Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Dec 2025

Project Reference Number

NIA2_NESO124

Project Registration

Project Title

Battery Reserve for Restoration

Project Reference Number

NIA2_NESO124

Project Licensee(s)

National Energy System Operator

Project Start

December 2025

Project Duration

0 years and 7 months

Nominated Project Contact(s)

Innovation@neso.energy

Project Budget

£250,000.00

Summary

The project investigates how distributed Battery Energy Storage Systems (BESS) , including Vehicle-to-Grid technologies, can support top-bottom restoration following a National Power Outage (NPO). The objective is to identify the technical and commercial potential of BESS assets at distribution level.
Key activities include stakeholder engagement, market analysis, and development of a simplified modelling framework, supported by a small case study.
Expected outcomes include indicative battery availability under uncertainty and strategic insights.

Third Party Collaborators

Arup

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

The GB electricity grid is undergoing a fundamental shift with rapid integration of renewable energy and distributed generation, challenging traditional restoration strategies that rely on large centralised generators and interconnectors, which may no longer be sufficient or cost-effective in future scenarios.In the coming years, the GB grid is expected to host over 200GWh of battery capacity,

whether from stationary storage or electric vehicles, creating a significant opportunity to leverage these assets for system restoration. Battery Energy Storage Systems (BESS), including Vehicle-to-Grid (V2G) technologies, offer fast response and grid-forming capabilities, but their role in restoration is not yet fully understood or integrated.
There is a critical gap in understanding how BESS assets, particularly at the distribution level, can contribute to system restoration following a National Power Outage (NPO), and current market structures and Grid Code provisions do not currently support their deployment for emergency restoration.

Method(s)

The project will be delivered across 4 work packages with work packages 1, 2 and 3 feeding into work package 4.

Work Package 1 will involve a comprehensive technical review to determine the feasibility and requirements for integrating Battery Energy Storage Systems and Vehicle-to-Grid technologies into grid restoration processes across all stages. This will include assessing the technical capabilities of these technologies through desk-based research, reviewing existing literature, manufacturer specifications, and operational case studies to evaluate their performance during black start, block loading, and system re-synchronisation. The review will also quantify the potential market size by analysing existing connection registers and queue data, applying statistical methods to estimate available capacity and future growth trends. A comparative analysis of grid-forming and grid-following inverter roles will be undertaken to assess stability margins, fault ride-through capability, and restoration speed under different configurations. Minimum BESS requirements for block loading, such as a 50 MW example, will be calculated using analytical methods to validate assumptions. In addition, the work will identify technical constraints, such as inverter control limitations and grid code compliance, and propose enabling solutions including advanced control strategies and hybrid configurations.

Work Package 2 will focus on evaluating the operational and market readiness of Battery Energy Storage Systems and Vehicle-to-Grid technologies for participation in grid restoration. This will include analysing economic incentives and disincentives that influence BESS engagement in restoration services. The work will also examine NESO service mechanisms alongside competing commercial arrangements to identify potential conflicts or synergies that could impact adoption. Regulatory constraints affecting storage deployment will be assessed by reviewing relevant grid codes, licensing requirements, and compliance obligations to determine barriers and opportunities for integration. This will be done through a combination of stakeholder engagements and market research.

Work Package 3 will focus on developing statistical models and applying them to a practical case study to assess the role of Battery Energy Storage Systems and Vehicle-to-Grid assets in grid restoration. This will include creating demand profiles at DNO level and selecting representative national power outage scenarios for analysis. State-of-charge behaviour (SOC) for BESS and V2G assets will be modelled under uncertainty using probabilistic techniques to capture variability in asset availability and performance. A statistical model will be developed to predict SOC trends and variability, complemented by a restoration model to enable scenario testing and visualisation of results. The methodology will be applied to a DNO Network case study to validate assumptions and demonstrate practical applicability.

Work Package 4 will consolidate the technical, operational, and regulatory findings from previous work packages into a strategic blueprint that provides clear, actionable guidance for enabling distributed storage participation in grid restoration. This will include developing a policy and regulatory roadmap that identifies key changes required to support the integration of Battery Energy Storage Systems and Vehicle-to-Grid technologies, addressing compliance, licensing, and grid code considerations. In addition, the work will recommend potential adaptations to existing market mechanisms to prioritise restoration value, ensuring that commercial arrangements incentivise flexibility and resilience.

In line with the ENA's ENIP document, the risk rating is scored 4.
TRL Steps = 1 (2 TRL Steps)
Cost = 1 (<£1m)
Suppliers = 1 (1 supplier)
Data Assumptions = 2
Total = 4 (Low)

Scope

The project is intended as a wide-ranging study to evaluate the role of Battery Systems in power system restoration and resilience, and it is structured as an innovation project where outcomes are uncertain and exploratory in nature.

Repurposing Existing and Planned BESS Assets in the DNO level.
The project will evaluate how existing and planned Battery assets originally deployed for non-restoration applications (eg peak shaving, frequency response, commercial arbitrage), can be repurposed or dual-purposed to support emergency restoration

scenarios. It will seek to identify the technical constraints and retrofit requirements (if any) to enable these assets to participate in restoration services. The project will also consider the implications of asset ownership, contractual obligations, and operational priorities on their availability during NPO events.

Grid Stability During Block Loading Events
Assuming the demand fluctuation vary across different times of day following an NPO, the project will assess how BESS can be optimally deployed to manage these temporal dynamics. Assess how BESS deployment influences the sequencing and stability of block loading at the DNO level.
The project will also seek to determine the minimum number, size, and distribution of BESS units required to deliver a measurable impact during block loading. For example, estimate the number and size of batteries required to support a 50 MW block load. Identify and evaluate other potential roles for BESS in supporting the grid at the DNO level post-NPO.

Inverter Capabilities and Grid-Forming Requirements
The technical and operational benefits of grid-forming inverters for a grid following an NPO to improve system resilience and restoration times will be investigated. Whether grid-forming capability is universally required across all BESS assets or only in specific locations or phases of restoration.

Aggregation and Control of Distributed Assets
The project will aim to develop an understanding of current aggregation methods and how they change under NPO conditions, including current grid code (eg. how can multiple assets that in total are over 50MW combined be managed assuming the MW limits on DNO levels, how G99 battery discharge provisions can be used). Evaluate the feasibility of real-time or near-real-time coordination under degraded grid conditions. Identify control strategies that can operate autonomously or semi-autonomously in the absence of centralised dispatch signals.

Market and Communication System Challenges
Discussions will be kicked off and a stakeholder list compiled to includeDNOs, potential V2G hubs such as bus depots, airports and train stations, and other relevant infrastructure operators to explore the potential for using batteries during a national power outage for restoration and assess whether this is a service that markets can support. Limitations in current market structures that may prevent BESS assets from participating in emergency restoration services will be identified. There will also be an assessment of the minimum communication and control requirements for BESS operability during an NPOand anexploration of contractual or regulatory mechanisms to ensure asset availability during rare but critical events.

Integration of Large EV Charging Hubs and Residential V2G
The project will assess the technical and operational feasibility of integrating large-scale EV fleet hubs (eg bus depots, logistics centres, airports) into restoration strategies. It will model the impact of residential EV charging behaviour on local demand profiles during outages. The project also aims to evaluate the potential contribution of residential V2G systems to localized restoration and resilience, including their responsiveness and SoC variability.

Statistical Modelling of Availability Under Uncertainty
By developing a model to estimate the availability of decentralised BESS and V2G assets during blackout events, accounting for unknown or partially known State of Charge
and the variability in usage patterns (eg. Bus operation times) the project aims to quantify the minimum volume of battery assets required to deliver statistically reliable restoration capacity under different scenarios

Case Study Validation
The project will Include at least one geographically and operationally relevant case study (eg a DNO region or urban area) to validate the framework.

Objective(s)

The objectives of this project are to:

- Quantify technical capability of decentralised BESS and V2G assets to support system restoration stages (grid-forming, grid-following, block loading) through a validated technical assessment.
- Evaluate operational and market readiness by identifying key regulatory and commercial barriers and enablers via stakeholder engagement and market analysis.
- Develop a probabilistic modelling framework to estimate asset availability under uncertainty, including state-of-charge and demand scenarios, and deliver an Excel-based restoration model with Power BI dashboard.
- Apply modelling outputs to DNO Networks case study to validate assumptions and provide geographically relevant insights.
- Produce a strategic blueprint synthesising technical, operational, and market findings into actionable recommendations for NESO,

including a policy and regulatory roadmap.
- Deliver new learning on technical and market readiness for distributed storage participation, ensuring knowledge dissemination through industry knowledge-sharing platforms (eg the Smarter Networks Portal).

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The proposed project will not impact consumers in vulnerable situations, except to the extent that (if the project & follow-ups are successful) they will also benefit from the faster and more efficient restoration.

Success Criteria

The project can be deemed successful if the following are achieved:
- Delivery of clear recommendations with defined next steps.
- A practical implementation plan, including proposed grid code updates and policy changes.
- Identification of potential follow-on projects to maintain progress.

Project Partners and External Funding

Partner: Arup

No external funding.

Potential for New Learning

- Quantified assessment of decentralised BESS and V2G technologies showing their capability to support different stages of restoration, including grid-forming and grid-following modes, block loading, and post-restoration services.
- Comprehensive report on operational and market readiness identifying regulatory and commercial barriers and enablers, with stakeholder insights on asset owner appetite and recommendations for adapting market mechanisms.
- High-level probabilistic modelling framework estimating asset availability under uncertainty, including state-of-charge modelling for batteries and EV fleets, demand scenario analysis, and an Excel-based restoration model with Power BI dashboard outputs, validated through a DNO case study.
- Strategic blueprint for NESO synthesising technical, operational, and market findings into actionable recommendations, including a policy and regulatory roadmap, guidance on adapting market mechanisms, and an assessment of the potential scale of opportunity for restoration services.

Any solution developed during the project will be made available free of charge as open source, provided it does not contain confidential material, and will be hosted on the NESO website.

Scale of Project

The project spans over 6 months with one project partner

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

Applicable across GB.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£250,000

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

The project has the potential to facilitate the energy system transition by reducing and potentially replacing fossil-fuel-based restoration services with battery-led solutions. By unlocking latent flexibility in existing and planned storage assets, the project enables dual use for resilience without adding carbon-intensive infrastructure

How the Project has potential to benefit consumer in vulnerable situations:

The project does not directly target consumers in vulnerable situations. However, if the project and subsequent initiatives are successful, these consumers will benefit indirectly through:
Faster restoration of electricity supply
Improved system resilience
Enhanced reliability of restoration processes

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

N/A

Please provide a calculation of the expected benefits the Solution

Not applicable as it is a research project.

Please provide an estimate of how replicable the Method is across GB

The method developed in this project is designed to be fully replicable across Great Britain, as it does not include any regional components that would limit its applicability

Please provide an outline of the costs of rolling out the Method across GB.

Any solution developed during the project will be made available free of charge and as open source, provided it does not contain confidential material

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems

and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☑ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☑ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

The learning generated by this project will provide network licensees with actionable insights into how distributed battery assets and V2G systems can support system restoration . This includes technical requirements for inverter capabilities, aggregation strategies, and operational coordination, as well as market and regulatory considerations for enabling participation. These findings can inform future restoration service tenders, guide updates to technical specifications, and shape policy changes to integrate decentralised flexibility into resilience planning. By sharing models, case study results, and strategic recommendations, the project ensures that network licensees can apply this knowledge to improve restoration strategies and reduce reliance on fossil-fuel-based solutions.

The learning from the Project will be disseminated through multiple accessible and inclusive channels to ensure broad reach and impact. All outcomes will be made available as open source, enabling unrestricted access and reuse. Key dissemination methods will include:

- **NESO Website**: A dedicated section will host all relevant documentation, tools, and learning materials.
- **Open Access**: All outputs will be free to access, with no licensing or usage restrictions, provided no confidential material is involved.
- **Engagement Activities**: Where appropriate, webinars, workshops, or briefings may be used to share insights and gather feedback from Network Licensees and other stakeholders.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

N/A

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

Based on our best of knowledge, this idea has not been explored in other NIA projects

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

N/A

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

This project is the first of its kind in Great Britain to explore how Battery Energy Storage Systems can support top to bottom restoration activities like block loading during system restoration, moving beyond traditional reserve-based strategies to unlock cheaper and more flexible battery capacity.
It investigates the restoration potential of Vehicle-to-Grid technologies in industrial and domestic settings such as airports, bus depots, and EV fleets while addressing critical technical challenges like communication during outages, asset visibility, and coordination complexity.
By leveraging batteries originally designed for other purposes, the project expands provider options and helps reduce costs, while tackling market barriers to improve accessibility and participation. Building on prior work without duplication, it pushes the boundaries of technical, commercial, and operational understanding and capitalizes on the expected growth of gigawatt-hours of battery capacity in GB to enhance resilience.

Relevant Foreground IPR

Comprehensive report on all aspects of the project, including examples, thorough documentation, and recommendations for further work

Python model and dashboard covering the statistical modelling of batteries under uncertainty

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

1. A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click 'Contact Lead Network'. National Energy System Operator already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
2. Via our Innovation website at https://www.neso.energy/about/innovation
3. Via our managed mailbox innovation@nationalenergyso.com

Details on the terms on which such data will be made available by National Energy System Operator can be found on our website: Data Sharing Approach | National Energy System Operator.

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

The project explores the application of batteries and V2G in innovative ways that have not yet been demonstrated within the context of electricity system Restoration. These activities involve a high degree of uncertainty and operational risk, which places them outside the scope of business as usual

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

The TRL of the overall project is low. Therefore, innovation funding is more suitable for exploring the project's potential and increasing the TRL before transferring into BAU activities. The use of NIA will also ensure that project outcomes and learnings can be shared with the industry.

This project has been approved by a senior member of staff

☑ Yes