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_NESO093

Project Progress

Project Title

Extreme Weather and Climate Modelling (Dunkelflaute)

Project Reference Number

NIA2_NESO093

Project Start Date

July 2024

Project Duration

1 year and 1 month

Nominated Project Contact(s)

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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.

Objectives

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

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?

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

The Discovery Phase of this project was designed to explore how weather and climate data could be used to stress test the Future Energy Scenarios (FES). The work was structured around two main objectives: first, to identify and prioritise weather-related stress events relevant to NESO's planning needs; and second, to evaluate whether existing datasets could be used to conduct meaningful stress tests on the FES.

To begin, NESO and the Met Office conducted a series of three workshops with internal stakeholders. These sessions were used to gather expert input on the types of stress events that could challenge the energy system. Participants discussed both short-term and long-term risks, such as short-duration power deficits and prolonged periods of low renewable generation. The workshops helped define two broad categories of stress events: those involving missing energy or power due to low renewable output and/or high demand, and those involving surplus generation during periods of high renewable output and low demand. These discussions also clarified the spatial and temporal characteristics of interest, such as sub-daily resolution and regional granularity, which are important for operational modelling.

Following the workshops, the team reviewed the Adverse Weather Scenarios for Future Electricity Systems (AWSFES) dataset, developed by the Met Office. This dataset includes physically plausible weather scenarios derived from historical observations, climate model hindcasts, and future projections. The team selected a subset of events from this dataset based on their severity and duration, using metrics such as the Wind Drought Index and Surplus Generation Index. These events were chosen to represent return periods of 1-in-5, 1-in-20, and 1-in-50 years, both for the UK and Europe.

The selected events were then processed and run through NESO's dispatch model, PLEXOS. This required converting the AWSFES data—originally in gridded NetCDF format—into time series profiles for wind, solar, and demand, aligned with the model's geographic zones. The testing protocol aimed to assess whether these events would trigger stress in the energy system and to evaluate the suitability of the dataset for future use. However, the results were mixed. Some events did not produce significant stress in the model, and for those that did, there was limited confidence in the return periods assigned. This raised concerns about the robustness of the dataset for NESO's specific needs.

Based on these findings, the team concluded that further work would be needed. Several limitations were identified, including the lack of a NESO-specific weather-to-energy conversion model and the limited number of historical weather years available in PLEXOS-

compatible format. As a result, the report recommends a Phase 2 of work. This could involve developing an in-house conversion tool, updating the AWSFES dataset with NESO-specific assumptions (such as updated demand profiles and installed capacities), and exploring enhanced climatology and future projections. The report also suggests that additional types of stress events—such as Dunkelflaute, sub-daily events, and cross-seasonal effects—should be considered in future analyses.
In summary, the work followed a structured and replicable approach: stakeholder engagement to define the problem, dataset review and selection, prototype modelling and testing, and a final gap analysis with recommendations for future development. This methodology provides a clear roadmap for others looking to assess the resilience of energy systems to adverse weather conditions and allowed NESO to streamline our approach to focus on achievable and meaningful analysis moving forward.

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

During the project, NESO transitioned to a new dispatch model (PLEXOS), which introduced delays and required adjustments to the data processing pipeline. The AWSFES dataset, provided in NetCDF format, had to be converted into time series profiles compatible with PLEXOS. This added complexity and limited the number of events that could be tested within the project timeframe.

The original plan included detailed probability estimates for various stress events across different UK grid regions. However, the final analysis was more qualitative and focused on national-level summaries. The report acknowledges that the limited number of historical weather years available in PLEXOS-compatible format constrained the ability to conduct robust statistical analysis or rank events by severity

Originally, the project aimed to conduct a detailed statistical analysis of stress events such as Dunkelflaute, wind droughts, and extreme cold spells. However, due to time and resource constraints from the changed approach, the focus shifted toward identifying "quick wins" using existing datasets—specifically the Adverse Weather Scenarios for Future Electricity Systems (AWSFES) dataset. This pivot allowed the team to test a limited number of pre-identified events rather than develop a comprehensive statistical framework from scratch.

Lessons Learnt for Future Projects

Challenges Encountered
During the project, we faced several challenges:
Defining Weather Stress Events: The complexity lay in determining what constitutes an extreme weather event, compounded by the co-dependence on energy system designs.
Dynamic Modelling Requirements: The need for a dynamic solution became evident as fixed weather scenarios were unsuitable for our ever-changing energy systems.
Multiple Stakeholder Requirements: Initially, we considered a broad range of testing requirements from various stakeholders. As the project progressed, it became apparent that the complexity of these demands made it challenging to effectively pinpoint our testing objectives. This realisation led us to narrow our focus and streamline our approach to ensure more targeted and meaningful testing outcomes.

Key Learnings
Dynamic Weather Solutions: Instead of relying on predefined weather events, we recognised the need for a comprehensive data set. This will allow us to independently select and test events against our system designs.
System Design as a Key Variable: We concluded that our focus should remain on energy system design, using weather data as a variable for testing rather than attempting to predict specific weather impacts.

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

Project Outcomes
Although we did not achieve our intended goal of explaining weather-related risks to stakeholders using our findings, the project was successful in several key aspects:
Understanding Complexity: We uncovered the intricate nature of defining and modelling weather stress events in conjunction with energy system designs.
Simplified Approach: We have streamlined our approach to focus on achievable and meaningful analysis moving forward.

Conclusion

In conclusion, although the project did not meet its original objectives, it has been pivotal in reshaping our approach to integrating weather data with energy system analysis. Initially, we underestimated the complexity of the problem, but we have successfully navigated these challenges. The problem is now well-defined and focused, allowing us to move confidently into the practical phase of implementation, setting the stage for significant progress and tangible results in future projects.

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

Final summary report outlining the findings from each work package and the associated datasets, with recommendations on priority areas for any further analysis

Planned Implementation

Internal Collaboration: We have identified other teams within our organisation engaged in similar projects. Going forward, we will collaborate with these teams where our requirements align, applying the lessons learned from this project to maintain a focused approach.
Collaboration with Weather Experts: We plan to engage with weather experts to obtain extensive weather datasets. This will provide the flexibility to define and test events tailored to our needs.
Generic Approach to Testing: By adopting a more generic approach, we aim to reduce complexity and focus on the broader impact of weather on energy systems.
Incorporating Weather Data into Modelling: Our next challenge is to effectively integrate the weather data into our modelling processes. Developing a robust method for incorporating this data will be crucial for accurately testing and analysing the resilience of our energy systems under various weather conditions.

Net Benefit Statement

Despite not meeting the initial objective of explaining weather-related risks to stakeholders, the project has achieved significant progress in redefining our approach to integrating weather data with energy system analysis. The challenges encountered, particularly in defining weather stress events and addressing multiple stakeholder requirements, led to important insights and adjustments in our strategy.

Tangible Benefits Realised:
Streamlined Testing Approach: By refining our focus and narrowing the scope of our testing objectives, we have enhanced efficiency in our analysis process. This streamlining has reduced unnecessary complexity, allowing for more targeted and meaningful testing outcomes.
Resource Optimisation: The shift towards a dynamic weather solution and the decision to use system design as a key variable have optimised resource allocation, ensuring efforts are directed towards the most impactful areas.
Intangible Benefits Observed:
Enhanced Internal Collaboration: The project has fostered better collaboration within the organisation, as teams engaged in similar projects are now identified, paving the way for future cooperation and knowledge sharing.
Improved Stakeholder Alignment: Although the initial goals were not met, the process of refining our approach has led to clearer communication and understanding among stakeholders, building trust and aligning expectations for future projects.
Increased Flexibility and Adaptability: The recognition of the need for comprehensive datasets and a generic testing approach has increased our flexibility in responding to varying weather conditions, enhancing the resilience of our energy systems.

Overall, the project has been pivotal in reshaping our strategies and laying a strong foundation for future success. As we move into the practical phase of implementation, we are well-positioned to achieve significant progress and tangible results in upcoming projects.

Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this

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