The future of flexibility

How local energy markets can support the UK's net zero energy challenge

European Union
European Regional Development Fund

centrica

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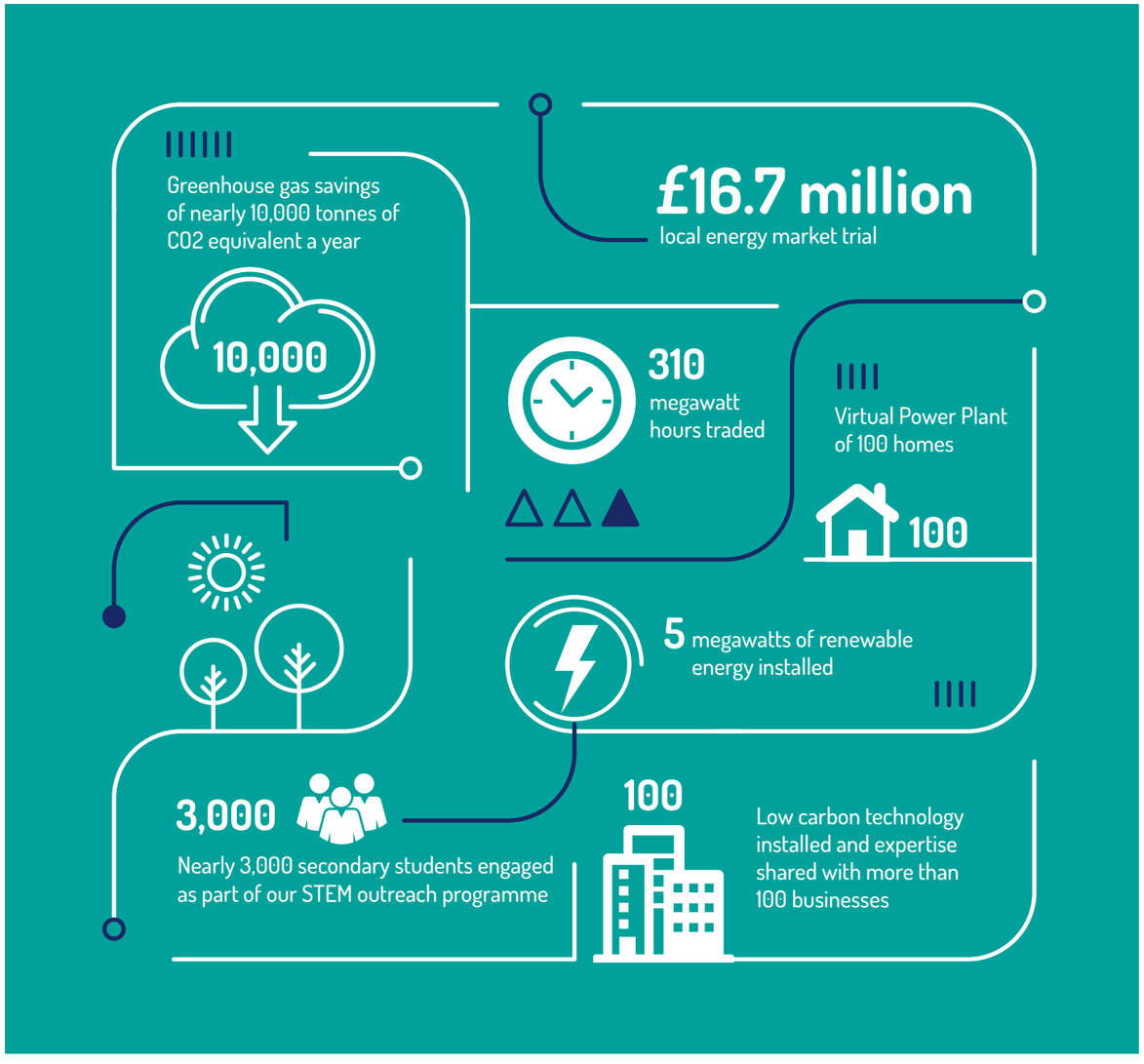


Executive Summary

In 2019, we achieved a world first. We enabled a distribution network operator and the National Grid Electricity System Operator (ESO) to buy flexibility simultaneously and in a coordinated fashion via a single third-party platform. It was all made possible by our ground-breaking Local Energy Market (LEM) trial in Cornwall.

Flexibility trading doesn't sound very exciting. In simple terms, it means paying businesses and homes to increase, decrease or shift the times that they use or produce power in response to the needs of the grid. But it is fundamental to creating a more efficient, lower carbon energy system and meeting the Government's legal obligation to achieve a net zero economy by 2050.

Flexibility is the answer to an important challenge, posed by our need to increase renewable sources of power generation as we decarbonise our world.

Because solar and wind are dependent on the weather, sometimes they produce too much power for the grid to accommodate and sometimes too little to meet demand. If not managed, this could lead to assets being switched off, which is expensive and inefficient; consumers experiencing power cuts; and expensive network upgrades to accommodate the increase in renewable generation.

Flexibility offers an alternative, more cost-effective way of tackling these constraints. It also gives consumers a real stake in managing the energy system.

Centrica has always supported the principle of flexibility and the introduction of an independent flexibility market to ensure fairness and transparency to customers who pay for the system. At a national level, the system is managed using flexible demand, battery storage and flexible generation, however, it is becoming increasingly important to manage network constraints at a local level too.

That's why three years ago we launched a trial in Cornwall – which already has a lot of renewable power and where connecting new generation to the network is a challenge – to see if we could create a market-based platform for flexibility and show how it might help to manage the network.

We Installed a range of smart, low-carbon energy technologies (including monitoring equipment, battery systems, solar panels, combined heat and power, and a wind turbine) in homes and businesses across the county. But the centrepiece was Centrica's pioneering auction-based marketplace, an online platform for trading flexibility, aimed at reducing constraints on the network. This virtual market place allowed the national system operator and the local network operator to buy flexibility simultaneously for the first time.

In designing the platform we were trying to create a tool that not only benefited the network and system operators, but also delivered the cheapest solution for energy bill payers, a key deliverable to increase participation. We wanted to show that homes and small businesses can play a role alongside larger industry. And we wanted to show that market-based procurement of flexibility gives us a genuine new tool in our low-carbon energy system toolbox.

The good news is that we did it and it works! We showed that solutions like the Cornwall LEM can pave the way for a smarter grid that is better able to accommodate renewable energy, reduce carbon emissions, and create new ways of making money from flexible energy resources. The LEM trial demonstrates that technical solutions do exist which can unlock and coordinate local energy flexibility services to support the local grid and help manage the national system. We would like to see the LEM (or similar technology) used across the UK and beyond to ensure the establishment of local flexibility markets that are open, transparent and foster competition on a level playing field. Ultimately, with the right policy actions by the Government, we believe that the UK can lead the world in creating solutions to integrate greater levels of renewables onto our energy systems, helping us all to secure the low carbon energy future we desire.

About the Local Energy Market

This was a three-year, £16.7 million project in Cornwall to test the role of flexible demand, generation and storage via a new virtual marketplace, supported by the installation of new technology in nearly 200 homes and businesses.

The trial was delivered in partnership with the local distribution network operator (DNO) Western Power Distribution, alongside National Grid ESO, Exeter University and Imperial College London, with additional support from the Belgian-based advanced energy analytics consultancy N-Side. It was funded by Centrica and the Centrica Energy for Tomorrow Fund, as well as a £11.6 million grant from the European Regional Development Fund.

The aim was to develop and test a market-based solution for energy flexibility trading at the local level, as part of national and global efforts to increase the penetration of renewable energy within our energy system. We chose Cornwall because it is already experiencing the challenges of managing a distribution network with high levels of renewable energy.

The LEM was a complex programme, split into four distinct projects – residential, businesses, software platform development, and a research project with Exeter University and Imperial College London – each with a project manager and a dedicated team.

In 2018 we began installing solar panels, smart batteries and monitoring equipment in 100 homes in Cornwall, enabling them to act as a 'Virtual Power Plant' (VPP), the largest of its kind in the UK. The energy they produced was aggregated and controlled remotely to provide a single, flexible block of power to the local and national grid.

We also installed or facilitated a range of technologies including combined heat and power (CHP), solar, wind, storage batteries and device-level energy monitoring in 87 local businesses. We conducted energy surveys and provided training with the aim of helping a further 26 businesses to unlock opportunities that reduced their energy costs.

We created an online virtual energy marketplace with our partners N-Side, Western Power Distribution and National Grid ESO. This allowed homes and businesses to adjust their energy demand or generation in response to the needs of the grid and receive payment for this service.

Our business team helped to deliver Cornwall's first, smart grid-connected wind turbine, and a 1.5-megawatt lithium ion storage battery in partnership with Cornwall Council. We also enabled a new 2.5-megawatt 'smart' solar farm, capable of powering up to 500 homes, built on a disused mica tip, and we installed energy monitoring equipment in businesses across the county.

Through our research project with Exeter University, we gained valuable insight and data from our customers about their experience and opinion of the trial, their understanding of energy flexibility and trading, and the value of energy monitoring for businesses. Our partnership with Imperial College allowed us to dig into the business case for flexibility and explore how the UK energy market needs to evolve to support LEMs.

2017

SPRING
Cornwall LEM trial launched; participants invited to register interest

SPRING
Market platform software development begins

AUTUMN
Energy storage machines installed at The Olde House holiday cottages

2018

SPRING
CHP units installed at Carbis Bay Hotel

SPRING
Energy monitoring equipment installed at Goonhilly Earth Station

JUNE
Market platform comes online

Residential

What we did

One hundred homes across the county had smart batteries and monitoring equipment installed, as well as solar panels where these were not already in place (54 homes). Powered by the solar panels, the energy in these batteries was aggregated and controlled remotely to provide a single block of power and flexibility to the local grid and national system, making it one of the most advanced examples of a domestic Virtual Power Plant in the UK.

Through the same VPP we also successfully deployed 75 of the batteries into the national Dynamic Firm Frequency Response market. DFFR uses fast responding assets, such as batteries, to respond to changes in frequency on the network. The entire power network operates at a frequency of 50 Hertz, which is determined by the number of directional changes alternating current (AC) electricity makes every second. However, just a 1% deviation from this begins to damage equipment and infrastructure, so it is vital that it remains consistent.

Through our domestic VPP, we were able to help to keep the grid within safe operating limits. Our network of decentralised home energy storage systems was approved by the National Grid ESO for its DFFR service, allowing the batteries to demonstrate another way in which smart energy devices can support an efficient, low-carbon electricity system.

Key Learnings

- Householders can play an important part in managing the local electricity network and balancing the national system. This can be achieved by using software (VPP) to link together smart devices, such as domestic batteries and electric vehicles. It is no longer just a role for large energy generators and big industry
- Smart systems, such as batteries coupled with solar photovoltaic (PV) panels, can reduce the amount of energy that households draw from the grid at peak times. This is more efficient than building oversized systems which are only fully utilised during short periods of high demand
- Households with smart systems don't need to do anything complicated to participate in LEMs. They can simply trade the energy that they aren't using themselves (this can be automated through an agent running a VPP) meaning they are neither impacted nor inconvenienced

Key stats:

100 homes in the VPP/ trading on the LEM

185 kW solar PV

617 kWh batteries

901 tC02e saved per year

CASE STUDY

Turning homes into power stations

Retired law lecturer David Corns and his wife Anna live in a converted farmhouse on Bodmin Moor, an hour's drive from the city of Truro. They are environmentally conscious, with two solar arrays already installed on their property, and so were keen to join the LEM when the opportunity arose.

In 2018, Centrica installed a 7.5-kilowatt battery system – supplied by the specialist firm sonnen – which charged from the solar arrays and was linked to the LEM platform via the internet. The batteries were set automatically to maximise the property's consumption of electricity generated by the solar panels, with the excess then traded as part of a Virtual Power Plant along with the other homes in the trial.

"I was really chuffed to take part in a proof of concept project like this," said David. "Every new house should have solar panels or Tesla tiles, or better still, a battery like this one, as that would go a long way towards helping out."

David and Anna also have an electric car, so they hope that in future this can all be combined in a totally integrated home and vehicle energy management system.

The energy bill savings of participants in the LEM trial varied depending on factors such as the size of the equipment and the household's energy use. The average saving was £357 a year. But the true value of the system to householders will only be realised once local energy markets become widely adopted.

2019

SUMMER
First residential installations

WINTER
Free energy training for Cornish businesses

WINTER
2.5 MW smart solar farm completed at Lower Ninestones

SPRING
Residential installations completed

SUMMER
Full flexibility trading on market platform goes live with DNO

AUTUMN
ESO trading introduced on the market platform

Businesses

What we did

We installed a wide range of technologies including CHP, battery storage, renewables and demand-side response in a variety of different businesses. We provided grants to 81 businesses to install device-level energy monitoring kit on their premises to help them identify and realise energy and emissions savings.

We also linked local businesses up to the LEM platform, so that they could interact directly with the network operators to vary their power use in a way that would help to manage the grid and get paid for it.

We provided surveys and training for businesses looking to improve their energy efficiency and learn about LEMs. Collectively, our business participants saved nearly 9,000 tonnes of greenhouse gas emissions each year[1]— savings which will continue.

Key Learnings

- Businesses, including those that have never traded flexibility before, can use technology like the LEM platform to make money and help improve the environmental and financial sustainability of our electricity system
- Energy insights alone can help businesses save money and greenhouse gas emissions
- Some of the ways in which distribution network connections are managed at present create barriers to flexibility solutions that can help to support the network
- Using flexibility instead of more traditional measures to manage grid constraint depends on the confidence of buyers that they will be able to procure the service they need. To provide the market liquidity which underpins this confidence, we need to remove the cost and complexity barriers (such as grid connections, metering and monitoring and control systems) which currently prevent businesses from unlocking the cost-saving potential of flexibility
- The technology that enables flexibility services will help to decarbonise our energy system. Building on work done by Imperial College London and the Carbon Trust, we have developed a methodology for attributing greenhouse gas emission savings to these services

1 Using the year in which the LEM programme started as our baseline.

Key stats:

2.62 MW / 3.61 MWh battery energy storage systems

2.3 MW wind

2.466 MW solar PV

70 kW CHP

81 businesses with energy monitoring equipment

113 business participated in the programme

8,781 tCO2e saved each year by our business participants

CASE STUDY

Unleashing the potential of battery technology

We wanted to demonstrate the role that battery storage can play as part of the LEM and show how flexible assets can help to manage the grid. So we installed a 1.5 megawatt lithium ion battery at Wave Hub, a business set up on the north coast of Cornwall to develop and operate wave and floating wind energy. The Wave Hub site is the world's largest and most technologically advanced open access site for the testing and development of offshore renewable power.

The battery is connected to one of the most highly constrained areas of the network in Cornwall. Initially, it will take and store power from the grid and use it to provide grid balancing services when required. This will create a lasting revenue source for Wave Hub and enable savings of around 1,400 tonnes of greenhouse gas emissions each year.

Over the longer term, the battery may support the interaction of new generation (wave power and floating wind turbines) with the local and national grid.

2020

OCT
STEM outreach programme begins

SUMMER
2.3MW wind turbine completed

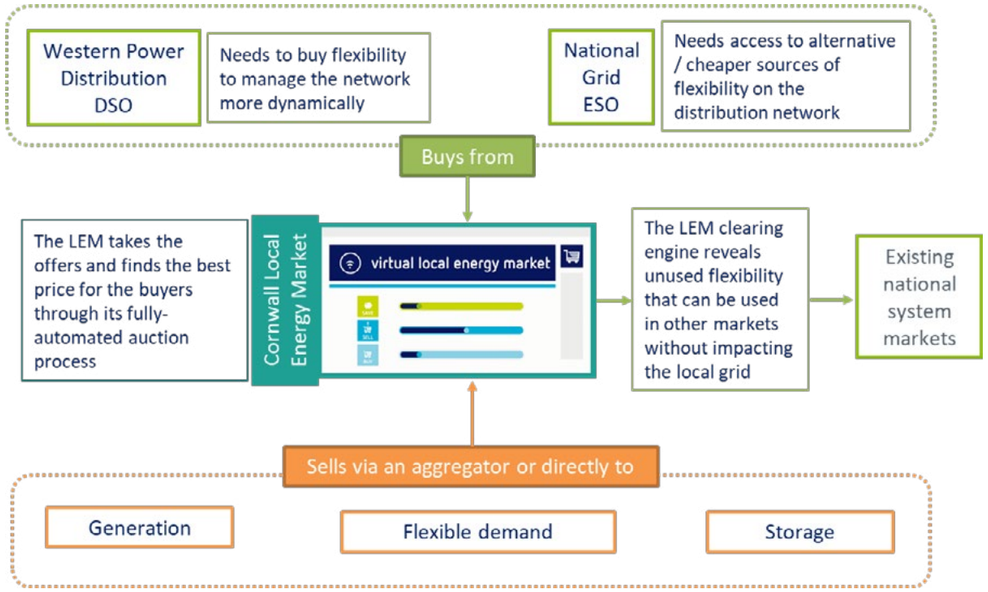
AUTUMN
Wave Hub battery completed

WINTER
Battery at Carland Cross Wind Farm complete

WINTER
Cornwall LEM trial concludes

How the virtual marketplace works

The virtual local energy market created in Cornwall is a global first. It offers a tool for network operators to buy flexibility from energy producers and consumers, including households and businesses, in an open, competitive but coordinated way. The computer technology that allows this to happen is very sophisticated. But using the virtual marketplace is easy. Trades are managed automatically to maximise energy savings and efficiency. The diagram below shows how it works.



When there are many flexibility providers and various technology types, the selection of offers can become very complex. To enable close-to-real-time trading of flexibility on a large scale, a robust automated decision-making engine is needed. So, as part of the LEM platform, we developed a set of algorithms which clear each auction with the best-cost solution, while also considering the capabilities of the technologies involved and the grid.

The LEM platform provides an independent and neutral solution to the challenge of coordinating multiple buyers in a way which protects the distribution network (it doesn't allow actions that lead to further congestion). It can also validate surplus flexibility before it is offered to existing national markets, again helping to prevent unintended congestion on the network. The LEM platform is technology agnostic. The market treats each unit of flexibility equally, irrespective of the technology used to produce it.

In designing the platform, we and our partners set out to create a solution that could be deployed at scale across a range of locations and scenarios. As a result, our virtual marketplace model not only addresses the issue of local constraints in Cornwall but provides a template which is applicable across national and international energy markets.

Key learnings

- DNOs can use a 'flexibility first' approach in managing constraints on the network, rather than shutting off renewable assets
- By creating a marketplace where the DNOs and the ESO procure flexibility simultaneously, it is possible to coordinate procurement and ensure that contracts at the national level do not jeopardise the local network and lead to power cuts
- Managing this process independently of the DNOs ensures that it is both transparent and neutral; and that network-based solutions are not being favoured over flexibility services
- By automating the decision making and the selection of available flexibility, we can enable close-to-real-time flexibility trading, allowing renewables and a wider range of technologies to participate
- Further regulation is required to define how local markets will interact with existing wholesale and national markets

Key stats

381 bids from network and system operator buyers

107 offers from flexibility service providers

89 contracts made

210 MWh reserve contracted

99 MWh utilisation contracted

CASE STUDY

How to freeze your energy bills

Dan Tonkin is the perfect embodiment of how the virtual marketplace works and the new benefits it can bring to customers. His freezing machine makes the ice for the fishing fleet that operates out of Newlyn Harbour. Without it, the fish caught each day would not be in a fit condition to sell to local supermarkets, restaurants and at the local market.

Dan's ice plant uses power equivalent to the demand from 300 homes when running at full capacity and can be switched on or off at any time. By trading that flexibility on the LEM platform, he was able to get paid for using or reducing power at certain times to help alleviate strain on the grid.

Dan saved a lot of money – by his calculations between 30% and 35% of his energy costs – by taking part in the trial. In doing so, he also demonstrated the role that smaller, local businesses can play in creating a more dynamic, efficient energy network – one that is fit to accommodate more renewable energy and help reduce carbon emissions.

Dan explained how the LEM benefitted him:

"The LEM platform alerts me when load is needed on the system. For example, they'll say that tomorrow they need two hours of me running at 100 per cent which means I almost make ice for free - you can imagine the savings. Sometimes they've needed up to eight hours in a week, which is enough for 32 tonnes of ice for little or no money! It really takes the stress out of what's going in and what's going out. I was pretty sceptical at first, but it's very transparent. You can look for yourself, I have half-hourly data – that alone is a great tool. Because we're a not-for-profit, everything we can do to build the portfolio up to look green, it all ticks big boxes for fishing right now. Anything we can do to get funding is phenomenal - it means I stay trading, which is what I want to do more than anything."

(Speaking to Network Magazine, May 2020)

The business case for UK plc

Various studies have tried to quantify the benefits of deploying more flexible resources, something which is paramount in supporting a sustainable energy future.

The Carbon Trust and Imperial College London estimated the net benefits of utilising flexibility (compared to current network operation strategies) to be in the range of £1.4 – 2.4 billion a year by 2030. A Committee on Climate Change study found the gross benefits to be £3 – 3.8 billion a year over the same period, while a study by the National Infrastructure Commission (NIC) stated that gross benefits could range from £2.9 – £8.1 billion a year.

The NIC study used a target grid carbon intensity of 50 grams of CO2 equivalent per kilowatt hour to produce the high end of its range; a target of 100g CO_{2e}/kWh was used in the other studies.

The LEM trial demonstrates that technical solutions do exist which can unlock and coordinate local energy flexibility services to support the local grid and help manage the national system. It also shows that an independent market platform can be used to ensure that flexibility made available to the ESO does not violate any distribution network limits, whilst ensuring optimal allocation of distribution network capacity for ESO flexibility.

With these tools the distribution network can be managed more dynamically, i.e. in a smarter way. This will enable more renewable assets on the system and reduce the need for curtailing generation and reinforcing the network.

However, to achieve this we need a significant improvement in the data available from the DNOs, particularly relating to congestion and constraint forecasting; network topology changes; the power-flow relationship between grid-nodes; and customer-to-network mapping.

Regulatory guidance is needed now on how the DNOs should assess, procure, dispatch and baseline flexibility. To allow local flexibility markets to become larger, the question of how they interact and coordinate with existing national and wholesale markets will become more important. Independence and neutrality are critical elements. This too will require regulatory guidance.

Transparent, liquid local flexibility markets are key to achieving net zero and DNOs should be encouraged to move away from long-term capacity contracts towards short-term procurement. This will allow a wider range of flexibility providers to participate, including renewables and intermittent generation; demand side response; and, in the future, electric vehicles and domestic heating technologies. By increasing the range of participants and reducing the dependence on long-term capacity contracts with low utilisation rates, short-term flexibility procurement can provide savings to the end consumer.

In particular, as we see greater penetration of electric vehicles, tools like the virtual marketplace — which allow decisions to be made in close-to-real time — will be critical in enabling the vehicle charging infrastructure to access the full range of network and system service markets. As well as increasing the demand for electricity, the batteries in EVs can play a role in helping to manage the network by storing and discharging power when the grid needs it. Without such technologies, these opportunities are likely to be limited in constrained areas of the network.

While it will not always be the most appropriate solution, there is no reason why DNOs should not use market-based flexibility services, like the LEM platform, to make flexibility their first resort in managing constraints and offering new connections to the network.

Inspiring the next generation

Alongside the LEM, we ran an outreach programme to engage secondary school children in the STEM (Science, Technology, Engineering, Mathematics) concepts behind our transition to a zero-carbon economy.

To facilitate this programme we designed and built an interactive, physical model of a net zero energy system using water as a proxy for electricity, with pumps and valves simulating the interactions between generation and demand. This model enabled us to deliver interactive lessons and demonstrations of how a zero-carbon energy system would work in practice.

The LEM draws upon all the core STEM subjects taught at Key Stages 3 and 4 in a way which reflects everyday life (reliable supply of electricity) and it also links to the defining challenge of our time (the climate emergency).

The intended learning outcomes (ILOs) for the students included the ability to understand and explain the greenhouse gas effect; the delivery systems for gas and electricity; renewable power generation; and concepts and challenges related to the management of the electricity network.

The workshops began in October 2019 and were intended to run until December of this year but had to be curtailed in March due to the Covid-19 lockdown. Despite this, the programme was very well taken up and we managed to engage with nearly 3,000 students, meeting our target set at the start of the programme.

Customer experience

Our partners at Exeter University conducted in-depth research to monitor the experience of the customers who participated in our trial and gauge their feedback.

Householder Survey Report

91 households were surveyed about their involvement in the trial. Overall, householders were thankful for their free equipment and for the opportunity to take part. They valued their contribution towards research and hoped that by being involved in the trial that they could help to prove that the LEM concept worked and could be rolled out to a wider audience. They also valued the opportunity to trial the equipment and to see what the personal impacts were on them as individual households in terms of behaviour changes, reduction in bills and greater energy awareness.

Most of the householders expressed a need for much more information and trusted advice about what future grid services might look like and what part they could play. They also thought that there needed to be much more communication with the wider public on what the future energy system might look like in response to addressing climate change and realising the UK's net zero ambitions by 2050.

Business Report

In 2019, Exeter University undertook a survey of the Cornish businesses and organisations which had participated in the LEM project.

23 organisations who had generating assets and monitoring equipment installed were asked about the impact on their organisation's energy usage or behaviours. Nearly half (11) stated that there had been a positive impact; three said there hadn't; and nine thought that it was too early to tell. Those who experienced a positive impact cited cost control and greater understanding of their own energy use as the main benefits:

"We are now able to generate almost as much electricity annually as we use."

"Understanding our energy consumption at an individual equipment level has allowed us to understand the impact of efficient use of each asset and the true costs."

"The amazing capability of these sensors to monitor individual circuits in the building, these little wireless sensors that they've got, that's all very impressive and tick box for that (sic)."

"One thing we were always struggling for was information on what buildings were actually billing, let alone what bits of their buildings were billing. So, this technology is just a transformation, the potential for it is enormous."

28 organisations were asked about the LEM concept, separately from their own experience of it. The overwhelming majority (23) thought that it was a good idea and five were neutral. No one thought that the concept was a bad idea. Local control of energy was perceived as a major positive:

"We are facing difficult and unsteady times so I think that anything we can do to come together as local markets and business groups is essential in order to continue being sustainable businesses both environmentally and financially."

"Local production and use of electricity are self-evidently better for the planet than relying on central generation from fossil fuels."

"It overcomes the shortcomings of the grid in accommodating embedded generation and provides local control, participation, ownership and incentive for everyone involved."

"Like the idea of generating, storing and using it locally. Less reliant on national generators."

"It's flexible, you choose what you put in!"

Actions

The Cornwall LEM trial has demonstrated that local flexibility trading works and can be coordinated with the national system. But if we do not build on the momentum created by the trial, we will lose an important advantage in our efforts to achieve net zero carbon by 2050. Here are the key actions which we believe the Government, the industry and the regulator can take to encourage flexibility and help create a lower carbon energy system:

- **Use the Energy White Paper to promote grid flexibility**
  The upcoming Energy White Paper is an ideal opportunity for the Government to identify grid flexibility as a vital component in the transition to an electrified future and set a policy objective for the deployment of flexibility at a local and national level to meet net zero at least cost to consumers.
- **Introduce flexibility markets to the energy system by 2023**
  We need more renewables on the system to replace fossil-fuel generation and meet increased demand from electric heating and vehicles. But this will create problems in balancing demand and supply. Flexibility is the key to managing these fluctuations at a local and national level. Our trial has demonstrated the viability of a platform-based model which coordinates local and national system operator buyers. We believe that local flexibility markets are needed by 2023 and we would encourage the Government to legislate for this.
- **Coordinate action between the Government, the regulator and the energy industry**
  We would like to see this report serve as a rallying cry to the industry to adopt independent local flexibility markets, and to the Government and Ofgem to ensure that LEMs are well established before the next funding settlement for distribution network operators in 2023.
- **Adopt a 'flexibility first' approach**
  We would encourage the Government, the regulator and distribution network operators to recognise that Active Network Management (ANM) can have an adverse impact on flexibility markets and commit to using market-based flexibility services as a first re-sort.
- **Move flexibility procurement closer to real time**
  It would be very helpful if DNOs would adopt flexibility market solutions that include close-to-real-time products (e.g. day-ahead trading). This would enable participation by the widest possible range of flexibility providers.
- **Flexibility markets should be independent**
  For flexibility trading to work properly, providers must be confident that procurement by DNOs is objective and that network-based solutions are not being favoured over flexibility services. We think the best way to ensure this is to create flexibility markets which are independent and will provide services to both the DNOs and the ESO.

The LEM trial has achieved widespread industry recognition. It was named the best 'Clean Energy Scheme' at the 2019 Regen Green Energy Awards, following wins at the Renewable Energy Association Awards (Smart Energy System), BusinessGreen Leaders Awards (Innovation of the Year) and the Solar and Storage Awards (Smart Energy Award). The LEM also helped Centrica to pick up the award for best large supplier at the 2019 GSK Environmental Sustainability Awards.

The Cornwall Local Energy Market Project is funded by Centrica (Centrica Business Solutions and the Centrica Energy for Tomorrow Fund), alongside the European Regional Development Fund (under the European Structural and Investment Funds Programme 2014-20) and the University of Exeter.

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