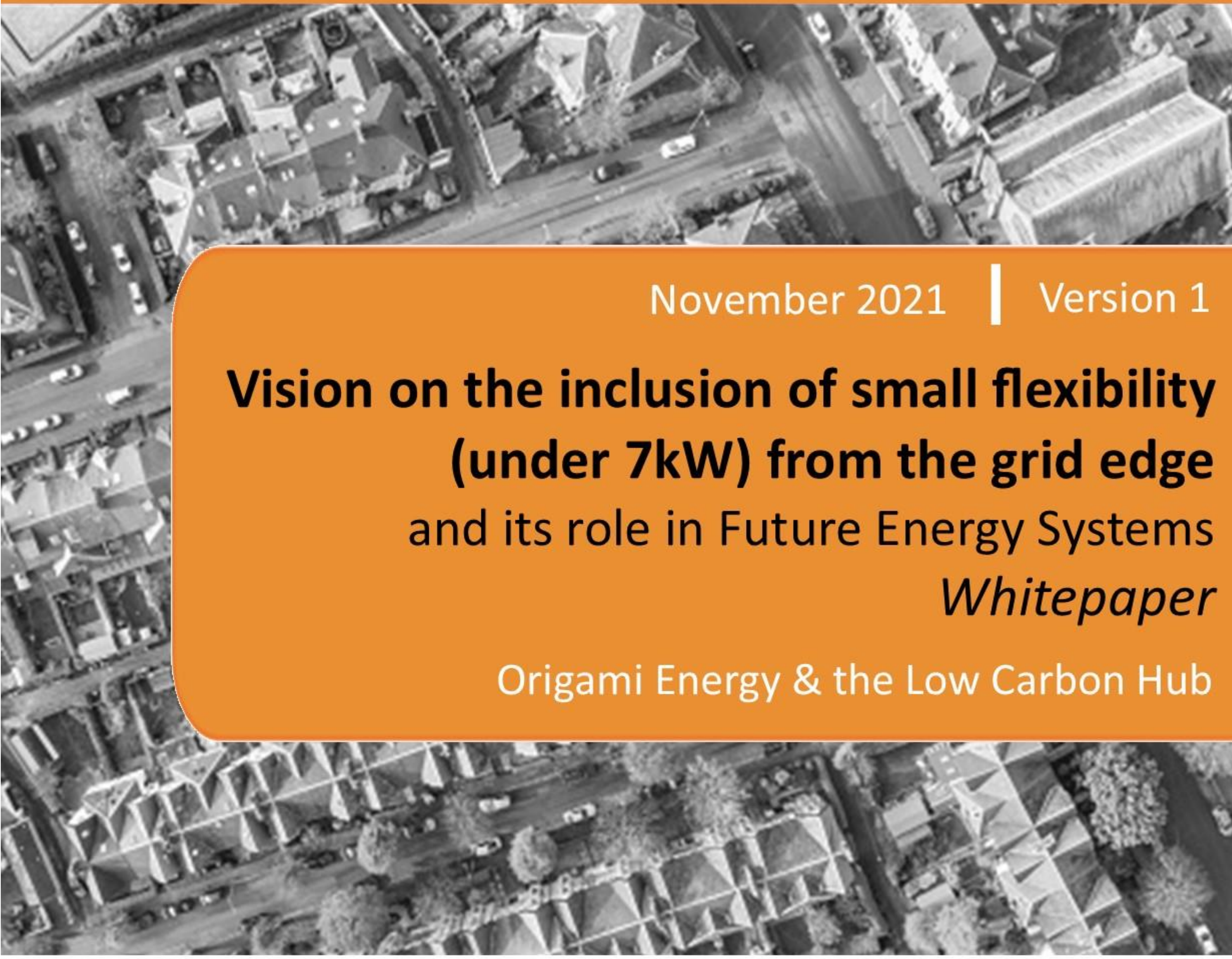
Local Energy Oxfordshire



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Vision on the inclusion of small flexibility (under 7kW) from the grid edge

and its role in Future Energy Systems

Whitepaper

Origami Energy & the Low Carbon Hub

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Context

The UK Government has legislated to reduce its carbon emissions to Net Zero by 2050. Meeting this target will require significant decarbonisation and an increased demand upon the electricity network. Traditionally, an increase in demand on the network would require network reinforcement. However, technology and the ability to balance demand on the system at different periods provides opportunities for new markets to be created, and new demand to be accommodated through a smarter, secure and more flexible network.

The future energy market offers the opportunity to create a decentralised energy system, supporting local renewable energy sources, and new markets that everyone can benefit from through providing flexibility services. To accommodate this change, Distribution Network Operators (DNOs) are changing to become Distribution System Operators (DSOs)

Project Local Energy Oxfordshire (LEO) is an important step in understanding how new markets can work and improving customer engagement. Project LEO is part funded via the Industrial Strategy Challenge Fund (ISCF) who set up a fund in 2018 of £102.5m for UK industry and research to develop systems that can support the global move to renewable energy called: Prospering from the Energy Revolution (PFER).

Project LEO is one of the most ambitious, wide-ranging, innovative, and holistic smart grid trials ever conducted in the UK. LEO will improve our understanding of how opportunities can be maximised and unlocked from the transition to a smarter, flexible electricity system and how households, businesses and communities can realise the benefits. The increase in small-scale renewables and low-carbon technologies is creating opportunities for consumers to generate and sell electricity, store electricity using batteries, and even for electric vehicles (EVs) to alleviate demand on the electricity system. To ensure the benefits of this are realised, Distribution Network Operators (DNO) like Scottish and Southern Electricity Networks (SSEN) are becoming Distribution System Operators (DSO).

Project LEO seeks to create the conditions that replicate the electricity system of the future to better understand these relationships and grow an evidence base that can inform how we manage the transition to a smarter electricity system. It will inform how DSOs function in the future, show how markets can be unlocked and supported, create new investment models for community engagement, and support the development of a skilled community positioned to thrive and benefit from a smarter, responsive and flexible electricity network.

Project LEO brings together an exceptional group of stakeholders as Partners to deliver a common goal of creating a sustainable local energy system. This partnership represents the entire energy value chain in a compact and focused consortium and is further enhanced through global leading energy systems research brought by the University of Oxford and Oxford Brookes University consolidating multiple data sources and analysis tools to deliver a model for future local energy system mapping across all energy vectors.

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Future energy system and small flexibility

As the UK focusses more on achieving its Net Zero targets, electrification of local and national infrastructures will bring many challenges and opportunities in all aspects of the energy system – societal, commercial, technical, and regulatory. The Future Energy Scenarios published by the Electricity System Operator (ESO) in 2021 (FES 2021) outlines three possible future scenarios that ensure that GB meets the goal of Net Zero by 2050. These scenarios present fundamental choices that go beyond the technical infrastructure of the energy system and require careful consideration of the structure of the marketplace to meet the new energy trilemma: reliable, environmentally sustainable and equitable.

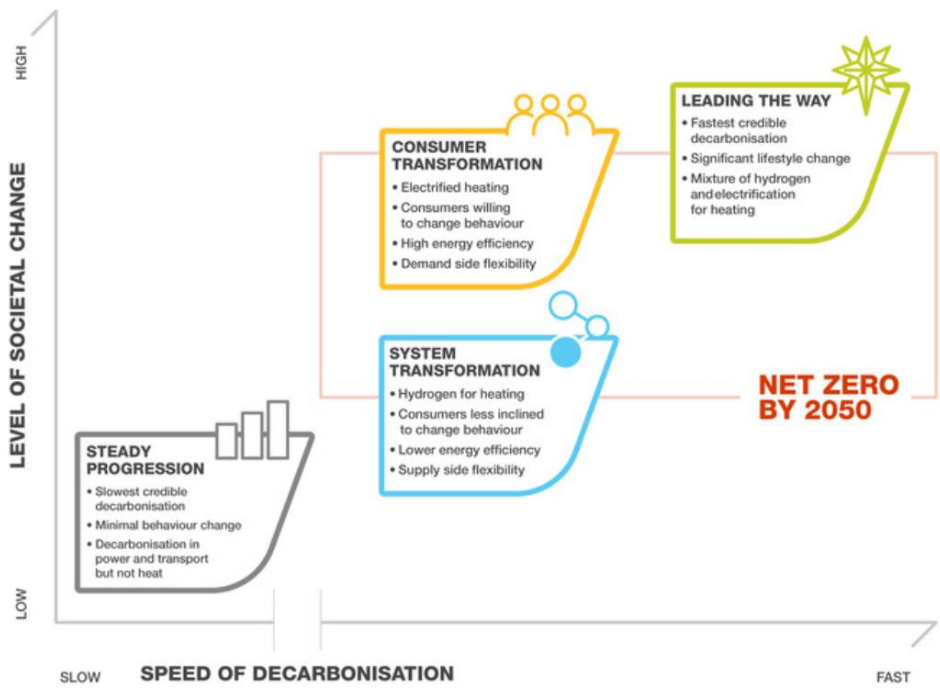

Figure 1 : National Grid Future Energy Scenarios [1]

Delivering Net Zero will require a transformation in the scale of active participation at the local level using flexibility within the low voltage network from end users: the grid edge. This will create opportunities to realise the (currently dormant) potential of millions of Distributed Energy Resources (DERs)[2] in Small and Medium-sized Enterprises (SME), public organisations and domestic premises to support the flexibility needs of the marketplace. These opportunities and needs for flexibility will, in turn, support the significant growth of low carbon technologies (LCTs) and help deliver electrification

[1] *FES 2021 Report, published by National Grid ESO, July 2021*

[2] *DER can be a device, appliance, or a unit capable of generating or storing energy or flexibility from energy consumption or generation.*

of major infrastructures and higher penetration of renewable generation. Despite the electrification of heat and transport potentially increasing annual electricity demand by over 50% (153 TWh) in 2050 compared to 2020 levels, both provide opportunities for smarter system operation using flexibility. For example, by 2025 the "Leading the Way" scenario envisage as many as 2.6 million homes will have thermal storage and heat pumps. As uptake continues to grow through to 2050 and combine with heat networks, residential heat is expected to deliver 12GW of flexibility. Electrification of transport also offers an opportunity to create flexibility[3] from smart charging of Electric Vehicles (EVs) with the potential to achieve over 55 GW of flexibility by 2050 under the "Leading the Way" scenario from Vehicle-to-Grid, Vehicle-to-Home or Vehicle-to-Building.

In order for these small-scale flexible DERs to participate in the flexibility markets and deliver a meaningful contribution, a number of challenges must be resolved. This paper explores how the technical, regulatory, commercial and societal challenges faced by these DERs could be addressed to support the delivery of the Net Zero targets. Figure 2 shows these four challenges in the order of their significance in 2021, with the biggest challenge being the Social aspect of flexibility, addressing issues of fairness and energy equity with Technical challenges being the least significant. The approach applied in this paper is to look back from 2050 at how these challenges were addressed to enable DERs with small level of flexibility to contribute to achieving Net Zero on a sustainable and reliable basis.

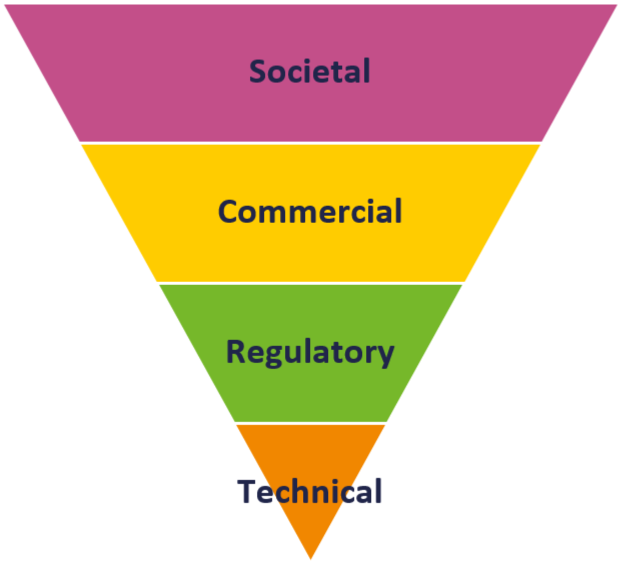

Figure 2: Pyramid of challenges and opportunities in achieving Net Zero

[3] Here flexibility is defined as changing the normal generation and/or consumption pattern of a Distributed Energy Resource (DER) in reaction to an instruction to deliver a Flexibility Service, external price signals or local needs.

Technical Challenges

The myriad of DERs with a small level of flexibility[4] presents technical challenges for the flexibility market and for the operators of the distribution network and national electricity system. In a world where flexibility is commoditised and each flexibility provider is rewarded for their contribution to managing the systems as a formal Flexibility Service, each flexible DER would need to pass three hurdles:

1. be controllable whether a simple state change or incremental changes;
2. prove it can deliver the requested flexibility reliably and safely without adversely affecting other market actors or the electricity system or network; and
3. prove the flexibility has been delivered (e.g., through dedicated metering and monitoring or state-based assumed delivery).

By the 2040s the majority of households are highly energy efficient with over 80% having smart appliances that have prevalence throughout all socio-economic groups and are no longer the preserve of early adopters or affluent households[5]. Manufacturers have embraced Internet of Things (IoT) technology (see Figure 3) and incorporated connectivity into appliances using industry-standard solutions[6] for coordination and automation, monitoring their energy use and the ability to deliver flexibility in response to price signals or market services.

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[4] In the context of this paper, by small level of flexibility and small flexibility we mean flexibility from appliances and energy resources in households, with capacity below 7kW, with a limited duration of response (e.g. 30 minutes) or with poor availability to deliver flexibility.

[5] FES 2021 Report, published by National Grid ESO, July 2021

[6] In 2021, British Standards Institute as part of Smart Energy Appliance programme (https://www.bsigroup.com/en-GB/about-bsi/uk-national-standards-body/about-standards/Innovation/energy-smart-appliances-programme/) published two standards designed to support testing and certification programme to motivate greater potential for demand response from residential sector.

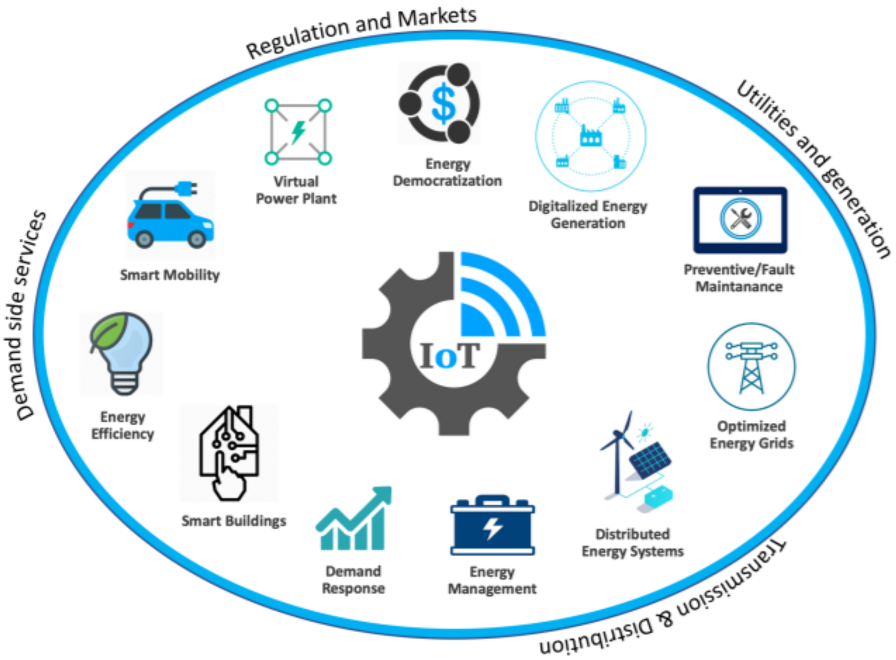

Figure 3: Aspects of the energy system and its building blocks that can be enhanced and delivered by IoT[7]

This approach will make these households truly Smart Homes! This provides real benefits for householders by automatically reducing consumption at expensive periods whilst being rewarded for the use of their flexibility, resulting in lower overall energy costs.

In the future, the Smart Home will optimise when a smart appliance (e.g. dishwasher, washing machine or tumble drier) is used within an agreed period (provided it has completed its function by the end of the period). This optimisation will allow the flexibility to be used to respond to local or market needs or to price signals, delivering benefit to the household, the community, the distribution network and the national system whilst providing benefits (financial and otherwise) for the household.

A similar concept was applied in 2016 and 2019 to smart EV chargers[8]: drivers set their planned departure time and required level of charge (mileage) for the battery and the smart charger charges the EV whilst considering the requirements of the system (e.g. network congestion, prices or carbon intensity of electricity supply). Similarly, in combination with advances in machine learning, optimisation and forecasting techniques, appliances with thermal stores (such as freezers or heat pumps), plan their operation to minimise their energy use at a required time to deliver flexibility when it is needed the most.

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[7] *Hossein Motlagh, N.; Mohammadrezaei, M.; Hunt, J.; Zakeri, B. Internet of Things (IoT) and the Energy Sector. Energies 2020, 13, 494. https://doi.org/10.3390/en13020494*

[8] *For example, in innovation projects My Electric Avenue (https://www.ssen.co.uk/myelectricavenue/) and Electric Nation (https://electricnation.org.uk/resources/smart-charging-project/)*

To achieve this level of smartness and distributed cooperation on a greater scale, both the flexibility provider and flexibility buyer must have the ability to gather data, make decisions and manage control instructions with a high degree of automation. To accommodate the number, geographical spread and diversity of flexible DERs / devices / appliances, there is a need for a distributed hierarchy to coordinate small flexible DERs: household, local (street/ neighbourhood), district, regional and national. Each hierarchical level understands the needs, resources and constraints of that level, and the needs and constraints for communicating with the levels above and below. Depending on where a network issue is and the available flexibility, the distributed hierarchy will seek available flexibility at each level to maximise the effect of available flexibility and the reward. This coordinating role is either a function of the Distribution System Operator (DSO) in collaboration with ESO or provided by a third-party coordinator / aggregator or supplier of bundled products or services to the ESO / DSO in a secure and reliable way. To enable coordination and aggregation, manufacturers of the appliances and devices adopt common standards for communications, coordination and control to allow automated and / or aggregated interaction for the ESO, DSO or marketplace or usage by the households to manage self-consumption and optimise energy use at home.

Regulatory Challenges

The interoperability of systems and smart appliances is facilitated by new standards from government or industry that specify reduced costs to participate and increase the level of flexibility at the grid edge. In addition, changes will be required to accommodate decentralised markets that provide services both within communities and at their connection with networks at the edge of grid.

Other changes include:

- the role of energy as an integral element of the planning process for local authorities to ensure planned developments, as well as existing housing stock, positively contribute to the local and national energy system and environment.
- enabling communities to provide fair access to members, manage their own energy and flexibility needs and interact with the network as a collective with low transaction costs.
- ensure flexibility is fairly rewarded for the benefits to all parties connected to and benefitting from that flexibility, including the local health and environmental benefits. This would allow incentives to limit returns and encourage investment in other LCTs.
- electricity regulation is focussed on increasing the utilisation of infrastructure, the alignment of demand with generation and increasing the penetration of low carbon technologies whilst minimising the scope for unintended consequences.
- recognition of the vital role that energy efficiency plays in delivering Net Zero and providing parity with other LCTs.
- recognition of the role that millions of DERs with low levels of flexibility distributed by geography and voltage play in increasing security of supply.
- consumers, self-generating consumers and systems operators are incentivised to optimise their multi-vector energy use in form of primary energy, energy storage and energy output

(e.g. hydrogen and electricity for heat, using building fabric as heat store and adjusting temperature set points on thermostats within comfort range).

Commercial Challenges

Reducing the barriers to market entry and the transaction costs for DERs with low levels of flexibility supports direct market access for flexibility but users of flexibility need critical mass that can only be achieved by aggregation. The rise of communities will encourage social aggregators who provide collective benefit and mutual sharing of the rewards. This also increases the reliability and availability of flexibility delivered to provide services to the ESO, DSO and other organisations. This increased focus on reliability and availability encourages greater transparency and understanding between the system operators (ESO and DSO will require more flexibility on a long-term basis) and a reduction in the spare flexibility held which encourages new flexibility to come to market and for new services to be developed.

In 2050, grid edge flexibility is fairly rewarded for the benefits provided to all parties connected to and benefitting from that flexibility, including the local health and environmental benefits. This will also encourage new flexibility to come to market and new services to be developed, particularly peer-to-peer services where users of the network provide services to one another to increase utilisation of the network and enable the growth of LCTs.

On a broader scale, Ofgem's market wide half-hourly settlement[9] introduced in the 2020s created the stimulus for the development of the supplier-hub models with suppliers taking a more active role in enabling and encouraging the creation of flexibility from their customer base (individually and within communities), particularly those with small flexible DERs which is then used locally and for DSO and ESO services. Initial innovation in tariffs and products from suppliers and controllability and visibility for DERs sparked a growth in flexibility from residential consumers which is used to deliver services and benefits across all levels of the energy system. The introduction of real-time metering has driven a transition from energy-based markets (based on energy used in a half hour) to power-based markets (based on power generated or consumed at intervals of minutes) with settlement periods of 5 minutes transforming how the market operates and balances and rationalised products and services across all markets, further reducing the costs for customers.

The significant growth in flexibility across all customer groups and innovation in flexibility services has enabled the deployment of large volumes of LCTs and resulted in the delivery of Net Zero in 2050. In addition to the system-level benefits, flexibility at the household and community level is delivering value to all households regardless of socio-economic status and communities, including those without flexibility, by effectively using local energy resources to reduce the operating costs but also recover the investment in the local energy system.

[9] *Electricity Retail Market-wise half-hourly settlement, Ofgem, 2020* https://www.ofgem.gov.uk/publications-and-updates/electricity-retail-market-wide-half-hourly-settlement-draft-impact-assessment

Societal Challenges

There has been great progress in addressing societal challenges within the energy sector, such as fairness and equity, but they still exist in 2050. In an attempt to resolve this, in 2030s the Government and key stakeholders in the energy industry developed a scheme to support the vulnerable and less affluent households to help them to benefit from LCTs and flexibility through investment in smart appliances and energy storage paired with embedded renewable generation. On top of the support for improvements in energy efficiency, reducing energy costs, such schemes deliver energy equity by distributing flexibility resources to the areas where the need for flexibility is high and where consumers are unable to fund their own flexibility and energy efficiency. For example, a combination of heating-as-a-service, e-mobility-as-a-service and energy-efficiency-as-a-service, has created an opportunity to offer Flexibility-as-a-service to customers. This third-party investment opens an opportunity to benefit the customer directly, their community and the wider energy system. Reflective of the benefit value and the welfare of the beneficiaries, the costs of such scheme are socialised and fairly distributed within communities, from the reinvested profits, and as a light levy on aggregators, generators and the major energy users.

By 2040s, within the communities, community energy schemes became more proactive in managing their energy consumption and generation, many at the boundary with the DSO. Communities as a whole share the benefits of a flexible, smart and local energy system, for example by sharing the energy generated locally at lower cost or the savings from deferred network reinforcement reflected in a dedicated local tariff. Wider desire to decarbonise their lifestyles, communities also used the benefits from flexibility to increase the uptake of low carbon technologies (individually and as a community, e.g., shared EV mobility) and integrate more renewable generation into the community.

Recommendations

Returning to the today's world, grid-edge flexibility has great potential to be the enabler of Net Zero as outlined by the "Leading the Way" FES scenario. However, the two biggest challenges facing the inclusion of small flexibility from the grid edge into delivering Net Zero are societal participation and commercial environment. A common pillar to both challenges is the value of flexibility which only partially reflects the benefits delivered through the flexibility markets. Today, each flexibility market is monopsonistic (market dominated by one buyer), segregated and short-term (there is a lack of long-term stability in the regulatory landscape). There is a need to standardise products and services across all flexibility markets to encourage greater transparency and involvement of flexibility as these flexibility markets grow.

To support the inclusion of grid-edge flexibility, the proposed recommendations include:

- To tailor the legislation and regulation to support the development of local communities who act collectively to manage their LCTs and interact with the flexibility markets and other users of the system at a single node (e.g. enabled by an iDNO) or multiple nodes.

- Create a new energy and carbon marketplace to encourage wider deployment of Smart Local Energy Systems where local generation and demand flexibility is recognised as being critical for a healthy and affluent society. The Flexible Services players are seen to add significant benefit to the local society and also provide support to the National scale economy.
- Align the energy policy, welfare policy and housing policy to deliver long-term strategy for Net Zero and beyond ensuring balanced distribution of costs and benefits associated with grid-edge flexibility and cost of energy.

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