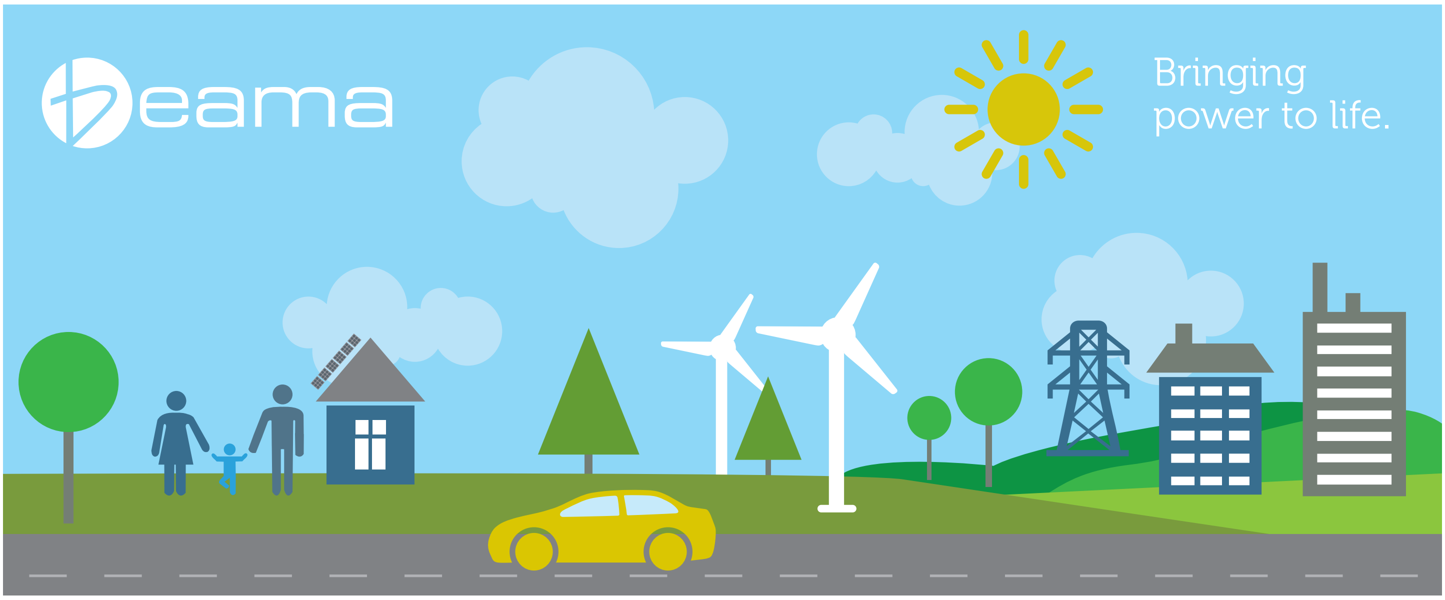
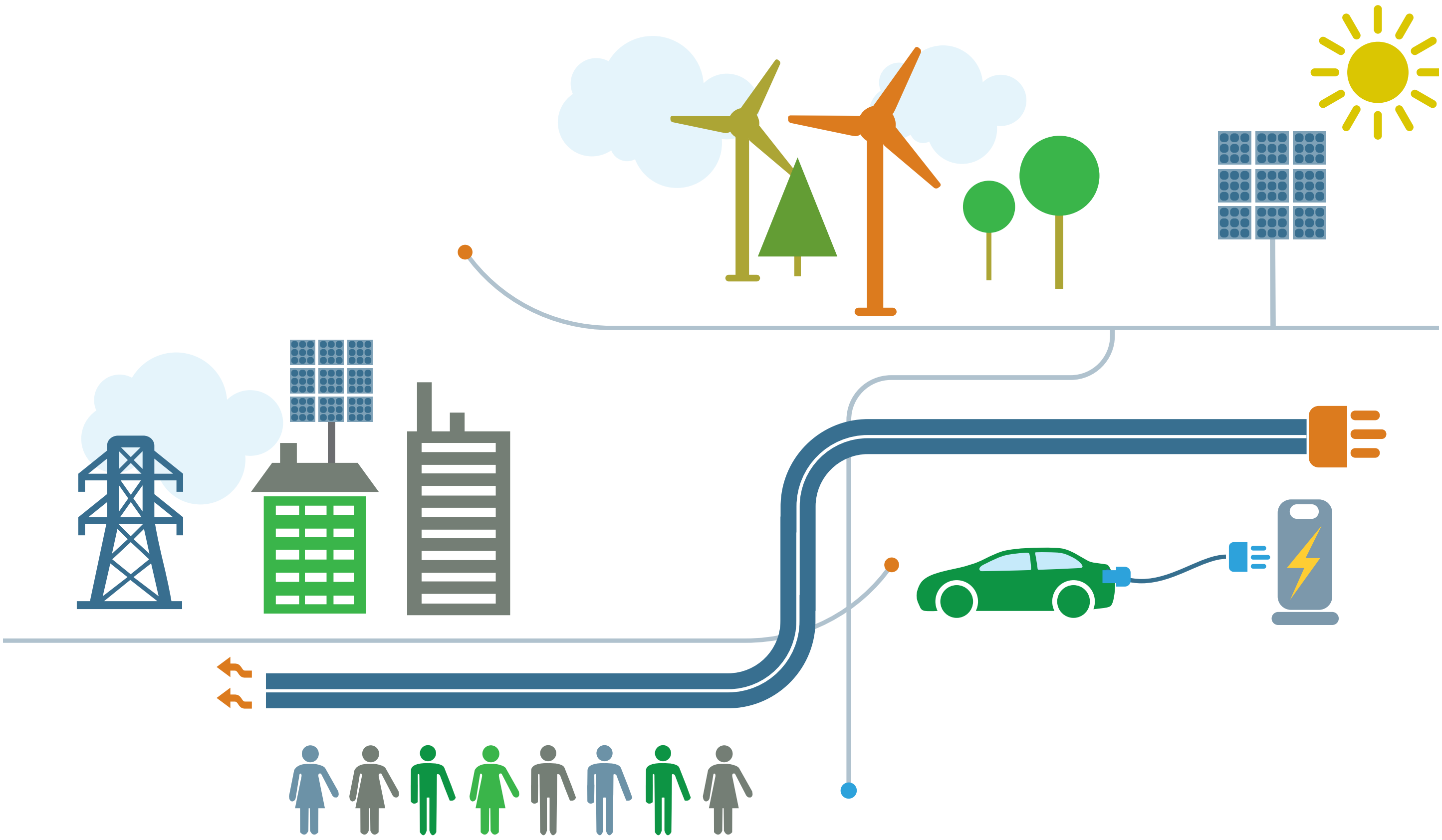


FLEXIBILITY BY DESIGN

DELIVERING A MARKET FOR FLEXIBILITY



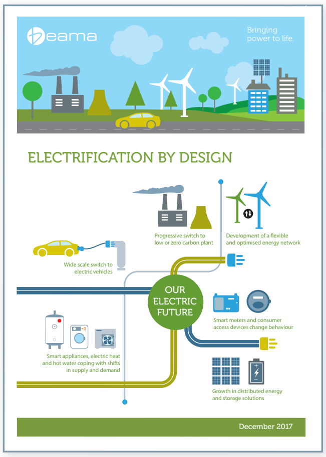
July 2018

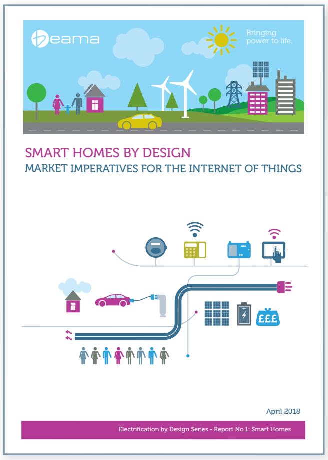
Electrification by Design Series - Report No.5: Flexibility by Design

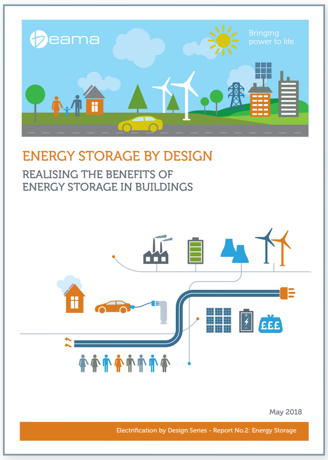
BEAMA Electrification by Design Series

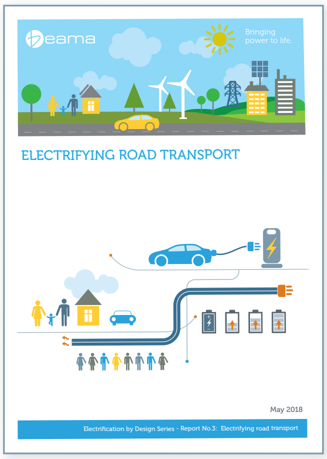
In December 2017 BEAMA published a report, Electrification by Design[1], exploring simple policy and market mechanisms to promote deployment of low-carbon electric systems. In it we identified critical enablers of a flexible and efficient low-carbon energy system. These include consumer engagement with energy use, energy storage, the electrification of heat and transport, automated demand-side energy management in buildings, and demand-side energy management.

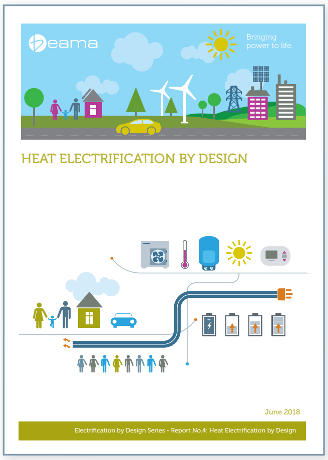
We also made recommendations for how Government, industry, consumers and other stakeholders can work together to enable and maintain the market for smart products and maximise their benefits to the consumer and to the electricity transmission and distribution networks. This report provides more context to BEAMA's view of how the market can identify and allocate the value of flexibility fairly, transparently and efficiently to support the decarbonisation of the energy system.











1 The report can be found here: http://www.beama.org.uk/resourceLibrary/electrification-by-design-pdf.html

CONTENTS

EXECUTIVE SUMMARY

The UK faces a revolution in the way that electricity is generated and used. The switch to renewable generation and electric heating and transport will have profound implications for all parts of the electricity system. Matching supply and demand was once a relatively simple task but the variability of output from renewable generators mean that new solutions will have to be found. Flexibility, defined as modifying generation and/or consumption patterns in reaction to an external signal, promises to be an economic solution, with major savings for consumers. Maximising flexibility can also increase the renewable generation output that can be captured, reducing the total capacity of renewable capacity that will have to be built.

Flexibility can be provided by generation, interconnectors, storage and demand side response (DSR) but all of these face similar requirements, schemes must be practical, controllable, quantifiable, commercial, reliable, timely and material. DSR schemes can also have very different scales, from individual, large industrial sites to many, small residential sites. Again, the same basic principles apply, but the appropriate implementation will be very different.

For DSR, there are different options for how the schemes can be implemented, for example, with variation in the role taken by aggregators and the customer. DSR could be controlled by remote signals to customer appliances, or homes can be automated so that loads are managed to minimise energy bills. It is not clear which of these options will be most acceptable for consumers or deliver the required levels of flexibility and it is important that government and the regulator ensure that all options can be developed to a point when the market can be relied on to deliver its own verdict. It will also be vital that the commercial arrangements are appropriate for each type of scheme, a flexibility service for large industrial sites will need very different arrangements to a service for residential customers.

Although there is lots of interest in flexibility, data shows that the market drivers are weak at this time as electricity demand has fallen with greater energy efficiency. This provides an opportunity to roll out services as the need for flexibility grows. This will also allow the technology to be fitted to the new markets and delivered to customers. There may also be a need for government to support the new services as they are trialled, for instance, the use of the Regulatory Sandbox for services that don't fit with existing market rules.

The government has identified smart metering, EV charging, smart appliances and consumer protection and cybersecurity as essential challenges to be unlocked for flexibility to be delivered. BEAMA add to these:

- The need to recognise the specific needs of the different forms of flexibility
- The need to develop all forms of flexibility in parallel, with an expectation that some forms will be delivered earlier and other response service offerings arriving later as the market develops
- Residential DSR will greatly benefit from network charging offering locational, time of use prices which can be used to drive consumer flexibility.

Provide enough confidence to flexibility providers to develop and invest in flexibility services and ensure that all forms of flexibility will be allowed to develop.

INTRODUCTION

The UK government has committed to decarbonising the energy system by 2050. Much of our future generation capacity will be provided by renewable wind and solar sources and it is expected that there will be a large shift to electric transport and heating. This will demand radical changes to our energy networks and keeping this transformation affordable for customers will be a major challenge. As we transition to Distribution System Operator (DSO) models, flexibility will be utilised to optimise and balance the system and to avoid making costly investments in network and generation infrastructure.

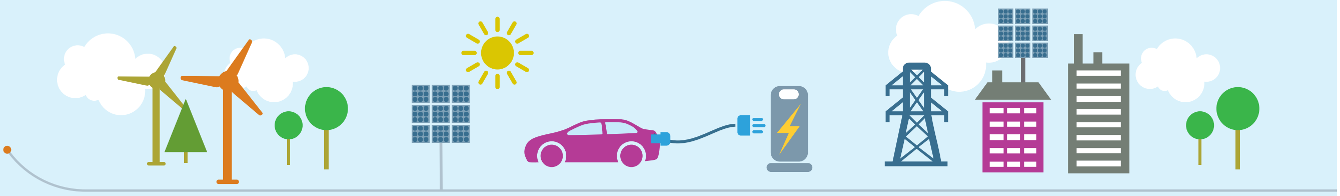
Flexibility refers to the task of matching how much power goes into the power network (generation) and how much is taken from it (demand or load). Treated fully, this is a very complex topic and the report "Roadmap for Flexibility Services to 2030"[2] provides much detail on this. This report is intended for those who will be affected by flexibility in the near future and want to get a better understanding of the key concepts and issues as well as setting out the needs of the supply chain in delivering flexibility and new energy services.

This paper only considers electricity networks, but flexibility does go beyond this. Heating systems, especially linked to heat pumps and district heating, offer much potential to modulate demand on the power network. This is reviewed in the BEAMA report *Heat Electrification by Design*[3], which is one of the reports in BEAMA's *Electrification by Design* series.

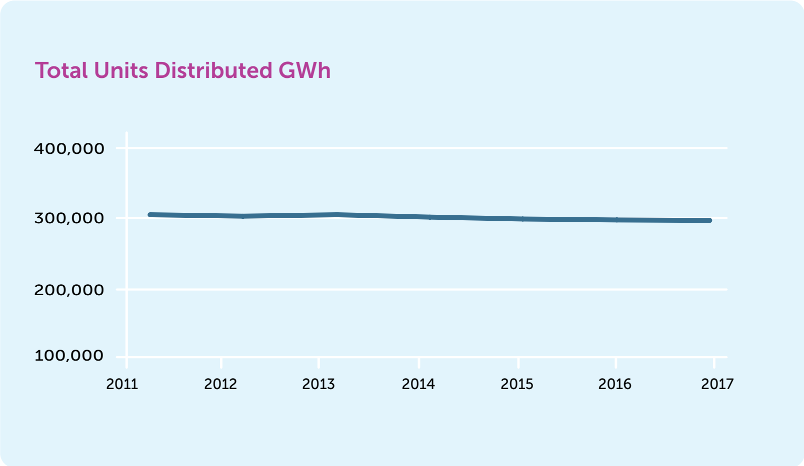
Challenges

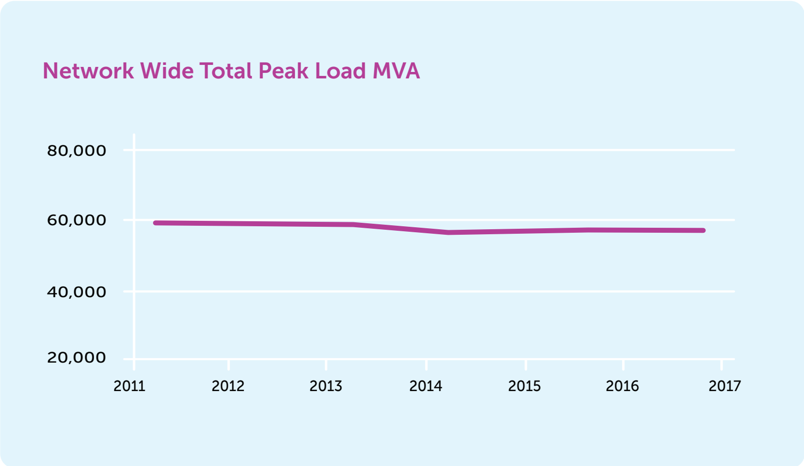
There are some important challenges for the introduction of flexibility:

- Analysis by Imperial College[4] supports the view that maximising the amount of flexibility on the network will increase the amount of intermittent renewable generation that the network can accept and reduce investment in nuclear and gas generation. Imperial College concluded that maximising the use of flexibility could save consumers £3.2b – 4.7b per year but this is not guaranteed and there is high uncertainty over how much flexibility can be achieved.
- The forms of flexibility vary in their network application, location and who requests and provides the flexibility. They will all require different commercial and market offerings, tailored to the needs of the customers. There cannot be a one size fits all approach and government, Regulator and other stakeholders need to work together to create attractive markets for all forms of flexibility.
- Obtaining flexibility from large industrial sites will probably be simpler that from residential properties and it makes sense to target these larger sites early and work through to the more complicated sites, such as individual homes, over time and as the need for flexibility increases.
- Flexibility should be based on a commercial deal between parties where one party changes their energy use pattern for the benefit of the other party and, in return, are rewarded. For networks, a major benefit will be avoiding reinforcement spend. At present, overall network loading is at a low level (see Figures 1 and 2) and there is little overall need for reinforcement, and, hence, little value for flexibility. There are, however, specific locations, for example, new distributed generation or housing estates, where there is network congestion and a value for flexibility. These sites should be used to develop the market and practical application of flexibility ready for wider application as network loading increases more generally with the adoption of electric vehicles and heat pumps.



2 *Roadmap for Flexibility services to 2030*, A report to the Committee on Climate Change, May 2017, Pöyry and Imperial College.
3 *Heat Electrification by Design, Electrification by Design Series* – Report No.4: Heat Electrification by Design, BEAMA, June 2018
4 An analysis of electricity system flexibility for Great Britain, November 2016, Carbon Trust & Imperial College London





Figures 1 and 2. Total units distributed by DNOs and average peak load.
Data taken from RIIO ED1 2016 – 2017 Annual Report, Ofgem, December 2017

1.

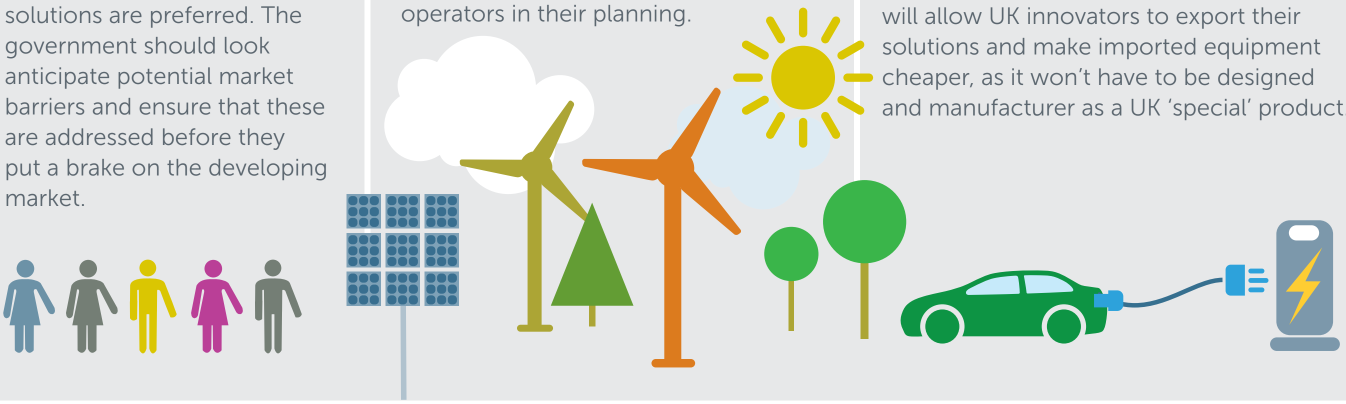
The key requirement from government policy should be to provide confidence in the developing market for flexibility. Government should seek to allow all options to develop and leave market forces and customers to choose which solutions are preferred. The government should look anticipate potential market barriers and ensure that these are addressed before they put a brake on the developing market.

2.

Flexibility solutions will be competing with more traditional responses, such as network reinforcement and there will be natural bias towards 'tried and tested' solutions. The government and Ofgem will have a role in ensuring that all options are considered by the transmission and distribution system operators in their planning.

3.

Government is currently considering its role in standardisation around EV charging and smart appliances. There will be a strong temptation to adopt standards that meet UK market needs but are not suitable for other international markets. This should be resisted as basing UK technology on International standards will allow UK innovators to export their solutions and make imported equipment cheaper, as it won't have to be designed and manufacturer as a UK 'special' product.



WHAT IS FLEXIBILITY AND WHY DO WE NEED IT?

Ofgem's definition of flexibility is 'modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system'.[5] Supply can be constrained by a lack of generation or by a lack of transmission or distribution capacity (see insert).

National Grid has traditionally managed the output of power stations to match the national demand and DNOs have ensured that the capacity of the networks can always meet the maximum local demand (see insert). Decarbonisation means that traditional responses are no longer adequate. Renewable generation, such as wind and solar, are increasingly distributed around the system as smaller units, and their generation output is not fixed but depends on when the sun is shining, or the wind is blowing. By 2050 we will also witness steep rises in power demand as markets grow for electric vehicles and heating[6]. These changes have three important consequences:

- Distributed generation is creating areas in the networks where there is not enough network capacity and generation is being constrained.
- When wind or solar generation output decreases due to fluctuations in the weather, there is a need to find ways to maintain network frequency.
- As the load for EVs and heat pumps grows, the distribution networks will run short of capacity and either they will need to be reinforced or enabled to sustain increased load via the adoption of smart solutions and flexibility, or both.

Flexibility refers to measures used to contribute to this balancing of the system. An example is energy storage, which can absorb electricity when there is an excess and release it when it is in short supply. Increasing the amount of flexibility available to the networks significantly increases the ability to absorb power from intermittent renewables and reduces the need for gas and nuclear backup, as shown in Figure 3.[7]

Significant changes will be needed to decarbonise the UK's electricity generation. In particular, we will need to solve the problem that a lot of renewably generated energy is produced at times when demand is low, and sometimes renewable energy is scarce when demand is high. Increasing the use of new sources of flexibility is expected to be cheaper than relying solely on traditional techniques, such as building additional baseload generation, in responding to this challenge. The report from Pöyry and Imperial College[2] found that for high levels of flexibility, savings could be made of "between £3.2bn and £4.7bn per year in a system meeting a carbon emissions target of 100g CO_2/kWh in 2030".

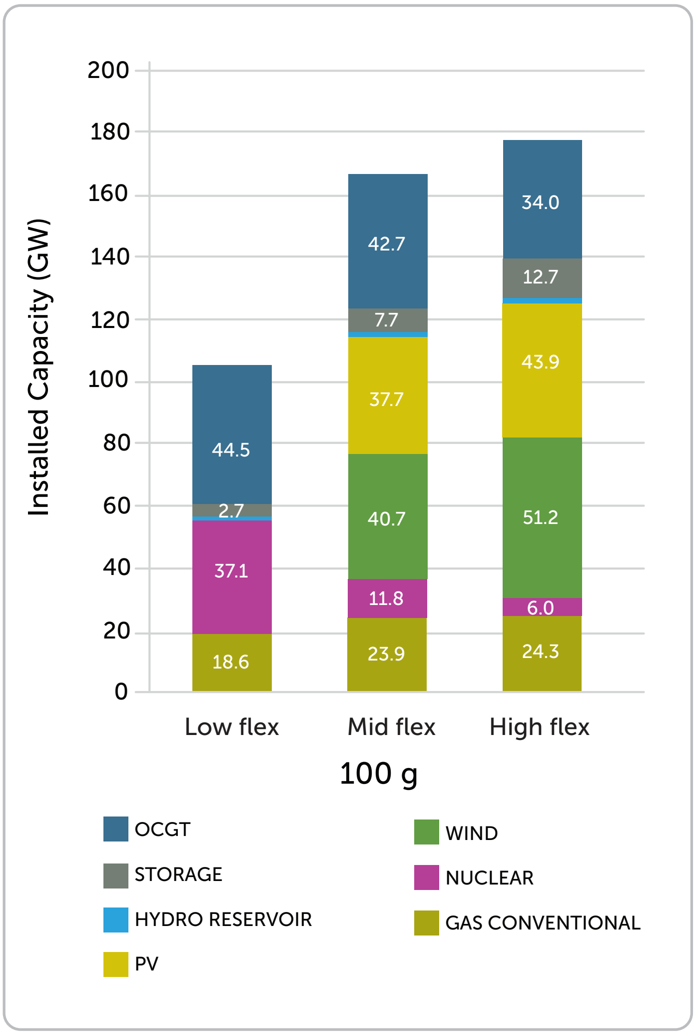
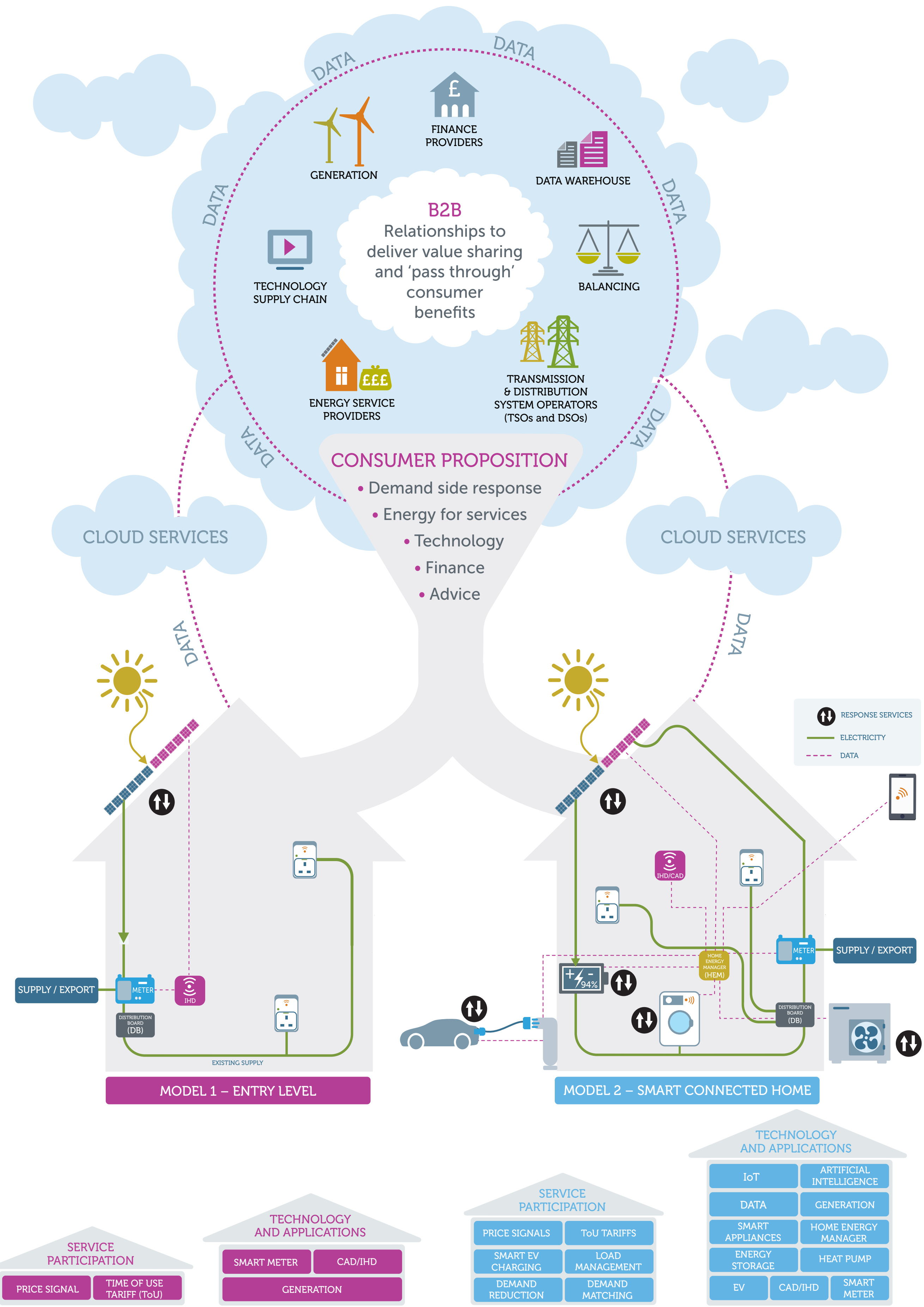


Figure 3: 2050 predicted energy mix for different levels of flexibility

Flexibility is not new; the UK has had an Economy 7 tariff for decades to increase load at night when demand on the power stations was low. What is new is the need for much greater amounts of flexibility and the need for a different kind of flexibility. Whereas in the past the patterns of generation and use have been predictable, now the system needs flexibility when the weather dictates (usually, availability of wind and solar power), which means that the system will need smart technologies to deliver this flexibility. This report examines the different types of flexibility that can be used and the critical factors for their successful adoption.

5 https://www.ofgem.gov.uk/electricity/retail-market/market-review-and-reform/smarter-markets-programme/electricity-system-flexibility
6 National Grid Future Energy Scenarios 2018, http://fes.nationalgrid.com/media/1357/fes-2018-in-5-minutes-web-version.pdf
7 "Delivering future-proof energy infrastructure", Report for National Infrastructure Commission, Goran Strbac, Ioannis Konstantelos, Marko Aunedi, Michael Pollitt, Richard Green, Cambridge University and Imperial College, February 2016

FLEXIBLE AND VALUE SHARED MARKET



Network and system constraints – Why we need to balance the System

A fundamental feature of

electrical networks
is that the amount of power going into the network must match the amount coming out.

Traditionally, this balance has been managed by adjusting the

output of generators
to match the demand. In practice, as the load increases, the network frequency tends to reduce as the generators slow while trying to meet the extra load.

This is referred to as a

frequency constraint:
if the frequency falls too low, the network **will fail.**

Supply to a specific location can also be constrained by the network itself. The wires that form the network heat up as current flows through them; more current means more heat.

This creates a thermal limit for the network, and the maximum amount of power it can carry is defined by the limiting cable temperature.

Thus, even though overall there is enough power being supplied to the network, it is possible to have locations where the network capacity limitations mean that demand cannot be met.

In trying to get power to a customer, it is possible to be constrained either by a lack of power or by a lack of network capacity.

Traditional Network Management

Under traditional network management,

National Grid
used extensive knowledge of customer demands to predict power demands a day ahead, and generation was contracted to meet this.

To deal with deviations from this forecast, a small amount of generation capacity was retained, ready to turn up or down at short notice as required.

As the day unfolded, National Grid would advise generators to turn their output up or down. National Grid has a statutory duty to keep the network frequency between

49.9 Hz and 50.1 Hz.

Power mostly came from a small number of large central power stations and was fed to the DNOs via Grid Supply Points (GSPs). The power was assumed to cascade from the GSPs through the DNO network to the customers.

The transmission system operators had little interest in what happened downstream from the GSP and, in turn, the DNOs could assume that the transmission system was an infinite busbar or source and would always provide the power they needed.

The system was designed to cope with the worst-case condition and contained a high degree of redundancy to ensure reliability.

It worked very well for many decades, but, as we move to renewable generation and the increasing electrification of transport and heating, it will be an expensive approach and, it is becoming less appropriate.

Flexibility now

National Grid now purchases a range of balancing services and, led by the Power Responsive Project,[10] is in the process of revising these to make them more useful. A full list of the balancing services can be found on their website.[11] Several of the services are set out here to illustrate the general approach and some of the key features.

Frequency Response Services (to balance supply and demand)

When demand exceeds supply, the network frequency drops. National Grid has put in place the following balancing services to respond to this.

Firm Frequency Response (FFR)

FFR is designed to complement other sources of frequency response and delivers firm availability. The tendered service of FFR is open to all qualifying providers thereby increasing the number of potential response providers and improving liquidity. Providers are required to provide a minimum of 1MW response energy and be able to respond to remote control signals.

All these services (and others) allow National Grid to meet variations in demand/generation across different timescales and for different time periods.

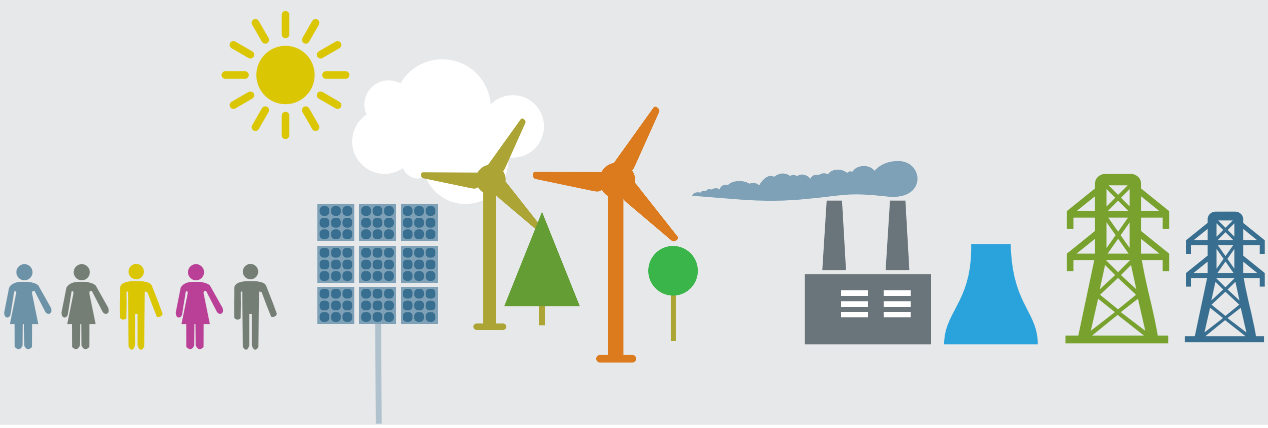
Enhanced Frequency Response

This is a new flexibility service introduced by National Grid, offering contracts for frequency response operating on a 1-second basis. Achieving this speed of response requires local frequency monitoring and is self-dispatching – the decision to turn on or off must be taken locally.

Fast Reserve is used, in addition to other energy balancing services, to control frequency changes that might arise from sudden, and sometimes unpredictable, changes in generation or demand.

Demand turn up

An interesting new service offered by National Grid is Demand Turn Up which has been "developed to allow demand side providers to increase demand (either through shifting consumption or reducing on-site embedded generation) as an economic solution to managing excess renewable generation when demand for electricity is low."[10] This is a useful service when demand on the transmission system drops so low that it become difficult to keep it stable or when there are high levels of output from wind generation at times of low demand.



8 http://powerresponsive.com/
9 https://www.nationalgrid.com/uk/electricity/balancing-services/list-all-balancing-services
10 http://www2.nationalgrid.com/UK/Services/Balancing-services/Reserve-services/Demand-Turn-Up/

WHAT FORMS DOES FLEXIBILITY TAKE?

As the need for flexibility grows, different forms of flexibility will be developed in parallel and at different scales. The report "Roadmap for Flexibility Services to 2030"[11] identifies four key areas of flexibility, each expanded on below.

Generation – Flexible generation requires the ability to control the output from generators to match the load, or demand, on the grid. For flexible generation the question is how fast and by how much the output can be changed in response to a control signals. For example, thermal generation has traditionally taken a long time to turn up and down and there are limits to how low its output can go. Flexibility means finding ways to extend the operational limits for thermal plant and increase the speed at which they can respond to controls. Technological and operational. innovation is increasing the ability of conventional generators to run at lower levels of continuous output and to ramp their output up and down faster. This makes them more supportive of and useful to the network. This technology will not be covered in this report, but we acknowledge the critical need for continued funding of innovation and of network support for such generators. The National Grid Future Energy Scenarios point to high levels of bio-gas used for flexible generation by 2050 and this technology will benefit from innovation increasing its speed of response.[12]

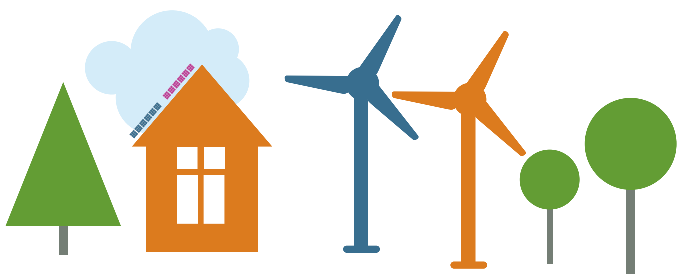
Interconnectors – the UK power system is connected to Ireland and the continent by several high-voltage DC interconnectors. Interconnectors allow the output of renewable generation across whole regions to be spread across even wider areas, so excess supply can be used to support the network at the other end of the connector if there is high demand there. The UK is also able to use its one-hour clock offset with the continent so that the two regions can support each other at peak demand periods. This topic is covered extensively in a report from Pöyry[13].

It will be important for the UK to remain a full participant in the European Internal Energy Market if it is to have the full benefit from these interconnectors. An analysis of possible scenarios following the UK's exit from the European Union[14] identified that it might be possible for the UK to remain connected to the European network but able only to trade bulk duty-free electricity rather than enjoy the full benefits of cross network flexibility.

Energy Storage – the use of power stores, such as batteries, allows supply and demand to be matched. This is covered in the BEAMA report Energy Storage by design.[15] Storage is a direct response to the need for flexibility and negates the basic assumption that power into the system must continuously equal power out of it. Batteries have always been available to network operators, but until recently they were too expensive to be used for flexibility. It is the huge improvement in the performance of storage technologies and their fall in price that makes them an option now. Cost still limits their applications but, as this falls further, and new types of storage are developed, more applications will become feasible.

Demand Side Response (DSR) – electricity users receive signals that ask them to modify their demand in response to power and network availability. Economy 7 is a simple example of DSR. As DSR is such a major feature of future flexibility, it is discussed in greater detail below. Customer might also be offered a variable maximum demand capacity, with perhaps a baseline level and access to higher levels when this is deliverable, or, conversely, suspension of this capacity when supply is constrained. This could be applied to electric vehicle contracts.

THE PÖYRY/IMPERIAL COLLEGE REPORT[16] SET OUT FIGURES FOR HOW MUCH FLEXIBILITY EACH OF THESE OPTIONS COULD PROVIDE AND AN ESTIMATE OF UNCERTAINTY ABOUT THE DATA FIGURE 4.



[11] "Roadmap for Flexibility Services to 2030", A report to the Committee on Climate Change, May 2017
[12] National Grid, Future Energy Scenarios, July 2018
[13] "Costs and Benefits of GB Interconnection", A Pöyry report to the National Infrastructure Commission, Feb 2016
[14] Brexit and Energy Policy, Workshop Proceedings, STUDY requested by the ITRE committee, Policy Department for Economic, Scientific and Quality of Life Policies, European Commission, June 2018
[15] Energy storage by design: realising the benefits of energy storage in buildings, BEAMA, May 2018
[16] Ibid, footnote 1

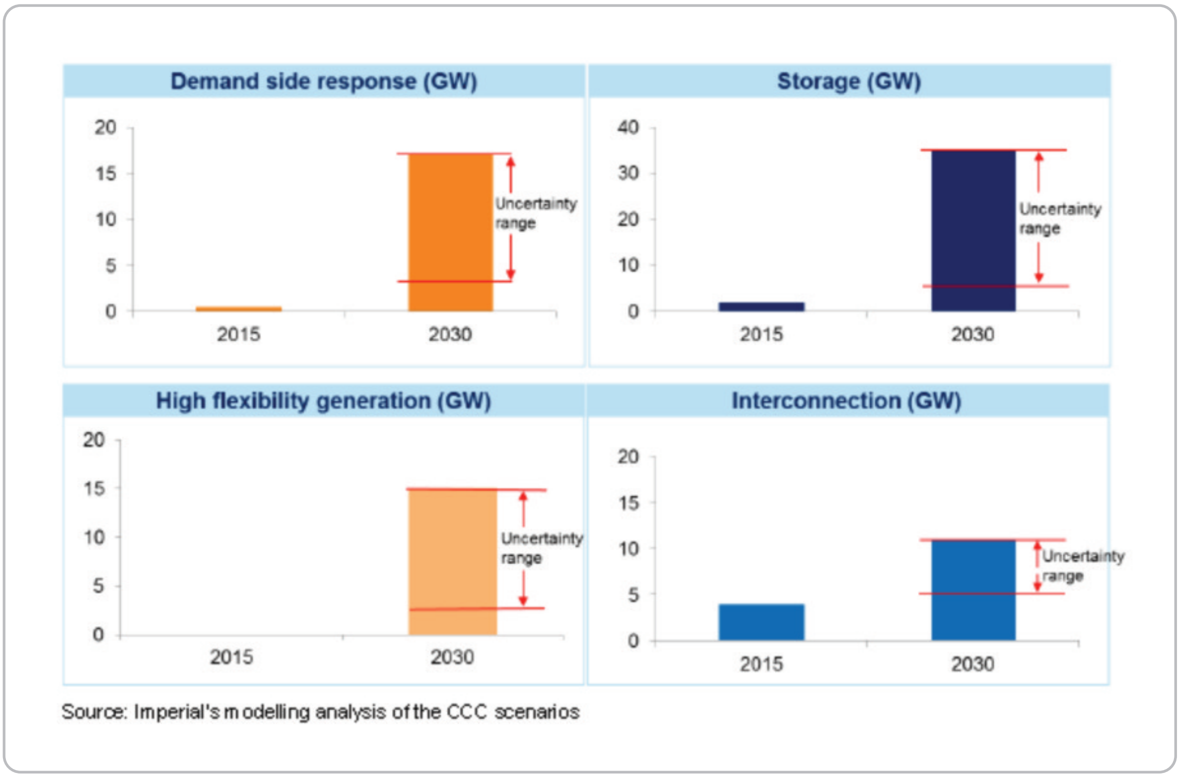


Figure 4. Indication of uncertainty in the deployment of different types of additional flexibility resource based on scenario modelling

IT IS APPARENT THAT NOT ONLY IS THERE A LOT OF FLEXIBILITY POTENTIALLY AVAILABLE, THERE IS ALSO A VERY WIDE RANGE OF UNCERTAINTY OVER HOW MUCH OF IT WE ARE ABLE TO ACCESS. IT WILL REQUIRE A COMBINATION OF CAREFUL MARKET AND COMMERCIAL DESIGN, TECHNICAL DEVELOPMENT AND MARKET EDUCATION TO UNLEASH ITS FULL POTENTIAL.

THE ESSENTIAL FEATURES OF FLEXIBILITY

Although they vary in detail, BEAMA contends that all forms of flexibility must meet certain critical requirements. Flexibility services must be:

- **Practical:** Administering the flexibility scheme should not be unduly complicated in relation to its value. This goes from one extreme, where an HVDC interconnector or a large industrial site can provide enough response to justify a lot of money being spent on agreeing a single contract, through to the aggregation of millions of residential properties, where the agreement will have to be based on standard and simple terms and conditions. This reflects the general rules of mass markets where it is normal to make a large investment designing and setting up the product, in return for very low individual transaction costs. This also applies to the processes needed to control, measure and reward any scheme.
- **Controllable:** There must be a mechanism to inform the providers of flexibility that there is a need for flexibility. For many forms of flexibility now in use, warning is sent out followed by a call for the flexibility, all within defined time periods. Flexibility providers will then be contracted for a given quantity and duration of response. Alternatively, control can be provided by monitoring a local parameter such as mains frequency or price, with the customer, or their smart devices, responding appropriately.
- **Quantifiable:** It must be possible to measure the flexibility response and to reward both parties appropriately. In the case of residential customers, their demand is changing all the time, so changes in demand and supply must be measured in a way that allows the system to know whether variations in demand are due to a response to a call for flexibility or just chance. For instance, a customer might turn off their fridge in response to a call to reduce load, but their dishwasher might turn on automatically with a possible net result that the load is the same as before but less than it would have been. If you cannot detect and measure response, it becomes impossible to reward it correctly.
- **Commercial:** All parties, whether requesting or providing flexibility services, must be able to gain from it; otherwise they have no incentive to take part. For instance, if a DNO tenders for DSR in place of network reinforcement, it must realise a genuine saving that it can pass to its customer. In practice, this is as much a regulatory issue as a technical and commercial one; regulation must allow the system to reward the DNO for not doing something as well as for investing in new assets. Likewise, a customer responding to a flexibility request by reducing load or increasing feed-in generation must be paid for it and the payment must be sufficient to attract customers and cover the cost of any equipment needed.
- **Reliable:** National Grid and the DSO must have assurance that when they call for flexibility there will be an appropriate response. In principle, this can be achieved at either extreme either by having a small number of providers under the direct control of National Grid or the DSO or, where a statistical response can be relied upon, by having many providers under less direct control. Flexibility schemes can also overlap with a commercially based scheme relying on voluntary customer response backed up with a more mandatory scheme that steps in if the initial response is too small to keep the network stable. On the Continent there are proposals for a traffic light system[17] where green means that the system is normal with no need for action, amber indicates that flexibility is required under commercial terms and red indicates that immediate, direct action is required by the network operator to maintain system stability.
- **Timely:** The flexibility offering must be fast enough to respond adequately to the imbalance, and the response must last as long as the imbalance does. Services can be combined so that the flexibility response can be purchased as fast, medium and long-term contracts that, combined, meet the overall need of the response (see insert on National Grid Balancing Products).
- **Material:** The flexibility must be sufficient to meet the needs of National Grid or the DSO. This can be achieved by small numbers of large sites or large numbers of small sites. A target response can be met by combining different forms a flexibility to create the overall response needed.

[17] "Flexibility in the Energy Transition, A Toolbox for Electricity DSOs", CEDEC, EDSO, Eurogas and GEODE, February 2018, p10

FLEXIBILITY FROM DEMAND SIDE RESPONSE (DSR)

In this section we look at some of these requirements when applied to DSR. DSR covers a wide range of applications, from large industrial complexes through to individual homes turning their demand up or down as required. In principle, in each case DSR is doing the same thing but in practice there is a world of difference.

Practical – As stated above, a flexibility scheme should not be unduly complicated or expensive relative to its value. Large industrial sites, which have a high value, would support the cost of negotiating an annual contract with the site and justify a direct communication channel between the DSO and the site's control centre. For individual residential customers, though, the value for each site will be much lower and it would not be practical to maintain individual contracts with every customer. Nor would it be practical to recruit residential customers through a tendering process such as is the practice with the current balancing markets. Different approaches will be needed to unlock this sector and such approaches are being developed and trialled. There is also general agreement that, for the residential sector, customer response will have to be automated as customers are not willing or able to devote their time to monitoring and responding to networks requests. The way that these schemes are rewarded will also likely be very different for residential customers. For instance, residential customers could be rewarded simply by offering them variable prices for each half hour period where the price reflects the real cost of energy and network capacity at that time. They, or their smart systems, could then minimise the energy costs. Such approaches to control are examined in more detail in the next section. Such a scheme would have a high cost to set up but a much lower per customer cost to operate. It is also possible for aggregators to act as an intermediary between individual customers and the network operators, with the aggregator, for example, offering a single bulk contract to the flexibility purchaser and multiple, identical contracts to the flexibility providers.

Controllable – Typically, at present most flexibility is controlled by National Grid sending an instruction to the flexibility provider and the provider responding within an agreed period for an agreed duration. For residential customers, technology is now being developed that allows the network to control devices in the home. One example of this is the protocol OpenADR[18] which is being tried out in the US, UK and elsewhere. Other protocols are being developed and the UK government is examining what actions it needs to take to ensure that customers can have confidence in entering this market[19].

There are two main control options that can be used, and their practicality will vary between sectors:

- **Option 1: Direct control –** In this option a signal is sent to the flexibility provider that results in an immediate response. Modern IT systems and communications infrastructure is making this more practical for large groups of customers. As an example of this, some DNOs are currently consulting on the need for them to be able to send out an instruction to home EV chargers to limit their maximum power when the local network is experiencing high local demand. In practice the DNO would send a signal, possible via a smart meter, to the customer's home charger to set a maximum charge rate. Alternatively, a command can be sent as an input to a local control system. Smart appliances are now allowing DSOs to control the devices in a customer's property using protocols such as OpenADR, one option explored on the commercial DSR trial of UKPN.[20] The customer would have to purchase appliances that respond appropriately and enter into an agreement with the DNO or DSO. There are a variety of ways to package this, one approach being to have an energy services agreement between the energy supplier and the customer, with the supplier providing the appliances and home controls and acting as an intermediary between the DSO and the customer.
- **Option 2: Local Control –** Flexibility is driven by monitoring a local parameter and using this to control flexibility provisions. In this case, domestic appliances could monitor the network voltage or frequency and adjust their load accordingly. For large sites, the National Grid Enhanced Frequency Response works in this way[21]. Another example of this is the frequency sensitive fridge that avoids operation during periods of low mains frequency. This approach would be very practical for residential customers as it does not depend on a communications link between the network and the customer. Local control can also respond to price signals or smart tariffs and it would be feasible for customers to be offered variable half-hourly prices for power so that they can then adjust their consumption to minimise their bill, much as Economy 7 works now.

18 http://www.openadr.org/

19 Consultation on Proposals regarding Smart Appliances, BEIS, March 2018

20 Industrial and Commercial Demand Response for outage management and as an alternative to network reinforcement, UK Power Networks, September 2014

21 Enhanced Frequency Response FAQs Version 5.0, National Grid, 29th Mar 2016

As we depend more on renewable generation, the availability and cost of electricity will be less predictable, and flexibility must deal with this. In this case, practical systems will depend on a high degree of automation linked to a home energy management device or service. To allow the system to minimise the electricity bill, it would need to understand the home's daily power demands and how much they can be moved and have prior knowledge of the electricity price for each half hour period during the day. Half hourly settlement, as currently understood, does not meet this requirement as the price of power is set after the event. The need for forward pricing could create a new service where companies forecast prices, either on a firm basis or as an advisory service, their payment depending on how much risk they accept for errors in the forecast. It is likely such a service would need to provide at least 24-hours' notice so that the home energy management software can optimise across a whole daily cycle.

One advantage of this approach is illustrated by EV charging. As currently conceived, EV charging is expected to produce an evening peak in demand when people return home and connect their vehicles. Now though, under this approach the forecast price would go up around 5pm and customers who were able to could shift their demand to later in the evening. If the home energy manager understands how much power the electric vehicle needs over the night, it can choose the time periods when the power will be cheapest. One further benefit of this approach is that this response would then lower the price at 5pm (as people shift to cheaper time periods) so that, over time, it should settle down with a smaller premium for the evening peak rather than a prohibitive or punitive price.

Smart appliances can be used to extend this to a whole house response, but this will face the problem that appropriate appliances are unlikely to become available until the DSR market is well developed, while the development of that market in turn relies on sufficient take-up of such appliances. One solution to this problem is to help establish the DSR market by rolling out network-enabled power sockets that can allow consumers to participate in DSR without smart-enabled appliances. This approach creates its own challenges and will likely only be a stepping point, as many appliances respond poorly to being turned off mid-cycle and will respond unpredictably. If a smart appliance is given an instruction to turn up or down, it can respond based on its understanding of the appliance's operational status, but a smart switch would not have access to that information. It is likely that a combination of these options will be necessary, as has been mentioned[22]. Option 2 could be offered to customers with the DNOs holding Option 1 in reserve in case the market approach does not yield enough response and network stability must be maintained.

Quantifiable – Unless the consumer's response to a request or demand for flexibility is simply rewarded on an assumed basis, the response must be both measurable and measured. At present most residential customers have Non-Half Hourly meters,[23] so little usage information can be recorded. The roll out of smart meters will do much to improve this situation as they record consumption over each half-hour period and can offer much richer usage data. However, identifying power not used can be difficult. National Grid's Enhanced Frequency Response requires sites to maintain daily demand profiles that can be compared to actual demand. The difference between the two figures shows the value of the flexibility response – see insert.

"[IN] 2016, DELIVERY OF THE SERVICE [ENHANCED FREQUENCY RESPONSE] WAS ASSESSED BASED ON PROVIDERS' FORECAST ACTIVITY (DEMAND OR OUTPUT) AND THEIR ACTUAL ACTIVITY. IF THE DIFFERENCE BETWEEN THE TWO WERE EQUAL TO THE MW VOLUME SPECIFIED IN THE UTILISATION INSTRUCTION, THE PROVIDER WAS DEEMED TO HAVE DELIVERED THE SERVICE. ……, A BASELINE METHODOLOGY IS UNDER DEVELOPMENT THAT WILL USE THE AVERAGE DEMAND OR OUTPUT OF PREVIOUS DAYS TO ESTABLISH A BASELINE. THIS IS SIMILAR TO OTHER BALANCING SERVICES."[24]

22 Ibid, Footnote 17
23 NHH means the meter simply records a total consumption figure. A HH meter records consumption every 30 minutes so that the customer can be charged for when they use energy as well as for how much they use.
24 https://www.nationalgrid.com/uk/electricity/balancing-services/reserve-services/demand-turn

Energy not used is often referred to as 'NegaWatts'. As set out above, it can be estimated by comparing a predicted usage pattern against the actual demand pattern. However, this becomes less reliable as you move to sites such as in individual homes. The flexibility response of some small loads, such as a home power storage unit, can be monitored and recorded. But the response to a general instruction to a household to reduce demand is harder to measure. An aggregator could act on behalf of the customers and hold a firm contract with the DSO based on the aggregator's expectation of the overall customer response. This, though, leaves the aggregator the problem of deciding which customers to reward. The danger is that, if they reward everyone and share the income between all customers, there will be a weaker incentive for customers to comply with the call for flexibility.

Another solution for this sector that would resolve this challenge is to drive residential DSR by tariff, so that the home (the householder or, more likely, an automated system) could respond to price signals and the reward for the flexibility response is simply a lower energy bill. This would also allow customers to choose whether to respond to the call or simply accept the higher price if they want or need power at a high-price period. Operating experience would lead to more reliable forecasting, price-signalling and monitoring. This would be like the concept of 'diversity', in which the combined response of a sufficiently large number of, individually unpredictable, customers can become predictable.

One risk for such aggregations is that a large number of homes with automation might respond together, overcompensating for a network imbalance and destabilising the system. This could result in big swings in half-hourly prices. If this were to be a real problem, it would be possible to design an element of randomness into the response of individual appliances to damp out such 'common-mode' effects.

Commercial – Demand for generation capacity and network capacity will increase as demand for electricity increases. The cost of the new investment in generation and network capacity that such changes will require could be inhibitive unless the network simultaneously becomes more flexible. Without flexibility, the level of investment in the network will need to be sufficient to meet peak demand; with it, demand peaks and troughs can be smoothed, adjusted to respond to fluctuations in generation, or reduced by storing power in buildings or networks. The best way to create an incentive for these mitigating actions is to establish a value for flexibility that can be realised by both parties (the provider and the buyer). For this to happen, cost signals will need a much higher resolution than they have currently.

In a maturing flexibility market, the cost of energy will become increasingly variable, depending on what plant is currently running to meet demand. But the cost of supply to the site will also vary depending on demands on the local and wider network. Again, this can vary from one location to another and by time of day. For network capacity this means that network charges will have to act as variable price signals to manage demand, so their calculation will become much more complicated. This will be examined in a future BEAMA report in the *Electrification by Design* series on network charging. Ofgem is currently working to understand how network charges can be developed. The Charging Futures Access and Forward Looking Charges Taskforces have recently published a report to inform Ofgem's assessment of the options for reform of the current network access and charging arrangements.[25]

'Stacking', or the practise of combining compatible flexibility services into a single contract, is an important way of maximising value for customers. There are many different types of flexibility response, each with its own value to the network (or to different networks or market participants). In practice though, flexibility providers can use their equipment to participate in more than one response markets. However, as the site capacity falls, if taking part in every response market needs an individual contract, it rapidly becomes uneconomic for the customer. Stacking can address this by effectively bundling different flexibility responses into one contract. For flexibility driven by variable half-hourly pricing, the equivalent would be to include all the cost elements (such as network capacity and energy cost) in the single half-hourly charge.

This approach also has the merit that it makes a customer less dependent on a single balancing market. For instance, if a DSO offers a lower capacity charge for customers to reduce their demand during peak periods in a specific power area, when this area is reinforced after a few years as demand continues to rise, the value for DSR will be taken away. The customers could then end up having invested in smart appliances and after a few years getting no further reward. If their flexibility reward is based on multiple income streams, this might result in a reduction in their reward but not an end to it.

The prospect of stacking raises concerns for DSOs and TSOs related to reliability. Their concern is that flexibility providers may receive multiple calls to provide flexibility from different parties and they will respond to the one offering the highest reward. This would leave the other parties with no response, or even a response opposite to what they had requested. In practice, familiarity may resolve this issue with customer response becoming better understood and more predictable. Where there is a danger that customers could receive conflicting calls for flexibility, this might be a point at which a 'system operator' with a broader perspective could be asked to intervene.

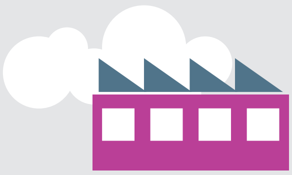
A further innovation that might increase the value of flexibility is Peer to Peer Trading, which is a radical approach to charging for power. In this market, any energy consumer can choose to purchase their power from any generator who has power available at that moment. Making this work would likely depend on implementing blockchain trading platforms. This would allow energy to be traded in real time in close to an economically perfect market, but it will raise issues around network charging unless this is accounted for in some form. If there is sufficient network capacity there is no need to consider any cost other than the power being generated with some billing mechanism for recovery of network costs, much as now. However, if there are network constraints then these would have to accounted for. This could be done by the generator factoring some additional (or reduced) cost into their charge or the network company providing a market for

25 Electricity Network Access & Forward Looking Charges: Final Report and Conclusions, A Report by the Charging Futures Access & Forward Looking Charges Task Forces, May 2018 http://chargingfutures.com/media/1203/access-and-flc-final-report-and-conclusions.pdf

network capacity that the users can access. Their trading would then have to consider the costs of energy and capacity. Interestingly, this might result in power becoming cheaper within a given network area as the export capacity is approached and local renewable generation constrained. This might look like NG's Demand Turn Up scheme but on a local scale. A consortium, including EDF Energy R&D UK and PassivSystems, is developing a proposal to enable a peer to peer with Ofgem using their Regulatory Sandbox[26]. Centrica has also announced a trial of peer to peer trading based on blockchain technology to create a local energy market in Cornwall[27].

DSR Summary

The table below summarises the different approaches possible for DSR for different customer groups.

CUSTOMER	CHARACTERISTICS	SOLUTIONS
Large Industrial 	Small number of high value sites with large response potential	Individual balancing contracts won by tender. Statistical approach to market response not appropriate. Direct communication between system operator and site. Potential for automated fast response.
Offices – small factory 	Large number of sites with moderate response potential	Role for intermediary to aggregate the sites. Standard contracts, mix of remote control and automatic
Residential 	Very large number of sites with small response potential.	Role for either an intermediary or via variable tariff offered by energy retailer. Statistical approach necessary to manage this sector. Control can be remote by network or intermediary or based on local calculation; c.f. home energy manager energy cost optimisation. Standard contracts essential and with very simple rules.

26 https://www.ofgem.gov.uk/system/files/docs/2017/07/update_on_regulatory_sandbox.pdf
27 https://www.centrica.com/news/centrica-and-lo3-energy-deploy-blockchain-technology-part-local-energy-market-trial-cornwall

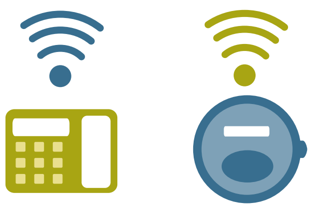
WHAT IS NEEDED FOR FLEXIBILITY TO BE DELIVERED

Flexibility has been recognised by Government as a key component of decarbonisation. The BEIS plans for "Upgrading Our Energy System"[28] and the Government's Clean Growth Strategy[29] both rely heavily on flexibility. BEIS assumptions include an additional demand-side response of 4.9GW and 0.3GW of storage by 2032. To put this in perspective, Open Energi[30] estimates that, based on its experience in larger industrial and commercial sites, 6GW of DSR capacity could be unlocked using their technology with little or no impact on users. However, the findings of studies by Imperial College are that the more flexibility that can be created, the lower the overall cost of decarbonisation.

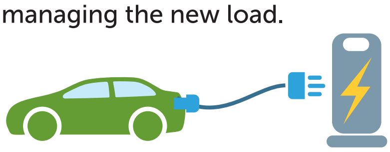
The capacity cited by Open Energi does not include the residential sector, but there is plenty of potential here that could be easily realised with the right financial incentives. The report "Roadmap for Flexibility Services to 2030"[31] identifies a potential volume of 18GW of DSR, but 15GW of this is uncertain and depends on the right market and policy actions. This suggests a strategic approach, with larger, industrial and commercial sites being looked to for early flexibility and the more complex, , smaller commercial and residential sites being developed over a longer timeframe.

The BEIS Smart Systems and Flexibility Plan[32] sets out the challenges to unlocking this capacity.

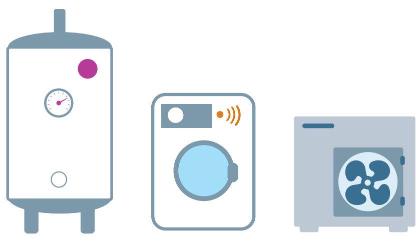
Half-hourly metering: smart meters providing half-hourly energy demand data are needed to ensure customers can be charged and rewarded for their time of use.



Electric vehicle charge points: an important and early need for flexibility will be managing electric vehicle charging. The Government is promoting the installation of charge points and developing a process for managing the new load.



Smart appliances: customers are unlikely to engage in flexibility if it requires frequent intervention, so widespread uptake will depend on smart appliances and home automation. For this to be effective, the appliances should be interoperable so that it is straightforward to purchase additional appliances and link them to the system. The Government has indicated that it will look at developing appropriate standards to support residential DSR.



Consumer protection: customers will have to trust and understand the new flexibility services.

Cybersecurity: both the customers and the power networks have to be protected from cyber-attack.

28 "Upgrading Our Energy System" Smart Systems and Flexibility Plan July 2017
29 The Clean Growth Strategy Leading the way to a low carbon future, BEIS, October 2017
30 http://powerresponsive.com/ai-shaping-future-energy/
31 Roadmap for Flexibility Services to 2030, A report to the Committee on Climate Change, May 2017, Pöyry and Imperial College
32 Upgrading Our Energy System, Smart Systems and Flexibility Plan, BEIS and Ofgem, July 2017

BEAMA supports all these points and, on behalf of the supply chain, would offer some more:

1.

Recognise that different forms of flexibility have their own requirements and tailor regulatory, market and commercial arrangements to meet their different needs.

2.

Develop different forms of flexibility in parallel to maximise the amount of flexibility mobilised. Some forms of flexibility will develop earlier than others, and these can meet early needs with the others coming in as the need for flexibility grows.

3.

Reform network charging to allow the full cost of electricity (power plus supply) to be passed to customers and translated into flexibility responses. Charges should be dynamic and locational.

4.

Aim Government policy at giving confidence to flexibility providers and the supply chain so there is a consistent incentive to the develop the markets and technology for flexibility. Government should allow all forms of flexibility to be developed and allow the market to decide which succeed.

MUCH OF THE TECHNOLOGY NEEDED TO DELIVER FLEXIBILITY ALREADY EXISTS, BUT IT NEEDS TO BE TAILORED TO MARKETS AND COMMERCIAL OFFERINGS AS THEY DEVELOP. PRODUCTS SHOULD BE BASED ON INTERNATIONAL STANDARDS SO THAT UK INNOVATORS CAN EXPORT THEIR PRODUCTS AND KEEP DOWN THE COSTS OF IMPORTING EQUIPMENT.

CONCLUSIONS

Flexibility is a key component of the UK's efforts to decarbonise electricity. It describes a wide variety of different routes to balancing supply and demand, all of which will need to be developed if the UK is to obtain full benefit.

Flexibility can make a major contribution to decarbonising the UK energy supply, especially as the demand for electricity for vehicles and heat pumps grows. But there are many forms of flexibility, and they apply to many different market sectors. They each have their own requirements, and all stakeholders must be sensitive to the requirements of each form of flexibility.

Having said this, all forms of flexibility should meet the requirements set out in this report. How those requirements are met will vary from application to application, but each form should be reviewed against this list.

CASE STUDIES

CASE STUDY 1

Industrial

Tarmac harnesses flexible energy demand to deliver new capacity to the UK grid

Tarmac, the UK's leading building materials and sustainable construction solutions company, has worked with Open Energi to install Dynamic Demand on over 200 bitumen tanks at it's 70 asphalt plants across the UK, helping to build a smarter, more responsive system which supports renewables and the wider UK transition to a zero carbon economy.

After trialling the technology on three sites, Tarmac commenced the rollout at the start of 2015, and by April 2016 has completed its installation at 70 asphalt plants, connecting over 200 bitumen tanks UK-wide.

Open Energi has worked with Tarmac to connect to over 200 of their electrically heated bitumen tanks. This means that they can Open Energi can turn the heaters on or off remotely and sell this flexibility to National Grid. The tanks rely on their thermal inertia to maintain their temperature when the heaters are switched off. They can also raise the temperature when there is excess power available on the grid. Interestingly, Open Energi note that the control system has also given Tarmac much better visibility of the performance of its tank heaters.[33]

CASE STUDY 2

Residential Heating

Scottish and Southern Electricity Networks have been exploring demand management for residential heating in their NINES project[34] They are working with Glen Dimplex and using the Quantum electric heating system. The Quantum heater is fan assisted so that its heat output can be boosted by turning on the fan. This also means that heat output when it is not needed is much reduced. The Quantum electric heater can be re-charged when there is surplus electricity and charging turned off when there is a shortage. This is integrated with the wind farm generation output. This has proven very effective and popular with customers in the trial and SSEN had installed the technology in 228 homes in 2016.

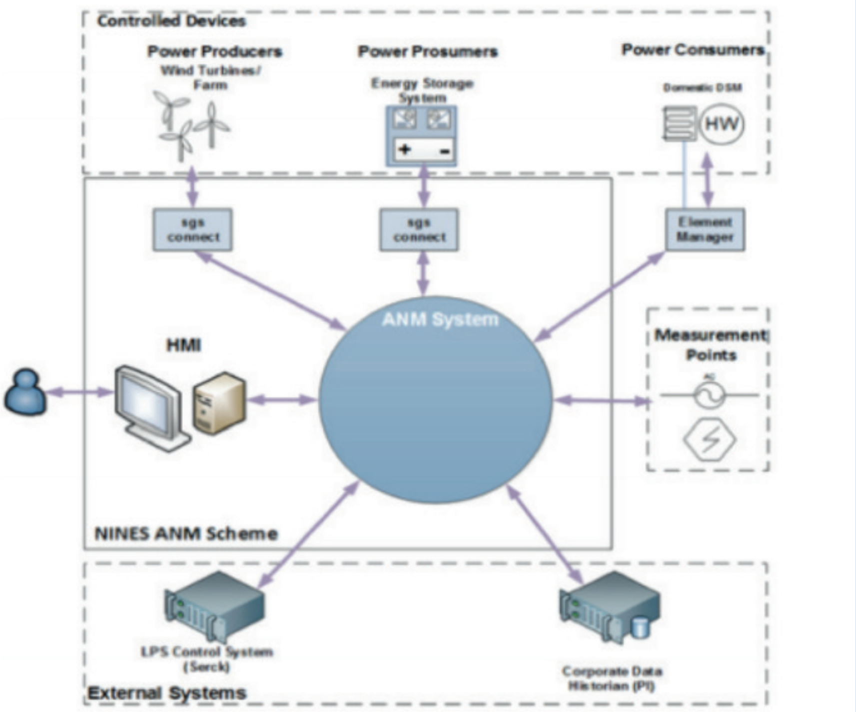


Figure 4. NINES ANM with DSM components and communications at top right.

33 http://www.openenergi.com/our-customers/tarmac/

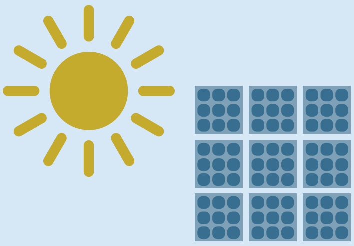
34 http://www.ninessmartgrid.co.uk/our-trials/demand-side-management/components-of-domestic-demand-side-management/

CASE STUDY 3

Residential Storage

Moixa Smart battery connects a home battery to the building's PV unit to capture output during the day when output is high and, typically, demand low and releases the power in the evening when demand is high[35]. The system can also use lower cost Economy 7 night rate power to charge the battery, making this power available during the more expensive day rate period. Moixa also offer customers the option of joining their GridShare service which allows Moixa to trade the battery capacity with income from the scheme being shared with customers.

There are two ways to charge your Moixa Battery with guaranteed savings



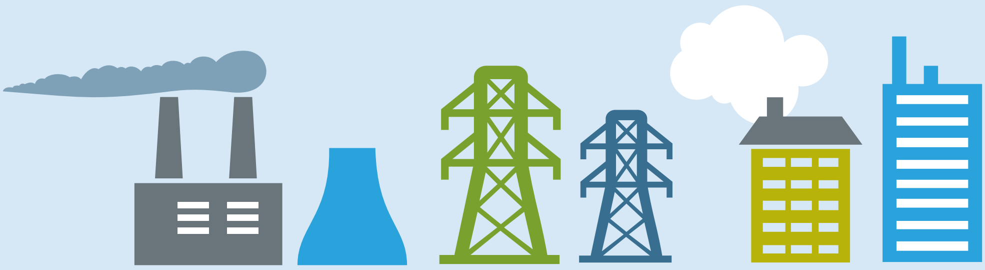
Solar Power Storage
Your solar panels will work throughout the day to power your home. Any excess energy will go to charge your Moxia Smart Battery, waiting to be used for free at night.

Economy 7 charging
The Moxia Smart Battery can charge during the day from spare solar, but also overnight. If you have a time-of-use tariff such as Economy 7. This gives you cheap electricity to use the next day.

CASE STUDY 4

Commercial Flexibility and Trading

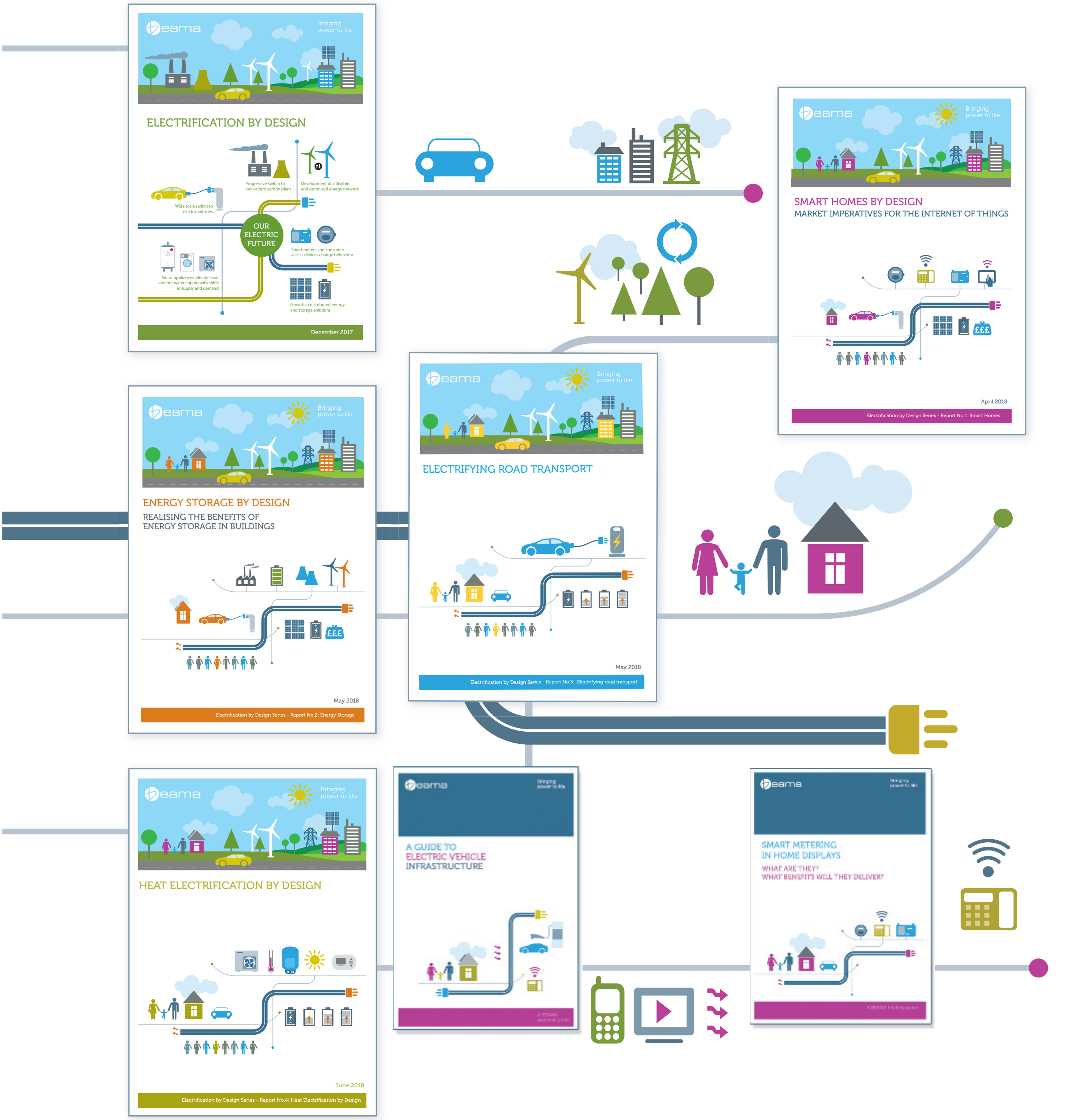
UK Power Networks has initiated a project with Open Utility to trial a new trading platform[36]. Open Utility is providing its 'Piclo' platform to enable local trading between generators, consumers and energy suppliers.



35 https://www.moixa.com/solar-battery/features-benefits/

36 UK Power Networks and Open Utility to trial new energy trading platform, Open Utility, 16th January 2018

For further reading on the subject of electrification, visit **www.beama.org.uk** and download one of our associated publications



Rotherwick House
3 Thomas More Street
St Katharine's and Wapping
London E1W 1YZ

www.beama.org.uk

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