UK Research and Innovation

Use case report for the Data Infrastructure for National Infrastructure project (DINI)

Building risk-informed redundancy in energy systems transitioning to Net Zero (BRINES)

Dr Hannah Bloomfield
Dr Ji-Eun Byun
Dr Colin Manning
Professor Sean Wilkinson

UK Research and Innovation

Contents

1. Use case Report

1.1 Background and Context

Building risk-informed redundancy in energy systems transitioning to Net Zero (BRINES)

Power systems are rapidly changing as we transition towards net-zero. The weather-sensitivity of demand is increasing as the heating sector is electrified. Supply is also becoming increasingly variable due to significant growth in renewable energy technologies (particularly wind power and solar photovoltaics). Extreme weather events are also becoming more extreme and variable owing to climate change.

This adds previously unseen levels of variability onto the system and creates compounded consequences caused by extreme weather events. For example, a long period of cold weather and low wind speeds will incur high demand and low wind power generation simultaneously. Conversely, stormy periods (with high winds and rainfall) could result in damage to the electricity distribution network. Damaged assets could increase the challenge of meeting peak demands if storms are followed by a cold spell (such as in winter 2023). Such compounding consequences require more rigorous treatment of uncertainties in energy model simulations so that their propagation can be accurately assessed through weather events (in both a present and future climate), structural damage of power generation assets, and impacts on supply and demand.

Another challenge arising from heightened meteorological variability is that power infrastructures require more redundancy (i.e. more generation units than for normal situations) and hence more investments. This leads to questions of how much and where such redundancy should be built. Deciding a suitable level of redundancy requires evaluation of relationships between redundancy and the risk (e.g. in terms of probability) of insufficient power generation. Locations of redundancy needs to be decided in a way to decouple risks with existing assets. This requires understanding the correlations between assets' fragility.

Quantifying impacts of climate change on energy systems requires new datasets. Weather-dependent models need to be developed with an inter-disciplinary calibration and design process. This requires a sustainable data sharing infrastructure.

BRINES explores the use of weather and climate data to highlight future resilience challenges to the UK power network from both an operational perspective (maintaining the balance of supply and demand) and from an asset management perspective (making sure assets are not damaged by extreme weather). The project identifies two primary challenges, higher variability from increasing weather-dependence and compounded consequences owing to weather-dependency of both demand and supply.

To address the challenges, the project will harness the collated meteorological data for probabilistic modelling. Thereby, the project will assess optimal design of system redundancy (i.e. construction of generation assets more than required to be armoured against high consequence events) from a risk-based perspective.

For the BRINES project we have not directly engaged with any stakeholders, but they were key in the previous development of the datasets that are being shared.

- Bloomfield has previously worked with the UK Climate Change Committee (CCC) on a consultancy project which developed electricity demand, wind power and solar datasets for a present and future climate, as well as present and future power systems.
- Manning and Wilkinson have worked extensively with the UK Energy Distribution Network Operators (DNOs), the Energy Networks Association (ENA) and the Department for Energy Security and Net-Zero (DESNEZ) to develop the indicators asset damage indicators as part of the CSNOW project.

1.2 Description of Activities

Datasets:

- Prepare existing hourly timeseries of weather-driven electricity demand, wind power, and solar power generation from historical observations (the ERA5 reanalysis) and the UKCP18 climate projections (1980-2080) as datasets for the DAFNI platform. These will be for present and future power system setups.
- Prepare existing timeseries of weather variables that can be used as proxies for asset damage from historical observations (ERA5 reanalysis) and the UKCP18 climate model (1980-2080) for use and visualisation on the DAFNI platform.
- From the data described in the previous two bullets, create jupyter notebooks for the DAFNI platform to assess the 'most challenging periods' from a combined operations (e.g. security of supply at times of high demand and low renewables) and asset management perspective.

Modelling:

- Develop a risk assessment tool of national energy system (subjected to variable weather and climate change) on the DAFNI platform.
- Assess the level of redundancy required (to meet a target annual reliability of energy supply) in a highly renewable UK power system

1.3 Benefits of Data Sharing

Access to datasets of these types is critical given the large barriers in upskilling when beginning to use weather and climate data. For example, to work with the UKCP18 climate projections to create wind power data over 25TB of .netcdf data needs to be loaded, subset, and processed at individual wind farm locations. The BRINES datasets convert these large (often inaccessible) meteorological fields in .csv files that are only a few MB in size and can be used for energy system modelling or climate resilience evaluation.

The datasets created through BRINES will be useful for energy sector stakeholders wishing to understand the importance of climate variability and climate change on both security of supply (e.g. times when we have high demand and low renewables now, and when we may require large amounts of storage in the future) or times where traditional extreme weather may cause weather-induced failures (e.g. extreme near-surface temperatures, rainfall and wind speeds). Examples of the datasets uses could include:

- Assessing the potential for asset damage (from near-surface extreme temperatures, wind speeds or precipitation) in an electricity distribution network region, in a present and future climate. This could be in the form of return period statistics, or a probability/impact of a weather-induced failure (although the later example will require some extra modelling steps such as the projects redundancy modelling).
- Understanding return periods of energy security challenges such as high-demand and low-renewables events for present and future power systems.
- Understanding potential future storage requirements at times of high-demand and low-renewables (e.g. in power systems with more electrification of heat and more renewable generation).

The extreme weather for local assets datasets were created as part of the CS-NOW project, in collaboration with DESNEZ. These datasets allow the gas and electricity distribution networks to begin to explore the impacts of climate change on their assets. Sean Wilkinson and Colin Manning are in ongoing conversations with the Distribution Network Operators about the use of climate projections using prototype tools like these. Sean Wilkinson and Hannah Bloomfield are also on OFGEM (Office of Gas and Electricity Markets, the national regulatory authority) climate resilience expert panel where the BRINES datasets have been highlighted as an example of how distribution network operators could think about climate resilience for stress testing exercises.

The demand, wind and solar power data were created as part of a consultancy project with the UK Climate Change Committee, which has now been published as a synthesis report alongside the 7th Carbon Budget (Bloomfield, 2025). Therefore, these stakeholders are already very engaged with using the datasets and there is more that can be gained through the existing relationships of the project team beyond the initial project timeline.

Bloomfield, HC., (2025) Reasonable worst-case stress-test scenarios for the UK Energy sector in the context of the changing climate. Available at: https://www.theccc.org.uk/publication/reasonable-worst-case-stress-test-scenarios-for-the-uk-energy-sector-in-the-context-of-the-changing-climate/ last accessed: 11th March.

1.4 Barriers for Data Sharing

The key barrier for data sharing from the BRINES project of existing weather-driven energy variable timeseries was learning how to use the DAFNI platform to upload them appropriately. Similarly for sharing the redundancy model some upskilling was required in how to link the project datasets to the model workflow. The DAFNI team have been very supportive of this process and provided bespoke training. However, we still had some issues at Newcastle with Docker, as we do not have local admin rights on our PC's so it was a bit challenging to work out the best setup. It turns out Docker Desktop works well though once we have that installed and there is a lot of flexibility through the online platform to upload datasets manually providing, they are not too big (e.g. files of less than a GB we did not have any problems with manual uploads and the main restriction was in the strength of internet connection).

As academics we require DOI's for datasets to be citeable. So, we will need to dual-host the datasets on Zenodo and the DAFNI platform for this purpose. This is not ideal as it creates some confusion with stakeholders if the datasets are the same, but this can be clarified through the README files, and through the fact that there is a space in the DAFNI dataset uploads to provide alternative DOI's/data locations.

We are not at the point that energy sector stakeholders are using these datasets through the platforms yet, but we hope this will be operational soon following the publication of reports that use the datasets with the UK Climate Change Committee (Bloomfield et al., 2025). The BRINES project has suggested the datasets as a starting point to OFGEM for their upcoming climate resilience stress testing exercise.

Privacy, legal and commercial barriers: The underlying climate data used to create these datasets and for the pypsa-GB network that the redundancy model is based around are all open access. The climate data is available through the CEDA archive and the pypsa data through their github repository, so we do not have issues here. The only commercially sensitive data in the process is thewindpower.net database that Hannah Bloomfield uses to create the national wind power generation output. This is not provided as part of the workflow as it is purchased for £800 under an academic license.

Security: Some of Hannah Bloomfields energy and insurance stakeholders have previously mentioned have download limits on their laptops. So they would not be able to download the BRINES datasets, but they could work with them directly on the DAFNI platform.

Cultural barriers: Future climate projections are very rarely used at present for energy system modelling, with limited examples even available in academia. The issue here is partly accessing the data in an appropriate format, and partly the need to recalibrate a energy system model to be able to work with climate data. Platforms like DAFNI are very helpful for the sector to begin to overcome these challenges on the route to net-zero. In terms of data sharing the quality of climate-related damage indicators could be significantly improved if the underlying data to make these of distribution network faults was open access (rather than accessed through academic licenses through Newcastle University). Similarly, the quality of the demand, wind power and solar power models could be significantly improved with more open access energy data. This has become significantly harder to access since Brexit and even aggregated at National level this is very useful!

Bloomfield, HC., (2025) Reasonable worst-case stress-test scenarios for the UK Energy sector in the context of the changing climate. Available at: https://www.theccc.org.uk/publication/reasonable-worst-case-stress-test-scenarios-for-the-uk-energy-sector-in-the-context-of-the-changing-climate/ last accessed: 11th March.

1.6 Results Data

Datasets created by the BRINES project:

- A dataset of UK demand, wind power and solar power data for climate change projections from 1980-2080 using UKCP18. As these are timeseries, rather than gridded climate data they are a few MB each in size. They will be uploaded as datasets on the DAFNI platform.
- A dataset of timeseries of potential infrastructure damage to UK assets from 1980-2080. Again, these are a few MB is size per variable and provided as timeseries. They will be uploaded as datasets on the DAFNI platform.
- An example Jupyter notebook for exploring the climate datasets.
- Risk assessment datasets, i.e. output data of the proposed risk assessment models, single numbers for different simulations, would not be stored as s dataset but would be scientifically useful.

All the datasets listed above can be shared fully openly through the DAFNI platform with accompanying README's explaining how the datasets were created and their intended use.

The demand, wind power and solar power datasets are created based on some preparatory datasets, that are not part of this project (e.g. thewindpower.net database that Bloomfield purchases or the NAFIRS national level fault database that Newcastle University have an agreement with the Energy Networks Association to use for research purposes). In each datasets README details of any additional datasets used to create the data will be given. Code to create the datasets will also be available in linked github repositories for the demand, wind power and solar power datasets.

1.7 Lessons Learnt and Recommendations

We have learnt that the DAFNI platform provides a good facility to share our meteorologically driven datasets and can allow them to be used as inputs to modelling frameworks on the platform. We believe this will be a good place for energy industry stakeholders (e.g. National Grid, NESO, OFGEM, DESNEZ, as well as the electricity and gas distribution network operators) to access these tools and explore other relevant platform tools.

We have learnt about a potential barrier of working with the platform from academic laptops without administrative rights, but found solutions to this using Docker Desktop (which we could request to be installed through our IT department). This is less likely to also be an issue for industry stakeholders as they will just be using the datasets rather than uploading them themselves.

We learnt about data collections from the DAFNI team and believe this will be a very useful way to synthesise all the created energy data options from ERA5 and UKCP18 to energy stakeholders when this feature is fully available. We have a number of datasets now on the platform and a mechanism to quickly synthesise them all to new users would be brilliant.

Integrating datasets and models together on the DAFNI platform has been shown to work well in BRINES. We had some teething problems around the visibility of the datasets once they had been uploaded, and as the UKCP18 and ERA5 data had to be stored in different hierarchies (one has ensemble members and one does not) we focussed on the UKCP18 workflow.

If there were future funding available the next steps would be to collaborate with more energy-modellers who could benefit from these types of bespoke weather-driven energy system datasets for demand, wind power and solar power or the potential for system damage and create DAFNI workflows to incorporate the datasets into their modelling chains. Hannah Bloomfield would like to create a prototype Energy system stress test on the platform, extending her work with the Climate Change Committee and to demonstrate best practise of incorporating meteorological data into energy system modelling.