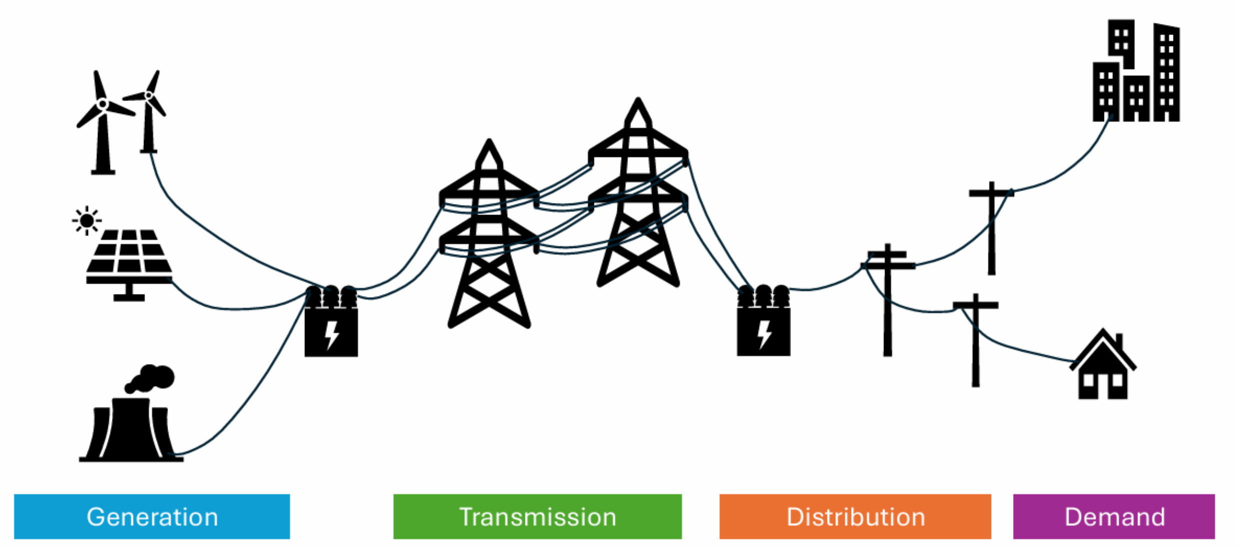
Powering Through the Storm: Building Resilient Power Systems for a Changing Climate

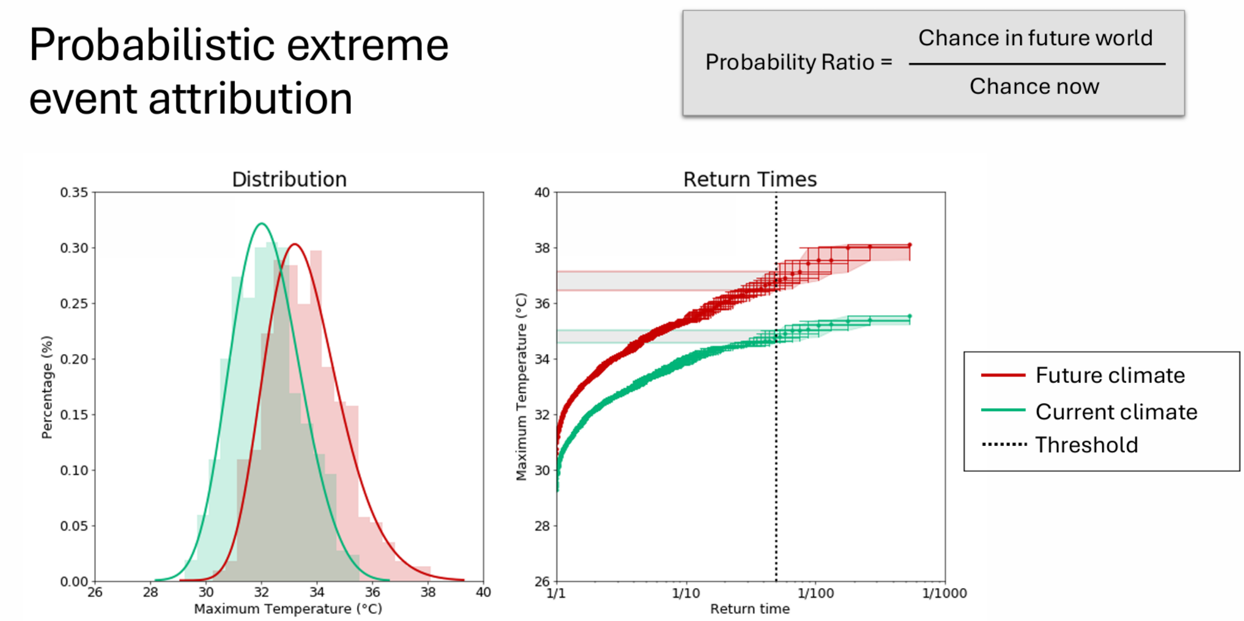
By Tamunoimim Kalada-Green

Wind-broken turbine blades, storm-fallen transmission lines, flooded substations. What do all these have in common? Weather and power systems.
Much of my MSc in Energy Systems has focused on how decarbonising energy production and consumption protects the climate. But in this seminar, Sarah Sparrow flipped the lens, asking:
"How are extreme weather events already affecting the energy system, and how could climate change make those impacts worse?"
Sarah is an Associate Professor in Environmental Impact at the University of Oxford e-Research Centre and Deputy Director of the Energy Systems MSc course. Her research uses large climate model simulations to study extreme weather impacts on energy, infrastructure, health, water, and finance. In the seminar, she explored how weather extremes affect the whole power system: generation, transmission, distribution, and demand.



Simplified Power System Diagram, Sarah Sparrow Seminar Slides

From a whole-system perspective, Sarah highlighted research from Eleanor McIndoe on Victoria, Australia, showing how heatwaves can stress every segment of the power system. Generation assets may be derated or disrupted by equipment failures and thermal constraints. Transmission networks can face heat-related constraints, asset faults, and bushfire or grassfire risks, while distribution networks experience overloads and asset failures. Consumers ultimately experience these stresses through load shedding and prolonged outages. The research also used **Probabilistic Extreme Event Attribution (PEEA)** to model future scenarios. Put simply, PEEA asks: **"How much more likely or severe could an extreme event become under future climate scenarios?"** The key finding was that heatwaves capable of stressing the entire system could become more frequent, equivalent to shorter return times between events. Future Victorian power systems will therefore need to be designed for more extreme conditions if they are to remain resilient.



Probabilistic Extreme Event Attribution for heatwaves in Victoria, Sarah Sparrow Seminar Slides

For generation, Sarah shared work by Sara Abdelaziz on UK offshore wind. The analysis showed that future climate scenarios could increase low-wind risks in some regions, shift seasonal production patterns, and alter exposure to extreme gusts. The key insight was that offshore wind siting should not depend only on today's best wind locations. A more resilient system will need geographically diversified wind assets that remain productive under future climate conditions.

Turning to transmission, Sarah drew again on Eleanor McIndoe's work to show how extreme heat affects power lines. As ambient temperatures rise, transmission lines can heat up and sag, increasing the risk of flashover, where electricity arcs across unintended paths. Since current also generates heat, operators may have to reduce power flows during high-temperature events to keep the system within safe limits. Static and dynamic line ratings can help by defining the maximum current a line can safely carry under different conditions. Yet the risk rises sharply with warming: in the analysis, a 2°C increase in mean ambient temperature made transmission overheating events almost ten times more likely.

Sarah also shared Weijia Yang's work on wildfire risk. This explored how fire-prone conditions can affect transmission lines and how the system can be made more resilient. Using the Fire Weather Index alongside a power system model, the analysis identified lines that may need to be predisconnected under high wildfire risk. This protects the system but can lead to load shedding. The analysis also showed that placing distributed wind generation closer to vulnerable grid nodes could recover some of the lost load, reduce emissions and become economically valuable once the wider cost of unserved electricity is considered.

For distribution, Sarah discussed Dermot Leggett's work on substation flooding in Norfolk. The project mapped substations across river catchment areas and combined flood-risk data with factors like access difficulty, proximity to roads, customer count, transformer numbers, and whether substations were indoor or outdoor. This produced a normalised risk map, showing that some secondary substations were especially exposed. By modelling future climate impacts, the work showed that flood risk could increase in certain locations, helping identify which substations should be prioritised for maintenance or reinforcement.

On demand, Sarah shared Aubrey Taylor's work on the 2021 Pacific Northwest heat dome, showing how extreme heat was linked to higher mortality and rising electricity demand. Natalie Sauter extended this idea to Brazil, analysing population density, income, future population growth, and heatwave patterns across the Northeast, Southeast, and South. Her work found that heatwave frequency and duration could increase significantly, while intensity rises slightly. When combined with demand data, this pointed to possible peak stress periods around 2040 to 2050.

Sarah also highlighted work by Nicole Miranda and others on cooling degree days. The key point was that while the largest absolute increases in cooling demand may occur in Global South regions, the largest relative increases may affect Global North regions where air-conditioning use is currently limited. This creates a major climate adaptation challenge.

In the Q&A, it was noted that much of the work is still research-led, although Weijia's wildfire-resilience work is progressing further to application. The discussion also highlighted the policy value of extreme event attribution, especially for identifying where resilience investments should be targeted. A final point was that technical findings need strong storytelling: policymakers are more likely to respond when the risks are framed around economic and social consequences.

Overall, the seminar showed that extreme weather is already affecting power systems and could intensify these pressures under future climate scenarios. As heating, transport and industry become increasingly electrified, building resilience into electricity infrastructure will become even more important. Extreme event attribution offers a powerful tool for identifying where those resilience investments can have the greatest impact.