Black Start from Distributed Energy Resources

Bid document to Ofgem

SP ENERGY NETWORKS

tnei

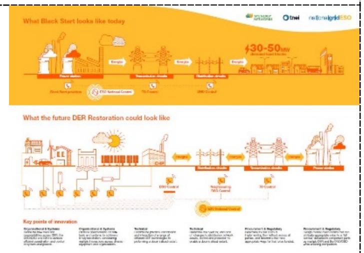
nationalgridESO

Project Code/Version Number:

ESOEN01_V03

Contents

Section 1. Project Summary

1.1. Project Title	Black Start from Distributed Energy Resources (DER)
1.2. Project Explanation	Black Start is the process of restoring electricity to consumers following a blackout. If funded, this project will demonstrate a world first – coordinating a number of DER to provide a safe and effective Black Start service. This will increase competition in the market, and deliver cost and carbon emissions reductions. 
1.3. Funding licensee:	National Grid Electricity Transmission (Electricity System Operator)
1.4. Project description:	**1.4.1. The Problem(s) it is exploring:** Black Start is currently a transmission-led approach of starting large generators and energising a skeleton transmission network. The GB electricity system is undergoing a revolution driven by decarbonisation & decentralisation, and Black Start services need to evolve accordingly. The key problem to solve is how to pull the organisational coordination, the commercial and regulatory frameworks, and the power engineering solutions together to achieve Black Start from DER. **1.4.2. The Method(s) that it will use to solve the Problem(s):** This project will develop and demonstrate groundbreaking new approaches to open the market to DER by designing and then testing technical, organisational, procurement and regulatory solutions. **1.4.3. The Solution(s) it is looking to reach by applying the Method(s):** Enabling DER to provide Black Start services will open a new market for DER (key to a low-carbon, decentralised GB electricity system), will increase competition and diversity in the market, and contribute to adequate Black Start provision in the future. **1.4.4. The Benefit(s) of the project:** Our analysis shows the project can deliver 0.81MT CO_2 reduction (cumulative) by 2050. The NPV of the project is expected to be £115m by 2050 due to increased competition and reduced costs associated with large generator readiness. This would be passed on to GB consumers through reduced BSUoS. This groundbreaking approach would be the first of its kind in the world, creating the blueprint for international adoption.

1.5. Funding

1.5.1 NIC Funding Request (£k)	£10,271.61k	1.5.2 Network Licensee Compulsory Contribution (£k)	£1,169.09k
1.5.3 Network Licensee Extra Contribution (£k)	£0	1.5.4 External Funding – excluding from NICs (£k):	£122.40k
1.5.5. Total Project Costs (£k)	£11,690.88k		

1.6. List of Project Partners, External Funders and Project Supporters (and value of contribution)	**Project Partners:** National Grid Electricity System Operator (Lead): £879.58k SP Energy Networks (SP Transmission, SP Manweb and SP Distributions): £289.51k TNEI Services Limited: £122.40k **External Funders:** None **Project Supporters:** Electricity Networks Association Open Networks Project, Energy Systems Catapult, Cornwall Insight, Various DER and Aggregator Companies

1.7 Timescale

1.7.1. Project Start Date	1 Dec 2018	1.7.2. Project End Date	1 April 2022

1.8. Project Manager Contact Details

1.8.1. Contact Name & Job Title	Mark Jones, Black Start Engineer	1.8.2. Email & Telephone Number	
1.8.3. Contact Address	National Grid House, Warwick Technology Park, Gallows Hill, Warwickshire CV34 6DA		

1.9 Cross Sector Projects (only complete this section if your project is a Cross Sector Project, i.e. involves both the Gas and Electricity NICs).

1.9.1. Funding requested from the [Gas/Electricity] NIC (£k, please state which other competition)	NA
1.9.2. Please confirm whether or not this [Gas/Electricity] NIC Project could proceed in the absence of funding being awarded for the other Project.	NA

1.10 Technology Readiness Level (TRL)

1.10.1. TRL at Project Start Date	5	1.10.2. TRL at Project End Date	8

Section 2: Project Description

2.1 Aims and objectives

The Problem(s) which needs to be resolved;

Black Start is the process of restoring the National Electricity Transmission System (NETS) following the highly unlikely, but highly impactful, event of a partial or total shutdown. National Grid Electricity System Operator (ESO) is responsible for ensuring there is an adequate provision for NETS restoration.

The current restoration strategy uses large power stations and interconnectors as Black Start providers as shown in Figure 2.1. These providers must meet certain technical parameters, including the ability to start up without external power supplies. Once this occurs, the Black Start provider energises sections of the transmission system, using local demand to establish a stable Power Island. Other generators then join this growing system to progressively restore demand across the country until full restoration is completed.

Currently there are four groups of organisations involved in restoration: ESO, Black Start providers, Transmission Owners, and Distribution Network Operators. Each organisation receives instructions, and implements its part of restoration plans using a resilient and secure private telecommunications network.

Figure 2.1 Restoration from large generator

However, the electricity system has transformed, driven by decarbonisation, decentralisation and digitisation.

Black Start services need to evolve in line with this and support the continued transition to a low-carbon, decentralised future. Now is the time to determine how Distributed Energy Resources (DER) can contribute more fully to Black Start. However, this will require an entirely new and more complex approach to restoration, which has not been achieved anywhere in the world. There are a number of technical, commercial, regulatory and operational risks that need to be worked through and mitigated before transition into Business as Usual (BAU), see infographic on back cover.

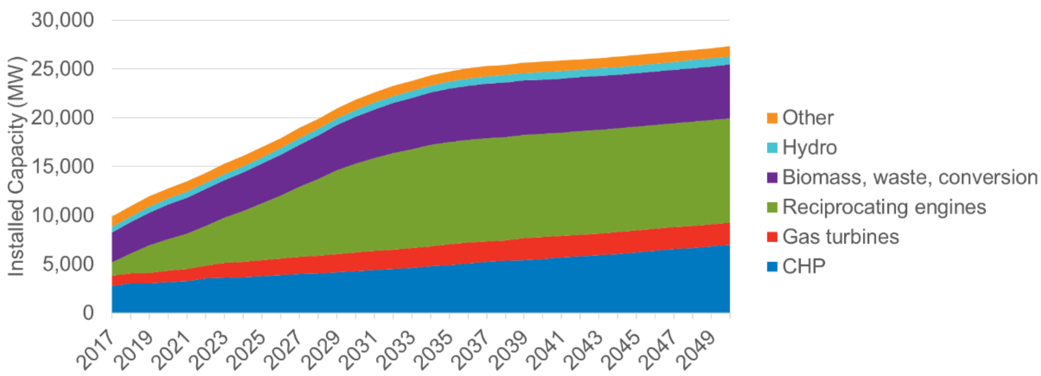
Black Start costs have risen steadily in recent years as the costs associated with keeping large generators on standby have risen. ESO will continue to procure Black Start services as economically and efficiently as it can. Creating a collaborative and comprehensive solution between ESO and DNOs now, to allow DER to participate in the Black Start market, will bring significant financial benefits to consumers through increased competition and lower costs. This will provide further support for community-led energy schemes and potentially achieve shorter restoration times.

DERs – a large and growing opportunity for a more open and transparent Black Start market.

There is an already large and growing pool of DERs who are currently unable to participate in the Black Start market due to existing network restrictions, restoration methods and technical requirements for service providers. Figure 2.2 shows the current and projected installed capacity of DERs, excluding wind, solar and battery storage[1] - currently ~10GW, rising to 25GW by the mid-2030s.

Historically, a significant proportion of Black Start provision has been from coal- or gas-fired generation, with some from pumped storage, hydro and biomass. ESO has also recently confirmed that combined services[2], interconnectors and sites with trip to house load[3] can provide services for Black Start within the existing arrangements. Rising fuel and carbon costs, Government policies and the falling cost of alternative technologies have impacted the economics of large thermal generators, with several having closed.

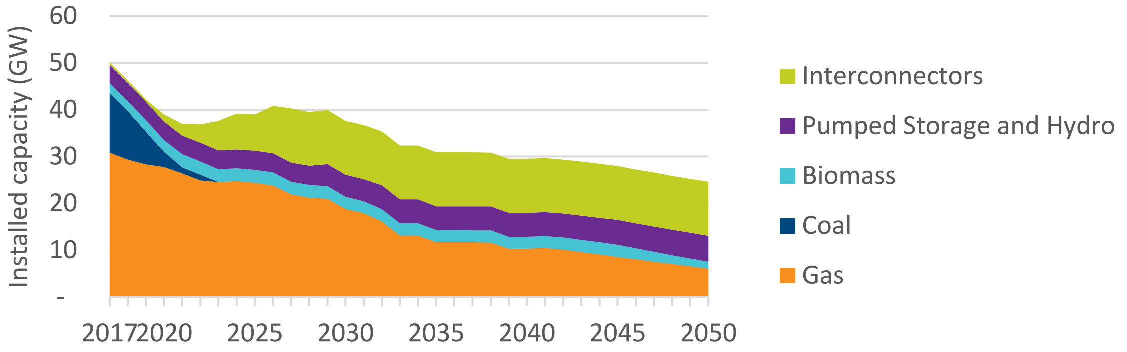
Figure 2.2: Despatchable DER by technology type (FES 2017, Slow Progression Scenario)



The overall capacity of traditional Black Start providers is likely to significantly decrease, Figure 2.3. By 2024 all the coal-fired generation is likely to be decommissioned, and gas-fired capacity is set to fall steadily out to 2050 in all scenarios. Voltage Source Converter (VSC) interconnector capacity is forecast to increase but, although technically proven, interconnectors are reliant on neighbouring energy markets. A smaller pool of providers would mean less competition, which would likely increase costs. ESO will continue to explore other options and will progress these when the level of risk to consumers and shareholders is sufficiently low.

[1] These technologies may be capable of providing some or all of the requirements of a Black Start provider, but we will be assessing their capability as part of a separate research (NIA) project, the learnings of which will add value to this NIC project.
[2] A combination of two providers is used for a Black Start service.
[3] After loss of grid supply, a generator continues operating as a Power Island, maintaining supply on its own site, which may include loads associated with the power generation process and on-site industrial processes.

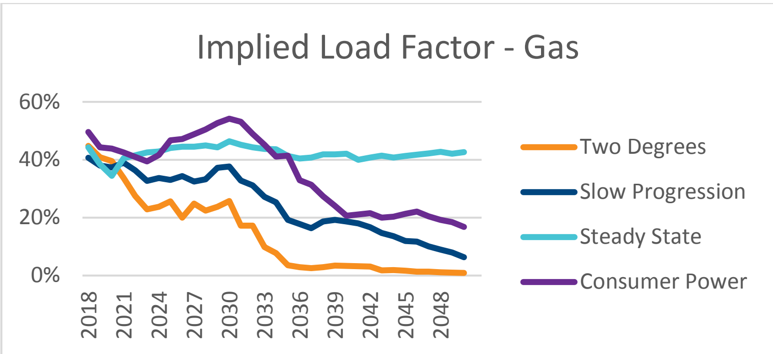
Figure 2.3 Capacity of transmission Black Start provider technology in Slow Progression[4]



The use of Future Energy Scenarios in this proposal This proposal is based on data from the 2017 FES. Our base case is the Slow Progression scenario, representing the least optimistic case for potential benefits from procuring Black Start from DERs[5]. We have since reviewed the 2018 scenarios following their publication in July, and these potentially present even more opportunities for using DERs for Black Start services (DERs capacity forecasts increase), while still presenting challenges when procuring from conventional providers (e.g. reductions in the frequency with which gas turbines are expected to run). More details of the comparison with FES 2018 can be found in Appendix B.

In addition, large thermal generators are running less frequently. This is already the case for coal, and will increasingly be the case for gas, with average load factors falling across all FES scenarios to 2050 reaching an average of 17% in 2050 across all scenarios. Figure 2.4 shows the average load factor for gas across all 4 FES scenarios. This could increase Black Start service costs, as ESO would need to dispatch these large generators more and more to have them on standby to provide the service[6].

Figure 2.4 FES Scenarios: Average Load Factor of Transmission Connected Gas



[4] http://fes.nationalgrid.com/fes-document/fes-2017/
[5] Two Degrees and Consumer Power are driven by greater levels of decarbonisation and decentralisation, with less fossil fuel generation. Steady State is similar to Slow Progression, with relatively little change in the energy system. The use of Slow Progression is discussed in more detail in Section 3.
[6] For example, CCGTs and coal generators need to be run once a week.

This has all put significant pressure on Black Start costs, which ultimately is charged back to the end consumer within the BSUoS element of their bill.

The method(s) being trialled

The method to be trialled in this innovation project is **Black Start from Distributed Energy Resources** (DERs). Fundamentally, this involves:

1. **Restarting an electricity system** from a DER, or combination of DERs, from a blackout (without external power supply).
2. **Maintaining energisation** of the newly-created distribution Power Island of aggregated DER and blocks of demand.
3. **Expanding and synchronising** with other Power Islands, energising further generation, and establishing a skeleton transmission network.

Some synchronous DER technologies are currently capable of self-starting and thus providing Black Start services. However, Black Start is not just about the essential power system parameters (inertia, reactive power, block loading, etc.), but also about the overall initiation and coordination of restoration using smaller, more numerous and dispersed resources.

The coordination of Black Start from DERs has not been proven anywhere in the world, so there are significant commercial, organisational, regulatory and technical risks and unknowns. To overcome these, we will adopt a comprehensive approach that is innovative, open and collaborative to test possible solutions and to minimise cost and maximise value for consumers. If this was implemented as BAU it would involve an iterative and piecemeal derisking of individual opportunities, resulting in a less holistic solution and at greater cost to the consumer.

Risks to procuring Black Start from DERs	
Organisational and Systems	➢ Roles and responsibilities may be difficult to efficiently split and DSO transition adds uncertainty ➢ Number of control engineers required due to complexity in Power Island growth is not practical for DSO ➢ Roles and skillset required for DER are challenging to resource ➢ Cost of providing sufficient resilience in telecomms means focussing on small number of large resources, limiting involvement of smaller DERs
Power Engineering & Trials	➢ Significant complexity to technical changes on distribution networks and DERs to facilitate DER-based restoration ➢ Demand volatility with smaller block loads is too much for DER, needs retrofit of costly energy storage ➢ Restoration speed slower - DER no faster than large power stations, DNOs switch smaller blocks at the same rate as large ones
Procurement & Regulatory	➢ Revenue stream not sufficient to interest DERs in sufficient numbers to match scale required ➢ Market mechanisms across multiple different parties (ESO/DSO/DERs) too complex and may be susceptible to distortion ➢ High cost of retrofitting existing DER and distribution networks (including systems and telecomms) and funding arrangements unclear ➢ Proposed Grid Code changes are challenged by various stakeholders

In this project we will consider as many different types of DERs as feasible in order to demonstrate that the solution is applicable across technology types and across all of GB. Our project is focussed on DER that have reached TRL 4-8 in the context of providing Black Start services (thermal power stations, small hydro stations, wind farms and small gas or diesel stations) although we are open to considering other technologies. The case studies identified so far have a mixture of synchronous and non-synchronous generation types, from both despatchable and intermittent resources, and this will provide an opportunity to explore technology options.

This project is designed to deliver tested and proven concepts and frameworks that can be directly implemented as BAU, assuming the concept is technically and economically viable. It will enable a Black Start from any DER technology once certain TRL levels are attained.

Project Methodology

This project will **Develop** and **Demonstrate** the power engineering & trials, organisational & systems, and procurement & regulatory requirements to accelerate the provision of Black Start services from DERs into business as usual. We will use case studies on real network locations to prioritise, analyse, plan and test proposals. A key success factor for innovation projects is industry engagement, learning and buy-in. This will take place through engagement and consultation, as well as through participation of DER owners/operators in case studies, and through a Stakeholder Advisory Panel, described in Section 5.

The **Development** phase will identify the viable options for de-centralised restoration, then progress on to the detailed design necessary to support testing and future roll-out. The following aspects of the method will be developed:

- Methods to assess DER and network capability and potential for Black Start for specific distribution network locations.
- Recommendations for adaptations of DER and distribution networks to facilitate Black Start safely and economically.
- Coordination and control solutions to ensure appropriate levels of resilience, efficiency and restoration times along with clear definition of roles and responsibilities.
- Procurement and regulatory frameworks, including contract design and proposals for any changes to codes, standards, licences and funding arrangements.

The first few months of the project will focus on the technical viability of the proposed method, in the case studies across GB. This will include assessment of power systems behaviour and the options for communications and coordination of Black Start. This early work will confirm the need for further **Development** and **Demonstration** of DER and network performance, new processes and tools for organisational coordination, and an appropriate commercial framework. We will engage and consult with stakeholders to test whether our options are fit for purpose for the industry.

The **Demonstration** phase will plan and carry out testing of the designed solutions. This phase will cover both practical testing on live power systems and process exercising (through desktop exercises) to enable the designed solutions to be tested in an appropriate and safe environment. Where incremental improvements are identified, they will be incorporated into the final proposed solutions. This phase will demonstrate that the designed options:

- Provide credible technical solutions for the provision of Black Start services from DERs, and that the requirements for Black Start are met by each DER type.
- Can be implemented in a Black Start situation using an appropriate process for coordination and control of DER as part of the GB restoration solution.
- Can be validated and tested, by developing a thorough and robust planning process for provider assessment and risk mitigation.
- Produce a framework for a viable service, demonstrated through desktop exercises and an industry consultation to assess market suitability and product appetite.

As we approach the end of the project the focus will increasingly shift towards implementation in BAU. The Power Engineering & Trials work stream will produce guidance notes and supporting materials to facilitate future assessment and testing of Black Start from DER across GB. The Organisational & Systems work stream will define how the Power Island will be coordinated and managed, with functional specifications for the systems and telecommunications for parties and roles that would be directly involved in restoration in different areas. The Procurement & Regulation work stream will finalise a competitive procurement approach and contractual terms to be used by ESO, DNOs and DERs. The regulatory aspects will be transferred out of the project and proposals forwarded by ESO into the wider industry, e.g. the proposing of code changes.

The Solution(s) which will be enabled by solving the Problem.

From our analysis, this project will enable:

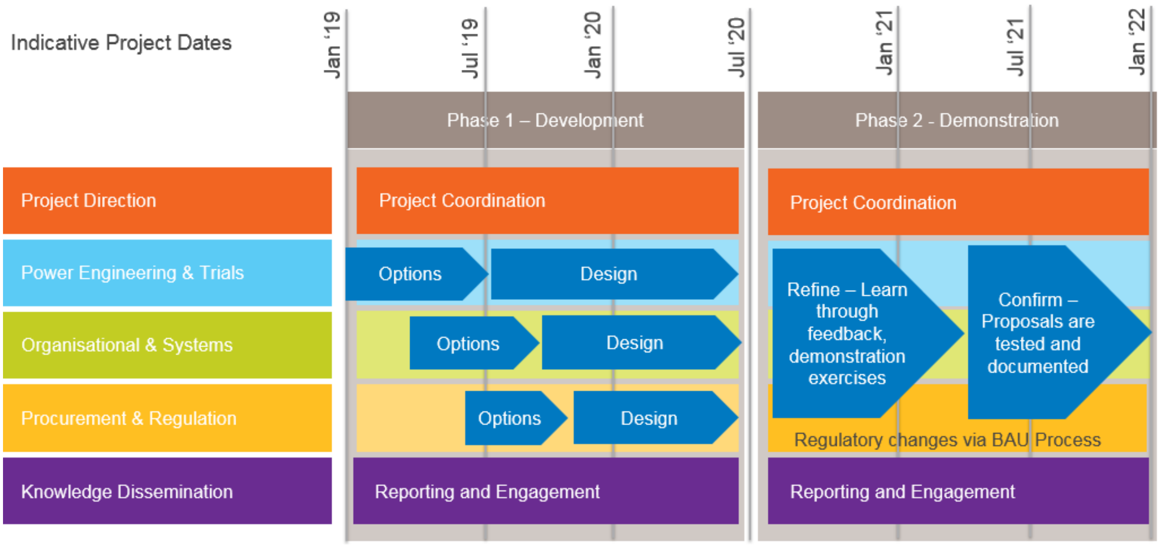
1. An entirely new more transparent and open market for DERs. This will be a key element of a decarbonised and decentralised electricity system for GB.
2. A significantly larger pool of potential Black Start providers, bringing increased competition, more diversity and ultimately, benefit to consumers.
3. Drastically new roles for DNOs, enabling them to actively manage DER on their network, through moving to a DSO model.

Once this project has delivered proposals to enable and bring about the changes detailed above, we believe that the barriers to achieving Black Start service products from the DER market will have been overcome.

2.2 Technical Description of Project

As described above, our innovation project is structured in two phases: **Development** and **Demonstration** which is shown in Figure 2.6.

Figure 2.6 Structure of Black Start from DER Project



Our intended approach to delivering the project, including a description of individual tasks, is explained more fully in Appendix G. We believe that fully addressing and deliver into BAU, the challenge of Black Start from DER should be tackled across three broad areas of activity: Power Engineering & Trials, Organisational & Systems, and Procurement & Regulation. Across all work streams we will use **Case Studies** to ensure the developed method works for actual networks and DERs.

Development

The **Development** phase is split into two stages, **Options** and **Design**. The **Options** stage identifies and prioritises challenges arising in each work stream area and will determine the basic viability of the method, before effort is invested in detailed analysis or developing new processes. The **Design** stage will develop the options in preparation for testing, and an industry consultation on proposed designs will be published for review.

We will develop detailed power engineering understanding of DER and network capability to deliver the energisation and restoration process using the **Case Studies**. Any necessary adaptations for DER or networks will be explored from a technical, financial and regulatory perspective. Detailed system studies and thorough engineering review will build understanding and confidence before testing in live trials.

We will explore and analyse current coordination and control mechanisms to assess the current level of resilience and efficiency, and whether this is sufficient or whether enhancements are required. The results of this may determine a requirement for additional functionality to be designed into existing or new systems. Should this be the case we will determine relevant processes, and appropriate roles, responsibilities and resources to support this implementation.

To create the basis for future procurement needs, we will develop contractual and regulatory proposals to implement the method in the most efficient and economical way. These proposals will be designed in close consultation with all key stakeholders.

Demonstration

The **Demonstration** phase is split into two stages, **Refine** and **Test**. It will demonstrate the delivered benefits of the designed solutions through a series of desktop exercises, offline testing and live system trials. Each of these will incorporate their feedback into the design for subsequent tests. By testing the Black Start service from DER in this iterative manner learning from each stage will be maximised, whilst minimising impacts on customers.

Operational processes and coordination of the control and instruction of Black Start from DER will be tested by structured process walkthroughs and **desktop exercising**. This enables all parties involved in the process to systematically walk through their roles in a process. Once the process has been designed, a practical test scenario (seating individuals from all parties around a table to role play their organisation's response and actions) can be designed to enable validation of the process, or to provide iterative feedback on improvements to be made. These tests examine the detail of communication between ESO-DNO-DER to ensure the correct information and data is passed to the relevant parties enabling the process to progress. This testing method focuses on the detail of information shared, rather than on the medium over which the information is shared.

The **live trials** will test the technical capability of DER and distribution networks to deliver the proposed Black Start process. The specific details of the tests will be developed during the project based on the restoration process devised for each case study, the learning to be gained from testing different aspects of the process or equipment performance, and the opportunities for testing given network and DER restrictions. Live trials will be organised for at least two case studies, energising up to 132kV.

Before live trials, hardware-in-the-loop testing may be used to evaluate the capability and performance of hardware and software controllers for DER during Black Start and restoration processes. A Real-time Digital Simulator may be used to emulate the behaviour of the grid in the test environment.

Overall, testing will involve significant planning and coordination between all impacted and participating parties and robust assessment of testing results must be carried out to validate designs and solutions. All live system testing will be subject to a thorough and robust planning process, assessing the risks and minimising disruption to customers (more details in Section 8).

2.3 Description of design of trials

The trials will demonstrate the proposed Black Start from DER method and the underlying hypotheses in a way that lets the whole industry learn and gain valuable experience in this area. It will do so through the following activities:

Case Studies: During the **Development** stage, DER solutions will be analysed and simulated in specific network areas. Two case studies will be carried forward into the **Demonstration** stage. This approach ensures that we begin the stage with a wide range of network and generation types, before focusing on specific examples in the **Demonstration** stage. In this way, the learning gained is more representative of the whole system rather than one or two specific network areas.

We have already identified a number of networks within the Scottish Power Manweb (SPM) and Scottish Power Distribution (SPD) licence areas and various generators within these networks have indicated their willingness to be involved in testing during the **Demonstration** phase. We will also consider case studies in non-SPEN distribution networks where these add value to the project and help to explore specific areas identified.

Desktop Exercising will test the ability for the organisations involved to coordinate and manage the creation of a DER Power Island. Within a class room environment the organisational process, roles and responsibilities will be tested via a prepared training scenario. Systems, tools and telecommunications provision will be emulated to fully test the end to end process. Each of the relevant DNO, DER and TO stakeholders role play their response in a simulated Black Start situation. These exercises address the operational and organisational interactions (i.e. who speaks to who at a certain point in the process, or what information is required to be passed from one organisation to another) of the process. Specific exercise scenarios can be developed for a number of the individual case studies and further learning, but elements to be tested may include:

- Initiating the Black Start restoration process
- Coordinating a number of DER providers in building up a Power Island
- Synchronising DER Power Islands together using the DSO control instruction

Two Live trials will be designed to demonstrate that the following can be achieved safely and with acceptable control of voltage and frequency:

- Self-starting and grid-forming behaviour of DER as the 'anchor' in a distribution-level Power Island, i.e. restart with a 'dead' network and energise to point of connection
- Energisation of distribution network circuits and transformers, including 'back-energisation' of transformers from the low voltage side to 132kV
- Restoration of demand, testing both the scope of DNO control and the ability of DER to accept blocks of load

- Connection of additional DER (including wind or other intermittent renewables) to grow the Power Island, testing the ability of converter-connected DER to operate in a very weak system and any interaction between DER
- Coordinated control of multiple DER to achieve an aggregated capability equivalent to a single, large generator
- Back-energisation of transformers at the transmission-distribution interface and energisation of transmission circuits

The case study descriptions in Appendix G include specific details of the live trials that might be undertaken at Chapelcross in Scotland and Aberystwyth/Rhydlydan in north Wales, although these are subject to detailed review and further discussion with stakeholders during the project. Proceeding with live trials will incur costs including the hiring of equipment like diesel generators and load banks and the possible installation of safety-critical equipment like earthing transformers and additional protection systems. Detailed technical and financial proposals for live trials will be developed during the project for approval by the Steering Committee.

Stakeholder Advisory Panel and consultation

The Stakeholder Advisory Panel (see Section 5) will ensure that trials are representative and applicable to all technologies and GB networks, and that they are delivering for consumers. We will also undertake industry-wide consultations at strategic milestones, particularly on the commercial and regulatory aspects.

2.4 Changes since Initial Screening Process (ISP)

Restructuring of Project Scope

Following careful consideration of Ofgem's feedback on the ISP, we have restructured the project significantly and have developed a much more robust project scope, plan and costing. The following items reflect the major cost changes since ISP stage:

- An increase in project trial costs based on a more detailed trial design
- Transfer of some ineligible research activities into an NIA project on capability of Black Start from emerging distributed energy resource technologies
- Transfer of remaining ineligible research activities into BAU
- There has also been a slight uplift in overall costs that reflects improved scoping and assessment of project risks.

As a result, the total project budget is now £11.7m including contingency.

DNO Partner Onboarding

During ISP preparations, we issued a DNO partner invitation to all 6 DNO companies. After careful consideration, SPEN was selected as partner due to its highly appropriate network characteristics, DER relationships and technical skillset.

All DNOs expressed a strong interest in being involved in the project as it develops, we will make sure this happens through the Stakeholder Advisory Panel and through our interactions with the ENA Open Networks Project.

Section 3: Project Business Case

This project supports the strategic direction of the electricity networks.

Section 2 described how Black Start services are likely to become less economic due to the energy system's transformation. There is likely to be a diminishing role for large scale thermal power stations, which currently provide the majority of these services, due to the increase in renewable generation (such as wind and solar) and the continuing decentralisation of energy resources on the distribution network.

ESO, SPEN and the wider electricity networks industry are responding to these trends. Companies and organisations across the industry have published research, roadmaps and strategies that further detail their response to these changes, including:

- ESO's Black Start strategy
- ESO's work on the future role of the electricity system operator
- ESO's work on the future of balancing services
- Work stream 3 (DSO Transition) of the ENA's Open Networks project
- The Energy Networks Association's Electricity Innovation Strategy
- National Grid System Operator's Innovation Strategy
- Ofgem and the Government's work on Smart Systems and Flexibility
- SPEN DSO Vision.

This work covers a wide range of topics; however, they feature some common principles about how energy networks may function in the future, including:

- Planning for *whole system outcomes* across both transmission and distribution
- Improving *transparency* and increasing *participation* in system services
- Increasing *competition* in the energy system
- Innovating in *procurement of services*, including procurement from DER.

Table 3.1 describes in more detail how this project links to each of these principles.

Table 3.1 How the project supports the future vision for energy networks

Planning for whole electricity system outcomes	This project will enable ESO to take a holistic 'whole system' approach to restoration. The large pool of energy resources on the distribution network will enable ESO and DSOs to consider restoration at this level, rather than relying on a smaller volume of power stations on the transmission network. DSOs will be critical to facilitating and managing this increased market competition, providing overall cost reductions to customers.
Increasing participation	Opportunities for participation in the Black Start service market by DER should significantly increase the size and breadth of the market.
Increasing competition	A larger number of providers will increase market liquidity, reduce concentration and enable a reduction in costs.
Innovation in procurement of services	Innovative and more transparent commercial arrangements will better enable new types of DER to take part in Black Start.

ESO and SPEN operate in a rapidly-changing environment, and we are constantly evolving and adapting our approach to maintain a secure, efficient and reliable system for consumers. This is because we understand the short-, medium- and long-term direction of the whole energy system. So we can position ourselves to respond to key changes. We achieve this through a combination of:

- Incremental improvements to how we currently do things, which is business as usual activity.
- Step changes, or complete overhauls in how we do things, which require new approaches that cannot be achieved within the activities outlined in current funding arrangements.

ESO's Black Start Strategy and Black Start Procurement Methodology, published originally in June 2017 and updated in June 2018, are the primary examples of how this works within the rapidly-evolving world of Black Start provision. As per Special Condition 4G of the Transmission Licence, these documents set out our short-, medium- and long-term view of how the strategy for Black Start provision may change. We explain how we need to change the approach to Black Start based on external changes over the next 5 years. Consistent with the SO Innovation Strategy and other strategic publications, these documents do not make any specific proposals about how to achieve their conclusions, but rather, provide our vision and goals for the future.

ESO has also recently published a Product Roadmap for Restoration[11] as part of its work on the future of balancing services. This sets out the vision for the future of Black Start:

> "… by the mid-2020s, we will be running a fully competitive Black Start procurement process, providing there is sufficient competition to enable a market-based solution. This would include submissions from a wide range of technologies connected at different voltage levels on the network, with DNOs playing a more active role in the restoration approach."

This vision is reflected in both the medium- and long-term Black Start strategy. In the medium-term strategy, the focus is on "whether a tendered approach to procurement can be established". The timeframe for this is 1-3 years, which overlaps with the development phase of this project. To incorporate DERs, we need to understand the service delivery requirements and options, the appropriate contractual structure, and how to deploy this solution. This project would ensure the robustness of a Black Start market in the longer-term through enabling participation of new types of DER within the restoration process. This would help to make procurement of Black Start services more open and transparent for customers and providers, which is another strategic goal of the ESO.

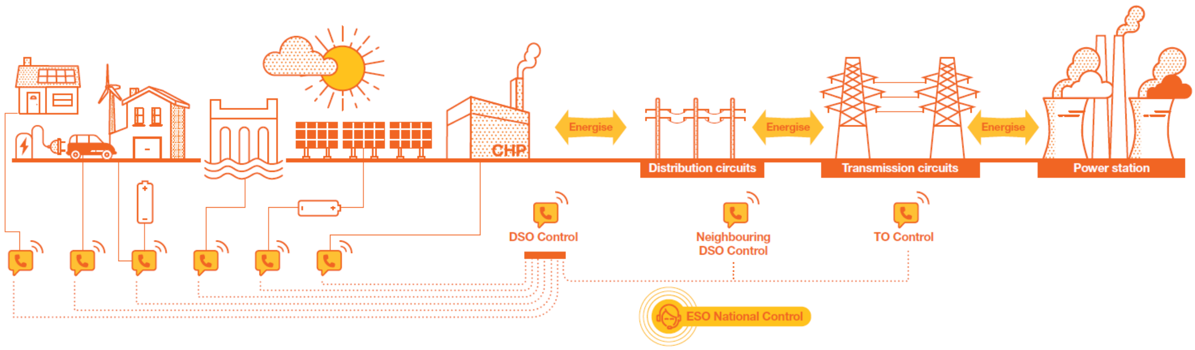
This project is needed to achieve a step change to deliver the vision for the future of the low-carbon, decentralised, whole electricity system which ESO, SPEN and others have endorsed in strategic publications. It is wholly aligned with the transformational change happening across the electricity industry.

The full scale of potential benefits can only be realised with innovation funding

We firmly believe that this project should be delivered as an innovation funded project, rather than through business as usual arrangements.

Based on the exploratory work we have done so far, we believe that all elements of the current Black Start process may need to be wholly redesigned to align to a new methodology, and tested rigorously in a safe environment. This is illustrated in Figure 3.1, which summarises how Black Start may work in the future when DERs are involved – and described in more detail in Appendix H.

Figure 3.1 How future DER restoration could look



Doing this requires an open and collaborative approach which involves the wider industry, including the DNOs and DERs.

It would be possible in principle to work towards this through business as usual. However, we believe there are additional benefits for consumers which can only be realised if the project is funded through the NIC.

First and foremost is the **pace and scale of change** which we believe can only be achieved through the NIC. We believe that funding through the NIC is the only way that the Black Start from DER method can be implemented both quickly and at a very large scale. Because the concept is innovative and inherently risky, funding through BAU would have to be to done in a much more sporadic way, and only once individual areas of work have been suitably de-risked for the end consumer and shareholders.

Under BAU, the ESO would continue to develop Black Start services, in accordance with its licence requirements, which might involve some development for smaller DERs. However, this would have to be piecemeal, less coordinated due to the timing of the transmission and distribution price controls, and at a much smaller scale than proposed in this project. Changes under BAU would be incremental, compared to the transformative change we are envisaging could be achieved from this NIC project.

Developing the project through the NIC allows ESO and SPEN to take more risks and be more innovative, which gives the industry the best chance of enabling this new approach and a large scale and at a much greater pace.

Second are the **benefits of collaboration** which the NIC will enable. This allows all parties to help shape the direction of the project, and helps to ensure that all solutions are best fits across the whole industry, and therefore easy to adopt. This engagement may also help to raise awareness of the challenges associated with system failure and restoration across a much wider segment of the industry.

Finally, there are a **range of further potential benefits** which might be realised when implementing the method at such a large scale. This may include potential new revenue streams for DERs, improved resilience of lower energy systems, and potential improvements in restoration times for end consumers.

This project can potentially deliver cost and carbon benefits to consumers

This project seeks to ensure that the cost of procuring Black Start services continues to remain economical. The project will achieve this through:

- Increasing the number of providers of Black Start services, leading to more competition and competitive prices for the service.
- Minimising current costly despatch of large-scale fossil fuel providers, for the purposes of maintaining Black Start services readiness within agreed timescales.
- Reducing the need to retrofit new self-starting auxiliary supplies to power stations, to enable Black Start provision from large-scale providers.

However, we recognise that contracting for Black Start services from DER could also lead to an increase in some costs. For example, equipment retrofitting on the distribution network. The financial and carbon benefits of our method have been explored in a detailed cost-benefit analysis. More information on the analysis is provided in Section 4 (a), Appendix A and Appendix B.

The cost-benefit analysis determines the lowest-cost combination of power station capacity that can meet ESO's Black Start requirements in each of the 6 Black Start zone, accounting for all of the costs and benefits described above. The 2017 Slow Progression FES scenario has been used as the basis of the cost-benefit analysis.

We have included many other innovations which will reduce the cost of Black Start within the Base Case. This is pessimistic for our bid, yet the project still shows a clear positive benefit which is an order of magnitude greater than our funding request. Most significantly, we have included the roll-out of **Black Start from DERs in the base case** as well as the method case. Despite this, there are still clear benefits to the project, due to (i) commencing the project now, rather than waiting for the method to be enabled more slowly under BAU and (ii) the efficiencies which we assume will be realised through funding within the NIC.

Based on this analysis, our method has the potential to deliver financial benefits of at least £115m (net present value in 2018/19 prices) and carbon benefits of 0.81MT of cumulative avoided CO_2e for consumers by 2050, breaking even by 2027 (within 5 years of the end of the project). These benefits are described in more detail in Section 4 (a).

A robust approach for project delivery

Section 2.2, Section 2.3 and Section 6 describe the project, the approach that we have developed in detail and the project's readiness. As discussed, we have adopted a two-phase structure, **Development** and **Demonstration** to foster tangible and practical learning. We have also built in consultation in each phase through **Case Studies.** We have identified work streams for organisational, power engineering, and procurement and regulatory aspects. These work streams are present in each phase of the project.

The scope includes testing of the method in the **Demonstration** phase through desktop exercises and testing of DERs. Testing of DER in a real network environment will provide significant learning on functional and testing requirements and coordination and control systems. Where online testing is not feasible due to operational limitations, we will use a programme of offline testing and system studies.

All partners have agreed in principle on an organisational structure and contractual terms to deliver this project. The scope and resourcing have been developed collaboratively between all partners with approval and commitment to delivery by individual organisations' senior management.

We have developed the programme to ensure delivery is in a timely manner to meet the challenges outlined in Section 2, which will start to manifest from the mid 2020s. The programme is ambitious but, based on the experience and assessment of the project partners, is deemed realistic and achievable.

There are risks, but these have been identified and assessed during bid preparation. We have developed risk mitigations, where appropriate, and put in place a contingency plan. ESO, SPEN and TNEI each have experience of delivering Ofgem-funded large-scale innovation projects. More supporting information for the project plan is provided in Appendix D.

The project has been costed carefully, and we believe represents excellent value for money for the consumer, considering the substantial benefits and learning it will generate.

Market research supports funding through the NIC

Section 2 summarised the changes in the energy market which will lead to procurement of Black Start services becoming more challenging and potentially less economical. This demonstrates the timeliness of this project, as the availability of existing Black Start providers will decline from the mid 2020s. More information about the relevance and timeliness of the project is given in Section 4(f).

To gather further industry feedback, all partners have undertaken engagement during the preparation of this bid. Workshops and meetings were held with DER owners/operators, aggregators and other stakeholders to gather views and feedback on the project scope and deliverables. As part of this engagement, participants were asked to complete a survey, the results of which are summarised in Table 3.3.

Table 3.3: Summary of survey responses from 23 participants

Timeliness	87% of respondents agreed that the project was timely, with only 8% saying it was either too late, or too early.
Readiness	57% of respondents said that the DER technology to support the method is available but not generally deployed, whereas 25% said that new technology is required.
Barriers	82% of respondents said that changes were needed to the commercial and regulatory regime to make the proposed approach an attractive opportunity.
Interest	Many of the respondents were interested in being involved in the project including through the Project Advisory Panel and online testing.

The results of this survey demonstrate there is a strong desire from industry for our project method. It is clear that the project is timely, and from a DER perspective, technology to support Black Start is available. However, there was an observation that changes will be required to the commercial and regulatory regime to make Black Start services an attractive market for DER. Engagement with other key industry stakeholders, such as ENA Open Networks, has resulted in knowledge sharing being added to ensure visibility of case studies, understanding of key dependencies with other industry projects e.g. DSO market models, and sharing of learning.

Feedback from industry has been considered in the project scope and verifies the unique and innovative characteristics of the method. Recognising ongoing changes within the electricity sector, engagement with the wider industry will continue throughout the project, as detailed in Section 5 and Appendix I.

Innovation funding is needed to deliver benefits

As mentioned, this project supports the electricity industry's transformation and, by enabling access to new sources of Black Start capability, has the potential to deliver significant benefits to consumers. We have developed a robust methodology to ensure the project delivers value for the consumer, and industry participants are supportive of its need and excited to be involved. However, we believe this can only be achieved at scale through innovation funding.

Section 4: Benefits, timeliness, and partners

(a) Benefits

The method delivers significant financial benefits to consumers compared with the base case. There is potential for customers to save at least £115m by 2050, if a GB wide implementation can take place from 2025, with 810 kT of avoided CO_2. The 'break even' occurs in 2027. This is based on the most conservative 2017 Future Energy Scenario for energy system change – Slow Progression. For scenarios with greater energy system change, financial benefits are expected to be even greater.

The base case (counterfactual) and method both assume that other innovations will drive down the cost of Black Start. This includes provision of services from interconnectors, but also future service provision from transmission-connected intermittent renewable generation, as well as innovations which reduce the costs associated with keeping CCGT in a state of readiness. We have even included a later and somewhat less efficient adoption of the proposed method in the Base Case too. This reduces Black Start costs in the base case, making the estimate of benefits more pessimistic.

To estimate the method's benefits to 2050, the Cost Benefit Analysis (CBA) model simplifies and removes aspects of the ESO's procurement of Black Start services. For example, ESO has currently procures three providers in each of the six Black Start zones to satisfy the existing restoration strategy. For the CBA, this is represented as a need for 3 GW of capability in each zone.

The CBA has generally used pessimistic assumptions, so represents a conservative view of the potential benefits. The analysis does not consider some elements which could increase financial benefits, such as:

- The possible need for life extensions of old plant.
- The potential to reduce the volume of Black Start capability from DERs, due to higher availability from a larger number of providers.
- Reduction in restoration time that could be achieved using DERs.

Further details on financial benefits are provided in Appendix A and Appendix B.

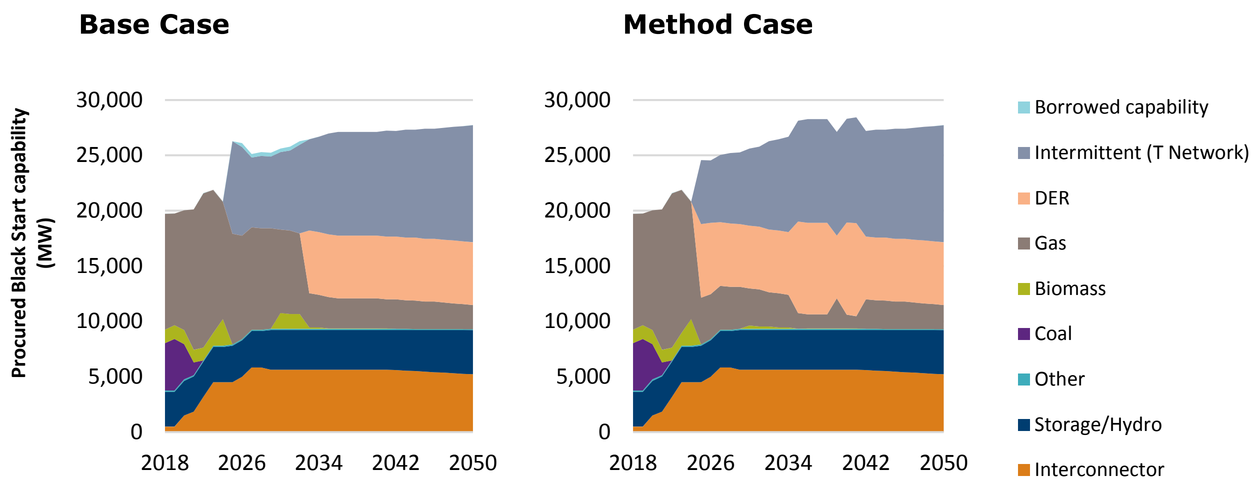
Financial Benefits through new sources of Black Start

Figure 4.1 illustrates the impact the method has on Black Start procurement.

In the base case, there is a continued reliance on gas generators, with some capability also provided by storage (almost entirely pumped storage), hydro, interconnectors and biomass.

This decreases somewhat when large-scale intermittent renewables become part of the service fleet (assumed to be in 2025) – it is assumed that this is almost entirely wind, with some limited marine energy. The CBA does not include any large-scale solar PV for Black Start services. To take account of resource intermittency for renewables, we assume that only around 30% of installed capacity should be considered to be available as energy from a wind farm when procuring services.

Figure 4.1: Procured capability for Black Start services in base case and method case



DERs significantly reduce the extent to which large-scale gas turbines are required as part of the service in the period 2025-2033. This is illustrated above in the forecast generation mix for Black Start capacity requirements by 2050 under Slow Progression, for the method. This could be largely comprised of 'despatchable' DERs, such as gas reciprocating engines, although there is increasingly likely to be some storage and intermittent DER providing Black Start capability towards 2050. In addition, a small amount of capability needs to be "borrowed" from neighbouring zones. This is described in greater detail in Appendix B.

Enabling new and alternative providers of Black Start Services will widen the pool of providers, helping to increase competition and keep costs competitive. This has been quantified by using a market concentration index (Herfindal Hirschmann Index) to estimate the degree to which prices are 'marked up' beyond cost. When DER are added to the generation index, market concentration decreases and the markup reduces. The increase in volume of smaller service providers will also provide better resilience through having greater diversity in both the technology and providers, although the benefit of this has not been quantified.

The most material changes in cost are due to:

- In the base case, there is a large cost associated with ensuring the readiness of transmission generators (particularly CCGTs). This reduces in the method case.
- On the other hand, the cost of retrofitting equipment increases in the method case. This is due to the need to retrofit equipment on the distribution network.
- The degree to which prices are 'marked up' due to market concentration reduces in the method case, as there is a larger number of potential providers.
- In the method case, there are increased 'centralised' costs compared to the base case. This includes the NIC project costs, implementation costs and an ongoing cost associated with additional ESO and DSO staff, although additional operational resourcing may be required anyway due to wider industry changes.
- Benefits accrue more slowly from 2033 onwards – this is the point at which the method is assumed to be adopted within the Base Case.

Carbon Benefits

Carbon benefits from the method are primarily due fewer actions to ensure readiness of large fossil fuel plants to provide Black Start services. Carbon benefits have been calculated annually, leading to an 80kT CO_2e reduction per annum (2025-2032) for the method compared to the base case. The overall carbon benefits are significant, totalling 0.81 MT CO2e by 2050. Further details are provided in Appendix A.

(b) Value for money

Value for money in the cost of the Black Start service: In Section 4a, we have shown that the provision of Black Start from DERs will bring financial and carbon benefits, meaning the cost of the service will continue to represent value for money to the consumer. Black Start is one of the ancillary service costs that make up the external component of balancing services use of system charges (BSUoS). This component covers reimbursement to providers for delivering balancing services. Assuming that a more decentralised market model is funded under the same arrangement, costs recovery via BSUoS will be lower leading to lower consumer bills. Under an alternative market model, consumers should still receive value for money via a different mechanism.

If this innovation project is not funded, the ESO will continue to develop Black Start services and discharge its licence obligations for Black Start through the continued running of gas stations, interconnectors, and the inclusion of large individual embedded generators. Further development in the area of smaller DER may also occur, but this will be piecemeal, less coordinated due to the timing of transmission and distribution regulatory price control regimes and initially at a much smaller scale. Incremental changes will be made to systems and processes to demonstrate value to other DERs to encourage their participation and changes to their respective systems and processes, rather than at the scale and speed of the rollout of a collaborative wholesale new solution that is made possible through the NIC mechanism.

The NIC funding and approach allows for a collaborative partnership approach with clear accountabilities on all parties to demonstrate the value for the consumer rather than solely with the ESO under standard market developments.

Project Cost and contributions: Project costs have been calculated by the three partners using a bottom-up approach based on the project scope, programme, and risks and uncertainties. All three partners are providing a contribution in kind against the total project cost.

The project costs have been peer reviewed by internal stakeholders and senior management to ensure value for money.

Resource and daily rates: Labour by the three partners is the majority of project costs, derived from estimates of the resources needed to deliver the scope. Resources and costs are consistent with the level of capability required to deliver this project, to deliver the method to industry, and the expertise and value-add of each partner.

Efficiency in procurement: Where external expertise beyond our partners is expected to be required, we have engaged with potential providers to understand likely costs. Any further external expertise will be selected through a competitive process to choose the preferred technical partners who can provide the necessary expertise at the best value.

Project Risk and Delivery: The project is structured to develop and evaluate options before progressing to demonstration. These will be refined through industry consultation before desktop exercises, offline and online testing. This ensures concepts are developed in a phased process to reduce uncertainty, manage risk and interdependencies, and maximise efficiency of spend. Using the case study approach, only activities that are likely to be successful or generate useful learning will be progressed.

(d) Innovation

ESO is constantly looking for new ways of doing things to improve system operability, discharge our licence obligations and ultimately help consumers, for example the recent addition of interconnectors to our Black Start market framework. Interconnectors fit neatly within our current framework as they are a large transmission-connected asset, and are well understood. The ability to control, instruct and despatch these providers on the transmission network is already in existence, so the actions required to develop the service from this "new" technology focused on the assessment of the capability of the technology and its impact on restoration.

The proposed project aims to put in place a wholesale, systematic change which is system and process driven to enable contribution from and coordination of a far greater number of embedded providers. It aims to achieve this at significant pace, ready for GB-wide rollout. For this to be successful, it requires involvement and real commitment from the entire industry, and resource to be in place that are not currently aligned for System and Network Operators to deliver.

The key points of innovation required as part of this change are as follows:

- **Organisational & Systems:** Define the new roles and responsibilities across DER, the DNO/DSO and ESO to achieve efficient coordination and control of a more complex system energisation.

- **Organisational & Systems:** Produce specifications for new tools and systems to achieve a timely restoration, considering multiple interactions across diverse equipment and organisations.
- **Power Engineering & Trials:** Confirm the practical contribution and interaction of a range of different DER technologies in performing a decentralised restart.
- **Power Engineering & Trials:** Determine the need for, and cost of, changes to distribution network assets, control and protection to enable a decentralised restart.
- **Procurement & Regulatory:** Determine the full costs of implementing the method, across all parties, and determine the most appropriate ways for that to be funded.
- **Procurement & Regulatory:** Design market mechanisms that can attribute appropriate value to a 'full service' delivered in component parts by multiple DER and the DNO/DSO while enabling competition.

Multiple risks across power engineering, organisational, commercial and regulatory aspects mean that, whilst there is potential and great interest in this concept, we cannot be sure it is definitely going to work – it would be inefficient to spend money through BAU activity to sporadically bring in DER assets in a piecemeal manner. Furthermore, given commercial implications for the ESO and DNOs such as sunk costs in rollout for an unproven concept, shareholders would not speculatively fund this innovation.

Table H.1 in Appendix H further outlines our current Black Start activities, and explains why bringing DER into the fold cannot be done under the current framework.

The method we are proposing has never been trialled before. The majority of the work that has been done thus far has been conceptual or has involved tests on microgrids. A microgrid is a group of electricity sources and loads that normally operates connected to the main grid but can also disconnect to 'island' mode and function autonomously if required. The microgrid concept is extremely relevant, microgrid RD&D will inform our approach to overall control of Power Islands including coordination of DER and demand volatility as well as issues like protection and earthing. Here we highlight international examples of particular relevance to our project:

Germany: A 15 MWh battery system, paired with a combined cycle gas turbine, has been used to successfully restart a disconnected microgrid in Germany.

China State Grid: A theoretical study on Black Start from a combination of PV, battery and diesel generators. Results suggested that the approach could be feasible and effective on a microgrid.

Fort Bragg, USA: One of the world's largest microgrids which integrates a variety of DER technologies.

Woodbridge Connecticut, USA: Microgrid based on a fuel cell, intelligent control of a load bank, and a novel approach to protection based on power quality monitoring.

Sydney, Australia: The microgrid at Legion House generates its own power through biomass gasification, with energy storage allowing independent operation.

Our NIC project will take conceptual learnings from these and apply them to our much larger-scale tests. But what we propose is very different: bigger kV and MW, equipment not designed for this purpose, multiple owners/operators, preparing for a rare event.

There is potential alignment with efforts to develop microgrid-style community energy schemes. It may be that the opportunity to provide restoration services, and potentially earn income, is enough to prompt progress on a community energy scheme.

Past and ongoing NIA and NIC projects, reviews and consultations focused on Black Start and management of DERs have also informed the scope and methodology of this project. These include Black Start Alternative Approaches ESO Network Innovation Allowance (NIA) projects and NIC projects such as Power Potential, TRANSITION and FUSION.

Black Start technical requirements for DER such as block loading, reactive power absorption and inertia capabilities may vary for different network characteristics and the local DER technology mix. Also, energising from the distribution network may require system adaptations. Only by demonstrating through live system trials along with thorough investigation and analysis, will we learn about technical capabilities, options for networks, and how to de-risk and implement this approach in business as usual.

Current bilateral commercial frameworks may not be the most efficient way of procuring this service. There will be much higher numbers and types of market participants, and the transition towards a DSO market model will influence commercial and regulatory frameworks for Black Start. Rather than bring new entrants into an existing market framework (the approach taken for interconnectors and the large embedded generator), we need to redesign and test entirely new commercial arrangements. We are envisaging a multi-lateral and multi-layered approach – this will require a significant amount of collaborative work to arrive at the best solution.

The step-change in the role of the DNO must not be understated. As discussed, the role of the DNO is fundamentally transformed from passive to active system operation.

Crucially, the operational processes for the ESO and the DNO to coordinate and control DER in a Black Start event are as-yet undefined and untested. Power Potential is demonstrating the collaboration of the SO and DNO to provide market services from DERs. However, our project is a step further, requiring efficient coordination in a complex and time-critical environment where resilience will be tested. Given the national security considerations in a Black Start scenario, it is essential that the method is first developed and demonstrated.

The capability of DER and networks has previously been explored at a high level in the Black Start SOF Report and the Black Start Alternative Approaches ESO NIA project. Based on outcomes from these, and further assessment during bid preparation, we consider the current TRL of this approach to be **TRL5**. This reflects the technical readiness of smaller scale thermal generation (other DER are less advanced). A complementary NIA project will identify and seek to increase the TRL of 'riskier' technologies such as renewables, controllable demand and storage that are not included for consideration in the NIC. The NIC project explores and tests the concept of Black Start from multiple generators (or DER) in combination, and is not dependent on the NIA outcomes. Learnings from the NIA project will l be available in the first half of 2019, value-adding by increasing the number of technologies that can participate in the NIC.

Of course, there is a risk that the proposed approach to Black Start from DER may not be a viable solution. We may come to the conclusion that the proposed approach is simply either too costly, or cannot provide the appropriate level of confidence of service delivery. This is why we need to explore the various ways in which the concept could be achieved, collaborating and consulting with industry and stakeholders. Also, the appropriate solutions need to be tested in a controlled environment, without sacrificing nor impacting current BAU activities. Implementing an incomplete and/or piecemeal solution will not deliver value to consumers and we feel that the NIC is the ideal vehicle to enable this open, innovative, whole electricity system and cross-industry project.

(e) Partners and Funding

Project Partners: This project is a collaboration between ESO, SPEN and TNEI.

In October 2017, the SO made a public call to non-network licensees for ideas that addressed our innovation priorities. We received 37 submissions, which were then prioritised according to SO Innovation Priorities. TNEI's proposal was chosen.

TNEI will provide the necessary expertise in generator technology, specialist modelling and analysis of transmission and distribution networks. They have significant experience in the technical characteristics and strategic development of distribution networks across GB. This is a valuable asset for the wider rollout of the method in future.

The SPEN network is rich in renewable energy resources and growth in DER has happened earlier, faster and to a greater extent than most other parts of the country. Many of SPEN's grid supply points (GSPs) now regularly export power to the transmission network, due to quantities of distributed generation. SPEN operates the most diverse networks of all GB DNOs, and has experience and ongoing responsibility for DER integration in the widest possible range of circumstances. The network is highly diverse, serving large, densely-populated urban and industrial centres as well as sparsely populated rural areas. The SPM area also benefits from a meshed network design. SPEN have been proactive in the Black Start topic with both industry and Government, going beyond their remit to engage and be a driver for change.

Across the 15 supergrid groups feeding the 132 kV network in SPM and the 65 GSPs feeding 33 kV networks in SPD, there are multiple opportunities for testing of Black Start from DERs. These include a mixture of synchronous and non-synchronous generation based on despatchable and intermittent resources. We may also consider case studies in non-SPEN distribution networks where this adds value.

In summary, ESO, SPEN, and TNEI are all fully committed to the success of the project and ultimately, providing benefits to the consumer.

Engagement with GB DER and DNOs: SPEN has held several meetings and workshops with DER who have connections in the SPD and SPM licence areas on the aims and objectives of the project. A number of DER have shown interest in being involved in trials, as well as helping to shape and guide the project through the Stakeholder Advisory Panel. Details of generators who have shown their support are provided in Appendix I, along with a selection of letters of support. This engagement exercise has helped inform the challenges from a DER perspective that we will need to consider.

We will carry out the selection of participants for online testing transparently with clear definition of criteria for selection and an independent review of the evaluation process at key stages. Selection for trials will be dependent on the suitability of the networks to which DER participants are connected. A preliminary shortlisting process will ensure that only suitable participants are invited to prepare more detailed submissions.

We will create a Stakeholder Advisory Panel to provide a forum for industry experts from DER and DNOs and other interested stakeholders to help create a level playing field for all parties. This Panel is described in more detail in chapter 5.

Offline testing facilities: We have engaged with operators of an 11 kV test facility who have provided advice for scoping and costing of offline and hardware in the loop testing.

Telecommunications consultants: We engaged with communications and control consultants during preparation to provide input on scope and costs.

Management of profits and returns: This project does not have the potential to deliver significant profits to any of the project partners. As part of the demonstration phase, we will enter a commercial agreement with DER trial participants; however, the financial contribution will simply cover their lost revenues during the trial.

Any underspent NIC Funding will be clearly identified as part of the Project Close Down Report and returned to customers through the next available funding direction.

Any new network equipment, e.g. an earthing transformer, will be paid for in full up front by the project, and not included in RAV.

Contractual agreements: We are developing contractual agreements between ESO, SPEN and TNEI to ensure best value for money and successful delivery. We will prepare other contracts based on our standard format for previous innovation projects.

(f) Relevance and timing

The proposal is both relevant and timely.

The number of generators capable of providing traditional Black Start services is declining and is predicted to continue to decline as shown in Section 2. This is reducing system resilience and driving up the cost of procuring these services. There is a clear driver to find alternative methods in the medium term to ensure the continuing security of the electricity system and avoid rising costs to the consumer. ESO is committed to ensuring that Black Start remains economic and efficient by exploring and opening the market to new technologies when the risks are sufficiently low.

The ability to use the increasing numbers of DER on the distribution network would help to address this problem. Our cost benefit analysis shows that there are clear benefits from demonstrating and proving the method without delay. However, technical capability of DER to provide these services has not been tested below 132 kV and there are substantial organisational, technical, procurement and regulatory risks to be understood and reduced to an appropriate level before implementation.

This project will prove the method in a real network environment to enable business as usual rollout following project completion, before the dwindling number of traditional service providers becomes an increasing cost issue. We do not anticipate the need for any follow-on innovation funding. However, we may find limitations in scope for practical implementation or not cost competitive and there is a possibility that the project identifies substantial gaps in technology or capability.

For large fossil fuel generators to re-energise in two to three hours, they need to be in a state of readiness. Providing Black Start from DERs and reducing the requirement for large thermal generators will also make a valuable contribution to the UK government carbon reduction targets.

The roles and responsibilities of a future DSO are under consideration by the ENA Open Networks project. One of its objectives is to "develop a more detailed view of the required transition from DNO to DSO including the impacts on existing organisation capability". Their definition of DSO functions include contribution to system defence and restoration following a major system incident. This project will provide valuable insight on how Black Start from DER could be implemented within a DSO model. It is important that this learning happens within the next few years to provide a clear view of the market requirements for Black Start within this context. This project will also deliver wider learning to shape and influence future DSO models and markets.

In the second phase of the IET & Energy Systems Catapult Future Power Systems Architecture Programme, it was noted that Black Start would increasingly need to be procured from alternative sources, such as local generation and demand, given a significantly different generation and demand portfolio in 2030. Various implementation barriers were also identified which have informed scope development.

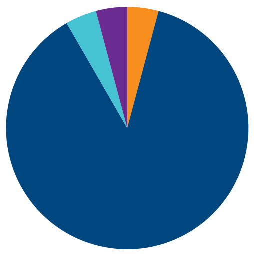
We have engaged extensively with the Department for Business Energy and Industrial Strategy.

The recently published ESO Restoration Roadmap sets out actions to progress towards a fully competitive market-based solution by the mid 2020s, enabling access to a broad range of potential participants. These include interconnectors, wind, distributed energy resources and storage. The Roadmap proposed that DER be evaluated through an innovation project. The learning from our project will directly support the actions corresponding to increased DER participation.

The involvement of SPEN as a project partner and their willingness to provide a contribution indicates their belief that the success of this project is a key priority. In SPEN's DSO Vision, Black Start and islanded running arrangements are defined as key enablers in the medium term for the DSO transition.

We have engaged with DER who have connections in SPEN to introduce the aims and objectives of the project and obtain feedback on our proposed approach, industry readiness and interest in trial participation. Whilst the sample size is relatively small, the response has overwhelmingly indicated that DER believe the project is timely. There has been strong levels of interest in involvement in trials and in the Stakeholder Advisory Panel.

Figure 4.3: Summary of questionnaire responses: "Do you agree that it is timely we address the question of Black Start from DER now?"



We have also engaged with other DNOs who demonstrated a keen interest in being involved in the project. We will include representatives on our Stakeholder Advisory Panel.

Timeliness of technology

In the 2015 NIA project report on Black Start Alternative Approaches, the technology readiness levels of distributed generation were considered. Thermal generation was given a TRL level of 9, although this only considered large generation connected at 132 kV, and it was noted that smaller generation connected at lower voltage levels would be less. No value was put on the TRL of smaller distributed thermal generators. All other distributed generation was shown to have a TRL of between 1 and 3.

To align with the NIC guidelines this project is limited to DER that have reached TRL 4-8 in the context of providing Black Start services. We believe the TRL of the approach in this **NIC bid is TRL5**. This is based on the estimated Black Start TRL of smaller-scale thermal generation and because no industry pilots of this scale have been undertaken. At this time, this leads to the position that all case studies should be built around at least one synchronous generator because this is the only technology (of sufficient TRL) that can be grid-forming and act as the 'anchor' for a Power Island.

We also recognise the opportunities for other types of DER to contribute to the growth of a Power Island. We believe wind has the biggest advantages, connected at 33 and 132kV for services such as frequency management. However, we will consider other technologies as described in Appendix G.

By its end we expect that the **project will be TRL8**. This is due to running a pilot in a live environment. We did not believe it to be TRL9 as there may be regulatory changes recommended before it becomes commercially viable, and their implementation will fall outside the scope of this project.

The TRL for **non-thermal distributed generation** is lower, at **TRL1-3,** based on the NIA_NGET0159 scores. project. The NIA project completing in the first half of 2019 will identify and seek to increase the TRL of 'riskier' technologies such as renewables, controllable demand, storage, etc. that are not currently included for in the NIC.

Section 5: Knowledge dissemination

Knowledge dissemination is a fundamental aspect of any innovation project. The groundbreaking learning from this project will be of interest to a wide network of stakeholders in the energy sector, ranging from end consumers, to DERs, academics, policy makers and network operators. The results of both simulations and real-world tests will be of immense value to industry and will have a profound impact in maintaining efficient and economical Black Start services in the medium- to long-term as the energy system decarbonises and decentralises.

Our proposed approach is a world first, so the learnings will also be of great interest to an international audience, who will want to adopt the approach for their country. We have already carried out active stakeholder engagement at the international level during the bid preparation to access the latest technology development and confirm the truly innovative nature of this proposal. For example, Tennet in Germany, Terna in Italy, and Fingrid in Finland have all expressed their strong interest in engaging with the project.

5.1. Learning generated

Knowledge capture and dissemination will form a separate work package that will be managed by a dedicated Knowledge Dissemination Lead, supporting the Project Manager. As knowledge is gained in the development and demonstrate phases, this and associated impacts will be shared with stakeholders in an efficient and timely fashion. This process is represented in Figure 5.1.

Figure 5.1: how the Knowledge Dissemination work stream interfaces internally with the project and externally with stakeholders

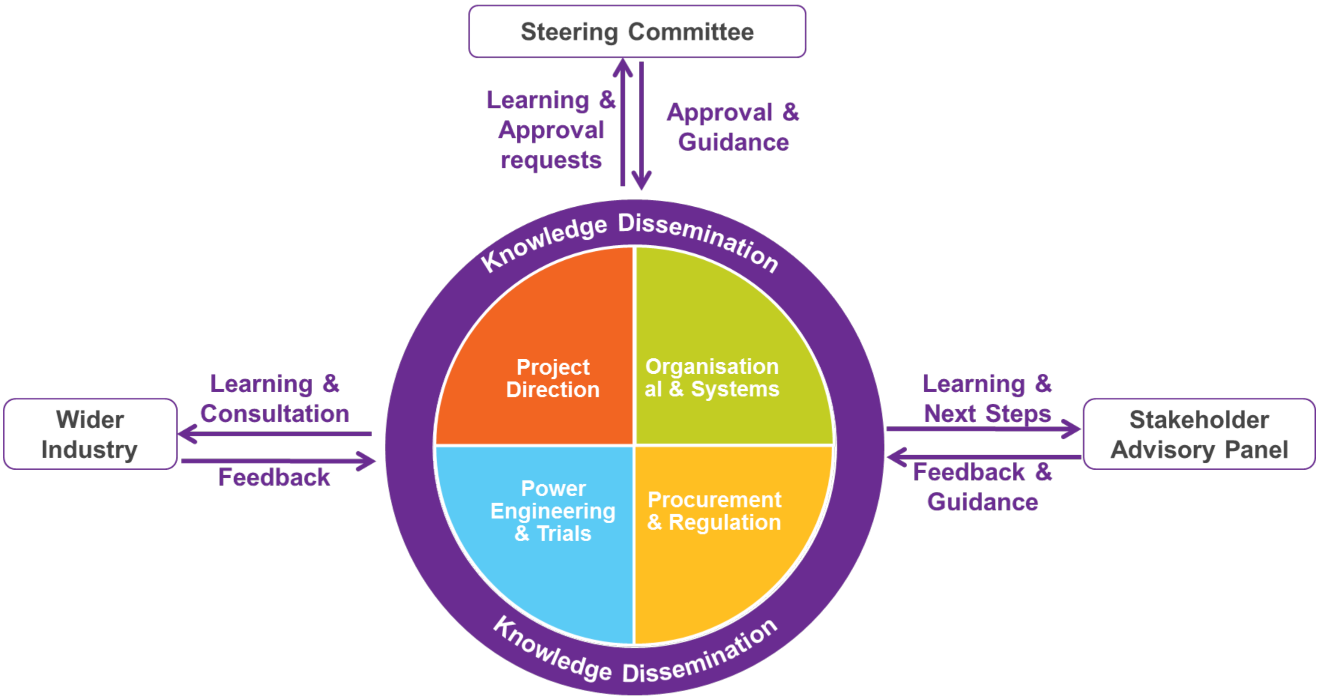


Table 5.2 outlines, at a high level, the key learnings that will be generated during the Development and Demonstration phases. We will consult and engage with stakeholders throughout the project, but there will be a thorough, industry-wide consultation on our

power engineering, organisational, procurement and regulatory proposals following the development stage.

Table 5.2: key learnings generated throughout Development and Demonstration

<table>
<tr><th colspan="3">Development</th></tr>
<tr><th>Power Engineering & Trials</th><th>Organisational & Systems</th><th>Procurement & Regulatory</th></tr>
<tr><td>• Criteria for Black Start services based on network characteristics and DER capability
• DER and distribution network requirements for Black Start (including investment required, testing specs, etc.)
• Network, generator and wider electricity system impact assessment from proposed approach (from network studies)
• Potential for Black Start from DER across GB
• Trial selection and testing criteria</td><td>• Options for operational coordination and control, and proposed approach(es)
• Options for roles and responsibilities, and proposed approach(es)
• Impact assessment for organisations (people, skills, systems, investment)
• Assessment of telecoms options to ensure resilience. Proposed functional requirements, adaptations and enhancements (incl. cost assessment)</td><td>• Procurement options, cost and operational effectiveness, and proposed approach(es)
• Commercial service design options and proposed approach(es), draft contract(s)
• Regulatory routes to enable proposed approach(es), from technical, commercial or organisational perspective (including codes, standards and network operator licenses, funding etc.)</td></tr>
<tr><th colspan="3">Industry-wide consultation on proposals</th></tr>
<tr><th colspan="3">Demonstration</th></tr>
<tr><th>Technical</th><th>Organisational</th><th>Procurement</th></tr>
<tr><td>• Observed impacts on network, generator and wider electricity system
• Assessments of any adaptations required for DER and networks
• DER and network testing specifications
• Investment or operational changes for any party which could improve DER’s contribution to system restoration</td><td>• Resilience and latency of telecoms option(s)
• Effectiveness of coordination process, including speed of restoration
• Assessment of new tools and systems
• Impact of approach on organisations (roles, resources)</td><td>• Effectiveness of procurement methodology
• Suitability of commercial service design

Regulatory changes will be consulted upon via BAU processes</td></tr>
</table>

5.2. Learning dissemination

We have developed our dissemination strategy to ensure that relevant learning and knowledge can be identified and shared effectively to key stakeholders and interested parties. Our aim is to ensure stakeholders understand outcomes and any impacts/opportunities for their respective organisations.

5.2.1 Key stakeholders

Stakeholder engagement is a critical part of our Knowledge Dissemination strategy, to both disseminate learnings to industry, and to bring valuable knowledge and steerage back into the project, as described in Figure 5.1. Our dissemination approach will be inclusive, transparent, and tailored to particular audiences and channels. Our key stakeholders are outlined below.

Stakeholder Advisory Panel

The purpose of the Stakeholder Advisory Panel is to provide a forum for interested stakeholders and industry experts to help shape the technical, commercial, and regulatory developments of the project, through providing different perspectives and ways of thinking to an area of focus. The Panel will support the fundamental principles of developing market solutions in a coordinated and transparent manner, whilst creating a level playing field for all parties.

- Fundamental principles that the Panel will encourage will include:
- Ensuring a competitive process
- Minimising barriers to entry
- Maximising engagement and participation
- Technology neutrality
- Ensuring there are no unintended negative impacts on other services

The Panel will take an advisory capacity and will not be part of the approval process for the project. Whilst the group will have no formal decision-making power, members will act as a sounding-board and their views will be valuable in informing technical and commercial decisions taken by the project team and the Steering Group.

We have received interest from the following parties to sit on the Stakeholder Advisory Panel:

- BEIS
- Open Networks
- Cornwall Insight (representing forums of >40 DER and flexibility organisations)
- Energy Systems Catapult

ENA Open Networks

Open Networks has identified 8 DSO functions, incl. 'System Defence and Restoration', the thinking of which sits in Work stream 1 of Open Networks (T-D Processes). Open Networks WS1 will help us to ensure we are delivering for the whole electricity system. Both the NIC and Open Networks projects have agreed that:

- We will work together during the NIC evaluation period (August to November) to map out points at which the projects will share learning with each other.
- A member of WS1 will take a seat on the Stakeholder Advisory Panel.
- The NIC project will present learnings and next steps to WS1 on a quarterly basis for feedback and guidance.

Department for Business, Energy and Industrial Strategy (BEIS)

We have agreed with BEIS that we will present them with a quarterly report on project progress. Appropriate representation of BEIS's interests as a key stakeholder will be present on the Stakeholder Advisory Panel.

Other key stakeholders

We have identified the key stakeholders as including (but not limited to): Distribution network operators, Transmission owners, ESO, generators and service providers, central and local government, industry trade associations, market specialists, policy makers (GB and international) and academia. Each of these is eager for a greater understanding of our approach, and how it could be implemented on a GB-wide scale.

5.2.2 Methodology and Approach for Learning Dissemination

Learning generated from the project will be tailored to suit the interests, objectives and relevance of each stakeholder. The various methods used are outlined below:

Regular progress reports: We will produce a 6-month project progress report whenever possible in addition to the minimum requirements set out in the NIC Governance (every 12 months). We will submit these reports directly to the Steering Committee and publish them on the ESO Innovation website.

Conferences & targeted dissemination workshops: We will hold regular workshops and stakeholder events. Some will be targeted at specific stakeholder groups or on specific topics, whilst others will share knowledge and obtain feedback from a wider audience. The project team and wider partners will also engage and participate in a number of industry conferences each year, including EPRI, CIGRE, IEEE and LCNI.

Webinars: this format has proven to be very successful in delivering key updates to, and gathering feedback from, a large group of targeted stakeholders at once.

Closedown Report: We will produce a final closedown report and submit this to Ofgem following completion of the project. This report will be shared with all interested stakeholder groups and will present the key findings as well as lessons learnt.

Multimedia, social media: We shall use various media channels to inform community groups and update all interested stakeholders on the latest events and progress.

Internal project briefings & updates: We will provide regular updates using internal publications, briefings, intranet, innovation learning events, roadshows and social media.

Press Releases and articles: We will release regular press releases and external articles highlighting key events and outcomes, again targeted at specific audiences.

5.3. Intellectual Property Rights

The Black Start Proposal will conform to the NIC default intellectual property rights principles. We do not anticipate the project will develop foreground IPR outside the arrangements defined in the NIC governance document. ESO's Legal and Procurement teams have developed a detailed collaboration agreement specifically for NIC projects based on the NIC governance document. This is reviewed and updated every year based on changes to the NIC governance document and experience gathered from previous NIC projects.

5.3.1 Conforming to Default IPR Arrangements

All partners will contractually agree to the NIC IPR requirements listed in the collaboration agreement. According to this agreement all foreground IPR and embedded background IPR will be made available royalty free to all network licensees. ESO also reserves the right to sub-license all relevant foreground IPR and embedded background IPR to project participants.

Section 6: Project Readiness

6.1 Readiness to start

We are confident our project can start in January 2019, following approval of NIC funding and a period of mobilisation in December 2018.

6.2 Readiness of partners and suppliers

All partners are in place (ESO, SPEN and TNEI) and an organisational structure and contractual terms have been agreed in principle. We have developed the project scope collaboratively between all partners, with approval and commitment to delivery by each organisation's senior management.

The project **organisational chart** is shown in Appendix E, and includes a **Project Steering Committee** and **Project Management Office (PMO)**. There is a clear definition of roles and responsibilities for each partner, aligned with project scope and deliverables, as well as the best route for solution implementation after the project. All partners have positions on the Steering Committee and in leadership.

The project team has engaged with the industry to identify and scope (at a high level) any additional expertise that may be needed. The communications and control requirement will be further scoped and procured competitively as required.

6.3 Readiness of project team

The project organisational chart in Appendix E outlines key project leadership, management and delivery roles, and the responsible partners for each role. We have identified and put in place experienced individuals with appropriate skillsets.

We have also considered the wider resource requirements needed for project delivery for each partner. We have received senior management commitment that the people with the skills we need will be made available for the project start. Experts in each relevant field from across the businesses have been involved closely in bid development and are ready to provide further contributions from January 2019.

We have prepared a **Project Plan** (Appendix C) based on the detailed scope and deliverables. It outlines specific activities, milestones and dependencies. We will review and refine the plan throughout the project to ensure it remains up to date and accurate.

We have also produced an active **Risk Register** (Appendix D), including risk probability, impact, comparative risk ratings, mitigation and contingency plans. This will be reviewed and refined to ensure that it represents a fully comprehensive, accurate and up-to-date list of project risks and planned mitigations.

6.4 Readiness of knowledge

The project builds on previous innovation projects such as Black Start Alternative Approaches, Power Potential, TRANSITION and FUSION; the System Operability Framework publication on Black Start; and the ENA Open Networks Project.

A complementary NIA project will identify the TRL of 'riskier' technologies such as renewables, controllable demand and storage and determine how their readiness could be increased. Although this NIC project is not dependent on the NIA, learning outcomes should be available in the first half of 2019, informing and enhancing the development phase.

To the best of our knowledge, there are no international examples of Black Start from DER at the scale we are proposing. There are however, smaller scale cases of operation of Power Islands of tens of MW. For example, Shetland is operated as an isolated power system by SHEPD and the Western Isles De-Synchronised Island Management process (STCP 06-2) provides for the operation of a desynchronised Power Island following an unplanned, or planned event. In addition, many customers have the ability to operate independent of the grid, typically using generation that is part of an industrial process or diesel generators as an emergency backup supply. Around the world, there is ongoing research and development into the microgrid concept, which often includes Power Island operation as an objective. Wherever possible, we will draw on available knowledge to feed into the project.

6.5 Readiness for case studies

We have analysed the SP Distribution and SP Manweb distribution networks to identify suitable locations for case studies and live trials. Each of the locations contains a significant number of DERs, already connected at 33 kV or 132 kV. Our case studies represent a variety of network locations, voltage levels and network topologies and include a mixture of synchronous and non-synchronous generation from despatchable and intermittent resources. We believe the samples are representative enough to provide learnings valid for all of GB.

To align with the NIC guidelines we will focus on DERs that have reached TRL 4-8 in the context of providing Black Start services. Furthermore, to deliver outcomes suitable for business as usual in the near term we will focus on DER that is already connected to GB distribution networks, or is known to be connecting soon. At this time, this leads to the position that all case studies should be built around at least one synchronous generator because this is the only technology (of sufficient TRL) that can be grid-forming and act as the 'anchor' for a Power Island.

We recognise the opportunities for other types of DER to contribute to the growth of a Power Island. Due to its deployment at scale on 33 and 132 kV networks across GB, and the readiness of the technology to provide the services required from secondary stations in Black Start, we believe wind has advantages over other types of DER. However, we are open to considering other technologies and the potential case studies described in Appendix G include a wide range of DER types. In particular, we recognise that batteries could be an extremely valuable resource and could be of great use in live trials, where they might emulate the behaviour of other demand customers or be assessed for their contribution to restoration.

The 10 potential case studies identified so far cover 47 individual DERs, ranging in size from 2.4 to 138 MW. It is estimated that 8 to 10 DERs will ultimately participate in two live trials. However, through our stakeholder engagement activities we will seek to engage all case study DERs in other aspects of the project, along with other stakeholders.

We expect participating generators to be compliant with existing codes as far as technical performance, e.g. reactive power capability, is concerned. We anticipate one of the outcomes of this project being a new set of technical requirements for DER participation in Black Start.

Our project is not reliant on further low carbon technology or renewable energy beyond what is already connected and operational. Where opportunities arise with the connection of new equipment, these will be considered.

6.6 Readiness of market

We have engaged with DER across GB, via workshops, presentations and bilateral meetings to understand their perspective on the readiness of technical, commercial and regulatory aspects. Many have expressed an interest in live trials, online testing, future Black Start services, and participating in the Stakeholder Advisory Panel, and their willingness to participate is key to the success of this project. A number provided letters of support, as evidenced in Appendix I.

Recognising that there is a challenge in ensuring participation of DER while avoiding inappropriate subsidy or providing participants with unfair advantage over potential competitors, and have designed the project scope to mitigate this. We propose to keep DER trial participants cost neutral while seeking as wide as possible participation in workshops and other aspects of the project. Where practicable, we will hire the equipment required to support the live trials rather than buying it, e.g. temporary generators for self-start. The intention is that DER trial participants will ultimately have to make their own investments in their capability to deliver restoration services. However, it is anticipated that a relatively small amount will have to be spent on DER sites to facilitate trials, as detailed in the project budget.

6.7 Senior management commitment

ESO, SPEN and TNEI senior management are strongly committed to the aims and success of this project. They have been engaged at key milestones throughout for guidance, approval and final sign-off. The Project Sponsor is the ESO Head of National Control.

The project partners have developed and refined the project scope, and assigned responsibilities according to the best skillset for the job. Senior managers have signed off these resourcing decisions.

We have also won the support of in-house specialists through regular project meetings with internal Black Start, Commercial and Regulatory teams. The guidance and input from these experts within ESO and SPEN, complemented by the expertise of our partner organisation TNEI, has enabled us to prepare a thorough project proposal.

6.8 How costs and benefits have been estimated

We have developed a cost benefit model with the input of technical, commercial and economic expertise across all partners. The methodology has been rigorously tested, with internal peer review provided by economists and external feedback from Imperial College London (ICL).

Inputs include publicly-available sources of data such as the FES, as well as sources internal to ESO and SPEN. Some of this data is subject to client confidentiality and/or national security concerns and is redacted from the public version.

6.8.1 Project cost estimates

Inputs for labour requirements have come from experts across all partners. Between us, we have drawn on extensive knowledge of equipment and services suppliers as well as previous and current innovation projects. We have identified the benefits of the project and its rollout based on:

- Professional/engineering judgement.
- Verifiable and credible sources for unit costs.
- Techno-economic modelling of the GB system.

We have taken a conservative approach to the calculation of these benefits. More detailed information on the CBA is provided in Appendix A and Appendix B.

6.9 Minimisation of cost overruns and shortfalls in direct benefits

There will not be any direct benefits accruing to ESO or SPEN as part of this project, i.e. case studies will not lead directly contracted Black Start services from DER. We will need to implement the method after the project, although this should be hugely accelerated as a result of what we have learned. There is no risk of shortfall in direct benefits.

Where an element of the project can be delivered by a range of vendors, we will identify suitable suppliers through a competitive tender process in line with existing procurement governance arrangements.

To deliver a project to time and budget requires industry-leading project management. This will be based on proven ESO and SPEN delivery methodologies, and established governance processes.

The Project Steering Committee is ultimately accountable for the project, and will comprise the key stakeholders and decision makers within ESO, SPEN and TNEI, including the Project Sponsor and senior responsible officers. It will assess major change requests, review the impact on the project business case, and identify and review associated risks or issues.

Through this best practice project management approach, we will be able to identify at an early stage where major risks are likely, deploy mitigation measures and escalate where and when required. This will identify the most appropriate course of action, either to suspend, or take appropriate remedial action, pending permission from Ofgem that it can be halted or amended. We have designed the programme in two phases with several intermediate milestones, to ensure we are constantly learning. So in the event of project suspension, the industry will still benefit. Notable milestones include:

- In July 2019 a review of outcomes from early tasks that will determine overall viability and scope for roll-out of the method before resources are committed to more detailed analysis and design of new processes.
- In June 2020 a review of the proposals for testing in the Demonstration phase, which will be subject to approval by the Steering Committee before proceeding with procurement and installation of equipment.

6.10 Verification of accuracy of proposal

ESO, SPEN and TNEI have endeavoured to ensure all the information included in this full submission is accurate. Information has been gathered from within ESO, SPEN, TNEI, DERs, suppliers and other experts. All this information has been reviewed, to ensure its validity and integrity.

A bid team, incorporating a full time bid lead, has worked with all partners to prepare and review the bid. Project partners have also ensured information provided by them has been through a thorough internal review and approval process before being provided to the bid team.

Section 7: Regulatory issues

7.1 During the project

The National Electricity Transmission System (NETS) and distribution systems are required to meet certain operational criteria. These criteria are stipulated in the Grid Code, the NETS Security and Quality of Supply Standard (SQSS), the Distribution Code and in associated engineering recommendations such as the Security of Supply standard (P2). We have reviewed these codes and standards to assess whether any of this project's activities could result in a breach of any of these requirements by a Licensee.

All analysis, simulations, desktop exercising and offline trials carried out under test conditions and environments will not have any impact on the Licensees' ability to meet their license obligations, license standards, or the relevant codes.

Outages required to facilitate the live system trials will undergo the standard outage assessments and will only proceed if adequate security of supply to non-participating customers can be maintained in accordance with License Standards.

Live trials may include conditions where the normal voltage, frequency, and power quality limits may be exceeded on parts of the network. These would only affect customers participating in the trial and would only proceed if the safety requirements of the host network owner and these customers are satisfied.

Based on the current intended scope for live trials, the understanding of required adjustments to networks, DER and associated systems, we do not believe it will be necessary for the host DNO licensee to seek derogation from the Distribution Code or any other license obligation. For example, modifications may be required to G59 protection (over/under voltage, over/under frequency, and loss of mains) at sites taking part in the trials, to ensure that the generators concerned remain connected to the Power Island during the trial. We believe that adjustments, such as to G59 or other protection, can be undertaken without the need for derogation.

Live trials will be screened before proceeding to assess their impact on customers not participating in the project. Arrangements will be made to ensure that these customers are supplied from a distribution network that complies with all the relevant license requirements in order not to reduce the security or the quality of supply of these customers below what is permitted. Therefore, there will be no need for any derogations to allow this project to progress as planned.

7.2 Following the conclusion of the project

Black Start details and associated roles and responsibilities are currently defined in the Grid Code, the STC and the Restoration Plan published by the ESO in accordance with The European Network Code Emergency & Restoration Code. The provision of Black Start from DER may require amendments to these codes and/or in other codes (e.g. the Distribution Code).

We will identify any changes to the relevant codes, standards, and regulatory frameworks needed to facilitate the provision of Black Start from DERs. These modifications will be implemented in accordance with the relevant industry governance framework as a Business as Usual activity outside, but aligned with, the project.

Section 8: Customer Impact

Customers, whether the owners/operators of DER or consumers in general, are central to the goals of this project. Proving the method is expected to open new opportunities for DER owners/operators across GB while reducing cost and maintaining provision for consumers in general.

8.1 Direct impacts and interaction

During the project, there will be impacts on customers and stakeholders, including both risks and benefits.

If we run live system trials on the network, there will be disruption and increased risk of interruption to a small number of customers. However, we have designed the project methodology to provide appropriate incentives to those DER customers disrupted by their participation in trials and to minimise the risk to non-participating customers, including other DER and consumers in general.

We have already started to engage with DER customers through a series of meetings and presentations by the Project Team at industry events. The survey results and letters of support in Appendix J provide evidence of this and demonstrate how the project is ready to proceed to implementation if funded.

We will engage with customers throughout the project. Each case study will be built around a minimum of at least one DER customer, often more, and there will be significant exchange of information to facilitate the required analysis, trial design and project learning. We will share results and conclusions with project participants before wider publication, subject to what is agreed with each customer in terms of confidentiality. We do not see this as a risk, either in terms of maintaining anonymity or in the sharing of project learning, because it will be possible to anonymise the case studies or derive the broader conclusions without reference to the specific details of a given trial. This engagement will allow the industry to feed into the solution, so that it can be adapted and moulded to industry needs. This will ensure a solution that 'works' for owners and operators of DER, and that rollout delivered with minimal challenge, making it more efficient for end consumers.

Participation in the project by DER customers will be voluntary and subject to detailed discussions. We have already identified a number of Black Start from DER case studies that can support the project objectives, including offering the potential for live trials. We have already started to engage with the customers concerned to gauge their interest and willingness to participate. The chance to take part will also be open to new customers, not yet connected to the network but willing to engage in relevant technical discussions and information exchange.

There are also clear benefits to be had post-implementation, if through the project we can demonstrate and prove the concept.

The delivery of a whole market solution allows for wide participation at scale and at speed, which reduces overall cost, and maximises the efficiencies and benefits to the end consumer. This is demonstrated in particular when considered against the base case, where de-risked but incremental changes lead to a much slower, less co-ordinated and more costly inclusion of DER.

The implementation of a solution to procure Black Start from DER will open up a new marketplace for community energy projects, which may encourage growth in this area. Alongside the social and environmental benefits of community energy projects, a new market will create revenue opportunities, resulting in lower costs and/or community investment, driving further benefits for end consumers.

An 'open' market for Black Start will drive further competition, which we believe will bring down the cost of the service across the board. It will improve resilience by reducing reliance on gas, and will future proof the service by developing the capability of assets that will ultimately replace the plant we currently contract with, at a point in time early enough to deliver benefits. A resilient service delivered at a lower cost by a more transparent and liquid market will benefit end consumers.

The learning created from this project being successful in totality or part will feed into the GB Black Start capability, increasing the efficient or economic delivery of a socially vital service. Concepts demonstrated via TRL 4-8 technologies, will reduce carbon emissions, with further carbon reductions then possible by enabling lower TRL renewable technologies to access Black Start markets when technically feasible.

8.2 Interruptions and power quality

Conducting live trials on the network may require some degree of network reconfiguration that exposes non-participating customers to a lower level of security of supply, e.g. by leaving a demand group on a single circuit supply while the second circuit is used for a test. If tests are conducted to create a separate Power Island from DER there is an increased risk of power quality deviating from normal limits within that Power Island, e.g. voltage or frequency deviating outside normal ranges, although remaining within statutory limits.

If a trial is to progress to the live stage, planned network outages may be necessary to install new equipment. For example, the development phase may identify a need for additional measurement equipment on the SPD/SPM network to provide improved visibility and control, or new switchgear to provide greater flexibility in network configuration. We will manage these planned outages through normal procedures.

DER customers participating in trials may have to interrupt their normal course of business and the details of this, along with any commercial implications, will be the subject of discussion in the development phase. We will try to optimise the timing of any live trial to suit each customer's current outage patterns, likely to be for maintenance reasons or for planned outages on the network.

8.3 Alternatives to trials

All live trials will be preceded by extensive studies to identify and quantify the risks to customers and the network owner. We will put in place protection, control room intervention or other mitigation as appropriate to ensure compliance with codes and standards, e.g. Engineering Recommendation P2 relating to security of supply, and to avoid damage to equipment. We will carry out tests in modular parts and incrementally, allowing for further assessment of risks and refinement of plans. An example is that before attempting to re-energise part of the SPD/SPM network using a DER, the DER equipment will be tested in isolation to validate this module of the test.

As explained, the project approach is such that live trials are valuable – the only way of truly proving the Black Start from DER concept – but the majority of project learning will be generated from other activities based on analysis, consultation and desktop exercises. In this way the impact on customers is minimised while still achieving the desired project outcomes. If any of the case studies do proceed to the final stage of live trials, this will only be after significant analysis and planning to assess the trade-off between the value of any test and the impact on customers in the trial area. If a test is considered too disruptive or that it carries too high a risk, it will not proceed and this learning will feed into project conclusions on what the longer-term approach to testing should look like.

8.4 Protection from penalties

There is no need for the project to request protection in respect of the Interruption Incentive Scheme or other mechanisms.

8.5 Customer participation

We aim to consider as many different types of DER as possible, but we recognise that some technologies are not, as currently deployed, capable of self-starting and grid-forming behaviour. We will consider the changes necessary to introduce this capability, but we expect that case studies will focus on those types of DER that already have the required capabilities, or could achieve them most readily. So it is most likely that the trials will be based around thermal power stations (CHP or otherwise), such as those burning biomass or waste, gas or diesel stations intended primarily for STOR or other system services, or small hydro stations. DER types with lower TRL with respect to Black Start will be examined outside of this NIC project.

Wind is the most dominant source of renewable energy in GB, particularly in Scotland and Wales, and the project will seek to include wind resources within the trials. While a wind farm may not be self-starting or provide the primary Black Start capability, we envisage that they could connect and help to grow a Power Island. Once energised and operational, even if not providing real power, a wind farm may enable further energisation of the network. Other DER technologies will be considered in a similar way.

We will share learning outcomes with all customers and other industry stakeholders through the channels described in Section 5. The project will deliver particular value in the desktop, or simulation, exercises which will be conducted as part of the process. These exercises will involve the project partners, customers and other stakeholders going through a detailed review of events and actions as may occur in a realistic Black Start scenario. Our goal is to test aspects of the plans, particularly the organisational and 'human' issues that cannot be properly explored in system studies. We will run these events in suitable training environments supported by simulated events that provide a real-time operational experience. We expect these events to be extremely stimulating and of significant value in terms of training for everyone involved.

The case study descriptions in Appendix G provide more information on the required interruptions and impact on customers. These will be examined in much greater detail in the early stages of the project and inform decisions on the need for, and value of, live trials.

Section 9: Project Deliverables

Table 9.1: Project Deliverables

No.	Deliverable	Deadline	Evidence	NIC Funding Request
Organisational Work Stream				
1	Organisational, Systems and Telecommunications viability assessment of the capability to deliver the high level concept.	8/11/2019	This report will document the outcomes of analysis for • Resilience assessment of telecommunications • Resilience and capability assessment systems relevant to Black Start from DER • Capability assessment of Organisational structures and skills. The conclusions of the report will highlight the main areas of challenge that will be the focus of the Design and later stages to address.	8%
2	Design of process, roles and requirements, and systems and telecommunication requirements to control and coordinate a Power Island created from Black Start from DERs.	2/10/2020	We will deliver a proposal in report format of how the Black Start from DER will operate as a process, including • A process map with task allocations • Organisational structures including roles and responsibilities • Requirements for systems or tools with initial outline design concepts • Telecommunications functional requirements	12%

3	Refine the Organisational, Systems and Telecommunications requirements by testing key areas and capturing the learning.	30/9/2021	Undertake a desktop exercise to test the Organisational capability for the process including, Systems and telecommunications where appropriate. Capture learnings from the exercise within an update to the Key Deliverable 2 report. Working with manufactures complete designs of systems and telecommunications to enable the timely delivery of the Power System Trials. Where appropriate undertake offline tests to prove capability of systems via hardware in the loop testing.	10%
Technical Work Stream				
4	Assessment of Black Start from DER viability in GB and proposed functional requirements	31/7/2019	This report will present the outcomes from the Options stage of the PET work stream including: • The choice of case studies and the potential options for network re-energisation in each case. • Initial proposals for the functional and testing requirements to apply for Black Start from DER. • The potential for roll-out of the method across GB. Industry consultation will be used to test whether the report is clear, comprehensive and justifies further work.	5%
5	Technical and financial proposals for demonstration	31/7/2020	This report will present the conclusions from detailed assessment of the power engineering aspects of Black Start from DER, using the case studies as examples, and make firm proposals for possible live trials. The report will be supported by the results of power system studies, shared subject to confidentiality restrictions relevant to each DER.	10%

			The report will be assessed in terms of completeness and clarity and whether it allows decisions to be made on live trials by the Steering Group and DER participants.	
6	Demonstration of Black Start from DER	20/12/2021	This deliverable will mark the completion of the live trials (as approved by the Steering Group). A report will be produced detailing outcomes and learning from the trials. This will be assessed against the testing objectives specified for the trials.	30%
Procurement and Regulation Workstream				
7	Functional requirements for procurement and regulation.	8/11/2019	Report on procurement options and the criteria for determining the preferred option. Report on commercial design of the service (e.g. term, obligations delivery and payment etc.…) with consideration of the learnings from the organisational and technical work streams. Report on gaps and blockers in relevant codes and licence conditions that will need to be addressed to enable proposed new Black Start services.	5%
8	High-level outline of contract terms and regulatory arrangements.	2/10/2020	Report on detailed design of the procurement process and contractual arrangements based on technical, procurement and regulatory options. Report on potential regulatory and funding arrangements, and consequential changes to relevant codes and Licence requirements.	5%
9	Final version of procurement generic standard terms.	20/12/2021	Generic standard terms of contract by which a service for Black Start could be procured reflecting industry engagement. These will include the contracted obligations on each party required in the delivery of the service and the	5%

			necessary commercial arrangements.	
All Work Streams				
10	Final proposals for functional and testing requirements for Black Start from DER.	End of Project	Report on learning and proposed approaches from project activities, across all work streams and external engagement. This is intended to form the basis for transition to business as usual. If the concept is successful this will include • Finalised process design with consulted organisational structures, roles and responsibilities. • Finalised functional specifications for telcommunications and systems • Finalised technical generic DER / Network / concept requirements • Finalised Generic contractual terms for procurement. If the concept cannot be successfully proven, the above will be prepared documenting the gaps.	10%
N/A	Comply with knowledge transfer requirements of the governance document.	End of Project	Annual project progress reports which comply with the requirements of the governance document. Completed Close Down Report which complies with the requirements of the governance document. Evidence of attendance and participation in the annual conference as described in the governance document.	N/A

Section 10: List of Appendices

Appendix A - Benefits Table

Appendix B - Cost Benefit Methodology

Appendix C - Project Plan

Appendix D - Risk Register and Contingency Plan

Appendix E - Organogram

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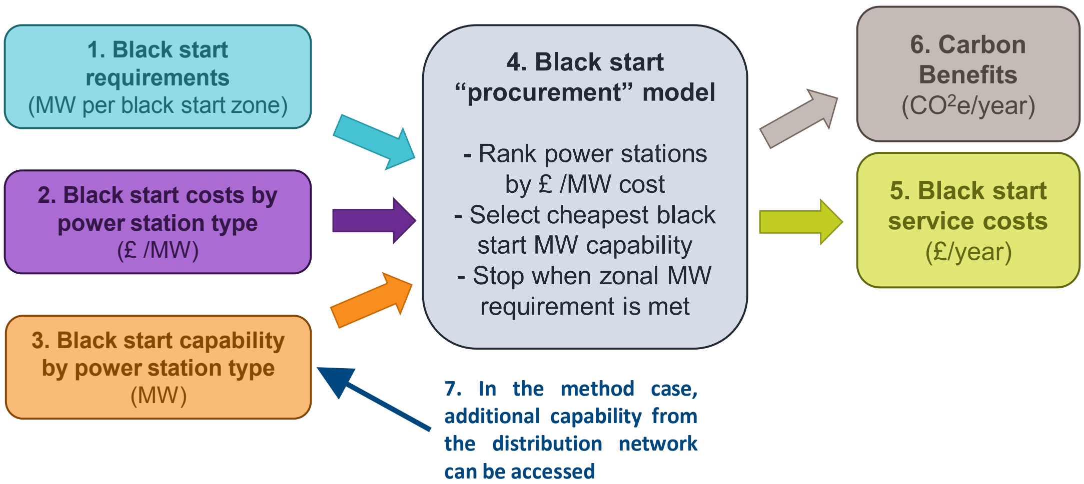
Appendix B – Cost benefit analysis methodology

Overview of methodology

We have explored the method in a cost benefit analysis (CBA) model. The methodology is described below, explaining how we have accounted for the key aspects of the business case.

The CBA method is summarised in Figure B.1.

Figure B.1: Overview of cost benefit methodology



The CBA takes three inputs:

1. The volume of required Black Start capability in each zone.
2. The cost per MW of Black Start capability by power station type.
3. The amount of Black Start capability, in MW, available in each zone in every year to 2050, separated out by power station type.

These inputs are combined in the model to determine the cost of the Black Start service:

4. We use a relatively simple model to simulate the procurement of Black Start services. By ranking the available capability in each zone in terms of cost per MW, we can determine what combination of power plants can provide the necessary Black Start capability at the lowest cost.
5. From this, we can determine the total cost in each year of the Black Start service by combining costs across zones. Additional costs, such as the cost of the NIC funding, are also included.
6. We quantify carbon benefits by assessing the despatch actions needed to ensure the availability of Black Start generation.
7. By including or excluding the capability of DERs, the costs and benefits of the method can be explored within the model.

We describe each of these steps within the CBA model in more detail below:

1. Requirement: The requirement for Black Start in each zone is calculated based on the existing procured capability. Currently, ESO procures three providers in each zone. The average size of these 18 providers multiplied by 3 is taken as the requirement in each zone within the model.

2. Unit costs: The per MW cost by power station type includes:

- Basic costs of providing Black Start service including providers time, maintenance, training, risk and return.
- Typical costs of retrofitting equipment for the generator.
- Costs incurred by the distribution network company to facilitate the method, for example retrofitting equipment to distribution networks.
- Costs required to ensure the readiness thermal plant which is not active in the electricity market, based on ESO's detailed modelling of the electricity market
- Costs for borrowing Black Start capability from a neighbouring zone when there is a shortfall in a given zone.
- A 'mark-up', applied to the overall cost to account for market concentration in each zone. This is calculated based on the Herfindahl-Hirschmann Index for market concentration.

In addition, central 'system' costs for the DSO and the SO are also included in the CBA. This includes implementation costs, and costs for the increased number of staff needed when involving a DSO in Black Start. These costs are higher when procuring using the method, to reflect for example, the incremental cost of the DSO's system and interfaces between the two or the increased burden of doing grid compliance tests for a larger number of smaller DERs.

3. Capability: The capability for Black Start in MW in each zone is calculated from the FES scenario information. This considers de-rating of each type of power station. De-rating factors have been taken from the capacity market – where these aren't available (e.g. for wind and solar) we have used typical load factors.

In both the base case and method case, we assume that new providers will become capable of providing Black Start. The model includes interconnectors as a capable source of Black Start if they use voltage source converter technology. We assume that wind and solar become capable of providing Black Start from the mid-2020s. For some types of power station, we assume that not all of the capacity is technically capable of providing the service. For example, we assume only 50% of wind will be capable of providing Black Start. It is also assumed that micro generation capacity on the distribution network (less than 1MW) will not be capable of providing the service.

4. Ranking: In each year, each type of power station is 'ranked' in terms of its cost to determine the capability which meets the zone's requirements at the lowest possible cost. This ranking takes account of the de-rating factor for each type of generation. This gives, as an output, the amount of Black Start capability procured in each zone, by fuel type.

If there is insufficient capability within a zone, this shortfall is assumed to be met by "borrowing" capacity from a neighbouring zone.

5. Service costs: By combining the procured capability of Black Start with the unit costs, we can determine the annual cost paid to service providers.

Added to this is are other 'central' costs associated with the funding of the NIC project, implementation of the method in the SO and DSO control rooms, and the additional staff required to include DER in Black Start.

6. Carbon benefit: By reducing the volume of fuel required to ensure the readiness of large scale generation, the project provides a carbon benefit for GB consumers. We have quantified this based on (i) the calculated readiness volume from the procured Black Start service (ii) data on the amount of CO2e released from different fuel sources and (iii) typical ESO assumptions on the efficiency of different types of power plants.

7. Method case: In the method case, we assume that all DER (including intermittent renewables) are capable of providing Black Start from 2025 onwards. This includes a pessimistic assumption of a 2-year implementation period following completion of the project. In the base case, DER are not assumed to be capable of providing Black Start until the start of RIIO-ED3 (2033).

Base case and sensitivities

The cost benefit analysis makes some very bullish assumptions about other new innovations which will help to reduce the cost of Black Start. These include:

- The method – Black Start from DERs – is adopted in the Base Case at a later date (2033) with slightly higher costs assumed due to inefficiencies associated with BAU implementation
- There is an increasing role for interconnectors in system restoration.
- Intermittent renewables on the transmission network also provide Black Start (mostly wind).
- There are innovations in gas thermal generation which reduce the costs associated with readiness, which partially offset costs incurred by these generators running less frequently.

All of these other innovations compete with the method being investigated in this project and therefore can be seen to reduce the estimated benefit to a more pessimistic level. Furthermore, with the exception of interconnectors, we believe that including these other possible future innovations goes beyond the requirement of the NIC governance, which is to include "current" and "proven" methods. However, even with these other innovations included, the project still shows a significant benefit.

We have explored sensitivities in which each of these other innovations (with the exception of interconnectors) is removed from the Base Case, and in which they are all removed. We have also explored a sensitivity in which DERs aren't available in the base case until 2038 (RIIO-ED3). The benefit observed for each of these sensitivities is shown in the table below, relative to the central case. This shows that there is potential for benefits to be much higher if some or none of these other innovations are implemented.

Key assumptions

Procurement of Black Start services is complicated, and it has been necessary in the CBA to abstract and simplify how ESO procures the service. For example, representing the procurement of Black Start as a MW requirement is not how ESO plans the service in practice, even though it is a useful way to treat the service in the model.

The key assumptions used in the model are:

- **Available years:** We assume that DER capability can start to be used for Black Start from 2025 onwards in the method case, and from 2033 onwards in the Base Case. This allows for a relatively pessimistic 2-year implementation period following the project's completion in 2022. We assume that intermittent renewables (wind, solar, marine) are capable of providing Black Start from 2025.
- **Technological capability:** For each type of power station which can provide Black Start, we assume that all capacity can be used for Black Start. The exceptions are intermittent renewables, for which it is assumed that only a fraction of the installed capacity will be capable of Black Start (50% for wind and marine, and 25% for solar). We assume that nuclear power stations and CSC interconnectors are incapable of providing Black Start.
- **Diversity in the portfolio of providers:** Most types of power station are restricted, so that they can only provide as much capability as the equivalent of one of three Black Start providers (1000MW) within a zone. This is to reflect that ESO prefers diversity when procuring services from interconnectors, storage etc. This limits the extent to which interconnectors can provide Black Start. This also applies to DERs, although meeting this requirement requires collaboration and aggregation between a large number of providers.
- **De-rating:** We assume that NGET procures a 'de-rated capability' to meet a rated requirement of 1000 MW. De-rating factors are taken from the CM where available, and other sources (e.g. load factors for intermittent renewables) where they aren't.
- **Core service costs:** We have estimated the 'core' cost of the Black Start service (to cover, for example, testing) based on the typical historic costs of Black Start per provider, which have been converted to per MW costs based on the typical provider size.
- **Retrofit costs:** These have been calculated for DER (based on a bill of materials provided by SPEN) and for transmission providers (
  . SPEN's bill of materials estimates the cost of making a selection of GSPs capable of providing Black Start, and the average of Black Start capability which each GSP can then provide.

  All DER are assumed to have the same retrofit equipment cost. For transmission, only coal, gas, and biomass are assumed to require retrofit costs. These retrofit capital costs are converted into an annual equivalent using an assumed lifespan and discount rate. A shorter lifespan of ten years has been assumed for the DER retrofit costs, compared to 25 years for the transmission provider cost. This is to reflect the fact that there has already been cost sunk into auxiliary generators for transmission providers. However, given that much of the distribution network equipment could have a technical life of up to 40 years, this is considered to be very pessimistic.

  In the Base Case, we assume that, due to inefficiencies associated with not completing the project through the NIC (as described in Section 3), the cost of DER retrofits is higher.

- **Readiness:** We have processed data from energy market despatch simulations to estimate the carbon and cost impact of readiness. We assume that gas, coal and biomass need to be made ready, as other generation types are either self-starting, don't need to be despatched in order to be ready (intermittent) or are always despatched in the market. Gas is assumed to need to be running weekly, and coal and biomass daily in order to be ready.
  The model assumes that new CCGTs, which could incorporate new technology, will require a lower volume/less frequent despatch for readiness (a third as much readiness-despatch compared to current CCGTs). New CCGTs start to connect in the 2020s, and make up a relatively high proportion of the overall capacity of CCGTs by the late 2030s.
- **Paying for gaps in Black Start capability:** We assume that, to meet any gaps in capability, ESO has to incur cost to ensure that sufficient capability is available. To avoid this cost, we assume that ESO "borrow" capacity from neighbouring zones. It is assumed that this is gas capacity.
- **Mark up:** We assume that providers mark up prices of the service in inverse proportion to the concentration of the Black Start market. This is done using a simplified calculation of market concentration and its links to price, and requires us to estimate the price elasticity of the demand for Black Start services. The model assumes, very conservatively, that this demand is perfectly elastic – this is pessimistic for the case, and reduces the impact which mark-up has on costs.
- **Implementation costs:**
- **Staff costs:** We assume that additional FTEs would be required for the DSO to be involved in Black Start in the method case – one for each DNO company, one for the ESO in each Black Start region, and two additional ESO FTEs for procurement of services. This is to cover the expected additional burden for DSO and ESO staff when DERs are involved in Black Start, for example, the need to undertake grid compliance testing for a much larger number of generators. These have been costed based on appropriate rates for DSO and SO staff. We expect to refine this cost estimate in more detail during the project.

Factors not considered in the CBA

A number of factors have not been assessed within the cost benefit analysis. These include:

- The potential for the number of zones to change when using a different approach to restoration.
- More detailed requirements on the number of providers required in each zone.
- The difference in service reliability if using DER, which could potentially reduce the amount of capability required from DERs.

In addition, there is potential for restoration times to change following introduction of the method, although it is currently unclear whether this would lead to faster or slower restoration times. Starting restoration from the distribution network may help to get customers back on supply sooner, which would reduce the overall amount of lost load. However, relying on smaller providers may also require smaller block load sizes, which would take longer to energise.

In addition, because a full system restoration is such a highly unlikely event, it is difficult to compare the anticipated cost associated with a restoration with the more certain costs associated with procuring the service.

Comments on Appendix A - Cost and benefits of an individual deployment

Due to the nature of the problem, we have completed the cost benefit analysis at a 'whole system' scale. Therefore, we have not directly calculated the benefits of an individual deployment.

To estimate this in Appendix A, we have determined the average cost and benefit in the method case and base case within a single Black Start region – this is the smallest scale at which the method would likely be deployed in practice. We have determined this by dividing the total cost and benefit by six (as there are six Black Start regions in total).

Scenario selection

The CBA uses the Slow Progression scenario from the 2017 Future Energy Scenarios. This scenario involves a relatively lower level of prosperity, but a relatively higher focus on green ambition. The Steady State scenario would likely have resulted in a lower net financial benefit for the consumer as it involves less of a change in the structure of the energy market. However, both the Consumer Power and Two Degrees scenarios feature a similar decline in the installed capacity of existing types of Black Start provider, with the Two Degrees scenario seeing even more displacement of thermal generation in the electricity market and the Consumer Power scenario featuring even more DER capacity and "despatchable" generation on the distribution network. Therefore, we believe it is likely that the net financial benefit would be comparable and potentially even higher under two out of these three scenarios.

New 2018 scenarios were published during the preparation of this NIC bid; however, the information in these scenarios was not available in time to be considered in this analysis. These scenarios are not directly comparable with the 2017 scenarios – for example, the Slow Progression has been replaced by two scenarios called Consumer Evolution and Steady Progression. We have compared some of the key variables and drivers relevant to this submission to the 2017 FES Slow Progression scenario. This is summarised below:

- The 2018 FES scenarios have a significant deployment of DER – three of the scenarios have a higher installed capacity of DER by 2050, with the remaining scenario featuring the same capacity by 2050. The new scenarios are therefore still identifying potential for significant opportunities to enable participation and increase competition in the market for Black Start services. A significant proportion of this DER capacity is 'despatchable' generation such as reciprocating gas engines.
- The 2018 FES scenarios have less frequent despatch for gas generation overall. The load factor calculated from the 2017 FES Slow Progression scenario is higher than in all the 2018 scenarios until the mid-2040s. This would likely increase the

cost of ensuring readiness for gas generation, making DER more attractive in comparison.
- The 2018 FES has more installed capacity from providers currently providing Black Start (e.g. thermal power stations on the transmission network, interconnectors etc.) in each scenario than in the 2017 FES Slow Progression scenario. This would reduce the extent to which capacity needs to be 'borrowed' from neighbouring regions as determined in the model, which might lead to a slight reduction in the calculated benefit.

Therefore, these updated scenarios potentially present even more opportunities for using DER for Black Start services (DERs capacity forecasts increase), while still presenting challenges when procuring from conventional providers (e.g. reductions in the frequency with which gas turbines are expected to run).

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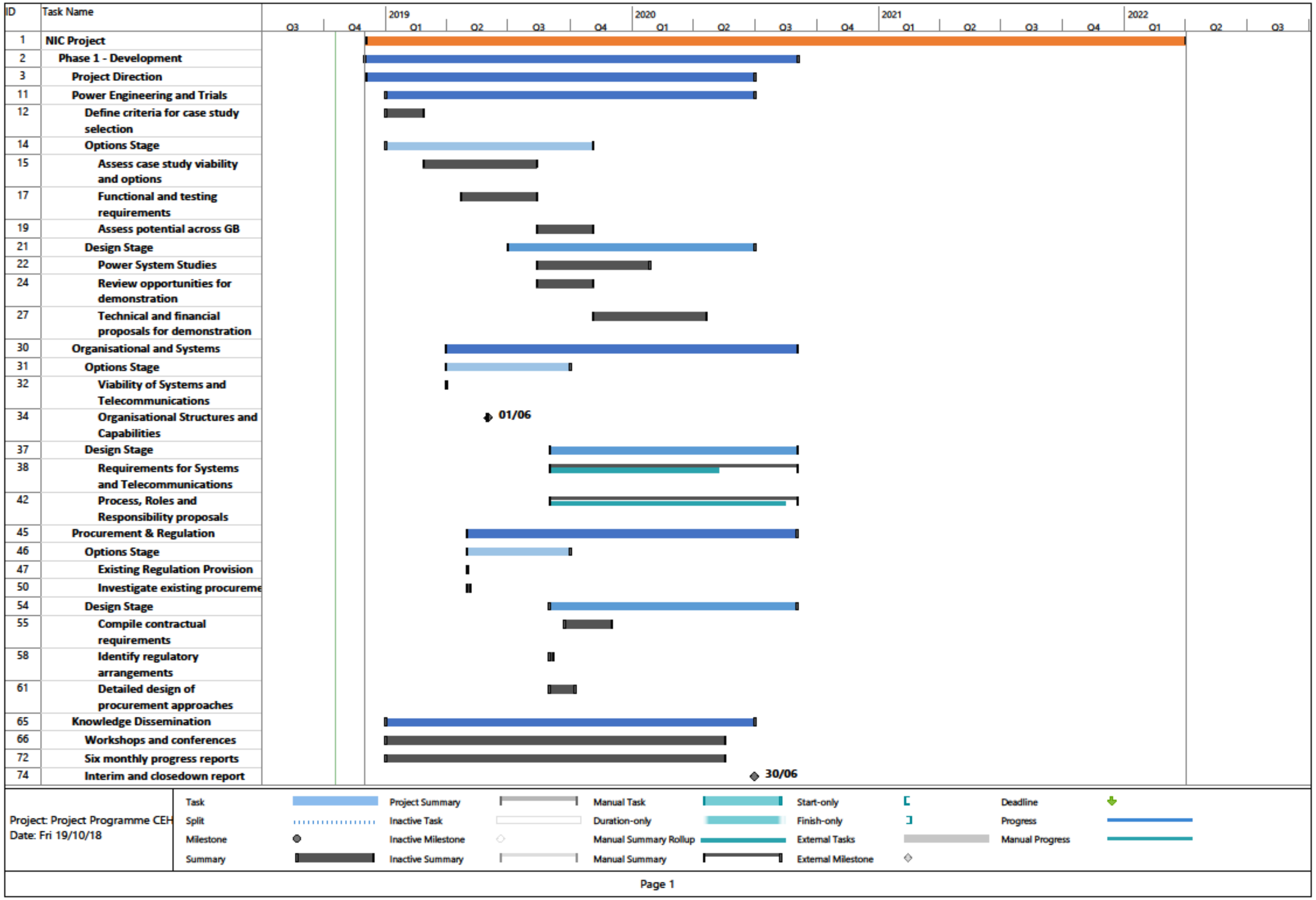
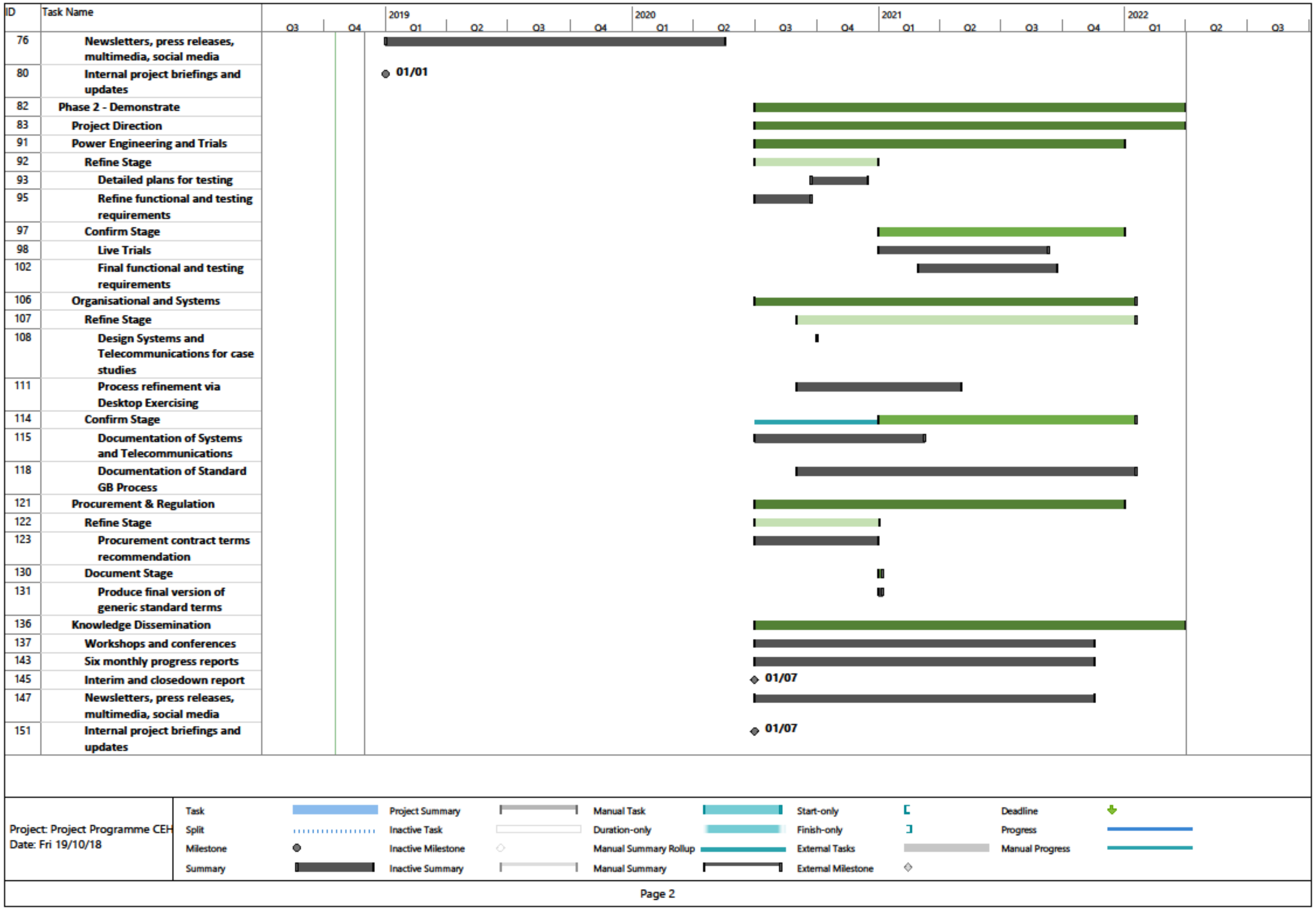
Appendix C – Project Plan




ID
Task Name
2019
2020
2021
2022
Q3
Q4
Q1
Q2
76 Newsletters, press releases, multimedia, social media
80 Internal project briefings and updates
01/01
82 Phase 2 - Demonstrate
83 Project Direction
91 Power Engineering and Trials
92 Refine Stage
93 Detailed plans for testing
95 Refine functional and testing requirements
97 Confirm Stage
98 Live Trials
102 Final functional and testing requirements
106 Organisational and Systems
107 Refine Stage
108 Design Systems and Telecommunications for case studies
111 Process refinement via Desktop Exercising
114 Confirm Stage
115 Documentation of Systems and Telecommunications
118 Documentation of Standard GB Process
121 Procurement & Regulation
122 Refine Stage
123 Procurement contract terms recommendation
130 Document Stage
131 Produce final version of generic standard terms
136 Knowledge Dissemination
137 Workshops and conferences
143 Six monthly progress reports
145 Interim and closedown report
01/07
147 Newsletters, press releases, multimedia, social media
151 Internal project briefings and updates
01/07
Project: Project Programme CEH
Date: Fri 19/10/18
Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress
Page 2

Appendix D – Risk Register and Contingency Plan

Below is an assessment of the key project risks and contingency actions we have identified during bid preparation. This is not an exhaustive list and we will develop a detailed risk register for the start of the project and maintain it throughout delivery. Risk scores take completed mitigation actions into account. The RAG rating is calculated from the greater of the financial impact or reputational impact, multiplied by the likelihood. A guide to the scores is provided after the table.

ID	Phase	Risk Description	Cause	Description of risk impact	Risk Owner	Status	Likelihood	Financial Impact	Reputational Impact	RAG	Mitigation Actions and Contingency
1	General	Insufficient resources allocated for the project.	Project resourcing plan is not realistic, insufficient buy-in from partners on resourcing.	Project does not start/tasks not completed in a timely manner.	PM	Open	2	2	3	6	We have produced a project plan and resourcing has been identified for all major scope activities. Partners have allocated resources appropriately and have budgeted for contractors where required. We will decide on any required resource reassignment plans during the bid review process in anticipation of a successful application. As part of preparing for the project, the provisional resource has been incorporated into the ESO succession planning process.
2	General	Critical staff leave National Grid, SPEN or TNEI.	Usual and unavoidable staff turnover.	Progress of project is delayed. The expertise to deliver the project is no longer within project team.	PM	Open	3	2	3	9	Knowledge of, and responsibility for, the project will not rest with one person through a well-designed team structure. Ensure that documentation and guidance exists to assist anyone joining project team. A thorough handover processes for individual roles will be in place.
3	Development	Restrictions on using DER for Black Start.	Designs to overcome blockers for distribution networks are very complex and/or costly.	Method is not applicable to some networks due to reduced benefits case.	ESO/ SPEN	Open	2	3	2	6	Expected modifications to case study networks to facilitate testing of Black Start from DERs have been included in the project budget. During the Development phase, we will assess the technical suitability of the case study networks. A key criterion for progression to online testing will be the cost of network modifications required.

ID	Phase	Risk Description	Cause	Description of risk impact	Risk Owner	Status	Likelihood	Financial Impact	Reputational Impact	RAG	Mitigation Actions and Contingency
4	Development	DERs not suitable for Black Start testing	DERs in SPEN licence area and other DNO licence areas are found to be unsuitable for testing of energisation or restoration without significant changes to technical capability.	Project unable to progress or requires significantly more time and budget	ESO/ SPEN	Open	1	3	3	3	All case studies are likely to be built around at least one synchronous generator. This is the only technology (of sufficient TRL) that can be grid-forming and act as the 'anchor' for a Power Island. Expected (minor) modifications to DERs to facilitate testing of Black Start from DERs have been included in the project budget. We have also engaged and continue to engage with a range of DERs from across GB to understand their perspective on the readiness of technical, commercial and regulatory aspects. This has indicated that the equipment capabilities and technical skills are more likely to be in place for embedded thermal generation and that more resource may be required for other DER types.
5	Demonstration	Online testing results in non-compliance with Grid Code and/or damage to customer equipment	Inadequate planning and analysis of proposed testing procedures.	Online testing is suspended due to safety concerns.	ESO/ SPEN	Open	2	3	3	6	We will thoroughly design and plan specific procedures before carrying out online testing, including individual risk assessments for each test to ensure that risks are carefully managed and mitigated.
6	Demonstration	Lack of DER interest in trials.	Lack of engagement with DERs, DER do not see the benefit of involvement in trials.	Project unable to progress or requires significantly more time and budget to get DER on board.	ESO/ SPEN	Open	1	3	3	3	We have already held a number of stakeholder events to gauge DER interest. Generators with connections in SPEN and other DNO networks have expressed an interest in being involved and we do not feel lack of engagement is likely. A Stakeholder Advisory Group will be set up upon project commencement for DERs, DNOs and other interested industry stakeholders to inform and guide the project. This should encourage further engagement from industry throughout the project lifecycle supporting future rollout.

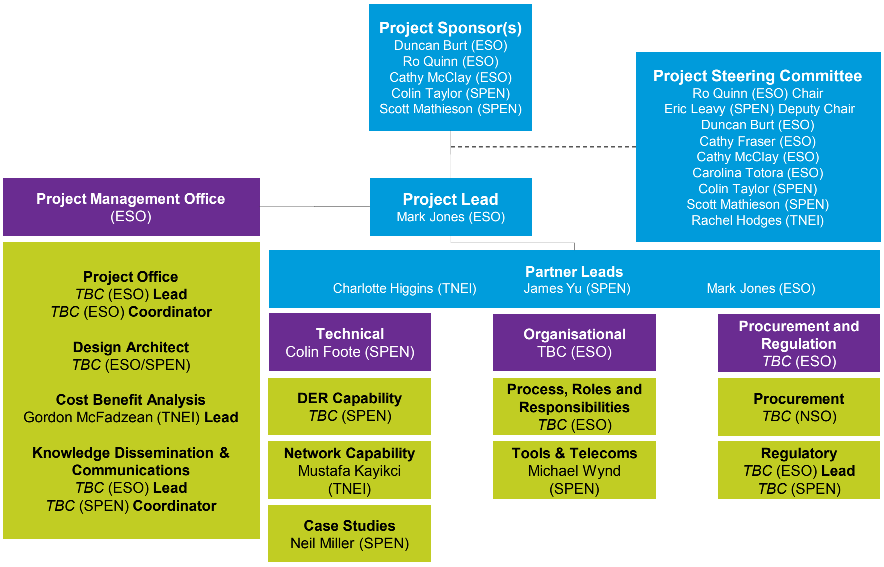
ID	Phase	Risk Description	Cause	Description of risk impact	Risk Owner	Status	Likelihood	Financial Impact	Reputational Impact	RAG	Mitigation Actions and Contingency
7	Demonstration	Delays to preparation and installation for offline and online trials.	Process and technology are not installed and ready for the offline or online trials.	Delays to project	ESO/ SPEN	Open	2	3	3	6	We have produced a project scope and plan and partners have allocated resources to achieve the relevant milestones.
8	General	Procurement time scales may be longer than expected.	May have to procure through framework rather than single source, procurement of innovative products or services may require additional approvals for single source procurements.	Delays to project	PM	Open	2	2	2	4	The procurement process will begin as early as possible. Asides from the procurement of DER services for testing, there is limited procurement of other products or services. Design for contracting of DER for testing will start being developing during Phase 1 - Development.
9											
10	Demonstration	Organisation, technical, procurement and regulatory proposals do not align.	Lack of communication and collaboration on proposals as these develop during the project.	Delays to project, budget impact.	ESO/ SPEN	Open	2	3	3	6	Design Architects are included in the Organisational structure to align outcomes across various work streams. This is based on learning from previous innovation projects.

Score	Reputational Impact		Financial Impact	Likelihood Impact		
	Description	Definition	£m	Description	Frequency	Probability
1	Internal	Internal – minor impact on stakeholders within ESO group	0 to 5	Remote	< Once in 20 years	< 10% chance
2	Intra-Group	Internal – major impact on stakeholders within ESO group	5 to 10	Less likely	< Once in 15 years	> 10% and < 40% chance
3	Local third party	External – impact on local stakeholders	10 to 30	Equally likely as unlikely	< Once in 10 years	> 40% and < 60% chance
4	National	External – impact on national stakeholders	30 to 50	More likely	< Once in 5 years	> 60% and < 90% chance
5	International	External – impact on international stakeholders	50+	Almost certain	One or more a year	> 90% chance

		Likelihood				
		1	2	3	4	5
Impact	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Appendix E – Organogram

Our project structure is presented below.



The Steering Committee will provide strategic direction, decision making, support and issue resolution, for our project and the Project Manager, throughout the lifecycle of the project. The Steering Group is made up of senior stakeholders internal and/or external who have a vested interest in the delivery and/or outcome of the project.

Steering Committee members will:

- Attend Steering Committee meetings prepared to participate, and represent their business area / company
- Provide project decision making, and issue resolution
- Identify and discuss any cross-project dependencies
- Cascade useful information related to the project, back to their respective teams, departments and organisations
- Advocate and champion the project for their respective business area / company.

Each member will receive one vote. The quorum (minimum number of Steering Group members that must be present at to make the proceedings of that meeting valid) is 2 representatives from each company (ESO/SPEN). Meetings will be held on a monthly basis.

Our core project team is comprised of highly-capable individuals with the right innovation and project management experience, as well as specialist knowledge and expertise. The team has led the development of this project bid.

Project Lead/Partner Lead (ESO) - Mark Jones BSc (Hons), MSc, CEng IET, MCMI
Mark joined National Grid in 2011 and moved to the Black Start team in 2016 where he has led technical, organisational and commercial interactions internationally. Mark's drive and capabilities have been demonstrated by proving new technologies, such as interconnectors as potential Black Start providers. Whilst delivering externally Mark has used his leadership capability to mentor and develop the contractual and technical teams within National Grid, combining this with delivering process changes to increase business

efficiency. Previous experience includes delivering major technology-led infrastructure projects to Highways England from concept to installation. Mark has already demonstrated this capability for this role by leading the bid submission for ESO.

Partner Lead (SPEN): James Yu is Future Networks Manager at SP Energy Networks. He is a Chartered Engineer and elected IET Fellow. He has taken various technical, commercial and managerial roles in the industry. James is accountable for innovation projects at company level and pushing innovation into business as usual. His team are working on various network innovation projects at national and European level.

Partner Lead (TNEI): Charlotte Higgins (BEng, PhD) has an extensive background in the energy sector, with over 18 years of experience in the field of systems analysis, particularly in power systems applications. Charlotte has expertise in the technology, economic and regulatory considerations for future development of transmission and distribution networks, including integration of renewable generation, smart grids, HVDC systems and low carbon technology. She has contributed to a number of successful network innovation bids and projects. Charlotte led TNEI's contribution as a project partner to the SPEN LCNF Tier 2 project Flexible Networks for a Low Carbon Future and is currently leading delivery of Northern Powergrid's NIA project Smarter Network Design Methodologies.

Case Studies: Neil Miller BEng MSc (Strathclyde) has a BEng in Electrical and Electronic Engineering. Following graduation, he worked for 8 years on the Scottish Power (SP) distribution network, gaining experience within the operations, maintenance and design departments, latterly specialising in the commissioning of protection systems. Following this, he worked for 4 years on the SP transmission network, gaining first-hand experience of operating the network, and primarily being involved with the commissioning of the protection systems. For the last 16 years, he has worked in the SP distribution/transmission network design department, being involved with the design, analysis and reinforcement of the networks to facilitate large volumes of renewable generation connections. He has gained a wide experience and in depth knowledge of both the distribution and transmission networks, and the issues associated with the connection of generation at voltages from 11kV to 400kV.

Tools and Telecom: Michael Wynd is the Head of Network Technical Services at SP Energy Networks where he oversees a team of more than 50 working on telecoms, real-time systems, network automation and smart metering. Mike is a Chartered Engineer and Fellow of the IET and has extensive experience across the electricity industry in both networks and generation. He is engaged in a number of innovation projects including SPEN's NIC-funded Phoenix project. Mike will ensure that SPEN deploys the most appropriate resources to deliver the project objectives on tools and telecoms.

Technical Lead: Colin Foote MEng PhD MIET MIEEE is the Systems Analysis Manager at SP Energy Networks where he leads a team of highly experienced power systems engineers. The team is responsible for modelling and simulation of the network, reviewing performance, informing planning and operation, and providing detailed technical advice on a range of subjects. Colin plays a leading role in activities relating to Black Start at SPEN, including power system studies in support of system restoration, and engagement with external stakeholders on opportunities for new approaches.

Network Capability: Mustafa Kayikci (BEng, PhD) is a specialist consultant at TNEI, with expertise in modelling of power system equipment and transmission/ distribution network analysis. He has considerable experience of assessing technical network phenomena such as power quality, fault level, harmonic assessments and filter design, and transient behaviour of generators and transmission/ distribution systems.

CBA Lead: Gordon McFadzean is a Senior Consultant at TNEI, where he works on strategy and analysis projects relating to network innovations, industry change, and systems operation. He has been involved in assessing the business case for previous NIC bids such as Celsius and Angle-DC**,** as well as innovations considered within the Carbon Trust's Offshore Wind Accelerator.

Appendix F – Project Partners

Organisation	National Grid Electricity System Operator	SP Energy Networks (SP Transmission, SP Manweb and SP Distributions)	TNEI Services Limited
Role	Project Partner	Project Partner	Partner
Organisation type/ description	Electricity System Operator	Transmission Networks Owner; Distribution Networks Operators	Energy consultancy
Contractual relationship	Under negotiation: National Grid and SPEN intend to sign a bi-lateral agreement.	Under negotiation: National Grid and SPEN intend to sign a bi-lateral agreement.	Under negotiation: TNEI will contract to National Grid as a supplier.
Project role summary	National Grid is jointly delivering the project with SPEN and TNEI and has active involvement in all of the project work streams with several of its team taking lead roles. ESO is taking overall lead of the project and delivering the PMO function.	SPEN is jointly leading the project with National Grid and TNEI, and has active involvement in all of the project work streams and the PMO, with several of its team taking work stream lead roles.	TNEI is jointly leading the project with National Grid and SPEN. TNEI will provide technical power systems expertise with active involvement in all of the project work streams and providing a partner lead role.
What does the project partner bring to the project?	Expertise in Black Start technical, organisational, commercial and regulatory requirements.	Understanding of distribution network infrastructure, DER and organisational capability and opportunity for Black Start from DERs. The SPEN licence area is highly diverse and contains a number of potential case study networks.	Expertise in generator technology and specialist modelling and analysis of transmission and distribution networks across GB and internationally.
Funding contribution	£879.58k	£289.51k	£122.4, via fee reduction
External collaborator benefits from the project	The project will deliver learning on new business requirements for both National Grid and SPEN, enabling Black Start to be procured from DER on SPEN's Network and other DNO networks across GB.	The project will deliver learning on new business requirements for both National Grid and SPEN, enabling Black Start to be procured from DER on SPEN's Network and other DNO networks across GB.	TNEI will not directly benefit from the outcomes of the project. However, learning outcomes will enable us to expertly support National Grid and GB DNOs in rollout of the method.

Appendix G – Technical Description of the Project

Project Scope Overview

We will deliver the project across five work streams that will achieve the NIC goals of Development and Demonstration.

The **Project Direction** work stream encompasses all project management activity to ensure the project's smooth running. It will provide design assurance to ensure that the other work streams are aligned and include industry developments outside the project. It will also revise the cost benefit analysis based on project learning to determine whether the proposed method delivers value for customers.

We have defined three areas of work to cover the wide range of issues to enable Black Start from DER. Each will consider a common set of case studies and proceed through four stages of identifying viable options, producing designs, refining those designs based on consultation and testing, and confirming the benefits.

- The **Power Engineering & Trials** work stream is concerned with assessing the capability of GB distribution networks and installed DER to deliver an effective Black Start service. It will identify the technical requirements that should apply on an enduring basis. This will be done through detailed analysis of the case studies and progression of selected cases through multiple stages of review and testing to achieve demonstration of the Black Start from DER concept in 'live trials' on SPEN networks.
- The **Organisational & Systems** work stream will consider the restoration process including different roles, responsibilities and relationships needed across the industry to achieve Black Start from DER at scale. It will specify the requirements for information systems and telecommunications, recognising the need for resilience and the challenges of coordinating Black Start across a large number of parties.
- The **Procurement & Regulation** work stream will address the best way to deliver the concept for customers. It will explore the options and trade-offs between competitive procurement solutions and mandated elements. It will make recommendations on the procurement strategy aiming to be as open and transparent as possible. It will feed into BAU activities to make changes as necessary in codes and regulations.

The **Knowledge Dissemination** work stream contains the activities carried out to consult and engage with the industry and share project learning, so that all stakeholders, including the ESO, network owners, DER, manufacturers, service providers and others are prepared to make Black Start from DER a reality in GB.

Work Stream 1 – Project Direction

We will set project direction, the other work streams will be coordinated, and overall delivery assured by the following roles, as illustrated in the Organogram in Appendix E.

Project Sponsors and Steering Committee - Representatives from each of the project partners will provide overall leadership and set the governance framework for the project.

Project Lead - Represent the project within ESO, to Ofgem and the wider industry, engaging with external stakeholders, and responsible for overall delivery of the project and final approval with the Project Sponsors and Steering Committee.

Partner Leads - Responsible for leading and coordinating delivery within the partner organisations, and being ambassadors for the project during stakeholder engagement activities.

Project Management Office - Providing a project tracking and progress reporting role. Responsibility for maintaining the project risk register, budget and spend. Organise internal project meetings and travel.

Cost Benefit Analysis - Responsible for updating the benefit analysis based on learnings to maintain a relevant and up to date CBA for the close out report.

Design Assurance - Provide design assurance and challenge across the all work streams to ensure alignment across all activities and with developments across the industry.

Work Stream 2 – Power Engineering & Trials

Before kick-off

Define criteria for case study selection – Based on the project goals and the work already done in bid preparation, including the bilateral meetings with the Expert Panel, we will define the criteria to be used in case study selection and prioritisation. Doing this before formal kick-off in January 2019 helps to advance the selection and assessment of the case studies and thereby confirm viability of the proposed method ahead of work being done on new processes.

Options Stage

Assess case study viability and options – Through review of opportunities across networks and expressions of interest from potential participants, we will choose case studies for assessment. There will be around 10 case studies based on their potential to deliver Black Start, support project objectives and cover a range of DER types and network conditions.

For each case, we will assess and develop the options for energisation and restoration in terms of the network and DER equipment. We will identify gaps in technical capability or barriers to implementation in each case, and inform the development of more general technical requirements for future roll-out. We will determine where delivery of Black Start will require new or untested technology or practice for the DER or network operator, and therefore determine the overall viability in each case study.

Functional and testing requirements – Using the project case studies as examples, we will consider different options for how the current Black Start requirements may be relaxed or otherwise modified to allow a potentially different type of service to be provided by DER without adverse impact on customers or unacceptable risk to any party.

Based on the technical assessment, we will specify the need for testing and the success criteria in each case study. The specification will describe the test goals, methods and expected outcomes, making clear what behaviour, equipment or processes should be tested on the DER or network to confirm the technical capability to deliver Black Start. This will inform the definition of test requirements used in the future roll-out.

Assess potential across GB – Based on the representative case studies and technical findings, we will make an initial estimate of the investment needed, on networks or on DER in each case study. We will then evaluate the potential for concept roll-out across GB by reviewing, at a high level, the network characteristics and DER currently installed. This will assess the technical suitability of networks and DER and quantify the scale of changes required, e.g. estimate how much equipment might need to be installed in other locations.

Design Stage

Power System Studies – We will perform power system studies using models of the case study networks and DER, plus other models as appropriate, to fully explore the technical capability and challenges within the case studies and identify the more generic issues for wider GB roll-out, e.g. provide guidance on network characteristics that make some locations more suitable than others. We will perform network design studies including:

- Energisation design studies for case study scenarios as necessary, e.g. load-flow, short-circuit, protection, RMS dynamic, EMT dynamic, power quality.
- Analysis of the ability of the networks and scenarios to sustain energisation, and to synchronise with neighbouring island regions.
- Strategic energisation studies for several additional scenarios/locations to assess resilience to anticipated system changes.
- Assessment of known asset and technical operational challenges for Black Start from DER in the case study areas, e.g. earthing, protection, back energisation.
- Propose designs to overcome network blockers.
- Inform design of procedures, specifications and agreements for online and offline testing.

We will carry out desktop review of the suitability of proposed networks to energise and restore the system. For a case study to be progressed to a trial that includes energisation of a transmission line, the technical analysis will have to confirm the following:

- Sufficient reactive range, and associated fast-acting voltage control, is available to absorb the capacitive gain from unloaded circuits (from the aggregate capability of the DER and any DNO reactive compensation in the Power Island);
- There is acceptably low risk of transient over-voltages that may damage equipment or trigger protection, which will be a function of Power Island 'strength', appropriate control before the critical energisation step, insulation coordination and protection settings;
- Harmonic resonances are of frequency and magnitude that do not present an unacceptable risk;
- Protection for all energised equipment is sensitive enough to detect a fault condition given the low short circuit level;
- Earthing on the Power Island is adequate to ensure safe operation including acceptably low rise of earth potential and step voltages on affected equipment; and
- Measurement equipment is suitable, and available, to adequately record test behaviour.

Review opportunities for demonstration – For each of the prioritised case studies, we will review the network configuration and expected conditions over the project period, including planned outages, new connections, etc. In this way, we can determine the specific restrictions and opportunities for live trials. We will look at the impact on participating and non-participating customers, e.g. reduced security, and decide on an appropriate communications strategy. We will make recommendations on the case studies that offer the best learning opportunities in live trials.

Technical and financial proposals for demonstration – For the case studies with the best demonstration opportunities (assume 4), this task will collect more detailed information, from all participating parties, on costs of filling gaps in capability or overcoming barriers in the proposed energisation and restoration process, on the network or DER, within each case study. From this we will produce a technical and financial proposal for live trials for review by the project Steering Committee.

The project budget includes estimated costs for taking two case studies to a live trial, which would involve testing self-starting of DER and energisation of parts of the distribution and transmission network made available for the trial.

Refine Stage

Detailed plans for testing – We will produce detailed plans for the case studies approved for progression to demonstration or further analysis (assume 4), including all outage plans, costs, risk assessments and test specifications concerned with the network and DER involved in testing. The technical and financial design proposals will be revised as necessary. We will involve case study participants as required to achieve consensus.

Refine functional and testing requirements – Based on the detailed analysis, the outcomes of industry workshops and consultation, and the findings from further work on the case studies, we will make firm proposals on the functional and testing requirements in terms of networks and DER. This will present the work stream view on the preferred options for how the current technical requirements should be modified to allow services to be provided by DER. This will be supported by evidence of the investment implications and potential scope for roll-out across GB. We will ensure that proposals are consistent with other industry developments, e.g. the Open Networks project and ESO strategy.

Confirm Stage

Live trials – We will deliver at least two live trials within the project, which will be developed from the case studies we use for detailed assessment and development of solutions across all work streams. It is our intention to energise a section of dead transmission system within the trials, as a minimum on the 132 kV network in Scotland but, if possible, on 275 or 400 kV in both the SPT and NGET areas. We believe that such a demonstration would be of international significance. We will collect and record all relevant data and outcomes from the live trials to maximise the benefit and learning.

Final functional and testing requirements – Based on the learnings across all work streams, and external engagement, we will produce the final proposals for functional and testing requirements. The outputs from this task are intended to form the basis for transition to business as usual. On completion of the project it is anticipated that opportunities for Black Start from DER will be explored across all of GB with some being progressed to detailed assessment and testing, following the guidance produced in this project.

Work Stream 3 – Organisational & Systems

Options Stage

Viability of Systems and Telecommunications – Understand the viability of existing industry systems and telecommunications resilience to assist the control and coordination of creating and managing a DER Power Island. Undertake assessment on what resilience is required of the systems and telecommunications to ensure they maintain capability to operate during a black out.

Organisational Structures and Capabilities – Evaluate options for a process to enable the Black Start from DER solution. Options will consider the current capabilities of the ESO, DNOs and relevant DER, and understand roles, responsibilities and skillsets currently in place across all organisations. Consider options for how these might be applied, or what modifications are required to enable Black Start from DER.

Information gained will inform the design stage, and the industry of the current resilience level. Combined with the organisational capability it will provide an indication as to the viability of the project and identify the key areas of focus for the design.

Design Stage

Requirements for Systems and Telecommunications – We don't envisage any new systems being required, however some systems may require additional functionality to manage the Power Island. We will develop a proposal for resilient systems and telecommunications requirements covering the ESO, DNOs and DER. Working with systems manufacturers we will develop the functional designs to meet the requirements of the process for capability and resilience. These will be tested offline in the Refine stage where needed to prove particular aspects of capability.

Process, Roles and Responsibility proposals – We will design a process to enable a Power Island to be created, controlled and coordinated from Black Start from DER. This will include solutions of how DER are instructed (in isolation and combination), despatched and controlled. This process will be applicable across GB, factoring in consideration of DNO and DSO models. The process will adapt around what is needed to achieve the management of the Power Island.

Refine Stage

Design Systems and Telecommunications for case studies – We will test the associated systems and telecommunications provisions on a modular basis. As these systems and provisions are already installed, and therefore validated, the testing will be carried out on areas where there are unknowns or uncertainties.

Each case study location selected to progress to a physical testing stage will have a design created around the functional requirements determined in the Design stage. Elements needed to run the trial will be rolled out, however some modules may use BAU communications to ensure that we don't spend budget unnecessarily.

Where systems and telecommunications are required for Power System protection systems or Micro grid components to manage the Power Island we have allowed a budget to test these in an offline testing facility. This hardware in the loop testing will prove the ability to manage the Power Island in an offline environment, where events can be simulated.

Process refinement via Desktop Exercising – The process will be tested within a Desktop Exercise, where we take the professionals and within a class room environment create a situation for them to manage a black out. This will incorporate the use of offline systems, tools, Power System Simulators, phone calls and information exchange to test any capability, skill or process gaps. This will simulate an end-to-end Black Start event and demonstrate how the process will integrate with the wider restoration plans.

We will capture learnings and timings from this test to further refine the process and demonstrate the concept. This is an important part of the refine stage to optimise the efficiency of the process and identify and remove any bottlenecks to process flow.

Confirm Stage

Documentation of Systems and Telecommunications – We will validate the solution based upon the case study locations and modular trials of systems and telecommunications to prove an end to end capability. We will document with the functional requirements budgetary costs needed to implement the concept for the creation of the Power Island and any wider recommendations to Industry on resilience. This detailed specification will enable the roll out of Systems and Telecommunications for the concept across GB.

Documentation of Standard GB Process– Concluding the previous stages will result in a refined process for providing Black Start from DER. We will document this process along with the relevant specifications for systems and telecommunications.

For this DER process to be fully integrated into Black Start restoration plans, the final, agreed process (and associated control and coordination process) will need to be included in relevant plans – most notably into the ESO's Black Start Strategy. We will explore how this is included and expanded to any local associated strategies in the DNOs.

Work Stream 4 – Procurement & Regulation

Stakeholder engagement will be ongoing throughout the project including the Grid Code Development Forum, the Distribution Code Review Panel, the Grid Code Review Panel, Electricity Networks and Futures Group, and the STC Review Panel. Regulatory proposals being developed, this will be taken into BAU by ESO to forward the changes to the relevant industry codes and licences.

Options stage

Existing Regulation Provision – We will review existing regulation and roles of industry parties with regards to achieving the project aims in case study areas. We will identify gaps and blockers that will impact new services in these codes and licence conditions.

Investigate existing procurement – We will investigate procurement options for balancing services procured from DER and outline options to be assessed. We will also outline the criteria for determining the preferred option.

We will review the recommendation of the organisational and technical work streams to understand the impact on what we need to procure, set out in industry codes or agreements, and how we are regulated. We will undertake commercial design of the service (e.g. firmness, energy reconciliation, relief events, etc.)

Design stage

Compile contractual requirements – With the case studies as worked examples, and in close collaboration with the other work streams, we will compile the contractual requirements based on the proposed technical solutions and proposed procurement approach. We will develop contractual arrangements across all of GB, based on both technical and procurement options.

Identify regulatory arrangements – We will identify potential regulatory arrangements and required changes to relevant codes (Grid Code, STC, and Distribution Code) and License requirements needed to facilitate the proposed Black Start process(es). We will identify any discrepancies between the existing arrangements/requirements and the arrangements/requirements necessary to facilitate the implementation. We will identify how the proposed arrangement would fit under the restoration plan required by European Codes (most notably Emergency & Restoration).

Detailed design of procurement approaches – We will determine the need for contracts, resources, IS systems, etc. and propose preferred solution(s), engage with legal support to develop the preferred procurement option and keep industry stakeholders informed. We will consult legal experts about contract requirements and produce a high-level outline of the contract terms.

Under BAU ESO will then forward the Regulatory proposals produced by the project within the relevant fields to implement any required changes.

Refine Stage

Procurement contract terms recommendation – We will work with relevant industry parties to review heads of terms to demonstrate the method is deliverable and gather feedback and understand changes required to terms.

We will engage with legal experts to explain industry feedback and develop detailed contract terms, plus deliver a draft version of the generic contract terms and review these with relevant industry parties.

We will investigate which procurement option(s) is/are most appropriate. Engagement with legal resource to validate assessment will take place and we will engage with industry on the procurement options.

Confirm Stage

Produce final version of generic standard terms – We will talk to legal experts to explain industry feedback and develop detailed contract terms. This will enable us to consolidate what we have learnt into contractual terms that will demonstrate to the industry the terms by which a service could be offered.

Work Stream 5 – Knowledge Dissemination

The routes through which we will share the learning are outlined here.

Workshops and conferences – We will hold regular workshops and stakeholder events to support the work streams. These events will take a variety of forms, e.g. in person and by webinar. Some will be targeted at specific stakeholder groups or focus on a specific case study location; others will share knowledge and obtain feedback from a national audience. This is critical to the project's success and to ensure that all stakeholder views have been considered when progressing with the project. The project team and wider partners will also engage in industry conferences such as those organised by CIRED, EPRI, CIGRE, IEEE and the LCNI annual conference.

Six monthly progress reports – We will submit these reports directly to Ofgem, updating on the progress of the project against the submitted project plan. These reports will be made publicly available on the ESO and SPEN websites.

Interim and closedown report – Reports will document the organisational, technical, procurement and regulatory findings of the project at the end of the development and demonstrate phases and at other appropriate milestones. We will produce and submit to Ofgem a closedown report following completion of the project. This report will be shared with all stakeholder groups at the drafting stage to ensure the full range of views have been taken on board. The report will present the key findings and recommendations.

Newsletters, press releases, multimedia, social media – ESO and SPEN have an established suite of tools to make content available to customers and engage them on a range of activities and initiatives. We will use these, including appropriate social media platforms, to inform specific audiences and to update all interested stakeholders on the latest events, consultations and progress.

Internal project briefings & updates – To share the project's progress for internal audiences in partner organisations, we will develop a range of communication media.

Overview of Potential Case Studies

The case studies that will be used as worked examples to develop and demonstrate the method will be selected in the early stages of the project and may include locations from across all of GB. In preparing this bid we have identified 10 potential test areas in SPEN areas, five in the SP Distribution (SPD) network, and five in the SP Manweb (SPM) network. The SPD network covers central and southern Scotland, operates at 33 kV and below, and is mainly radial in nature. The SPM network covers Merseyside, Cheshire, north Wales, and north Shropshire, operates at 132 kV and below, and is mainly interconnected in nature.

We identified case studies by reviewing the DER connected, or soon to connect, across SPEN networks and identifying locations that offered:

- Generators that, based on present TRL with respect to self-starting and grid-forming behaviour, might feasibly be used as the 'anchor' machine in a Power Island.
- Other DER that could be used in combination with the anchor machine to grow the Power Island and extend its reach.
- A range of network topologies and characteristics, including opportunities for hosting live trials.

A detailed description is given for one case study in each region, and a high level description given of the remaining four. The case studies represent a variety of locations, voltage levels, network topologies and DER types, which will lead to outcomes valid on a GB-wide basis. The 10 case studies demonstrate genuine opportunities are available to conduct detailed assessments and progress to live trials.

Distributed Energy Resources

We will thoroughly investigate the requirements to make the anchor generators in each case study 'Black Start ready' including factors such as their ability to self-start and maintain a stable Power Island. In addition, we will assess the ability of the other DER to join and help grow the Power Island, including their ability to contribute to voltage and frequency control.

Demand Behaviour

The prediction of and response to demand behaviour, particularly the volatility of small blocks of load, has been highlighted as a particular challenge for the project and will be subject to detailed study to determine whether existing DER will be capable on its own or if resources like flywheels or batteries will have to form a part of any distribution-led re-energisation.

This project does not include any new research or deep analysis of the temporal behaviour of demand post-blackout. The emphasis will be on using the best information available from other sources. When we examine the case studies in detail, we believe that simulations and analysis in collaboration with DER owners/operators and equipment manufacturers can go a long way in determining the capability of DER and building confidence that stable Power Islands can be established and maintained. In the physical tests we plan to use adjustable, programmable load banks or temporary batteries to emulate the dynamic behaviour of demand, although we recognise that this will be limited by the practical size of this temporary equipment. The selection of case studies will depend in part on the availability of suitable demand or batteries.

Network

We need to consider factors such as the reactive gain of energising sections of the distribution network, the practical sizes of block loading that can be achieved with network switching, effects of inrush currents when energising transformers, suitable protection and earthing arrangements on an islanded network and the best points on the network for splitting and synchronising.

Communications

For a Black Start scenario, reliable communications between the DER, the System Operator (SO), Transmission Owner (TO) and Distribution Network Operator (DNO) control rooms will be essential. In addition, we will need to consider the level of automation associated with network restoration. We will undertake a review of the communications infrastructure to identify the required enhancements.

Appendix H – Summary of Necessary Innovations

The table below sets out the innovation required to deliver the method, compared to current BAU activities.

Table H.1: How this NIC project aims to explore a step-change in ESO's Black Start activity

Stage	Current Activity	From DERs
Capacity assessment	Black Start requirements are determined based on the ability to meet published restoration times for the GB network. This is then interpreted into the current 3 stations per each of the 6 zones to provide some redundancy for failed start ups and to enable a rapid geographically dispersed restoration along the skeleton network. Simply put, the capacity assessment uses the current restoration method and assesses how many providers are required to meet that timescale. Current technologies are well understood in how their technical parameters contribute to restoration and an assessment can take this into consideration.	Capacity assessment needs an understanding of the suitability of providers to the overall restoration, as well as their relative effectiveness and reliability. This is not something currently known, and the volume required to meet requirements is also an unknown.
	Currently we understand the boundaries of the service as a whole, and are developing a combined service where 'self-start' capability and 'block loading' capability are delivered from 2 conventional providers separately.	From DER, it is likely that provision will be split into more elements, such as frequency response only, or reactive power only, as well as the traditional self start and block loading elements. For these, the technical parameters of each element will need to be designed and agreed. In addition, a mechanism for stacking these into a combination that delivers the minimum service level, and can compare the value of these elements separately and in combination, needs to be created to ensure efficient spending.
Initial discussions and feasibility	Feasibility studies are undertaken for every new provider. These typically cost hundreds of thousands of pounds. We undertake discussions with new providers of any proven technology on an individual basis,	DERs, specifically combinations of DERs, are not proven to be able to contribute to a restoration. The project will be determining a whole new set of technical capabilities and requirements that are aligned to this new set of potential providers. Once we understand what technical capabilities will be required from a provider, we will need to formulate a method for efficiently

Stage	Current Activity	From DERs
	using standardised documents and communications. NGESO is required to maintain sufficient Black Start capability to be able to restore the network after a shutdown. Prior to contracting, we need sufficient assurance that the potential provider has BS capability, we do this at the moment through Feasibility Studies. Currently, 'Feasibility Studies' are defined as work undertaken by the licensee and potential New Provider in order to assess their ability to provide Black Start services. At the moment, this involves assessing the provider against a set of known, required capabilities.	assessing a large number of providers against these new requirements. Currently, we engage bilaterally with a provider and reimburse reasonable costs incurred by them proving their capability. This will not be efficient to continue for large numbers of providers, each delivering a much smaller individual contribution. We will need to develop a new, industry-wide technique for evaluating the combined capability of a network area, and in addition, to define roles and responsibilities in relation to this. As an industry, we will need to find the balance between ensuring the correct level of assurance of capability and the associated cost to manage this. This will be a complex activity, and will need industry input and consensus to develop a solution that will: be widely accepted and fit for purpose; provide the correct level of assurance that Black Start capability is available and that restoration timescales will be met; and will ensure the solution is economic and efficient.
Contracting, procurement design, and value assessment	ESO enters into a bilateral contract with the Black Start provider. If there are 2 or more potential Provider contracts, ESO will manually run a competitive event, but the outcome will still be a bilateral contract.	In the case of a number of DER coordinating to provide the service in a zone, with different assets potentially delivering individual service components (e.g. frequency control or reactive power), a bilateral assessment and contracting methodology will not work. We will also need to explore more efficient procurement methodologies and identify the best option for determining the route to market, tender structure and logistics. We need to design a methodology for determining what will be procured and all of the associated parameters, including: - Procurement timeframes (do certain providers need to invest or build – does this disadvantage them?), - Contract durations and service start proximity to real time – with much greater liquidity could we use frameworks and call off at week ahead or day ahead for short periods? - Framework for determining how much of each component is required, is this fixed

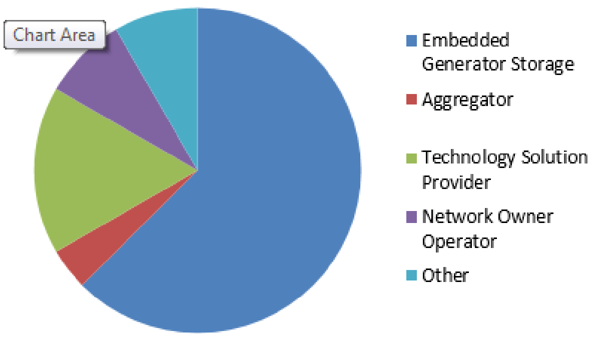
Stage	Current Activity	From DERs
		or does an increase in one component reduce the need for another? We need a methodology that will allow us to assess the value of each individual service component, and to assess the commercial offering from each provider. This will be complex and is likely to require a system solution. - Determine how current providers will be assessed against new providers (especially if new providers requirement investment). - Determine whether certain service components are more valuable than others, how much more valuable and whether the value is dependent on other factors. The appropriate sharing of risk between all the different parties will be complex to apportion and will require a new contractual design, or a new suite of contracts based on the outcome of what the service components are, what will be procured and how it will be valued/assessed. This NIC project will explore new and innovative commercial arrangements, and develop and test the most appropriate option(s).
Construction	CAPEX required to make the generator Black Start ready is agreed and paid for by ESO before works are undertaken.	For unproven DER technologies, we do not yet understand what generator enhancements or requirements could be needed to ensure Black Start readiness. The same goes for enhancements to the distribution network. This NIC project will assess and test what these need to be in each Case Study. If enhancements are required, we will need a methodology for determining whether this will be funded, and if so, what the parameters are.
	Local Joint Restoration Plan agreed through trilateral conversations will all parties. Routes and restoration are studied and validated before being built into skeleton network restoration plans. Each provider has a direct phone line to the control room which would be	In the method approach, we will need to develop a whole new approach to Local Restoration Planning, where a complex combination of different DER needs to be coordinated to provide different services to power local islands; and those islands need to grow and integrate with other islands. The role of the DNO needs to be transformed, from facilitating restoration by switching in blocks of demand, to actively coordinating DER and

Stage	Current Activity	From DERs
	used for coordination of activity in a Black Start event.	managing multiple Power Islands. This NIC project will explore different coordination approaches and innovative new tools to bring all of this together. The current infrastructure/equipment for communications in a Black Start event is unlikely to be fit for purpose to accommodate potentially hundreds of DER providers.
	Commissioning, training and testing require resource to complete the tasks, which are completed on a case-by-case basis for each provider.	In the same way, as for feasibility studies, this NIC project needs to examine how we might achieve these labour-intensive activities in a way that is economically feasible for potentially hundreds of new Providers.
Availability assessment, performance monitoring and settlement.	Currently, each provider is responsible for making declarations of availability to the control room by fax, and the control room pass these on to Settlements to record and adjust monthly payments accordingly. Settlements make an annual assessment on an individual provider basis, referring to individual contract terms using spreadsheet tools only.	We will need a new methodology for ESO control room to monitor the level of availability/service provision at any time, as individual faxes will not be viable as the number of providers increase. Further, if the DER solution leads to shorter term contracts/closer to real time procurement/more frequent changing of providers, this will exacerbate the challenge of monitoring and operation. The same applies for performance monitoring for contractual purposes. With the new contractual design, there will need to be a new suite of Events of Default (EODs) and corresponding penalties. It will not be feasible to monitor this using the current spreadsheet system, and by relying on provider declarations. Further, for Settlements to accurately settle this, there will most likely be a requirement for a system upgrade to account for: - increase in number of discrete service components - increase in number of providers - new and varied payment structures (depending on service component) - new and varied EODs (depending on service component)

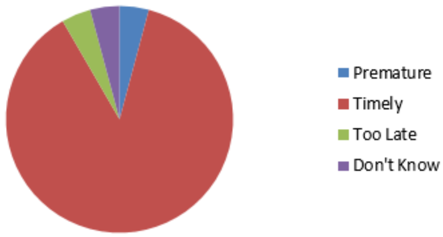
Appendix I – Industry Survey Results & Letters of Support

During the ISP and FSP stages, we have started engaging with industry stakeholders, and this has informed the preparation of the bid document. In addition, we approached all the stakeholders with a short survey, and the results are summarised below:

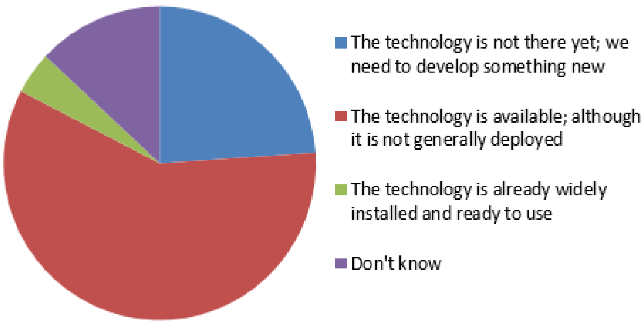
Which sector do you represent?



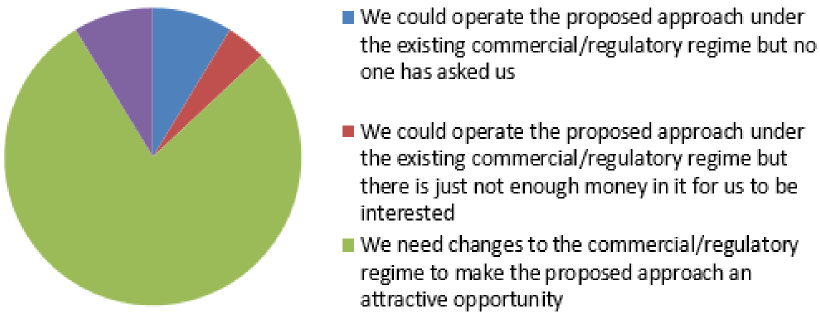
Do you agree that it is timely we address the question of Black Start from DER now?

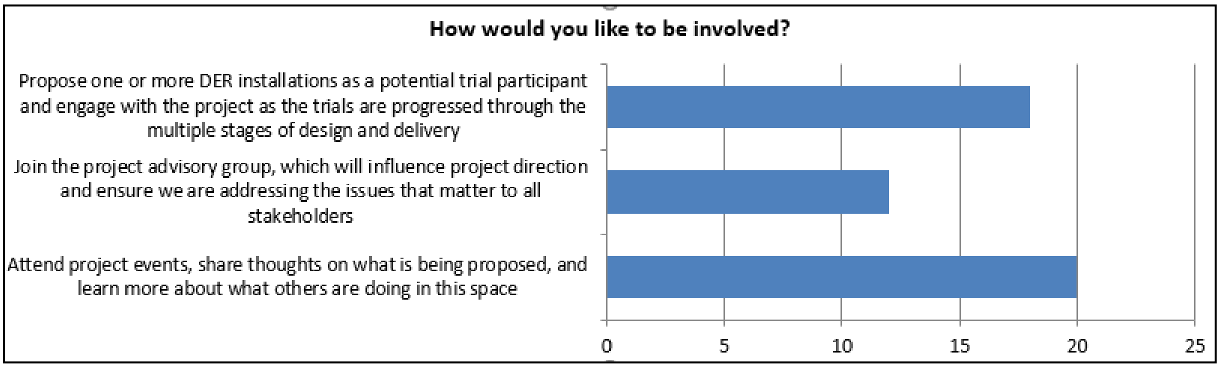


Based on your understanding of your sector and the equipment that is currently available, do you think that the technology (in your sector) is capable of supporting the proposed approach?

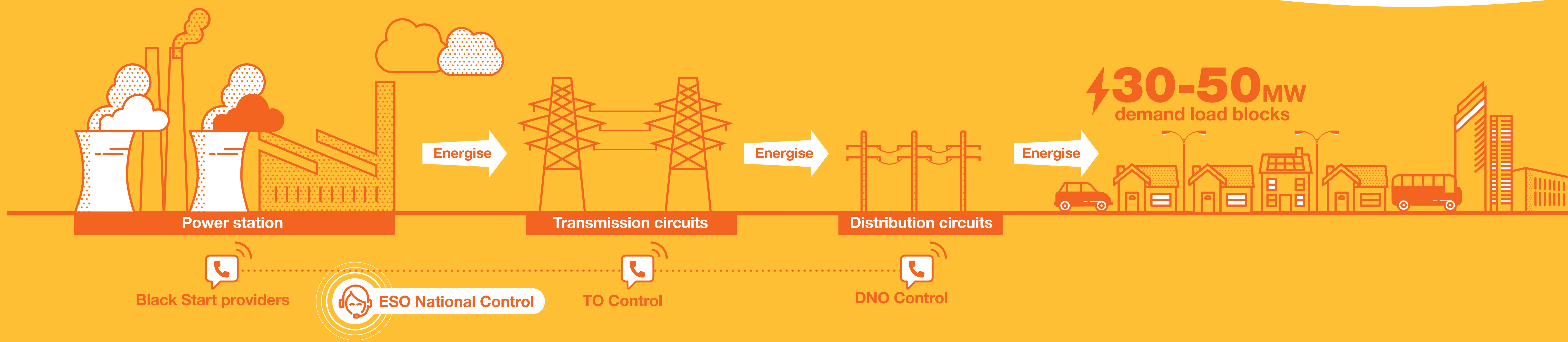


Based on your understanding of your sector, do you think that the commercial/ regulatory framework is ready for the proposed approach?

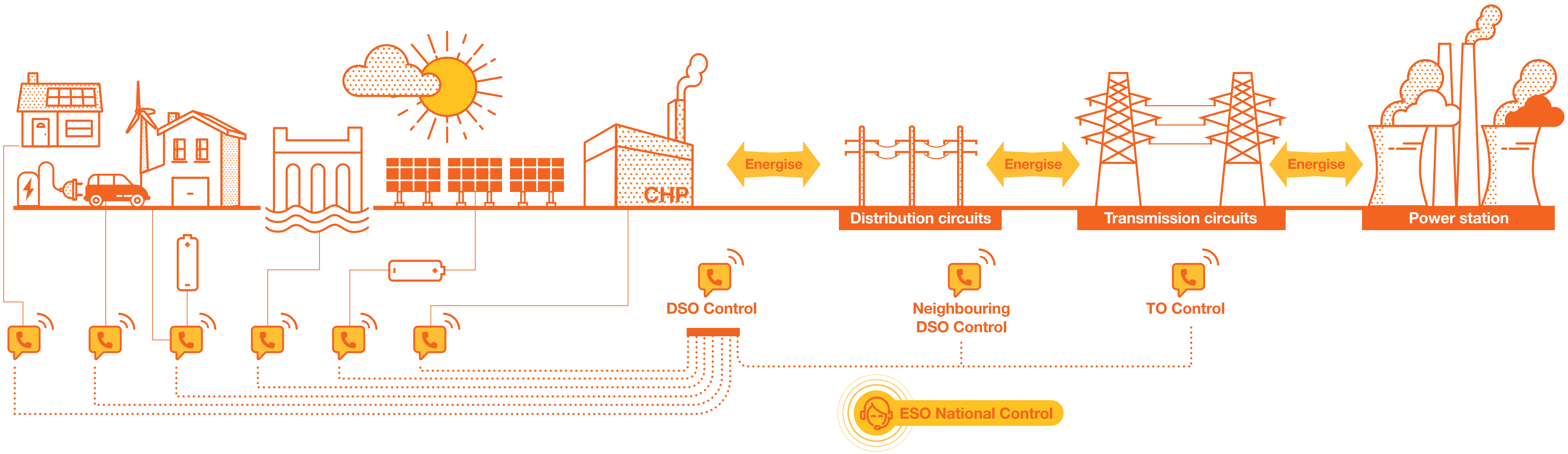




What Black Start looks like today



What the future DER Restoration could look like



Key points of innovation

Organisational & Systems
Define the new roles and responsibilities across DER, the DNO/DSO and ESO to achieve efficient coordination and control of system energisation.

Organisational & Systems
Produce specifications for new tools and systems to achieve a timely restoration, considering multiple interactions across diverse equipment and organisations.

Technical
Confirm the practical contribution and interaction of a range of different DER technologies in performing a decentralised restart.

Technical
Determine the need for, and cost of, changes to distribution network assets, control and protection to enable a decentralised restart.

Procurement & Regulatory
Determine the full costs of implementing the method, across all parties, and determine the most appropriate ways for that to be funded.

Procurement & Regulatory
Design market mechanisms that can attribute appropriate value to a 'full service' delivered in component parts by multiple DER and the DNO/DSO while enabling competition.