# Three versions of interdependence

## *The ITRC's national infrastructure system-of-systems modelling capability*

*Prof Jim Hall*

*4 April 2014*

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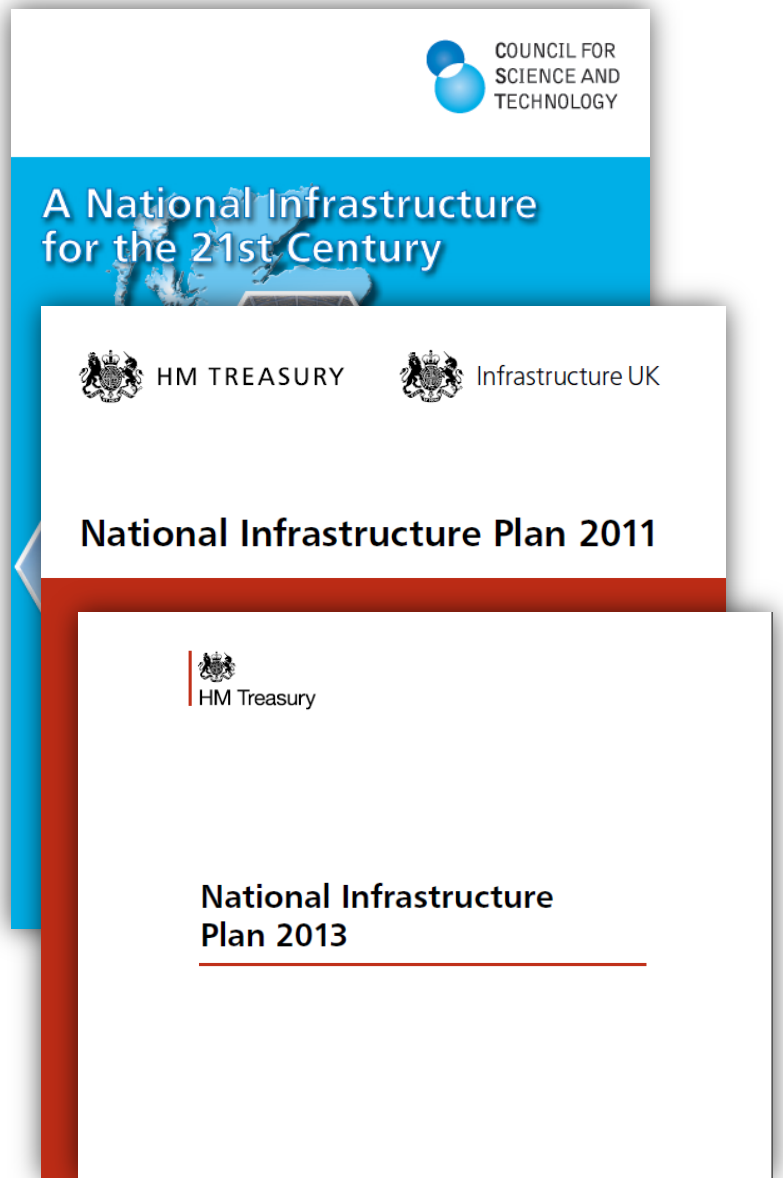
# Motivation

*"The stakes are high. Failure to develop and implement a vision for our infrastructure will mean the UK falls behinds its competitors, loses out both economically and socially, and could miss its carbon reduction targets"*

*"Britain will not be able to compete in the modern world unless we improve our infrastructure."*

*"The government recognises that meeting the UK's infrastructure ambitions requires a long-term sustainable plan, which means taking a cross-cutting and strategic approach"*

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# The UK Infrastructure Transitions Research Consortium (ITRC)

***Aim*:** To develop and demonstrate a new generation of simulation models and tools to inform the analysis, planning and design of national infrastructure

***Ambition*:** Enabling a revolution in the strategic analysis of NI provision in the UK…

whilst at the same time becoming an international landmark programme recognised for novelty, research excellence and impact.

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# The consortium

Prof Jim Hall
(University of Oxford)) is Director of the ITRC

Prof Nick Jenkins
(Cardiff University) is an expert in energy supply and transmission

Dr Nick Eyre
(University of Oxford) is an expert in energy demand

Prof John Preston
(University of Southampton) is an expert in transport systems

Prof Chris Kilsby
(Newcastle University) is an expert in water resource systems

Prof Tom Curtis (Newcastle University) is an expert in waste water systems

Prof William Powrie
(University of Southampton) is an expert in solid waste and geotechnics

Prof Cliff Jones
(Newcastle University) is an expert in the reliability of computer-based systems

Dr Seth Bullock
(University of Southampton) is an expert in complex systems

Dr Stuart Barr
(Newcastle University) is an expert geospatial data analysis

Prof Robert Nicholls
(University of Southampton) is an expert in the impacts of climate change

Prof Peter Tyler
(University of Cambridge) is an expert in regional economics

Prof Mark Birkin
(University of Leeds) is an expert in analysis of demographic change

Dr Jim Watson
(University of Sussex) is an expert on socio-technical transitions and the governance of energy systems

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# Research questions


1. How can infrastructure capacity and demand be balanced in an uncertain future?

2. What are the risks of infrastructure failure and how can we adapt National Infrastructure to make it more resilient?


3. How do infrastructure systems evolve and interact with society and the economy?

4. What should the UK's strategy be for integrated provision of NI in the long term?

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# Analysing the solutions:
# The National Infrastructure Systems Model family


**NISMOD-LP**

A national model of the long term performance of interdependent infrastructure systems


**NISMOD-RV**

A national model of risks and vulnerability in national infrastructure systems


**NISMOD-RD**

A model of regional development and how it adapts to infrastructure provision


**NISMOD-DB**

A national database of infrastructure networks, demand and performance

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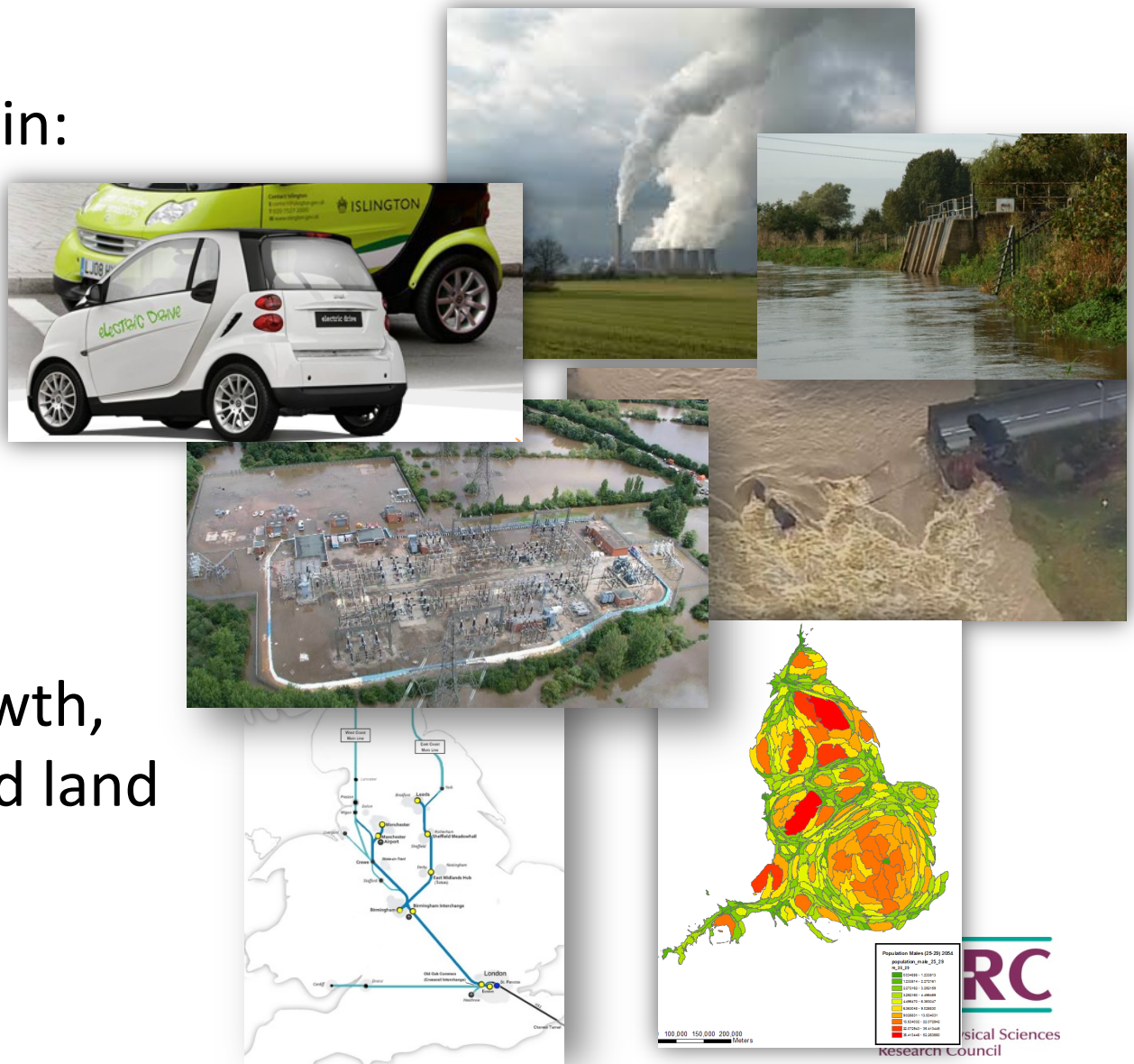
# Three versions of interdependence

Interdependence in:

1. Demand
2. Failure
3. Economic growth, population and land use change

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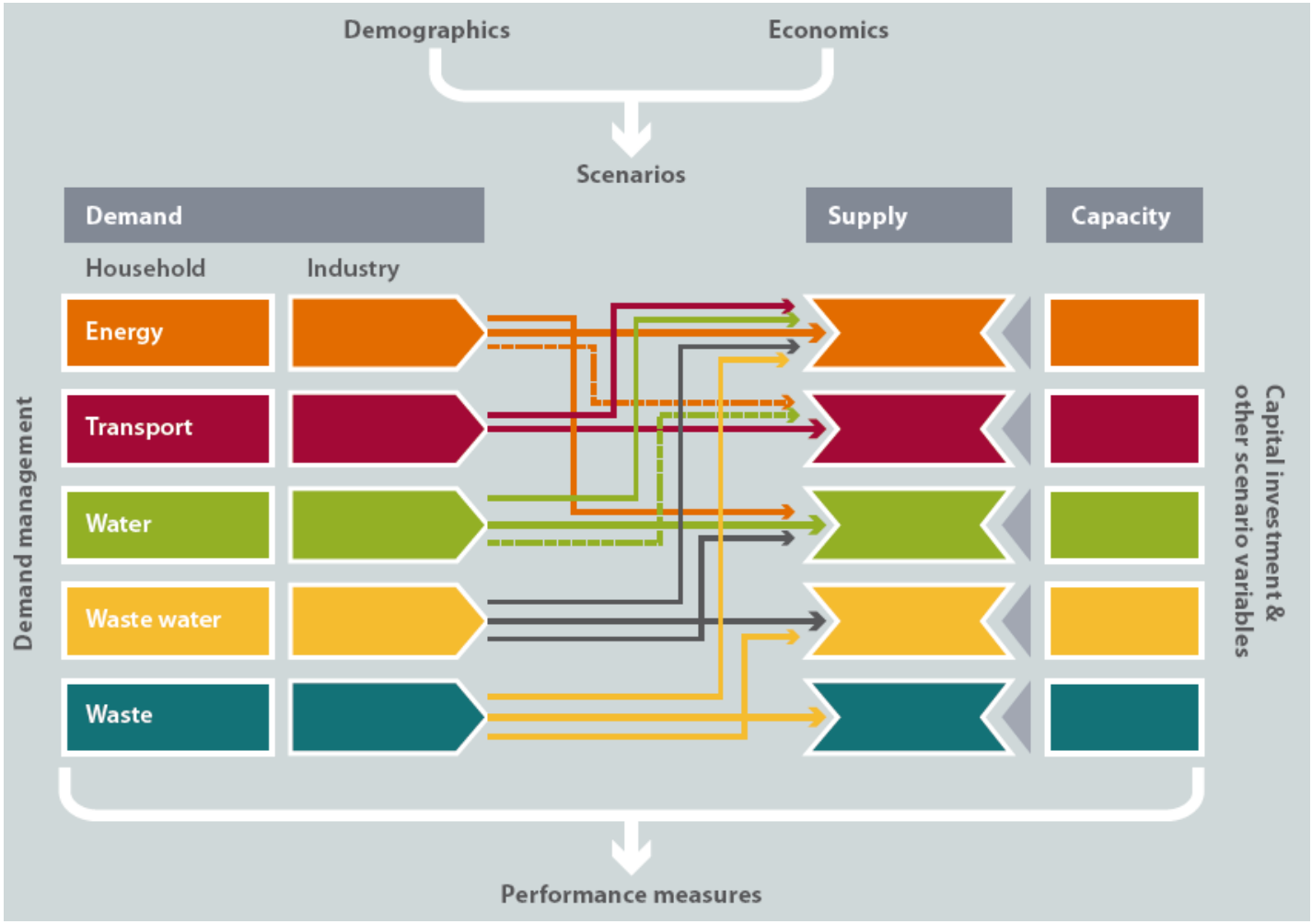
# Analysing long term performance of NI

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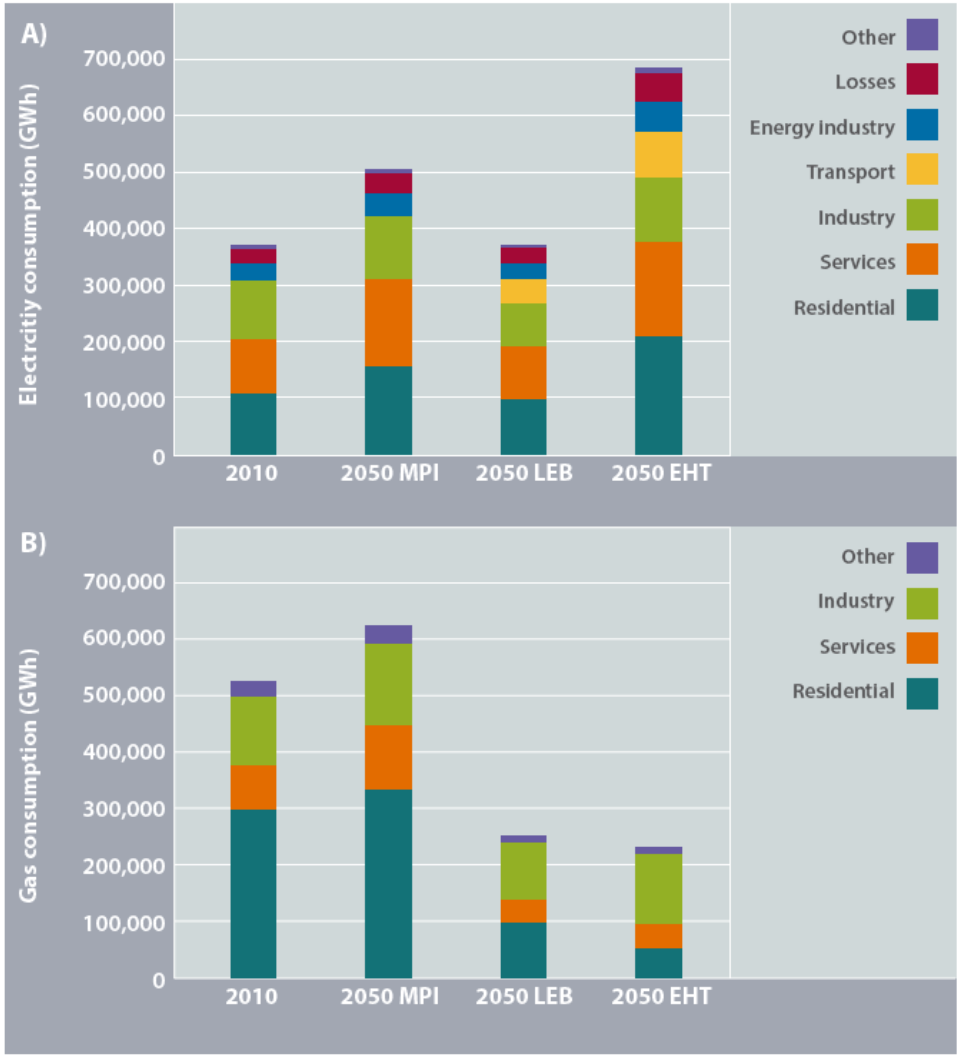
# Demand interdependence: transport and energy

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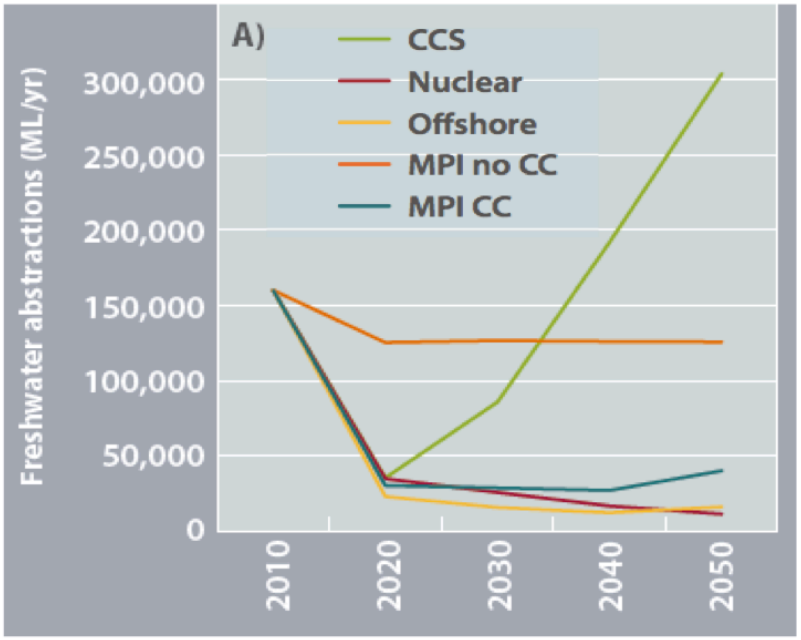
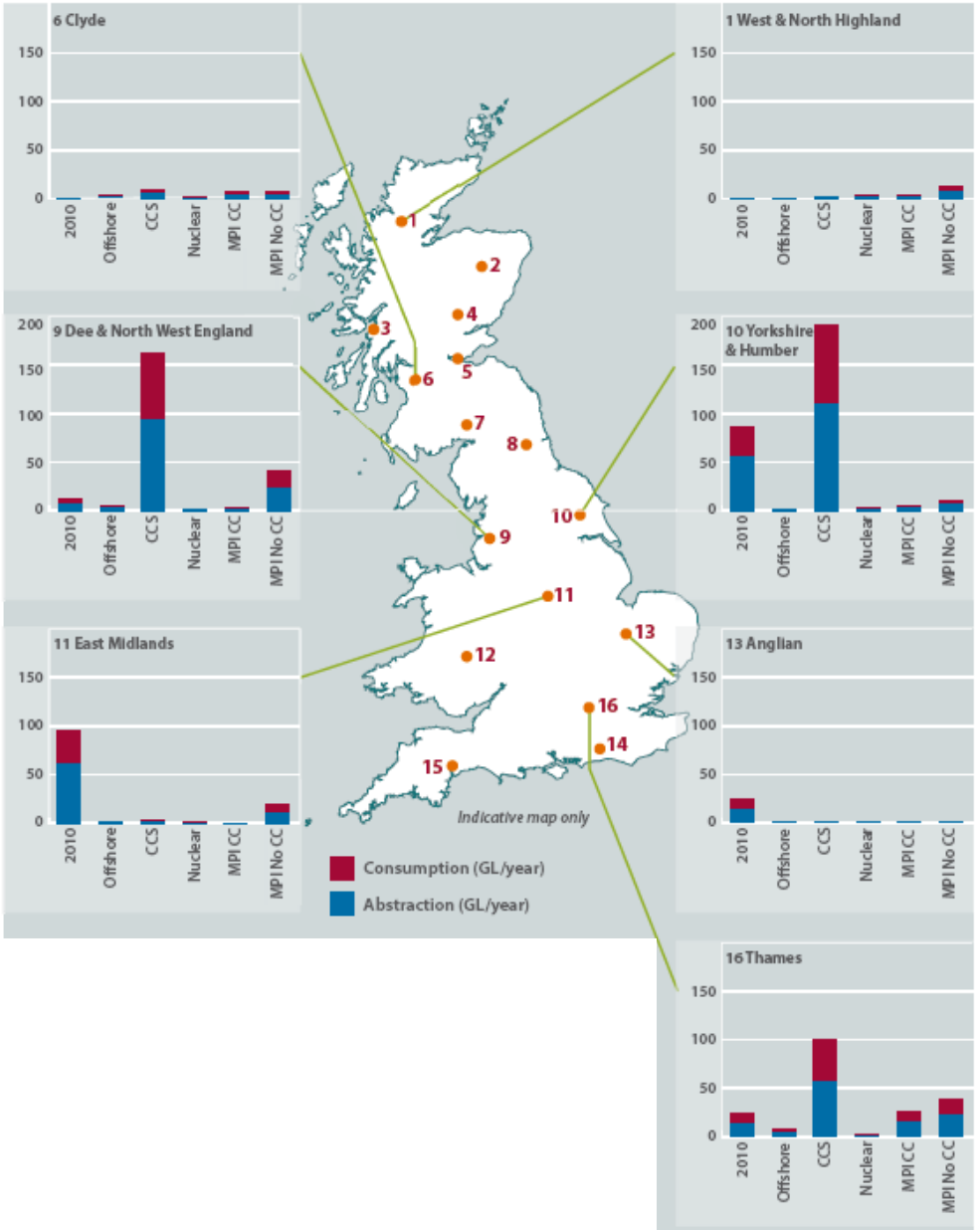
# Demand interdependence: energy and water



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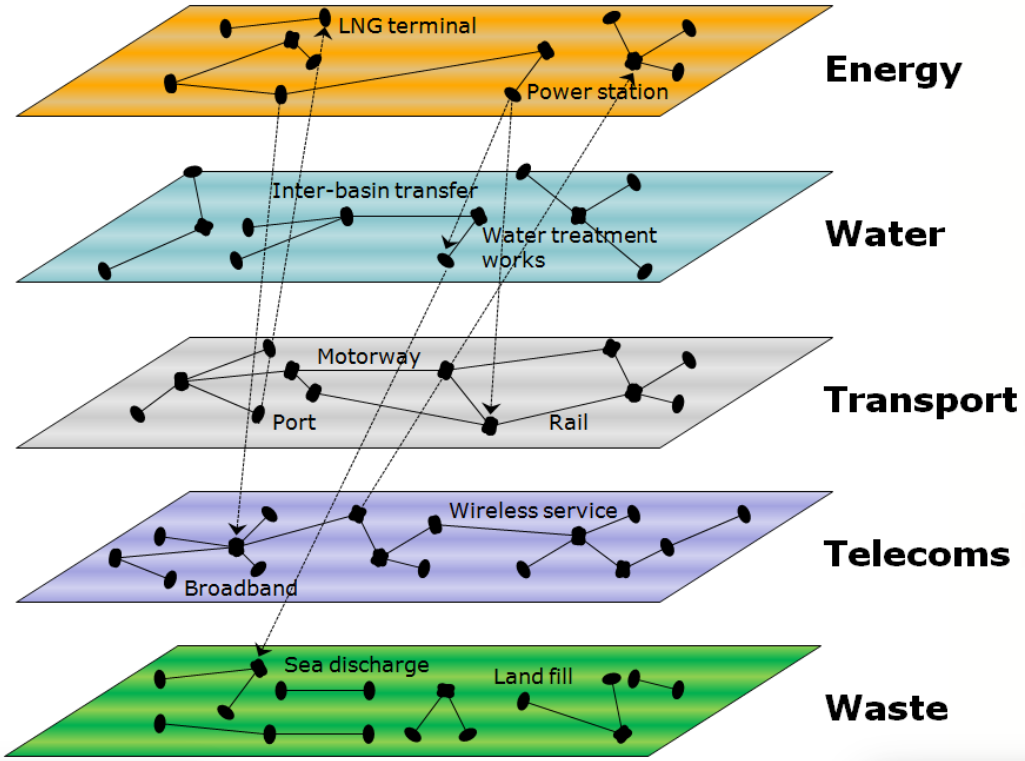
# Understanding the future risks of infrastructure failure

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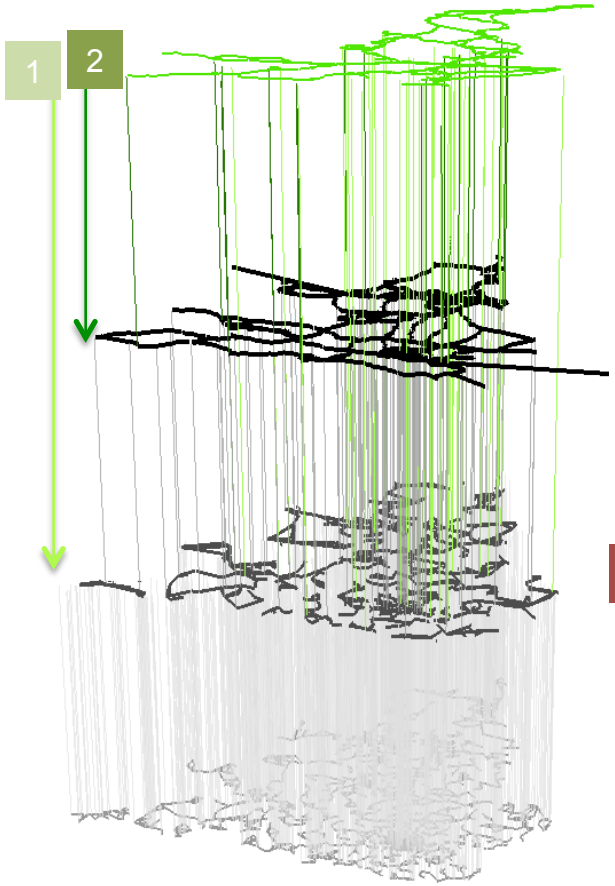
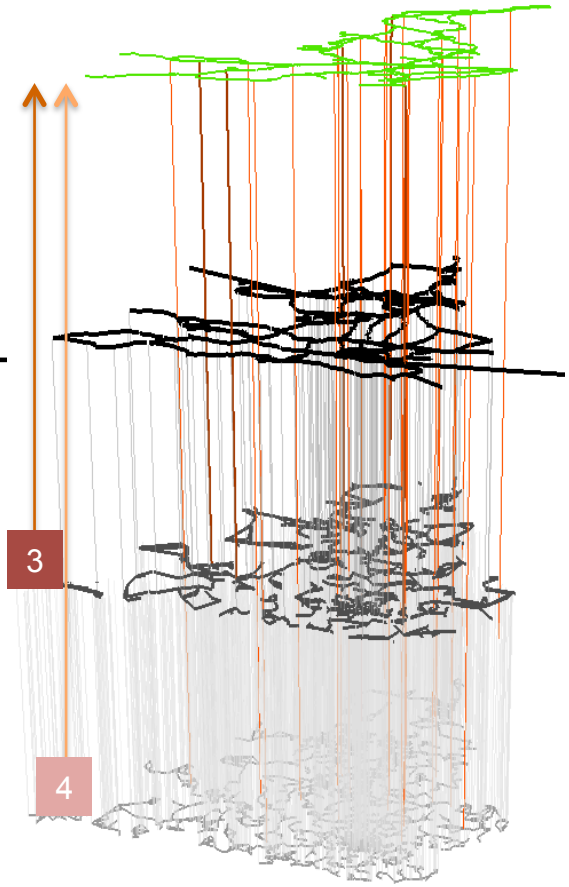
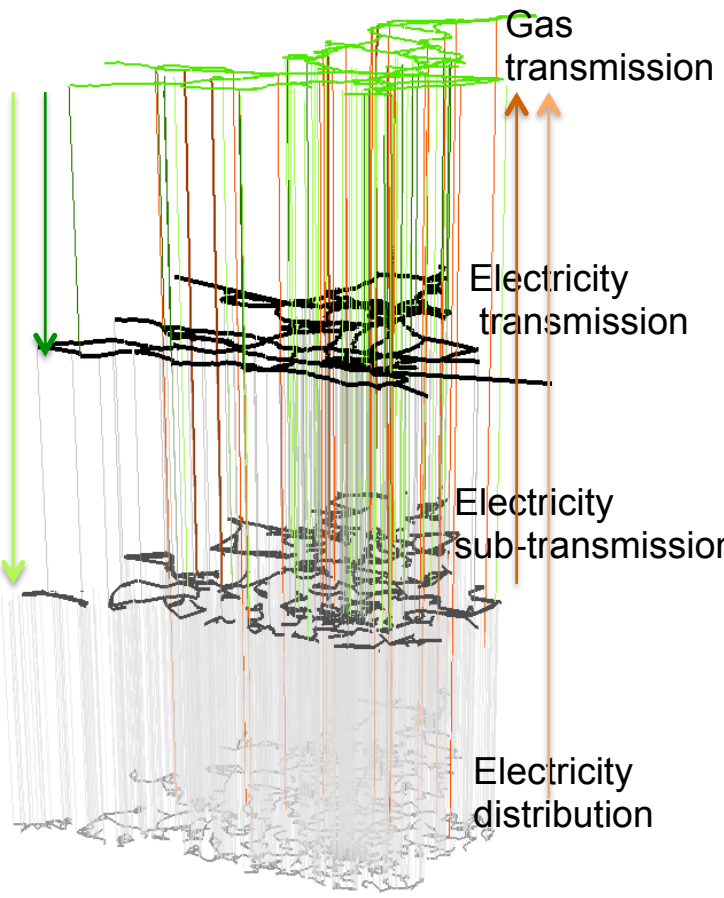
# Mapping network interdependencies




***Electricity dependency on Gas***

- 1) Large power stations @ transmission level
- 2) Medium power stations @ 132kV level

***Gas dependency on electricity (selected)***

- 3) LNG @ 132kV level
- 4) Compressors at 33kV level

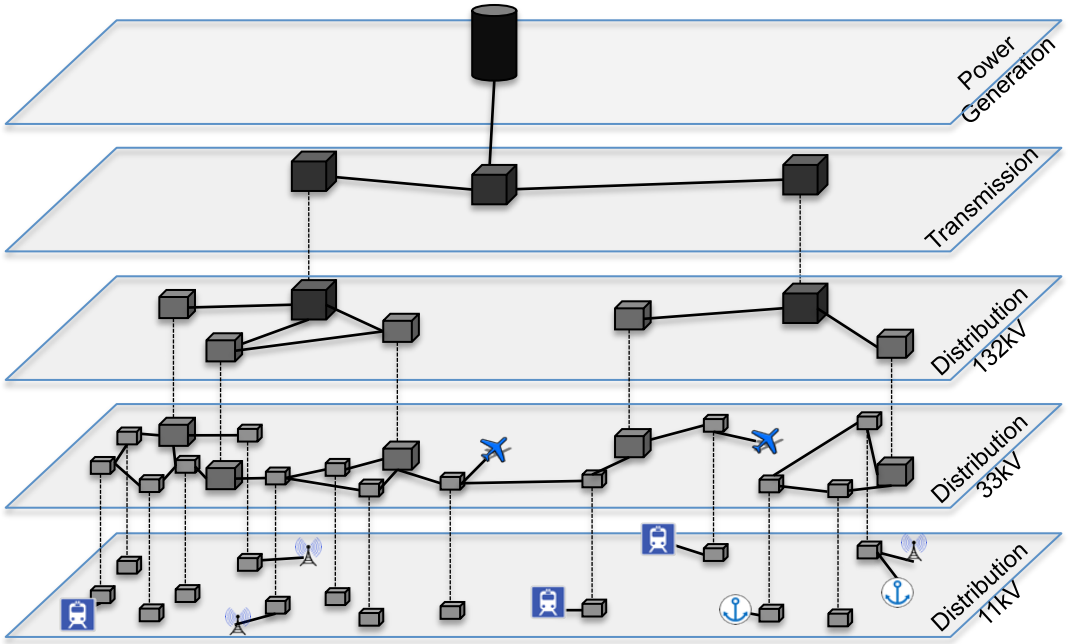
***Interdependency representation***

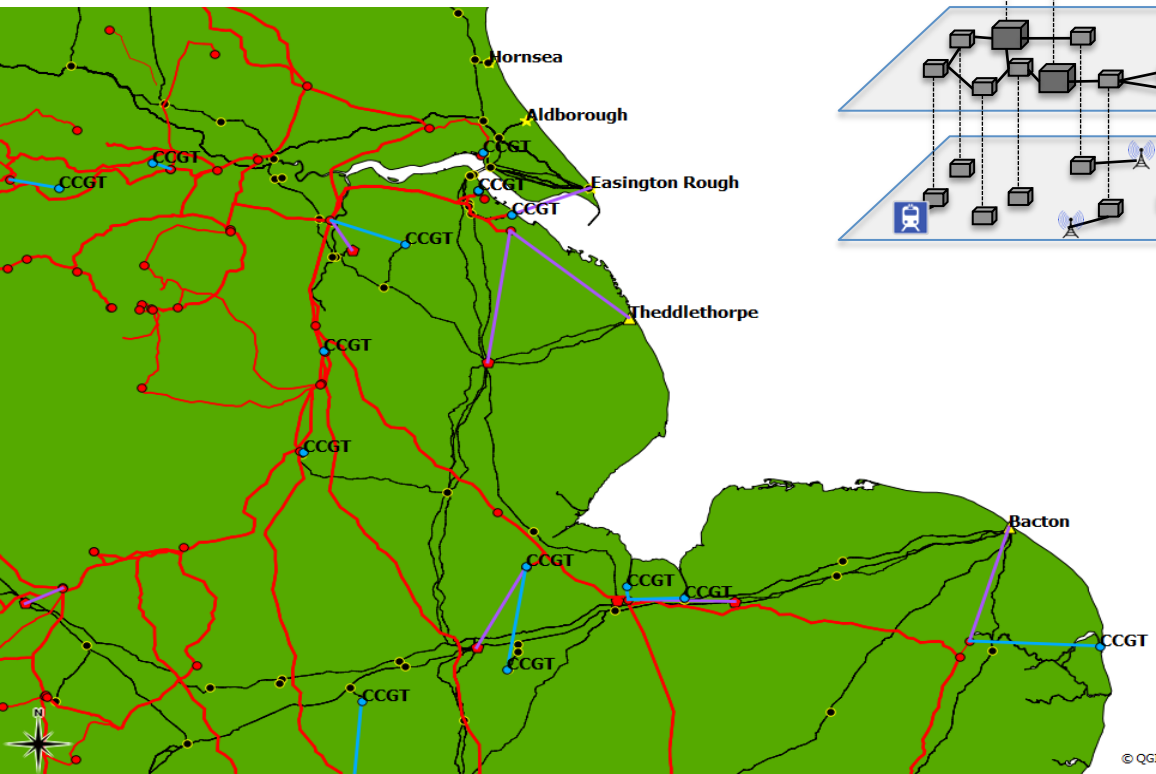
- 2 way flows highlighted..

NISMOD-RV

# Mapping network interdependencies

## Interdependent networks

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# Mapping customer demands

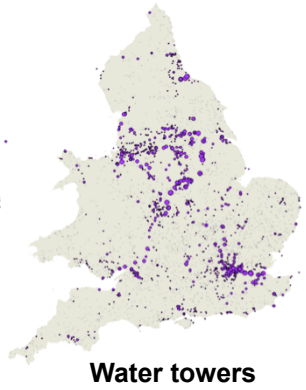
## Direct customer demands

**Electricity** customers

## **Indirect customer demands** on Great Britain's electricity network

**Sewage treatment**

**Telecom masts**



**Water towers**

**Railways**

**Airports**

**Ports**

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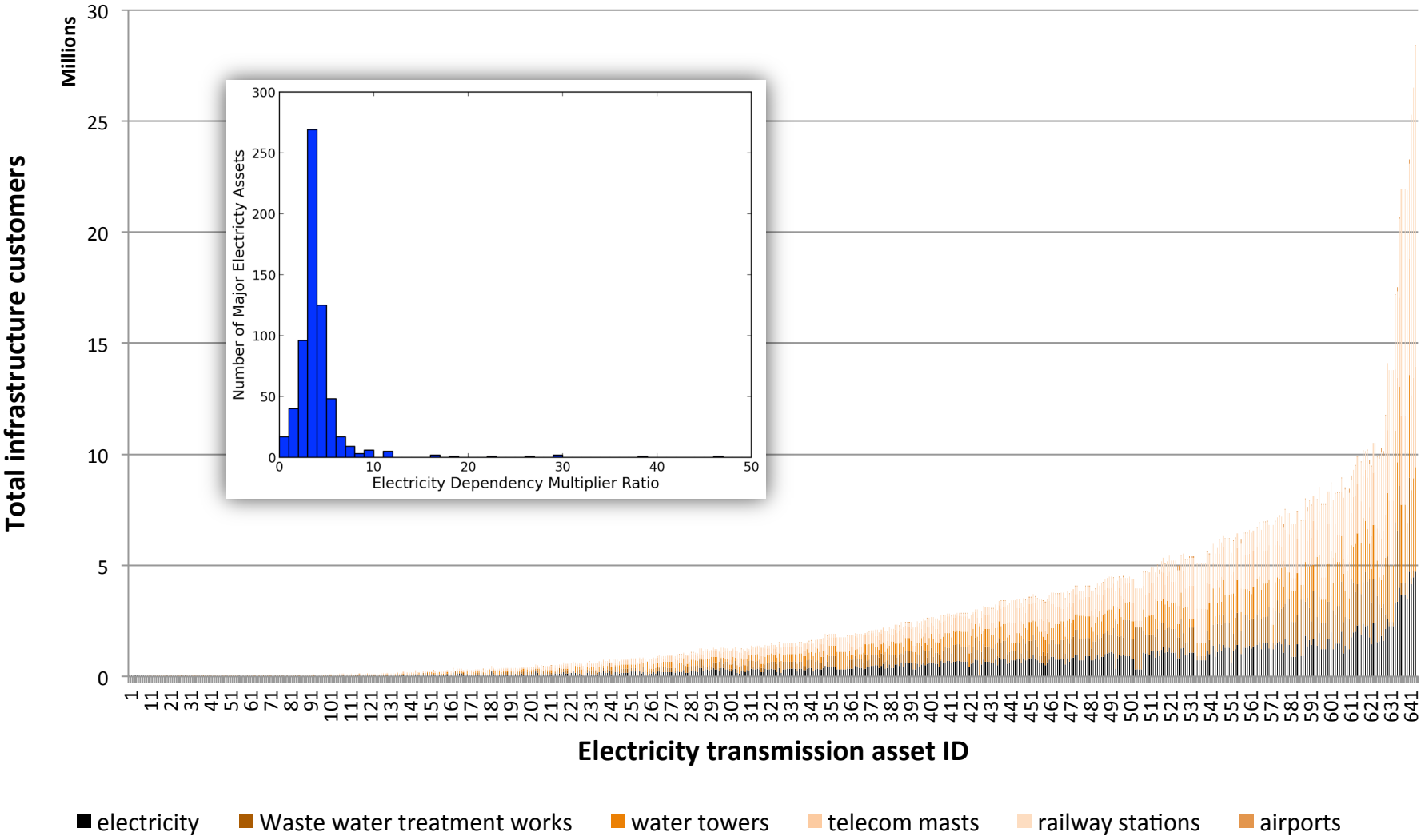
# Calculating potential customer disruptions: electricity



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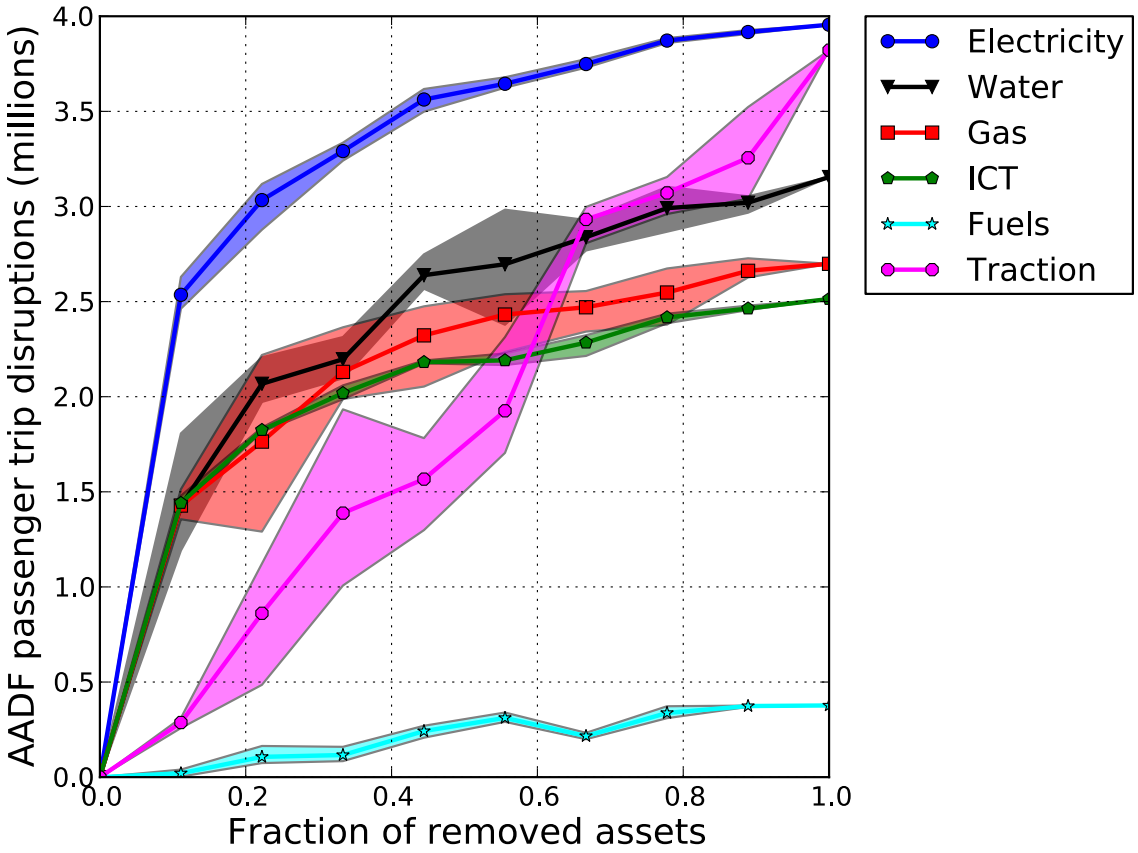
# Calculating potential customer disruptions: rail

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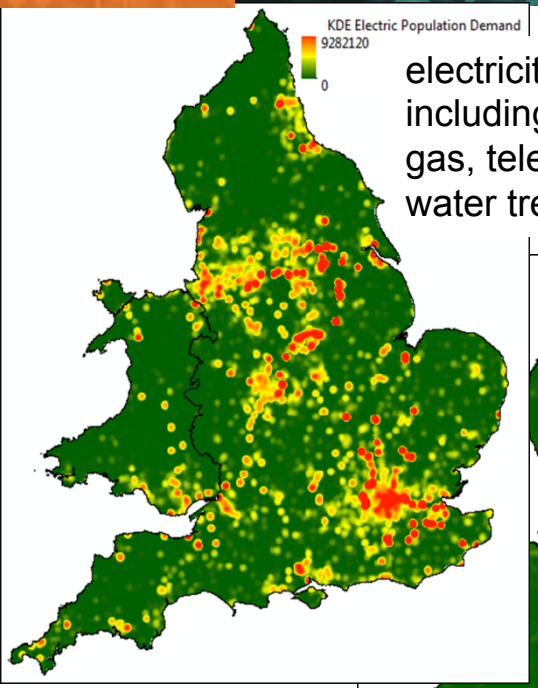
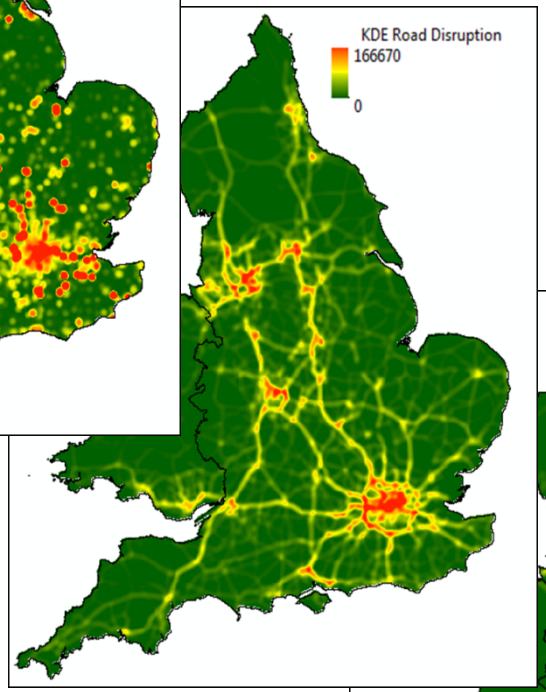
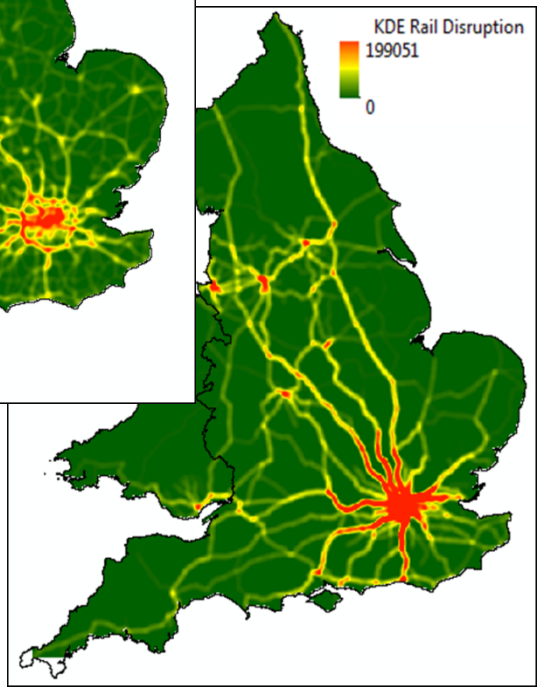
# Identifying criticality hotspots

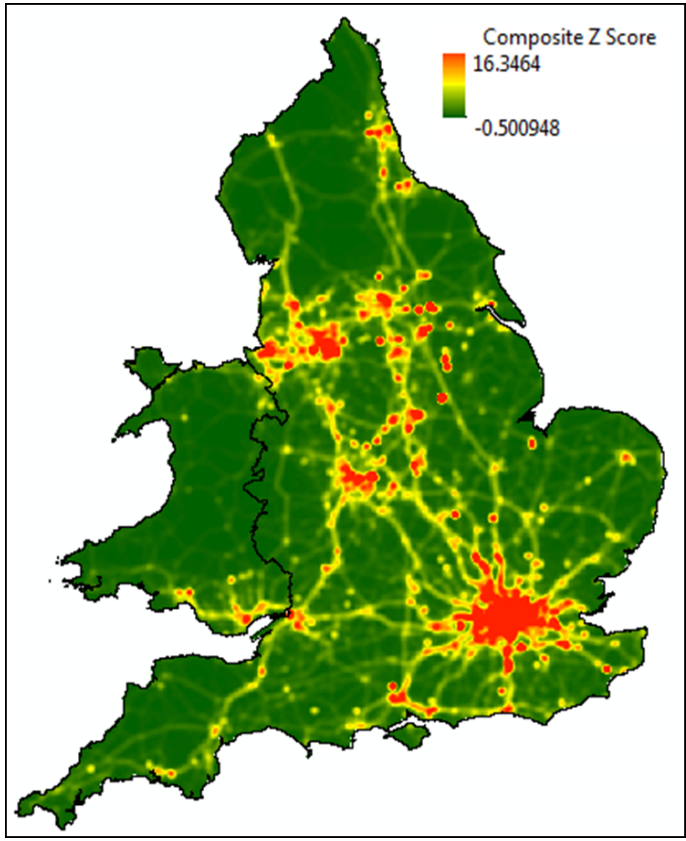



electricity customer demand including dependency on GSP, gas, telecoms, water and water treatment assets




Composite criticality map

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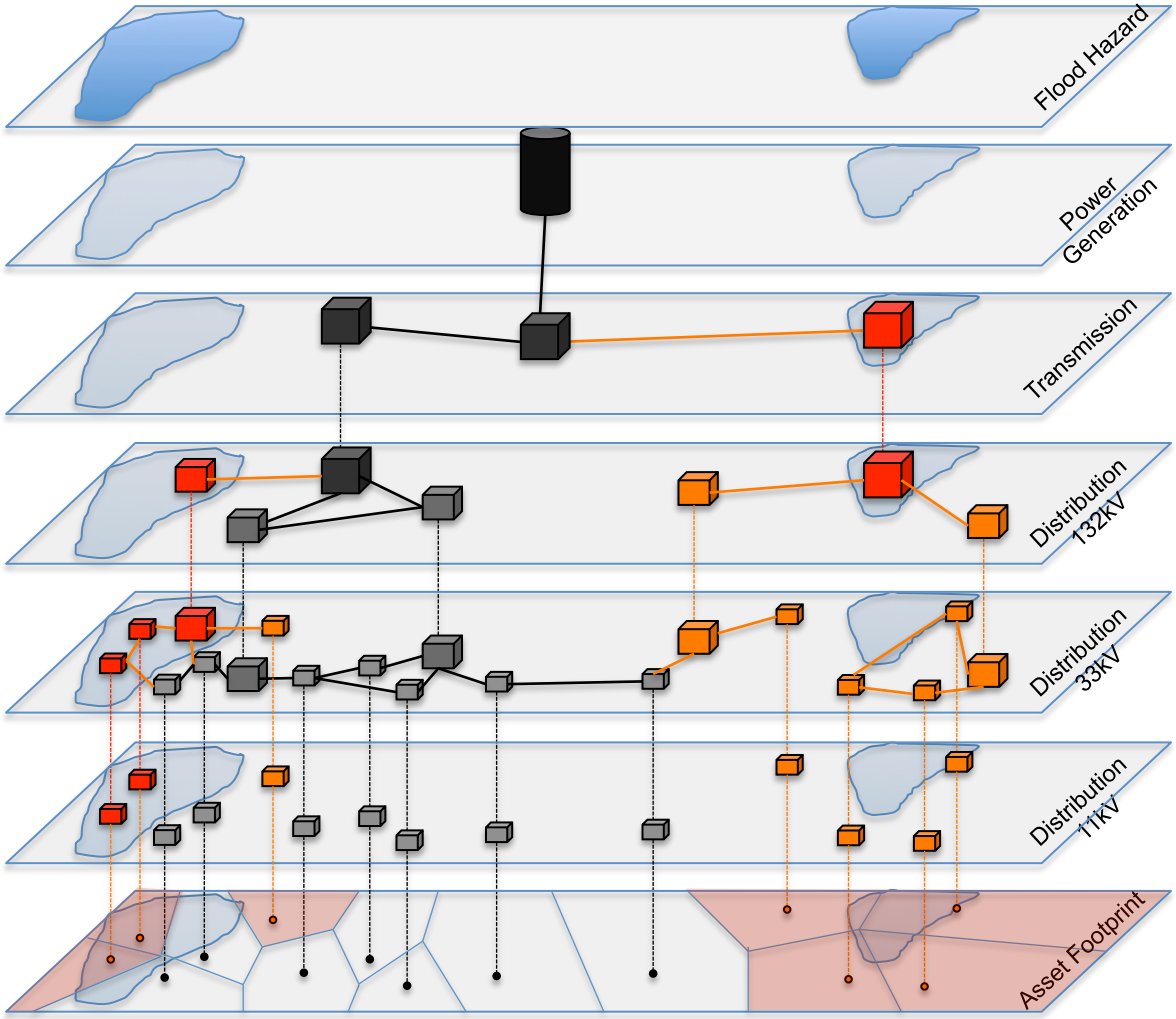
# Superimposing hazard maps




- Asset – Direct failure
- Asset – Indirect (network) failure

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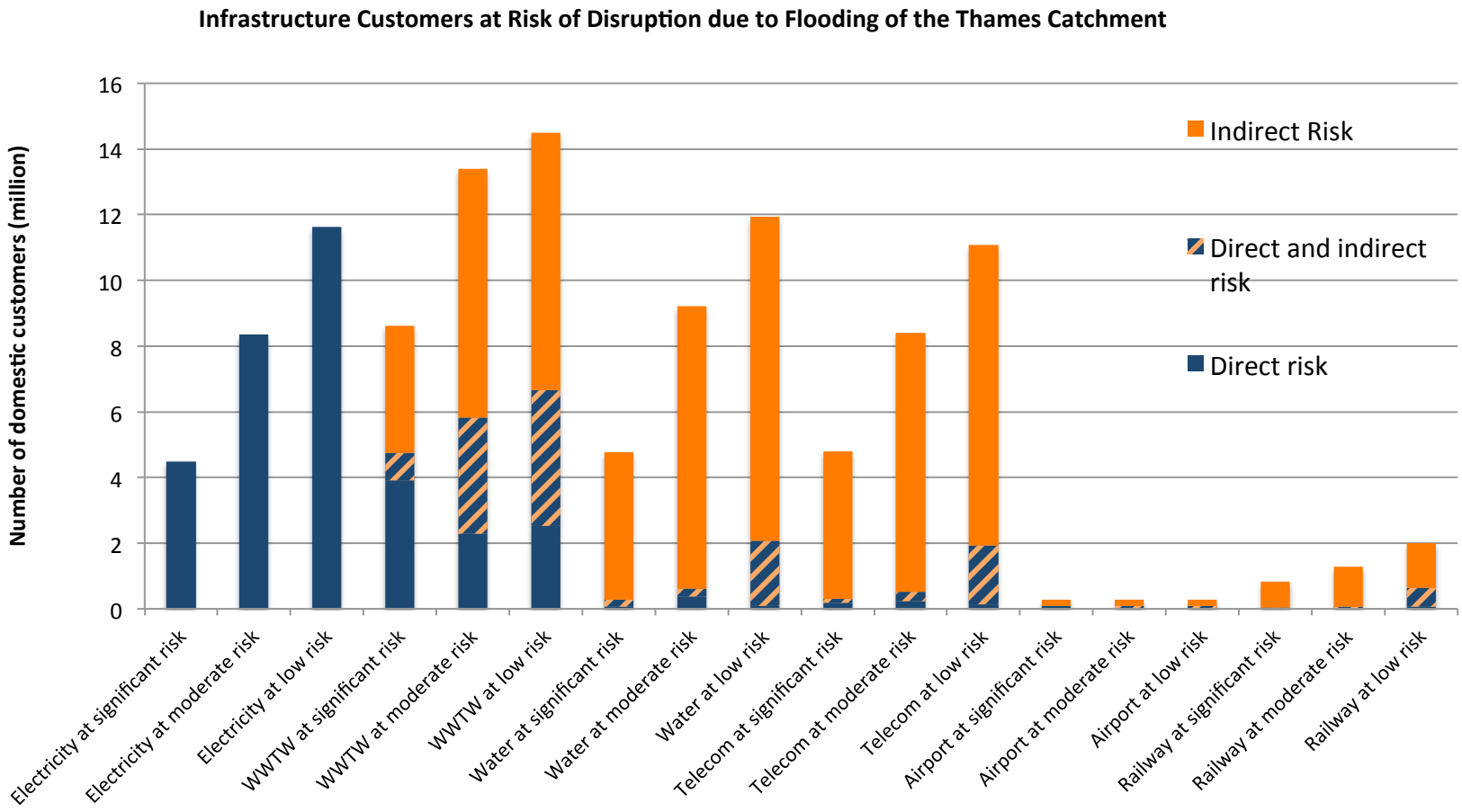
# Thames flood risk analysis

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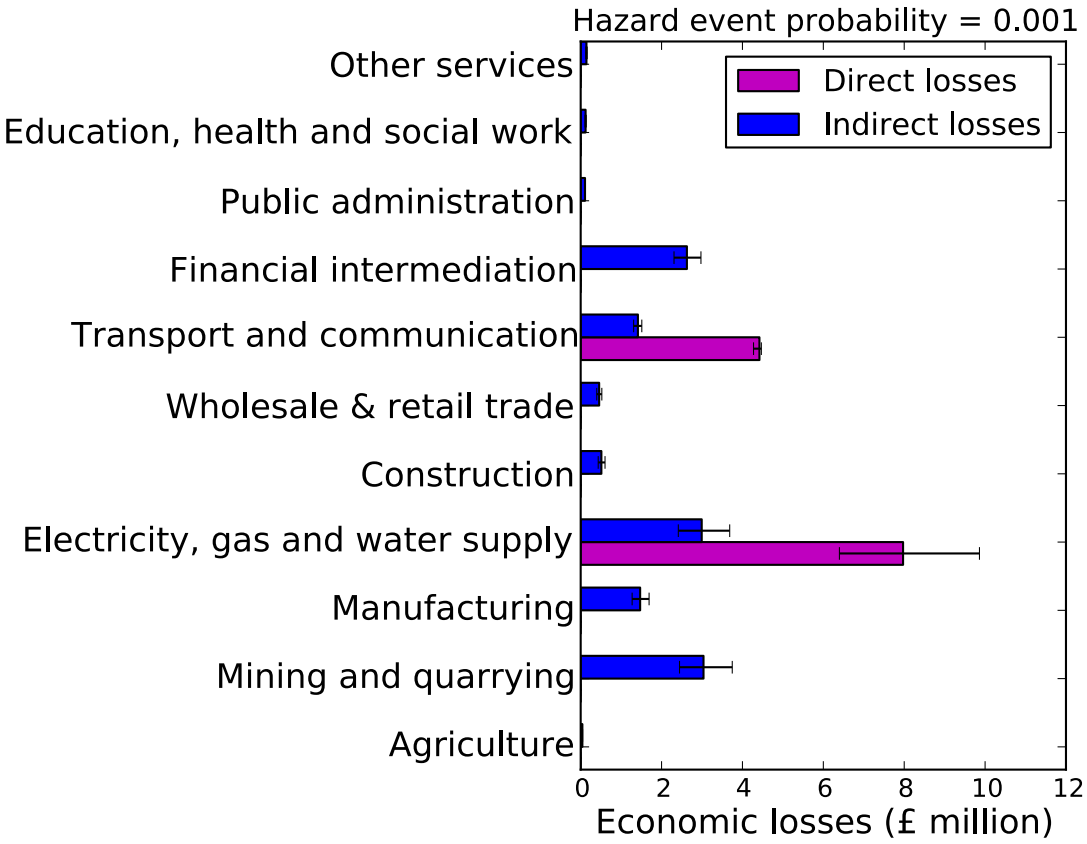
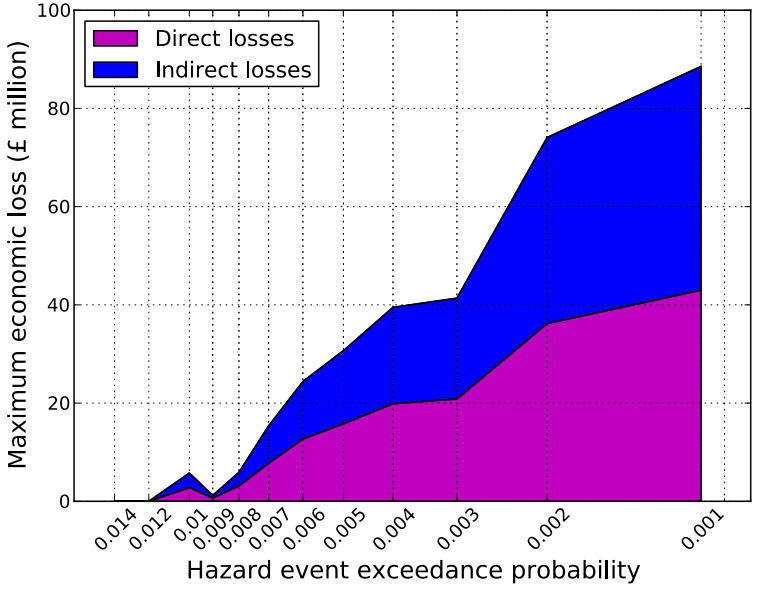
# Indirect impacts on the economy

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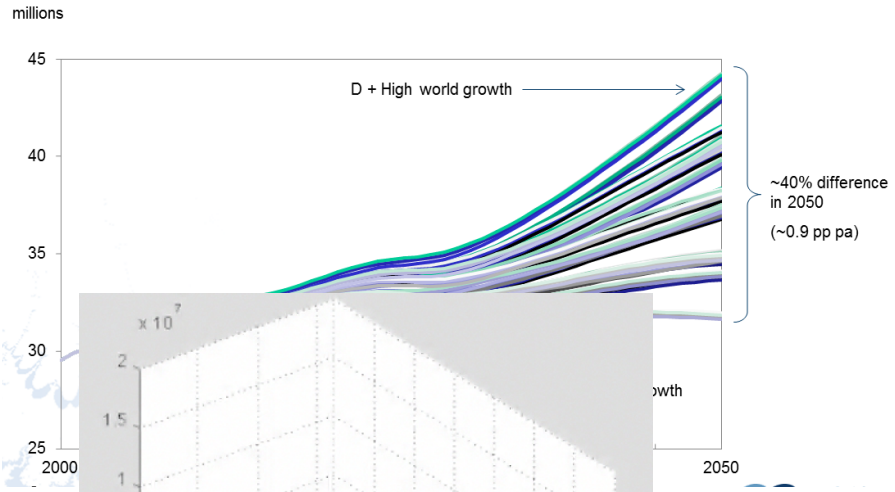
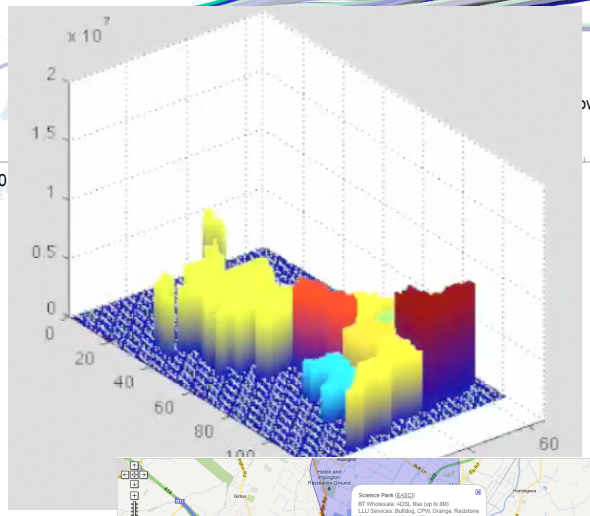
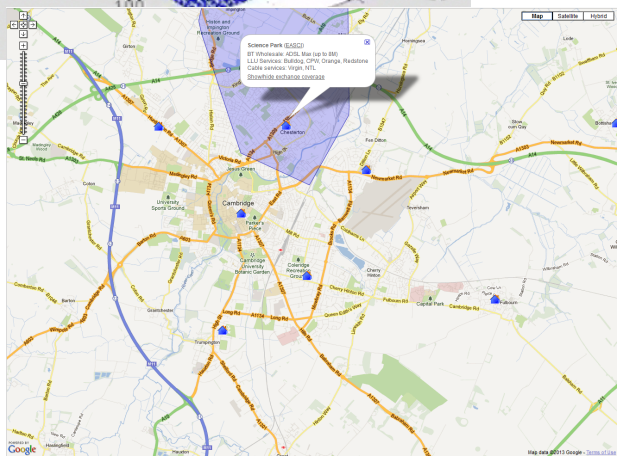
# Simulating the relationship between infrastructure, the economy and land use

- The role of infrastructure in the macro economy
- A multi-regional model of demography and growth
- Understanding the influence of infrastructure on business location decisions

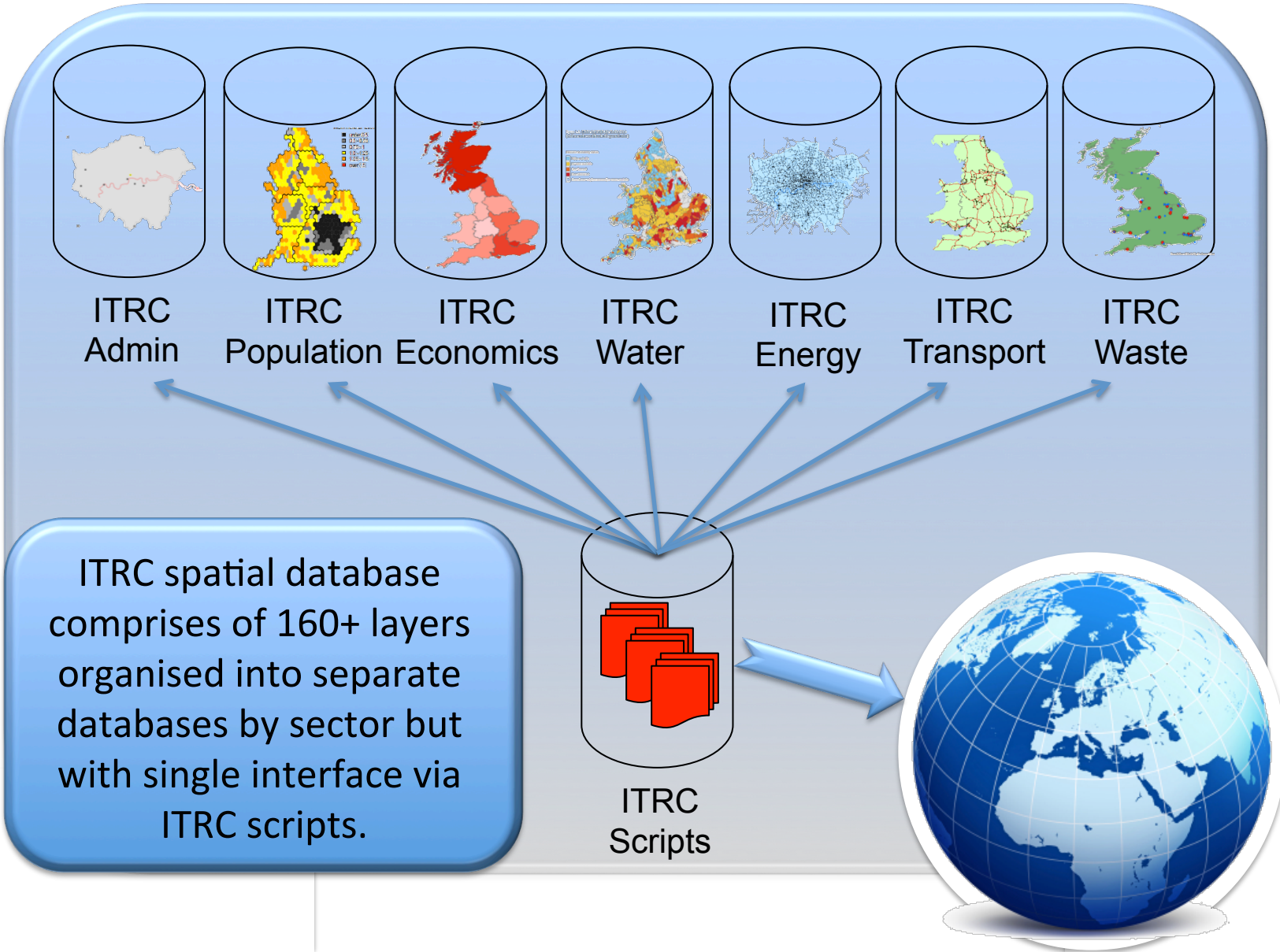


NISMOD-DB

# National Infrastructure Database



# Outcomes of our 'systems of systems' analysis and modelling

For the first time, globally, tools to analyse strategic pathways for national infrastructure provision that are:

- cross-sectoral
- long term
- national scale

in order to provide evidence to:

- build long term visions for national infrastructure and plan how it can be delivered
- identify vulnerabilities and adapt to risks
- understand uncertainties and develop robust strategies

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# Progress

2011 Fast Track Analysis of strategies for infrastructure provision in the UK

2012 Development of the NISMOD models and database

2013 Quantified assessment of the performance of national infrastructure strategies

Programme mid-term review

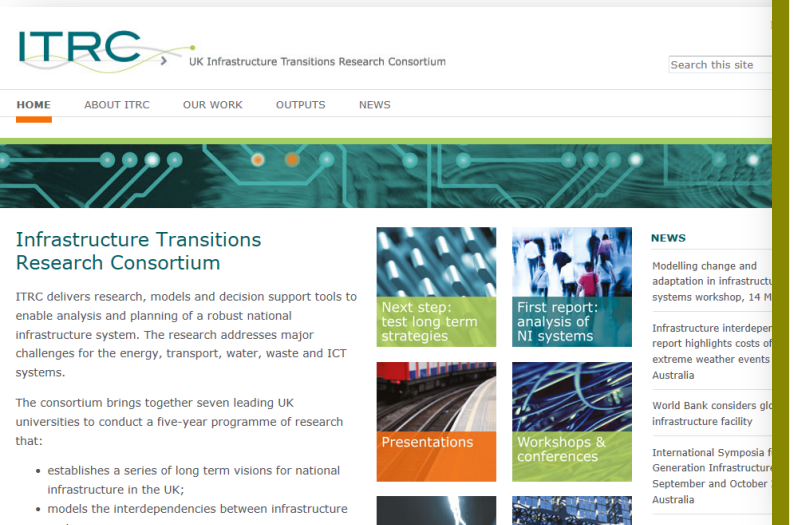
2014 ITRC first National Infrastructure Assessment

Integration of the NISMOD system

2015 NISMOD results and analysis tools available on-line

# Stakeholder engagement, communications and impact

- International Expert Advisory Group
- Enthusiastic group of stakeholder partners
- Ongoing collaboration with Infrastructure UK and other government departments
- Stakeholder champion



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