Tyndall°Centre
for Climate Change Research

Critical Decade for Climate Action Conference: Session 9

Achieving resilient net zero

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Respondents: Suraje Dessai, Claire Hoolohan and Rob Wilby
Rapporteur: Anowyesha Dash
Chair: Ruth Wood

Climate change impacts on low carbon electricity in the UK

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Dr Hannah Bloomfield

Outline

1. Introduction & context
2. Overview of Climate Risks & Impacts on Supply, Network and Demand
3. How impacts manifest? Two UK Case studies
4. Representation of Users, People, and Society within impact assessments
5. How Climate Extremes are captured in evaluations
6. Compound events and cascading Impacts
7. Existing research gaps and challenges
8. Conclusions & Recommendations

Introduction & Context

A decarbonised electricity system is central to delivering Net Zero, characterised by:

- ✓ Generation: Significant portion of variable renewables (wind, Solar)
- ✓ New demands: Heat pumps, Electric vehicles, hydrogen production, desalination

Climate change impacts on generation, network, and demand are already visible & users are vulnerable to power loss.

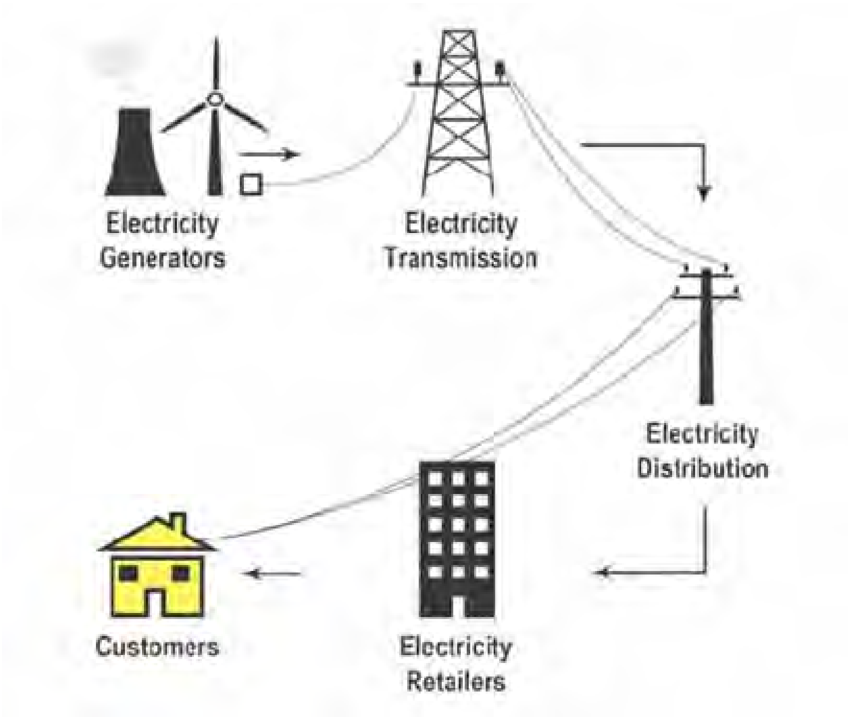
Net Zero strategies bring new levels of vulnerability due to the criticality of power supply to end-users

Context: UK electricity system setup

Impact assessments vary for stakeholders.

Department for Energy Security & Net Zero

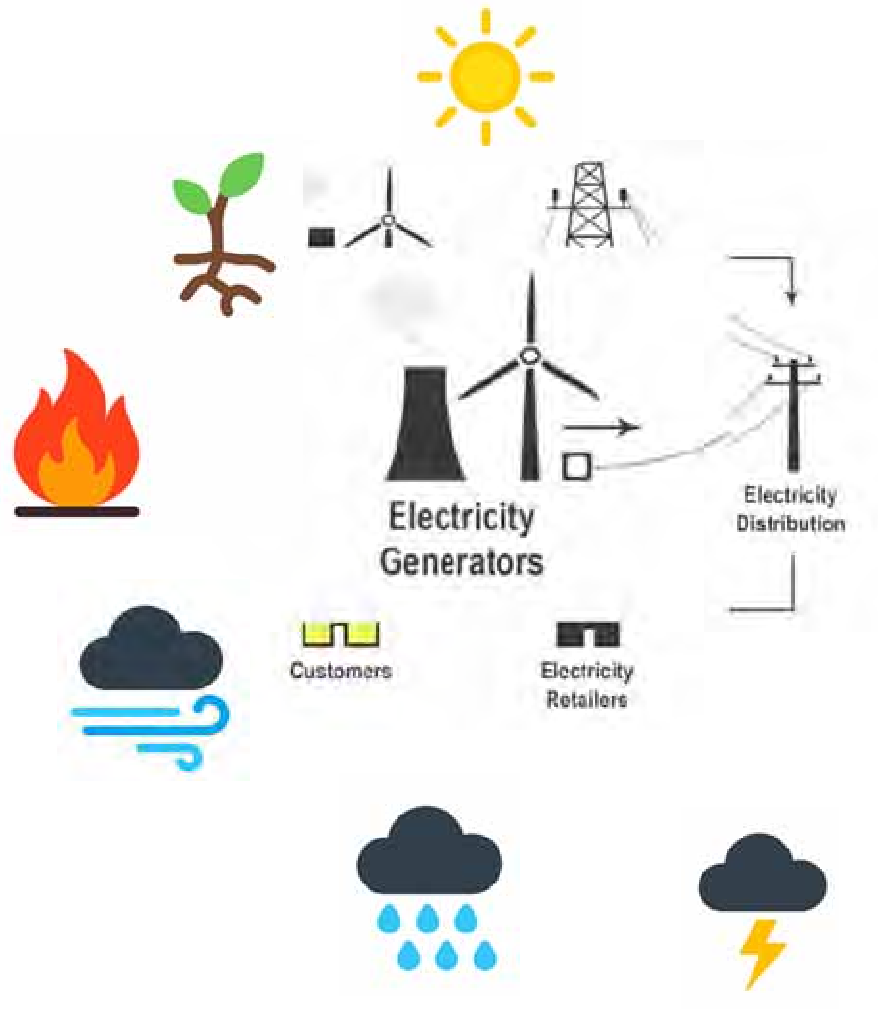
ofgem



NESO National Energy System Operator

ELEXON

Power generation technologies



Climate Risks

- Physical damages to the structure/ equipment.
  (e.g. turbine foundation, solar panels)

- Changes in daily output
  (e.g. drop in efficiency for solar, thermal, hydrogen production)

- Changes in seasonal outputs
  (Reduced wind power generation in summer & autumn. Increased solar power generation in summer due to reduced cloud cover)

Impacts

- Changes in revenue and losses for generators;
- Balancing challenges for the system operator.
- Focus of impact studies: changes in annual output, potential duration of outages from individual technologies.

Electricity end-use technologies





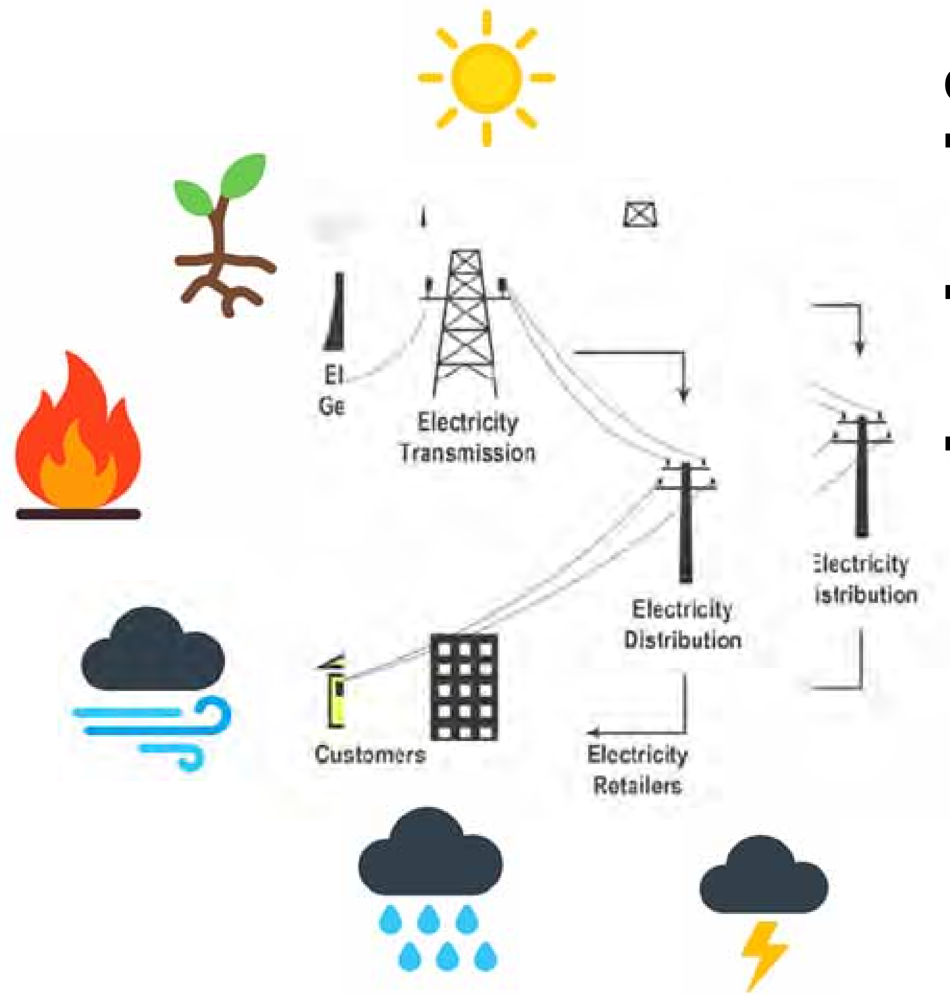

Climate Risks

- Reduced annual heating demand; Peak heating demand same.
- Increased demand for cooling (afternoons& overnight)
- Reduced performance of batteries decreases mileage for EVs
- Demand Flexibility market during extreme events likely to fail.

Impacts

- Increases overall electricity demand during extreme heat
- Focus of impact studies: Changes in demand but lacks heterogeneity of different users.

Power network



Climate Risks

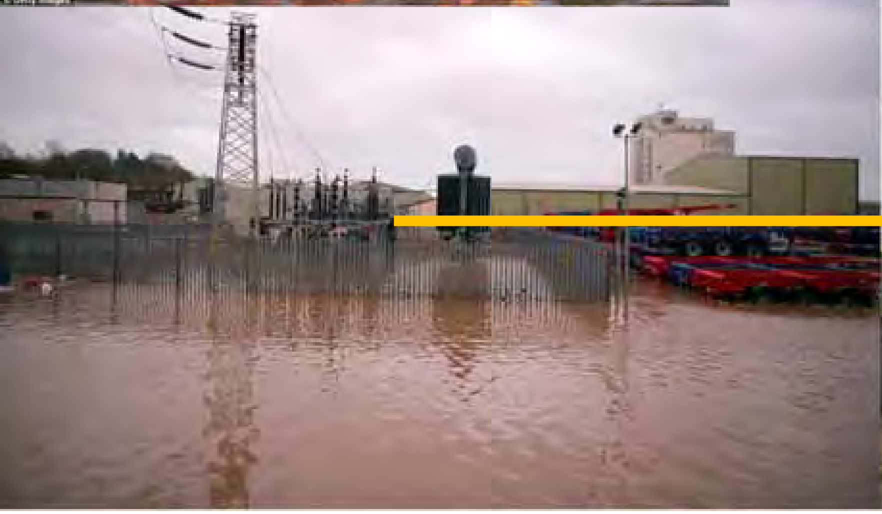
- Damage to infrastructure/ failure of equipment
  (Poles, substations, foundations, line sagging etc.)
- Power carrying capacity of cables get reduced
  (derating of UG cables/OH lines from drought/ extreme heat)
- Reduced equipment lifespan
  (e.g. transformers, switchgears from extreme heat)

Impacts

- Increased operational costs;
- Potential increase in demand restrictions and outages
- Focus of Impact studies: Estimate failure rates under different climate projections.

Storm Desmond 2015 (highest level of rainfall ever in the UK)

Mass floods in Lancaster, after defences on the River Lune that were **designed to withstand a 1-in-100 years flood** were breached (55,000 people were left without power).



Storm Arwen 2021 (98mph winds)

- Sustained winds with gusts >90 mph, from the north-east (unusual), affected trees that do not normally have to yield to those winds, damaged network (40,000 customers no supply for >3 days).

- Saturated ground from heavy rain loosens tree roots, making them more vulnerable to strong winds, especially in areas with clay soil.

- A small proportion of damage was caused by ice accretion in higher areas.

https://www.bbc.co.uk/news/uk-england-61744518

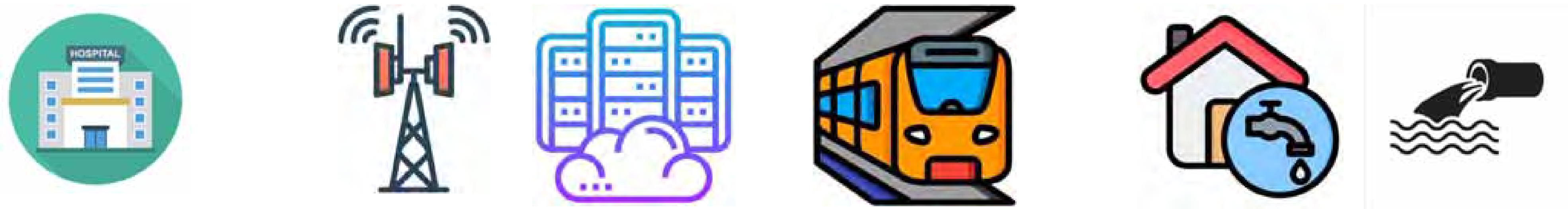
Chopped up furniture to fuel clay stove
https://www.bbc.co.uk/news/uk-england-tyne-59456973



Representation of Users, People, and Society

Electricity users are diverse:

“Critical” service providers: *some but not all have higher levels of protection from power outages*



Business and industry: offices, factories, data centres, supermarkets and more

Domestic: city vs rural, high rise vs low rise, high vs low adaptive capacity

Impacts of power cuts and restrictions are also diverse, and unequally distributed

(elderly, disabled, low-income groups, medical eqpt, social isolation, etc)

Need for improved understanding of the broader societal consequences from both power cuts and their interruptions to wider services. (e.g. social vulnerability indices in impact assessment)

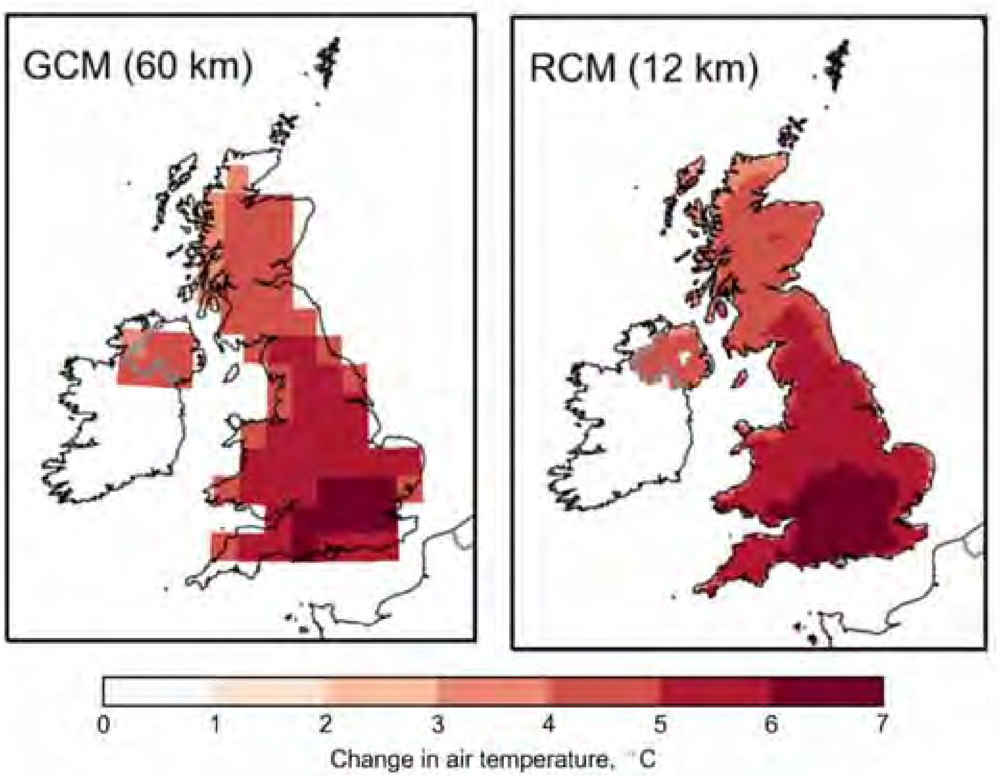
Climate impacts on end-users

- Limited understanding of how climate change and power outages affect customers across diverse settings.
- Extreme events, rather than average changes in weather causes the damage & impact
- Reliability concerns may shape public response to adoption of low-carbon technologies such as Heat Pumps and Electric Vehicles.
- An unadapted / non-resilient power supply could drive negative public sentiment toward climate action.
- **Responsibility for resilience:** where responsibility lies— providers, policymakers, or consumers?

What tools do we have to capture climate extremes?

'Best' for long-term energy system planning

Many years of data, but relatively coarse resolution. Can get to extreme return periods or HILP events.



'Best' for asset level resilience assessment and renewable resource siting.

Better representation of key surface weather conditions. But limited data volumes.

Limitations & Gaps

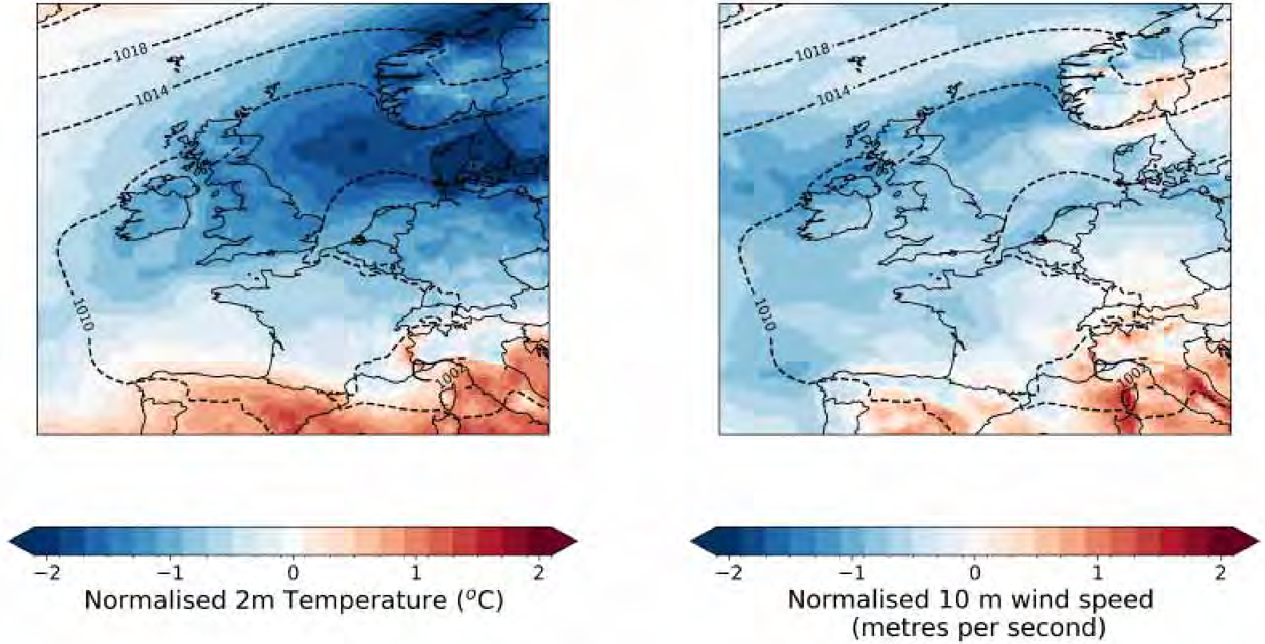
- Extremes often **underrepresented or simplified** in energy assessments.
- Most studies are focussed on **mean climate changes**, with less attention on **tail risk(s)**.

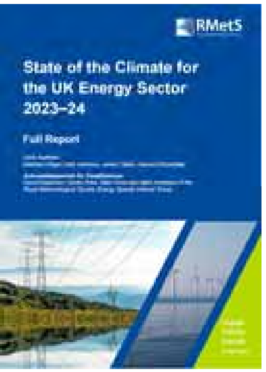
Source: https://www.carbonbrief.org/in-depth-qa-the-uk-climate-projections-2018/

Compound events

Energy system security of supply

- **Low wind cold snaps:** Winter high demand and low renewable generatio
- **Key metric(s):** LOLE, LOLP, electricity price.
- Example 21st Nov –3rd Dec 2023
- Extensively studied in historical climate!
- Hard to do in the future due to uncertainty in wind speed projection ai challenges modelling future demand (more cooling and less heating)





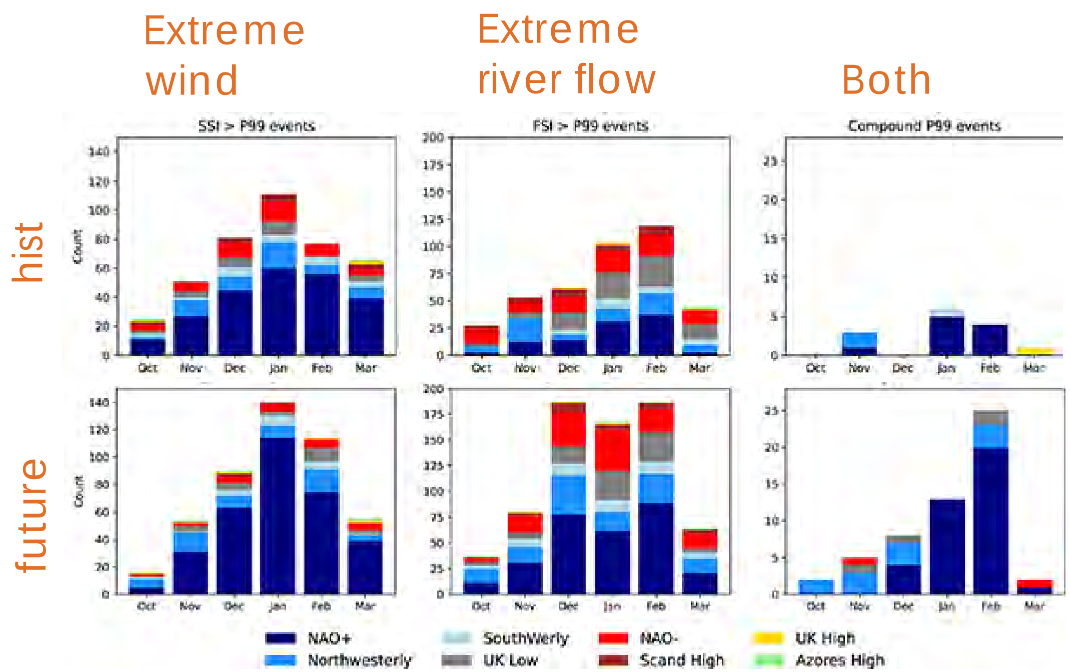
Similar problems in summer in a future climate when we have a summer-peaking demand from air conditioning.

Excess renewables will also become a problem in future energy systems

Compound events

Energy system operations:

- **Compound wind and flood risk:** if a compound event, then a lower threshold for each hazard is required for an impact.
- **Storm Surge + Heavy Rain** → compound flooding at coastal substations & infrastructure
- **Heat + Drought** → cooling water shortages + high electricity demand; reduced hydro output.
- **Key metric:** customer minutes lost.
- Much less well studied from an energy systems perspective. But lots of interest of users!

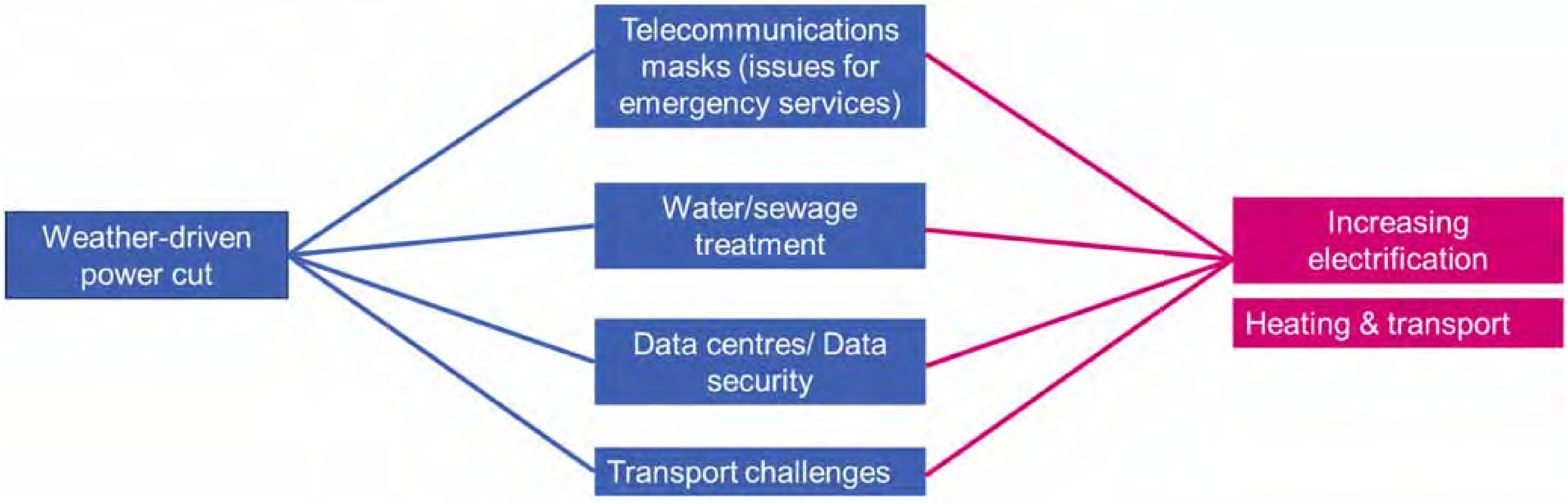


Bloomfield et al., (2024)

Increasing numbers of problems in a future climate when we have more of the extreme events.

Cascading events

- Cross-sector cascades: power → telecoms/water/transport are very understudied.
- These sector-level models don't easily communicate with each other.



Sectors become increasingly connected if we move towards hydrogen electrolysis (needs a lot of water!)

Existing research gaps and challenges

Key Gaps

- Limited integration of **compound & cascading extremes** → reliance on single-hazard studies.
- Understudied **cascading socio-economic impacts** (equity, skills, labour, affordability).
- Weak representation of **user behaviour & social vulnerability** in system models.

Technical & Data Challenges

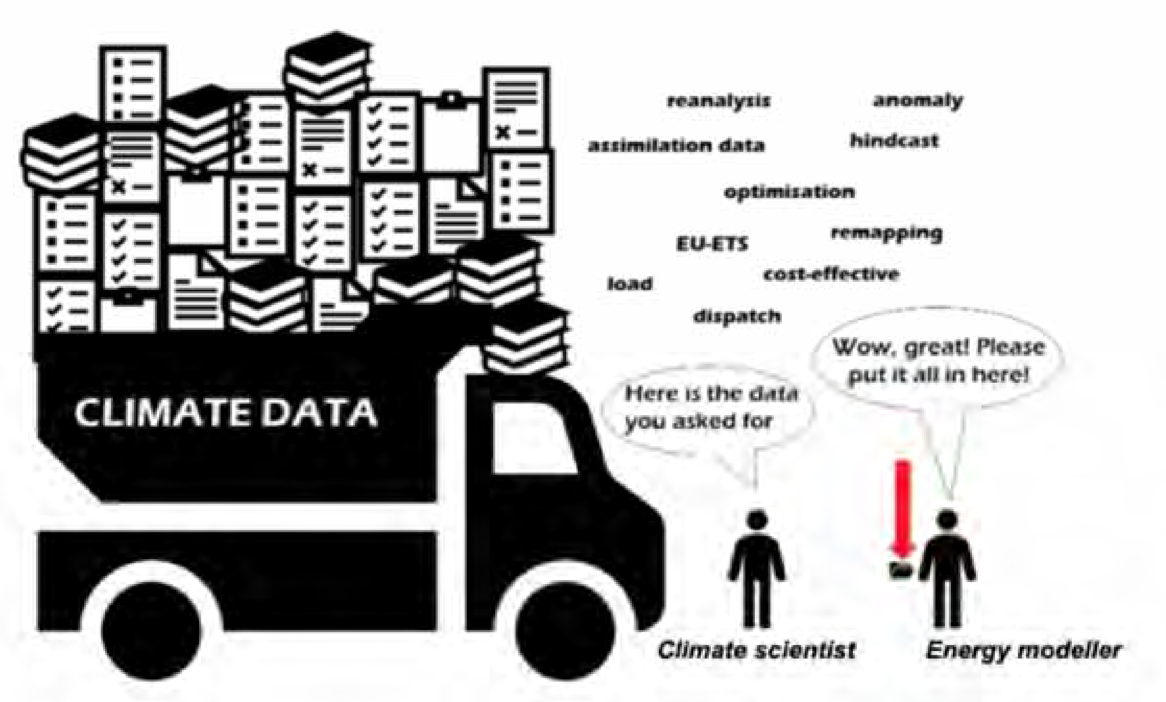
- **Spatially coherent extremes** for power system stability & market simulations.
- Need **open fragility libraries** for UK assets; limited validation with fault/outage data?
- Data governance barriers: asset locations, incident logs, curtailment/balancing transparency.
- Scaling: linking **local hazard detail** to **national system models?**
- Cost Benefit Analyses of adaptation and resilience measures

Opportunities & Emerging Frameworks

- Greater integration of **social science**: equity metrics, health outcomes, demand flexibility.
- Real-time **decision-support tools** for adaptation and emergency planning.

Existing research gaps and challenges

- There are very **few specialists** in climate data AND energy modelling AND social science.
- One discipline can't physically model the whole cascade of impacts.
- We need to **collaborate** to solve these very interdisciplinary problems.



Bloomfield et al., (2021)

Conclusions and Recommendations

Evolving power systems: The shift to net-zero **increases the weather-dependence** on both supply and demand.

Climate hazards are intensifying: The frequency and severity of **extreme weather** events is increasingly affecting the UK electricity across supply, networks, and demand.

These challenges will **cascade** through to other sectors that are increasingly reliant on electricity (e.g. transport sector).

We have a lot of tools available to model these climate risks. It is very important that the right climate data is used for the task in hand (e.g. exploring the **trade-off between run length and spatial/temporal resolution**).

Collaboration is essential between climate scientists and energy modellers to understand the climate resilience of the power sector both now and in the future.

Better understanding of what is needed or what the system must withstand, and how **responsibility of resilience** should be shared across providers, policymakers, and consumers.

Power network resilience has significant implications for people, society and the economy.

The success of Net Zero depends on a climate resilient power network.

Thank you

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DARe

National Hub for Decarbonised, Adaptable, and Resilient Transport Infrastructures

Climate Impacts on Low Carbon Transport

Tyndall Centre 25th Birthday Party

9th September 2025

Dr Alistair Ford (Newcastle University)

Department for Transport

UK Research and Innovation

Engineering and Physical Sciences Research Council

About DARe

The UK National Hub for Decarbonised, Adaptable, and Resilience Transport Infrastructure

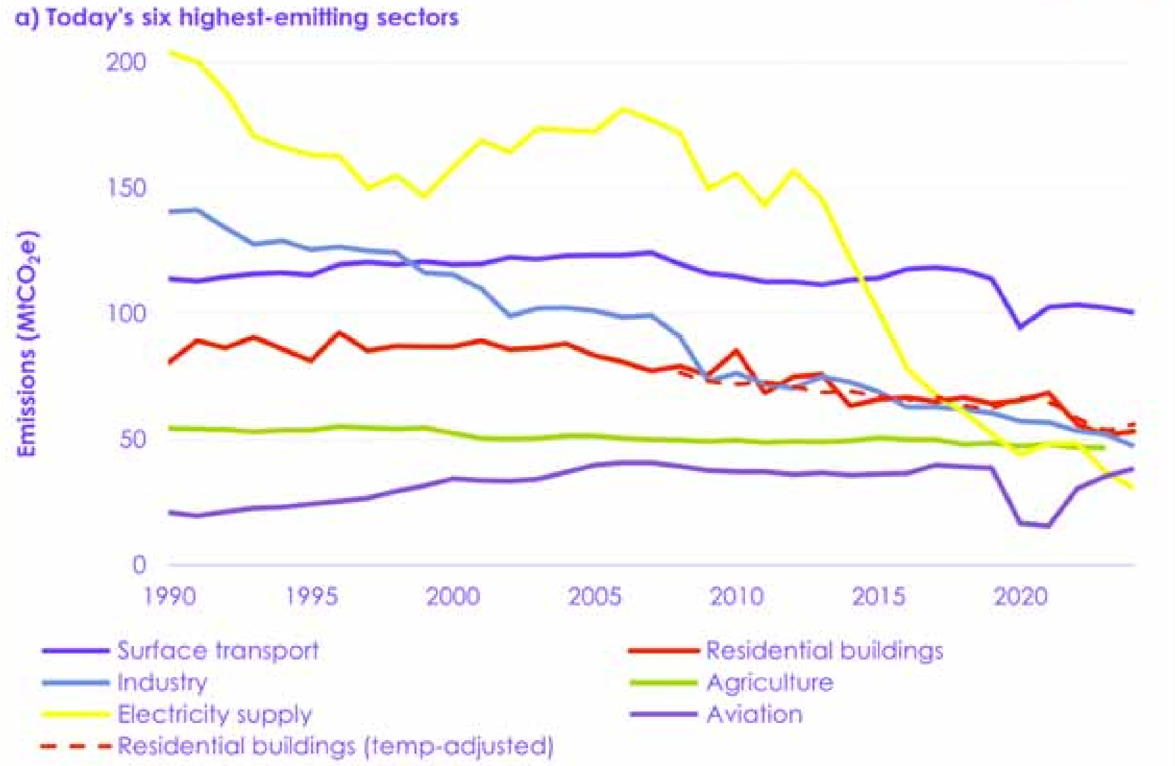
- How will the transition to Net Zero in the transport sector impact the resilience of transport systems to future climate change?
- What future scenarios of climate, land-use, transport, and the economy will help with decarbonisation without compromising resilience to extreme weather?
- How do we identify win-wins for future transport infrastructure to support mitigation and adaptation?

- *Funded by UKRI, DfT, ALBs (National Highways, Network Rail, HS2, TfL), led by Newcastle University.*

Transport Decarbonisation

- “Progress in surface transport is promising, with emissions savings from electric vehicles doubling every two years over recent years. **This sector will need to deliver much of the reductions for the remaining years of this decade**.” [UK CCC, 2025]
- Demand reduction? Mode shift? Infrastructure decarb?

Figure 1.3 UK emissions by sector since 1990



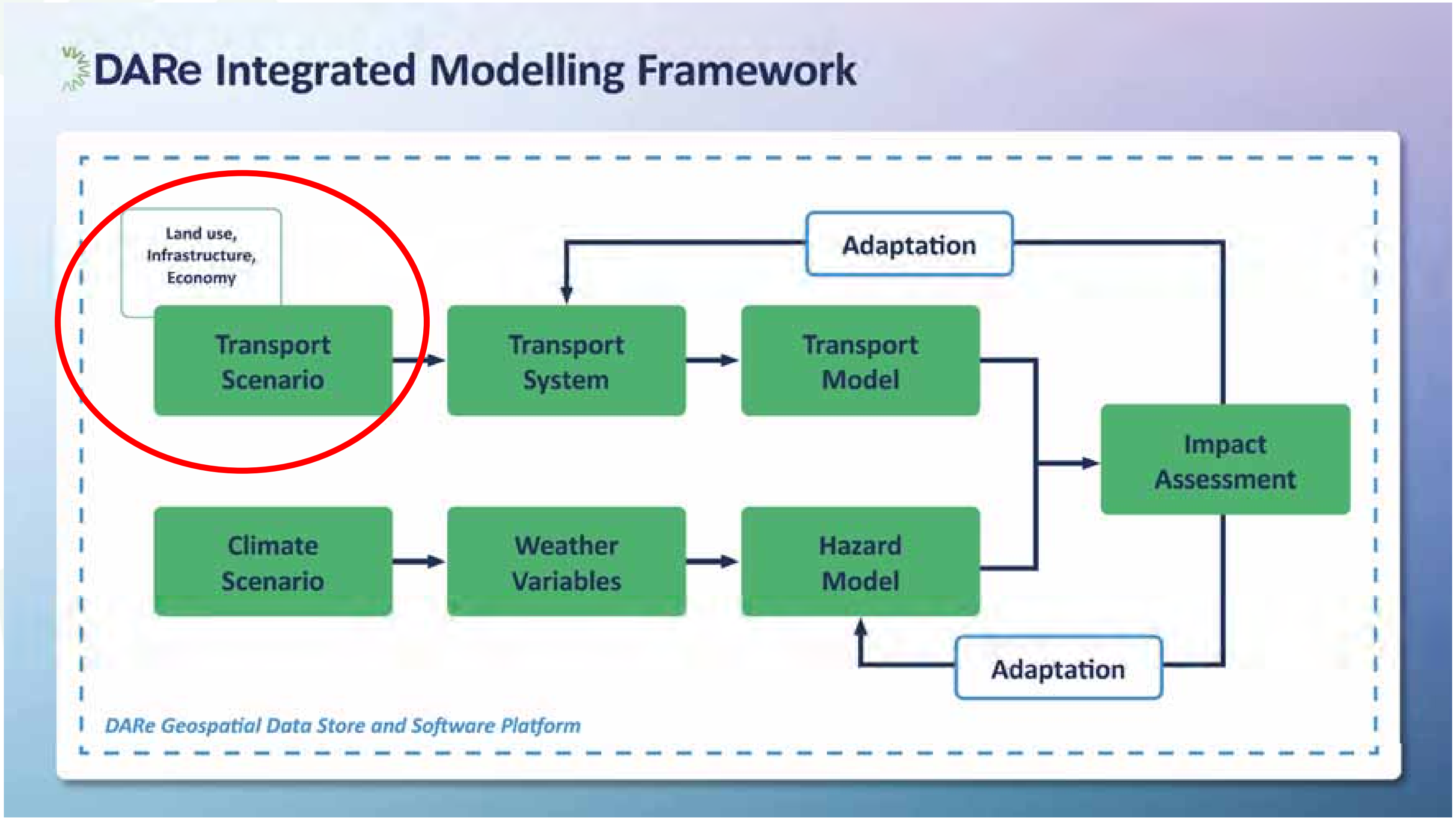
Transport Adaptation

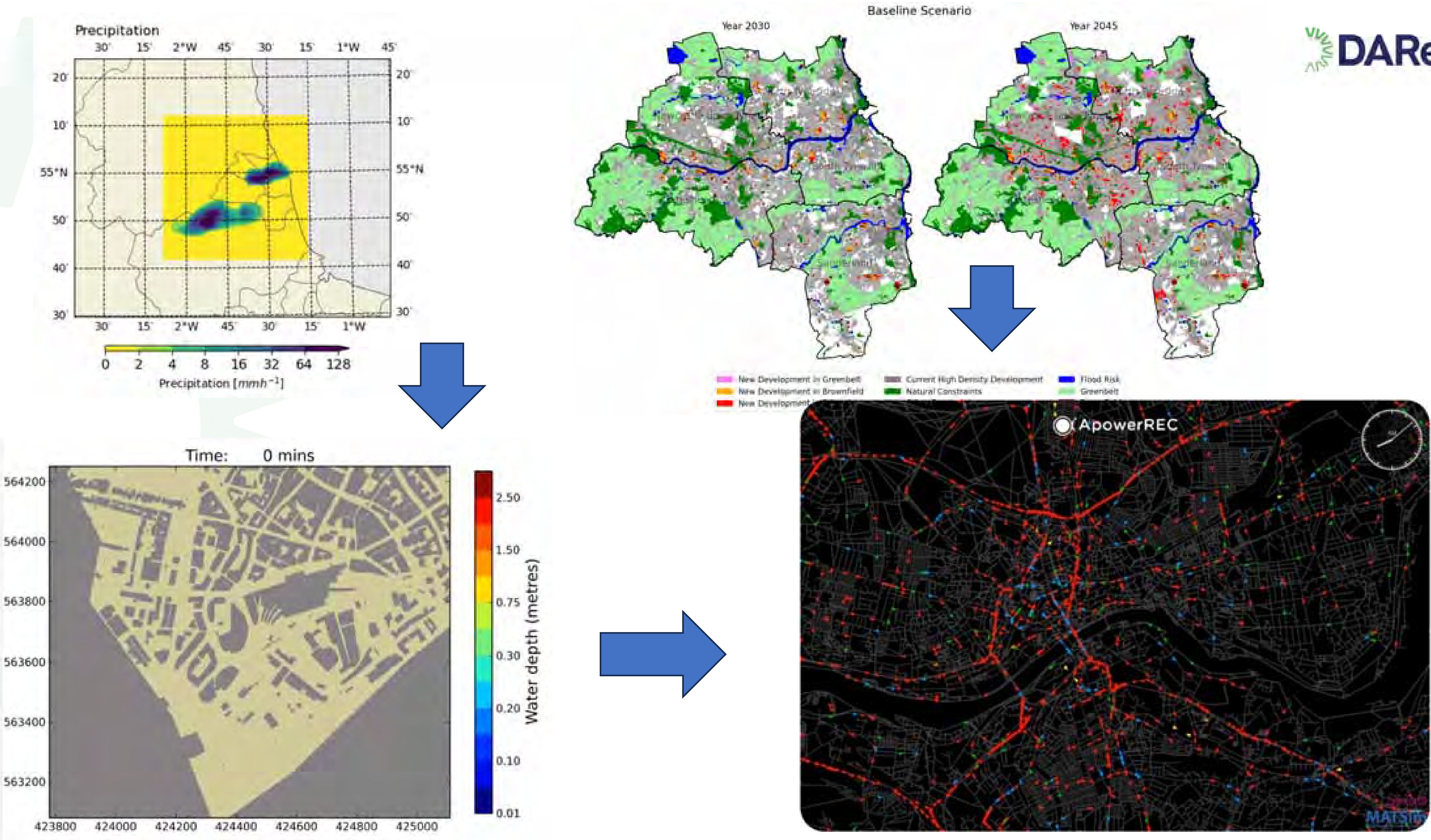
Towns and cities	Places are resilient to river and coastal flooding.	Partial	Partial
	Places are resilient to surface water and groundwater flooding.	Limited	Limited
	Sustainable coastal management in place.	Limited	Partial
	Urban heat risks are managed.	Unable to evaluate	Limited
	Planning system prioritises climate resilience.	Unable to evaluate	[illegible]

Transport	Asset and system level reliability of rail network.	Limited	Good
	Asset and system reliability of strate network.		
	Asset and system reliability of local		
	Asset and system reliability of airpo operations.		
	Asset and system level reliability of port operations.	[illegible]	Limited
	Interdependencies identified and managed.	Limited	Limited

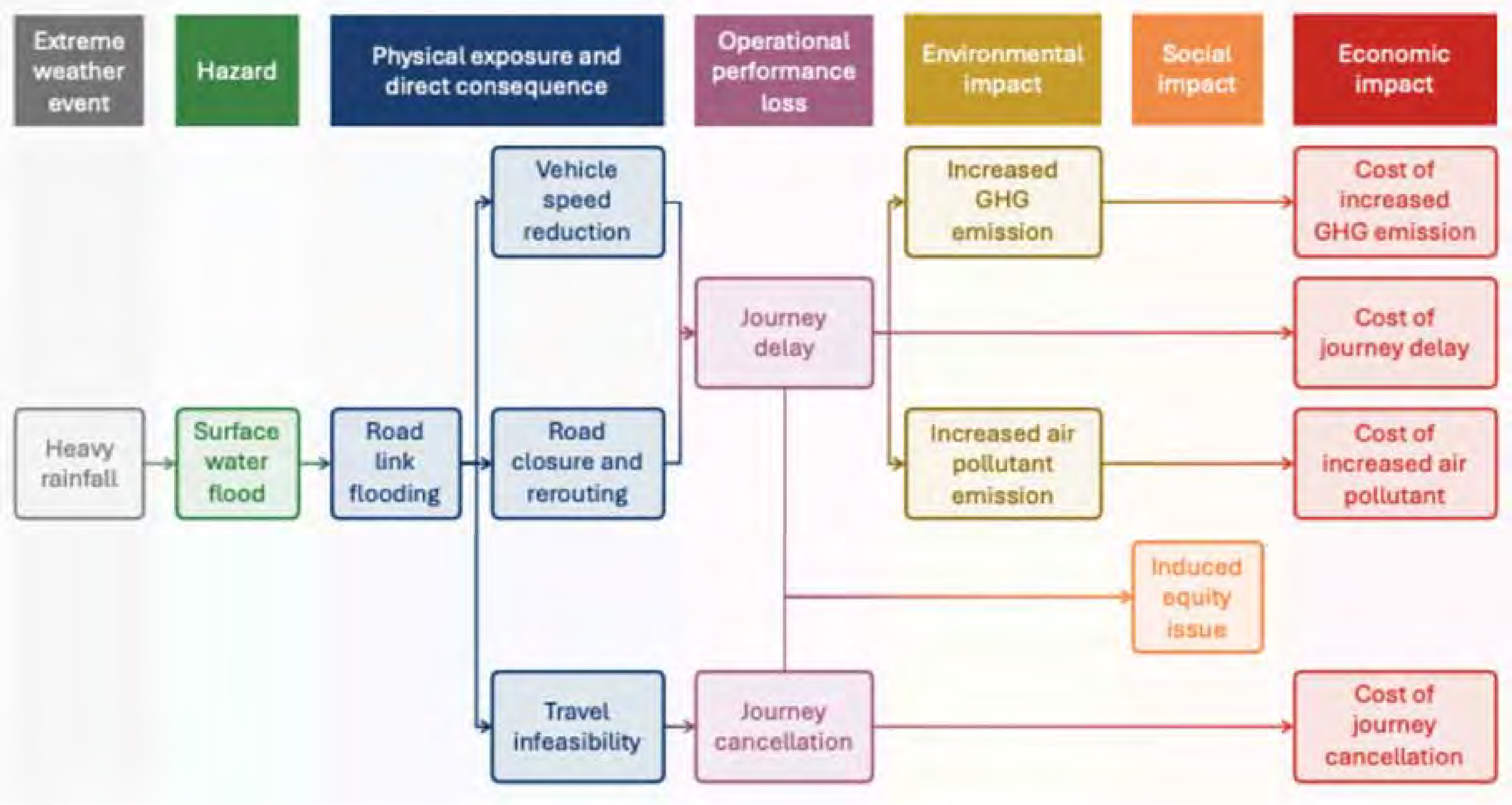
Energy	Reduced vulnerability of energy assets to extreme weather.	Limited	Partial
	Climate-resilient supply.	Limited	Limited
	Interdependencies identified and managed.	Partial	Insufficient

How will decarbonisation affect resilience?




Precipitation
Precipitation [mmh^{-1}]
Baseline Scenario
Year 2030
Year 2045
New Development in Greenbelt
New Development in Brownfield
Current High Density Development
Natural Constraints
Flood Risk
Greenbelt
Time: 0 mins
Water depth (metres)
ApowerREC
MATSim

Example impact chain



Wei Bi and Kristen McAskill, Cambridge

Adaptation Options – Flooding Example

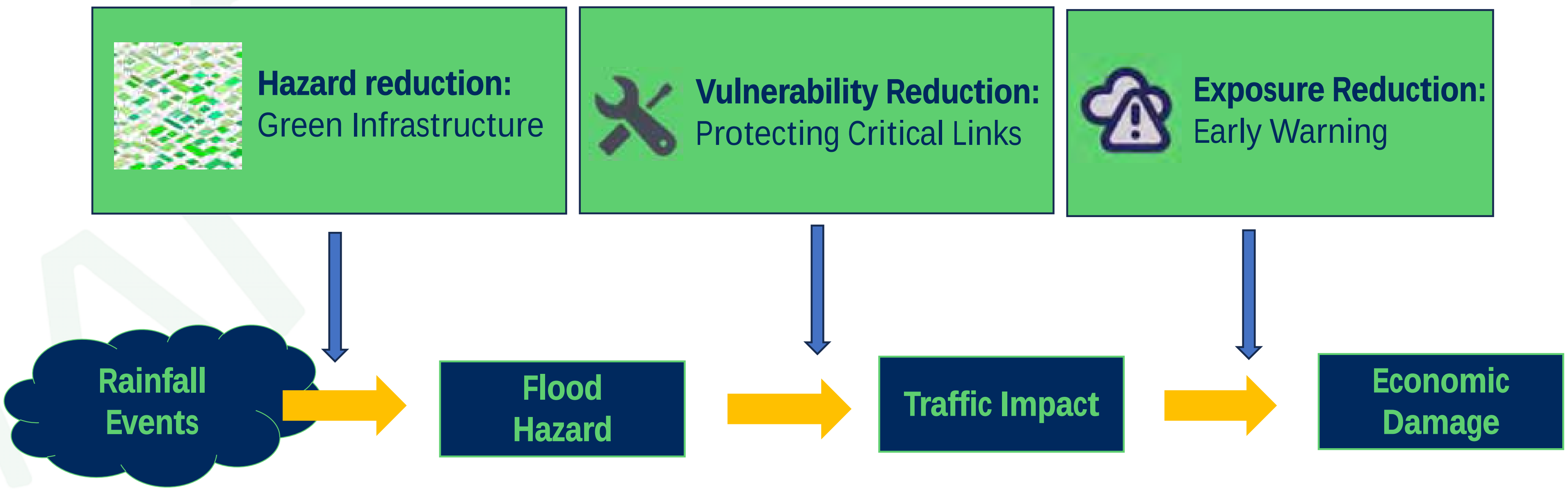
Hard Adaptation

Green roofs implemented on all buildings, increasing infiltration rate to 12mm/hr.

Critical links selected by pareto-optimal sorting on flooding duration, traffic volume, and betweenness centrality.

Soft Adaptation

Demand reduction in the ABM, simulating an order to work from home where possible before the morning commute.



Understanding responses to climate extremes

						HGV
Extreme Rainfall						
High Temperatures						
Windstorms						
Cold						

"Understanding, modelling and forecasting individual travel behaviours represents one of the key challenges of our time" in transport research

(Cherchi, 2020, p. 20)

Difficult decisions


Craig Rodaway


Dave Kelly

Maintaining existing and building new transport infrastructure must be done with both resilience and decarbonisation in mind **including changes to transport demand**.


Seimens

Key points

- Transport policy must consider decarbonisation in line with CCC carbon budgets but also resilience
- It is unclear how some decarbonisation policies (e.g. electrification of road freight) will impact resilience to extreme weather
- Modelling tools required to explore impacts and identify win-wins (equity, health, economy, wider sustainability)
- Demand reduction has a role to play in both mitigation and adaptation but trade-offs must be considered

DARe

National Hub for Decarbonised, Adaptable, and Resilient Transport Infrastructures

Newcastle University

University of Cambridge

University of Glasgow

Heriot Watt University

Department for Transport

UK Research and Innovation

Engineering and Physical Sciences Research Council

dare.ac.uk

Panel questions

What are the implications for achieving resilient net zero and research to support it?

- Decision making
- People and their lifestyles
- Climate services

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Thank you

To continue the discussion please
find us in the SU!