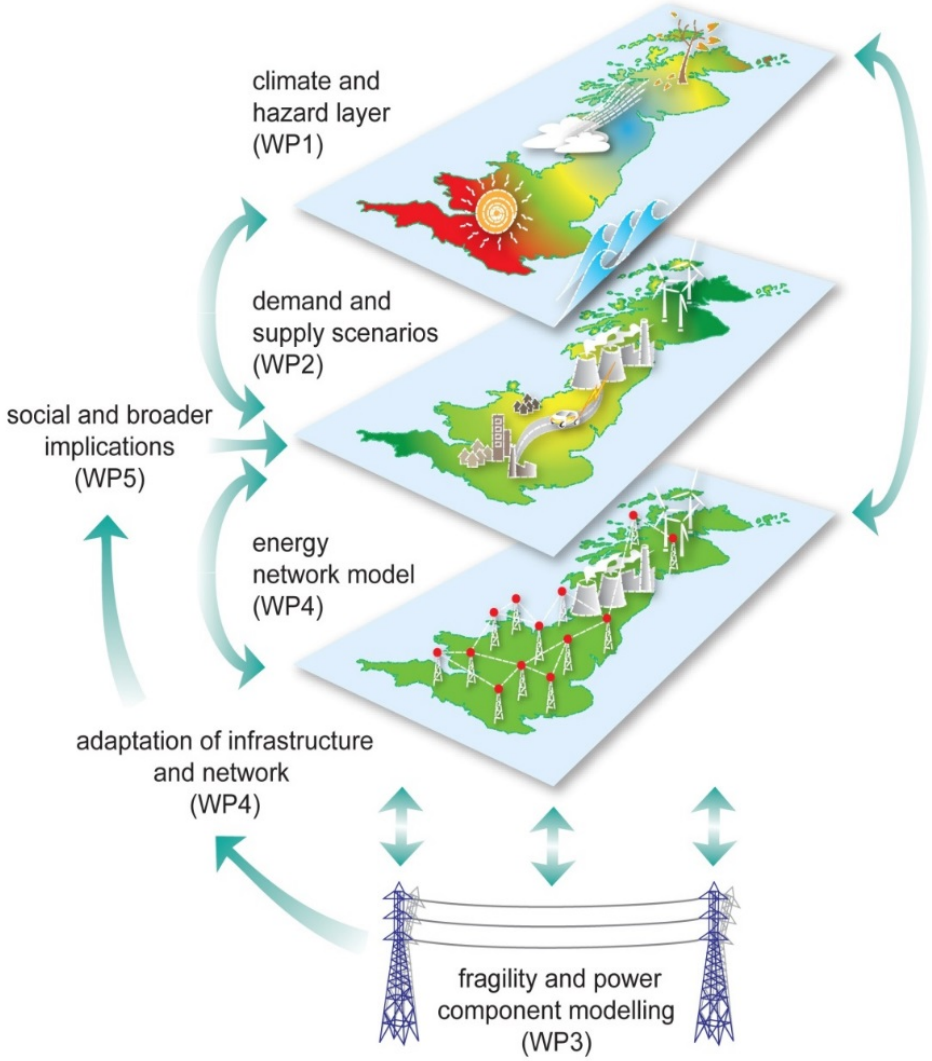
RESNET key messages

Future delivery of energy in a changing climate: Risks and solutions

London, 13th October 2015



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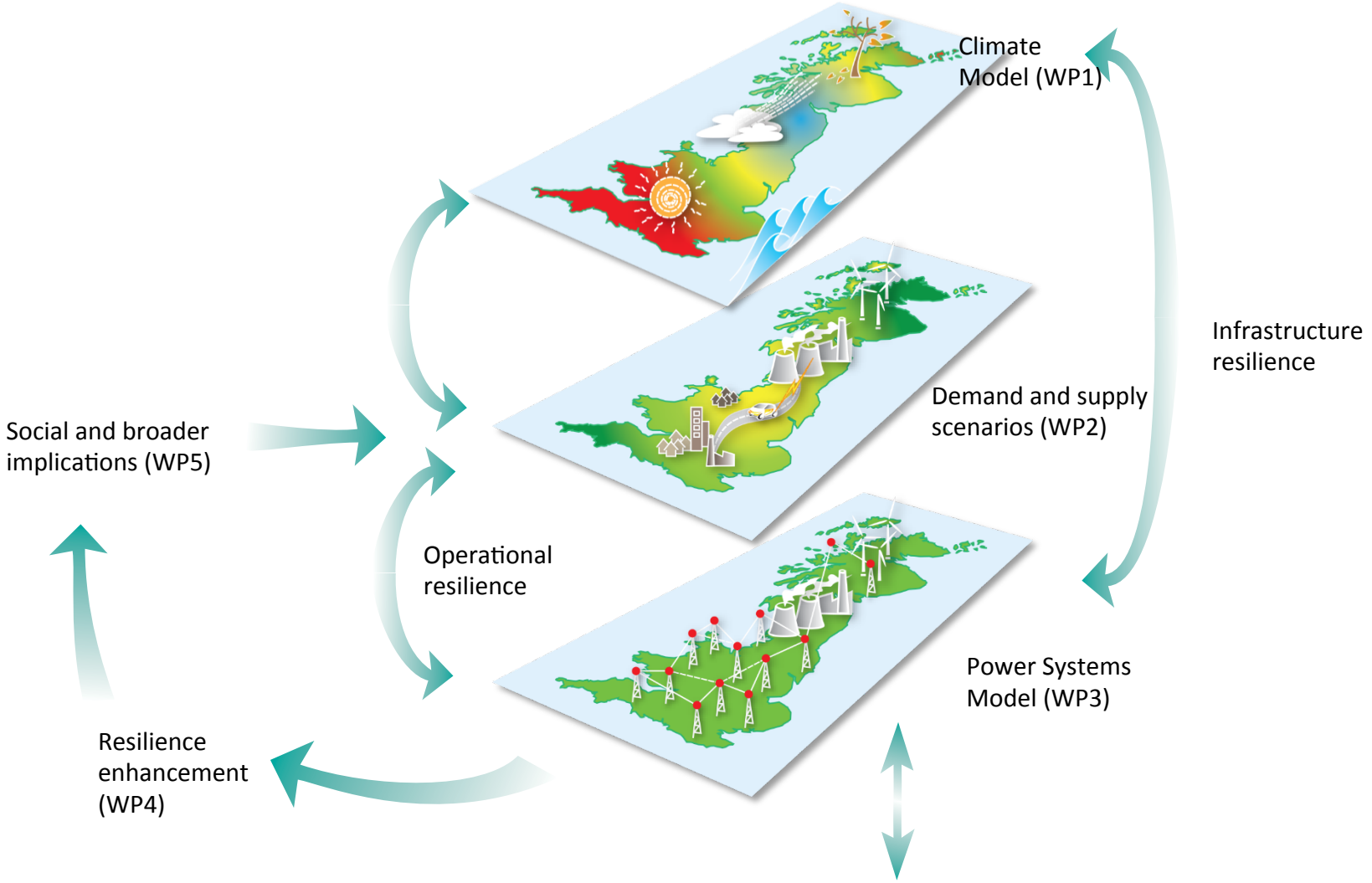
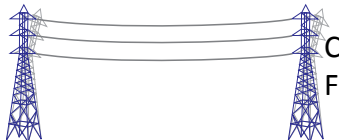
Key Questions

- In a changing climate, is our current electricity transmission system capable of providing a service that is equally reliable as the one we enjoy today?

- What are robust responses to future challenges?

Modelling strategy





Component Fragility (WP3)

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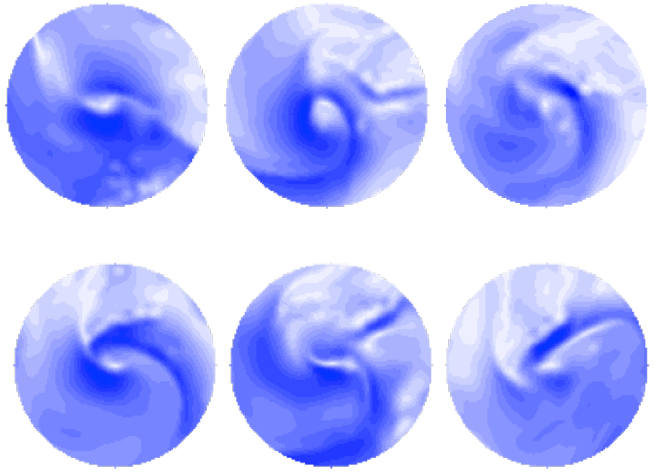
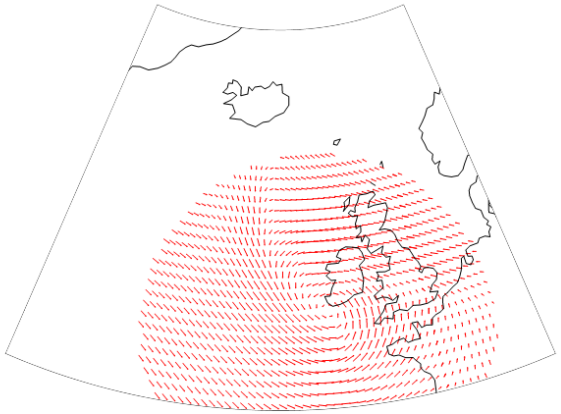
Climate model - GB wide model for high winds





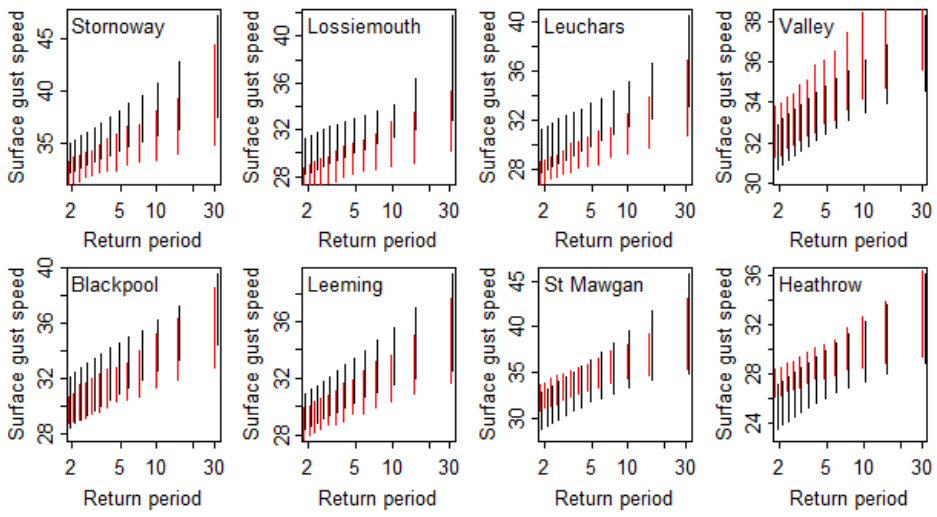
Simultaneous winds across GB characterised by historical storm wind profiles

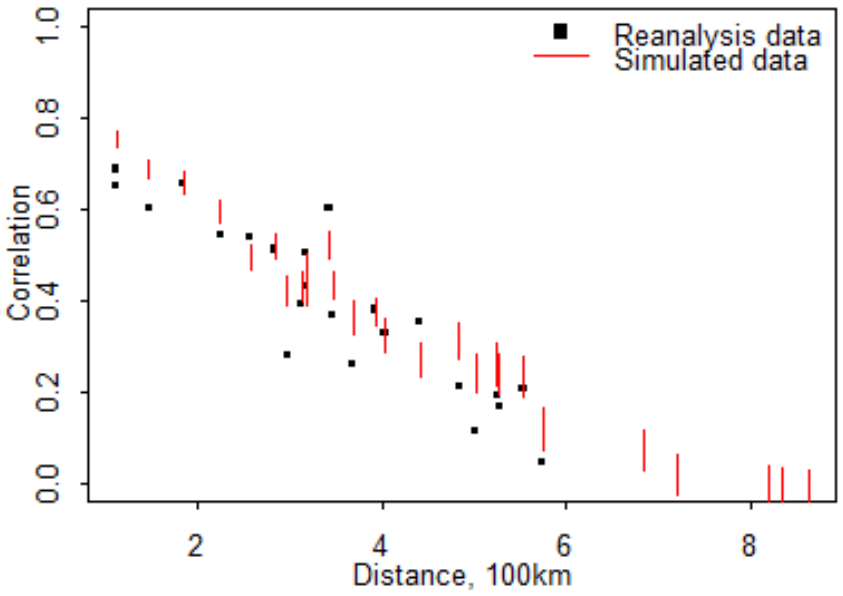
Distribution of pressure centres on windy days

Monte Carlo simulation of storm location and strength

Simulation at 850hPa height (1.5 km); relate to near-ground winds using regression relationships from high resolution climate model runs.

10m (surface) extreme wind and spatial correlation



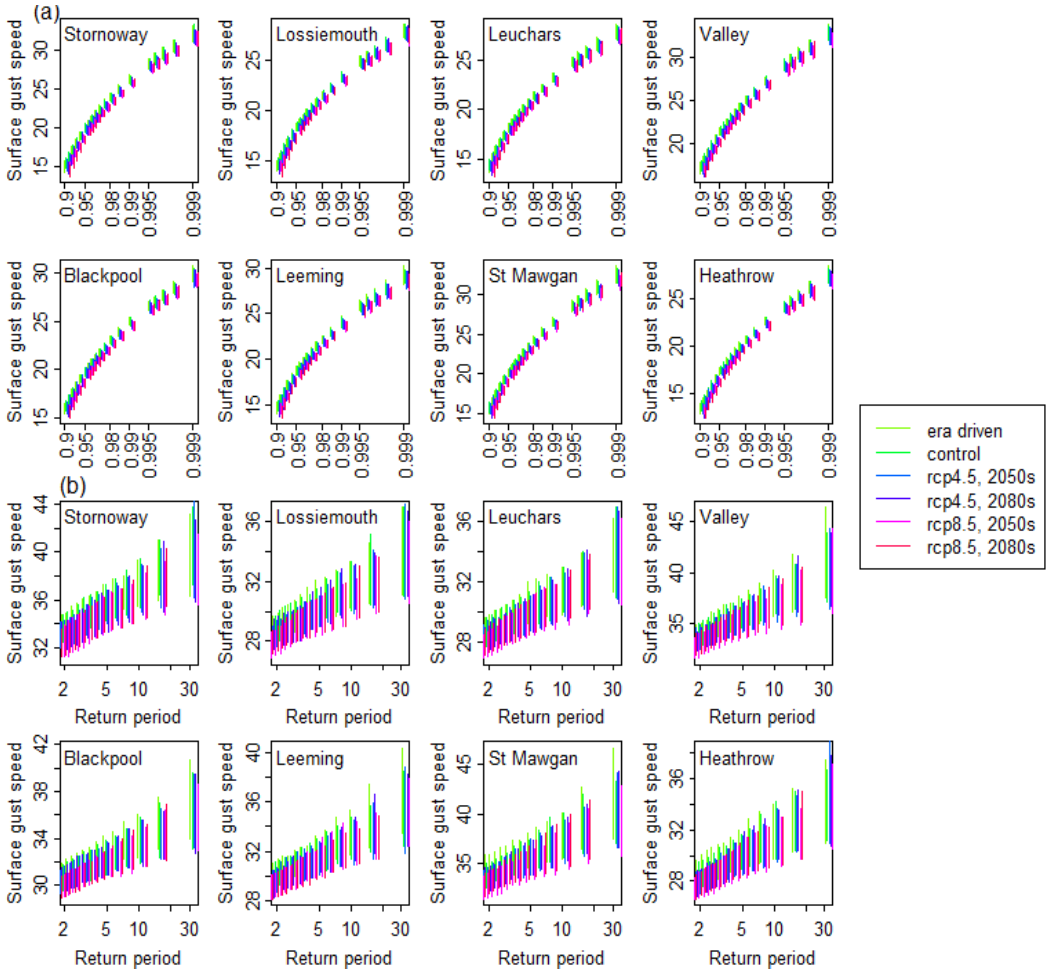


Comparison between 95% confidence intervals on the annual maxima of model output and of observed surface gust speed at selected locations.

NOTE: Y axis does not start at zero

Decay of spatial correlation of surface wind gust with distance for days where wind speed is somewhere over the 98th centile

Model output for future extreme wind at 10m



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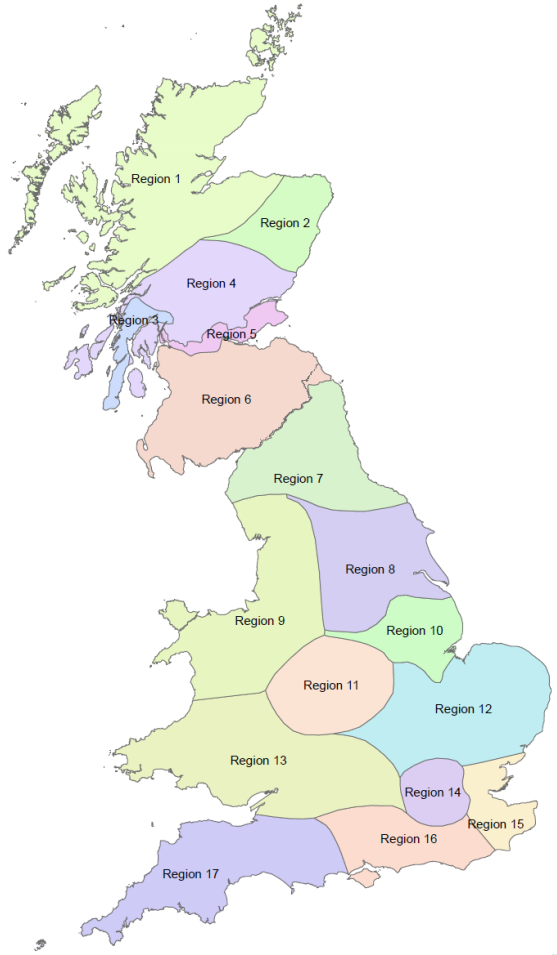
Storm model - summary

- Storm generates “event based” storm simulations at specified locations (Lat, Long) for current climate at 6 hourly intervals.
- Can be perturbed to perform sensitivity studies for possible future climates.
- Climate projections not included as the latest models still have too large an uncertainty to be used credibly

Demand Model – Aim & Objectives

- To produce resilience testing scenarios of diurnal load profiles
  - » Winter and summer
  - » Temperature dependent
  - » Disaggregated by sector and end-use
  - » Include 'new' forms of electricity demand (EVs, heat pumps)
  - » Spatially disaggregated to 17 zones



Scenario assumptions

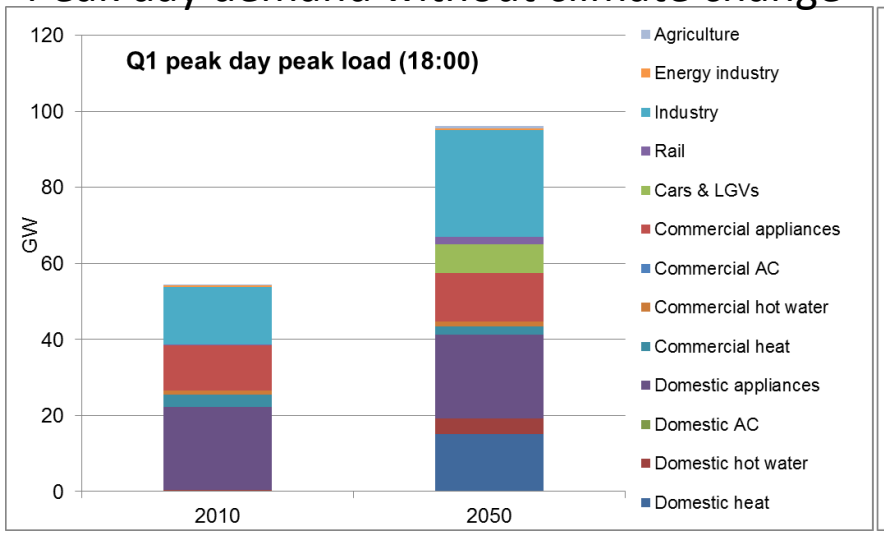
- Deliberately chosen to generate a high electricity demand scenario

  - » Uses National Grid's 2011 Future Energy Scenarios 'accelerated growth' uptake rates in electric vehicles & heat pumps
  - » Coupled with high build rates, high economic growth and conservative efficiency improvements
  - » High adoption rate of domestic and commercial air conditioning
  - » Air conditioning demand has a strong relationship with external temperature
  - » Uses UKCP09 High Emission Scenario temperature outputs – using the 95th percentile representative hottest & coolest days of a year to model 'peak' daily demand.

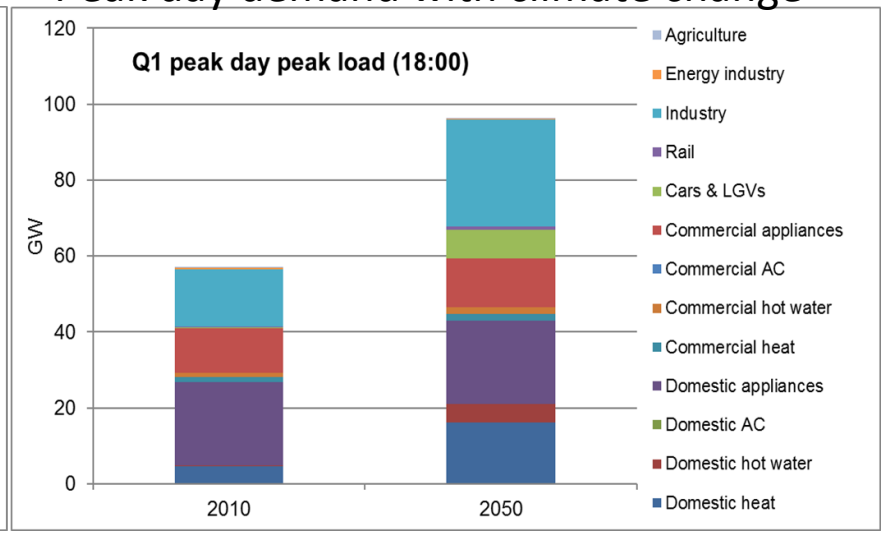
  - » Result: extreme, yet plausible, demand scenarios to test network resilience

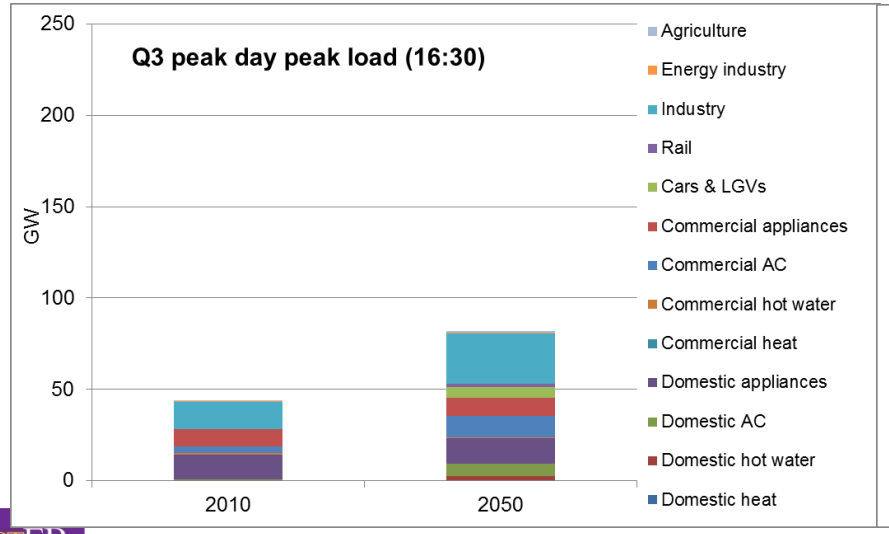
Maximum daily demand, winter and summer (2010, 2050) with & without climate change

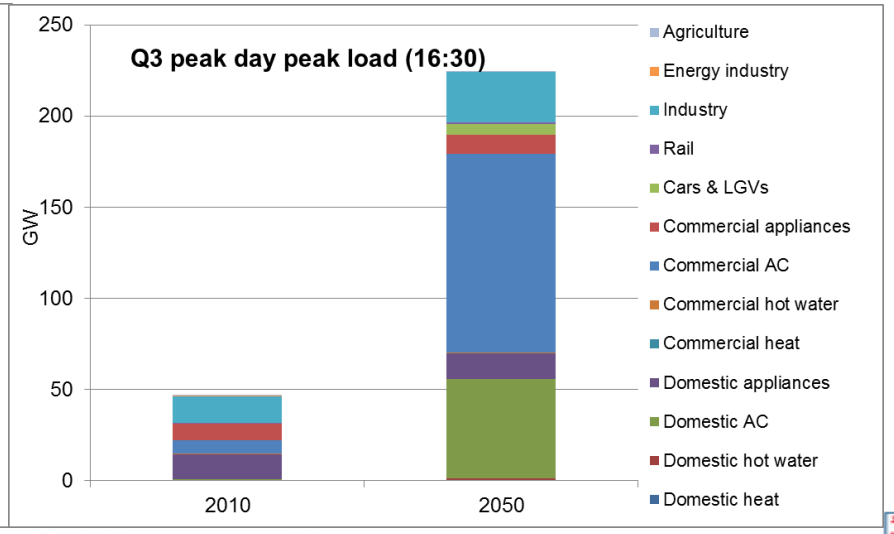
Peak day demand without climate change



Peak day demand with climate change







Temperature changes based on UKCP09 High Emissions Scenario

Demand model - summary

- Increasing levels of intermittent supply will have repercussions for grid operation, but the electrification of heating as well as road transport will place substantial new loads on the grid, with associated implications for societal resilience to interruptions in the electricity supply.
- The increased electrification of household energy services such as heating if not coupled with significant efficiency savings could lead to additional demand of approx. 46TWh per annum (based on 45% of households installing heat pumps).
- In the event of widespread adoption of air conditioning within the commercial and domestic sector when coupled with increasing temperatures associated with climate change could lead to a significant increase in summer electricity demand, ***potentially*** shifting peak annual demand from winter to summer before 2030.

Operational resilience – transmission network capacity

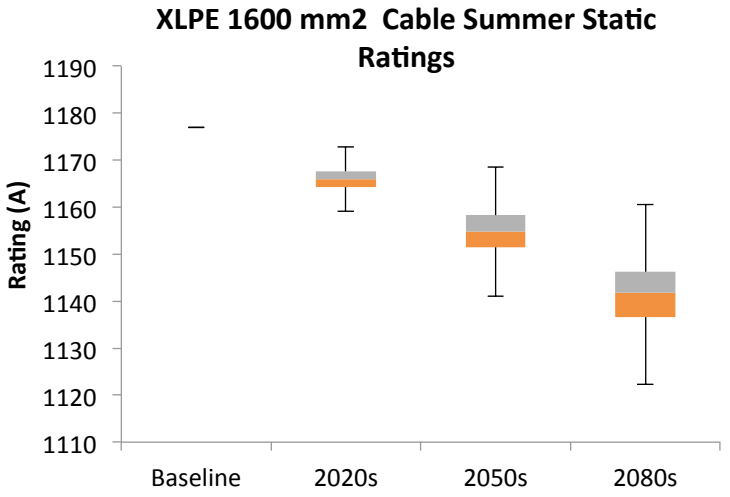
- Assessment of the impacts of climate change on Transmission Network Capacity
- The network components assessed include:

Overhead Line

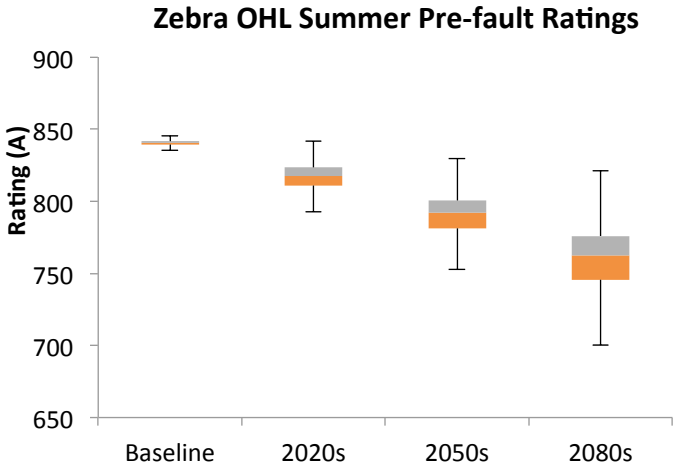
Underground Cable

Transformer

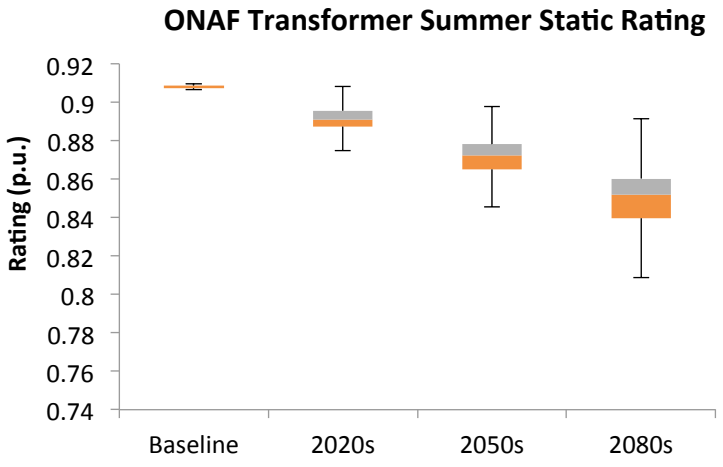
Changes in Component ratings



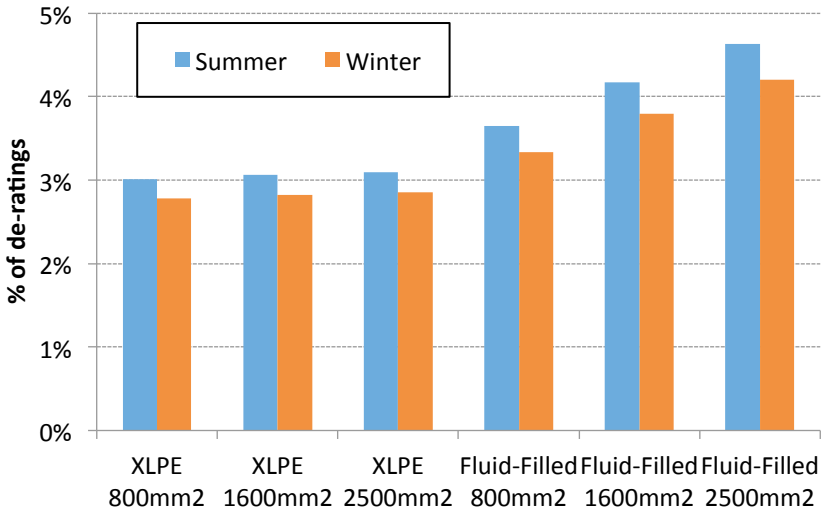
Projected XLPE 1600 mm2 summer pre-fault ratings in Slough in high emission scenario



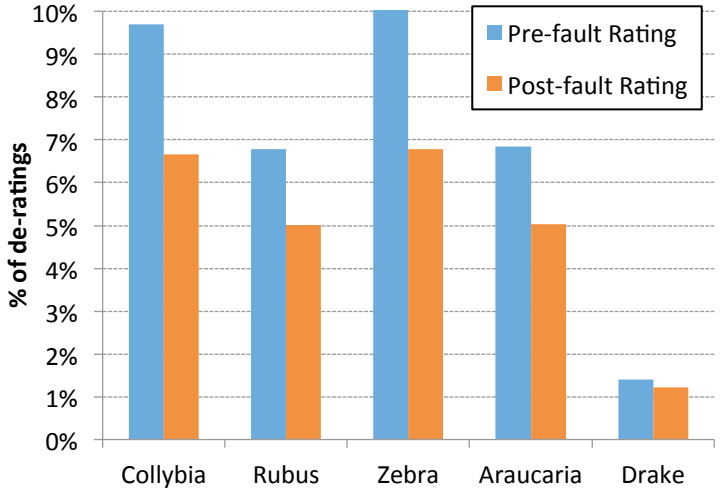
Projected Zebra OHL summer pre-fault ratings in Slough in high emission scenario



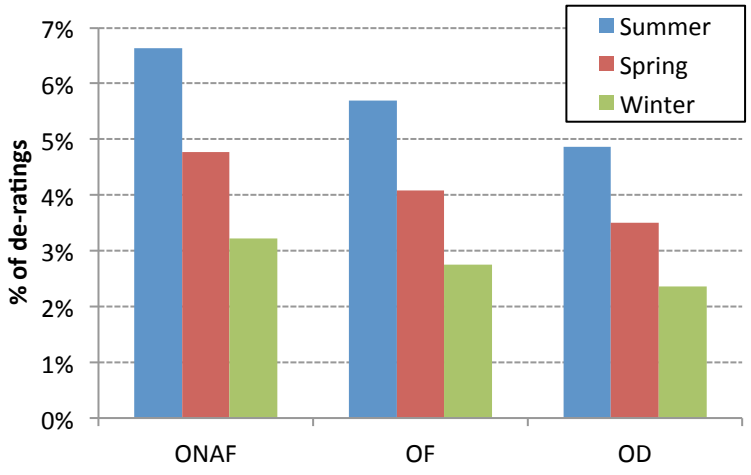
Projected ONAF transformer summer pre-fault ratings in Slough in high emission scenario



Average de-ratings of different types of cables in Slough in 2080s in high emission scenario



Average de-ratings of different types of OHLs in Slough in 2080s in high emission scenario



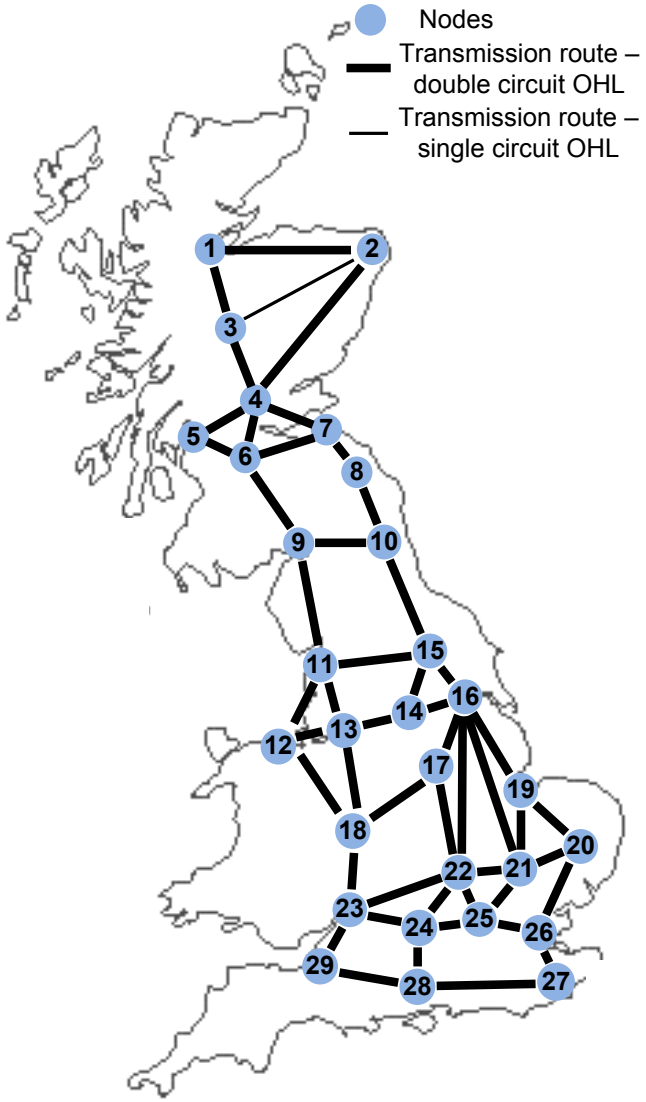
Average de-ratings of different types of transformers in Slough in 2080s in high emission scenario

Transmission network capacity - summary

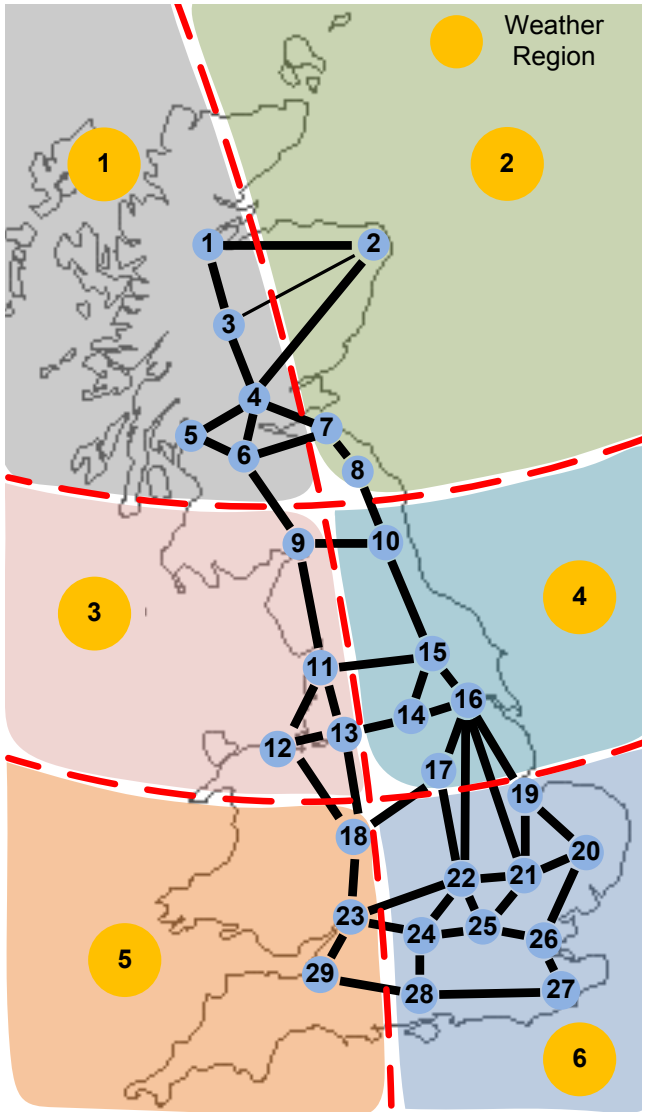
- The impacts of climate change on power system component ratings have been assessed using a probabilistic approach which describes the likelihood of a specific reduction in rating.
- Overhead lines are the most sensitive to climate change among the three components examined with a maximum rating reduction of 27% being possible. The use of high temperature conductors is a straightforward way to mitigate this risk.
- Soil temperatures are expected to increase and this will have a detrimental impact on cable ratings with a 10% reduction being possible. Consideration also needs to be given to cables buried in tunnels that use ambient air for cooling as these are likely to be more vulnerable.
- Transformers may see a rating reduction of just under 17%. This will be accompanied by an accelerated loss of life and is likely to require increased capital investment in new transformer assets. The heat island effect is likely to add to the pressures on transformers.

Integrated modelling of infrastructure resilience – power system model

29-bus GB transmission network



Weather Regions



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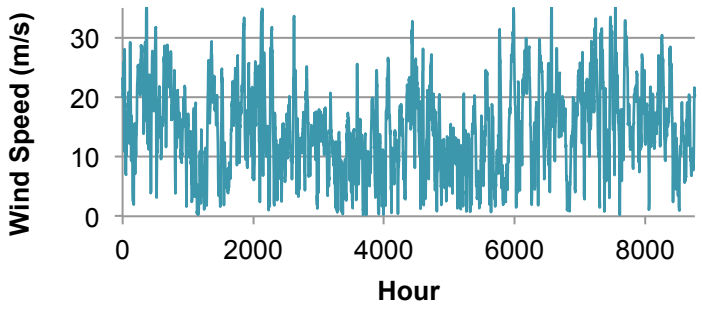
Resilience simulation

Input
- Weather regions
- Hourly Wind profile
- Fragility curves

Simulation:
Obtain the weather-dependent failure probabilities and restoration times of the components

Output
- LOLF (occs./year)
- LOLE (hours/year)
- EENS (MWh/year)

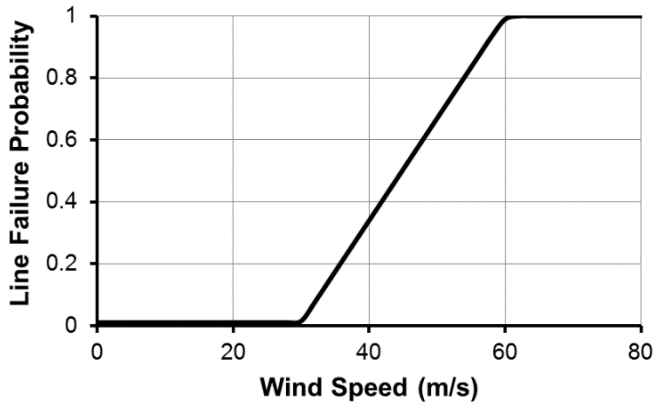


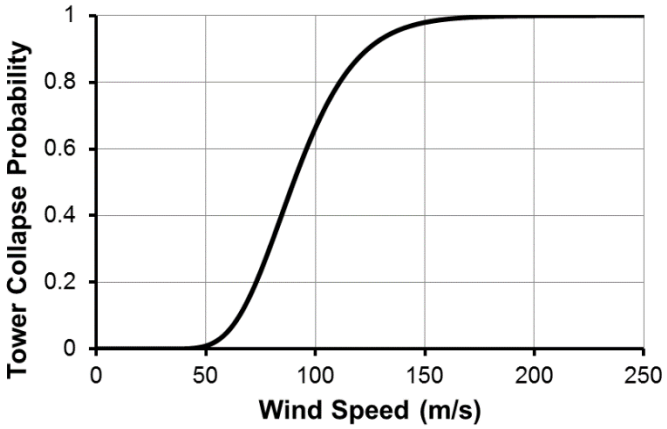
Line failure:

$$F_L(w_i) = \begin{cases} 0, & if\ P_L(w_i) < r \\ 1, & if\ P_L(w_i) > r \end{cases}$$

Tower collapse:

$$F_T(w_i) = \begin{cases} 0, & if\ P_T(w_i) < r \\ 1, & if\ P_T(w_i) > r \end{cases}$$





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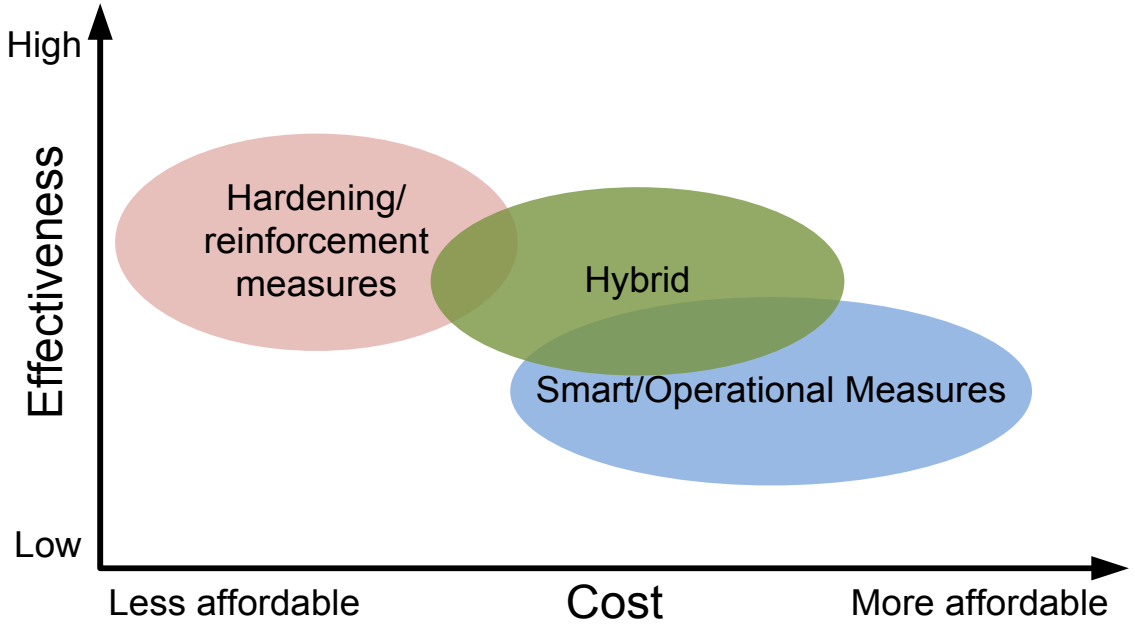
Resilience enhancements



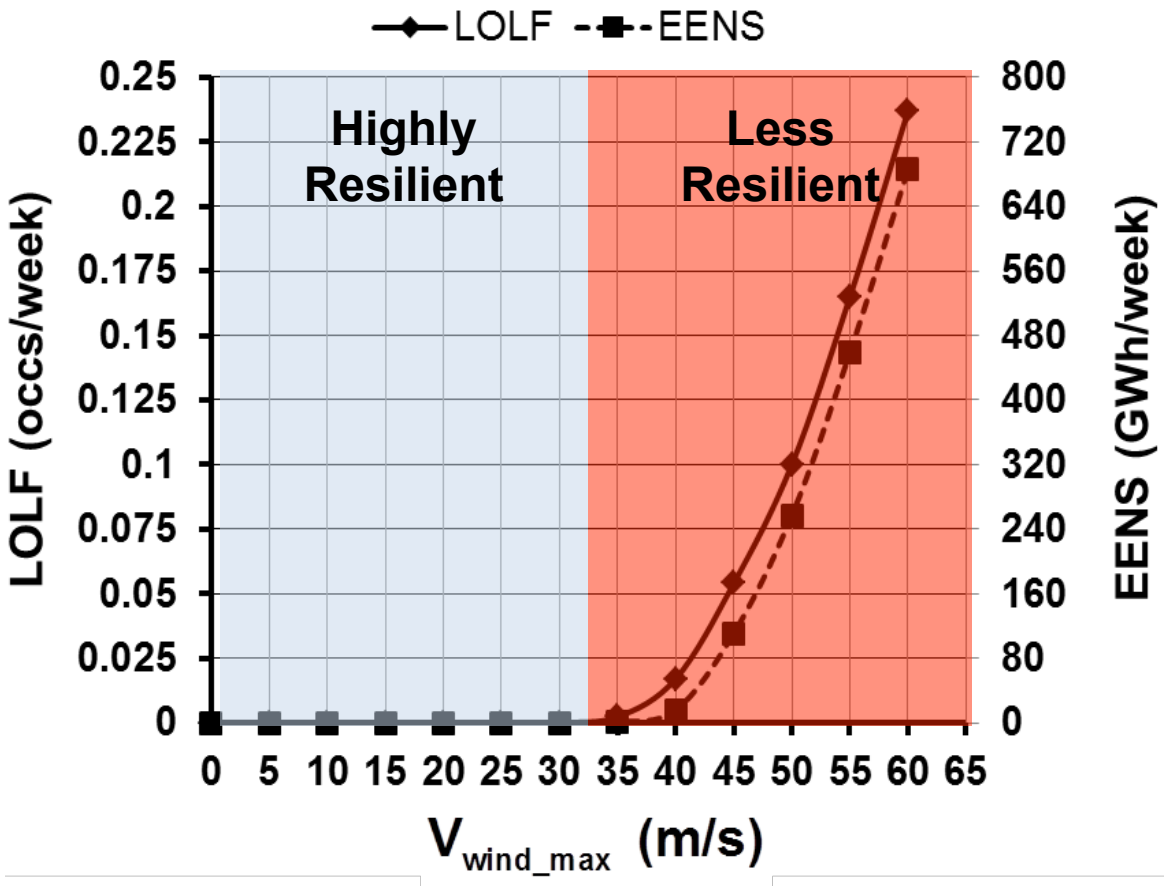
Hardening measures

- Undergrounding lines
- Upgrading components with stronger materials
- Elevating substations and relocating facilities
- Redundant transmission routes
- Re-routing transmission lines

Smart solutions

- Energy storage
- Distribution generation
- Demand side management
- Microgrids
- Advanced control and protection schemes
- Advanced visualization and information systems

Simulation results



Risk-based resilience enhancement

Resilience achievement worth (*RAW*): percentage decrease in LOLF, LOLD or EENS when each component is individually considered 100% reliable

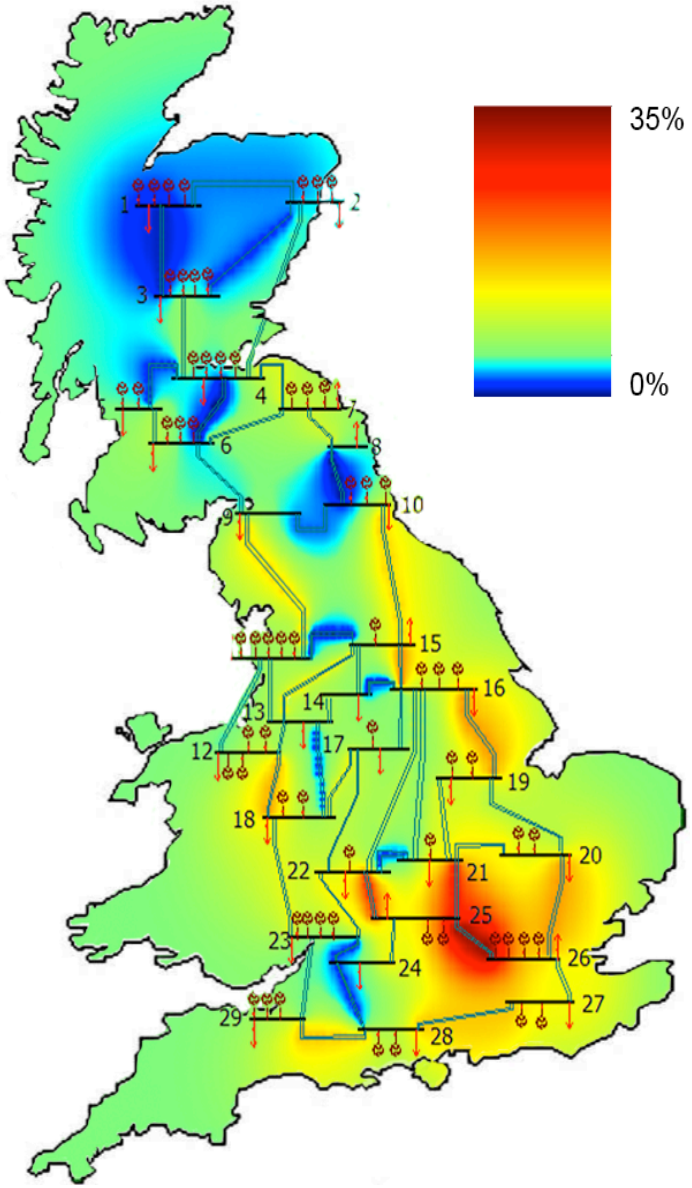
$$RAW = \frac{R_s - R_s(R_n = 1)}{R_s} \times 100$$

Resilience enhancement procedure:

1) Estimate the *RAW* indices of each individual transmission corridor
2) Rank the transmission corridors based on their *RAW* indices (i.e., criticality)
3) Apply resilience enhancement strategies (redundant, robust and responsive)

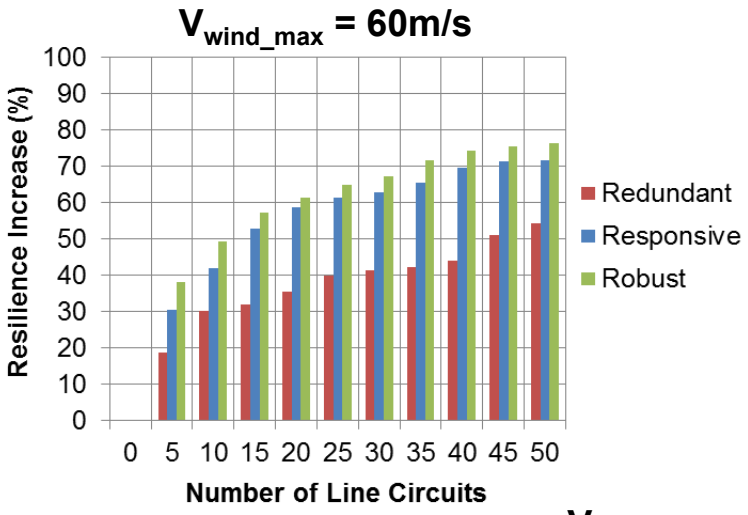
Perform this analysis for different windstorm intensities to determine the criticality of each transmission line under different wind conditions.

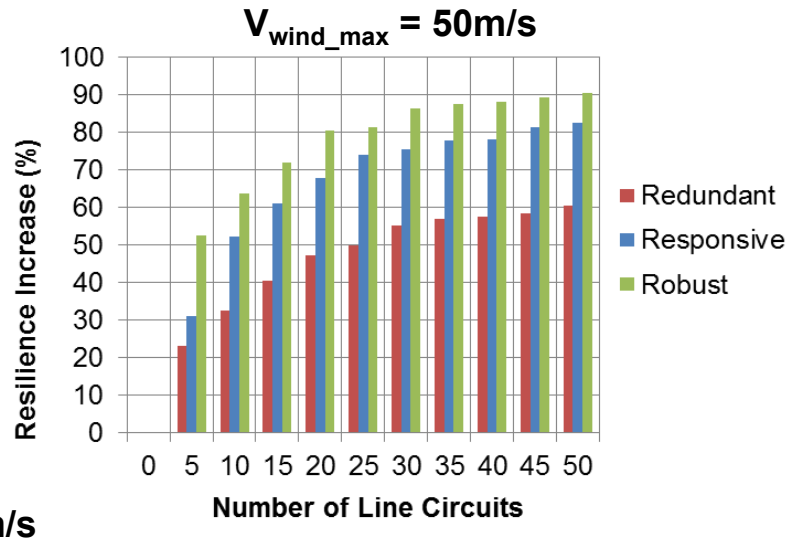
RAW_{EENS} mapping for V_{wind_max} = 40m/s

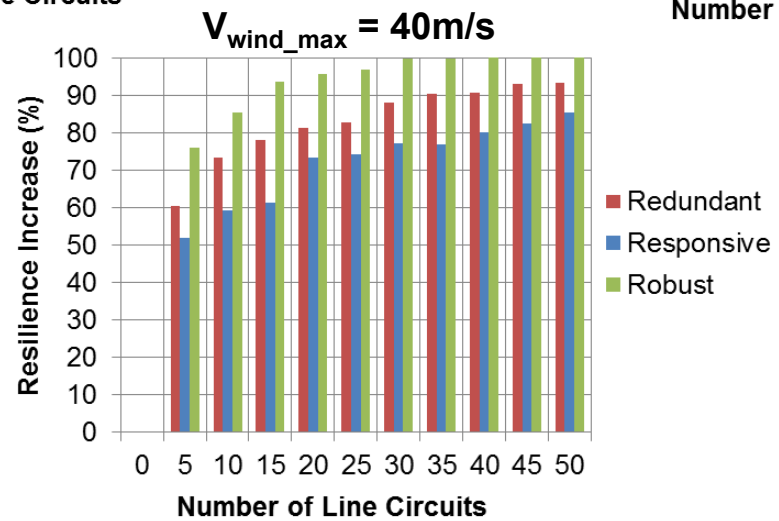


Resilience enhancement results

The resilience enhancement case studies are applied subsequently for ten groups of 5 circuits each based on their RAW indices, i.e. for the first 5 critical circuits, 10, 15 and so on up to 50 circuits that are included in the test network.







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Integrated modelling of infrastructure resilience - summary

- Time-series driven, climate change resiliency assessment model gives in depth understanding of resilience and the ability to develop resilience-oriented power systems
  - » Clear view of critical assets that will cause system vulnerability as we get more extreme wind events
  - » Ensuring our assets are robust is a better choice than redundancy / responsiveness

Social responses to adaptation measures

- What changes in everyday social practices (at the organizational and household levels) are needed to realise resilience and adapt to impacts of climate change upon electricity networks?
- Infrastructure resilience
  - » Interviews with households and organisations to explore responses to and impacts of power outages (n = 19)
- Operational resilience
  - » Focus groups exploring the responses of householders to measures intended to increase the resilience of power networks (n =60)

Household resilience in the event of a power cut

- Designing out resilience – increasing reliance on electricity services
  - Increasing electrification in the home for convenience, comfort and cleanliness
  - Changing norms and lifestyle requirements, e.g. laptops, entertainment and security systems.
- Adapting practices to maintain resilience
  - Importance of material aspects
  - Importance of 'know how'
- Community resilience central to the resilience of households
- Communication

Responses to adaptation measures

- Reducing demand in response to a request
  - » Reluctant acceptance that this can be put up with for 'the greater good'

"these are extraordinary weather conditions and, you know, we do have our regular supply and reserve but there's going to be such a high demand. We're asking you to switch off this, that and the other so everyone gets through this period"

- Rota load disconnection
  - » Limited acceptance – the advance notice would allow people to plan
  - » Widespread negative perceptions

"Well I think, at the end of the day, to start having announcements about power going down at certain times or to use less power, I think sends out a very iffy message about what position we're in as a country."

"Are you telling me Wayne Rooney's house is going to be shut off at any stage? I don't think so."

Social responses to adaptation measures - summary

- Demand side management is a new concept for the majority of the people involved in our research
- Huge concerns over implementation
- Adaptation measures for protecting the network against storms are more readily accepted
- Resilience needs to be considered at multiple scales
  - » Measures to improve the resilience of the electricity network, may reduce the resilience of consumers

RESNET headline messages

- The physical infrastructure is resilient to direct climate change impacts over the coming twenty years, depending on changes in electricity demand
- While higher temperatures will impact transmission capacity, there are a range of measures that can easily mitigate this in the short term.
- The impact of the future wind climate on electricity networks is still uncertain; this is particularly true for wind extremes.
- Increasing levels of intermittent supply will have repercussions for grid operation

RESNET headline messages

- Electrification of heating as well as road transport will place substantial new loads on the grid, with associated implications for societal resilience to interruptions in the electricity supply.
- Widespread adoption of air conditioning within the commercial and domestic sector, would significantly summer electricity demand, potentially shifting peak annual demand from winter to summer before 2030.
- The grid will need very substantial upgrading if the UK is to make the changes necessary to deliver on its 2°C commitments, driven by both rapid increases in electricity demand and the addition of new generating plants.
- RESNET modelling suggests that even very high levels of investment in reinforcing the transmission grid will likely be insufficient to guarantee resilience if increases in extreme weather events are realized through climate change.