Annex 4.3

WHOLE SYSTEMS STRATEGY

The purpose of this annex is to explain:

- what we mean by whole system;
- our whole system outcomes and deliverables; and
- how we expect to collaborate to achieve them.

Supporting documents - please see also:

- Northern Powergrid 2023-28 business plan;
- Northern Powergrid 2023-28 business plan annexes:
  - 1.5 Detail on our Consumer Value Propositions (CVP);
  - 3.3 Detailed engagement findings - whole systems;
  - 4.1 Scenarios and investment planning;
  - 4.2 DSO strategy;
  - 5.1 Innovation strategy; and
  - 6.7 Engineering Justification Papers (EJPs) – relevant references included within this document.

The whole system and our role within it

Electricity networks are at the heart of the ongoing transformation of the energy system

As described in the scenarios and investment planning section of our plan, we are exploring the range of credible decarbonisation pathways that could materialise and have developed our planning scenarios in relation to a broad range of plausible outcomes. All credible decarbonisation pathways that deliver net zero by 2050 see electricity playing a central role in decarbonising society's energy needs across transport, heating, and industry. The optimal pathway to decarbonisation is unlikely to involve just electricity; hybrid, cross-vector technologies such as hydrogen could be vital in enabling decarbonisation across all sectors.

We need to ensure that the electricity system is ready to play its part in this whole system decarbonisation. This is both an opportunity and a challenge. We think the timing is perfect – as it comes at a time the distribution network operators (DNOs) are making the transition to a distribution system operator (DSO) and are poised to make significant investments in the grid. The opportunity lies in optimising our investment initiatives in a whole system context from the outset.

Much of our 2023-28 investment is being targeted at digitalisation of our low voltage (LV) network – this is providing us with the ability to monitor the local growth in network use (be that from heat pumps, electric vehicles (EVs) or community energy). We may then manage this growth using customer and network flexibility and invest further in reinforcement when required (noting that conventional LV reinforcement may often be the right whole system solution as it enables customers to use their flexibility to deliver a wider set of energy market benefits). The data flows created by the increased digitalisation will require collaborative innovation with other parts of the energy system so that may make use of other data sets (e.g. smart meters) as well as provide open data that unlocks wider customer benefits.

Underpinned by our network investment plans and DSO transition, our whole system plan focuses on how we are integrating whole system thinking into our business, as well as the specific actions we will take to facilitate whole system solutions.

Our whole system plan will deliver significant benefits within the energy sector and beyond

By embedding whole system approaches, and investing £16m on specific initiatives, we will help deliver a greener, lower carbon electricity system at a lower cost for customers as we make more efficient use of existing assets. We will also help drive improved service and cost in other sectors such as transport and heat, and help achieve a net zero carbon economy.

The benefits associated with these initiatives are difficult to quantify by their nature, largely because they are realised at a whole system level, but also because they involve complex interdependencies between multiple parties. However, if stakeholders collaborate to take forward decisions that are optimal for the whole system the scope for benefits that materialise can be significant. Recent work by the Carbon Trust and Imperial College has found that optimising costs across the whole electricity system rather than at the individual distribution network level would lead to savings of £0.6bn per year (under an electric heating and high flexibility pathway) – equivalent to £6bn over 10 years.[1] A subset of these benefits are also reflected in the National Grid Electricity System Operator (ESO) business plan, where the ESO estimated £1.4bn of net benefits over the next 10 years from specific actions in relation to:

- taking a whole electricity system approach to connections;
- taking a whole electricity system approach to zero carbon operability; and

[1] Carbon Trust and Imperial College London (May 2021) Flexibility in Great Britain, https://prod-drupal-files.storage.googleapis.com/documents/resource/public/Flexibility_in_GB_report.pdf, p.146

- delivering consumer benefits from improved network access planning.[2] Our whole systems initiatives will contribute to these outcomes and more, going beyond the energy system to deliver benefits in the heating, transport, and other sectors.

Given the challenge associated with quantifying the system-wide benefits accruing from our whole system initiatives, we have estimated the net benefits of two initiatives where benefits are more clearly quantifiable:

- Our voltage optimisation initiative will deliver estimated net benefits in excess of £243m over the next 10 years[3] (at which time the rollout will be complete), through reduced electricity bills for consumers, and reduced carbon emissions: both delivered through the reduced electricity consumption associated with a reduction in supply voltage.[4] Beyond this period, the initiative will deliver an estimated net benefit of around £63m per annum.

- Our microgrid roll-out initiative will deliver estimated net benefits of around £10m over the next 10 years,[5] initially through the societal value attributed to the improved system resilience as experienced by customers, and increasingly through the support the microgrids provide to wider system security as the network loading increases as we approach net zero.[6] Out to 2050, this initiative will deliver an estimated total net benefit of around £20m.

These benefits are consistent across the various decarbonisation pathways described in the scenarios and investment section.

Defining the whole system and our role within it

Historically, our industry has focused on the whole system at the level of the electricity networks, but the whole system captures many other sectors and industries that are seeking to decarbonise.

Our work with customers, other energy system parties (e.g. the ESO, gas networks and energy suppliers) and stakeholders outside the energy sector (e.g. in transport and industry) has demonstrated that there are whole system opportunities to deliver even greater efficiency, emissions reductions, and better value for customers.

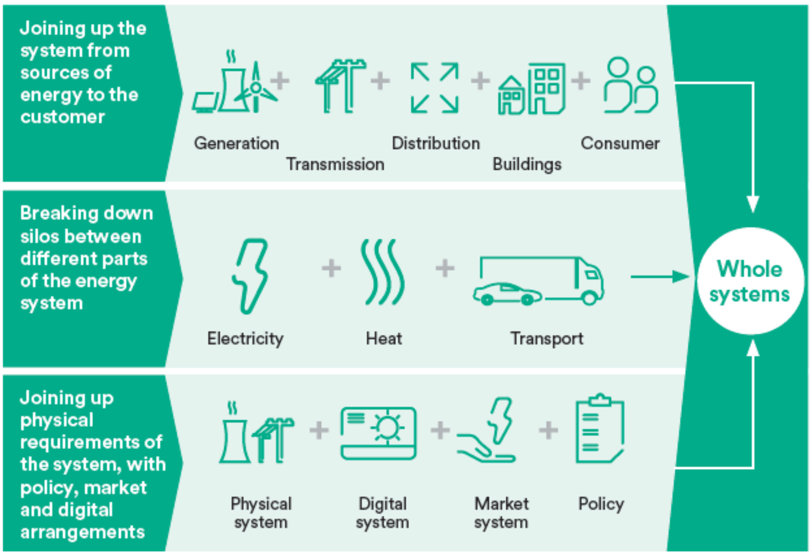

Figure 1: Energy system components mapped to a whole system model

[2] National Grid ESO (January 2020) RIIO-2 Business Plan Annex 2 Cost-Benefit Analysis Report. https://www.nationalgrideso.com/document/158061/download, p.16, Role 3 Theme 4 total
[3] Around £34m in the 2023-28 period and around £209m in 2028-33 period (assuming a five-year price control period).
[4] By 2023 we expect to have deployed this technology in three primary substations to manage energy efficiency.
[5] Around £1m societal benefits but around £6m total net benefits in the 2023-28 period, and around £16m total net benefits in the 2028-33 period.
[6] By 2023 we expect to have rolled out two microgrids on LV networks.

We will improve the whole energy system through widespread collaboration, lowering costs and improving quality of the energy services our customers receive

To achieve this, we are working to ensure that whole system thinking is integral to all of our operations in two ways:

- First, in understanding and playing our role within the whole system transition. This involves proactively managing the uncertainty around the decarbonisation pathway, understanding the potential roles of other vectors within the system, and investing in our network in a way that ensures we keep open all possible decarbonisation pathways. More details on our investment plans are provided in annex 4.1, scenarios and investment planning.

- Second, on a more day-to-day level, we are fostering a whole system way of thinking within our organisation and reflecting that in everything we do. In practice this means identifying issues affecting the wider energy system, and proactively exploring our part in addressing those issues. In some cases, our role will be to lead on innovative solutions, coordinating across sectors (for example, developing flexibility markets with the ESO). In others it might be to collaborate under the guidance of another sector, say by sharing relevant open data and information about our networks; please refer to DSO outcome 3.1 open insights in the main plan for further details. In others still, it may simply be to maintain a watching brief and keep open to opportunities where we are able to help.

Achieving our vision is important for wider sustainability as well as for customers. By enabling more efficient use of assets and helping unlock sources of both generation and demand-side flexibility, we can minimise the need to build new infrastructure on our own network and in the wider system (refer to DSO outcomes 4-5 in the main plan for more detail). It also supports our strategy to optimise whole system losses whilst facilitating net zero (refer to the losses strategy).

Progress made in the period 2015-23 has given us a strong foundation to take forward wider, more innovative whole system solutions

In the 2015-23 period we made significant progress in a number of areas, improving coordination and whole system thinking across electricity networks. Work is still ongoing in these areas, but some key examples of the progress made so far include:

- Planning: our investment planning processes now consider the ESO's future energy scenarios (FES) and Climate Change Committee (CCC) forecasts for GB as a whole (refer to annex 4.1, scenarios and investment planning, for further details). Our involvement in the Energy Networks Association (ENA) Open Network engagements has also improved our network development process (capacity signposting report). In March 2021 we also published our local area energy plan (LAEP) charter with Northern Gas Networks (NGN), setting out our commitment to four principles where we will support local authorities (LAs) in developing LAEPs. Further, the ongoing routine engagement on planning and new connections activity has developed with the statement of works and active network management (ANM) processes. More broadly, we have engaged with other sectors on flood defence measures and other climate change adaptation plans.

- Operations: we have improved coordination with the ESO through the summer 2020 COVID-19 lockdown system balancing arrangements. We have also been working with other DNOs through the ENA Open Networks project on network capacity, procurement, use of flexible resources, and maintaining system operational limits.

- Data and digitalisation: we are taking a more coordinated approach to gathering and sharing data with other networks (including independent distribution network operators (IDNOs)) and local authorities, including through the distribution future energy scenarios (DFES) consultation process and open data access.[7] Through the ENA we have been exploring new approaches that could be taken across gas and electricity on data triage and energy systems mapping.

- Innovation: facilitating whole system thinking has featured in the innovation projects we have undertaken. For example, we have established Integrated Transport Electricity and Gas Research Laboratory (InTEGReL), a whole

[7] https://odileeds.org/projects/northernpowergrid/dfes/

system test site built in collaboration with NGN and Newcastle University. InTEGReL is the UK's first test site that enables large-scale testing of whole system ideas bringing together the transport, electricity, and gas sectors.

- We are trialling dynamic voltage reduction that can only be implemented on the DNO system but will bring benefits outside our costs via customers' energy use and bills.
- Future microgrid enabled networks will increase dependability of electrical energy, facilitate local energy production and storage, and incentivise decarbonisation in communities.
- Optimising the value of the system for customers and customer assets: we have progressed rollout of ANM, voltage reduction at bulk supply points (BSPs); and static voltage optimisation at high voltage (HV)/LV.

Building on this experience, we plan to explore further whole system innovations broadening our view of the whole system beyond electricity networks and into other sectors.

In planning for the future, our stakeholder engagement has shaped our vision

We have engaged with a broad set of stakeholders within the energy sector and across other sectors (heat, transport, water, and industry), including regulatory bodies, consumer groups, and industry representatives including energy equipment manufacturers. Refer to annex 3.3, detailed engagement findings, for further details.

The key messages we heard from that engagement included:

- the need for sharing data and technical understanding (e.g. with LAs to help develop LAEPs);
- the desire for a collective approach to explore solutions to regulatory and commercial barriers; and
- stakeholders have a wide range of energy-related interests, many of which are about energy use rather than energy systems. Therefore, initiatives that improve demand and generation customers' lives or finances are of more interest than initiatives that are specific to improving the network.

We have put together an initial plan to respond to these stakeholder needs. While this plan makes good sense today, we need to keep it under review with our stakeholders and adapt it through the 2020s in accordance with what we hear from them and what we learn. We are encouraging our regulator to give us this room to adapt and to support this view that the plan should be ever changing to respond to customers' needs and capture the benefits from technologies or other developments that are not yet known.

Driven by what we have heard from our stakeholders, there are four strategic objectives guiding our whole system planning

Drive whole system decarbonisation	🟡	As increased use of our network facilitates decarbonisation, we will look to use whole system solutions to optimise carbon reduction and improve performance, at an affordable price.
Unlock value for customers	🔵	Customers will be able to realise value from their assets through active engagement, providing services to the energy system and to each other, releasing whole energy system cost savings.
Create a network for the next generation energy system	🟢	We will set out the blueprint for a next generation local energy network that links up energy sources and vectors, balancing in real time, to ensure a reliable and dependable energy service for customers.
Collaborate with proactive whole system planning	🟣	Customers' future needs will be met through cross-sector planning, both across the energy system and with suppliers and developers of technology, allowing customers to take advantage of new opportunities.

Figure 2: Our four strategic objectives

These strategic objectives have shaped our whole system plan for the next five years. Guided by these objectives, we set out in the next two sections:

- the whole system approaches we are undertaking across our business, to ensure that our strategic objectives are reflected in our day-to-day decisions; and

- the whole system outcomes we will deliver through specific initiatives.

Whole system thinking drives planning and decision making across our business

Our strategic objectives will ensure that a whole system approach features in our operational decisions day-to-day and that whole system thinking is central to all areas of our business. Below we describe some of the key approaches that we are implementing across our business to achieve this.

- A flexibility first approach to network development. In investing in our network to enable decarbonisation, in particular with increased digitalisation and data analytics, we will take a flexibility first approach where we can deploy customer or network flexibility ahead of network reinforcement. This will help us optimise the value of our own and our customers' assets. As explained in the scenarios and investment annex, we will invest £87.4m on flexibility-enabling actions in the period 2023-28, to deliver £169m of benefits for customers in the period.

- Understanding and managing cross-sector interdependencies. We will collaborate with other regional infrastructure operators (e.g. gas network operators and water companies), together with the Environment Agency and regional bodies such as Local Resilience Forums, to build a better understanding of cross-sector interdependencies. We will work together to formulate regional plans to mitigate the highest risks both from and to our network (e.g. flooding causing the failure of bridge structures carrying multiple utilities); understand the changing needs of other sectors and our impact on them; and improve resilience on our network (see the climate resilience strategy). We will invest around £2m, including contributions to collaborative projects.

- Using data and partnerships to enhance support to vulnerable customers. Targeted support through data sharing will make priority services and support tools available amongst trusted partners. Information on priority service membership (PSM) and our enhanced service offering, access to affordability services and social indicator mapping tools will be made available and shared to support the most vulnerable within society. This will also allow for collaboration referrals and targeted support for hard to reach and seldom heard customers (see our vulnerability strategy).

- Continuous data exchange with the ESO. We will build on established data and information sharing processes, to continue identifying and using opportunities for more efficient operation of the whole system. We will implement near-real-time two-way data exchange with the ESO to enable efficient short-term market operation. By providing two-way visibility of our actions to trigger flexibility, we can ensure that our actions are complementary. We will also continue to explore alignment in the way that the DNOs and ESO implement new flexibility services. We will aim to ensure that the specification and design of these services enables participants to participate in efficiently co-existing transmission and distribution flexibility markets.

We will undertake more specific whole system deliverables to achieve four outcomes, generating value and enabling decarbonisation in collaboration with other sectors

We have identified four specific outcomes that we will aim to deliver, in order to achieve our strategic objectives. Each of these outcomes will be delivered through a number of deliverables, such as targeted innovation projects.

We plan to invest £16m to deliver these initiatives, resulting in excess of £253m of savings for customers over the next 10 years (around £28m in the 2023-28 period and around £225m in the 2028-33 period).[8] We are not proposing uncertainty mechanisms to deliver this investment, but we are proposing a claw-back of the reward if we fail to deliver our outcomes.

[8] Note: where a whole system benefit has been quantified, this has been calculated using Ofgem's standard cost benefit analysis (CBA) template and expressed in cash terms, not net present value (NPV).

Below we set out each of the four outcomes. Details about each of the underlying deliverables are provided in the following section.

WS1	***We will remove barriers for customers to use their equipment to support the whole energy system***. To deliver this outcome we will identify barriers, such as information gaps and coordination challenges, which limit the ability of customers to connect, invest, use their assets efficiently, or use the energy system efficiently. We will work with these customers to understand their needs and then develop and implement solutions accordingly. This will enable customers to benefit more from the efficient use of their own assets and the existing system, facilitating cost savings as well as quicker and cheaper decarbonisation. By doing so, this outcome contributes to all four of our strategic objectives.
WS2	***We will ensure our customers' future needs are met through cross-sector and cross-vector planning***. We will work closely with energy industry parties and other stakeholders to ensure that network planning, as well as planning of wider investments such as storage and generation is carried out as efficiently as possible from a whole system perspective. This outcome cuts across all four of our strategic objectives.
WS3	***We will develop the blueprint for the next generation network by rolling out proven innovation***. As society becomes more dependent on electricity, we will seek ways to maintain and improve reliability, availability, and efficiency throughout the seasons. Many of these innovative solutions will require coordination with other energy sector stakeholders, and/or may be more expensive than traditional solutions but can deliver net benefits when costs and benefits are assessed on a whole system basis. This outcome delivers across three of our strategic objectives: whole system decarbonisation, unlocking value for customers and enabling a next generation energy system.
WS4	***We will exchange knowledge with those specifying future low carbon technology (LCT) and low carbon use cases***. We will work with partners beyond the energy system to foster whole system thinking in product and service design. If future products can be designed in a way that optimises their performance, reflects whole system needs, and minimises their impact on the electricity system, this will help contribute to low-cost decarbonisation. This outcome delivers across two of our strategic objectives: whole system decarbonisation and collaboration for whole system planning.

Figure 3: Whole system outcomes

Achieving our whole system objectives relies on specific, core elements of each of our three business plan enablers:

- Innovation: as well as building on recent successful innovation projects, we will explore, test and challenge new ideas to enable whole system decarbonisation through both incremental and large-scale innovation projects;
- Data and digitalisation: we will invest in our systems, as well as sharing data and information to facilitate cross-industry and cross-sector collaboration; and
- Workforce: we will train and recruit colleagues to embed a whole system mind-set in our business culture.

Our whole system deliverables and initiatives

We will deliver the four outcomes detailed through 18 specific whole system deliverables and initiatives. Deliverables are measurable activities that we will carry out, and initiatives are other supporting activities that are less measurable – both will contribute to delivering the four outcomes set out in the previous section.

The table provides a summary of the deliverables and initiatives. We have categorised these under the main outcome that they deliver, however we note that most deliverables and initiatives contribute to more than one outcome. A breakdown of costs showing which deliverables and initiatives are funded through whole systems, which are costed in the DSO strategy, and which are expected to be funded through innovation allowances is included in appendix A.

Outcome				
WS1: We will remove barriers for customers to use their equipment to support the whole energy system.				
Deliverable/initiative		2023-28 investment		Measure (2023-28 target)
		£m	FTE	
Deliverables	**WS1.1 Inter-seasonal storage** We will work with relevant stakeholders to understand the potential for inter-seasonal storage on the system, as well as identifying what else we need to do to facilitate and enable this future market.	0.3	0.5	Innovation project findings published (by March 2028)
	WS1.2 Connections matchmaking scheme We will set up an internal database and take an active role in matching connection parties that could have complementary energy needs, helping realise synergies in connection cost and speed.	0.4	0.2	Matchmaking scheme live (2025-26)
Initiatives	**WS1.3 Peer-to-peer trading** We will lead work engaging with Ofgem, BEIS, suppliers, customers and relevant trading platforms to identify any network-specific barriers to peer-to-peer trading, and options for solutions. In particular we will identify the information required by market participants to ensure safe network operation.	0.1	0.1	Innovation project findings published (by March 2028)
	WS1.4 Customer-led system balancing from distributed energy resources We will explore opportunities to use our existing ANM system to allow customers to provide services to third parties. In particular, the ANM system could potentially be used to allow customers to provide balancing services, by allowing aggregators or the ESO to call off flexibility using these systems. (Refer to DSO4.4 – costs recorded in the DSO strategy.)	1.0	0	Number of customers providing service (≥10)

Outcome				
WS2: We will ensure our customers' future needs are met through cross-sector and cross-vector planning.				
Deliverable/initiative		2023-28 investment		Measure (2023-28 target)
		£m	FTE	
Deliverables	**WS2.1 Enhanced cross-sector and cross-vector collaboration to improve network planning data** We will lead annual workshops and bilateral engagement to improve network planning data – particularly forecast load profiles. The aim will be to improve the DFES planning scenarios, to more fully reflect decarbonisation pathways across more vectors, and layer on the impacts of technological development in other sectors.	0.5	1	Workshops held (annual)
Deliverables	**WS2.2 Better understand the impact of mobile demand and generation** We will partner with other whole systems stakeholders, including other DNOs, energy suppliers, fuel suppliers, aggregators, town planners, highways agencies and others, to improve our understanding of mobile loads (primarily EVs). For example, we will explore what the key drivers of mobile loads are, how they are likely to react to certain triggers, and what this means for the range of potential load profiles. This improved understanding will then feed into more sophisticated modelling and network planning.	1.2	1	New network planning tool implemented (2025-26)
Deliverables	**WS2.3 Inter-seasonal energy planning** We will undertake an innovation project to understand how technological changes and consumer behaviour is likely to impact seasonal loads in the future. This will allow us to add to today's existing telemetry information, allowing us to provide more accurate and granular load forecasts, enabling effective planning and investment in inter-seasonal storage.	0.1	0.1	Innovation project findings published (by March 2028)
Deliverables	**WS2.4 Whole energy system batteries** Building on previous innovations, we will collaborate with NGN and other partners to better understand the technical characteristics of different cross-vector storage options, and how that technical capability might best be used to address both long-term and short-term storage needs.	0.2	0.1	Number of cross-vector innovation projects over the period (≥2)
Initiatives	**WS2.5 Trial commercial aspects of microgrid technology to enhance system resilience, particularly for remote customers** We will carry out work to better understand the commercial case for microgrid technology. For our early microgrid trials, we will partner with individual generation/storage providers that are willing to connect to the microgrids. We will work closely with them to understand the commercial barriers and challenges they face. We will also carry out work to help inform the commercial decisions taken by generation/storage providers, such as how frequently microgrids are likely to operate autonomously.	1.5	1	Commercial requirements identified and initial solutions in place (2025-26)
Initiatives	**WS2.6 Understanding the behaviour of flexibility specific load** We will carry out a study to better understand the behaviour of flexible loads, engaging with potential	0.3	0.1	Innovation project findings published (by March 2028)

	providers of flexibility to do so. In particular we will focus on understanding how responsive different types of loads are, differentiating between loads with flexibility built in (e.g. hybrid heat pumps, domestic heat batteries) and loads with flexibility potential (e.g. EV charging).			
	WS2.7 Understand the interaction between networks in flexibility scenarios We will work with other networks, in particular the gas networks and transport networks, to identify interactions created between networks through flexibility, and how best the impacts of these interactions can be managed.	0.3	0.1	Innovation project findings published (by March 2028)
	WS2.8 Local Area Energy Planning (LAEP) This initiative is covered in our DSO strategy. We are referencing it here because it has a strong whole system aspect. We will recruit a team of LAEP advisors who will provide useful input and feedback to local authorities on their plans using knowledge of the network, customers and the wider environment. These advisors will also support our network planning by generating better and more comprehensive local insights. To ensure a requisite level of granularity and local knowledge, we will employ one advisor in each of our six operations regions. (Refer to DSO3.2 – costs included the DSO strategy.)	2.3	6.0	Number of LAEP engagements reported (annually)

Outcome				
WS3: We will develop the blueprint for the next generation network by rolling out proven innovation.				
Deliverable/initiative		2023-28 investment		Measure (2023-28 target)
		£m	FTE	
Deliverables	**WS3.1 Roll-out of microgrid technology to enhance system resilience, particularly for remote customers** We will roll out fixed microgrids across 30 of our most vulnerable LV networks. We will also roll out six SilentPower vans, which will power homes while their electricity supply is being restored.	6.9	1	Number of microgrids rolled out on LV networks (30)
	WS3.2 Voltage optimisation for energy efficiency Building on our Boston Spa energy efficiency trial (BEET) Project, in the 2015-23 period, which is currently seeking to trial voltage optimisation technology at a larger scale at three primary substations; we will seek to roll this out across the network, should this project prove successful. Around 80 per cent of the network is expected to be appropriate for this approach, and 35 per cent will be done during the 2023-28 period. This project will deliver whole system benefits by reducing customers' energy usage.	8.1	5	Number of large-scale sites using voltage optimisation (196)
Initiatives	**WS3.3 Regulatory requirements for local microgrids** We will carry out an innovation project to identify and address regulatory and market barriers to microgrid rollout. We will partner with other DSOs, policy makers and relevant third parties.	0.5	0.1	Regulatory barriers identified and initial solutions in place (2025-26)
	WS3.4 Distribution asset-based ancillary services to ESO During the 2023-28 period we will work with the ESO to understand how we can best deliver value through the lessons learnt from CLASS (Customer Load Active System Services, an ENW innovation that uses voltage management to reduce electricity consumption at peak times). We will seek to provide this form of load reduction as an ancillary service to the ESO if we establish that it will deliver value. (Refer to DSO 4.3 – costs are included in the DSO strategy).	4.4	1	Percentage of network that can provide flexibility to ESO (50%)

Outcome					
WS4: We will exchange knowledge with those specifying future LCT and low carbon use cases.					
Deliverable/initiative		2023-28 investment		Measure (2023-28 target)
		£m	FTE	
Deliverables	**WS4.1 Optimisation of industrial and commercial customers' future equipment** We will collaborate with designers and manufacturers of industrial and commercial equipment, and their trade bodies. We will provide input on how equipment can be designed for optimal performance of the equipment itself, and our network. Our aim is to ensure that standards for both future equipment, and our network infrastructure, is specified for optimised performance and costs.	0.03	0.1	Number of manufacturers stakeholders engaged (≥15)
	WS4.2 Optimisation of domestic customers' future equipment As above, we will collaborate with designers and manufacturers of equipment, and their trade bodies – however here the focus is on domestic customers' equipment.	0.03	0.1	Number of manufacturers engaged (≥15)

Table 1: Initiatives and deliverables

The sections that follow are organised by outcome area. Under each outcome, we provide detail on each deliverable and initiative that will contribute to that outcome, including the context, the work we are proposing to carry out and the associated costs.

Remove barriers for customers to use their equipment to support the whole energy system

To deliver this outcome we will identify barriers, such as information gaps and coordination challenges that limit the ability of customers to connect, invest, use their assets efficiently, or use the energy system efficiently. We will work with these customers to understand their needs and then develop and implement solutions accordingly. This will enable customers to benefit more from the efficient use of their own assets and the existing system, facilitating cost savings as well as quicker and cheaper decarbonisation. We provide details below of the deliverables and initiatives that will enable us to deliver this outcome.

WS1.1: Inter-seasonal storage

Context

The energy system and customer needs are evolving, meaning that there is increasing seasonal variation in electricity generation and demand. In particular as heat becomes increasingly electrified, winter loads will increase. Conversely, the increasing use of solar generation means that the availability of renewable, low-cost energy will be greater in summer.

This seasonal mismatch in supply and demand could slow the pace of decarbonisation because fossil fuel generation will still be needed to help meet winter peaks, while solar generation assets are underutilised in the summer.

Inter-seasonal storage, using batteries and other energy storage technologies, can help address this seasonal mismatch in supply and demand, and speed up the rate of decarbonisation. It would allow energy to be harvested and stored when energy is plentiful and prices are low (e.g. in summer) and used when demand and prices are high (e.g. in winter). This will help to optimise and decarbonise the energy system by allowing excess renewable energy to be stored for when it is needed.

This is a new area where there is limited knowledge surrounding the required magnitude and characteristics of inter-seasonal storage, and the system impacts of different storage options. This lack of understanding and uncertainty could act as a barrier to the future storage market.

Our proposal

We will carry out an innovation project to understand the potential for inter-seasonal storage on the system, as well as identifying what else we need to do to facilitate and enable this future market. We propose to seek £0.3m of network innovation allowance (NIA) innovation funding to carry out this work (a full cost breakdown over the course of the 2023-28 period can be found at the end of this sub-section). We are well placed to carry out this work given our detailed understanding of local storage requirements and network capabilities, and the practical impacts of balancing these requirements and capabilities.

We will undertake initial work to identify the relevant stakeholders who may play a role in the future storage market. This could include solar generation operators (who may wish to operate their own storage, or partner with storage providers), other generators, retailers, etc. We will then collaborate with those stakeholders to understand the network-related barriers they might face, and how we can overcome these. The work is likely to involve exploring the following questions:

- What are the inter-seasonal storage needs likely to be in different local areas, and how might these evolve? (This will need to coordinate and tie in with deliverable 2.3: Inter-seasonal energy planning, where we will work with stakeholders to improve our seasonal load forecasts).
- What types of inter-seasonal storage options are available, and which might be best suited to meet the identified needs?

- What might the system impacts of these different storage options be? What challenges might there be in providing connections for these options, and can they be overcome?
- Are there different pathways to an optimised storage future? For example, in some areas it may make sense to use gas as a form of storage that can help meet winter peaks – this could initially be natural gas but then transition to hydrogen.

Overall, this deliverable will ensure that we are facilitating the storage market and enabling a future energy system where the optimal balance between generation and storage can be reached. This will ensure that seasonal variation in generation and demand doesn't slow the rate of decarbonisation.

WS1.2: Connections matchmaking scheme

Context

Decarbonisation and the use of LCTs increasingly means that there are potential synergies that could be captured by collaboration between different connection customers who have complementary needs. These customers could either be seeking new connections, or introducing new load on existing connections.

For example, a solar generation farm looking to connect to our network might face high connection costs based on its generation capacity during the summer, despite the fact that it would generate far less during the winter. If the solar farm could partner with a battery project also looking to connect in a similar location, there could be significant synergies in a joint connection. The battery could store the excess solar energy generated during the day, and release it overnight, reducing the likelihood that the connection will trigger capacity constraints and reinforcement. Both parties could benefit from lower connection costs as a result.

Many other types of partnerships could be possible, for example between intermittent generation and industrial users looking to invest in large fleets of EVs, or between large load sources that would be willing to coordinate their electricity usage to limit their total impact on the system.

These types of partnerships would not only result in cheaper more timely connections for customers, but could have wider decarbonisation benefits by increasing the amount of renewable generation connecting to the network.

There is a coordination barrier to realising these synergies because the relevant parties do not currently have access to information about other parties' needs, or a platform through which to meet and engage with one another.

Our proposal

We will invest £0.4m to carry out an innovation project to overcome this coordination barrier. We will do this by setting up an internal database, and then take an active role in matching parties that could have complementary needs. Once the initial engagement between parties has been facilitated, they can then work directly with one another to determine whether their needs are suited to a joint connection application.

We will need to be mindful of confidentiality requirements, so the match-making process will need to take place internally (rather than through an open database that parties can explore themselves), at least initially.

Eventually, if confidentiality requirements allow, we will collaborate with other network operators in our region to create an open register and process that allows interested parties with complementary energy needs to find each other.

WS1.3: Peer-to-peer trading

Context

Peer-to-peer trading allows parties connected to the grid to directly buy and sell energy from one another. For example, a consumer with solar panels on their roof can sell excess electricity that they generate to other users through a secure platform. More generally, peer-to-peer trading could be used for trading generation, storage and demand generated by solar panels, EVs, heat pumps, home batteries, and more.

This solution can deliver various benefits to customers, over and above the current approach of feeding electricity into the grid in return for a payment from an energy supplier (under the smart export guarantee, suppliers are obliged to offer a tariff and make payments to small-scale low carbon generators for electricity exported to the grid). It would mean that customers do not need to use an energy supplier as an intermediary to sell their energy, capturing the margin that would otherwise be paid to the supplier and receiving a better rate for the electricity they export. This would help customers get a better return on their investment in LCTs, and would help speed up the rollout of these technologies and enable efficient decarbonisation.

There are currently regulatory and legislative barriers limiting the availability and use of peer-to-peer trading. Fundamentally this is due to the supplier-centric model used for the GB electricity market, where, as energy passes out of a customer's network onto the public electricity network, it is sold to an energy supplier meaning that suppliers take their fee twice (once through each meter) on a trade between two next door neighbours. This is akin to a car manufacturer demanding that one sells a car back to them before a neighbour can buy it. Moving to a customer-centric model would assist in addressing this barrier to market entry for non-suppliers.

Our proposal

We will carry out an innovation project seeking to address the commercial and regulatory barriers faced by customers who wish to engage in peer-to-peer trading. We will seek £0.1m of NIA innovation funding to carry out this work. (This assumes we can link this study with work in this area by other parties.)

We will lead work engaging with Ofgem, BEIS, suppliers, customers and relevant trading platforms (e.g. Elexon) to identify any network-specific barriers to peer-to-peer trading, and options for solutions. In particular we will identify the information required by market participants to ensure safe network operation.

WS1.4: Customer-led system balancing from distributed energy resources

Context

During the 2015-23 period, we have been rolling out enhanced ANM control systems across our network. These control systems allow us to remotely monitor and manage generation and load, to help keep the system within operating parameters and avoid constraints. For example, some generators have non-firm/interruptible connection agreements, meaning we can automatically curtail their generation under certain conditions, which helps us avoid network reinforcement and means that generators can access cheaper connections. We explain our plans to upgrade and better integrate our ANM system in the DSO strategy, deliverable DSO4.4, as well as our outlook on deployment in the connections part of our plan.

There may be opportunities to use our ANM system for other purposes, delivering benefits to customers and other whole system parties.

Our proposal

We will invest £1m to carry out work to explore opportunities to use our existing ANM system to allow customers to provide services to third parties. In particular, the ANM system could potentially be used to provide balancing services, by allowing aggregators or the ESO to call off flexibility using these systems. This would avoid the need for those parties to install their own control and switching equipment, so reduce the whole system cost of balancing. If this service was commercialised, it would also help achieve better value for the ANM investments we have made, benefitting customers.

We will collaborate with our customers, the ESO, aggregators, and other third parties to explore these services. If successful, we will continue to work with relevant stakeholders to bring these services to market.

Ensure our customers' future needs are met through cross-sector and cross-vector planning

We will work closely with energy industry parties and other stakeholders to ensure that network planning, as well as planning of wider investments such as storage and generation, is carried out as efficiently as possible from a whole system perspective. Below we provide details of the deliverables and initiatives that will enable us to deliver this outcome.

WS2.1: Enhanced cross-sector and cross-vector collaboration to improve network planning data

Context

Currently, our network planning is based on modelling techniques designed for a more traditional energy system where loads were fixed and fairly predictable. However, technology has changed significantly, and continues to evolve, since those techniques were developed. The use of LCTs such as EVs, heat pumps and distributed generation means that efficient network planning is much more complex than it was in the past, and loads are harder to forecast.

In particular, the way that transport and heat technology develop in future could lead to significant variation from our current planning assumptions. For example, while EV ownership is growing, and we expect that most people will own an EV by 2050, it is also possible that developments in automation will enable a world where transport is based on automated EV taxis with far lower EV ownership than we currently expect.

We need a more detailed understanding of how future load profiles may evolve, particularly on the local LV system where we are using digitalisation in the form of LV monitoring in combination with external data sources to monitor and manage the load growth ahead of reinforcement. By collaborating with others and sharing open data we may capture developments across the whole system, in order to facilitate net zero at least cost to our customers.

Our proposal

This deliverable will involve more regular cross-sector engagement to improve network planning data – particularly forecast load profiles. The aim will be to improve the DFES planning scenarios, to better reflect decarbonisation pathways across more vectors, and layer on the impacts of technological development in other sectors – similar to the current FES.

We will invest £0.5m to undertake annual workshops and additional bilateral engagement as needed, to ensure a wide range of stakeholder input. To ensure that the approach and outcomes of this work are technology neutral and not influenced by our role as an electricity network operator, we would propose that an independent auditor is involved throughout.

Our focus will be to understand technological developments and wider sector developments that could affect planning scenarios. Some examples of areas we will engage in are:

- The transport sector - we will engage with EV manufacturers to understand how EV technology is likely to evolve. For example, trickle charging may become the main form of EV charging, rather than customers fully charging their EVs in one session.

- The heating sector - we will engage with heat pump manufacturers to understand what types of heat pumps they are designing for the future. For example, future heat pumps might integrate battery-like heat storage materials that would allow heat to be boosted during times of peak use, without increasing electricity usage.

- Gas networks - we will engage with gas networks (particularly NGN, the gas distribution network in our area) to understand how their research around the future role of hydrogen is progressing, and how the role of the gas networks is evolving.

- Energy suppliers - engaging with energy suppliers will help us understand developments in time of use tariffs and customer attitudes to flexibility, which will have impacts on how we plan our network.

We will also explore how we can best coordinate and collaborate with the ENA on its related work on National Energy System Map project as detailed in the digitalisation strategy and action plan.

By reflecting whole system developments in our network planning data, we will be able to facilitate the transition to net zero as cost efficiently as possible, while keeping the door open to all potential pathways.

WS2.2: Better understand the impact of mobile demand and generation

Context

Flexibility, time-of-use tariffs and the use of EVs mean that electricity demand is becoming more mobile, both in terms of where consumers use electricity, and when they use electricity. For example, customers have a choice of whether they charge their EVs near their workplace during the day, or at home during the night – and electricity prices, along with a multitude of other factors such as holidays or traffic disruption, could impact this decision. Vehicle to grid technology also allows EVs to store electricity and discharge it back to the grid when needed, creating a source of mobile 'generation'.

This uncertainty creates a challenge for network planning. One-off triggers may soon be able to cause significant shifts in behaviour that the current network is not designed to handle, and we need to start preparing for this.

Our proposal

We will partner with other whole systems stakeholders, including other DNOs, energy suppliers, fuel suppliers, aggregators, town planners, highways agencies and others to improve our understanding of mobile loads. For example, we will explore what the key drivers of mobile loads are, how they are likely to react to certain triggers, and what this means for the range of potential load profiles. We will seek £1.2m of NIA innovation funding to carry out this work.

This improved understanding will then feed into more sophisticated modelling and network planning. For example, if we can understand what loads are likely to look like throughout the year on a half-hourly basis and at different locations, rather than planning around just the winter peak, this may allow us to invest in and operate our network more efficiently.

WS2.3: Inter-seasonal energy planning

Context

As described for WS1.1, inter-seasonal storage will be an important part of decarbonising effectively and efficiently. WS1.1 is about understanding the potential for inter-seasonal storage on the system, as well as identifying what else we need to do to facilitate and enable this future market.

Beyond the commercial considerations around the need and potential for inter-seasonal storage, storage investors will need to make practical decisions around where to locate storage, how much storage to install, and the type/characteristics of that storage. In order to make well-informed decisions and have more certainty around the commercial case for their investment, storage providers will need to have access to reliable and granular information about forecast loads at a local level. In particular, investors will need to understand storage needs in different network areas.

While we do produce load forecasts, they are not sufficiently granular for this purpose (both in terms of time and location), and the rapid pace of technological change means that seasonal loads may evolve differently from what we currently expect. For example, heat pump trials to date (e.g. through the customer-led network revolution (CLNR) project) have been relatively limited, meaning that the detailed load patterns generated by heat pumps are not well understood. Those load patterns could change in future; for example consumers may increasingly use heat pumps to cool their homes in the summer, meaning that summer loads are higher than we currently expect. This aspect of heat pumps being used as for cooling is a good example of an area where we consider we are light in evidence currently to inform our scenario planning.

Our proposal

We will undertake an innovation project to understand how technological changes and consumer behaviour is likely to impact seasonal loads in the future. This will allow us to add to today's existing telemetry information, to reflect the latest view on the likely direction of future changes. We will then be able to provide more accurate and granular load forecasts, enabling effective planning and investment in inter-seasonal storage. We will seek £0.1m of NIA innovation funding to carry out this work.

We will first engage with potential storage providers to ensure we are developing the right types of data to meet their needs. Then we will identify the key drivers of changes to future loads, and collaborate with other stakeholders to understand how these drivers will evolve. For example:

- working with heat pump manufacturers to understand how their technology is evolving and how it will impact loads in future, potentially organising further trials;
- working with customers at all levels, from industrial, to domestic, to battery operators, to understand how their needs and behaviour are likely to evolve;
- working with gas networks to understand which areas may be more likely to adopt hydrogen;
- working with town planners to understand how EV usage is expected to evolve;
- working with energy retailers to arrange trials to better understand the impact of time of use tariffs; and
- working with aggregators to understand how flexibility will impact loads.

Our ultimate aim is to be able to provide open-source data on local, granular load forecasts that storage providers and other interested parties can use to inform their investment decisions. This will be shared with stakeholders through our Open Insights platform, described in DSO deliverable DSO3.1 in the DSO strategy.

WS2.4: Whole energy system batteries

Context

Energy storage technology is likely to be an important part of decarbonisation, helping to decarbonise efficiently and manage the challenges created by intermittent generation. Cross-vector energy storage technologies are an exciting part of this. Some examples of these storage methods include:

- Using gas as storage**:** for example, during the summer, excess electricity could be used to create 'green' hydrogen from water. That hydrogen could then be physically stored, possibly using the storage capacity inherent in the existing gas network as it is moved away from natural gas, and used to heat homes in the winter. Hydrogen might also be used in an electrolysis – fuel cell closed loop system and we have spoken with developers who are interested in this.
- Heat batteries**:** these contain a heat storage material, which can store up energy when electricity prices are low, and release that energy as heat when it is needed.
- Heat pumps combined with thermal storage**:** the technology can be a hot water tank or a phase change material to provide sufficient load turn-down for a period of one to two hours without impacting comfort levels.
- Existing storage battery systems**:** these have potential for instantaneous to short term storage.

Traditionally the kinetic energy stored in the rotors of large generators has been used as a battery for system balancing with frequency as the control. As we move away from rotating plant for generation, we might look to other large sources of electrically connected kinetic energy such as the rail or underground network where system-wide acceleration or deceleration might be used as a battery. This is undoubtedly more complex to control than the frequency-based system rotating plant used, but as we fully-decarbonise rail travel by 2035 and 2040 (dependent of which country of GB is in question) it becomes worth discussing.

The thermal mass and insulation of a building's fabric might be used as short-term heat battery. This is the basis of some flexibility in heat proposals.

All of these technologies offer opportunities to optimise across the whole energy system, helping decarbonise efficiently and delivering value to customers. Further work is needed to take advantage of these opportunities, as the characteristics and cross-vector impacts of these technologies are not yet well understood.

Our proposal

Building on our joint InTEGReL[9] and Winlaton hydrogen project, we will collaborate with NGN, the gas network in our region, and other partners to develop an understanding of cross-vector energy storage technologies. The aim will be to better understand the technical characteristics of different cross-vector storage options, and how that technical capability might best be used to address both long-term and short-term storage needs. We will seek £0.2m of NIA innovation funding to carry out this work.

WS2.5 Trial commercial aspects of microgrid technology to enhance system resilience, particularly for remote customers

Context

Decarbonisation and technological progress is driving increasing use of, and reliance on electricity. While the electricity grid is highly reliable, at 99.992 per cent availability, the value to consumers of improved network resilience is likely to increase as electricity becomes an even more integral part of their lives, and as they switch from other, more reliable alternatives such as gas or fuel. Please see our business plan section on reliability and availability for more detail in how we are using digitalisation and automation to improve customer outcomes.

This is particularly relevant for customers in remote areas that have lower levels of resilience. Traditional solutions to this (e.g. improving resilience by reinforcing or building redundancy into the network) can be costly, and not effective for dealing with outages caused by faults on the high voltage network. Microgrids can help deliver drastic improvements in resilience for consumers that need it the most, and deliverable WS3.1 will trial the technology by rolling out 30 microgrids over the course of 2023-28 period.

Before we can operate those microgrids in a future world where there is a significant increase in the number of digitally enabled Distributed Energy Resources (DERs) on the LV system, we need to understand their commercial viability and overcome any commercial barriers. This is because a microgrid is essentially a small, self-contained market that requires generation, demand, balancing, and trading between parties. For example, microgrids need to be connected to a source of storage or generation in order to be self-sufficient when disconnected from the wider grid. If potential investors don't perceive that there is a commercial case to connect to microgrids, the technology may not be viable.

Our proposal

We will carry out an innovation project to better understand the commercial case for microgrid technology. We propose to seek £1.5m of NIA innovation funding to carry out work that will involve engaging with stakeholders to explore questions around the commercial framework for microgrids. Some of the key areas to be explored are set out below.

- For our early microgrid trials, we will partner with individual generation/storage providers that are willing to connect to the microgrids. We will work closely with them to understand the commercial barriers and challenges they face.

[9] InTEGReL (Integrated Transport Electricity and Gas Research Laboratory) is a whole system test site built in collaboration with NGN and Newcastle University.

- We will also carry out work to help better inform the commercial decisions taken by generation/storage providers, such as exploring how frequently microgrids should operate autonomously (i.e. should they only disconnect from the wider grid in response to potential outages, or are there significant benefits to self-balancing more regularly?) Given that microgrids are costly, under what conditions (e.g. what types of locations) do they deliver net benefits?

- We will engage with Ofgem, BEIS and other relevant parties to explore who should run the microgrids - the relevant DNO, or a third party? If a third party, should they be regulated?

- We will engage with Ofgem, BEIS and potential battery operators to explore the options for battery ownership and operation in microgrids. For example, is the battery owner a service provider to the DNO?

- We will work with peer-to-peer platforms, other DNOs, academics and others to understand how peer-to-peer local energy trading can fit in with microgrids.

We plan to run this project from 2023-24 to 2025-26. It is part of a mutually supportive suite of activity which can also be found in WS3.1 and WS3.3 and the learning in these commercial, technical and regulatory areas will be complementary.

WS2.6: Understanding the behaviour of flexibility specific load

Context

The rising uptake of LCTs means that customers are increasingly able to provide flexibility to the electricity system; switching off their loads temporarily to help avoid constraints and earning compensation in return. In our DSO strategy, we set out in detail our plans to upgrade our capabilities to maximise the use of network and customer flexibility during the 2023-28 period.

Flexibility has an important role in whole system decarbonisation. It means that wider stakeholders in the energy sector, such as generation, demand, and storage operators, provide alternative potentially more cost-effective solutions to dealing with network constraints, beyond traditional network investment. This helps deliver decarbonisation at pace, and cost effectively, by making better use of assets and reducing the need for fossil fuel generation.

There is still a lot of uncertainty around the characteristics of flexibility, which limits the accuracy with which we can factor it into our network planning. In particular:

- Given a customer’s equipment, what is their inclination to use it flexibly?

- Some technologies, such as hybrid heat pumps or domestic heat batteries, have flexibility built in (i.e. they are designed to be able to shift their electricity usage based on triggers such as price). How does the flexibility of these technologies differ from loads that have flexibility potential but which require customers to change their behaviour, such as EV charging?

- How responsive are loads to different levels of payment, and how does this vary with the technology being used? For example, turning off a heat pump for an hour might be less disruptive than turning off a gas boiler for an hour, and therefore customers with heat pumps may be more likely to provide flexibility.

Our proposal

We will carry out a study to better understand the behaviour of flexible loads, engaging with potential providers of flexibility to do so. Through empirical stakeholder engagement in the form of non-invasive trials of response to flexibility incentives, we will build a picture of the cost of flexibility against the benefit of avoided reinforcement or avoided storage. In particular we will focus on understanding how responsive different types of loads are, differentiating between loads with flexibility built in (e.g. hybrid heat pumps, domestic heat batteries) and loads with flexibility potential (e.g. EV charging). We will seek £0.3m of NIA funding to carry out this innovation project.

This work will also explore the commercial framework for exploiting flexible loads.

WS2.7: Understand the interaction between networks in flexibility scenarios

Context

As explained for WS2.6, the rising uptake of LCTs means that customers are increasingly able to provide flexibility to the electricity system.

Some of this flexibility is cross-vector, meaning that loads can switch between energy vectors in response to price or other signals. For example, hybrid heat pumps can operate as a normal heat pump, but also have a gas boiler. This means that the heat pump can optimise between using gas and electricity. We have explored these and other possible future pathways in the scenarios and investment section and supporting annex.

Such hybrid technologies creates interdependency between networks, in this case between the electricity and gas networks. A peak on one network may have a knock-on impact on another network.

Similarly, increasing uptake of EVs, and vehicle-to-grid services, will create interactions between the electricity and transport networks. A change in electricity prices might impact travel patterns.

Hybrid, cross-vector solutions are likely to be an important part of the path to decarbonisation, so it is important that we facilitate such solutions in an efficient way. It is therefore important that we understand how different vectors may interact in future, and how best to manage that interaction.

Our proposal

We will carry out a study to better understand the interactions created between networks through flexibility. We will work with other networks, in particular the gas networks and transport networks (e.g. Highways England) to understand:

- What interactions might be created between our networks as a result of flexibility?
- What are the potential impacts on the affected networks?
- How can these impacts best be managed and planned for?

Understanding the cross-vector impact of flexibility will help ensure that flexibility is economic, efficient and coordinated beyond just the electricity distribution network; providing better whole system outcomes.

We will seek £0.3m of NIA innovation funding to carry out this study.

WS2.8: Local area energy planning

To achieve net zero, policies for facilitating decarbonisation will need to be a part of a coherent energy policy framework that optimises across the whole system. An effective, affordable, timely, and fair transition to a low carbon energy system will require coordination between local and national government, network operators, energy suppliers, businesses, and individual consumers. Currently there is no structured whole system planning process in place to help manage this transition.

National policy decisions and funding will, to great extent, dictate the approach local authorities will be taking to decarbonisation, which includes the development of LAEPs. LAEPs are a relatively new concept, introduced by the Energy Systems Catapult. An LAEP is the product of collaborative planning, involving a wide range of stakeholders to agree on the optimal long-term energy solution for an area. It considers the entire energy system – heat, electricity and transport and the supply chain from energy generation to homes and businesses – and looks at what the best value-for-money approach is at the local level.

There is as yet no universal definition of what LAEPs could and should comprise, whether they should be part of the spatial planning process, or how they should be funded.

Energy Systems Catapult have placed the emphasis on local government to act as a leader and enabler, in conjunction with other stakeholders who can help to achieve area visions and targets, bringing energy considerations into the planning process to facilitate emissions' reduction, especially when it relates to decarbonisation of heat.

Ofgem expect that LAEPs should include elements of:

- wide-range stakeholder engagement;
- cross-vector approach for heat decarbonisation (whole system solutions); and
- improve (local) investment planning decisions.

As outlined in Ofgem's guidance, a LAEP should possess the following attributes: transparent; independent; consensus-based; based on robust evidence; aids decision-making; uses a whole-systems approach.

The CCC recently endorsed the production of LAEPs.[10]

LAEPs are therefore key to achieving whole system decarbonisation. We are developing our approach to LAEP as part of our DSO Strategy, where we are proposing to support the design of LAEPs by investing £2.3 million to employ a team of LAEP advisors, across our operational regions. We are also planning to improve our stakeholder engagement in this area. Please see annex 4.2, DSO strategy, and refer to DSO3.2 for more detail.

Further detail showing the breakdown of costs is included in appendix A.

Develop the blueprint for the next generation network by rolling out proven innovation

As society becomes more dependent on electricity, we will seek ways to maintain and improve reliability, availability, and efficiency throughout the seasons. Many of these innovative solutions will require coordination with other energy sector stakeholders, and/or may be more expensive than traditional solutions but can deliver net benefits when costs and benefits are assessed on a whole system basis. Below we provide details of the deliverables and initiatives that will enable us to deliver this outcome.

WS3.1: Roll-out of microgrid technology to enhance system resilience, particularly for remote customers

Context

As described for WS2.5 (where we will trial commercial aspects of microgrids), the value to consumers of improved resilience is likely to increase as electricity becomes an even more integral part of our lives, and as consumers switch from other, more reliable alternatives such as gas or fuel oil. This provides a pull effect as described in our innovation strategy. There is also a push from the availability of customers DERs that offer flexible or export capability as the number of heat pumps, EVs or community energy (generation and storage).

Microgrids are local energy grids on the LV network which operate normally while connected to the wider grid, but have the capability to disconnect and operate autonomously when an outage happens on the HV network. They can help deliver drastic improvements in resilience for consumers that need it the most.

[10] The Committee for Climate Change, June 2020. Reducing UK emissions. Progress Report to the Parliament. "LAs should have a key role in LAEPs, alongside network operators and Ofgem, especially in relation to building community consensus on plans for decarbonising heating".

In addition to the direct customer value associated with events on our network, such microgrids will have value during widespread events such as Black Start and we have been in conversation with ESO regarding the microgrid contribution to their Project Restart ideas. Also of note is the Reliability as a Service (RaaS) Network Innovation Competition (NIC) project where we are supporting Scottish and Southern Electricity Networks (SSEN); which is looking at larger, less-targeted storage-based microgrids. These are aimed more at the replacement of existing fossil fuel generation based microgrids but there are elements of the concept that are transferrable between the RaaS project and our LV microgrids work.

Our proposal

Building on our MicroResilience project, in the 2023-28 period we will invest £6.9m to roll out fixed microgrids across 30 of our most vulnerable LV networks. We will also roll out six SilentPower vehicles, which are electric response vehicles equipped with an onboard energy storage system (ESS), meaning they can help power homes while their electricity supply is being restored thereby reducing the length of outages. These are a quieter, cleaner alternative to diesel-powered generators. You can read more about SilentPower in our customer vulnerability strategy. We will target these microgrids at the locations where they will deliver the most value (based on net present values (NPV) assessments). Longer term rollout will be dependent on the learnings of this trial and other related initiatives.

Approximately 50-60 per cent of outages are caused by faults on the high voltage system (and we are likely to target parts of our network for microgrids where this rate is even higher, around 65 per cent). The mainstream approach to improving performance in this area is direct investment in the HV network. Microgrids offer the potential of an alternative whole system solution, which brings together network investment and generation/storage involvement to deliver a highly robust solution that is more cost effective than the traditional solution of HV investment in targeted areas.

Microgrids can also potentially facilitate peer-to-peer energy trading, and enable customers to maximise the value of their energy assets (e.g. solar panels) by providing energy to both the local microgrid and the wider system.

Whilst, on average, microgrids are a more costly approach to improving resilience compared to traditional approaches, there are some areas where microgrids can deliver net benefits. We will use whole systems cost benefit analysis to target areas where microgrids will deliver most benefit and where alternative network solutions are more costly, in order to deliver whole systems value.

This work will also contribute to a just transition for consumers (including those who are vulnerable) by ensuring we target those customers that will benefit most from microgrids. We will do this by improving resilience for customers on vulnerable sections of our network, or vulnerable customers – and ideally both.

The project will be carried out in conjunction with WS2.5 and WS3.3, which will explore the commercial and regulatory challenges around microgrids, and how these can be overcome. We will need to complete those projects, so that at least initial solutions are in place to address any commercial or regulatory barriers before we can start operating the microgrids that we roll out as part of this deliverable. However, we can progress the building of the key microgrid infrastructure in parallel with those other projects. We are confident that we will be able to operate the microgrids by March 2028 because only minor tweaks are needed to the regulatory framework,[11] and if there are significant commercial barriers we could own small batteries for resilience purposes, to enable the microgrids to operate.

This initiative will maintain customers supplies and energy resources (such as solar generation) at times when they would otherwise be unavailable due to network outages, and it will facilitate peer-to-peer trading due to the increased incentive to do so in a balanced microgrid. The potential customer value that can be provided by this initiative is an NPV of £2.4m over 10 years, increasing to £13.8m overall. This will initially be provided through the societal value attributed to the improved resilience as experienced by customers. Increasingly however, value will be provided through the support the microgrids will provide to wider system security as the network loading increases, as we approach net zero. Further detail is included in annex 1.5, detail on our CVPs, as well as the further detail in appendix B.

[11] Frequency issues are the main concern and at small scale it is essentially similar to using generators for fault restoration.

WS3.2: Voltage optimisation for energy efficiency

Context

We are legally required to ensure that the electricity received by consumers falls within a certain voltage range as defined within the Electricity Safety, Quality and Continuity Regulations (ESQCR). This voltage range is from 216.2V to 253.0V. Historically, voltage was only actively managed at primary substations, and we had no means of measuring the voltage actually received by consumers (which varies based on their location on the network). To ensure voltage compliance, we generally provide a voltage towards the upper end of this range, as this accommodates higher demand periods, coupled with the potential for system outages.

We also know that a reduction in voltage creates a proportionate reduction in energy consumption. This means that if we can lower the voltage received by customers without falling outside our legal limits, we could reduce energy consumption without any negative impact on customers (in fact most electronic devices are designed to work optimally at a lower voltage than customers tend to receive).

Smart meters now enable us to monitor the voltage that customers receive, and smart grid enablers allow us to monitor the network in real time and communicate with substations to carry out more active voltage management. So it may be possible to reduce the voltage at primary substations while still ensuring that the electricity received by consumers remains within legal limits.

Our proposal

Building on our Boston Spa Energy Efficiency Trial (BEET) Project, in the 2015-23 period, which is currently seeking to trial voltage optimisation technology at a larger scale at three primary substations; we will seek to roll this out across the network should this project prove successful. It is expected that it will be appropriate on 80 per cent of the network and we will complete 35 per cent by March 2028.

While this deliverable goes beyond our legal requirements and creates net costs from our perspective, it creates whole system benefits. On a whole system cost benefit analysis this project delivers significant savings for customers, as well as wider sustainability benefits, through reduced energy usage.

We will invest £8m across the period to carry out this work. This is mainly the cost of modifying our information technology (IT) and operational technology (OT) systems to enable the mass collation of data and the implementation of voltage optimisation, along with installing new servers to carry out the data analytics required for the voltage optimisation. Once the infrastructure costs have been incurred and the solution is up and running, the costs beyond the 2023-28 period will be minimal.

Based on conservative assumptions, the average consumer's energy consumption could be reduced by four per cent (or 120 kilowatt-hours (kWh) per year), a typical saving of £20 p.a. We have estimated that this project will deliver an NPV of £58.7m over five years, and £255.7m over 10 years, through reduced bills and reduced carbon emissions. Further detail is included in annex 1.5, detail on our CVPs, and the further detail in appendix C.

WS3.3: Regulatory requirements for local microgrids

Context

As described for deliverable WS3.1, the potential benefits of microgrids in improving system resilience and consumer experience are clear.

There are regulatory and market barriers that, unless resolved, could stand in the way of a large scale microgrid rollout. For example, the existing regulatory framework includes requirements for the ESO to take responsibility for frequency management and they would lose control of that. Either the ESO would have to be content that they were responsible for things outside their control, or the regulatory framework would need to be adapted to enable microgrids to operate autonomously, or under the control of a DSO.

Our proposal

We will carry out an innovation project to identify and address regulatory and market barriers to microgrid rollout. We will partner with other DSOs, policy makers and relevant third parties to:

- identify barriers;
- develop and agree solutions (e.g. amending regulatory requirements, codifying new market arrangements) that are broadly supported by relevant stakeholders; and
- collaborate with relevant stakeholders to begin implementing these solutions.

Some of the resulting changes that may need to be made include:

- amending regulatory, legal and safety requirements to give DSOs the ability and accountability to control voltage and frequency for microgrids;
- enabling contracts between DNOs and local demand, generation and storage providers;
- align with BEIS's December 2020 review of engineering standards covering;
    - voltage limits;
    - frequency, operability and stability;
    - reliability and security of supply;
    - resilience and black start;
    - network capacity for new developments and network reinforcements; and
    - smart energy system interoperability.

We propose to seek £0.5m of NIA innovation funding to carry out this work.

WS3.4: Distribution asset-based ancillary services to ESO

Context

In the 2015-23 period, Electricity North West (ENW), one of the other electricity DNOs, carried out the CLASS innovation project.[12] This project demonstrated that system loads can be reduced at peak times by managing voltage on the distribution networks. This solution requires 'voltage controllers' to be installed at substations, but is overall a low cost solution to managing network constraints.

It is likely that significant benefits can be delivered through this innovative approach. More work is needed for us to embed the learnings of CLASS and offer this form of flexibility as a service to the ESO, providing the ESO with a low-cost, whole system solution to balancing.

[12] CLASS (Customer Load Active System Services) is an approach developed by ENW. It uses voltage control to reduce electricity consumption at peak times using 'voltage controllers' in its substations. It carried out a 12 month trial where voltage controllers were installed at 60 substations, and found that customers didn't notice any change in their electricity supply as a result of the voltage management. See: https://www.enwl.co.uk/go-net-zero/innovation/key-projects/class/what-is-class/

We are encouraging our regulator to clarify the framework under which we may provide this service to the ESO as the benefits case produced by ENW[13] demonstrates the value that we may provide to customers through this active management of the grid.

Our proposal

Through our 2015-23 period smart grid enablers programme, by March 2023 we will have already installed much of the equipment required to allow us to manage voltage.

During the 2023-28 period we will invest £4.4m to work with the ESO to understand how we can best deliver value through the lessons learnt from CLASS. We will seek to provide this form of load reduction as an ancillary service to the ESO if we establish that it will deliver value. The collaboration will focus on ESO learning from early operation with ENW as well as other flexibility providers to ensure efficient delivery of the service.

We will also need to understand how this approach interacts with deliverable WS3.2 (voltage optimisation for energy efficiency). Both innovations rely on voltage management so it may not be possible to implement both solutions in the same parts of our network. If that is the case, we will need to understand how best to target each solution in a way that maximises benefits. Please refer also to DSO4.3 in the DSO strategy.

[13] See Baringa analysis conducted in June 2021 in collaboration with ENW and the other DNOs.

Exchange knowledge with those specifying future low carbon technology (LCT) and low carbon use cases

We will work with partners beyond the energy system to foster whole system thinking in product and service design. If future products can be designed in a way that optimises their performance, reflects whole system needs, and minimises their impact on the electricity system, this will help contribute to low-cost decarbonisation. Below we provide details of the deliverables and initiatives that will enable us to deliver this outcome.

WS4.1 and WS4.2: Optimisation of industrial and commercial customers' future equipment, and optimisation of domestic customers' future equipment

Context

The importance of electrification in the path to net zero means that interactions between the electricity grid and other sectors are becoming increasingly common and important. For example, EVs and electrified trains are increasingly common and create significant interdependencies between the transport and electricity sectors. Similarly heat pumps are bringing together the heating and electricity sectors.

It is therefore increasingly important that new technologies are designed with other sectors in mind. If an electric train or a heat pump can be designed in a way that takes into account its impact on the electricity system, customers in both sectors can benefit, and decarbonisation can be achieved more efficiently.

Our proposal

We will collaborate with designers and manufacturers of equipment, and their trade bodies. We will provide input on how equipment can be designed for optimal performance of the equipment itself, and our network. Our aim is to ensure that standards for both future equipment, and our network infrastructure, is specified for optimised performance and costs. We will invest £0.1m to carry out two projects:

- one will focus on equipment supplied to industrial and commercial (I&C) customers; and
- the other will focus on equipment supplied to domestic customers.

Some examples that could be useful to explore include:

- Electric train design**:** we would work with electric train manufacturers to help them understand which sections of the rail network do not have access to an electricity supply, and therefore may require trains to run temporarily on battery power. This will help manufacturers optimise their trains to the conditions they will need to operate under. Hitachi Rail have already shown interest in this.
- Heat pump design**:** by working with heat pump manufacturers, we could help them design products and systems (e.g. blended with storage) that are more efficient for customers to run, and which avoid contributing to peak demand.
- Meters in EVs to allow cheaper more flexible charging arrangements**:** Nissan have indicated that while they are not against this it would have to be a cross-industry action amongst car manufacturers.

Ongoing stakeholder engagement

We will continue to engage with our stakeholders to ensure we are adapting our whole system strategy as the path to net zero unfolds

There is inherent uncertainty in how decarbonisation will unfold, with new technologies and policy decisions emerging frequently. The optimal whole system solutions are therefore changing, both as new challenges emerge and as technological developments present opportunities for new solutions.

Ongoing collaboration with other industry parties is therefore key to ensuring that we are unlocking whole system benefits as new challenges and opportunities arise. For example, engaging regularly with energy suppliers will mean that we are aware of developments around time of use tariffs and can plan our network accordingly. Throughout the next five years we will continue to engage with stakeholders and refine our whole system approach.

We will continue to track factors that could impact our assumptions about the possible energy pathways and the implications for whole system decarbonisation. We will take this forward mainly through our interactions with stakeholders on improving the DFES. Please refer to our scenarios and investment planning annex, and the decarbonisation – scenarios and investment section of our main plan, for further discussion of how we will manage this uncertainty.

Appendix A: costs summary

Ref.	Initiative title	Total 2023-28 cost estimate (£m)				
		IT	OT	People	Network	Total
1.2	Energy matchmaking scheme	0.3	-	0.1	-	**0.4**
2.1	Enhanced cross-sector and cross-vector collaboration to improve network planning data	-	-	0.5	-	**0.5**
3.1	Roll-out of microgrid technology to enhance system resilience, particularly for remote customers	0.4	0.6	0.5	5.3	**6.9**
3.2	Voltage optimisation for energy efficiency	2.1	3.2	2.8	-	**8.1**
4.1	Optimisation of industrial and commercial customers' future equipment	-	-	0.0	-	**0.0**
4.2	Optimisation of domestic customers' future equipment	-	-	0.0	-	**0.0**
	Total initiatives funded through whole systems	**2.9**	**3.8**	**4.0**	**5.3**	**16.0**
1.1	Inter-seasonal storage	-	-	0.3	-	0.3
1.3	Peer-to-peer trading	-	-	0.1	-	0.1
2.2	Better understand the impact of mobile demand and generation	0.5	0.3	0.3	-	1.2
2.3	Inter-seasonal energy planning	0.1	-	0.1	-	0.1
2.4	Whole energy system batteries	-	-	0.2	-	0.2
2.5	Trial commercial aspects of microgrid technology to enhance system resilience, particularly for remote customers	0.5	0.3	0.5	0.1	1.5
2.6	Understanding the behaviour of flexibility specific load	0.1	-	0.2	-	0.3
2.7	Understand the interaction between networks in flexibility scenarios	0.1	-	0.2	-	0.3
3.3	Regulatory requirements for local microgrids	0.1	0.1	0.3	-	0.5
	Total initiatives funded through innovation funding	**1.4**	**0.7**	**2.2**	**0.1**	**4.4**
	Total whole systems cost estimate	**4.3**	**4.5**	**6.2**	**5.5**	**20.4**
	Whole systems initiatives costed in DSO strategy:					
1.4	*Customer-led system balancing from distributed energy resources - DSO4.4*	*-*	*1.0*	*-*	*-*	*1.0*
2.8	*Local Area Energy Planning - DSO3.2*	*-*	*-*	*2.3*	*-*	*2.3*
3.4	*Distribution asset-based ancillary services to ESO - DSO4.3*	*-*	*4.1*	*0.4*	*-*	*4.4*
	Total	*-*	*5.1*	*2.7*	*-*	*7.7*

Table 1: Whole system costs

Appendix B: WS3.1 microgrids additional detail

Detailed initiative description

- As society becomes more dependent on electricity, we will seek ways to improve reliability, availability and resilience, and to enable decarbonisation at least cost.
- This initiative seeks to roll-out of resilient microgrid technology to enhance system resilience, particularly for remote customers. We will install 30 fixed microgrids across our most vulnerable LV networks, and roll out further mobile microgrid units.
- Microgrids are local energy grids on the LV network which operate normally while connected to the wider grid, but have the capability to disconnect and operate autonomously when an outage happens on the HV network. They can help deliver drastic improvements in resilience for consumers that need it the most.
- We propose to use asynchronous links and storage to provide resilient LV networks for HV outages. Customer storage and generation is preferred as the energy source and will be incorporated where possible in both the fixed and mobile solutions.
- Fixed microgrids offer both a solution to HV reliability issues, particularly sub-three-minute outages which automation does not address, and security of supply issues in sparse networks[14], which will grow as decarbonisation drives system loadings higher.
- This initiative will maintain customers' supplies and energy resources such as solar generation at times when they would otherwise be unavailable due to network outages, and facilitate peer-to-peer trading due to the increased incentive to do so in a balanced microgrid.
- Fixed microgrids are presently being trialled as part of our MicroResilience NIA project.
- Mobile microgrids developed in our SilentPower project offer lowered noise levels, lower NOX and CO2 emissions relative to the mobile diesel generators they replace and add the ability to support customers' generation, which is particularly useful with customers' solar generation.

Deliverable and initiative mapping

- WS3.1: Roll-out of microgrid technology to enhance system resilience, particularly for remote customers;
- WS2.5 Trial commercial aspects of microgrid technology to enhance system resilience, particularly for remote customers; and
- WS3.3 Regulatory requirements for local microgrids.

Envisaged deployment

- We will seek to implement fixed microgrids at 30 distribution substations to support the on-going operation of the LV network in the event of a loss of the infeed from the HV network.
- We have identified around 25 rural teed circuits where alternative HV supplies are not available and this resilience option would be beneficial in the short term.

[14] Where these networks are sparse both in terms of the number of customers connected, and the level of network connectivity, in that they do not offer an alternative supply route. Subsequently, an issue that impacts the radial 'spur' will result in customers being off supply until the network is repaired.

- These same teed circuits are expected to experience load growth due to decarbonisation that would require security of supply investment and the microgrid will provided a solution to this at a significantly reduced cost to the traditional methods.
- Additionally, we will be rolling out further SilentPower type units to offer mobile microgrid solutions to maintain customers' microgeneration, storage systems and demand during faults and other outages as appropriate.
- The deployment will seek to encourage LV customer participation in trading energy, storage and other services to maintain the microgrid in balance for extended periods with a view to developing a storm response in addition to the short-term interruption response.
- The deployment will seek to ensure that regulatory and legal issues (e.g. responsibility for frequency) are addressed in light of the technical and commercial potential for the technique.
- Deployment will commence in the second year of the 2023-28 regulatory period, with completion by March 2028.

Cost

- Note that all costs shown here exclude real price effects (RPEs) as required for Ofgem cost benefit analysis (CBA) - in the main section of this document the costs include RPEs.
- £6.0m for fixed microgrids; £0.5m for mobile microgrids.

2023-24	2024-25	2025-26	2026-27	2027-28
£0.5m	£1.0m	£2.0m	£2.0m	£1.0m

Benefits

- We forecast £0.7m of reliability benefits by 2028 and £0.3m per annum thereafter on a value of lost load basis as calculated in the CVP CBA analysis. Only the first five years is included in line with the interruptions incentive scheme (IIS) ratchet. Note however, that the on-going societal benefits of improved reliability will continue for the lifetime of the microgrid (assumed as 20 years), and therefore the modelled benefit is conservative within this justification paper.
- As demand rises due to decarbonisation, we forecast £19.5m of avoided security of supply-based reinforcement between 2028 and 2035, and a further £11m by 2040, addressing 21 tees with a total of 30 microgrids.
- Considered in regulatory period terms, this is £0.7m of societal benefits but -£5.8m net benefits in the 2023-28 period, and £15.7m net benefits in the 2028-33 period (assuming a five-year price control period), summing to £9.8m net benefits across the 10 year period.

Milestones

- March 2023: Conclude MicroResilience NIA project. Subject to learning/success of MicroResilience;
- Commence rollout of mobile microgrids in 2023 and fixed microgrids in 2024. The high-level plan is:

2023-24	2024-25	2025-26	2026-27	2027-28
6 mobile microgrids	5 fixed microgrids	10 fixed microgrids	10 fixed microgrids	5 fixed microgrids

Risks

- MicroResilience not being completed in time, or proves too difficult to implement. For example, the power electronic device upon which it depends may prove inefficient in this application or have a shorter useable life than the assumed 20 years.
- Provided MicroResilience is successful, there is a risk of delays and difficulty regarding rollout.
- Increasing EV uptake may place inflationary pressures on components for electrical storage systems, increasing prices, and increasing the chance of supply-chain issues.

Assumptions, constraints and dependencies

- Assumes MicroResilience successful and completed in time.
- Assumes electrical storage systems are available in line with current costs.

Optioneering

- Option one: accept existing network arrangements. While acceptable now, this will forgo the improved reliability offered by the microgrid, which is likely to become essential to customer uptake of LCTs in rural areas. Should LCT uptake be to the high levels anticipated, these teed networks would be loaded to levels outside the security of supply standards in the future.
- Option two: reinforce these overhead line tee networks as they reach the security of supply limits.[15] While acceptable now this will forgo the improved reliability offered by the microgrid. It would also incur significantly higher costs for maintaining security of supply as load decarbonises. This may not be an issue if such networks do not decarbonise, but lack of decarbonisation has not been seen as realistic. This scenario, including load decarbonisation, has been taken as the counter factual in the NPV calculations.
- Option three: install microgrids at 30 rural substations on teed overhead networks and acquire six mobile microgrids. This is the option described in this paper.

Analysis and costs

- Cost assumed as £200k per fixed microgrid. In some cases multiple microgrids will be required to address larger overhead line circuit tees.
- Cost per mobile microgrid £80k.
- Volume of fixed microgrids is 30 and mobile microgrids is six.
- Cost maturity is low, as the MicroResilience trial has not been concluded yet.
- Avoided costs or traditional security of supply reinforcement assumed as £1.5m per feeder. This is based on the scope of works and unit rates for reinforcing four of our worst performing (rural) feeders.
- Analysis of our rural feeders identified that 30 microgrids (optimally located across the rural feeder population) will result in an estimated 21 feeder reinforcements being no longer needed.
- The proposal becomes NPV positive in year six (2029), and has a positive NPV of £2.4m in year 10, rising to over £8.51m by year 20.

[15] Security of Supply reinforcements relates to the requirement to ensure an increased level of reliability once demand within a group (in this case, the network ‘spur’) exceeds a threshold of 1 MW. Our modelling has identified that this will be triggered generally between 2030 and 2040. A microgrid offers an alternative method of providing the required reliability increase.

- Two sensitivities were undertaken looking at reduced or delayed benefits:
  - A benefit of 52 per cent of the expected £1.5m per circuit addressed resulted in a positive NPV being realised in year 10 (2033), with a positive NPV of £0.00m in year 10 improving to an NPV of £2.52m by year 20.
  - A five-year delay of reinforcement benefit resulted in a positive NPV being realised in year 14 (2037), with a negative NPV of -£2.62m in year 10 improving to a positive NPV of £2.74m by year 20.

Deliverability and risk

Our deliverability and risk is as follows:

- The fixed initial installations have been deliberately delayed until 2024-25 to allow time for assimilation of the MicroResilience learning and mobilisation of the roll out.
- All of the 30 fixed microgrids are expected to be completed over the remaining four years to 2028 and we do not expect to need to have security of supply issues on any of these circuits prior to this time.
- The mobile microgrids will be deployed in the first year of the 2023-28 regulatory period.
- Likely equipment suppliers have been or are being identified in the MicroResilience project, although this will be subject to tender.
- Constraints will be the need for communications installation into the installation sites and power system studies on a low carbon transport, heating and generation basis.
- The commercial risks of lack of interest in storage provision for resilient microgrids can be offset by technical and ownership responses. The legal and regulatory position over frequency control and generation / storage ownership for resilience purposes is acceptable now (frequency control always delegated to the DNO when generation is used for restoration, Ofgem guidance specifically allows generation for resilience purposes) but will need formalising in this context.

Conclusion

Our conclusions are:

- The potential customer value that can be provided by resilient microgrids is significant. At an NPV of £8.51m over 20 years (for an investment of £6.5m; thus a benefit to cost ratio above two), it is in our customers financial interest to pursue this technology and the commercial and regulatory arrangements associated are acceptable now, though they will need formalising.
- We are proceeding this this initiative on the basis that the technique will be successful, and that we will be in a position to implement microgrids during the 2023-28 period.
- The value of microgrids is difficult to quantify, and is likely to be higher than the easy-to-quantify benefits we have modelled. This initiative is crucial to developing the blueprint for the next generation network.

Microgrids Cost Benefit Analysis

Term (years from first year of the next regulatory period (i.e. April 2023))	NPV (£m)
10	2.4
20	8.5
30	10.9
45	13.1
Whole life NPV	**13.8**

Table 1: NPV outputs

Refer also to CBA-30-microgrids.

Appendix C: WS3.2 voltage optimisation additional detail

Detailed initiative description

This initiative seeks to implement dynamic voltage optimisation across 80 per cent of our primary substations, over a nine year period starting in April 2024. This will result in about 36 per cent of our (551) primary substations having dynamic voltage optimisation implemented by March 2028.

Dynamic voltage optimisation is currently being trialled as part of the our NIA project 'Boston Spa Energy Efficiency Trial'. The trial is due to end by March 2023, however we believe it is the right thing to do for our customers to:

- assume that it will be successful; and
- implement the technology to provide the significant customer benefit. For this reason, we are proposing that we will implement dynamic voltage optimisation, despite not the innovation project being a work in progress.

The core principles of voltage optimisation are:

- Smart meters can provide near-real-time voltage information across the network.
- We have analysed network voltages from the smart meters on our network, and have identified that customers typically receive a voltage of 240V or higher.
- It has been demonstrated from numerous trials[16] that reduction of voltage from 240V (to a value closer to 230V) reduces energy consumption. This is a well-known effect, known as conservation voltage reduction (CVR). The statistical analysis from the numerous trials identified a typical (conservative) relationship of every one per cent of voltage reduction yields a one per cent energy consumption reduction.
- Whilst we do currently provide voltage compliance (i.e. a voltage within the ESQCR limits of 216.2V to 253.0V), we recognise that we could provide additional value to our customers, by also providing an optimised voltage. Based on the typical 240V provided today, a reduction to 230V would represent a four per cent voltage reduction, hence a four per cent consumption reduction for our customers is assumed as the typical level of voltage optimisation that we could achieve.
- Near-real-time data from smart meters will be used to optimise the network voltage. This requires investment in the IT and OT systems that connect to the smart meter gateway, together with a central system that analyses this data to determine optimum voltage for each primary substation. In addition, we will need to upgrade our systems that ultimately pass the optimal voltage target to the primary substations. The majority of these upgrades are being undertaken during the 2015-23 period (a part of our smart grid enablers programme), therefore the incremental investment to deliver voltage optimisation is focussed on the system that will analyse the data, and its integration with our other systems.

Envisaged deployment

We will seek to implement this at all of our substations, however it is likely there will be technical reasons why this cannot be achieved (such as an insufficient tapping range available on our transformers to provide the required voltage). We therefore assume final deployment will be 80 per cent of our network, consisting of:

- 49 primary substations per year (with 7,121 customers on average at each); and

16 Such as ENW's 'Smart Street' project, and our own statistical analysis of voltage reduction on our network, available at https://www.northernpowergrid.com/downloads/4117

- commencing in year April 2024, and continuing for nine years (i.e. into the 2028-33 period), resulting in 441 substations total.

Cost (£m)

Note that all costs shown here exclude real price effects (RPEs) as required for Ofgem CBA (in the main section of this document and in the CVP calculation the costs include RPEs):

- £7.5m total;
- £1.5m/year for each year of the 2023-28 period; and
- negligible costs post the 2023-28 period, hence zero cost have been assumed for that timeframe.

Benefits

We forecast £41.9m of benefits by 2028, £251.2m of benefit by 2033, and £62.8m p.a. thereafter. This benefit is based on the following:

- assuming a four per cent voltage reduction yields a four per cent consumption reduction;
- with a typical domestic consumption of 2,900 kWh p.a.;
- there is a 116 kWh p.a. energy consumption reduction per customer;
- applying a typical unit rate of 17p/kWh, the per customer benefit per year is £20; and
- given that a typical primary substation has 7,121 customers, there is a total annual customer saving per primary substation of £142.4k.

Considering the net benefits in regulatory terms there will be £34.4m net benefit in the 2023-28 period and £209.4m net benefit in the 2028-33 period (assuming a five-year price control period), totalling £243.7m over the 10 years.

This number is conservative as other benefits such as enhanced operation of the network and improved capacity to connect are not quantified.

Milestones

- March 2023: Conclude BEET NIA project. Subject to learning/success of BEET;
- Commence rollout of voltage optimisation at 49 primary substations per year over a nine year period (reaching 196 substations by 2028 and 441 substations by 2033).

Risks

- BEET not being completed in time, or proves too difficult to implement. For example, a key project risk is that of poor smart meter performance, likely linked to the DCC and smart meter gateway infrastructure.
- Provided BEET is successful, there is a high risk of delays and difficulty regarding rollout. It is probably that the latter cumulative targets are achievable, and a back heavy rollout plan will be required to compensate for early difficulties.

Assumptions, constraints and dependencies

- Assumes BEET successful and completed in time.

- Dependent on reliable DCC infrastructure (ranging from the smart meters, the Arqiva communications network, the DCC servers, and our EnergyIP smart meter gateway).

Optioneering

- Option one: continue with static voltage optimisation. No benefit provided over and above the existing network performance.
- Option two: implement Voltage Optimisation. NPV analysis (c.f. table 1) identifies a conservative NPV of £237.5m, whilst sensitivity analysis (c.f. table 2) shows the benefits are generally at this order of magnitude.

Other options considered, but not analysed via NPV include:

- Applying load drop compensation – unlikely to provide significant benefit, as shown during the BEET Phase 1 trial; and
- Use of traditional infrastructure to provide voltage optimisation, i.e. use of on load tap changers, regulators and/or reactive power devices. Not considered appropriate given significant capital cost, and the NPV would ultimately be lower than that of the proposed approach. In addition, the rollout would be limited to locations where (expensive) new hardware is installed; i.e. the scalability of this approach would result in little overall value to our customers compared to the proposed (scalable) approach.

Analysis and costs

- Cost assumed as £1.5m p.a. for each of the five years of the 2023-28 period (i.e. £7.5m in total).
- Cost maturity is low, as the BEET trial has not been concluded yet (and still in the relatively early stages).
- Cost is based on the forecast BEET cost of £1.25m being required for each of our six operational zones. A bottom-up analysis would significantly underestimate the cost; that is often the case with projects that are complex and IT/OT-centric.

Deliverability and risk

- Voltage Optimisation hardware and IT/OT upgrades at Control Rooms in year one of the 2023-28 period; likely to be expanded in later years as more sites added. Specific number of servers subject to BEET learning.
- Rollout at 49 primary substations a year, starting in year two of the 2023-28 period.
- Key constraint for delivery is the integration of voltage optimisation hardware with our EnergyIP system and the network management system (NMS).
- Secondary constraint is that power system studies are likely to be required ahead of each primary substation rollout.

Conclusion

The potential customer value that can be provided by voltage optimisation is significant. Voltage optimisation is a five-year £7.5m investment, with a net benefit of £243.7m over 10 years and a whole life NPV of £237.5m, representing a benefit to cost ratio of over 30 on either metric. It is in our customers' interests to seek to implement this in a prompt manner. Whilst the BEET innovation trial has not yet been completed, we are proceeding with this initiative on the basis that it will be successful, and that we will be in a position to implement voltage optimisation during the 2023-28 period.

Voltage optimisation – cost benefit analysis

Term (years from first year of the next price control (i.e. April 2023))	NPV (£m)
10	196.4
20	239.3
30	238.4
45	237.6
Whole life NPV	**237.5**

Table 1: NPV outputs

Customer energy bills benefit (£m NPV)							
Customer saving per annum		£5	£10	£15	*£20*	£25	£30
Roll-out Rate (% of network)	20	8	23	39	54	69	85
	40	23	54	85	115	146	176
	60	39	85	130	176	222	268
	80	54	115	176	**237.5**	299	360
	100	69	146	222	299	375	451

Table 2: NPV – sensitivity analysis outputs

Please refer also to CBA-19-voltage optimisation.

Table 2 shows how the calculated customer benefit changes according to percentage roll-out on network and the customer saving per annum. Our whole life NPV of £237.5m is based on a £20 annual bill saving and an 80 per cent roll-out on the network.