REACH (Rural Electricity & Community Heat)

WS-A4 Horizon Scan Report

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Electricity Distribution

nationalgrid

Contents

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Introduction

Project Background

REACH will work closely with several rural community energy groups previously identified and engaged during the Discovery Phase of this Strategic Innovation Fundd project. This project is funded by network users and consumers under the Strategic Innovation Fund, and Ofgem programme managed in partnership with UKRI. Their role will facilitate the project's understanding of their decarbonisation priorities and contribute to defining the design requirements for a modular rural energy centre aimed at accelerating their decarbonisation efforts. The final solution will offer communities with coordinated low carbon heating, rapid EV charging, and renewable generation in an area where commercial markets may not serve customers and where the electricity network has limited capacity.

Working closely with community energy groups, National Grid Electricity Distribution, and innovative suppliers, the project will evaluate the feasibility of a novel solution to help customers make cost effective decarbonisation plans. This will be coordinated with wider development plans while continuing to horizon scan for other potential interventions that could offer a preferable outcome to the conventional reinforcement upgrades that would have historically been the default approach. In the Alpha phase we also want to ensure that we identify any other competitive and complimentary solutions that could similarly address such challenges and design an analysis tool that helps match community needs with optimal solutions.

The primary deliverable from the REACH alpha phase will be a techno economic assessment of using energy centres to provide electrical capacity to customers in rural areas of the network. In addition to this we will map out the logic and flow process for an options tool that may be developed into a software-based facility to rural communities. The purpose of which will be to collaborate and guide them through a process that will analyse the specificity of the constraint issues and future requirements of the community. Through this process we intend to help communities navigate what would otherwise be a highly complicated interaction requiring specialist knowledge on their part. At this stage we have not yet completed the wider assessment of the hypothesis that a REACH energy centre will address the constraint challenges that may result from LCT adoption. Other work packages within the wider project will verify if the concerns are justified and can be managed through proposed novel solution. To that end, we will not be building and deploying the options tool during the alpha phase, in favour of developing a functional design that will be implemented in the Beta phase if an application is approved. The benefits of a tool in BaU, will make it possible for communities to input their expected adoption of LCTs, land availability, population growth and other variables to establish viable solutions. Similarly, National Grid will provide the empirical data and probabilistic load forecasting that will ensure that the options reflect the true physics of the community needs. If introduced into BaU the tool will significantly simplify and enhance the customer journey through the multiple variables through their ability to repeatedly test the impact of variables on selection of an optimal solution.

Ideally the tool will not exist simply for the purpose of identifying the most appropriate specification for a REACH energy centre, from the many different configurations that are possible with its modular design approach. Instead, it will support the selection of the most optimised solution from an array of different technologies and manufacturers to ensure that they achieve the most suitable solution from a competitive exercise. We would therefore like to invite readers of this document to contact National Grid Future Capabilities team if they are aware of any other viable solutions, either already deployed or currently in development which may be worthy of future inclusion.

The Rural Challenge

Previous research has demonstrated that the adoption of LCTs is incompatible with existing infrastructure due to the potential increase in peak demand in excess of 20 kW per household. To support these higher loads, a whole system approach to network planning is required. In many cases the most cost-effective long-term means to deliver secure capacity to customers is to upgrade electrical networks.

In addition to the high costs associated with this reinforcement, current solutions can take significant time to deliver the required capacity which may delay the connection of rapid EV chargers, the transition from high carbon heating (oil/gas), and disenfranchise rural communities. We seek to create a solution that allows rural communities to adopt low carbon technologies more rapidly or cost-effective

While some of the challenges we will face are also experienced in cities, such as limited off-street parking or insufficient capacity for very large clusters of homes to access low carbon heat there are significant differences.

These and other obstacles to widespread adoption of LCTs are won't necessarily be resolved in the same way to metropolitan locations as the economics for private investment are very different, as well as the existing infrastructure restrictions.

Problem Statements

1. Domestic EV Charging

Potential first time EV owners may be unaware of dependencies outside of their control that could impact the availability of an EV charger to their household. This may be related to looped supplies or location of the consumer supply / fuse board being located inconveniently to the preferred exterior location of their charger. These can cause delays and some added expense but are generally addressed on a case-by-case basis.

Within the REACH project we have identified a potential issue, particularly in remote or rural environments, that could result in significant delays to provision of a new home charger(s). For example, if someone within a constrained community has decided to get their first EV, they may even have purchased the car or signed their lease agreement before attempting to order a charger.

Often this is left to the installer to complete the process of contacting their DNO to inform them that the householder wants to install a charger. Although DNOs are obliged to fulfil any demand connection requests, it may come with certain conditions attached, including delays if the capacity is not readily available. In the case of some rural communities, the delay could be quite significant particularly if being considered from the perspective of someone who has just agreed a 3 year lease deal on a new car.

2. Electrification of Heating

The heating scenario has similarities to EV charging, at least in respect of the underlying issues and that the major impact is not that a household can't electrify their heating source, but that it would be potentially significant to a household if they were faced with any protracted delay in the commissioning of a heat pump or similar.

The reason this is likely to be so problematic is that the replacement of a heating system commonly has timing dependencies. For example, it will often be associated with the end of life of the existing heating system or part of planned improvements such as refurbishment or extension of an existing property.

This is compounded by the number of households that are not served by the gas grid and therefore they already have a more limited options, with oil fired boilers being the most common method of heating.

This equates to over 1.5 million households in the UK on oil but it is recognised to be more carbon intensive that either gas or electricity so the government had previously tabled a motion to ban oil-boilers from 2026 although this has been delayed but will require the fuel itself to be phased out in favour of lower carbon alternatives such as HVO. While this will extend the life of some boilers, it is expected to be substantially more expensive and encourage many households to seek an alternative technology that use electricity instead.

3. Small scale housing development

The final scenario that will probably be less common is most likely to be the most disruptive to any linear growth models and potentially result in the greatest level of dissatisfaction, relates to the expansion of communities themselves.

The labour government has set an ambitious target of 1.5 million new homes over the next 5 years coupled with compulsory targets for local councils. We therefore expect to see an increase in the number of small developments, expanding existing rural communities in line with some softening of planning conditions.

Combining scenarios, A & B with the desire to add these technologies in additional housing could result in the perfect storm from a network capacity perspective. If a developer is investing in acquiring land and all the costly bureaucracy of obtaining planning permission, it will not reflect well on DNOs if they are one of the key barriers to proceeding with building.

Document Purpose

The purpose of this document is to outline the findings of a horizon scanning exercise that sought to identify alternative approaches and their applicability for supporting rural communities avoid delays in the event of capacity constraints and accelerate connection time of low carbon technologies. Given the specific context of rural communities' face, we base our analysis on seeking to overcome the three main problem statements outlined above.

Horizon Scanning: Approach

The alternative solutions were identified through a 2-phase search strategy show in Figure 1. In the first phase a high-level horizon scan was conducted. The initial focus of this activity was a comprehensive search of the existing database of projects that have been previously registered for innovation funding through LCNF, NIC, NIA and SIF. The initial method for this was a search of the ENA innovation portal which has almost three thousand previous projects and initiatives contained within its records focussing on searches that relate to either capacity restrictions or rural environments to capture a broad range of scope that may relate to the objectives of REACH. With such a large number of projects now contained within the database and very limited summaries provided within the initial search results it was necessary to download and review the registration forms to get a sufficient comprehension of the scope for comparison. From this we did identify some initiatives from UKPN, SPEN & SSEN that recognised barriers to LCT adoption, focussing on the potential upgrades to fuses/cut-outs/looped services and remove the potential for delays when they wish to install an LCT. To some extent the UKPN 'CommuniHeat' demonstrates some parallels with the REACH initial hypothesis, that rural networks could experience capacity issues resulting from LCT adoption, although as the name suggests, the focus was primarily on electrification of heat as well as support to local authorities in the way they approach their LAEPs. However, following a thorough assessment of the innovation portal we are confident that the REACH project is the first project to isolate the issue of rural constraints potentially impacting the ability of domestic households being able to freely adopt LCTs without impact to the network.

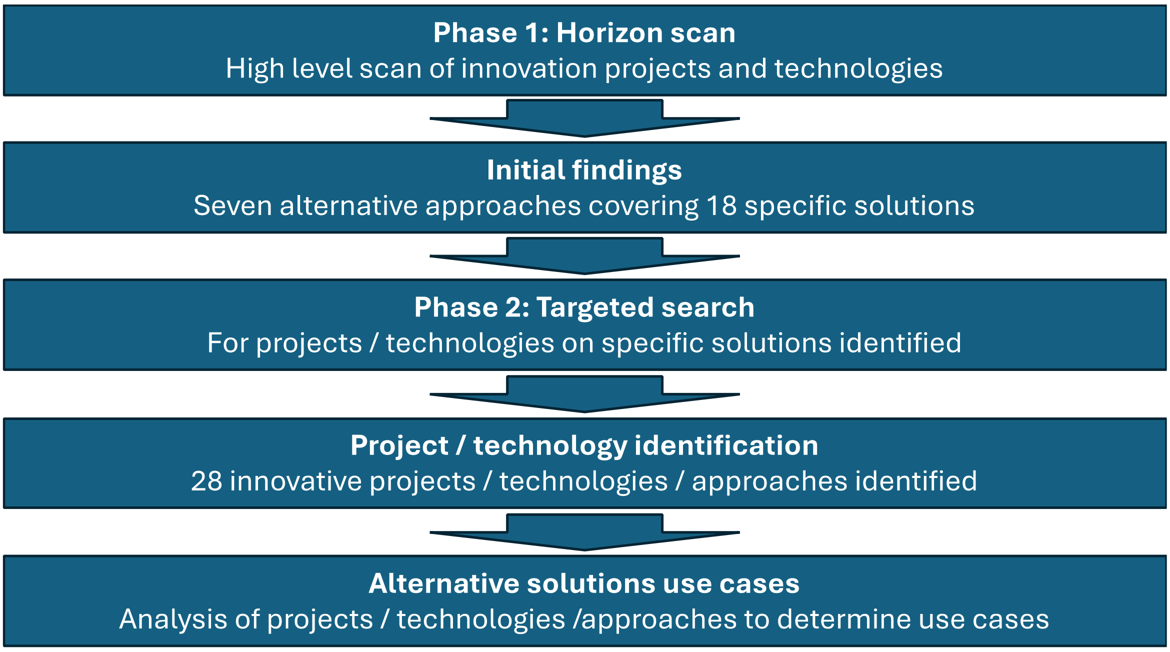
Based on the outcome of the initial searches, which were largely intended to identify alternative solutions to the constraint issues and determine the different circumstances in which each may be most suited, we felt it important to share our hypotheses and seek feedback on the likelihood of such issues occurring across other distribution licence areas. We therefore produced and shared a video with appropriate representatives at the other DNO/DSOs and followed it up with meetings to obtain their views and feedback. This was a very worthwhile exercise as the result was a general recognition across all the interviewees that there is a very real potential that unexpectedly high uptake could potentially circumvent the assumptions that are generally applied when modelling rural demand, particularly at LV, leading to the need for an intervention that would supplement available capacity or limit the increase in demand. SSEN provided valuable input that they would utilise their existing policies that would utilise a 'Flexibility First' approach and they would most likely publish a notification that they wish to launch a Constraint Management Zone (CMZ) to identify any potential providers that could shift demand at peak periods. This feedback has been incorporated to the REACH assessment to determine community suitability and precedes any proposals to deploy a temporary energy centre. If however, there is insufficient flexibility from providers to manage the constraint(s) then a DNO should progress to consider other options that should include the temporary use of generation or energy storage in lieu of existing demand capacity. Further to this engagement with the other DNO/DSOs it is the intention of the project team that when the Alpha Phase is completed and as part of the Beta application process, we will request a peer review of the Alpha output reports and a letter of support for the Beta submission.

The above completed the expected scope that was part of the initial WPA2 work package to carry out a horizon scan of suitable technologies to address the 'problem statements' that were listed in the previous section of this document. However, with no significant alternatives to the REACH solution identified it was determined that the scope of th horizon scan should be broadened to include a wider search of general technologies and international innovation programmes. For this less scientific approach two separate individuals, one with industry expertise and the other without carried out a series of investigations utilising web searches and AI to identify any additional technologies. The 'layman' approach limited the focus to UK based technologies while the Subject Matter Expert (SME) included international investigations as well. The results of the 'non-expert' searches have been included within the report as Appendix A.

The SME searches were able to be more targeted by virtue of the greater understanding of the challenges facing rural communities and prior knowledge of the options identified within the layman exercise so as to be able to eliminate them sooner. The international investigations did provide a limited number of alternatives that could be broadly categorised alongside the SSEN approach of declaring a CMZ and managing low voltage constraints through demand shifting and control at a household level. However, the market structures were very different to those within the UK and therefore have the ability to already visualise the entire network all the way down to individual households. A good example of this is the mPresst system operating in Israel where monitoring and control through their DERMS (Distributed Energy Resource Management) platform[1] is provided down to individual households by default and demand reduction is mandated within their customer supply agreements. While this is of great benefit in this specific use cases it is not appropriate for comparison as they have a nationalised system that would not be viable within the UK market and governance and therefore, we have opted not to include a list of inappropriate solutions as its unclear what would be an appropriate set of conditions or scope for inclusion.

Following this first phase, 7 main approaches were identified and used to conduct a more targeted search for relevant innovation projects or technologies. These 7 approaches included: (1) network reinforcement, (2) smarter network management, (3) flexible connections, (4) flexibility procurement (5) community scale assets, (6) demand side flexibility, and (7) community microgrids. We review project overviews, key outputs, and/or technology websites. We analysed this secondary data to gain insight into potential benefits of each solution and challenges in terms of deployment, particularly in the rural context.

Figure 1: Horizon scanning overview



Findings from this secondary document review were supplemented with insights from a workshop held with NGED DNO and DSO teams. During the workshop a subset of the 7 approaches focussing on DNO/DSO led options were discussed in terms of their benefits, implementation challenges, and potential use cases.

[1] https://mprest.com/mprest-products/mderms/

Horizon Scanning: Findings

Findings from the horizon scanning process revealed relatively few solutions have been designed or built with the intention to resolve this specific predicament facing network owner / operators that project REACH is seeking to address. This section therefore considers the range of innovation projects and/or implemented solutions that could be adapted to address the three problem statements identified earlier.

Network Reinforcement

Key considerations when looking to reinforce networks include firstly understanding where the overload is, and which issues are likely to emerge in which order (i.e., voltage issues appearing before thermal overload). Currently, network assessment is triggered when multiple low carbon technologies are connected to the same network. Theoretical assessments based on analysis of load profiles in a pessimistic winter scenario. If issues are identified in this theoretical analysis, network reinforcement plans are put into place. The primary issue observed to date is EV charge points tripping out when voltage levels rise. However, as these calculations are based on pessimistic scenarios, they are very rarely seen in practice. That said, if theoretical issues were not addressed, problems would be likely to arise in the future.

Once the need for network reinforcement has been identified, the main challenges relate to bottlenecks arising from legal issues, regulatory planning, and construction activities. This results in a gap between the need arising and delivery of the solution. One potential pathway to overcome this ‘gap' would be to running existing conductors ‘hot' (e.g. at 60-70 degrees rather than 50) for a short time while bottlenecks in reinforcement are overcome. This would be a quick temporary fix requiring only minor engineering works and a survey to re-rate the overhead line.

Updates to Elexon load profiles[2], specifically Profile Class 5, would also be beneficial to support more accurate assessment of needs. These load profiles can heavily influence decisions that are made, but they are outdated and do not consider the impact that newer energy or flexibility tariffs may have on demand. Additional solutions such as single wire earth return (SWER), pop-up networks, and high temperature low sag (HTLS) conductors were identified in the horizon scanning exercise. However, discussion of these with DNO teams suggested that none were viable in this context.

SWER, while implemented in certain contexts (e.g., highly remote regions in New Zealand), were not thought to fit within current engineering policy and seen as bringing safety concerns. Pop up networks were discounted due to regulatory issues; DNO teams did not see the benefit over a permanent installation if Section 37 of the Electricity Act 1989 was still necessary. HTLS were considered too expensive and risky for a low voltage scenario. As they are constantly loaded this also provides a challenge from a losses perspective, and it was suggested that due to their size (in the REACH context) it would be better to simply run a normal conductor hot for a temporary period until regulatory, policy and construction bottlenecks can be overcome and network reinforcement undertaken.

Smarter Network Management

Solutions in this category aim to defer the need for reinforcement by supporting more efficient running of existing networks through enhanced data and control.

Dynamic Line Rating

Dynamic line rating is the process of using prevailing weather conditions to run overhead lines at higher ratings to take advantage of conditions such as cold temperatures. This approach was

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[2] https://www.elexon.co.uk/bsc/settlement/profiling/

assessed in Project FALCON in 2015, and recommendations made that dynamic line rating for 11kV overhead lines was not a feasible solution for addressing network constraints. While the report did show benefits in specific contexts (e.g., for lines associated with wind generation where increased loading from generation output correlates with wind speed that could enable an increase to the line rating), the improvements in ampacity cannot be relied upon where reasonable planning certainty of capacity is required. In addition, cost, complexity, and the need for dynamic control of the network are prohibitively high for a context where LV metered customers cannot be curtailed. DNO staff suggested that this solution would be better suited to larger conductors and tower type applications, where dynamic management and curtailment of assets is feasible.

Phase Balancing

Homes and businesses are connected to the low volage network in a way that attempts to balance the load across the three phases of the network. When these are unbalanced, the hosting capacity of the network is reduced, and this can hamper the ability to connect additional low carbon technologies, increasing the need for network reinforcement.

NGED have an active innovation project (Phased Switch System (PSS), running September 2024 to January 2028) exploring dynamic phase reconfiguration of a Low Voltage (LV) feeder cable to reduce phase imbalance. This builds on a UKPN NIA project which demonstrated autonomous operation of the PSS system can balance the demand across phases.

However, the ability to balance demand across phases relies on both the accurate knowledge of demand on each phase (which is currently based on assumptions) and the ability to manage demand, which in rural domestic contexts may be limited.

On Load Tap Changers

This includes both ground mounted and pole mounted transformers. Typically, primary substations have on load tap changers, while secondary substations include off load tap changers. However, it is possible to use on load tap changers for secondary substations though they incur a higher cost.

While on load tap changers require regular maintenance and monitoring to support reliability and longevity, they are able to cater for voltage changes at the grid edge (e.g. due to solar generation during the day or EV operation at night) and DNO staff report they have the potential to treble the amount of generation that can be connected to the LV network, and may also be able to enhance the amount of connected demand. In part this is due to the way demand capacity is currently calculated; networks are currently assessed based on a worst-case scenario basis, however, dynamically controlling voltage to maintain 240V alleviates the need for such a pessimistic assessment.

NGED are in the process of trialling 6 ground mounted on load tap changers for secondary substations and are waiting for pole mounted solutions to become available in the UK to trial.

Smart Transformers

Building on the concept of on load tap changers, NGED are exploring the potential for smart transformers in their ongoing LV-ACT NIA project (August 2024 – October 2025). This explores the potential for smart transformers to alleviate LV constraints via active power control and feeder meshing. In addition to managing voltage levels, the smart transformer will be able to absorb harmonics and support power factor corrections. Costs are higher than for on-load tap changers, but it is anticipated that in appropriate deployment contexts, benefits may include significant financial savings and reduced outage times. However, a full cost benefit analysis and evaluation of use cases for this technology has not yet been conducted. In addition, there are concerns regarding the asset life of the power electronics incorporated in the transformer; typically, transformers are installed in a “set and forget” mindset, but the added complexity of this solution may require regular maintenance and monitoring.

Flexible Connections

Solutions in this category are focussed on delivering flexible connections of demand side assets. The two primary approaches include active network management (ANM) and market based flexible connections.

ANM

NGED currently use ANM to support both generator and demand connections across constrained parts of its network. Connections at 11kV and above can be controlled by the ANM system to manage constraints from primary transformers up to the transmission network interface. The system monitors the network conditions, and a centralised control system calculated the required set points for each ANM connection to ensure the network does not become overloaded.

Critical to the operation of ANM is the ability to monitor and manage loads. Due to insufficient network visibility, ANM could not currently be deployed to manage constraints at rural secondary substations (though those connections could be managed by the ANM system if they were contributing to higher voltage constraints). Therefore, while ANM connections are available for demand assets (including solo assets which can be controlled for import, export or both), it is not suitable in the REACH context due to the insufficient network visibility. The addition of monitoring and control panels or other actuation techniques would also add a considerable cost to connections at this level.

Market Based Flexible Connections: ExtenDER project

SSEN's ExtenDER project[3] by SSEN (Aug 2023 – Dec 2025) is testing the feasibility of a market-based connection agreement to connect demand assets on a non-firm basis. ExtenDER is primarily focused on addressing export constraints within the electricity network. Its main goal is to facilitate earlier connections. The rationale for customers, particularly generators, is to enable peer-to-peer trading of flexibility. This approach aims to alleviate the challenges arising in the Greater London area, where transmission constraints often hinder the development of new distribution connections. The ExtenDER project is examining the potential for a market-based approach to connections. If successfully developed, SSEN plans to compare this approach to existing methods, such as Active Network Managed connections and Constraint Managed Zones, for addressing constrained networks. An example use case is provided in Figure 2, which illustrates exporting electricity from generation sources to the broader grid.

The project focusses solely on market-based connections and does not consider DNO flexibility methods. Instead, customers would trade with others already connected to the network in a local flexibility market to access the required input capacity. This would allow customers to connect earlier under transmission constraints by enabling peer-to-peer trading of flexibility. The project is evaluating risks associated with this type of market-based connection, assessing feasibility of implementation, and demonstrating potential market viability. However, it may suggest DNO flexibility methods where market-based connections are not suitable.

Feature	ExtenDER	Traditional Flexibility / ANM
Market model	Peer-to-peer	DSO-led central dispatch
Trading participants	Broad (generators + loads)	Mostly generators or aggregators

[3] https://smarter.energynetworks.org/projects/nia_ssen_0067/

Feature	ExtenDER	Traditional Flexibility / ANM
Location targeting	High-resolution, constraint-based	Medium to low
Control mechanism	Negotiated market logic	Deterministic (ANM) or tendered
Goal	Export curtailment avoidance via local optimisation	Constraint relief via control or dispatch

Phase 1 of the project has now been completed and focussed on: (1) confirming the potential viability of a market for market-based connections, (2) identifying the risks and mitigation options associated with market-based connections, and (3) developing a skeleton market-based connection agreement.

SSEN undertook a high-level analysis to determine that there were sufficient customers waiting in the connections queue for whom a market-based connection approach may be suitable to support their connection earlier than anticipated.

They also identified several risks associated with market-based connections, including:

- Network Resilience – If market sellers don't turn down on a constrained network there is a chance of circuits tripping and customers losing supply.
- Commercial Regulation – Distribution Use of System (DUoS) charging will be impacted as new market-based connections do not fit in with the current processes and systems.
- Market liquidity – Low market liquidity reduces the chance of successful peer to peer (P2P) trades occurring. This may reduce the likelihood of potential buyers engaging in this service due to unpredictable energy availability.

Phase 2 of this project is now underway. This will provide a better understanding or the value of market-based connections (compared to, for example, ANM). It will create a replicable market design and market-based connection tool and provide clear processes for market-based connections to operate. It will also enhance understanding of the interactions with existing connection agreements and other customers and provide a fuller examination of risks.

However, as yet this approach is untested, and a lot of upfront effort is needed to mitigate risks and design safe working practices, which may limit its viability for rural networks and the specific problem statements being addressed in the REACH project.

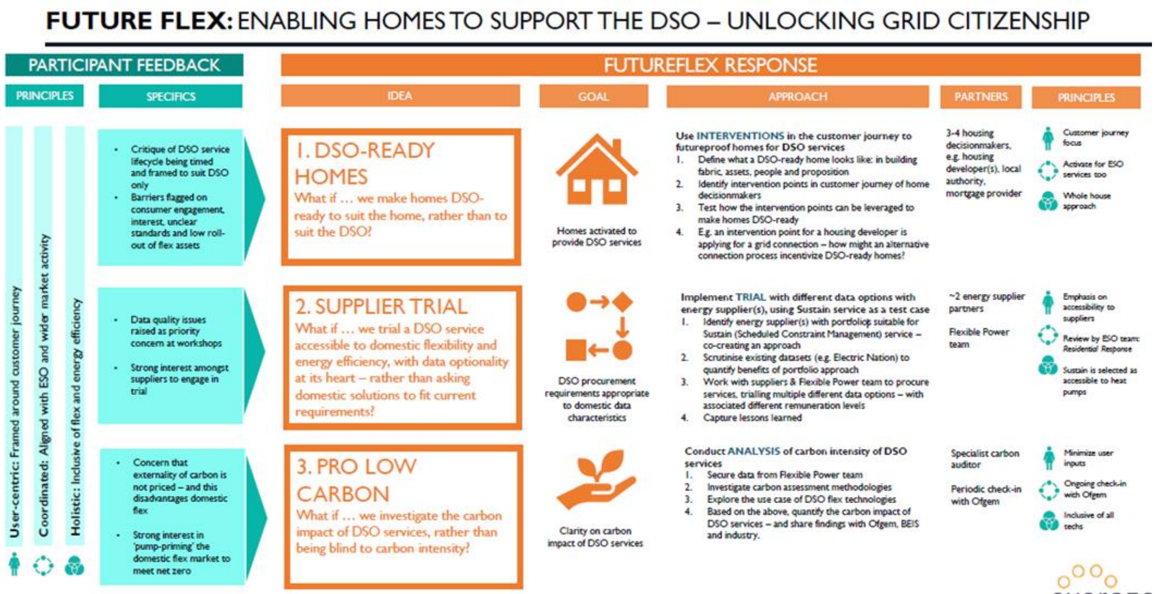
Flexibility Procurement

In recent years, procurement of flexibility providing grid services at both national and local levels, has become increasingly open to smaller assets. This has allowed community scale assets, as well as aggregated household scale assets, to bid into various flexibility services. Here we highlight some key innovation projects exploring opportunities for flexibility procurement.

Future Flex

NGEDs Future Flex project ran from 2019-2021 and aimed to explore opportunities and mechanisms for unlocking residential demand side flexibility. The project developed and deployed innovative flexibility procurement for domestic scale assets, seeking to increase savings potential and improve market liquidity. In addition, the project explored options to help homes become DSO ready, taking a participant led approach.

Figure 2: Future Flex project overview. Image from Project Closedown Report[4]



The project developed and trialled the Sustain-H service; an aggregated, scheduled demand reduction procured from households with LCTs and energy efficiency solutions. Key learnings include:

- **Alignment between TOU tariffs and DSO services**: there may be benefits to a time-of-use approach baked into network charging arrangements, including less administration, avoiding tricky baselining, avoiding asset qualification requirements.
- **Customer relationships**: there is a lack of clarity around who holds the relationship with the customers engaging in DSR including suppliers, independent aggregators, etc. Opening services to both licensed suppliers and asset aggregators introduces the risk of double counting homes.
- **Asset use cases**: this is especially true for behind the meter storage, where demand patterns are heavily reliant on the use case, for example, demand profiles for a 24/7 FFR use case would be very different to a use case with surplus solar capture and export during evening peaks.
- **Use of standardised contracts**: the ENA's standardised Flex Services contract was found to be long and cumbersome, and resulted in delayed signatures from participants and/or the need for additional support to review.
- **Value:** there was consensus across participants than the value of DSR was insufficient. This remained a core challenge for scheduled services, and risks remain as to whether payments can be sufficiently high to mobilise enough engagement. In particular, the trial showed that remuneration based on the value of an average CMZ is insufficient.
- **Automation:** Procurement, validation, data delivery, assessment and payment processed should be automated to minimise administrative burden.

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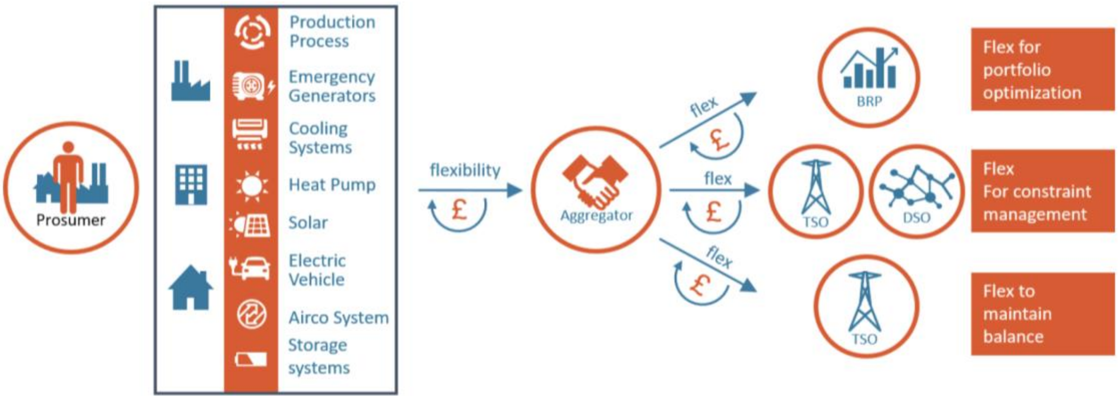
[4] https://smarter.energynetworks.org/projects/nia_wpd_047/

Project Fusion

SP Energy Networks Project FUSION trailed an approach to commoditise local demand-side flexibility through a structured and competitive market, working with two aggregator partners (GridImp and Orange Power) to access DERs. It utilised a standardised market-based framework; the Universal Smart Energy Framework (USEF). The USEF provided a Market Coordination Mechanism, a framework for automating the flexibility trading processes, and a standardised approach to flexibility services.

Through the USEF 'prosumers' are contracted by an aggregator to provide specific flexibility services using Active Demand and Supply (ADS) assets (see Figure 3). This focuses the procurement on explicit demand-side flexibility (i.e., committed, dispatchable flexibility that is exposed to energy markets and system operation products and can be traded on the different energy markets such as wholesale, balancing, system support and reserves markets) rather than implicit demand-side flexibility (i.e., flexibility which is provided by consumers as a reaction to price signal) or peer-to-peer energy trading. Through this project, a 5-step approach was taken to market co-ordination: (1) contract, (2) plan, (3) validate, (4) operate, (5) settle.

Figure 3: USEF model of interoperable roles, centred around the Aggregator role. Image from Project Fusion closedown report[5]



During the two-year project, Project FUSION tested three of the Energy Network Association's (ENA) standardised products: Sustain, Secure and Dynamic. Over an 18-month window, over 700 requests for flexibility were raised; 94% of requests received at least one offer from aggregators, resulting in the delivery of close to 50MWh of flexibility over the trial period.

Equinox

Equinox is a live NIC project, led by NGED, exploring commercial and technical arrangements to unlock flexibility from residential low carbon heating. Specifically, NGED are exploring three commercial methods, to be procured from customers via a supplier working with an aggregator:

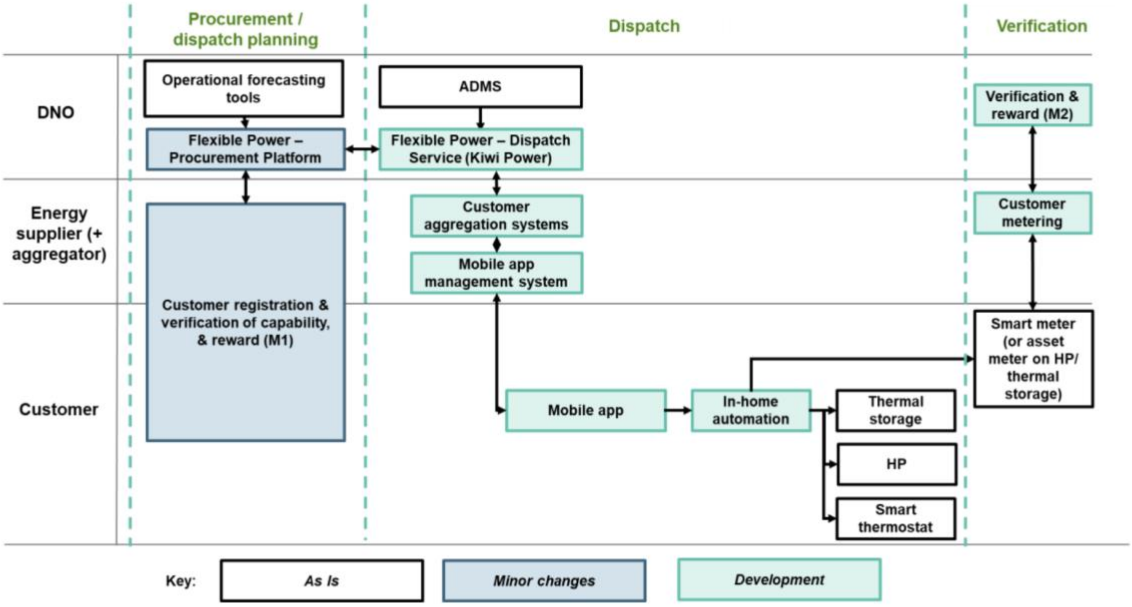
1. Save in advance. The energy supplier, and in turn, the end customer, receive an upfront flexibility payment in return for offering a fixed, minimum obligation of flexibility.
2. Save as you go. The energy supplier, and in turn the end-customer, are not committed to a fixed, minimum obligation but instead have more control over the flexibility they offer based on (near) real-time signals delivered in an automated way.

[5] https://www.spenergynetworks.co.uk/userfiles/file/FUSION_Close_Down_Report_CLEAN_020224.pdf

3. Save in advance & boost as you go. Combines aspects of upfront flexibility payments and dynamic price signals.

An overview of the Equinox conceptual architecture is shown in Figure 4.

Figure 4: Overview of Equinox conceptual architecture. Figure from NGED project submission report[6]



NGED enrolled over 1,000 customers across 3 winter trials working with supplier and aggregator partners. Findings[7,8] suggest that overall, participants found the trails easy to navigate and customer satisfaction levels were generally high.

Participants were generally happy with day-ahead notification of events, and the cadence of 2-3 events per week and with each event lasting two hours. They also felt in control of their heating throughout the trial period.

Fewer people opted out of DR events when they were being paid per event (compared to a monthly payment scheme). Those who had their assets controlled by aggregators were also less likely to opt out.

It is important to note that trial participants do not fully represent the UK population and tended to be wealthier and have a greater degree of concern over climate change and its impacts. While this may be problematic when trying to generalise finding to the wider UK population, it is less of an issue for REACH, as the community groups involved are typically highly engaged with climate and energy.

Demand Diversification

Over the past 50+ years SSEN have been developing and deploying flexibility services, with Load Managed Areas (LMAs) first implemented in the 1950s. In more recent years they have started to put increased focus on LV flexibility, particularly through CMZs and now market driven Demand Diversification Services (DDS), which they see as the future of LMAs. In past years LMAs were

[6] https://smarter.energynetworks.org/projects/wpden05
[7] https://www.nationalgrid.co.uk/downloads-view-reciteme/643709
[8] https://www.nationalgrid.co.uk/downloads-view-reciteme/671038

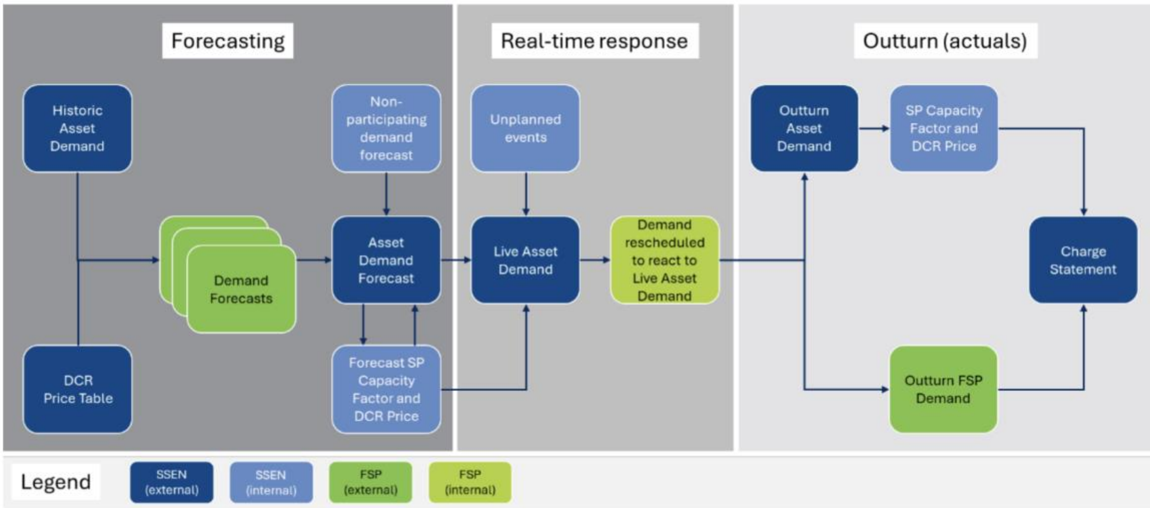
managed through the Radio Teleswitch Service (RTS). However, the turn off of this service in 2025 is leading to a shift to market-based flexibility services for DDS.

SSENs' process, for identifying and managing LMAs is as follows[9]:

> **IF** - The measured / forecast demand in an area of the network is likely to breach a predetermined minimum headroom (and there are coincidental and schedulable loads)
>
> **THEN** - Check if the network assets are scheduled for replacement/reinforcement. If not, or too far in the future….
>
> **THEN** – Demand Diversification Service (Flex for LV) should be implemented. If not feasible…
>
> **THEN** – Reinforcement should be assessed. If not feasible (due to cost or time)…
>
> **THEN** – Other solutions should be considered in conjunction with other stakeholders.

Two forms of market-driven DDS are currently being considered by SSEN in this NIA funded innovation project: (1) Allocated Capacity, and (2) Dynamic Congestion Response (see Figure 5). In the first approach each supplier is allocated a Maximum Demand Limit (MDL) based on units consumed and number of customers in each "zone"; by managing their demand portfolio below this limit they receive a Service Payment. Dynamic congestion response is a real time response to real time congestion, whereby suppliers and aggregators reschedule smart loads; suppliers and aggregators are paid to provide the service, but they pay a penalty for using the network when congestion is high.

Figure 5: Dynamic Congestions Response (DCR) approach. Figure from SSEN report on Demand Diversification Services[10]



Currently SSEN are working with the Energy Systems Catapult, Connected Response (storage heating control) and Homely (heat pump control) in a project[11] to:

- Signal up to 200 homes to flex use of EV chargers, heat pumps, and storage heaters.
- Simulate virtual networks to analyse how flexible assets can balance demand across different network conditions.

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[9] https://www.ssen.co.uk/globalassets/our-services/flexible-solutions/november-2023-flexiblity-startegy-webinar.pdf
[10] https://www.ssen.co.uk/globalassets/about-us/dso/the-future-of-load-managed-assets/dds-detailed-design---dynamic-congestion-response-v1.0-external.pdf
[11] https://es.catapult.org.uk/project/innovative-demand-management-for-net-zero-networks/

- Deliver insights into flexibility's ability to replace RTS services while ensuring network and consumer outcomes are achieved.

Findings are not yet available, but SSEN aim to use insights to support the integration of new flexibility services into their Business-as-Usual operations.

NGED DSO Approach

NGED's current approach to flexibility procurement builds on the work done by past innovation projects. Where known constraints exist (see NGEDs Flexibility Map for flexibility status across different licence areas), NGED enters into contracts with Flexible Service Providers (FSP's) who are paid to deliver flexibility services.

An FSP can be the owner, operator or appointed third party, responsible for the operation of assets capable of providing flexibility services. Examples include:

- Residential demand response through assets such as EV charge points and heat pumps through energy Suppliers and Aggregators.
- Industrial and commercial sites who can reduce their demand, switch to backup generation or generate energy to the grid.
- Owners and operators of storage and generation such as battery energy storage site, gas turbines peaking assets and biomass.

FSP's must first register their asset on NGEDs Market Gateway. An Asset is the smallest entity that can be considered, which represents the lowest level at which the FSP can meter. Examples of an asset include: (1) a grid scale battery with metering at either the asset level or the Point of Connection, (2) individual EV charge points or Heat Pumps with DER Level metering, or a property with its associated Low Carbon Technologies, with Point of Connection metering.

Once Assets are approved by NGED, they are assigned into logical groups called Meterable Units, which groups assets into a joint metering feed. This grouping is also used for baselining purposes. The FSP must provide metering for each Meterable Unit.

NGED procures flexibility from Meterable Units across four Active Power (in MW) services: Sustain (via SU_SPPP), Secure (via SU_SEP), Dynamic (via SAOU_DA), and Restore (via OU_15), and across two different timescales; Short Term and Long Term (see Figure 6 to Figure 8).

Figure 6: NGED flexibility product offerings

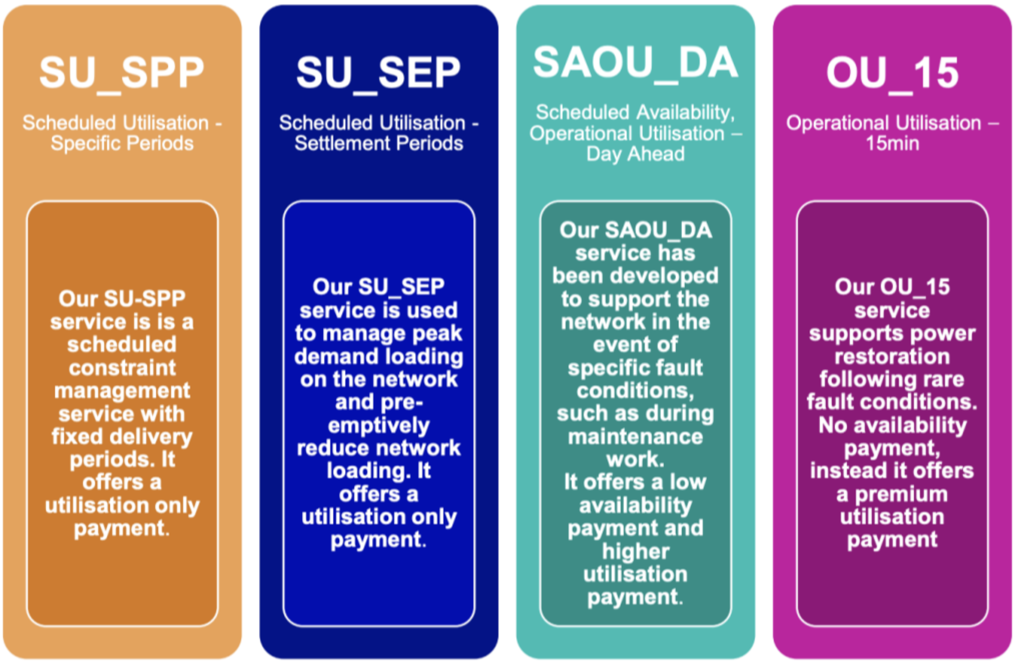


Figure 7: Short term flexibility offerings

Every Thursday **From midday**	**Short Term Trade Opportunities for FSPs open for bids**
Every Tuesday **By midnight**	Deadline for Trade Responses
Every Thursday **By midday**	Trade Awards announced for delivery from the next Monday

Figure 8: Long term flexibility offerings

In August **(exact date announced via our Engagement and Procurement Timetable)**	**Publish flexibility locations and requirements for;** - **SU_SPP** - **SU_SEP** - **SAOU_DA** - **OU_15** **to the Connected Data Portal**
+4 weeks	Trade Opportunities for FSPs open on the Market Gateway
+6 weeks	Deadline for Trade Responses. Launch date +6 weeks
+6 weeks	Trade Awards announced

The delivery of Flexibility Services is settled monthly and includes payments for availability (SAOU_DA only) and utilisation (all flexibility products).

Availability payments are made for being ready to respond to a dispatch instruction and can be recovered should the delivered capacity be lower than the contracted capacity. Utilisation payments are made for delivery of flexibility after the dispatch instruction.

Baselining (at the Meterable Unit level) is critical for setting the levels of delivery expected, for verifying delivery of services, and for allowing quantification of settlements. Baselining is performed in different ways for different assets, as outlined in the following table.

Asset Scale	Response Type	Metering Location	Baseline
Industrial OR Commercial	Generation	Any	Zero
Industrial OR Commercial	Stored Energy	Any	Asset Capacity
Industrial OR Commercial	Demand	Any	Self-Nominated
Domestic	Demand	Any	Baseline calculated by NGED based on Planning Profiles. Calculated Baselines=Capacity
Domestic	Stored Energy	Any	Baseline calculated by NGED based on Planning Profiles. Calculated Baselines=Capacity
Domestic	Generation	DER Level	Zero
Domestic	Generation	Point of Connection	Baseline calculated by NGED based on Planning Profiles. Calculated Baselines=Capacity

An asset is able to participate in both short term and long-term trades, but the same asset cannot be entered into different trades for the same delivery period. In addition, NGED do not impose inclusivity on their services. This allows for FSP's to value stack where other services allow.

See https://dso.nationalgrid.co.uk/flexibility-markets for further insight into current and evolving DSO opportunities.

Community Scale Assets

Community energy has predominantly focussed on renewable electricity generation; low carbon transport; and energy efficiency, retrofit and advice services. However, more recently clean heat and battery storage projects have begun to emerge.

With regards to clean heating, two projects particularly relevant to the problem statements REACH is addressing, include the Swaffham Prior Heat Network and the Stithians Heat the Streets project.

Swaffham Prior, like many rural villages, is not connected to the gas network, meaning that many customers rely on oil and other stored fuels for heating and hot water. The project was started by Swaffham Prior Community Land Trust to address fuel poverty and environmental issues caused by this reliance on oil heating. A feasibility study undertaken in 2017 identified a marginal economic opportunity to develop a heat network. However, this required 70% of homes in the area to connect, highlighting the importance of strong community engagement and collective action. Over a period of 5 years the heat network was developed such that since 2022 it has been delivering reliable, renewable heat to 300 homes in Swaffham Prior. The project also included the development of a private electricity network to power the energy centre with renewable electricity. The project relied on grant funding support from the BEIS Heat Network Development Unit (HNDU) and Heat Network Investment Project (HNIP), as well as a strategic investment by

Cambridgeshire County Council who own the energy company and heat network assets. Homes connected to the system pay a variable charge for the heat they use, measured via a heat meter installed in their homes, as well as a standing charge which was set to be equivalent to the cost of owning and maintaining an oil boiler.

The Heat the Streets project in Stithians is a street by street retrofit program, whereby ground source heat pumps replace legacy carbon intensive heating systems (oil / LPG). Each home has its own ground source heat pump, so households can have full control over the heating, with independent billing and the ability to switch energy suppliers at will. This project, led by Kensa, has been heavily supported by grant funding from the European Regional Development Fund, such that households received the equipment with no upfront cost. They then pay a monthly standing charge to access the heat network.

In addition to heat network projects, innovative community scale battery storage projects are starting to emerge. Regen, working with the ENA and DNO's, published an Electricity Storage Guide for communities and independent developers, outlining opportunities for household and community scale storage solutions. Alongside the potential to provide revenue for the community (as with generation projects), these also offer potential to deliver grid services.

UKPN's Balancer project explored opportunities for creating network and community value (with a focus on disadvantaged customers) from front-of-the-meter community batteries providing multiple services to communities, flexibility providers and DNOs. Three business models were explored:

1. Community Network. Aiming to improve the quality of the local network, reducing the need for reinforcement and supporting earlier rollout of LCTs via flexibility services, voltage control services, and (potentially) resilience services
2. Community Storage. Enabling the local community to consume locally produced renewables and shift their consumption to off-peak times, via storage services provided direct to local community.
3. Market. Aiming to reduce overall system costs through shifting supply/demand and voltage control via Electricity System Operator markets such as balancing market, capacity market, ancillary services, and wholesale market arbitrage.

The EcoJoule battery explored in the Balancer project is specifically focussed on rural grids with both pole and ground mounted options, and incorporates Advanced Grid Support (AGS) algorithms to optimise across community storage, voltage support, phase balance, peak load management, virtual power plan services, and battery life.

Other advances in this space include a community energy battery installation at the Trent Basin housing development in Nottingham, and a co-ownership community offer in Bristol.

The Trent Basin project (a grant funded demonstration project supported by Innovate UK) comprises a variety of technologies, including household and community PV, fed via private wire to the battery, which is grid connected. There is also a heat pump network and thermal store powered by the PV/battery combination. Revenue streams come from grid export and sale of heat services, as well as a frequency response-type contract for the battery system. However, to operate the community energy scheme as a commercially viable entity, it relies on a minimum amount of PV being used for generation.

In Bristol, Thrive Renewables is offering up to 20% investment in a new battery energy storage project. This allows residents to own a share of the asset through BEC (Bristol Energy Co-operative). The project was developed in response to the shared ownership model, which enables community efforts led by BEC and Residents Against Dirty Energy (RADE). Together, they successfully opposed a previously proposed diesel-fuelled Short Term Operating Reserve (STOR) plant on the same site. In recognition of this, Thrive Renewables has extended the co-investment opportunity to local residents, allowing them to take on the entire risk and financial underpinning of a community-scale battery. The Feeder Road battery has the capacity to deliver 1-2 hours of electricity, providing flexibility services such as frequency response and balancing services to the national and local grid. It will also participate in both wholesale market trading and future Capacity Market auctions.

While these projects do provide exciting exemplars, community energy initiatives suffer from three main challenges:

1. **Lack of skills**. While some community groups are able to push forward innovative projects, this tends to rely on the voluntary involvement of local “specialists” who have the necessary skills and knowledge to establish the project, source funding, and interact with technical experts to deliver. By its nature, this limits the ability of community groups to initiate and drive projects, and risks injustices occurring given the disparity and availability of skills and time contributions across different communities.
2. **Lack of funding**. Community scale projects typically rely on some form of grant funding. Loans can be problematic as backers tend to look for certainty in returns, which, since the demise of the feed in tariff, does not exist. The additional uncertainty introduced by the review of market arrangements add further challenges.
3. **Grid connections**. This is a major issue for community groups who often do not understand how to navigate this landscape. They often take considerable time getting projects established and then have to navigate a long queue for connections, which can completely derail their projects. For communities behind constrains, this can bring further challenges.

These three challenges make opportunities like the Bristol Thrive project particularly interesting, enabling communities to engage with, and benefit from, community scale assets while not requiring them to have the background skills to lead the development and delivery. This marks the first time in the UK that a commercial standalone battery storage project has offered community co-ownership.. However, there is also a risk with shared ownership / third party led developments that once the project is up and running, the commercial organisation buys the community out and doesn’t deliver the anticipated local benefits. The standardisation of contracts and appropriate legislation could be key to ensuring community benefits from shared ownership projects.

Demand Side Flexibility

Demand side flexibility involves reducing household demand when electricity prices are high or when networks are constrained. Typically, this involves turning down demand in response to a signal, either when prices rise on a time varying energy tariff, or in the presence of a demand response signal. While behaviour-based approaches are available, require households to manually modify demand, and usually require day ahead notification, and pre-specified times during which to turn down (or up) demand. However, there are also some systems that support automated demand side flexibility, particularly for high energy and power appliances that enable power draw to be somewhat decoupled from usage, most notably for space heating, water heating, and EV charging. The following sections provide some examples of how this can be implemented.

Storage Heating: Connected Response

Connected Response is a company providing smart charging for residential electric storage and water heaters. The system includes:

- A smart load control switch situated next to the resident’s smart meter
- A temperature and humidity sensor in the resident’s living room
- Building-level gateways to interact with connected devices
- The Connected Response cloud-based server to manage the system

These elements allow for existing storage heaters and water heaters to draw power from the grid according to resident's heating preferences, actual home temperature and the next day's local weather forecast. Further dynamic optimisation according to wholesale energy prices or levels of local renewable generation is also possible.

Connected Response devices are also being used to enhance diversity of demand in load constrained areas, for example, as part of SSEN's Load Managed Area (LMA) Project. This allows for storage heaters to be recharged at times of lower network demand, reducing the need to increase network capacity.

Heat Pumps: Passiv

Passiv produce a smart thermostat that leverages local weather forecasts to determine optimal times for heating homes and hot water via connected heat pump control. This can help households save money on their bills, for example, by aligning heat draw with times of low energy costs (e.g., through dynamic TOU tariffs) or with high levels of rooftop solar generation.

In addition, the Passiv system integrates with Greener Grid Payments, the UK's first automated Demand Side Response Service for heat pump owners, by automatically responding to network signals.

EVs: Electric Nation

Electric Nation was a National Grid NIA project running from 2020-22. It focussed on exploring the impact of Vehicle-to-Grid (V2G) charging on the LV network, and the role that V2G could play in managing network demand. Through the project, 97 EV chargers were installed across four different customer supplier propositions provided by Centrica, Green Energy UK, and Igloo Energy. In all cases, the CrowdCharge EV charging optimisation platform was used to manage demand.

V2G operation was shown to support evening peak management by allowing the "house load to disappear from the LV network" by leveraging energy stored in the EV. However, this then means that the peak overnight load was higher with V2G chargers than non V2G (even with tariff-based charging) because vehicles were frequently discharged in the early evening and therefore required greater levels of to recharging overnight.

The project also encountered a number of barriers, mainly due to: (1) the presence of multiple EVs at a single address, which created technical complications and often meant the second vehicle couldn't charge; (2) long lead times for G99 grid application approvals for charger installations and lack of standardised response across NGED depots; and (3) lack of auto fault detection processes.

In addition, while this project demonstrated the potential for V2G to support demand flexibility in the household / behind the meter context from a technical perspective. However, it's not clear what the customer value proposition might look like in terms of accessing multiple value streams in a BAU deployment. Further, while this may work for individual homes, it is less likely to be appropriate for public charging, where customers have less time flexibility, and business models rely on maximising the number of cars charging over the course of the day.

Community Microgrids

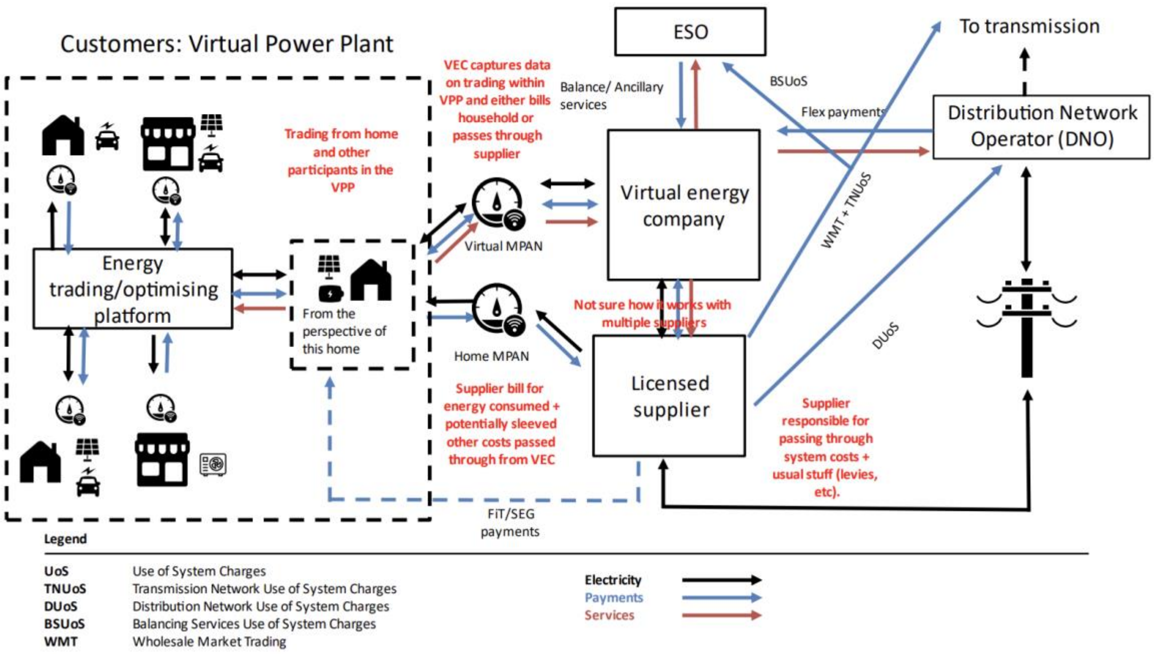
Almost all examples of community microgrid projects were drawn from the recently completed Prospering from the Energy Revolution (PfER) programme, led by Innovate UK. Substantial analysis on the PfER funded demonstration and design projects has already been conducted by the EnergyREV Research Consortium, the Energy Systems Catapult, and Sustainable Energy

Futures. Here we draw heavily on analysis presented in the 2023 report to Innovate UK[12], led by Jeff Hardy, Jess Britton, and Laura Sandys, as well as the ‘Smart local energy systems: lessons for innovators’ report[13], prepared by Simon Gill for Innovate UK.

Virtual Power Plants (VPP)

This category of solutions focussed on optimising assets behind a ‘virtual meter’, with a goal of achieving various energy system related outcomes. An overview of a VPP configuration is depicted in Figure 9, which shows the electrical, financial, and service-related relationships between NESO, their DNO, supplier, virtual energy company, and individual homes and businesses with assets capable of providing services (e.g. trading or sharing of energy, resolution of local constraints, maximisation of self-consumption of local renewables, etc).

Figure 9: Virtual Power Plant configuration. Image from [12]



The projects that have begun developing a VPP approach include ReFLEX Orkney and Liverpool Multi-Vector Energy Exchange.

ReFLEX Orkney

ReFLEX (Responsive Flexibility) Orkney was a £28.5 million project aiming to create an integrated energy system (IES) in Orkney, Scotland. The project was funded through the PfER programme, with a goal of locally linking transport, power and heat networks into “one controllable, overarching system, digitally connecting distributed and variable renewable generation to flexible demand.” At

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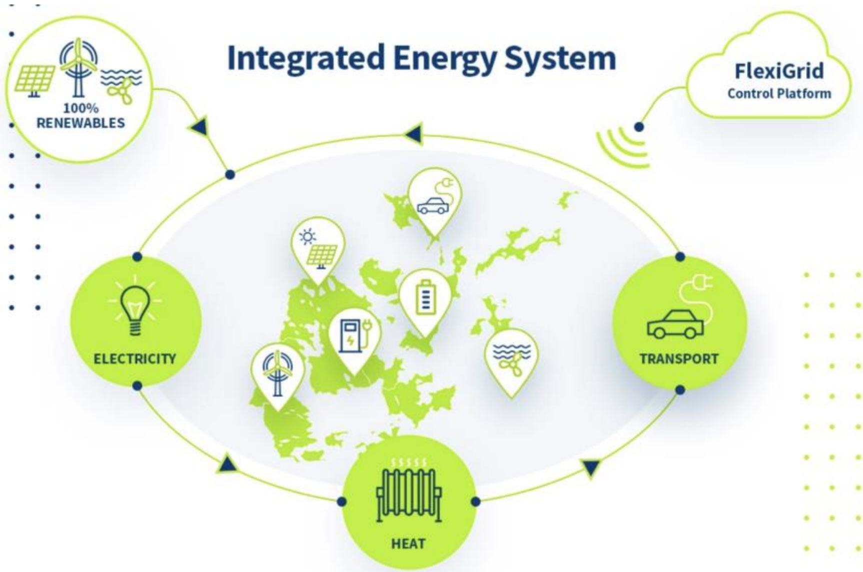
[12] Sustainable Energy Futures Ltd., (January 2023). [Enabling Decentralised Energy Innovation: Analysis and methodology]. Report prepared for InnovateUK.
[13] Gill, S. (April 2023). [Smart local energy systems: lessons for innovators]. Report prepared for InnovateUK.

its core, the project aimed to demonstrate the potential for household scale technologies, including battery storage, EVs, and smart chargers to provide flexibility services, which in turn aimed to help:

- maximise the use of local renewable generation;
- ensure higher quality and more affordable energy services; and
- accelerate local decarbonisation efforts.

Through a FlexiGrid control platform (see Figure 10), the IEG manages connected assets (e.g. EV chargers, household scale storage) to meet both customer and network requirements. Value is generated for flexible assets through the provision of grid services.

Figure 10: Orkney's IES and FlexiGrid platform



The project showed the potential for EV charging to help reduce the curtailment of local generation in situations where chargers are co-located behind the same network constraint. While this approach to EV charging worked well for household level chargers, there could be challenges in translating this to the context of community scale chargers, as it required flexibility in charge time and duration. This aligns with the use case of people plugging their cars in at home, where they have longer and more flexible time periods for charging. However, the use case for community chargers may have less temporal flexibility – people are likely to want to use the charger while out (e.g. while shopping) and may not have the luxury of waiting for the "best" time according to network conditions.

Other barriers were identified by the project, including:

- **Regulatory**. Existing regulatory arrangements limit the value that can be provided to customers, especially in generation constrained areas.
- **Financial**. Long payback periods and significant debt risk for investors affected the financial viability of ReFLEX's no-upfront-cost model for domestic PV and battery systems.
- **Customer Experience**. The combination of multiple user-facing elements (solar, storage, EV chargers, demand management etc.) means that there is a complex customer experience as households need to interact with different manufacturers, service providers, financing companies, and operators separately.
- **Business Model**. The IES requires a business model that requires a reimagining of all aspects of the energy system and operating models. For example, managing the IP owned by individual organisations and supporting pre-agreed licence mechanisms to ensure IP owners get benefits while also enabling whole system implementation. The

ReFLEX project estimates setting up appropriate business models to handle the complex arrangements requires a budget of £1M for set-up and £0.5M per year to operate.

- **Data Security**. The use of multiple data sets across a complex, multi-partnered project needs detailed planning and resource from the start.

It's also important to remember that the context of the ReFLEX project was grounded in overcoming the substantial curtailed energy generation on the island, and even in this context, struggle to deliver value. Without local generation, it's not clear: (1) if there would be sufficient local supply to balance local demand downstream of the network constraint, and (2) whether sufficient value could be captured through flexibility services alone.

Liverpool Multi-Vector Energy Exchange (LMEX)

The LMEX project focussed on the design of a local trading pool, business models to attract investment and drive market liquidity, and an energy and flexibility services marketplace known as the Liverpool Energy Exchange (LEX).

All connected assets are monitored, and software dispatches local energy assets based on market and network conditions. Revenue comes from trading energy and flexibility via the LEX, which participants need to pay a fee to join, that reflect the value and opportunity they will get from participating in the market.

An energy exchange model was developed for the LEX, as was a controller to integrate end use assets with the exchange, and a market platform including user interfaces. However, these technologies were not tested in the real-world context, and findings are thus based on simulation and analysis. However, analysis suggests significant financial benefits at a city level (i.e., based on 600 buildings).

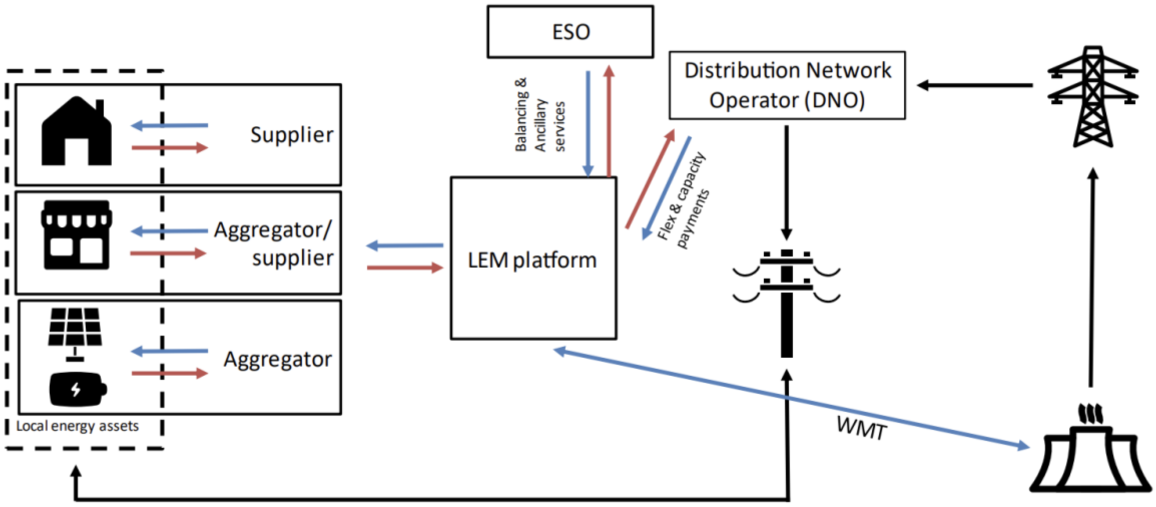
The project also uncovered some key challenges:

- **Supply Licence**. A supply licence is required to enable local peer-to-peer trading within the marketplace. In the LMEX project this presented a significant challenge, requiring the LMEX market operator to become a licensed supplier, or partnering with a licensed supplier. However, in the REACH context this may be more manageable as licence exempt routes do exist for smaller projects.
- **Markets**. Current market arrangements are based on national wholesale energy trading. These don't preclude local trading, but the lack of data on local energy system operation and constraints hampers the business case for local flexibility and local markets.
- **Standardisation**. Current software and hardware lack standardisation of protocols, products, and services.

Flex-Enabled Business Models

This includes projects like Local Energy Oxfordshire (LEO) and GIRONA. In this approach, business models are developed that help unlock flexibility from local assets to provide local (and national) energy system services. Typically, the driver for such an approach is the presence of local grid constraints, as well as a desire to capture local value from local assets.

Figure 11 Flex-enabled business model architecture. Image from [12]



Assets may be behind the meter or may be grid connected, with different commercial arrangements needed for the different contexts (e.g. via local supplier for homes and small businesses, or directly with aggregator for other assets). This approach aims to match local flexibility services with DNO (or ESO) needs.

Local Energy Oxfordshire (LEO)

Project LEO (undertaken in parallel with SSEN's project TRANSITION) couples two approaches:

1. Bottom-up support for local energy projects operating at the grid edge; and
2. Top-down development of local DSO flexibility markets

As well as supporting the development of local trial projects (e.g., V2G EV charging, household demand side management, local solar), Project LEO has developed a market framework to enable both procurement of DSO services and local peer-to-peer trading. Two sets of DSO market trials were run whereby local assets were used to provide a range of DSO services, including peak management, and fast, dynamic response following a network fault. This has helped provide insight into value streams for grid edge assets, although the project summary report notes that future trials are needed to explore additional value and revenue streams.

The project also identified some challenges with a flex-enabled business model:

- **Limited Participation and Value**. Limited number of assets able to trade behind the limiting network constraint. In addition, low commercial value, with high upfront costs are needed to enable participation; the Low Carbon Hub reviewed its portfolio of generation and storage assets and identified a maximum 10% upside on expected income from flexibility services depending on the asset type.
- **Market Liquidity.** Not enough participating assets to support DSO service offerings. In the Sustain Peak Management service, all bar one auction were illiquid with less capacity offered than required.
- **Data**. A wide range of data is needed, and data management proved to be a major project activity; the process of standardising data formats and ensuring and maintaining data quality took significant resource, which may be prohibitive in smaller contexts like REACH.

GIRONA

The focus of the Girona project is to create a micro-grid of approx. 60 homes in the Greater Coleraine area of Northern Ireland, including household scale microgeneration and storage. The approach developed in the project focuses primarily on behind the meter assets rather than community scale assets and aims to save customers money on their energy bills through optimising household level demand. A renewable energy management platform (PARIS), operated by The Electric Storage Company, leverages forecasts of energy production, energy demand, network constraints and market prices and dispatches resources to determine whether household assets should use energy, store it, trade, or provide grid services.

The PARIS platform provides data interfaces compatible with industry standard schemes (e.g. SCADA), and the local behind-the-meter assets were managed to minimise loading on the local distribution network; this helped overcome local network constraints which would otherwise have limited the ability to connect new capacity.

However, the project struggled initially with signing up households, despite the clear benefits and requiring no cost to participate. It's not clear that such a "no cost" approach would be suitable outside of an innovation project such as GIRONA, given the challenges experienced by other PfER project in developing sustainable business models where value streams from assets cover high capital costs of deployment and set up.

In addition, the project experienced challenges related to contracting and legal arrangements with tenants, and bespoke documents needed to be drawn up and agreed before deployment.

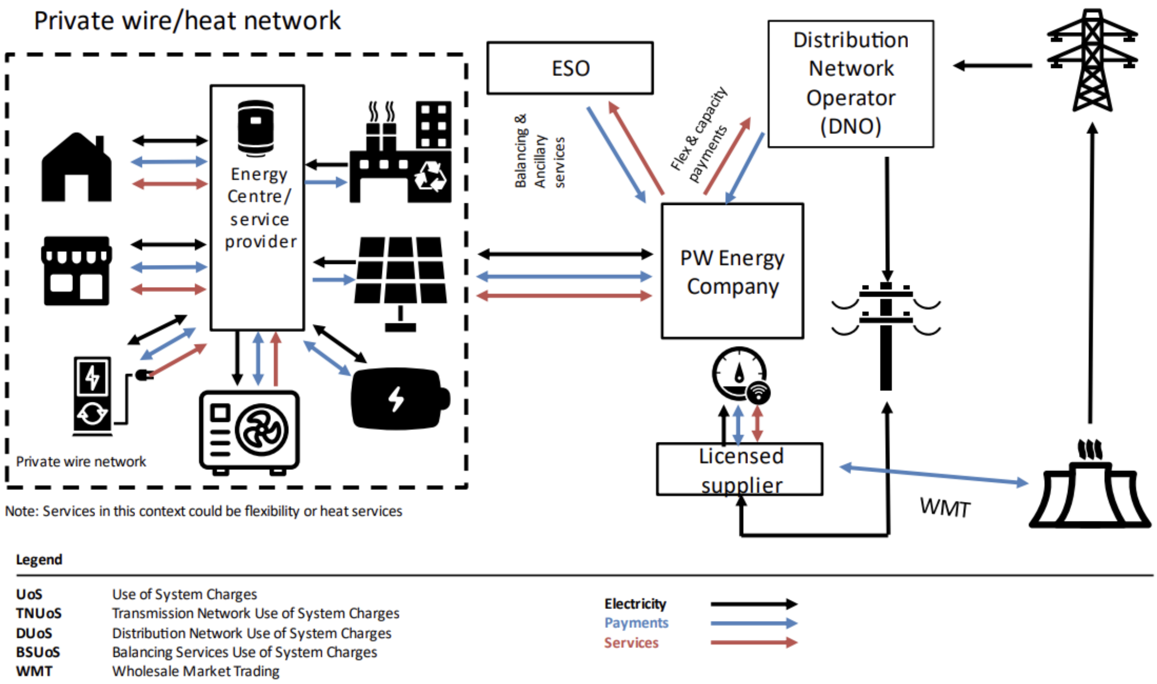
Private Networks

Within this model a private wire network is created for the purpose of delivering electricity and/or heating services to customers. For electricity networks, an energy company will need to operate the network, optimise demand, create contractual billing relationships with customers, and interface with the wider (non-private) distribution (or transmission) network. For heat networks, similar functions are required, but the heat network operator may not need to interact with the wider electricity system.

However, there are challenges with delivering capacity using this approach:

- **Regulatory**. Exemptions are needed from both supply and distribution licences. This can create constrains on network ownership and management. While licence exemptions are possible, these are only allowed under specific circumstances, for example, whereby the organisation that generates electricity is the same organisation that supplies it to end users. In the PfER project REMeDY, regulations around licence exemptions meant that the private wire model could not include domestic customers' electricity supplies or their behind-the-meter PV generation and battery storage.
- **Ownership**. Private wire networks must be owned either by the generator, the customer, or the owners or tenants of the property where the electricity is generated or consumed.
- **Economics**. Revenue streams from the sale of heat or electricity provide very long return on investments and may make schemes unattractive to investors unless additional value streams can be identified and captured.

Figure 12: Private wire network approach. Image from [12]



Summary of Alternative Options

Approach	Benefits and Challenges	Implications for REACH
Network Reinforcement	Once need is identified, key challenges relate to bottlenecks creating delays. Potential to overcome through re-rating overhead lines and running existing conductors "hot" until upgrade can be undertaken.	Ability to run lines "hot" will be on a case-by-case basis. This may be suitable if only minimal additional demand (e.g., EV charging) is needed, but for substantial new demand (e.g., new housing development) this may not be sufficient.
Dynamic Line Rating	Leveraging weather conditions to run lines at higher ratings is beneficial in specific contexts, but adds substantial cost, complexity, and the need for dynamic control.	Unlikely to be a suitable alternative for REACH where LV metered customers cannot be curtailed.
Phase Balancing	Balanced phases increases hosting capacity of the network. However, it requires accurate knowledge of demand on each phase and ability to manage demand.	Unlikely to be a suitable alternative for REACH given lack of accurate network knowledge and inability to manage demand in rural domestic contexts.
On Load Tap Changers	Can support voltage changes on grid edge and increase network capacity for both generation and demand. However, they are expensive.	Ground and pole mounted solutions may be sufficient to alleviate rural network constraints until reinforcement can be provided, however, pole mounted options are not yet available, and costs/suitability would need to be explored on a case-by-case basis.
Smart Transformers	Can alleviate constraints through managing voltage levels and provide additional benefits in absorbing harmonics and supporting power factor corrections. Expensive.	For the REACH use case these may be overly complex and costly for the benefits they provide. Also require regular maintenance and monitoring, which may be limited in rural contexts.
ANM	Can provide both generation and demand management through automated control of assets.	Due to insufficient network visibility, ANM cannot manage constraints at rural secondary substations.
Market Based Flexible Connections	Benefits and challenges are not yet clear as this is an ongoing project, however, insufficient market liquidity has been identified as a potential risk.	In the rural context with limited traders behind the network constraint, a lack of market liquidity is likely to present challenges.
Flexibility Procurement	A range of approaches / projects exploring flexibility procurement generally show potential and interest from households. The main challenges relate to contractual arrangements being overly cumbersome, and not providing enough value for customers to invest in new flexibility technologies.	This approach could align with a rural modular energy centre to provide an *additional* revenue stream for both the community scale battery and aggregated DSR from homes. The modular energy centre could sit between the DSO and customers, helping streamline contracting

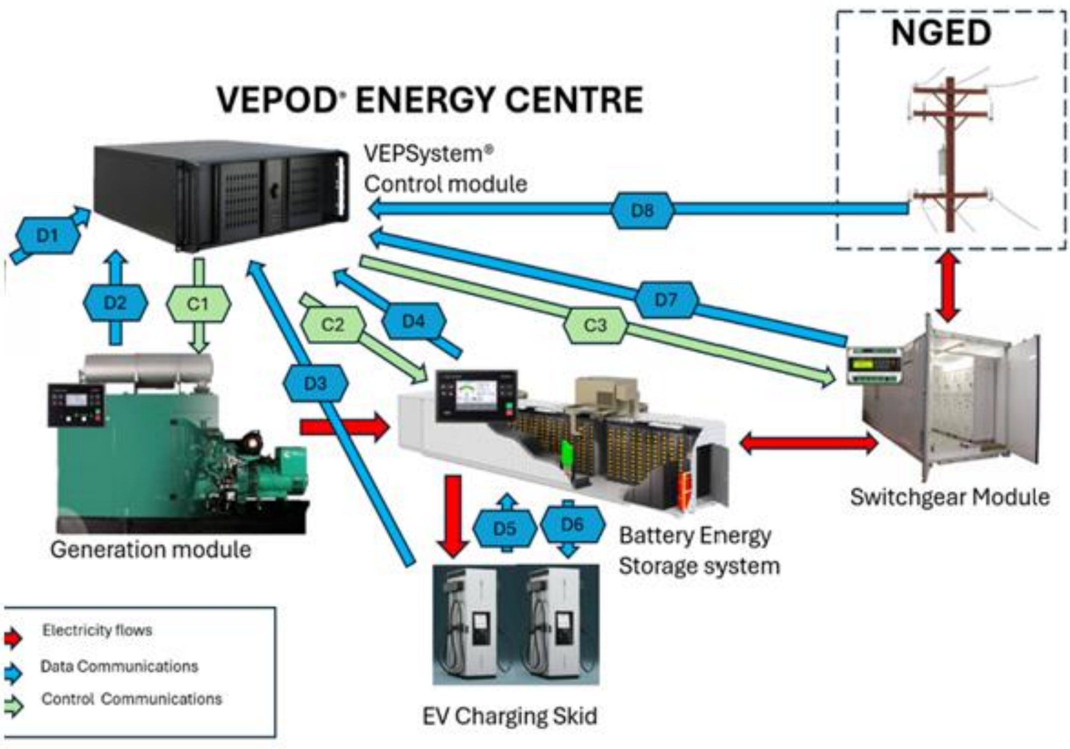
Approach	Benefits and Challenges	Implications for REACH
		processes and overcoming market access issues for individual homes.
Community Scale Assets	Can provide environmental, social and financial benefits to communities. However, setting up schemes is costly, risky, and requires appropriate skills and "know how". Grant funding and shared ownership models can overcome some of these challenges but may not be desirable for some communities who want to fully own the asset.	The modular energy centre could incorporate community owned / shared ownership assets (e.g., the battery unit) to provide benefits back to the community. Different models could be developed for different community preferences and needs. A commercial partner could also work with the community to navigate contractual, regulatory, technical and financial barriers.
Demand Side Flexibility	Can provide an attractive opportunity for households to see financial benefit from assets they already own. Some behavioural or technology changes may be needed.	In the REACH context, integrating demand side flexibility into new heating technologies may provide a revenue stream that supports initial capital investment (by households or a third party) with limited impact on home heating outcomes. The energy centre could act as an aggregator to further streamline processes. However, this may not be an appropriate solution for public EV chargers with less flexibility around time of use.
Virtual Power Plants (VPP)	Enables household and community scale assets to be optimised for various outcomes. In the VPP approach assets trade energy/flexibility behind a 'virtual meter', however, market liquidity and system complexity may present challenges.	In the rural setting with limited demand and very few (if any) generation assets behind the network constraint, market liquidity is likely to prevent trading. In addition, the data requirements are likely to be beyond the scope of REACH.
Flex-Enabled Business Models	This approach develops business models that map local energy assets to value streams for energy system services via a LEM platform. However, market liquidity, data complexity, and limited value streams for end users present challenges.	Similar to the VPP approach, this model may be overly complex for the rural setting, and lack of interest/participation may make this unsuitable.
Private Networks	While this approach may completely overcome existing network issues, it presents significant challenges, including regulatory exemption requirements, ownership challenges, and unattractive economics.	This approach may be suitable for new housing developments, though significant challenges are likely to exist with regards establishing and running the system. However, for most rural use cases (e.g., heat pump

Approach	Benefits and Challenges	Implications for REACH
		and EV adoption) this approach is unlikely to be suitable.

REACH Modular Energy Centre

Reviewing the range of alternative options, it appears that many are compatible with the REACH Modular Energy Centre and their applicability would depend on the specific context within which it was deployed.

For example, flexibility procurement options could provide additional value streams for the battery and enhance financial viability. The battery and EV chargers that form part of the modular energy centre could form community scale assets should there be interested in whole or part ownership by the community. Demand side flexibility could be provided through both the EV charging and heat pump elements, and the integrated system could be operated as a community microgrid with the modular energy centre providing the management platform



The main approaches that *might* negate the need for the modular energy centre (specifically the storage and local biofuel generation components) to support adoption of LCTs (heat pumps, EV charging) in rural settings include network reinforcement or smarter network management approaches. Given that network reinforcement is likely at some point in the future, and the role of the modular energy centre is to enable LCT adoption earlier than planned reinforcement, it is possible that re-rating lines and running them hot could provide the buffer needed in some cases. This would make sense, particularly in locations where the upgrades include line replacement and where the waiting period to carry out the work is relatively short-term (<18 months). In addition, deployment of on load tap changing transformers / smart transformers and updates to P5 load profiles, may provide sufficient headroom for LCT adoption until network upgrades are possible. This would need to be determined on a case-by-case basis and would likely depend on the scale of additional new demand from LCTs, the timing of that demand (and changes to load profiles), the speed with which that demand was needed, and the aspirations of the community to own/manage community scale assets.

Conclusion

At this stage there is still further work to be done within network assessments, as in spite of the acknowledgement from all of the DNOs that there is a theoretic issue resulting from rapid demand increases in areas where reinforcement is protracted, it is difficult to forecast when and how often the situation will occur. As expected, the high-level analysis of the network and more detailed studies of the seven participating communities within the Alpha Phase did not flag any actual constrained communities in normal operating conditions. It did reveal that there are in some issues in ‘n-1’ fault conditions, highlighting the already reduced headroom in certain areas that could develop into the constraint scenarios that may be appropriate for a REACH type intervention. ‘n-1’ conditions are normally quite transient and often resolved relatively quickly to restore normal running which render such scenarios as being unsuitable for a REACH Hybrid module. This is a fairly common situation and DNOs already have more appropriate, quicker and lower cost alternatives to manage and restore normal running. It is therefore important that we balance the need to develop a solution for new longer duration constraints ahead of need, in line with a responsible approach to the use of customers money to fund innovation. There will therefore be a brief hiatus between the end of Alpha and the submission of a Beta project application. During this time NGED will carry out further analysis to identify suitable communities that are more likely to encounter constraints that fit the problem statements outlined earlier in the document.

Even with the additional work that will precede a Beta application there is a low expectation of identifying multiple incidences of constraint scenarios that will require a REACH ‘type’ solution. The conditions that would bring such constraints about are most likely to be the exception rather than the rule and will be far more likely as we start to see greater volumes of households shift towards LCTs, away from ICE vehicles and fossil fuelled heating technologies. That doesn’t mean that impacted communities can be disregarded, and it is important that work continues towards further the understanding of the risk, the regulatory conditions relating to the cost of providing a solution as well as the engineering challenges of developing such novel solutions. The research carried out in this work package highlights the lack of alternative options currently available that would be suitable for rapid deployment that are capable of resolving the problem statements. It is also worth noting that the current regulatory settlement neither requires DNOs to provide a rapid solution for them or affords the authority to own and operate a generator / battery hybrid that is allowed to operate in the commercial schemes that have been included in the Cost Benefit Analysis (CBA).

As demonstrated in the table of alternative options, there is little else currently available, beyond flexibility service programmes and sweating existing assets harder to manage the period between identification of a constraint and the reinforcement of the network. In fact, these two strategies, if viable, should be preferred options to precede a REACH solution, as they are likely to be far lower cost options with almost no disruption necessary. If flexibility and re-rating assets are insufficient, then in the absence of any other interventions it may be necessary to introduce a moratorium on any new LCT installations to households within the impacted communities. This too will need to be considered by the regulator to ensure that DNOs have adequate powers and the industry has sufficiently robust processes to enact new policies of this type.

Probably one of the biggest positives that is being evolved through the REACH approach, and as a direct result of the learning through the SIF process has been the recognition that there is a significant opportunity to leverage the conditions to ultimately trigger a new community energy scheme. Through the engagement that will be necessary to work with the community and provide a temporary solution, and the groundworks necessary to deploy, there could be a strong catalyst for a community to work with NGED and the options tool to investigate commercially feasible configurations of modules including public EV chargers and community scale storage that deliver enduring benefits.

Appendix A – Layman Search Results

Initial look at GOV.UK guidance on "How to register energy devices in homes or small businesses: guidance for device owners and installation contractors"

This page was helpful and gave guidance on which energy devices need to be registered with your local DNO as well as links to building regs and planning permissions.

https://www.energynetworks.org/assets/images/Resource%20library/G99%20Type%20A%20Final%202020.pdf

https://www.energynetworks.org/assets/images/Resource%20library/Electric%20Vehilcle%20Chargepoint%20and%20Heat%20Pump%20Combined%20Installation%20Process%20Flow%20Chart%20v1.3.pdf?1738248421

there were also links to legislation, process flowcharts and application forms which were very complicated and daunting.

At no point does it say that you might not be accepted for approval by your DNO.

I googled 'power supply to remote areas' and I got several terminologies to make further searches

- Wikipedia gave me Stand-alone power system (SAPS)
- Off-grid power system

I got several results for these searches:

Marlec renewable power – this company small scale energy solutions for remote areas using solar and wind for illuminated signage, lighting, security cameras, bus shelters, EV chargers.

https://www.marlec.co.uk/

Leading Edge – this company manufactures small scale solar panels and wind turbines along with long lasting deep cycle batteries to support radio communications, meteorology, telemetry, environmental monitoring and rural broadband.

https://www.leadingedgepower.com/

- these two companies offer solutions, but on a very small scale

Base Power – New Zealand company offering complete independence from grid power supply. They provide the solar panels to harness the energy from the sun, an energy storage unit (ESU) with batteries, optional backup generator, skid mounted and pre-wired for rapid install and connection.

https://basepower.co.nz/stand-alone-power-systems/

- This company offers a permanent solution to a rural area. May not be easily relocated to another site once the grid infrastructure is upgraded to support the local community.

I spoke to an event management company, **Live Event Management** regarding how they get power to their clients for rural events. They use a mix of diesel generators and a hybrid model with generators, batteries and solar panels.

I also looked at how **Glastonbury Festivals** powers it's event which is on a large scale.

https://www.glastonburyfestivals.co.uk/news/glastonbury-2023-to-run-fossil-fuel-free/

These are very temporary solutions to getting power to a remote location and probably not sustainable for a long period of time.

A search of 'Off-grid power system' gave the best results:

Sunstore – Sunstore Solar off-grid systems include everything required to generate renewable energy. They are ideal in situations where no grid connection exists or where the power supply is not sufficient or reliable. They are also perfect for supplementing energy requirements from renewable sources.

https://www.sunstore.co.uk/solar-power/off-grid-solar-systems/

Powerguard – they provide power to any location, whether commercial or residential, from small self-contained units right through to large commercial properties and everything in between.

https://powerguard.co.uk/off-grid-systems/

Energy Solutions – this company offer off grid power systems supplying high quality hybrid power systems to residential and commercial customers across the UK and internationally for whom connection to the grid is not a viable option.

Their range of Off Grid Solutions includes EasyGrid – a plug and play hybrid solution for homes and businesses looking for a straightforward, affordable way to generate their own power and Containerised systems – robust, semi bespoke systems ideal for isolated projects.

https://www.energy-solutions.co.uk/applications/off-grid

https://www.energy-solutions.co.uk/applications/off-grid