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 2024

Project Reference Number

NIA2_NESO093

Project Registration

Project Title

Extreme Weather and Climate Modelling (Dunkelflaute)

Project Reference Number

NIA2_NESO093

Project Licensee(s)

National Energy System Operator

Project Start

July 2024

Project Duration

1 year and 6 months

Nominated Project Contact(s)

innovation@nationalenergyso.com

Project Budget

£50,000.00

Summary

With wind and solar power increasingly vital to the GB energy system, understanding extreme weather events that could drastically affect power production and consumption is crucial. Dunkelflaute events, which cause simultaneous low wind and solar power production, are raising significant concerns among stakeholders.

This project aims to address knowledge gaps regarding the likelihood and impact of Dunkelflaute events and cold spells, both separately and together, especially during peak electricity demand. By improving our models and assumptions, the project will enhance the accuracy of our Future Energy Scenarios, ensuring we are better prepared to manage Dunkelflaute periods effectively.

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

It is widely acknowledged that transitioning to a renewable-dominated electricity system introduces new challenges for ensuring security of supply. One of the most pressing challenges is the lack of a well-understood optimal mix of flexible solutions to support this transition.

Key gaps in knowledge include:

- Limited understanding of Dunkelflaute conditions (periods of low wind and solar power).
- Uncertainty about how frequently these events occur, their duration, and their likelihood of coinciding with high-demand cold weather

conditions.
- Insufficient analysis on the geographic extent of these events and the implication for flexibility needs.

What is flexibility and why do we need it?
Flexible solutions include technologies such as interconnection, storage, and demand side response. Some technologies that are currently seen more as baseload (e.g. dispatchable thermal generation) will increasing be relied on as a low annual usage but highly flexible asset to help fill in renewable output gaps. There is also future potential for Hydrogen to form part of a flexible system via its generation (e.g. electrolysis), storage and subsequent use (e.g. hydrogen fuelled power stations).

Considering just energy balancing (i.e. to limit the scope by excluding operability factors such as inertia, and network constraint management), flexibility is required to:

Avoid loss of load when it is not windy and/or sunny
Avoid curtailment and its associated cost (e.g. having to pay generators in receipt of CfDs off the system, price cannibalisation at lower levels of installed capacity)

How does weather affect the need for flexibility?
Traditionally our system has relied on the flexibility of thermal power stations to turn up or turn down to meet the energy demand. However, as we transition to a renewable led system, the level of supply will predominantly be dependent on the weather conditions. New forms of flexibility are required to adjust demand to the available supply, and to manage prolonged periods of low wind and low solar periods (herein referred to as “Dunkelflaute” conditions, literally translating as “dark doldrums” or “dark wind lull”).

To determine an optimal mix of flexibility, we must first understand these “Dunkelflaute” conditions in more detail: how frequently do they occur and for how long, what is the probability that they coincide with cold weather when demand is likely to be high, and how geographically widespread are they?

These and similar questions are not well understood and therefore require further statistical analysis. This will enable us to better use our analysis to highlight where different types of flexibility or storage durations are needed and where policy or market changes would be required.

Method(s)

This project will follow a staged approach, based around an initial exploration stage followed by a more in-depth analysis stage. This will provide the opportunity to build upon the early stages of the analysis by, e.g. including the future impact of climate change and the breadth of potential hydrogen interactions, and then focus more in-depth analysis on a sub-set of the impacts which are most pertinent to NESO in developing the future energy scenarios and supporting the modelling work going forward.

Work Package 1: Literature Review
A review and summary report on existing literature on Dunkelflaute events, wind droughts, and extreme cold spells.

Work Package 2: Identification of Relevant Datasets
The project team will identify various observational and modelled datasets which will be suitable for statistical analysis. Their inventory will include both historical as well as future projection datasets.

Work Package 3: Retrospective Analysis: UK
During this work package, the project team will quantify the following statistics based on historical datasets:
• probability of Dunkelflaute events and wind droughts in winter months (in terms of amplitude and duration);
• probability of extreme cold spells (in terms of amplitude and duration);
• probability of Dunkelflaute events and wind droughts coinciding with peak electricity demand;
• probability of Dunkelflaute events and wind droughts coinciding with extreme cold spells;
All these probabilities will be dependent on temporal scales and will be tabulated as such. For example, it is expected that the probability of Dunkelflaute events longer than 72 h will be lower than events ranging from 24 h – 48 h in duration. It is also likely that 1-in-20-year coldest day and 1-in-20-year longest cold spells occur in different years.

All the analyses will be conducted for the entire UK (as national averages) as well as separately for different grid regions of UK (e.g., SP Energy Networks, Northern Power Grid). Gridded meteorological (observational and reanalysis) data in conjunction with measured electricity consumption data will be analysed. Various approaches (e.g., peak over threshold method) from extreme value theory will be

used in the analysis. For most of these quantifications, the project team will propose specific “thresholds” for coldest, calmest, dimmest conditions based on robust statistical criteria.

Work Package 4: Future Projections: UK
Similar to work package 3, the project team will quantify the following statistics based on climate projection datasets:
• probability of Dunkelflaute events and wind droughts in winter months;
• probability of extreme cold spells;
• probability of Dunkelflaute events and wind droughts coinciding with extreme low temperature;

Since projected electricity demand data will not be available to the project team, the analysis will be limited to meteorological variables.

Work Package 5: Retrospective Analysis and Future Projections: Western Europe
During this work package, the TU-D team will extend analysis to Western Europe.

In line with the Electricity Network Association (ENA’s) ENIP document, the risk rating is scored Low
TRL Steps = 2 (3 TRL steps)
Cost = 1 (<£500k)
Suppliers = 1 (1 supplier)
Data Assumptions = 2
Total = 6 (Low)

Scope

This project will analyse Dunkelflaute events, wind droughts, and extreme cold spells to address critical knowledge gaps and improve NESO’s future energy scenarios. It includes:
•Reviewing existing literature to summarise current knowledge.
•Identifying and compiling relevant datasets.
•Conducting statistical analyses on historical and future weather data for the UK and Western Europe.
•Providing insights and recommendations to inform scenario development and prioritise further analysis.

The project will deliver reports on findings, datasets, and recommendations, enhancing system resilience and stakeholder understanding of weather-related risks.

Objective(s)

The final outputs will include:

- a report on existing literature on Dunkelflaute events, wind droughts, and extreme cold spells.
- a comprehensive table of available datasets for characterisation of Dunkelflaute events, wind droughts, and extreme cold spells.
- a report of statistical analysis including tables of summary statistics. Some of these tables will be devoted to joint statistics of calm and cold, dim and cold, etc.
- a report of statistical analysis including tables of summary statistics when consideration of future weather projections are taken in to account.
- a report of statistical analysis including tables of summary statistics where the analysis is expanded to Western Europe
- Insight and feedback for the Future Energy Scenarios team to inform FES development
- Final summary report outlining the findings from each work package and the associated datasets, with recommendations on priority areas for any further analysis

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

NESO does not have a direct connection to consumers, and therefore is unable to differentiate the impact on consumers and those in vulnerable situations.

Success Criteria

The following will be considered when assessing whether the project is successful:

- Findings from the project can be used to explain weather related risks to our stakeholders
- The project delivers against objectives, timescale and budgets as defined in the proposal
- A greater understanding of what an optimal mix of flexibility might look like such that anergy balancing can happen during challenging

weather patterns

- Evidence provided can support an industry discussion about risk appetite – e.g. should we build flexibility to cover the most extreme cases?

Project Partners and External Funding

The Met Office will be carrying out the work, no external funding required.

Potential for New Learning

This project will help NESO understand the answers to some fundamental questions:

- probability of Dunkelflaute events and wind droughts in winter months;
- probability of extreme cold spells;
- probability of Dunkelflaute events and wind droughts coinciding with extreme low temperature;
- how these results might change as the climate changes;
- how a wider European study affects the results.

Scale of Project

The project spans 18 months with 1 project partner. The project consists of desk-based research and workshops with the relevant NESO and wider network teams.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The project will be based upon GB NESO area of operations.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£50,000

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:

With a target of 50 GW offshore wind by 2030, the transition to renewables in expected to be rapid. Our power system is set to be net zero by 2035. This renewable led system will require new flexibility in order to adapt to the level of supply available. As this supply is set by the weather conditions it is essential that we have a solid understanding of weather patterns, their probability, and the likelihood that two concerning weather conditions (low wind and cold temperatures) coincide. This project seeks to use statistical analysis of historic weather data to determine these probabilities and to therefore feed into the thinking about what an optimal mix of flexibility looks like.

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

n/a

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

N/A

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

The method will be run for GB. The outputs, report and process could be replicated for other regions subject to suitably available data. Furthermore:

- Dissemination events will be held upon completion of the project to share the outcomes and gain feedback from wider GB stakeholders
- Based on the feedback and the outcomes of the reports we hope to then develop further projects with to address potential next steps (e.g. modelling enhancements within the Future Energy Scenarios/FES, discussion with the industry on risk appetite for extreme weather events)

The project will also help shape our assumptions on the optimal mix of flexibility included within the FES which in turn will improve the modelling for the Network Options Assessment which is our recommendation for which reinforcement projects should receive investment during the coming year.

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

This project will provide an assessment for the whole of GB.

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 need to cost effectively decarbonise the power sector affects all network licensees. As noted above a renewable led system will require large volumes of flexibility and these assets (which could include assets that interact with the gas system) will likely connect to all networks at multiple voltage and pressure levels. All networks will therefore experience changes to their flows as a result of flexibility and weather. The networks will be better placed to prepare for this change through this project (i.e. the direct outputs) and will also benefit from any changes made to the FES as a result of the learnings from this project.

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.

The proposed project will start with a literature review and is thought to be the first to provide an in-depth analysis of the probabilities of weather events set out above.

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

Although NESO has analysed individual historic weather years against our Future Energy Scenarios, we do not have extensive knowledge of “Dunkelflaute”. As renewable deployment has increased, stakeholders have raised increasing concerns about the potential impact of “Dunkelflaute” with some speculating that these weather conditions can last for 2 weeks. The probability and full extent of these events is still relatively unknown, particularly in regard to duration and severity, and coincidence with other weather concerns (e.g. cold weather, low wind across a wide area of Europe). Therefore, this research project aims to address the current gaps in understanding and provide NESO with a more in-depth breakdown of possible weather patterns and their statistical likelihood. This will enable the NESO to determine optimal flexibility mixes that our future system will require.

Relevant Foreground IPR

Literature review
Final report

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’. NESO 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 NESO can be found in our publicly available “Data sharing policy relating to NIC/NIA projects” at https://www.neso.energy/about/innovation.

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

Due to the nature of the project and that it is researching potential future impacts to the grid based largely on assumptions, this does not fall into current BAU.

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 framework is relatively low. Therefore, innovation funding is more suitable for exploring the project's potential and increasing the TRL before transferring into BAU activities.
- There are increased risks associated with the availability of required data and a high level of assumptions, which makes this project better suited to NIA.
- Conducting this project with NIA funding will ensure that the project findings can be shared more widely with other interested network licensees.

This project has been approved by a senior member of staff

☑ Yes