A Chain Reaction: Disruptive Innovation in the Electricity Sector
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Foreword

Innovative technologies and business models can help countries to use renewable distributed energy resources efficiently and hence facilitate the transition to a low-carbon economy. The growing number of small producers that both consume and produce (“prosumers”) increases connectivity between participants in the electricity market. With a two-way connection to the grid, prosumers can buy from the grid when renewables go off-line (or when the price is low); and can sell to it when they have a surplus (or when prices are high). These resources add to the share of renewable generation on which the grid increasingly relies. However, intermittency problems arise because these energy sources, although often free, are also variable. This intermittency appears set to trigger a further round of disruptive innovation since it creates incentives for new technologies and business models that may disrupt traditional models and cut costs by balancing the grid more efficiently.

This report explores the impact that these innovations are likely to have on the electricity sector and examines priorities for regulatory policies that governments will need to put in place to negotiate the energy transition to a zero-carbon economy.

The report was prepared by Chris Pike of the OECD Competition Division with the help of Dirk Röttgers of the OECD Investment Division following the OECD Competition Committee Roundtable on Radical Innovation in the Electricity Sector (1). This report contributes to the OECD Going Digital project that provides policy makers with tools to help economies and societies prosper in an increasingly digital and data-driven world. For more information, visit www.oecd.org/going-digital.
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1. Introduction

The rise of the digital economy has caused disruptive innovation of business models in numerous markets. This has shaken incumbent firms and benefited consumers. Electricity markets have also been disrupted by new types of generation, though this disruption has not been entirely organic or spontaneous. Instead, government intervention and entrepreneurialism has played an important role in stirring this disruption. To realise potential benefits, the sector must adapt to two important features of these new models. The first feature often involves “distributed energy resources (DERs)” provided by producers who both produce and consume, which increases connectivity between participants in the electricity market. The second, by increasing renewable generation capacity, exacerbates a problem of “intermittent”, or variable, supply. The impact of these changes is pushing both markets and regulators to move to prices that change over time and by location (real-time location-based pricing) in order to manage local imbalances between demand and supply.

More efficient pricing will incentivise the introduction of innovations that threaten to disrupt the existing business models of both retailers and grid operators. This report explores the impact that growth of renewable DERs is likely to have on the electricity sector and examines priorities for the regulatory policies that governments will need to negotiate the energy transition to a zero-carbon economy. Section 2 explains what renewable DERs are and why they are growing. Sections 3-5 set out the prospective impacts on retailers, the grid and consumers. It is too early to predict where this upheaval in the market will lead. The future is uncertain and the direction unclear, but however it plays out, and whichever innovations gain momentum, the prospect of lower prices will help governments to negotiate the energy transition.

One possibility is that business models that increase our interconnectedness will thrive. In the 21st century, these businesses might disintermediate supply chains and connect us directly, allowing users to sell unused (or cheap) energy through digital trading platforms, like an Airbnb for electricity. They might also interconnect the great (often state-sponsored) infrastructural achievements, electricity grids that first connected us in the 20th century, which would help to facilitate trade with those located in more distant locations.

Another possibility is that business models that disconnect us and instead bet on the localisation of electricity markets might prosper. These might allow consumers and local communities to become self-sufficient by generating and storing their own electricity, enabling them to cut their costs by going off-grid. Most likely, a combination of models involving demand response, storage, and trading, will emerge to help governments negotiate the energy transition in the smoothest possible fashion. However, as with all transformational changes, the effects are unlikely to fall equally upon all households and may result in distributional effects (section 5). The report finishes in section 6 by looking at the role that regulators and competition agencies can play in helping to facilitate an efficient energy transition. For example, regulation needs to be proactive in facilitating innovation, while remaining neutral between the different types of innovative business
model that are emerging. This means creating the infrastructure, such as smart meters, that are required for change, using dynamic pricing tariffs as a default, setting out proportionate regulation for prosumers, and setting up regulatory sandboxes for emerging business models. Meanwhile, competition agencies need to watch carefully for signs of strategic entry deterrence by incumbent retailers and grid operators, and for acquisitions of start-ups that reduce potential competition.

2. The disruptive appearance of renewable distributed energy resources

The current disruption of the market begins with the appearance of renewable DERs. What is distributed energy and why is it growing?

What is a distributed energy resource?

Traditionally power stations were few in number, large in size, powered by fossil fuels, and heavily reliant on a huge grid to send their electricity over long distances. In contrast, DERs are small-scale power generators, typically renewable, that are distributed or scattered across a region, instead of centralised in one location. They include: photovoltaic solar panels (PV) that households may install on their roof or that farms and businesses might install on their land; as well as small wind turbines; small hydro-kinetic units; and small biomass, biogas, and geothermal energy generating units. In 2015, installed global DER capacity was estimated to be 135 Gigawatt (GW), or 2.1% of a total capacity of approximately 6 414 GW in 2015 (IEA, 2017a, p.666). However, some industry estimates suggest that DER capacity will grow to more than 530 GW by 2024, by which time the deployment of DER capacity will be outstripping the deployment of centralised generation capacity by more than 5-to-1. In some countries, DER is already playing a bigger role. In Germany, for example, where renewables account for a third of installed generating capacity, systems below 1 MW accounted for 68% of all solar PV capacity added to the country’s grid in 2014.

DER can be provided with one or two-way connections either to the central grid or into a local micro-grid (which itself might have a one or two-way connection to the central grid). The two-way connection allows households or businesses to both receive and deliver the electricity they generate (and do not store) onto the grid. With a two-way connection, prosumers can trade their unused or unwanted electricity. In 2015, there were nearly 5 million prosumers in the European Union and some estimates suggest that 83% of EU households will become prosumers by 2050 (CE DELFT, 2016). There has also been a steady growth of solar household and business prosumers in the United States, though this growth was interrupted in 2017 (SEIA, 2017).

One important threat to the growth of installed prosumer capacity is the response to complaints from domestic solar module and cell producers against producers of imported products. For instance, in the United States, following a complaint by Suniva and SolarWorld, the US International Trade Commission in September 2017 found that modules and cells imported from Mexico, Korea and Canada had injured domestic producers. Suniva and SolarWorld requested that minimum prices or quotas be imposed.
upon imported products, which, it was argued, could double the cost of solar installation. In November 2017, the Commission recommended that 30% tariffs and quotas be applied and these were approved in January 2018. Solar generators expect these tariffs to reduce US solar installations by 11% by 2022 as well as 23,000 job losses in the first year.

**Why is distributed energy resource capacity growing?**

There are a number of drivers behind the growth of distributed energy.

Firstly, industrial and environmental policy provided strong support for increasing the share of renewable electricity capacity, not only through centralised generation (fixed-tariff power purchasing agreements, PPAs) but also through consumer level initiatives such as net metering, and feed-in tariffs that have been important incentives for those considering becoming prosumers. For instance, in the United States, ARPA-E was launched in the wake of the financial crisis and has enjoyed considerable success in stimulating innovation and developing clean, affordable, and reliable energy (National Academy of Sciences, 2017).

There has been some concern about the distortionary effect of these subsidy policies (OECD, 2010). However, the market is already distorted by failure to account for negative externalities created by fossil fuels and subsidies and support measures for fossil fuels. Policies that support an expansion in the capacity of renewable generation counteract that distortion. Policies to support the expansion of renewable DER also help to counteract the inefficiency caused by sending electricity over long distances. For instance, around 8% of electricity is lost (up to 20% in India, and even more in developing countries) as it travels across the grid through the transmission and distribution system. Losses from distributed generation are, in contrast, much lower since the electricity does not travel as far. Moreover, as explained below. Results of this policy support appear to have had the welcome effect of pushing this highly regulated market to adopt more efficient pricing arrangements. Therefore, the impact of any distortions from the policy of expanding renewable DER capacity may be less important than it appears when considered in isolation.

Secondly, rising electricity prices have made it more attractive for consumers to begin generating their own electricity, both to reduce the quantity they purchase from the grid and in order to sell to the grid at a higher price. In addition, part of the higher price is taxes that help finance renewable generation. It is therefore unsurprising that consumers have invested in subsidised renewable generation capacity since this allows them to recapture some of the higher price they pay to fund these subsidies.

Thirdly, the cost of photovoltaic technology has fallen substantially. For large generators, by 80% between 2010 and 2015, and this continues to fall (e.g. USD 1.80 per watt in the United Kingdom in 2013, down to USD 1 per watt at the start of 2017, and just US 65 cents per watt in India). Moreover, estimates suggest this cost is likely to continue falling by a further 27% over the next five years. Falling costs come at a time when consumers are becoming increasingly familiar with the idea of selling the capacity they do not use (or attach little value to) through digital trading platforms, and increasingly consider this when investing (e.g. to buy a house).

More generally, for developing countries, small scale distributed generation is an attractive solution where the grid infrastructure is not in place to transport energy from centralised power stations into people’s homes (see Box 1).
Box 1. Distributed energy in emerging and developing countries

Distributed generation can be a particularly good opportunity to increase energy access in emerging and developing countries. In advanced countries, DER is disruptive as it changes an existing market. However, in emerging and developing countries, it can help to establish a previously non-existent electricity market. As of 2014, 15% of the world's population were without access to electricity, of which almost all lived in developing countries, and the vast majority in rural areas where connection to the grid would be costly (World Bank, 2017).

DER can help to connect rural areas in emerging and developing countries, overcoming the challenge of connecting small villages and towns to a country's grid. In many developing countries that use DER already, distributed solar electricity is the favoured technology. The geography of many developing countries provides the resource for solar panels to work efficiently. This helps build micro-grids and off-grid electricity generation that does not have to rely on a regional or national grid. Falling prices for DER components are likely to accelerate this development (World Bank, 2017).

In addition to the challenges pointed out in this chapter, DER in emerging and developing countries suffers from particular drawbacks. The lack of economies of scale, and especially transportation costs, can hinder the scaling-up of distributed electricity. Rural areas that are not yet connected to the regional or national electricity grid are also likely to be poorly connected to roads or railroads. Further, remote micro-grid and off-grid installations need maintenance, and therefore specialist personnel who may not be readily available in rural areas, or only at high cost.

Despite challenges for DER in emerging and developing countries, several business models are helping DER installations to succeed. These include Pay-as-you-go programmes, leases, and direct cash sales (GOGLA, 2017). Some, more technically advanced methods, even implement micro-grids using existing decentralised telecommunications technology. This technology can also allow companies to manage payments and, more generally, their customer relationships.

To help overcome challenges and provide financing, some emerging and developing countries have adopted policies to support DER. Net-metering, as explained below, is a popular policy in emerging and developing countries (REN21, 2017). In other cases, incentives are provided to encourage small and distributed energy generation to be built away from residential areas (OECD, 2016). This offsite electricity generation can then be used to offset electricity use onsite. It therefore effectively allows net-metering for physically separated units of a company or household.

Micro-grids and off-grid installations in emerging and developing countries allow for a bottom-up energy development approach. Conventionally the main regional or country grid would be extended to remote areas. However, with DER, development can be decentralised and wherever it is needed most, independent of the grid. Provided technology allows, DER can be integrated into the main grid later, in principal forming an electricity distribution similar to advanced countries that connect DER into existing grids.
3. The impact on retailers: intermittency and innovation

While disrupting traditional business models for electricity generation, DER also exacerbates the challenge of intermittent supply in renewable generation. If this triggers a move to real-time location-based pricing (prices that vary over time and by location on the grid) this will in turn incentivise the introduction of innovations that disrupt existing retailer business models.

The intermittency problem

The variability of weather dependent renewable power sources, be they distributed or otherwise, creates an intermittency problem that poses a challenge for the market. As renewable generation increases, this challenge gets bigger by the year. Solar panels, for example, generate electricity for approximately 10-30% of the time, i.e. during daylight hours on sunny days. Where solar generation adds significant capacity, it can have a big effect on net demand from the grid. This can be seen by taking the forecast load (demand for electricity) and subtracting the contribution from electricity produced from intermittent renewable sources. This gives the famous graph (Figure 1) of “net load” requirements (known as the “duck curve”).

**Figure 1. Actual 2012 and Predicted Net load (California) – 11 January**

(Electricity demand net of intermittent renewable supply)

Figure 1 shows that at 4 pm in California – as the sun goes down, solar production falls, people get home from work and electricity demand increases - a large and growing shortfall opens up between demand and the supply that must be provided by sources other than intermittent renewables. In the absence of storage capacity, this needs to be met by other sources of generation (nuclear, hydro, coal, gas etc.). To meet this shortfall, a capacity that is 50% larger than that feeding the grid at 1 pm is required. This means that the grid will need an increasingly large capacity that will not be used during the day (see the energy mix in Figure 3). This underutilisation has an efficiency cost, since it means grid operators need to increase the network’s capacity so that peak demand can be covered and blackouts avoided. This investment inevitably inflates consumer bills.

Reducing the fixed costs involved in maintaining the capacity to respond to peak demands requires finding ways to flatten the net load curve. This requires that either: a) renewable capacity is reduced (thereby reducing the depth of the dip at 1 pm); b) demand is reduced and/or moved (reducing the morning and evening peaks); c) the shortfall is plugged by trading renewable power generated in regions still generating with renewables at that time of the day; or d) that production during the day is stored locally and used in the evening.

Source: CAISO, 2018 and OECD calculations.\(^\text{17}\)
Figure 3. Hourly average breakdown of total production by resource type (California) – 25 April 2018


While reducing renewable capacity – or curtailing generation from capacity already installed – would reduce intermittency, it would make it almost impossible to meet the commitments made under the Paris Agreement on Climate Change to keep the global temperature rise this century well below 2°C.\textsuperscript{21} IEA estimates suggest, for example, that unless additional flexibility measures are developed in Europe, it will not be possible to increase the generation share of variable renewables beyond 27% (IEA, 2017b), despite the need for a share of around 60% to meet the 2°C target.\textsuperscript{22} Instead, generation from renewable sources would be curtailed (turned off) and replaced by other sources of generation, including gas-fired generation that would emit additional carbon dioxide (CO2).

Reliance on renewable sources should therefore be expected to rapidly increase over the next decade, thereby exacerbating the intermittency problem. For example, California’s solar capacity is expected to hit 34.5 gigawatts by 2022 against peak springtime demand of under 30 gigawatts.\textsuperscript{23} In this context, while each of the other responses might play some role in resolving or at least mitigating the problem, the question remains as to which will dominate, and how they might come to do so, for example, will they be directed by the state, or will they emerge as market solutions.

The State Directed Approach

One way to address the challenge is through a ‘state directed’ approach, in which government intervenes directly (perhaps via its state controlled entities) to invest in, or to favour one or more of the three options. However, in the absence of any signals to guide it, the state’s ability to identify the most efficient of the three solutions, to identify and effectively support the most efficient business models for achieving that solution, and to gauge that support in order to ensure the model delivers an efficient share of the burden, is highly doubtful. This is not to say that state owned (or controlled) enterprises might not play an important and active role in developing these models, simply that they and other enterprises will require reliable signals that provide direction on where to focus their efforts and investments.
The Market Driven Approach

The alternative way to make the necessary adjustments is to take a market-based approach that uses price signals that reflect immediate local market conditions. Ideally, the price that energy consumers face should equal the marginal cost to the network of additional generation at that time and in that location. For example, at times of mild demand in regions generating huge supply, the price of generation might be zero or even negative (as is already happening in California). This would reflect the fact that the marginal cost of generating an additional kilowatt at that time and place is wasteful and inefficient for the network. In contrast, when demand is high and supply is scarce the price will surge. The variations in these real-time local prices across the day then creates an opportunity for profit for those that invest in solutions that better balance supply and demand.

Crucially, efficient real-time location-based pricing does not only incentivise investment in effective balancing solutions. It also rewards those solutions and business models that address the problem in the way that best reflects the trade-offs that energy consumers themselves would make. For instance, where energy consumers can choose between models, they can select those that offer them the most value, not only in terms of cost but also in terms of usability, reliability and risk. In effect, real-time location-based pricing therefore creates the business case for investing in the types of technology and business model that provide the solutions that energy consumers want. Furthermore, real-time location-based pricing offers the most efficient solution to renewable generation’s intermittency problem. This makes it likely that the shift towards renewable energy resources has been and will be a key driver of a regulatory move to adopt real-time location-based pricing (see below).

The remainder of this section identifies some of the business models that, if real-time local pricing becomes a reality, may compete to shape the future, or at least to carve a niche within it. It describes these models and how they create value, before considering where they currently stand and what is required for them to disrupt the market.

Model 1: Demand response

The first set of business models helps demand to respond to real-time location-based pricing. These models can be broadly categorised into those that help consumers to respond individually and those that allow consumers to outsource their response to an intermediary that aggregates those responses across a larger consumer group.

Individual response

The most straightforward of these models is one in which retailers simply pass on the real-time location-based prices to consumers by offering real-time (or “dynamic”) price plans. These plans send direct price signals to consumers to shift their consumption to use more electricity when supply in their location is ample, rather than when demand is high and supply is scarce. To be most effective, these plans will have to ensure that the price signal is successfully transmitted and is not smothered by other costs that are typically reflected in retail consumers’ energy bills. In the European Union for example, the price of energy is just a third of the average consumers’ retail bill. The remainder is the price of network access and taxes.
Given the difficulties that consumers have demonstrated in engaging in electricity markets, significant doubt exists about the extent to which the additional information from smart meters and the incentives from dynamic prices will change consumer behaviour. Recent research in the United States suggests that consumers do react to price cuts, at least initially. For instance, it found that consumers reduced their power usage by approximately 12% when they received text messages notifying them that prices were higher. However, it found broadly the same response to price hikes of 5 cents per kilowatt-hour as to increases of 3 dollars per kilowatt-hour. This suggests that consumers may have just a few simple heuristics/rules-of-thumb that they use to respond to price signals. While automated devices might make consumers more sensitive to price changes, all of this additional information seems unlikely to work for everyone. Many customers may prefer instead to outsource their demand response to a firm and allow the firm to take a share of the savings that can be made by responding to price signals.

**Outsourced response**

One option for consumers who want to outsource their response is an “aggregated demand response programme”. This involves an intermediary, for instance a demand aggregator, a retailer, or a utility, agreeing a contract to provide cheaper electricity to a consumer in exchange for the aggregator being able to cut or reduce supply, for example, when the price increases above a specified value. The aggregator then sells this potential flexibility onto the market where parties that are responsible for balancing the grid purchase it. This allows the aggregator to earn a margin that it can divide between the price reduction that it offers to attract consumers, and a share that it takes as profit. This framing of the programme has the helpful appearance of paying consumers for reducing their demand below a baseline that reflects their normal energy use, rather than charging them more for using energy when it is scarce.

Aggregated demand response programmes have already proved to be successful where firms sell to industrial customers. However, they have proved less successful with residential customers. In Europe, the increase in renewable generation and continued overcapacity of non-renewable generation has meant that for now, there is always sufficient capacity, and so the value of demand responses from households is small. This has in some cases led to misguided attempts to subsidise residential demand response aggregators.

In US households, the model is more popular, as the gains from responding can be bigger; however, more fundamental issues have arisen with the model. In particular, firms have been unable to identify a reliable baseline counterfactual for what “normal” use would have been in the absence of the demand response. This can lead to aggregators delivering large reductions in demand on a given day, but failing to obtain a discount from the grid operator.

For example, on unusually hot days, air conditioner usage will be much higher than accounted for in the baseline. This is because the baseline for that day is typically set on the previous year’s usage on that date, which was not as hot. As such even a dramatic reduction in usage on the day might fail to bring demand down to below the expected baseline for the day. If that happens, the reduction is not recognised and the aggregator is not paid for delivering anything, but nevertheless has to pay its consumers for reducing their demand, and so loses money. This blocks price signals and damages the business case for aggregating demand response.
Setting the baseline using the amount of demand prior to the reduction is an alternative option. However, this allows aggregators to game their baseline by inflating demand to engineer discounts for their subsequent reductions. See, for example, the case of the Baltimore baseball stadium that left the lights on all day in order to raise its baseline and obtain discounts for turning them off. More generally discounts for demand reductions from any baseline inevitably hand discounts to many consumers that are not actually changing their behaviour but are simply fortuitously using little energy at the time (e.g. they are out of the house that night).

Of course defining a baseline for normal consumption at each time of the day is only necessary because it allows the firm to characterise the programme as a discount or payment to consumers for reducing their demand. Setting a baseline of zero and charging for each unit consumed would resolve these issues. Moreover, once again this need not involve the consumer paying the dynamic price. It is simply the price that the consumer would have to pay if they were to choose not to fix part, or all, of their payment in advance. In this sense, it is comparable to the walk-up price of an airplane ticket (or a taxi ride) which many (few) consumers tend to purchase in advance in order to insure themselves against the risk of a high real-time price.

As in insurance markets, better value can often be found if the consumer permits the insurer (in this case the aggregator) to monitor their behaviour (e.g. car-driving monitors) and use risk avoidance devices. In this case, intermediaries might offer a cheaper fixed price plan to consumers that want a fixed price in exchange for fitting sensors and automated devices around the home that enable the firm to increase the energy efficiency of the home or system and thereby reduce the energy purchased during high price phases. Large reductions in the cost of such sensors and the so-called Internet of things (IoT) which enables devices to communicate directly with a service provider, make this increasingly feasible. However, the profitability of this model will depend on the variation in the real-time electricity price.

In this model, the firm monitors dynamic wholesale prices and is able to respond using sensors and automated technology to adjust the household’s energy consumption to fit into the most cost efficient pattern that can be achieved without compromising the consumer’s level of comfort. For example, appliances like washing machines can be defaulted to run during price troughs, while air conditioning, heating and lighting can be dialled down during price peaks.

These intermediaries might be demand aggregators, or existing retail utility firms, but could also be the Electricity Service Companies (ESCOs) that already provide these services to factories, buildings and other large customers. ESCOs might be well placed to bring this energy efficiency service into a residential setting as the cost of sensors diminishes and the automation of the home becomes a reality. Indeed, it may be that Multi-Utility Service Companies might emerge that provide efficient electricity services alongside efficient water, electric vehicle, and waste services.

Consumers on dynamic price plans who do not want to split the profit made from demand response with a firm can also purchase and set up these technologies themselves in the same way that some investors prefer to manage their own investment portfolios. For these consumers, the more relevant business models will be those that offer (perhaps as a bundle) dynamic price plans alongside the devices and software they need to manage their demand themselves, or that offer access to wholesale markets via an online platform. Such consumers may also purchase insurance to effectively fix or partially fix their retail price, in which case firms that only offer insurance might have a role to play.
**How developed is this model?**

Demand response requires real-time location-based prices, and these are beginning to appear in a number of countries. They are becoming increasingly popular in New Zealand where the fastest growing retailer in the market is offering a tariff based on the real-time local price (as are two other retailers). Nearly half the customers from Arizona’s largest utility, APS, are on time-of-use rates. In the European Union, dynamic price plans are becoming popular in some countries. For example, in Finland, approximately 10% of the population is on a dynamic price plan. In Estonia, the figure is nearer to 35%, helped by the early rollout of smart meters. In Norway, 65% of electricity delivered is purchased on spot-indexed prices – including 90% of customers of its largest retailer (Hafslund). This will increase since under new European Commission rules it will become mandatory from 2020 onwards for firms to offer European consumers an option to choose a dynamic price plan.

Some countries have already gone a step further, and provided a regulatory nudge by making dynamic price plans a default option. For example, Spain introduced default dynamic price plans for all small consumers (less than 10 KW) and now has 12.1 million customers on these plans. Denmark introduced a default spot price plan for all households in 2017 and California is also preparing to transition customers to default time-of-use rates. This reflects insights drawn from behavioural economics that have identified significant inertia and reluctance to switch energy providers, even where lower prices are available. Worryingly, studies also suggest that many of those residential consumers who switch do so to tariffs that result in them paying more than they previously did, suggesting an inability to process information and predict their future usage (Wilson & Waddams Price, 2010, pp 647-668). However, smart meters that collect data on when and how much electricity consumers use will allow those consumers that are willing to share that data, to obtain much more accurate quotes, and hence to make better switching decisions.

In terms of outsourced demand response, estimates suggest that global demand response accounted for approximately 39 GW in 2016, growing to an expected 144 GW in 2025. Much of this remains industrial and public buildings, even if on the west coast of the United States residential demand response accounted for approximately 20% of committed capacity. Industry bodies in Europe suggest that despite progress, significant regulatory barriers to demand response remain (SEDC, 2017). Indeed, estimates of the current value of demand response in Europe are extremely low, partly as result of current overcapacity.

Smart meters have already been rolled out across many countries and are in the process of being rolled out across others. The cost of sensors is just 2% of the 2008 level and so IoT solutions are already viable (IEA, 2017b). Therefore, there are few technical barriers to this model. Indeed, the ESCO market is already considerable – USD 26.8 billion worldwide in 2016, half of which is in China and growing quickly (IEA, 2017b). However, for now, the vast majority is accounted for by the industrial, rather than the residential, market.

Demand response in its various forms is therefore perhaps the most developed of the innovations that are looking to tackle the intermittency issue. However, it remains small relative to its potential. The IEA estimates that globally around 6900 TWh (terawatt hours) of consumption could be flexed under demand response programmes by 2040, around 20% of total consumption at that time (IEA, 2017c). Under a scenario assuming a continuation of existing policies and trends, without ambitious additional action, the IEA assumes that 15% of this potential flexibility might be included in demand response.
programmes by 2040, providing 185 GW of flexibility.\textsuperscript{39} Access to this additional flexibility would avoid approximately USD 270 billion in investment in additional generation capacity. The majority of this flexibility is hoped to come from residential sources, and so the IEA envisages that in 2040 a billion consumers will participate in demand response programmes using 11 billion connected appliances and 150 million electric vehicles.

Model 2: Battery storage

Perhaps the simplest solution is for innovative firms to improve the ability of generators (both centralised power plants and decentralised prosumers) to store the energy they generate and allow them to sell it onto the grid when the price is higher. Storage solutions might take the form of huge battery farms,\textsuperscript{40} household appliances the size of a washing machine,\textsuperscript{41} or the batteries of electric vehicles via vehicle-to-grid (V2G) systems.\textsuperscript{42} Centralised power plants and decentralised prosumers would each be increasingly willing to pay for the capability to store their energy as the variation in price increases. The risk of power outages and grid failure (for instance resulting from natural disasters) could also be expected to drive demand for storage solutions. Prosumers might therefore begin to purchase a battery in the way that they purchase a household appliance, with an upfront fee and some extended warranty.

How developed is this model?

At this stage, the cost of battery storage has fallen by 85\% since 2008 but remains significant (IEA, 2017d). More importantly, most prosumers do not face dynamic prices themselves and so have little incentive to invest in battery storage. Therefore, the business case for purchasing in order to arbitrage and help balance the grid is a weak one. However, with costs rapidly falling, and the new rights for prosumers in the European Union to receive a spot price on the energy they sell to the grid, this may change and trigger investment that benefits consumers around the world. In any event, the growth in electric vehicles, which has been strengthened by pre-announced plans to ban petrol fuelled cars, will increase the demand for battery storage (and associated incentives for development of cost and size reducing technology) that might also strengthen the appeal of this solution to energy prosumers. Firms such as Tesla are for example already active in bridging these fields (electric vehicles, battery storage, and solar generation) in order to exploit synergies.

The IEA reports that in 2016 additional non-hydro energy storage capacity was slightly over 500 MW, and that nearly 1 GW of new capacity was announced in the second half of 2016.\textsuperscript{43} The report envisages 21 GW of energy storage capacity being added by 2025 and suggests that growth in battery storage is on track to meet that goal. Navigant Research reports that residential energy storage is expected to grow from approximately 95 MW in 2016 to 3 773 MW in 2025.\textsuperscript{44}

Model 3: Trading

A third option is to purchase from alternative sources of supply when local prices are high. These alternative sources can be connected to the local grid or they can be in more distant locations where power supply is plentiful and prices lower. In the latter case, an interconnection between local grids or a “super-grid” is required to facilitate this access. These are considered in turn.
**Peer-to-peer trading**

Purchasing from local distributed energy resources requires some form of peer-to-peer (P2P) trading platform that can offer consumers and prosumers direct access to local wholesale markets where they can buy and sell electricity.

Normally, where prosumers generate their own electricity they can deduct this from the energy they purchase from their retailer. When they have a surplus that they are unable or prefer not to use, they sell it back to the retailer. The price is typically regulated since the retailer has considerable power to offer an extremely low price. However, with direct access to market through a P2P platform they would have the opportunity to sell their energy directly to other users. This cuts out intermediaries and potentially eliminates costs while creating arbitrage opportunities.

For example, where prosumers have some storage capability, they might engage in small-scale arbitrage by generating and storing their supply until the spot price hits a certain threshold. At this point, they could draw on their stock of stored energy. For those without storage capacity, access to the platform would create an incentive not just to avoid buying expensive energy during price peaks, but also to avoid consuming their own energy at such times. Any surplus energy that they can easily avoid using, could then instead be sold onto the market at a significant premium (recall Figure 5 in which the spot price varied from −USD 5 to USD 60 per MWh across a single day). As a result, the Australian Energy Market Commission says a P2P trading platform could help lower energy prices.45

Furthermore, P2P trading that is blockchain-enabled (Box 2) can remove the need for electricity retailers and hence eliminate the costs that they incur. For instance, this disintermediation avoids: the operating costs of the retailer, meter reading, billing, payment reminders, debt collection process, banking costs and certification of renewable energy, amongst others. Where P2P trading occurs with those that can only be accessed via the distribution or transmission grid (rather than neighbours on a micro-grid), it will not remove the need for the grid and an operator to transport the electricity and to manage any congestion that arises. These costs would therefore need to be factored into the total price paid in P2P transactions (again blockchain or more traditional means might be used to identify the specific costs of a trade between two parties on the basis of their location and the congestion at that time of the trade). This additional cost might be expected to drive consumers to trade with more local producers and prosumers (or even those located on the same micro-grid) when possible since the costs incurred in such trades would be lower.

P2P trading platforms also create the opportunity for consumers to trade according to their preferences. For example, consumers might prefer to buy from, and sell to, other local renewable prosumers (or low-income households). The platform, or a blockchain mechanism, may certify the identity of the counterparty to the trade and therefore enable the platform to identify both the grid infrastructure utilised by each trade and any congestion charge incurred at that time and place. This offers the basis for pricing that reflects only the costs of grid elements that are used. Indeed, reforms along these lines have already been proposed to the UK energy regulator by P2P energy platform firms such as Open Utility.46 Prices would then be comparatively low for more local trades since less grid infrastructure would be used to transport the electrons - for instance, the transmission grid might not be involved at all, and less power would be lost during transportation.47
Box 2. Energy blockchain

Distributed ledgers for electricity

Smart meters record the electricity generated by one producer, and the electricity used by a consumer. If the producer and the consumer agree to trade on certain terms then the contract terms, the electricity feed-in to the grid, and the electricity consumption can all be recorded synchronously on a blockchain to provide trust between the buyer, the seller and the network operator.

As with a traditional accounting ledger, a distributed ledger, or blockchain, records each deposit, withdrawal and trade. However, it does not store the ledger on a central set of books or servers. Instead, it stores the trading data across vast networks of computers that constantly check and verify information with each other.

How it works

Individual electricity trades are grouped together in a block (e.g. all trades in the last five minutes). To be added to the blockchain, this block needs to be validated by 51% of all the computers connected to the blockchain. To validate the block, these computers need to solve complex mathematical equations. They are incentivised to do so by the reward of earning a payment for being the first to solve an equation. When a block is validated by 51% of these computers, it receives a timestamp and a ‘hash’ and is added to the blockchain in chronological order. This hash will form the basis of the next block and ensures that the next block cannot be solved without reference to its place within the blockchain.1

Security

The blockchain is secure because it is distributed (not held in one place), consequential (no block can be changed without changing the whole blockchain), open (any change can be seen by all), verifiable (any error is obviously incorrect) and relies on consensus.

Trials

Blockchain-enabled P2P trades have been demonstrated around the world and are now attracting investment from some of the biggest players in the energy market. The first trial was held in April 2016 in Brooklyn. This was conducted by LO3 Energy who have since partnered with Siemens to provide micro-grids and have recently received investment from the UK energy giant Centrica.2 Similar trials followed in Australia in August 2016. These were run by Powerledger who recently raised AUD 34 million through an initial coin offering. It is currently working with local utility giants (Origin in Australia, and Vector in New Zealand).3

In Europe, Enerchain executed the first P2P electricity trade via blockchain at a conference in Amsterdam in November 20164 Meanwhile Electron, in a consortium that included University College London and EDF, and was supported by Siemens, has become one of the first entrants into Ofgem’s regulatory sandbox with a P2P local energy-trading platform.5 Finally, Conjoule, a start-up backed by Innogy Innovation Hub, that is running pilots in Germany recently received USD 5.3 million in funding from Tokyo Electric Power Company and others.6

1 This is in the case of public non-permissioned blockchains. However to speed-up transactions and reduce the very considerable energy cost of transactions, firms are increasingly expected to instead use private permissioned blockchains that require solving by a computer that has already been certified as trusted (and hence permissioned).
4 https://enerchain.ponton.de/index.php/11-first-european-energy-trade-over-the-blockchain
A P2P platform might be set up and/or operated by government (Box 3), by the grid, by a not-for-profit consumer association, or by another firm (for example, a technology firm). There might be just one or a number of competing platforms (as there are hotel-booking platforms). Where a firm runs a platform it needs to find the optimal balance of charges for each side of the market in order to increase volumes traded on the platform and maximise its profit. It might therefore charge for membership, for use, or for both; it might set the price of the transaction in the way that Uber sets the price that users pay to drivers; or it might charge a commission in the way that Airbnb or Booking.com do. It might even be that the platform is able to introduce a third side to the market and charge advertisers in the way that YouTube does, allowing it to set zero, or close to zero prices for both prosumers and consumers in exchange for them tolerating advertising messages (e.g. delivered via their IoT-enabled appliances and vehicles).

### Box 3. Examples of platforms that enable P2P trading

#### New York REV (Reforming the Energy Vision)

The New York REV project is “A new distribution level market for energy and related electric products from distributed energy resources (DER) and a state-wide digital platform to facilitate financial transactions in that market.”

The white paper for the project specifies that the platform will be responsible for three major functions at the distribution level: integrated system planning, grid operations, and market operations. […] DER would sell three core electric products in that market: real energy, reactive power, and reserves. […] These core products can be bundled or unbundled, sold days ahead or in real time, or aggregated individually in time and space.

It goes on to explain that the design of the new market draws upon extensive experience with electric market design at the wholesale level. It suggests that a key lesson from that experience is the importance of getting the price right. Prices in the new market should therefore reflect the value of core electric products from DER as a function of the time at which DER produces those products and the location at which DER produces them. ¹

#### Piclo

In the United Kingdom, a firm, Open Utility, has piloted a P2P platform called Piclo, and is extending the trial to the Netherlands (in partnership with the Dutch utility firm Essent) and Italy (with the renewable generator ERG). It is also receiving funding from the UK government to pilot a platform for the trading of flexibility.² The platform collaborates with retailers rather than bypassing them and so does not use blockchain technology. It explains that due to regulatory restrictions the platform is not yet available to residential customers.


The role of the platform may differ from that which has proved so profitable in other markets. In particular, if the blockchain removes the need for a platform to provide trust in the trading that takes place upon it, through its brand and/or review system, then a competitive process might lead consumers towards a platform that involves just a simple,
low-cost, no-frills interface. This might not leave space for a technology firm to intermediate or engage in regulatory arbitrage in the same way that has been done in other markets. For example, it may be that P2P electricity trading leapfrogs the evolution of P2P trading in the taxi market, which remains centralised, and proceeds directly to decentralised blockchain-based P2P models. These leave the intermediary function of the platform to the decentralised blockchain and instead fulfil only the important matching function, leaving producers to set prices and operate autonomously. Note, however, that a blockchain model does not remove the need for a matching platform.

A key risk is that prosumers may display the same lack of engagement with energy markets as consumers have often done. In this case, a pure P2P model might be unlikely to gain traction. Nevertheless, variations on this theme might be more successful. For example, prosumer-to-grid models where prosumers sell their electricity to a central (local) market, from which other prosumers and consumers purchase, may be more likely to take root with agents that have limited availability to fully engage in trades. Alternatively, groups of prosumers might aggregate their generating and storage capability to create a virtual power plant that can provide both generated energy and flexibility to the market. Indeed, by adding the generating and storage capacity of these prosumers to the capacity of consumers willing to adjust demand (particularly when enabled through automated IoT appliances), these virtual power plants might become key players that can either meet all the energy needs of their constituents, or can demand significant discounts on fixed tariffs from retailers.

**Trading and importing via super-grids**

As discussed, direct trading over P2P platforms might more directly interconnect consumers and prosumers within a region, and drive greater localism by balancing local markets, making smaller grids more efficient and thereby reducing prices. However trading by peers or retailers over platforms might also create a more globalised energy market. In this model, grid operators would interconnect their regional grids using ultra high voltage direct current (UHVDC) transmission lines to form super-grids (rather than AC interconnectors with little capacity). Depending on the future of electricity retailers, this could enable either platform-based direct P2P trading across vast distances, or for retailer intermediaries to import energy resources across these same distances. In either case, a larger share of electricity might then be generated in more distant locations where the supply is more plentiful, demand is weaker and the price is low.

These interconnecting transmission lines would, in many cases, cross national boundaries, and, while UHVDC transmission can radically reduce energy loss during transmission, these lines might therefore be vulnerable to political volatility, necessitating insurance that would add to their cost. However, like storage, demand response, and local P2P trading, they would avoid the need for inefficient investment in additional underused non-renewable power plants. If the cost advantage of generating in these distant locations is significant enough, consumers might be able to access lower electricity prices that outweigh the higher contribution they would have to make to covering the cost of the additional grid infrastructure. As a result, potential investors might expect a good return, particularly if storage solutions are too expensive, and consumers are unable or unwilling to modify their demand.

If intermediating retailers retain their role, the higher costs of interconnected grids can be passed onto consumers. However, even if retailers are increasingly bypassed by platforms, consumers may still value the opportunity to use the super-grid infrastructure to trade with generators on more distant grids (perhaps for ethical as well as financial
reasons, for instance supporting small solar generators in developing countries rather than, coal or nuclear generators).

As elaborated further below, it may be that storage, local trading and demand response will drive some prosumers to defect from the grid. In that case, the grid may respond to this risk by investing to improve the value that their grid offers by increasing these interconnections in order to encourage consumers to remain on the grid. Of course, for those consumers that have no option to defect from their local grid there is no choice as to whether they choose a grid that is highly interconnected or a cheaper one that is unconnected (since multiple regional grids remain uneconomic). One possibility is that consumer groups who feel the grid is offering them poor value could respond by re-mutualising their grid. Another possibility is that a blockchain could enable grid operators who wish (or are required) to certify which users are trading with generators on other grids. They could then apportion the costs of interconnections to those consumers that use these interconnections rather than to those trading with local generators (or those on retailer tariffs where the retailer purchases wholesale from local generators rather than more distant ones).

**How developed is this model?**

At present, P2P trading is still in an embryonic state but pilot projects have taken place (Box 3). As noted, energy blockchain trials have also been successfully completed around the world and big investors such as Siemens, Centrica, EDF, Origin, Vector, Innogy and Vattenfall are investing in these projects (Box 2). However, as yet, there are no fully-developed, operational platforms that are available for prosumers to join. Even if platforms were available, while generous guaranteed feed-in tariffs and net metering arrangements that incentivise investment in DER capacity remain, there will be little incentive to sell via a platform. While there is much speculation on the potential of blockchain-enabled P2P platforms, it remains unclear how big a role they will play. The role of regulators and competition agencies in enabling these platforms and other innovative models to compete on a level playing field will be examined below.

The development of super-grids is also at a relatively early stage (though standard AC interconnections are common). While the technological capability already exists, there are few completed projects that cross national boundaries, and nine of the world’s ten largest capacity lines are in China (accounting for nearly half of the world’s existing UHVDC transmission lines). Other schemes in larger countries (United States, India, Brazil), or connecting to offshore resources, are also in planning. More speculative projects to link Japan, Korea and China have been suggested while academics have also made ambitious proposals for a grid that links Europe with North Africa.

The obstacles are financial and diplomatic but not technological. It is notable that gas and oil lines frequently cross national boundaries, which illustrates that where flexibility provided by the interconnection is valuable enough, a solution can be found. Hence, if the business case for super-grids becomes convincing, say because of the introduction of real-time locational pricing, then further examples are likely to appear quickly. Most likely, these would be within-country projects of the type that are currently in development. In the United States, California already imports nearly half of its requirements from neighbouring states at certain times of the day (Figure 2). Of the international schemes, the most likely would seem to be those between friendly and stable neighbours. For example, the European Union has a target of a single energy market in which more than 10% of its flexibility requirements can be met through cross-border purchases.
The value of flexibility is certainly increasing as the penetration of intermittent renewables grows. The question is how big a role super-grids will play in the energy transition. For grid operators they certainly appear to be the least disruptive of the possible solutions and so the industry can be expected to ensure that they remain part of the conversation. However, alternative disruptions that have been examined potentially allow for big savings from increased localisation and reduced, rather than increased, investment in the transmission grid and its interconnections.

4. The impact on the grid

The growth of DER which has disrupted traditional non-renewable generating businesses also threatens, alongside the growth of centralised renewables, to unleash a wave of innovation that will shake the traditional energy retailer business model. Indeed, perhaps unsurprisingly, it seems likely that none of the key players in the energy market will come out unscathed. This section looks at the impact on the grid that the growth of renewable DER has set in motion.

The grid as a platform

Electricity grids are platforms in the sense that they have traditionally agreed contracts with both power plants and energy retailers to create transactions between those parties and ensure that there is sufficient generation capacity to meet the needs of consumers (as represented by the retailers). In addition to balancing supply and demand (turning on or off additional generation capacity, purchasing demand flexibility and, on rare occasions, managing rolling blackouts), they also operate and maintain the physical infrastructure of the grid and manage congestion. Their role therefore bundled together the physical platform (the grid) and the market platform.

The grid was also a two-sided platform in that each side of the platform valued greater participation by the other side. Retailers and their consumers value additional generation capacity and a degree of diversity in that capacity since these improve supply security and reduce the risk of blackouts. Meanwhile generators value additional consumers and greater demand as these increase their utilisation rate and thus their profitability (since there are typically fixed costs to operating).

In this sense, the grid potentially meets the definition of a two-sided platform market. However, while the product (the grid) shares the characteristics of a two-sided market, it is, of course, not a competitive market since the activities of the grid are protected as statutory regulated monopolies. This means retailers, consumers and generators have no real choice over which platform to use (though at least at the planning stage generators do have the option of locating their power plants on different grids). In any case, as a regulated monopoly the grid does not have the same incentive that platforms typically have to increase the trade that takes place on the platform and to minimise infrastructure costs in order to increase its profitability. To the extent that the grid is allowed to make a profit, this generally does not come from increasing the volume of transmitted energy. Instead, regulators typically ensure that the grid’s costs of transmitting energy are
reimbursed, perhaps subject to an improvement target. Most opportunities to make a profit will therefore arise where the operator can earn a rate of return on its investment in infrastructure projects (which may lead to overinvestment).

The impact of DER on the grid

The rise of DER has introduced a risk that both retailer platforms and the platform provided by the grid operator might be bypassed. As discussed above, retailers can be bypassed either by consumers opting to buy and sell through a different intermediary (e.g. an aggregator) or trading directly over a platform. However, a bypass risk also exists for grid operators. For example, since prosumers can self-supply they can become increasingly self-reliant, particularly where they can supplement their generation capability with storage capability. This potentially takes them off-grid, either entirely or at least for a large proportion of their needs. McKinsey forecast that full grid defection will become an attractive option for some by 2030, as will partial grid defection as early as 2020. Partial defection here refers to those that are self-sufficient for 80-90% of their needs.

In addition, prosumers and consumers can set up local micro-grids that again have the impact of taking them off-grid for a large proportion of their needs, and potentially for long periods of time. In addition to catering for the demand for localised generation (whether through necessity or preference), their smaller size also offers increased resilience at a time when environmental catastrophes increasingly threaten to disrupt supply from the main grid which is inevitably exposed to more risks than a micro-grid (see Box 5).

The threat from a full bypass is fairly straightforward. As consumers defect, the grid is increasingly left to spread its largely fixed costs of maintaining its infrastructure across a smaller number of consumers. This increases the cost of remaining on the grid and makes defection an increasingly attractive proposition. This can create a potential death spiral that threatens their viability.

Less clear is what threat is posed by partial bypass, which seems both likely to be more frequent and to arrive sooner. Partial bypass describes a scenario in which the consumer rarely uses the grid but needs to retain access to it. For example, for those times when its own generation does not cover its needs, as well as those times when it prefers to sell its energy onto the grid at a premium rather than consume the energy itself. Indeed trading with anybody other than neighbours will at least require connection to the distribution grid, if not the national transmission grid. On the one hand, this fall-back option to access the grid will remain of value to these consumers since it will help them guard against blackouts. However, on the other hand, consumers that use the grid only as a fall-back option may attach less value to the grid and so might not be willing to make the same level of contribution as those consumers that rely continuously on the grid.
Box 4. Micro-grids

Many existing micro-grids were developed to ensure resilience and a guaranteed power supply rather than to reduce costs. Purchasers have therefore typically had particular geographic locations (islands and remote locations) or particular needs (universities, forts, jails, and hospitals). However, they demonstrate that the technological capability exists and so, as the costs of setting up micro-grids fall, the market is expected to grow. For example, Carnegie, the firm behind the world’s first Wave and Solar based micro-grid on Garden Island in Western Australia, has forecast the potential for the global micro-grid market to reach around USD 40 billion by 2020.

Recent examples include the Marcus Garvey village in Brooklyn, which includes 625 social housing units and has opened its own 400KW micro-grid at a cost of USD 4 million in order to cut the Village’s costs by 10-20%. However, the generating power behind the grid is not sufficient to meet all of the village’s needs.¹

In contrast, utility company Ameren and smart grid company S&C Electric Company, announced in August 2018 that they conducted a successful 24-hour islanding test at its USD 5 million micro-grid facility in Champaign, Illinois. Located at Ameren’s Technology Applications Center (TAC) near the University of Illinois campus, the micro-grid provides multiple sources of distributed generation—including solar (125KW), wind (100KW), natural gas (1MW) and lithium-ion battery storage (500KW) to support the centre and more than 190 homes and businesses².

The test started at 8 a.m. with the battery’s charge at 97%. Once the charge was depleted to 90% capacity, solar and wind generation energy kicked in, keeping the battery’s charge steady. Throughout the day, the battery’s charge never dropped below 88%. During the test, the micro-grid functioned on 100% renewable energy throughout the day.

In the same month in Germany, Siemens also successfully conducted an islanding test in which it operated separately from the main grid at their micro-grid in Wildpoldsried. This is a small community of approximately 2,500 people. The micro-grid connects 100% renewable energy sources and produces seven times the electricity that the town requires over the course of a year. This means it can meet its own peak load requirement when necessary while also enabling them to sell their energy to the market.³

Earlier micro-grids have also successfully demonstrated the ability to help improve resilience, for example during hurricane Sandy in New York and the Japanese earthquake and tsunami during which the Sendai micro-grid kept hospital power running. Notable examples of micro-grids also include those at: Fort Carson; Fort Collins; Santa Rita Jail; New York University; University of California San Diego; Hangzhou Dianzi University; Kythnos; Bornholm Island; and the Isle of Eigg.⁴

⁴ https://building-microgrid.lbl.gov/examples-microgrids,
Indeed, regulatory pricing principles would usually identify the advantages of moving towards pricing access to the grid (to recover the efficiently incurred costs of investment) in a way that better reflects the elasticity of demand (how responsive demand is to a change in price). For example, it would be possible to use a two-part tariff that not only reflects the value of having the option to connect to the grid (even if it is rarely used), but also ensures the price reflects the degree of use of the grid infrastructure. As noted above such proposals are already being made by new entrants and are only likely to grow in future. If the structure of prices were to change, a gentler version of the same spiral that is sparked by grid defection might occur. Once again, the cost of maintaining the network would fall more heavily on those that remain reliant on the grid. This would again incentivise consumers to follow others and reduce their grid usage thus exacerbating the problem. However, so long as most consumers consider access to the grid to be a necessity, a funding stream for the grid will remain (the fixed component of the price would be expected to rise as low usage becomes the norm). This would not constitute a death spiral.

Indeed, as noted, many of the innovative business models which might thrive as a response to DER rely heavily on the continued existence and upgrading of the grid. While the threat from storage is a very real one, it is far from clear that storage alone will dominate. Meanwhile both trading and demand response solutions require the infrastructure of the grid, as well as the congestion management services of the grid operator. Indeed the role of the distribution system operator seems set increasingly to resemble that of today’s transmission system operators in its complexity as a result of the two-way nature of increasing numbers of distribution grid connections.

In particular, if trading energy over long distances via super-grid interconnections becomes a key part of the response to the challenge of intermittency, then the use of the grid infrastructure might increase. Indeed, paying more for access to a much larger network might allow for lower total prices. For example, it might reduce both the need for investment in adding low utilisation local power plants, and provide access to generators with lower costs (perhaps through greater scale or a higher utilisation rate due to a more reliable supply of solar/wind). Consumers or their intermediaries might therefore welcome such access and this might counteract a possible contemporaneous move by others towards grid defection. However, this will depend on the scale of the cost advantage of generating electricity in distant locations.

5. The impact on consumers – the pros(umers) and cons(umers)

The disruptive effects of the most efficient of these innovative business models should ultimately deliver better value sustainable energy to consumers. This creates an opportunity for countries to negotiate their way through the energy transition in the smoothest possible fashion. However, as with so many transformational changes, the effects are unlikely to fall equally upon all households. Distributional effects may occur in a number of ways that regulators with an inclusive regulation objective need to recognise.
The impact of Prosumerism

The growth of prosumerism itself may have an impact on the distribution of wealth since not all consumers can easily become prosumers. The installation of solar panels either has a significant upfront cost or requires access to credit, neither of which will be options for low-income households. Installation is also easier where consumers own their own homes and hence can be considered an investment that enhances the value of the property. For tenants, securing the ongoing value of the investment may not be possible if the landlord is unwilling to purchase it at the end of the tenancy. Home ownership amongst low-income households is much lower than higher-income households. Home ownership within flats and other multiple-unit structures (more common amongst low-income consumers) may also create complications since a degree of coordination with other homeowners within the block will be necessary. Therefore, without careful policymaking, DER risks increasing inequality by creating a ‘prosumer divide’.

One potential policy solution lies in separating the idea of distributed generation from the home itself. For instance, households might be enabled to invest in remote distributed generation. This would still be the consumer’s own supply, but would be located in a different location, perhaps where the supply of solar or wind is less variable. If the generation from this remote self-supply can be validated and matched to the owner, whether through blockchain or more traditional means, then the consumer could have access to their own supply at zero cost even during price peaks (subject to a transportation and congestion charge). In terms of consumers’ ability to finance their own supply, as it does with other necessities, the state might decide to provide guaranteed access to loans for low-income households seeking to invest in distributed generation (in the same way that it provides guaranteed access to student loans).

The impact of different innovations

It is likely that there will also be distributional consequences whichever combination of innovative business models best resolves the intermittency challenge. Where consumers face real-time locational prices, it is likely that some groups of consumers face surge pricing at times when their demand is unavoidably inelastic. For example, low-income families may have little scope to respond to price signals on the heating of their home or the timing of children’s baths. Even if these groups choose to insure themselves against these prices, they may find themselves paying a large premium to do so (as their demand for insurance might identify them as inelastic consumers). Wealthier, tech-savvy, consumers might also be more likely to adopt the new devices and systems that will allow consumers to increase their efficiency and shift their demand to make savings.

As has been noted in the context of financial markets, there are circumstances in which the presence of active well-informed “sophisticated” consumers can help protect “naïve” consumers by holding down prices. However, there are also circumstances in which sophisticated consumers benefit from the presence of naïve consumers. For example, where naïve consumers pay additional add-on prices (for example unarranged overdraft charges), the base price might be reduced, thereby benefiting more sophisticated consumers that take steps to avoid the add-on price. For now at least, electricity retail markets would appear more like those in which all consumers benefit from increasing the numbers of sophisticated buyers. Meanwhile, empirical work on the impact of dynamic pricing suggests that the responsiveness of low-income groups to dynamic prices is not significantly different from that of higher income groups. It suggests that approximately
3% of consumers would end up paying significantly more under real-time locational pricing and these would not be predominantly low-income consumers. Indeed there are reasons to think that if P2P trading becomes a possible supplement to real-time pricing, then it may be that wealthier consumers choose to pay a little more to satisfy their preferences for locally or ethically generated electricity (as in food markets), while low-income consumers purchase simpler options at lower prices. Low-income households with generating capacity might also gain an additional revenue source with which to cover their fixed price payments (particularly by selling during price peaks). For example, Airbnb suggests that 13% of their hosts from ten of the largest US cities say their Airbnb income has helped them avoid eviction or foreclosure, and that half say their hosting income has “helped them afford to stay in their homes.” While the gains for middle-income households from Airbnb are larger still, the more homogenous nature of electricity as a product means the potential gains for low-income prosumers might be larger, providing they have the capability to generate.

This goes towards two key policy questions for governments. Firstly, do they seek to support those that are adversely affected by the evolution of the market? This is perhaps the easier question since by doing so they can help entrench the legitimacy of the transition and protect the aggregate gains that it offers. The second and more difficult question is how best to do so; do they invest to equip and empower consumers to participate/act and respond effectively to market signals (either individually or collectively)? Or, instead, do they regulate outcomes? For example, intervention to provide vouchers for generation or storage capability rather than setting price caps might empower those on low-incomes, and help facilitate an inclusive energy transition in a more effective way than simply capping prices.

6. Regulation will have a key influence on the direction that is taken

The disruption of the market for generating electricity, which was triggered by the state taking a proactive role in making and shaping new markets has, in turn, triggered disruptive innovation in downstream electricity markets. It would therefore seem likely that there will be an ongoing opportunity for government to take a proactive role in shaping the market. This might involve the provision of incentives that internalise the effects of purchasers’ decisions, or improving links between academia and business. It may also include making sure capital markets are meeting the needs of firms willing to invest in higher risk longer-term projects that pursue well-defined missions with important social benefits (provided the support is neutral on which technologies should be used to achieve those missions).

While governments did not remain neutral between generation from renewable or non-renewable sources, and instead acted to address market failures that saw underinvestment in generating renewable electricity, the challenge for regulators in the midst of this disruption, is to facilitate the integration of renewable distributed generation into the energy system. To do so, they need to remain neutral, avoid distorting innovation and provide a level playing field that ensures the most efficient business models prosper. However, this is not to say that their role is a passive one. Regulators also need to play a neutral but active role in driving the transition by creating and shaping markets and ensuring that the infrastructure of an effective marketplace is in place.
Regulatory neutrality to maintain a level playing field

To remain neutral, regulators should avoid supporting particular business models. Such support risks encouraging the delivery of less effective, more expensive solutions, the costs of which are often shared and hence damage the case for addressing the problem in the first place.

In practice, this means not providing specific support for residential demand response aggregators. These models are economic in some countries but, for now, are not economic in others. Regulators should explore why the incentive for take-up of such a solution is not yet there, rather than pre-emptively engineering one of a range of possible solutions.

Neutrality also means that virtual power plants and other demand side aggregators should not be prevented from accessing the wholesale market. Lavrijssen (2017) calls attention to unhelpful restrictions. For example, some markets in Spain, Italy and Germany are closed to demand response aggregators, while in the Netherlands, aggregators can only participate in the market through firms that are licensed as ‘balance responsible parties’. Moreover, some countries, such as Poland, only allow industrial customers to access the market.

Maintaining neutrality also means not providing targeted subsidies to non-renewable powered generators if those subsidies are not available to renewable generators. Instead, if a market is for some reason unable to provide sufficient capacity (and less distortionary solutions have been considered), then as a last resort, the payment of distortionary subsidies for capacity can be justified. However, these should be determined on a competitive basis, and should be open to participation from across the market. For example, storage providers and demand response aggregators should be eligible, as should non-variable renewable generators and foreign-based generators. For example, in the United Kingdom, one and four-year capacity auctions are used to ensure sufficient capacity exists (Box 6).

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**Box 5. Capacity markets in the United Kingdom**

The European Commission considers capacity remuneration as a last resort for ensuring sufficient generation. It has encouraged member states that see a need for such schemes to award this remuneration to ensure it does not distort the internal electricity market. For instance, on the United Kingdom’s scheme, it notes that: “Demand side response and electricity storage are eligible to provide capacity. Electricity demand reduction is not yet eligible, but is currently subject to a pilot. Low carbon capacity is not eligible if it receives another form of support. Providers of Short-Term Operating Reserve are not allowed to participate unless they terminate their contract if awarded via the capacity auction. Providers can offer capacity and balancing services and can receive a payment for both. Interconnection capacity is not eligible but its participation is under assessment. Eventually, the United Kingdom aims to enable foreign generators to participate explicitly.”

Regulators should not necessarily fear grid bypass, but where it provides a valuable competitive incentive for grid operators to invest efficiently in the grid’s infrastructure, they should welcome it. For example, if the rate of return on grid investment that the grid operator receives is dependent on the rate of grid defection, then inefficient investments would become less attractive so long as consumers have a viable option to switch away from the grid. This would complement their own regulatory efforts to ensure investments are efficient. Therefore, regulators should remain neutral on grid defection and take care not to be captured by any stability arguments made by those that they regulate.58

Finally, regulators should take care to avoid favouring state-owned, or state controlled entities that often operate in these markets. Such enterprises may play a useful role in actively trying to meet policy goals without the need for the same financial incentives (Prag, Rötgerters and Scherrer, 2018). If these entities help them resolve market failures by serving markets that are underserved due to non-internalised externalities, or are able to identify and implement innovative efficient solutions before private firms do so, then this is to be welcomed. However, regulators should not allow them to receive favourable support that gives them advantages that their rivals do not have. This would risk distorting competition in their favour rather than resolving a market failure. Strong competitive neutrality rules can be helpful in this respect.

Pro-active regulatory steps to drive the energy transition

Governments and regulators also have a role in ensuring that the infrastructure of an effective marketplace is in place.

Firstly, this means empowering consumers by allowing them to understand what they are consuming and at what cost. In practice, this means ensuring consumers have access to smart meters that provide real-time consumption data. It also means ensuring they at least have the option of selecting a real-time tariff if they wish to do so. Regulators might also consider whether making this an opt-out default tariff, rather than an opt-in tariff, would help to drive the transition forward in a neutral fashion. Certainly, barriers to the introduction of default real-time pricing are unlikely to be helpful.69

Secondly, there is the question of how to regulate the generating capacity of small-scale prosumers that stands ready to be unlocked if the potential of this sharing economy can be successfully integrated into the wider electricity market. For these prosumers to make the most effective contribution possible, they require a right to two-way access to the distribution grid, and to be paid real-time location based prices for the energy they produce. If they do not have two-way access they cannot sell onto the grid and are limited to using their generation and storage to reduce their own demand. Furthermore, they cannot trade their surplus and therefore cannot help balance the grid when prices are high. Their status as prosumers, rather than businesses, also needs to be recognised.70 The requirements for them to obtain a license to sell electricity should therefore be proportionate to the risks they pose. For instance, they should not need to submit their own demand forecasts to the network operator, or to meet universal service obligations.

Prosumers also need cost reflective, transparent and non-discriminatory network charges. For example, when the grid becomes congested, the operator might consider that the cheaper easier option is to cut access to the grid for smaller prosumers (rather than large power plants), therefore it may be necessary to enforce a right to non-discriminatory (or even priority) grid access and dispatch for small-scale prosumers.
Another pro-active step for regulators is to follow the growing trend towards regulatory sandbox initiatives (e.g. Ofgem’s Innovation Link). This is a supervised space in which a regulator works closely with innovators to ensure the regulatory compliance of their business model. It can offer tools such as restricted authorisation, individual guidance, waivers and no enforcement action letters. It may involve trials using customised regulatory environments for each pilot – including safeguards for consumers. The intention is to reduce time-to-market and lower entry costs, while ensuring that innovative entry is not blocked without good reason. Such an approach may for example be particularly valuable for firms offering blockchain-enabled P2P platforms, virtual power plants, and micro-grids.

A second innovative step is the regulatory use of defaults. These have developed from the insight from behavioural economics that many consumers have a significant default bias. This leads them to stick with the default option when they purchase, and regulators can preserve choice where it is valued, while influencing behaviour where it is not. For example, they can frame the default option themselves rather than allowing firms to do so. As noted above, some European countries (as well as Sacramento in California) have moved towards default real-time tariffs. An interesting insight from an experimental move in Sacramento to adopt default real-time prices is that while the default worked as expected, and an additional 77% adopted the dynamic tariff as a result, many of these apparently passive consumers then actively shifted demand in response to the variations in price.72

Another example is the proposal by academics in the United Kingdom that the government look at opt-out collective auctions in which vulnerable passive consumers are identified, and retailers and aggregators are invited to bid to supply them, with the winner being the supplier who offers the best deal. This strengthens the incentive to compete for otherwise passive groups that might otherwise not be competed for (given the unlikelihood that they would switch).73 Research from the US suggests such schemes might reduce prices by as much as a quarter.74

Alongside such innovative regulatory approaches, more traditional pro-active enforcement of structural separation between the grid and potentially competitive markets (as recommended by the OECD) will be important for ensuring that these markets remain competitive (OECD, 2001). For instance, grid operators (both at the transmission and distribution level) are likely to manage congestion and the balancing of the grid. They will need to purchase from prosumers, interconnecting grids, storage providers, and demand response aggregators, as well as from physical and virtual power plants. It is therefore important that they are not allowed to enter into the provision of these services themselves since the scope and incentive for them to use their regulated monopoly to distort those markets is too great.

**Competition agencies will need to be alert and pro-active**

The most productive response by incumbent suppliers to disruptive innovation is to compete to innovate and adopt new technologies or business models. However, the easier or cheaper option can be to respond in an anti-competitive fashion. Therefore, competition agencies have a key role in ensuring that disruption stimulates competition that benefits consumers, rather than efforts to evade the need to compete.

By facilitating the entry of millions of small prosumers into the generation and flexibility markets, the P2P sharing economy model potentially creates a highly competitive fringe
of price-taking sellers. While individually these pose little threat, in aggregate, for example via P2P platforms or virtual power-plants, they may pose a greater risk to incumbents. Therefore both incumbent retailers and grid operators’ behaviour needs to be watched carefully for signs of strategic entry deterrence. For example, following a complaint from a rival (Direct Energie), the French state-owned enterprise, Engie, was recently fined EUR100 million for setting prices at predatory levels designed to drive rivals out of the market in order to increase prices. This risk of exclusionary foreclosure is a particular concern in cases where structural separation has not been introduced. In these cases, utility companies that operate power plants and grids, or grids and retail offerings have both the incentive and ability to raise the costs of rivals, and particularly those that threaten to disrupt their entire business model.

However, it should be noted that the most important barrier to entry might be a regulatory one, and so competition agencies would do well to look closely at the rules and regulations that incumbents are lobbying for with a view to protecting themselves from disruptive innovation (rent-seeking). For example, net metering rules are being debated in many US states, and while there are arguments for and against net metering, one result of their removal would be the creation of an opportunity for incumbents to push for new rules and regulations that might deter certain innovative business models.

Merger control will also have a role to play. The acquisition of innovative start-ups by an established incumbent can be part of a strategy to compete by adopting new technologies. However, it can also be a defensive move to remove competitive threats. In order to distinguish between these possibilities it is important to assess the likely future competitive constraint of the innovator which would be lost, rather than the innovator’s existing market share, which may be small.75
Notes

1 For convenience, intermittent is used to refer to both intermittent and variable supply. There may sometimes be a distinction between these terms but this is not relevant for this report.

2 Notably the state’s role in the current disruption is again significant, having played a key role in stimulating DER capacity, as well as the creation of the digital infrastructure that is required for disruptive innovation to take place (e.g. smart meters).

3 Large scale centralised renewable power stations, using wind and solar, are now of course more common, while large hydro projects have been around for some time now.

4 Notable DER can include non-renewable DER such as diesel-powered generators. This report does not consider these further.


6 Note that disruption can have a huge impact without necessarily earning huge market share. For instance, Airbnb remains at 3-4% of the accommodation market across 13 cities while having a huge effect on the overnight stays market in those cities, www.str.com/Media/Default/Research/STR_AirbnbHotelPerformance.pdf.


8 In Germany, the regulator requires central registration of all solar PV systems and so very detailed data are available, www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015_Onlinebook_low1.pdf


10 Net metering allows consumers who generate their own electricity to use that electricity at any time, instead of when they generate it (in effect this means dialling the meter backwards when energy is generated). Feed-in tariffs are long-term agreements where the state guarantees access to the grid and guarantees to pay households and other generators a cost-based price for the renewable electricity they supply to the grid. Similar guarantees are available through Power Purchasing Agreements, though these are typically agreed directly between a consumer and an electricity generator.


12 See World Bank: https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?view=map

13 Proportionally, the losses from the higher voltage long distance transmission grid are smaller than those from the distribution grid. However, energy lost to resistance increases as the length of the line increases, and bypassing the transmission grid entirely could significantly reduce total
losses. For instance, losses from step-up/step down transformers and transmission lines are estimated to be in the order of 4-8% in addition to the further 4-6% that is lost through the distribution network. Avoiding the use of the transmission network and step up/step down transformers might therefore save perhaps 4-8% in a typical country: https://blog.schneider-electric.com/energy-management-energy-efficiency/2013/03/25/how-big-are-power-line-losses/.

14 Simone Pront-van Bommel, 'A Reasonable Price for Electricity' (2016) 39 Journal of Consumer Policy. The average network component in consumer bills has increased by 25% since 2008. Electricity price has increased from 0.14 in 2006 to 0.21 in 2016 (Eurostat)


16 Ibid. See also IEA, 2017e.


18 https://www.gses.com.au/technical-articles/the-duck-curve-and-electricity-supply/Note however that the power blackouts experienced by South Australia in September 2016 were not related to the issue of net load. See IEA, 2018.


21 Which have now been ratified by 171 of the 197 parties: http://unfccc.int/paris_agreement/items/9485.php

22 The Sustainable Development Scenario in IEA World Energy Outlook 2017


24 Wolfram (2017) https://energyathaas.wordpress.com/2017/04/24/is-the-duck-sinking/. Negative prices may occur because shutting down and then restarting power stations is costly, or may result from production tax credits, or distortionary targets. Bushnell and Novan (2018) identify the while the solar expansion in California has substantially lowered wholesale electricity prices on average, this average price impact masks a substantial decrease in mid-day prices and an increase in wholesale prices during morning and evening periods.

25 Location-based pricing is important not only where renewable generation can vary from location to location (e.g. where the wind is blowing or the sun shining), but also because many grids have limited capacity, and therefore can quickly become congested. This imposes additional marginal costs on the generation of electricity in particular locations.

26 However, as explained below, this is not to say that consumers themselves need to be on a dynamic tariff.

27 Location-based prices of energy should be distinguished from location based fixed costs of access to the grid. Regulators will typically have duties of non-discrimination in relation to these allocating these costs – for example – between urban and rural consumers.


29 “Dynamic Pricing, Attention, and Automation: Evidence from a Field Experiment in Electricity Consumption” Gillan, November 2017, Electricity Institute at Haas, WP284
https://ei.haas.berkeley.edu/research/papers/WP%20284.pdf


32 Consumers might use simple automated trading applications to set parameters and decision rules for such trades. Alternatively, more complex trading algorithms might be included within the application.

33 See presentation slides from the New Zealand Energy Authority at the OECD: www.oecd.org/daf/competition/radical-innovation-in-the-electricity-sector.htm


39 http://unfccc.int/paris_agreement/items/9485.php

40 See https://www.treehugger.com/solar-technology/tesla-will-kill-duck-australia-100-days-or-its-free.html


43 https://www.iea.org/etp/tracking2017/energystorage/


46 See the Piclo white paper: “A glimpse into the future of Britain’s Energy Economy” available at https://www.openutility.com/piclo/

47 As noted earlier power loss on transmission system amount to 10-20% in different systems

48 https://www.weforum.org/agenda/2016/12/goodbye-car-ownership-hello-clean-air-this-is-the-future-of-transport/ see also Arcade City and La’Zooz.


51 See GE blog: https://www.geenergyconnections.com/inspire/how-supergrid-could-make-world-lot-smaller-and-connected

54 https://www.geenergyconnections.com/inspire/how-supergrid-could-make-world-lot-smaller-and-connected
57 https://institute.global/insight/renewing-centre/tony-blair-foreword-technology-many
58 Armstrong and Vickers
59 www.jstor.org/stable/41799506

61 The storage solution also seems likely to favour wealthier consumers, for example those that invest in storage capability via electric vehicles that are expensive luxuries for those on lower incomes.

62 See, for example, the investment in clean technology by ARPA-E in the United States. Mazzucato (2013) The Entrepreneurial State
64 'Balance responsible party' means a market participant or its chosen representative who is responsible for its imbalances in the electricity market. However, the EU’s winter directive recognises a right for aggregators to enter the market without consent from other market participants and prohibits the requiring of them to pay compensation to suppliers.

68 How to be fair to both those that defect and those that remain will be the real challenge given the consequences for redistribution.

70 EU winter package: not considered as energy suppliers if they feed into the grid less than 10 MWh for households and 500 MWh for legal persons on an annual basis.

71 This may include the question of the legal nature of these digital platforms in P2P. Would the platforms and their members be subject to the same obligations as energy suppliers? Would they be considered an “information society service” – see FTC ‘The “Sharing” Economy: Issues Facing Platforms, Participants & Regulators’. In the EU, ECJ will have to solve a preliminary reference made by a Spanish Court (C-434/15 - Asociación Profesional Elite Taxi)
Dellar, Hviid & Waddams (2015),
https://assets.publishing.service.gov.uk/media/55e6be84e5274a55f800034/University_of_East_Anglia_-_Centre_for_Competition_Policy RESP to PFs.pdf.

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