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. Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

# NIA Project Close Down Report Document

### Date of Submission

Jul 2025

### Project Reference Number

NIA2_NGESO076

## Project Progress

### Project Title

Battery Storage Modelling for Enhanced Connection Assessments (BaTSeC)

### Project Reference Number

NIA2_NGESO076

### Project Start Date

May 2024

### Project Duration

0 years and 9 months

### Nominated Project Contact(s)

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### Scope

This is a significant departure from existing network design practices for utility scale BESS in GB. Individual components of this project have been tested but not combined at a whole system level before as the commercial incentives are to develop models for individual batteries. The analysis of historic market data in order to take a probabilistic approach to coincidence thereby being able to generate "reasonable worst case" scenarios for connection assessments is a novel approach to connections. This will provide an invaluable model to ESO as BESS connection applications increase and should reduce the connection timescales and costs. The modular approach to the model will allow each of the components to be adjusted in the future, for example, updating the market module given future market conditions.

### Objectives

The project aims to deliver a model that can achieve the following objectives:

- Analyse historic market data to be able to quantify the likelihood of market scenarios.
- Be able to generate synthetic pricing signals to produce a “reasonable worst case” scenario for use within the model.
- Be able to adjust battery parameters and behaviours to get representative operating profiles.
- Use a probability distribution to account for variations in response to market behaviours.
- Generate power flows from the market and battery information.
- Integrate the generated power flows into the ESO dispatch model.

### Success Criteria

Develop a model which generates battery half hourly timeseries based upon battery and market parameter selection. These timeseries will be suitable for use in the ESO's dispatch model.

## Performance Compared to the Original Project Aims, Objectives and Success Criteria



The project addressed several key issues related to traditional network analysis and battery behaviour:
Traditional Network Analysis Assumptions: By developing a probabilistic modeling approach, the project provided a more nuanced understanding of battery behaviour, allowing for more accurate and less conservative assessments. The project analysed historic market data to quantify the frequency with which Battery Energy Storage System (BESS) units participate in different markets, and to quantify their reserved capacities for each market i.e., market participation stack, and their dispatch profiles.
Opaque Battery Behaviour: The project investigated the complex behaviour of batteries, which stack services like arbitrage and frequency response. By analysing these behaviours and their impact on network areas, the project improved the understanding of battery operation, which is expected to lead to optimised connection design processes and better policy formulation. BATSEC uses historic market activity data to model how Battery Energy Storage System (BESS) operate in the Frequency Response (FR), Balancing Mechanism (BM) and Wholesale Markets and is run using the Python-based Jupyter Notebook in Azure Machine Learning Studio generating the respective profile to be used in POUYA (POwer Uncertainty Year-round Analyser) for the Construction Planning Assumptions (CPA) process.
Optimising Connection Design and Policy: The improved understanding of battery operation is expected to facilitate the optimisation of the connection design process and the development of appropriate policies. This, in turn, is expected to release network capacity and reduce connection timescales and network reinforcement costs. It is implemented as a markets-informed power dispatch model, i.e., a model that reflects a BESS unit's market participation over time and calculates a power dispatch profile per BESS unit.
Performance Relative to Aims, Objectives, and Success Criteria
Reduction of Conservative Assumptions: The project successfully reduced the conservative assumptions used in connections assessments by quantifying the necessary level of conservatism through probabilistic modeling. This approach will allow for a more accurate assessment of network capacity and mitigate the commercial and technical impacts of under-estimating network capacity.
Unlocking Network Capacity: By providing a more accurate understanding of battery behaviour, the project is expected to unlock upstream network capacity, enabling more efficient use of existing infrastructure and reducing the need for costly network reinforcements.
Reduction of Connection Timescales and Costs: The project's probabilistic modeling approach and improved understanding of battery behaviour will lead to a reduction in connection timescales and network reinforcement costs, making the connection process more efficient and cost-effective.
Integration to Existing Systems: The model is being successfully integrating into the existing systems with minimal changes ensuring compatibility and seamless data flow providing flexibility for comparison of different scenarios, enhancing the accuracy in the economic dispatch.
Modular Model for Future Revisions: The project developed a modular model that can be revised to account for inevitable commercial, technical, and policy changes over the multi-decade lifetimes of connected assets. This ensures the model remains relevant and adaptable to future developments.
The project successfully developed a model that generates battery hourly timeseries based on market parameter selection and matching generation profiles that align with market scenarios. It takes into consideration the historical markets participation of batteries and provides flexibility to align with future markets as well. The model is being integrated into the existing Economic Dispatch tool used for Construction Planning Assumptions increasing the accuracy of the existing model. This model provides valuable insights into battery behavior which will enable more informed decision-making for Transmission Owners. By incorporating market-driven

dispatch profiles BATSEC enhances the accuracy of network capacity assessments, which is expected to reduce proposed connection dates and the extent of required network reinforcements.

## Required Modifications to the Planned Approach During the Course of the Project

During the course of the project, several modifications were required to address unforeseen challenges and ensure the successful completion of the planned scope.

A key focus within WP1 was an Exploratory Data Analysis (EDA) to understand battery behaviour on the grid. The primary driver for the increased scope of this work package was the lack of access to data that was initially expected to be available early in WP1. The original plan was to analyse the following data which it became apparent was unavailable:

- Historic market price data (BM/DFR/SCL)
- Battery output profiles (HH)
- Generator output profiles (HH)
- Historic frequency data
- Other inputs to dispatch model

Historical data was sparse or incomplete, especially for newer Battery Energy Storage Systems (BESS). The quality of available data was inconsistent, with gaps in state of charge, metered volumes and market participation records. There was a lack of correlated datasets that could clearly link battery behaviour to market signals such as Frequency Response (FR), Balancing Mechanism (BM), and Wholesale pricing.

To address the unavailability of this data and maintain alignment with NESO's timescale requirements, the project relied more substantially on open-source data than originally planned. The additional activities undertaken over three months included:

- Investigating the best open access data sources, considering differences between 2023 and 2024 data.
- Collating the data.
- Scrubbing the data of non-physical entries.
- Conducting additional analysis to determine the best readings to use when different options were available.
- Processing data across different time periods to ensure alignment with settlement periods.
- Calculating energy dispatched to quantify the state of charge.
- Performing additional verification and approval activities associated with each of the above tasks, in accordance with quality assurance accreditations.

Once these tasks were completed, the project was able to deliver the originally planned scope for the EDA.
These modifications ensured that the project remained on track and successfully achieved its aims, objectives, and success criteria despite the challenges encountered.

## Lessons Learnt for Future Projects

Data Availability & Quality: One of the key challenges faced during the project was the unavailability of expected data. This highlighted the importance of securing reliable data sources and having contingency plans in place. Relying on open-source data required significant additional time for acquisition and processing, emphasising the need for thorough data validation and quality assurance processes.

Integration Approaches: The integration of the model with existing systems required careful planning and testing. Ensuring compatibility and seamless data flow between systems was essential for successful integration.
Addressing security and compliance requirements early in the integration process helped prevent delays and facilitated smoother collaboration.

Stakeholder Engagement: Effective communication and collaboration with stakeholders were key to the project's success. Regular updates and workshops helped in presenting findings and capturing design requirements collaborating with different teams involving

Markets, SCADA, Battery working groups, Analytical Tool Development and Network Development. Establishing clear data sharing agreements and confidentiality protocols ensured that data was handled appropriately and securely.

Modular and Phased Development: The modular design of the project allowed for future adjustments to individual components, making the model adaptable to evolving market conditions. Dividing the project into multiple phases, including exploratory data analysis, model development, and system integration, helped in managing the project effectively and meeting milestones.

Flexibility and Adaptability: The project demonstrated flexibility by adapting its model design approach in response to early insights from data analysis. This included developing alternative model configurations that aligned with the available data and reflected historical market participation patterns. To support seamless integration, multiple implementation options were explored from the outset, ensuring adaptability to different system environments and user needs.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

## The Outcomes of the Project

Development of a Market-Informed Battery Dispatch Model: The BATSEC project successfully delivered a new battery dispatch model tailored for direct and easy integration into NESO's Construction Planning Assumptions (CPA) process. This model simulates how Battery Energy Storage Systems (BESS) behave in the Frequency Response (FR), Balancing Mechanism (BM) and Wholesale markets, using historical market data to generate realistic dispatch profiles.

Accurate Power Flow Modelling: The project has successfully developed a model that generates timeseries power flow data for either a single battery or multiple batteries connected to a given network node. This model provides valuable insights into battery behaviour and its impact on network capacity, supporting more informed decision-making and planning.

Reduced Connection Timescales and Investments: Provided detailed guidance on the implementation of the model into connection assessments which is expected to reduce the connection timescales and network reinforcements. This will eventually support faster and more cost-effective connection offers, especially under high volumes of BESS applications. As the Exploratory Data Analysis results have identified Battery activity within the Wholesale, Frequency Response and Balancing Mechanism markets, the reduced capacity will be utilized in the POUYA arbitrage for the despatch as per the historical distributions.

Improved Battery Energy Storage System (BESS) Behavior Understanding: The project enhanced understanding of Battery Energy Storage System (BESS) operation from both the system operator and network operators' perspectives. This will lead to better policy decisions and more efficient network management.

Data Strategy and Challenges: The project initially faced delays due to limited access to high-quality BESS datasets. To mitigate this, the team developed a custom dataset using open-source data from Elexon and verification from NESO portals. Also, the quality of the data from the BESS developers have been enhanced after identification of quality issues.

Modular Architecture and Easy Integration: The model has been designed with a modular structure that allows for future updates and integration of new market services or battery technologies without overhauling the entire system.
Further, the model has been designed to interface with the existing *POUYA model, NESO's economic dispatch tool for ease of integration and reduced complexity.

*POUYA – POwer Uncertainty Year-round Analyser is NESO's internal economic despatch tool to evaluate the impact of generation on the NETS – through a detailed year round probabilistic modelling and statistical analysis of network flows.

## Data Access

Details on how network or consumption data arising in the course of NIA funded projects can be requested by interested parties, and the terms on which such data will be made available by NESO can be found in our publicly available "Data sharing policy related to NIA projects (and formerly NIC)" and Innovation | National Energy System Operator.

National Energy System Operator already publishes much of the data arising from our NIA projects at www.smarternetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

## Foreground IPR

The following Foreground IPR have been generated through the BATSEC project:

- Alpha Model: A preliminary version of the BATSEC model with full documentation, used for integration testing with NESO's POUYA model.
- Beta Model: A refined model based on Jupyter Notebook, incorporating Frequency Response, Balancing Mechanism, and Arbitrage functionalities, delivered in two phases.
- Technical Notes: Supporting documents detailing exploratory data analysis, model architecture, and battery behaviour characterisation.
- Final Report: A comprehensive summary of the project's methodology, findings, and recommendations for future development opportunities.

## Planned Implementation

BAU Model Integration: The deliverables of the project, specifically the modules of the BatSec tool, will be integrated into the existing CPA process to enhance the ability to model Battery Energy Storage Systems (BESS) participating in Frequency Response (FR) and Balancing Mechanism (BM) markets. The POUYA team has already begun working on the integration of the BatSec modules into the POUYA tool which should be completed by Q4 2025.

Modules of BatSec
Markets Module: This module generates individual BESS FR and BM market participation time series based on historic FR and BM market participation data and future procurement predictions. It provides valuable insights into market dynamics and helps forecast BESS participation in these markets.
BESS Module: This module performs state of charge management, degradation analysis, and round-trip efficiency calculations. It ensures accurate modelling of BESS performance and longevity, providing essential data for optimizing battery operations.
Dispatch Module: This module performs the integration to the existing Economic dispatch model and BM dispatch given boundary flow time series data and outputs updated BESS dispatch and boundary flow profiles based on FR and BM dispatch. It enables efficient management of BESS dispatch operations, ensuring optimal utilization of battery resources.

Enhance Model Flexibility and Scenario Analysis: Expand the model's ability to simulate a wider range of market behaviours and battery configurations. Incorporate additional scenario analysis capabilities to support strategic planning and policy evaluation.

Improve Data Pipelines and Market Representation
Refine the data pipeline to better align dispatch data across markets (e.g. FR, BM, wholesale) and settlement periods.
Continue improving the statistical distributions used for market participation modelling. Consider extending the model to include additional services or market mechanisms as they evolve.

## Net Benefit Statement

BatSec has significantly advanced the understanding and optimisation of battery behaviour and network analysis, delivering both financial and non-financial benefits across the organisation.

Non-Financial Achievements:

Digitalisation & Automation: The project enabled increased digitalisation and automation of probabilistic economic dispatch processes. This will eventually lead to measurable energy savings (in MWh) and a reduction in greenhouse gas emissions (tCO▮e).

Operational Efficiency: Streamlined workflows and numerous process improvements enhanced overall operational efficiency.

Workforce Development: The initiative supported employee upskilling, resulting in improved network workforce capability, higher average productivity, and increased employee satisfaction.

Data Quality: BATSEC highlighted critical data issues and drove improvements in data quality, strengthening the foundation for future modelling and analysis.

Financial Benefits:

Improved Connections: By incorporating market participation behaviours into dispatch modelling, BATSEC improved the accuracy of BESS impact forecasting. This will help in reducing the risk of misjudging system constraints, enabling more efficient and reliable connection assessments.

Operational Savings: Digitalisation efforts led to the avoidance of operational costs by embedding accurate battery behaviour into the existing processes.

Network Investment Optimisation: The project is expected to contribute to the streamlining of required network reinforcements, resulting in avoiding infrastructure costs.

Labour Efficiency: Enhanced workforce capability translated into avoided labour and operational costs, reinforcing the project’s value across economic and operational dimensions.

## Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this Report due to their proprietary nature. Should the viewer of this Report (“Viewer”) require further details this may be provided on a case by case basis following consultation of all Publishers. In the event such further information is provided each and any Publisher that owns such confidential information or intellectual property rights shall be entitled to request the Viewer enter into terms that govern the sharing of such confidential information and/ or intellectual property rights including where appropriate formal licence terms or confidentiality provisions. Dependent upon the nature of such request the Publishers may be entitled to request a fee from the Viewer in respect of such confidential information or intellectual property rights

## Standards Documents

N/A