Met Office

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Case Study

Extreme climate analysis ensures nuclear safety for decades to come

Overview

Sellafield, one of the world's most complex nuclear sites, manages more radioactive waste than any facility globally. Following the Nuclear Decommissioning Authority's 2012 strategic decision to cease oxide fuel reprocessing, the site faced a critical challenge: storing spent nuclear fuel safely until at least 2085, when it can be transferred to a future Geological Disposal Facility.

Spent nuclear fuel continuously generates heat from radioactive decay, requiring robust cooling systems to maintain fuel integrity and storage safety. To support this extended interim storage period, Sellafield initiated a project to replace the existing cooling system in its spent fuel storage facility with new infrastructure designed to last through the end of the century.

The selected heat rejection technology uses the atmosphere as the final heat sink. Therefore, the new cooling system needs to withstand the effects of climate change on air temperatures and reliably manage extreme temperature and humidity conditions possible between now and 2100.

Including its climate risk assessment, the system design would also be subject to scrutiny by the Office for Nuclear Regulation (ONR) as part of the permissioning process. For this safety case, there was need for robust evidence that the system could withstand once-in-10,000-year climate extremes.

How we help

The Met Office conducted a comprehensive Extreme Value Analysis (EVA) of ambient air temperatures through to 2100. The work was split into 3 work packages spanning from November 2023 – November 2025. This statistical approach provided the evidence that Sellafield needed to design a resilient cooling system and meet regulatory requirements.

The methodology

Due to the situation of the Sellafield site, on the coast and close to Lake District's high elevations, careful selection of data sources was critical. The Met Office used a hybrid statistical framework for their advanced climate risk analysis combining:

- Historical observations: Local weather data from Walney Island weather station near Sellafield
- High-resolution climate projections: Over 1,200 years of simulated data from UKCP18 climate projections at 2.2km resolution (12 ensemble members, each of 100 years in length)

The analysis focused on the RCP8.5 climate scenario, which assumes minimal global action on emissions, and a simplified 4°C global warming scenario.

Innovative analysis

The analytical approach addressed the challenge of estimating extremely rare events:

- **Pre-processing**: Adjusting the data to remove long-term trends and correct any differences between observed and modelled data. Climate change trends are added back after extreme value modelling.
- **Extreme Value Modelling**: Applying a statistical model to estimate the most extreme temperatures and humidity levels that could occur over daily, weekly (7-day), and 20-day periods for both high temperatures in summer and low temperatures for winter.
- **Uncertainty Checks**: Advanced techniques to quantify confidence in the results.

The study leveraged UKCP18 climate projections and credible maximum scenarios, meeting the expectations of the Office for Nuclear Regulation (ONR) for regulatory scrutiny.

Our impact

This work supports the UK's nuclear decommissioning programme and contributes to national security and resilience.

The EVA provided Sellafield the confidence that their cooling system design basis is robust to manage decay heat throughout the interim storage period through 2085 and beyond. Without this analysis, demonstrating compliance with ONR requirements would not have been possible.

This collaboration between Sellafield and the Met Office exemplifies how climate science underpins nuclear safety. By integrating advanced climate modelling into engineering design, the project ensures that critical infrastructure remains resilient well into the next century. The methodology could be applied to other nuclear sites, energy infrastructure, or critical national facilities requiring extreme resilience.

The analysis showcases the Met Office's capability to bridge the gap between climate projections and regulatory compliance for industries where safety is paramount.

"This work helped Sellafield meet strict regulatory requirements and ensured that nuclear waste management remains safe, even in the face of climate change. It's a vital step in protecting people, the environment, and the integrity of the UK's nuclear infrastructure."

Ian Turner
Sellafield Ltd

"The Sellafield EVA project sets a new standard for nuclear operations by uniting advanced engineering and bold climate analysis. Through this forward-thinking collaboration, we will support the nuclear sector to deliver safer, smarter, and more sustainable solutions that transform industry challenges into opportunities for progress."

Simon Marshall
Business Manager - Energy

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