In a world with more extreme weather, how can we avoid digital blackouts in healthcare?

A Systems Thinking Approach

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The NHS have partnered with Transform UK to map the effects of extreme weather events (like heatwaves and floods) on digital services – examining weak points across the full supply chain: from emergency procedures to data centres; from telecomms to energy and water suppliers. Our findings so far? Digital services are complex systems with multiple actors, requiring climate risk to be shared. Cascading climate damage affects entire value chains and resilience should be approached as a team game, planning interventions as a system.

Our Climate Reality

Here we are, in 2025, 10 years after the world committed to keep global heating to 1.5 [1] degrees (above pre-industrial average).

But this slow-down of carbon emissions is showing no sign of occurring; in 2024 we had the first year globally above the relative safety of the 1.5-degree threshold [2], and annual carbon emissions are still growing [3].

Worse still, we are sailing perilously close to dramatic tipping points in the climate system[4], and our scientific models are not keeping up with the intensity of climate-driven extreme events [5], for example receiving sometimes three times more intense rainfall than predicted [6].

This situation is already leading to a variety of extreme events including catastrophic heatwaves, flooding and storms, the current magnitude of which would be virtually impossible without global heating [7].

1. The Paris Agreement
2. World Meteorological Organization
3. Carbon emissions Global Carbon Budget
4. Tipping points in the climate system Global Systems Institute
5. Climate-driven extreme events Science Direct
6. More intense rainfall than predicted Nature
7. American Meteorological Society

The Heathcare System Multiplier

Climate risk presents a huge challenge to the stability of the health system - we face a multiplier effect between an increase in population health issues, driven by climate change (like vector-bourne diseases, and heat exhaustion), and a simultaneous challenge to operational delivery issues, caused by increasingly frequent extreme events [1].

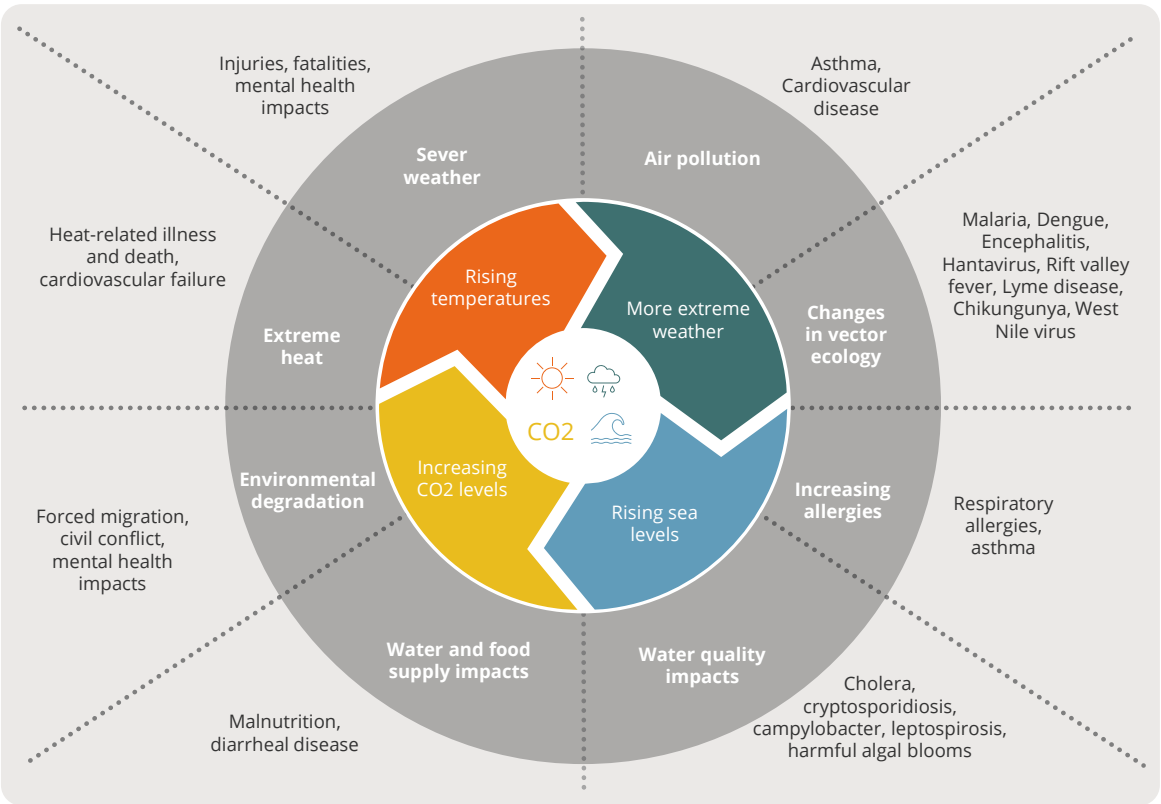


Figure 1: How climate change impacts Human Health (Health System Third Round ARP)

Climate events create a negative multiplier effect in healthcare – more population health issues, made harder to treat by operational delivery issues

1. UK Climate Org

Resilient Digital Services Underpin Adaptation

NHS England's Greener NHS programme [1] has used the World Health Organisation's "Climate Resilient Health System Model" [2] to bring structure to climate risk (Figure 2). It is clear that many of our prospective solutions (e.g. early warning systems, health climate research) are reliant on digital services, and *their* resilience.

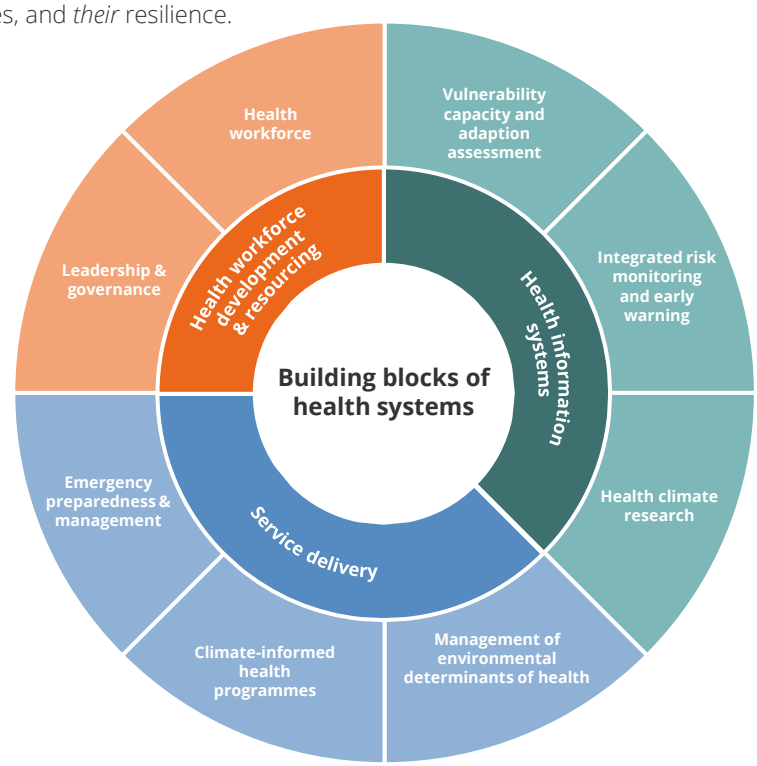


Figure 2: WHO Climate Resilient Health System Model

The UK Health Alliance on Climate Change, in their recent white paper, critiqued the UK's progress, making a stark call for accelerated progress. This take was recently echoed by the BBC – sharing the Climate Change Committee's (CCC's) warning to UK government on their lack of preparation, calling for increased action. It is clear that digital solutions are going to be central to navigating the storm ahead, and indeed are already in use to mitigate climate events:

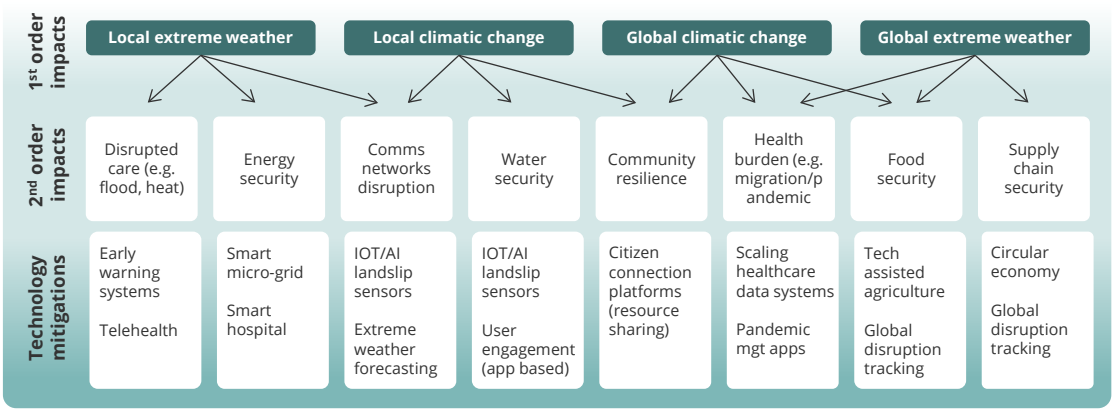


Figure 3: Examples of how digital can create health system climate change resilience (Ben Tongue)

1. NHS England's Greener NHS programme
2. World Health Organisation's "Climate Resilient Health System Model"

A House of Cards?

Into the future, we will need to think of digital services as a valuable lever for climate resilience. However, this only works if our digital systems are themselves resilient to climate change.

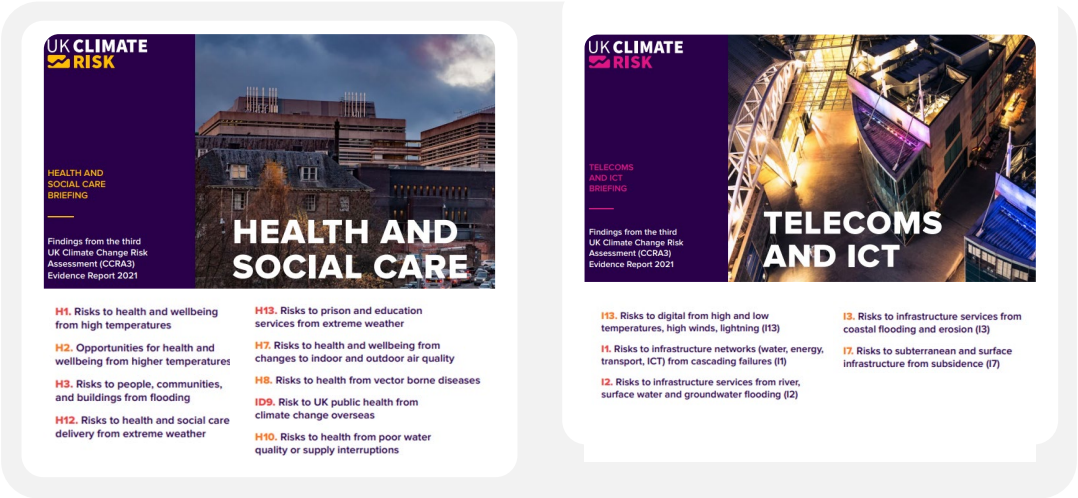


Figure 4: Climate Risk Sector Summaries for health and digital (UK Climate Risk)

Figure 4 highlights the direct risks posed by climate change to health and social care delivery, telecoms and ICT, giving an idea of potentially compounding forces such as high winds affecting hospitals and transport, while also risking power outages for digital healthcare.

Large scale digital infrastructure is considered Critical National Infrastructure in law, but all other CNI sectors are themselves dependent on digital services to function. In our modern world of increasing dependence on digital platforms, this starts to feel like a house of cards: with risk-impact cascades knocking out much beyond the digital during incidents, as seen through the impacts of electrical failures during Storm Arwen [1].

Unfortunately, the recent parliamentary enquiry on the UK's infrastructural climate change readiness was scathing. It *"implored the government to get a grip on [the] national security risks posed"* [2].

The most recent Adaptation Progress Report (2025) from the UK Climate Change Committee presents a similar view, highlighting a significant lack of readiness within health and infrastructure [3] (including telecoms and ICT).

Into the future, we will need to think of digital services as a valuable lever for climate resilience

1. Electrical failures during Storm Arwen
2. National Security risks posed: UK Parliament
3. Health & Infrastructure Sector Summaries

Digital Service Failure

The digital 'house of cards' became especially obvious in our health system during the unprecedented 40-degree heatwave in July 2022, when Guys and St Thomas (GSTT) Hospital experienced data centre failures due to a lack of effective cooling. This then caused huge impacts to clinical delivery.

The extensive impacts of this event led to a greater appreciation of climate risk among senior digital leadership: as a present-day challenge, that needs to be addressed now. GSTT have since done incredible work socialising a full-blown lessons learnt report[1] highlighting what went wrong, and why, including an extensive series of improvement recommendations for the sector. As will become obvious, however, the resilience of on-premise data centres is only a sub-problem of the bigger challenge: of digital service climate resilience.

Case study: Heatwave-induced IT system failures

In July 2022, during a period of extreme heat in London with temperatures reaching 40°C, cooling systems failed at 2 data centres supporting London's largest NHS trust.

This caused a critical IT outage at Guy's, St Thomas' and Evelina London hospitals, forcing a switch to paper-based operations and disruptions to patient care.

Over 100 treatment delays were reported, including a case of moderate harm where a patient missed an organ transplant.

Service delivery dropped significantly, with referrals at 64%, outpatient appointments at 84%, elective surgeries at 71% and diagnostic tests at 68% of typical July levels.

The incident also strained staff morale and impacted healthcare partners across southeast London.

Emergency IT systems were restored in 5 days, with full recovery extending over several weeks and incurring £1.4 million in additional costs.

Source: https://www.guysandstthomas.nhs.uk/sites/default/files/2023-01/IT-critical-incident-review.pdf

1. GSTT lessons learnt report

Millions to Billions: Understanding the Scale of Comparable Outages

Here, we explore relevant digital outages with costings and context; financial risk exposure is often Millions to Billions per event – potential impacts that cannot be ignored by digital leaders.

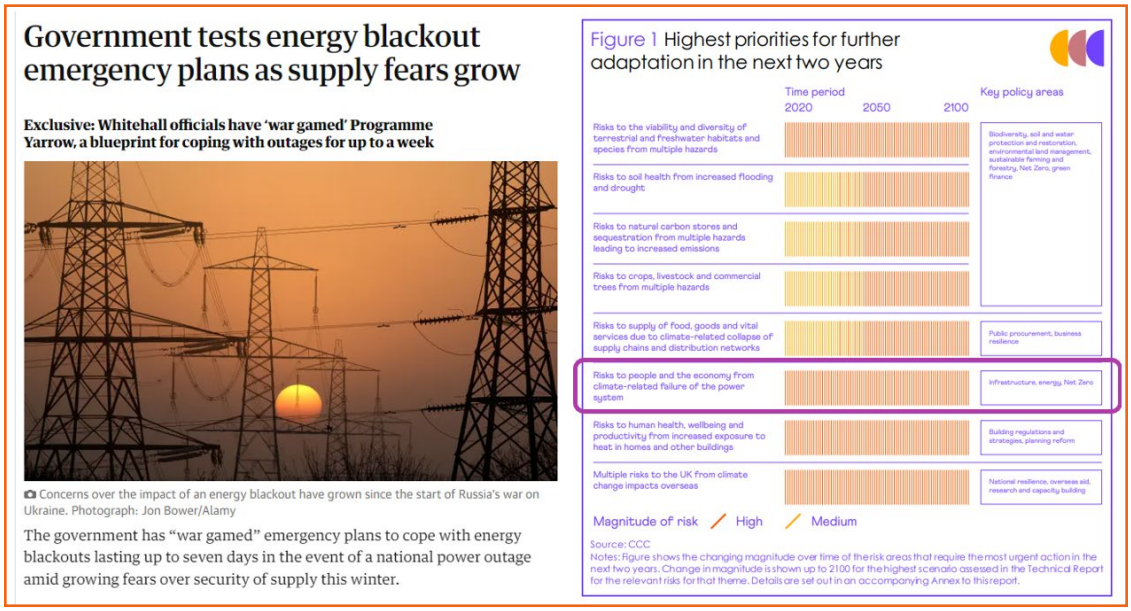
Event & Description	Trigger & Cascading Impacts	Estimated Cost (Health Impact)	Downtime & Patient Safety Impact	Additional Sources
Guy's & St Thomas' Heatwave Outage (UK, July 2022)	Extreme heat (climate change). Cooling systems failed; backup systems also failed. Impacts: 100+ appointment delays, organ transplant missed, staff stress, manual paper processes.	£1.4M (IT recovery, third-party services, cloud backup migration).	6 weeks; missed transplant, delayed diagnostics, manual fallback increased risk.	
Storm Arwen (UK, Nov 2021)	Extreme weather (storm). Impacts: 1M+ households lost power; hospitals reliant on generators; delayed care; comms failures.	Up to £300M (overall damage; health-specific costs unclear but significant due to emergency care disruption).	Several days; emergency care delays, reliance on paper records.	
Lancaster Floods (UK, Dec 2015)	Flooding (climate-related). Impacts: 61,000 properties lost power; hospitals reverted to manual processes; comms collapse; delayed treatments.	Not quantified for NHS, but major operational disruption and emergency generator deployment.	~1 week; manual fallback, delayed elective care, increased emergency risk.	
WannaCry Cyberattack (Global/NHS, May 2017)	Cyberattack exploiting unpatched systems. Impacts: 19,000 appointments cancelled; A&E diversions; delayed cancer care.	£92M (lost output £19M + IT recovery £72M).	Several days; critical care delays, cancelled surgeries, increased mortality risk.	
Iberian Peninsula Blackout (Spain & Portugal, Apr 2025)	Grid instability (possibly climate-related). Impacts: Hospitals on generators; EHR inaccessible; cold-chain failures for vaccines; dialysis delays; excess mortality (+167 deaths in Spain).	€1.78B Spain + €356M Portugal (economic loss; health-specific costs not isolated).	8–10 hrs; dialysis delays, vaccine cold-chain risk, mortality spike.	
J&L Cyberattack (2025)	Cyberattack (likely ransomware). Impacts: Business interruption, data loss, delayed care.	Global losses $16B (healthcare share unclear; individual orgs often face multi-million costs).	Weeks; delayed procurement, elective care backlog, reputational harm.	
CrowdStrike Outage (Global, July 2024)	Software failure (not attack). Impacts: 759 US hospitals affected; EHR and imaging offline; elective surgeries cancelled.	$1.9B for healthcare sector (US).	1–2 days; elective surgery cancellations, diagnostic delays.	
AWS Cloud Outage (Global, Oct 2025)	Cloud infrastructure failure. Impacts: EHR inaccessible; billing halted; telehealth down.	$62,500 per hour (healthcare-specific estimate).	7 hrs; telehealth disruption, billing delays, minor clinical impact.	

Cyber attacks have many analogous effects to climate events (e.g. power outage), but climate risk also acts as a multiplier for cyber risk. Recovery from digital health service outages [1] (for any reason) make systems more vulnerable to cyber attack, due to reduced monitoring, workarounds and legacy recover plans.

1. Healthcare System Cybersecurity

Emergency Planning Activity Underway

It's clear we need to prepare as a health system, and as a nation. Luckily, we are not starting from scratch - a great start has been made by initiatives like TechUK's work on direct risk to telecoms and digital infrastructure [1]. In addition, a large scale 'what if 'proxy-exercise has recently taken place. Operation Mighty Oak gamed out how the UK government would respond to national power outages, an existential risk to digital and other sectors. Mighty Oak, and its input from thousands of government colleagues is a crucial learning point for digital resilience in the face of climate change.



Government tests energy blackout emergency plans as supply fears grow

Exclusive: Whitehall officials have 'war gamed' Programme Yarrow, a blueprint for coping with outages for up to a week

Concerns over the impact of an energy blackout have grown since the start of Russia's war on Ukraine. Photograph: Jon Bower/Alamy

The government has "war gamed" emergency plans to cope with energy blackouts lasting up to seven days in the event of a national power outage amid growing fears over security of supply this winter.

Figure 1 Highest priorities for further adaptation in the next two years

Time period: 2020, 2050, 2100

Key policy areas

Risks to the viability and diversity of terrestrial and freshwater habitats and species from multiple hazards

Risks to soil health from increased flooding and drought

Risks to natural carbon stores and sequestration from multiple hazards leading to increased emissions

Risks to crops, livestock and commercial trees from multiple hazards

Biodiversity, soil and water protection and restoration, environmental land management, sustainable farming and forestry, Net Zero, green finance

Risks to supply of food, goods and vital services due to climate-related collapse of supply chains and distribution networks

Public procurement, business resilience

Risks to people and the economy from climate-related failure of the power system

Infrastructure, energy, Net Zero

Risks to human health, wellbeing and productivity from increased exposure to heat in homes and other buildings

Building regulations and strategies, planning reform

Multiple risks to the UK from climate change impacts overseas

National resilience, overseas aid, research and capacity building

Magnitude of risk: High, Medium

Source: CCC

Notes: Figure shows the changing magnitude over time of the risk areas that require the most urgent action in the next two years. Change in magnitude is shown up to 2100 for the highest scenario assessed in the Technical Report for the relevant risks for that theme. Details are set out in an accompanying Annex to this report.

Figure 6: Extracts from The Guardian and UK Climate Change Commission 2021 Risk Assessment

Resilience is a core principle of digitisation, making the addition of climate events to the risk spectrum an extension to thinking, rather than a whole new endeavour. The utilities sectors have faced relevant legal mandates [2] for some time, and healthcare colleagues managing cyber risk [3] continue to curate risk-management approaches suited to climate events.

Resilience is a core principle of digitisation

1. TechUK: Climate Adaptation Report
2. Water Industry Environmental Requirements
3. Secure By Design: Managing cyber risk

Our Responsibility to Act

There is a clear need to de-risk our digital system, and our dependencies on it, in the face of climate change. So it's good news that the health system is legally compelled to adapt to climate change through the Health and Care Act 2022. This act gives accountability to the Greener NHS programme, and its Green Plan requirements on the system. Further, the Department of Health and Social Care (and its ALBs) must work to the Greening Government Commitments, which compel action to adapt.

Perhaps most importantly, the recent publication of the Accounting for the Impacts of Climate Change requirements (of the government's Green Book business case rule) mean that all large-scale digitisation programmes **must** present delivery options which are either resilient to a 2-degree world (a significantly worse scenario [1] than our current 1.5); or factor in contingency costs to deal with climate driven extreme events.

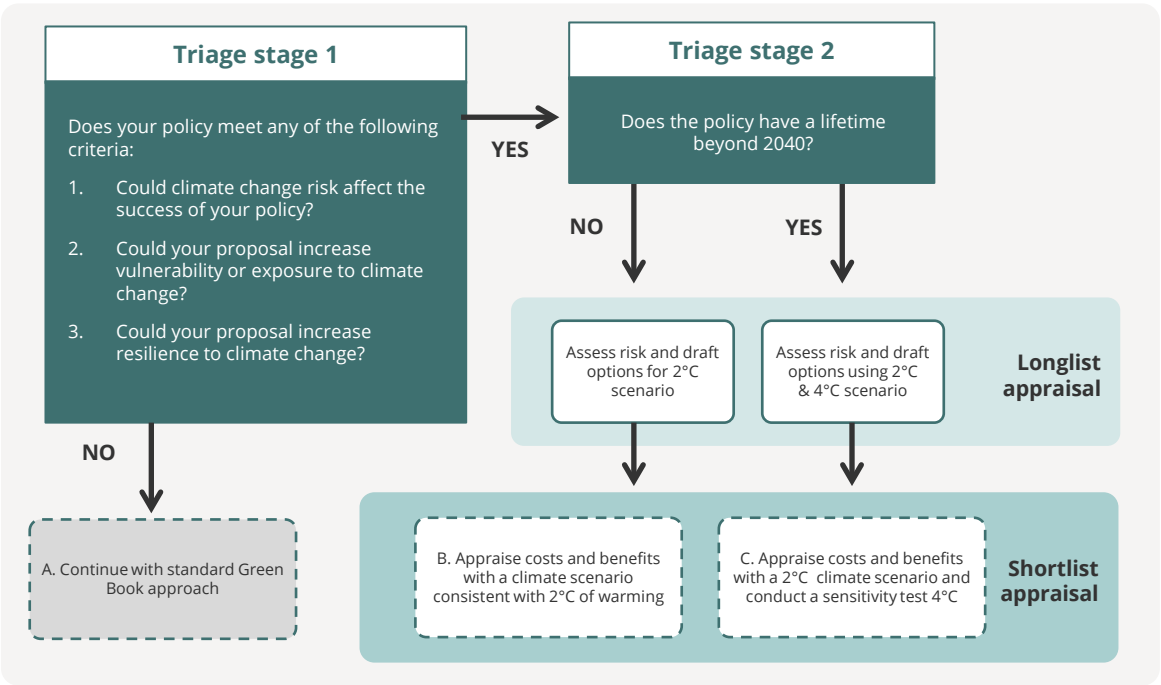


Figure 7: Extract from The Green Book's 'Accounting for Impacts of Climate Change' (April 2025)

While it is easy to say 'be resilient to a 2-degree world'; what this means for digital services is far from simple. We are hoping to give those involved in digital service delivery the confidence that they are implementing appropriate and meaningful climate adaptation measures to ensure their services become more resilient to climate change.

A systems thinking approach provides the way forward: to guide suitable interventions in the system, we must first understand the complex connections in the system and how they interact.

1. World Economic Forum

Mapping the Complex System

Modern large-scale digitisation depends on a large network of geographically dispersed actors to move and use data as well as a wide array of interdependencies in the form of energy, water, supply chain and service demand (image).

With digital failure showing up as part of a risk-impact cascade, attention must also be given to boundarising our problem (the direct causes and consequences of climate driven digital failure).

Thankfully our path is supported by great examples, such as CReDo [1] and the effectiveness of systems approaches on other complex problems, like Net Zero [2].

Our systems map explores the question "How can we ensure our digital service is less likely to fail, and quicker to recover when climate risks occur?" *[NB: for this proof-of-concept stage the primary climate risk under consideration was heatwaves, we will broaden this with iterations]*

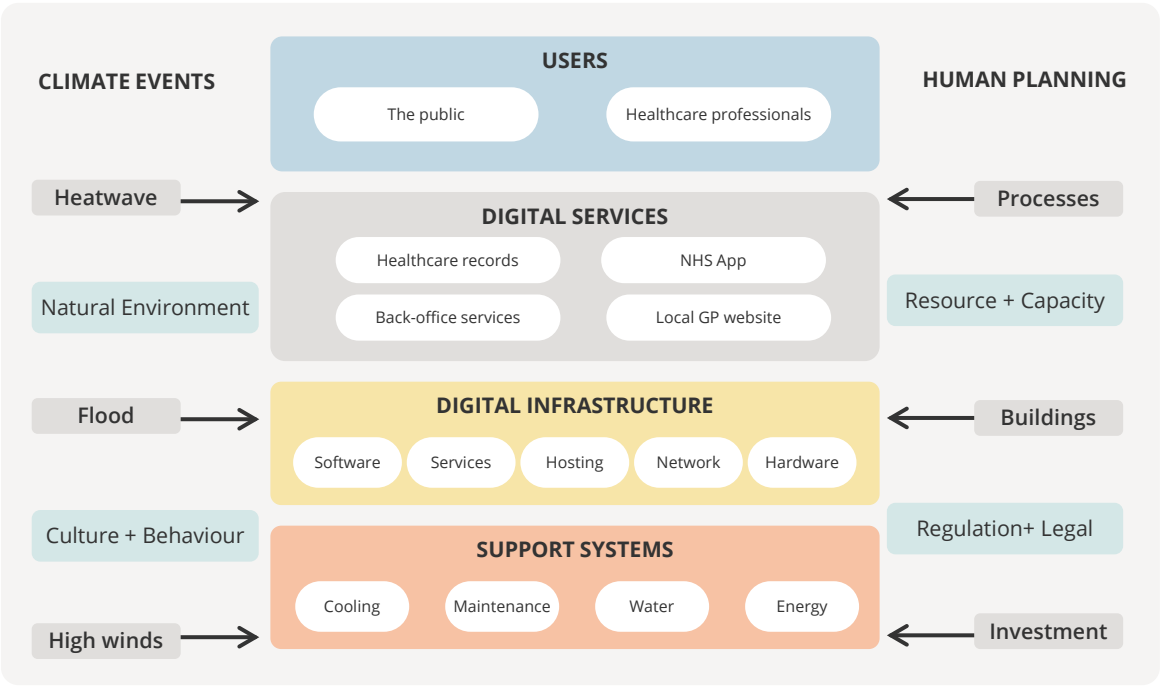


Figure 8: High level system map for digital health system delivery (Claire Robinson)

Our exam question: "How can we ensure our digital service is less likely to fail, and quicker to recover when climate risks occur?"

1. CReDo – Climate Resilience Demonstrator
2. Effectiveness of systems mapping: Gov UK Policy Lab

Visualising Connections

Digital healthcare services are a complex system to map with many interplaying variables across physical and digital worlds: from the integrity of electronic patient records; to the resilience of data centres that provide the underlying data storage and compute; to the energy that powers them and the maintenance services that keep them in good working order. We boundarised our proof of concept by defining layers (Figure 8 above) and limiting variables to direct causes and consequences which materially affect these layers.

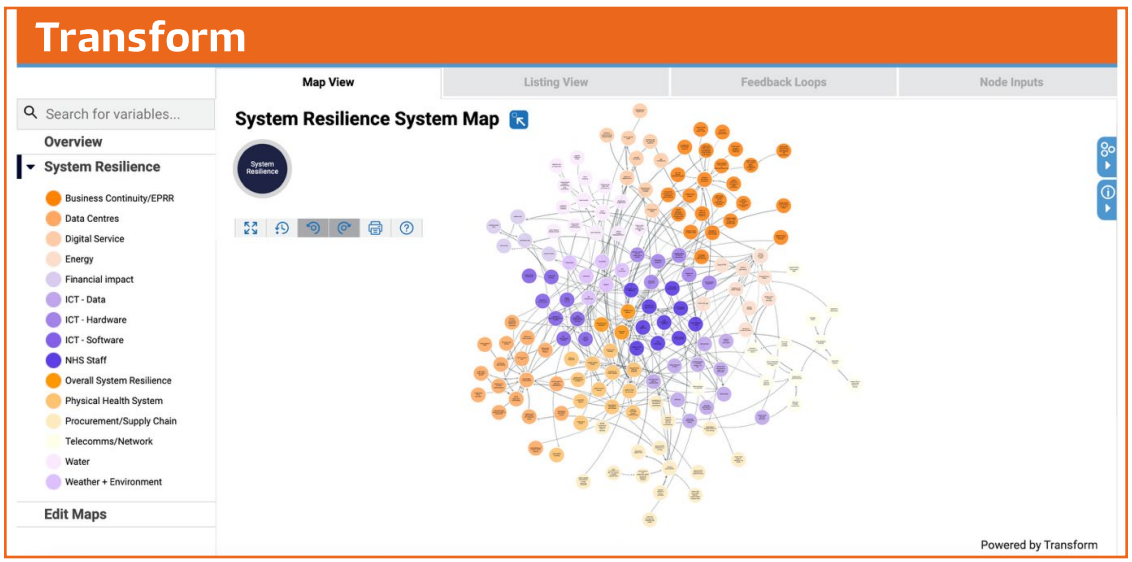
NHS and Transform UK conducted desk research into the ways climate events affect each layer, including recently published Adaptation Report documents from healthcare, telecoms, water and energy sectors, and of course the Guys and St Thomas 2022 heatwave report. We identified a list of subject matter experts who could flesh out further details of how the system operates (for example the emergency preparedness and business continuity teams within NHS who define human interventions during crises, and the data centre operators who triage workloads).

This research enabled us to build a conceptual map of actors within the system and the relationships between them, which we then translated into a working prototype using Transform's data visualisation tool, based on opensource software D3.

The map is colour coded by actors, with low, medium and high correlations and 'same' or 'opposite' relationships between each.

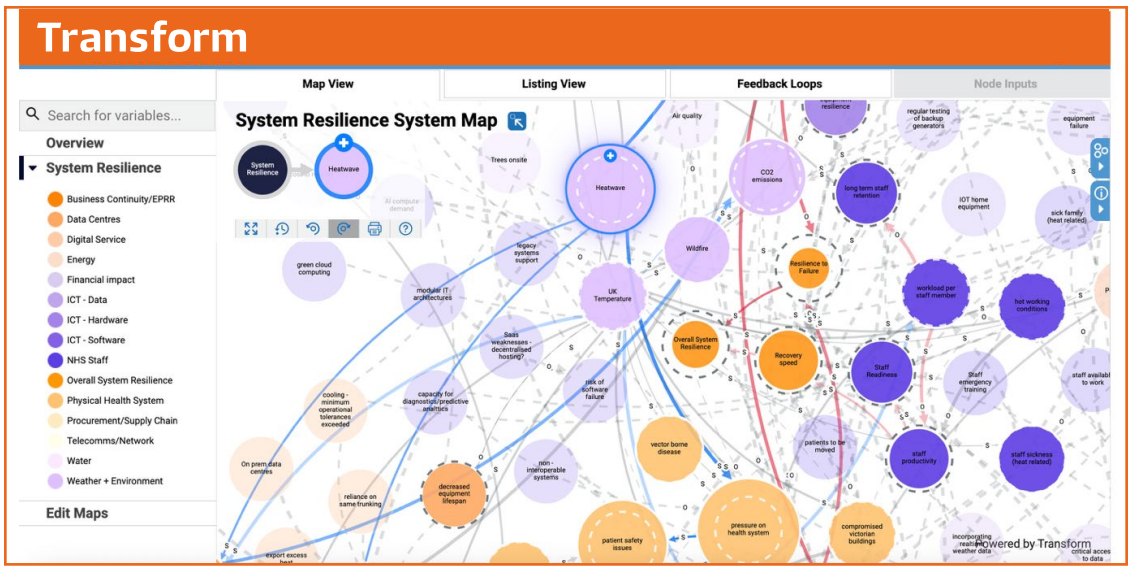
For example, the relationship between power outage and increased pressure on the healthcare system is 'same' (an increase in one creates an increase in the other), but the relationship between frequency of wildfires and air quality is opposite (an increase in one creates a decrease in the other).

The map passes influence through multiple nodes so it's possible to model compound effects.

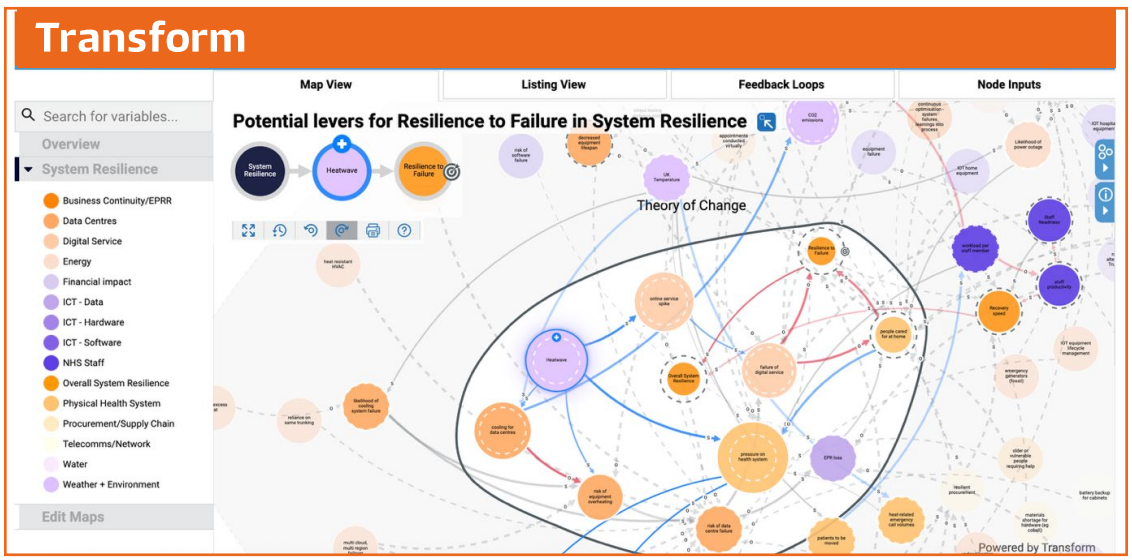


Interrogating the data, creating Theories of Change

Users can interrogate the map, projecting consequences of changing variables (here increased frequency of heatwaves), to see the effects on the number of people who can be cared for at home, on staff productivity and overall resilience to failure:

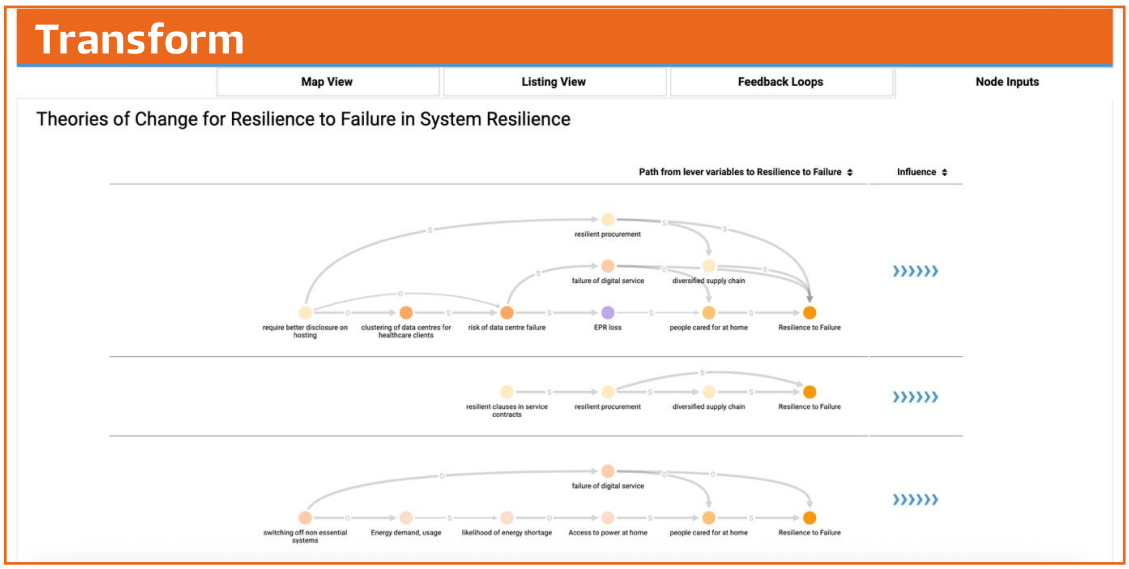


The map also enables the creation of Theories of Change towards a target variable (here, resilience to failure of digital services which shows data centre resilience as a key lever):



Ranking Interventions

The tool also enables ranking of interventions towards that desired outcome, creating a prioritised list of actions to increase resilience:



Summary of Initial Findings

The map we created is a Proof of Concept, which we intend to build out in subsequent phases with further quantitative and qualitative data. Initial findings, from applying a systems lens to the knotty problem, include:

- Systems thinking unearths unknown risks, vulnerabilities and single points of failure, so planning interventions should be done as a connected supply chain - increasing efficiency of investment across actors, saving time and money
- When interventions are planned from the perspective of a single organisation, they can miss crucial points of failure or, at worst, undermine the system
- Resilient digital services increase overall resilience - digital service capacity is a valuable continuity lever, so digital infrastructure should be prioritised for energy availability
- Procurement is the biggest lever for change, and focussed activity on specification (awareness, training, tools, support) can mitigate the top risks , supporting longer-term value-for-money
- Cyber Security is helpfully analogous in effects and approach (not causes), so linking the climate resilience agenda to this established risk and learning agenda can increase visibility of climate risks and efficiency of intervention (especially in the digital outage recovery phase)

While the insights on improved resilience are qualitative at this stage, the process so far has identified new vulnerabilities and points of failure. We can already enable teams to be more aware of meaningful adaptation actions and therefore ensure they're asking the right questions of team members, suppliers and partners.

Where to Next?

Our early interviews produced a 'wow moment 'when a data centre provider considered it 'not their problem' if the network providers they transmit data through failed due to climate events. But as those events become more common, sharing risks and interventions across supply chains needs to become a new norm.

Creating systemic interventions is a true collective action problem – with so many players involved and invested in the outcome of resilient digital healthcare services, we need everyone playing on the same team.

Our approach provides an entry point for digital colleagues to raise the profile of climate vulnerability into BAU (Business as usual) risk management. This will be bolstered once we have a more quantitative evidence-led understanding of our risk exposure to digital failure, enabling us to build an effective business case for change.

The next iteration of our model hopes to move towards creating 'actor specific ' guidance through a more quantitative focus for variables in the model. For example reducing regional reliance of healthcare providers on geographically co-located data centres (more likely to be impacted at the same time by the same physical climate risk).

The end goal is to zoom out, creating a national tool where users can input their context (local risks and topography, services running, digital set up) and receive a checklist of tailored interventions to support resilient digital services.

During the next phases of our programme we'll be calling for more partners and collaborators to join us in this important work. If you'd like to be involved in tackling the effects of climate change, and making our health service more resilient, this is your opportunity to help us do it, together.

An integrated risk planning and management process shares risk across entities, ensuring efficiency of resilience investments across supply and value chains.

If you'd like to contribute to developing our systems map, please get in touch – we're looking for datasets to enhance and validate the map, subject matter experts to interview across the digital healthcare supply chain, and passionate people to evangelise the project and findings – we'd love to hear from you!

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