially the challenges of

incorporating intermittent renewables and the new role for flexible demand to match increasingly uncertain generation output.

The UK

In the UK, in the first quarter of 2020, generation from renewables exceeded that from fossil fuels for the first time. With the still significant nuclear component, this meant that the dominant element in the cost structure of generation was capital rather than marginal cost, and that the flexibility of generation diminished substantially. Meanwhile, generation from decentralized sources has grown – for instance, output of solar power (mainly decentralized) at its peak on 20 April 2020 met around 30 per cent of UK demand, a record. At times, intermittent renewables as a whole have reached 60 per cent or more of generation. During the weekend of 23–24 May, renewable generation in the UK amounted to 73 per cent of the total while, not coincidentally, carbon intensity reached the lowest level recorded, at 46g/kWh – well below the target for 2030 and a reduction of over 90 per cent compared with the 1990 baseline. Changes on the supply side are capable of meeting even very ambitious carbon targets.

But there have also been challenges. Output from renewables has been volatile – for instance, during the week commencing 4 May, wind averaged 9.2 per cent of the generation mix for the first six days of the week before jumping to 41 per cent on 10 May. In short – in line with expectations for the future – the system has been much less carbon intensive, but it has also had to adapt much more rapidly and flexibly than in the past and without the tools it used to rely on.

It may prove helpful that the future has arrived more quickly than expected (even if this is only temporary). In the process, we may be able to learn some practical lessons which, while consistent with the general trends above, were not necessarily obvious in advance. For instance:

- **Role of nuclear –** Many industry observers have seen decarbonization as paving the way for a nuclear renaissance, arguing that no other source can provide large quantities of secure, carbon-free baseload power. But experience in 2020 suggests that nuclear may not be such a good fit in a decarbonized system – the concept of 'baseload' is becoming less relevant, and large quantities of inflexible generation are proving to be more of a problem than a solution in a renewables-dominated system. An agreement reached this spring between the UK System Operator and EDF Energy to reduce output from the 1.2 GW Sizewell B nuclear power station was one illustration of the problem. If nuclear is to have a role in the low-carbon future, this may have to be in providing flexibility rather than baseload power. Indeed, in France, this seems to be happening already – the French System Operator has described itself as acting like a 'permanent acrobat'. The design and operation of any new nuclear plants may need to be based on their acrobatic abilities.
- **Role of the demand side –** Although overall energy demand has seen the big shifts described above, electricity demand has in fact changed relatively little (at least in terms of the scale of the changes needed to make a significant contribution to decarbonization), and its role may need to be rethought. Traditionally, the demand side has been seen as passive and the main policy focus has been on energy efficiency. Even in relation to 'demand response', most attention has been on shifting consumption away from times of peak demand. But recent experience has created a new focus on peak supply and the need to find efficient ways of increasing demand to match it (for example by filling storage). However, the instruments for doing so remain rudimentary – negative wholesale prices rarely get through to consumers (and sometimes not even to generators sheltered by support schemes for renewables). They have been supplemented by ad hoc instruments, such as the UK System Operator's Optional Downward Flexibility Management service, which encourages large users and generators to increase demand or reduce generation during low-demand periods, but these remain marginal elements. In the longer term, more fundamental market reforms will likely be needed to encourage active consumer

participation, for example as outlined in a 2017 OIES proposal for a 'two-market' model,[2] as explained below.

- **Platforms –** The old model of electricity supply was straightforward: electricity flowed from a central generating unit, through transmission and distribution systems, to the consumer. Now the picture is much more complicated. Not only are consumers increasingly active participants via flexible demand, they may also be producers themselves (for example via rooftop solar panels), and their demand patterns may be more complex (such as through electric vehicle use), while more real-time information about their consumption is available via smart meters. Meanwhile, a host of other sources (for instance decentralized generation, storage, and community energy systems) also need to be coordinated. Future business models may depend on the effectiveness of a company's platforms for integrating all the sources in real time (just as Uber, which is essentially a platform, has revolutionized the car hire business). Two recent developments may illustrate this: in March 2020, Octopus Energy announced a partnership with E.ON in the UK to migrate about 6 million customers to its Kraken platform[3] over the next two years; and in May, Origin Energy, one of the three big Australian suppliers, acquired a 20 per cent stake in Octopus Energy, reportedly attracted by its platform. When these rollouts are complete, some 17 million customers will be on the Kraken system.

California outages

In August, California's system operator (CAISO) intentionally scheduled rolling blackouts due to a shortage of resources available to keep the lights on in the evening (once the sun had set and solar energy output had dropped). This was the first time since 2001 that rolling outages like this had occurred in California. Many people were quick to offer their diagnosis of the problem. President Trump, for instance, blamed the outages on California's use of solar and wind. Others suggest there is a recurrence of 2001 Enron-type market manipulation. Meanwhile, serious analysts have identified a number of pre-existing problems that led to the outages.[4] Here are three of the key problems, which are related.

- **Absence of flexible resources to balance the system** – Since wind and solar technologies run when they are available, and availability depends on the wind and sun conditions at any moment, there is a requirement for other firm and flexible resources that can be ramped up or down to balance supply and demand when needed. Flexibility can come from other generation units, pumped-storage hydro, interconnection, batteries, or demand. As it happened, there was a shortage of these alternatives.
- **Absence of clear responsibility for keeping the lights on –** Another central problem, which explains the first one, was the absence of clear responsibility for keeping the lights on. In some countries and regions, distribution or other companies are responsible for investing in, or contracting for, sufficient firm capacity to keep the lights on. In others, markets use auctions or other mechanisms to meet this responsibility. In California, the system operator is responsible for dispatching power plants but not for investment decisions. The regulators are responsible for lining up sufficient resources. This has to be resolved, apparently through the actions of the California legislature and the Federal Energy Regulatory Commission, which regulates CAISO.

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[2] *The Decarbonised Electricity of the Future: the 'Two Market' Approach*, Oxford Institute for Energy Studies, June 2017. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/06/The-Decarbonised-Electricity-Sysytem-of-the-Future-The-Two-Market-Approach-OIES-Energy-Insight.pdf

[3] Octopus Energy's 'Kraken', is a cloud-based energy platform for interacting with both consumers (via the web, mobile, and smart meters) and the industry (e.g. data flows, consumption forecasting, trading on the wholesale market). https://octopus.energy/careers/back-end-developer/

[4] See for instance, Cheryl Lafleur of the Earth Institute at Colombia University in 'What´s Ailing California´s Electric System?', 2 September 2020. https://blogs.ei.columbia.edu/2020/09/02/whats-ailing-californias-electric-system/

- **Absence of market or regulatory instruments to incentivize investment and real-time provision of flexibility** – The first problem (absence of flexible resources to balance the system) reflects the absence of regulatory or market incentives to develop the required flexible resources; this is the consequence of confusion over responsibility for keeping the lights on.

In the end, the outages have been mitigated by calls on large battery owners to provide electricity and by pleas from the government and experts for consumers to reduce the use of air conditioning in the evening, after the sun goes down (and solar generation falls). Both of these involve demand flexibility; for consumers to either adjust their consumption downward or to use energy from storage. But price incentives to encourage flexible demand are not part of the California regulatory regime for small consumers. This glimpse from California is further confirmation that decarbonized electricity systems will require new market or regulatory incentives for flexibility, including from the demand side.

The two-market approach – demand flexibility

These glimpses from the UK and California demonstrate that while new technologies such as wind and solar are needed to reduce carbon emissions, they are not the end of the story. Their effect is to change the whole underlying operation and dynamics of the system. The electricity sector is moving from a position where flexible generation responds to uncertain demand, to one where flexible demand is needed to respond to uncertain generation output. This is especially true in areas where local demand flexibility can match local renewable output. Furthermore, we are not speaking about shifting demand from predictable peaks to predictable off-peak periods for an entire system. Rather, we need demand to respond to very uncertain solar and wind output that can be very local (imagine cloud cover reducing solar output at short notice).

There are many proposals being discussed to introduce flexible demand, ranging from different time of use (ToU) tariffs to encourage demand response, to allowing the sale of demand flexibility in energy and ancillary service markets.[5] Without going into the details, we would note that most traditional ToU tariffs do not adequately reflect the very uncertain nature of the intermittency of renewables or their local characteristics.

We have developed a different approach, involving the use of incentives to consume electricity when renewables are available and producing. The two-market approach is described in detail in an OIES paper referenced at the beginning of this Comment. Here are the five central features; these are reflected in the graphic below, which differentiates between On Demand (OD) and As Available (AA) markets.

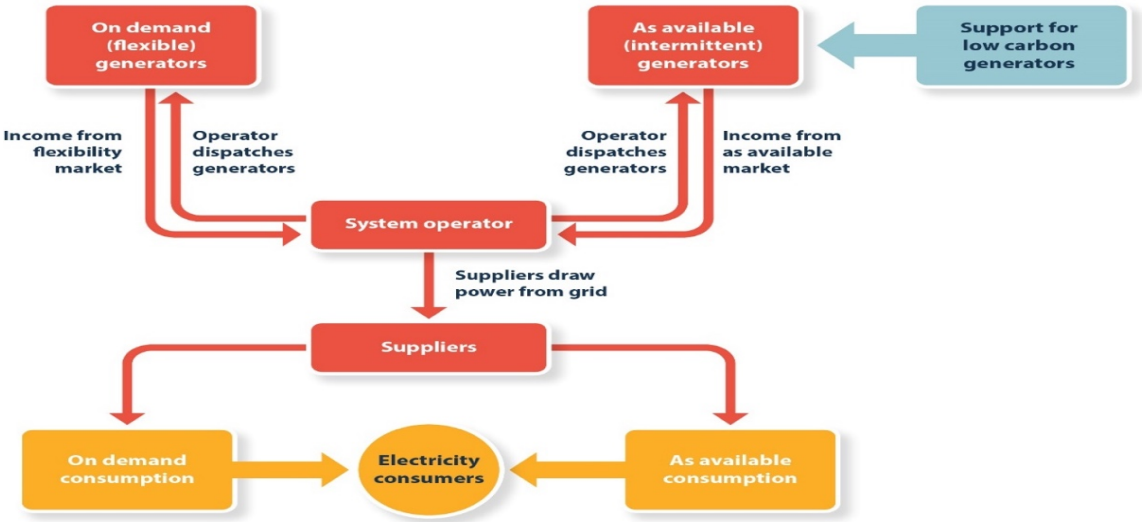
- **Upstream, On Demand conventional generation** (such as gas and coal plants) operates and is remunerated as in the current energy-only market. These plants are dispatched in merit order and paid the short-term system marginal price (p/kWh) in the OD market. This price is volatile and will internalize carbon emission prices when the marginal plant emits CO_2.
- **Upstream, As Available generation** includes assets with intermittent output (such as solar PV and wind) which operate when they are available and are paid (p/kWh) on the basis of the long-term average cost of the technology (p/kWh). These AA prices will be stable. For them to be attractive to users, they must be lower on average than OD prices. It may be necessary initially for government to subsidize the AA prices; hence the box that refers to

[5] For example, see: IRENA, *Time-of-use tariffs: innovation landscape brief*, 2019; Faruqui, A. and Sergici, S. 'Arcturus; international evidence on dynamic pricing', *The Electricity Journal* 26(7), pp 55–65, 2013; and Sarah Darby, 'Demand response and smart technology in theory and practice: Customer experiences and system actors', *Energy Policy*, Volume 143, August 2020, 111573.

'support for low-carbon generators' in the graphic. However, as renewable generation costs fall and carbon emission prices rise, this support will become unnecessary.

- **Downstream, On Demand consumption** refers to energy that the consumer can always consume at a retail price that reflects the OD generation market price. In other words, the consumer will pay a price that reflects the cost of the reliability provided by the OD markets.
- **Downstream, As Available consumption** refers to consuming when AA generation is operating; the AA retail price reflects the stable AA generation price. The higher a consumer's AA consumption, the less it relies on the OD market.
- **Connecting upstream and downstream**, the system operator dispatches all of the plants, with the AA generation running when available and the OD generation called in order of merit. The two markets are balanced separately. Generators are paid the prices that correspond to the market in which they operate. Suppliers sell both AA and OD energy to final consumers, who are free to select their preferred mix. The electrons actually consumed are, of course, not the same as those generated by contracted generation (OD or AA). However, consuming contracted AA energy at the same time as it is being generated (rather than when it is not) essentially means that the system is relying more on renewables and less on fossil fuels. This coordination is now possible; the renewable generator meters its output and its consumers meter theirs; any imbalances are settled according to contracts.

The two-market approach



The benefits of this approach are as follows.

- **System benefits** – In the short term, the two-market approach won't make any real difference to the system. As now, renewables will get priority dispatch either by law or because they can bid in at zero cost. However, in the longer term it may encourage demand shifting and use of storage, which helps the overall resilience of the system.
- **An exit strategy for subsidies** – This approach offers an exit strategy for subsidies on renewables and for the remuneration of reliable capacity (in the OD market). Initially, as mentioned earlier, to make AA energy attractive, government may choose to subsidize the price paid by consumers who select it. However, as the cost of renewables falls and the CO_2 price for fossil fuel generation rises, consumers will have an incentive to contract AA energy without a subsidy. Furthermore, the incentive to consume AA energy and the ability to avoid OD energy will make it easier for governments to allow OD energy prices to rise to

levels that remunerate investment in reliable generation. This should also reduce the total amount of firm capacity that the system needs, thereby lowering overall system costs.

- **Consumers' benefits** – Consumers will have an economic incentive to consume AA energy at a stable and attractive price, avoiding paying for OD energy at higher and volatile prices. Contracting for AA energy will also give consumers the ability to determine when they rely on the system for reliability and how much they are willing to pay for reliability. All consumers connected to the network will continue to receive electricity. Consuming electricity when AA energy is not available does not affect the right to buy OD energy; it means that the consumer will pay for OD energy, typically at a higher price than for AA energy. There are other benefits that matter to many individual consumers and to energy communities, in particular to have control over the mix of energy that they buy and use, and to contribute to the reduction of emissions.
- **Supply chain opportunities –** The challenge for the consumer of AA renewable energy is to adjust consumption (including storage) to follow as closely as possible the time when contracted renewables are generating. This will stimulate the need for smart devices, smart metering, storage, and services that enable the consumer to consume when renewables are available. This is an important new business opportunity with global market potential.

Experimenting with the two-market approach

Although we think that this approach is a suitable model for the future decarbonized electricity system, it would require fundamental changes to existing markets. We believe that experimenting with the introduction of individual elements of the proposal would deliver considerable benefits and could be introduced without major disruption. Here are some examples of how the concept could be introduced, in particular focusing on incentives for AA energy consumption.

- **Individual or collective self-consumption –** Individual consumers and energy communities can produce and use their own renewable energy, consuming the renewable output (or storing it) when it is generating. In that way, they avoid buying system electricity (often generated from fossil fuels), as well as reducing network losses; they also reduce congestion on the network. This requires legislation that encourages efficient self-generation (individual or collective) and incentivizes the use of AA electricity, for instance through direct subsidies or by exempting AA consumers from certain taxes and levies (for instance related to renewable support).
- **Contracting for AA energy** – Individual consumers and energy communities may choose to contract AA renewable energy produced externally by others, consuming or storing it when the renewables are available and operating. For instance, the external renewable generator could sign a contract with consumers, or with the energy community, for X MWh of AA energy over a ten-year period. This contract may be attractive because the cost of the contracted AA energy is lower than the cost of the consumer generating itself and much more stable than the cost of energy from markets or on other system tariffs. Initially, the government could subsidize this sort of AA contract to make it more attractive.
- **Aggregator or supply contracts** – Aggregators or suppliers may offer AA contracts to their consumers. The supplier or aggregator could contract AA energy from a number of renewables plants and sell it to their consumers. Again, the government could make this form of contracting more attractive through subsidies, fiscal incentives or in other ways.

A special AA auction in Spain?

One way to implement AA contracting quickly is through centrally organized auctions for intermittent renewable power. Ideally, the auction would be two-sided, with multiple buyers on the demand-side and multiple renewable generators on the supply-side. A simpler approach would be for a central auctioneer

to contract for a volume of AA renewable energy whose sale price per kWh generated would be fixed through the auction. Having acquired the AA energy, the auctioneer could sell the contracted renewable energy to consumers (individuals or collectives) or retail suppliers on a special AA tariff. The contractual condition would be that the energy be consumed at the same time it is generated; which requires suitable metering. In return for this demand flexibility, consumers would enjoy a stable price and pay much less than if they were buying electricity on other tariffs or on the spot market. The lower cost to the consumer could be reflected not only in the lower energy price, but also through a direct subsidy, or with exemptions or reductions for certain taxes, levies, or access charges. Any AA energy acquired through the auction that did not find a final buyer would be sold into the spot market.

One of the main attractions of having an AA auction is to reduce costs for consumers. One problem with the present approach to past auctions is that the falling cost of renewables doesn't really come through to consumers. The AA auction could potentially help remedy this problem and so should help stimulate both flexible demand and new renewable supply.

One country that might wish to experiment with AA renewable auctions is Spain, where the government is about to hold central auctions for renewable energy. The Spanish Government recently issued a document for public consultation that outlines their proposed approach, which we think is compatible with an auction for AA renewable energy. In particular, it has mooted the idea of paying a price per kWh and has identified auctions for different product characteristics, including location and firmness of the output (for instance, with or without batteries or other backup). The proposal states that the government will pass on the benefits of lower prices for renewables – compared to expected system energy prices – to consumers and also enable energy communities to benefit from these conditions. One of the auction products could be for AA renewable energy (namely, for energy actually generated). The inclusion of an AA renewable energy product in the Spanish auctions would be a means of experimenting with a potentially important new contractual opportunity to promote demand flexibility, while also enabling consumers to benefit from the falling cost of renewables.

Concluding comment

The changes in the electricity sector brought about by the COVID-19 lockdown and the heatwave in California are providing not only glimpses of what a decarbonized energy future might look like, but also some useful practical lessons on how businesses and consumers might need to respond. The key message is that while new technologies – in particular solar PV and wind power – are needed to reduce carbon emissions, they are not the end of the story. Their effect is to change the whole underlying operation and dynamics of the system. For policy makers, the challenge is to rethink market design and regulation to reflect this new reality. Fundamental changes are under way in electricity – the intention should be to let consumers participate actively in the process. The aim of the two-market approach is to open the way for them to do so.