

CReDo+ AND DAFNI

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27 March 2024

DRAMATIS PERSONAE

Who is behind CReDo? (today)

Connected Places Catapult – project lead



Anglian Water – asset owner



CMCL Innovations – software, models



BT – asset owner



STFC Hartree – data science, models



UK Power Networks – asset owner



STFC DAFNI – trusted infrastructure, software

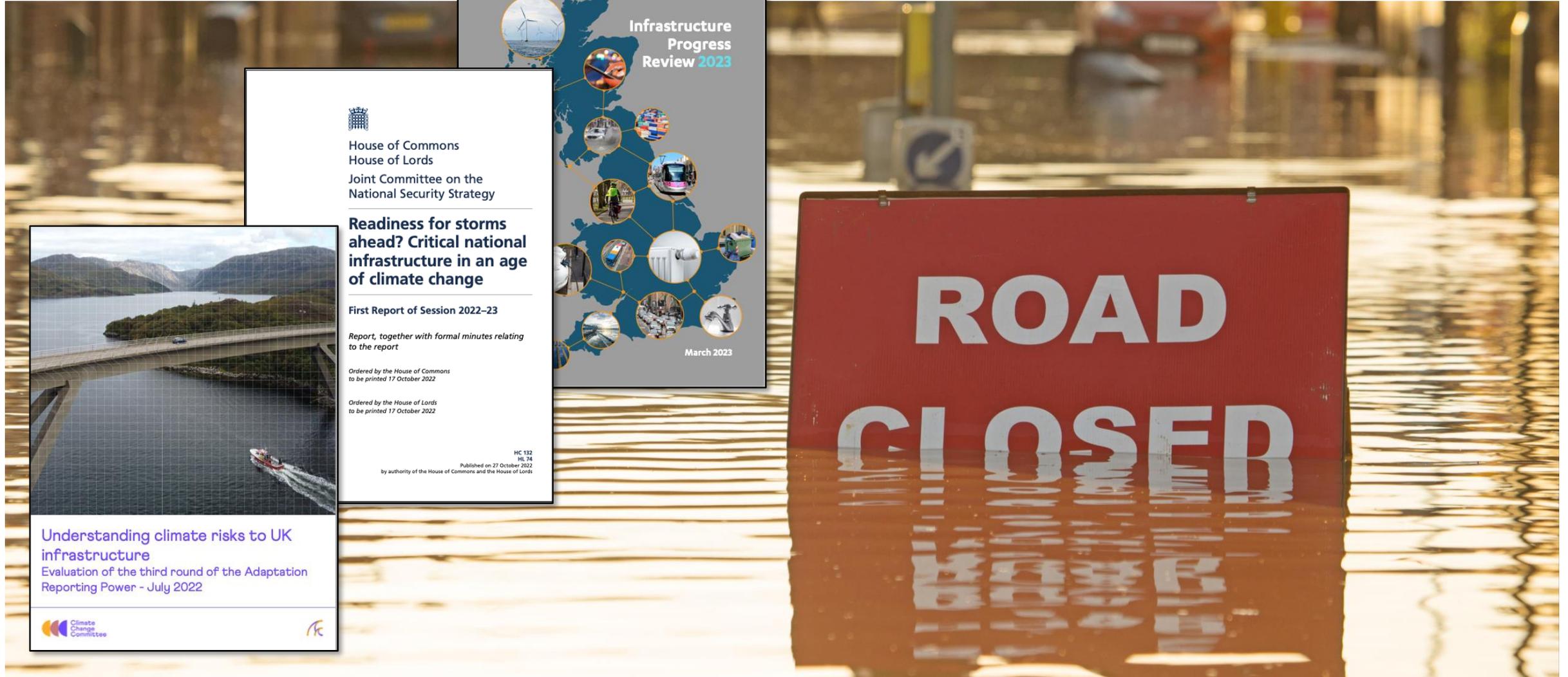


DNV - assurance and risk



1. CReDo+ OVERVIEW AND BENEFITS

INFRASTRUCTURE INTERDEPENDENCIES



CReDo IS A CLIMATE CHANGE ADAPTATION DIGITAL TWIN

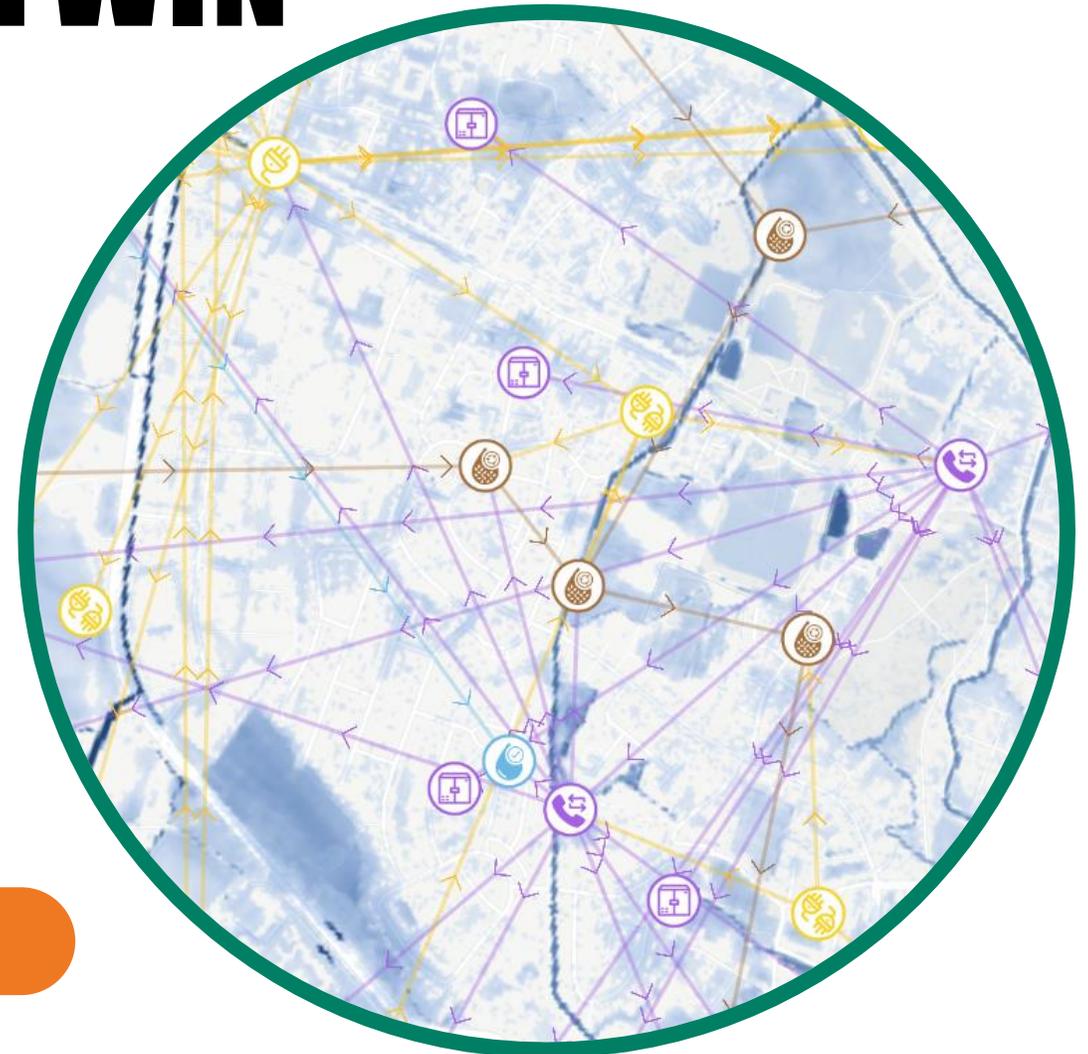
Bringing together data across energy, water, and telecoms networks

- Anglian Water: water and sewerage assets,
- BT and Openreach: communication assets,
- UK Power Networks: electricity distribution assets.

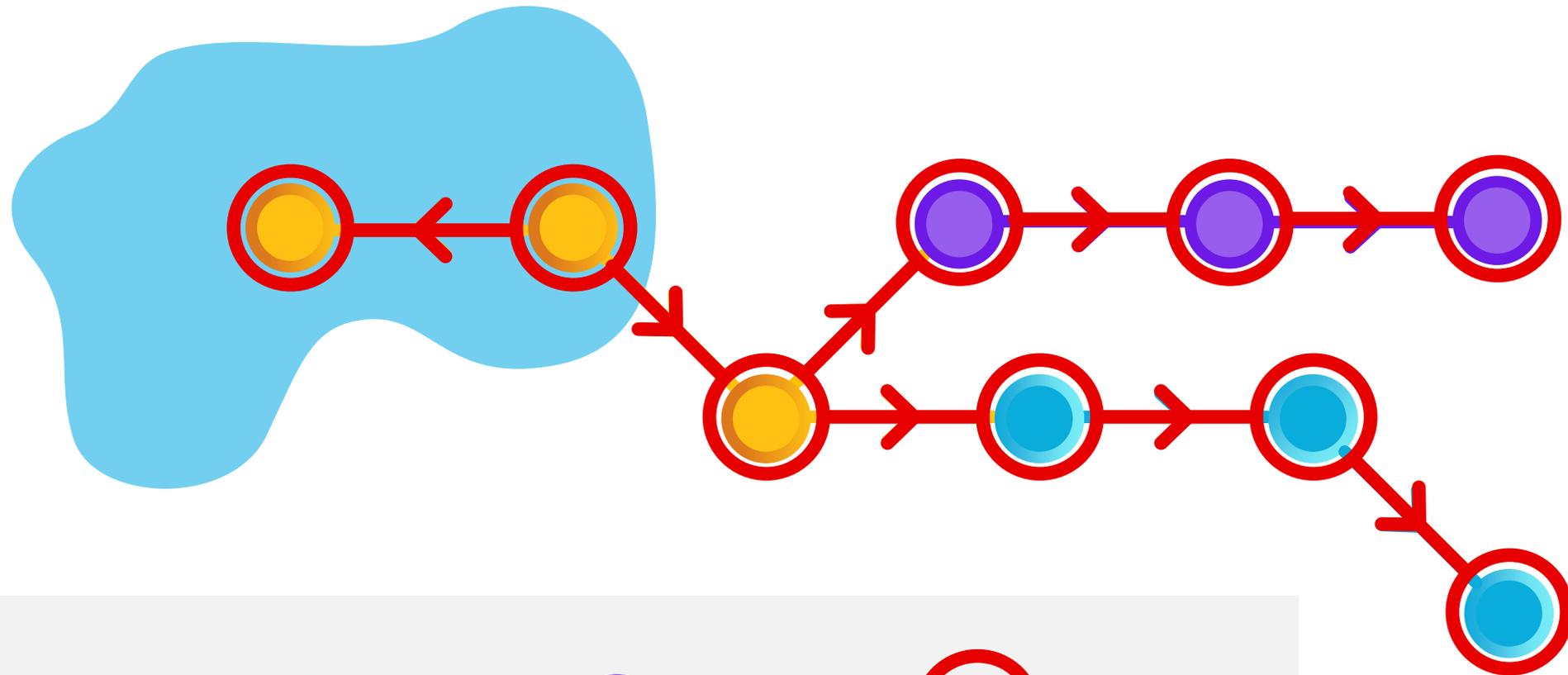
With weather and infrastructure data

- Infrastructure interdependencies
- Asset failure and system impact
- What can we do to prepare or respond?

HOW DO WE INCREASE SYSTEM RESILIENCE AND ADAPT?



A CONNECTED UNDERSTANDING TO CASCADING RISK



Key



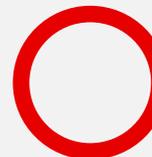
Electricity



Water

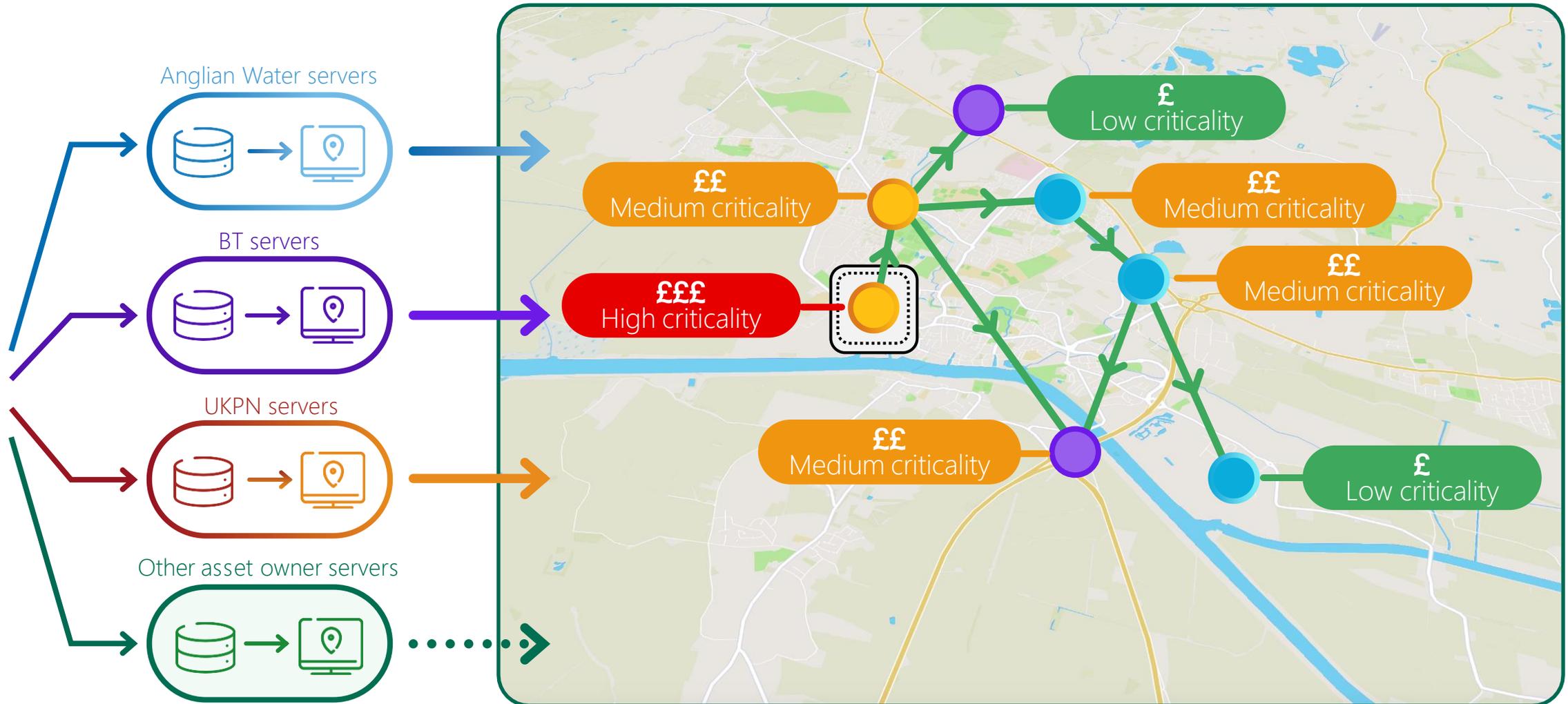


Telecoms



Failure

...FOR COORDINATED RESILIENCE PLANNING



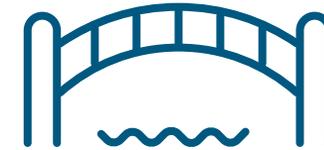
CReDo MISSION & USP

Climate Resilience Demonstrator → Climate Resilience Decision Optimiser



MISSION

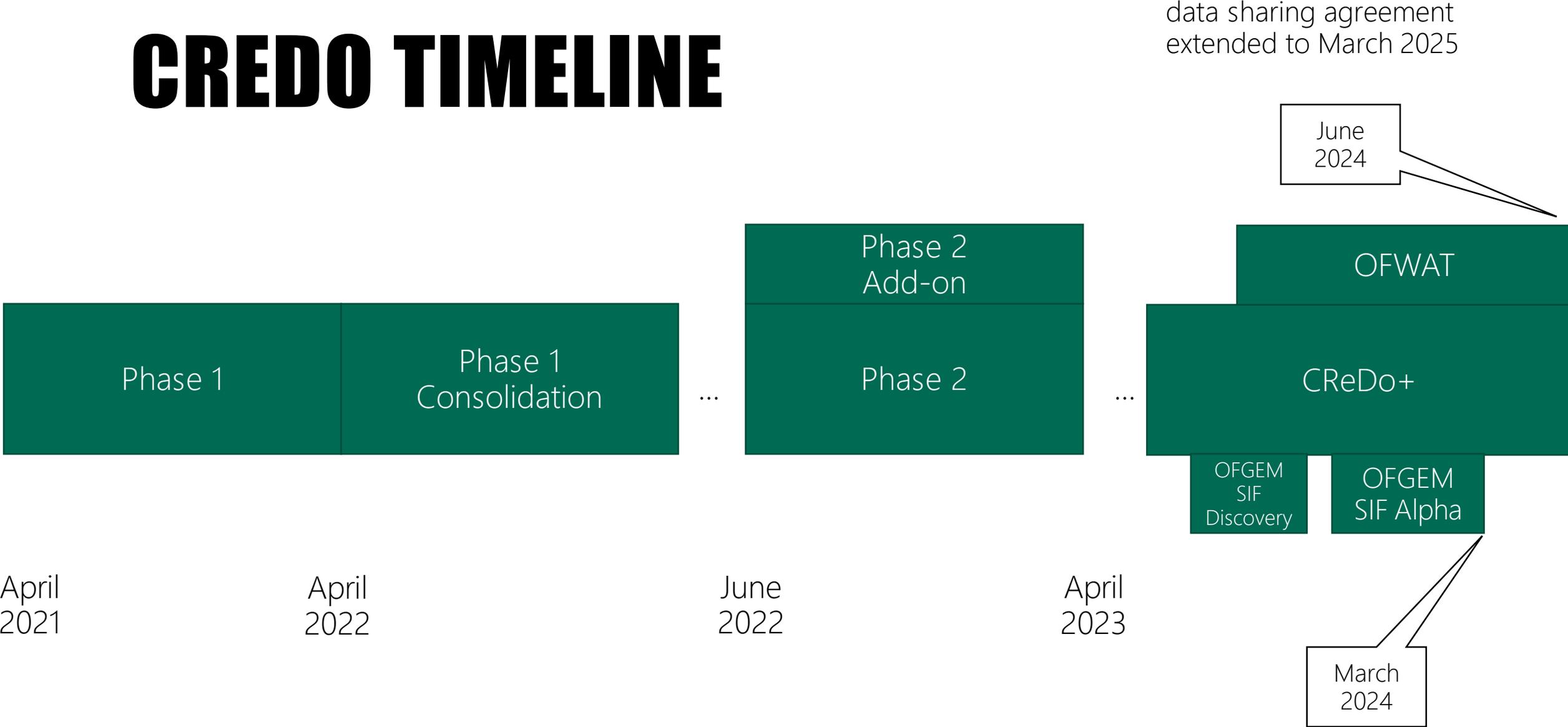
Enable coordinated decision making and efficient investment by understanding interdependencies and cascading risk across critical national infrastructure, so that together we can increase resilience to extreme weather and adapt to climate change.



USP

CReDo connects data across siloed organisational boundaries, enabling a whole system approach to modelling infrastructure interdependencies. This allows users to see who they are dependent on and cascading climate risk from extreme weather, supporting better decision making and reporting.

CREDO TIMELINE



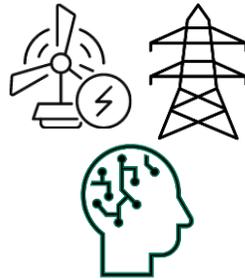
CReDo+ ALPHA PHASE

Prototype a scalable pipeline for cascading risk modelling, test for extreme heat, and integrate with CReDo



User friendly
Digital Elicitation Tool

Create a working
prototype to test
scalable approach to
risk modelling



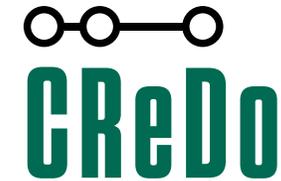
Bayesian asset
risk models

Run elicitations with UKPN
subject matter experts and
engineers to encode tacit
knowledge into Bayesian
risk models



Library of models
for all weather

Link asset data to create
the library of Bayesian
risk models for extreme
heat



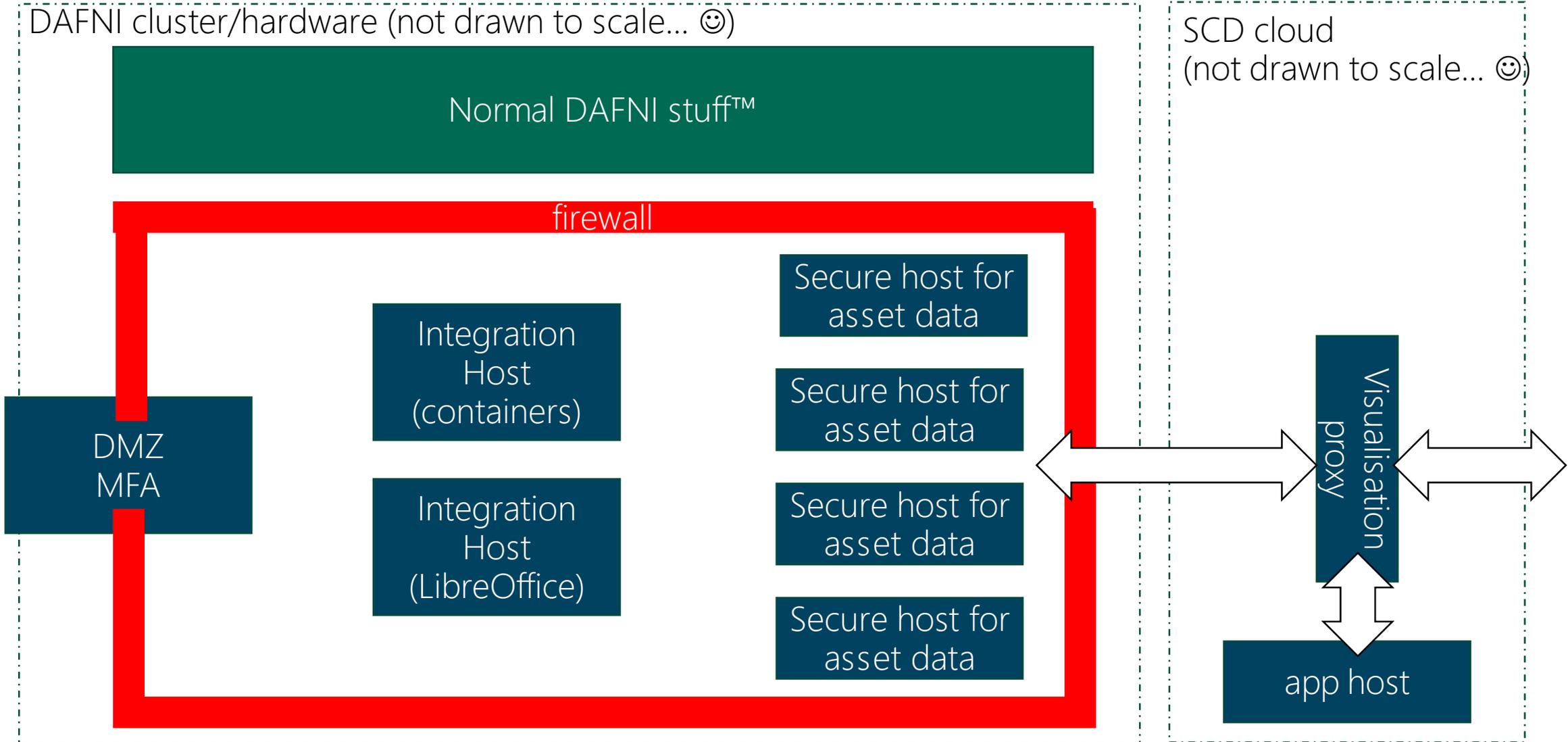
Digital twins and
other technologies

Integrate into CReDo stack
with new visualisation, and
connect asset risk models
to understand future heat
failure cascades

2. CREDO ON DAFNI

In DAFNI? Near DAFNI?

DAFNI SERVICES – CREDO+



Supporting different kinds of users

DAFNI user	Technical skill	Main tool	Support	Todo
Build models	☠️	Docker	training	Builder
Workflows	😊	DAFNI	🚩	Debugging
Explore visualisations	😎	Jupyter, data explorer	🚩	
Find data	🚩	NID		Non-NID

CRedo user	Technical skill	Main tool	Support	Todo
Build models	☠️☠️	podman		
Workflows	N/A	N/A	N/A	??
Explore visualisations	😎	custom	CRedo	
Explore data	😞	libreoffice calc, VS code		More data, more formats

CREDO ON DAFNI

Some parts of CReDo are on Normal-DAFNI

- Flood modelling based on HiPIMS
- CReDo group on Normal-DAFNI has synthetic infrastructure data
 - Designed to mimic interesting features in real data
 - Utility models, eg uncompressing data
 - Visualisation built with support from Rose

3. ASSET MODELLING

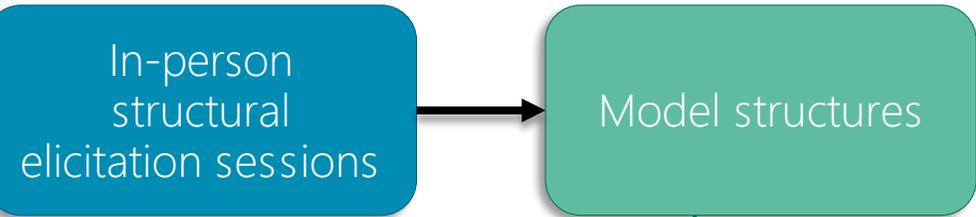
ELECTRICITY DISTRIBUTION

FAILURE MODELS FOR ELECTRICITY NETWORKS

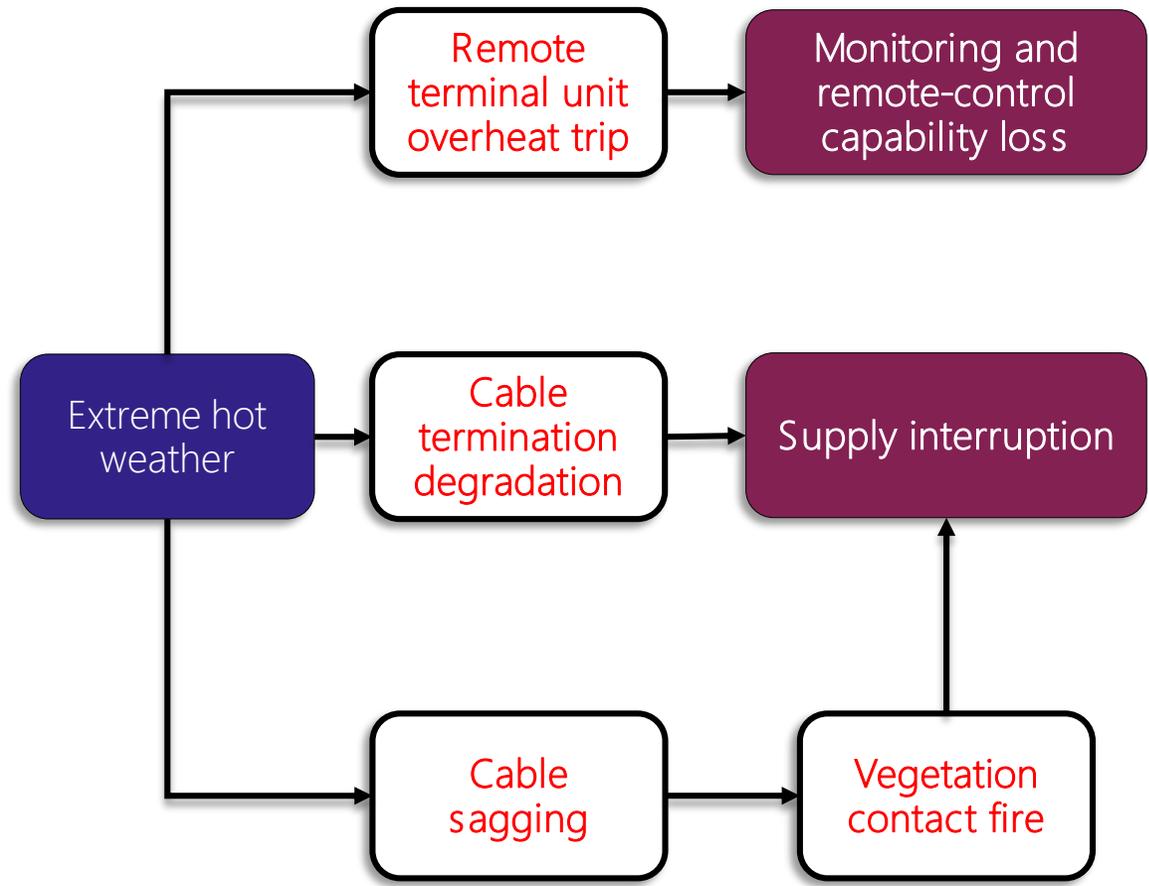
CREDo – Expert elicitation

A method to formalise and document tacit knowledge from your expert staff into readily usable mathematical

How does it work?



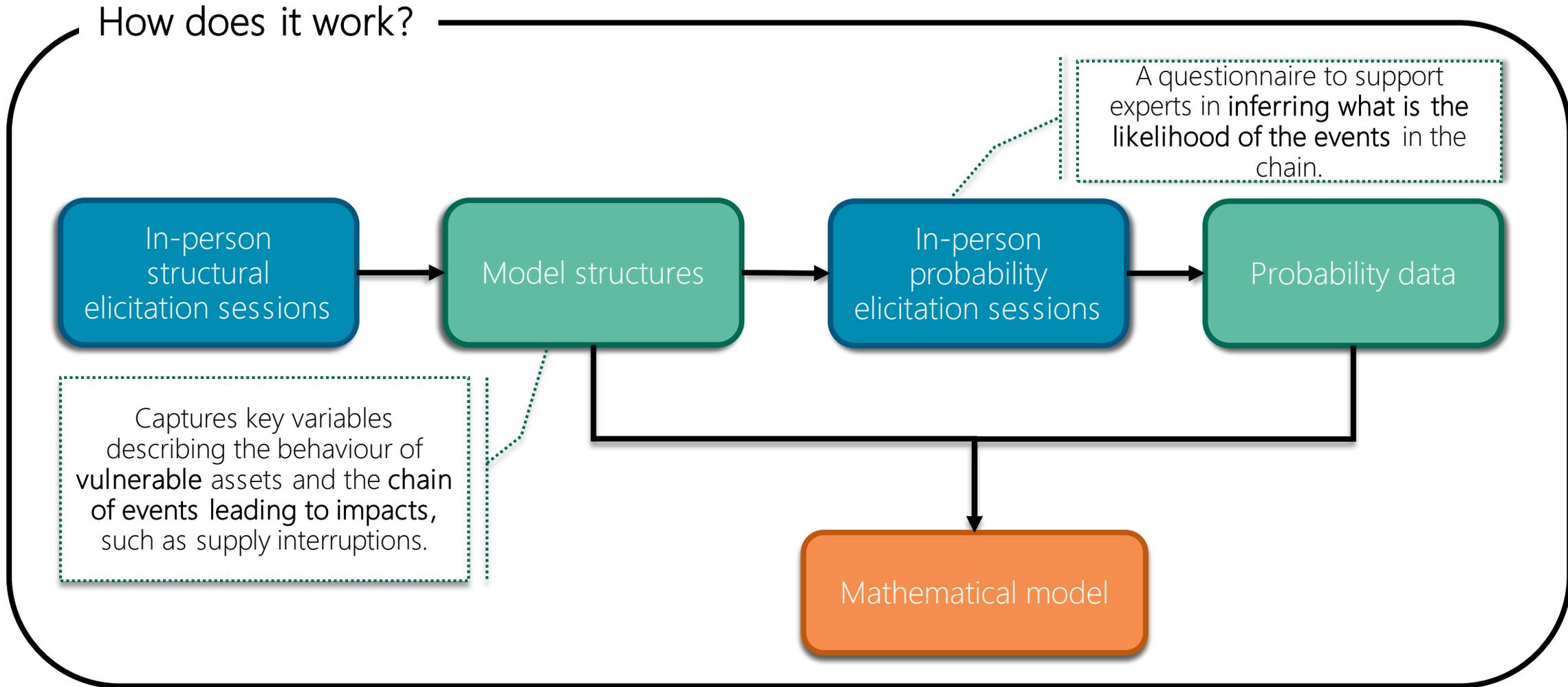
Captures key variables describing the behaviour of vulnerable assets and the chain of events leading to impacts, such as supply interruptions.



Example model structure

CREDo – Expert elicitation

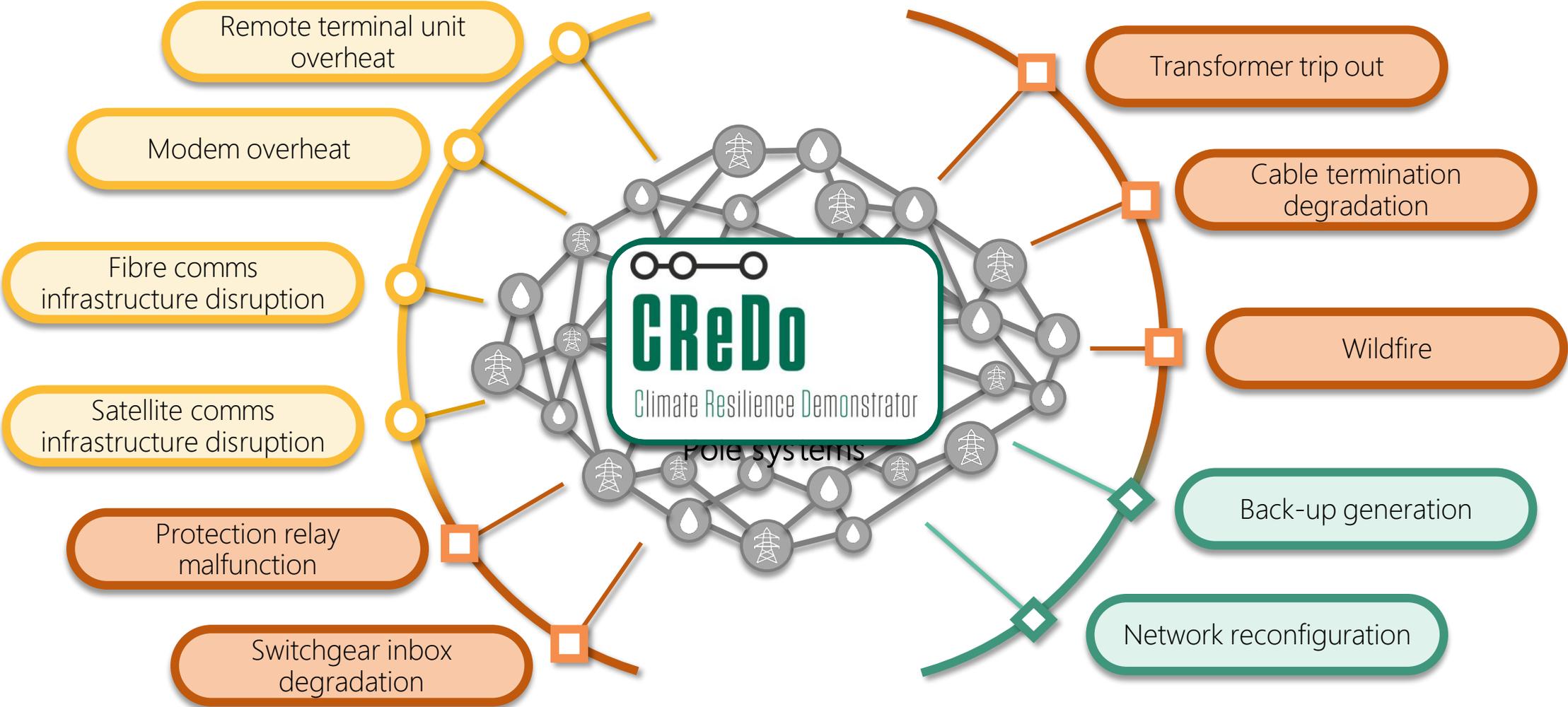
A method to formalise and document tacit knowledge from your expert staff into readily usable mathematical models



ASSET MODELLING

A SUMMARY OF ELICITATION OUTPUTS

OUTPUTS OF ELICITATION VULNERABILITIES & MITIGATIONS

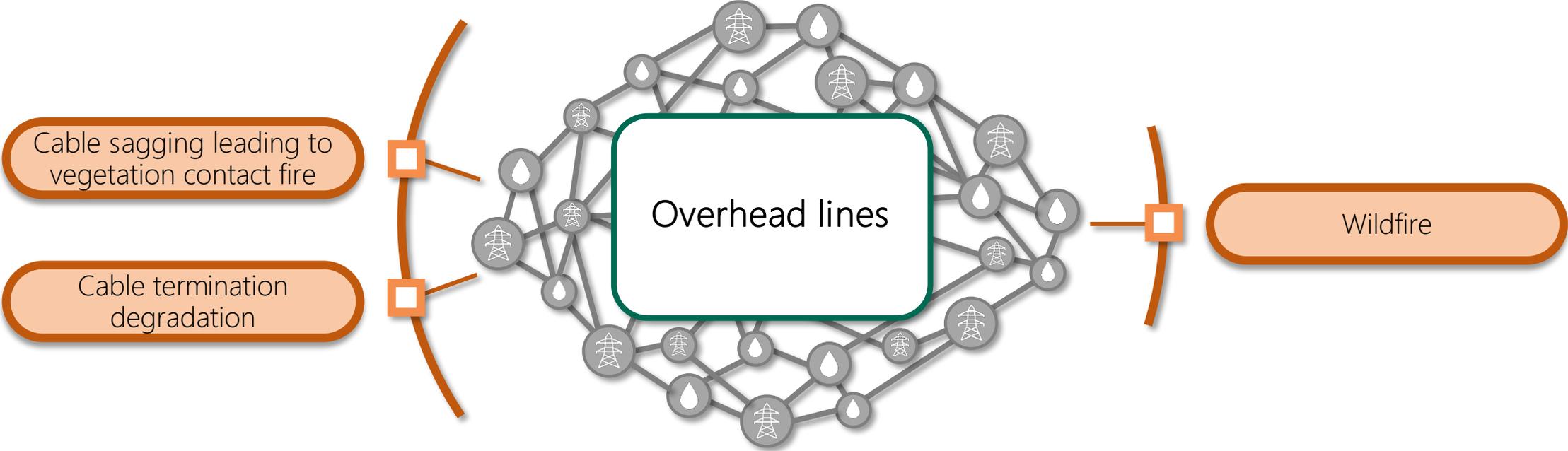


 Monitoring and remote-control telecoms faults

 Supply interruption faults

 Mitigation measures

OUTPUTS OF ELICITATION VULNERABILITIES & MITIGATION (2)

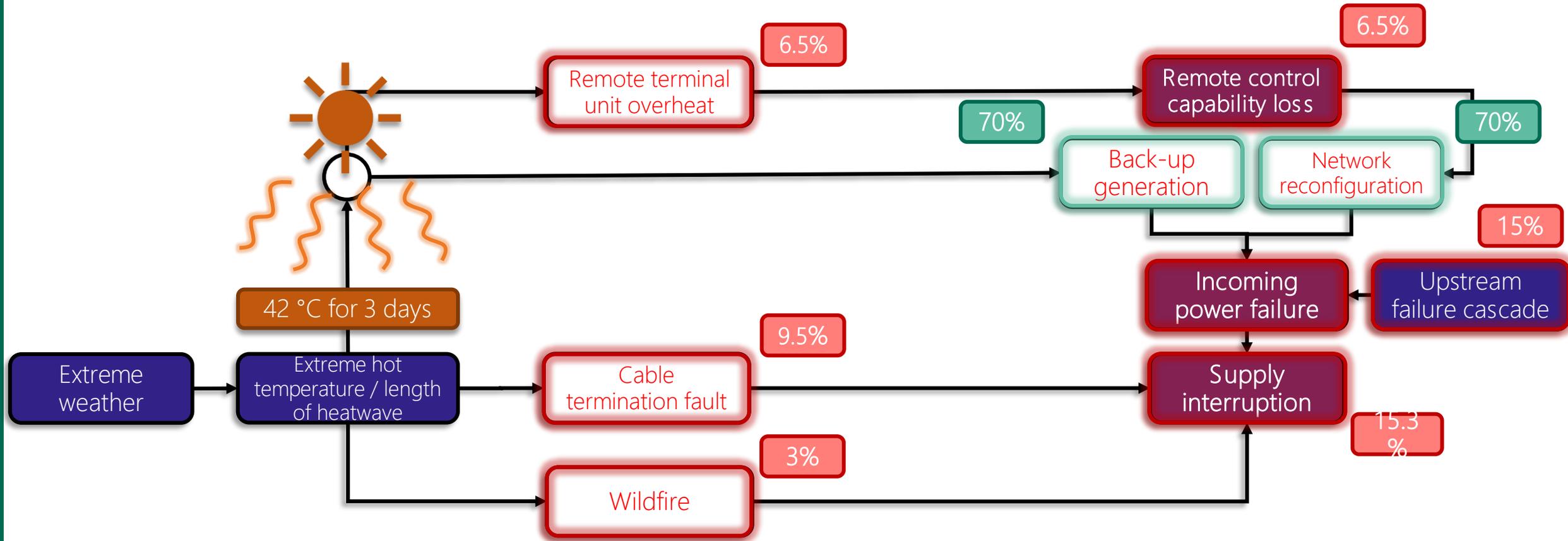


Supply interruption faults

ASSET MODELLING

OBTAINING OUTPUTS WITH THE NEW MODELS

RUNNING MODELS FOR EACH SITE TO EVALUATE RISK



! What is the chance that each individual event takes place?

⚡ What is the likelihood of a supply interruption?

📶 What is the probability of losing telecom services?

🔗 What is the chance of being impacted by other sites?

Now, it is possible to run the models to understand what could happen.

ASSET MODELLING

EXPERT ELICITATION - ADVANTAGES AND CHALLENGES

ADVANTAGES AND CHALLENGES IN EXPERT ELICITATION



Advantages

Flexible

It is possible to model many different types of events.

Little data

You do not need vast amounts of processed data, mainly expertise

Tailored complexity

You can make simple or very complex models, depending on what your objective is.



Challenges

In-person

Requires a mathematical expert leading the process and lengthy interviews to obtain the information.

Mathematical nuance

The process seems simple, but there is a lot of mathematical detail to consider to ensure robustness.

Generalisation

The interviews need to be specific, so how do you generalise the results of one site to many?

4. DIGITAL ELICITATION TOOL

DIGITAL ELICITATION TOOL

Building an elicitation tool prototype

The goal is to extract information from people's heads...

- Structural elicitation – which factors can cause failure or degradation
- Probabilistic elicitation – how likely is each factor to affect the asset

The importance of sharing failure models

- Several people contribute
- Continuing work on models to build more sophisticated models

Deploy failure models into the CReDo Digital Twin

- Real assets, real scenarios, simulated failures

Digital Elicitation Tool: Challenges

What are the challenges we are aiming to solve through the tool?

1. Scalability
 - Lots of substations – all similar to each other, yet all are different from each other
 - Deployment of models into real world scenarios
2. The need for contributions from different experts for a single failure model
 - Capturing asset-specific structural and probabilistic failures
 - Underlying mathematical models (e.g Bayesian models, probability distributions)
 - Continuous improvement of models by adding details
 - QA and correctness of models

MODELS LIBRARY

-  Stephane
-  Dashboard
-  New Model
-  My Models ▼
-  Reviews 2
-  Approvals 1
-  Model Library
-  Help

Dashboard

Model Search

My Models

Draft: 3
Review: 3
For Approval: 1
Approved: 3

My Reviews

Structural: 1
Probabilities: 3
Model Approval: 1

Quick Links

[CREATE NEW MODEL](#)

[VIEW MY MODELS](#)

[VIEW MY REVIEWS](#)

Latest Activity

- George has approved model, primary substation 1
- Alice has completed probability elicitation for model, primary substation 1
- John has completed probability elicitation for model, primary substation 1
- Bob has completed structural review for model, primary substation 1

My Most Recent Model

Secondary Substation

In Review

Description

This is a model that provides understanding of the behaviour/degradation of remote terminal units, modems, switchgear, distribution transformers and cable termination because of extreme heat conditions. It also considers the possibility that there is a wildfire in close proximity that may damage equipment.

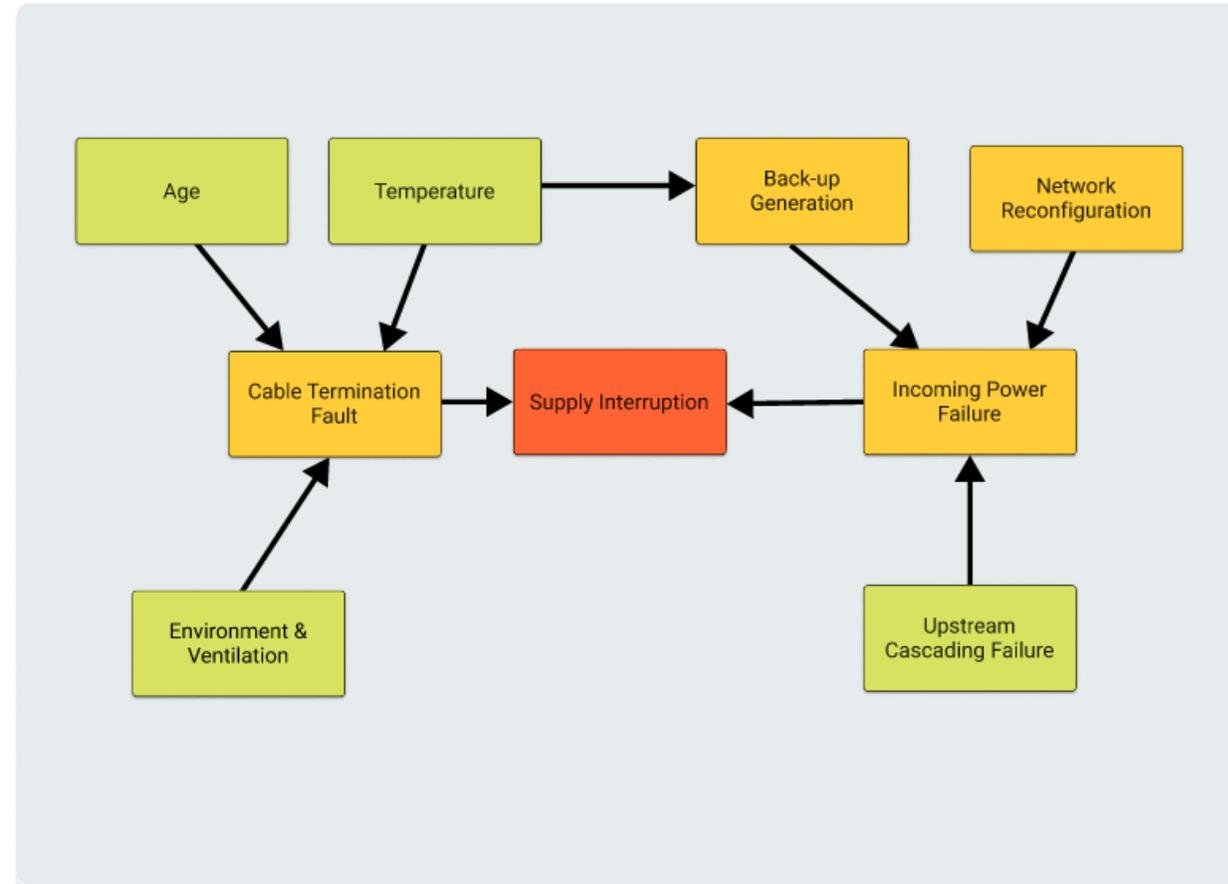
-  Extreme Heat
-  North City
-  21/10/23
-  10/10/23
-  Substation

STRUCTURAL ELICITATION



Model Builder - Structure

- Stephane
- Dashboard
- New Model
- My Models
- Reviews 2
- Approvals 1
- Model Library
- Help



ADD VARIABLE

REMOVE VARIABLE

REVIEW COMMENTS

Probabilistic

Input

Output

CONTINUE TO MODEL INPUTS

BACK

HELP

SAVE & EXIT

PROBABILISTIC ELICITATION

map is here

- Bob
- Dashboard
- New Model
- My Models
- Reviews 2
- Approvals 1
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- Help

Elicitation Questionnaire

Question 5: 5/10

Think about cable terminations in this area during a peak in demand in summer. What is your probability in the described scenario:

"of a cable termination fault due to temperature and solar radiation"

In the case that the ambient maximum temperature for that day/s outside is:

Between 35 °C and 40°C for a day:

Chance of fault:



Rationale

Between 35 °C and 40°C for 7 days in a row:

Chance of fault:



Rationale

Between 35 °C and 40°C for 14 days in a row:

Chance of fault:



Rationale



VIEW SCENARIO

PREVIOUS ANSWERS

SITE PLAN

VISUALISATIONS

3D ASSET VIEW

SITE IMAGES

CONTINUE

BACK

CReDo+

DIGITAL ELICITATION TOOL

What next for the elicitation tool?

Using DET in BSRW...

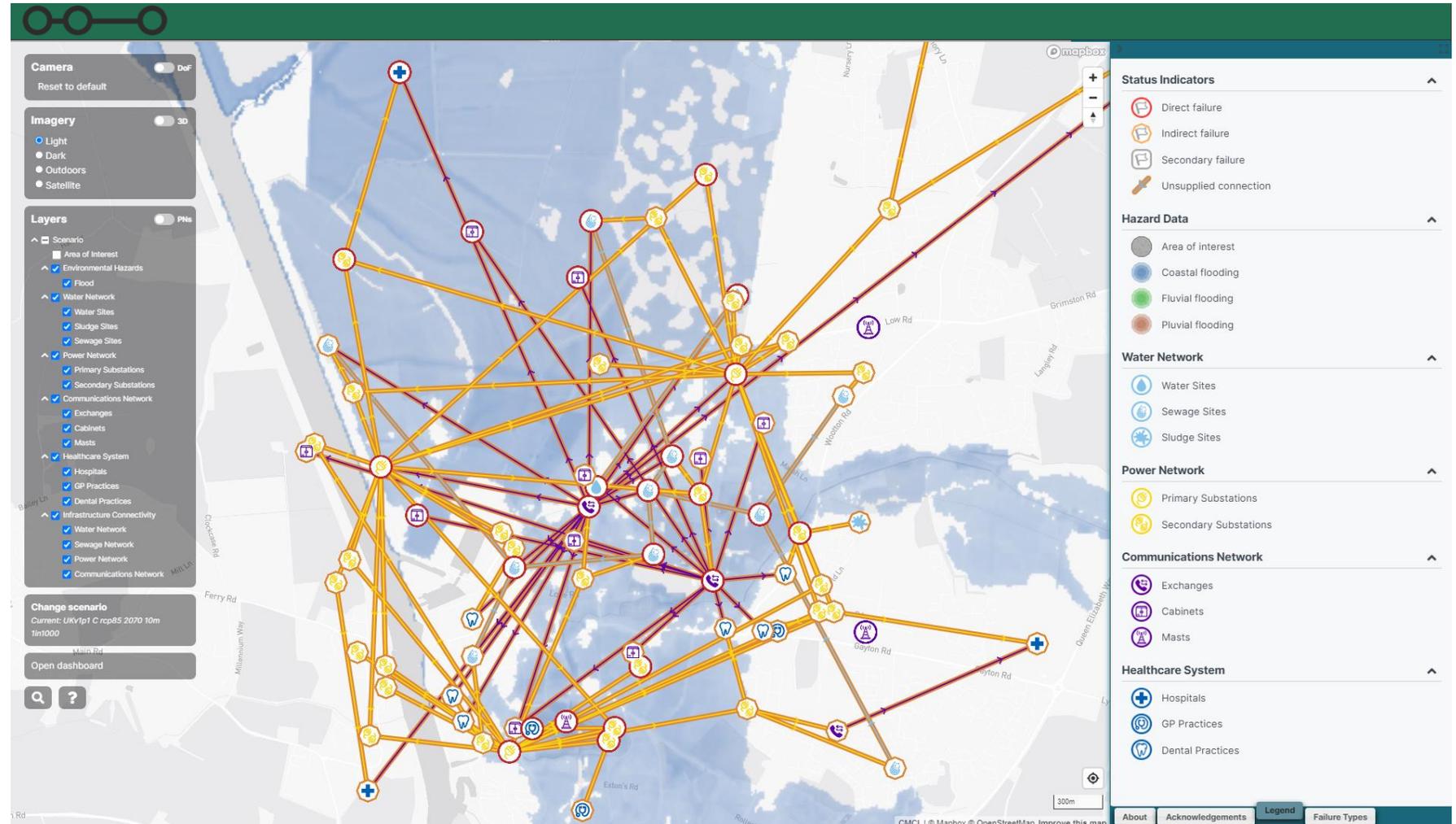
1. Take out power network specific things; adapt embedding of failure model into non-CReDo DT
2. Can we combine with e.g. USARIS failure models?
3. Make available to all DAFNI users and feed back into CReDo
- \$. Demonstrate at the September conference

5. DIGITAL TWINNING

CREDO PLATFORM

Integration of asset and weather event data for different climate scenarios

Effect of flooding on combined energy, water and telecoms network



CREDO PLATFORM

Integration of asset and weather event data for different climate scenarios

Extreme heat weather events

The screenshot displays the CREDO platform interface. On the left, a sidebar contains several control panels: 'Camera' with a 'DoF' toggle and 'Reset to default' button; 'Imagery' with a '3D' toggle and radio buttons for 'Light', 'Dark', 'Outdoors', and 'Satellite'; 'Layers' with a 'PNs' toggle and a tree view showing 'Scenario' expanded to include 'Area of Interest', 'Environmental Hazards' (with 'Heat' checked), and 'Power Network' (with 'Primary Substations', 'Secondary Substations', and 'Infrastructure Connectivity' expanded to show 'Power Network'); 'Change scenario' with 'Current: Heat'; and 'Open dashboard'. At the bottom of the sidebar are search and help icons. The main map area shows a map of the United Kingdom with a heat hazard overlay in shades of orange and red. A timeline at the bottom of the map allows selection between 'November 2049' and 'November 2050'. On the right side, there is a 'mapbox' logo and zoom controls. At the bottom right, there is a '100km' scale bar and a 'mapbox' logo. A large orange speech bubble on the left contains the text 'Extreme heat weather events'. On the right side of the interface, there is a 'Project partners' section with logos for various organizations including UK Power Networks, BT Group, and others. Below this is a paragraph of text describing the project's collaboration and goals. At the very bottom right, there are navigation links for 'About', 'Acknowledgements', 'Legend', and 'Failure Types'.

Project partners

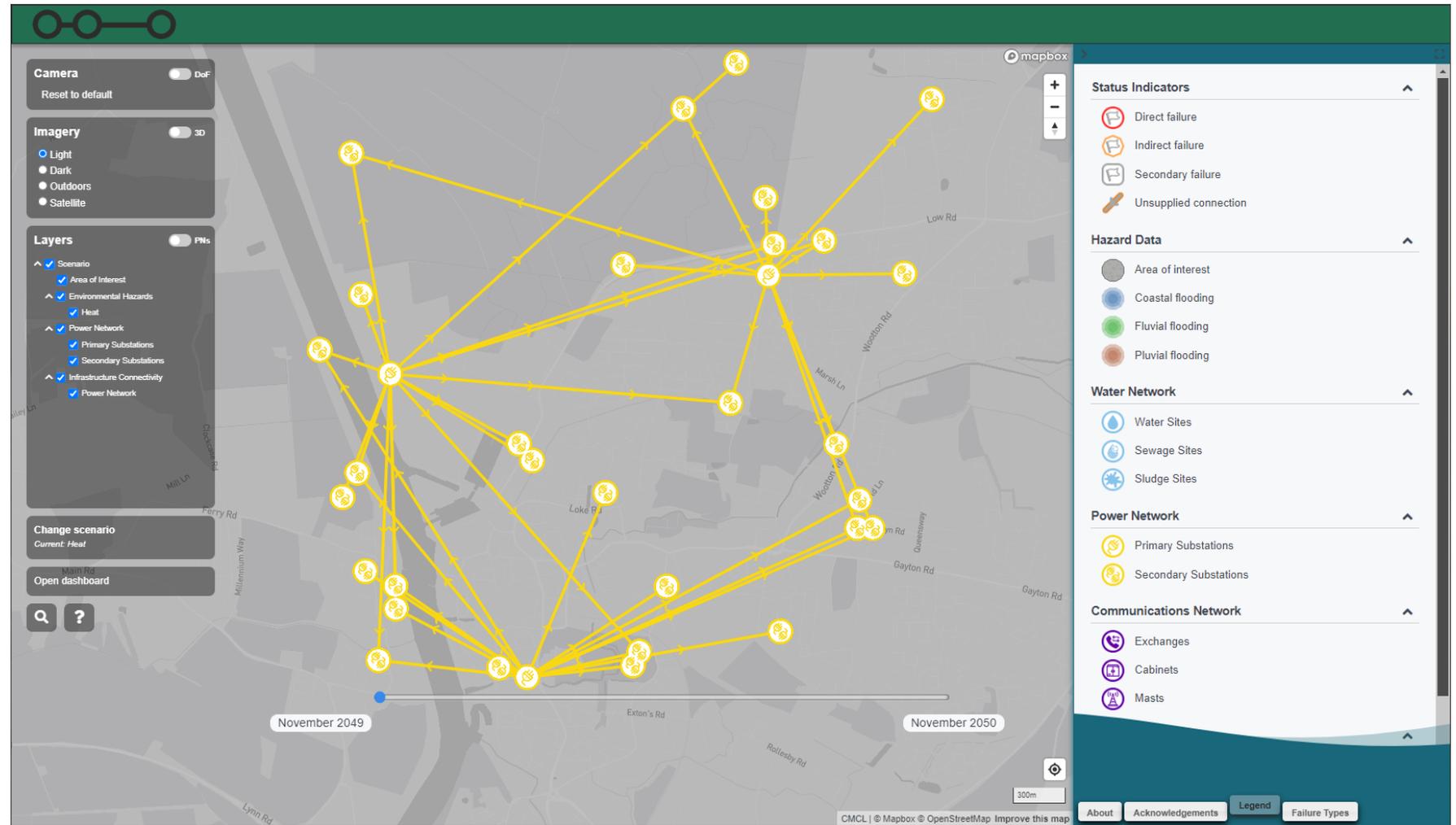
Collaborating on the first phase of CREDo were Anglian Water, BT and UK Power Networks, who used their asset and operations data as well as weather data supplied by the Met Office on a secure, shared basis to inform an increased level of infrastructure resilience. These data sets were securely shared to create a digital twin of the infrastructure system for energy, water and telecoms. This enabled insights from the data that can inform decision making concerning capital and operational planning and real time operations reducing the cost and disruptive impact of extreme weather events. CREDo was delivered through a collaboration of research centres (Universities of Cambridge, Edinburgh, Newcastle, and Warwick along with the Science and Technology Facilities Council, and the Joint Centre of Excellence in Environmental Intelligence) and industry, funded by BEIS, the Connected Places Catapult and the University of Cambridge.

About Acknowledgements Legend Failure Types

CREDO PLATFORM

Integration of asset and weather event data for different climate scenarios

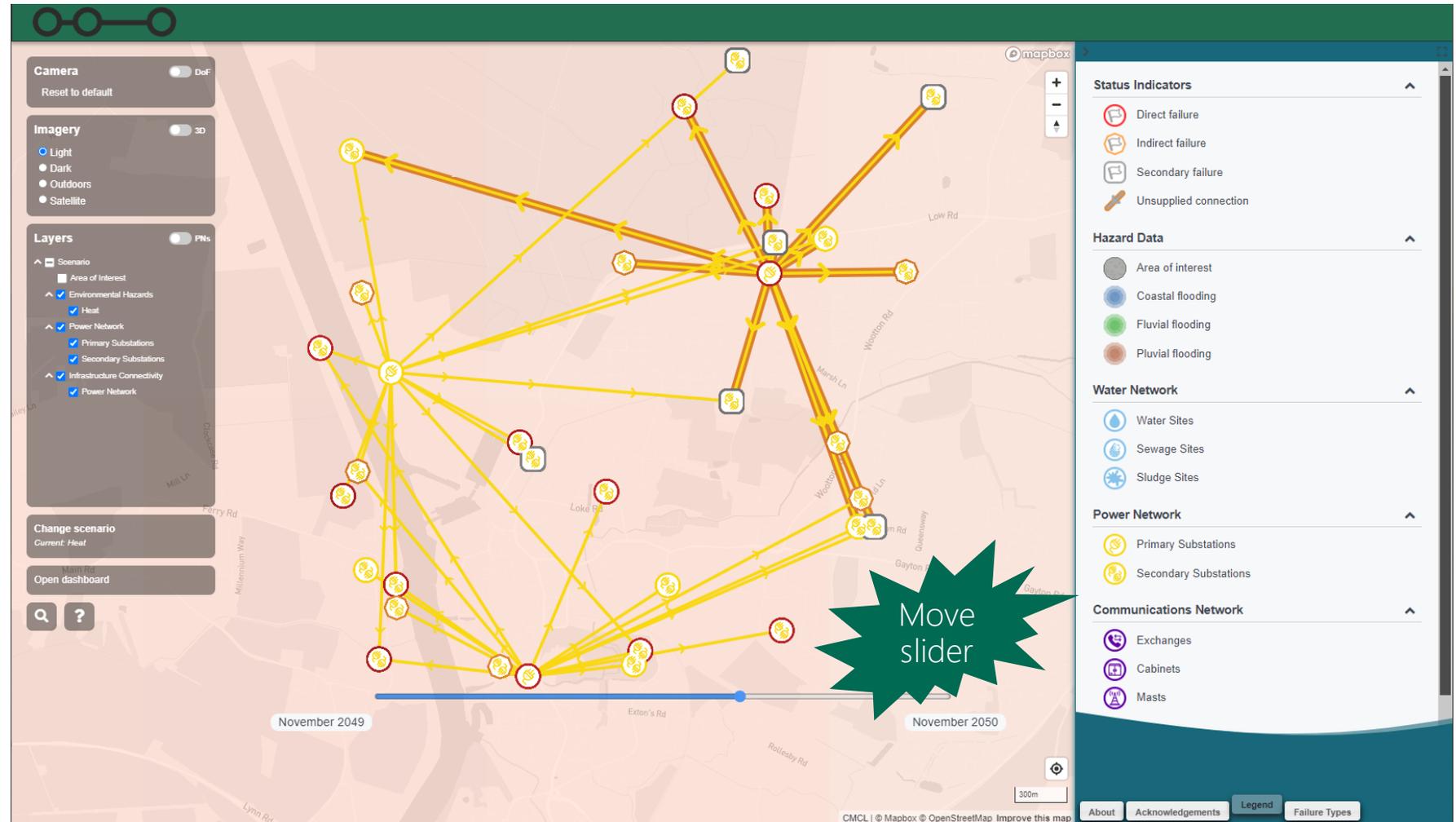
Asset networks



CREDO PLATFORM

Integration of asset and weather event data for different climate scenarios

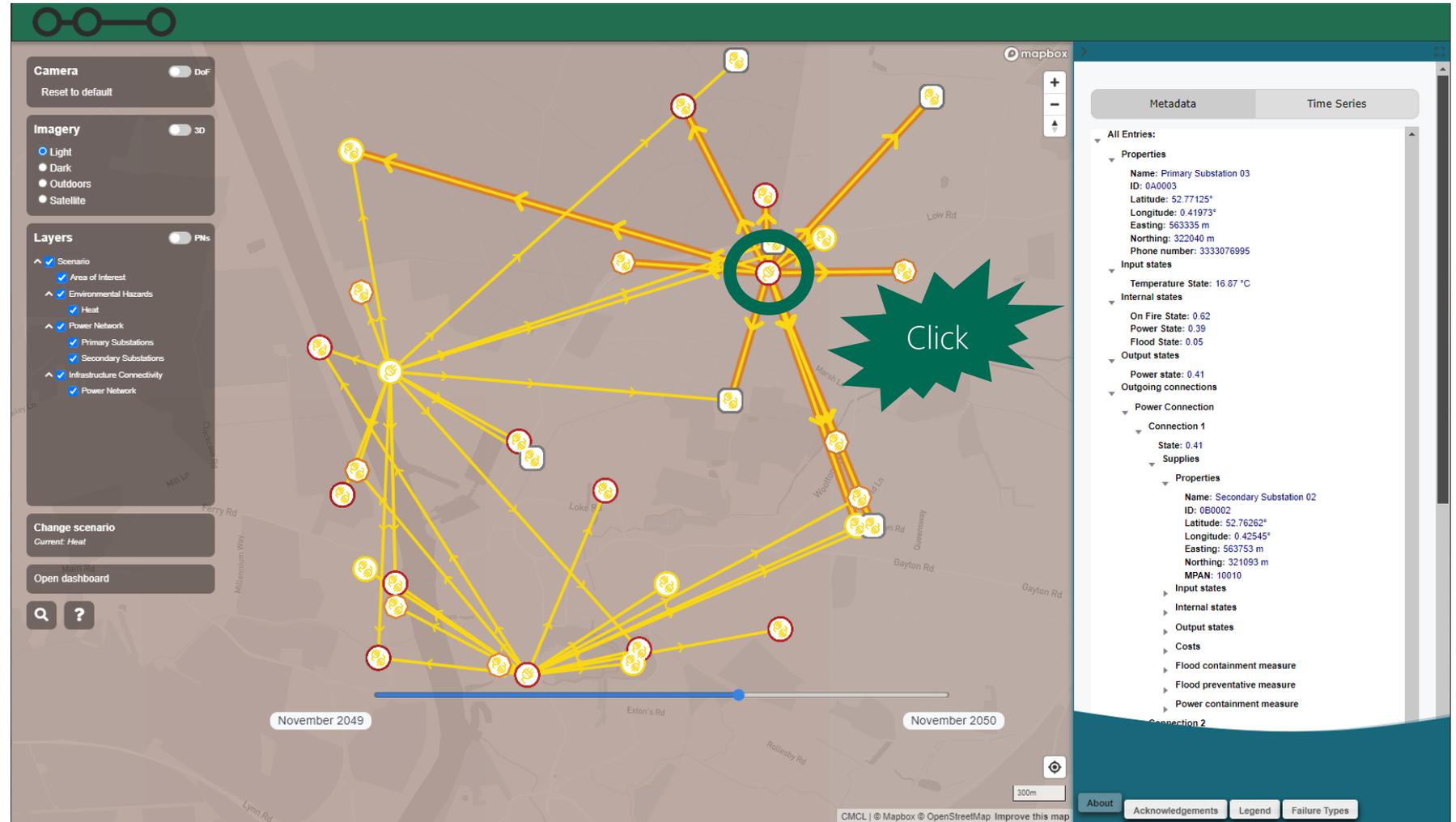
Failure model
connected to
each asset



CREDO PLATFORM

Integration of asset and weather event data for different climate scenarios

Asset data



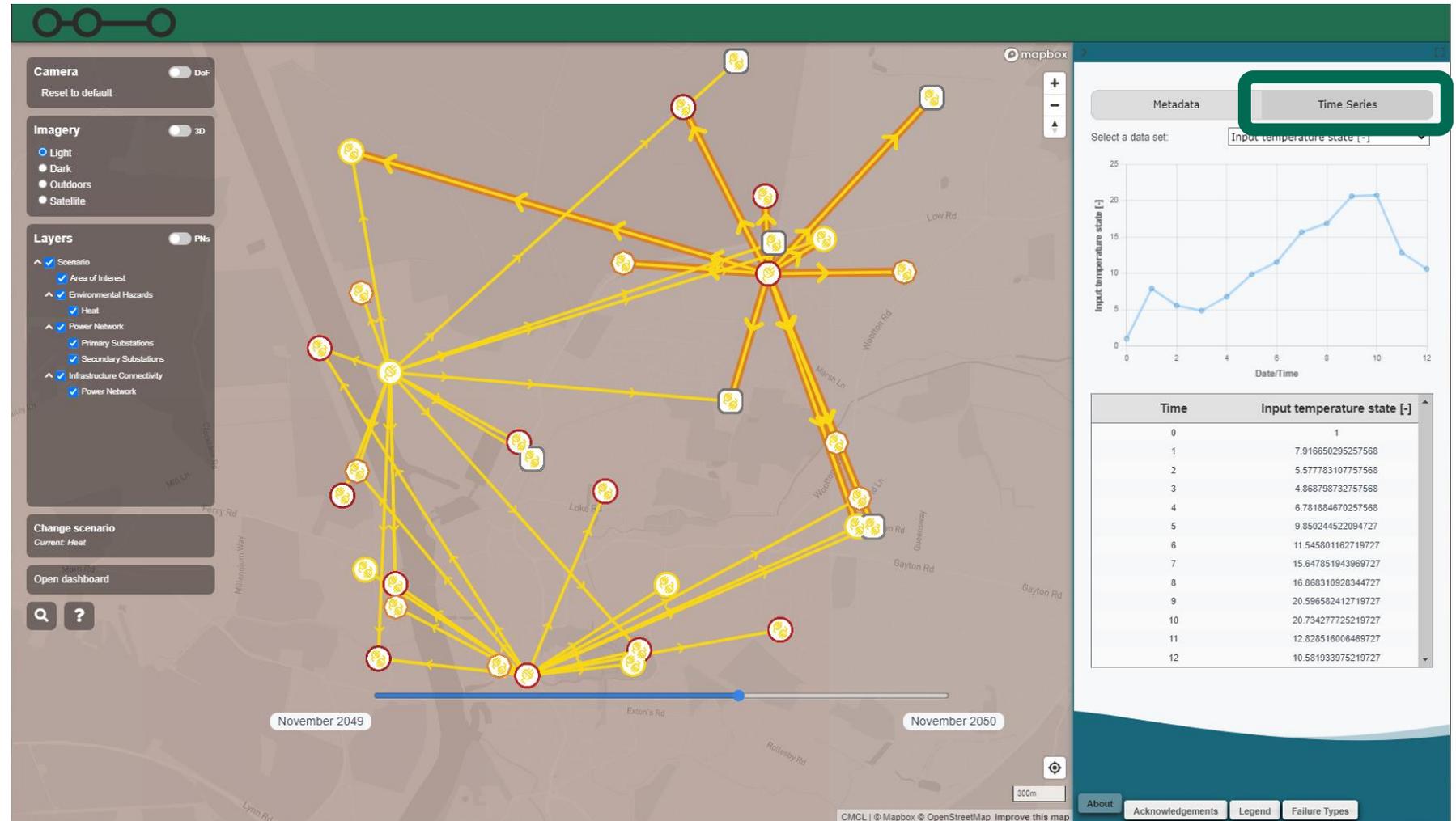
The screenshot displays the CREDO platform interface. On the left, a control panel includes sections for Camera (DoF), Imagery (Light, Dark, Outdoors, Satellite), Layers (Scenario, Area of Interest, Environmental Hazards, Heat, Power Network, Primary Substations, Secondary Substations, Infrastructure Connectivity, Power Network), Change scenario (Current: Heat), and Open dashboard. The main area is a map showing a network of yellow lines and nodes, with a central node highlighted in a green circle and a green starburst labeled 'Click'. A timeline at the bottom shows dates from November 2049 to November 2050. On the right, a metadata panel is open, showing details for 'Primary Substation 03' and 'Secondary Substation 02', including ID, coordinates, and various state and connection parameters.

CREDO PLATFORM

Integration of asset and weather event data for different climate scenarios

Click

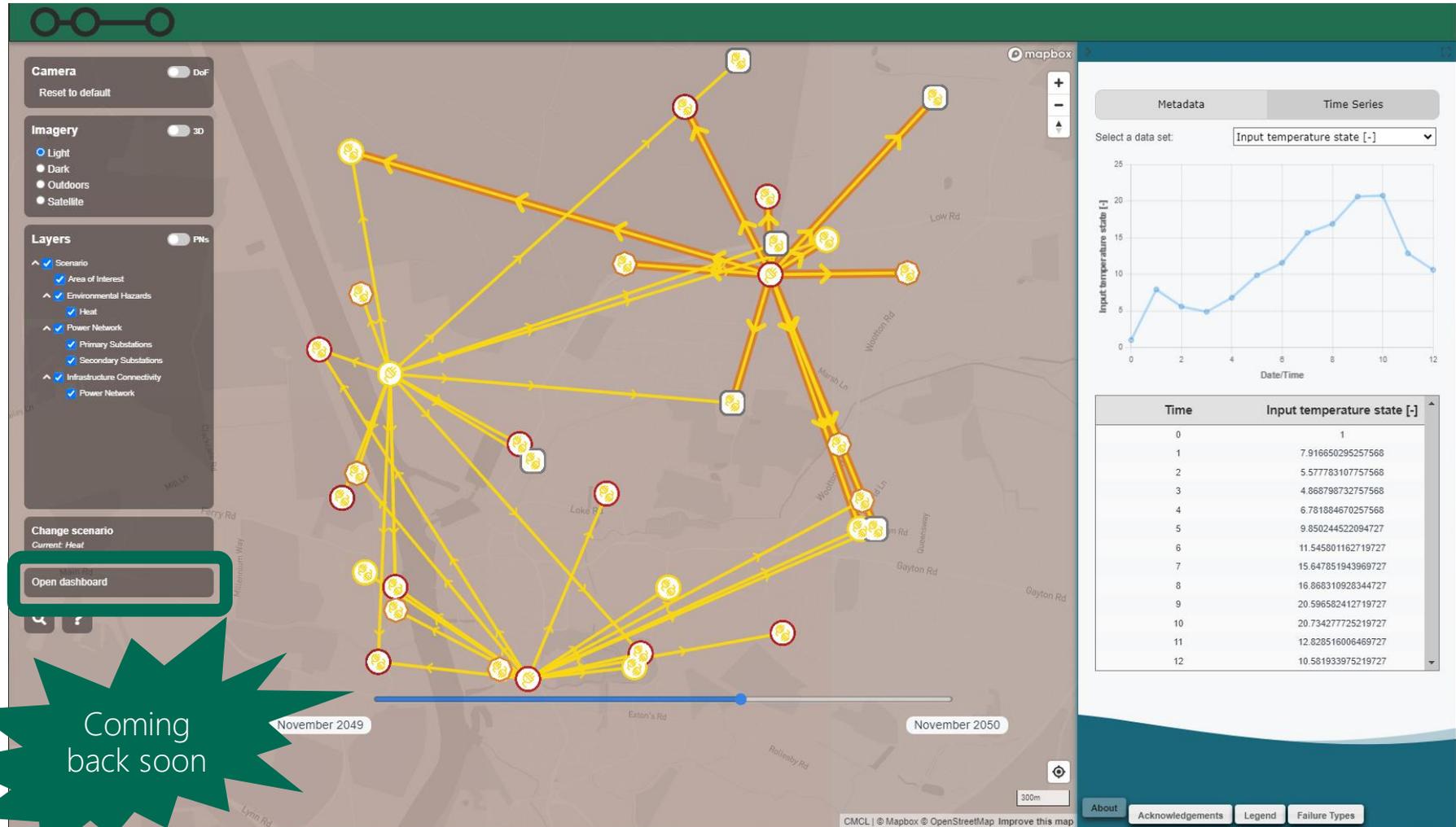
Time history



CREDO PLATFORM

Integration of asset and weather event data for different climate scenarios

Summary information across scenarios



The screenshot displays the CREDO platform interface. On the left, there are control panels for Camera (DoF), Imagery (Light, Dark, Outdoors, Satellite), Layers (Scenario, Area of Interest, Environmental Hazards, Heat, Power Network, Primary Substations, Secondary Substations, Infrastructure Connectivity, Power Network), and Change scenario (Current: Heat). A button labeled 'Open dashboard' is highlighted with a green box. The main area shows a network map with yellow nodes and arrows, overlaid on a satellite map. A timeline at the bottom indicates the current date is November 2049, with a slider extending to November 2050. On the right, there is a 'Time Series' panel with a dropdown menu set to 'Input temperature state [-]'. Below the dropdown is a line graph showing the input temperature state over time. Below the graph is a table with the following data:

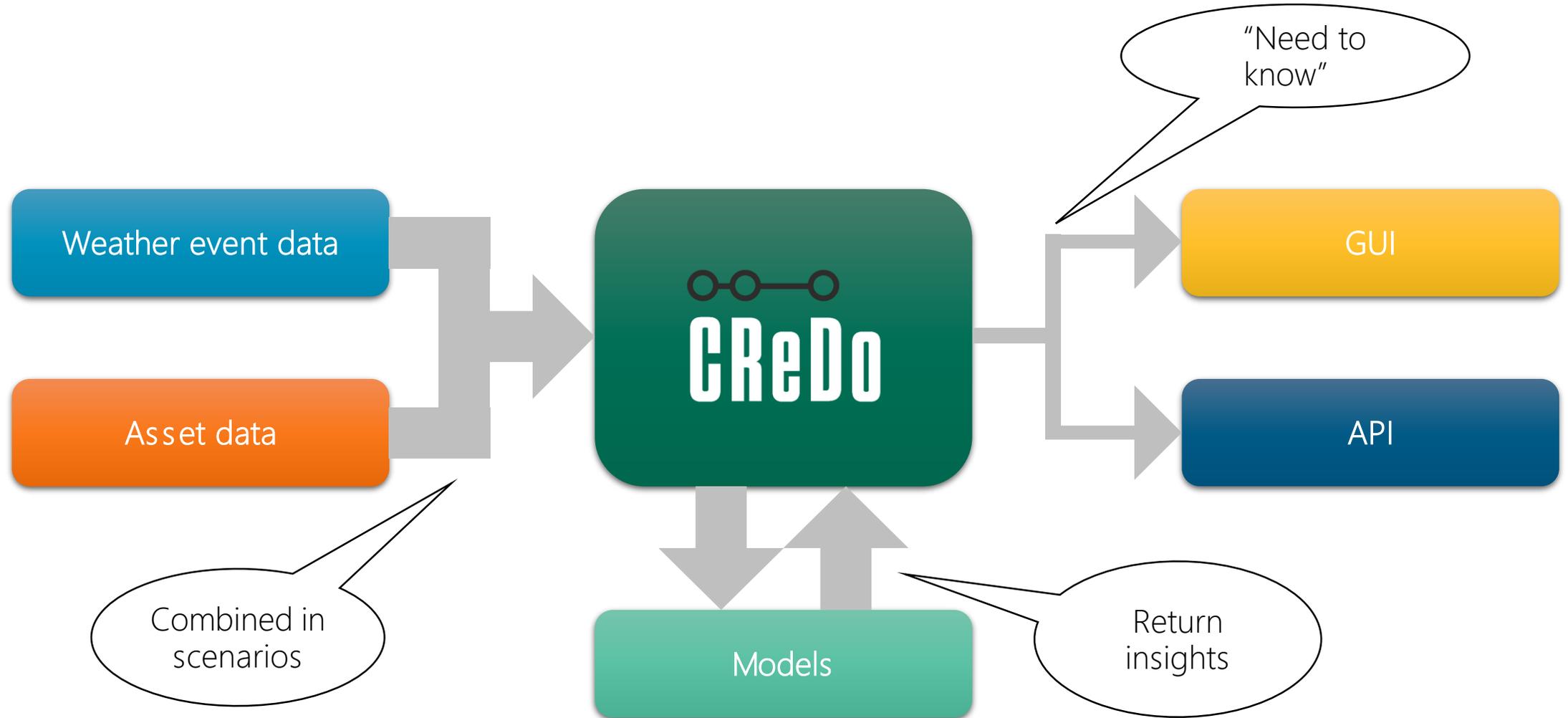
Time	Input temperature state [-]
0	1
1	7.918650295257568
2	5.577783107757568
3	4.868798732757568
4	6.781884670257568
5	9.850244522094727
6	11.545801162719727
7	15.647851943969727
8	16.868310928344727
9	20.596582412719727
10	20.73427725219727
11	12.828516006469727
12	10.581933975219727

At the bottom right, there are links for 'About', 'Acknowledgements', 'Legend', and 'Failure Types'. A green starburst graphic at the bottom left contains the text 'Coming back soon'.

Coming back soon

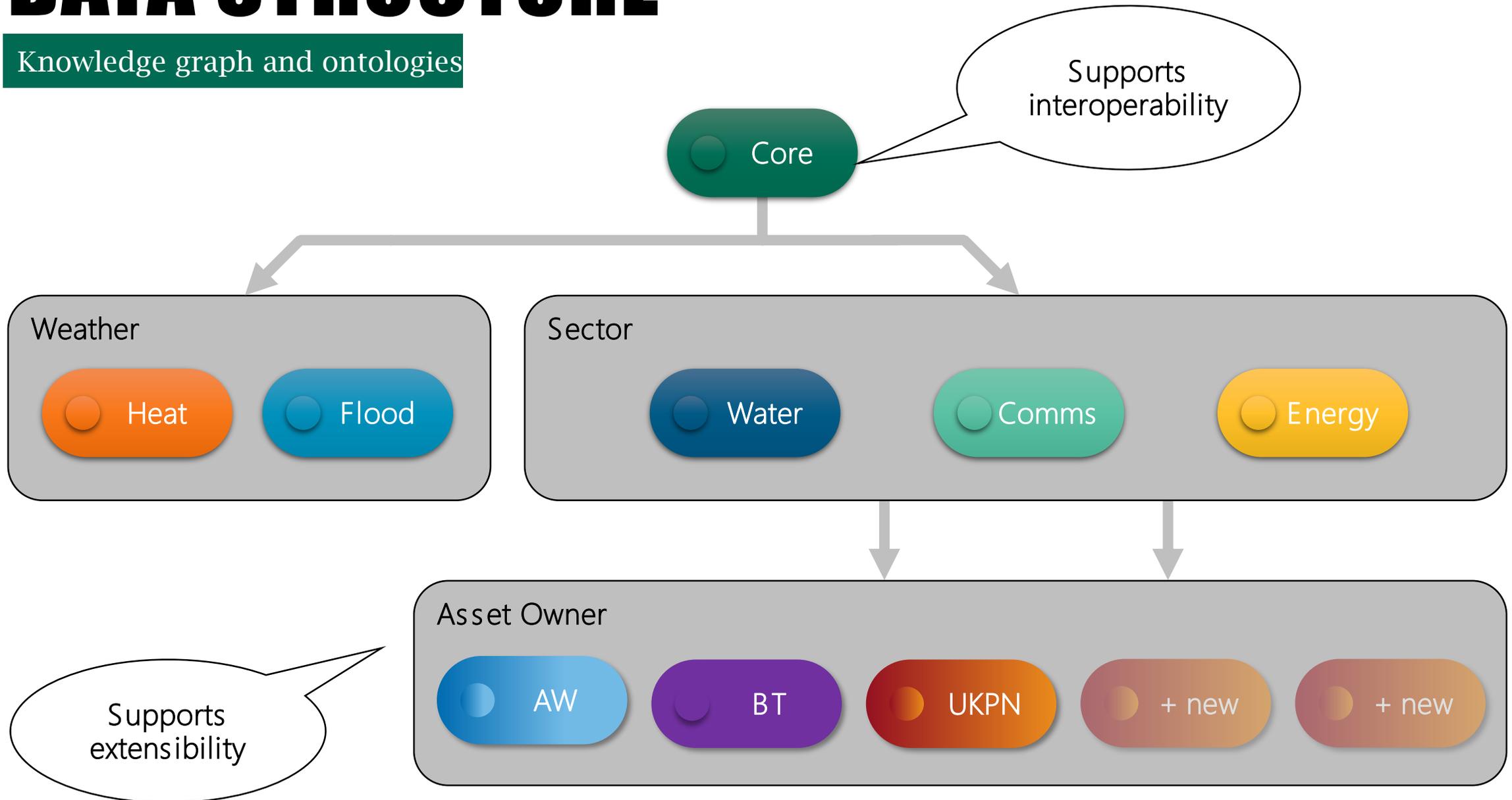
CREDO DATA FLOW

Integration of asset and weather event data for different climate scenarios



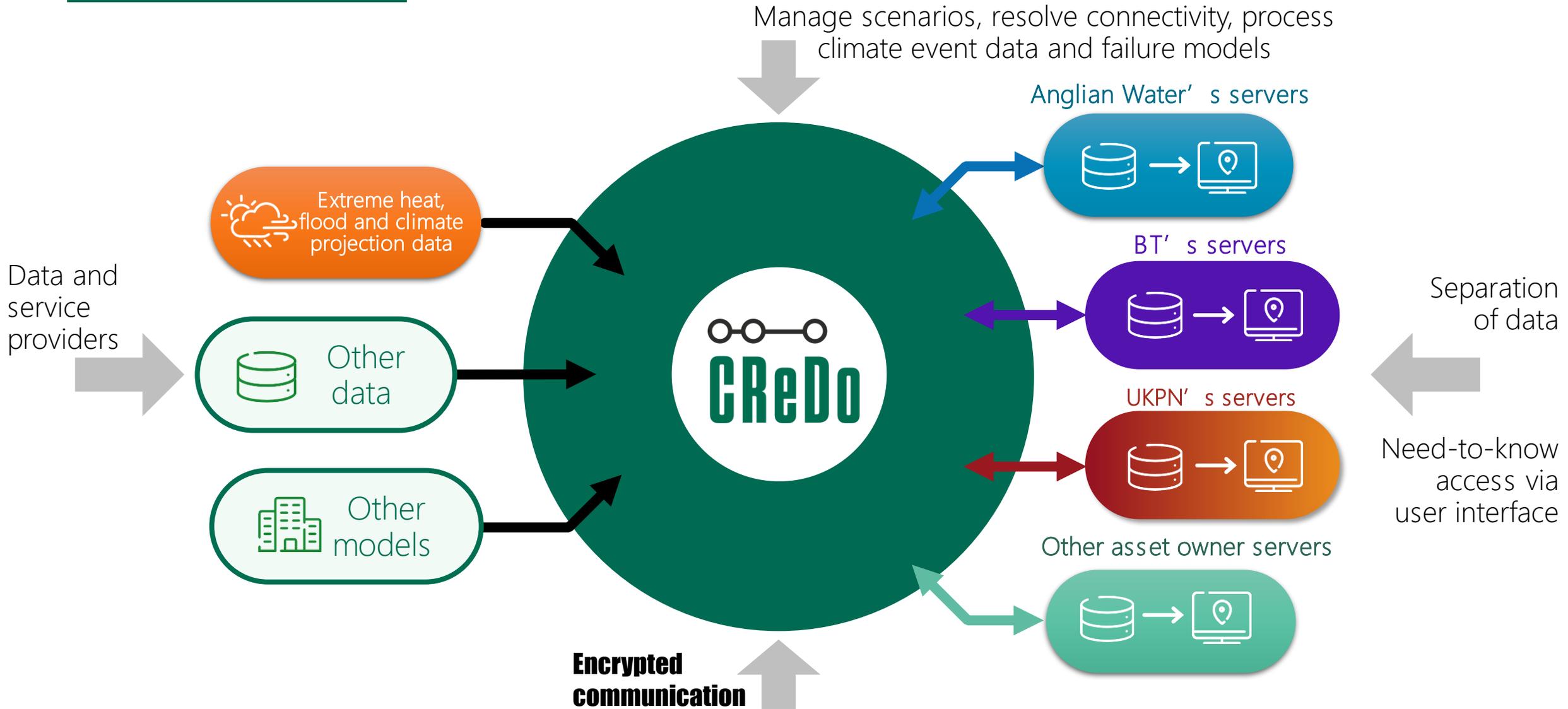
DATA STRUCTURE

Knowledge graph and ontologies



DATA SHARING INFRASTRUCTURE

Distributed Architecture



6. FUTURE

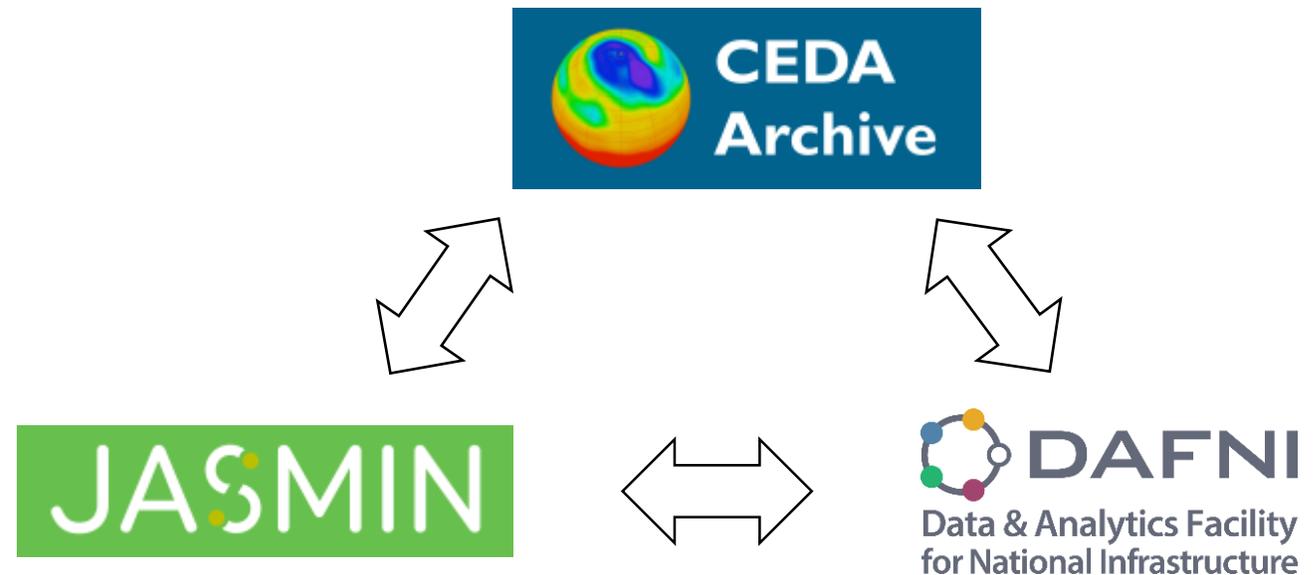
CREDO AND DAFNI

Ask not what you can do for CReDo

SUPPORTING CLIMATE PROJECTS

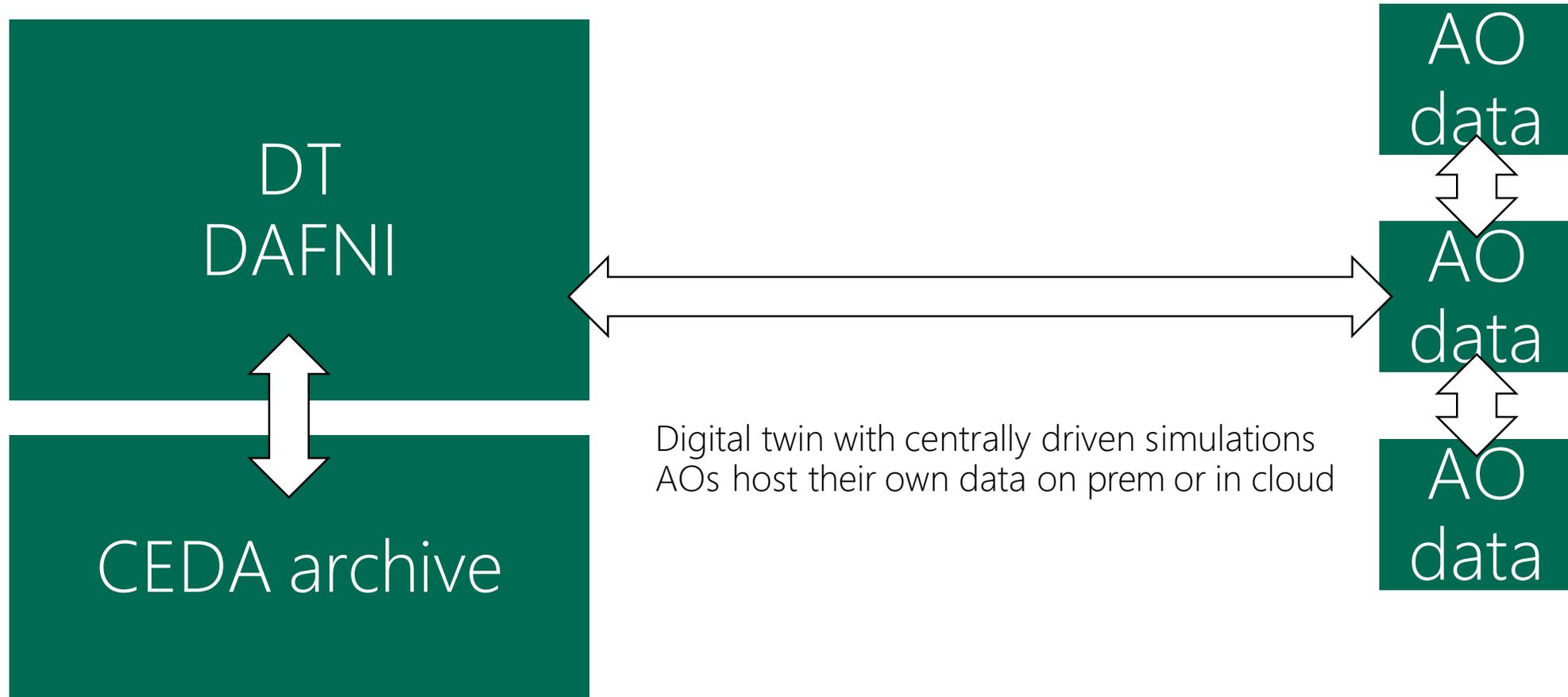
DAFNI already has loads of NERC-funded stuff

- Closer integration between JASMIN, DAFNI and the CEDA Archive
- OpenCLIM and CGFI are examples of NERC funded projects on DAFNI
- Like CReDo, DAFNI projects have flooded many locations, such as Newcastle ☺
- More climate resilience in BSRW



TOWARDS HYBRID INFRASTRUCTURE

Asset owners running their own data hosts



HANDLING CONFIDENTIAL DATA

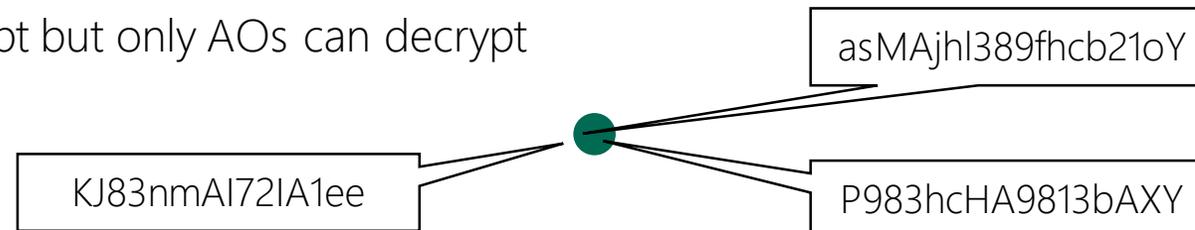
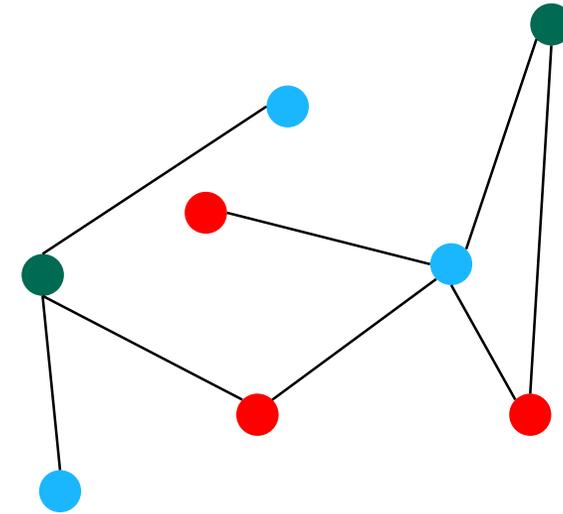
... towards a trusted research environment?

- JASMIN and DAFNI use cases for TRE
 - Though neither of us has healthcare data (nor do we want it thank you very much)
 - We have contacts with the DARE UK projects and the Manchester group(s)
- CReDo needs a higher LoA than normal-DAFNI can provide
- Normal-DAFNI uses old school username/password to ensure the LoA

HIDING SENSITIVE DATA

Using computational complexity and more advanced crypto

- For cascade effects, the *graph* is important
 - But locations are not
 - Finding isomorphisms between graphs is NP-complete (I think)
- For environment effects, the *location* is important
 - Hide location with a one way trap door function
 - Encoded nonce prevents replay and ensures each location has multiple encodings
 - The central DT can encrypt but only AOs can decrypt



6. CREDO IN UNAM TERRAM

Building a Secure and Resilient World

UKRI BUILDING A SECURE AND RESILIENT WORLD (2023-29)

<https://www.ukri.org/what-we-do/browse-our-areas-of-investment-and-support/building-a-secure-and-resilient-world/>

The aim is to:

- strengthen social and economic resilience
- enhance national security across virtual and physical spaces
- ensure the UK can absorb adversity, deal with change, and respond to emerging threats and opportunities

Potential target areas include:

- the UK energy supply grid
- resilient supply chains, including food and critical materials
- UK response to global risks
- adaptation to change and robust decision making

DAFNI CERIA

Centre of Excellence for Resilient Infrastructure Analysis

<https://www.dafni.ac.uk/the-centre-of-excellence-for-resilient-infrastructure-analysis/>

- Can we combine the work from CReDo and DAFNI BSRW?
 - Strengthen asset resilience modelling tools for non-electricity assets
 - Feed back into future CReDo activities
- Improve user support on DAFNI domain experts with less technical patience
- More sharing Useful Stuff™ across digital twins on DAFNI
 - CReDo stuff in credo group

THANK YOU

For more information, please contact:

credo@cp.catapult.org.uk