Electricity Supply Resilience

Keith Bell
Holder of the *ScottishPower Chair in Future Power Systems*
and a co-Director of the *UK Energy Research Centre*
http://www.strath.ac.uk/staff/bellkeithprof/

All-Energy, Glasgow, May 2023

Events disturbing the electricity system

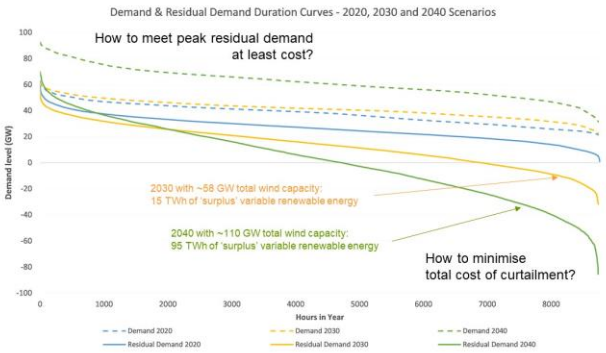


Image: PA
https://inews.co.uk/news/more-than-19000-homes-still-without-power-six-days-after-storm-arwen-1331091

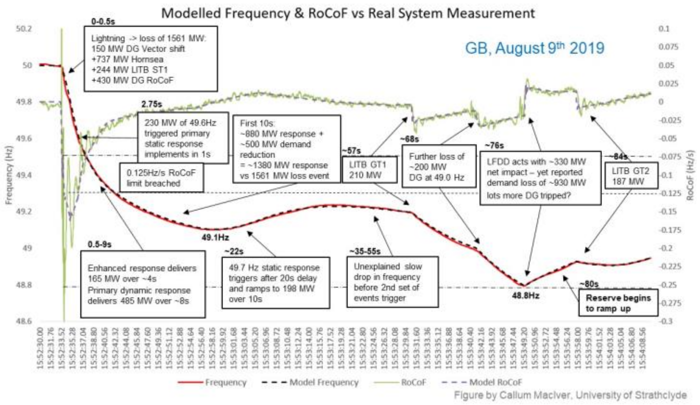
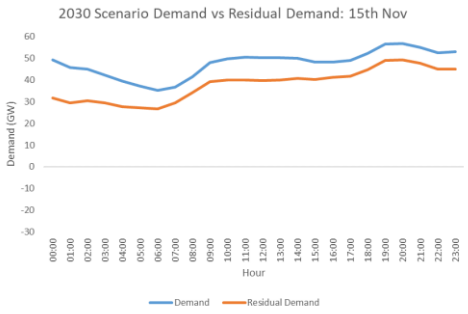
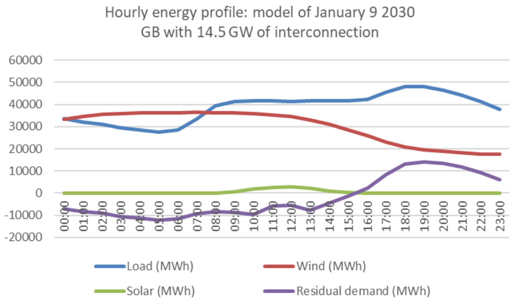


Image: NGESO





Weeks Days Minutes Milliseconds Microseconds

Energy supply

Network resilience

Ramps of residual demand

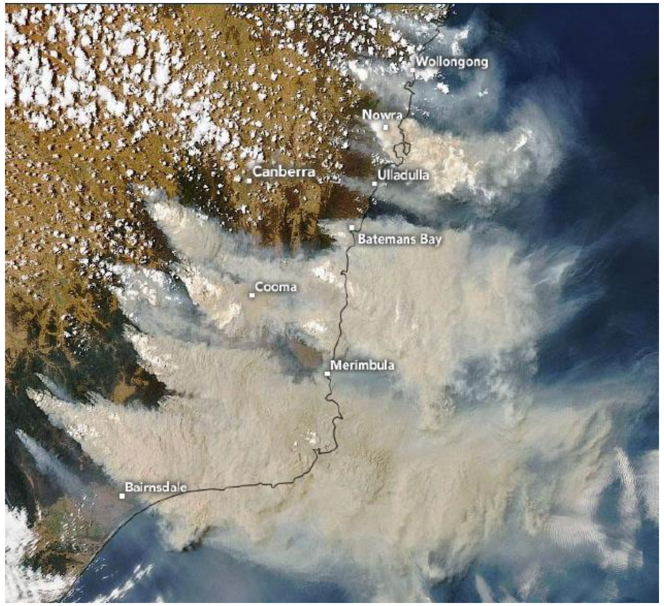
Electromechanical stability

Operation of protection

System stability with inverters

Compound, common mode or correlated events

Impacts of weather, climate change, geopolitics, type faults, …



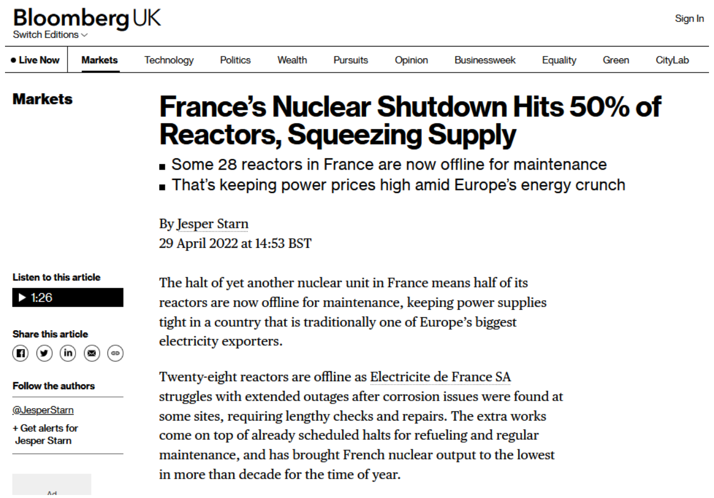
December 2019 and January 2020 ”Black Summer” with bushfires and extreme heat in Australia

- Unexpected temperature derating of wind farms
- Reductions in PV output due to smoke, particulate and voltage fluctuations
- Numerous local distribution and transmission outages
- The separation of NSW and VIC, with frequency excursions
- The later separation of NSW and QLD

Image: PA
https://inews.co.uk/news/more-than-19000-homes-still-without-power-six-days-after-storm-arwen-1331091

Storm Arwen, late November 2021

- Severe weather in the UK, winds reaching up to 98 mph (158 km/h) in some areas
- Approximately 40,000 customers were without supply for more than three days
- Nearly 4,000 customers were off supply for over a week.



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Markets

France’s Nuclear Shutdown Hits 50% of Reactors, Squeezing Supply

- Some 28 reactors in France are now offline for maintenance
- That’s keeping power prices high amid Europe’s energy crunch

By Jesper Starn
29 April 2022 at 14:53 BST

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The halt of yet another nuclear unit in France means half of its reactors are now offline for maintenance, keeping power supplies tight in a country that is traditionally one of Europe’s biggest electricity exporters.

Twenty-eight reactors are offline as Electricite de France SA struggles with extended outages after corrosion issues were found at some sites, requiring lengthy checks and repairs. The extra works come on top of already scheduled halts for refueling and regular maintenance, and has brought French nuclear output to the lowest in more than decade for the time of year.

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Gazprom

Nord Stream 1: Gazprom announces indefinite shutdown of pipeline

Russian energy company had been due to resume gas delivery to Germany on Saturday morning

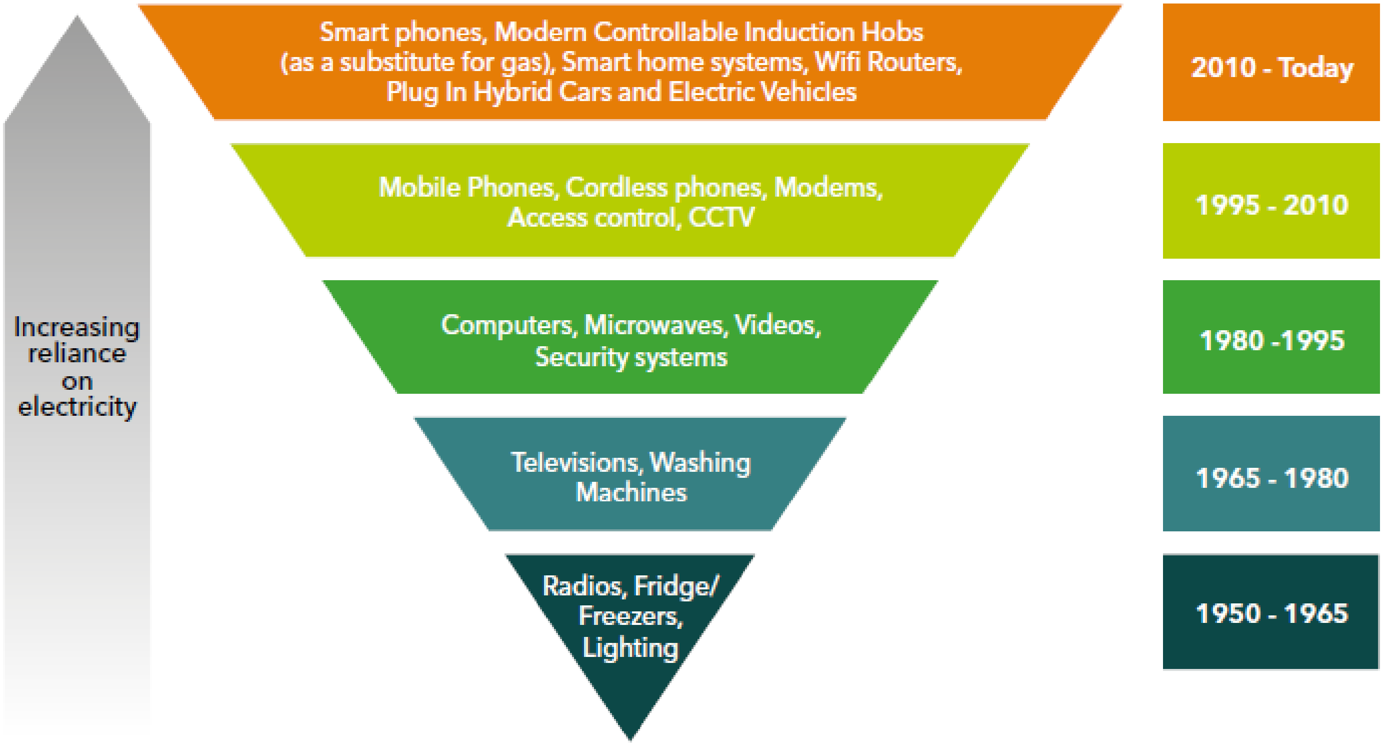
Alex Lawson and agencies

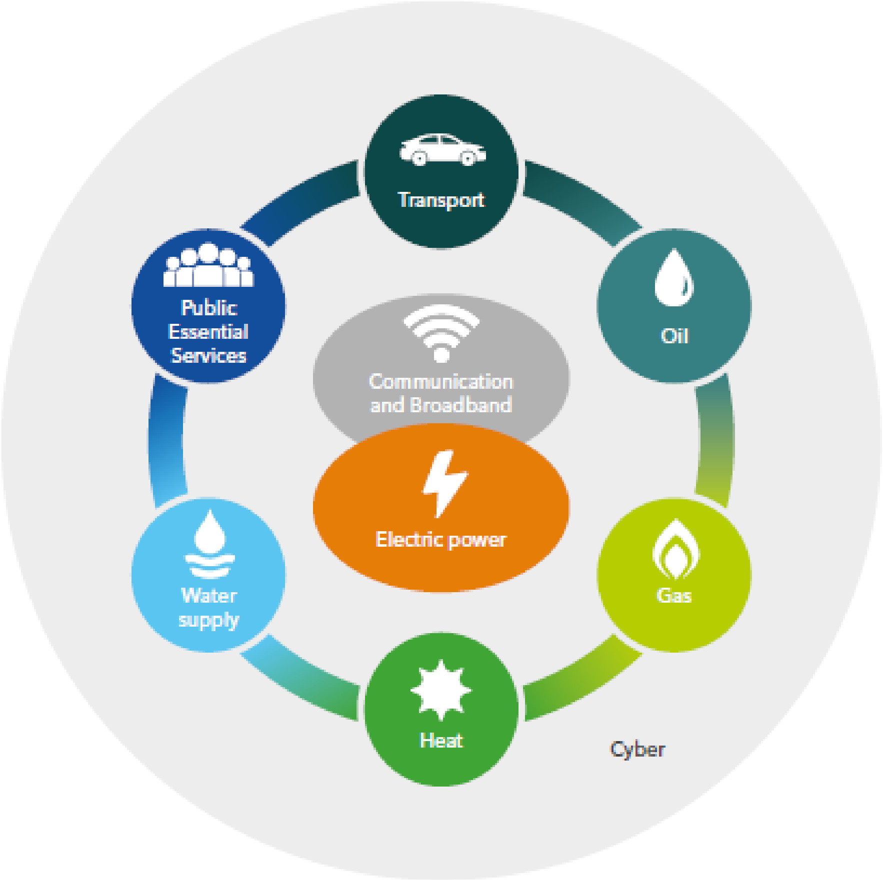
The Nord Stream 1 gas pipeline in Lubmin, Germany. Photograph: Hannibal Hanschke/Reuters

The Russian energy major Gazprom extended the shutdown of gas flows through its key Nord Stream 1 pipeline to Germany on Friday evening, providing no timeframe for a reopening.

The critical importance of electricity

University of Strathclyde Engineering





Figures: https://erpuk.org/project/future-resilience-of-the-uk-electricity-system/

Surviving disturbances

Resilience

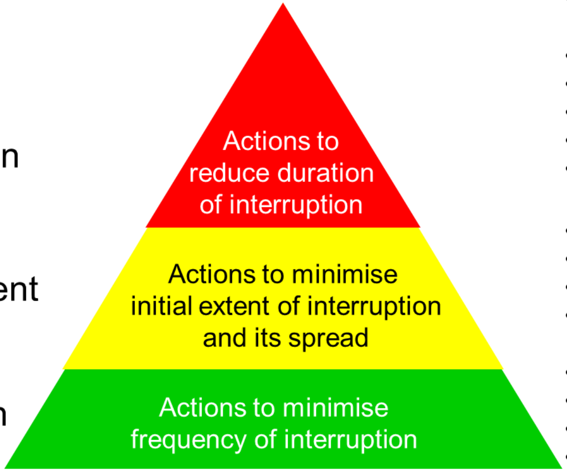
Prevention of
Containment of
Recovery from

interruptions to supply

Restoration

Containment

Prevention



Measure

- Defence plan
- Special protection scheme
- Restoration plan
- Online security management
- …

- Defence plan
- Special protection scheme
- Online security management
- …

- Planning policy
- Maintenance policy
- Online security management
- Power system analysis
- Telecommunications
- …

- Is there enough generation to meet demand?
  - Can it respond quickly enough?
- Is there enough network capacity to get power from generators to demand?
- Is the system resilient against the changing climate?
- *How does the system respond to unplanned changes, e.g. faults?*
  - Are the generation and network responses (protection, reactive compensation, UFLS, …) coordinated well?
  - Frequency and size of supply interruptions?
  - Speed of restoration of interrupted demand?
  - Can the system perform a black start?
  - What happens to energy users in the meantime?

See CIGRE WG C1.17, "Planning to Manage Power Interruption Events", Technical Brochure 433, CIGRE, Paris, October 2010

Disturbances and ensuring resilience

University of Strathclyde Engineering

The power system

Resilience

Design of
- Primary equipment
- Monitoring, protection and control equipment
- ICT systems
- The power system

Investment in
- Primary equipment
- Monitoring, protection and control equipment
- ICT systems
- The power system

Processes and structures
- Construction
- Maintenance & repair
- Planning & investment
- Operation
- Stakeholder relations

Reliability

- Quantification of probability of preventing adverse outcomes
- Operational rules for prevention & containment of adverse outcomes

Prevention of adverse outcomes

Containment of adverse outcomes

Recovery from adverse outcomes

Everything that a power system utility does
- A network owner?
- A system operator?
- Generators?
- Owners of loads?
- Retailers?

Need for codes and standards to govern the relationships?

Disturbances

System users' actions

Actions of malicious actors

Policy makers' actions

Equipment failure

Weather

The natural environment

Society, technology and the economy

Climate

Who is responsible for supporting energy users in the event of loss of grid?

Our panel

Cara Labuschagne	Lead Analyst - Resilient Infrastructure, *Climate Change Committee*
Niall McDonald	Chief Engineer, *Ofgem*
Lissa Stewart	Head of Operations support, Resilience Division, *Scottish Government*
Scott Mathieson	Network Planning & Regulation Director, *SP Energy Networks*
Nick Winser	Commissioner, *National Infrastructure Commission*

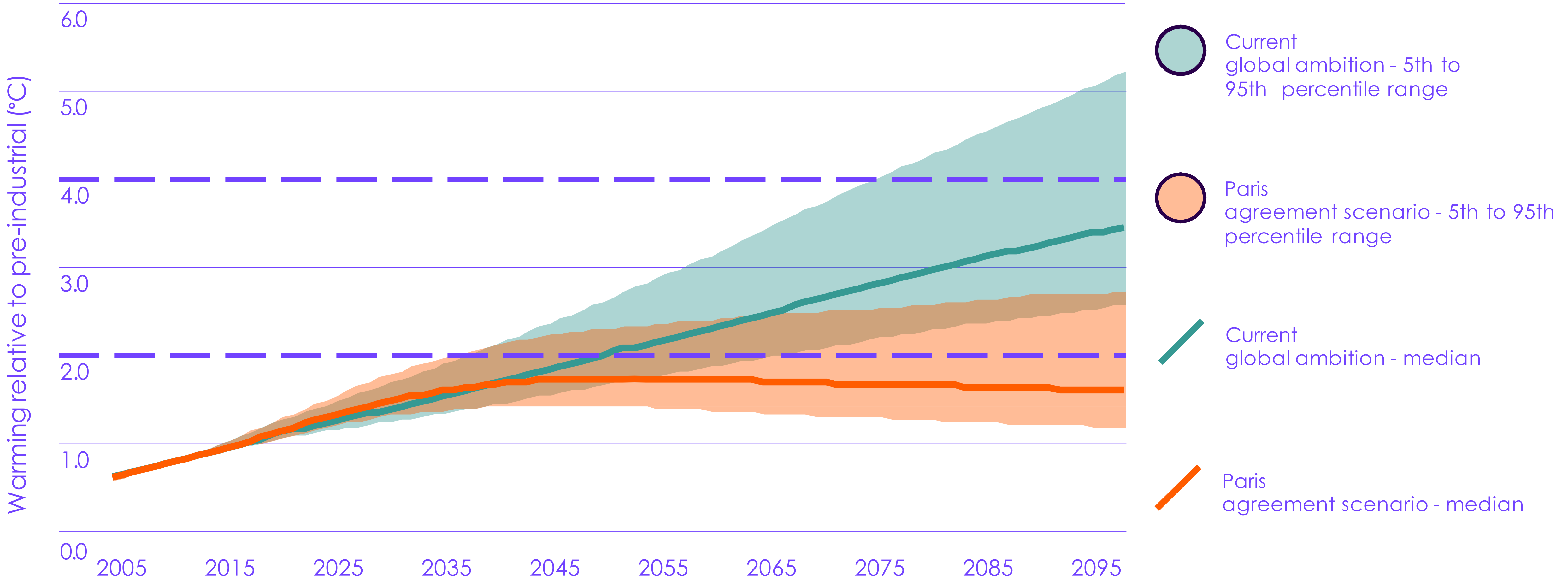
10th May 2023

Climate change impacts on the electricity system

Cara Labuschagne

Our climate is changing

Projected changes in global mean annual surface temperature compared to 1850-1900



Climate Change Committee

Source
CCC Analysis

Bringing changes to a number of critical hazards

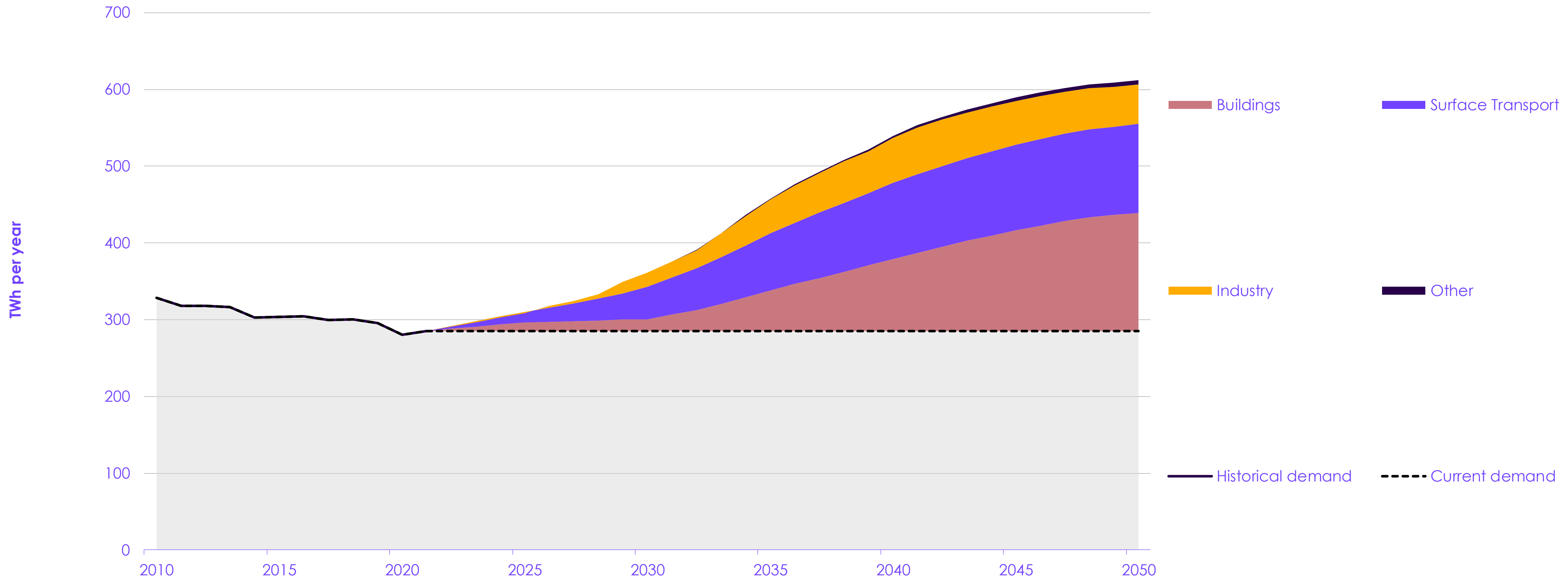
Observed and projected changes in UK hazards due to climate change

	Observed change	Expected change by mid-century	2°C global warming by the end of the century	4°C global warming by the end of the century
Average annual UK temperatures	**0.6°C** from 1981 - 2000	**~1.3°C** from 1981 - 2000	**~1.5°C** from 1981 - 2000	**~3°C** from 1981 – 2000
Hot summer occurrence – '2018 summer'	**10 – 25%** chance each year	**~50%** chance each year	**~50%** chance each year	**>>50%** chance each year
Average summer rainfall	**0** no significant long-term trend	**~10%** drier than over 1981 - 2000	**~15%** drier than over 1981 - 2000	**~30%** drier than over 1981 - 2000
Average winter rainfall	**0** no significant long-term trend	**~5%** wetter than over 1981 - 2000	**~5%** wetter than over 1981 - 2000	**~20%** wetter than over 1981 - 2000
Heavy rainfall	**0** some increase, but not significant long-term trend	**~10%** increase	**~20%** increase	**~50%** increase
Sea level rise	**~6.5cm** above 1981 – 2000	**10 – 30cm** above 1981 – 2000	**25 – 45cm** above 1981 – 2000	**55 – 80cm** above 1981 – 2000

Source
UKCP18 projections

Demand side impacts

50% increase in electricity demand by 2035 and a doubling in electricity demand by 2050



Climate Change Committee

Source
BEIS (2022) Energy Trends; CCC (2020) The Sixth Carbon Budget

Supply side impacts

The risk of extreme weather events is increasing

Climate hazard	Expected change by 2050	Potential impacts	
		Generation	Transmission & distribution
Heatwaves	~50% chance of 2018 summer each year (around 10-25% currently)	Efficiency loss at thermal generation plants Higher demand for electricity for cooling meaning more generation required Maximum operating temperatures for components exceeded	Efficiency loss on transmission lines at high temperature Restrictions of thermal ratings of assets
Flooding (river, surface and coastal)	~5% wetter winters on average (compared to 1981-2000) ~10% increased intensity of heavy rainfall 10 – 30 cm increase in average sea levels (above 1981-2000 levels)	Loss of generation capacity due to inundation	Loss of transmission & distribution capacity due to flood damage
Drought	~10% drier summers on average (than over 1981 – 2000)	Loss of generation capacity due to lack of water supply for cooling or other production processes	-

Climate Change Committee

Source
UKCP18 Projections; summarised in CCC (2021) Independent Assessment of UK Climate Risk

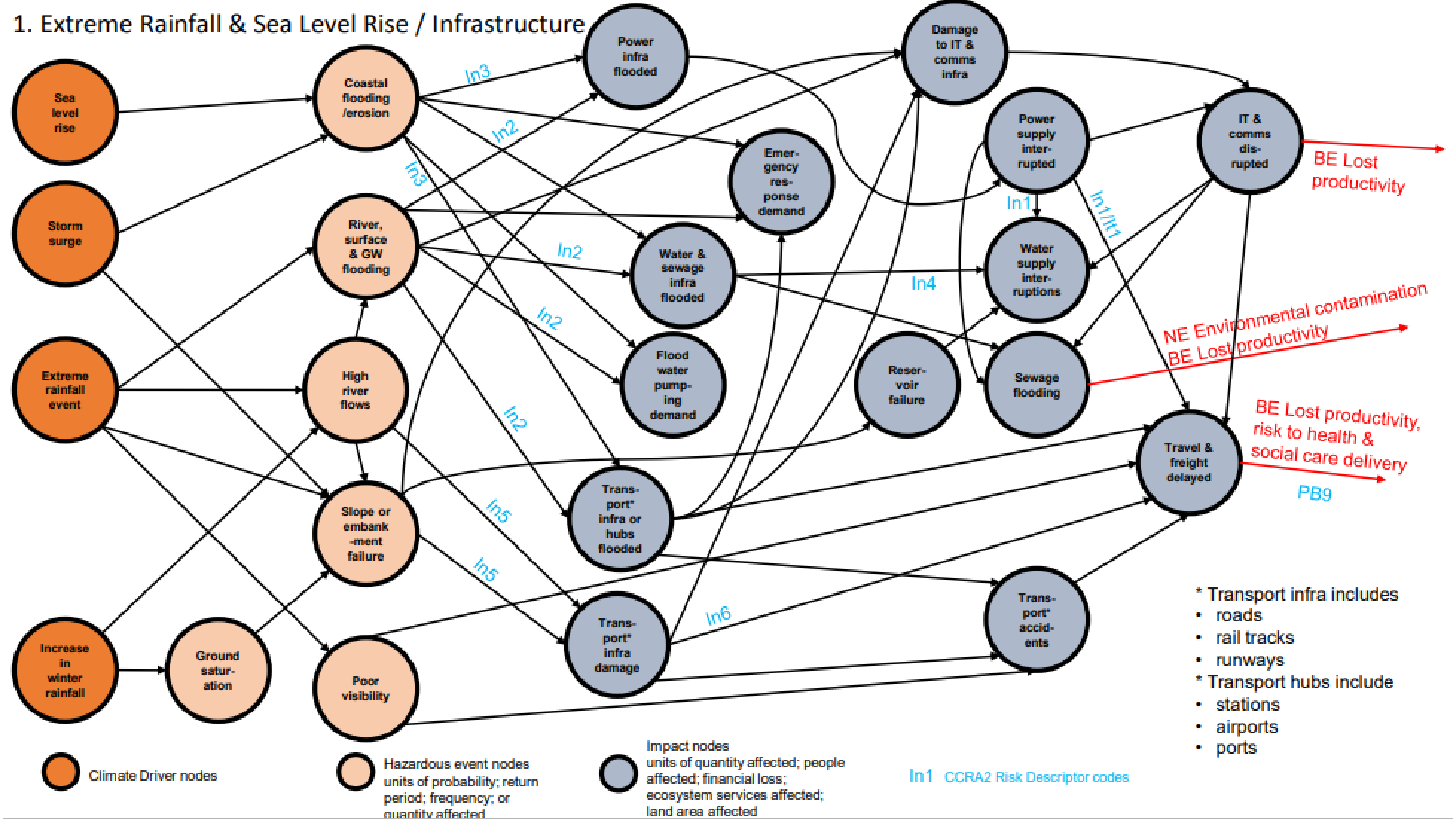
Supply side impacts

For some critical hazards, future impacts remain uncertain

Climate hazard	Expected change by 2050	Potential impacts	
		Generation	Transmission & distribution
Wind strength and wind regimes	Highly uncertain	Potential large-scale and coordinated loss of wind generation during wind droughts Potential large-scale and coordinated loss of wind generation during high wind speed shutdown of turbines	Loss of network capacity due to damage in high winds
Storminess and occurrence of storm events	Highly uncertain	Loss of generation capacity due to damage during storm events Potential large-scale and coordinated loss of wind generation during high wind speed shutdown of turbines	Loss of network capacity due to damage in storm events

Source
UKCP18 Projections; summarised in CCC (2021) Independent Assessment of UK Climate Risk

1. Extreme Rainfall & Sea Level Rise / Infrastructure



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Source
WSP (2020) Interacting risks in infrastructure and the built and natural environments

The solutions are clear and actionable

We need to design and build the future energy system so that it can continue to operate under these changing conditions

- Future climate impacts must be reflected in site selection and design, as well as in maintenance and life extension of existing assets.

- Minimum resilience standards are needed to enable this, covering regulated parties and all relevant climate hazards identified in the UK Climate Change Risk Assessment (CCRA).

- Changes in demand due to climate change need to be factored into future planning.

- Changes in weather hazards which remain uncertain are challenging but need to be planned for, such as wind droughts and the implications of reduced water availability.

- Further research is needed to improve understanding of how climate change will alter key weather hazards that will impact the energy system. A more systematic assessment of risks posed from cascading impacts due to failures of the energy system is also needed.

- Key enablers to achieve these outcomes include clearer governance remits for resilience, better indicators and incorporation of resilience into Net Zero investment decisions.